Technology in Warfare: The Electronic Dimension, The Role of Electronic Warfare since its Inception into a Central Aspect of the Gulf War in 1991

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Abstract

Technology in Warfare: The Electronic Dimension, The Role of Electronic Warfare since its Inception Into Central Aspects of the Gulf War in 1991.

This qualitative study investigates the impact of electronic warfare since its inception into central aspects of the Gulf War in 1991, explores how the world military understands electronic combat. The struggle for use of the electromagnetic spectrum to collect and distribute information while denying information to the enemy can determine who wins tactical firefights, large scale engagements, theater-wide campaigns, limited wars, and even global crises. The struggle for use of the electromagnetic spectrum affects the likelihood of nuclear war, and how it would be fought.

The struggle for the control of the electromagnetic spectrum is called electronic warfare because the spectrum is one of the most important channels through which information must pass. However, skills in electronic warfare is the touchstone of modern armies. Without it, armies are vulnerable to an enemy who invested more time, thought, and money in the preparation for electronic combat.

Any successful war is the product of multiple factors that combine to generate success. These factors are "people, leadership, training, technology, and doctrine." On balance, the Coalition forces in the Gulf were better trained and motivated than their predecessor. Thus, the Air Forces, Navies, Armies, and Marines Corps, with minor exceptions, fought as they trained.

The role of technology in the Gulf War can be summarized with reference to the following dimensions: the depth dimension – the capability to destroy point targets anywhere in enemy territory; the vertical dimension – for the intelligence and air assault; the night dimension – the 24-hour battle; and the electronic dimension – for command and control, and electronic warfare. In all these dimensions, with the exceptions of field intelligence, results were very impressive.

Finally, while electronic warfare did not alone win the war, and may not have been used to their optimum advantage, the lessons remain clear. The West saw that control of the electromagnetic spectrum means control of the battlefield. I believe if there is a World War Three, the winner will be the side that can best control and manage the electromagnetic spectrum.

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Preface

The world of electronic warfare (EW) has been constantly in flux from the war between Russia and Japan, which began in February 1904, in which radio, or wireless telegraphy as it was called in those days was first used. Since then EW technologies have existed in a state of perpetual evolution. This EW evolution continues through the present day and into the future, locked in an endless point/counterpoint game. Threats must be identified and evaluated and, in response, countermeasures must be developed and deployed. As those countermeasures prove their effectiveness, however, the threat landscape then shifts. Existing threats are either replaced by newer, more effective threats or modified to best current countermeasure capabilities.

However, since the first use of the electromagnetic spectrum to improve military effectiveness, almost every decade has seen a further enrichment in the terms and acronyms used to describe these technologies and techniques: from electronic warfare (EW) and electronic combat (EC) to suppression of enemy air defense (SEAD) and–the newest term–information warfare (IW). Regardless of the term used, however, it is the impact the techniques and technologies have on military operations that must be addressed.

Today, and in the foreseeable future, large-scale weapon systems depend and will depend on electronic technology. Most newly developed systems and those under development take integration a step further, fusing radar, infrared (IR), and electro optical (EO) systems into a comprehensive electronic support measures (ESM) system tailored to the system they are designed to protect. These next-generation systems represent a new emphasis on digital and knowledge-based technologies.

Threat systems have not, of late, been introduced at the pace seen during the 1970s and 1980s. There have been a number of improvements to radar-, infrared-, and electro-optically guided weapons, taking advantage of improvements in digital technology to weapons' overall performance and reduce their vulnerability to countermeasures. Multimode weapons systems, for example, which use two or three levels of control and a variety of active, semi-active, and passive sensor systems for various phases of flight, provides new and more complex challenges to countermeasure systems–especially in the terminal phase, when highly accurate sensors are used. Stealth is another challenge to be faced, as it allows operation in dense threat environments with high levels of success. The F-117 was able, during the Gulf War, to successfully operate against targets defended by intense and complex threat environments, using only stealth as a countermeasure. The point/counter point game never ends, however, as demonstrated by the shoot down of an USAF F-117 during Operation Allied Force. Likewise, adversaries' command and control capabilities will continue to improve, taking advantage of low-probability-of-intercept techniques and frequency hopping to achieve a certain measure of resistance to countermeasures.

Operation of today's expensive and operationally critical offensive weapons platforms requires consideration of countermeasures, both in terms of survivability and offensive effectiveness. Deployment considerations should include the following: Has the platform been detected? Has it been targeted? Has a weapon been launched? Was sort of weapon is it and what are the countermeasures options? These answers must be provided –rapidly by an ESM (electronic support measures) system, be it on the threatened platform or on another connected via a high-speed data link.

ESM/SIGINT (Signal Intelligence) systems are at the heart of most methods of assessing the electromagnetic environment. SIGINT systems typically provide information on the electronic order of battle, as well as parametric characteristics of threats faced. SIGINT systems can also be employed in indication and warning modes in advance of possible hostilities, as well to provide direct support to combat operations. They typically operate the lethal envelope of all but the longest-range threats. Examples of SIGINT platforms are the USAF RC-130, the UK Nimrod and certain ground-based and seaborne collection systems. Typical ESM systems, on the other hand, are integrated into countermeasures systems and provide direct support to combat systems. In fact, many ECM suites have integrated ESM capabilities, providing a front-end "brain" that cues the right countermeasure–ranging from a tactics recommendation to an active countermeasure–as the right time. The U.S. EA-6B Prowler aircraft houses the quintessential ESM System, adding to its ability to suppress air defenses with jammers or missiles.

The importance of these electronic weapon systems to the overall concept of warfare is often obscured in detailed discussions of specific systems. For this reason, a broad understanding of the principles involved is essential. It is significant that these principles involve both engineering science and military strategy. In electronic warfare the term "radiation" and "detection" must be considered in the same light as "offense" and "defense" are in strategic and tactical warfare. To be sure, the engineering aspects of the problem must be given analytical treatment; however, operational questions must be considered if a broad appreciation of the principles of electronic warfare is to be achieved. The treatment presented here is intended to achieve a balance between these technical and tactical aspects of the problem. Therefore, it is hoped that both those concerned with deployment and tactics and the professional engineer as well, will find many points of interest here.

Some aspects of the Electronic Warfare (EW) problem have intentionally been omitted because security requirements impose an important constraint on the selection and treatment of topics.

There is no discussion of specific equipment in this study. There are two reasons for this intentional omission. First, a discussion of operational equipment is not our objective; second, such a treatment does not represent a fundamental approach to the problem. A sincere attempt has been made to bring reasonable generality to all mathematical analysis.

This study originally grew out of a question by certain experts and specialists in the field of electronic warfare, military commanders, strategic defense analysts, political leaders, military historians, cadets of various military institution, journalists, and many people who witnessed the Gulf War of 1991. Initially it concerned itself with the role of electronic warfare in the Gulf War of 1991. However, over the course of years many military and defense institutions and specialists performing research and consultation in the field of strategy of electronic warfare became associated with this study and even much classroom instruction. From that marriage arose the realization that the important issues in electronic warfare today are not so much what, but why? And how much? And most of the concerned ones who are associated or linked to electronic warfare and the average officer and cadet is more likely to have to address the latter questions in his career as an Air Force officer than the former. So this study has evolved toward a broader view of electronic warfare and its role in the Gulf War of 1991.

About the same time it became evident, this broader concept of electronic warfare was not well understood throughout the military services. Electronic warfare has been concerned with particular techniques to defeat particular equipment. But electronic warfare does not exist in a vacuum, there are other ways of accomplishing the same objectives, and electronic warfare must compete with all of these. Thus, we need a good understanding of the broader concept of electronic warfare so that we can properly evaluate its role and usefulness.

As I attempted to write these broader concepts, I gradually come to realize the fact that electronic warfare is not "electronic" in the common usage of that term, for there are large quantities of avionics which do not concern electronic warfare, such as an Aircraft Autopilot, or an inertial navigation system (INS), or global positioning system (GPS). Electronic warfare is jargon for conflict carried out using electronic energy as the battleground. And these broader issues really become strategic and tactical principles to be observed in this conflict. Because electronic warfare conveys an image of highly sophisticated technology to many of its practitioners, I decided that it would be much more appropriate to title this study consistent with its content, and also more to the point of my first objective, the typical electronic warfare specialists.

Finally, books about the Second World War, Korean War, Vietnam War, and the Gulf War have been rolling off the press for many years. Writers have produced memories and documents, which have done much to educate the public on campaigns, tactics, errors, and military successes. Yet, little has been said about the electronic aspects of those global conflicts.

As a result this study is written with this varied audience in mind. How well it meets the needs of all, I leave to the reader's judgment.

Chapter 1

Basic Definitions

Early Definitions

For many years there has been wide misunderstanding of electronic warfare and its purpose. Part of this problem stemmed from the classified nature of the subject, but a large part of the difficulty has been due to a confusing variety of definitions of the common terms in electronic warfare. Recognizing this problem, the Joint Chiefs of Staff issued a policy defining the basic terms.

Electronic Warfare (EW)

EW is defined as a military action involving the use of electromagnetic and directed energy to control, determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum and action which retains friendly use of the electromagnetic spectrum. EW is organized into the four major categories: 1. Intelligence, 2. Electronic Support Measures (ESM), 3. Electronic Counter Measures, and 4. Electronic Counter-Counter Measures (ECCM). These major areas and several ancillary areas are depicted in Figure 1-1.

Intelligence

Intelligence is that division of EW involving in the acquisition of as much data as possible about the electromagnetic emissions of a potential enemy.

Signal Intelligence (SIGINT)

An area that is closely allied to ESM involves the gathering and collection for intelligence for intelligence purposes of electromagnetic data, which is radiated by potentially hostile sources. A distinction is made between the collection of communications (COMINT) and non-communications (ELINT) electromagnetic data, but both activities come under the umbrella of *signal intelligence* (SIGINT).

Communication Intelligence (COMINT)

COMINT is defined as intelligence derived from potentially hostile communications by other than the intended recipients.

Electronic Intelligence (ELINT)

ELINT is defined as intelligence information that is the product of activities in the collection and processing for subsequent intelligence purposes, of potentially hostile, non-communications electromagnetic radiations, which emanate from other than nuclear detonations and radioactive sources.

Radiation Intelligence (RINT)

RINT is the third division of SIGINT and is defined as intelligence derived from potentially hostile communications and weapons systems by virtue of their unintended spurious emissions, even when in a non-transmitting mode of operation.

SIGINT is basically a strategically oriented activity, which in the U.S. come under the cognizance of the National Security Agency (NSA). SIGINT data generally focuses on producing intelligence of an analytical nature that is not as time critical as ESM data. The prime customers for SIGINT data are upper echelons of military forces, which can include the commanders at national levels.

ELINT is generally performed on a regular basis in times of peace prior to specific missions, but can occur under actual war conditions or during an attack. Peacetime operations have the objective of securing the maximum possible data on the complete electromagnetic environment within those areas of interest to any one nation. Special ships, aircraft, and satellites, as well as fixed and mobile land-based ELINT facilities are employed, often operating on comprehensive reconnaissance schedules.

The basic targets for ELINT are all types of radars (land, sea, or airborne for surveillance, fire control navigation, and other applications) that are detected, located, and identified by their signatures in all their operating modes (e.g., search, tracking) and their transmissions hence recorded. These recordings contain the radar characteristics such as pulse repetition frequency (PRF), pulse width (PW), transmitter frequency, modulations, and any other parameters constituting the signature of radar, which enables it to be identified without being seen. Other electronic reconnaissance targets, which are given similar attention, are navigation systems, command and telemetry links, and data links.

ELINT data is used in several ways. First, there is the straightforward intelligence function where the recorded signals are analyzed for the purpose of establishing the likely function and mode of operation of each individual piece of electronic equipment. The information may also permit an assessment of the equipment's performance or that of its associated system.

ELINT and its subsequent analysis also fulfill a number of tactical functions. That determines of an enemy's electronic order of battle (EOB), which is used to form a threat library for use in ESM and ECM equipment. Also, in tactical engagements, special ELINT missions may be mounted for the purpose of gaining data to use in planning a specific attack. A typical mission might be the determination of the numbers, activity, types, and locations of defensive search radars, acquisition radars, and weapon control radars in a particular area. These data are intended to be used to determine the best mode of attack and deployment of ECM equipment in order to suppress these radars.

Electronic Support Measures (ESM)

That division of EW involving actions taken to search for, intercepts, locate, record, and analyze radiate electromagnetic energy, for the purpose of exploiting such radiation in support of military operations. Thus, ESM provides a source of EW information required conducting electronic countermeasures (ECM), electronic counter-countermeasures (ECCM), threat detection, warning, avoidance, target acquisition, and homing. ESM is for tactical purposes that require immediate actions as contrasted with similar functions that are performed for intelligence gathering, such as signal intelligence (SIGINT) and its constituent parts of electronic intelligence (ELINT), communications intelligence (COMINT), and radiation intelligence (RINT).

An example of an ESM system is a radar-warning receiver (RWR) that intercepts radar signals and analyzes their relative threat in real time. To accomplish this analysis, the RWR must have a threat library representing the enemy's electronic order of battle (EOB) stored in its microprocessor. The EOB is obtained through ELINT or electronic reconnaissance, which collects and records for subsequent analysis as much data as possible on enemy non-communications equipment.

An important advantage of ESM, when used as a detector of enemy systems, is that it is completely passive. Also, it provides the potential of detecting enemy radiations from such sensors as radar, laser, and sonars at much greater ranges than the maximum range of those sensors. However, it has the disadvantage that range to the intercepted emitter must generally be obtained through triangulation from multiple ESM fixes on the target.

To defeat ESM systems, a military force generally practices emission control (EMCON), which restricts transmissions until it knows it has been detected. Active or radiating weapons are often designed such that the active sensor is only turned on for its terminal phase (on the order of 10 to 30 seconds), so that minimum warning and reaction time is given to the target. Completely passive weapons such as anti-radiation missiles and heat-seeking missiles provide no warning from ESM.

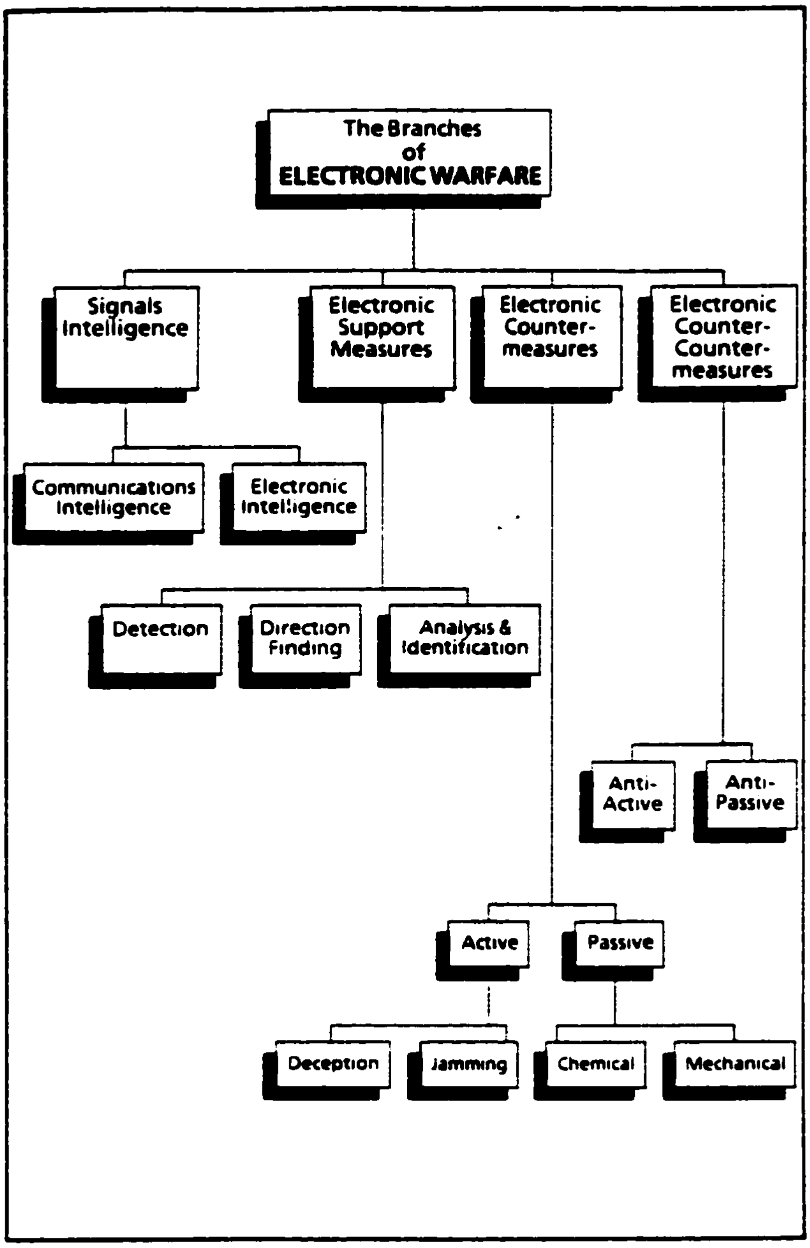


Fig. 1-1 Electronic Warfare Areas

Electronic Counter Measures (ECM)

ECM is that division of EW involving actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum. ECM includes jamming and deception.

Jamming

Jamming is the deliberate radiation or reflection of electromagnetic energy with the object of impairing the deployment of electronic devices, equipment, or systems being used by a hostile force.

Deception

Deception is the deliberate radiation, re-radiation, alteration, absorption, or reflection of electromagnetic energy in a manner intended to mislead a hostile force in the interpretation received by his electronic systems. The two categories of deception are manipulative and imitative.

Manipulative Deception

Manipulative deception implies the alteration of or simulation of friendly electromagnetic signals to accomplish deception.

Imitative Deception

Imitative deception consists of introducing radiation into hostile channels that imitates a hostile emission.

The key features of ECM are jamming, disrupting, and deceiving. The broad objectives of most ECM systems are to deny the enemy the information he seeks, or to surround his return with so much false target data that the true information cannot be extracted, or to supply so much false data that the information handling capacity of the victim system is swamped.

The most common form of ECM is active noise jamming, intended to neutralize the opposing radar or communication system completely, using either spot or barrage noise.

Spot Noise Jamming

Spot noise is used when the frequency parameters (center frequency and bandwidth) of the victim system to be jammed are known and confined to a narrow band. However, many types of radar are frequency agile over a wide band as an ECCM measure against spot jamming. If the rate of frequency agility is slow enough, the jammer can follow the frequency changes and maintain the effect of jamming. Alternately, some jammers are swept across the band of interest using spot noise to interfere intermittently with the victim system.

Barrage Jamming

Barrage or broadband jamming is simultaneously radiated across the entire band of the radar or communications spectrum of interest. This method is used against frequency-agile systems whose rates are too fast to follow, or when the victim's frequency parameters are imprecisely known. In general, barrage noise requires considerably more effective radiated power (ERP) of the jammer than does spot noise for equal effectiveness. Barrage noise jamming through radar or communication system's side lobes is usually difficult to achieve because of the large required ERP.

The aim of deception jamming is not to swamp the victim's system with external noise so that the true signal cannot be detected, but rather to falsify deliberately the indicated system response. This technique can also be used to confuse by providing sufficient false but realistic data to the victim system as to make extraction of the valid data impossible.

Deception jammers are generally more sophisticated and of higher complexity than noise jammers. The main reason for the higher complexity is that the jammer's performance characteristics must be more closely matched to those of each type of system to be jammed than do those of a noise jammer. There is also a need for far more detailed knowledge of the victim system's performance parameters and modes of operation, both in advance and in the course of the actual jamming mission. The need for real-time analysis must be met with on-board equipment designed to monitor and analyze the victim system's transmissions, while the *a priori* system information is obtained using ELINT equipment.

Smart Noise Jamming

A hybrid type of jamming which incorporates some of the features of both spot and barrage noise and deception jammers is called "smart Noise" jammer. This is a repeater-type jammer used in a transponder mode to generate responsive noise over a short span of range, synchronized to the victim radar. This type of jammer generates a noise burst whose duration occurs before and after the actual target return, thereby covering the true number of threat radars by way of time-sharing.[1]

Decoy

Other active ECM techniques include the use of decoy devices that can range from simple drones, which simulate attacking targets, to more complicated expendable devices that simulate the electronic signature of actual attacking aircraft or missiles. This type of ECM is generally referred to as expendables, and their primary effect is through the deception and confusion they create and their capability of overloading the defensive system. The limited number of expendables that can be carried by an attacking force makes the timing of their deployment critical for maximum effectiveness.

Chaff

The most widely known and used from of passive ECM is called chaff. Basically, chaff consists of quantities of radar reflecting material, such as aluminum foil, which has been cut to lengths of approximately one-half wavelength of the radar frequency band that is of interest. In airborne applications rockets fired in the direction of the victim radar usually dispense the chaff. The chaff then blooms, or spreads through a wide area, and its high reflectivity either conceals the true targets or confuses the defending radar.

Important Consideration

In the foregoing, ECM has been considered from the attacker's point of view, but ECM techniques are also available to and used by the defender. He, too, has much to gain by depriving his opponent of as much information as possible and, to this end, passive methods of target detection are preferred to active methods. Where passive detection is possible (e.g., by ESM), the attacker will not know that he has been detected, nor the location of enemy radar nets. In addition, jamming of the attacker's navigation systems (e. g., *terrain following radar*) may force the attacker into a more vulnerable situation with respect to the defender's weapon systems.

ECM Against Communications Systems

The discussion up to this point has emphasized ECM against radar targets. This will be the most prevalent type of ECM in airborne or naval engagements. However, in land engagements, a major part of EW activity is the interception and location of short range and low power, HF, VHF, and UHF radio transmissions used by the enemy in the forward battle area. Typical ESM units include both interception and direction finding (DF) capabilities.

The philosophy of ECM against communications emitters is somewhat different than that against radars. A major reason for this is that intercepted communications traffic becomes a major intelligence source that is available to the commander. Also, the density and methods of operating tactical radios, particularly the netting, is different from radar. An essential ingredient to communications jamming is radio direction finding (RDF).

Electronic Counter-Counter Measures (ECCM)

Electronic Counter-Counter Measures (ECCM) is that division of EW involving actions taken to insure friendly effective use of electromagnetic spectrum despite the enemy's use of EW. One characteristic of that ECCM is mostly concerned with techniques that are embodied in the design of electronics equipment (e.g., surveillance radar), while ECM usually requires a separate item of equipment that operates in its own right and not as an adjunct to another system. However, the battle of the ECM *versus* the ECCM designer is basically a battle of resources. A truism in the ECM/ECCM world is that any radar or communication system can be jammed and any ECM can be countered, depending on the resources that either side is willing to commit.

Defense Suppression

The objective of lethal defense suppression is the physical destruction of a radiating emitter that is a component of an enemy defense system. An ancillary principle of this form of defense suppression is that an enemy will be inhibited in the full use of the electronic systems by the presence of a potentially lethal destroyer of radiation sources.

The most prominent lethal defense suppression system is the anti-radiation missile (ARM). ARMs are primarily directed against radar-type emitters, although any radiation source is potentially vulnerable. The *high-speed anti-radiation missile* (HARM) system is typical of current ARM technology. This high-performance, air-to-ground tactical missile utilize a broadband RF monopulse sensor to seek out, home on, and destroy an enemy radar.

Current Definitions

However, the terms and definitions in this study are those appropriate to the time frame described. The current (1998) military definitions for electronic warfare and related areas given below. Readers should note, however, that this subject is continually evolving and definitions are liable to change or new ones might appear.[2]

Electronic Warfare (EW)

A military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to the attack the enemy. The three major subdivisions within electronic warfare are:

Electronic Attack (EA)

That division of electronic warfare involving the use of electromagnetic or directed energy to attack personnel, facilities or equipment with the intent of degrading, neutralizing or destroying enemy combat capability. The term includes those aspects of the subject that previously came under the heading of **Electronic Countermeasures (ECM)**.

Electronic Protection (EP)

That division of electronic warfare involving actions taken to protect personnel, facilities and equipment from any effects of friendly or enemy employment of electronic warfare that degrade, neutralize and destroy friendly combat capability. The term includes those aspects of the subject that previously came under the heading of ***Electronic*** **Counter-Countermeasures (ECCM)**.

Electronic Warfare Support (ES)

That division of electronic warfare involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify and locate sources of intentional and unintentional radiated electromagnetic energy for the purpose of immediate threat recognition. Electronic warfare support provides information required for immediate decision involving electronic warfare operations, threat avoidance, targeting and other tactical actions. The term includes those aspects of the subject that previously came under the headings of **Electronic Warfare Support Measures (ESM)** and **Signal Intelligence (SIGINT)**.

Command and Control Warfare (C^2W)

The integrated use of operations security (OPSEC), military deception, psychological operations (PSYOP), electronic warfare (EW) and physical destruction, mutually supported by intelligence, to deny information to, influence, degrade or destroy adversary command and control capabilities against such actions. C^2W applies across the operational continuum and all levels of conflict. C^2W is both offensive and defensive. The term includes those aspects of the subject that previously came under the heading of **Command, Control and Communications Countermeasures (C^3CM)**. The two major subdivisions within Command and Control warfare are:

Counter C^2

To prevent effective C^2 of adversary forces by denying information to, influencing, degrading or destroying the adversary C^2 system.

C^2 Protection

To maintain effective command and control of one's own forces by turning to friendly advantage of negating adversary efforts to deny information to, influence, degrade or destroy the friendly C^2 system.

Information Operations (IO)

Actions taken to access and/or affect adversary information system, while defending one's own information and information systems.

Information Warfare (IW)

Information Operation conducted during time of crisis or conflict to achieve specific objectives over a specific adversary or adversaries.

Chapter 2

Fundamental Concepts

Science and Technology

Science is the search for relationships that explain and predict the behavior of the universe. *Technology* is the application of these relationships to our needs and goals.

Matter

The world around us is filled with objects of many kinds. There are people, chairs, books, trees, and lumps of sugar, ice cubes, drinking glasses, doorknob, and endless number of other familiar objects. Each of these objects may be characterized by its size, shape, use, color, and texture. Many unlike objects have certain things in common. For example, a tree and a chair are both made of wood. Millions of other objects with different shapes and purposes may also be made of wood. The word *material* is used in referring to a specific kind of matter (such as wood). Familiar materials include wood, steel, cooper, sugar, salt, nickel, concrete, and milk.

Scientists call all material matter. Matter may be as difficult to observe as the particles that produce the odor of perfume. It may be as easy to observe as a block of steel. *Matter is usually defined as anything that has mass and occupies space*. All the objects in the universe, since they occupy space and have mass, are composed of matter. The property of occupying space is often easily perceived by our senses of sight and touch. The property of *mass* of an object pertains to the quantity of matter that the object contains. Hence, the force required to give an object a given acceleration, or the resistance of the object to being moved (*inertia*), is a measure of its mass.

Inertia

Also, scientists define matter as anything has the property of inertia. What is inertia? *Inertia* is the resistance of matter to any change in motion. This change can be in either the direction or the rate of motion, or in both. For example, suppose you are riding in a moving car. When the car is stopped suddenly, your body tends to continue to move forward. If the car makes a sharp turn, your body tends to continue to move in its original direction. Thus, you are thrown against the side of the car opposite from the direction of the turn. In both cases, your body is showing the property of inertia. All matter has the property of inertia.

There are different ways of describing the quantity of matter. Volumes are often used for this purpose. You commonly buy milk, oil, juices, and other liquids by volume. Weight is another way of describing the quantity of matter. You buy bread, for example, by weight. However, volumes and weights are not always reliable for describing the quantity because they change under different circumstance. The volume of a sample of matter, for example, may with its temperature. (This property of matter is put to good use in thermometers.) Weights change with location. The weight of a body is lightly less at the top of a mountain than at sea level. Its weight is much less on the moon than on earth.

For specifying the amount of a particular sample of matter, we need a property of matter that is constant. Such a property is the mass of a body. Mass is a measure of the quantity of matter. The mass of a body is not affected by temperature, location, or any other factors that known to make other measures of quantity unreliable.

A balance is usually used to measure masses. A common type of balance has two pans (or platforms). On one platform the object of unknown mass is placed. On the other platform objects of known mass are placed until the two platforms balance each other.

The mass of the unknown is equal to the sum of all the known masses. In physics and chemistry it is common to measure masses in grams.

Energy

Energy is defined as the capacity to do work. Work is done whenever a force is applied over a distance. Therefore, anything that can force matter to move (or force moving matter to change speed or direction) has energy. The following example may help you understand this definition of energy. When you wind a watch, you bend a steel spring into a position of strain. The bent spring then exerts a force on the gears in the watch. This force causes the gears to turn. Therefore, as the spring unwinds, it does work on the gears. After a time, the watch stops because the spring is unwound. When the spring is unwound, it no longer exerts a force on the gears. In its wound-up condition, the spring had the capacity to do work. In other words, it contained energy. In its unwound condition, it no longer has that capacity. All objects possess energy. So is an automobile, an atom, and an electron. The word energy comes from a Greek word meaning "work-within." We may interpret energy as meaning the capacity to do work

Energy is sometimes quite noticeable because we have sense organs that are able to detect its presence in various forms. Our eyes respond to visible light energy. Our ears detect sound energy. Special nerves are sensitive to temperature, an indication of heat energy. Other nerves respond to electric energy.

Scientists have discovered forms of energy in addition to those that can be detected by our sense organs. Special detecting and measuring instruments had to be developed to record these forms of energy in a form that we can sense. For example, we cannot directly sense X-rays, a form of energy similar to visible light. But X-rays can affect special photographic film. Under visible light, we can look at a piece of exposed and developed X-ray film and tell where the X-rays have affected the film. As another example, we cannot directly sense small amounts of infrared radiation, an invisible form of energy similar to visible light. (We can feel large amounts of infrared radiation as heat.) However, a special thermometer exposed to infrared radiation registers an increase in temperature. We can study the behavior of the thermometer and say that invisible radiation is present. By means of devices much as these, scientists have extended the range and sensitivity of the human senses. Among the forms of energy that fall into this "extrasensory" category that humans cannot directly detect are chemical energy, gravitational energy, nuclear energy, and forms of energy similar to visible light, such as X-rays and infrared rays.

Classes of Energy

All energy can be grouped into two classes–stored energy and energy of motion. In the previous section we used a wound-up watch spring as an example of something that has energy–the capacity to do work. However, unless the spring is allowed to unwind, no work is done by the energy it contains. We think of this energy as being *stored* in the wound-up spring, ready to do work under certain conditions. Such stored energy is called *potential energy*.

Once the watch spring starts to unwind, its motion enables it to do work–to move the gears of the watch. The stored-up energy is "released" as moving energy, or energy of motion. Such is called *kinetic energy*. All matter in motion has kinetic energy.

Forms of Energy

We gradually give special names to energy depending on the conditions under which it appears. Energy associated with chemical change is called *chemical energy*. When energy is used to exert a force and produce motion, as in a watch, the energy of the moving parts is called *mechanical energy*. An electric current carries energy and can do work. It can turn an electric motor, for example. The energy in electric current is called *electrical energy.*

Radiant Energy

Energy is observed in various other phenomena. For example, light waves carry *electromagnetic (or radiant) energy.* Sound waves carry *sound energy. Magnetic energy* can be stored in the space around a magnet. This space is called the magnet's magnetic field. Finally, there is a very common form of energy called *heat.*

Energy can be transferred between objects in two ways: through direct contact and through electromagnetic waves. An example of direct transfer is the collision of two billiard balls. Kinetic energy is transferred directly from one ball to the other. An example of electromagnetic waves is the transfer of energy from the sun to the earth. Energy being transferred by electromagnetic waves is often called *radiant energy.*

Conversion of Energy

Many other terms we use to describe energy are special cases or combinations of potential, kinetic, and radiant energy. Energy can be transformed from one kind to another. For instance, think about battery-alternator system of a car. As the starter switch is turned on, the chemical energy in the battery is converted to electric energy. The car starts and chemical energy in the gasoline is converted into the energy of the moving car. As the crankshaft gains speed, its mechanical energy is transferred by belt and pulley to the alternator. In the alternator, the mechanical is converted into electrical energy. This electric energy is transferred to the battery where it is converted to chemical energy. The battery is thus recharged. During this time, other energy transformations result in the production of heat and sound. With the exception of nuclear change, all such transfers of energy occur without an observable loss or gain in the total amount of energy.

The Relationship Between Matter and Energy

For years, scientists thought that the total amount of matter and the total of energy in the universe were each constant. They stated their observations in the form of two laws. These laws of conservation of matter and the law of conservation of energy.

The *law of conservation of matter* states that matter is always conserved. This statement means that the ideal amount of matter in the universe remains constant. Matter is neither created nor destroyed. It is only changed in form.

The *law of conservation of energy* states that energy is always conserved. This statement means that the total amount of energy in the universe remains the same. Energy is neither created nor destroyed. It too, is only changed in form.

In the early 1900's, Albert Einstein showed that matter could be changed to energy. He also showed that energy could be changed to matter. Einstein expressed this relationship in his famous equation:

$$E = m c^2$$

In this equation, E is energy, m is mass, and c is the speed of light in a vacuum (a constant).

According to Einstein's equation, mass and energy are equivalent. Thus we see that the two conservation laws are really just one law. This law is known as the law of conservation of matter-energy. Because mass is a measure of the amount of matter, this law is usually called the law of conservation of mass-energy. The *law of conservation of mass-energy* states that mass and energy are always conserved and that their sum cannot be increased or decreased. Mass and energy can, however, be changed from one to the other. Changes of energy to mass and mass to energy are observable only in nuclear reactions.

Waves

If a particle applies a force to another particle through a distance, then a transfer of energy has taken place through *particle collision*, one particle will gain energy, and the other will lose energy. If we are to believe the law of conservation of energy, and we know of no instance where the has failed, then the increase of energy of one particle will be equal to the decrease of energy of the other, assuming we neglect heat losses. In all cases, we find a transfer of energy takes place whenever two or more particles collide with one another.

When matter is disturbed, energy emanates from the disturbance; this emanation of energy is known as wave motion. For example, a stone dropped on the surface of a pound of water will disturb the water, and energy will be transferred outward from the disturbance as wave motion.[3] However, energy is always needed to make waves.

A similar situation can occur in a solid. For example, during an earthquake a disturbance takes place because of a slippage or other cause, and this disturbance is transmitted to all parts of the Earth as wave motion. Again, this is a transfer of energy, not matter. *The transfer of energy takes place with or without a medium.*

Sound waves in the air and waves upon stretched strings and steel wires are examples of energy transmission that require a medium (air, strings, and wires in the above cases). The neighboring particles of the media react upon one another to transfer the disturbance. *Electromagnetic waves, including radio, infrared, light, and X-rays, are transferred without a medium.* We say these disturbances are radiated through space.

Our eyes and ears are two wave-detecting devices that serve to link us to our environment. Since a study of wave motion seems relevant to an understanding of our physical environment, knowledge of wave motion is essential to understanding of many scientific principles.

The disturbance generating a wave motion is usually periodic; that is, the disturbance is repeated again and again at regular intervals. However, the disturbance, and the resulting wave motion, does not necessarily have to be periodic; it may be a simple pulse, or shock wave, such as the one originating from a book hitting the floor or from a jet plane passing through the sound barrier.

When the disturbance moves with the velocity vector parallel to the direction in which the particles were displaced. The velocity is known as *wave velocity*; when the particle displacement and the wave motion are in the same direction the wave is called a *longitudinal wave*, sound waves are of this type.

The term *transverse wave* is used to denote wave motion in which the individual particles are displaced perpendicular to the direction of the wave velocity vector. An example of a transverse wave in a stretched rubber cord. The cord is disturbed from its equilibrium position by moving the end of the cord up and down. Moving the cord end from side to side–or in any direction–will also produce a transverse wave.

The transfer of energy by transverse waves can take place in the absence of a medium. *All electromagnetic radiation is of this type of wave motion.* The study o wave motion has resulted in certain terms that are used to explain the action of all waves. *Velocity describes the direction and magnitude of the wave motion. The velocity of a longitudinal wave depends upon the properties of the medium.*

The wave consists of a hill and a valley. The hill is called the *crest*. The valley is called the *trough*. The distance between the crest of one wave and the crest of the next wave is the *wavelength. Amplitude* is the height or depth of the wave. Fig. 2-1 A sinusoidal Wave: Wavelength is the distance from crest to crest. Amplitude is the height of the wave.

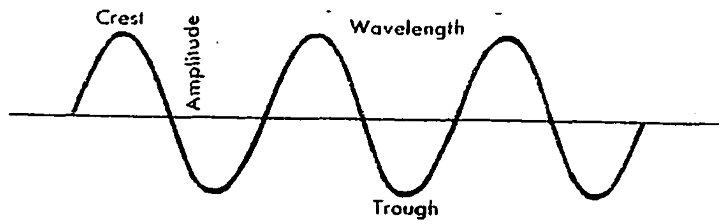


Fig. 2-1 A sinusoidal Wave: Wavelength is the distance from crest to crest. Amplitude is the height of the wave.

Frequency

The frequency is the number of oscillations, or complete waves, that occur during a given period of time, usually one second. The units of frequency are *cycles per second.* This unit is given the name *Hertz.* One Hertz (Hz) is one cycle per second. For example, if five complete wave crests pass a given spot in one second, the frequency would be five cycles per second or five Hertz.

Period

The *period* of a wave is the time it takes for one complete wave oscillation. If five crests pass by a given point in one second, one crest or complete cycle would pass in one-fifth of a second, and the period would be 1/5 second. The frequency would be 5 cycles per second. From this example it is to se that:

Frequency = 1/Period or

$$f = 1/T$$

Wavelength

The *wavelength* of a wave is measured in units of length. One wavelength is the distance from any point on a wave to an identical point on the adjacent wave. A simple relation between wave velocity, wavelength, and period (or frequency) exists. This can be written as:

$$v = \frac{\lambda}{T} \quad \textbf{Or} \quad v = \lambda f$$

Where v = wave velocity measured in meters per second or any other velocity units,

λ = Wavelength, measured in length unit,

T = Period of the wave, usually measured in seconds.

f = Frequency of the wave, measured in cycles per second or Hertz.

Amplitude

The amplitude of a wave refers to the maximum displacement of any part of the wave from its equilibrium position. The amplitude of the wave does not affect the wave velocity. The energy transmitted by a wave is related to the square of its amplitude. Amplitude depends on the amount of energy in a wave. As the wave energy increases, the amplitude increases. For example, if you drop a large rock instead of a pebble into a pond, a bigger wave results. The amplitude is greater.

The Atomic Structure

The Molecule

One of the oldest, and probably the most generally accepted, theories concerning electric flow are that it is comprised of moving electrons. This is the **Electron Theory**. Electrons are extremely tiny parts, or particles, of matter. To study the electron, you must therefore study the structural nature of matter itself. (Anything having mass and inertia, and which occupies any amount of space, is composed of matter.) To study the fundamental structure or composition of any type of matter, it must be reduced to its fundamental fractions. Assume the drop of water was halved again and again. By continuing the process long enough, you would eventually obtain the smallest particle of water possible–the molecule. All molecules are composed of atoms.

A molecule of water (H_2O) is composed of one atom of oxygen and two of hydrogen. If the molecule of water were further subdivided, there would remain only unrelated atoms of oxygen and hydrogen, and the water would no longer exist as such. This example illustrates the following fact–the molecule is the smallest particle to which a substance can be reduced and still be called by the same name. This applies to all substances–liquids, solids and gases.

When whole molecules are combined or separated from one another, the change is generally referred to as a *Physical* change. In a *Chemical* change the molecules of the substance are altered such that new molecules result. Most chemical changes involve positive and negative ions and thus are electrical in nature. All matter is said to be essentially electrical in nature.

The Atom

In the study of chemistry it soon becomes apparent that the molecule is far from being the ultimate particle into which matter may be subdivided. The salt molecule may be decomposed into radically different substance–sodium and chlorine. These particles that make up molecules can be isolated and studied separately. They are called *Atoms*.

The atom is the smallest particle that makes up that type of material called an *Element*. The element retains its characteristics when subdivided into atoms. More than 100 elements have been identified. They can be arranged into a table of increasing weight, and can be grouped into families of material having similar properties. This arrangement is *called Periodic Table of the Elements*.

The idea that all matter is composed of atoms dates back more than 2,000 years to the Greeks. Many centuries passed before the study of matter proved that the basic idea of atomic structure was correct. Physicists have explored the interior of the atom and discovered many subdivisions in it. The core of the atom is called the *Nucleus*. Most of the weight of the atom is concentrated in the nucleus. It is comparable to the sun in the solar system, around which the planets revolve. The nucleus contains *Protons* (positively charged particles) and *Neutrons*, which are electrically neutral.

Most of the weight of the atom is in the protons and neutrons of the nucleus. Whirling around the nucleus are one or more smaller particles of negative electric charge. *These are the Electrons.* Normally there is one proton for each electron in the entire atom so that the net positive charge of the nucleus is balanced by the net negative charge of the electrons whirling around the nucleus. *Thus the Atom is Electrically Neutral.*

The electrons do not fall into the nucleus even though they are attracted strongly to it. Their motion prevents it, as the planets are prevented from falling into the sun because of their centrifugal force of revolution.

The number of protons, which is usually the same as the number of electrons. For example, hydrogen has a nucleus consisting of 1 proton, around, which rotates 1 electron. The helium atom has a nucleus containing 2 protons 2 neutrons with 2 electrons encircling the nucleus. Near the other extreme of list of elements is curium, an element discovered in the 1940's, which has 96 protons and 96 electrons in each atom.

The *Periodic Table of the Elements* is an orderly arrangement of the elements in ascending atomic number (number of planetary electrons) and also in atomic weight (number of protons and neutrons in the nucleus). The various kinds of atoms have distinct masses or weights with respect to each other. The element most closely approaching unity (meaning 1) is hydrogen whose atomic weight is 1.008 compared with oxygen whose atomic weight is 17. Helium has an atomic weight of approximately 4, lithium7, fluorine 19, and neon 0, as shown in figure.

The atom is then further reduced to its subatomic particles–the protons, neutrons, and electrons. Subatomic particles are electric in nature. That is, they are the particles of matter most affected by an electric force. Whereas the whole molecules or whole atom is electrically neutral, most subatomic particles are not neutral (with the exception of the neutron). Proton is inherently positive, and electrons are inherently negative. It is these inherent characteristics, which make subatomic particles sensitive to electric force.

When an electric force is applied to a conducting medium, such as copper wire, electrons in the outer orbits of the copper atoms are forced out of orbit and impelled along the wire. The direction of electron movement is determined by the direction of the impelling force. The protons do not move, mainly because they are extremely heavy. The proton of the lightest element, hydrogen, is approximately 1,850 times as heavy as an electron. Thus, it is the relatively light electron that is most readily moved by electricity.

When an orbital electron is removed from an atom it is called a **Free Electron**. Some of the electrons of certain metallic atoms are so loosely bound to the nucleus that they are comparatively free to move from atom to atom. Thus, a very small force or amount of energy will cause such electrons to be removed from the atom and become free electrons. It is these free electrons that constitute the flow of an electric current in electrical conductors.

If the internal energy of an atom is raised above its normal states, the atom is said to be *excited*. Causing the atoms to collide with particles that are impelled by an electric force may produce excitation. In this way, energy is transferred from the electric source to the atom. The excess energy absorbed by an atom may become sufficient to cause loosely bound outer electrons to leave the atom against the force that acts to hold them within. An atom that has thus lost or gained one or more electrons is said to be *ionized.* If the atom loses electrons it becomes positively charged and is referred to as a *Positive Ion.* Conversely, if the atom gains electrons, it becomes negatively charged and is referred to as a *Negative Ion.* Actually, then, an ion is a small particle of matter having a positive or negative charge.

Magnetism

The magnetic properties of the mineral lodestone[4] (magnetite, Fe_3O_4) were known to the Greeks as early as 600 B.C. Thales of Miletus (640-546 B.C.), an early Greek mathematician and astronomer, was aware of the properties of attraction and repulsion of lodestone with similar pieces of lodestone; he also knew of an electrostatic effect called the amber effect, that is, the attraction bits of straw to an amber rod that had been rubbed with wool.[5]

The word "magnet" seems to have been derived from Magnesia, a province in Asia Minor (not too far from home town Aleppo), where the Greeks first discovered lodestone. The Chinese were probably the first to use the lodestone as a compass, both on land and sea. Early records indicate that ships sailing between Canton, China, and Sumatra, Indonesia, as early as 1000 A.D. were navigated by the use of magnetic compass.[6]

In the thirteen century, a Frenchman, Petrus P. de Maricount, described the magnetic compass in some detail and applied the term "pole" to the regions on the compass where the fields of influence were strongest. The north-seeking pole he called N, and the south-seeking pole he called S. the attraction of unlike poles, the repulsion of the poles, and De Maricount also described the formation of new unlike poles when a magnet was broken into two pieces.

In 1600 Dr. William Gilbert (1540-1603), court physician to Queen Elizabeth, published his book on magnetism, De Magnete. The book contained all information then known about electricity and magnetism, plus experiments carried out by Gilbert. These experiments included information on the dip (the angle the Earth's magnetic field makes with the Earth's surface) and declination (the angle the compass needle deviates from the geographical north) of the compass, the loss of magnetism by a magnet when heated, and experiments with a sphere-shaped magnet, which led him to conclusion the earth act like a huge magnet.[7]

Gilbert was also aware of the amber effect. We now know that this effect is due to repulsion and attraction of electric charges. Gilbert carried out many experiments on the amber effect with an instrument he called a *versorium* (Latin, *verso*, to turn around). The versorium was nothing more than a slender arrow-type non-conducting material balanced on a pivot point so as to give a high degree of sensitivity to the force of attraction when an amber rod or other substances were placed in its vicinity. With his versorium he discovered that many substances possess the amber effect. Gilbert is responsible for the word "electron," which is very familiar today. He classified those substances possessing the amber effect as "electrics" (Greek, *electron*, amber).[8]

A similar major study of electricity and magnetism took place in the eighteenth century, when Charles Coulomb (1736-1806) established the inverse square law of attraction and repulsion between electrostatic charges, and verified the same law to hold for magnetic poles.[9]

Electric and magnetic phenomenon was studied in detail during the 1800s. in 1820 Hans Christian Oersted (1777-1851) found that a compass is deflected by a current-carrying wire. In 1931 Michael Faraday (1791-1865) and Joseph Henry (1797-1878) independently found that a magnet plunged into a coil of wire would induce an electric current.[10]

The laws of electricity and magnetism discovered by Coulomb, Oersted, Faraday, Henry, and others were studied in detail by James Clerk Maxwell (1831-1879), a Scottish physicist, Maxwell wondered why the physical laws were symmetric when expressed in mathematical form. By applying the concept of symmetry he discovered an additional law, which completed the equations of electromagnetism in 1865.[11]

By 1885 experimental confirmation of the electromagnetic theory was achieved by the German physicist Heinrich Rudolf Hertz (1857-1894). Hertz showed that light transmissions and electrically generated waves are of the same nature. Of course, many of their properties are different because of great differences in frequency.[12]

Maxwell studied these equations and found that according to the equations, light is made up of electromagnetic waves. Radio waves were also predicted at much lower frequency than visible light waves. The theoretical fact that electromagnetic waves of radio frequency are possible led to experiments in which radio waves were generated and detected. This opened up a new ear or wireless communication and eventually brought us commercial radio and television and a host of other devices including electronic warfare.

A substance is said to be a magnet if it has the property of magnetism–that is, if it has the power to attract such substances as iron, steel, nickel, or cobalt, which are known as *Magnetic Materials*. A steel knitting needle, magnetized by a method to be described later, exhibits two points of maximum attraction (one at each end) and no attraction at its center. The points of maximum attraction are called *Magnetic Poles*. All magnets have at least two poles. If the needle is suspended by its middle so that it rotates freely in horizontal plane about its center, the needle comes to rest in approximately north-south line of direction. The same pole will always point to the north, and the other will always point toward the south. The magnetic pole that points northward is called the *North Pole*, and the other the *South Pole*.

A *Magnetic Field* exists around a simple bar magnet. The field consists of imaginary lines along which a *Magnetic Force* acts. These lines emanate from the north pole of the magnet, and enter the South Pole, returning to the North Pole through the magnet itself, thus forming closed loops.

A *Magnetic Circuit* is a complete path through which magnetic lines of force may be established under the influence of a magnetizing force. Most magnetic circuits are composed largely of magnetic materials in order to contain the magnetic flux. These circuits are similar to the *Electric Circuits*, which is complete path through which current is caused to flow under the influence of an electromotive force.

Magnets may be conveniently divided into three groups:

1. *Natural Magnets*, found in the natural state in the form of a mineral called magnetite.
2. *Permanent Magnets*, bars of hardened steel (or some form of alloy such as alnico) that have been permanently magnetized.
3. *Electromagnets* composed of soft iron cores, which are wound coils of insulated wire. When an electric current flows through the coil, the core becomes magnetized. When the current ceases to flow, the core loses most of its magnetism.

Permanent magnets and electromagnets are sometimes called *Artificial Magnets* to further distinguish them from natural magnets.

Natural magnets

For many centuries it has been known that certain stones (magnetite, Fe_3O_4) have the ability to attract small pieces of iron. Because many of the best of these stones (natural magnets) were found near magnesia in Asia Minor (now is known Turkey), the Greeks called the substance **Magnetite**, or **Magnetic**.

Fundamental Concepts of Electricity

The word "electric" is actually a Greek-derived word meaning *Amber*. Amber is translucent (semitransparent) yellowish mineral, which, in the natural form, is composed of fossilized resin. The ancient Greeks used the words "electric force" in referring to the mysterious forces of attraction and repulsion exhibited by amber when it was rubbed with a cloth. They did not understand the fundamental nature of this force. They could not answer the seemingly simple question, "what electricity?" This question is still unanswered. Though you might define electricity as "that force which moves electrons," this would be the same as defining an engine as "that force which moves an automobile." You would have described the effect, not the force.[13]

We presently know little more than the ancient Greeks knew about the fundamental nature of electricity, but tremendous strides have been made in harnessing and using it. Elaborates theories concerning the nature and behavior of electricity have been advanced, and have gained wide acceptance because of their apparent truth and demonstrated workability.

From time to time various scientists have found that electricity seems to behave in a constant and predictable manner in given situations, or when subjected to given conditions. These scientists, such as Faraday, Ohm, Lenz and Kirchhoff, to name only a few, observed and described the predictable characteristics of electricity and electric current in the form of certain rules. These rules are often referred to as "laws." Thus, though electricity itself has never been clearly defined, its predictable nature and easily used form of energy has made it one of the most widely used power sources in modern time. By learning the rules, or laws, applying to the behavior of electricity, and by learning the methods of producing, controlling and using it you will have "learned" electricity without ever having determined its fundamental identity.

Radiation

When we look up at the sky on a clear, moonless night, we can see points of light called stars. We are able to see them because stars are really huge balls of glowing gases that constantly send out light across the vast distances of space.

Light from the stars is a form of radiation. Like all radiation, it travels in waves. But unlike other kinds of radiation, light waves are the only ones our eyes can see. When we look at the stars through a telescope, the lens collects and concentrates the light waves into images, making the stars appear brighter and clearer to us.

Besides lights, stars and other objects in the universe send out, or emit, other forms of radiation. Part of this radiation is sent out as radio waves. Special radio receivers here can detect some of these waves on earth. These receivers gather and concentrate the radio waves, just as optical telescopes collect and concentrate light waves.

To fully appreciate what radio wave involves, it is essential to look briefly at the nature of the phenomenon that makes this science possible–the spectrum, or range, of the radiations that fill our universe.

If you switch on an electric lamp, rays of light spread out in all directions. These *light waves,* as they called, are a form of radiation. If you stand close to a warm radiator, you can feel the heat coming to your body. The radiator is radiating heat waves, another form of radiation. When a broadcaster speaks into the microphone at a radio station, his voice is changed into a form of radiation. Radio radiations, or radio waves, spread out from the station in all directions. When you turn your radio on, you pick up these radio radiations, upon which have been superimposed the voice of the broadcaster. X-rays and ultraviolet waves are other forms of radiation. Yet all of them travel at the same speed through empty space–186,282 miles per second or 300,000 kilometers per second.[14] Different forms of radiation can be detected in different ways.

- Light can be seen.
- Heat can be felt. But some radiation,
- Such as radio waves, can only be detected with instrument; in radio astronomy, the key instrument is the radio telescope.

Scientists know that most kinds of radiation are forms of electricity and magnetism. For this reason, most radiation is known as *electromagnetic radiation.* Radiation can have electrical effects; for example, a beam of light can operate an electrical device that opens the doors of supermarkets, hotels and banks for us. But magnetic fields also have an effect on radiation. The famous English physicist Michael Faraday discovered that a beam of polarized light could be twisted if the beam was passed through certain substances along their magnetic lines of force.

But how is radiation actually produced? The answer is, most of it starts inside atoms. Scientists have learned that each has a center, or nucleus. Each kind of atom also contains a particular number of electrons. An atom of hydrogen, for example, contains one electron; an atom of iron has twenty-six electrons; and so on. The electrons circle around the nucleus in orbits, or shells. They may be several shells around the nucleus of an atom, and each shell may have one or more electrons.

Sometimes an electron is hit by another particle or some tiny bit of incoming energy. When it is, the electron jumps to another shell that is farther from the nucleus. The new orbit, however, is not its natural one. The electron does not belong there, so it quickly falls back into its own orbit. As it falls back, it releases a small quantity of energy. Electron may be knocked out of their orbits over and over again, and as they fall back the tiny quantities of energy will be released very quickly from the atom. This rapid release of energy is known as radiation.[15]

In order for an atom to radiate energy, it must first absorb energy. Its electrons are knocked out of their orbits by energy from outside the atom. The amount of energy an atom can radiate is usually the same amount of energy it absorbed.

The atoms of an object can also give off two or more kinds of radiation at the same time. For example, a piece of red-hot iron radiates both heat and light at the same time. For many decades, scientists tried to find out why radiation takes different forms. The first clue came when they discovered that all radiation travels outward from atoms in the form of waves. Think of an electron falling back in its orbit as being like a pebble falling into a pond. When the pebble falls, tiny ripples or waves spread outward in the pond. If the pebble falls from a great height, more energy in the form of bigger waves results.

The Nature of Wavelength

In the same way, when an electron drops back into its original orbit, waves of radiation are sent out. If the electron has fallen from an orbit near the original one, the waves will carry only a little energy. But if it has fallen from a more distant orbit, the waves created will carry more energy. Scientists observe this greater energy as a difference in the length of the wave that an atom emits. The length of a wave of radiation is the distance between the crest of one wave and the crest of the next. This is called the *wavelength.*[16]

Electromagnetic Waves

When charged particles such as electrons are vibrating, energy is radiated away from them in the from of *electromagnetic waves*, electromagnetic waves consist of vibrating electric and magnetic fields. A drawing of an electromagnetic wave is shown in

Fig. The drawing shows the wave traveling in the x direction. The electric and magnetic field vectors are at angles of 90° to one another, and the velocity vector of the wave is at an angle of 90° to both of the field vector. These are vectors fields. In electromagnetic waves they radiate outward at the speed of light, which is $3x10^8$ m/s. A model of an electromagnetic wave at a given instant is shown in Figure 2-2.

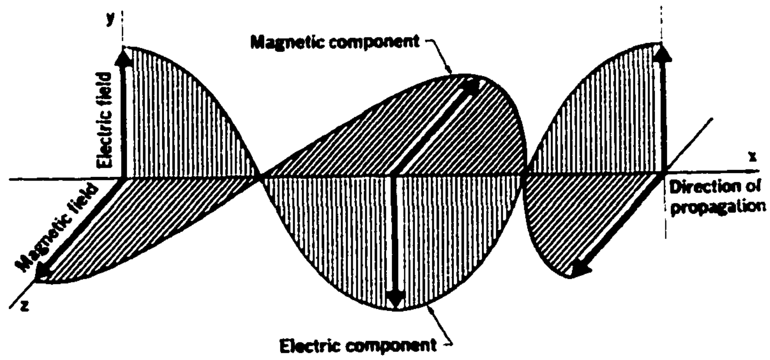


Fig. 2-2. Electromagnetic Wave. The electric and magnetic fields are each at right angles to the direction of propagation.

The production of Radio Waves

Charged particles are accelerated in many different ways to produce electromagnetic waves of various frequencies. Waves with low frequencies, or long wavelength, are known as *radio waves* and are produced primarily by causing electrons to oscillate, or vibrate, in a resonant circuit. The frequency of oscillation controlled by physical dimensions and other properties of the tuned circuit.[17]

The production of electromagnetic waves with frequencies greater than radio waves is accomplished by molecular excitation. In such cases, radiation occurs from the collision of molecules in hot gases and solids. Since the molecules carry charged particles that are greatly accelerated as the molecules vibrate, the particles will radiate electromagnetic waves ranging from 10^{12} Hz to 4.3 x 10^{14} Hz. This portion of the electromagnetic spectrum is called the *infrared* region.[18]

As the temperature of gases and solids is increased to higher and higher values, the atoms composing the molecules become more excited and electromagnetic radiation in the *visible* and *ultraviolet* regions of the spectrum is emitted. Still more energy applied to the atom will generate wave higher frequencies, called *X rays*, with range from $3x10^{17}$ to $3x10^{19}$ Hz.

If sufficient energy is applied to the atom to disturb the nucleus, radiation known as gamma rays is emitted. The major portion of the electromagnetic spectrum is shown in Fig.2-3. The portion of the spectrum visible to the human eye falls between the infrared and the ultraviolet wavelengths.

Electromagnetic Spectrum

Radiation wavelength varies from very long to very short. Scientists use a special kind of chart to list and identify the various wavelengths of electromagnetic radiation. It is called the *electromagnetic spectrum*. As can be seen in the Fig. 2-4 it is made with lines indicating every important wavelength from the longest to the shortest.

The whole range of electromagnetic wavelengths covers an amazingly large span. In the longest wavelengths on the spectrum, there may be miles between one crest and the next. At the other end of the spectrum, gamma rays have such short wavelengths that hundreds of millions of them could fit across the width of your fingernail.

Light Waves

The range of wavelengths that represents visible radiation–light waves–is only a very small part of the whole electromagnetic spectrum. The wavelengths of visible light, and their location on the spectrum, are halfway between the longest and shortest wavelengths.

Even within the visible light range of the spectrum, there is a great variety of wavelengths. Light radiation such as that from the sun is made up of every color. (When all the colors appear together, we see them as white light.) Each color has its own wavelength. Red light has a longer wavelength than any other color–about 33,000 waves cover an inch of space. It is the longest wavelength that can be seen by human beings. Violet is the shortest wavelength radiation that can be seen and is about 66,000 waves per inch.

The word *light* is commonly given to visible electromagnetic radiation. However, only the frequency (or wavelength) distinguishes visible electromagnetic radiation from the other portions of the spectrum. Our human eyes are only sensitive to certain frequencies or wavelength, but other instrument can detect other portions of the spectrum. For example, a radio receiver can detect radio waves.

Ultraviolet Rays

The electromagnetic spectrum extends past both sides of the visible light portion. Just past the shortest violet wavelengths is radiation in what scientists call the *ultra-violet range*. Ultraviolet rays are emitted strongly by the sun, and their wavelengths range from just above those of violet light to more than two and half million waves per inch. Farther across the spectrum are waves of even shorter wavelength–the X-rays. Widely used today in medicine and dentistry, some X-ray wavelengths are so short that 1000 of them are shorter than a single ultraviolet. And beyond the X-rays is another form of radiation entirely–gamma rays. These are the shortest wavelengths of all electromagnetic radiations and are emitted by certain radioactive substances.

On the other side of the visible light portion of the spectrum, immediately after the color red, is infrared radiation, which has a longer wavelength than red visible light. It is heat radiation. You cannot see it, but you can feel it. Kitchen appliances such as toasters and rotisseries toast and cook largely by means of infrared rays; the faint red color you can see inside a toaster is, of course, in the visible range of the spectrum.

Radio Waves

Beyond infrared rays, the next longest wavelengths in the spectrum belong to radiations that cannot be seen or felt. They can be detected only with radio equipment and are called *radio waves*. Radio wavelengths cover an immense range, from many miles in length to the shorter radio waves, such as those used in television and *FM* broadcasting that can be measured in feet and inches. It is in this band, or orange, of the shorter radio waves that the radio astronomer works with his radio telescope.

Since all electromagnetic radiation travels through empty space at the same speed–186,282 miles per second–heat rays, light rays, and other rays emitted by the sun take about eight minutes to reach the earth from 93 million miles away. But the short radio waves studied by the radio astronomer may take many millions of years to reach the earth, because most originate from places much farther away than the nearby sun.

Radio waves are not sound waves. They electromagnetic waves that are detected and then amplified by the radio frequency circuits of the radio receiver. The radio frequency signal is then demodulated. That is, the audio signal is separated from radio frequency carrier. The audio signal is amplified, and then applied to the speaker system that produces sound waves.

Sources of Radio Waves

Emanating from the vast depths of interstellar space, the origin points of these radio emissions are called *radio sources*. Sometimes astronomers call radio sources discrete, meaning that they come from separate or individual area sources in the sky. If, however, a radio source that can be picked up on a radio telescope emits continuous energy yet cannot be pinpointed in the heavens, it is called *radio noise*. The totality of these radio emissions, as they are discovered and mapped on various charts of the heavens, has come to be called the *radio universe*.[19]

Actually very little of the electromagnetic radiation that continually pulses through the universe succeeds in reaching the earth's surface. Most of it is absorbed or blocked by the earth's atmosphere. If this is so, how can radio astronomy be possible? Or, indeed, human sight itself, which depends on light-wave radiation? Fortunately, there are two narrow "windows" in the atmosphere that admit certain electromagnetic wavelength. Although not windows in the physical sense, they are two bands of electromagnetic radiation that penetrate the earth's atmosphere. They may, therefore, be thought of as two windows in an otherwise opaque atmosphere.

One of these may be thought of as the optical window, through which we can view the universe with the naked eye and telescope, making use of the wavelengths of visible light. The other is the radio window, through which passes the band of radio wavelengths used by the radio astronomer. The radio window is the wider of the two, as shown in the diagram. This band of radio wavelengths is capable of penetrating the earth's atmosphere, and it ranges from less than 1 centimeter on the short-wave side to 30 meters or more on the long-wave side. (One centimeter equals 0.39 of an inch; one meter equals 39.37 inches, or 3.28 feet.)[20]

It is within this radiation band that radio astronomers must detect and analyze the radio wavelengths arriving from outer space. However, in recent years scientists have developed photographic equipment that has extended the optical window on either side of the spectrum; that is, such radiation can be photographed and studied. Also, scientists can now arrange for recording and photographic equipment to be sent aloft in balloons, airplanes, satellites, and space ships to "listen in" on other parts of the electromagnetic radiation arriving from elsewhere in the universe. Hence, there are now such new branches of astronomy as ultraviolet, infrared, and X-ray astronomy.[21]

Radio astronomers have learned that there are two basic kinds of radiation in the radio spectrum that are produced by bodies in space. Some of these bodies, such as the sun, are so hot that they give off all kinds of radiations–heat, light, radio, and so on. The radio waves that emanate from such hot objects are called *thermal radio radiation.* ("Thermal" comes from the Greek word meaning "heat.") Radio astronomers deserve thermal radio radiation coming in from the sun, from a few other stars, and from clouds of hydrogen gas that surround some of the hottest stars.[22]

The second kind of radio waves that astronomers can observe is called *nonthermal radio radiation.* This radiation is produced when an object gives off almost all of its radiation as radio waves. The radio waves you receive on a radio set are nonthermal. They come from a broadcasting antenna that never becomes hot as it transmits the radio waves. A broadcasting antenna is an example of a nonthermal radiation source.[23]

Certain bodies in space, sometimes referred to as radio stars, are sources of nonthermal radio waves. This does not mean that they are necessarily stars like our sun. They may be clouds of interstellar gas or dust or other matter in space. Such dark substances may not be visible through an optical telescope, but radio telescopes are able to locate them. Today most astronomers prefer the term radio source to radio star.[24]

Actually nonthermal radio emission from space is produced by a much more powerful mechanism than that which produces thermal radiation. Scientists call this mechanism synchrotron emission. Interstellar space contains a vast storehouse of energy between the stars in the form of high-energy particles called *cosmic rays*, as well as an extensive magnetic field. When interstellar matter collides with these cosmic rays, electrons of high-energy content are rejected. They are then forced into spiraling paths by the magnetic field along its lines of force. Boosted along at speeds approaching the speed of light, these spiraling electrons emit radio energy in the same direction as their motion. Were it not for the synchrotron mechanism, radio astronomers would not receive nearly the amount of emission signals that they do. The synchrotron process gets its name from a similar radiation produced by laboratory accelerating machines called *electron synchrotron.*[25]

Sometimes, for the fun of it, radio astronomers hook up their radio telescope's antenna to a loudspeaker so that they can hear these broadcasts from space as audible sound waves. When they do, they can hear radio sources both inside the solar system and light-years away from it. (A light-year is the distance of light waves travel n one year, about six trillion miles.) Astronomer's say that they sun "sighs" intermittently, the Milky Way (our own galaxy consisting of billions of stars) "hisses" incessantly, and the planet Jupiter makes a deep, mournful, rumbling noise. The ancient Greeks, in their mythology, talked of the "music of the spheres"; by "spheres" they meant the stars and other heavenly objects. In a very literal sense, such audible sighs and murmurs heard by radio astronomers make up the true "music" of the spheres.[26]

Fig. 2-3 Electromagnetic Spectrum

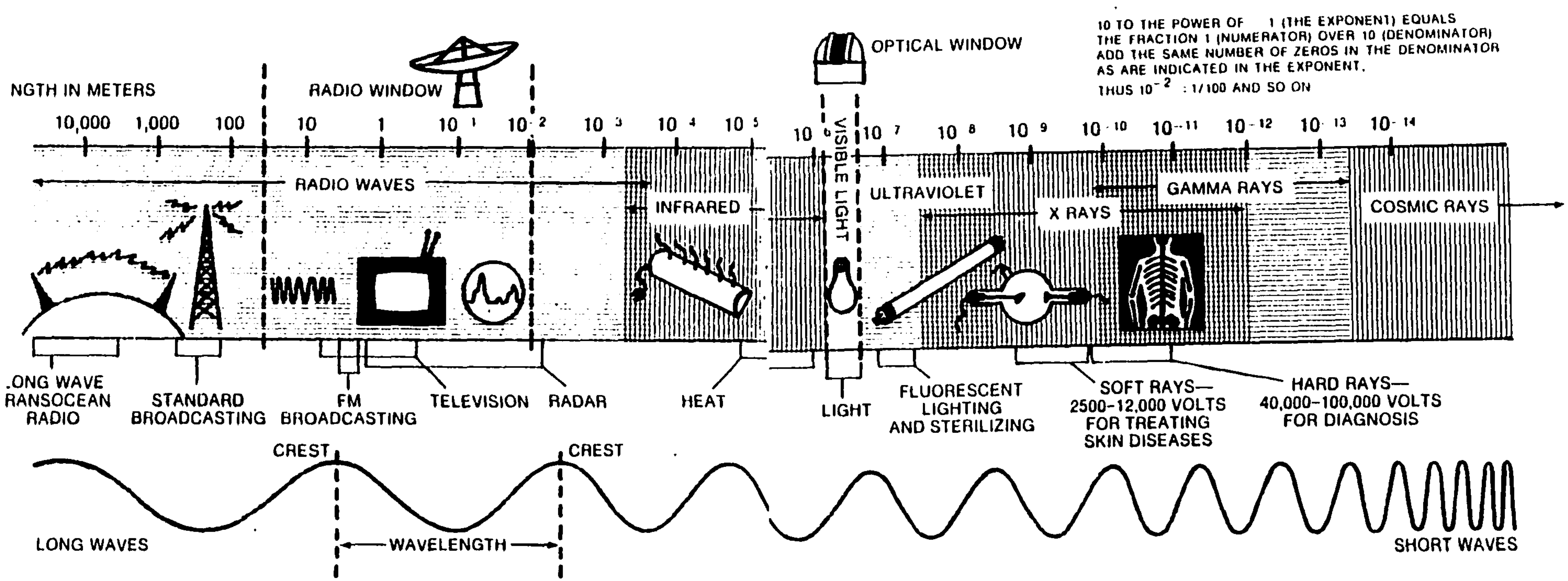
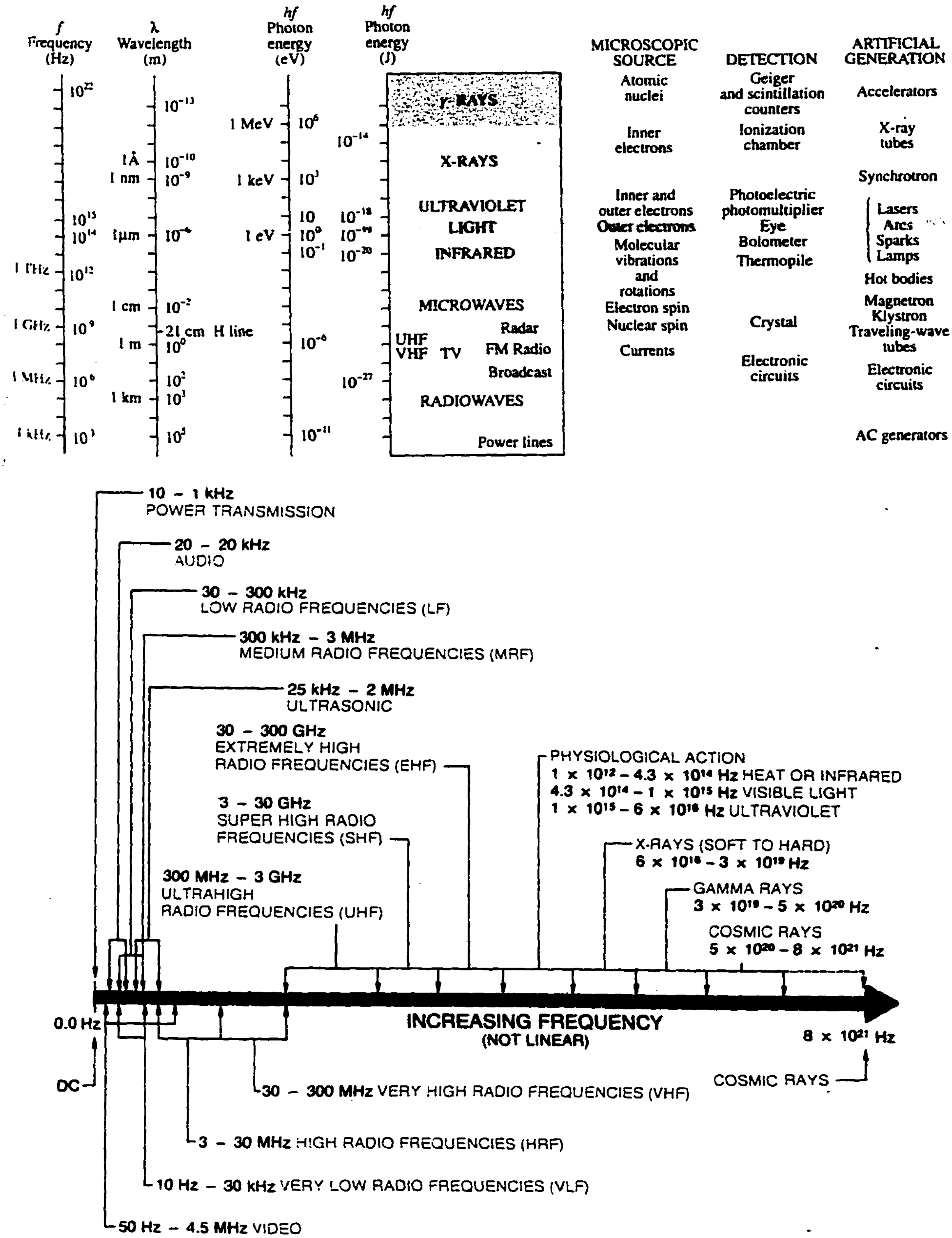


Fig. 2-4 Electromagnetic Spectrum (expanded).



Chapter 3

Electronic Warfare Basic Concept and Overview

The proliferation of modern electronically controlled, directed, and commanded weapons has caused a rapid expansion in the field of applied science, which is generally called *electronic warfare* (EW). The basic concept of EW is to exploit the enemy's electromagnetic emissions in all parts of the electromagnetic spectrum in order to provide intelligence on the enemy's order of battle, intentions, and capabilities, and to use countermeasures to deny effective use of communications and weapon systems while protecting one's own effective use of the same spectrum. A generally accepted military principle is that victory in any future war will go to the side that can best control the electromagnetic spectrum.

EW is dynamically changing field, which must through necessity respond to continually changing threats. This is reflected in the evolution of EW from its early beginning in the dawn of Twentieth Century, which I will trace until I arrive to the modern concept of EW as a vital and basic element of military strategy, which, then used in concert with other military assets, provided a method of neutralizing an enemy force (*force divider effect*) while simultaneously enhancing the power of a friendly force (*force multiplier effect*).

The modern concept is that EW is an important part of an overall military strategy, which concentrates on the neutralization of an enemy's command and control (called C^3 to emphasize the importance of communications, the third C) system while maintaining the capability of operating one's own C^3 systems. However, the basic rationale is that jamming radar or communication system in itself may have little effect on the operation of an enemy's weapon system, particularly if this component is part of a redundant net. What is necessary is to break a node of the enemy's weapon system, and EW by itself may not be the best way to accomplish this.

The requirement for a command and control system relates to the pace of modern warfare, which is continually increasing due to the mobility of platforms and the range and lethality of the weapons. The pace and the distance involved demand electronic means for controlling the application of weapons, assessing their effectiveness, and generally managing the overall weapons engagement. The general structure which links together the sensors, battle management command posts, and communication centers forms the command and control system. It is through this structure that a commander exercises authority over his forces to accomplish his assigned mission. The communication links, command posts, sensor, and intelligence/sensor correlation centers are all prime targets for counter command and control system action.

The Soviets have developed a strategy called *Radio Electronic Combat*, or REC, which they define as the integration of electronic warfare with weapons of physical destruction to deny the enemy electronic control of his force.[27] REC is an integral part of their battle plan. Their strategy in the event of a NATO conflict is to destroy, by artillery and air attack, as large a portion of NATO forces as possible before the main battle. At the same time, a large number of selected elements of NATO's command and control systems will be subjected to REC, leaving them confused and effectively neutralized. The remainder, if the plan succeeds, will be so weakened that they will be quickly overcome.[28]

The Soviet's appreciation of the REC concept apparently stems from their emphasis on "top-down" control and reliance on planned missions in their military strategy. This has resulted in a heavy reliance by the Soviets on their command and control structure, which is reflected by a very robust and redundant use of communications and command posts.[29] Therefore, that if command and control is so essential to one's own strategy, then disrupting an enemy's command and control by REC will be an effective way of neutralizing an enemy's capability.

An U.S. strategy equivalent to REC has been in 1980s articulated [30] and is called C^3 countermeasures (C^3CM). C^3CM is defined as the integrated use of operations security, military deception, jamming, and physical destruction supported by intelligence so as to deny information to, influence, degrade, or destroy adversary C^3 capabilities and to protect friendly C^3 against such actions. EW is an element of this strategy whose function is to control the electromagnetic spectrum just as weapons, fighter aircraft, intelligence, communications, and other military disciplines have specific tasks within this strategy. The implementation of this strategy is still in a formative stage within the U.S. Department of Defense (DoD) and has not as yet received emphasis of the individual services.[31] The truism of the overall C^3CM strategy is, however, inescapable and thereby establishes the trend for future efforts in the EW field.

A way to look at current EW systems is through mission requirements. A convenient breakdown is by threat against air, naval, or army platforms. EW techniques, which apply against the different threats, are given in Table 3-1[32].

Table 3-1

EW Requirements

Platforms	Threats	EW Techniques
Aircraft	SAM's, AAA	Threat Warning and Location Support Jamming, Self-Protection Jamming, Chaff/Expendable, and Jammers/Infrared Countermeasures.
Aircraft	Optically Aimed	High Energy Arc Lamps/Paint/Smoke/Abatement/Laser.
Aircraft	Airborne Interceptors	Threat Warning and Location Self-Protection Jamming, Communications Jamming, standoff Jamming, and Infrared Countermeasures.
Ships	Air-to-Surface (Missiles and	Threat Warning and Location Self-

	Bombs)	Protection Jamming.
Ships	Surface-to-Surface Missiles	Decoys (Spinners and Helicopters).
Ships	Sub-Surface-to-Surface Missiles	Chaff (Mortars and Rockets), Infrared Countermeasures.
Troops	Battlefield Surveillance and Counter Mortar Radars	Threat Warning and Location.
Troops	VT Fused Artillery	VT Fuse Jammers.
Troops	Tactical Communications	Communications Jammers and Noise Jammers.
Troops	Anti-Tank Weapons	Infrared Countermeasures.

A current design philosophy primarily employed by the US and its NATO allies is "stand-alone" EW. This is illustrated in Table 1-1 by the self-protection EW mission that is common to all platforms. The fundamental consideration here is survival, and it is difficult to subordinate this function to an overall C^3CM strategy.

Thus, most current platforms that operate against enemy action have at a minimum a Radar Warning Receiver (RWR) with at least quadrant threat direction-finding capability. The threat function is many times coupled with a defensive capability in the form of a self-protection jammer in combination with decoys, such as chaff or flares, which can divert weapons from the defended target.

The stand-alone EW design philosophy is a carry over from the electronic threat environment, which existed from World War II through the mid 1960s. The threat in this time period consisted of a few radar-directed threats, well known in their principles of operation as well as frequency bands. EW was then a simple countermeasure taken against a thinly deployed (both spectrally and geographically) array of hostile weapons. The basic EW encounter was a one-on-one situation, and each platform carried EW equipment necessary for success in this environment. Although this philosophy still exists, it is difficult for any one platform (particularly airborne platforms which have weight limitations) to carry enough EW counter today's sophisticated threats, even in a survival sense.

Another current EW mission is the Suppression of Enemy Air Defenses (SEAD). This mission requires a mix of EW techniques from multiple platforms combined with other non-EW military assets. The SEAD mission lends itself to the application of the C^3CM strategy. The function of EW in this strategy is to neutralize certain critical enemy radar and communication links, which helps degrade the overall enemy air defense C^3 capability, which is directing the suppression mission.

Electronic Warfare: Principles, Capabilities and Limitations

The purpose of this section is to make the readers aware of the basic principles of the electronic warfare (EW), its capabilities, limitations and applications. In fact, electronic warfare is not electronic, it is not conducted using electrons; but it is electromagnetic (EM) and it uses as its battleground the total spectrum of electromagnetic radiation. Granted that this radiation is usually generated by "electronic" equipment, the converse is definitely not true, that all electronic equipment is involved in this conflict. However, the advent of new, modern weapons systems seems to correspond to progressively greater reliance upon victory in this electromagnetic conflict as a prerequisite for victory in battle. Hence every commander must understand the principles involved in this silent and invisible battle so he can turn it to his advantage; he must understand the effects this battle can have on his weapons so he can manage it to his advantage.

It is this silent and unseen electromagnetic conflict that is the subject of this research. Traditionally, this conflict has been called electronic warfare. Although clarity might be somewhat advanced by using a more descriptive term, we would lose in communication with the myriad of people who speak the jargon of electronic warfare. And in the field where specialized terms abound, adding another is not a mark of distinction. Hence we will use the term electronic warfare for the most part, reserving electromagnetic conflict for those cases where we wish to emphasize the true nature of the conflict.

Much of the information pertaining to electronic warfare is classified and can be expected to remain so. A great portion of this classified information is very detailed and thus beyond the scope of this study. The basic principles, however, are easily derived and are unclassified. We shall therefore concentrate on basic principles and leave the details for other studies.

The Nature of Electronic Warfare

For sound military reasons during and immediately after these global conflicts, the details of electronic warfare in World War II, the Korean War, the Vietnam War, and the Gulf War remained a closely guarded secret. Because of the shortage of primary source material, accounts published previously on the subject are replete with errors, half-truth and major omissions. It is to be hoped that the availability of the different institutions and organizations' historical collection and material and government and historical libraries will ease my task.

By its very nature, electronic warfare is a reactive science. That is to say, it involves counters to measures taken by the enemy, and those very countermeasures may be the subject of counter-countermeasures, which may have in turn to be countered. Without a clear picture of the enemy systems and tactics, no accurate assessment of an electronic conflict can be possible. Because of this I will use my engineering background to explain in some detail the radars and tactics used by all fighting forces, and the counters they attempted against each other.

Peculiarity of Electronic Warfare

Electronic warfare systems occupy a special position in that their primary function is to be responsive to enemy action or potential. The character of effective electronic warfare systems and their development cycle does not follow the pattern set by other active weapons and electronic systems and subsystems. The salient points of difference may be listed as follows:

(a) The need for EW systems is recognized when the existence of enemy electronic aids has been established or postulated.

(b) The characteristics of EW systems are determined by the nature of enemy electronic devices–known or anticipated.

(c) The effectiveness of an EW system cannot be demonstrated independently of enemy devices, either real or simulated.

(d) The future course of EW can only be predicted in terms of the anticipated electronic environment to be created by the enemy.

The dependence of EW methods on the present and future enemy electronic posture places the entire field of EW in a particularly close relationship with the intelligence community. The technique of signal intercept, analysis, and location are primary tools for electronic intelligence (ELINT) and communication intelligence (COMINT). Conversely, the information on enemy activity and its interpretation is basic to EW development and planning. In the case of a complex transmission system, classification of the signal as ELINT or COMINT may not be simple matter.

Research

The development of electronic countermeasures (ECM) systems places unusual demands on techniques and components research in that:

(a) Operational requirements are continually changing with the development by the enemy of electronic aids to warfare, which are the potential targets of countermeasures.

(b) Characteristics and vulnerability of target systems are known only through tests made with the aid of countermeasures and reconnaissance equipment developed to meet these operational requirements.

(c) The potential utilization of the complete frequency spectrum, all types of modulation, and maximum efficiency and security of information handling in the target system requires extreme versatility in devices and techniques in terms of design and operational parameters.

Frequently these demands require the use of techniques and components, which are not fully matured. Much of the research is directed toward the evaluation of feasibility and "trade-offs" inherent in the choice from a multiplicity of alternative approaches to a given problem. An intercept or jamming system designed specifically for a given target system is limited in its application to other target systems. On the other hand, a system designed to handle a number of target systems is limited in its capability against specific targets and is usually extraordinary complex from an operational standpoint.

Early Concepts

One of the first leaders in World War II to recognize electronic warfare as a vital phase of military operations was Winston Churchill. In his war memoirs he said:

> "During the human struggle between the British and German Air Forces‹ between pilot and pilot, between A. A. batteries and aircraft, between ruthless bombing and fortitude of the British people, another conflict was going on, step by step, month by month. This was a secret war, whose battles were lost or won unknown to the public, and only with difficulty comprehend, even now, to those outside the small high scientific circles concerned. Unless British science had proven superior to German, and unless its strange, sinister resources had been effectively brought to bear

in the struggle for survival, we might well have been defeated, and defeated destroyed."[33]

Churchill called this secret war "The Wizard War" and we know it was "Electronic Warfare". In the quote he was specifically referring to activities, which occurred during the bombing of Britain by the Luftwaffe. These made an ardent electronic warfare supporter of Britain's Prime Minister.

The Gulf War

Any successful war is the product of multiple factors that combine to generate success. The short answer to this question is " people, leadership, training, technology, and doctrine." On balance, the Coalition forces in the Gulf were better trained and motivated than their predecessors in any war since the Second World War. They had excellent equipment, and maintained it well. Their training had been realistic, against identifiable potential foes and weapons, and consistent with the doctrinal underpinning of the various services. Thus, the Air Forces, Navies, Armies, and Marine Corpses, with relative minor exceptions, fought as they trained.

The technology the services employed was reliable, adaptable, maintainable, and appropriate for the tasks at hand. Some systems proved extraordinarily valuable. But some weapons failed. For example, the Patriot, it turned out that its main effect was psychological, in calming the population. Ironically enough, the primitive Iraqi al-Hussein, which broke up into several pieces in the air, turned out to be a very difficult target (or, rather several targets), which the Patriot guidance system could not easily cope with. Particularly significant were the F-117 (stealth), GPS (Global Positioning System), JSTARS (Joint Surveillance Target Attack Radar System), AWACS (Airborne Warning And Control System), and Laser-Guided Weapons (smart weapons).

The frustrations that accompanied America introduction to war in earlier conflicts–for example, the discovery that Japanese and German fighters were superior to American ones at the beginning of World War II, or the shock of encountering T-34 tanks in the opening phase of the Korean War, or the disastrous introduction of the M-16 rifle into combat in Vietnam–were unknown in this war.

The Nature of the Gulf War

Attempts to identify" lessons" from previous conflicts for application to future ones are fraught with danger. If they are rigidly applied, the general is accused of preparing to fight the last war all over again. If they are ignored, he has "learned nothing from history". Even if the "correct" lessons are shrewdly and objectively extracted, they may prove quite inappropriate to a future conflicts elsewhere. The most difficult task for the analysts is therefore to distinguish those features of a conflict which are transient and unique in time and place from those which are likely to recur elsewhere in the future.

Only the future will confirm which aspects of the Gulf War were unique; but certainly the combination of circumstances and features of this conflict were unusual, they were interactive and to a great extent they had a synergetic impact on the application of electronic warfare. Indeed, as the combined impact was so favorable for the application of electronic warfare it is necessary to reflect that on many occasions in military history defeat has been snatched from the jaws of victory.

The Gulf War fought by the Coalition was distinguished by skilful diplomacy, intelligent planning, clear identification and pursuit of objectives, imaginative and inspiring leadership and executed with comprehensive professionalism and dedication. But even if on this occasion air power with strong impact and influence of electronic warfare did win the war, or at least dominate and determine its outcome, it does not automatically follow that the face of warfare will be changed everywhere else. An examination of this war's circumstances and features, together with the postulation of an alternative scenario, induce caution about such a projection.

The interactive factors on this occasion which facilitated such an overwhelming impact by electronic warfare included an unusual degree of international consensus about the justification of Coalition action; favorable geography, topography and climate; massive technological superiority; considerable numerical superiority; Iraqi strategic ineptitude; and unprecedented Coalition supremacy in the quality of the combatants. From the outset, these features were identified and exploited by Coalition commanders to an extent rarely seen in the history of warfare.

The Impact of Electronic Warfare on the Gulf War

During the Gulf War, the Coalition's electronic warfare (EW) systems, operations, and tactics may have lacked drama and media attention, but were vital to the success of the entire war effort. The war demonstrated lessons in all the elements of EW: electronic support measures (ESM), electronic countermeasures (ECM), and electronic counter-countermeasures (ECCM) with scope of sophistication that far exceeded anything seen before. The EW investment made in the 1980s defense build-up was intended for a Soviet-NATO conflict in central Europe. Refined in exercises such as the U.S. "Green Flag" series against a postulated formidable Soviet threat, allied EW triumphed against the much weaker Iraqis.

The Coalition's EW completely disrupted Iraq's command, control, communication and intelligence (C^3I) system. EW severed the command links from Baghdad to field forces, which led directly to the spectacular collapse of the Iraqi Army as soon as the ground offensive began. In the air war, EW increased the impact of Coalition airpower, which quickly defeated Iraqi air defenses, and lowered losses in Coalition aircraft. As one pilot said, "If it had not been for ECM...50% of our aircraft would not have returned."[34] EW also allowed the Coalition to look keep into the Iraqi operational and strategic depths, while denying them the same advantage, and the deception that accompanied the ground offensive was made possible by EW superiority.[35]

EW resulted in a low loss of Coalition aircraft despite the Iraqi air defense system, composed of 17,000 surface-to-air-missiles (SAMs), nearly 10,000 anti-aircraft-artillery (AAA) pieces, and a wide variety of sophisticated communications links. A major factor in this imbalance was the fact that the Iraqis were weakened by a limited EW investment. Iraq never faced a technically sophisticated air threat from Iran, and it was confident that it could deal with the threat posed by its other Arab neighbors. Thus, it had made limited investments in air defense system modernization.[36] Maintaining what some have described as the world's fourth largest war machine with a gross national product (GNP) about equal to Portugal's. The vast force structure was built on a Third World economy, which meant that there were far too few technical personnel to support military and its associated industries. To compensate, it relied on foreign advisors and technicians, particularly Soviet advisors, and when these were withdrawn, the military's EW capability was weakened.

In a great manner, F-117 and E-3 illustrate the Coalition's domination of the electromagnetic spectrum in *Desert Storm*. F-117 exposed the limitations of relevant Iraqi technology. E-3's uninterrupted activities illustrated the Coalition's mastery of what one neutral commentator has labeled "the fourth dimension" of warfare.[37] in the hours of *Desert Storm*, Iraqi air defense were blinded, paralyzed and decimated by an electronic and firepower offensive unparalleled for scale and intensity in the history of warfare, while Baghdad's attempts at counter-EW were totally ineffectual. There were about 100 specialists Coalition EW aircraft in-theater, together with defense suppression F-4G *Wild Weasels* and USN (United States Navy), EA-6B jammers and weapon carriers. During

Desert Storm, Iraqi communications and radars were monitored by USAF (United States Air Force), USN, USMC (United States Marine Corps), RAF (Royal Air Force) and French signals-intelligence gatherers. Alert to, but powerless to avoid the dangers of conceding SIGINT (Signal Intelligence), the IQAF (Iraqi Air Force) switched off several of its air defenses radars, but to no avail. Indeed, Coalition surprise was so complete on 17 January that several of the radars were still switched off.

The overwhelming electronic combat achievement laid the basis for all subsequent Coalition military success. Stand-Off, barrage and escort jamming of Iraqi radar and fighter control communications by EF-111A, EA-6Bs and EC-130s blinded and paralyzed Iraq's air defense system. When US Army and Navy unmanned decoys stimulated SAM (Surface to Air Missile) radars, they were attacked by F-4Gs and EA-6Bs carrying HARM (High Speed Anti-Radiation Missiles). Subsequently, RAF *Tornados* contributed to defense suppression with the parachute-loitering ALARM (Air-Launched Anti-Radar Missiles). The destruction or jamming of long-range surveillance and early-warning radar allowed the attackers to approach undetected. Ground intercept and control radars, together with missile-guidance and acquisition radars were jammed simultaneously or subsequently. IQAF interceptors could not hear their ground controller and could not see their opponents. SAMs and AAA (Anti Aircraft Artillery) either fired autonomously or without guidance, or both. Meanwhile, continuous Coalition monitoring of the remaining Iraqi frequencies provided target information for defense-suppression aircraft within 10 minutes.

Supremacy in electronic combat permitted the swift seizure of command of the air. That in turn enabled the systematic destruction of strategic and tactical targets, the isolation, destruction and demoralization of the Iraqi ground forces, the denial of any

Iraqi aerial reconnaissance and the uninterrupted, undetected deployment, build up and redeployment of Coalition ground forces.

Like stealth and AWACS (Airborne Warning and Control System), electronic combat was not an innovation in the Gulf War. Steady evolution since World War II had erupted dramatically over the Beka'a Valley in 1982, leading to the destruction of 84 Syrian aircraft without any Israeli loss. Then, one or two Israeli ELINT (Electronic Intelligence) aircraft, a handful of jammers and superior fighters and weapons were confronted by brave, but obviously uncomprehending Syrian aircrew. In 1991 the scene was repeated, but on many times the scale, and the IQAF was much quicker to recognize the inevitable, seeking refuge first in its HAS (Hardened Aircraft Shelter) and then across the border of Iran.

Mission & Objective

My mission is to study the role of electronic warfare in the dramatic international environment from World War II to the Gulf War 1991.

I will examine in detail the electronic warfare in the Gulf War and its impact on the course of war.

I will expose the Impact of technology and the effectiveness of precision-guided weapons.

As happens with all wars, the conclusion of the Gulf War has led to an intense interest in understanding how it came about, how it was prosecuted, and why it turned out as it did. Not surprisingly, much of this discussion hinges on its implication for future war.

There are several factors and elements that have to be taken into consideration in the Gulf War--for many reasons. First, the characteristics of the adversaries, the balance of power between them and the way they conducted the war were all unique. Of particular note in this regard is the passive Iraqi approach. Thus, this was a one-sided war. It was completely different from most and perhaps all wars in that it featured a lengthy air campaign followed by a very short and easy land campaign. Second, it was fought in an open desert arena, where air forces, intelligence and precision weapons can achieve best results. Finally, a long period of time, nearly half a year, was available to the Coalition forces for thorough preparations and detailed planning of the campaign. Moreover, the rapid destruction rate achieved using precision weapons accelerated the enemy's collapse, e.g., the flight of Iraqi aircraft to Iran.

These results were achieved under ideal conditions, after Iraq's air force and air defense has been neutralized. Against a more formidable adversary, results would have been worse, both for precision and conventional weapons. On the other hand, the better the air defense of the adversary, the greater the superiority of precision standoff weapons over conventional bombs that require aircraft to approach the target in order to achieve sufficient accuracy.

There are a number of more specific opinions and charges that have surfaced since the Gulf War, and it is worth examining some of them, as they reflect current interests and interpretations of the role of electronic warfare.

Did stealth prove its value? Could cruise-missile attacks have substituted for manned aircraft?

Conclusion

EW is no longer just the "wizard war." Rather it is now so integral to effective war making that it is difficult to isolate and analyze it as a separate entity. Sophisticated technology is a part of daily life, and fears that any level of technology higher than of the mid-1960s would prove unsupportable in sustained combat were proven invalid in the

Gulf War. The war showed that, if quality people and good training support it, EW works.[38]

The war showed once again that having hardware and manpower does not translate directly into a military effective force, especially in the Third World. The Coalition's air campaign and EW turned the Iraqi military into an ineffective rabble.

There is the question of the role EW will play in the force-structuring and thinking of both the United States and "medium" forces, such as those of Great Britain and France, who saw EW's importance in the war, but are unlikely to have the resources in the 2000s to afford many of the new technologies, considering the deep defense cuts that are currently looming.

Finally, while EW did not win the war and may not have been used to its optimum advantage, the lessons remain clear. The Soviets saw the power of Western electronic war fighting and the uselessness of their own systems in the hands of the hapless Iraqis; certainly disarming news in Moscow. The West saw that control of the battlefield means control of the electromagnetic spectrum.

Chapter 4

The Evolution of Electricity: from Static to Dynamic

A few years before the Battle of Trafalgar,[39] a major advance was made in the science of electricity. Volta[40] invented his "Voltaic pile" or what we now know as a primary battery, which was capable of producing electricity in a steady flow by chemical means.

Electricity itself was not new discovery. It had been known as early as 600 B.C., when the Greeks had found that if they rubbed amber it had the property of attracting or repelling light bodies. They had also found that some fish could impart electric shocks. The systematic study of these phenomenons did not begin however, until the sixteenth century and only made real progress during the eighteenth century. Development was limited, although with the invention of the Leyden jar in 1745, electricity could be accumulated and stored. Many leading scientists applied themselves to the subject, and by the end of the eighteenth century had not only made a systematic study of many materials with the same electrical properties as amber, but had found that sparks were strong charges and had realized that electricity was connected with lightning.[41]

They had discovered too that electricity could be conducted, and that some substances conducted better than others did. They had found that there were two kinds of electricity, positive and negative and that like kinds repelled and opposite kinds of electricity attracted each other. Many important facts had therefore been established but electricity was as yet of interest only to the scientist and had not left the laboratory. A number of proposals were indeed made for various kinds of telegraph but none of them was practical, and the study of electricity was continued mainly as a contribution to knowledge in general.

It is only possible to identify two useful outcomes of all this work. The first was the invention of the lightning conductor by Benjamin Franklin in 1752 and the second was the exploding of gunpowder by electricity by Sir William Watson, who had actually fired a musket by electricity in 1747. The method used made it hopelessly impractical and less efficient than conventional methods, and it was over a century before this discovery was put to effective use. By 1805, although the existence of electricity was known and had been subjected to much study, it had occurred to no one that it would have the slightest effect upon sea power.[42]

The Invention of Telegraph

During the next thirty years immense progress was made in the laboratory, especially in the theory of electricity and its measurement. Many improved types of primary battery were produced; the phenomenon of induction was discovered as well as the power of electricity to magnetize steel. The main practical application was still seen to be some form of telegraph and a vast number of proposals were made. Few of these proved commercial propositions and many, such as one with a separate wire for each letter of the alphabet, were altogether too unwieldy. Nevertheless, the essential ingredients were there, and in 1828 a telegraph worked over a distance of eight miles on Long Island in the U.S.A. It used a single wire with earth return and a coded system of signaling that was recorded on litmus paper. A few years later the telegraph became cheaper when it was found that that a line conductor need not be insulated over its whole length but only had to be supported by insulators at intervals. In the late eighteen-thirties and early forties Morse perfected his code, short lines were laid in both England and the U.S.A.[43] and telegraph companies were formed. The "Electric Telegraph" as a reliable method of communication now began to spread throughout the civilized countries of the world.[44]

It was in the Crimean War of 1854-5 that the telegraph was first used during hostilities.[45] It cannot be claimed that it made very much difference technically. No great strategic move was achieved by its existence and its influence on plans was marginal. Indeed there were many who claimed that the interference it caused was an actual disadvantage. Nevertheless, it greatly increased the control of the central governments and made communication with the theater of war much more rapid. It is probable that in administrative matters and logistics it paid greater dividends.[46]

In the war between Italy and Austria in 1866, the telegraph was first used for what could be called a tactical as opposed to a strategic purpose. In July of that year, the Italian fleet, of which the Government had demanded some action, sailed from Ancona to try to capture the fortified island of Lissa off the Dalmatian coast. Lissa was connected by cable with the mainland and at once reported the position of the Italian fleet to the Austrian naval Commander-in-Chief at Pola. A number of amplifying messages got through before the Italians cut the cable. The Austrian fleet sailed at once and on 18 July 1866, completely defeated the Italians at the Battle of Lissa. Without the telegraph it is unlikely that this famous battle would ever have been fought.[47]

There were other military uses of electricity during this period, the first of which had a profound effect on night actions. In the preceding three centuries of naval warfare, the vast majority of sea battles were fought by day. It is difficult to find more than a dozen examples of fighting at night, and of these all except a handful [48] were actions begun by day and continued after dark. It was more normal for actions to cease at sunset and the reason is clear enough. There were no means of illumination to enable the contestants to see what they were doing. Candles or oil lanterns of about eight candlepower were useless except for lighting up the interior of ships or for providing a mark to show where ships were. Night actions were therefore a very risky business in which the superior fleet was reluctant to indulge and in which the inferior fleet preferred to slip away rather than fight.

With development of Gramme's "electro-magnetic induction machine" or what we would now call a dynamo, the arc light became a practical proposition. The dynamo was the result of research by many eminent scientists during the first half of the nineteenth century and was brought to a practical form in the late sixties. In 1874 Mr. Wilde's "electric light" was tried in H.M.S. *Comet*, a corvette. It consisted of an arc light enclosed in a directional case, 22 inches in diameter, the beam being concentrated to 3-4 degrees by lenses. Current was supplied a Wilde Dynamo driven by a small steam engine of 6 h.p. The result was an intense light of about 11,000 candlepower. [49] The ship using the "electric light", although it gave away its position by doing so, could not itself be seen by the attacking ship through the glare of the light, thus, its course and movement could not be ascertained. "The value of the light is decided and considerable," the committee reported, and the next year an improved "electric light" was fitted in the battleship *Minotaur* of the Channel Squadron. In the next few years a "searchlight", as it came to be called, was fitted in all new ships. [50]

Searchlights were first used in war during the operations that led to the bombardment of Alexandria in 1882. It was the searchlights of the fleet, which detected that the Egyptians were strengthening the fortifications at night and mounting additional guns. After the bombardment that was carried out by day, searchlights were used to try to assist the landing parties at night by illuminating the shore. The searchlight was not a British prerogative and other nations developed and fitted it simultaneously. Indeed, in 1880 the British believed that the French and the Russians were ahead of them. The searchlight was therefore, the second important effect of the electron upon sea power. It opened up the possibility of fighting at night and was, with the quick-firing gun, an important counter-measure to the menace of the torpedo.[51]

In the middle of the nineteenth century the sea-mine came into use as a weapon in naval warfare. It was employed by the Russians in the Crimean War of 1854-6 without any great success, the mines being fired by mechanical means similar to a gunlock or by chemical means in which the contact of the ship broke a glass phial and allowed acid to mix with another chemical. There is indication that the Russians had some mines, which were fired electrically, and this method was definitely used ten years later in the American Civil War. In 1865 the Federal armored gunboat *Commodore James* was sunk in the Roanoke River by a 1,000 pound mine fired electrically from the shore.[52]

The Birth of Wireless

While the developments with electricity, were being put into practice in the fleets of the world, scientific experiments continued. Not only did practical uses for electricity improve but scientists also broke entirely new ground. In the sixties and early seventies of the nineteenth century, a brilliant British mathematician and physicist, James Clark Maxwell, building upon the ideas and theories of Faraday and others, predicted the propagation in space of electromagnetic waves and asserted that they would travel with the speed of light. His mathematical equations were by no means accepted universally and indeed were known only to mathematicians and physicists. It was a decade before the German scientist Heinrich Hertz actually propagated electromagnetic waves in his laboratory and proved the accuracy of Clark Maxwell's theories. Hertz's apparatus was, in fact, the first radio transmitter but it had a range of only twenty-five feet.

In a remarkable series of experiments he confirmed that electromagnetic waves were radiated in all directions and moved with the speed of light. He showed that they could be reflected and refracted and would penetrate some materials opaque to light.

Hertz's experiments set many other scientists working in this field of research but most of them seem only to have been interested in the pure physics of the subject. Although the results of Hertz's experiments were published in 1888, no suggestion that electromagnetic waves would be useful for communication or any other purpose was made for four years. Then a noted British scientist, Sir William Crooks, published an article in which he forecast the use of electromagnetic waves for communication. Hertz had made his experiments on a wavelength of about 4 meters, that is a frequency of 75 MHz, which is in the middle of what we now know as the VHF band. His conclusion that radio waves behaved like light were correct for this frequency, but the conclusion was drawn that communication by any electromagnetic waves could only be established by stations which could "see" each other and so was bond to be of very limited range.[53]

At this time the telegraph had already made communication between any part of the civilized world rapid and reliable. The development of wireless as a rival would merely be another way of doing the same thing. For ships at sea, however, it was a very different matter. Once they were out of sight of land they were completely isolated. Merchant ships could not report if they were delayed or in distress and could not receive news, weather reports or any other information. Warships could not given instructions or report the enemy until they contacted a shore signal station. The need for some such communication system as wireless at sea was therefore urgent and seemed promising, as experiments already showed that electromagnetic waves traveled better over the sea than over the land.

The development of wireless over this period was dominated by Marconi's astonishing achievement in December 1901 in sending a message across the Atlantic. With most pure scientists clinging to Hertz's findings that radio waves traveled in straight lines, they believed that the curvature of the earth made any really long-range communication out of the question. The Atlantic can be visualized as a mountain a hundred miles high and so, they maintained, mast two hundred meters high on both sides of the ocean would be necessary to establish communication by electromagnetic waves.[54]

We now know that Hertz's experiments were correct for the very high frequency he used but they do not apply to low frequency transmissions. Transmissions on this band are propagated in the form of a ground wave that follows the curvature of the earth out of a distance of about a thousand miles. There are also reflections between the troposphere and low ionosphere and the earth's surface that have much the same effect as a modern wave-guide. The ground wave has a greater range over sea than over land, but the wave-guide effect means that transmissions can be heard at any distance providing they are sufficiently powerful. To get sufficient power into the aerials these had to be very large and so the frequency had to low. Marconi had long realized that high power and low frequency were the secret of long range and it is probable that his faith and perseverance in proving that wireless could be used world wide was the most important success of his whole career.

In the 1902 British maneuvered in the Mediterranean the problem was to investigate the blockade of a fleet in harbor using cruisers that were to call up their own battle fleet by wireless if the "enemy" tried to escape. Most of the large ships were fitted with wireless and the danger of interference with each other was appreciated. Instructions were issued that wireless was only to be used if the intelligence to be reported was really important and that all reports were to be addressed to the flagship. Cruisers were told not to answer wireless signals unless they were actually addressed. Ships were still fitted with semaphore at the top of their masts and the cruisers on blockade duty were stationed within touch of each other. In theses exercise jamming was used extensively. When the blockade squadron escaped to sea it effectively jammed all the enemy reports made by the blockading cruisers. Considerable trouble was also experienced with vibration and atmospheric and, in spite of the instructions issued before the exercise, with interference by ships of the same side with each other.[55]

Conclusion

During the nineteenth century, therefore, especially in the second half of it, the electron had a very distinct influence upon sea power. Without doubt, its most important effect came with the invention of the telegraph, especially in the form the submarine cable. The second most important effect was in the invention of searchlight that made night fighting, especially to repel torpedo craft, a practical proposition. The controlled mine, by greatly increasing the effectiveness of harbor defense, also made its contribution. From 1870 onwards many minor uses for electricity in warships were developed, including electric firing for guns, electric lighting and electric power for laying and training guns and supplying ammunition, these were not essential; there were reasonably efficient alternatives and the innovations can only be classed as minor improvements. On the other hand, electric power, in the form of accumulators and electric motors, made the development of the submarine possible. Although by 1900 it was little more than a toy, it was to become one of the major developments in maritime war of the twentieth century.

Chapter 5

Electronic Warfare: Early Development

The Russo-Japanese war, which broke out in February 1904 as a result of conflicting between St. Petersburg and Tokyo, was the first war in which radio, or wireless telegraphy as it was called in those days, was used by both sides to communicate with their respective forces.[56]

Guglielmo Marconi has invented wireless telegraphy only a few years earlier but it had been immediately made use of, mainly by the naval forces, for long distance communications between ships, and between ships and land. The Japanese had installed wireless sets on all their ships; these were copies of Marconi's original invention but their performance was decidedly inferior as they could operate on only one frequency and had a range of barely 60 miles. The Russians, too, had wireless sets on board their warships in the Far East and in numerous ground stations situated near their naval bases.

Right from the beginning of the war, the Russians used radio not only for normal communications but also, albeit in a somewhat improvised way, for purposes other than that for which it had been invented. These uses of radio could be considered to be the embryonic stage of electronic warfare. For example, Japan had started the war with a surprise attack on the Russian warships anchored in the ports of Chemulco and Port Arthur on the west coast of the Korean peninsula in the Yellow Sea but, during the frequent subsequent Japanese attacks on Russian ships at Port Arthur, Russian radio operators often noticed that before an attack they could hear in their head-phones a great exchange of signals, increasing in intensity, between the Japanese ships; this was possible because the Japanese were using radio without taking any precautions to conceal transmissions. Since these signals were intercepted long before the enemy ships were sighted, the Russians were warned of the imminent attack and could therefore alert their ships and coastal batteries before the Japanese started their bombardment.[57]

On one particular occasion several Russian ships left the port of Valdivostok to make a surprise attack on the Japanese naval base of Gensan in the Sea of Japan, but the Japanese had discovered their departure and were waiting for them. However, as the Russian ships drew closer and closer to Gensan they intercepted radio communications, increasing in intensity, which indicated the presence of numerous Japanese warships also bound for Gensan. The Russians, therefore, abandoned their plans, which would doubtlessly have ended in disaster since the entire enemy fleet was waiting for them at Gensan.[58]

These were not the only occasions on which the Russians used radio for a purpose other than that of telecommunications in the first year of the war. On March 1904, the Japanese attempted to carry out an attack on Russian ships anchored in the inner roads of Port Arthur, and thus not visible from the open sea. They sent two armored cruisers, *Kasuga* and *Nisshin*, to bombard the roads by indirect fire, using a small destroyer favorably located near the coast to observe where the shells fell and to transmit correct firing instructions to the cruisers. However, a wireless operator at the Russian base heard the signals the Japanese ships were exchanging and, although he did not really understand what he was doing, he instinctively pressed the signaling key oh his spark transmitter[59] in the hope that this might interfere in some way with the communications between the enemy ships. As a result of his instinctive action no Russian ships were damaged by Japanese naval bombardment that day since the Japanese; their communications jammed, cut short their action and withdrew.[60]

However, it was exploitation of the potential of radio by the Japanese, combining with a refusal by the Russians to make use of that potential, which brought the Russo-

Japanese war to a conclusive end. Naval operations in 1904 were unfavorable to the Russians who, in the various battles with the Japanese fleet, lost most of their warships stationed in the Far East. For this reason, Russian leaders in St Petersburg decided to send the Baltic Fleet to the Far East to replace the lost ships and to seek revenge for the defeats that they had suffered. Admiral Zinoviy Petrovitch Rozhestvenskiy, who was become the leading figure in one of the most dramatic events in the whole of naval history, as chosen to command the fleet.[61]

Wireless proved of most value to the Russians during the siege of Port Arthur from the warning it gave of the approach of Japanese ships. The Russian receivers were always able to pick up the Japanese radio before they sighted the ships from the shore signal station, which was particularly valuable in low visibility. This was not the only use of radio warfare the Russians; on 15 April they were able to jam the Japanese wireless signals when they were trying to spot their fall of shot during a bombardment. On 24 April 1904 the Valdivostok Squadron under Admiral Jessen put to sea to attack Gensan. It passed a Japanese Squadron under Admiral Kamimura quite close in fog on an opposite course. The Russian Squadron realized what happening by listening to the Japanese wireless transmissions while the Japanese were quite unaware of the situation. As a result Admiral Jessen met no opposition off Gensan and his raid was a success. On another occasion, when the Valdivostok Squadron set out on a raid, it was able from the Japanese wireless traffic to deduce that the sortie had been detected and to avoid running into a trap. The active use of Russian wireless was of value too. It warned Admiral Makaroff when he was at sea on one occasion that Japanese ships were in sight from the signal station at Port Arthur and on another warned the Vladivostok Squadron that mines had been laid the port during their absence.[62]

When the Russian fleet left from Port Arthur on 10 August with the intention of proceeding to Valdivostok, it was seen and reported by wireless by the Japanese cruiser *Kasagi*. As a result it was brought to action by the main Japanese fleet later in the day. Throughout the Japanese concentration they used their wireless freely. The Russians on the other hand do not seem to have used it at all. When the Russian flagship. *Tsarevitch* was hit in the conning tower and Admiral Vityeft was killed, the helm jammed hard over and the fleet was thrown into confusion. The masts of the Second-in-Command's flagship had been shot away and he was unable to hoist any signals to really the fleet, indeed there was doubt that he was still alive, as his flag was not flying. His wireless antennas were shot away too. Admiral Reitzenstein, next in command, in his flagship the *askold* was undamaged but had no more success in rallying the fleet by visual signals. In this emergency it does not seem that any attempt was made to use wireless, but it seems unlikely that, even had this been done with the state of wireless communications in the Russian Navy, the signal would have been received by more than a few ships. As a result the Russian fleet disintegrated, most of the ships returning to Port Arthur in disorder, some making for neutral ports and only one trying to get through to Vladivostok. There was some delay in the Japanese fleet in pursuing the scattered ships as it was their practice to dismantle their wireless sets in action was stow them below the armored deck. Many detached ships who called up the *Mikasa* for instructions could therefore get no answer. Wireless was subsequently used freely to try to round up the escaping ships but there was great difficulty in getting through on a number of occasions and operations were much handicapped. Some ships had to put into harbor to use the telegraph. Nevertheless Admiral Kamimura, using wireless, did succeed four days later in concentrating against the Valdivostok Squadron that had come out, and defeating it at the Battle of Ulsan.[63]

The second Pacific Squadron that sailed from Libau for the Far East October 1904 under Admiral Rojestvensky was equipped with German Slaby-Arco apparatus. This system was undoubtedly an improvement and was by now standard in the German and American Navies. The Slaby-Arco equipment was by no means perfect however, as was soon demonstrated in the Great Belt when the tug *Russ* with a Marconi set had to tell the battleship *Orel* that she was being called by the flagship and had to act as wireless link for her. The main communication between the Russian Admiralty and the Second Pacific Squadron, and indeed the Third under Admiral Nebogotoff which followed it, was by the international cable system at the various ports at which they called. The fleet was in fact cut off from the world between ports; for instance, no news was received from the time is left Libau on the 15th until it arrived at Vigo on 26 October. During the long stay at Nosse Be in Madagascar, while waiting for the Third Squadron, the ciphered telegrams had to be sent by destroyer to a small port near Diego Suarez where there was a telegraph station. Wireless was really only of use for tactical purposes within the fleet. Not all of the Russian fleet was fitted with standard Slaby-Arco equipment. The armed merchant cruisers *Ural* had a specially powerful Slaby-Arco set which was supposed to work up to 500 miles, and the auxiliaries *Korea* and *Kitai* had commercial Marconi sets. Admiral Rojestvensky complained that no ship was able to receive messages at a greater distance than sixty-five miles except for *Korea*, which picked up at ninety miles.[64]

In February 1905 as Nosse Be in Madagascar, Admiral Rojestvensky directed the *Ural* to get into touch with the cruiser *Oleg*, which was joining the fleet from Russia as reinforcement. The *Ural* failed to establish communication at all and it was the *Korea* with her Marconi set which first picked up the *Oleg*'s signals. In April, in Kamrahn Bay, Admiral Rojestvensky complained that after strenuous efforts over eight months to perfect wireless telegraphy in the fleet, the results were hopeless. When at sea exercising he wished to send a message to a ship in harbor and called her for an hour and a half without reply although she was only fifteen miles away. He then tried another ship without success while four more ships that were supposed to be keeping wireless watch failed to relay the message. At the same time three armed merchant cruisers returning from scouting failed to get messages through as they rejoined the fleet. Finally the flagship tried to call the armed merchant cruiser *Rion* on patrol and could get no answer at all. Admiral Rojestvensky asked in a general order on 20 April, 'Is the Captain of the *Rion* quite clear in his mind as to how useless his patrolling service is if his wireless apparatus is not in working order?' Three weeks later at Van Fong there was similar trouble communicating with ships on patrol. Exasperating as these deficiencies must have been to Admiral Rojestvensky, too much blame cannot be put on the Slaby-Arco equipment which did not claim a range of more than seventy miles and with which the U.S. Navy trials only obtained sixty-two miles. The company's representatives sailed with the fleet but returned to Germany from Madagascar. It is probable that maintenance of the equipment suffered during the long voyage and there is no doubt that the officers failed to supervise the operators sufficiently.[65]

Admiral Rojestvensky made a final effort to use wireless in his fleet as it passed month between Formosa and the Philippines. He tried to push his advanced screen ahead and to keep touch with it by wireless. After almost total failure to communicate he had to withdraw it back into visibility distance. He himself had a clear idea of the advantages and indeed the advantages of wireless. In his final approach to the Straits of Tsushima, his object was to try and get through to Vladivostok without a battle. He prohibited the 'sending of all telegrams' or in modern parlance imposed strict radio silence on his whole fleet. As he approached the Straits of Tsushima his ships reported they could hear fragments of signals which they took to be Japanese wireless messages. On the evening of

25 May many ships in the Russian fleet heard the Japanese scouts talking to each other. The *Ural*, with her powerful wireless set, asked permission to jam the transmission but Admiral Rojestvensky rightly refused. The Japanese in consequence were unable to get any information of the Russian approach by radio intelligence.[66]

The Japanese, with their aim of finding and bringing the Russian fleet to action, had an entirely different policy. There were three routes by which the Russian fleet could get to Vladivostok. The first was by the Straits of Tsushima which had the advantage that they were the most direct and the widest route. The other two routes were by the Tsugaru Straits between Honshu and Hokkaido and the Straits of La Perouse between Hokkaido and Sakhalin. The distance from all of these straits to Vladivostok was approximately the same. Admiral Togo therefore based his fleet at Mesampo Bay in south-eastern Korea, from which place with his superior speed he would be able to engage the Russian fleet before it could reach Vladivostok by any of the three ways into the Sea of Japan. For this plan to succeed, however, it was essential that reports from his patrols in these defiles should reach him without delay. For the Straits of Tsushima he relied entirely on wireless and for the two northern straits upon a combination of wireless and the telegraph. His outer line of scouts in the Straits of Tsushima consisted of four armed merchant cruisers spaced at twice the visibility distance apart. They advanced south-westwards by day and at sunset turned back to the north-eastwards to avoid missing the Russian fleet during the night. This line was backed up by six protected cruisers patrolling fixed beats on a line across the Straits sixty miles southwest of the Island of Tsushima. The old battleship *Fuso* was stationed just south of Tsushima to act as a wireless link between the scouts and Admiral Togo in Mesampo Bay. Admiral Togo's strategy therefore depended entirely on wireless and telegraphic communication, without which he would have had to adopt a different and far less satisfactory plan such as a close patrol with his whole fleet off Vladivostok or an advance into the South China Sea to meet the enemy.[67]

Early on the morning of 27 May the armed merchant cruiser *Shinano Maru* sighted the Russian fleet and reported its position by wireless. The message was at once relayed and within minutes was received not only by Admiral Katoaka at the advanced base at Takeshiki on Tsushima Island and Admiral Togo at Mesampo Bay but by all the ships of both scouting lines. The Russians also received this report and heard it being repeated farther and farther away into the distance. Although now fairly certain that he had been sighted, Admiral Rojestvensky stuck to his policy and still refused to jam in the vague hope that he was still undetected. The main Japanese fleet at once put to sea and the cruisers closed in on the Russians. During the forenoon the Japanese cruisers and other ships which had left Takeshiki made contact and gave Admiral Togo an accurate position, course and speed of the Russians and also a description of their formation. As a result the Japanese fleet was able to bring the Russian fleet to action during the afternoon. The Japanese battle orders were clear and well understood and few directions were needed. Admiral Togo did, however, use wireless to tell Vice-Admiral Katoaka that he intended to cover the eastern channel and he in his turn directed the elderly Seventh Squadron to cover the western side of Tsushima in case any Russia ships attempted to get through that way. During the approach Admiral Togo also asked which side the enemy main body was stationed and ordered the shadowing cruisers to report at once should the Russians alter course.[68]

On sighting the enemy, Togo ordered his Fifth and Sixth Squadrons to attack the enemy rear. In general, while the Russians maintained strict wireless silence, the Japanese used this new method of communication with great skill, not only to report the position and course of enemy but to give essential tactical direction to their fleet. All this was done without any important signal going astray or any confusion due to too many ships trying to send messages at once. The maneuvering and action signals during the battle were made by visual signals by both sides and after the action became general, wireless was little used. At sunset all the large Japanese ships broke off the action automatically in accordance with the battle orders so as to leave the field clear for torpedo craft to attack. The disintegration of the Russian fleet after sunset could have been prevented by efficient wireless communications.[69]

It is not known why Admiral Nebogotoff did not use it to rally the fleet, especially after what had happened on 10 August. Nevertheless had he done so, the defeat of the remnants of the Russians next day was virtually certain whether concentrated or dispersed. At sunset Admiral Togo then used his dispatch vessel, the *Tatsuta*, to contact his scattered squadrons to give them a rendezvous near Matshushma Island at dawn, but later he used wireless to order the Seventh Squadron to search the battle area for damaged ships. As soon as it was light reports began to come in from various Japanese ships by wireless of four groups of surviving Russian ships all of which were brought to action and either sunk or captured during the forenoon.[70]

Conclusion

In the Battle of Tsushima wireless telegraphy as used by the Japanese was an outstanding success and its employment must take a share of the credit for the resounding Japanese victory. On the other hand, it is doubtful if in fact the lack of efficient Russian wireless contributed much to their defeat. Admiral Rozhestvenskiy's policy of wireless silence was undoubtedly the correct one in the circumstances. He might have achieved something by jamming the very first enemy report but this would have needed a degree of skill and alertness of which his operators were scarcely capable. Naval wireless communication came of age in the Russo-Japanese War. Japanese strategy was often based upon it, and its efficiency in their hands contributed much to the defeat of the Russia. What we now know as electronic warfare was surprisingly well developed especially by the Russians. Nevertheless the unrestricted use of wireless by the Japanese gave them much more information than the Russians obtained from listening.

Chapter 6

Development Prior to the World War I

The success of the Marconi long-range wireless stations created a demand for similar facilities in other countries. With the lower frequencies on which they operated in order to obtain longer ranges, it was soon found that the difference in wavelength was sufficient for them to be worked at the same time as low-power stations without interference. The first country to order a high-power station was Italy and they gave the contract to Marconi in 1903. The station was built at Coltano near Pisa, and when opened in July 1904 had the most powerful transmitter in the world. It was able to communicate with Eritrea, a distance of 2,238 miles and also, of course, available for broadcasting to ships of the Italian Navy wherever they might be in the Mediterranean.[71]

In 1905 the U.S. Navy decided to cover the Caribbean area with shore wireless stations because of its increased strategic importance with the construction of the Panama Canal it could not be covered by a network of low-power stations in U.S. territory, as they would be too far apart to communicate with each other. They decided therefore to install four high-powered long-range stations at Key West in Florida, San Juan in Puerto Rico, Guantanamo in Cuba and in the Panama Canal Zone itself. The contract was given to the American De Forest Company who provided 35 Kw, alternator driver spark transmitters with a range of about 1,000 miles. To complete the coverage a fifth station with a power of 10 Kw was installed at Pensacola. All these stations were completed successfully by early 1906 and were able to provide wireless communication between the United States and the Panama Canal Zone as well as coverage for ships in the Caribbean Sea.[72]

In 1907 the American De forest Company developed a radiotelephone set. The value of such a system for tactical communication in a fleet was obvious and the Navy

Department purchased two sets and fitted them in the U.S.S. *Connecticut* and Virginia for trials were made somewhat hastily but the sets proved successful. This system was, however, far ahead of its time: the transmitter used the Poulsen arc and the receiver a mixture of crystal and thermionic valves, all of which were completely new inventions. [73]

By 1908 radio was installed in all surface vessels of the U.S. Navy, including torpedo craft. There was still no standardization of equipment and there was a large number of different types fitted both ashore and afloat. The transmitters were all still spark sets that blanked out practically the whole known radio spectrum. There was still only one frequency used by both ships and shore stations, which was approximately 400 meters. (750 KHz). Nevertheless, this material was ahead of the organization. Senior officers still showed little interest in wireless and there had consequently been no serious development of radio for strategic or tactical purposes.[74]

During 1909 the U.S Navy decided to install a very powerful transmitter that could send messages a distance of 3,000 miles. A contract for this set was awarded to the Fessenden Company who designed a 100 Kw rotary spark transmitter. The contract included two smaller 10 Kw sets to be installed in ships with which they were to be able to send messages at 1,000 miles. At the end of the year trials with the light cruisers *Salem* and *Birmingham*, in which these sets had been fitted, showed that they could only maintain touch at 600 miles and could not hear the shore station at more than 900 miles by day or 2,186 miles by night. The Fessenden equipment did not therefore meet its specification but it was accepted, as it was undoubtedly the best on the market at that time.

Attention was then switched to wireless set for seaplanes and early in 1912, with an aerial selected across the wings, a transmitting range of eight to ten miles was obtained on 257.5 meters (116.5 KHz). Nothing at all, however, could be received in a seaplane in flight because of the noise and interference of the engine. Later in the year a French Rouzet set was purchased, which weighed only 70 pounds and a synchronous rotating spark gap with a power of ¼ kw. With this set thirty miles was obtained using a trailing aerial and four more sets were ordered, but reception was still impossible with the engine running. A more powerful Rouzet set (I kw) was used for airships. By 1914 *Vernon* had designed a new aircraft set of 2/3 kw, using an alternator and a synchronous spark transmitter, and reception up to a range of thirty miles had been achieved with it. Similar results were obtained in the U.S. Navy, and at first they too were unable to receive anything in fight. By 1912 they were receiving at fifteen miles but little further progress was made until 1915.[75]

Besides from an unsuccessful attempt in 1903, no interesting fitting wireless in British submarines was shown until 1910. In that year, the Devonport flotilla began to experiment on their own and the submarine B_3 was able to receive messages from a torpedo gunboat at a arrange of thirty-five miles. Later in the year B_4 tried a transmitter and D_1 received a message from a ship in Torbay as she was entering the Needles Channel. A submission was then made to the Admiralty that submarines should have wireless and in April 1911 they ordered the *Defiance* to design a submarine set table to send and receive messages at thirty miles. The set was designed therefore with a power of only ½ kw and because of the limited size of aerial, a wavelength pf 200 meters (1,500 KHz). The transmitter was a simple alternator driven spark set while the receiver used the magnetic detector and both were put in a small silent cabinet inside the submarine. Submarines were progressively fitted with, this No. 10 set, as it was called, and by 1913 all the modern submarines of the "C", "D", and "E" classes had them.[76]

In the same period technical progress continued in the U.S. Navy. The Naval Radio Laboratory had already decided after the trials of the Arlington station that the future lay in the arc transmitter used with a heterodyne receiver. By 1914, however, most of their transmitters both ashore and afloat were either of the quenched spark type designed by Telefunken, Chaffer or Lowenstein or the rotary spark type designed by Fessenden. The decision had, however, already been reached to change to change to the Poulsen arc and ten 30kw sets of this type had already been ordered for the ten new "Dreadnought" battleships under construction. The German Navy was also equipped with the Telefunken quenched spark transmitter and large ships also had auxiliary wireless sets. Surprisingly the French Navy had now gone over to wireless almost entirely and visual signals were seldom used. The French made a very slow start in this field and as late as 1909 were signaling slowly *en clair* with practically no drill or procedure and using plain aerial, considerable power and coarsely tuned receivers on a single wavelength.[77]

Conclusion

The development of wireless was the outstanding influence of the electron on sea power in the first fourteen years of the twentieth century. In addition to the very substantial advances in wireless telegraphy, there is no doubt that electricity had improved the efficiency of warships by 1914. It was used for a large number of purposes and it would now be difficult for ships to function at all without it.

Chapter 7

Electronic Espionage: War of Intercepts

Radio, envisioned by its inventor as a great humanitarian contribution, was seized by the generals soon after its birth in 1895 and impressed as an instrument of war. For it immeasurably magnified the chief military advantage of telegraphy: instantaneous and continuous control of an entire army by a single commander. By eliminating the need for physical linkage by wire, radio speed communication between headquarter, joined through the ether units that could not connect by wire because of distance, terrain, hostile forces, or rapid movement, opened communications with naval and air forces, and eased the economic burden of producing immense quantities of wire.

But few blessings are unmixed. Just as the telegraph had made military communications much more effective but had also increased the possibility of interception over that of hand-carried dispatches, so radio's vast amplification of military communications was accompanied by an enormously greater probability of interception. The omni-directional nature of radio transmissions, which makes wireless communication so easy to establish, makes it equally easy to intercept. It was no longer necessary to gain physical access to a telegraph line behind the enemy's front to eavesdrop upon his communications. A commander had only to sit in his headquarters and tune his radio to the enemy's wavelength. Radio thereupon introduced two revolutionary factors in the interception of communications: volume and continuity.

Communications are intercepted, of course, so that they may be submitted to cryptanalysis. Cryptanalysis has a potential that cryptography does not. Cryptography can at best conserve it. Cryptanalysis can bring countries into war, engender naval battles and win them, compel besieged cities to yield, condemn queens to death and prove innocent the unjustly accused. Cryptanalysis hammers upon the real world. Cryptography does not.[78]

Consequently, the telegraph, which affected only cryptography, had had a wholly internal influence upon cryptology. That a hierarchy of special systems had arisen to displace the nomenclator interested only cryptologist; it did not matter to generals or statemen. And although the telegraph greatly increased the volume of communications, wiretapping could produce intercepts only at rare and irregular intervals. Cryptanalysis could exercise only transient and haphazard effects. Its potential remained largely unfulfilled. Kerckhoff's accurately regarded it as an auxiliary to cryptography, a means to the end of perfecting military codes and ciphers. Cryptanalysis during the telegraph years was interesting but inconsequential, intriguing but academic–an ideal topic to pass a Victorian tea-time, perhaps, but not much more.

The radio, however, turned over to the commander a copy of every enemy cryptogram it conveyed. It furnished a constant stream of intercepts. And with these, cryptanalysis could bear continually upon operations, could bear continually upon operations, could be depended upon for information, and could affect events decisively. The generals and the statemen took notice. This was no longer a polite trifling discussion; this had become a weapon, a pursuit entailing all the savagery of warfare and life against death. Radio made cryptanalysis an end in itself, elevating it to an importance coordinate with that of cryptography, if not superior to it. Radio's impact upon cryptology reverberated in the outside world. Wire and wireless thus complemented one another. The telegraph created modern cryptography; the radio, modern cryptanalysis. The one developed cryptology internally, the other externally. The telegraph had given cryptology shape and content; now the radio carried it out into the arena of life. One gave it form; the other, meaning. The completed the work that the telegraph had begun. And so it was that radio, first widely used in the Great War of 1914 to 1918, brought cryptology to maturity.[79]

During World War I the interception of diplomatic radio traffic reached incredible proportions. The British intelligence services broke the top-secret German codes and, for three years were able to intercept and decipher all the messages that the German Foreign Ministry sent to its embassies abroad. The British managed to keep this secret and only mentioned it to their American allies when the Germans, who were totally unaware of this leak in their intelligence service, tried to entice Mexico into the war with the promise of the annexation of Texas, Arizona and New Mexico.[80]

The Austrians were the first to realize that intercepting radio transmission was an excellent means of acquiring political and military intelligence previously sought only through costly and dangerous espionage undertakings. In fact, when a political crisis arose with Italy in 1908 as a result of the Austro-Hungarian Empire's annexation Bosnia and Herzegovina, the Austrians intercepted and deciphered Italian radio traffic and used the electrically acquired intelligence to shape their foreign policy.[81]

In 1911, during the Italo-Turkish war, the Austrians gave another demonstration of the capability of their intelligence service. Still extremely interested in Italian political and military affairs, the Austrians intercepted every radio message transmitted between Rome and Tripoli, where the Italian had landed, which provided them with information about the movements of the troops and daily combat situation.[82]

This was doubtlessly the first time in history that technical means (radio), instead of traditional means, such as spies or cavalry scouts, had been used to follow, step by step, the course of a campaign conducted hundreds of miles away.

Another nation, which, like Austria, had always cultivated the art espionage in warfare, was France. In the years preceding World War I, the French intelligence service managed to intercept and record all the transmissions made by foreign embassies in Paris to their respective governments and all diplomatic messages coming from aboard.

An outstanding example of French electronic espionage was the interception of a long message transmitted to the German ambassador in Paris from the German Foreign Minister containing a declaration of war to be delivered to the French, who had already cracked the code in which the message was sent, not only intercepted the dispatch but to garbled its contents that the German ambassador could at first make nothing of it, while the French gained valuable time in which to prepare for mobilization.[83]

However, from the electronic point of view, World War I is to be remembered mainly for some important events, which can be considered the true beginning of electronic warfare.

Chapter 8

The Great War (World War I) 1914-1918

During World War I espionage experts directed their efforts against enemy communications–radio and field telephones. Even though military radio was only seventeen years old when World War I began, it was already widely used. Army trucks, warships, airplanes, and airships could all be equipped with transmitters and receivers–and quite a few were.

The transmitter, naturally, can be depended upon to do everything in his power to make interception difficult in wartime; therefore, intercept operators must be supplied with receivers that are many times more sensitive than those normally employed for radio communications. In 1914, the most sensitive radio receiver in common use was the crystal set. But radio Intelligence operators needed something better, and engineers designed it for them by hooking an amplifier to the crystal set to boost its feeble output. The amplifier used a device invented only seven years before, the electron tube. This early radio intercept receiver of World War I was the first item of electronic equipment to be used in warfare.[84]

The initial objective was to intercept enemy radio messages recording every squeak transmitted. The first thing to find out about any radio station is its frequency. If, for example, you are in New York and want to listen to WABC, you set the radio dial to 77. In doing this, you are actually tuning your receiver to a frequency of 770,000 cycles per second c/s or Hz. Since in war both sides take elaborate measures to keep their frequencies secret, specially trained radio operators are assigned to tune receivers back and forth until they find the enemy's station. After they know the frequency, they leave their receivers tuned to it and intercept all the messages sent.[85]

Because the cycle-per-second is inconvenient unit with which to measure frequency, it is customary to talk about frequencies in multiples of the basic unit: kilocycles (thousands of cycles per second, abbreviated kc/s) or KHz, megacycles (millions of cycles per second, abbreviated Mc/s) or MHz, or gigacycles (thousands of million of cycles per seconds, abbreviated G c/s).

Radio signals behave differently according to their frequency, and these differences determine how far a signal will travel. Moreover, the size of radio receiving and transmitting apparatus depends upon the frequency of the signals. The higher the frequency, the smaller the parts used in the transmitters. Table I lists the principal frequency regions and summarizes how signals behave at these frequencies.

Table 8 - 1 Radio Frequencies at a Glance

Frequency	Name of Region	Behavior	Range
3 KHz to 30 KHz	Very Low Frequency (VLF)	Bend around the earth	Around the world. Can penetrate earth or water if sufficiently powerful
30 KHz to 300 KHz	Low Frequency (LF)	Bend around the Earth	Up to 500 miles
300 KHz to 3MHz	Medium Frequency (MF)	Bend around the earth by. Bounce of layers electrically charged gas 50-400 miles above the earth (ionosphere) by night	Up to 50 miles by day (further if over water). Between 500 miles and 5,000 miles by night.
3 MHz to 30 MHz	High Frequency (HF)	Bounce of ionosphere	Up to 5,000 miles
30MHz to 300 MHz	Very High Frequency (VHF)	Travel a line-of-sight (like light beams) Bounce of ionosphere under peculiar conditions	Up to miles on earth's surface (further if no an airplane) Up to 1,500 miles when ionosphereic bounces occur
300 MHz to 3 GHz	Ultra High Frequency (UHF)	Line of sight	Up to 20 miles on earth's surface (further if no an airplane)
3 GHz to 30 GHz	Super High Frequency (SHF)	Line of sight	Up to 20 miles on earth's surface (further if no airplane)
30 GHz to 300 GHz	Extra High Frequency (EHF)	Line of sight	Up to 20 miles on earth's surface (further if no airplane)

In the first few years of World War I the frequencies generally used for radio communications were between 150 and 750 Kilo Cycles per second (K c/s), or KHz. It was known that frequency determines many aspects of radio transmission, mainly relating to range, but also that, the higher the frequency; the smaller could be the components of the radio set. In other words, the performance and dimensions of such sets depended also on the frequency used. Thus, in many cases, high frequencies were used so that smaller sets could be built to install in aircraft, for example. Toward the end of World War One, the frequencies used were between 750 KHz and 1MHz (one million Hz), tending to increase as each side tried to make it more difficult for the enemy to intercept their transmissions.[86]

The aim was to intercept, record and analyze all messages transmitted by the enemy, whether in plain text or in code, including those which were barely perceptible. Code-breakers were employed to decipher coded messages. For them to be able to do this, it was necessary to intercept a large number of coded enemy messages. Statistical techniques, such as counting the number of times characteristic phrases like "in answer to" or "nothing new" were used, provided data which was extremely useful in breaking the enemy's code. However, it was not always necessary to decipher the whole of an enemy coded message in order to glean the essential information. Vital information regarding the enemy's positions and intentions could nearly always be obtained from a first analysis of radio traffic. To improve reception of enemy communications, receiving sets were equipped with amplifiers using a device invented only a few years previously, the electronic or amplifying valve.

In order to intercept enemy communications, the first thing to do is, obviously, to find the frequency on which the enemy is transmitting. Since, in wartime, this is often changed in an attempt to maintain secrecy, great patience was required from the highly skilled operators who spent hours tuning they found the frequency being used by the enemy. Once the frequency had been located, all radio traffic was received and recorded until the enemy changed frequency.

In 1914, just after Great Britain had declared war on Germany, a remarkable incident took place in the Mediterranean. The German cruiser *Goeben* and *Breslau* were being shadowed by the British cruiser *Gloucester*, which was under instructions to radio all movements of the German ships to the Admiralty in London. The Admiralty would then send orders to the Mediterranean Fleet to intercept and destroy the two German cruisers. Unfortunately, the British had no idea which route the cruisers would take since they could head for Italy, at that time neutral, or a friendly Turkish port. The German cruisers who, at an opportune moment, decided to shake off their pursuers by disturbing their communications intercepted radio communications between the *Gloucester* and the Admiralty. They did this by transmitting a chaotic noise on the same frequency at that used by the British. The British changed the frequencies of their transmissions several times but to no avail. The German ships suddenly changed course and headed at full speed for the friendly waters of the Turkish Dardanelles.[87]

This communication jamming could be considered the first real action of electronic warfare since, for the first time in history; electromagnetic waves had been used, not for communication, but for jamming enemy communications.

Electronic warfare was also engaged, although in a less obvious way, on the home fronts. A few years before the outbreak of World War I, Austria and France had set up special units to intercept army radio traffic. Germany did not set up such a system until several months after the war had begun, strangely enough, so Austria furnished the German intelligence service with precious information gleaned from intercepted enemy communications. To be fair, many other nation as well as Germany, had been slow to grasp the importance of intercepting enemy radio transmissions.[88]

The Russians–despite their experiences in 1904–were particularly uninformed and naïve regarding the use of radio. At the beginning of the war, they did not even seem to realize that radio transmissions could be received by anybody who happened to be listening on the same frequency. German interception of messages transmitted in plain Russian contributed greatly to General Hindenburg's victory over the Russians in the Battle of Tannenberg. Later, the Russians realized that it was necessary to send their messages in code but the skilful Austrians were able to break the code promptly and decipher their messages. The Germans, therefore, received daily information regarding Russian movements on the Eastern front right up to the Bolshevik revolution in 1917 and the Armistice.

The French were also well organized in these activities and right from the beginning of World War I were able to intercept and decipher radio communications transmitted by the Germans who, like the Russians on the Eastern front, inexplicably committed various serious errors in their employment of radio.

By now, all the various military leaders and their respective staff were beginning to understand and appreciate the operational advantages to be gained from intercepting enemy communications and were requiring greater support in this new field. And so electronic espionage was born, an activity, which was to play an increasingly important role in modern warfare.

Although barely fifteen years had passed since Guglielmo Marconi had invented it, radio had already evolved to the stage where it could be effectively employed on ships, aircraft and in both fixed and mobile ground stations. This had been done right from the beginning of World War I but it soon became apparent that electronic espionage required equipment that was more sensitive than the receivers then in common use.

Radio Direction Finding

Since the beginning of the war military engineers and technicians had been devoting their efforts to the construction of more sophisticated equipment, not only to improve communications among their own units, but also to discover and locate the enemy's radio stations. This was made possible by the development of radio goniometric system designed by the Italian scientist, Artom, who had discovered the "orienting" action of the loop antenna; that is, the ability of such an antenna to establish the direction from which an electromagnetic emission originates.[89]

Artom's antenna was used in the Bellini-Tosi Direction-Finder (DF) which consisted of two crossed loops and was ideal for discovering the direction of radio stations transmitting on medium-wave and long-wave frequencies. Guglielmo Marconi, who had moved to England a few years previously, perfected the method invented by his compatriot Artom using a new, extremely sensitive amplifier tube capable of picking up even the faintest signals which the normal crystal radio sets had been unable to detect. As early as 1914, this new equipment made it possible to intercept enemy electromagnetic emissions and determine the direction from which they were coming, thus establishing the position of the transmitting station.[90]

The direction finder thus became a precious instrument in electronic espionage, and for acquiring information about the enemy. The use of the radio by the armed forces was not very widespread in those days so the localization of an enemy transmitting station nearly always indicated the presence of a large military unit in the area; moreover, the territorial distribution of the radio stations gave a very clear idea of organization on the enemy front and changes in location of a radio station provided a fairly exact picture of troop movements. The French and British were particularly well organized in this field and since 1915 had employed effective radio-goniometric systems of interception which enabled them to establish the location of large enemy unit, movement of troops and plans of attack. All this contributed greatly to the success of the Allies in wearing down the enemy and forcing them into a static position with a high attrition rate.[91]

The direction finder achieved its greatest success in maritime operations during World War I. The British, in particular, scored outstanding successes in determining the movements of German submarines, which were obliged to surface to transmit information to their commands. Many submarines sunk in those days could be credited to the British direction-finding system, which supplied the anti-submarine warships with information regarding the movements of enemy submarines. Actually, it was not very difficult for the British to acquire such information as the German submarines used radio without taking any precautions. Equipped with powerful transmitters operating on a frequency of 750 KHz, the German submarines surfaced at fixed times to transmit long messages to their commands. These messages were rather stereotyped which greatly facilitated the work, not only of the code breakers, but also of the British DF operators who had to determine the direction of the transmissions and the exact position of the submarines themselves. [92]

Advances in Direction Finding

Radio direction finding by the British Army during World War I resulted in two important scientific developments that improved radio Intelligence operations. While assigned to the direction-finder station at Abbeville in 1915, Lieutenant E. W. Tremellen, a Marconi Company engineer serving with the British Army, discovered the "night effect," a development that made possible a greater accuracy for bearings taken at night.[93]

During the day, medium-frequency radio waves travel only the surface of the earth. These waves are oriented vertically like the vertical arms of the loop antenna and are accurately picked up by them with no error in reporting the bearing. However, at night these same medium-frequency radio waves also bounce off layers of ionosphere fifty to four hundred miles above the surface of the earth. They travel a ricochet path and are oriented horizontally, like the horizontal arms of the loop antenna. The reception of the signals simultaneously by both the vertical and the horizontal arms confuses the apparatus and results in erroneous bearings. Engineers tabulated the errors likely to be introduced by the night effect, and these tables permitted direction-finder operators to incorporate factors into the bearings they reported.[94]

The same confusion of horizontal and vertical signals occurred when direction-finder stations attempted to obtain bearings on transmitters sending from aircraft. Part of the signal was oriented vertically and part of the signal was oriented horizontally. Lieutenant F discovered the airplane effect. Adcock while serving at a British Army direction-finding station. Adcock's discovery permitted direction-finder operators to correct for erroneous bearings taken on airborne transmitters. Later, Adcock developed a special radio direction finder consisting of four vertical antennas, with the horizontal wires connecting them buried below the ground. Unlike the horizontal arms of a loop, the buried wires could not pick horizontally oriented signals coming from the airplane or bouncing off the ionosphere layers. The Adcock direction finder picked up only the vertically oriented signals, and the cause of erroneous bearings was eliminated.[95]

In February 1915, the British Army in France began to use a new rotating-frame direction finder. Its antenna consisted of a large single loop of wire that was suspended between two 30-foot masts and was many times larger than the loops of conventional sets. The loop was rotated by an automobile steering wheel turned by the operator. The rotating-frame direction finder intercept frequencies from 2 to 4.3 MHz and obtain bearings on German airplanes reporting the results of shell fire by field artillery batteries. Artillery spotting was one of the most valued activities of military aircraft during World War I. Information reported by planes overhead permitted gunners on the ground to correct range errors. By using rotating frame direction finders, Army Intelligence operators were able to warn British troops of impending–and probably more destructive–artillery bombardment and to tell fighter pilots of the RFC where to look for German spotting airplanes. This special direction finder enabled the RFC to shoot down eleven spotting airplanes in a single week. Another rotating-frame device was developed late in the war. Its antenna which consisted of 22 turns of wire and looked like a spider's web, measured 7 ½ feet in diameter and was used to focus the receiver exclusively on the desired station and eliminate interfering signals. The equipment intercepted German press transmissions on very low frequencies.[96]

Impact of the New Technology

Technical progress in the field of radio and its accessories made it possible to build smaller, lighter direction finders, which could be transported by undercover agents. The German in their airship raids on England exploited this development.

When the German started bombing London at night, they realized that they would have to solve the problem of how to reach the target in the dark. At first the German airships used astral navigation systems, but these proved unsatisfactory due to the intrinsic unsuitability of the airship, and to atmospheric conditions such as fog and clouds. So the Germans abandoned these systems and adopted instead a long-range radio-guidance system using a network of transmitters installed in Germany. However, this system also proved ineffective as the on board receivers were not capable of sufficient accuracy either because of the great distance or as a result of errors caused by multi-path night fading.

Finally, the German sent undercover agents to England who installed themselves, with portable radio beacons, in a house just outside London. From there were able to guide the airship to their target with sufficient precision in spite of the dark or fog. But the presence in the air of strange electromagnetic signals just before a bombardment soon roused the suspicions of the British Secret Service who, using direction finders mounted on vehicles, began a systematic search for these emissions.

The German airships committed serious errors in their use of radio as, like the submarines, they always transmitted on the same frequency and always used the same code-names when communicating with ground stations. Moreover, they flew at fairly low speed. All in all, it was fairly easy for the British to know when a raid on London was imminent. It was also quite easy for the British to locate the building used by the German agents, who were arrested. Instead of dismantling the clandestine station, however, the British used it the following night to guide the airships to an inhabited area on the North Sea coast where British fighter aircraft were waiting for them; the result was total destruction of the enemy airship.

After this incident, airships were no longer used as bombers as it had become more than apparent to the Germans that they were exceedingly vulnerable to enemy fighters. Bomber aircraft, such as the Gotha, were sent to bomb London while the airships were relegated to perform subsidiary tasks.

The most interesting and successful operation ever carried out by the British direction-finder network as which took place just before the great naval battle of Jutland. In 1916, British public opinion registered grave discontent regarding the passive conduct of the Grand Fleet, which had failed to impede the German Fleet's incursions in various coastal areas of Great Britain. The bitter memory of the battle of Dogger Bank, in which Admiral Hipper of the German navy had successfully eluded the actions by the British fleet commanded by Admiral Beatty, pained the very souls of those who felt they ruled the waves and they demanded revenge! However, the geographical situation, distances between bases and other relevant factors, all favored the German fleet, which always managed to "hit and run" before the British arrived; it was a problem of timing which was difficult to solve.[97]

For the end of May of the same year, the Germans planned a major naval incursion against the British coastline in which submarines and airships would participate. To prevent the British direction finder network from detecting the departure of their fleet from port, the Germans planned to deceive the British Admiralty by means of an electronic stratagem.[98]

A few days before weighing anchor, the Germans exchanged the radio telegraphic code-name of their flagship the Friedrich der Grosse with that of a radio station at *Wilhelmshaven*, where the German fleet was based. In this way, the British, who regularly intercepted the flagship's transmissions, would think that the German fleet was still at *Wilhelmshaven*.[99]

However, towards the end of May, British radio operator noticed a sudden increase in the number of transmissions made by an unknown ship in the port of *Wilhelmshaven*, which requested canal sweepers, and so forth. These messages were a clear indication that the German fleet was preparing for an important sea operation; so all radio stations along the British coast were put on the alert to keep an eye on what was happening at *Wilhelmshaven*.[100]

On 30 May the faith that the British navy had placed in its interception and direction finding service paid off when changes in direction of the unknown ship's transmissions were noticed. These changed convinced the Admiralty that the German ship, and probably the whole fleet, had left its base and was once again planning to bombard a target in Great Britain. The Admiralty gave immediate orders to Lord Jellicoe, Commander-in-Chief of the Grand Fleet, to weigh anchor and set sail with all haste for the Gulf of Heligoland.[101]

While the two fleets were sailing at top speed towards each other, the German sent their *Zeppelin* airships to explore the sea area to the west of the Danish peninsula. This reconnaissance proved fruitless for them but not, however, for the British ships whose direction finding stations on the French coast picked up the airships' signals, thus confirming that the German fleet had, in fact, put to sea.[102]

The outcome of all this was the battle of Jutland, one of the most important battles in naval history. Much has been written about this battle but possibly no one has pointed out that it would probably have never taken place without the British interception and direction finder service!

Conclusion

The great value of the information was that it actually gave warning of impending movements in time for countermeasures to be taken; yet the exact intentions of the enemy were seldom broadcast by wireless for Intelligence to decipher. The radio intelligence also proved of great value against the Zepplines whose raids began in March 1915 and continued during the summer. The *Zepplines* used wireless freely and always reported as soon as they were airborne.[103]

Military men who used radio communications learned a paradoxical lesson from the success of electronic intelligence in World War I: it pays to keep quiet. The enemy is always listening in, and given enough time and a little luck he can break the most cleverly secret codes and thus learn all your plans, your strength, and your weaknesses. With radio direction finders, an enemy can find the sources of your radio signals and thus discover the exact locations of army detachments, airplanes, submarines, and surface ships.

During the last years of the war, radio intelligence gained some notable information and continued to be of immense value to the Allies. Also radio intelligence was certainly the most important electronic factor in the defeat of the U-boats but was not the only one.

Clearly the main influence during the World War I was in the sphere of communications, and other influences had a comparatively minor role. The telegraph cable was of exceptional value to he Allies. It proved astonishingly invulnerable in the hands of those who commanded the air and sea but useless to those who did not. It had the great advantage that the enemy could not, with only rare exceptions, intercept messages. Communication was therefore immune to crypto- or traffic analysis and gave nothing away. Wireless telegraphy had the great advantage over the cable, on the other hand, that it could contact ships at sea and could broadcast messages simultaneously to a large number of stations. It could also send messages across hostile territory, which was of particular service to the Germans.

Wireless was of very great value for the control of army, naval, and air forces at land ,sea and air, and taking all factors into account, it proved of more value to the allies than to the Germans. Wireless, however, had the very great disadvantage that it could be intercepted by the enemy and subjected to analysis and even the breaking of codes. The fears of early years that it would be easily jammed or counterfeited did not materialize. Without doubt it provided a better source of intelligence than had ever been available before.

The effect of the electron on military power was generally to make conventional methods of waging war more effective. In other words it did not produce a new dimension in maritime warfare as did the submarine but it greatly increased, for instance, the effectiveness of a battle fleet. It is also clear that it aided the stronger fleet, the anti-submarine campaign and the raider hunters more than the weaker fleet, the U-boats or the raiders themselves. For Great Britain its effect was the opposite to that of the two other great innovations of the twentieth century. The electron helped those who commanded the sea, whereas the submarine and aircraft were of more assistance to the weaker power.

World War I taught both sides to look out for the "third ear"–the enemy ear–and to assume that everything said by radio will be overheard and used against the transmitter by the interceptor.

Chapter 9

The Interwar: 1919-1939

At the end of the World War I long-distance communication by wireless depended, as it had from the beginning on long waves and high power. In this the USA now held the lead. From their 350 kw arc transmitters in the Pacific chain they had gone on to a new 500 kw transmitter at Annapolis and a 1,000 kw station building in France for the U.S. Navy. Nevertheless, by 1924 Marconi felt he knew enough about high-frequency wireless to be sure that a reliable long-range system was possible. He therefore recommended that the low-frequency high-power concept for an Imperial Wireless scheme should be scrapped and a high-frequency system substituted.[104]

There was one interesting development which was discovered almost by chance. It was found that a totally submerged submarines could receive the new G.P.O stations at Rugby transmitting on 15 KHz without raising an aerial above the surface. This meant that submarines on patrol in war could receive messages submerged by day as well as on the surface at night. A special insulated loop aerial was designed and fitted for this purpose and special routines for submarines were instituted when required.[105]

The Birth of Radar

Radar, like most of the major technological advances during the twentieth century, did not result from a sudden and inspired line of thought pushed to the point of fulfillment by one inventor. As with the other great innovations, the basic idea preceded the invention by several decades, and it was only when certain special means had been developed that its realization became practicable. Again, as with the other great inventions of this century, once the background work was complete development proceeded independently in several nations simultaneously.

The development of airplane and the turbo-jet engine are good examples in point: Sir George Cayley had laid down the important scientific principles necessary for powered flight as early as 1857. He failed to build the airplane as we now it merely because he had no means of producing the necessary power without incurring a crippling weight penalty. When this became technically possible, the Wright brothers and Langley in America, and Ader in France were all working along broadly similar lines. In the case of the turbo-jet engine, Mélikoff had designed a "helicopter" as early as 1877, whose rotor was to be powered by a gas turbine, consisted of eight curved chambers, into each of which charges of the vapor of ether mixed with air are to be successively exploded by an electric spark, and the charge allowed to expand in doing work. This line of thought had come to nothing at the time because the piston engine was far more efficient at low speeds than the turbo-jet; moreover, the metals able to withstand the extremely high temperatures generated in gas turbines did not exist for another half century. When they did, the device reached fulfillment in the late 1930's, quite independently, in both Britain and Germany. This pattern of "pre-invention" holds for radar as well; for it was on 30th April 1904 that the Royal German Patent Office granted a patent, to cover the basic radar idea, to a young German inventor, Christian Hulsmeyer.[106]

The Roots of Radar

The manner in which a bat successfully avoids the walls and jutting stalactites of a totally dark cave makes fascinating reading. Investigation has shown that if its mouth is gagged or its hearing impaired the bat can no longer avoid such obstacles. From this, it has been concluded that the bat's uncanny ability to navigate derives from the emission of cries–inaudible to the human ear–which are then reflected from any obstacles in its path. These reflected echoes allow the bat to orient itself with respect to the obstacles and thus maneuver to avoid them.

The bat uses the fundamental principle of radar. The basis of the system has been known theoretically since the time of Hertz, who in 1888 successfully demonstrated the transfer of electromagnetic energy in space and showed that such energy is capable of reflection. The *transmission* of electromagnetic energy between two points was developed as "radio," but it was not until 1922 that practical use of the *reflection* properties of such energy were conceived. [107]

It is often thought that radar was a British invention, perhaps because the British were the first to use it systematically in the field of air defense. However, research was also being carried out simultaneously in Germany, Italy, France, and the United States.

The general principles of radar had been formulated some time before and were known to all. In 1888, the German physicist Heinrich Hertz had proved that electromagnetic waves, thereafter called "Hertzian" waves, behave like light rays in that they can be channeled into a single beam and bounced off a metal surface, giving rise to a return echo which can be picked up.[108]

A few years later, in 1904, an engineer from Dusseldorf called Christian Hulsmeyer requested a patent for a "radiophonic measuring apparatus", which consisted of a transmitter and a receiver mounted side by side. The two devices were built in such a way that waves emitted by the transmitter would activate the receiver if reflected by a metallic object. This apparatus, which the German engineer called a telemobilscope was able to pick up sounds, like the chiming of a bell by receiving electromagnetic waves bounced of metallic objects at a distance of a few hundred yards. However, despite the success of an experiment carried out at Rotterdam, the big shipping companies showed no interest in Hulsmeyer's apparatus. It was perhaps too early for people to appreciate the potential value of such an apparatus. In fact, at that time little was known about radio waves; there were no means of amplifying a signal, protecting it from external interference, or controlling the electromagnetic emissions produced, and so on.[109]

Little technical progress had made by 1922 when Guglielmo Marconi, during a conference held at the Institute of Radio Engineers in the U.S., expounded practical ways of using radio waves for maritime navigation. He envisaged on apparatus capable of radiating a beam of electromagnetic waves in a fixed direction that, on meeting a metallic object such as a ship, would be bounced back.[110]

In 1933, in the presence of Italian military authorities, Marconi demonstrated "interference" in the reception of signals caused by motorcars passing in the vicinity of a radio station, using a wavelength of 90 centimeters (cms) linking Rome and Castelgandolfo.

Marconi's initiative resulted in a formal proposal, approved by the Italian Ministry of War in 1935, for the construction of a Radio Detector Telemeter (RDT). Of the three armed forces, the Italian navy was the most interested in, and best equipped to deal with electronic research and development. A research project was therefore set up under the direction of professor Tiberio at the Institute of Mariteleradar, in association with the Naval Academy of Livorno.[111]

However, both finances and labor were in extremely short supply so professor Tiberio, who had meanwhile been appointed a naval officer, had to develop the prototype almost single-handed. It was only in 1941, after the battle of Cape Matapan in which the Italian navy lost three cruisers, two destroyers and 2,300 men, that the authorities learnt that the British had electronic equipment for night-sighting on board their ships. The Italian Admiralty had received the impression, during the battle, that the British were using such equipment to direct their maneuvers and firing. This was, in fact, confirmed by interception of a coded message from Admiral Cunningham, the commander of the

British naval squadron. Immediately, the Italian authorities released sufficient funds for the completion of the "Gufo" radar sets, which were, then still at the experimental stage at Livorno.[112]

However, two U.S. physicists, Gregory Breit and Merle Tuve, made the most important contribution to the development of radar in 1924. The set up experiments using radio pulses to determine the height of the layer of ionized gas, which surrounds the Earth. By measuring the time these pulses took to reach the gas layer and return to Earth, they discovered that the ionized gas layer was at a height of about 70 miles and that it reflected radio waves.[113]

In Germany, in the early 1930s, Doctor Rudolph Kunhold, head of the research division of the German navy, was trying to develop an apparatus capable of detecting objects underwater by bouncing sound waves off them; this apparatus now goes by the name of sonar. In these experiments Dr. Kunhold realized that what was accomplished underwater could also be accomplished above it, using radio waves. He conducted several experiments in this new field and incorporated into his apparatus a new electronic tube capable of generating power of 70 watts on frequency of 600 MHz–truly exceptional in those days. With this new electronic tube, produced by the Philips Company of Holland, Kunhold completed the construction of his radar apparatus in 1934 in the research laboratories of the German navy at Pelzerhaken. Of the new apparatus to high-ranking naval officers was great success as, besides being able to detect a ship at a distance of 7 miles, the radar also located a small aircraft, which happened to be passing by.[114]

In the United States, radar research was being carried out both by the Signal Corps and the Naval Research Laboratory, which were working independently. In 1936, the Naval Research Laboratory developed a prototype operating on 200 MHz and the first series of these systems, bearing the trademark CXAM, were installed on board major navel units in 1941. In 1939-40, the Signal Corps developed a long-range system designated SCR-270. One such system was in operation at Pearl Harbor on the morning of 7 December 1941 but, although the radar operator received signals of approaching aircraft, nobody alerted the ships in port.[115]

In Britain, studies in the field of short wave signals were initially undertaken for purely scientific purposes, such as determining the height of certain conducting layers of the ionosphere discovered by the British physicist E.V. Appleton (Appleton layers) in 1926. However, war clouds were gathering on the horizon, and the realization that Britain was particularly exposed to air raids, led to a drastic increase in scientific effort in an attempt to make up for lost time.[116]

The first result of this effort was when the physicist Robert A. Watson-Watt, a descendant of the famous James Watt who gave his name to the unit of electrical energy, succeeded in visualizing radio signals by means of Braun's cathode ray tube, and in determining electro-optically the emission propagation time. A few years later, in 1935, Watson-Watt developed the first practical equipment for detecting the presence of airplanes.[117]

Radar is considered one of the most important instruments in electronic warfare. Radar is an electronic eyes which can see in the dark and fog and which can penetrate smoke screens. It can detect the approach of the enemy at much greater distances than the naked eye can; it can direct gunfire in conditions of poor visibility and can even provide information regarding the topographical features of the zone.[118]

Radar set consists of a transmitter, a receiver, an antenna (aerial), and an indicator or display. The transmitter sends out pulses of electromagnetic energy via a highly directional antenna pointing in fixed direction. If a pulse meets a target, for example an airplane, during its journey, it is bounced back, or reflected, towards the receiver. The time-lapse between the transmission on the pulse and receipt of the return echo is measured by a special device incorporated into the radar set and, since it is known that electromagnetic waves travel at a speed of 300,000 kms per second or 186,000 miles per second, it is an easy matter to calculate the distance of the target. The operator can thus read directly on his radar display both the distance and the bearings of the target.

There were two popular radar indictor displays in that time: A-scope display and the plan-position indicator (PPI). The A-scope display was used in conjunction with a dial called a servo repeater that told the direction in which the antenna pointed, and a range indicator that resembled a car's mileage meter. On the display face of the cathode-ray tube (CRT) was a horizontal green sweep, or trace; a range marker moved along the trace when a crank on the indicator was turned. When the transmitter fired, a large spike appeared at the extreme left the trace and the echoes from targets showed up as smaller spikes further along the trace to the right. Some radar had an automatic feature so that range marker met the desired echo it could continue to follow the target.

The plan-position indicator (PPI) display showed the radar stations the center of a circular map, with targets and terrain features appearing as bright green blips around it. The direction in which the radar antenna pointed was shown by a rotating radial trace. The distance to a target was estimated by measuring the distance from the target blips to one of a series of concentric range resembling the scoring circles of a bull's-eye.

Conclusion

The greatest British advance in electronic warfare in this period was undoubtedly a technical one. The direction-finding stations of the First World War worked on low frequency and were simple and accurate. It was expected that signals made by ships at sea would normally be on high frequency.

In general, however, the influence of the electron on all branches of armed services during this period between the wars was substantial. The range of radio communication and the increase in the number of channels made worldwide communication possible without having to rely on cables. The invention of asdics was of exceptional importance as an anti-submarine measure in spite of the fact that it was of comparatively short range. Nevertheless, Winston Churchill's description of it as a "system pf groping for submarines" was not far off the mark and the British undoubtedly overestimated the effect that it would have on naval warfare. The invention or the development of radar was probably to be in the end the greatest advance of this period. The total number of sets at sea in the British, American and German Navies was seven but its great potential was recognized although it was realized that, in the same way as wireless transmissions in the World War I, it could give away the position of the user.

Chapter 10

World War II: The Evolution of Electronic Warfare

Electronic warfare evolved further in World War II, when radar itself emerged. The astonishing employment of electronics is one of the most notable features of that struggle. Winston Churchill, who was intimately involved with the warfare of theses invisible radiations during the Battle of Britain, gave it the grandiloquent name of "The Wizard War." "This was a secret war," he wrote, "whose battles were lost or won unknown to the public, and only with difficulty comprehended, even now, by those outside the small high scientific circles concerned. No such warfare had ever been waged by mortal men." It was vital. "Unless British science had proved superior to German, and unless its strange sinister resources had been effectively brought to bear on the struggle for survival, we might well have been defeated, and, being defeated, destroyed." One of the battles was that the KNICKBEIN, a German navigational beam whose two sections crossed over British cities and which the British scientists twisted so that the *Luftwaffe* bombers unloaded most of their high explosive during the Battle of Britain into empty field and the Channel.[119]

During World War II electronic espionage experts directed their efforts against enemy radio communications, electronic navigation aids, and radar. The interception of enemy radio signals and use of radio direction finders not surprisingly played a larger role of radio World War II than in World War I.

The Emergence of Electronic Countermeasures

By the summer of 1940, Germany had conquered nearly all the continent of Europe and could now dedicate all her efforts at Great Britain, her old enemy! According to Hitler, the only way of dealing with the British was to invade their island. To this end plans were drawn up, code-named "Sea Lion", in the form of a landing to take place around mid-September of that year.[120]

The first step was to put the British Royal Air Force out of action. Then the *Luftwaffe* would keep the British Home Fleet out of the area while German forces crossed the English Channel. Field-marshal Göring, Commander-in-Chief of the *Luftwaffe*, had about 2,600 aircraft at his disposal. These comprised both bombers, such as the Heinkel He 111 and Junkers, Ju 87 and Ju 88, and fighters, mainly Messerschmitt Bf 109s and Bf 110s. The date of the air offensive, the famous "Aldertag" (Day of the Eagle), was fixed for August 10, 1940.[121]

Göring's instructions were precise: first, they were to attack all airfields where RAF fighters, particularly Spitfires and Hurricanes, were based, and put the fighters and their airfields, out of action, and, secondly, they were to paralyze aircraft production by attacking and destroying all aircraft factories.

The German air offensive actually began on August 12, 1940.[122] The attacks took place by day, according to plan, and involved formations of hundreds of aircraft. However, day-by-day, hour-by-hour, the British fighters systematically placed themselves in advantageous positions. Taking-off from their airfields, they managed to time their confrontations with the enemy to take place over the English Channel, much to the surprise of their victims, normally the German bomber pilots who did not expect to meet the enemy so soon. "How do they do it?" they asked themselves. Luftwaffe commanders, however, were well informed of the existence of strange and very high antennas located along the south coast of England, and, finally, understood how it was possible for the British to detect the arrival of the invading air formations so soon.

In 1939, the German intelligence services had informed their High Command of the construction of Antenna as high as 300 feet-long the English coast from Southampton to Newcastle. At first, the real significance of these antennas had escaped the German whose undercover agents in England spoke of radio transmission stations operating on very short wavelength, from 1.5 to 2 meters. In fact, the use of this wavelength was merely a cover for the real wavelength of 40 meters used by the British in their new electronic system of long-range sighting, the Chain Home radar stations.[123]

The explanations furnished by the German secret services did not allay the suspicions of their leaders, particularly Hitler, who also wanted to know what point the British had reached in their preparations for war, above all, in the field of radar. So, on August 2, 1939, just before the outbreak of World War II, one of the last German airships, *Graf Zeppelin*, took-off from an airfield in northern Germany and headed for the English coast: its mission was to intercept and record the emissions coming from those strange antennas with the aim analyzing their characteristics to find out the British had a radar better than that currently being developed in Germany.[124]

Some extremely sensitive receivers and other special electronic measuring devices had been installed on the airship. Several specialized technicians were on board, as well as the head of the *Luftwaffe's* Signal Corps, General Wolfgang Martini.[125]

The airship cruised along the chain of antennas and the technicians on board tried various means to tune in to the British frequencies but no suspicious signals were received. The reasons for the failure of this mission are not known even today. One theory is that the British, having been forewarned of the imminent mission, had detected the airship by radar long before it reached their coast and had immediately ordered their radar stations not to transmit. Another theory is that the receivers on board the airship did not cover the frequency band used by the British, especially the short-wave bands, and therefore could not pick up those transmissions. Others think that the receiver on board the airship had broken down just after take-off and the operator had not had the courage to notify his superiors!

Whatever the reason, the fact remains that after that flight the Germans tended to underestimates the danger: Marshal Göring was convinced that they need not worry too much about British radar and, furthermore, that it was not worth spending more time and money on electronic research to develop new radar equipment. According to Göring, the Third Reich in a very short time would win the war, thanks, to the extraordinary power of the *Luftwaffe* and the *Wehrmacht*.[126]

Consequently, many electronic technicians and engineers were removed from radar research laboratories and employed in other sectors while, in Great Britain, no less than 3,000 highly-skilled people were employed to study all aspects of radar, their allotted funds being much higher than the Their Reich's.[127]

The flight of airship *Graf Zeppelin* is memorable mainly because it was the first mission of electronic intelligence (ELINT), today a routine activity of all modern armed forces.

A few days later, World War II broke out. The *Luftwaffe* went from success to success in the skies of Poland, Norway, and France, where there were no traces of equipment capable of detecting aircraft from afar.

However, when the Battle of Britain began, that invisible electronic wall which had been erected along the English coastline began to annoy Göring. It was making it easy for the RAF to counter the German attacks, so, two or three days after the fighting began, Göring gave orders for it to be attacked and destroyed. The frequency employed by the Chain Home had, by this time, been pin-pointed and by listening to enemy transmissions the Germans had determined that the RAF fighters were guided by ground command centers using the new system of sighting whose eyes were, in fact, those strange antennas along the coast.[128]

The first attack was launched on five coastal stations. German fighter-bombers, each carrying two large, 500-kilo externally mounted bombs, made lightening attacks on the antennas, and all five stations were hit and seriously damaged. Despite the fact that only one antenna had actually collapsed, all five had, in fact, been silenced instantaneously.[129]

But three hours after the attack, the British radar stations were again transmitting! Actually, it was a trick devised by the British to make the German think that the Chain Home had not been seriously damaged; they had installed some ordinary transmitters to give the impression that the destroyed equipment was still working. In fact, the new apparatus were not capable of receiving echoes, as they were only transmitters, and could not therefore sight any target. The Germans, however, thought that the damage had been repaired already and were convinced that it was useless to attack the antennas since they could be "silenced" for a couple of hours at most. So the British scheme paid off, as the Luftwaffe, under the illusion that the Chain Home was indestructible thereafter refrained from attacking it during the entire remaining period of the Battle of Britain.[130]

During August 1940, formation of hundreds of German bombers and fighters crossed the English Channel to attack RAF airfield and their hangers. But the RAF fighters, about 700 Spitfires and Hurricanes in all, always managed to be in the most favorable position for intercepting and shooting down the raiding aircraft, particularly bombers. On August 26, 1940, after barely two weeks of combat, the Luftwaffe had lost about 600 aircraft, while the RAF had lost only 260. However, RAF Fighter Command was also in dire straits, as it did not have enough reserve pilots.[131]

At this point, Hitler intervened with the order to cease bombing enemy airbases and, instead, to systematically bomb London. This change of targeting, while providing a welcome respite for the exhausted British fighters, did not have any really decisive effect. However, it soon became apparent that the German He 111 and Ju 88 bombers were too lightly armed to defend themselves and were thus extremely vulnerable to day-time attacks by Spitfires and Hurricanes. Moreover, even the most advanced Luftwaffe fighters, such as the Bf100, did not have sufficient endurance to operate both as escorts for the slower bombers and as free fighters.[132]

Having been defeated in daytime combat by the omnipresent RAF fighters, the Germans decided to change tactics and commence night bombing. Obviously, the attacking forces required adequate navigation and blind bombing systems, while the defenders had to deal with the problem of how to counter this move and defend the country from such attacks.[133]

This was the beginning of a new phase in the air battle of Britain, or rather a new type of war which the British Prime Minister, Winston Churchill called the "Wizard War". He was specifically referring to the electronic counter measures (ECMs) employed by the British to neutralize the radio navigation aids used by the German aircraft. Churchill wrote:

This was a secret war, whose battles were lost or won unknown to the public, and only with difficulty comprehended, even now, to those outside the small high scientific circles concerned. Unless British science had proven superior to German, and unless its strange, sinister resources had been effectively brought to bear in the struggle for survival, we might well have been defeated, and defeated, destroyed.[134]

For a better understanding of how this secret war between the Germans and the British developed, we must go back a few years to see how the former acquired their radio-guided bombing technique, used by the *Luftwaffe's* bombers, and how the latter discovered this system.

In 1930, the German company Lorenz designed and developed a radio-electric navigation system to be used for night landings or for landings in conditions of poor visibility. The Lorenz system marked the flight-path by the equal-strength method, used today in many radio navigation systems. It consisted of two identical directional antennas, placed side by side in such a way that their radiation patterns overlapped. The antennas were connected to two transmitters, which were identical except gor, their modulation: one emitted a series of Morse code and the other a series of dashes. A mobile receiving station (e.g. an aircraft) moving within the overlapping section would hear both signals at the same time end, since they were complementary, a continuous signal, or uninterrupted sound, would be heard. This would enable the pilot to know that he was on course. If the aircraft moved off course, the pilot would hear either a series of dots or a series of dashes and could thereby easily deduce which side of the equal strength line he was on. By comparing the relative intensity of the two signals, he could also correct his course to get back on the line leading to the transmitting station (in this case the airbase), which functioned as a directional-beacon. The ingenious Lorenz system as immediately adopted in both civil and military airports not only in Germany but also in many other countries, including Great Britain.[135]

In 1933, the German scientist Dr. Hans Plendl began to study the possibility of using the Lorenz system to increase the accuracy of bombing systems in conditions of bad visibility or at night. Dr. Plendl's called *X Gerät* (X-apparatus), consisted of a certain number of Lorenz beams, one of which was the main radiopath-guide along which the air formation was to navigate, while the others, beamed across the main radiopath, interrupted it at predetermined intervals. These secondary beams usually crossed the main beam above places, which were marked, on the navigation map, enabling the pilot to know his exact position. This system was combined with a "time-command" which automatically released the bombs when the main beam was crossed by the final secondary beam. With this system, bombs were dropped on target at night with accuracy, which was truly exceptional for those days. The Germans installed a network of *X Gerät* on the north coasts of France and Belgium just after their occupation.[136]

This so-called "blind" system of bombing had its beginning by fire on the night of November 14, 1940, with the city of Conventry as the target. Two formations of approximately 450 German bombers took-off in the middle of the night from the airfield of Vannes in occupied France. Nearly all the bombers were equipped with the new Plendl apparatus and, with the guidance of the *X Gerät* beams, they reached the their target and dropped their bombs on the city center, practically razing it to the ground. That night marked a big step forward in the ever more indiscriminate use of bombers against defenseless civilians, to be followed by the bombing of London, various German cities and, finally, Hiroshima.[137]

This method of night bombing adopted by the Germans was not a complete surprise to the British. On November 4, 1938, the British naval attaché in Oslo had received a secret file from a German citizen claiming to be a "well-meaning scientist". These papers revealed that the Germans were constructing a whole range of new, secret weapons, such as missiles, rocket-propelled bombs and magnetic mines, and that they were developing in electronic system using radio beams which would enable an airplane to measure its distance from special ground stations. Mention was also made of top-secret research, which was being carried out on the island of Usedon in the Baltic Sea at a small town named Peenemunde. Most of the things described by mysterious German scientist were completely new to the British but the little they already new concerning German weapons corresponded perfectly to what was contained in the file.[138]

Of course, the document gave rise to strong differences of opinion among the intelligence service, military staff and the scientists who were researching and developing new weapon. Some were convinced that it was a trap designed to mislead the British war effort or a propaganda measure intended to discourage Great Britain from declaring war on Germany; others maintained that the Germans wanted to mislead British scientists and technicians into fruitless fields of research. One group, however, felt it wise to investigate the details of this precious piece of information closely: among these was Winston Churchill who, when the war broke out and the threat of electronically-guided bombing was imminent, wrote: "If these facts correspond to the truth, represent a deadly danger."[139]

He immediately set up a committee of scientists to study, not only what was alluded in the Oslo papers, but also the possibilities of using applied electronics for military purposes, a use which Churchill was advocating more strongly.[140]

Meanwhile, the Germans had decided to perfect their electronic method of bombing as it had shown two serious shortcomings. First of all, with this system the bombers had to fly along the radiopath for too long a period of time with the almost certain danger of being attacked by British fighters which always seemed to be positioned along their flight paths, much to the surprise of the Germans. Secondly, the Lorenz system was rather complicated and pilots and operators had to undergo long training courses. For these reasons, the Germans had started studying simpler, improved systems of radio-guidance and were soon trying them out.[141]

The that the Germans were using electronic systems for night bombing gained in Britain following interrogation of captured *Luftwaffe* pilots and analysis of electronic equipment found in the wreckage of a German bomber shot down on British territory.

On 21 June 1940, all doubts about the existence of such electronic systems disappeared when the pilot of an RAF Anson on a routine electronic reconnaissance flight heard in his earphones something he had never heard before: a series of particularly clear and distinct dots transmitted in Morse Code shortly followed by a continuous signal (or whistle). Still flying on the same course, he then began to hear in his earphones a series of dashes transmitted in Morse code. The Anson was, in fact, crossing the radio beam emitted by a German station to guide the German bombers to their target. This incident provided further confirmation of the truth of what was written in those mysterious documents handed over to the British attaché in Oslo.[142]

Following this lucky discovery, the British began to study all the possible ways of opposing the German system in order to reduce or, if possible, neutralize its effectiveness. These became known as electronic countermeasures (ECM).[143]

One countermeasure, which was considered by British scientists, was to transmit a continuous noise, produced by an electric machine, on the same frequency as that used by the Lorenz system. A medical cauterizing instrument turned out to be the most suitable machine for this task and the large London hospitals were immediately consulted! The electrical discharges produced by such an instrument would have disturbed the German transmissions enough to render their guidance system unless. Another way of obtaining the same result would have been to place a microphone near the spinning propeller of an airplane and transmit the noise on the same frequency as that used by the Lorenz system (200-900 KHz).[144]

However, these ways of interfering electronically with the Lorenz system had the serious disadvantage that the enemy would be aware that the interference was deliberate and, consequently, that their Lorenz system had been discovered. They would then think up some devilish new method, which, no doubt, would have even more serous consequences for the British cities, which had by, now become the main target of the Third Reich's night bombing.

To avoid this, British scientists devised a means of deceiving German plots by transmitting signals of the same type as those they expected to hear but containing deliberate distortions (such as direction of arrival), which were intended to deceive them without arousing any suspicion. This system had to be put into effect immediately as the Germans had already inaugurated their radio guidance system in the bombing of Coventry and were relentlessly returning every night to bomb the island.[145]

Following a period of intensive research, the British finally found an antidote to the Lorenz system, which they called Meacon (Masking Beacon). This countermeasure consisted of retransmitting the signal emitted by the Lorenz after having tampered with it. A receiver and a transmitter were installed about 10 miles apart in the South of England: the receiver picked up the Lorenz signals and sent them by cable to the transmitter which then immediately retransmitted them using a much greater power and a directional antenna which emitted the radio beam in a slightly different direction from that of the original beam coming from the Lorenz apparatus. At a certain point, German points flying along the radio beam would hear two signals, the original becoming fainter and the retransmitted one becoming stronger. They would automatically pay attention to the stronger signal, which would take them off course away from the target to be bombed.[146]

With this trick, German pilot ended up bombing open country instead of the assigned cities, and, in many cases, lost their way and had no alternative but to land in

England. After some time, the Germans realized that their Lorenz system had been completely neutralized by British countermeasures and immediately modified their radio-guidance system for navigation and bombardment.[147]

The new system (named "Knickebein" by the Germans and referred to as "Headache" by the British) consisted of two inter-connected transmitters, which sent out a series of dots and dashes. The difference between this and the old Lorenz system was that, instead of having many cross beams, there was only one, which crossed the main beam exactly above the target city. Besides being simpler, the new system was also much more accurate as the continuous signal was within a 3 degree sector with a margin of error of less than one kilometer.[148]

As soon as this new system was introduced, the German bombers began to achieve better results. However, the British had found out about the "Knickebein" some months previously when they found, in the wreckage of a Heinkel III, a paper headed "Navigational Aid" which mentioned "Knickebein" and contained data regarding times, places, routes and so forth. Interrogation of captured German pilots and careful examination of every radio apparatus found in shot-down German bombers soon revealed the main characteristics of the "Knickebein" (especially its operating frequencies, the most important of which was 30 Mc/s (MHz) and the British promptly came up with the "Aspirin" (electronic countermeasure) for the "Headache". They reinforced one of the two German signals (dots or dashes) by transmitting the same signal at a much higher power with the result that the main beam was slightly inclined to either right or left, thus taking the German bombers off course.[149]

The British Radio Intercept Systems also managed to pinpoint over which city the cross-beam traversed the main beam in time to alert the population and organize air defense, concentrating RAF fighters in the area, of the expected attack. At this point, both sides had suffered heavy losses. By the end of September 1940, the Germans had lost 1,100 aircraft and the British at least 630 fighters.[150]

By now, it was clear that the German plan to conquer the skies above the Channel and the south of England had failed and Hitler had to put off indefinitely his much-desired invasion, operation "Sea Lion". Moreover, in the late fall (autumn) of 1940, bad weather forced the Germans to slacken their pace and cut down on air raids which, by now, were nearly always at night as only the darkness could protect the bombers from the inevitable relentless attacks by British fighters.[151]

Meanwhile, an intense struggle was going on in the laboratories of both countries in an attempt to devise more sophisticated electronic equipment, especially now that radar was proving more and more to be an indispensable means of pinpointing the enemy and directing fire against him. However, as soon as one side came up with a new electronic measure, the other side to neutralize or at least reduce its effectiveness immediately devised an appropriate countermeasure.[152]

During this dramatic phase of the war, the British Broadcasting Corporation (BBC) had been ordered to use the same frequency for all its transmissions as it had been discovered that German pilots who had lost their way, due to British ECM or bad weather, used BBC radio stations to get back on course. They used the direction finders they had on board to measure the course or bearing to two or three BBC stations in order to fix their position, by triangulation.[153]

Another radio station, which was used for military purposes, was Radio Paris. Unlike the BBC, which mainly transmitted entertainment, war news and political speeches designed to keep up morale, Radio Paris offered a continuous, round-the-clock program of lighter fare in the form of songs and variety shows, interspersed by Nazi propaganda. These programs were listened to by a great number of British people who tolerated the Nazi propaganda in the same way we tolerate the commercial breaks which interrupt our television programs nowadays.

After a while British listeners noticed that the volume would increase every now and then would have to turn their sets down; they also noticed that this usually happened just before a German air raid. This strange coincidence was soon made known to the proper authorities that, after detailed investigations, discovered that, indeed, the transmissions increased in volume in those cities which were bombed shortly after and also that the volume was proportionately weaker with distance. It was concluded that the Germans must have been using Radio Paris to guide their bombers over the cities.[154]

This was, in fact, the case; before every air raid, the Radio Paris transmissions were switched from the normal omni-directional antenna to a highly directional antenna aimed at the city to be bombed. The German pilot would thus be directed to London or Liverpool simply by listening to the French songs transmitted by Radio Paris! Another narrow ray, intersecting the main beam above the target city would signal the bomb-release point.

This new system, which operated on a frequency of 70 Mc/s (MHz) and was called "Ruffian" by the British, is something of mystery even today. It is difficult to understand how the Germans managed to transmit such very narrow (3 degree) electromagnetic beams with the limited electronic technology then at their disposal.[155]

The British took a long time to detect this fiendish system, but eventually came up with an effective countermeasure, which they called "Bromide". This consisted in re-transmitting the Radio Paris programs on the same frequency but using an omni-directional antenna thus neutralizing the German's directional aid.[156]

With the electronic countermeasure the British managed to completely disorientate the German bombers, which flew haphazardly over Britain dropping their bombs at random. Later, the British managed to achieve directional transmissions, which enabled them to induce the bombers to drop their bombs at se. to keep the Germans in the dark regarding the success of their electronic countermeasures, the British Press attributed these random bombing to diverse actions organized by the Germans against the Spitfire bases. This countermeasure did not last long, however, at the beginning of 1941, the Germans came up with another bombing-aid system which they named "Benito" in homage to their Italian ally, the "Duce" of Fascism.[157]

In this period, frequency modulation was almost unknown and so the Germans, convinced that the British had no means of listening to this type of transmission, set about trying to exploit it in order to elude British surveillance. A number of secret agents, equipped with portable FM (frequency modulation) radio sets, were positioned along the main routes in Britain and France and could furnish German pilots with positional and other information, including their exact distance from the target.

It was not easy for the British intelligence service to understand what was happening but they eventually managed to intercept the communications between the German secret agents and pilots and immediately devised a simple but effective countermeasure. They employed German- speaking operators who would, using the same frequency, transmit false information to the enemy pilots. This countermeasure, called "Domino", was so effective that several German pilots were induced to land at British airbases without realizing it![158]

However, "Domino" was not without its drawbacks. One grave consequence of its shortcomings was when, on the night of May 30/31, 1941, the "Domino" operators accidentally directed a formation of German bombers to attack Dublin, capital of the neutral country of Eire.[159]

Finally, the Germans resorted to firebombing; the glow from the fires caused by these bombs was sufficient to illuminate the area to be bombed by the successive formations of planes. The British reacted by setting up huge fires to act as bait for the German formations. This was, of course, done outside London in open country where the Germans, ignorant of the trick, regularly dropped their bombs.

However, by now, the Battle of Britain was already petering out and German aircraft were beginning to be transferred from France to the eastern front in preparation for the invasion of Russia. After months of fierce air combat, heavy bombing and desperate fighting against Britain's air defenses, the German had failed to conquer the skies of Britain and their plan to invade the island had gone up in smoke. The RAF had emerged victorious even though its losses were probably almost as heavy as those of the enemy. Approximate losses were 1,500 British and at least 1,700 German fighters.

Conclusion

There are many factors that favored the final victory of the RAF. Rightly considered to be a turning point in World War II. The victory is usually credited to the superior performance of the British Spitfire and Hurricane fighters, the courage and experience of their pilots, the effectiveness of the integrated early warning and fighter control system and appropriateness of the tactics of No 11 Group, Fighter Command; moreover, the *Luftwaffe* made a number of tactical errors. However, a careful study and analysis brings to light other considerations which documentation and statistics available today confirm.

The British were on home ground and, whilst their fighters were obviously faster than the slow German bombers, the latter had to endure long fights, often in bad weather conditions over the threatening waters of the English Channel and the North Sea. The British also had the benefit of an excellent warning and command system, the very effective electronic countermeasures, which deceived the German pilots by leading them to believe that they were attacking the right target when, in fact, they were often dropping their bombs in open countryside or in the sea. It has been estimated that the only a quarter of the bombs carried by the Germans reached the urban areas and factories which were their targets.

Secondly, those electronic countermeasures devised to interfere with navigation caused the German pilots to fly in an insecure state of mind, not knowing whether to rely on their navigational instruments or on their senses, which had a debilitating effect on the operative efficiency both of the crew and the aircraft.

Despite alternating periods of success and failure, the various systems of electronic countermeasures devised to neutralize or reduce the efficiency of the radio navigation systems used by the enemy carried great weight in deciding the final outcome of the Battle of Britain.

Chapter 11

The Electronic Battles in the Battle of the Atlantic

Another important chapter in the history of electronic warfare was the desperate struggle between Axis submarines and Allied air and sea anti-submarine forces in the so-called Battle of the Atlantic.

At the beginning of the war, the only means available for detecting submarines was Asdic (Anti-Submarine Detection Investigation Committee), now commonly referred to as Sonar (Sound Navigation and Range). It involves sending out sound waves into the water, which, on meeting an object, are reflected back; the distance of the object is calculated by measuring the time taken by the wave to return. This is called echo ranging.

In the summer of 1940, Admiral Dönitz, Commander-in-Chief of the German submarine fleet, decided to make a radical change in the tactics of submarine warfare. He had noticed that the Allied convoy's naval escorts mainly consisted of rather old destroyers since the best ships of the Royal Navy were being used to fight German merchant raiders. Taking advantage of their weak defense, Dönitz decided to attack the enemy convoys by night on the surface rather than under water. In these conditions, Asdic (whose range was minimal near the surface) would be impotent against the fast German U-boats which, protected by the darkness, would be able to attack and retreat without submerging. At night, the low superstructures of the submarines would be difficult to make out in the vast expense of the ocean while massive dark forms of the merchant ships, standing out against the slightly lighter sky, would be easy targets for the submarines.[160]

The commanding officers of the U-boats, realizing their advantage, became more and more audacious in their attacks, penetrating into the midst of the slow convoys and causing enormous damage. They were also greatly helped by the German radio interception service, Service B, which picked up and deciphered not only the messages transmitted by the British convoys at sea but also the route instructions transmitted by the British Admiralty to the ships.[161]

As the number of merchant ships sunk rose day by day, Britain began to face the awful prospect of having her supply lines from the British Empire and the United States cut off completely. Alarmed by this prospect, the British decided to install on some of their escort ships and RAF Coastal Command aircraft ASV (Anti-Surface Vessel) radar. However, the Mark I performed poorly in submarine warfare and at the beginning of 1941 was replaced by the Mark II, which was installed on aircraft. With the aid of this apparatus, an aircraft flying at an altitude of 1,500-3,000 feet could detect a submarine on the surface at a distance of 8 miles. But the Mark II also proved inadequate because when the aircraft closed in to bomb the submarine sea-clutter (echoes reflected from the sea) masked the target echo on the radar screen making night bombing of submarines on the surface ineffectual.[162]

The enemy, however, was unaware of this limitation and so the presence of radar on board the aircraft helped to lower the number of British merchant ships sunk, at least in the coastal waters off the west coast of the British Isles out to the limits of the range of Coastal Command aircraft.

At this point, the German submarines began to use a new tactic introduced by Admiral Dönitz. This was the "wolf-pack" method of attack, which involved concentrating a number of submarines at strategic point so that, when an enemy convoy tried to pass, it was attacked from all sides for several days running. This new tactic, applied mainly out of range of British aircraft, created great difficulties for naval escort units and caused havoc in the convoys; many British merchant ships were sunk as a result of this new method of attack. After the United States entered the war, German submarines could also operate along the American coastal routes used by a great number of merchant ships which, unarmed and escorted, were totally defenseless against the underwater menace. Thus, the number of ships sunk rose astronomically. In the month of May and June 1942 alone, 200 merchants ships were sunk along the American coast![163]

While this fierce combat was going on at sea another challenge was being met in the laboratories. Scientists were busy devising a series of electronic measures, countermeasures and counter countermeasures, which were to sway the course of the Battle of the Atlantic.

The Allies began by installing a new L-band radar, i.e. operating on frequencies between 1,000 and 2,000Mc/s (MHz), in aircraft which had the rang and endurance to allow the main convoy routes between Great Britain and the United States, to be covered from bases in these nations. Thus, in the of 1942, Allied aircraft were able to begin night bomb attacks on German submarines using a very powerful searchlight–the Leigh –which could illuminate them from a distance of about a mile. Now that the Allies had found a way of covering the whole Atlantic and had overcome the problem of loss of radar contact at close quarters by using a searchlight, the number of German submarine sunk began to rise.[164]

The Germans countered this by installing Metox Radar Warning Receiver (RWR) on their submarines. As previously mentioned, this type of receiver was able to pick up enemy signal before it was itself detected by the enemy. The French firm, Metox, already had the RWR in stock but the antennas had to be hurriedly improvised by winding wire round a wooden cross; this improvised antenna was jokingly referred to as "Biscay Cross", alluding to the Bay of Biscay where the German submarines had to contend not only with the storms for which it is famous, but also with concentrations of Allied aircraft and warships. The Metox, by providing early warning of the enemy aircraft or ship, enabled the submarine to crash dive in time.[165]

This countermeasure had immediate effect and the number of submarines sunk declined noticeably. The Allies, of course, realized that something new was happening in the electronic field and started work on new radar, the Mark III. This radar worked on a frequency of 3,000 Mc/s (MHz) corresponding to a wavelength of barely 10 cm, in the S-band (2,000-4,000 Mc/s (MHz)), a much higher frequency than its L-band predecessor. The Mark III was introduced in the early months of 1943. The Metox receivers, which were supposed to warn the German submarines of approaching enemy aircraft or warships, unable to intercept high frequency transmissions, remained silent. Thus the U-boats, relying on their Metox receivers, having unsuspectingly surfaced to recharge their batteries were easy targets for the Allied aircraft equipped with the new radar.[166]

As submarine losses began to increase once more, German technicians frantically tried to discover what had changed in the Allies' locating methods. Although the surviving U-boat commanders reported that their receivers before the attack had picked up no emission of electromagnetic energy, for some reason the German technicians did not consider the possibility that a higher frequency was being used. Instead, they surmised that a new device was being employed using infrared rays, for example, an extremely sensitive radiometer capable of detecting the heat emitted by a U-boat's engines. So, following this false trail, they embarked on a lengthy project to suppress the heat emitted by the submarines. After moths of search and experiment, heat shields were installed on the sides of the U-boats but the only effect this had was to reduce their speed. Meanwhile, the number of U-boat sunk was rising; in the months of May and June 1943 alone, about one hundred were lost.[167]

The *Luftwaffe* came to the aid of navy technicians when they found, among the wreckage of British aircraft shot down near Rotterdam, some pieces of the radar H_2S that revealed a technology hitherto unknown to German experts. Through this lucky find, they came to realize that the Allies had the famous Magnetron, a very sophisticated electronic tube operating on a wavelength of about 10 cm. German industry immediately set about building an RWR could pick up transmissions in the S-band. The new receiver, which was called "Naxos", took time to develop and proved to be inadequate, having insufficient sensitivity and range of only 4-5 miles.[168]

Meanwhile, the Allies were sinking more and more U-boats and so the German tried other methods of avoiding detection. One such method employed decoys code-named "Bold", in the form of rubber balloons launched from the submarine, which rose to a height of about 30 feet. These were attached to one or two metal cables intended to reflect the enemy radar emissions and thus create a false echo. The balloons were moored to floating buoys, which used to drift about but the chances of deceiving patrolling aircraft were very slim indeed.[169]

Toward the end of 1943, a measure of success was obtained with the *Schnorkel*; a tube fitted with a special valve, which enabled the submarines to recharge their batteries while submerged. These were covered with a special anti-radar material, which absorbed instead of reflected enemy radar emissions.[170]

When the long-awaited "Naxos receivers were finally ready, it was too late; too many submarines had been sunk and the battle of the Atlantic was, by this time, irretrievably lost.

Interception of U-boat radio transmission contributed greatly to the Allies' victory in the battle of the Atlantic, especially in the period of greatest losses of convoy ships. The submarines would periodically surface, usually at night, to recharge their batteries, check their position and transmit operational reports to headquarters or exchange information by radio with other submarines in the area. These transmissions were intercepted by Allied escort ships, which had direction finders on board and could, by taking bearings, locate the enemy vessel. Its position would then be communicated to the hunter-killer groups, which had the task of finding and sinking the submarine. These groups, which usually consisted of two or three destroyers or frigates, would head for point indicated and mercilessly hunts down the unfortunate enemy.

To avoid this, the Germans devised a system for making extremely, rapid or "squirt" transmissions; they recorded the messages and compressed them by sending-up the recorder until the message could be sent in less than one second. The recorder would automatically slow down the recording for normal reading. The direction finders then in existence were not fast enough to intercept and locate the transmitter in such a short time and so the U-boats were able to pass fairly peaceful nights for a while.

However, in 1943, the Allies came with countermeasures, an automatic direction finder called "Huff-Duff" which was able to pick up the brief transmissions and calculate the direction in the fraction of a second that they lasted. "Huff-Duff" sets were installed not only on board ships but also at shore stations of favorably located to get a good triangulation of the transmissions intercepted. As soon as a German submarine transmitted a message, the ground stations and ships at sea could immediately finds its position and send anti-submarine ships and aircraft to attack and sink it.[171]

Conclusion

The Battle of the Atlantic constitutes an important lesson for those in charge of the planning and conduct of electronic warfare: it teaches that it is not sufficient to know what kind of equipment the enemy is using on the battlefield at the moment but that it is vital to find out what is being developed for use in future operations. General Martini had made a wise decision when, in 1939, he decided to fly along the British coasts in the airship *Graf Zeppelin*. He thus affected the first electronic reconnaissance flight; an operation aimed at finding out what the enemy is doing in the field of electronic warfare. The *Luftwaffe* should have carried on with such activity during the war by sending not just bombers and fighters over Britain but also a few aircraft equipped to intercept electromagnetic emissions present in the British sky. The German electronic industry already had sufficient know-how to explore the electromagnetic spectrum; crystal video receivers, ideal for this task, were already in use and the Germans could, and should, have employed them to pick up pulses transmitted by the new British radar sets while these still being tested.

In neglecting electronic reconnaissance, the German high command not only underestimated the impending threat but also deprived themselves of the possibility of acquiring knowledge of technical innovations, which might have proved extremely useful for developing electronic countermeasures capable of neutralizing these impending threats.

Chapter 12

The Proliferation of Electronic Warfare in Germany

After the serious losses suffered in the Battle of Britain, the German air force was withdrawn from the Western front and redeployed to air bases in eastern Germany to take part in the Russian campaign, which was designated "Operation Barbarossa". The RAF was therefore free to initiate a massive retaliation involving intense air-bombardment of Germany as part of the strategy of destruction, which was to secure victory for the Allies.

Long range day bombing had proved unsuccessful, largely due to vulnerability of bombers to enemy fighters and the inability of RAF fighters to provide more than short-range escort because of limited range, so it was gradually phased out in favor of night raids. Now the roles of the Germans and the British in the "war of rays" were reversed; this time, the British had to devise foolproof systems to guide their bombers onto targets and the Germans had to find effective countermeasures.

During the Battle of Britain, the British had noted how difficult it was for the German bombers to hit their targets despite the sophisticated electronic aids at their disposal. The British were faced with exactly the same problems in their raids over Germany.

How could the British possibly hope to hit their targets in Germany without having accurate radio-electrical navigational and bombing aids? RAF commanders were extremely special about the effectiveness of the first bombing of Germany. Air Marshal Saundby, chief of RAF Bomber Command, connected to his Chief of Staff that, when a squadron of bombers reported that bombs had been dropped on a certain target, one could only be sure that they had been "exported" toward the target.

Fortunately, the British already had a navigational aids system, which had been designed in 1938 but had not been put into production at that time as priority had been given to other projects. This system, called Gee, consisted of three radio transmitters positioned along the coast at 100-mile intervals. They were synchronized to send out a complicated sequence of pulses in a certain order. Bomber navigators had a special receiver, which could measure the time-difference between the receptions of the pulses coming from the three stations. By referring to a special grid-map of Europe, the navigator could determine his position with a margin of error of about 6 miles, at a distance of 400-500 miles from the transmitters.[172]

Gee was not as easy to fathom out by electronic countermeasures as the early radio-guidance systems employed by the Germans has been. However, it was not long before the Germans noticed that British bombing had become notably more accurate and devoted every effort to finding out what the new guidance system was. By 1942, they had succeeded in doing this and, to counteract it, they built powerful electronic jammers, which were called "Heinrich". These were installed in ground stations in occupied France, Belgium and Holland and managed to neutralize almost completely the Gee electromagnetic emissions, rendering it practically useless on the European continent.[173]

The British, following the neutralization of Gee, tried various navigational aids systems, but none of them provided the necessary accuracy for bomb aiming. Finally, they came up with OBEO (Observation Bombing Over Enemy), which was the outcome of careful study of the German "Knickebein" system. Oboe consisted of a transponder to emit signals, installed on the bomber, and two ground stations a certain distance apart equipped with interrogators (to receive signals). These were called "Cat" and "Mouse", respectively. The ground stations were able to measure their distance from the flying aircraft automatically. The Oboe system had considerable success in the "Allied bombings of the Krupp works at Essen in December 1942.[174]

After a while, the Germans who immediately developed appropriate electronic countermeasures to interfere with its transmissions discovered the Oboe system. So, to replace Oboe, or at least make up for its shortcomings, the British preferred a system called H_2S. This had the dual function of clearly indicating the route and of ensuring greater accuracy in night bombing. Unlike the previous systems, H_2S did not need ground stations: its "heart" was recently developed radar, which could be installed on the aircraft. This apparatus utilized a special high-power valve (electronic tube), called Magnetron, which generated energy of 10,000 watts on a wavelength of 10 cm. For this reason, the new radar was called centimeter radar to distinguish it from preceding radars, which used considerably longer wavelengths.[175]

The prototype was installed on a test and evaluation aircraft and tested for use in night-fighters. These test fighters demonstrated that the new radar was capable of distinguishing built-up areas from countryside and the sea from the land. The rest flights were made in 1941 but the system did not enter operational service until much later as the British were afraid that it might fall into German hands and be copied for use on their aircraft. The final decision to use H_2S was prompted by the ever-increasing losses of RAF bombers in night raids over Germany.[176]

The British high command was also worried about whether the Germans had anti-aircraft radar. Many people were convinced, at least at the bombing of the war, that they did not as no giant antennas like those along the British coasts had been built in Germany or the occupied territories. However, the German did, have anti- aircraft radar right from the beginning of the war but, since they had always been on the offensive, the had not deemed it necessary to build an air defense radar chain requiring huge antennas like those of the British Chain Home.

The increasing number of RAF bombers lost over Germany made it imperative for the British to learn more about German radar anti-aircraft defense in order to devise appropriate countermeasures to neutralize the systems. So, for several months Allied secret services collected as much information as possible to achieve this end. Frequent reconnaissance flight were made over Germany to search for radar antennas, prisoners were interrogated and all German aircraft brought down in Britain were carefully scrutinized, piece by piece.

In November 1940, an interesting aerial reconnaissance photograph had been taken in the area of Cherbourg in occupied France. It contained an otherwise unidentified object, which could be radar, but, since the photograph had been taken from a very high altitude it was not possible to make a positive identification. It was not until February 1941 that the RAF managed to take a series of photographs from a low enough altitude to be able to distinguish the mysterious object; in fact, it turned out to be the antenna of one the early German radars called "Freya" (the Scandinavian goddess of beauty and love) which had first been built in 1939. Its main function was to detect enemy aircraft at the greatest possible range, what we now call early warning.[177]

This radar operated on a 2.5-m wavelength and had a range of about 100-120 miles. Up to a minimum distance of 20 miles, it could detect and track an aircraft, with an accuracy of about half a mile in range and 1 degree in bearing. It was equipped with a transmitting antenna made up of a series of dipoles.[178]

The first "Freya" radar sets were installed in fixed positions along the northern coasts of France, Belgium and Germany on RAF bomber routes. To compensate for the shortcomings in its secondary AA defense role resulting from its 20 miles minimum range limitation, powerful searchlights were used in association with the radar to illuminate the aircraft. However, this method was too susceptible to poor weather in the area, especially cloud, and so Germany industry had to produce another radar to produce, more reliably, the information required to direct anti-aircraft artillery and interceptors on to enemy bombers at close range.[179]

The British, having discovered the operating frequency and other characteristics of the "Freya" radar, were now able to devise appropriate electronic countermeasures to neutralize or, at least, diminish the efficiency of the German radar. Initially, this was easy because all the "Freya" radar operated on the same frequency (120-130 MHz) which was easily covered by the jammer invented by the British and named "Mandrel". This apparatus emitted random noise on the same frequency as that used by the "Freya", thereby blinding it "Mandrel" jammers were installed on special aircraft which accompanied the bomber formations on their raids, helping them to penetrate German airspace. The Germans tried to avoid being jammed by continually changing frequency so the British, to follow suit, had to produce more jammers, of varying types, to cover the different frequencies used.[180]

For a short time British losses showed a slight decrease but toward the end of 1942 casualty figures got worse again. The Germans had produced a new, extremely sophisticated radar, called Giant Wûrzburg, which operating on a wavelength of about 50 cm (565 MHz), had a range of about 45 miles and was able to measure not only the distance and direction of an enemy aircraft but also its altitude. It also had a very narrow beam and, with all these qualities, was able to provide with great accuracy all the essential information for two extremely important functions in air defense: guiding fighters to intercept enemy bombers and directing anti-aircraft gunfire.[181]

Further progress was made in the field of radar when the Germans produced a new apparatus called Liechtenstein BC for installation in night fighters, although it had a range of only 7.5 miles, it played a very important part in the integrated air defense system. This modular system was made up of numerous stations, each of which had the task of covering a certain zone within a grid covering the west of the Reich. These stations were given the name "Himmelbett" (four-poster-bed.) Each one contained one "Freya" radar and two "Wûrzburg" radars, an operational control room and a communication post. "Freya", who immediately communicated the sighting to the operational control room, normally made the initial sighting of a British formation. A night-fighter equipped with "Liechtenstein BC" radar would immediately be vectored using one of the "Wûrzburg" sets, to intercept the enemy. The other "Wûrzburg" tracked enemy aircraft and controlled the laying and firing of anti-aircraft artillery (AAA) once the aircraft were within firing range. All data regarding the positions and altitudes of enemy bombers and intercepting night-fighters were reported on a special table called a "tactical table" from which the operator could make the necessary calculations for interception. Information such as route, speed and altitude was transmitted, via the appropriate communications post, to the night-fighter pilot who was thus guided to the target from astern wherever possible. When the German fighter was within one or two miles of the enemy plane, the operator switched on his airborne "Liechtenstein BC" which, having acquired the target guided the fighter to it. When the fighter was within firing range, the "Liechtenstein BC" was used to direct the fighter's guns. At this point, the enemy bomber's chances of escaping were slim indeed.[182]

This system functioned extremely well and can be considered the forerunner of modern air defense systems despite its limitation of being able to deal with only one bomber at a time. Using this system, a network of air defense was set up along the northern coasts, starting from France and proceeding eastwards. Outside Germany, the systems were positioned at 20-mile intervals whereas in the German hinterland they were spaced at 50-mile intervals.

By the end of 1942, losses of Allied planes to *Luftwaffe* night-fighters and AAA batteries were becoming unacceptable to the Allies. The British stepped up their jamming of the "Freya" radar sets, frequently sending aircraft equipped with "Mandrel" jammers along the German coast to prevent the "Freya" radars from making long-distance sightings. However, when their losses showed no decrease in spite of such measures, it became apparent that the success of the German air defenses depended not so much on the "Freya" radars as on the pairs of "Wûrzburg" radars which the British did not know enough about to be able to jam.

Meanwhile, the Germans decided to try to find a way of protecting the "Wûrzburg" radars from eventual jamming by the enemy. They decided to change frequency continually but this task proved much more laborious than they had expected because they ran up against considerable technical difficulties. However, they managed to devise a system of triple interchangeable frequencies for the "Wûrzburg" radars.[183]

While this was being done, the British intelligence service had discovered near Le Havre in occupied France the existence of a complex of radar sets, one of which was definitely a "Freya", while the other two were thought to be the ones their bombers had come up against, the "Wûrzburg" sets. Since they knew nothing about the electronic characteristics (frequency, pulse duration etc.) of this radar and, therefore, could not devise appropriate electronic countermeasures, they had no alternative but to capture one.

So, on the night of 27/28 February 1943, a company of paratroopers was dropped on the radar station at Bruneval, near Le Havre; their mission was to bring back to Britain the main components of the "Wûrzburg" radar sets. Dressed in black, their faces smeared with "soot", the paratroopers managed to enter the radar station and after overwhelming the guards were able to dismantle the "Wûrzburg". The task was soon completed and the company made for the coast a few miles away where a submarine was waiting to take the men and their strange booty back to England. As soon as they had their hand on the components, British technicians set about trying to devise a countermeasure to neutralize the "Wûrzburg".[184]

One night in May 1943, a German Junkers Ju 88R-1 whose crew had decided to defect, landed at a British airfield. This was an unexpected piece of luck for the British who immediately set about examining the JU 88's radar. They even went so far as to stage test flight attacks against a British Handley-Page Halifax bomber. In this way, much useful information was obtained, the most important of which was that it had limited antennas opening of only 25 degrees. Faked combat with the Halifax showed that a slight dive would take the bomber out of range.[185]

The Germans were not resting on their laurels and they too had found ways of neutralizing British radar by means of electronic disturbance. They built a jammer for every type of British radar, including their fire-control radars.

The Allies soon came up with a new jamming transmitter, called "Carpet", which was able finally, to jam the German "Wûrzburg" radar sets. It was also installed in the first American Boeing B-17 Bombers, and, thanks to these new electronic warfare systems, Allied bomber losses showed an immediate and progressive decrease: during the bombing of Bremen by the U.S. 8th Air Force, Allied losses decreased by 50 percent.[186]

However, the worst was yet to come for the *Luftwaffe*. In the late evening of 24 July 1943, the German radar station in Ostend detected a formation of British aircraft approaching from the North Sea. The "Wûrzburg" radars in Hamburg also located the enemy formation and communicated to regional headquarters: "Enemy aircraft approaching at an altitude of 10,000 feet". That was their last sighting because the echoes on the screens of all the "Wûrzburg" sets suddenly grew out of all proportion, totally bewildering the operators who could not believe that there really were thousands of invading aircraft. They eventually reported that their sets were no longer functioning properly and requested instructions.[187]

Meanwhile, the Allied formation had almost reached the outskirts of Hamburg, the anti-aircraft batteries and fighter squadrons having failed to react to the threat due to lack of commands from the "Wûrzburg" radars. Partially obscured by something the Germans could not understand, the huge formation, composed of 718 four engine and seventy-three twin-engine bombers approached the city center undisturbed. The anti-aircraft defense commanders at Hamburg, frustrated by the lack of data, which would enable them to direct their fire, and in order not to give the enemy confirmation of the effectiveness of his electronic countermeasures, gave the order to fire blindly at the bombers, but the latter, on reaching their target, successfully carried out one of the most terrible raids in history.[188]

What had happened was that a simple but effective electronic countermeasure had been used for the first time against the "Wûrzburg" radars–"Window". This countermeasure consisted in releasing from the aircraft thin strips of tin strips of tin foil of a specific length. To effectively jam enemy radar, the length of the tin foil strip had to correspond to half the wavelength of the frequency used. Released in bundles, which burst open upon ejection, scattering the tin foil widely, these strips produced return echoes on the ground station radar screens, which camouflaged the echoes, produced by the aircraft or simulated the presence of huge numbers of aircraft. The radar operators were totally bewildered by myriad white blips, which appeared on their radar screens and were unable to determine the number or position of the approaching enemy aircraft.[189]

The British had come up with this countermeasure a year previously, shortly after the commando raid at Le Havre in which pieces of the "Wûrzburg" radar had been captured, but they had hesitated to use it for fear that it would fall into enemy hands and be used against them. Finally, Winston Churchill himself gave orders to use it in the Hamburg raid, planned for July 1943. Orders for the use of this countermeasure by the RAF were given in clear with code words "Open the Window", and so the tinfoil strips were thereafter referred to as "Windows"; the Americans, on the other hand, referred to them as "chaff", the term which is now applied to such forms of ECM.[190]

This counter measure had a high degree of success in the raid on Hamburg. Confused by all the false echoes on their radar screens, the German AAA batteries were unable to direct their fire and fighters no longer received instructions from the ground. Other factors, which contributed to the success of the Allies, were the excellent meteorological conditions and the clarity of the images on the screens of their H_2S radar, which was due to the sharp contrast between the reflection of the ground and that of the water in the estuary of the River Elbe.[191]

The destruction and casualties caused by the British air raid on Hamburg were enormous. In only two and half-hours, 2,300 tons of bombs were dropped on the port and city center. The intensity of the fires started resulted in a fireball which sucked in huge quantities of air to feed itself upon, draining the city of oxygen, and giving rise to tremendous winds which uprooted trees and swept objects and people into the sea.

Of the 791 bombers used in the raid, only twelve failed to return; this loss-rate less than a third of the average for the most recent night raids on Germany. Moreover, the chaos that had been wrecked in German air defenses had enabled the British to bomb the city with greater accuracy than ever before. The Hamburg raid was undoubtedly the most successful raid ever carried out by RAF bombers and its success must be largely attributed to that simple but effective electronic countermeasure which employed ordinary tin foil!

It is ironic that the first to have the idea of using tin foil in this way had been the Germans themselves. They had developed the idea in the course of their research on radar a few years before that war broke out. When Hitler had been informed of the possibility of using tin foil strips, which the Germans called *Dûpple*, he gave order to break off research and destroy all the relative technical documents. Like the British, he was afraid that the countermeasure might fall into enemy hands and be copied. Consequently, the local air defense system was taken completely by surprise when the measure was put into effect during the Hamburg raid. On that terrible night, in which tens of thousands of people were killed, nobody had the slightest idea what was happening not even high-ranking officers of the German air defense command who it is reported, gave out the order, "Don't touch those strips, they're probably poisonous."[192]

It was a long time before the German people learnt that those strange objects raining from the skies constituted the simplest means of confusing their radar detection and guidance systems. A mere twenty-five strips were sufficient to create on the radar screen an echo equivalent to that of an airplane; coincidentally most radars operated on frequencies between 550 and 570 MHz the most vulnerable to jamming, and therefore required a minimum for tin foul strips to create interference. During the Hamburg raid, two tons of these were dropped from each of the aircraft dedicated to this role–a total of 2,000 strips every minute![193]

Two nights later, a second raid was made on Hamburg, followed by further raids on other large German cities all utilizing the new electronic countermeasures. During the first six of these raids, 4,000 individual sorties were flown with a loss of only 124 bombers (3 percent of the total) that was much lower than in previous raids. A few months later, General Wolfgang Martini, head of the *Luftwaffe* telecommunications service, conceded that the tactical success of the enemy was absolute.[194]

However, as always happens in electronic warfare the party was soon over for the British. After the initial shock the Germans soon found ways of getting round the new problem. After a while, the more experienced radar operators noticed that it was possible to distinguish between the echoes from the bombers and the "Window", since the former moved at a regular speed in a fixed direction while the latter seemed to be immobile on the radarscopes. The British retaliated by dropping enormous quantities of tin foil strips, which completely blanked out the enemy radar screens.

At this point, the Germans decided to produce these precious tin foil strips themselves and six weeks after the Hamburg raid put them into effect, with extremely positive results, in a bombing raid on a British airbase.

The Germans also came up with a series of electronic counter-countermeasures in an attempt to improve the functioning of the air defense system. Some of these techniques for distinguishing echoes reflected by aircraft from those reflected by other metallic surfaces. Another much used device permitted a radar to change frequency as soon as it was jammed by the enemy. Yet another system exploited the Doppler effect, the change in frequency, which occurs as a result of the relative movement of the source of a wave and its receiver, thus, allowing the radial velocity of a target to be calculated. In this case, the Germans switched from "video" to "audio", substituting the radar screen for earphones through which the night fighter pilot could hear a particular sound made by the enemy radar. With this system, changes in the enemy airplane's speed were indicated by a change in tone and the operators were able to distinguish even whether the enemy was in a dive or climb.[195]

These devices aimed at neutralizing or reducing the efficiency of ECM were called electronic counter-countermeasures (ECCM) nowadays; every military radar has a certain number of ECCMs incorporated into it at the design level; this usually done by manipulating the circuits of the apparatus or varying in parameters (frequency, pulse rhythms, etc). Many techniques are used today in devising ECCM and, indeed, the possibilities are infinite since, for every countermeasure there is a counter-countermeasure and, for every counter-countermeasure, a counter-counter-countermeasure, and so on.

However, in spite of all the measures taken by the Germans to remedy the situation, night-by-night they watched their cities being systematically destroyed by RAF Bomber Command. During the summer of 1943, increased use of "window" by Allied bombers had managed to nullify the German air defense system almost completely during the night and conditions of poor visibility when it relied heavily on the "Wûrzburg" radars. So, the best electronics brains in Germany were put to work to find ways of restoring the efficiency of their all important air defense system.

It was necessary to build new radar, which would use a frequency fro removed from those of the "Wûrzburg" and "Liechtenstein BC", whose wavelengths were in adjacent bands in order to avoid the interference produced by the Allied ECM, both active (such as "Carpet" jammers) and passive (such as "Window"). Research was conducted at a frantic pace as every night and day that passed could mean he destruction of another German city.

In October 1943, the prototype of the new apparatus was ready and, in the early days of 1944, the new radar, called "Liechtenstein SN_2", was installed on nearly all-German night-fighters. It operated on a wavelength of 3.3 m, corresponding to a frequency of about 90 MHz, much lower than that of either the "Liechtenstein BC" or the

"Wûrzburg", and although the resultant antenna was much bigger and more cumbersome, they had the distinct advantage of being able to cover a 120 degree sector over the nose; such a wide beam was made possible by the higher power of the radar which made it unnecessary to transmit directionally. Now, it would be almost impossible for the British bombers to escape once this radar had detected them, but the greatest advantage of the wide beam was that the German fighters would now be able to track down the enemy bombers unaided, once they had received information regarding their formation and approximate route. Detection of the enemy bombers was facilitated by two other factors: the excellent range of the new radar installed on German night-fighters, which was 40 miles, and the fact that the British bombers had recently adopted a new tactic for approaching their target which actually made their discovery much easier for the new German system. Being aware that the German air defense system could only track one aircraft at a time, they had decided to fly bomber streams instead of staggered attacks as they had done previously. Still these huge formations could be detected from the ground even without the aid of radar.[196]

Thanks to the new radar, German defense tactics were completely revised and up-dated since zone defense strictly dependent on ground radar control could be dispensed with. Now, ground control stations had merely to direct the fighters toward a formation and the fighters were then able to operate independently. They penetrated the enemy formation from behind and proceeded to massacre the unfortunate allied bombers. Previously, once the bombers had got past the defending wall of radars, they only had to contend with AA defenses over the target area; now, they were constantly under threat of attack all the way from Belgium and Holland on their way to the target and all the way back to the North Sea after the mission.

The progress made by the Germans in the field of electronics did not stop here. A new RWR was installed on the fighters, which were already equipped with "Liechtenstein SN_2" radar. An RWR is an apparatus, which has the function of detecting the presence of a radar transmitter: it picks up radar signals but does not itself transmit. The function of these airborne RWRs can be compared to that of the Metox sets installed on German ships and submarines at the beginning of the war. As stated, it has two important advantages over radar: first, it is a completely passive instrument which does not emit electromagnetic energy that could reveal its presence to the enemy and, secondly, it has a greater range than a radar since it receives emissions from the enemy radar before the latter is able to receive a signal returned from the platform on which the RWR is installed. In practice, this meant the RWR installed on board German fighters were able to receive the radar emissions of the Allied bombers at almost double the distance at which the bombers' radar were able to detect the German fighters had plenty of time to pan their maneuvers. The RWRs were also able to guide the fighters to the enemy formation as, although unable to measure their distance from the enemy radar, they gave a fairly accurate indication of the direction from which the transmission was coming. Moreover, being completely passive, the RWR was immune to disturbance from the tin foil strips, which had caused so much trouble on other occasions![197]

By the beginning of 1944, the German had two types of RWR installed on their fighter planes. One, the "Naxos" was able to pick up British H_2S radar had been, for the moment, only installed in aircraft of the specialized RAF Pathfinder Force (PFF) which had the task of marking the targets to be bombed by dropping phosphorus flares for target illumination, the "Naxos" guided the German fighters directly to these aircraft, which had such a vital function in British strategy.[198]

The second German RWR the "Flensburg", was tuned to receive transmissions from another type of British airborne radar "Monica", which, installed in the tail of RAF bombers, gave warning of the approach of enemy fighters to enable the bombers to take the appropriate evasive action. The Germans had found one of these radars among the wreckage of a shot-down enemy bomber and had the bright idea of exploiting its transmissions to get the British right by the tail, as it were![199]

The "Flensburg" RWR constituted an authentic self-guidance system leading the fighter on to the enemy's tail, where their radar was installed. The "Flensburg" RWR consisted of a comparison receiver and two identical antenna installed in the front of the fighter at an angle of 60 degrees away from each other. When the antenna on the left received a signal showing up on the radarscope, it simply meant that the bomber was to the left of the fighter whereas, if the antenna on the right received a signal, it meant the bomber was to the right. When the two antennas intercepted a signal of equal intensity, it meant that the enemy bomber was dead ahead. With this exceptional radio electrical device, the *Luftwaffe* obtained, initially, outstanding results.[200]

In 1944, the total destruction of Berlin was prevented largely due to the progress made by the Germans in the field of electronics. The efficiency of the German night-fighters, with the support of the well-organized anti-aircraft artillery, prevented RAF raids from causing destruction on the same vast scale as that of Hamburg.

During this period, RAF losses rose considerably and morale dropped proportionately. Many of the best British pilots had reached the limits of their endurance and often, at the slightest sign of danger or difficulty, dropped their bombs in the sea or open country. As soon as they heard the noise of the inexorable approach of enemy fighters, the bombers' terrified gunners began to shoot at anything they saw or imagined they saw and sometimes they shot down one of their own aircraft by mistake.

This chaotic state of affairs reached its culmination on the night between 30/31 march 1944 when German fighters, guided by their RWR, zeroed in on an RAF bomber formation over Brussels and engaged it in an air battle which went on all the way to Nuremburg, the target of the raid, and all the way back. The Allies lost ninety-five of the 795 bombers sent out on that mission, while another seventy-one returned to base badly damaged and twelve more crashed on landing. The final toll was 115 bombers and 800 highly trained crew members lost. It was a great victory for the Germans; one pilot claimed seven kills and many had two or three. The victory can be largely attributed to German supremacy in the field of electronic warfare at that stage of the war.[201]

The situation was becoming extremely critical for the RAF until by an unexpected stroke of luck, it was able to remedy the situation by appropriate electronic retaliation. At dawn on July 13, 1944, one of the most modern German night fighters, a Junkers Ju 88G-1, landed in England as the result of a navigational error. It was equipped with all the latest electronic equipment (SN_2 radar, "Flensburg" RWR and some highly efficient new radio sets), except the "Naxos" which, fortunately for the Germans, had not yet been installed on that particular aircraft. British experts immediately started a thorough examination of all the equipment and were utterly dismayed when they realized what the purpose of the "Flensburg" was. Instead of protecting them from enemy fighters, the tail-mounted radar was attracting them like flies to meat and was enormously facilitating their attack.[202]

To convince the incredulous RAF commanders a trial flight was organized in which seventy-one Lancaster bombers, all equipped with tail radar sets, were ordered to fly toward Germany as though on a real mission. A Ju 88, piloted by British crew, took off and all the bombers were then ordered to switch on their electronic equipment. The "Flensburg" RWR managed to pick up the electronic emission of the British radar at a distance of nearly 50 miles and without turning on its own radar, the Ju 88 was able to come up behind the Lancaster bombers and get into very best position for firing at them. There was no doubt about the efficiency of the "Flensburg" radar and all radars equipment was promptly removed from the tails of RAF bombers.[203]

Meanwhile, huge quantities of tin foil strips, cut to the correct size for the wavelength of the "Liechtenstein SN_2", were produced and, toward the end of July 1944, this new "Window", were already in use. British losses in night raids over Germany began to show a significant decrease as a result both of the use of the new "Window" and the removal of the tail radar from their aircraft.

The Germans then tried other technical measures to reduce the electronic disturbance caused by the "Window", such as modifying their radar antennas. When the British became aware of this, they started using very long metal strips (up to 400 feet) attached to little parachutes, each capable of simulating the echo of a large airplane. The Germans were obliged to modify their radar further in an attempt to eliminate the effect of the new British countermeasure.[204]

Meanwhile, as the war dragged on, the Germans were experiencing various problems, such as the increasing losses of their courageous and highly skilled pilots, difficulty of training new ones to replace those lost and the increasing scarcity of fuel.

At the same time, the British were becoming more and more convinced that every effort must be made to neutralize the electronic components of German air defense. To this end, they set up special squadrons, mainly composed of Short Stirling aircraft, equipped with "Mandrel" jammers capable of jamming the "Freya" early warning system. This Stirlings also carried huge quantities of "Window" which enabled them singly or in pairs, to cause echoes to show up on the enemy radar, which falsely indicated the presence of large formations of bombers. This would distract the attention of German air defense from the real bombers, which were attacking elsewhere.

However, before the war came to an end, German industry managed to come up with two new radars against which these Allied ECMs were ineffective. The first was called "Neptune" and worked on a combination of six frequencies from 158 to 187 MHz, corresponding to wavelengths between 1.9 and 1.6 m, which could not be jammed by "Window". The second was radar called "Berlin". It was a revolutionary invention, in its time, working on a centimeter wavelength. Its antenna was no longer a complex system of dipoles installed on the outside of the aircraft but a parabolic antenna inside the nose.[205] Only a few models of the "Berlin" radar were manufactured before the end of the war.[206]

The Junker 88G-7b was equipped with the "Neptune" radar as well as with a device capable of distinguishing enemy from friendly aircraft; this was the forerunner of IFF (Identification Friend or Foe), which is installed on all modern military aircraft, and can distinguish enemy from friendly aircraft. It was also equipped with a radio-altimeter, a radio-compass, a secure navigation receiver that printed out in clear Morse code the aircraft's position as transmitted by a ground-station, blind landing instrumentation and two new HF and VHF radio sets. Since the "Neptune" relied on beamed high-powered transmissions and the teleprinter signals had good "break through" qualities, like Morse code, the systems were highly jam-resistant. The Junker 88 G-7b also carried the "Naxos" while the "Flensburg" RWR was replaced with an infrared (IR) ray device "Kiel" that reacted to heat radiations from "hot spots" such as the exhaust of the enemy aircraft's engines.[207]

During the last months of the war, both sides used the trick of creating false targets. Radar is not capable of determining the form or nature of the object detected and so it was easy to use various metal surfaces to create an echo which, in the right circumstances, would be taken for that of an aircraft, ship, etc.

Germans in the Berlin area to prevent the total destruction of their capital city used false targets extensively. They set up numerous metal targets in the nearby lakes, hoping to deceive the Allied bombers, which used the H_2S radar for blind bombing.

Both contenders used these and other more sophisticated devices in final stages of the war. In the skies over Germany a continuous struggle was going on between radar, electronic countermeasures and their counter-countermeasures. It was certainly one of the most dramatic challenges in the whole of World War II both on a scientific level, the opponents being equally matched in technical expertise, and on an operative level, both sides fighting with desperate determination and great skill and courage.

After the United States entered World War II, the number of aircraft participating in each battle grew considerably. During the final moths of the war, Germany was being bombed daily by forces of no less than 1,000 bombers, escorted by between 600 and 700 fighters, and nightly by almost the same number of RAF bombers.[208]

Conclusion

The struggle between the fighters themselves, tactics for day or night fighting, the organization and efficiency of air defense, the continuous improvements made in detection, guidance and ground control were all very important factors which rendered the outcome of the struggle uncertain right until the final day. Allied air losses over Germany were extremely high; it is thought that between about twelve and fifteen thousand aircraft were lost.

As in the battle of Britain, the struggle between radar and electronic countermeasures played an extremely important role in the air battles over Germany, first favoring one side, then the other according to the efficiency of the new electronic devices introduced and the surprise element, which would catch the enemy off-guard.

Chapter 13

The Evolution of Electronic Deception: Operation Overlord

With the invasion of Normandy, code-named "Operation Overlord", began late in 1943. Electronic countermeasures for the first time in history played an integral part in strategic plans. They were, in fact, one of the more important elements in the overall plans drawn up by the Allies for one of the most complex military operations in history.[209]

This invasion was of vital importance but its success was by no means certain. It is well known that the critical stage of landing operation is the period during which the troops are being carried from the ships to the beach by the landing craft. This period can last for several hours and, if the enemy is in a position to attack them on landing, the result can be a massacre as the troops are extremely vulnerable when they first "hit the beach".

It was, therefore, of the utmost importance for the Allied Command to deceive the Germans about the actual landing area, and thus delay the movement of their strategic reserves toward the area to counter a possible landing. It was decided to try to convince the Germans that the landings would take place near Calais when, in fact, they would take place on the beaches of Normandy. The electronic plan was extremely complex and, of course, tops secret. It would be put into effect several days before D-Day and involved a combination of actions, some real and some fake.[210]

The beaches of Normandy, which the Allies chose for their landings, were heavily fortified, as was the entire northern coast of Europe. Field Marshal von Runstedt was in command of the sixty divisions, which manned the so-called Atlantic Wall, the system of fortifications, which ran from Holland to the Bay of Biscay. The already famous Field Marshal Rommel was in command of the sector between Holland and the Loire.[211]

The Germans, of course, knew that the Allies were planning an invasion of Europe and that they would certainly land somewhere in northern France. Von Runstedt was convinced that they would land at Calais; Rommel, on the other hand, surmised that the landing would take place on the beaches of Normandy.[212]

German government leaders were also divided in their opinions as to where the landing would take place. These differences of opinion were due to a series of deliberate actions taken by the Allies to try to device the Germans into thinking that they would land at Calais.

The Germans, naturally, did all they could to complicate the Allies' plan, conducting a propaganda campaign featuring the impregnability of the Atlantic Wall. In radio transmission in March 1944, about two months before D-Day, they claimed that their radar chain surrounding the whole of Germany was so efficient that each and every enemy craft would be under constant observation and, with these assets at its disposal, German defense could operate with extreme speed and efficiency.[213]

The Allies were well aware of the fact that the German had installed at least 120 radars along the northern coast of France for the purpose of detecting British convoys in the Channel and directing costal gunfire. Through photographic and electronic reconnaissance, they knew all about the entire German radar chain, which consisted of radars positioned at 10-mile intervals and, in some parts of the coast every half a mile.[214]

British electronic experts had begun to devise detailed countermeasures well in advance. They had chosen a stretch of beach along the Scottish coast, which closely resembled the coast of Normandy and had installed three captured German radar sets, representing the three main types of radar guarding the beaches of Normandy. Every day, aircraft, naval vessels and landing craft furnished with EW equipment carried out practice landing operations on the Scottish beach. Officers who were experts in electronic warfare umpired the maneuvers to determine how successful the "invaders" had been in jamming the enemy radar. From these exercises, there evolved a detailed table of equipment requirement for the ships and aircraft that were to take part in the invasion. Every skipper and pilot was given explicit instructions regarding what he had to do on D-Day.[215]

Basically, the plan involved two main actions. The first was to jam German radar in the Normandy area to prevent detection of the approaching naval force. The second action involved deceiving German radar in the Calais area by simulating the presence of large fleet sailing toward Calais. Other supportive measures were planned to operate in conjunction with these two actions. Intense fictitious radio traffic was instigated in the Dover area to give the impression that the troops were assembled in that region, ready to invade in the Calais area. Undercover agents to further confuse the issue spread rumors and false reports. Troops were concentrated in irrelevant areas and, finally, enemy radio communications were routinely jammed.[216]

The invasion was scheduled for 06:30 On 6 June. On the night of 5/6 June, a huge fleet, composed of about 2,700 ships of all types with hundreds of thousands of men on board, weighed anchor from various ports in southwest England and sailed slowly toward the coast of Normandy. At the same time, twenty aircraft, equipped with powerful "Mandrel" electronic jammers, flew along the south coast of England, at an altitude of about 18,000 feet in order to mask the presence of the approaching ships from German radar on the Normandy coasts.[217]

Almost simultaneously flotillas of small vessels left various harbors in the vicinity of Dover carrying special metallic plates and towing buoys and metallized balloons to create radar echoes of equal strength to those produced by large warships. Shortly afterwards, several aircraft, flying overhead, dropped huge quantities of "window", or "chaff", to give the impression of convoy of ships approaching the French coast in the vicinity of Calais.[218]

As the hour for the landing drew near, all the ship borne electronic warfare equipment was switched on simultaneously, producing sufficient interference to neutralize the efficacy of German coastal gun control radar.

Conclusion

All went according to plan and the invasion of Normandy was a great success for the Allies. The effectiveness of electronic warfare planning ensured that the German strategic reserves were kept out of the way until the Allied troops had safely established their beachhead. Allied losses were contained, as there was no major confrontation with the enemy with the enemy during the actual landings. The confusion created by the electronic measures continued the day after the landing, inducing German leaders, including Hitler, to make serious errors of judgment and take wrong decisions.

The success of electronic countermeasures employed in the invasion of Normandy is best expressed in the words of Winston Churchill:

Our deceptive measures before and after D-Day were planned to provoke confusion of ideas, their success and the consequences long withstood during the battle.

Chapter 14

Electronic Warfare in the Far East

Electronic countermeasures played a less important role, and were somewhat different in character, in the Pacific than in the Northwest European theater of war. This can be attributed mainly to the low level of Japanese technology and to the geographical characteristics of the area.[219]

Japanese radar equipment was decidedly inferior to that of the German and the Allies both in quantity and quality, and never posed a real problem for U.S. forces. However, the vastness of the Pacific required a large number of suitable devices in order to carry out electronic espionage and, thereby, find out how many radar sets had been installed by the Japanese and what type of equipment was employed. This was a difficult task as many radar stations were situated at great distances from American bases.[220]

The first episode of American electronic espionage in the Far East took place in March 1943 in the Aleutians, a chain of rocky islands running from Alaska to the Sea of Japan, some of which had fallen into Japanese hands. Since the Pearl Harbor disaster on 7 December 1941, the Americans had been conducting systematic photographic reconnaissance missions over the Japanese-occupied islands in order to prevent further such surprise attacks. During these missions a photograph had been taken of the island of Kiska that showed that the Japanese had recently erected two structures that looked like huge billboards on the top of the highest mountain. Examination of this photograph by electronic warfare experts showed that they were, in fact, radar antennas for long range search.[221]

Further electronic reconnaissance flights, in which special receivers were used, collected data regarding frequency, pulse width and other parameters, on the basis of which it was possible to establish not only the type of radar, but also its coverage and the emission diagram of the antennas.

This information proved extremely valuable for the Americans when they began to bomb the island because analysis of the radar had shown that there was a "blind" sector where the radar beam was in the "shadow" of one of the mountain peaks. Consequently, the American pilots could approach the island without being detected by the radar installed there.[222]

This episode constitutes an important chapter in the history of electronic warfare since it showed how valuable that type of exploratory mission could be for military operations. The aircraft used in these missions were called "ferret" planes as, like ferret, they keenly searched out their prey, which, in this case, was radar.[223]

This type of mission was not limited to aircraft, however. Many warships were equipped with suitable instruments and sent out on similar missions in the Pacific Ocean. The range at which these ships could pick up enemy radiations was decidedly inferior to that of aircraft, which have the advantage of altitude. On the other hand, the ships could stay longer in the area under observation, which gave electronic specialists on board more time to pick up, record and analyze the radar emissions.

For such tasks, the U.S. Navy also equipped many large aircraft with intercept receivers and DF. The best-equipped aircraft for such "electronic reconnaissance" missions was the four-engine Consolidated-Vultee PB_4Y_2 Privateer, a maritime version of the company's famous B-24 Liberator bomber. Each Privateer carried a dozen operators on board as well as the crew and could be considered a real radar interception center. The aircraft were easily recognized because the fuselage was covered with radomes made of special synthetic material, which covered the numerous antennas installed to pick up enemy radar signals. Because of their ugly appearance, individual aircraft were given names of the strangest and most horrible animals.[224]

The Privateer performed an invaluable service throughout the whole Pacific War. Two of them are particularly worthy of mention. They patrolled the whole of the south Pacific, from Australia to the island of Borneo, ferreting out radars, which were subsequently bombed, and supporting naval forces against Japanese merchant traffic.[225]

Submarines were also equipped for this type of mission. They provided an ideal platform for transporting equipment used in electronic espionage and, being able to lie in wait for long periods of time with only their conning towers above water, they managed to listen to and record enemy radar transmissions and communications. These interceptions were then used to prepare appropriate electronic countermeasures, and often even enabled the submarines to avoid surprise attacks by the enemy.[226]

One such case "early warning" was when two others were escorting an American submarine, which had been seriously damaged in combat, to base. While the small formation was sailing through the mist, one of the escort submarines intercepted radar emissions from a Japanese aircraft which was flying nearby. Given their precarious situation, the Americans were caught on the horns of dramatic dilemma: whether to submerge or remain on the surface. If they remained on the surface, all three might be sunk.[227]

The commander of the EW-equipped submarine decided to use the receivers on board to explore the whole range of frequencies employed by American airborne radar in the hope of finding one of their own aircraft in the vicinity. The exploration was successful and the radar operator on board the submarine was able to give the pilot of the friendly aircraft information, which would enable him to find and attack the enemy. While both aircraft were flying towards the unfortunate submarines, the Japanese pilot noticed that he was being followed and dropped his bombs prematurely, completely using the target. The American pilot was then able to shoot down the enemy aircraft right before the eyes of the bewildered submarine crews![228]

When the war in the Pacific reached a turning point in favor of the Americans, who were able to launch strategic and tactical air raids and sea-landings against Japanese-held territory, electronic warfare took an active, and rather different, part in the various operations. For example, during their invasions of the well-fortified Japanese-held islands, the American bombers were generally equipped with systems for electronically neutralizing the Japanese radars, such as jammers or chaff, as they had done in their bombing of Germany. Later, each America wing was equipped with converted bombers, which carried extra fuel and jamming equipment instead of bombs. Because of their spine-like antennas, these aircraft were nicknamed "porcupines". Flying over the target with the first wave of bombers, they jammed or neutralized Japanese anti-aircraft gun control radar. They remained in the area until the last bomber had dropped its load.[229]

Jamming Japanese radar initially presented some technical problems due to the unfamiliar characteristics of their equipment. Unlike German radar, the Japanese sets operated on such low frequencies that they were almost invulnerable to the electronic deception of chaff, which had been so effective in Europe. The reason for this was that the tin-foil strips were nowhere near half the wavelength of the radar to be jammed and so did not produce the desired effect.[230]

To overcome this problem new strips were devised. Made of aluminum, they were much longer (30m x 3cm) and were called "ropes" because of their shape. The use of this modified electronic countermeasure considerably reduced American losses during incursions over the various airbases built by the Japanese on the occupied islands, which were defended by radar-controlled anti-aircraft gun batteries.[231]

When the Japanese got their hands on some of the new strips launched by the American aircraft, they immediately took steps to install at their airbases other types of radar that operated on even longer wavelengths. They also installed a large number of powerful radar-controlled searchlights, which were positioned near the gun batteries. The American bombers, which had recently begun to attack the airbases only by night to cause difficulties for Japanese defense, now found themselves trapped in a web of light beams, which continuously illuminated them in spite of their attempts to jam the radar controlling the beams. As soon as signs of interference showed up on the Japanese radarscope, the operator automatically switched the searchlight control onto radar using a different frequency to ensure that the searchlight would continuously illuminate the bomber under fire. Using this system, the Japanese managed to inflict high losses on U.S. Army Air Force (USAAF) in the Pacific: over 80 percent of the Boeing B-29 Superfortress bombers shot down by Japanese anti-aircraft fire can be attributed to the radar-searchlight-gun system.[232]

Nevertheless, electronic countermeasures did influence the outcome of events in the Pacific to some extent. In the final analysis, the drop in American aircraft losses must be attributed to the large number of jammers carried on board their aircraft (some B-29 carried as many as sixteen), together with the simultaneous use of automatically launched "ropes" of varying lengths. Electronic warfare also played a major part in attacks on ship convoys and in amphibious operations.[233]

As we have seen, one of the biggest problems facing the Japanese was to keep sea-lanes open between the mother country and all the occupied islands that were now their territory. When the Japanese entered the war on 7 December 1941, they had a merchant navy of about six million tons but by the middle of 1943 they had already lost two million tons, which could not be replaced due to the limited capacity of their shipyards. As the Japanese-occupied territories expanded, it became more evident that their merchant navy was unable to meet the growing need for long-distance supply transportation to the various islands.[234]

Knowing this, the Americans naturally set about systematically sinking as many Japanese merchant ships as possible by submarine. In an effort to stop this happening, the Japanese equipped their merchant ships with a radar which would give them early warning of the presence of an enemy submarine. However, the Americans countered this by equipping their submarines with RWR and the submarines were, therefore, able to detect the enemy before they were themselves detected. The result was just the opposite of what the Japanese had hoped for, because the American submarines, on intercepting emissions from an enemy merchant ship. Were able to home in on it and sink it.[235]

Naturally, the RWR on board American submarines was equally effective against Japanese warships and, particularly, submarines. During the memorable Battle of Leyte Gulf, an American submarine managed to detect these enemy submarines by EW and sink them all.[236]

Two other episodes had important consequences for the war in the Pacific. One was the Battle of Midway, which marked a turning point in the war between the United States and Japan.[237]

The Japanese attack on Pearl Harbor, the tragic outcome of which can be largely attributed to serious shortcomings in American electronic organization, had brought the U.S. Navy to its knees. Consequently, on the eve of the great naval air Battle of Midway, Admiral Nimitz, Commander-in-Chief Fleet (CINCPAC) found himself with only three aircraft carriers and no battleships at his disposal. On the other side, Admiral Yamamoto, Commander-in-Chief of the Japanese fleet, was in possession of five aircraft carriers and eleven battleships. Nimitz, however, and something which Yamamoto did not have, and this turned out to be of crucial importance.[238]

As a direct result of the Pearl Harbor disaster, the Americans had set up an electronic surveillance network unequalled in the world. All enemy transmissions, both meaningful (such as radio communications) and meaningless (such as radar emissions) were picked up night and day by aircraft, ships and ground stations. All intercepted signals were channeled to a bunker on the island of Oahu where they were analyzed by code-breakers and electronic experts.[239]

Among the many achievements of this exceptional electronic warfare center was the cracking of the secret Japanese cipher system and the detection of periodical changes in all enemy coding.

On 20 May 1942, a few weeks before the Battle of Midway, Yamamoto transmitted a coded message to his naval high commands in which he informed them of his planes for the next military operation, plan "MO". By one of those curious twists of fate, which turn out, to be of crucial importance, the message was mistakenly transmitted in the old code, which the Americans had already cracked, and not in the new one which would have been more difficult to interpret.[240]

After week's work the American code-breakers at the Oahu center were able to understand the text of the top secret Japanese message. Nimitz was duly informed that Yamamoto had decided to attack "A.F." probably on 3 June, and had organized a fake attack in the Aleutians to divert the Americans from the site of the main attack at "A.F.". The problem now was to find out what locality was indicated by the letters "A.F."! How they did this was another masterpiece of American electronic espionage.[241]

Through an accurate analysis of Japanese radio communications the Americans arrived at the conclusion that the site of the attack must be the island of Midway. An ingenious scheme was devised to confirm this theory. The U.S. forces on Midway transmitted an easily decipherable coded message to headquarters informing them that their water-distillation plant and broken down. The Japanese fell into the trap and, a few days later, Admiral Yamamoto transmitted a message stating that "A.F." was short of water due to a breakdown of their water-distiller![242]

Admiral Nimitz now knew where to go and wait for the enemy. He gave orders for the immediate preparation of his three aircraft carriers, *Hornet*, *Yorktown* and *Enterprise*, and set course for Midway. As the two fleets converged on the island, American carrier-borne aircraft made a series of devastating attacks, sinking the Japanese aircraft carriers one by one and forcing the invasion to be cancelled. This American victory and extremely important consequences for the outcome of the war.[243]

The other episode, made possible by the superb organization of American electronic warfare, was that in which Admiral Yamamoto himself was the target.

In April 1943, the Commander-in-Chief of the re-united Japanese fleets decided to visit his advanced bases to follow the Guadalcanal operations and to inspect defenses. On 13 April, the Commander of the Japanese Fleet transmitted a message to other commands concerned regarding the admiral's planned itinerary. The message stated that Admiral Yamamoto would leave Rabaul on 18 April at 06.00 hours on board a light bomber escorted by six fighters bound for the island of Bougainville at the southeast tip of the Solomon archipelago, where he would inspect the bases at Ballale and Shortland. Arrival at Ballale was scheduled for 08.00 hours on the same day.[244]

The American radio stations that were on duty night and day listening to and recording all enemy electromagnetic emissions intercepted this message. It was then sent to the decoding department where it was promptly deciphered.

On the morning of 18 April, eight USAAF Lockheed P-38 Lightning fighters took off from Henderson Field on Guadalcanal and waited for the Japanese admiral's aircraft 35 miles to the north of Ballale. When it arrived, they shot it down. Yamamoto was killed.[245]

Thanks to electronic warfare, an American pilot was able to eliminate from the Pacific scene the man who had masterminded the attack on Pearl Harbor, the highly intelligent and greatly revered Admiral Yamamoto. His loss was deeply felt by the whole Japanese Navy.

However, the greatest contribution made by electronic warfare to the Pacific war was in the amphibious landings that took the Americans from Guadalcanal right into the heart of Japan. It was a continuous, though almost unacknowledged, contribution, both prior to and during each operation.

As soon as the Japanese occupied an island, they immediately set up all sorts of early warning and the fire-control radars. The American electronic warfare units had to locate all these radars from the Solomon Islands to as far a field as the coasts of China and then, to reduce the loss of life during the crucial phases of the operations, neutralize fire-control radars in the areas designated for landing operations.

During the invasion of the Marshall Islands in the central Pacific, ships equipped for electronic warfare intercepted the early warning radar installed by the Japanese on one of the islands to warn the local forces of the approach of American ships or aircraft. After studying the technical parameters of the radar, suitable tactics were devised. The information gained from the radar installed in the Marshal islands proved extremely valuable for the U.S. Navy when they attacked the island of Palau a few months later. They were able to install on board their ships jammers tuned accurately to the frequencies of the local radars.[246]

Even more extensive use was made of electronic warfare tactics during the American invasion of the Marianas islands. Prior to the invasion, the Americans carried out thorough electronic reconnaissance of the radar systems operating in the area. These efforts were well worthwhile as they discovered a "hole" in Japanese radar cover, which allowed the invading forces to land undetected by enemy radar.[247]

Conclusion

The importance of electronic measures was again shown in the course of operations in the Philippines. Prior to the operations in the Gulf of Leyte, the Americans discovered two radar stations; one was installed in the Gulf of Leyte itself and the other was on the island of Mindanao. These guarded the means of access to the respective beaches and could compromise the success of the invasions. They were therefore attacked and destroyed in order to facilitate landing operations.[248]

Another important event in electronic warfare took place during the famous and dramatic invasion of the island of Iwo Jima. While a U.S. cruiser squadron was moving in to bombard the island, electronic warfare operations noticed that the Japanese had a certain number of fire-control radar sets on the island. Again, it was possible to analyze the characteristic parameters of these instruments and transmit the information to the escort ships. The latter then turned on their jammers to prevent the Japanese from using their radar to aim their coastal batteries at the American landing forces.[249]

Chapter 15

The Impact of Telecommunications on Electronic Warfare

Throughout the whole of World War II, the protagonists constantly jammed their opponents' radio broadcasts in order to hinder the spread of propaganda by this means. Many people noticed a great deal of interference while tuning their radio sets and sometimes transmissions were completely drowned by metallic noises, the chiming of bells and so on.

Military communications by radio were also jammed, although to a lesser degree, to prevent the enemy from making effective use of their radio sets. One of the first cases of such jamming took place in November 1941 when the British Eighth Army was preparing a large-scale offensive against the Axis troops on the Libyan Front to regain their lost positions.[250]

During the earlier daring operations of General Rommel's armored columns, the British had noticed that the success of the Germans was partly due to well-organized radio communication between command and the tanks. The British considered that by disrupting these communications, they would be able to paralyze movements of the enemy armor forces. Therefore, a number of rudimentary 50-watt frequency-modulated (FM) radio transmitters were installed on Wellington bombers. These transmitted the noise of the aircraft's engines, producing a deafening, chaotic noise, on the same frequency as that used by the Germans. Initially, the jamming caused great confusion among the German armored columns but as soon as they identified the source of the interference they sent out Bf 109 fighters to shoot down the Wellington bombers. This was an easy task as the Wellington Bombers were slow and were not provided with an adequate escort.[251]

As we have seen in the operations in the Atlantic and Pacific Oceans, one of the most fruitful activities of electronic warfare during World War II was the interception of enemy radio communications. This activity was carried out by the warring nations not only with the aim of gaining useful information from the decoded messages, but also for the purpose of discovering espionage networks based in their own territory. An interesting case involving the latter activity was a German operation intended to locate a clandestine Russian radio station operating in German occupied territory.

In 1941, the German military intelligence service, the Abwehr, intercepted at least 500 coded messages, which they had been unable to decipher. The Abwehr realized that there was a Soviet espionage network operating in Western Europe. Nazi leaders in Berlin were infuriated by their inability to get their hands on this spy network which, being to well-equipped with short-wave radio sets and accessory electronic devices, had been nicknamed the Red Orchestra (*Rote Kapelle*). It was extremely humiliating for them to know that messages containing military information were being transmitted to the Russian military command from inside German territory, but all their efforts to ferret out that den of Russian spies had so far been in vain.[252]

Direction finders then in existence were not sophisticated enough to give an immediate and accurate fix on the clandestine radio station which, moreover, was continually changing location. It was like a foxhunt between the clandestine station and the "Peilung", the German direction finders, to which service technical improvements were continually being made.[253]

The clandestine station transmitted continuously for four to five hours each night. The Germans systematically intercepted the transmission and, using their DF, calculated the bearings of the station. But, every time, the station was transferred to another locality before the Germans located it. Eventually, they managed to establish that the main transmitting station of the Red Orchestra was in a Belgian city. Germany's most skilled DF operators were sent to the city to try to discover the exact location of transmitting station.[254]

The Russian spies had stayed in one place for too long and this error proved fatal for them. On the night of 13 December 1941, the expert German DF operators located the building used by the clandestine station. The spies were caught red-handed by German soldiers who had entered the building undetected, wearing thick socks over their boots to muffle the sound of their footsteps.[255]

It is well known that systematic interception of enemy radio transmissions was an activity that the British, more than other nations, had been engaged in for some time and in which they had gained considerable experience. Immediately after World War I, they had set up clandestine receiving stations all over the world to intercept communications of potential enemy states. All the intercepted messages were analyzed and, if possible, decoded with the aim of gaining information that might be useful to them for political or military purposes.

In those days, the decoding of a message was still an activity whose success depended entirely on the skill and intelligence of people who were experts in the field. The encoding of messages was also done by human hand and the secret files containing the codes were kept under lock and key and guarded night and day.

The coding of a message was a long job that involved "translating" the plain text into a series of numbers and letters that were often doubled-coded to make the enemy's task of decoding even more difficult. Obviously, the greater the number of alphabetical and numerical combinations used, the more difficult the code was to break.

Just before the outbreak of World War II, the Germans built a special message-coding machine; called "Enigma", which was able to come up with a far greater number of combinations than had been possible in the previous manual coding procedures. It was an electrical machine with a keyboard to be used by the operator and was able to produce over four million combinations. The German high commands were convinced that the problems of coding would be entirely solved by this machine, as it would make the enemy's task of decoding all about impossible.[256]

Due to a series of events initiated by Richard Lewinski, a Pole who had worked as an engineer and mathematician in the Berlin factory where "Enigma" had been built, this was not to be. One day in 1938, Lewinski walked into the intelligence service headquarters in Warsaw and offered to sell information regarding "Enigma" for the sum of £ 10,000 Sterling and a passport that would allow him and his family to immigrate to England, at that time an ally of Poland.[257]

The Polish and British secret services could not believe their luck, especially as it seemed extremely likely that they would shortly enter into war with Germany. However, the mere possession of the machine was not enough to rapidly decipher the messages, as the Germans changed the "code-keys" every day. To overcome this problem, the British decided to build a new machine capable of performing all the necessary operations so rapidly find the current "keys". These would then be fed into the decoding machine, which would give out the enemy message in plain text. About thirty mathematicians set about calculating all the numerical and alphabetical combinations of the "Enigma" coding-machine, which they had by now been able to construct with Lewinski's help. When this had been done, the calculated combinations were electronically stored in the enormous decoding machine, which was thus able to produce, by electromechanical means, the right key to decode "Enigma" messages.[258]

This system, which was called "Ultra", was a kind of rudimentary electronic calculator, although the electronic technology used was a far cry from that of modern computers.[259]

When World II broke out, the British found themselves in a particularly advantageous position, thanks to "Ultra" and their worldwide network of intercept stations, they were able to intercept orders from Germany army, navy and air force commands to their respective forces, communications among themselves and even orders given by Hitler himself before every important military operation.[260]

This incredible "scope" by the British secret service had extremely important consequences, especially in the first years of the war. British foreknowledge of enemy operations, provided by "Ultra", regarding strategy, troop alignments and movements of enemy forces greatly influenced the outcome of many battles.[261]

To give an example, the British victory in the Battle of Cape Matapan on 28 March 1941 can almost certainly be attributed to British decoding of messages sent by the German high command to their Air Corps (X CAT) in Italy a few days before the Italian fleet, which it was to escort, left Taranto.[262]

As we have seen earlier, the Italian navy had planned a surprise attack on British convoy ships in the east Mediterranean using one battleship, four heavy cruisers and six destroyers. The success of this operation depended on the element of surprise and the Italians did all they could to keep their plan secret. However, they asked their allies, the Germans, to help them by sending X Air Corps fighters to protect their fleet "Enigma" coded messages relating to this matter transmitted by the Germans were picked up and deciphered by the British "Ultra". In this way, the British were informed of all the main elements relating to the mission of the Italian naval squadron: date, time, ships employed, air support and so on.[263]

In the light of this information, Admiral Cunningham, ordered the British naval squadron, anchored in Alexandria, Egypt at the time, to get ready for an immediate departure. In order to deceive Italian spies in the port of Alexandria, the British admiral went ashore dressed in civvies and carrying his golf clubs. Under cover of darkness, he secretly returned on board and the fleet put to sea.[264]

"Ultra" also facilitated the destruction of numerous Italian convoy ships bound for North African ports. The British deciphered messages from the German high command to General Rommel and to their Air Corps in Italy regarding departures and arrivals of supplies sent by sea to the Afrika Korps, providing information such as the departure and arrival times of the convoys, ports of departure and destination and the route the ships would take. In this way, the British were kept constantly informed of the departure of enemy convoy ships and could promptly send out units to attack them. Moreover, systematic aerial photo-reconnaissance of Italian ports constituted a great, though little known, advantage for the British as it provided them with further information regarding the convoy ships escort cargo and so on. Another factor in the success of the British fleet in the Mediterranean was the possession of radar, which enabled them to fire at night.[265]

On the occasion of the occupation of the island of Crete by German paratroopers in 1941, the British were greatly helped by information gained by the interception and deciphering of messages transmitted by the *Luftwaffe* command to their participating units. Although the Germans succeeded in occupying the island, their losses were extremely high as the British deployed their troops in the precise area where the German paratroopers landed.[266]

Many other Anglo-American successes of World War II have been attributed to the diabolical machine, "Ultra": the Battle of Britain, the Battle of El Alamein in North Africa and the invasion of Normandy, to name a few. It is difficult to judge exactly how far "Ultra" contributed to the success of these operations but there is no doubt that it provided the British with extremely valuable information, which must have swayed the course of many conflicts. Perhaps the Italian navy and merchant marine paid the highest price as a result of the "Ultra" decoding system that provided the British with so much valuable information about their activities.

Conclusion

Knowledge of the enemy's activities and intentions gained by interception and deciphering of communications, together with adequate defense of one's own communications, has always been a major factor in warfare. Considering the great progress that has been made in the field of electronics for military uses and the growing need for command and control of the armed forces, it has become an absolute necessity to protect communications not only from decoding but also from electronic countermeasures (interception, jamming and deception). Protection of communications is, in fact, a top defense priority in every country today and is considered to be just as important as the acquisition of weapons, the training of forces and all the other major components of modern warfare.

Chapter 16

Electronic Warfare in the Cold War

The Korean War

When World War II came to an end, both the Americans and the British rapidly demobilized their war machines and EW equipment fell into disuse. Some of it deteriorated due to lack of maintenance and use. Some of it was even sold to army surplus dealers. Electronic countermeasures fell into oblivion and most of the people who had gained experience in this field during the war disappeared from the scene or moved on to better paid jobs in the electronics industry. Radar, on the other hand, made continuous progress, as it had become an indispensable navigational aid for ships and aircraft, above all at night or in conditions of poor visibility.

Unlike Great Britain and the United States, Russia, the other victorious Great Power, was not so quick to demobilize and Soviet forces continued to dominate the scene in Europe and Asia. Using the skill and knowledge of hundreds of German scientists who had been captured in the occupied territories, the Russians carried out extensive research in the field of electronics for military use and began to build electronically guided missiles.

During World War II, the Russians, like the Germans, had used their air force almost exclusively to provide tactical support for ground forces and had not, therefore, built large aircraft, like the British and American four-engine bombers, specifically designed for strategic bombing. In the aftermath of the war, they decided to remedy this deficiency in their arsenal by producing hundreds of B-29-type bombers, copied from an American Boeing B-29 Superfortress strategic bomber which had fallen into Russian hands after a forced landing in Siberia.[267]

Meanwhile, as a result of unclear and contentious areas in the peace treaties, disagreements soon arose between the Western Powers and the Soviet Union.

During the early postwar period, it was the atomic bomb, then only in the hands of the Americans, that prevented a new outbreak of war; the threat of an atomic reprisal was a sufficiently strong deterrent to prevent the Russians from taking military action. To give an example, it was the atomic deterrent, as it was called in those days that prevented war from breaking out when the Russians began their blockade of West Berlin in 1948. The important ex-capital, marooned in Russian-occupied East Germany, and divided into British, American, French, and Russian sectors, with two million citizens living in the Western sectors, was brought to its knees when the Russians refused to allow supplies to be transported by road through East German territory. When the Americans, British and French decided to set up the famous Berlin airlift between West Germany and Berlin, the Russians could easily have occupied the western sectors of Berlin. Their decision not to do this was due to their fear of an atomic reprisal by the Americans, against which they had no defense.[268]

The blockade of Berlin ended in May 1949. It was a moral victory for the western world but also marked the beginning of what came to be called the Cold War between the Soviet and Western Powers. The Cold War continued for a considerable time and was characterized by brief periods of open hostility and an atmosphere of reciprocal suspicion, which resulted in the formation of the two major formal alliances, the North Atlantic Treaty Organization (NATO) and the Warsaw Pact.[269]

Electronic jamming of communications became an extremely important strategic component of the Cold War. the first act of electronic warfare, in this, in this context, was Russian jamming of programs transmitted by the Voice of America (VOA) and the

British Broadcasting Corporation (BBC) which, transmitted in the Russian language, were aimed at the countries of Eastern Europe behind the so-called "Iron Curtain".[270]

When American and British diplomats protested to Moscow and the United Nations that such action was unjustified in peacetime, the Russians replied that the VOA and BBC transmissions constituted an act of psychological warfare against which the Soviet Union had the right to defend itself by paralyzing the enemy broadcasting stations.

Russian jamming of western broadcasts went on for many years in spite of the tremendous expense such activity involved. The VOA alone had eighty-five broadcasting stations in Europe and North Africa and employed sixteen different frequencies on both medium and short wavelengths. According to an estimate made in those years, the Russians had something like 1,500 jammer-transmitting stations, 800 of which were in Russia and 700 in the satellite countries.[271]

Jammers were designed and built *ad hoc* and were controlled by an extremely efficient interception network. As soon as the VOA changed frequency to avoid interference, Soviet receivers immediately pinpointed the new frequency and continued their jamming. The Russians were so well organized that the time of their jamming coincided almost exactly with those of the VOA and BBC transmissions. Although the Americans often managed to avoid being jammed by the Soviets, the latter went on with this activity right up to September 1959 when the Soviet leader, Kurshchev, made an official visit to the United States.[272]

This type of electronic warfare was not confined to Europe. The Chinese, under the leadership of Mao Tse Tung, soon learnt the art of electronic "interference".

According to clauses contained in the peace treaties, the Americans had the right of access to Chinese seaports. During the famous "Long March" to the eastern and southern regions of China, led by Mao himself, the U.S. Seventh Fleet, deployed in the

Pacific, did all it could to protect these rights. A few months before the march, a ship specially equipped for communications had been stationed in the Chinese port of Tsingtao to ensure that radio communications could be made between U.S. ships and naval high commands on Guam and other Pacific islands.

One day, however, American radio communications stopped functioning and strange interference was constantly present throughout the whole network. Suspecting that they were being jammed, the Americans organized an electronic reconnaissance mission, using a small ship equipped with direction finders, to locate the source of interference. This was rapidly done and the U.S. Marines promptly put the Chinese transmitter, which had been causing the interference, out of action.[273]

It was in this uneasy political-military atmosphere that war broke out between North and South Korea in 1950.

When Roosevelt, Churchill and Chiang Kai-shek met at Cairo in 1943 to decide the future of Japanese-occupied territories in the Far East, it was decided that the Korean peninsula would become an independent free state after the war. However, shortly after the Japanese withdrawal, the Russians occupied the northern part of the peninsula and the Americans occupied the south. Two separate Korean states were thus established. The theoretical border between the states along the 38th parallel soon became the major bone of contention in the growing struggle between the Russians and the Americans all over the world.[274]

Relations between the two new states, communist North Korea and non-communist South Korea, became more and more strained until, on 25 June 1950, North Korean forces crossed the 38th parallel, invading South Korean territory. The United Nations demanded that the aggressors withdrew and called for the intervention of all U.N. member states. An Expeditionary Force consisting mainly of Americans was assembled.

Meanwhile, the North Korean, with the support of the USSR and China, advanced rapidly southwards, occupying most of South Korea including the capital, Seoul.[275]

Five days after the invasion had begun American aircraft based in Japan came to the aid of the South Korean forces, providing them with air support. Shortly afterwards, troops from the U.S. and other non-communist countries went into action in support of the South Koreans. This was the beginning of the long, difficult and bloody Korean War, which lasted for three long years, 1950 to 1953.[276]

In the first few months of the war American B-29 Superfortress bombers were able to operate almost unhindered against both tactical and strategic targets, but the situation changed drastically when Russian-supplied MiG-15 jet fighters appeared on the scene. The Russian fighters had the advantage of being able to use the airbases and long-range radar stations situated on the Chinese side of the River Yalu, which marked the border between China and the Korean peninsula. It therefore became extremely dangerous for the large American bombers to fly daylight missions over North Korea, so they decided to operate only by night, which considerably improved the situation for some time as the North Koreans did not have an adequate night-sighting system.

The only equipment available to the North Koreans were old radar sets from World War II, given to them by the Russians or the Chinese, and these had very limited range. Two basic types of radar has been developed by the Russians during World War II: Rus I (Dumbo) and Rus II. They both operated on a low frequency band and were mounted on trailers pulled by trucks and sometimes even by horses. They were only able to measure the distance to an aircraft and give an approximate indication.[277]

However, the North Koreans had also received from the Russians a number of Mark II fire-control radar sets, which the Russians themselves had got from the British during World War II through the lend-lease program. The Russians also provided them with several SJ search radar sets which had originally been provided by the United States and which the Russians had subsequently copied and mass-produced.[278]

Although, the American themselves were ill prepared for electronic warfare, they were lucky enough to find themselves already in possession of a radar warning system on board their aircraft. During air raids over North Korea, American pilots noticed that, just before they came under fire from enemy anti-aircraft guns, the signal light on their instrument landing system began to flash, thus warning them of the imminent danger. The reason for this was that the Rus II search radar sets used by the North Koreans operated on a frequency (72 MHz) very close to that used by the American instrument landing system (75 MHz). By this fortunate coincidence, the signal light on the flight panel of the American aircraft, besides telling the pilot that it was time to start coming down for landing, also warned him, while flying over North Korea, that he had been discovered by enemy radar. This warning gave the pilot sufficient time to enable him to take appropriate evasive action.[279]

This piece of luck was short-lived, however, as the North Koreans soon acquired a new radar system, given to them by the Chinese, which used a much higher frequency in the X-band i.e. between (8,000 and 12,000 MHz). As soon as their improvised RWR ceased to work, American losses increased considerably, since they now had no way of knowing that they were within range of Korean anti-aircraft artillery (AAA) which, in the meantime, had been considerably strengthened.[280]

The Americans also noticed that enemy anti-aircraft fire had become more accurate even in conditions of poor visibility. They became convinced that the North Koreans must have got hold of a new type of radar. They therefore hastily retrieved equipment, which they had disposed of at the end of World War II. They even had to buy some of it back from army surplus dealers! As soon as this equipment was in working order it was sent to the Far East and installed on aircraft operating in North Korea. These old receivers were not capable of picking up the emissions of the new enemy radar, thus confirming the Americans' suspicion that this new radar operated on a much higher frequency.[281]

As soon as the Americans installed new receivers and acquired detailed information regarding the characteristics of the new enemy radar (frequency, pulse width and pulse repetition, etc.), World War II jammers were modified and installed on old North American B-25J Mitchell bombers which were then given the task of protecting the B-29 bombers during their air raids over Korea. The old system of jamming enemy radar by means of tin-foil strips, called chaff by the Americans, was also resurrected.[282]

Confronted by these electronic warfare devices Korean radar was no longer able to pick-up the enemy bombers or guide their searchlights and AAA onto them: American losses once again began to decrease.

While all this was happening in the skies above Korea, the war on the ground progressed erratically, first in favor of one side, then the order. In 1950, a few months after the war broke out, U.N. Forces had managed to regain all the territory constituting the Republic of South Korea, thanks to the landing of Inchon, on the west coast of the Korean peninsula, behind enemy lines. Fighter-bombers from four aircraft carriers and the 5th Air Force, 250 ships, 70,000 men, including a division of US Marines, took part in this landing which was made difficult by the geographical features of the area, including the steep cliffs which had to be scaled, very powerful tidal flows and frequent typhoons.[283]

It had been clear from the start that the success of the operation depended on the choice of the date for the landing and on the coordination between the landing troops and the supporting air and naval forces. The date was fixed for 15 September and, a few days before, continual photographic and electronic reconnaissance flights were made to locate the radar stations that had to be put out of action. However, thirty-six hours before the time set for landing, a violent typhoon hit Japan and Korea, causing serious difficulties for the smaller ships and landing aircraft, as well as for air operations. The landing, nevertheless, took place according to plan, following a massive air and naval bombardment. Thanks to perfect planning and the support of hundreds of F_4U Corsair and AD-1 Skyraider close support aircraft, the amphibious assault was a complete success and, after seven hours of fighting, all the objectives of the operations had been achieved.[284]

When the UN Forces, having crossed the famous 38th parallel, drew near to the border of Red China, the latter started to send an ever-increasing number of volunteers to help the North Koreans. The Americans and their allies were forced to retreat southwards. It was a bloody struggle with disappointing results. In spite of the thousands of aircraft from US Navy and Royal Navy aircraft carriers and the US Marine Corps, air support did not achieve great results due to the lack of important military targets on Korean territory.[285]

UN losses amounted to over 1,300 aircraft and, according to later calculations made by American experts; this figure would have been trebled if the electronic actions mentioned above had not been carried out.[286]

The war ended on 22 July 1953, leaving things more or less as they had been before. The 38th parallel was once again the theoretical border dividing the two Korean republics which where governed as before but which were even more poverty-stricken. The devastation of the entire peninsula left a toll of almost two million dead, wounded or missing, among whom were Koreans, Chinese, Americans and UN soldiers.[287]

The Impact of Electronic Warfare on the Korean War

The Korean War provided yet another demonstration of how electronic warfare can help to cut losses, especially in the air. Consequently, immediately after this war, there was a great "electronic rearmament". All the major world powers dedicated their efforts to producing new types of equipment to enable their bombers to penetrate enemy air space without being detected by radar and fired at by electronically guided weapons systems.

Shortly after the Korean War, the USSR exploded her first atomic bomb and the two great world powers, the United States and USSR, began to realize what disastrous consequences would ensue if one of them were to launch an atomic attack against the other. The possession of the means to cause such tremendous devastation made both countries extremely wary of each other.[288]

The advent of atomic bomb and, subsequently, the hydrogen bomb (H-bomb) gave war a new aspect and new theories concerning strategy were proclaimed, such as NATO's "massive response" –a devastating nuclear reprisal against any attacker.[289]

The United States began concentration of large, so-called "strategic" bombers, which, in a single air raid, could cause unimaginable destruction by dropping their load of atomic bombs. The first atomic bombs dropped on Hiroshima and Nagasaki at the end of World War II had been carried and dropped by Boeing B-29 Superfortress bombers and, in the early years of the Cold War it was the B-29 which was used by the American Strategic Air Command (SAC) to carry the lethal weapons.[290]

In the 1950, the B-29 was replaced by the new B-50 bomber and, later, by the gigantic Convair B-36. In addition to sox piston engines, they also had four jet engines under the wings, giving them a ceiling of nearly 50,000 feet, a range of 10,000 nautical miles and a speed of approximately 430 mph. At the end of the 1950s, the first jet bomber, the Boeing B-47 went into service. These were in turn replaced by the famous Boeing B-52 Stratofortress which could carry a huge bomb load, flew at an altitude of nearly 55,000 feet, at a speed of over 630 mph and had a range of 12,500 miles. On the Russian side, strategic bombing by the late 1950s was entrusted to the Tupolev Tu-16 (code named Badger by NATO) and the Tu-20 (Bear).[291]

Meanwhile, Great Britain and France had also developed the atomic bomb[292] and they too began to build aircraft suitable for delivering new weapon. Since their sphere of action was limited to Europe, these aircraft were not so impressive as the American bombers. The British built a series of medium-range bombers, the Vickers "Valiant", the Avro "Vulcan" and Handley-Page "Victor", while, for their *force de frappe*, the French built the Dassault-Mirage IV-A, which entered service in 1964.[293]

At the same time, construction of huge, complex air defense radar chains was begun. These had the function of providing early warning in the event of an enemy air attack. The United States built three such radar chains to protect their territory. One ran along the northern border of the United States, another stretched across the central part of Canada and the last, the most advanced, ran from Alaska to Greenland. A complex cable and radio communications network connected all the radar stations, which was in operation twenty-four hours a day.[294]

As well as guarding the Arctic, the United States built a network of radar stations along the Pacific and Atlantic coasts. A number of these radar stations were installed on special platforms in the ocean several miles from the coast. Finally, to ensure detection of hostile aircraft coming from either the east or west, a very advanced surveillance service was put into operation, using four-engine Lockheed C-121 Constellation aircraft equipped with long-range radar and other special devices for long-range detection.[295]

In Europe, the NATO countries also began construction of a gigantic radar chain, which was to stretch from Norway to Turkey.

Between 1947 and 1949, before the Korean War, the Russians had also dedicated their efforts to building an air defense radar chain, guided missiles and a force of heavy bombers. All this was done in great secrecy and very little information managed to leak out even through the usual channels.[296]

In order to fly past these radar chains without being detected, it was, of course, indispensable for bombers to carry electronic equipment capable of neutralizing the radar. The Western Powers, who had learnt, often at their expense, how important it is to know the characteristics of enemy's radar systems, realized that they knew practically nothing about Russian radar and were, therefore, unable to develop appropriate electronic countermeasures. The international political situation was extremely delicate and there was the constant danger that serious tension between East and West, such as that caused by the Berlin crisis, could transform the Cold War into a Hot War![297]

Aware of this possibility, western nations, particularly the United States, set about gaining information concerning Soviet radar by conducting intensive electronic intelligence (ELINT) missions; the Soviets, of course, retaliated by doing the same thing.

From 1949 onwards, the gathering of electronic data regarding a potential enemy became a top priority activity involving specially equipped aircraft and naval units and disguised ground reception stations. Real electronic espionage had begun and was carried out along the borders of potentially hostile countries, at the limits of their territorial waters or in the skies above the countries themselves.[298]

The instruments used in these ELINT missions were mainly the following:

- Receivers and interceptors of various types to pick up the electromagnetic emissions of the radars of potentially hostile countries analyzers to examine the intercepted emissions and ascertain their main characteristics;[299]
- Direction finders to establish the direction of arrival (DoA) of the emissions themselves and to pinpoint the location of the emitting station;[300]
- A series of recorders of various types to store the information for further, more detailed analysis.[301]

The aim of such activity was to find out the enemy's "electronic order of battle", in other words, the deployment of radar stations in all areas under observation, in order to devise appropriate countermeasures to be used if or when they were called for.

Knowledge of the electromagnetic situation of a potential enemy and of variations of his situation has many important side effects. One is that it permits experimental launchings of new, intercontinental ballistic missiles by the potential enemy to be monitored because such test launchers entail a series of checks on radar guidance systems, tracking radar, radio communications equipment and the telemetric instruments of missile itself. Interception and analysis of these electromagnetic emissions can reveal whether the experimental launching of a new missile is, in fact, being carried out, while the electronic information gathered reveals whether new missiles have been deployed in certain zones and what technological progress the enemy has made in the design and construction of electronic systems. This electronic intelligence also permits a fairly accurate picture of the enemy's defenses and sometimes even his political-military intentions to the built up. In short, one can obtain a general picture of what is commonly called the "threat", which is merely the sum total of the sum total of the capabilities and intentions of the opponent, in an act of 360 degrees around one's own country. From a strictly electronic point of view, the threat comprises all the actual or potential enemy's method of utilizing electromagnetic energy for the guidance of weapons, command and control of forces, and surveillance of the theater of operation.

These electronic reconnaissance missions, called "ferret missions", were quite risky as it was necessary for the aircraft or vessel to penetrate the potential enemy's air space or territorial waters in order to achieve the aims effectively. In fact, it was not merely a case of collecting data concerning radar and radio but was often also "challenge" to test their reaction in terms of time and efficiency.[302]

In a typical ferret mission, an electronic reconnaissance aircraft would stimulate the role of a bomber operating enemy air space. it would fly directly towards the border of the "enemy" country, often even flying over it. In this case, it was usually detected and tracked by the country's long-range radar system. On no account had the aircraft to attempt to avoid detection because electronic warfare specialists had to record the frequency and PRF (Pulse Repetition Frequency) of the enemy's long-range search radar and locate its position on the map. Immediately after target acquisition by the enemy search or acquisition radar, enemy interceptor aircraft would be launched to intercept the intruder. At this point, the crew of the spy-plane had to measure the electronic parameters of the search radars' emissions and determine how much time had elapsed between target acquisition and the interceptors' taking off. If anti-aircraft batteries were brought into action, the ELINT operators in the spy-plane had to measure the characteristics of the fire control radars too. Sometimes, they even had to take note of the time it took the batteries to fire the first round and, where possible, evaluate the accuracy of their fire.[303]

The highly-specialized crew members who took part in these missions were men of great skill and ability and, above all, tremendous courage; with every mission they flew, they risked both their own lives and the possibility of providing extremely serious diplomatic incidents.

In spite of this, such missions were an everyday occurrence and no government dreamt of protesting. The governing principles of the time was that of reciprocal action; tit for tat, as is often the case with international relations in peacetime. The only rule was, whatever you do, do it well without getting caught.

The aircraft used in these missions had to have a very long range and had to be able to fly at very high altitudes outside the range of enemy anti-aircraft artillery and at a speed which would make it difficult for interceptors to catch them.

In the early days, the Americans used World War II bombers, specially equipped and structurally modified for the purpose of electronic espionage. Among these was the B-24 Liberator, and the US Navy version, the PB_4Y_2 Privateer.[304] B-29 Superfortress and B-50 bombers, respectively redesignated RB-29 and RB-50 (R standing for reconnaissance), were also used occasionally. Besides the normal crew, those carried a number of electronic operators, each of whom was responsible for surveying a sector of the electromagnetic spectrum. Later, the US Navy twin-engine Lockheed P_2V Neptune, a maritime patrol (MP) aircraft, was used in ferret missions. The Neptune was famous in its time as it held the record for the longest flight ever made. Cruising range was fundamental characteristics to be considered when selecting an aircraft for this type of mission. Ferret aircraft often had to patrol the area under observation for long periods of time before the enemy radar emitted pulses, which they could intercept and record. For this reason, transport aircraft, such as the C-47 and the C-18, were also for these missions. The American's successor to the Neptune was the P-3C Orion, also built by Lockheed, the military version of the Electra turboprop transport.[305]

When the risk of being attacked by enemy fighters became a real possibility, the US Navy introduced the Martin P_4M_1Q Mercator which was specially designed for this particular activity, had excellent range and four engines, two of which were jets, enabling it to accelerate rapidly and escape attack should an enemy fighter suddenly appear on the horizon.[306]

On the Russian side, ferret missions were carried out by Tupolev Tu-16 *Badgers* who, in the original version first observed in 1953, were long-range bombers each carrying two air-to-surface *Kennel* missiles, later replaced by missiles of similar type code-named by NATO *Kelt* and *Kipper*. The Tu-16D version was employed solely for ELINT and was easily recognized by the radomes (domes covering radar) on its fuselage. At first, these aircraft operated in the Pacific, carrying out electronic reconnaissance on the US Seventh Fleet and its bases in the Pacific Ocean. Their main base was at Petropavlovsk on the Kamchatka peninsula. Each Tu-16D carried, beside the crew, seven operators and a radar-officer, all specially trained in electronic reconnaissance. The sphere of their reconnaissance was later extended to the Mediterranean and the North Sea.[307]

Soviet ferret missions were, of course, similar to those carried out by the Americans. Every operator had a receiver to intercept electromagnetic signals in a specific sector of the spectrum, a pulse analyzer, a direction finder to calculate the direction of arrival of the emissions and, finally, a number of special recorders to record them. Each operator had to carefully survey the portion of the spectrum assigned to him, noting down in his logbook all signals intercepted and recording those that seemed particularly interesting. The L-band (1,000-2,000 MHz) and X-band (8,000-12,000 MHz) frequencies were the most commonly used in this period.[308]

In the course of a typical Soviet ferret mission in the Pacific the aircraft would take-off from Petropavlovsk and fly towards the assigned zone. The operator in charge of the L-band sector would begin to intercept the first weak signals coming from American search radar installed in the Aleutian Islands, which had the task of detecting potentially hostile aircraft at long range. The aural signals emitted in L-band were easily distinguishable in the operator's headphones due to the characteristic tone produced by PRF.[309]

As the aircraft continued on its course, the operator dealing with the x-band frequencies would begin to hear in his headphones the fast bleep of the fire-control radar, which usually operated on this frequency band. This meant that the Soviet aircraft had been picked up by the American radar and was being tracked as a potentially hostile target. If, at this point, the aircraft did not change course and head away from the missile base, it would probably be an easy target for the Nike-Hercules surface-to-air missiles (SAM), which, with the Hawk missiles, were the main air defense weapons, then deployed by NATO countries. Therefore, at this point, the Tu-16D headed back to base with its previous reels of magnetic tape on which were recorded American radar signals and radio-telegraphic communications between posts, control centers and air bases in the Far East and the Pacific. As soon as the aircraft had landed, this material was sent to the Russian Signal Intelligence Service Center that was located in a concrete bunker hidden in a forest near Moscow. Here electronic warfare experts who tried to determine the characteristics of American radars in that area and discover any innovations made closely analyzed the signals.[310]

Soviet aircraft also carried out missions of this kind over the waters of Alaska where the chances of intercepting American radars signals were much greater due to the presence of the long-range search radar chain and numerous military bases, and the substantial air, naval and ground forces stationed in the Alaska area. Russian aircraft sometimes penetrated as far as 50 miles into American territory in this region. During one such mission, which took place some years ago, two Russian aircraft, flying at a speed of over 650 mph and an altitude of about 33,000 feet, stayed over Alaska for about half an hour, but kept out of range of the Nike SAMs. The Americans sent out a patrol of four F-102 interceptors to warn off the intruders that headed back to their base as soon as they sighted the F-102s.[311]

As electronic espionage activity in which the Russians excelled was that involving the leech-like presence of specially equipped ships and aircraft in all the areas where NATO naval units carried out their periodic sea exercises to monitor electronic activity. Russian aircraft often flew right over the NATO naval formations, particularly the aircraft carriers, and the NATO forces had no option but to use fighters to chase them away.

The Russians also employed a number of large motorized fishing vessels, which were usually stationed along the American coasts. Besides carrying fishing nets, these boats also had a large number of receivers and special antennas whose function was obvious. These vessels were often stationed near NATO missile-launching bases, lying in wait for the launching of any new type of missile. That this was their main aim can be easily deduced from the presence of multiple helical antennas, the type of antenna most suited to the interception of electromagnetic emissions from missile guidance or fire control radars. [312]

In April 1960, the Russian spy-trawler *Vega* carried out a lengthy ELINT mission in the waters off Long Island, USA, where the Americans were conducting test launches of the Polaris missile from the first US Navy nuclear submarine *George Washington.*[313]

The Russians also employed large, specially modified oceanographic ships for electronic intelligence. Besides collecting oceanographic data during their long missions, they also collected data concerning electronic warfare. Both the Americans and Russians also used submarines for this purpose, although they were totally unsuited to the task, particularly because they had nor surface in order to pick up radar signals and, thus, risked being detected by those same radar stations. Nevertheless, electronic espionage carried out by Soviet and American submarines must have been fairly intense because, in 1961, diplomatic protest was made by both sides regarding this activity.[314]

However, Soviet aircraft was not ever shot down during the course of an ELINT mission nor were there any serious incidents involving other kinds of platform used by the Soviets for such activities. On the other hand, about twenty-six American aircraft were either shot down or forced to land in Russian territory or elsewhere behind the Iron Curtain.[315]

There are two main reasons for this discrepancy. First, Soviet aircraft rarely penetrated deep enough into enemy air space to come within range of NATO missiles while American aircraft, on the other hand, often penetrated the air space of the Communist block and even flew right across their territory. Secondly, the NATO nations were reluctant to launch their missiles against unidentified aircraft, particularly because, in that period, many pilots from east European communist countries defected to the west with their aircraft and, consequently, it was difficult to know whether the pilot of a military aircraft coming from a communist country was a spy or a defector seeking political asylum.[316]

The Soviets also differed from the Americans in their observation or radio/radar silence. Where the Americans kept their radars functioning virtually all the time, the Soviets nearly always turned off their radar equipment when they detected American spy-planes, thereby denying the Americans the opportunity of intercepting missions and thus locating the Russian's radar stations. Only when suspicious foreign aircraft penetrated communist air space to the point where they feared an attack, did the Russians switch on their radars. It was precisely for this reason that American pilots on ELINT missions, which involved penetrating communist air space were ordered to simulate a real attack so that the radar operators would indeed switch on their equipment. Only by using this deception could American aircraft intercept and record communist radar and radio emissions. Unfortunately, using this tactic risked provoking the air defenses into responding with live weapons.

One of the first incidents, which can be attributed to this risky activity, was the disappearance, in April 1950, of a US Navy PB_4Y_2 Privateer. This large aircraft, which carried a crew of ten, six of whom were electronic technicians, took off from Wiesbaden in West Germany 8 April 1950. It was officially flight-planned to fly to Copenhagen, but it is extremely likely that its main task was to carry out an ELINT mission in the Baltic Sea area. At 14.40 hours, it made its last radio transmission over Bremerhaven in West Germany. [317]

According to the Soviet, an aircraft, which they identified as a B-29 bomber, was picked up at a distance of about 350 miles from Copenhagen, over Leyeya (Latvia), 7 miles within Soviet territory, where it was intercepted by a patrol of Soviet fighters and ordered to land at a Soviet airfield. The Russians maintained that the American aircraft had opened fire on the fighters, which had then shot it down.[318]

All evidence seemed to point to the fact that the "B-29 bomber" was, in fact, the Privateer, and the US government bestowed military decorations on the crew who had sacrificed their lives in the performance of their duty.[319]

Incidents of this kind happened all over the world, from the Baltic Sea to East Germany, from USSR to Czechoslovakia, from the Black Sea to the China Sea, from Korea to Siberia, but many of them have never been brought to light.

To get an idea of the strictness of Soviet radio and radar silence, it is enough to look at the occasion of Kurshchev's visit to Britain in April 1956. The Soviet Communist Party Secretary, Kurshchev, and the Soviet Premier, Bulganin, left a port in the Baltic Sea on 16 April 1956on board the cruiser *Ordzonikidze* escorted by destroyers, *Smortryashchy* and *Sovershenny*, bound for Portsmouth, England. Several NATO secret services had set up a network of receivers along the route the Russian ships would take, using naval units, ELINT aircraft and ground intercept stations. However, during the entire voyage, which lasted three days, the Soviet ships emitted not a single signal.[320]

While the *Ordzonikidze* and her escort were anchored at Portsmouth, Lieutenant-Commander "Buster" Crabb, a British ex-corvette captain and renowned frogman, disappeared in the waters of the port; his headless, armless body was found only after several days. Rumor had it that he had met his end while trying to collect data regarding the Russian ships' sonar and the operating frequency of their underwater emissions: this rumor has yet to be disproved.[321]

An important instrument for gathering electronic warfare data is formed by networks of ground stations which, positioned opportunely, can intercept a large number of radio communications or radar signals and pinpoint, by triangulation, the positions of the various transmitter. Consequently, all world powers, great and small, began to set up, or strengthen, these special networks of receiving stations. Naturally, this activity was top secret. Nevertheless, it is common knowledge that extremely efficient radar intercept systems were set up along the border between East and West Germany, one by NATO and the other by countries of the Warsaw Pact. It is also beyond doubt that an excellent piece of interception work carried out in the Persian Gulf, between 1948 and 1950, by a team of British electronic operators masquerading as archaeologists![322]

However, the most important SIGINT (Signals Intelligence) center was set up in Iran. The countries of the west were particularly interested in this zone of the Middle East as the Russians had established a ballistic range at Tyuratam, between the Caspian Sea and Lake Aral. In order to follow Russian progress in the field of guided weapons and, at the same time. To acquire information regularly the characteristics and performance of the relative radar-guidance systems, the Americans decided to set up special receiving stations in Iran close to the Russian missile range.[323]

These stations, equipped with the most sensitive and precise instruments the electronic industry could produce, were set up at Kabkan, near Mashhad, in the northern mountains near the Russian border, and the Behshahr on the Caspian Sea. They were in operation continuously and, whenever the Soviets on new missiles carried out tests, the American operators were able to calculate the missile's trajectory by triangulation, and measure all the parameters of the new radars. In this way, the Americans could devise appropriate ECM to jam or deceive these radars in the event of war.[324]

Conclusion

During the Cold War period, American interest was not limited to the interception of data regarding intercontinental missiles. They were also interested in the strategy and tactics of Soviet air forces. To acquire information in this field, new and more sophisticated listening posts were set up in England (Chicksands), Germany (Darmstadt and Berlinhof), Italy (Brindisi), Turkey (Karamursel and Trabzon) Crete and in a number of locations in the Pacific. The main task of these stations was to intercept and record all communications between Russian aircraft and between the aircraft and their commands. The aim was to acquire information regarding the performance of the aircraft, and their missiles and radar, as about operational procedures employed. Some of these stations had gigantic dish antennas covering 360 degrees, which were able to pick up radio signals coming from aircraft thousands of kilometers away.[325]

During the worst period of the Cold War, aircraft were also targets for electronic deception, which sometimes led to highly dramatic moments, although such incidents are not widely known. False radio navigational signals were transmitted to aircraft by dummy stations. Amongst the fake signals were ADF (Automatic Direction Finding), radio beacons, TACAN[326] (Tactical Air Navigator) and other navigational aid systems. In Turkey and West Germany, for example, there were several cases of NATO military aircraft being deceived into landing on the wrong side of the Iron Curtain. Operating on the same frequency, Soviet radio beacons would use the code-names of western radio stations in bordering countries or simply furnish false information regarding the route the aircraft should take to come in for landing. It was reported that a Soviet warship, anchored in the port of Alexandria, Egypt, in the Mediterranean, imitated the coded response of a US aircraft carrier's TACAN to an F-4 Phantom aircraft that almost caused a serious accident.[327]

Chapter 17

Electronic Espionage in the Cold War

The Secret of the U-2

In the early months of 1956, a strange airplane was sighted in the skies of England, Turkey and some other NATO countries. It the object of great curiosity among of these countries, some of whom wrote to their local newspapers to find out what type of aircraft it was and what it was doing there. When interviewed by the press, representatives of the various military air forces invariably gave an evasive response or refused to make any comment whatsoever. An official explanation was finally given by the United States, maintaining that it was a Lockheed U-2 aircraft used for collecting data regarding air turbulence and current, cosmic rays and the concentration of elements such as ozone and aqueous vapor in the atmosphere.[328]

The Americans did all they could to keep the aircraft hidden from "unauthorized eyes" but, in spite of their precautions, several people managed to catch a glimpse of it and those who got a close view immediately realized that it must be an aircraft specially designed carry out top-secret missions. In Russia, where many pilots had seen the aircraft flying at altitudes they could not reach, the U-2 was nicknamed "the black lady of espionage".[329]

The aircraft was in fact; painted all black to make it difficult to sight optically at very high altitudes and its real missions was to fly beyond the Iron Curtain, taking photographs and collecting data concerning electronic warfare. It had been designed in 1950 for the purpose of keeping the governments of the United States and other western power informed about Soviet missile systems and the electronic characteristics of the radars used to control them. [330]

The USAF (United States Air Force) had not been satisfied with the results of the numerous photographic and electronic reconnaissance flights carried out over Russia in the years 1950-1955 using ordinary aircraft; during this period, there had been fifteen "accidents", in which a total of ten American aircraft had been lost. Consequently, the task of organizing reconnaissance over the USSR had been assigned to the Central Intelligence Agency (CIA). Their first step had been to commission the Lockheed Aircraft Corporation to design and build an aircraft suitable for this type of activity.[331]

The U-2 was a real gem of aeronautic technology. It was a cross between a jet fighter and a glider, with a single turbo-jet engine and high aspect ratio wing with a span of approximately 100 feet. It had a ceiling of over 100,000 feet, a range of 4,500 miles, a top speed of about 500-mph and an endurance of about ten hours. To make lighter in flight, and therefore, give it a greater range, it was able to drop-release its landing gear after take-off and land like a glider on two skids.[332]

Aircraft capable of reaching such high altitudes as these had been built by the Americans, the Soviets and the British, and perhaps by others too, but these were all experimental aircraft built for the purpose of making or breaking records. They could only fly at such high altitudes for every short periods of time and their ability to maneuver was severely limited by the rarefied atmosphere and their narrow wings. Moreover, according to CIA experts no surface-to-air or air-to-air missile then in existence was capable of reaching such incredible heights. The U-2 could, therefore, operate in safety, high in the skies over the Soviet Union, with no fear of being attacked by an enemy aircraft or missile.[333]

On several occasions, the Soviets had tried to shoot down U-2s with fighters and missiles, but all their attempts had failed. Moreover, the U-2 was practically immune to radar detection as it was constructed mainly of plastic and plywood. Only the engine reflected radar waves but this was insufficient for the aircraft to be detected unless its exact position and route were already known. Very few of the U-2's flights over Russia were detected by Soviet air defense, as its echo on the radarscopes was barely perceptible, even for the most experienced and expert operators.[334]

The features mentioned above were not the only wonders of the U-2! There were eight fully automatic cameras on board which could photograph almost any object on the sea or land, in daylight or darkness, in fair weather or foul, from incredible heights; the images produced by these cameras were so clear that, from an altitude of about 80,000 feet, one could distinguish a pedestrian from a cyclist or a man in uniform from one in civilian clothes; from an altitude of about 50,000 feet, one could read the headlines of a newspaper or the billboards posted on the walls of a city; from an altitude of about 30,000 feet, one could even see a nail lying in the road! In less than four hour's flying time, a single U-2 could photograph an area of 780 km by 4,300 km; a country the of Russia could be photographed in the course of a few weeks![335]

The CIA had also ordered extremely sophisticated electronic equipment to be built for electronic espionage over Russia. The normal equipment of a U-2 comprised an intercept receiver capable of picking up all signals coming from Russian radars, a receiver capable of picking up all Russian air defense radio communications, a DF to measure the direction of arrival of all intercepted emissions, a very special magnetic tape-recorder which recorded all intercepted electronic emissions, plus, of course, a radio-compass, an autopilot and a UHF radio.[336]

Everything concerning the U-2 was cloaked in the utmost secrecy and both official documents and aviation journals referred to it as a meteorological reconnaissance aircraft; in fact, in 1957, it was given out that the U-2 had photographed a typhoon in the Caribbean Sea. However, in spite of all the efforts made to keep the real activity of the U-

2 top secret, the curtain of silence began to rise following several incidents involving the aircraft, which made people rightly suspicious about the mysterious airplane.[337]

Regarding the first three or four incidents, which happened in the United States and Germany, the press merely spoke of an airplane which carried out missions classified as "top secret" but, when a U-2 was obliged to make an emergency landing in a glider field in Japan, a local journalist who happened to be there at the time was able to inspect the aircraft for a full fifteen minutes before soldiers arrived and surrounded the damaged aircraft, pointing their machine guns threatening at bystanders to make them go away. The journalist, who was a pilot, saw the pilot of the U-2 climb out of the damaged aircraft and noticed that he had no stripes on his flying suit and that he was carrying a gun. The journalist put two and two together and came to the conclusion that the aircraft was used, not for meteorological reconnaissance, but also for espionage purposes.[338]

The US aircraft that took off from the air base at Incirlik, in Turkey, at 6.00 pm on 27 April 1960[339] to fly a photographic and electronic reconnaissance mission over the heart of the Soviet Union was also a U-2. The pilot was Francis Gary Powers, a 30-year-old former US Air Force captain and unanimously considered to be an excellent pilot and a superb navigator. Powers had logged over 500 hours on the U-2, mainly over Russia, and these missions had become a matter of routine to him; he jokingly referred to them as the "milk run". The CIA conducted these flights on a regular basis as it was only in this way that effective and useful results could be obtained: in fact, by flying over and photographing a certain area at regular intervals and by comparing photographs and recordings made during each flight, it is possible to acquire important information regarding planned military installations, radar stations, missile ranges, submarine bases and so on.[340]

The route Powers was to take was as follows: Adana (Turkey)-Peshawar (Pakistan)-Kabul (Afghanistan)-Sverdlovsk (Russia)-Bodö (Norway). Powers carried a 22 caliber pistol and, hidden in a silver dollar in an inside pocket, a tiny syringe containing a lethal dose of the poison curare, for use in the event of a forced landing. The injection was, according to CIA instructions "optional"; being a spy-pilot on a salary of $ 35,000 a year had its risks![341]

The first leg of the trip was simply a positioning flight from Incirlik to Peshawar, where he would stay four days to rest and re-fuel before starting the long flight over Russian territory.[342]

On 1 May 1960, Powers got back into the cockpit of the U-2 to accomplish his "mad flight" which would take him a distance of 3,525 miles, flying at an altitude of 100, 000 feet, over the Urals, the Russian cities of Stalingrad, Kirov, and Murmansk and the two important missile ranges at Tyuratam and Kapustin Yar, which had been recently discovered by US espionage services.[343]

The U-2 took off about an hour behind schedule as the "go-ahead" from President Eisenhower, normal procedure for all flights over Russia, was late arriving. While he was waiting, Powers had checked the equipment on board the plane several times and no doubt felt some apprehension when his eye fell on the button marked "Destruction", to be pressed in an emergency to prevent certain items of top secret electronic equipment falling into Soviet hands. According to the directions written beside the button, the explosive would destroy only the equipment itself but Powers knew that the explosive charges were attached to the inner walls of the pressurized part of the fuselage and, given the enormous pressure differential at very high altitude, the explosion would also mean the certain end of the aircraft itself.[344]

After take-off, the U-2 began a rapid climb and, by the time it was over Kabul, the capital of Afghanistan, it had already reached an altitude of 68,000 feet;[345] at this point, Powers switched on the equipment which could pick up and record all electromagnetic emissions present in the atmosphere, including military radio messages and radar signals, on all frequencies in current use. The equipment would automatically record the main parameters of every radar: frequency, duration of individual pulses, PRF and ARP (antenna rotation period). These parameters constitute the "signature", a fingerprint of radar and, by analyzing them, one can determine the type of radar in question and the particular operative purpose for which it is employed. By taking two or more bearings (measurements of the direction of arrival of electromagnetic emissions made in such a way as to allow triangulation), one can determine the location of the radar and, consequently, where the weapons system it is used to control, is located. When the radar belongs to a potentially hostile country, this information is extremely useful for devising electronic measures and countermeasures for future use by one's own pilots who might have to penetrate enemy air space.

A primary use of such parameters is to store them in, or have them memorized by an RWR, which warns a pilot of the presence and direction of enemy ground-based or airborne radar constituting a threat. Forewarning of an imminent missile or anti-aircraft artillery attack is, obviously, a vital factor in the success of a mission and the survival of the pilot himself who is thus enabled to make an immediate evasive maneuver or effect the appropriate electronic countermeasure to deal with the threat. There are many different types of electronic countermeasures, and the choice of which to use depends on the contingencies of the particular situation. For example, the pilot can jam the enemy radar to neutralize its effectiveness or use electronic deception to send a missile off course by sending back a false electromagnetic signal to the radar guiding the missile. "Chaff", which enjoyed such great success in World War II, can be used to divert the missile from the real target by creating numerous false echoes in the vicinity of the aircraft. Chaff is now manufactured from various materials such as silver-plated nylon, lead-plated aluminum, aluminum-plated fiber and other combinations. Various types of dispensers in patterns and manners now launch the strips automatically from the aircraft for specific purposes.[346]

Powers was not an expert in electronic warfare. But as a U-2 pilot, he had undergone the usual CIA training and knew that, should a Soviet MiG-21 flying about 30,000 feet beneath him, launch an air-to-air missile to try to shoot him down, he could rely upon the new, extremely sophisticated electronic apparatus installed on board the aircraft to confound the radar of the Soviet missile. This apparatus was, in fact, one of the very first deception jammers (DJ). It had been specially designed, at the request of the CIA, by three leading American companies in the field of electronic warfare equipment and was, of course, "top secret".[347]

Powers also knew that the Soviets had been extremely annoyed by previous U-2 flights, although they had maintained a dignified self-restraint since they could not do anything about the matter. The Russian radars were no doubt lying in wait for him and would try to locate him as soon as the U-2 entered Soviet air space. However, Powers was confronted by the thought that his aircraft could fly at such a high altitude that no Soviet interceptor or missile could reach him.[348]

US radar stations in Pakistan and Afghanistan were able to track Powers until he crossed over into Soviet territory and disappeared from their radarscopes. The only contact from then on was via CIA listening stations which intercepted Soviet air defense radio communications; no direct contact with Powers was possible as he had to maintain strict radio silence.[349]

Shortly after powers had left Afghanistan, a Soviet radar began to signal to other stations that it had detected an unidentified aircraft and, and as the U-2 penetrated into the heart of the Soviet Union, news of the sighting was passed on from one station to another. Suddenly, CIA operators heard an excited voice saying over and over again in Russian, "Target hit!" At that very instant, Powers felt himself being flung forward in the cockpit and dazzling red light illuminated the fuselage of the U-2 from outside, as though there had been a violent explosion behind the aircraft. The aircraft went out of control and began losing altitude in a slow spin. Powers opened the roof of the cockpit to bale out and was catapulted out of the aircraft by centrifugal force. His parachute opened at the height of about 30,000 feet and he slowly descended into Soviet territory.[350]

Powers was subsequently taken prisoner. When interrogated, Powers maintained that he worked for Lockheed and had been test flying aircraft intended for espionage over USSR.[351]

All this took place just before a summit meeting in Switzerland where the President of the United States, Eisenhower, and the Soviet Prime Minister, Krushchev, were to meet to discuss peace. Kurshchev took advantage of the occasion to humiliate the United States before the whole world.[352]

Powers was, naturally, tried in Moscow before a military tribunal of the Soviet Supreme Court where he was described as a typical unscrupulous young American who, in his greed for money, had not hesitated to commit a criminal action which might have caused a nuclear war. The public prosecutor introduced as evidence reels of magnetic tape recovered from the wreckage of the U-2. These contained the characteristic bleeps of Soviet air defense radar indicating the PRFs of the radars. Photographs of the U-2's electronic equipment were also shown onto a screen in the courtroom.[353]

The sentence was severe, although, as it was stated in the verdict, limited to ten years' segregation, three years of which were to be spent in prison. Powers, however, was released after seventeen months, in exchange for the KGB master-spy Lt. Col. Rudolph I. Abel, who had been arrested and imprisoned in the USA.[354]

As soon as he set foot on American soil, Powers was grabbed by the CIA and subjected to incessant interrogation for a period of over twenty days; there were many points in the affair that the CIA wanted to clear up. They were most interested in learning whether the failure of the U-2's mission was due the existence of new Soviet surface-to-air missile or to an act of treason committed by Powers and, above all, whether the Russians had acquired the means of preventing American bombers equipped with electronic devices from penetrating Soviet air space in the event of war.[355]

During his trial in Moscow, Powers had claimed that the aircraft had been hit at an altitude of somewhere between 45,000 and 73,000 feet, instead of the 100,000 feet recommended altitude for that type of mission. Powers explained that the U-2's jet engine had stooped due to a fuel blockage and he had, consequently, lost a considerable amount of height while attempting to re-start it.[356]

Other mysteries, which needed to be clarified, concerned Soviets radar detection and the actual shooting down of the U-2. How had the Soviets been able to locate the aircraft so quickly, given that it was made of radar-resistant material? And, if a missile had hit it, how had its photographic and electronic equipment remained intact? According to Kurshchev, the U-2 had been fired on and hit by a single missile at about 65,000 feet. If this were true, the CIA asked themselves, why had the RWR and DJ failed to work?

Secret US sources of information inside Russia said that, just as Powers was about to over-fly the missile range at Sverdlovsk, the Russians had sent two MiG fighters to intercept the American aircraft and, immediately thereafter, had launched three surface-to-air missiles (SAMs). It would seem that two of the SAMs had hit the MiG fighters, shooting one of them down, but that the third missile had exploded near the tail of the U-2.[357]

This information has never been verified but, if this were in fact what happened, a possible explanation could be that the U-2's ECM equipment had managed to send two of the SAMs off course but, saturated by emissions from the first two missiles, had been unable to receive and successfully counter the electromagnetic signals coming from the third missile, which had continued on course towards the U-2. Nevertheless, considering that the U-2 had not received a direct hit from the missile, one wonders why Powers did not use his ejector seat, which, when it was fired, was probably designed to trigger the aircraft's self-destruct mechanism, to abandon the aircraft, instead of wasting precious time getting out under his own steam. And, if he had had so much time to spare, why had he not pressed the DESTRUCTION button and thus destroyed the top-secret electronic equipment on board the aircraft?[358]

After being interrogated by the CIA, various government commissions and even spoke to Congress also interviewed Powers but no satisfactory answers were given to the above questions.[359]

The CIA even engaged one of its most attractive lady secret agents to try make Powers talk, employing methods which are not exactly orthodox! But the outcome of this was simply that Powers divorced his beautiful wife, Barbara, and married the lady whom the CIA had hoped would bring him before a special tribunal.[360]

A few years later, a link was noticed between the operations U-2 aircraft and Lee Harvey Oswald, the man who assassinated the American President, John Fitzgerald Kennedy. It seems that, while in the US Marines Corps, Oswald had served as a radar controller in the air traffic control station at the American military base at Atsugi in

Japan. Un this capacity, he was not only able to observe U-2s taking off and landing but also had access to secret, high-level information regarding aerial espionage over the USSR and China. Since exchange of communications between a U-2 pilot and controllers at the air base before take-off was a routine procedure, Oswald was able to listen to requests for meteorological information for the specific routes and altitudes of the U-2 during its special missions. Oswald later defected to Russia where he stayed for a while until the KGB sent him back to America where he would be more useful to them.[361]

The hypothesis that it was Oswald who furnished the Soviets with information regarding U-2 routes and altitudes provides a fairly plausible answer to the questions cited above; that is, how had the Russian radars been able to detect and track the flight of an aircraft made of radar-resistant material and, secondly, how had the Russians been able to hit the U-2 with missiles whose range was inferior to the flying altitude of that aircraft?

This hypothesis also gives weight to the rumor that the U-2 was the victim of sabotage, and that, according to some reports, agents working for the KGB had placed a small radio-controlled or timed explosive device in the tail of the U-2 before take-off which had caused the aircraft to lose altitude when it exploded.

On 1 August 1977, Francis Gary Powers died tragically in a helicopter accident, at the age of forty-eight. The helicopter, which belonged to a Los Angeles television company, crashed in the middle of a forest-fire which the ex-U-2 pilot had been filming. His charred body was found and carried away in a sack, carrying away, at the same time, any possibility of clearing up the many mysteries of the flight which had caused such an unprecedented international outcry and which had remained an enigma even for the CIA.[362]

Conclusion

The remarkable fact about the reconnaissance flights is not that Powers's aircraft was brought down, but that the U-2's were able to operate for so long without any protection from electronic countermeasures before one was shot down. While the long-range bombers could not reach the same altitude as the U-2, they would penetrate the defenses in large numbers and they had the powerful advantage of electronic countermeasures for their protection. The fact that a single non-jamming aircraft could be shot down at high altitude certainly did not prove that a large force of bombers flying at a slightly lower altitude with the protection of jamming could be prevented from destroying its targets.

During the years immediately following the destruction of the U-2, however, the deployment of large quantities of new defensive equipment increased the vulnerability of the high-flying bomber. Supersonic fighters fitted with radar were now entering service in large numbers. Moreover, to reach their targets, the long-range bombers now had to penetrate successive belts of surface-to-air missile batteries; many of the latter had been re-equipped with second-generation weapons, which had been designed to operate in the face of jamming.

The B-47 Stratojet

Immediately after the U-2 incident-involving Powers, which took place on 1 May 1960, the American President, Eisenhower, suspended all U-2 flights over Soviet territory and ordered military authorities to devise other systems for collecting electronic information and photographing Soviet territory. The idea of using artificial satellites for such purposes no doubt arose at this junction; these could operate unmanned and would be out of the range of any weapons system then in existence.

However, such an ambitious project would take time to develop and, meanwhile, the CIA could not afford to be deprived of data concerning Russian radar systems, data held to be vital for the defense and even for the survival of the American nation. The head of the CIA, Allen Dulles, held that real task of American intelligence was to carry out espionage activities behind the "Iron Curtain" and that traditional means of doing this were no longer viable. He remarked that the KGB could buy for five cents, the price of *The New York Times*, information that the CIA could not buy even for $10,000! In the USA, all projects concerning rockets, missiles and so on have to be approved by Congress and are therefore publicly discussed. All airbases are marked on ordinary road maps and news of any atomic explosions made in the desert of Nevada is published in every newspaper. The Russians, on the other hand, keep quiet about such things. The smallest and most insignificant piece of information requested by the Defense Department can mean the death of the American agent asked to supply such information. The gist of Dulle's argument, which he continually restated, was that the Americans let the Russians know too much while the latter did not let them know anything![363]

To overcome their disadvantage, the Americans had to accelerate their progress in the field of technology, especially electronics. New listening posts were set up in countries bordering Russia which were allies, or on friendly terms with, the United States. Their extremely advanced receivers could intercept up to two million words a day, which were immediately retransmitted to Washington to be deciphered.[364]

In this way, the Americans had access to interesting Russian communications. For example, in 1958 they managed to listen to a discussion between two Russian fighter pilots as they were attacking a Lockheed RC-130 Hercules, which was on a ferret mission. In April 1967, they were able to follow the dramatic adventure of the first Russian Soyuz spaceship with the cosmonaut, Komarov, on board. As the space capsule was hurtling towards the Earth, Komarov, who was alone on board, realized with horror that the controls, which should have operated the capsule's parachutes, were not working. On the ground, his wife and the Soviet Prime Minister, Kosygin, tried to keep up his morale by telling him that he had been awarded the country's highest honor, but Komarov continued to scream, "I don't want to die! Do something!" until the space capsule finally disintegrated.[365]

Although The USSR was the main focus of interest, the Americans also intercepted and deciphered all military, diplomatic and commercial communications of other key countries, especially in periods of international crisis. This type of activity comes under the authority of the National Security Agency (NSA). At this point, the Americans were able to intercept radar emissions from potentially hostile countries in any part of the world. Once the main characteristics of the radar had been determined, NSA electronic experts would physically reconstruct the radar in question for detailed analysis and training.

New long-range radars were installed in many bases surrounding Russia. These had a coverage of about 1,000 miles into Russian territory and were able to follow experimental missile launches at Tyuratam and even those which took place at the missile range of Krasniy-Yar, 750 miles from the Turkish border. The radars were able to track a missile until it landed in the desert of Kuezuel Kumm near the Russian border with Afghanistan. Other new stations for intercepting, recording and analyzing the emissions of Soviet radars were established wherever friendly countries granted permission for them to be set up.[366]

In spite of all these provisions, many Russian radar emissions could not be intercepted for the simple reason that, the Soviet territory being so vast, the emissions from radars situated in central Russia or Siberia did not reach the borders. It was necessary; therefore, to send aircraft to locate or confirm the locations of new Russian radar stations in areas far away from American intercept stations. Thanks to their mobility and altitude, these aircraft enormously extended the reception coverage, even though, after the recent U-2 incident, they no longer flew directly over Soviet territory and U-2s were no longer employed in such missions.[367]

On 1 July 1960, an ERB-47 a version of the six-engine strategic Boeing B-47 Stratojet (ER standing for electronic reconnaissance), took off from the British base of RAF Brize Norton on an ELINT mission, which would take it along the extreme northern coasts of the USSR. The ERB-47 had a ceiling of 43,000 feet, a range of 3,200 miles and a maximum speed of 725 mph. It was to follow a triangular route, starting from a point 100 miles west of the island of Novaya Zemlya, then fly parallel to the coast of this island until it reached the extreme north-eastern trip from where it would begin its return journey via the Barents Sea. The last radio contact made with the aircraft was when it was 300 miles to the west of Novaya Zemlya, where the Russians tested their intercontinental ballistic missiles (ICBMs) during the summer months.[368]

The ERB-47 was located by Soviet air defense radar and fighters were promptly sent out to intercept it. Five hours after take-off, the six men on board the American bomber, which was flying at an altitude of about 32,000 feet, saw the first MiG fighter-flying overhead. Shortly afterwards, another MiG approached from the right and opened fire. The EBR-47 returned fire with its tail guns but was no match for the Soviet fighters, which had no difficulty in shooting it down.[369]

As in the U-2 affair, the Soviet Prime Minister, Krushchev, who once again accused the United States of violating Soviet air space, released the news. The Russians maintained that they had intercepted the aircraft 22 km (13.5 miles) north of Cape Svyatoy on the Kola Peninsula and that they had shot it down because it was heading for the major Russian port of Archangel. The Americans, on the other hand, held that the aircraft had been shot down 50 miles north of Cape Svyatoy.[370]

A few hours after the American aircraft had been shot down; Soviet ships began to search for survivors in the Barents Sea. A trawler picked up two survivors, First Lieutenant John McKone and Freeman B. Olmstead and the body of one of the pilots; no trace was found of the rest of the crew.[371]

The two surviving officers were tried for espionage, convicted and imprisoned. The new US President, John F. Kennedy, later released them, on 25 January 1961, following a personal intervention.[372]

The Crisis of the Spy-Ship Pueblo

In 1963, the Americans also began to conduct electronic espionage mission in Asia. Sixteen missions were carried out by US ships along the eastern coasts of Siberia, China and Korea but the only incidents worth mentioning involved the *Banner*, a spy-ship operating with the *Winnebago* in the Pacific. As she was carrying out her final mission, Russian warships molested her, one of which trained her guns on the *Banner* and hoisted signal flags that, in International Signal Code, meant "Halt or I shall open fire". One of the Russian torpedo boats came up very close that nothing happened. On another occasion Chinese trawlers surrounded the *Banner* and trained their guns on her. The captain of the *Banner* handled the situation brilliantly by steaming full speed ahead at the trawlers, putting an end to their harassment.[373]

On 1 December 1967, USS *Pueblo* arrived in the Japanese port of Yokosuka, where American spy-ships were based. She was coming from a major refit in the USA during which radical modifications had been made to convert her from a supply ship into a ship for "auxiliary general environment research", as was indicated by the letters AGER 2 painted on both sides of her bow. This was the official classification of the *Pueblo* and, to give credence to this, two civilian physicists and special equipment for oceanographic research had been placed on board the ship before it had left the USA. However, the true purpose of the Pueblo was (SIGINT), in other words the collection of data regarding electronic warfare. Eight antennas covered by radomes dominated the superstructures of the ship and, in a large ELINT operations room under the bridge; there were two large intercept receivers capable of picking up any electromagnetic emission coming from radio or radar even at great distances. All transmissions were automatically and very accurately recorded on special tape by the latest digital equipment. These tapes were later taken to CIA centers for analysis and evaluation.[374]

The *Pueblo* displaced 900 tons, was 53.20 meters long and 9.75 meters wide and had a maximum speed of 9 knots. Her captain, 39-year-old Lloyd M. Bucher, was not a graduate of the prestigious Naval Academy of Annapolis; he had, in fact, been educated at a "Boys' Town" boarding-school in Nebraska from whence he had joined the US Navy and, after graduating from University of Nebraska, became a naval officer. The security officer was 21-year-old Timothy L. Harris, in charge of all intercept activity and related secret documents. The crew totaled eighty-one, and comprised six officers, twenty-nine ELINT operators, the two physicists mentioned above, and forty-four seamen.[375]

At the end of December 1976, the *Pueblo* received her orders from the Commander-in-Chief US Navy in Japan to proceed on her first mission of electronic espionage; this entailed intercepting radio and radar emissions from North Korea and observing Soviet naval maneuvers in the Tsushima Straits.[376]

On 5 January, the ship departed from Yokosuka and, sailing past the island of Kyushu arrived at the Japanese port of Sasebo on 9 January. Bucher received detailed instructions regarding the mission and information about Russian ships, which he might encounter.[377]

On 11 January, before daybreak to avoid being seen, the *Pueblo* left the port of Sasebo and headed for the Tsushima Straits and the Sea of Japan where she was to carry out her mission. Her instructions were to record the radar emissions from North Korean coastal defense systems so that the United States could devise ways of neutralizing these radars in the event of war. The captain's plan was first to collect electronic information concerning North Korean radar and then to observe Russian naval maneuvers on his way back to Sasebo. He was authorized to approach "not closer then 200 meters" to Russian warships for the purpose of obtaining close-up photographs. The operating zone was between the latitudes of 39 degrees and 42 degrees North. Orders were to maintain strict radio and radar silence; only in an emergency was the use of radio permitted. The reason for this silence was, of course, to avoid detection by Russian ships, or by patrol ships from other potentially hostile countries.[378]

After several hours of navigation, the *Pueblo* headed due north towards the island of Ulung Do but ran into a violent storm en route was forced to reduce speed and change course to avoid foundering. When the storm had passed, Captain Bucher headed towards his first objective, the waters outside the North Korean port of Chongjin. He arrived there on 16 January and stayed in the area for two days, sailing against the wind at minimum speed, almost at a standstill, while electromagnetic emissions were intercepted and recorded. During the day, the *Pueblo* usually kept at a distance of 14-18 miles from the coast but, at night, she withdrew to 20-25 miles because of the difficulty of determining her exact position in the darkness. At regular intervals, the ship's engines were stopped so that the two scientists on board could carry out their oceanographic research, measuring the sea temperature and collecting water samples. The data provided by this kind of research is very important in anti-submarine warfare because it can be used to determine how temperature, salinity and other physical characteristics of sea water in that particular area affect the performance of sonar, used for submarine detection.[379]

After leaving the waters of Chongjin, the *Pueblo* headed south and, on 18 January, arrived near Songjin where she remained for about two days without noting anything of particular importance.[380]

The ship then sailed towards Mayang Do where she stayed until 21 January; just as the sun was going down, Bucher sighted a North Korean submarine chaser sailing at a speed of about 25 knots. Thinking that the ship probably had not to signal the sighting to his Command in Japan since the radio communication might alert the North Koreans to the *Pueblo's* presence. It would seem that Bucher gave immediate orders to leave the area and set course for the important North Korean port of Wonsan. Whether conditions were very bad with continuous high winds and snow; nevertheless, the mission was, at this point, proceeding according to schedule. *Pueblo* arrived off Wonsan on the morning of 22 January and, as usual, set about its task of intercepting and recording coastal radar emissions, always keeping clear of North Korean territorial waters, at least according to the ship's navigation officer, which began 12 miles from the coast.[381]

At about 13.30, a seaman on watch signaled hat two trawlers had left the port and were heading towards the ship. When they arrived at a distance of about 50 meters from the *Pueblo*, they began to sail around the foreign ship slowly. They were unarmed but the unwelcome visit was obviously the consequence of the previous day's encounter with the North Korean submarines-chaser.[382]

Bucher ordered all hands to remain below deck so that the North Koreans would not see how many men were on board–certainly there were an unusual number for a ship that, to all intents and purposes, was supposed to be carrying cargo! At the same time, he ordered a signal to be sent to the US Navy radio station at Kamoseya in Japan informing them that the *Pueblo* had been discovered by the North Koreans.[383]

For hours, the operators tried to transmit their message on the *Pueblo's* WL-7 transceiver but, for some unknown reason, they were unable to do so. Meanwhile, followed by the two trawlers, the ship continued to navigate slowly at about 15 miles from the entrance to the port of Wonsan. At 9.00 on 23 January after about sixteen hours. Pueblo's message to Kamoseya was finally transmitted![384]

Around midday, a North Korean navy SO-1 submarine chaser arrived, sailing at full speed, with her guns already manned and trained-on the *Pueblo*. The North Koreans sailed once around the ship to get a close look at her and then asked her to communicate her nationality. In the meantime, four North Korean torpedo boats had left the port of Wonsan and were approaching at full speed. When, in answer to the request for identification, the *Puebio* raised the American flag, the sub-chaser signaled, in International Signal Code: "Halt or we shall fire".[385]

The Americans, while continuing to steam slowly out to sea, replied by signaling that the *Pueblo* was an oceanographic ship. However, the North Korean submarine chaser, which had now been joined by the torpedo boats, ordered the *Pueblo* to follow her.[386]

Captain Bucher signaled that he was in international waters and intended to sail out to sea. The North Koreans replied by firing at the *Pueblo*, wounding, although not seriously, two sailors and Captain Bucher himself.[387]

It was now 14.20. At this point, Bucher ordered the helmsman to steer towards the port of Wonsan and the security officer to destroy the electronic equipment and secret documents. He consulted some of his officers, to see what could be done in the circumstances, and asked for the exact position of his ship at that moment; it was 15.6

miles off the island of Ung-Do, which was situated near the entrance to the port of Wonsan. Bucher signaled that the North Koreans were opposing his right to sail in international waters but received no reply from the submarine chaser, which was now sailing parallel to the *Pueblo,* while the four torpedo boats were positioned on either side, one at the stern and one at the bow of the American ship. The officer in charge of the *Pueblo's* weapons, which consisted of two 40-mm guns, reported to Bucher that they were encrusted with ice and still covered by their protective tarpaulins, which made then extremely difficult to fire. In fact, the temperature was very low and Bucher realized that, if he scuttled the ship, the crew would not survive five minutes in those ice-cold waters.[388]

The *Pueblo's* only chance to get help from US air or naval forces stationed in South East Asia. He therefore transmitted a radio message asking for help. Meanwhile, the ship was proceeding as slowly as possible in order to give the crew time to destroy the electronic equipment and secret documents; this operation was not going too well, however, as there were huge quantities of material to be burnt and insufficient devices to burn it with. Finally, an answer came from the US Navy in Japan saying: "Your message received. Try to hold out as long as possible. We have ordered Command in South Korea to send Republic F-105 Thunderchief fighter-bombers. Good luck!" A few minutes later, as if by a joke of fate, two North Korean MiG-21s flew over the *Pueblo* and disappeared over the horizon.[389]

Bucher decided to heave to in order to give the crew more time to destroy the secret material, which, on no account, should be allowed to fall into enemy hands. The North Koreans on board the submarine chaser reacted by firing the 57-mm machine guns, wounding other members of the crew, while the torpedo boats aimed their torpedo launching tubes at the *Pueblo.* After a short while, one of the torpedo boats moved alongside the *Pueblo* and about ten soldiers, armed with machine guns and bayonets, boarded the ship. An officer who, gun in hand, started to give orders to the bewildered American sailors led them.[390]

Thus, USS *Pueblo* surrendered without a fight. Besides the dishonor, that surrender did untold harm to the United States because, together with the ship herself, the most technologically advanced electronic warfare equipment and the most top secret military documents then in existence fell into the hands of the communist North Koreans.[391]

As soon as the news of the capture of the *Pueblo* reached Washington, the President of the United States, Lyndon B. Johnson, was woken up in the middle of the night and informed of what had happened in the Sea of Japan. As was his wont, Johnson replied, "Thank you", and went back to sleep.[392]

The Commander of the 5th Air Force was informed of the incident by telephone and, at 15.55, immediately ordered his Command in Okinawa to prepare all available aircraft to be sent to Wonsan; but, as these carried only nuclear weapons, they could be sent, for obvious reasons.[393]

The Commander-in-Chief of the Pacific Area ordered Fleet Command to send a destroyer to free the *Pueblo*, but it neither could nor reach the area until 12.00 the following morning.[394]

As soon as the Commander of the US Navy in Japan, Vice-Admiral Frank L. Johnson, Bucher's immediate superior, received the news, he rushed to headquarters in Tokyo and, on his own initiative, ordered the nuclear-powered aircraft-carrier USS *Enterprise*, then at a distance of 600 miles from Korea, to head for Wonsan. Armed aircraft could not be sent from Japan because of an agreement made with the Japanese government forbidding American military aircraft to fly combat missions from Japanese soil. Vice-Admiral considered that it would be useless to send rescue aircraft because it did not seem that the Pueblo was in danger of sinking.[395]

On 23 January at Wonsan, the sun set at 17.41 and it was dark by 17.53, by which time it was already too dark for either aircraft or ships to come to the aid of the *Pueblo.*[396]

No concrete help came from Washington, either. In spite of the pressure of public opinion, no military action was taken against North Korea. Only a formal protest was made to North Korea, while an appeal was made to the United Nations Security Council calling for the immediate release of the ship and crew, whose capture the US Government considered to be simply an act of piracy as the *Pueblo* had been in international waters.[397]

Conclusion

So, for one reason or another, the Pueblo was abandoned to her fate! The members of her crew were imprisoned for almost a year. On 22 December 1968, they were released and allowed to return home, with the exception of one crewmember that had died as a result of injuries received during the seizure of the ship.

Two days after the crew had been returned the Commander-in-Chief Pacific Fleet ordered a Court of Inquiry to be set up to investigate the circumstances relating to the *Pueblo.* A sub-committee, made up of high-ranking officers of the three US armed forces, was assigned the task of making a preliminary evaluation of the implementations for national security resulting from the loss of the classified material, which had been on board the ship.

The Incident of the EC-121

During the course of these hearings, the Pentagon suddenly announced on 14 April 1969, that, at midnight, the military forces of the Republic of North Korea had shot down a US Navy EC-121 which had been on a mission of electronic reconnaissance, about 50 miles off the North Korean coast. Given the similarity to the *Pueblo* incident, from a national security viewpoint, the sub-committee of the three armed forces decided to extend its inquiry to cover the loss of the EC-121. In fact, many parallels could be drawn between the two incidents and both revealed serious shortcomings in the chain of command.[398]

The EC-121 was part of a reconnaissance squadron under the command of the Pacific Seventh Fleet and the Commander-in-Chief Pacific. However, the commander of the 5th Air Force was responsible for supplying aircraft to protect the EC-121 if necessary. However, when the spy-plane took off from August in Japan at 17.00 on 14 April 1969, it also departed from the operational control of the squadron command, but no other command took over operational control, even though various US Air Force, Navy and Army radar control centers followed its flight on their radar screens and tactical plots.[399]

The first indication that the EC-121 was in danger came from the squadron command officer then on duty who reported that the command's radio station had intercepted a message from another American radio station warning that hostile aircraft were approaching the EC-121 in the skies over the Sea of Japan. The squadron commander then requested that the main American radio station in the Far East, at Fuchu, send copies of all radio messages transmitted by the EC-121 and, using all available sources of information, clarify why the mission had been interrupted. For over an hour and a half, the squadron commander called the radio station at Fuchu but no clarification of the matter was forthcoming. He therefore decided to transmit a lightning message, which would take precedence over all other transmissions, asking all relevant US command radio stations for news of the EC-121.[400]

Immediately afterwards, squadron command received a message saying that the EC-121 might have been shot down by North Korean fighters over the Sea of Japan. At this point, the squadron commander asked the 5th Air Force to organize a rescue mission immediately and received a confirmation that a C-130 Hercules was being made ready for such a mission. The local time was 1.09, 15 April, and, probably because of the darkness, no trace of the EC-121 or its twelve crewmembers was found.[401]

The Navy Court of Inquiry into the capture of the *Pueblo* was composed of five admirals and was presided over by Admiral Harold G. Brown. The Crew of the *Pueblo* and everybody who had been directly or indirectly involved in the mission were interrogated over a period of two months. All five admirals had fought in the Korean War, one of the toughest wars ever fought by the United States. They had been chosen for the Court of Inquiry for this very reason and, naturally, were not very lenient with Bucher. Had surrendered his ship to the enemy without resistance and this, for them, was unforgivable; a Captain must never surrender his ship, whatever the circumstance. As a last resort, if he is really out-numbered, the ship should be scuttled. The verdict was severe; the Court asked that Captain Bucher be brought before a Court Martial and tried on five charges: allowing his ship to be searched when he still had the means to resist; failure to take immediate offensive action when attacked by the North Koreans; obeying North Korean orders to follow them to the port of Wonsan; failure to ensure, before taking to sea, that his officers and crew had been prepared and drilled for the destruction of the secret documents and electronic equipment on board the ship; and failure to destroy these documents and the equipment through negligence, thus allowing them to fall into the North Koreans hands.[402]

The Court also asked that Vice-Admiral Frank L. Johnson, Commander-in-Chief of US Navy Forces in Japan, be reprimanded for not having ensured that *Pueblo* was adequately prepared and protected and, likewise, that Captain Everett B. Glanding, Security Chief of the Pacific Command, be reprimanded for not having confirmed that the efficiency of the *Pueblo's* data-collection section was adequate to meet the severity of potential demands upon this vital section.[403]

However, on the very same day that the Court issued these recommendations, the Secretary of Navy sent out a communiqué stating that no action would be taken against the crew of the *Pueblo*, as they had suffered enough during their imprisonment, and that no judgment could be made either to absolve or condemn the officers and the captain since the premise upon which the activity of ships like the *Pueblo* was based–the freedom to sail in international waters–had been violated by the North Koreans' attack outside their own territorial waters.[404]

The inquiry conducted by the sub-committee of the three armed forces to investigate electronic surveillance re-examined many aspects of the case dealt with the Navy Court of Inquiry and, finally, drew up a report containing some very interesting revelations, conclusions and recommendations.

The *Pueblo* and the EC-121 Warning Star operations were part of a costly national defense plan to acquire military information about potentially hostile countries. According to experts in the science of modern warfare, national security is based on knowledge of the military capacities of potential enemies and, to acquire this knowledge, the best technical means must be employed to collect, analyze, evaluate and exploit information relating to these capacities. To this end, the United States had begun to conduct large-scale surveillance, both open and covert, using specially equipped ships and aircraft to collect the necessary technical and operative information.[405]

Both USS Pueblo and the EC-121 brought down by the North Koreans were used for such purposes, and, as ship and aircraft respectively, had both had their advantages and limitations. However, generally speaking, both ships and aircraft had proved themselves to be extremely useful for this kind of activity, whether they operated separately or together.

In the early period of the Cold War, the US Navy and ordinary warships, cruisers, torpedo boats and so forth, for collecting electronic warfare data. However, this practice was abandoned after a few years as there were several serious disadvantages: first, warships had to be taken away from their normal duties; secondly, the presence of a US warship in a sensitive area could be seen as a provocation by the country whose shore it was near which, therefore, limited the warship's capacity to undertake electronic espionage; thirdly, according to various treaties and international conventions, warships are subject to a number of restrictions which do not apply to other ships; finally, warships did not always have enough space for all the necessary electronic devices and for the technicians needed to operate them. Therefore, the authorities decided to use merchant ships for electronic espionage activity. In some cases, ships were designed and specially built for such missions, in others; existing ships were suitably modified for their new role.[406]

The first ship designed specially for electronic surveillance was ordered from a New York shipyard in July 1961. She was named USS *Oxford* and bore the letters AGER-1. She closely resembled the famous Liberty ships built during World War II, especially her hull. Later, a further six ships of this class were ordered and named *Georgetown, Jamestown, Belmont, Liberty, Valdez* and *Muller*.[407]

By 1965, these ships were judged to be too few to cover the national need for the collection of electronic information and so the US Government authorized a number of auxiliary ships, like the *Pueblo*, to be converted into spy-ships. Built during World War II to fulfill US Army maritime transport requirements, they had been decommissioned in 1944 and placed in reserve. The first two ships to be refitted were the *Banner* and *Pueblo*, followed by *Palm Beach*. The US Navy was highly satisfied with this type of spy-ship and plans were approved for the deployment of fifteen such vessels in seas all over the world. Another factor, which contributed to the US Navy's enthusiasm, was the much lower cost of using ships compared to other types.[408]

The main advantage of using surface ships for electronic reconnaissance, according to US Navy, was their ability to remain on station in one area for great lengths of time (a ship of "Pueblo" class had an endurance of 4,000 nautical miles!) and are therefore bound to pick up new enemy radar signals sooner or later. Another great advantage was that such ships are protected by international conventions signed by all countries in the world, which state that a ship is part of the territory of the nation whose flag it flies and that it therefore cannot be attacked or captured. Finally, as mentioned above, the financial aspect was favorable.[409]

In practice, however, the *Pueblo* did not possess any of those qualities which had initially made the US Navy do keen to use ships of this type; on the contrary, she was not 100 percent sea-worthy, and she was poorly armed, slow and unreliable with hopelessly inadequate devices for the destruction of secret documents and equipment. These factors were probably the real reason why no action was taken against the captain of the *Pueblo* and his crew after the inquiries. Moreover, the orders Bucher received were vague and incomplete and there was not even a semblance of organized assistance for the ship in an emergency.[410]

The lesson to be learned from both the *Pueblo* and the EC-121 incidents is that, the more difficult the mission, the clearer and more unequivocal the chains of command need to be. This absolutely vital because gaps in the chains of command at critical moments can lead to disastrous consequences.

Another lesson to be learned, particularly from the *Pueblo* incident, is that such vessels must have an appropriate defensive capability. They must be adequately armed in order to be able to defend themselves; they must be equipped with suitable early warning systems in orders to sight a potential enemy before being sighted themselves; and they must be fast enough to get away from a danger area quickly, before they run into serious trouble.

As we have seen, ships like the Pueblo operated as part of an integrated program of electronic surveillance and espionage drawn up by the US Navy in 1965. Those stationed in the Pacific were under the overall command of the Commander-in-Chief Pacific via the Commanding officer Pacific Fleet who gave operating orders directly to peripheral naval high commands. The *Pueblo's* mission was part of the general plan to cover areas, like Japan, where there was a notable shortage of information regarding electronic warfare systems. Missions carried out in that area, therefore, came under the operative control of the naval command in Japan. But, at the moment of need, no command seemed able to take a decision.

There are still many unanswered questions concerning the capture of the *Pueblo* and the shooting down of the EC-121. One question of immediate interest regards the position of the *Pueblo* at the moment of captures; was she outside or inside North Korean territorial waters?

Conclusion

As all sailors know, it is not always possible to determine with absolute certainty the exact position or "fix" of a ship, due to various factors such as wind, sea currents, the lack of conspicuous landmarks along the coast, and the reliability of the ship's navigation system. As a result, frequent disagreements arise regarding the position of a ship near the limits of territorial waters. In the case of ships like the *Pueblo*, the main reason for this uncertainty was the lack of precision of the navigational systems used. The *Pueblo* used the LORAN (Long-Range Navigation) system, which fixes a position by transmitting synchronized impulses from various radio stations situated at great distances from one another. With LORAN, or, for that matter, any other similar radio-electronic system, there can be a margin or error of several miles, especially near the coast, and, consequently, whether the *Pueblo* was inside or outside the territorial waters of the republic of North Korea is simply a matter for conjecture, and the truth will never be known.

Another important aspect of the *Pueblo* incidents is the question of responsibility. After transmitting a radio message informing his command that the ship had been discovered by the North Koreans, Bucher had to wait almost twenty hours before he received a reply. This fact, coupled with Bucher's failure to take any initiatives, is perhaps the main reason for the loss of the ship.

The case of the EC-121 was somewhat different. When a slow, unarmed and otherwise undefended aircraft is attacked, the crews do not have many options open to them. Consequently, active operational control of the aircraft by higher authority is of even more crucial importance. Those who planned the EC-121's mission should also have provided for its defense. Two main errors were committed: first, after what had happened to the *Pueblo,* an undefended aircraft should not have been sent to operate in an area where it was quite likely to be attacked and where it would be difficult to intervene in an emergency, given the precarious operational situation of the US Air Force which was already involved in the Vietnam War; secondly, the responsibility for the operational control of that admittedly difficult mission had been divided too many different commands, with the result that, at the crucial moment, it was not clear who was responsible for the aircraft and, consequently, nobody did anything to defend or rescue it.

One thing that the two episodes have very much in common is of an extremely serious nature: the failure by those who had ordered the mission to take subsequent responsibility for their outcome.

Modern Espionage

Modern secret service agents are somewhat different from those characterized in spy stories. Nowadays, the pilot of a spy-plane can collect more information in a single mission than a hundred traditional spies, of the kind employed in World War I, could collect in the course of a year! Those famous tales of beautiful women hiding in their throbbing bosom precious, minute maps stolen from the room of some sentimental captain or womanizing general now belong to the past. That is not to say that traditional forms of espionage are no longer useful. On the contrary! One famous case of classic espionage occurred in the post World War II ear when Russian agents managed to obtain British atomic secrets from the British scientist Klaus Fuchs, who has been called the "spy of the country". However, perhaps this was an exceptional case as the British traitor was strongly influenced by communist ideology.

This type of espionage is called "penetration" because it involves penetrating the operative centers of potentially hostile country by placing an agent inside or close to those centers who can then steal important documents or listen to discussions regarding the country's defense. this form of espionage is extremely difficult to carry out because there are strict checks and security measures to prevent the placing of external agents. This difficulty has been largely overcome by using internal agents, people who already have a position in such organizations and who, for ideological reasons or for money, aspire to who for enemy intelligence services.

However, apart from very important documents and plans, most of the information-desired can be intercepting and deciphering enemy communications and, above all, by conducting electronic and photographic reconnaissance missions. With the development of extremely sophisticated photographic and electronic equipment for long-range monitoring of nuclear tests and missile launching, espionage has become more of a technological and scientific discipline.

When, in the 1950s, the possibility of a sudden, catastrophic nuclear attack became a real threat, the only means of foreseeing such an event was by espionage. Foreseeing such an attack is extremely difficult since, unlike traditional warfare where aggressive acts are preceded by the mobilization of troops, tanks, ships, etc., preparations for a nuclear attack can be made in secret.

Consequently, secret services in the atomic age must have up-to-date information on the offensive capacities of other countries, above all those concerning nuclear weapons and their launching systems. This involves being informed of the deployment of guided missile bases and of technological progress made in the enemy's missile guidance systems. Moreover, since the only way of discouraging the enemy from making a surprise attack is the threat of a massive reprisal, it is also important to know the enemy's defensive capacities in order to study and plan ways of operating his defenses with a reasonable chance of success and survival of one's own forces.

Although it is possible to hide missile launchers in underground silos, and to camouflage missile guidance radars and resort to many other cunning tricks to deceive the enemy regarding one's activities and intentions, nobody has yet found a way to keep hidden the electromagnetic emissions of a radar which is nearly always linked to a modern weapons system. Sooner or later, during installation of the weapons system, training of the nuclear operators or, above all, during experimental launchings, the radar must be switched on; it is then inevitably detected and located by electronic reconnaissance. It is as though the radar leaves its "signature", or "finger prints", in the atmosphere for anybody to pick up, as happens in classic cases of murder detection. Once the radar has been detected and located and its emissions have been analyzed, appropriate ECMs can be devised to neutralize or reduce its performance at the opportune moment.

The Cuban Missile Crisis

Since World War II, there have been several major international crises, crises in which electronic warfare has played a critical role. The most potentially explosive crisis began in the fall of 1962,[411] when the US Navy spy-ship *Muller*, patrolling and listening in the Caribbean Sea, intercepted unusual radar signals coming from the nearby island of Cuba. The tapes on which these signals were recorded were immediately sent to Washington for analysis to try to identify this new type radar. The Americans were dismayed to learn that it was Soviet radar normally used to guide ballistic missiles with nuclear warheads.[412]

To confirm this discovery, maritime patrol aircraft were sent to the Caribbean on ELINT missions while that in the course of a few days, extremely sensitive intercept receivers were installed along the south coast of Florida, their antennas pointing towards Cuba. All radio communications transmitted and received by the island of Cuba were also intercepted.[413]

Shortly afterwards, on 14 October, a U-2 was sent on a reconnaissance mission over the island. The photographs, taken at an altitude of about 100,000 feet, were developed that very night and immediately examined by CIA experts. They were compared with other photographs taken over Cuba two years earlier–in January 1960–during a mission made by another U-2, using an infrared camera system. This mission had succeeded in photographing every inch of Cuba without arousing the slightest suspicion among Castro's defense units.[414]

The photographs were subjected to close analysis and, the following evening, indications of an MRBM (Medium Range Ballistic Missile) base in the area of San Cristobal were discovered. Further reconnaissance flights over Cuba confirmed that the Russians had, in fact, already installed a number of such missiles and were in course of setting up launch pads for longer-range missiles. The range of these missiles would be about 1,000 miles, which meant that the Cubans would be able to hit and destroy many American targets, including Washington, the Panama Canal and a number of Strategic Air Command (SAC) bases.[415]

The US President, John F. Kennedy, was informed of this on the morning of 16 October and immediately conferred with his closest advisors, asking them to make an in-depth study of the dangers these installations represented for the USA and what action could be taken.[416]

The working-group examined various proposals and these were discussed over the next five days while U-2 reconnaissance flights were stepped up. A few days later, the Soviet Foreign Minister assured President Kennedy that Russian had supplied Fidel Castro with "defensive" weapons only.[417]

On 27 October 1962, a U-2 on a reconnaissance flight over Cuba was shot down by a Russian SAM-2 Guideline missile and its pilot, Major Rudolf Anderson, was killed. U-2s were immediately taken off such missions and replaced by Tactical Air Command McDonnell RF-101 Voodoos in Florida. These could fly at twice the speed of sound at altitudes ranging from 50,000 feet down to treetop level. They were equipped with electronically controlled cameras and flare-ejectors for night photography.[418]

After a brief but intense series of low altitude night and day flights by RF-101s, the Americans received confirmation, not only from the photographs taken but also from what the pilots had seen with their own eyes, that forty-two launch pads for MRBMs and twelve launch pads for IRBMs (Intermediate Range Ballistic Missiles) had been prepared, along with radar equipment to guide the missiles. It was also confirmed that Cuba had forty-two Ilyushin Il-28 jet bombers, 144sites for SAM-2 missiles, forty-two MiG-21 fighters and several Russian-built missile-armed boats as well as about 20,000 Soviet military advisors and technicians. Ground intercept stations provided confirmation that the frequencies of the emissions previously intercepted by ships and aircraft were indeed those of radars normally associated with ballistic missiles. The presence of nuclear warheads was not confirmed; these, along with the missiles, were probably being transported by the numerous merchant ships, which were then sailing from Russia towards the Caribbean.[419]

On the basis of this irrefutable evidence, President Kennedy decided to take action, informing the American nation and its allies of what had happened and what was about to happen.

Of the few solutions open to him to favorably resolve the situation, Kennedy had decided on a naval blockade of the island. All ships carrying arms, whether their nationality, would be prevented from reaching Cuba. To allow the Russians to save face, the action was called" quarantine".[420]

At that time, eighteen Soviet merchant ships, loaded with missiles and their accessories, were sailing towards Castro's island. A naval encounter between the Russians in the Atlantic seemed inevitable and the whole world waited with bated breath for what might mean the outbreak of World War Three.[421]

The approaching Soviet ships, escorted by submarines, were kept under constant surveillance by the Americans. When the first ships were stopped, inspected and asked to change course immediately, USSR authorities gave orders for the fleet to turn back.[422]

Never since1945 has the world been so close to a nuclear catastrophe as it was in the October of 1962. If the US Navy had not collected and evaluated the electronic information relating to the Soviet radars so promptly, thus allowing the Russians time to install more missiles in Cuba, the consequences for world peace would have been much more serious as, once installed. It would have been extremely difficult to effect their removal.

After this humiliating climb-down in the Caribbean, the Russians initiated a massive shipbuilding program to strengthen their fleet. In charge of this program was Admiral Sergei Gorshkov, Commander-in-Chief of the Soviet navy. Every year, new warships of all types, armed with surface-to-surface and surface-to-air missiles, were launched, swelling the Soviet navy which is now the second most powerful in the world. The wide range of electronic equipment, which was gradually installed on the new Russian ships, revealed by the forest of antennas on the rigging, was very impressive both in quality and quantity. In order to avoid hindrance from enemy ECM, progressively higher frequencies and increasingly sophisticated technology were employed in the design of the new Soviet radars.[423]

Parallel to the strengthening of Soviet naval forces and the spread of Moscow's strategic influence, efforts were also made to increase the merchant navy with its cargo and auxiliary ships, including oceanographic ships and large fishing trawlers. Many of these auxiliary ships, which were under the direct control of the navy and which, according to Admiral Gorshkov, were to be considered an integral part of soviet naval power, were adapted for the purposes of electronic espionage. Referred to by NATO as AGI (Auxiliary, Intelligence Gatherer) vessels, these ships constitute the eyes and ears of Russian naval intelligence which, like the other Soviet armed forces, has to gather information regarding the deployment and operative procedure of the radar, radio, radio-navigational systems and so forth of potential enemies, beginning with NATO countries.[424]

Since the NATO countries use many different types of radar and other radio-electronic systems and the area to be covered is fairly extensive, the number of AGI ships grew from four in 1962 to more than 160 in 1979. They were distributed among the various Soviet Fleets (the Pacific Sea Fleet, the North Sea Fleet, the Baltic Fleet, the Black Sea Fleet and the Mediterranean Fleet) and operate continuously wherever there are electromagnetic emissions to be intercepted. They are almost always present in an area where NATO air and naval exercises are being conducted, in the vicinity of missile ranges during missile test firings and along all coasts where NATO radar stations have been set up.[425]

AGI ships vary greatly in their tonnage, range, endurance and so forth. For example, ships of the "Primorye" class displace 5,000 tons, have a large number of antennas on the masts and superstructure and two large rooms below deck, which probably house electronic equipment for analysis of intercepted signals. They also possess a large number of receivers and transmitters for intercepting all communications made between NATO ships and their respective commands; they themselves can communicate with Soviet Fleet Command either directly or via satellite. Other classes of AGI, which are important not only for the quantity but also for the quality of their electronic equipment, are the "Mayak" and the "Okean" classes.[426]

The Invasion of Czechoslovakia

A classic example of the large scale of use of ECM in an operation conducted in peace time, is the invasion of Czechoslovakia by communist Warsaw Pact forces, mainly Soviet, on the night of 20/21 August 1968.[427]

Just before the invasion, to mask the build-up of armored vehicles along Czechoslovakia's borders, the Russians engaged in extensive jamming of all frequencies used by both Czechoslovakian and NATO surveillance radar in central Europe.[428]

Numerous jammers were used for this purpose, such as the "Mound Brick", "Tube Brick" and "Cheese Brick" types, to use MATO code-names. These were mounted on vehicles and covered all the frequencies used by the Czech and NATO search radar. R-118 communication jammers were also used, mounted on trucks, to prevent or, at least, interfere with NATO and Czech communications.[429]

Besides this jamming equipment, on the night of the invasion, the Russians also used large quantities of "chaff" to completely blank out Czech and NATO radarscopes. Consequently, nobody was aware of the tanks advancing or the huge transport aircraft depositing men and arms at airports in Prague and other Czechoslovakian cities. The Russians managed to screen the presence of huge numbers of vehicles transporting the invading forces from all radars in the vicinity, thus maximizing the element of surprise and their own safety in all phases of the operation. In short, this jamming operation completely paralyzed any attempt at resistance, as the Czechs simply did not know what was going on.[430]

Conclusion

The world was presented with a *fait accompli*. Western European countries and the United States could do nothing except follow a cautious policy of non-intervention and make a series of protests and accusations. The US Government also protested that the Soviet Union was trying to prevent, by jamming, "Voice of America" transmission from reaching the countries of the Eastern bloc.

However, the invasion of Czechoslovakia made American and allied military commands realize that their knowledge of Russian electronic warfare capabilities was severely lacking and they immediately stepped up electronic intelligence activity along their borders with Warsaw Pact countries.

The Soviets Build-Up of Electronic Warfare Capabilities

The Russian's near perfect use of ECM in the invasion of Czechoslovakia was a real surprise for the Western powers and showed the importance of the Russians attached to electronic warfare and the progress they had made in that field.

However, those who had read Marshal V. D. Sokolovkiy's book "Soviet Military Strategy", published some years previously, should not have been so surprised. In this book, the ex-Vice-Minister of Defense of the USSR clearly specified the role of electronic warfare in his country's strategy. He defined the basic tasks of electronic warfare as preventing the enemy from effectively using electromagnetic emissions and protecting one's own emissions from enemy ECM. He wrote that ECM and ECCM were now in common use and their application was of the very greatest consequence, and that developments in the field of electronics were now of equal importance with developments in the fields of missiles and nuclear weapons, which themselves could be of little use without electronic equipment.[431]

The organization of electronic warfare in the USSR is very complex and is the responsibility of two large departments: the KGB and the GRU.

The KGB (*Komitet Gosurdarstarvenoi Bezopasnot*–Committee for State Security), is the senior of the two insofar as it comes under the direct supervision of the government. It collects every type of information pertaining to National Security by all possible means, from common spies to artificial satellites, from field intercept stations to stations installed in embassies and consulates abroad. It comprises four main Directorates, seven autonomous departments and six special sections. The KGB has a vast number of employees and huge material resources.[432]

The GRU (*Gosurdarstvenoi Razvedyvatelnaya*–State Military Information Agency), on the other hand, comes under the supervision of defense chiefs of staff and operates almost exclusively in the military sector. Like Western military information services, it deals with the gathering of operational and technical information regarding weapons systems, operational procedures and "electronic orders of battle" of potentially hostile countries.[433]

In their electronic warfare operations, the Russians make wide use of airborne radar for the obvious reason that it has a greater range. Many different types of aircraft of varying sizes have been modified for the purposes of electronic warfare. At first, civil aircraft were used, such as the Ilyushin Il-14 *Crate*, a twin-engined aircraft which entered service in 1954 in the passenger transport role, and the turbo-prop An-12 Cub, which entered commercial service in 1959 and was used for a while in Egypt to obtain information about Israeli electronic systems.[434]

Certain types of fighter-bomber aircraft were also modified for the purpose of electronic warfare. One of the first of these was the MiG-21 *Fishbed-H* which carried its electronic equipment in a pod attached to the underside of the fuselage[435].

Another fighter-bomber used in electronic warfare has been the MiG-25, NATO code-named *Foxbat*. The high performance of this aircraft was an unpleasant surprise for the United States and countries of Western Europe when it began in development trials in the mid 1960s. At altitude, it could travel at Mach 3.2 (over three times the speed of sound) for short periods, although it was subsonic at sea level, had a ceiling of about 80,000 feet (24,400 m) and seemed altogether superior to its western counterparts. The photographic/electronic reconnaissance version first appeared in 1971 and was code-named *Foxbat-B* by NATO. Its sophisticated camera, IR-Linescan and side-looking radar

(SLAR) and other electronic equipment aroused great curiosity and interest in Western intelligence services.[436]

MiG-25s made regular flights over China and the Middle East. During the Yom Kippur War of 1973, the Israelis tried several times to intercept them using F-4 Phantom interceptors, armed with AIM-7 Sparrow medium range air-to-air missiles, but they could not get near enough to the Soviet aircraft to shoot them down. Moreover, attempts made by Western intelligence services to acquire information about the aircraft's capabilities were unsuccessful because the airbases where MiG-25s were stationed were subject security. The aircraft was "taboo" even among the Russians themselves and official documents referred to it as "Product No. 84".[437]

Nevertheless, it was a Russian, a pilot named Viktor Belenko, who finally satisfied the desire of Western intelligence services to know more about this aircraft. On the morning of 6 September 1976, Belenko landed at the airport of Hakodate in Japan in a MiG-25 which had taken off from its base at Sakazovka, 190 kms north of Vladivostok in Siberia. Many other Soviet pilots had defected to the west in their aircraft but the one Belenko arrived in and that was something special! Electronic warfare and avionics experts were hastily sent from the United States to Hakodate to examine the aircraft's equipment. They dismantled the radar (a type, code-named *Jay Bird* by NATO, which operated on a frequency between 12,880 MHz), the RWR (NATO code-named *Sirena* III), the ECM devices and the dielectric panels installed in the aircraft's nose to absorb radar emissions; all these were then subjected to close inspection and analysis.[438]

Towards the end of 1976, information about the characteristics of the MiG-25 *Foxbat's* electronic equipment was made known to all NATO Commands and the Soviet aircraft was no longer the terror of Western pilots.

Conclusion

However, a comparative evaluation of the *Foxbat* and contemporary American and European aircraft showed that Russian technology in this field, both in general construction and in its electronic equipment, was much less advanced than that of the Western world.

The two types of Soviet aircraft most commonly used for electronic reconnaissance have been the famous heavy bombers, the Myasischev Mya-4 *Bison* and the Tupolev Tu-16 *Badger*. The latter, in the *Badger-D*, *F* and *H* versions, is still in use today for collecting information. It carries an impressive load of electronic and electro-optical equipment as can bee seen from the many antennas (about a dozen), which, under their covers, protrude from all over the fuselage. The most recent version, the *Badger-H*, besides carrying a *Sirena III* RWR and passive receiving equipment (ESM) is also well-equipped with jammers for carrying out active ECM and can thus be used to provide EW support for raiding bombers.[439]

Another important protagonist in the electronic war between Russia and NATO is the Tupolev Tu-95 *Bear-D*, an electronic and maritime reconnaissance version of the Tu-95 heavy bomber, which, with its four turbo-prop engines, has an endurance of 7,800 miles without refueling. It has often been seen flying over "hot" zones during international crises to keep the situation under observation. The US Government has often complained of their presence in the Caribbean. Obviously in the region to intercept the electromagnetic emissions of the radars nearby US Air Defense Commands.[440]

Chapter 18

The Experience of Electronic Warfare in the Vietnam War

On 24 July 1965, during a raid over North Vietnam, an American McDonnell-Douglas F-4 Phantom was shot down by a Soviet-built SAM-2 surface-to-air missile.[441] It was neither the first time that a U.S. aircraft had been shot down by a missile; five years previously, a U-2, piloted by Francis Gary Powers, had been shot down over Russian territory by a SAM.[442] However, the loss of the F-4 was of great importance in another way because it marked the first appearance of Soviet missiles on the battlefields of Southeast Asia. Along with the missiles, the Soviets had also sent expert advisors to help the North Vietnamese.

The shooting down of the F-4 exposed the deadly threat constituted by Russian-built SAMs to the US Air Force, which had until then enjoyed air supremacy over North Vietnam. Vietnamese air defense assets had, been limited to Russian-built MiG-17 and MiG-21 fighters and radar-controlled anti-aircraft guns. Now those ground-to-air missiles had also been deployed, North Vietnamese air defenses were considerably strengthened.

US Air and Naval aviation losses had so far been acceptable, but now the situation changed dramatically. US aircraft found themselves without an adequate defense and losses began to increase daily. It was imperative to find an effective way of dealing with the new weapon.

In the USA, top-level meetings were immediately held to study the problem. It was unanimously acknowledged that the only way of dealing with the new threat was to develop airborne electronic warfare systems to neutralize the radars used to guide the ground-to-air missiles. The task of developing such systems, assigned to leading US companies specializing in that particular field, was given top priority as a result of alarming increase in aircraft losses over North Vietnam.

At the same time, great efforts were devoted to gathering technical and operational information about the SAM-2 missile system on the basis of which suitable antidotes could be devised.

The basic components of the Soviet SAM-2 system were the missile itself (NATO code-named *Guideline*), and the missile's tracking radar "*Fansong*". Since its appearance in 1958, various modifications had been made to the system, particularly to the *Fansong* radar. In 1965, one SAM-2 system consisted of six missile launchers and one radar capable of guiding three missiles simultaneously. The whole system was transported on towed trailers and could be set up in about six hours.[443]

The missile had a range of about 15 miles, a speed of Mach 3.5, and an explosive warhead weighing about 80 kgs. It had "Command"-guidance; a system in which the information needed to guide the missile is fed to it by an external source, in the case radar.[444]

In the SAM-2 system, the information was provided by the *Fansong* radar, which locked unto the target and tracked it on frequencies between 2,940 and 3,060 MHz, transmitting via UHF radio the orders necessary to guide the missile onto target.[445]

The *Fansong* radar also had TWS (Track-While Scan) capability, utilizing two radar beams, positioned at an angle to each other in the shape of a fan, which moved up and down like a bird flapping its wings. Three beams were radiated at right angles to each other, which swept the sky from level to very high altitude, and from right to left in an arc of 10 degrees each. This system permitted simultaneous coverage of an area of sky 3 to 4 kms wide and 3 kms deep around the target. The system also had a flat antenna, which transmitted command signals guiding the missile.[446]

While they were waiting for US industry to develop appropriate ECM systems, the only chance of survival for the pilots of fighter-bombers operating in Vietnam was to try to evade *Guideline* missiles launched in their direction by violent maneuvers![447]

The gathering of electronic warfare (SIGINT) information had revealed several shortcomings in the SAM-2 system, which could be exploited. For example, it took the *Guideline* missile a full sic seconds, after launching, to be picked by the tracking radar, which would guide it onto target. Another limitation of the system was the missile's poor reception of the command signals transmitted from the ground and its slowness in executing the orders contained in the signals.[448]

Exploiting the weak points of the system, the Americans came up with an evasive maneuver, which immediately produced good results. It consisted in nose-diving in the direction of the SAM-2 battery as soon as the pilot saw a missile, or missiles, being launched. After its initial near vertical launch, the missile would veer downwards to get on course towards its target. At this point, the American pilot would suddenly pull up as hard as possible into a steep climb, flying inside the trajectory of the missile. Since the missile was incapable of making the violent maneuver necessary to "capture" its target, the US aircraft usually managed to escape. But this evasive tactic did not always work as clouds sometimes blocked the pilot's view of the missile.[449]

By the end of 1965, the Americans, ever more deeply involved in the Vietnam War, had lost about 160 aircraft, most of them shot down by SAM-2 missiles.[450]

Ground warfare in Vietnam was also difficult for the Americans because it was conducted according to the unorthodox guerilla principles clearly expounded by the leader of the People's Republic of China, Mao Tse Tung, in the following four rules, formulated many years previously:[451]

- When the enemy advances, we shall withdraw

- When the enemy stops, we shall torment him
- When the enemy avoids battle, we shall attack him
- When the enemy withdraws, we shall pursue

Vietnam was ideal for this new type of warfare and the Americans, who, for various reasons, could not use their nuclear weapons, found themselves in serious difficulties. There were no divisions or regiments of soldiers to confront in open battle but an ever-present, invisible army of men who could hide as they wished among the civilian population in houses, fields and, for the most part, in the endless jungle.

Not finding military or industrial targets worth hitting, the Americans directed their air attacks against enemy supply lines–most particularly the famous Ho Chi Minh trail, a secret route through the jungle and mountains of eastern Laos used for taking supplies from North to South Vietnam.

The Vietcong had dug, numerous underground tunnels forming completely organized shelters. Many of the tunnels had concrete structures, first aid centers, warehouses, command centers, and so on; they even had electric light and a water supply and were provided with air by natural animal holes made by moles and rabbits. The entrances and exits to these tunnels were well camouflaged and, after a guerrilla attack, the Vietcong would disappear underground like rabbits.[452]

The tunnels had observation posts manned by sentries to keep an eye on what was happening above ground. When there was a low-level air raid, the Vietcong would prepare themselves and as soon as one or more aircraft had completed a pass and started to turn back, they would surface and fire at the disappearing aircraft, often managing to shoot them down.

In the early stages of the war, tear gas, and, possibly, other, more harmful types of gas, was used to drive the Vietcong out of their dens but, when news of this reached

America and other parts of the world, there was a wave of protest which caused the Americans to curtail the practice.[453]

The Americans then turned to other methods of detecting the presence of Vietcong. One of these methods employed common insects, which can "sense" the presence of human blood to which they are attracted. An electronic device was used to pick up and retransmit the "emissions" which these insects made on sensing the presence of a man; these signals were then amplified so that the operators could hear them in their earphones. Another device used for the purpose of detecting the presence of the Vietcong picked up heartbeats and other physiological sounds made by the internal organs of the human body; these were transmitted directly to airborne aircraft.[454]

Thee Americans also developed an electric device capable of detecting the seismic vibrations produced in the ground by moving vehicles or troops. The devices were dropped from aircraft and their antennas, which were about a meter long, were camouflaged to merge in with the surrounding vegetation.[455]

Another type of seismic detector, called an "anti-intrusion" device, was used by foot patrols and small ground units to give them warning of a prepared ambush. The device consisted of small seismometers and a receiver, which picked up their emissions. The troops planted and recovered the device themselves. If there were any "intruders" in the area, the smallest vibrations caused by their footsteps would be detected, thus warning the troops of the presence of the enemy.[456]

In order to reveal the presence of Vietcong guerrilla at night or in thick jungle, the Americans used all the technical and scientific means they had at their disposal. One instrument used was able to detect the radio-electrical pulses emitted by the spark plugs of engines, thus detecting the presence of motorized convoys, while magnetic detectors, by detecting variations in magnetic field caused by the presence of metallic masses, were able to warn of the presence of arms or vehicles.[457]

Another ingenious method involved making a chemical analysis of the air, which, by detecting changes in the proportions of its components exploited the fact that human beings take in oxygen and expel carbon dioxide and nitrogen. If there were large numbers of Vietcong present, the air would contain proportionally slightly less oxygen and more of the other two elements.[458]

Perhaps the strangest device for detecting Vietcong guerrillas was one that emitted electromagnetic waves when touched or moved by somebody walking past it. The emissions were picked up by a small opportunely positioned transponder, which amplified and transmitted the sound waves. The amplified signals were picked up by an electronic computer, which processed the data, which was then passed to commands.[459]

For reasons relating to the frequencies used by these devices, it was nearly always necessary to set up a relay station to retransmit the signals to the processing centers. Specially-equipped aircraft were generally used as relay stations. The first type used for this purpose was the Lockheed EC-121R Super Constellation, a huge transport aircraft which could hold all the equipment necessary for processing the data transmitted by the small spy-devices scattered all over the jungle. The aircraft, flying at very high altitudes, covered vast areas and, on the basis of data received, could direct tactical fighter strikes on targets.[460]

However, the use of Super Constellation proved to be too costly and, being unarmed, they were easy prey for enemy MiGs. They were therefore replaced by modified, suitably equipped single-engined to be used; these RPVs (Remotely Piloted Vehicles) also carried out reconnaissance and ELINT missions.

Tactical action taken by US strike aircraft against Vietcong information through the jungle was often preceded by missions, using specialized aircraft, in which special chemical defoliants were sprayed on the surrounding vegetation. While facilitating the task of the strike pilots, this action caused almost irreparable damage to plant and animal life.[461]

Processing of data acquired by the use of various types of detectors played a useful role both in tactical and strategic warfare in Vietnam. The following episode, described in a US command report, gives an idea of the tactical use of such data processing.

In an area just south of the border between North and South Vietnam, a detector system had revealed the presence of an enemy unit, which had infiltrated the area named Hill 881 by the military. Information concerning the movement of the unit, together with knowledge of guerilla fighting methods, enabled the US commander in that area to determine exactly the itineraries of the approaching enemy unit. Consequently, just as the enemy unit was lining up to attack, an overwhelming artillery barrage hit them from America artillery pieces hastily moved in to opportune positions.[462]

However, the most important use of these data processing centers was in the field of strategic warfare, mainly in the interdiction effort to halt the flow of men and supplies along the Ho Chi Minh trail, the vital artery of the Vietcong. Contrary to what the world "trail" suggests, this was not one, but a series of trails which crossed the Laos-Vietnam border over an area of about 100 kms. There were two main trails, each roughly 500 kms long, running from north to south and linked by a series of side roads running at right angles to them which afforded considerable flexibility in their utilization.[463]

To avoid large concentrations of vehicles, which would attract the attention of US aircraft that had already destroyed many bridges, road junctions and supply depots, the

North Vietnamese had sub-divided the trail into sections, each one of which was the responsibility of a local command. Each command had its own vehicles and drivers who knew every inch of their stretch of road and could therefore get off the main route quickly at the slightest hint of danger. The disadvantage of this system was that the vehicles had to be unloaded at the end of every section and the goods had to be kept well hidden until they were re-loaded onto the new vehicles of the next local command. These operations were, of course, always carried out at night. Infrastructures had been built, including rest areas and loading areas, and SAMs and AAA protected each transit station.[464]

Early attempts to sever this umbilical cord to South Vietnam by means of "area" bombardments along the trail were not very effective. The Americans, therefore, adopted the tactic of "selective" bombing, which meant that the target had first to be clearly located and identified. It was in this phase that US forces made extensive use of the various detecting devices described earlier. After detecting the presence of a column of vehicles moving along the trail and determining its position, the column would be kept under observation and the time it would take to reach the point chosen for attack would be calculated. A number of control points were set up along the trail with various types of detectors: electronic, magnetic, infrared and so on. Wherever possible, the detectors were planted manually by experts; otherwise, they were dropped from aircraft, attached to metal spikes, which would become embedded in the ground on landing.[465]

The information gathered by this system–the "Igloo White" system–was sent to surveillance center where it was processed by specially programmed computers and correlated with data acquired from other sources, such as deserters and spies. In this way, it was possible to plot the progress of the convoy and estimate its approximate speed, and to make an assessment of the number and the types of vehicles comprising the column. If, at a certain point, the calculated speed fell too far below average, it could be deduced that a transfer and rest station had been set up at that point. To determine the exact position of the station, further detectors could be launched, usually acoustic types, or infrared (hear-detecting) types, which could detect the infrared energy, emitted by vehicles or human bodies.[466]

Once the position of the stationary convoy had been established the surveillance center transmitted the relevant data either directly or via a relay aircraft to the aircraft, which were to make an attack. The pilots to calculate the course they should fly to reach and attack the convoy fed this data into the navigation computers.

In 1966, the Vietnam War escalated and the Americans bombed targets other than those along the Ho Chi Minh trail. These new targets were often further north, sometimes as close as 10 kms from Hanoi, the capital of North Vietnam. As the distances that US strike aircraft had to fly to reach their targets increased so the bomb-load they were able to carry decreased and, consequently, B-52 strategic bombers, with their huge bomb loads, began to be employed. These had very sophisticated electronic equipment and flew so high that the Vietcong could not hear them. Consequently, the bombardments took the Vietcong by surprise and caused great destruction to their communication lines.[467]

The year 1966 also saw the start of the great dogfights between MiGs and F-4 Phantoms over North Vietnam, such as the one that took place on 23 April between sixteen MiGs (fourteen MiG-17s and two MiG-21s) and fourteen phantoms. The F-4s armed with passive radar homing AIM-7 Sparrow and IR-bombing AIM-9 Sidewinder missiles and podded 20 mm cannons, were faster and, more importantly, had better maneuverability than the MiG-21–let alone the completely outdated MiG-17. The most feared enemy of the F-4 Phantom was neither of these. The real danger was from the SAM-2.[468]

By the beginning of 1966, the US electronics industry had produced airborne electronic warfare equipment capable of intercepting pulse emissions from the *Fansong* radars and providing timely warning to the pilot that his aircraft had been locked –on and, within four seconds, could be hit by a *Guideline* missile. This RWR equipment was based on the "crystal video" technique of signal detection, tuned into the frequency band used by the enemy radars. As soon as RWR picked up SAM-2 radar emissions, the pilot received an immediate warning.

RWR was first installed on modified B-66 bombers. During air raids, an RWR-equipped B-66 would precede the formation, alerting it when SAM radar emissions were intercepted so that they could make appropriate evasive maneuvers. Further progress made in the field of electronics led to the development of smaller RWRs which could also be installed on the strike aircraft themselves, although installation was still handicapped by the minimal space available inside such aircraft.[469]

When RWR's antennas picked up electromagnetic emissions from radar, the system's receiver immediately passed them to a computer, which compared their main characteristics with the stored parameters of radars, acquired by electronic espionage. If the characteristics matched those of the SAM-2 radar, the receiver would immediately tune into those emissions, a red light would come on in the cockpit and the pilot would hear a signal tone produced by the radar pulses in his earphones; when the *Fansong* radar passed from the "search" to the "lock-on" phase, the tone would suddenly change and intensify due to the increase in the PRF as "lock-on" was achieved. At the same time, the device indicated the quadrant of direction of arrival of the signal and therefore of the missile.[470]

The American pilots called the sound they heard in their earphones the "SAM song", when they heard it, they knew that a missile was on its way and that they had to make a quick evasive maneuver.[471]

Air losses in Vietnam dropped for while following the introduction of this new RWR. However, as improved versions of the SAM-2 arrived from Russia, the situation once again became unfavorable for the Americans. American pilots were no longer content merely to have a warning system, which enabled them to resort to a last minute evasive maneuver which was becoming increasingly dangerous because, the Vietcong having analyzed the tactic, it often led the Americans into the sights of another battery which would immediately launch its own missiles (missile trap).[472]

A few months later, a missile capable of destroying an entire SAM-2 missile battery, without too much risk for the pilots was sent from the United States. It was an anti-radar missile (ARM), the AGM-4 Shrike, which, by means of electronic equipment in its nose, was able to guide itself onto the enemy radar beam and follow it to its source, the radar itself, which it would then destroy.[473]

The new US tactic for destroying SAM-2 missile batteries invoked sending between two and four two-seat aircraft, usually F-105 Thunderchiefs or F-4 Phantom, to launch Shrikes. Each aircraft carried an EW operator whose task was to detect and locate SAM-2 batteries using an RWR to establish the direction of arrival of the radar Shrike. At this point, there was no hope left for the SAM-2 battery, as its own radar emissions would inexorably attract the very missile, which would destroy it.[474]

These mission were called "Wild Weasel" and had a considerable measure of success. As a result of the effectiveness of the Shrike ARM and the RWR system, the number of US aircraft lost in proportion to the number of Vietcong missiles launched showed a significant reduction. SAM-2 missiles shot down only forty US aircraft in 1966, versus great many SAM-2 batteries destroyed, in spite of the fact that the SAM-2 batteries had been considerably strengthened. According to American statistics, in 1965 one US aircraft was shot down for every ten missiles launched whereas, at the end of 1966, it was one in 70 (see the histogram Fig.18-1).[475]

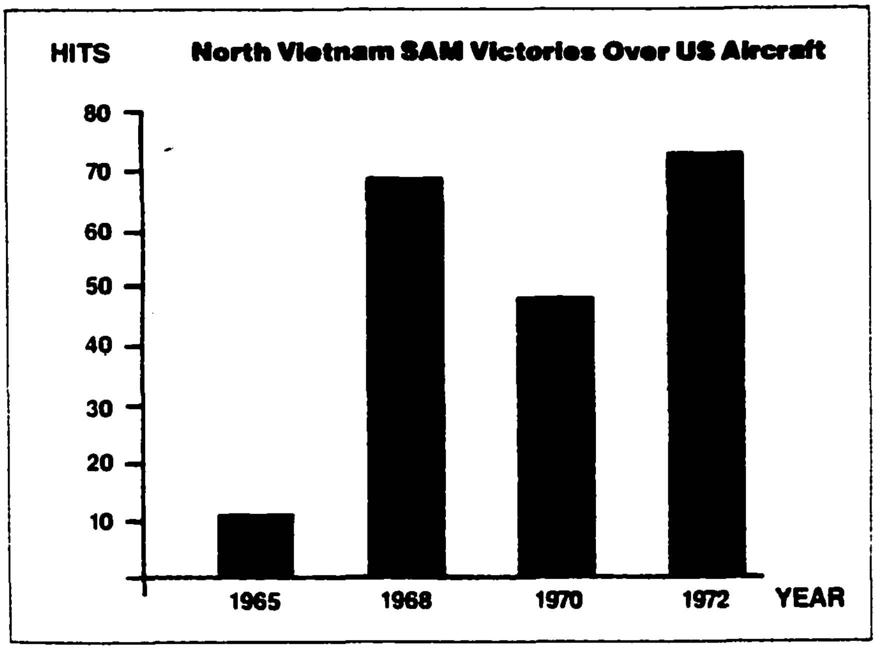


Fig. 18-1 Histogram: the number of US aircraft was shot down with the respect to the number of missiles.

In 1967 and 1968, more compact devices were installed on US fighter-bombers for maximum protection. The main problem with such installations was the lack of space inside the aircraft. This was solved by installing them externally in metal containers, or pods, hooked under the wings or fuselage.[476]

The first type of device to be installed in this way was a simple noise-emitting electronic jammer. Subsequently, more sophisticated jammers were installed; these were able to evaluate the threats posed by the various radars, establish priorities and jam accordingly. Automatic chaff-launching devices, with similar evaluative capacities, were also installed in pods.[477]

The huge B-52 bombers also benefited indirectly from the new ECM as "Wild Weasel" units in their air raids always escorted them over North Vietnam.

However, American supremacy did not extend to the situation on the ground. The Vietcong were gaining more and more control of South Vietnamese territory and attempts made to weaken support for the Vietcong by means of psychological warfare had proved useless. Such "psy-war" attempts involved air dropping thousands of propaganda leaflets; going into the villages to talk to the people; using special devices which emitted terrifying noises in the hope that the Vietcong would think it was the evil spirits of the forest; fitting loudspeakers to small aircraft which flew low over the villages, urging the rebels to surrender; and using Vietcong deserters to try to persuade their comrades to desert and go back to their families.

However, these forms of psychological warfare had little success. The Vietcong were far more successful in their regular mortar attacks on American airfields in which numerous aircraft and helicopters were destroyed.

In 1967, in an attempt to take the pressure off South Vietnam, where the Vietcong were becoming more and more enterprising, the Americans decides to bomb Hanoi, the capital of North Vietnam, and Haiphong, the most important port in North Vietnam. Airbases where MiG-17s and MiG-21s were based also became targets for air raids but the North Vietnamese government soon transferred these aircraft to airports on Chinese territory from where they could operate freely without fear of attack. Shortly afterwards, the North Vietnamese strengthened their air defense system with arms and equipment provided by Russia and China; this system included SAM-2 missiles, anti-aircraft guns and fighter aircraft, all coordinated by one central command.[478]

With the success of US "Wild Weasel" attacks on SAM-2 missile systems, the North Vietnamese increased the number of radar-controlled anti-aircraft guns until they had about 10,000 altogether. Most US aircraft lost in 1967 were, in fact, shot down by anti-aircraft gunfire while flying low to bomb bridges, roads, military bases and factories.[479]

The SAM-2 missile sites were concentrated mainly around Hanoi, to defend the North Vietnamese capital from high-flying B-52 bombers: there were by then, only about thirty SAM-2 batteries still in operation. On the whole, the North Vietnamese air defense system was comprehensive and well organized, covering practically all their territory and operating with unprecedented efficiency.[480]

The bitter struggle between anti-aircraft defenses and US aircraft was interrupted every now and again when the Americans suspended their air raids in the hope of being able to resolve the conflict by political means, allowing them to pull out of this missy war which was becoming more and more unpopular in the United States.[481]

However, the war went on, and the US Navy F-4 Phantoms and A-4 Skyhawks were sent into action over North Vietnam, operating from the US Navy carriers *Kitty Hawk* and *Ticonderoga*. These aircraft were normally escorted by Douglas EA-1E (AD-5Q) "Queer Spads" (Skyraiders) and Douglas EA-3A (A3D-1Q) Skywarrior ECM aircraft equipped with the latest electronic warfare devices, which greatly facilitated penetration of enemy air defenses.[482]

As the destruction caused by the Vietcong's nightly mortar attacks on US airfields in South Vietnam increased, operations carried out by these Navies aircraft were stepped up likewise. In the Gulf of Tomkin, there were twenty-five ships of the US Seventh Fleet, four of them aircraft carriers carrying a total of 600 of the latest strike/attack aircraft.[483]

However, it soon became apparent that EW-equipped escort aircraft, which were usually slower than the strike aircraft they were escorting, were insufficient to reduce losses further. To achieve this, it would be necessary to improve the electronic equipment on board the strike aircraft themselves.

Further improvements were therefore made to RWRs, as the pilots of the strike aircraft needed a warning system capable of evaluating accurately and immediately the nature of the threat, which lay behind intercepted enemy radar emissions. Whenever a pilot penetrated enemy air space, he knew that sooner or later he would be "illuminated" by missile guidance radar; in the stressful circumstances of carrier-borne attack operations the task of interpreting warning lights and strange acoustic signals produced by on board EW devices had to be as rapid and simple as possible. The equipment also had to have maximum reliability, as any failure during combat meant the certain loss of the aircraft.[484]

The Americans, therefore, set about producing a new generation of EW devices, which were a great improvement over their predecessors. In particular, a whole range of more powerful airborne jammers were built, capable of totally jamming all types of enemy radar, and improvements were made to intercept receivers. Superheterodyne analysis receivers used in conjunction with automatic time/threat-visualization correlation circuits proved to be particularly useful.

Over the next few years, US commanders and strategy makers were changed, while the frequency and intensity of Vietcong night assaults and ambushes were stepped-up. US bombing raids on Hanoi and Haiphong by B-52s became more intense, but with equally frequent intervals of suspension.[485]

The Soviets provided North Vietnam with new SAM-2 missile batteries, which featured a new version of the *Fansong* radar (there were at least seven versions altogether). The main difference between the first and the second version was that it operated on a higher frequency, in the 4,910-4,990 and 5,010-5,090 MHz bands, while the first type operated in 2,965-2,990 and 3,025-3,060 MHz bands.[486]

A new type of Soviet ECCM was also introduced which used a highly original and effective new scanning technique in which a "non-scanning" beam was used to illuminate the target, while the reflected signal was received by a scanning antenna which did not itself radiate electromagnetic energy. This ingenious technique, named LORO (Lobe-On-Receive Only), proved extremely effective and showed how far the Soviets had progressed in the field of electronic warfare. Once again, life became more difficult for US pilots in Vietnam. Meanwhile, air raids over Hanoi using B-52 bombers had been stepped up.[487]

The North Vietnamese had also introduced an invention of their own, a simple but effective electronic "trap" for the B-52 bombers. The US aircraft, based on the island on Guam in the middle of the Pacific Ocean, had little choice as to the route they could take to reach Hanoi or Haiphong and so, knowing their route, the North Vietnamese placed simple transmitters along the way to simulate the presence of *Fansong* radars. These would be turned on as US aircraft approached thus inducing the US pilots to launch their anti-radar missiles. This deception worked very well and US pilots frequently expended their whole load of ARMs on the false targets, leaving them vulnerable to attacks by real SAM-2 missiles over the target and on the return journey.[488]

Immediately the American realized the shortcomings of the ECM equipment on their B-52s, particularly the jammers that proved unsuitable for missions carried out at such high altitudes, they set about modifying existing equipment and installing chaff-launching dispensers. However, the North Vietnamese countered this ECM by endowing their own radars with the ability to rapidly change frequency at the first sign of jamming: this ECCM is called "frequency agility".[489]

Nevertheless, losses of B-52s throughout the LINBACKER II operation, the bombing of Hanoi and Haiphong, decreased considerably. In the course of 700 missions, about 1,000 missiles were launched by the strong and sophisticated enemy anti-aircraft defense systems but only fifteen bombers were shot down, showing a loss-rate of 1.5 percent. US Air Force commands have estimated that, if the B-52s had not been fitted with all the most modern electronic warfare equipment, the number of aircraft shot down during these emissions would not have been less than seventy-five. The highs and lows in the loss-rate of fighter-bombers also showed a close correlation with the advent of new arms systems and ECMs.[490]

At this stage, US air power was the only way of exerting pressure on the North Vietnamese government to force them to negotiate and put and end to the fighting. On the ground, the Americans were on the defensive, and the war was already lost from a political of view.

However, 1968 and 1969 were successful years for the North Vietnamese, not only on the ground but also in the air mainly due to massive reinforcement of their anti-aircraft defenses. In one month alone, the Americans lost over ninety aircraft; most of them shot down during air raids over North Vietnam. Increasing numbers of aircraft were sent on such raids, reaching a peak of 400 aircraft on 1 May 1968.[491]

Conclusion

From 1970 onwards, until the end of the war, air losses decreased progressively, mainly due to steps taken to facilitate penetration of enemy defenses. Technological progress led to improvements in airborne EW devices, particularly RWRs in which digital techniques, hybrid microcircuits and special microwave components were incorporated.

In this period, the computer-controlled RWR was produced with the ability to simultaneously and instantaneously analyze the parameters of all intercepted electromagnetic signals.

In 1971, a new aircraft entered service, the Grumman EA-6 Prowler, specially designed for electronic warfare. Besides RWR it was equipped with powerful jammers to jam enemy search radars while the fighters went in to attack enemy anti-aircraft batteries. During these missions, the jamming aircraft had to stay out of range of the missiles themselves and, for this reason; this type of jamming was named Stand-Off Jamming.[492]

Finally, the Americans fitted their aircraft with a piece of equipment belonging to the new generation: the "smart" or deception jammer. This was able to deceive enemy radar by producing a false echo on the radar's screen, giving false information regarding the distance, direction and speed of the real echo. The result was that a missile was guided towards a non-existent target and away from the real one.

In spite of so many new, sophisticated inventions in the field of military technology, the Americans after having been involved directly in that "semi-war" of Vietnam for almost ten years, had to quickly and definitively withdraw from that troubled area of Southeast Asia.

There is no doubt that, during the whole war, the application of ECM led to a decrease in air losses. At the beginning of the war, the loss-rate was 14 percent whilst by the closing stage of the war it had dropped to 1.4 percent. This was not steady decrease, however. Whenever the North Vietnamese came up with weapons controlled by new EW equipment to counter these threats were installed on US aircraft, they began to fall again.[493]

In the conflict between radar and ECM, and between ECM and ECCM, the dynamic nature of electronic warfare is thus clearly demonstrated.

Chapter 19

The Arab-Israeli Wars

The Six-Day War

After the Sinai campaign of 1956, the second in a long series of short wars fought in the Middle East, there followed a fairly long period of calm in that troubled part of the world. During this period, both Arabs and Israelis set about modernizing their armed forces on the basis of what they had learnt from the last conflict.[494]

The Israelis received a number of Hawk ground-to-air missiles from the United States and Centurion tanks from Great Britain. France supplied them with Dassault-Breguet Mirage III and Super Mystere jet fighters, which greatly improved the quality of the Israeli air force (Chel Ha' Avir). The Israelis were now in possession of a highly efficient air force, equipped with excellent aircraft and helicopters.[495]

Meanwhile, Russia was supplying Egypt with a various number of weapons, such as MiG-21 fighters and Tupolev Tu-16 bombers.[496]

In the first few months of 1967, relationships between Israel and neighboring Arab countries began to deteriorate following a series of incidents along their borders. In the spring of that year, Egypt asked the United Nations to withdraw neutral forces which had served as buffer in the Sinai peninsula and sent 100,000 of her own troops and about 1,000 tanks into the area. Tension reached a climax when the Egyptian President Nasser, closed the Straits of Tiran, thus preventing Israeli ships from reaching the Red Sea from the Gulf of Aqaba. Israel immediately mobilized her troops in readiness for strategic action, which would have to be in the form of a lightning attack. The reasons for this operational necessity were not only that international intervention would put an end to hostilities as soon as it became apparent that Israel was winning but also because nationwide mobilization would soon lead to the economic paralysis of the country.[497]

The Arab nations (Egypt, Syria, Iraq and Jordan) deployed nearly a quarter of million soldiers, 700 combat aircraft and over 2,000 tanks along their borders with Israel, ready to attack to attack the enemy from all sides. [498]

The whole world waited with bated breath, wondering whether they were on the brink of a third world war. The various electronic information-gathering systems of the major world powers were all focused onto the situation in the Middle East.

The ships of the Soviet fleet in the Mediterranean, particularly those specially adapted for electronic espionage, were constantly tuned in to all frequencies of the electromagnetic spectrum to keep an eye on the delicate situation.[499]

The US Sixth Fleet was cruising in the eastern watres of the Mediterranean and special aircraft equipped with the most advanced electronic devices kept the area of Israel, Sinai and practically the whole Middle East area under constant surveillance. The US Navy SIGINT ship USS *Liberty* was on continuous patrol off the coast of the Middle East, just outside territorial waters. She was equipped with highly sensitive electronic equipment, which could intercept and decipher all radio communications transmitted by both Arabs and Israelis and intercept and analyze all their radar emissions. The British were also keeping a close eye on the situation from their vantage point of Mount Trudos in Cyprus.[500]

Naturally, all Egyptian radar stations were on constant alert; there were twenty-three altogether, sixteen of which were situated in the Sinai Peninsula. All air space and coastline surrounding. Egypt was covered by their early warning radar systems. The Israelis were also continuous radio and radar alert.[501]

The Six-Day War broke out on 5 June 1967; this day also marked the beginning of a series of electronic challenges, which was to continue for many years. At exactly 07.45, the Israelis launched surprise attack intended to ensure their total air superiority, which would in turn enable them to achieve their other objectives. Their very elaborate and precise plan of action was to attack enemy airbases and destroy all the enemy's combat aircraft whilst they were still on the ground. The *sine qua non* for the success of this action was that surprise and that all his communications take the enemy and surveillance systems are paralyzed. On order not to arouse the slightest suspicion of the imminent attack, the Israelis had also drawn up elaborate plans to deceive the enemy. Regular morning training flights were carried out as usual, the attack being scheduled for 07.45 when the Egyptian pilots, having been on the alert from dawn to 07.30–the period in which attacks are normally launched and wars normally break out–would be going to have breakfast in the airbase canteens and staff officers would be going to their offices.[502]

Previous aerial reconnaissance flights had shown the exact deployment of enemy air squadrons and radar stations, radar coverage and blind spots; the Israelis had even managed to plot a route through the towers and minarets of Cairo whereby, flying at such a low altitude, they would be masked from enemy radar and could launch a surprise attack on the West Cairo airbase which housed not only the MiG-21s used for defense of the capital city but also the huge Tu-16 bombers which would be used for air raids on Tel Aviv. By skilful interpretation of reconnaissance photographs, the Israelis had managed to distinguish the real aircraft from the dummy aircraft, which the Egyptians had set up to deceive enemy pilots.[503]

Instead of flying directly towards their targets, the first wave of Israeli aircraft flew out to sea off the Egyptian coast, swung round and, flying low just above the water, approached from the West, exactly the opposite direction to which the Egyptians would expect them.[504]

The attack took place at exactly 07.45 as scheduled. At that time, every Egyptian aircraft was on the ground except one, a twin-engined Ilyushin that was flying towards the Israeli border with three of the highest-ranking officers of the Egyptian armed forces on board. One of them was the Chief of Defense Staff, General Amer. They were listening in on communications transmitted on the frequency used by Israeli pilots during their normal flights but nothing unusual had been intercepted on that frequency. Suddenly, the control tower of an Egyptian military airbase communicated to the generals that the base was under enemy air attack. It was exactly 07.45; the Ilyushin turned back immediately and, while they were heading back to base, the generals radioed to ground commands to try find out what was happening, but all they could hear was a babble of voices and other noises. Every time they tried to land somewhere, they realized from the few clear words they managed to pick up that the base was under attack. They tried several times to land at one of the many Egyptian air bases on the Sues Canal but they were all under attack and their runways had been put of action. Finally, the Ilyushin managed to land at Cairo International Airport and the three generals rushed to high command headquarters where they were informed that practically the entire Egyptian air force had been wiped out.[505]

Given the limited number of aircraft at their disposal and the fact that the distance they had to cover was fairly short, the Israelis were able to send each aircraft out several times, thus multiplying the number of missions that could be accomplished. After the initial attack, which came as a complete surprise to the Egyptians because their radar and radio communications had been blanked out, the Israeli aircraft returned to base to be re-fueled and re-armed and were then sent out again with new pilots. After having destroyed

300 of the Egyptian air force's 320 aircraft, the Israelis immediately went on to destroy the air forces of the other Arab states bordering Israel. In quick succession, the Jordanian, Iraqi and Syrian air forces were wiped out.[506]

In less than two days and with a fairly small number of aircraft at their disposal, the Israeli air force flew about 1,100 missions with many pilots flying eight to ten missions a day.[507]

Now that they had gained absolute air superiority,[508] the Israeli air force could be committed to tactical air support for ground forces. The Egyptian expeditionary corps in the Sinai, made up of 100,000 men, was completely overrun by Israeli armored columns and fell back in disarray, abandoning many brand new weapons systems, including tanks and electronic equipment only recently received from Russia.[509]

The Egyptian President Nasser, could not believe that the Israelis had achieved such outstanding results in such a short time without outside help. Arguing that it was impossible for such a small air force to accomplish so many missions, he tried to convince his ally King Hussein of Jordan that aircraft had helped the Israelis from the United States and Great Britain. However, the Israelis, who had been systematically intercepting all enemy electromagnetic emissions, made public their recording of a radiotelephone conversation, which they held had taken place at 04.45 on 6 June between President Nasser and King Hussein. From this conversation, it was quite clear even to the Russians that the two Arab leaders were plotting to spread the rumor that the USA and Great Britain had participated in the Israeli attacks. As a result of the interception of this conversation, international tension was diffused and the prospect of a war involving major world powers was avoided.[510]

On the afternoon of 8 June the US Navy spy-ship two Israeli Mirage fighters and three gunboats near El Arish attacked *Liberty*. The unfortunate ship was badly damaged and thirty-four of the crew were killed and seventy-five injured. The US government accepted Israeli explanations and apologies, although it was not really clear how the Israelis could have mistaken a spy-ship for a destroyer. Lt. James Ennes, electronics officer abroad USS *Liberty*, stated that the attack had been too well coordinated to be a mistake. On the other hand, the US Department of State's explanation of what the spy-ship was doing near Egyptian territorial waters was not very clear either. The ship was said to be there to "ensure" communications between American listening posts in the Middle East.[511]

The truth of the matter is that USS *Liberty* and similar Soviet SIGINT ships were stationed in the area to intercept and record radio communications and radar emissions and retransmit them to their respective governments, both of which were keen to keep an eye on developments in that explosive part of the world.

How had the Israelis managed to destroy the whole Egyptian air force in the space of two hours, giving the Egyptians no time to react?

For obvious reasons of secrecy, the Israelis have never revealed their electronic plan of action. Nevertheless, considering the twenty-three Egyptian radar stations and numerous US and Soviet spy-ships in the area, it is difficult to accept that all the operators were asleep at the time of the attack. It is also difficult to accept that no orders were given to Egyptian pilots before and after each air raid.

The explanation lies in the fact, in 1967, ECM was for the Israelis more than a mere memory of actions taken by the British during World War II, when they transmitted false information, distorted signals used to guide enemy bombers and jammed enemy radars. The Vietnam War had been going on for some years and the Israelis knew that the Americans had resorted to electronic jammers to deal with Soviet SAM-2 missiles and radar-controlled 57 mm anti-aircraft guns.

The Israelis against Egyptian radar took no electronic warfare action until 07.45 on 5 June, because the surprise element was essential for the success of the operation and, therefore, the Israelis could not risk arousing the enemy's suspicions. At 07.45, the most far-off radars were attacked and put out of action while those within range of Israeli electronic equipment were subjected to jamming. Moreover, during and after the initial attack, Israeli radio operators who spoke fluent Egyptian Arabic transmitted into the enemy air defense radio communications network, giving false orders, canceling correct orders and generally causing confusion and preventing Egyptian commands from using the radio. The Israelis also jammed Russian and American radar and radio communications, in some cases.[512]

The War of Attrition

The Israelis naturally expected that their victory in the lightning Six-Day War would ensure a long period of peace and allow them to negotiate a lasting peace from a more favorable position.

The conviction was supported by all the results of their short but successful campaign: the entire Egyptian war machine had been destroyed, Jordan had lost most of its army and some of its territory and Syria, too had lost important military positions, such as the Golan Heights. Most important of all, the Israelis now occupied the Sinai Peninsula, which would be a comforting buffer zone between themselves and a belligerent Egypt. Here they could set up a network of warning radars and other sensitive electronic systems to maintain surveillance of the hostile region, something they had wanted for a long time.[513]

However, this ideal state of affairs was not to be. The end of the Six-Day War marked the beginning of a long series of military actions by both sides–the so called "War of Attrition"–made possible by the increasingly sophisticated electronic warfare equipment possessed by both sides.

The Soviet, fearing that the Suez Canal might fall into Israeli hands, quickly replenished the depleted Egyptian war machine by supplying aircraft, tanks and modern artillery to discourage any attempt by the Israelis to cross the Canal. Only two weeks after their defeat, the Egyptians received from Russian 200 aircraft, mainly MiG-21s and Sukhoi Su-7s, modern T-55 tanks and a number of radar-controlled anti-aircraft guns. Egypt thus replaced 70 percent of her losses and now possessed weapons of much higher quality than before the war.[514]

Since, during the Six-Day War, most Egyptian aircraft had been destroyed on the ground, very few pilots had been lost and so the Egyptian air force was able to send many of them on training courses in Russia without unduly depleting their operational force.

For the Israelis the loss of forty aircraft in combat was a major blow considering the limited size of their air force. For political reasons, Israel's usual supplier, France, had placed on embargo on the delivery of a further fifty Mirages and the United States was reluctant to supply the A-4 Skyhawk fighter-bombers that they had promised.[515]

Peace negotiations were shelved as the Egyptians continued to pile up new weapons. Egypt refused to accept the new territorial situation, in favor of the Israelis, and began sporadic bombing of Israeli positions along the East bank of the Suez Canal.[516]

On 21 October, a few months after the Six-Day War, an incident took place which greatly boosted Egyptian morale: the 1710-ton Israeli destroyer *Eilat*, the ex-British World War II *Zealous*, was hit and sunk by missiles launched from two Egyptian torpedo-boats anchored in Port Said. Of the 202 men on board the Eilat, forty-seven were killed and ninety-one were injured. The incident caused great consternation because it was the first time that a warship had been sunk by missiles and also because there was little in common between the two versions of what had actually happened.[517]

According to the Israelis, the *Eilat* had been at a distance of 14 miles from Port Said, 2 miles outside Egyptian territorial waters, when she had been hit by two Styx missiles launched from Soviet-built "Komar" class patrol boats. The Soviet-built missiles had radar-guidance to a range of 25-30 miles and an explosive charge of 880 pounds. On being hit, the Israeli ship had keeled over but had not gone down. Two hours later the Egyptians, seeing that the ship was still afloat, launched another two Styx missiles, one of which sent the ship down while the other exploded in the water, killing or injuring many crew members.[518]

According to the Egyptians the *Eilat* had been at a distance of only 10 miles from Port Said within Egyptian territorial waters. Only two missiles had been launched but these had been sufficient to sink the Israeli ship immediately. The Egyptians also denied allegations that they had Soviet advisors on board their patrol boats.[519]

Whatever the case, the sinking of the *Eilat* was great victory for the Egyptians, strengthening their faith in their armed forces and their determination not to discuss peace with Israel.

From a more objective point of view the sinking of that destroyer by missiles launched from small patrol boats had a strong effect on naval thinking and marked the beginning of many changes in the design of warships and their weaponry, not to mention the tactics governing their use. This incident was a rude awakening for all the world's major navies, forcing them to realize that even their largest warships were practically defenseless against this new threat from missiles which had a greater range than naval guns and, moreover, could be launched from small fast boats like torpedo-boats or patrol boats. But what caused the greatest consternation among major navies of the West was the fact that Russian has supplied several minor navies, some from communist bloc countries, not only with "Komar" class fast attack boats but also with a number of larger "OSA"–Class boats which could launch more missiles than "Komar" class vessels.[520]

Israel's response to the sinking of the Eilat was quick and violent: on the afternoon of 24 October, the Israelis first bombed the city and port of Suez and then attacked two large petroleum refineries, situated in the coastal zone, which produced about five million tons of fuel annually. Israeli aircraft also attacked the base in the port of Alexandria where "OSA" and "Komar" missile boats were anchored.[521]

After these attacks, the banks of Suez Canal became the scenes of frequent fighting with daily artillery duels, commando raids, air battles and bombing attacks, particularly by the Israelis who had local air superiority.[522]

Not having fire-control radar, Egyptian anti-aircraft artillery was unable to cope with Israeli air raids. To redress the balance, at the end of 1968, the Russians decided to provide Egypt with SAM-2 missile systems; these had made their first appearance in 1965 in Vietnam and had been used towards the end of Six-Day War on the Syrian Front. They were deployed in a 16-mile wide strip along the West Bank of the Suez Canal. However, as in Vietnam, the SAM-2 system did not have great success due to intrinsic limitations. Beside these shortcomings, two other defects were revealed in the war theater of the Suez Canal: the first was the limited mobility of the system, which had to be towed on a trailer and required time to set up before going into action; the second was that the radar-guidance system only worked above 6,000 meters and was therefore ineffective against low flying aircraft.[523]

Like American pilots in Vietnam, the Israelis had also learnt to recognize the famous "SAM-song", the characteristics sound of the SAM-2 radar pulses, which meant that a missile was heading towards their aircraft. It would seem that the Israelis had captured a SAM-2 system 1967 during the last phase of the war fought in the Golan Heights in Syria; there is certainly no doubt that they knew its precise operating frequencies since they had already devised appropriate jammers which could only have been done on the basis of such knowledge.

Thus an "undeclared" war had broken out in the Middle East, an electronic war fought "by proxy" since neither Egypt nor Israel had an industry capable of producing such technologically advanced electronic systems as were necessary and, therefore, used equipment supplied by the Soviet Union and Western powers respectively.

In order to devise ECMs to counter radar guided missiles effectively, it is first necessary to know the precise characteristics of the radar used. Therefore, in 1969, both the Israelis and the Egyptians started to make raids on enemy territory whose aims were to capture radar sets in which they were interested, or, at least, one of the set's main components, often enough to yield the information sought.[524]

In June 1969, the Egyptians made three raids in which they managed to destroy several Israeli radar installations. In the same month, the Israelis also made a raid in an area about 6 miles south of Suez in which they claimed to have destroyed an enemy radar installation. Again in June, the Israelis announced that they had captured an Egyptian coast guard boat in the Gulf of Suez. In July, an Israeli Commando attacked a fortification on Green Island in the northern part of the Gulf of Suez. The tower where the radar was installed was surrounded by high walls, which the Israelis scaled and, after killing the guards, removed the desired parts of the radar and destroyed the rest. The whole operation took about one hour.[525]

On 9 September, the Israelis organized a full-scale military operation on the south coast of Egypt. At dawn, a small convoy of gun-boats and landing craft carrying six tanks and three armored cars set sail from somewhere on the Sinai coast and headed for the south coast of Egypt. The vehicles were all Soviet-built and had all been captured during the Six-Day War and still bore makings, which showed they belonged to the Egyptian Army. The 150 Israelis on board wore Egyptian uniforms and spoke perfect Arabic. Just after daybreak, the disguised Israeli commandos landed about 30 miles south of Suez and, headed straight for the radar installations near El Khafayer undetected, which they quickly dismantled. They then landed south along the coast road where they were joined by air and naval escorts, which helped them to destroy all enemy military installations along the route.[526]

Radar installations near Ras Darg were the first to be destroyed followed by those near the small port of Ras Zofarana, about 56 miles south of Suez; they captured some new Soviet-built armored vehicles which they took back to Israel, along with all the captured electronic equipment, for further examination.[527]

The most significant episode, from an electronic point of view was the Israeli capture of complete P-12 *Spoon Rest* radar set from the Egyptian naval base of Ras Ghaleb on the Red Sea in a raid which took place on 27 December 1969. The Soviet-built radar had recently been installed at Ras Ghaleb to complete Egyptian early warning radar coverage. With a range of 270 kms it was able to detect an aircraft taking off from any Israeli airbase on the other side of the Suez Canal and track it until it was within range of Fansong SAM-2 radar. The two radars, *Spoon Rest* and *Fansong*, worked in conjunction; at a certain point, the aircraft would be turned over to the Fansong radar which would guide a missile towards it.[528]

The *Spoon Rest* radar weighed seven tons and needed two large trucks to move it. The Israelis knew practically nothing about its electronic characteristics and so, if they wanted to devise effective ECM, they had no alternative but to capture a set and examine it. This was the purpose of the commando raid at Ras Ghaleb, about 115 miles south of Suez.[529]

To distract attention from this operation, an air raid on the Egyptian side of the Canal was scheduled to take place at the same time. After landing, the Israeli commando skirted the radar installation and, going via the desert, came in for attack from the landward side. After they had occupied the base, two large helicopters were flown in to pick up the radar and take it back to Israel.[530]

Having an actual example of the enemy radar set in their possession greatly facilitated the Israeli's task of devising ECMs to jam or deceive radars of the type. They were able to discover the exact operating frequency and other important features, including ECCMs incorporated into the set to protect it from enemy ECMs.

Israel was not alone in its anxiety to find ECMs capable of impairing the effectiveness of the *Spoon Rest* radar. The countries of the NATO alliance were also very interested and interested and it was not long before Western electronics experts came up with appropriate devices for jamming and deception.

Towards the end of 1969 the Israelis again hit the newspaper headlines by removing five 250-ton fast patrol boats from France. These were the last of twelve boats ordered by Israel before the embargo decreed by President de Gaulle. The five vessels were being held at the port of Cherbourg with a limited number of crew members on board each. On Christmas night, taking advantage of laxer security during the festivities, the vessels slid out of port and, once out to sea, the Israeli crews made full speed ahead to their homeland, arriving on New Year's Eve at Haifa where a joyous crowd eagerly greeted them. The five gunboats, like the other seven already in Israel, were equipped with surface-to-surface Gabriel missiles built in Israel as well as with active ECM equipment.[531]

Meanwhile, the undeclared "war of attrition" along the banks of the Suez Canal was becoming more and more intense, each commando raid being followed by a reprisal from the other side. Israeli aircraft began to be used as flying artillery against SAM-2 missile ranges along the banks of the Canal. Many Egyptian missile systems were hit but many Israeli aircraft were brought down.

Assistance for the Israelis soon arrived from the United States, which supplied McDonnell Douglas F-4 Phantoms. The F-4 had played a leading role in air battles over Vietnam. They were excellent in the role of interceptor but were equally suited to providing tactical close air support for ground forces and making ground attacks. But perhaps the most important thing was that, along with the F-4 Phantoms, the Israelis received electronic warfare equipment, housed in special pods fitted externally to the aircraft.[532]

Pods containing RWR were also installed on the A-4 Skyhawk light tactical fighters; the pods also housed new jammers capable of totally blanking out *Spoon Rest* radars, based on the research done on the Spoon Rest captured some months before. These new jammers, and other devices capable of surveying the electronic situation in the entire Suez area, were also installed on several modified Boeing B-47 Stratocruisers. The B-47 had been one of the first aircraft to be dedicated exclusively to electronic warfare. These aircraft proved to be of great value to the Israelis. At high altitudes and, for obvious reasons of security, far away from enemy lines, they flew parallel to the Suez Canal and the Syrian border and were able to monitor enemy air activity and, when necessary, paralyze their air defense radars.[533]

In the first three to four months of 1970, Israeli aircraft, protected by this electronic shield, were able to penetrate more deeply into enemy territory. Their first target was the enemy radar network along the Canal; next, it was the turn of the inland air defenses comprising the search and fire control radars deployed around the Egyptian capital, the Aswan Dam and other important installations.[534]

The Egyptians retaliated with repeated artillery shelling along the Canal and air raids, using MiG-21s, which penetrated deeper into Israeli territory. However, these were not successful as the Israeli air raids, which reached Cairo and beyond, headless of SAM-2 missiles, thanks to their new EW equipment.[535]

Egypt asked the Soviet Union for more effective arms and equipment to deal with Israeli air offensive. In the spring of 1970, the Soviet duly furnished Egypt with SAM-3 missile systems, NATO code-name *Goa*. The SAM-3 had a range of 34 kms much greater mobility than SAM-2, being mounted on ordinary vehicles and was also effective against low flying aircraft (300-45,000 feet). Each SAM-3 system had four missile-launchers, which worked in conjunction with two radars; a search radar (NATO code name, *flat Face*) and an acquisition radar (NATO code-name, *Long Track*). The former had the task of detecting the intruders while the latter tracked intruders once acquired and tracked them with sufficient accuracy to enable missiles to be launched at them.[536]

USSR also delivered a new version of the MiG-21, the MiG-21J which was equipped with a new, more sophisticated type of radar and, compared to earlier models, had a superior endurance enabling it to operate deep into Israeli territory.[537]

Ever increasing numbers of Soviet technicians, instructors and pilots accompanied the new equipment, and after a few months the Soviets assumed control of Egyptian air defense organization. The Israelis soon realized, through their recordings of Egyptian flight communications, that many MiG-21Js were flown by Russians and wondered with some consternation what would happen if one of them were shot down, an event which was sooner or later bound to happen.[538]

The employment of Soviet pilots, although limited to the Cairo zone and other important inland locations, greatly helped the Egyptian air force, freeing the Egyptian pilots to concentrate on offensive actions and reprisal raids against Israel. Both sides suffered heavy losses in the frequent air battles over the Suez Canal although reports about them seldom tallied. Meanwhile, both sides continued to receive new, sophisticated arms and electronic equipment from the Great Powers who seemed to think the Middle East was one huge missile range where they could try out their new weapons systems under real tactical conditions.

The Israelis received an electronic apparatus, which can be considered the most secret of all electronic warfare equipment: a deception jammer. This is an electronic device capable of falsifying data regarding distance and speed, which enemy missile-guidance or fire control radar is trying to acquire. If a missile is heading towards a target (land, air or sea) equipped with a deception jammer, signals are produced in the missile-guidance radar by the deception jammer, which show the target in a different position to its actual position. Thus the missile, instead of continuing on course towards the real target, is sent off course by this misleading information.[539]

The remarkable advantage of this process is that the enemy radar does not become aware of the deception because the return echo from the target is always exactly what is expected. This possible because the distance of a target is calculated by measuring the time-lapse between the transmission of an electromagnetic pulse and its return echo. When the deception jammer-equipped target aircraft or ship is illuminated by the enemy radar, it is sufficient to simply delay the return echo or modify its width in order for a wrong distance or direction to be shown on the enemy radar screen.[540]

Deception jammers are quite small and can easily be installed on aircraft, either internally or externally in pods attached to the same hard points as those used for bombs or external fuel tanks. From an industrial point of view, the manufacture of a deception jammer requires very sophisticated technical capacity and an extremely advanced technology, which is not easy to acquire.

The arrival of these new electronic gadgets was a real morale booster for the Israeli forces and General Moshe Dayan predicted a hot "electronic summer", which promptly arrived.[541] In June 1970, a dramatic duel between Israeli aircraft and Egyptian missiles began which resulted in the destruction of nearly all SAM-2 systems in Egypt. At this point, the Egyptian air force received the first of the eagerly-awaited Soviet MiG-23s: these ultra-modern, multi-role "swing-wing"(variable-geometry) fighters, given the NATO code-name *Flogger*, were equally adept at interception, ground-attack an reconnaissance and were well-equipped with new radar-controlled missiles for air combat. Being faster than the Israeli F-4 Phantoms and A-4 Skyhawks, their appearance in the skies of Egypt produced a notable slackening in the pace of Israeli air raids.[542]

Above all, the introduction of the MiG-23 meant that Israeli reconnaissance flight had to be reduced since the aircraft used for this purpose were unarmed and, therefore, extremely vulnerable. The Israelis were deprived of the information, which is indispensable in modern warfare. To overcome this problem, they resorted to US built Teledyne Ryan 124-1 RPVs, which carried only electronic or photographic equipment and were controlled from the ground.[543]

During Israeli air raids over Egypt, there seemed to be a tacit understanding between Israeli and Soviet pilots to avoid direct conflict at all costs. This lasted until 25 July 1970 when two Soviet-piloted MiGs suddenly and quite deliberately attacked on Israeli A-4 Skyhawk, which, however, managed to get away. After this encounter, the Israelis had no option but to abandon all precautions. Thus, on 30 July, when a squadron of Israeli Phantoms was intercepted and attacked by sixteen Soviet-piloted MiGs, Israeli

Mirage fighters came to the rescue and, after a few minutes of fierce combat, five MiGs had been shot down. The Israelis also suffered losses, albeit undeclared: theer Phantoms did not return to base that day and were probably shot down by Egyptian anti-aircraft artillery on their way home.[544]

By now both the Egyptians and the Israelis, who were fighting a sort of "proxy" war for the two superpowers, realized that this war was no longer worth fighting because they risked provoking a general war which neither side desired at that particular moment. Consequently, on 7 August 1970, they accepted without too much argument a cease-fire proposed by the USA that put an end to almost three years of inconclusive and bloody fighting. Both sides suffered heavy losses, although these were officially either not admitted or minimized for propaganda reasons: it is, therefore, difficult to give exact figures but it can be reasonably estimated that the Israelis incurred casualties of no less than 400 dead and about 4,000 injured while the Arabs suffered casualties of about 1,500 dead with about 7,000 injured. Estimates of air losses are probably more accurate as there was some agreement between different sources: about 105 Egyptian and sixteen Israeli aircraft were shot down, of which only seven were brought down by missiles.[545]

This great discrepancy in favor of the Israelis can be largely attributed to the EW equipment installed on board their aircraft, which in the duels between missiles and aircraft saved the lives of many Israelis pilots.

The October 1973 War

On 6 October 1973, the Jewish Day of Atonement or Yom Kippur, the Egyptians made a surprise attack of unprecedented violence while almost the entire population of Israel was celebrating. At 14.00 hours, 200 Egyptian aircraft began to attack Israeli defenses and airbases in the Sinai while about 4,000 guns of various calipers began a massive barrage of the Bar-Lev defense line and other important installations on the Suez Canal.[546]

The Egyptians then started jamming Israeli radio communications, making it impossible for the Israelis to exchange battle orders. In addition, special teams of Egyptian scuba divers destroyed some Israeli radio and radar stations along the Canal.[547]

On the Syrian Front, Soviet-built Sukhoi aircraft of the Syrian air force swooped down on the Golan Heights and destroyed nearly all-Israeli defense installations in that area.[548]

A few minutes later an avalanche of 800 Russian-built Egyptian tanks swept across the Suez Canal, crossing it at many points by mobile pontoon bridges which had been set up in record time. The Israelis were caught completely off-guard and, since many troops had been given home leave for the holiday, defenses were greatly reduced. The Bar-Lev defense line was completely overwhelmed by the mass of tanks advancing across the Canal. Israeli napalm defenses, which should have set fire to the whole Canal zone, had been carefully disconnected by Egyptian scuba divers that had worked undetected for several nights before the attack.[549]

After a few hours of total confusion, the Israeli high command managed to rapidly sketch together a defense plan. The air force reacted first, sending Phantoms and Skyhawks to attack. The Israelis were confident of the superiority of these aircraft; mainly because the sophisticated EW equipment they carried on board had already demonstrated their superiority in battle with the enemy. However, their confrontation with the advancing Egyptian armored columns was nothing less than a disaster. The Israeli pilots did not hear the usual "SAM-song" and could therefore do nothing to avoid enemy missiles. In the first two to three days of the war a great number of Israeli aircraft were shot down.[550]

Obviously something had changed in the electromagnetic spectrum, as the electronic devices installed on Israeli aircraft were no longer effective. A first appraisal of the situation showed that the radars used to guide Egyptian missiles and gunfire were operating on a higher frequency and using more sophisticated guidance techniques than the SAM-2 and SAM-3 missile systems.

The Israeli pilots who survived that veritable massacre of Phantoms and Skyhawks reported that the advancing enemy columns were protected by an extremely effective and varied mobile anti-aircraft defense. First of all, there was a screen of ultra-modern SAM-6 *Gainful* missile systems mounted on armored vehicles; next, came the four barrel 23 mm radar-controlled ZSU-23-4 *Shilka* anti-aircraft guns mounted on tank-chassis; finally, there were the light man-portable, shoulder launched SAM-7 *Strela* infrared missiles, for low–level AA defense. Together these formed an almost impenetrable air defense ring, a mobile umbrella under which the armored tanks could advance in safety, sheltered from air attacks.[551]

The real strength of this system lay, not in its firepower or other factors of that nature, but solely in its weapon-guiding systems, which constituted a great technological surprise not only for the Israelis but also for all the Western powers.

The SAM-6 system, whose main task was to provide anti-aircraft defense for field forces, comprised two tracked vehicles, one of which carried three *Gainful* missiles and the other the radar, code-named *Straight Flush* by NATO. The novelty of the system was that it used continuous waves (CW), unlike the SAM-2 and SAM-3 systems, which used pulse waves. A target was illuminated by a low-power CW signal emitted by the *Straight Flush* radar, and the SAM-6 missile would home on to it by following the reflected energy. Since the receivers on board Israeli aircraft were designed to intercept pulsed signals, these CW emissions were not picked up. To make things even more difficult, the

Straight Flush radar operated on two different frequencies. Thus, as a result of these two technological innovations, the *Guideline* missile could now approach the enemy aircraft without being discovered jammed or deceived by the Israeli electronic devices.[552]

Another technological surprise was the *Gun Dish* radar used to control the mobile 23 mobile 23 mm ZSU-23-4 *Shilka* AA guns. To avoid enemy ECM, this radar used a much higher frequency than any previously used by the Egyptians. The Israeli receivers, which were built to intercept frequencies of up to 12,000 MHz (12 GHz), were unable to reach the electromagnetic emissions of the *Gun Dish* radar, which had a frequency of about 16,000 MHz (16GHz).[553]

Another innovation was the small *Strela* anti-aircraft missile that a soldier could carry on his back. This had a completely new kind of guidance-system, using infrared (IR) rays.[554] All the soldiers had to do was aim the missile in the direction of a low-flying enemy aircraft. The missile's infrared detector would detect their heat emissions from the aircraft's jet engines, passing signals giving range and bearing to the control and guidance system, which would guide the missile onto the target. Such a missile guidance system is termed IR-homing.[555]

These new weapons systems, together with those already in existence (SAM-2 and SAM-3), constituted a truly exceptional air defense system, permitting the Egyptians to advance even though their air force had not achieved air superiority. Israeli aircraft, committed to battle in support of their ground forces, by attacking enemy armored columns, found that there was no way to avoid that network of fire; if they dived to low altitude to avoid SAMs, they inevitably flew straight into vicious flak from the rapid-firing *Shilka* guns, or became targets for small *Strela* missiles. Israeli air losses were so high that ground commands decided no longer to request air support against enemy armored columns.[556]

The situation was hourly becoming more critical for the Israelis on both fronts as, in addition to the huge number of aircraft lost during the first days of the war their tanks had also been massacred, easy targets for the new Russian-built *Sagger* anti-tank missiles. Launched by infantry at close range, these wire-guided missiles were extremely accurate.[557]

Having by now realized that their nation was in serious danger of being overrun, the Israeli high command had to make the extremely important decision as to which front would be given defense priority. They judged the greater danger to be on the Northern front and, therefore, decided to concentrate on blocking the Syrian advance while trying to fend off Egyptian attacks in the Canal Zone. The only hope for the air force, however, taken completely by surprise from the EW point of view, was to try as quickly as possible to come up with effective electronic and infrared countermeasures, and thus reduce the absolutely unacceptable loss rate.[558]

In those very first, dramatic days of the war help arrived for the Israeli air force in the form of large quantities of chaff and chaff dispensers. Chaff was, nothing new, of course having been used extensively in World War II and Vietnam. The only alternations to the system were the adjustment of the length of individual strips to the frequencies of the new radars to be jammed. The chaff was contained in capsules in turn contained in pods attached to an aircraft, and was launched on command from an aircraft's pilot.[559]

Besides chaff, the Israelis also received IR flares to deceive IR-guided missiles. These were used in the same way as chaff except that the flares generated heat, or IR energy. To achieve the purpose for which they were intended, the energy released had to be of the same frequency as that generated by the jet pipes of the aircraft's engine, but, obviously, had to be much more intense in order to create a false target towards which the SAM-7 missile could be guided.[560]

As soon as the chaff and IR-flare-launchers had been installed on Phantoms and Skyhawks, the Israelis were able to devise tactics which would allow their pilots to penetrate that ring of fire which the Arabs had set up with some chance of successfully accomplishing their mission and surviving. Most of these tactics involved attacking the enemy missile system directly. A very risky but effective attack maneuver developed for a single-aircraft attack on a SAM-6 system took advantage of the SAM-6's poor low elevation capability and the slow speed at which it could be elevated. The aircraft flew towards the launching vehicle at an extremely low altitude to avoid detection by the system's anti-aircraft radar, hiding in the false echoes produced by ground reflection "ground clutter". Once he had passed the target, the pilot had to pull up sharply into an almost vertical climb, and then immediately dive at the target, launching his missiles or bombs at the right moment. During this dive and his subsequent escape, the pilot, still at an extremely low altitude, had to launch first chaff to deal with any SAM-6 missiles which might be launched against his aircraft and then carry out further evasive maneuvers to avoid SAM-7 IR-guided missiles. The simplest of such maneuvers was to launch flares and then turn towards the missile so that the jet tailpipe, the hottest part of the aircraft, would be pointing away from the missile.[561]

Even more complicated techniques were used. One involved two aircraft flying side by side which, as soon as they realized that an IR-guided missile had been launched (or were informed of the fact via radio by helicopters patrolling the area), carried out a maneuver which involved one of them intersecting its own previous flight path, thus creating a zone of intense heat which, being IR energy, attracted the SAM-7 missile.[562]

Another very effective tactic exploited the limited rate and range tracking ability of the SAM-6 system. A Phantom and a Skyhawk would approach at a high altitude, one behind the other: the first aircraft, the Phantom, would launch a large quantity of IR-flares and chaff to jam enemy radars and guidance-systems thus enabling the Skyhawk to dive on the target and release its bombs or missiles with a good chance of success and survival.[563]

All these tactics relied upon drastic, almost desperate, maneuvers that the missile's guidance-system was unable to follow; such aerobatics demanded excellent reflexes and coordination of the pilots.

Later, the aircraft were equipped with new RWR in pods capable of intercepting the very high frequency electromagnetic emissions emanating from the SAM-6 batteries and the *Shilka* AAA batteries' fire-control radar.[564]

With these new systems, the Israelis not only reduced their aircraft loss-rate considerably but also managed to destroy forty out of a total of sixty missile systems. Having regained air superiority, previously held by the Egyptian and Syrian anti-aircraft missile systems, the Israeli air force was once again able to provide tactical air support for their ground forces, not only defensively to block the advancing Arab forces but also offensively during the famous Operation "Gazelle" in which the Israelis crossed the Suez Canal and penetrated deep into Egyptian territory.[565]

At the close of hostilities, the final toll was 102 Israeli aircraft lost, a high figure considering the size of the Israeli air force; most of these had been shot down by the new weapons systems which had taken the Israelis by surprise, finding them without effective electronic and infrared countermeasures.[566]

The results of Arab-Israeli sea warfare were, however, quite different. We have already seen how, during the Six-Day War, the Israeli destroyer *Eilat* being equipped with neither RWR nor ESM (Electronic Support Measures, without which ECMs could not be carried out) nor chaff, nor other jamming equipment, had been sunk by Soviet-built Egyptian fast patrol boats launching a salvo of Soviet-built *Styx* missiles against the unfortunate ship without even leaving port. After this disaster, it was decided to update and improve the Israeli navy. The first step was to start construction of a new class of warship, the "Reshef" class of Fast Attack Craft. These displaced 410 tons and were armed with launchers for locally made Gabriel missiles.[567]

On the other side, the Egyptian and Syrian Navies had a large number of Soviet-built "Komar" and "OSA" class vessels all equipped with *Styx* missiles, which, until then, had never once failed to hit their targets. They had proved their worth in the1971 Indo-Pakistan War when, between 4 and 8 December, numerous Pakistani warships in the area of Karachi, as well as three merchant ships anchored in the port itself, had been sunk by Styx missiles launched from Indian "Komar" and "OSA" class boats.[568]

The Israeli Gabriel Missile was more accurate than the Styx but its range was decidedly inferior, by a ratio of 2:5. In practical terms, this meant that an Israeli "Reshef" or "Sear" class boat carrying *Gabriel* missiles would have to penetrate a danger zone of 20-30 kms, in which it would be within range of enemy *Styx* missiles, before it could launch its own. It was, therefore, imperative to find a workable tactic for combating enemy naval squadrons armed with *Styx* missiles. The search for such a tactic became the prime concern of the Israeli navy.[569]

Experience had shown that the problem could not be solved by traditional defense systems, which had proved themselves to be impotent in the face of these anti-ship missiles. The Israelis soon recognized completely new was required and that the solution lay in the field of ECM.

Consequently, they equipped all their missile-launching boats with electronic jammers and deceivers and covered their ships with material, which partially absorbed, rather than reflected, energy from any radar waves, which might strike it. Such radar absorbent materials (RAM), called "microwave absorbents", were able to irreversibly transform energy from electromagnetic waves into another type of energy, in this case heat, which could be easily dispersed into the air and water. It was also decided that the best maneuver to adopt, during attack, was to face the enemy bow-first so as to present the enemy radar with the smallest possible reflective surface.[570]

When the October 1973 War broke out, the small but well-armed navies of the Middle East were well prepared for the for that series of naval conflicts which remain unique and of great importance in modern naval history.

On that first night of the war in October 1973, the Israeli naval command fearing that the Syrians might launch a naval attack on the port of Haifa, ordered five fast attack missile-boats–*Reshef, Mivtach, Hanit, Gaash* and *Miznag*–to sail north and search for enemy units.[571]

The Syrians, for their part, were also worried about their own lack of coastal defenses and sent out three "OSA" and "Komar" class missile-boats, as well as various other vessels, on surveillance and patrol missions.[572]

The Israeli formation skirted the Lebanese coastline to reach Syrian waters where, at 22.28, they sighted a Syrian torpedo boat on patrol off the coast near Latakia. The Syrian boat tried to take refuge in a nearby port but was caught and sunk by gunfire from the five Israeli ships.[573]

The Israeli formation then turned eastwards, splitting into two columns to commence a sweep in the direction of Latakia. During this phase of the mission, *Reshef* sighted a Syrian minesweeper that it promptly sank with one of its missiles. But the minesweeper was probably baited to attract the Israeli towards the three Syrian missile boats, which were preparing to attack the Israeli formation.[574]

The ESM equipment on board the Israeli vessels gave the alert and an analysis of the radar emissions intercepted furnished data regarding the attacking vessels' type and armament. Both the Syrian and Israel formations immediately maneuvered towards favorable firing positions. They were now 25 miles from each other, but the distance closed rapidly as they raced towards each other at full speed.[575]

At this point the Syrians enjoyed the advantage since, unlike the Israelis with their shorter range *Gabriel* missiles; they were now within launch range for their *Styx* missiles. They launched their first Salvo from a distance 37.5 kms and the Israelis immediately activated their Deception Jammers to send the *Styx* missiles off course and launched quantities of chaff to further distract them. The Israelis fired both long and short-range chaff in their prepared plan to create maximum confusion for the *Styx* seeker heads.[576]

There was great tension among the crews of both the Israeli and Syrian units who were well aware that their fate now depended on the electronic equipment they had on board–the missiles on the Syrian side and the deception jammers and chaff on the Israeli side. It was the first battle in naval history between two missile-launching formations and there was no telling what might happen! This not a classic naval battle in which gunfire was directed and corrected by men; the result of this encounter depended on electronic equipment, masterpieces of technology which could do incredible things but which, nevertheless, each had shortcomings. Missiles need radar to lock onto and track the target and radar is vulnerable to ECMs.

The sinking of the *Eilat* had taught the Israelis the great importance of electronic warfare and they had learnt their lessons well. As soon as the ECM equipment on board their ships was put into action, the Syrian *Styx* missiles immediately deviated away from their real targets towards non-existent targets and, after wild and uncontrolled maneuvers, crashed harmlessly into the sea.

Having avoided the first missile attack, the Israeli ships continued at full speed ahead, in two lines, until they came within launch range of their own *Gabriel* missiles.

They opened fire at 23.36 and the Syrian boats, lacking electronic warfare equipment of the kind used by the Israelis, suffered heavy damage. One "Komar" craft and one, "OSA" craft sank shortly thereafter, while the other "Komar" craft drifted onto a sandbank where it was then destroyed by gunfire from two of the Israeli ships.[577]

The following evening the Israeli navy took part in another naval battle in even more dramatic circumstances, this time against the Egyptians the Israelis had discovered, intercepting enemy communications that an Egyptian naval formation was going to move out of Alexandria that night and sail to the naval base at Port Said, nearer to the front. The Israeli high command immediately sent out their missile-boats *Reshef, Keshet, Eilat, Mifgav, Herev* and *Soufa* to intercept and destroy the enemy naval formation.[578]

The Israeli ships sailed towards the Egyptian cost, maintaining strict radio and radar silence; only passive electronic warfare equipment was in operation, that is, those, which emit no electromagnetic energy (RWR and all ESM receivers).[579]

The Egyptian formation, consisting of four "OSA" class attack craft armed with *Styx* missiles, left Alexandria just after sunset and headed for Port Said. At about 21.00, one of the Egyptian ships switched on its radar for a few seconds to check the route and to find out whether there were any enemy ships nearby. This electromagnetic "indiscretion" was promptly picked up by the Israelis, informing them of the presence and location of the Egyptian formation.[580]

Navigating in total darkness the naval formations drew closer. At 23.00, the Egyptians picked up the six enemy units on their radarscopes at distance of approximately 26 miles. As soon as they were within firing range, 24 miles, "OSA" gunboats launched a salvo of twelve Styx missiles. However, the Israeli ships' ECM devices–noise and deception jammers and chaff-launchers–sent all twelve missiles off course and they ended up in the sea.[581]

The Israeli units sailed on at full speed towards the enemy and, after twenty minutes, were near enough to launch their own missiles. The Egyptians, having no ECM equipment on board their "OSA" boats, were powerless to counter the *Gabriel* missiles launched against them and three of their boats were hit and sunk. The fourth unit was badly damaged and drifted onto a sandbank near Baltim.[582]

The importance of the role played by ECM in these battles needs no comment! The opposing naval formations never came within visual range of each other; everything was done electronically and, in each engagement, the side with the more effective ECMs emerged victorious.

In the naval battles of Latakia and Damietta-Baltim, none of the fifty-two *Styx* missiles launched against Israeli units hit their target, a fact that speaks for itself. These results were due to the planning and efficient use of EW equipment by the Israeli navy, and they brought to an end the threat of the *Styx* missile for the navies of the Western Powers.[583]

Conclusion

While these naval battles did not greatly affect the outcome of the October 1973 War, they certainly marked a turning point in the history of naval warfare.

The participation of Russia and the US, although they did not officially intervene in the war, at any point was, nevertheless, of crucial importance. The two "Superpowers" did much more than merely provide arms, electronic systems, logistic support and so on; they used the Middle East like a huge "missile-range" where they could try out their latest arms and equipment.

It's a proven fact that the Americans used Israeli aircraft to evaluate, in real tactical situations, AGM-65 Maverick missiles, which are guided laser-beams and rarely miss their targets. Similarly, a new version of the AGM-45 Shrike air-to-surface missile, which guides itself onto the enemy radar by "riding" the radar's own electromagnetic emissions or similarly "rides" enemy jamming signals (Home-on-Jam) to source, were also tested in real combat situations.[584]

The Russians tried out their new air-to-surface missile, AS-5 *Kelt* which has a range of over 200 miles, on the very first day of the war. an Egyptian-piloted Tupolev Tu-16, flying over the Mediterranean, launched one such missile in the direction of Tel Aviv. By sheer chance, the missile was sighted by an Israeli Phantom, which intercepted it and shot it down.[585]

The Soviets also used the Middle East war to test the effectiveness of their wire-guided anti tank missiles, *Snapper* and *Sagger*, and the latest version of their *Frog* surface missiles (*Frog*-7), which were used on the Syrian front. Similarly, the US anti-tank missile, TOW (Tube-launched, Optical-Tracking, Wire-guided), was tried out by the Israelis. TOW is a system consisting of a tube-launcher and an optical-tracking device attached to a tripod. The missile is wire-guided and controlled by a computer, which automatically sends route-signals to the missile in flight.[586]

New aircraft were also tried out in the October 1973 War. Special reconnaissance missions were carried out by the US Lockheed SR-71Blackbird spy-plane, which has a speed of over Mach 3 and a ceiling of nearly 100,000 feet, and also by the Soviet MiG-25 *Foxbat-B*, which has a speed of Mach 3.2 and a ceiling of approximately 80,000 feet. Several supersonic Sukhoi Su-25 *Flagon*-A and Su-20 *Fitter*-C fighters were also reported to have been sighted over Israeli territory, as was the most recent version of the French Dassault Mirage over Arab territory.[587]

Pilots from neutral countries were also involved in the war for various reasons, such as training, testing new equipment and acquiring first-hand experience of the latest air tactics. Interception of flight communications revealed the presence of Pakistani, Cuban and Libyan pilots on the Arab and South African pilots on the Israeli side.

A lot of hasty conclusions have been drawn from the experience of the October 1973 War. For example, it has been said that the advance of missiles marked the end of tanks and aircraft, but it is outside the scope of this study to evaluate the validity of such an assertion. However, the experience of this war can teach valuable lessons about electronic warfare.

One of most important teachings of the October 1973 War regards the extremely serious consequences, which can derive from an inadequately functioning intelligence service. The Israeli intelligence services were accused, not unjustly, of failing to provide the government with sufficient warning of the imminent Egyptian-Syrian attack, a failure, which threatened the very existence of the Israeli nation. A second serious shortcoming was that the Israeli armed forces found themselves without adequate ECMs to counter the enemy's new, sophisticated electronic weapons systems, and this resulted directly in very severe losses of both men and equipment.

All this could have been avoided if the electronic sector of the intelligence service, called SIGINT, had been more efficient; this is surely the duty of any State concerned about its own security and survival. It is impossible to know precisely whether the shortcomings of the Israeli SIGINT service lay in data gathering or in evaluation and analysis. Nevertheless, it is certain that, if the Israelis had been more thorough in their interception and deciphering of Arab communications and analysis of radar emissions in peace-time, they would not have suffered those terrible twin surprises – the attacks themselves, and the new-generation weapons systems deployed by the Arab forces.

Egypt, on the other hand, certainly did not neglect military intelligence but, rather, had made excellent use of it before the outbreak of the war. After the bitter experience of the 1967 war, they had no intention of being caught by surprise again. With Soviet help, they completely modernized their intelligence service, first, by acquiring all kinds of up-to-date equipment for electronic espionage: highly sensitive radio receivers, radar surveillance receivers, tape recorders, direction finders and so on.

During the war, the Israelis managed to capture, among other things, Egyptian maps showing, in great detail, their defense installations, planned operations along the Canal, the code-names of bases in the Sinai and so on. They also had the good fortune to capture a number of complete SAM-6 systems, SAM-7 missiles and ZSU-23-4 batteries that provided them with precious information about their respective radars and the technological level reached by the Soviets in the field of electronic warfare.

The October 1973 War is an excellent example of limited, as opposed to general, warfare. it was a war with a limited objective, limited time and limited space, sponsored by two Superpowers who wanted to try out their latest weapons. The presence of so many electronic devices controlling the various weapons systems made it extremely difficult to keep the situation in check; this was further aggravated by communications jamming, particularly by the Egyptians. In fact, lack of air control led to several instances of both sides shooting down their own aircraft. This last problem should be kept in mind by those responsible for planning future defenses and weapons systems, since the kind of incidents, which took place in the air, could also happen in ground or naval warfare, with more serious consequences.

To sum up it is essential for all armed forces to be equipped with a complete range of EW equipment, even in peace-time, and to have an efficiency-run intelligence service, with up-to-date equipment for electronic espionage (SIGINT), able to stay constantly abeam of the technological progress of hostile nations.

Technology in Warfare: The Electronic Dimension, The Role of Electronic Warfare since its Inception into a Central Aspect of the Gulf War in 1991

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Volume II

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Chapter 20

Small Scale of EW: Limited Wars, Invasions, Conflicts, and Crises

The Entebbe Raid

Besides major international crises, electronic warfare has also played a useful though little known role in a number of smaller scale conflicts, which have taken place in recent years, such as those caused by international conflicts and crises.

A typical example of the use of electronic countermeasures in one such "small scale conflict", as they are now called, was the Entebbe Raid when an Israeli commando force freed 102 hostages who were being held at Entebbe airport, situated about 20 kms from the Ugandan capital of Kampala. The series of events aroused worldwide interest and probably everybody remembers the story. However, few people are aware of the role played by electronic countermeasures in this enterprise or to what a great extent they contributed to the success of the Israeli operation.

On 27 June 1976, Air France flight 139, an A-300 Airbus, flying from Tel Aviv to Paris with 254 passengers on board, had just taken off from Athens when four people belonging to the Front for the Liberation of Palestine hijacked the airliner, ordering the pilot to fly first to Benghazi (Libya) and then to Entebbe.[588]

The Israelis organized a special commando to free the hostages. They sent four C-130 Hercules transports and two Boeing 707s, escorted during the first part of their flight by F-4 Phantoms. No longer escorted, the Hercules flew in low over Lake Victoria and landed at Entebbe while the two Boeing 707s stayed in the air, functioning as operational command and control centers.[589]

After a violent shoot-out, the commando freed the hostages and boarded them on one of the Hercules which immediately took off and flew to Nairobi where the wounded were disembarked, to be followed by the other three Hercules some thirty minutes later, after they had dealt with the remaining resistance, and sabotaged the Ugandan air force MiGs based at Entebbe.[590]

The return trip to Israel meant an eight-hour flight for the Israeli aircraft during which time they were exposed to Ugandan and Arab air force fighters. To avoid possible air attacks, the Israelis used the jammers on board one of the Boeing 707s to blind all airborne and local air traffic control radars. Thus, any possible intervention by Amin's air force was prevented and the Israeli aircraft were able to return to Israel undisturbed.[591]

The Sino-Vietnamese War

After several weeks of continual border incidents, at 05.30 on 17 February 1979, twenty Chinese divisions, supported by hundreds of aircraft, tanks and artillery pieces crossed the 1,200 km-long Chinese borders with Vietnam.[592]

Although Chinese leaders repeatedly declared that they only intended to teach the Vietnamese a lesson, the Chinese aggression seriously endangered world peace and created serious problems for the two Superpowers. The Soviet Union had signed a military assistance pact with Vietnam only four months previously, so naturally a Soviet armed intervention was greatly feared. The Soviet Union, uncertain whether to run the risk of starting a third World War, nevertheless took the precaution of placing all their air and ground forces stationed in Siberia on full alert and dispatching a naval formation, including missile-armed cruisers and destroyers, to the China Sea. The Americans also sent, as a precautionary measure, several aircraft carriers of the Pacific Seventh Fleet, to the troubled area. Both Superpowers placed all their nuclear attack forces on increased alert, starting with their submarines, carrying ballistic missiles with multiple nuclear warheads.[593]

Meanwhile, what little news that reached the outside world about events along the Chinese border with Vietnam was, as usual, full of contradictions. The Chinese claimed that they had penetrated 80 km into Vietnam while the Vietnamese triumphantly proclaimed that the border was littered with the invaders' bodies and their destroyed tanks.

If the actual fighting of this conflict in Southeast Asia followed traditional, conventional lines, the electronic battles going on in the atmosphere were, on the other hand, highly advanced, with both sides using the most up-to-date systems provided by the two Superpowers to acquire all possible information and to spy on each other.

First of all, both the Russians and the Americans immediately launched supplementary photographic and electronic reconnaissance satellites for battlefield surveillance. These were able to take photographs of what was going on and intercept all electromagnetic emissions present in the atmosphere, particularly messages and orders exchanged by military high commands.[594]

In order to have full reconnaissance coverage of such a complex zone as the Indochina peninsula and to keep an eye on the movements of enemy air and naval forces, the Russians also sent a number of Tu-95 maritime and electronic reconnaissance aircraft, equipped with the latest electronic surveillance equipment, to the Gulf of Tonkin. The Americans, on the other hand, sent a number of Grumman E-2C Hawkeyes to their strategic base of Okinawa, Japan. Specially designed and built for electronic reconnaissance at sea, these aircraft were to keep a close eye on the Russian naval units and to intercept all their electromagnetic emissions, both radio communications and radar signals. Expert analysis and interpretation of these emissions would provide the

Americans with a clear picture of Soviet operational intentions. Thus, whereas no journalist, "special correspondent", military attaché or secret agent was able to get hold of any reliable information about the Sino-Vietnamese War, the CIA and the GRU got all the information they needed via their eagle-eyed satellites and their electronic reconnaissance aircraft.[595]

Conclusion

The Sino-Vietnamese War provided the Americans with an excellent opportunity to try out, under real conditions, their system of command, control and communications to which the nuclear defense and strike capabilities of the United States are entrusted. To his great surprise and consternation, President Carter learned that this whole system was now vulnerable to new Soviet space weaponry.

The Sino-Vietnamese conflict came to an end after a few months with no conclusive victory for either side. Both the Chinese and the Vietnamese officially declared that they had achieved their set objectives but it seems more likely that the little conflict was brought to a halt by the high losses sustained by both sides.

A few months after the end of the conflict the People's Republic of China reported that many of their soldiers had been hospitalized in Canton for eye and brain lesions. The Chinese suspected that the Soviet had taken advantage of the conflict to try out a new secret weapon, most probably a high-energy laser, using the Chinese soldiers as guinea-pigs.

Strategic Arms Limitation Treaties and the Iranian Crisis

The Sino-Vietnamese War broke out just when the USA and USSR were about to sign an agreement for the limitation of strategic arms (SALT-2). Great efforts had been made by both sides to overcome the two large stumbling blocks of new US cruise and Pershing-2 missiles and Soviet Tu-26 *Backfire* bombers. Soviet opposition to the cruise missiles, which are equipped with a revolutionary guidance system called TERCOM[596], comprising a computer and radio altimeter and can thus fly with great navigational precision at very low level, arose from the fact that the Russians had not yet managed to devise any countermeasures, electronic or other, to them.[597]

Opposition to US Pershing-2 missiles to be based in Western Europe also stemmed mainly from considerations regarding electronic warfare. Although these missiles have a shorter range than similar Soviet missiles installed in Eastern European countries, they were greatly feared by the Russians because of the difficulty of devising effective ECMs to their extremely sophisticated guidance system which, being of the inertial type linked to a special radar, is almost immune to jamming or deception.[598]

The Americans, on the other hand, expressed concern about the Soviet *Backfire* bomber, the official reason given for this concern being that there were more of them than the equivalent US F-111, which had only been produced, in limited numbers. The EW version, EF-111, was considered indispensable for escorting bombers in deep penetration of enemy air space.[599]

The signing of the SALT-2 agreements, which took place in Vienna at the end of June 1979, was a source of much controversy in the United States mainly because it was feared that America was no longer able to verify whether the Soviet actually kept to the agreements. Many people remembered the flight of the CIA from Iran where, following the Islamic revolution and the deposition of the Shah, the US had lost its precious listening posts which had been operating for years along the Iranian-Soviet border. The CIA pointed out that, without the aid of the listening posts in Iran, they were no longer able to monitor whether the Soviets were keeping to the agreed limitations as far as new ballistic missiles were concerned.[600]

Every new Russian missile, before going into operation, has to undergo a series of test flights, on average more than twenty, which are carried out over a one-year period. During this period, it is absolutely essential to use radar guidance and radio command and control systems. This requirement enables the Americans to monitor the electronic characteristics of the missile and, consequently, to access its operational performance. The CIA had always acquired such knowledge of Russian missiles via the ELINT listening posts in Iran.[601]

Conclusion

Many US Senators expressed grave concern about this “intelligence Vacuum” and wanted to withhold approval of the SALT-2 agreements until a project had been devised and developed to compensate for the loss of stations in Iran and to restore adequate electronic surveillance capabilities using other systems.

The Invasion of Afghanistan

The signing of the SALT-2 agreements was further held up by the Soviet invasion of Afghanistan. As had been the case in Iran before the Islamic revolution, there were evident shortcomings in US intelligence prior to the invasion of Afghanistan. A special inquiry was held to try to find out how the massive movement of so many Russian forces had escaped the attention of the various branches of the CIA.[602]

CIA analysts had reported that only 15,000 Soviet troops were deployed within easy reach of the Afghanistan border. In fact, the number of troops massed in southern Russia was much higher and at least 85,000 actually took part in the invasion. Most of them landed at the airports of Kabul and Bagram, airlifted by 350 large transport aircraft, between the 24 and 27 December 1979, while four tank divisions and motorized infantry swept across the border. Moreover, many of these troops had been transferred some days previously from the Baltic to bases in central Asia and these movements had also escaped the notice of American intelligence-gathering satellites and other sensors because the Soviet had used deceptional tactics.[603]

And yet, US listening stations had intercepted certain pre-recorded messages containing appeals to the Afghan people; these messages were for later re-transmission from Kabul at the moment of occupation. This demonstrated that the section of the US Intelligence Community that functioned best in the circumstances was radio interception (COMINT). This was further demonstrated by the fact that, while occupied Kabul was isolated from the rest of the world, only interceptions managed to provide any information about what was happening in central Asia. One must, therefore, deduce that shortcomings were in the area of analysis and evaluation of information received, an activity, which is usually carried out at the highest national levels.[604]

The Failure of the American Raid in Iran

When the US President, Jimmy Carter, made a surprise announcement on the morning of 25 April 1980 to the effect that a secret commando operation, undertaken during the night, to release the US hostages being held in Teheran had failed tragically due to a technical hitch, the whole world was gripped by alarm and apprehension at the specter of a nuclear war. When the US Defense Department later furnished detailed explanation, the reaction was one of consternation mixed with incredulity. How could it be, people asked themselves, that greatest military power in the world, master of the most advanced technology, had had to call-off an operation of such crucial importance for the American nation simply because a few helicopters had broken down?[605]

Military experts in several western countries were not convinced by the official explanation and put forward the hypothesis that the real reason for the US failure concerned ECMs actuated by the Soviets during the operation. What, then were the real reasons for the failure of the operation and how far was electronic warfare responsible for this failure?

The idea of a *blitz* operation, like that of Entebbe, to free the hostages held in the US embassy in Teheran had been under consideration since November 1979, shortly after the embassy was occupied. However, it soon became apparent that an operation similar to that carried out by the Israelis was out of the question since the situation of the hostages in Teheran was completely different to that of the hostages held at Entebbe.

Various plans, secretly drawn up by small groups of Pentagon experts, were considered, the choice finally falling on a rather complicated plan involving the use of helicopters. The choice of what type of helicopter to use was not simple. Since they would certainly take off from an aircraft carrier, it had to be a naval type, and the best choice seemed to be the Sikorsky S-65, variants of which–the CH-53A Sea Stallion and the RH-53D–were operated by the US Navy and the Iranian Navy, and thus, when the US helicopter approached the Embassy to release the hostages, the Iranians might think that it was one of their own machines.[606]

The operation was divided into two stages. In the first stage six C-130 Hercules, carrying the ninety men of the commando and a large amount of fuel, would take off from an Egyptian airport, fly over the Red Sea, skirt around the Saudi Arabian peninsula and land at an old, unused salt airstrip in the desert of Dash-el Kevir near the Iranian town of Tabas, about 450 km from Teheran. At this landing field, "Desert One" a rendezvous was fixed with eight RH-53 helicopters from the aircraft carrier *Nimitz*, cruising in the Gulf of Oman. The purpose of this rendezvous was to refuel the helicopters after their 500-mile mission and the transfer the commando to the helicopters.[607]

In the second stage of the operation, which never took place, the commando on board the helicopters had to transfer first to a secret location in the mountains and thence to Teheran where, with the help of infiltrated secret agents and possibly sleeping gas, they would penetrate the Embassy, rescue the hostages and transport them to safety. Provision was made for instantaneous satellite relay communications between the commando and the Pentagon.[608]

As in all operations of this nature, surprise and speed were absolutely essential pre-conditions for success. It was evident from the early planning stage that, with regard to these two elements, there were two particularly crucial problems to be solved: first, to avoid being discovered by enemy radars or other EW equipment and, secondly, to avoid any armed conflict with the Iranians.

To achieve the first aim, detailed EW plans were devised to be put into operation both before and during the mission itself. First, the Americans began to intercept all radio communications between the Iranian Embassy in Washington and the Foreign Ministry in Teheran to provide the Pentagon with information that might be of use in the planning of the mission. Secondly, so as not to arouse the suspicion of the numerous Soviet warships cruising in the Gulf of Oman and the Arabian Sea, nightly exercises were carried out by US air and naval forces using helicopters which frequently flew right up to the Iranian coast. Every night, other US ships, positioned away from the aircraft carrier, *Nimitz*, launched from special rockets, false targets consisting of radar reflectors to simulate the presence of helicopters in flight and thus occupy and confuse the Soviet radar operators.[609]

US ships and aircraft in the zone transmitted false exchanges of radio messages each night so that, on the night of the actual operation, there would be no increase in radio traffic to arouse the suspicions of the ever-present Soviet spy-ships which systematically intercepted all radio-telegraphic traffic. In short, the aim was to make the Russians think that the departure of the eight RH-53 helicopters on the night of the actual mission was just routine nocturnal exercise.[610]

The operation was code-named "Eagle Claw" and this name was used in all radio communications regarding the operation. It was essential to ensure maximum security of communication between the Pentagon, the aircraft carrier *Nimitz*, abroad which a special command structure was established to be in charge of the operation, and the forces taking part in the operation. To achieve this, the United States, at the beginning of January, secretly launched two communications satellites that used new transmission and coding techniques, which rendered their communications almost completely immune to jamming and deciphering. At the same time, a reconnaissance satellite was launched into geostationary orbit over the Indian Ocean to ensure full photographic and electronic reconnaissance coverage of the area. In order to provide warning of any aircraft approaching the US C-130s and helicopters flying towards Iran, several USAF Boeing E-3A Sentry AWACS would be present: these were each equipped with a very long-range radar capable of detecting aircraft or helicopters at a distance of several hundreds of miles.[611]

The most difficult problem to solve was that of penetrating and operating in Iranian air space undetected. Luckily, the Iranian air defense radar system had been designed and built by US industry some years previously and so, aided by the new electronic reconnaissance satellites, a "blind" radar corridor was identified between the area covered by two Iranian radars through which the US aircraft and helicopters stood a good chance of flying undetected.

Both the C-130s and the RH-53s were equipped with electronic jammers to be used along their route to jam or confuse any communications between Iranian fighters and their ground control centers. Two C-130 Hercules were also armed with rapid-fire 7.62 mm machine-guns to support the assault on the US Embassy if necessary.[612]

Finally, about 200 attack aircraft from the aircraft carriers *Nimitz* and *Coral Sea* would be ready to intervene if the commando got into difficulties.[613]

Two weeks prior to the date fixed for the raid, a C-130 was sent out at night through the "blind" corridor to land at "Desert One". Its mission was to check the feasibility of penetrating Iranian air space undetected and to take earth samples of the salt desert for analysis to ensure that the heavy aircraft and helicopters could safely land there.[614]

The actual operation began on the evening of 24 April when the six C-130 Hercules took off from the military airport of Khena in Egypt. Later, at 19.30, the eight RH-53 helicopters took off from *Nimitz*, cruising in the Gulf of Oman.[615]

To confuse the radars of the Soviet ships in the area, numerous false radar targets were launched from other US ships, not only in the Gulf of Oman but also in the East Mediterranean. Further confusion was created on the Soviet radar screens by the presence of numerous Israeli warships which (perhaps by sheer coincidence) had decided to carry out air and naval exercises that very night!

To avoid detection, the C-130s flew very low, first over the Red Sea and then the Gulf of Aden. Here, they had to switch on their jammers to blind Soviet radars installed I South Yemen and on the coast of Eritrea. After a brief stop at Masirah airport in Oman for refueling, they then flew on to "Desert One". The helicopters took off from *Nimitz* and headed directly for the Iranian coast. They also flew at a low altitude along a route far from populated areas to avoid being detected.[616]

To aid them in their ground-hugging flight, the C-130s and RH-53s were all equipped with the most advanced and accurate navigation systems then in existence, including INS (Inertial Navigation System) and Omega (a Highly accurate very low frequency radio navigation system), as well as night vision devices.[617]

The helicopter formation had hardly covered a third of the distance between *Nimitz* and "Desert One" when a warning light on the instrument panel of the Helicopter No. 6 lit up, indicating a risk of main rotor failure, a rare but potentially very serious occurrence.[618]

The helicopter immediately landed near small lake over which it had been flying. In accordance with pre-arranged procedures for maintaining radio silence, the last helicopter of the formation, No. 8, automatically followed No. 6 to provide assistance. On landing, a quick examination of the rotor blades confirmed the gravity of the situation. The commander decided to abandon the helicopter and he and his crew boarded Helicopter No. 8 that immediately took off and headed for "Desert One".[619]

Then, the formation suffered another setback when they ran into a sudden, violent sandstorm. Visibility dropped sharply to almost zero and it became impossible for the helicopter crews to see the other helicopters in the formation even with their sophisticated night-vision devices.

At 21.30, the first C-130, carrying the men who were to set up the refueling base, landed at "Desert One", but, after only a few minutes, there was another unexpected setback. A bus carrying about forty Iranian civilians suddenly appeared coming along a dirt road that passed near the landing strip. The US officer in charge of the first group of men immediately stopped the bus but not knowing what to do with the passengers, radioed the *Nimitz* for instructions. He was told to hold them but keep them well away from the refueling zone. To crown it all, a few minutes later a tanker and a truck appeared, their headlights on, heading towards the airstrip where the other C-130s were just landing. The drivers of the tanker and the truck came to a halt when faced by this unusual spectacle and then fled into the darkness.[620]

Meanwhile, the helicopter formation was still fighting its way through the sandstorm. Just before midnight, the crew of Helicopter No. 5 experienced gyro failure rendering unreliable both navigation instruments and more importantly, stability reference systems, the loss of which made it extremely difficult to follow the route accurately and keep the helicopter straight and level. The formation was just then approaching a chain of mountains reaching up to 10,000 feet lying across the route to "Desert One". The commander of Helicopter No. 5 therefore had to make a very difficult decision: whether to fly along the valleys as planned or over the mountain chain. The first option seemed extremely dangerous given the faulty gyros, while flying over the mountains would expose the helicopter to the search radars of both Iranian and Soviet defense systems. Probably for the latter reason, the pilot decided to fly back to the Nimitz.[621]

At 00.30, the Pentagon received the news via satellite that No. 5 was returning to the aircraft carrier. The fact that now two helicopters, because of breakdowns, were no longer able to take part in the operation caused great consternation in Washington. But it was too late to replace them; in fact, no contingency plans had been made for replacements![622]

Shortly afterwards, a warning light came on in the cockpit of Helicopter No. 2, this time indicating a drop in pressure of the secondary hydraulic system which regulates the pitch of the rotor blades and, consequently, the speed of the helicopter.[623]

Between 00.50 and 01.40, the six remaining helicopters finally landed at "Desert One". Examination of No. 2's hydraulic system showed that the fault was too serious for the helicopter to be used in the mission.[624]

At this point, according to the official version of what happened, the three commanding officers (of the helicopters, the commando and the "Desert One" base) conferred and came to the conclusion that the mission could not be carried out with only five helicopters. They radioed command on board Nimitz who in turn transmitted a report to Washington suggesting that the operation be cancelled. President Carter was in agreement and gave orders for the aircraft and helicopters to return to their bases.[625]

Back at "Desert One", during the confusion of the preparations for their return, an RH-53 helicopter and a C-130 collided, causing a fire in which eight US soldiers died.

This id the official version of events but is not very convincing, not only for the reasons given but also because of more specific considerations.[626]

First of all, it is difficult to understand how the Americans, who had had hundreds of helicopter experts based in Iran for several years during the Shah's regime, could have to underestimated possible technical problems arising from a 500-mile flight of delicate machines in a desert area where sandstorms are hardly a novelty. It is also difficult to understand why, for such a complex operation, it had not been deemed necessary to have reserve helicopters on board either *Nimitz* or another ship ready to replace any helicopter that might become unserviceable.

It must also be pointed out that, since each RH-53 helicopter could carry up to fifty-five people, the five remaining helicopters would probably have been adequate to rescue the fifty-one hostages and various secret agents. It has been reported that many of the commando's officers wanted to go ahead with the mission using the five remaining helicopters and tried to convince those who held that five helicopters were insufficient. Since there was no single officer in overall command, heated discussions ensued which ended only when Carter's orders to return arrived at 02.30. After the tragic collision, which Happened at 03.18, there was great confusion at the base and this could also explain the almost incredible fact that operational plans and various top-secret electronic devices were left on board the abandoned helicopters.[627]

As we have already seen, Iranian territory, particularly the area near the Soviet border, had been in the Shah's time a "hot" zone from the point of view of EW: on the one hand, there were the Americans trying to intercept the emissions of Soviet radars during test-launches of new missiles at Tyuratam in Kazakhstan; on the other hand, there were the Russians trying to prevent such interceptions by ECMs and ECCMs. With the advent of the Islamic revolution, the US surveillance establishments had been dismantled whereas Russian systems had remained intact and perhaps had even been strengthened because of the crisis in the Persian Gulf. It must also be borne in mind that the route followed by the US helicopters is well within the range of Soviet air defense radars installed along the Soviet/Iranian border.[628]

Conclusion

Thus, from the point of view of EW, the first hypothesis one can make is that the Soviets, having located the helicopter formation by radar or other electronic means, jammed the American's radio communications and navigation systems, thus hindering navigation and preventing the exchange of orders and reports between the helicopters themselves, the commando force and secret agents whose helps was needed for them to reach the US Embassy in Teheran.

Another hypothesis, which has been put forward, is that Soviet reconnaissance satellites intercepted the radio and radar transmissions of the US aircraft and helicopters and followed their movements over Iranian territory. Since, to reach "Desert One", the US formations had to fly in the direction of the Afghanistan border, the Russians may have feared an attack on their forces in Afghanistan. Brezhnev might have got Carter on the famous "hot-line" to dissuade him from undertaking any military operations in that part of Asia.

A third and perhaps more credible hypothesis is that, convinced that the numerous radio transmissions made by the helicopters during their various difficulties and by the commando following the unexpected appearance of the bus-load of Iranians had been intercepted by unfriendly stations, the Pentagon feared that the operation had lost the element of surprise which was indispensable for its success. Consequently, Carter, fearing a direct encounter with the Iranians, decided that it would be wiser to order the force to withdraw before it was too late.

However, according to various statements made by the Americans, neither Navy surveillance systems nor the E-3A AWACS flying over the zone had intercepted message or signals indicating that Soviet radars, including those in Afghanistan, had discovered the presence of hostile or unidentified aircraft flying low over Iranian territory. Moreover, neither the Russians nor the Iranians have to this day made any declaration claiming responsibility for the failure of the American raid.

Regarding control of radio-electric emissions, given the secrecy required for such a mission, the exchange of messages with Washington and the aircraft carrier should have been avoided. Even though the ultra sophisticated transmission and coding techniques employed are highly resistant to interception (spread spectrum, pseudo-random-noise and so on), in an area to crowded with SIGINT platforms–ground stations, satellites, ships and aircraft–as in the Middle East, there was always some risk that messages could be intercepted and deciphered.

International Crisis Management

In addition to those already described, crises of varying gravity have taken place and, in fact, continually take place all over the world–recently, for example, in Central

America, the Horn of Africa, Cambodia, Angola, Namibia and the Persian Gulf as a result of the war between Iraq and Iran, to name a few. Crises frequently occur in areas where, for political military or geographical reasons, the acquisition of information on the local situation via normal channels is difficult if not downright impossible.

However, the two Superpowers have a vested interest in every international crisis. Directly or indirectly, each crisis affects the strategic and military balance of power, for example, due to concern for oil supplies, between the two alliances, NATO and the Warsaw Pact, with the omnipresent danger of a direct confrontation with the consequent risks of nuclear catastrophe. The aim of both Superpowers is to reap the maximum advantages from the crisis without committing their own forces to actual warfare and, at the same time, to prevent the other Superpowers from the resolution of the crisis.[629]

They must also ensure that they do not lose control of situations and thus risk becoming involved by error or by chance in a nuclear conflict. Where international agreements for the maintenance of a certain balance of political and military power exist, each side is constantly on guard in case the other side should try to cheat. Therefore, it is absolutely vital for world powers to rapidly acquire and accurately evaluate all possible information regarding every international crisis in order to actuate appropriate countermeasures (political, military, electronic and so on).[630]

There were serious shortcomings in this activity, as carried out by US Intelligence services on the eve of the Iranian crisis and the invasion of Afghanistan that aggravated the dramatic problems facing the United States. These served as a reminder of the need for instruments capable of following the activity of potentially hostile forces in areas involved in international crises, and of detecting build-ups of armor and troops along the borders of threatened countries and of following their movements day and night. Apart from satellites, this type of surveillance can also be carried out very effectively by aircraft and ships equipped for SIGINT.[631]

Conclusion

This new task, which is both strategic and tactical and involves both air and naval forces, has been appropriately named "Crisis Management". Such surveillance missions must be carried out from a safe distance, never involving flying over the "hot" zone but rather flying around the edges of the zone by night and day, employing electronic, photographic and IR equipment which can operate from great distances. Among Western aircraft equipped for crisis surveillance are the latest US reconnaissance aircraft, the TR-1 and EF-111A, the Boeing E-3A Airborne Warning and Control System (AWACS), and the EA-6B Prowler, E-2C Hawkeye, S-3A Viking and OV-1 Mowhawk, and the British Bae Nimrod and others. Among Soviet aircraft equipped for the same function, besides the ever present TU-95 *Bear*, the TU-16 *Badger-H* and the MiG-25 R *Foxbat* which have already been mentioned, there are also the ECM-escort Yakovlev Yak-28 *Brewer-E*, the TU-22 *Blinder* and the Tu-26 *Backfire-B*, not to mention the Tu-126 *Moss* which has a long-range radar system very similar to that of the US AWACS.[632]

Many of these aircraft have been used during the course of the conflict between Iraq and Iran, in conjunction with the huge naval forces deployed in the Gulf of Oman, to follow events in that "hot" zone. In particular, the Americans use four AWACS, based in Saudi Arabia, to monitor the entire air space of the Middle East and so avoid surprise attacks on their own naval forces operating in those seas.

The Falklands War

On the night of 2 April 1982; a few miles from Port Stanley, the capital of the Falkland Islands, ninety marines transferred from the Argentinean destroyer *Santissima Trinidad* to landing craft and headed towards the coast. On landing, the commando split up into two groups: the first, composed of thirty men, headed for the British Governor's residence in Port Stanley, while the other, composed of sixty men, headed for the Royal Marines barracks. This was the first stage of "Operation Tom"–the military occupation of the Falkland Islands–or the Islas Malvinas–by Argentina.[633]

The thirty men of the first group, led by a lieutenant commander, met with strong resistance from the Royal Marines at the Governor's residence. Their officer himself was killed but the Argentineans had overwhelming superiority in firepower, and the Governor felt that he had no option but to order the Royal marines to surrender.[634]

Meanwhile, the main body of the Argentinean invasion force had landed on the Islands, arriving on board the corvettes *Granville* and *Drummond*, a submarine, various other ships, and several C-130 Hercules and Fokker transport aircraft. They soon overcame resistance and raised the Argentinean flag over the disputed islands.[635]

Three days later, a British Task Force set forth from Portsmouth to regain the Falkland Islands–"Operation Corporate"–while desperate attempts to solve the problem diplomatically were being made. Nothing happened for almost a month while the British Task Force continued to sail towards the Falklands, their pace seeming to indicate more a diplomatic gesture than serious military intentions. The whole world followed the anachronistic affair with great curiosity and incredulity.[636]

Meanwhile, the Soviet Union had begun to send a series of spy-satellites into orbit to keep an eye on events in the South Atlantic. They had also hastily sent a number of Tu-95 *Bears* and the usual spy-ship disguised as a fishing-trawler to maintain surveillance of the British Task Force. The largest Soviet naval aircraft the Tu-95 *Bear* has been produced in several versions. The *Bear-D* is used for maritime reconnaissance and surveillance missions. For surveillance in the South Atlantic, they usually operated from a

Cuban-controlled military airbase in Angola. Such aircraft also have ELINT capabilities.[637]

The first Soviet satellites were sent into orbit on 31 March, two days before the Argentinean landing. They were the satellites Cosmos 1345 and Cosmos 1346 and their main tasks were, respectively, to intercept radar emissions (ELINT) and listen to and record radio communications (COMINT). On 2 April, a photographic reconnaissance satellite, Cosmos 1347, was also sent into orbit: this would drop capsules containing exposed film each time it passed over a fixed point in the USSR. Between 16 and 23 April, the satellites Cosmos 1350, 1352, and 1353 were launched to replace those in orbit and to continue their surveillance activities. On 29 April, the satellite Cosmos 1355, specializing in oceanic surveillance, was launched.[638]

The Soviets then sent into orbit other satellites (Cosmos 1356, 1357, 1366, 1367, 1360 and so on) for the specific purpose of monitoring operations in the Falklands. Some of these satellites were able to establish the positions of all ships present in the South Atlantic and to take photographs, which were simultaneously transmitted, to Russian ground stations for interceptions.[639]

The Americans had already been following, via satellite, the course of events in Argentinean ports and had, in fact, warned the British of the imminence of a landing in the Falkland Islands. Their surveillance was not limited to the South Atlantic, however, According to unofficial sources; the Americans used their mammoth National Security Agency (NSA). The Agency has satellites for communications (COMSAT), very well equipped ground intercept stations and decoding centers employing huge computers specially designed by IBM. NSA used these assets to intercept Argentinean communications and break the codes, thus enabling them to furnish the British with valuable information regarding the deployment of Argentinean forces in the Falkland Islands and the movements of Argentinean ships.[640]

It is not known whether the Russians managed to break the Royal Navy's tactical codes in time to be of use to them. However, there is no doubt that the British ships kept their radio transmissions to the absolute minimum when a Russian satellite was passing overhead.

On Sunday, 2 May dramatic news arrived from the far reaches of the South Atlantic that the British nuclear-powered submarine *Conqueror* had torpedoed the Argentinean cruiser *General Belgrano* off the coast of Patagonia. The *General Belgrano* was an ex-US Navy World War II-vintage 13,645 ton "Brooklyn" class cruiser, USS *Phoenix*. The cruiser had been sailing towards the Task Force but was still outside the 200-mile Total Exclusion Zone that the British had declared must not be entered. She carried no anti-submarine warfare (ASW) equipment but was escorted by two smaller ASW ships that nevertheless lacked modern anti-submarine equipment. Like the Argentinean ships which had taken part in the landing operation, the *General Belgrano* had used radar and radio rather imprudently, perhaps not understanding that all her electromagnetic emissions were being intercepted by the Americans who allowed access to all such information to their NATO ally, Great Britain.[641]

It was not difficult for the British submarine, its nuclear propulsion enabling it to travel fast underwater, to reach the old Argentinean ship and place itself in a suitable position for firing. However, before launching torpedoes, the commander of submarine, Commander Christopher Wrexford-Brown RN, rightly decided to radio London for instructions. The British Prime Minister Margaret Thatcher advised that the Argentinean ships constituted a clear threat to the approaching Task Force gave the order to the submarine's Captain to torpedo the enemy ship.[642]

At 16.00, the first torpedo hit the cruiser under the water line near the aft engine-room. The electricity supply was immediately cut off and the ship was plunged into total darkness. Three seconds later, another torpedo hit near the bow. At 16.07, the ship began to list so badly that, 15 minutes later, the Captain, Bonzo, gave the order to abandon ship. The sea was very rough and the two escort ships, fearing that they would also be hit, rapidly withdrew. Rescue operations were difficult and about 400 Argentinean sailors lost their lives in that controversial, widely criticized, engagement, whose operational necessity was called into question. At 17.00 on 2 May the cruiser went down with her flag still flying.[643]

From an operational point of view there was nothing surprising about the sinking of the *General Belgrano*. The southern force of an Argentinean naval pincer movement designed to encircle the British Task Force and bring it to battle, she constituted a serious threat to the Royal Navy and the embarked land forces, whether or not she entered the Total Exclusion Zone, the declaration of which apparently limited British offensive operations. Interestingly, the commander of Argentine Naval forces in the South Atlantic asserted (on BBC television in 1984) that the sinking of the *General Belgrano* outside the Total Exclusion Zone was a legitimate and necessary act of war and one he would have taken.[644]

What is surprising about the episode is the ease with which *Conqueror* dispatched the cruiser. As she lacked anti-submarine equipment and an adequate escort, it was virtually inevitable that she would be sunk. However, *Conqueror* had been tracking the cruiser for many hours, and, moreover, sank her with World War II-vintage (Mark 8) acoustic torpedoes, because her commander distrusted the modern, wire-guided Mk-24 Tigerfish type although they employ highly sophisticated equipment the total system reliability is inadequate. If *General Belgrano* could be sunk with such comparative ease by torpedoes whose basic design was some forty years old, fired from relatively close range, the question is raised of what warships can do against deadly modern homing torpedoes fired from long range by fast nuclear-powered submarines.[645]

Countermeasures can be used, with a certain measure of success, acoustic measures since electromagnetic waves cannot be propagated in water as effectively as can sound waves. The classic method of avoiding acoustic torpedoes, devised during World War II, was by means of acoustic deception; a noise-generator, transmitting the same kind of noise as that produced by the ship, but louder, was towed by the ship one sought to protect, and the torpedo was thus diverted towards this false target rather than the ship.

Naturally, devices used today are quite different from those used in World War II. Technological progress in this field has led to the development of new systems for deceiving or destroying torpedoes, which are computer-controlled and completely automatic, for example, anti-torpedoes. Since modern torpedoes, including wire-guided torpedoes, are equipped with an acoustic homing system for the final phase of the attack, acoustic measures, countermeasures and counter-countermeasures have been devised. These are constantly being refined, each side trying to out-do the other, just as in the electromagnetic conflict in the airwaves.

The Argentinean ships were no match for the British nuclear submarines and the sinking of the *General Belgrano* gave clear proof of which country ruled the waves!

The problem of countering nuclear submarines faces the largest navies, including those of America and Russia in rather greater degrees. Great efforts have been dedicated to the construction of chains of computer-controlled underwater acoustic sensors, which are able to detect submarines long before they are in a position to attack.[646]

The Argentineans soon retaliated for the sinking of the *General Belgrano*. On 4 May 1982, an Argentinean PV2 Neptune maritime patrol aircraft sighted a British naval formation, consisting of one large ship and a smaller one, at a distance of about 70 miles to the southeast of the Falklands. These were the aircraft carrier HMS *Hermes* and the Type 42 destroyer *HMS Sheffield*; the latter was operating as radar picket about 20 miles from the larger ship. Two Super Etendard strike aircraft, both armed with AM-39 Exocet missiles, were immediately sent out by the Argentinean high command to attack the two ships.[647]

The two aircraft flew low, skimming the tops of the waves, to avoid radar detection. The PV2 Neptune, which had sighted the British naval formation, guided the two Super Etendards to their targets and also controlled their brief climb to enable target acquisition by their nav-attack radar. At a distance of about 25 miles from the point where the British ships had been sighted, the two Super Etendards climbed rapidly to 500 feet, briefly switched on their radars to locate the two naval targets and thus programmed the Exocet missiles' computers, and the returned to their previous low altitude. Weather conditions were bad with fog that reduced visibility to quarter of mile. At a range of about 23 miles each aircraft launched its missile and then headed back to base, having "seen" the targets only by radar.[648]

However, during those few moments in which the two Super Etendards had had their radar switched on, a British ship in the area had intercepted their emissions. The interception was immediately relayed to all ships of the Task Force, including *Hermes* and *Sheffield*. The *Hermes*, the formation's Air Defense Control Ship, identified the intercepted emissions as probably coming from Argentinean Mirage III interceptor or tactical strike aircraft and not from Super Etendards. This error of judgment probably meant that time was wasted in discussion and that the danger was seriously underestimated. Besides, the fact that the two aircraft had already turned back seemed to indicate that they had decided not to attack. Moreover, the British considered that the

Argentineans were not as yet trained to launch Exocet missiles from Super Etendards. For all these reasons, the British did not attach due importance to the intercepted radar emissions.[649]

At that precise moment, *Sheffield* was transmitting and receiving message via satellite[650], an operation that requires all equipment emitting electromagnetic energy to be switched off to avoid interference with the satellite communications system: this was probably a major reason why the ship's radar did not detect the enemy aircraft in time. Moreover, *Sheffield's* ESM (Electronic Support Measures Systems) did not pick up the radar emissions of the missile, either, which is strange as the missile's radar seeker activated at a distance of about 10 kms from the target.[651]

On the other hand, there was a dense electromagnetic environment in the zone, coming from radio communications IFF and radar equipment on board the British warships and the numerous merchant ships that had been sent to the Falklands to provide logistic support for the Task Force.[652]

Meanwhile, the two undetected sea-skimming missiles traveling at close to the speed of sound covered the distance separating them from their targets in around two minutes. Just four seconds before impact, a lookout on the *Sheffield's* bridge saw one of the missiles just in time for the Captain to order the crew to take cover. The missile hit the *Sheffield* amidships, about 6 feet above the water line and penetrated the Operations Room. The other missile ended up in the sea, probably due to malfunctioning of its guidance system or, perhaps, for some other reason. The missile which it *Sheffield* penetrated the hull caused a terrible fire in which twenty men died, and twenty-four were injured. Fed by the residual fuel of the missile, the fire raged for some time, like a huge torch. Electric cables, the ship's nervous system, also caught fire and the ship's pressurized ventilation system allowed the fire to spread throughout the ship. The hull was white-hot where it had been hit and the crew could hardly move because of the thick smoke that had filled the whole ship making it difficult to breathe. Nevertheless, they desperately fought the fire for four hours, trying to save the ship, but when the flames encroached dangerously near the missile and combustible stores the Captain gave orders to abandon ship.[653]

But *Sheffield* did not explode or sink immediately. She was to put in tow with the hope of getting her back to Britain; however, after six days at sea, the badly damaged and burnt ship finally went down on 10 May, during a severe gale. It has been suggested that, although the Exocet may not have detonated, *Sheffield's* bottom plates were severely damaged by blast and fire.[654]

The *Sheffield* was the first of a class of twelve destroyers designated Type 42: The ship design had been criticized for lack of both defensive and offensive armament; in fact, these 4,100-4,700 ton ships, total armament is comprised of one twin-Sea Dart–SAM-launcher, one 4.5inch gun, two 20mm Oerlikon cannon and six ASW torpedo tubes, plus one Lynx ASW helicopter. Modern warships protect themselves against anti-ship missiles by using either "soft-kill" weapons (Electronic Counter Measures) or "hard-kill" weapons such as anti-missile missiles, for example, the British Sea Wolf, and very rapid-firing guns.[655]

In terms of "hard-kill" weapons, the *Sheffield's* Sea Dart SAM system had an anti-missile capability, but had a shorter range than the Exocet. Moreover, the British had no AEW aircraft, having abandoned them with their aircraft carriers, so any warning of attack was limited to "line-of-sight" detection by shipborne radars–in fact; *Sheffield* was acting in the EW capacity. This meant that the Super Etendards could launch their missiles from outside the range of Sea Dart missiles, this favorable situation being referred to as "stand-off"[656] capability. The aircraft were in no danger of being shot down, and their missiles dropped to sea level for their attack. *Sheffield* was not equipped to counter a sea-skimming threat, her equipment having been developed before missiles with this capability entered service, and, moreover, Britain had not expected to be at war against NATO weapons. The only possible "hard defense" that *Sheffield* could attempt was bursts from her 20mm cannon, which would have been totally ineffective against the tiny target of oncoming Exocet missile.[657]

Analysis of "soft-kill" weapons on board *Sheffield*, in the absence of any firm official documentation on this sensitive subject, necessities examination of the ship's superstructure, masts and antennas, of all, which can be clearly seen on photographs. A photograph of the ship taken after she had been hit by the Argentinean Exocet shows, on the mainmast, the antennas of ESM equipment called UAA-1 Abbey Hill, a well-known ESM receiver produced by the British firm MEL Equipment Co. Ltd and introduced into the Royal Navy in 1973.[658]

UAA-1 is a radar intercept and direction-finding system designed for use in surface ships operating in a dense radar environment. Developed in 1965-70 and, therefore, limited to the technology of that period, the two main operational functions of the system are:

1. Early warning of the presence of radar-type transmissions from ranges beyond the horizon constituting a top-priority threat to the ship.
2. General surveillance of the electromagnetic spectrum, intercepting, analyzing and identifying radar-type transmissions within the frequency band 1-18 GHz together with an indication of the direction of arrival.

To perform these functions, it is necessary that specific characteristics of potentially hostile radars, frequency, pulse width, PRF, etc., which have been found by automatic or manual analysis, are stored in a section of the equipment generally known as the "library". Top–priority threat emissions, such as enemy missile radars, are stored in a section called the "warner" for automatic identification and alarm; whenever emissions from such radars are intercepted in a real tactical situation an immediate alarm signal automatically warns of the presence of a priority threat. The identification of potentially hostile radar signals is carried out by automatic comparison of the parameters of the signal with the "dictionary" stored in the "library". Fully automatic warning is given if any one pre-programmed hostile signal is detected. Displaying onto the operator's console screen all the emissions present in the air carries out the surveillance function. The operator can quickly analyze and distinguish hostile emissions, and can initiate in bearing of selected signals.

In the specific case of *Sheffield*, the Abbey Hill equipment did not perform either of these functions. No warning was given by the equipment, perhaps due to electromagnetic interference or perhaps because the radar parameters of the Exocet missile had not been stored in the "Warner", and having been programmed as a top priority threat.[659] The emission itself was not analyzed since the operator did not have time to undertake the necessary operations.

The *Sheffield* was also equipped with two Corvus (or-Protean) chaff-launchers but these were not used for the simple reason that neither the missile nor the aircraft they were launched from were discovered in time to feed the chaff-launcher with the necessary data. In order to be effective, "chaff" a passive ECM, must be launched at precisely the right moment and in the precise direction and pattern to "lure" the radar-seeker of the missile away from the ship.[660]

Like most ships of the Royal Navy, the Sheffield was probably also equipped with active ECM devices: a Bexley 669 deception jammer for self-protection against missiles and a 667/668 noise jammer for jamming the search radars of hostile ships or aircraft, both of which had been originally designed to counter the Soviet *Styx* missile and other missiles of that generation. But also these devices were not activated for the same reasons given above.[661]

Perhaps the most serious deficiency was the lack of an Infrared Warning Receiver (IRWR) and a more up-to-date deception jammer as these should have been the last line of defense for *Sheffield* when all its other systems had failed.

It must be pointed out, however, that devising ECMs capable of countering Western missiles the Exocet, let alone the new generation Otomat, Harpoon and so on, is no easy task. The Exocet, although in use since 1973, incorporates several different types of sophisticated ECCMs that make it highly resistant to ECMs, including deception jamming. It is a missile of the "fire and forget" type that means that, having launched the missile the launching aircraft can immediately withdraw, thereby reducing the risk of being detected and shot down. The Agave radar[662] on board the aircraft only has to locate the target; once this has been done, data regarding the distance and direction of the target are automatically entered into the missile's computer-controlled guidance-system. All the pilot then has to do is launch the missile and go home; he does not even have to see the target. Once the Exocet missile is launched, it follows an initial course under inertial guidance, which is immune to ECMs, flying at an altitude of less than 30 feet above the sea under the control of its radar altimeter. At approximately 6 miles from the target, small radar called Adac, which is located in the nose of missile, turns itself on, acquires and locks on to the target and guides the missile to it. Adac is a monopulse tracking radar, operating in the X-band (8.5-12.5 GHz) and is highly resistant to ECMs. The monopulse technique is not new, having been used in Soviet SA-8 missiles and the more recent SA-10 and SA-11 missiles.[663]

The Exocet also has other complicated anti-jamming and anti-deception devices. One such ECCM, known as frequency agility, enables the radar to change frequency when jammed. Another, called Home-on-Jam (HOJ) automatically homes the missile towards the source of the jamming; a third device, called Leading Edge, is highly sophisticated and top secret. Consequently, it is no easy task to build ECM equipment capable of deceiving or disturbing this type of missile.

However, this does not mean that such a task is impossible. What is certain is that the sudden outbreak of the Falklands War found some British ships, including *Sheffield*, lacking the latest electronic warfare equipment capable of countering technologically advanced western missiles like the Exocet. The main reason, however, why a ship like Sheffield was not adequately equipped is purely economic. Cuts in the British Defense budget had forced the Royal Navy to delay refitting the class to which Sheffield belonged. However, in spite of the cuts, the Royal Navy had to replace the Abbey Hill ESM systems with new Cutlass systems; old active ECM devices were also in the process of being replaced by Ramses 670 deception jammers and Millpost jammers.[664]

It must also be pointed out that the first ECM devices installed on NATO warships had been built with Soviet anti-ship missiles in mind and would therefore probably be ineffective against a more sophisticated western missile. Moreover, the time element is of crucial importance where ECMs are concerned; they must be applied immediately, at the first sign of danger, which was not the case on board *Sheffield* where the Argentine aircraft and missiles were sighted too late.[665]

In the final analysis, it must be concluded that the Abbey Hill equipment on board *Sheffield*, if, indeed, it was in working order, was not able to distinguish and instantaneously interpret the electromagnetic signals coming from the radars the Super

Etendards and the Exocet missiles, either because of interference or because of its own intrinsic limitations.

On 7 May, Great Britain stepped up her naval blockade, declaring that all Argentinean military ships and aircraft encountered at a distance of over 12 miles from the coast of Argentina would be dealt with accordingly. A few days later, the Argentinean government announced similar restrictions for British ships and aircraft.[666]

On 9 May, two British BAe Sea Harrier multi-role STOVL aircraft, flying a patrol, sighted the fishing-boat *Narwal,* which had already been seen in the vicinity of the Task Force ships the previous week. Certain that it was an Argentinean spy-ship, the Sea Harriers dropped several bombs, one of, which hit the ship, injuring fourteen men and seriously damaging the hull. The *Narwal* was forced to surrender and a Task Force helicopter arrived to pick-up prisoners. According to the British, the electronic equipment and documents found on board the fishing-boat, not to mention the presence of an Argentinean naval officer, provided clear indication that the ship was being operated for intelligence operations. On the same day, Task Force ships, supported by aircraft and helicopters, bombarded the Falklands for the first time, intending to disrupt Argentinean Communication and Command and Control Centers.[667]

The Soviets probably furnished the Argentineans with data regarding the dispositions of the British Force, collected by their numerous spy-satellites in orbits passing over the Falklands. Besides this source, the Argentineans also had four-jet Boeing 707 airliners modified for electronic surveillance and maritime reconnaissance, Lockheed P-2V Neptune maritime patrol aircraft, Grumman S2F Trackers and Gates Learjet 35A aircraft, all built in the USA.[668]

The British also appreciated the benefits to be derived from satellite surveillance and maritime reconnaissance systems. Although they did not have their own satellites, their ships were fitted with special Scot Skynet antennas, which were able to receive data transmissions from the US Big Bird and the newer KH-11 satellites. The latter are generally considered to be the most sophisticated of all satellites, being able to receive and record earth images in digital form and immediately retransmit them to ground stations all over the world in a form which can be immediately utilized.[669]

During the next few days the Russians with a special interest in EW and tactical operations sent further satellites into orbit, which passed over the Falklands at twenty-minute intervals. One of these was the Cosmos 1372, for oceanic surveillance, equipped with nuclear-powered radar; the others were the Cosmos 1370 for photographic reconnaissance, the Molniya for communications and the Cosmos 1371 for SIGINT. A further small satellite for communications was also launched from the Salyut 7 space station that was already in orbit.[670]

Meanwhile, the British Task Force was beginning to make preparations for a beach landing in the Falklands. The British increased air strikes and naval bombardments of Argentinean coastal military installations and were carrying out the following pre-landing actions:

- Clandestine reconnaissance of the islands in order to choose a suitable beach.
- Clearing the selected landing site of all natural and man-made obstacles on the seabed by special underwater demolition teams.
- Installation on East Falkland Island of special automatic electronic sensors to provide data regarding the deployment and movement of Argentinean troops on the island.

- Commando raids on the various islands to destroy stores and installations (the raid on Pebble Island was particularly successful, the British destroying ten Argentinean Pucara aircraft and a large ammunition dump).
- Diversify actions on beaches other than that chosen to confuse the Argentineans as to where the landing would in fact take place.

At the same time, both the British and the Argentineans were building-up their forces in preparation for the final battle. Britain dispatched six more warships, twenty more Harriers and the luxury liner the 67,140-ton *Queen Elizabeth 2*, carrying 3,000 soldiers. Having been made aware of the electronic shortcomings of some of their ships in the *Sheffield* incident, large quantities of chaff were also dispatched for use by such ships during air attack. Tactics were also studied for using helicopters to launch chaff. Subsequently, chaff was frequently used to blank out enemy search or to divert approaching enemy missiles. For further protection from attacking aircraft, the British devised a method of launching chaff from ships' funnels, mixed in with the exhaust gases. However, the employment of chaff in the South Atlantic did not always achieve the desired result as it was often dispersed by the gale force winds.[671]

The Argentinean Expeditionary Force, consisting of roughly 10,000 men was equipped with German-built wire-guided anti-tank Cobra 2,000 missiles, night-vision devices, the up-to-date Franco-German Roland SAM, and FMA IA-58 Pucara and Aermacchi MB 326G and MB 339 ground-support aircraft.[672]

On 21 May, two hours before sunrise, the British landing operation to regain the Falklands got underway: Task Force ships sailed into San Carlos Water and began shelling coastal batteries near Port San Carlos. This was followed by the landing of 2,500 men, mainly Royal Marines and Paratroops, who established a beachhead in San Carlos Bay, well sheltered from the South Atlantic gales. The Argentineans, who had not expected the landing to take place at Port San Carlos, did not put up much resistance. Their retaliation arrived, however, from the air, in the form of MB 326s, Skyhawks and Mirages that furiously bombed and rocketed the British ships in the Bay, five of which were hit. One of them, *Ardent*, a 3,250-ton Type 21 frigate, was very severely damaged and, again, caught fire violently; twenty-two men died, thirty were injured and the ship continued to burn uncontrollably until she finally sank.[673]

On 22 May, the British beach-head was consolidated by landing a further 2,500 soldiers at San Carlos; they were equipped with night-vision devices (light intensifiers and infrared goggles), Scorpion light tanks, armored vehicles which Rapier SAMs, Blowpipe man-portable SAMs, 105 mm air portable light guns, mortars and several anti-aircraft radars.[674]

On 23, 24 and 25 May, the Argentineans made a series of air attacks on the British beach-head; wave after wave of Skyhawks and Aermacchis, supported by Mirage and Dagger fighters repeatedly bombed both the beach-head and the Task Force ships in the Bay of San Carlos. On 23 May, during one of these attacks, the British Type 21 frigate *Antelope*, on a reconnaissance mission in Falklands Sound was hit by a 5000-pound bomb that penetrated the engine room, but did not detonate. It exploded while bomb experts were trying to de-fuse it, killing two officers, and breaking *Antelope's* back.[675]

In spite of extremely heavy losses, Argentinean aircraft continued their day-long attacks on the British ships with great courage and skill throughout 24 and 25 May. At 18.30 on the 25 May, a formation of Skyhawks bombed and sank the Type 42 destroyer HMS *Coventry*. Another air formation, including Super Etendards armed with Exocet missiles, headed for a large target, which they mistook for the aircraft carrier *Hermes*, it was in fact the container-vessel *Atlantic Conveyor*. An Exocet hit the ship, which was transporting Wessex and Chinook helicopters and spare parts. She was badly damaged and sank shortly after the crew had abandoned ship. The loss of equipment on board the *Atlantic Conveyer* was a very severe blow to the Task Force. The tactics used in attack were almost identical to those employed against *Sheffield.* When the pilots of the Super Etendards "popped-up" to an altitude of 500 feet to check the situation in the area, their radar screens showed a large target surrounded by several smaller targets, which were the escort ships. as soon a they were alerted, the escort ships began to launch huge quantities of chaff which was effective in confusing and deviating the Exocet missiles. However, quite by chance, one of the wandering missiles hit the *Atlantic Conveyer* which, being a merchant ship, had no electronic self-protection equipment.[676]

During the next few days, the 6,200-ton "County" class destroyer *Antrim,* the 4,000-ton Type 22 destroyer *Broadsword* and the 3,200-ton Exocet-armed "Leander" - class frigate *Argonaut,* as well as several landing craft and logistic vessels, were damaged during Argentinean air raids. During these attacks, the Sea Wolf anti-missile system installed on Broadsword was used for the first time, scoring a hit and destroying an Argentinean Skyhawk. Another Task Force ship, *Brilliant,* was also equipped with the Sea Wolf system, but neither ship had an opportunity to use these anti-missile missiles against the Exocet during the Falklands war.[677]

The tactic adopted by the Argentinean pilots was simple but clever. Their attacks were carried out of dusk in formations of from four to ten aircraft of various types. These would all head for the same target in order to "saturate" the ship's radar and other AA defenses. They flew in almost at sea level and headed for the northern tip of the archipelago, using the islands and their hills to shield them from the British ships' radars. They would then suddenly swing round and all appear simultaneously from behind the coastal ridge of the northernmost island and attack their chosen target-ship from all sides. The British radar operators were unable to track all the hostile aircraft simultaneously and one or two of them almost always managed to slip through and launch their bombs and rockets. The ships' ESM equipment also proved ineffective, when this situation tactic was used, as the Argentineans flew with their radars switched off, so there were no electromagnetic emissions in the air to be picked up.[678]

Meanwhile, the troops, which had landed at Port San Carlos, by this, time well organized from a logistic point of view, began their march towards Port Stanley, following two routes. One group marched toward Douglas and Teal Inlet over very difficult terrain while the other group marched toward Darwin and Goose Green in the southern part of the island.[679]

On 27 May, a major battle for the conquest of Goose Green airfield began. Pucaras and the British troops supported the Argentinean troops by Harriers. The battle lasted about fourteen hours, most of it fought by night, to the advantage of the British troops who were equipped with light intensifiers and infrared goggles and were thus able to employ NATO night combat tactics.[680]

The Argentineans put up strong resistance but were unable to prevent the two important locations of Darwin and Goose Green falling into British hands. It was soon apparent that the British soldiers, all volunteers, were far superior to the Argentineans, most of whom were very young, inexpert conscripts. Moreover, the cold climate of the Falklands favored the British Marines and Paras who had been acclimatized to cold environments during NATO training exercise in Northern Europe beyond the Arctic Circle.[681]

Both sides suffered heavy losses in the battle of Goose Green. According to the British, the Argentineans lost 250 men, while 1,400 were taken prisoner. The British suffered seventeen dead and thirteen wounded. The conquest of Goose Green provided the British with a base from which they would advance toward Port Stanley.[682]

30 May brought yet another fierce Argentinean attack on the Task Force that had meanwhile stepped up its air and naval bombardments of installations at Port Stanley. The Task Force was stationed at a distance of 95 miles to the northeast of the Falklands, from where Sea Harriers took off from *Hermes* and *Invincible* to attack Port Stanley. Taking part in the Argentinean attack were two Super Etendards, one carrying the last remaining Argentinean Exocet missile, four A-4 Skyhawks and six Mirages and Daggers (Israeli-built Mirage developments) which had the task of distracting and busying the radars on board the British ships. before the Super Etendards came in to attack, Skyhawks and Daggers, approaching from the east, managed to get round British ground anti-aircraft defenses and attract the attention of the British radars and lure up the interceptors from the *Invincible*. While this was going on, the Super Etendards came in to launch the last remaining Exocet missile, which, according to Argentinean sources, hit *Invincible*. Two Skyhawks were shot down during the attack, and the British repeatedly denied any damage to *Invincible*.[683]

The Argentinean lost about a third of their aircraft in the course of these air attacks. The lack of equipment for electronic warfare on most of their aircraft no doubt contributed greatly to these heavy losses. The only aircraft that had such equipment were the Super Etendards and Daggers, which were fitted with RWRs', provided by French and the Israelis, respectively.[684]

British losses, on the other hand, were aggravated by their choices of Port San Carlos as the site of their landing-operation. The clutter created by the surrounding hills considerably reduced the effectiveness of the British air defense radars. It is also worth pointing out that British losses would have been much greater if all the bombs that hit their ships had exploded. The failure of many bombs to explode was probably due to the fact that the Argentinean pilots were forced to fly so low that there was not enough time between launching and impact for the bombs to auto-activate.[685]

The British troops continued their advance toward Port Stanley using a "leapfrog" tactic that involved covering short distance rapidly by night. Attacks were preceded by air and naval bombardments of Argentinean defenses and were supported by artillery and mortar fire aided by infrared and electro-optical aiming systems.[686]

Firing was directed and coordinated by three interacting electronic systems. The first, called FACE was a mini-computer which calculated firing data; the second, called ALICE, automatically transmitted this data to field artillery; the third, called AWDATS, programmed the simultaneous firing of twenty-four artillery pieces at various locations.[687]

British mortar and gunfire was extremely accurate, as a result of these electronic systems, and Argentinean positions suffered heavy punishment and their radars and other communications systems were frequently put out of action. The British also had an excellent information service based on interception of tactical communications and on reconnaissance carried out by special scouting squadrons. In this way, British commanders always knew where the enemy was and what he was doing. On one occasion, jus after a bombardment, they intercepted a radio message in which Brigadier General Mario Benyamin Menendez expressed the fear that, if things went on that way, the Argentinean situation might worsen rapidly; the British, therefore, had the advantage of knowing just how precarious the Argentinean situation was.[688]

On 6 and 7 June, with the final attack on Port Stanley close at hand, numerous commando raiding parties of highly trained men were sent behind Argentinean lines to destroy radar and radio installations, with the aim of paralyzing enemy communications. Again in the field of communications the British misinformed the enemy by means of deceptive measures, propaganda and infiltration, greatly assisted by the cooperation of the Falkland islanders.[689]

Besides having their messages read by the British, the Argentineans also had the misfortune to receive information from the Soviets, which often turned out to be mistaken or out-of-date. On the other hand, the Argentineans could always get accurate information regarding British actions via interception of tactical communications between aircraft, ships and ground forces.

On 8 June, the Argentinean air force initiated another series of deadly attacks on British ships and troops in Port Stanley area, causing the British to delay their assault on the capital. During one of these attacks, the two landing-ships, *Sir Tristan* and *Sir Galahad*, were badly hit by Argentinean aircraft, causing many casualties among the troops who were trying to land. The Argentineans were greatly helped by a mobile radar unit, a Westinghouse AN/TPS-43, which had been set up in a place called "Supper Hill". This large American 3D radar was part of the Command Information and Control Center (CIC), which the Argentinean air force had set up in the Falklands to coordinate air defense operations. The British made several attacks on this radar, one using anti-radar AGM-45 Shrike missiles launched by a Vulcan long-range bomber. However, these attacks were unsuccessful and the radar functioned effectively right up to the end of the war.[690]

On 11 June, during another Argentinean air attack in the Falklands Channel, the 2,800-ton frigate *Plymouth* and the assault-ship HMS *Fearless* were badly damaged.[691]

Meanwhile, British troops were getting closer to Port Stanley and on the night of 11 June, with the help of Lynx Helicopters armed with rockets, they made a surprise attack on enemy defenses. The Argentinean soldiers were sleeping but nevertheless reacted with fierce determination, engaging in hand-to-hand combat for several hours. They were finally forced to retreat, however, leaving Two Sisters hill to the British.[692]

Meanwhile, Task Force ships continued to bombard installations in the area of Port Stanley. On 11 June, during one of these shore bombardments, the large 6,200-ton missile destroyer *Glamorgan* was hit by an MM-38 Exocet missile launched from a shore-battery; the ship was hit in the stern, 2 meters above the water-line and, although the missile did not explode, ten members of her crew were killed and seventeen injured. *Glamorgan* had been located by the Westinghouse AN/TPS-43F radar and, given the accuracy of this system and that of the Exocet missile itself, it seems strange that the ship was hit only at an extremity and not mid-ship, as in the case of *Sheffield*, especially since she was drawing near the coast at the time. Unofficial British sources attributed this to the combined use of active ECMs (presumably a Bexley deception jammer) and chaff.[693]

The British had by now occupied all the hills surrounding Port Stanley and, on 12 and 13 June, kept up steady, accurate and selective bombardment on the Argentinean Garrison who had withdrawn into the built-up area of Port Stanley itself. In these last phases of the air-to-ground battle, laser beams were used as support measure for aircraft at close quarters. Harriers launched in particular, laser-guided bombs against laser-illuminated targets, employing tactics similar to those used by the Americans in Vietnam.[694]

The first attacks took place in the area between Two Sisters farm and Mount Tumbledown. Two separate attacks were made using Harrier GR3s which launched Paveway laser-guided bombs[695] from a distance of 6-7 kms. In both cases, the bombs missed their target as the laser was switched on prematurely. Both times the Harriers, each carrying two bombs, came in from the south-west at an altitude of 500 feet, their approach masked by Mount Harriet. The pilot guided by a predetermined landmark, would then drop altitude and, at a pre-programmed waypoint, launch the bombs, informing the FAC (Forward Air Controller) at the moment of launch. He would then make his escape, never having sighted the target optically. The FAC, from a vantage point which enabled him to see the target without himself being seen by the enemy, would then, shortly after receiving the communication, direct the laser-been onto the chosen target. This system was also used to bomb the airfield at Port Stanley but the results were rather disappointing.[696]

Special weapons were also used in an attack on the above-mentioned Westinghouse AN/TPS-43 radar used by the Argentinean air force. At the beginning of the war, two Vulcan B2 long-range bombers had been equipped for radar suppression tasks with four anti-radiation AGM-45 Shrike missiles they operated from Wide-awake airfield on Ascension island, the nearest airbase to the Falklands available to the British involved complex pre-planning and several in-flight refueling from Victor tanker aircraft. The Vulcan raids on the Falklands were the longest combat missions ever flown. One Vulcan, serial XM 597, was used to carry out the first mission on the night of 28 May. This mission was never completed, however, due to difficulties with the in-flight refueling from one Victor tanker. Two days later, the Vulcan being coordinated with Task Force Harrier strike repeated the mission, with the attack, but its outcome was uncertain. The outcome of the last attack, made on 2 June, was inconclusive; the same Vulcan, XM 597, stayed in the area for almost an hour trying to provoke enemy radar emissions but the Argentineans switched off the radar whenever the aircraft approached for attack and so the Shrike missile was denied the emissions it needed to guide itself to the radar.[697]

However, by this time the British had the Argentinean garrison firmly in their grip and, after another surprise attack on 12 June, the latter had no alternative but to request an armistice, thus putting an end to the war.[698]

At the end of the war, both sides issued reports on losses suffered and those inflicted on the enemy but these figures did not tally. The British maintained that only one Harrier and no Sea Harriers had been shot down by missiles.[699] This type of aircraft took part in many battles in the Falklands and the fact that it avoided being shot down by missiles is probably due to the superiority of British electronic warfare equipment, all British aircraft being equipped with RWRs chaff-launchers and IR flares. Harrier pilots declared that they had often managed to avoid Argentinean Roland SAMs by making an abrupt evasive maneuver as soon as their RWR warned them that a missile was on its way. Although Sea Harriers can carry jammer pods, the only British aircraft integrally equipped with active ECM devices, however, were Vulcan bombers. Prior to their departure for the Falklands, these aircraft were equipped with US AN/ALQ-101 jammers housed in pods that had been taken from BAe Buccaneers. This is no doubt one of the reasons why no Vulcans were lost.[700]

The Royal Navy Sea Harrier, being a multi-role aircraft, was already equipped to carry the US AIM-9L Sidewinder air-to-air missile, whilst the RAF Harrier tactical attack aircraft was hastily modified to carry AIM-9Ls AAMs as the Task Force sailed for the Falklands. The AIM-9L belongs to the third generation of the famous infrared guided AIM-9 Sidewinder family which is in service with many NATO and other western air forces. Being designed with an "all-aspect attack capability" (ALACA), it has radically altered the air combat equation since, unlike previous IR missiles; they can also be launched head-on. During the Falklands conflict twenty-four out of twenty-seven AIM-9L missiles launched successfully brought down Argentinean planes, a record that speaks for itself.[701]

Conclusion

Assessing the Falklands War from the point view of electronic warfare, several innovations were employed in ground combat, such as extensive use of night-vision systems and new night-combat tactics. However, nothing really new emerged in the air and naval fields. Argentinean use radar in air combat was rather limited and this, together with the fact British forces were equipped for electronic warfare in situations quite different from those in which they actually had to fight, meant that the real capabilities of electronic warfare systems could not be exploited to the full. A major factor is training: the British captured considerable quantities of Argentinean night-fighting and similar sophisticated electronic equipment, such as IR-goggles, and, if anything, the individual Argentinean was better equipped but lacked the training and motivation of the British professionals. It should also be mentioned that some ship of the Royal Navy were poorly equipped to deal with new threats, such as the western anti-ship missiles, in such a confused electromagnetic environment. The Argentineans made very little use of electronic warfare systems in air attacks. On the other hand, they distinguished themselves in the field of passive electronic warfare, using rapidly modified airliners, such as the Boeing 707, for ELINT missions and ESM.

The Arab-Israeli War Over Lebanon

At 11.25 on 6 June 1982, after two days of heavy air attacks and naval bombardments, the Israeli armed forces launched their long awaited and greatly feared attack on Palestinian strongholds in south Lebanon. Their declared aim was to create a 50-km buffer zone along the Israeli-Lebanese border to prevent the Palestinian from attacking Israel.[702]

As Israeli troops advanced northwards, easily overcoming Feddayeen resistance, the danger of a confrontation with the Syrian ADF (Arab Dissuasion Force) stationed in

Lebanon became more and more likely. The situation exploded on Thursday, 9 June as the Israelis approached the Bekaa Valley where 600 Syrian tanks were based, protected by an AA "umbrella" consisting of twenty surface-to-air missile batteries: Russian-made SAM-6 (mobile) and SAM-2 and SAM-3 (fixed).[703]

The entire Syrian air force was on the alert. When, in the afternoon, the three central columns of the Israeli armored forces came into contact with the advanced guard of two Syrian armored brigades, the Syrian high command immediately sent sixty MiG-21s and MiG-23s to provide close air support for their tanks. The Israelis were not taken by surprise, however, as their US made E-2C Hawkeyes, with their enormous Early Warning radars, were already orbiting along the Lebanese coast to watch for the take off of any Syrian aircraft from their bases inside Syria and guide the Israeli fighters to them. They thus immediately sent out a total of ninety aircraft: ultra-modern US-built F-15 McDonnell Douglas Eagle and General Dynamics F-16 Fighting Falcon fighters for air-combat, Israeli-made IAI Kfirs and veteran McDonnell Douglas F-4 Phantoms for air-to-surface attacks and McDonnell Douglas A-4 Skyhawks for close air support. A four-jet Boeing 707, equipped for EW, was also sent up to intercept and jam enemy radars and communications from outside the range of Syrian's weapons (stand-off jamming). As the Syrian aircraft approached the "hot" zone, the Israelis, thus cutting off route and attack instructions jammed radio communications between them and ground commands.[704]

The Israeli pilots, on the other hand, were perfectly vectored by the E-2Cs to the optimum positions from which to attack the Syrian MiG aircraft. The Israeli aircraft were all equipped with the latest automatic computer-controlled EW equipment, as well as laser devices for target designation, Infrared AIM-9L Sidewinder air-to-air missiles and AGM-45 Shrike and AGM-65 Maverick anti-radar missiles. Thus, confident in their utter professionalism and electronic superiority, the Israeli pilots flew at full speed toward the enemy.[705]

Every Israeli aircraft was equipped with an HUD (Head-Up Display) that greatly reduced the pilot's workload. In this system, data for navigation and combat are calculated by computer and transmitted to a presentation processing unit which transform the data into blue and orange phosphorescent optical images which are then projected onto a glass screen just behind the windscreen. HUD systems usually operate in conjunction with a radar or LLLTV system and provide the pilot, whatever the conditions of visibility, with an accurate "picture" of his immediate surroundings and the enemy air situation so that he is not distracted by constantly having to look down at the various flight instruments in the cockpit or make difficult navigational calculations.[706]

The Israeli aircraft were also equipped with the very latest fully automatic, computerized deception jammers which were able to send even the most advanced missiles off course, thus ensuring the survival of the pilot, and RWRs which immediately warned him that his aircraft was being "locked-on" by a tracking radar or the radar-seeker of a missile itself. Each Israeli aircraft was also equipped with expandable passive countermeasures, both chaff and IR flares, to be launched at the right moment to "distract" oncoming missiles.[707]

As soon as the ninety Israeli aircraft penetrated the air space over the Bekaa valley, they were immersed in a huge mass of electromagnetic emissions coming from hundreds of enemy radars and radios present in the zone. In moments such as this, it is imperative for the pilot to immediately analyze and identify all air defense radars and ground-to-air missiles and to determine the position of enemy interceptors, all of which constitute a serious threat to his survival. Neither his own brain nor traditional avionics are able to deal with such a large number of threatening signals and ascertain which constitute the greatest dangers. It is at this point that computer "software" (i.e. all the programmed information and logic previously and preventively fed to the computer) proves to be the vital asset. In this way, the Israeli pilots were able to approach the enemy aircraft, mainly by following the vectors received from the E-2C Hawkeyes.[708]

The RWR on board his plane would alert the pilot that the radar of a SAM battery had locked on to his aircraft. Almost instantaneously, the EW computer would analyze and identify the various threats, determining their priority and the most effective defensive action to counter each individual threat.[709]

The battle went from 9 to 11 June. Throughout the combat, the Israelis made extensive use of deception jammers to divert electronically guided missiles and IR flares to divert IR-guided missiles. As soon as an Israeli pilot located a Syrian MiG via his HUD, all he had to do was to superimpose the firing symbol on his HUD over the enemy aircraft, push the relevant button to operate the most appropriate arms system decided by the computer. The IR sensor of the implacable Sidewinder did all the real work.[710]

The Syrian aircraft, on the other hand, were not furnished with EW equipment, as the Soviets usually remove such equipment from aircraft supplied to foreign countries. The Syrian pilots were also at a great disadvantage because their radars and radio communications were jammed by the Israeli Boeing 707. Furthermore, support from ground AA batteries was very limited due partly to Israeli jamming of their radars and partly to the large number of aircraft present in the sky, which meant that there was a great risk of hitting their own planes.[711]

As usual, there are discrepancies between declared losses of both sides. The Israelis affirmed that they had shot down seventy-nine enemy planes, damaged at least seven and destroyed nineteen of the twenty deployed SAM-2, SAM-3 and SAM-6 batteries while their own sustained losses amounted to only one aircraft. The Syrians declared that they had shot down nineteen enemy aircraft.[712]

Besides their extensive use of EW systems, the Israeli victory must be in part attributed also to new tactics that were used for the first time in this battle. The most important of these was the tactic used for attacking SA-6 missile batteries. Some time previously, the Israelis had installed a certain number of mock-up SA-6 batteries in the Negev desert for training purposes, against which they flew both ordinary aircraft and RPVs.[713]

The suppression of enemy AA defenses is an indispensable preliminary to actions that require the penetration of enemy air space and the establishment of air supremacy. The Israeli Air Force, therefore, set about destroying, both before and during the air battle in the skies of Lebanon, Syrian ground-to-air missile batteries, which constituted a deadly threat to their own strike aircraft. All available means were used to this end, including the Israeli-built Scout and Mastiff RPVs.[714]

These RPVs are very small–with a wingspan of just 3.60 m, the Scout is only 3.51 m long and 0.94 m high; moreover, they are made of fiberglass, which is transparent to radar. Consequently, they are difficult to detect and locate by enemy radars and are thus able to penetrate enemy air space with minimal risk of being shot down. For this reason, they are ideally suited to the tasks of battlefield reconnaissance and surveillance. Some versions were equipped for such missions with a TV camera with zoom lenses and a transmitting system that could send back to its ground controller a continuous flow of pictures of enemy positions. Other versions were equipped with a radar reflector, which returned radar echoes comparable to those of an attack aircraft. Others functioned as ESM platforms, intercepting and analyzing enemy radar emissions and retransmitting them to ground stations or to an aircraft in flight. Finally, some were equipped as laser-designators to illuminate a target to be attacked by laser-guided missiles.[715]

The anti-SAM operation began with a series of reconnaissance flights made by RPVs equipped with TV cameras.[716] As soon as one of them discovered a SAM battery and transmitted the images to ground command, two more RPVs were sent out, one the radar decoy, would simulate an attacking aircraft with the intention of provoking the SAM battery into switching on its radar,[717] while the other, the ESM craft, intercepted emissions from the SAM radar, analyzed them and retransmitted them to airborne E-2C and Boeing 707s.[718] The emissions received were then processed by the computers on board these aircraft to produce, in real time, data for the guidance of anti-radar missiles. One of these aircraft then gave the order for the launching of an Israeli-built Zeev surface-to-surface anti-radar missile, if the SAM battery was within its range of about 40 kms, otherwise, a Shrike-armed F-4 Phantom strike would be ordered.[719]

Sometimes, the Syrians realized that the enemy was using RPVs to intercept the emissions of their radars and thus launch anti-radiation missiles at them and would immediately turn off the radar in question to deprive the Israeli missiles of their electromagnetic homing beam. In this case, the Israelis would send out a laser-designator RPV and an attack aircraft armed with laser-homing AGM-65 Maverick missiles. Once the radar had been destroyed, the now blind SAM battery was attacked by cluster bombs that destroyed both the missiles and their associated vehicles.[720]

By this alternate use of RPVs and Phantoms, perfectly coordinated by the E-2C and Boeing 707 aircraft, the Israelis managed to destroy nearly all SAM batteries in the area, thus depriving the Syrian armored columns of AA defense.[721]

The unprecedented successes of these air operations were no doubt enhanced by the experience gained during the war between Iraq and Iran when the Israelis made a lightning air attack on the Iraqi nuclear reactor under construction at Tammuz, about 20 km from Baghdad. The raid was carried out on 9 June 1981 by a formation of eight F-16s and F-15s flying at very low level. They flew over the northern part of Saudi Arabia, along the Jordanian border and through Iraqi air space as far as Tammuz. They attacked the target and, without meeting any resistance, took the direct route through Jordan back to Israel. As a result of the meticulous planning and use of ECMs, the Israeli aircraft managed to avoid detection by Saudi, Iraqi and Jordanian radar surveillance as well as the very advanced airborne radars of the AWACS on loan to Saudi Arabia from the US Air Force![722]

Another new air combat tactic used for the first time in Lebanon by Israeli pilots was that of effecting the final phase of an attack against enemy aircraft from the side in order to have larger target areas.

On the ground, outstanding results were achieved by laser rangefinders, laser target-designation systems and wire-guided TOW missiles, all controlled by computer. During one of the first actions between Israeli armored columns and the advanced elements of the two Syrian armored brigades, which took place on 9 June at the southern end of the Bekaa valley, the Syrians lost about sixty T-55 and T-62 tanks. The next day, further north in the Bekaa valley, there was a major battle between 300 to 400 Israeli tanks and about the same number of Syrian T-55 and T-72 tanks deployed along the road running from Beirut to Damascus. Israeli artillery and helicopters armed with TOW missiles also took part in the battle and, according to the Israelis all the Syrian tanks were put out of action, many of them being captured.[723]

Alarmed by the poor performance of the aircraft and missiles they had supplied to Syria, the Soviets immediately sent a group of experts, headed by the vice commander of the Soviet air force, to Lebanon and had a damaged T-72 tank sent to Russia for examination.[724]

As a first step toward making up for the losses of the SAM-6 launch pads, the Russians supplied the Syrian air force with a number of ground-to-air SAM-8 *Gecko* and SAM-9 *Gaskin* missile systems. The SAM-9 was first seen in November 1975 in the annual military parade to commemorate the October Revolution. It was, therefore, by no means new, but, in Lebanon, it almost immediately succeeded in shooting down an F-4 Phantom on 25 July, probably because the Phantom was not electronically prepared to meet the new IR threat. The Israelis later managed to capture SA-8 and SA-9 missile systems, as well as T-72 tanks, about which systems little was known in the West. This led to the development of ECMs that enabled the Israelis, in September 1982, to destroy five or six such missile batteries in Lebanon.[725]

Generally speaking, these battles in the Bekaa valley proved the effectiveness of the coordinated use of electronically controlled arms with the necessary EW back up. But, above all, those air and surface conflicts together provide the first example of warfare in "real time"; warfare in which air reconnaissance, the distribution of its results to attacking forces and the attacks themselves were carried out almost simultaneously in rapid succession, closely coordinated with the extensive use of EW systems. The outstanding results achieved by the Israelis show that the new concept of "real-time" warfare, supported by accurate planning of EW actions, was the real key to their success. Military commanders from all countries should give thought to the events that took place in the Bekaa valley in July 1982 as they give an idea of what future battles will be like.[726]

French and American Air Operations over Lebanon

The Israeli victory in the Bekaa valley in 1982, like their previous victories in 1967 and 1973, did not solve any of the problems of the Middle East. The bloody war in

Lebanon dragged on inexorably. Throughout 1983, there was a long sequence of battles between the opposing factions, assault, massacres, air raids, Israeli aircraft and RPVs shot sown, all culminating in the terrible truck-bomb attacks on the barracks of French soldiers and US Marines of the international peace force in October 1983, in which hundreds of men were killed and injured.[727]

Of course, it was not long before reprisals were sought and the first to take action were the French. On the afternoon of Thursday, 17 November 1983, eight Super Etendards took off from the aircraft carrier *Clemenceau*, which was cruising about 100 miles off the Lebanese coast. The aircraft headed inland toward Baalbeck to attack the old Lebanese barracks of Sheikh Abdullah, occupied by Islamic volunteers suspected of having organized the bloody attack on the barracks of the French paratroopers.[728]

The target-area assigned to the pilots of the Super Etendards was very small and a thorough air-photographic reconnaissance had been carried out a few days previously. Orders for the mission had come from Paris but the choice of the day had been left to Rear-Admiral Klotz on board the *Clemenceau*, depending on local weather conditions and other relevant factors.[729]

The eight Super Etendards each carried one 400-kg bomb and three 250-kg bombs. Air cover was provided by two French F-8E (FN) Crusader fighters flying patrol above the Super Etendards, ready to intervene if Syrian aircraft should appear. However, the chances of success of such a mission would have slim indeed without the protection of standoff EW-equipped aircraft.[730]

It is no secret that the Syrians, through Russian aid, have set up unprecedented AA defense coverage of Lebanese airspace comprising: SAM-2 missiles with a range of 25-30 miles, SAM-3s with a range of 16-19 miles, SAM-5 (based in Syria) with a range of 185 miles, SAM-6 with a range of 19-38 miles and SAM-8 with a range of 8 miles (all with radar guidance), portable IR-guided SAM-7 with a range of 6 miles and new IR/radar-guided SAM-9 missiles with a range of 5 miles and numerous conventional AAA batteries of the 23 mm ZSU-23-4 and 57 mm ZSU-57-2 types (both with radar guidance).[731]

The need for EW-equipped aircraft was obvious and, since the *Clemenceau* was not carrying any such aircraft, the French sought help from the US Sixth Fleet, which had for some time been present in the watres of the east Mediterranean. The Americans provided Grumman EA-6B Prowlers for standoff jamming; during the entire raid carried out by the Super Etendards, the Prowlers jammed enemy search radar and weapons-guidance radar from a position outside their range.[732]

Guided by their inertial navigation systems (INS), the French pilots managed to achieve a surprise attack, each group making a single-pass attack of first two, then four, then two aircraft. The first six dropped their bombs as scheduled but the last two were prevented from doing so by fierce AA fire from the ground.[733]

On completion of the mission, the French air commander decided that, as the massive Syrian air defenses were now alerted, it would be unwise to send a photoreconnaissance Etendard IVP to confirm the results of the mission. Nevertheless, the mission was held to have been technically 100 percent successful.[734]

A few weeks later, on 4 December 1983, the Americans organized a reprisal mission against Syrian missile bases that had, in the last few days, attacked US reconnaissance aircraft patrolling the area. At dawn, sixteen Grumman A-6E Intruders and twelve LTV A-7E Corsairs II attack aircraft took off from the aircraft carriers *John F. Kennedy* and *independence*. As is usual for this type of mission, called air defense suppression, E-2C Hawkeye Early Warning aircraft were first sent on missions of stand-off deep search to locate Syrian missile batteries. A number of CAP (Combat Air Patrol)

Grumman F-14Tomcats escorted the formation from a distance. Last, but not least, there were, of course, the ECM-equipped EA-6B Prowlers, which had the task of jamming enemy radars.[735]

The task of suppressing the Syrian AA batteries was shared by the A-7E Corsairs and the A-6E Intruders: the former had to attack the SAM radars and AAA radars with Shrike anti-radiation radar missiles (ARM) while the latter destroyed the missile launchers.[736]

However, the departure of so many aircraft did not escape the notice of the Soviet cruiser and spy-ship which, as usual, were shadowing the US Sixth Fleet formation, presumably, fearing another disaster in which the weapons they had delivered to the Syrians might be demolished and the Soviet military advisors in the zone harmed, the Russians immediately informed Damascus via radio of the departure of the large US air formation. Consequently, the Syrians had all the time they needed to prepare a suitable reception for the pilots of the US Sixth Fleet.[737]

Thus the US aircraft encountered about seventy Syrian SAM batteries plus an unknown quantity of AAA batteries waiting for them in full alert. They went into attack in a long stream that made it easy for the Syrians to adjust their fire. The Syrian radar operators used their radars only intermittently, which meant that not all the ARMs could be launched. During the fourteen or fifteen minutes that the attack lasted, at least forty missiles were launched and countless rounds of AAA ammunition fired against the US aircraft. When the US formation set course back to the carriers, one A-6E and one A-7E were found to be missing while another aircraft was flying with its jet pipe partially destroyed by an IR-guided missile. The pilot of the A-7E, which had been shot down, had managed to eject from his aircraft and had been picked up from the sea near Jounieh by a

Lebanese navy patrol boat. The pilot of the two-seat A-6E was killed and the navigator was taken prisoner, but was released on 3 January 1984 after a month in prison.[738]

According to US Navy officials, the mission achieved the result of preventing further Syrian attacks on US reconnaissance aircraft. Nevertheless, the loss of the two-aircraft was felt by many to be a humiliation for the US Navy, especially after Israeli aircraft carried out two similar attacks in Lebanon, on 3 and 4 January 1984, with no casualties. Twelve aircraft took part in the first of these raids, on the Islamic Volunteers training camp at Baalbeck; only four aircraft Israeli-built IAI Kfir attack aircraft, actually carried out the attack, while the other eight provided air cover and ECM escort (jamming of enemy radars and the launching of chaff and IR flares). Sixteen Israeli aircraft took part in the second raid and this time only two carried out the actual attack while the other fourteen were used for long range escort and for surrounding the attackers with a protective barrier of chaff, heat balloons and IR flares.[739]

It was inevitable that the American raid should be compared to those carried out by the French and the Israelis; there was almost unanimous agreement that the difference lay not in the expertise of the pilots, nor in the performance of their aircraft nor the tactics employed, but solely in the countermeasures used. According to US Navy officials, the cause of the loss of the US aircraft and the damage inflicted on the third was that the Russians had modified the IR sensors of their ground-to-air SAM-7 and SAM-9 missiles. More precisely, in fact, it was the wavelength and filters of the sensors, which had been changed, enabling the missiles to home onto the exhausts of the aircraft without being decoyed by the IR flares launched by the Americans. These modifications made by the Soviet electronics industry were, however, predictable given the high susceptibility of SAM-7 missiles to IR countermeasures shown in all conflicts from the October 1973 War onwards. The cause of this susceptibility to IR flares was that the uncooled heat seeker was easily "pulled out" of its lock-on to the aircraft's heat signature, being attracted by the greater heat produced by the IR flare. The new SAM-7B version has the following characteristics, according to US Navy experts:[740]

- Improved filters better to distinguish a real from a false target.
- A different wavelength.
- A more sensitive cooled heat-seeker.

These improvements were also made to SAM-9 *Gaskin* missiles, which are mounted on a vehicle in-groups of four, unlike the SAM-7 which is a man-portable shoulder-launched missile. To enhance the acquisition capability of new SAM-9 arms system, *Gun Dish* radar was mounted on the vehicle endowing the system with remarkable precision. This well-known fire-control radar id used to control the Russian ZSU-23-4 *Shilka* system of four-barreled 23 mm cannon.[741]

Furthermore, it is probable that the Syrians deployed not only the whole range of Soviet SAM systems, from the SAM-2 to the SAM-9, but also the latest SAM-10, SAM-11 and SAM-13 systems designed to replace the SAM-4, SAM-6 and SAM-9, respectively.[742]

To counter such an impressive display of AA arms, the US A-6E and A-7E did, nevertheless, have a range of ECM systems just as respectable as those of the aircraft of the Israeli air force. Presumably, the US A-6E and A-7E had the following equipment: two AN/ALE-39 Countermeasures Dispensers each capable of launching thirty RR-129 chaff units and thirty IR flares; an AN/ALR-45 RWR with automatic chaff launching; and an ALQ-126 deception jammer, a latter version of the ALQ-100.[743]

However, what the Israeli aircraft did have and the US A-6Es and A-7Es did not have was a simple infrared countermeasure which considered in lengthening the jet pipe of the engine so that a missile would detonate at a point sufficiently removed from critical structures to reduce resulting damage to survivable proportions. The Israelis also used this device on the General Dynamics F-16 Fighting Falcons they received from the United States. Unfortunately, it cannot be applied to carrier-borne aircraft since, with such long jet pipes, aircraft would not fit in the lifts used to transfer them between the hangars to the flight deck.[744]

However, the Americans did have an IRCM device, the AN/ALQ-123, which deceives a missiie's infrared seeker reticule. IR deception operates in a similar way to EW deception of a conical scan radar. In practice, an IRCM device emits a suitably modulated emission of IR energy which, when combined with the heat (IR energy) emitted by an aircraft's jet pipe, creates an angular deception signal which causes the missile's seeker to aim in the wrong direction.[745]

So far, however, neither the AN/ALQ-123 system nor IR flares have been effective enough to ensure the survival of the pilots of aircraft equipped with such IRCMs, because the pilot never knows exactly when to activate the systems. Each aircraft can carry only a limited supply of flares that may, in certain circumstances, already have been exhausted before the point of greatest danger is reached. The other system, active deception, can have counter-productive results if activated too soon or at the wrong moment.[746]

The only solution to these problems is an effective infrared warning receiver (IRWR), but it seems that the main defect of IRWRs–that of false alarms–has yet to be overcome by the Americans. Modern IRWRs are extremely effective in detecting a source of heat but, unfortunately, this heat can come from any nearby source, not only a missile, and the result in an unacceptably high number of false alarms (the same problem affects IR homing missiles). Few nations have managed to solve this difficult technological problem and those that have naturally keep their finding top secret.[747]

In the first analysis, one can safely say that the two American aircraft were shot down and the third damaged, once again, because of shortcomings in their protective EW systems that were not sufficiently advanced to counter the latest threat. Even the United States of America, which spends astronomical sums of defense and possesses the most advanced technology in the world, found themselves imperfectly prepared in Lebanon as far as IRCMs were concerned, just as had been the case with ECMs in the Vietnam War.

Important Lessons from the Falklands and Lebanese Wars

The events so far described once again show that the face of warfare has changed, in that new elements and new operational concepts have come into play in the military arena.

The first new element derives from computer technology. The Royal Navy, with its centuries-old tradition of glorious naval warfare, owes its success in the Falklands also to the excellent organization of command, control, communications and Intelligence. The integration of these disciplines has been designated C^3I in the West, the exponential expression (C *cubed* I) being used to underlines the multiplied effectiveness gained by joining together and strengthening the individual networks of command, control and communications. [748]

In air, naval and ground warfare, command decisions must be fast and based on accurate information. Modern computerized C^3I systems are able to furnish, in "real time", those responsible for making decisions with all the intelligence needed to provide an overall picture of the situation so that they can make a rapid evaluation and take the most appropriate action to deal with the threat or threats.[749]

The Israelis have also exploited C^3I systems in their air and ground operations with excellent results. Particularly, in their coordinated use of aircraft and RPVs for reconnaissance in "real time" and in their attacks on the Syrian SAM bases in the Bekaa valley. C^3I systems enabled the Israelis to acquire all relevant information about the enemy and pass it on without delay to those in command.

Another element, which contributed greatly to the Israeli success in Lebanon, was the coordinated use of ECMs against enemy command, control and communications systems. These countermeasures, which are not only electronic, are designated C^3CM.[750]

In all the conflicts between the Arabs and the Israelis in the last ten years, losses have been in favor of the Israelis, but never to such a degree as in their battles against the Syrians in Lebanon. A ratio of aircraft losses of over 50:1, the suppression of the entire network of Syrian SAM systems in the Bekaa valley with every little damage to themselves, and the destruction of so many enemy tanks can be attributed to many factors, two being better tactics and better training.[751]

However, this time there were extra elements. First, the widespread, coordinated application of ECMs and weapons systems against enemy command, control and communications systems. Just before or just at the outset of a battle, weapons systems and ECMs were used against enemy radars, communications networks and command and control centers with the result that the enemy was paralyzed, unable to see, hear or communicate in any way. A clear demonstration was given of how to conduct Electronic Warfare, taking maximum advantage of the concept of C^3 Countermeasures (C^3CM) and fully exploiting "real-time" reconnaissance. The Israelis demonstrated the highest degree of coordination between RPVs, guidance and control of their own aircraft using E-2Cs, jamming of radar and communications using the Boeing 707 and, finally, the actual means of material destruction themselves, such as aircraft armed with anti-radar missiles or RPVs, full of explosive, targeted against enemy radars and SAM-6 batteries.[752]

If C^3CM systems continue to progress at the rate they have been doing in recent years, the point will soon be reached where battles can be won before they even begun! It will be sufficient to use ECMs and appropriate arms (anti-radar missiles, anti-antenna munitions and so on) just before the battle is about to begin to paralyze the "brain and central nervous system" of the enemy, –his C^3I organization. In addition, the use of computers and microprocessors has also revolutionized fire control and missile guidance technology, making modern weapons increasingly accurate.[753]

Events in Falklands and Lebanon have also shown that Airborne Early Warning radar (AEW) will be indispensable in future air battles. The Israeli's intelligent use of E-2C Hawkeyes to detect and track the Syrian fighters as soon as they left their bases, together with the use of passive ESM systems to locate and identify enemy radar and missile installations are two more important factors in their success. In contrast, the British sorely lacked an Airborne Early Warning capability during the Falklands War and, consequently, enemy aircraft and missiles could surprise their ships.[754]

The importance of RPVs for the purposes of Electronic Warfare has also emerged from the operations in Lebanon and these will no doubt have more widespread use in future.

Today, a Task Force must have an integrated defensive coverage composed of systems covering a series of concentric circles of decreasing radii. Proceeding from the outer perimeter to the center of the Task Force, these circles contain the following elements:

- Airborne Early Warning radars (AWACS, E-2C, etc.) linked to combat air patrol or interceptor aircraft to shoot down enemy aircraft before they are within range to launch their missiles or expend their bombs.
- Surveillance systems, installed on ships and/or helicopters deployed some distance away from the main body of the Task Force and consisting of ESMs for detection and identification of the threat; naval radars to search for the

threat and for target designation; jammers to be used against enemy search radar and to prevent, or at least delay, attacks by enemy aircraft.

- Long and medium range SAMs and AAMs to be used against any aircraft that manage to penetrate the above defenses.
- ECM helicopters to create artificial false radar targets and dispense decoy chaff and flares.
- Infrared Support Measures (IRSM) to detect low-flying missiles and/or aircraft via heat-emission, and for precise arms designation.
- Anti-missile deception jammers, anti-missile missiles and expandable missile anti-homing deception jammers for use by ships under missile attack.
- Modern anti-missile guns (Close In Weapons System-CIWS).

Ships of the *Sheffield's* class, Type-42 destroyers, could certainly have been equipped with more advanced Electronic Warfare systems than they actually were, since such systems were already, in fact, in production by the British defense industry. The reason why such ships were not equipped with the latest equipment is perhaps that, because of the usual cuts in the British Defense budget, the Royal Navy thought they would install their latest EW equipment only on new ships of later construction, and not retrofit existing classes.

The Task Force ships also lacked modern passive IR systems for the detection of aircraft and, above all, low flying "sea skimmer" missiles. A modern, panoramic IR search system would certainly have enabled the British ships to detect and locate Exocet missiles, even at extremely low altitudes, since IR systems, unlike radar, are immune to clutter.

Events in the Falklands teach the important lesson that, in order to detect the deadly threat of modern missiles, ships can no longer rely solely on radar and ESM on board but must have recourse to all the latest findings and improvements which modern technology places at their disposal. In addition to the aforementioned IRSMs, the fleet must be equipped with modern, expandable ECM systems–for example, deception jammers launched by missiles against an anti-ship missile–and helicopters dedicated to EW which, taking advantage of their mobility should place themselves between the threat and the ships threatened, jamming or deceiving the missiles and their command platform.

It emerges, from all the air and sea battles fought in the Falklands, that the anti-ship aircraft-missile combination in this case (the Super Etendard-Exocet) has truly revolutionized sea warfare. However, no definitive conclusion can be drawn about the performance of this combination versus warships off the Falklands since, in the final analysis, most of the British ships lost in the South Atlantic sank due to inadequate damage control and fire-fighting systems.

The Falklands War, like those modern wars examined previously in this book, also brought to light shortcomings in the field of intelligence. Despite clear signs of imminent Argentinean action against the Falklands, Great Britain failed to foresee the invasion. It would have been sufficient to send nuclear-powered submarines and a number of aircraft and ships to dissuade the Argentineans from an undertaking, which, as the events themselves have shown, was destined to fail.

The gravest error on the Argentinean side was that of underestimating the British reaction. They deluded themselves in believing that the *fait accompli* would sooner or later be accepted by the British who, in the last ten years, had divested themselves of more important dependencies than the Falklands, and who were on the verge of making further drastic reductions to their fleet.

However, at the tactical level, especially the British took great care with intelligence, and it was one of the factors that most influenced the outcome of the battles in the Falklands. In fact, drawing on a variety of technical and other sources, the British Forces always had substantially better information regarding Argentinean force levels, deployment, tactics and intentions compared to the quality and quantity of information the Argentineans had regarding UK forces. one can accurately say that British Intelligence had a strong influence on the outcome of ground battles in the Falklands and the British campaign would have gone on much longer without the contribution.

In general, the experience of the Falklands demonstrated the necessity of having precise, up-to-date information regarding the performance of weapons and sensor (i.e. radar, IR, laser, etc.) systems of all world powers, whether potential enemies or allies. Above all, it showed the need to make a greater effort in collecting and analyzing information regarding all potential threats and not only what is considered by the Western nations to be the greatest–the USSR.

Events in Falklands and Lebanon have also provided confirmation that ground warfare has changed substantially. In the Falklands, the British nearly always attacked by night, using night-vision devices and weapons especially designed for night fighting and employing tactics involving making quick, surprise attacks on the enemy without being seen. In Lebanon, the Israelis employed modern anti-tank techniques, which they had devised themselves and led to the destruction of a number of T-72, tanks–the pride of Soviet military industry.

Consequently, in order to survive, modern armies must make sure that their tactics are in step with the latest developments in electronic and electro-optical technology, which, along with rigorous training and aggressiveness, are the winning factors on the battlefield.

In the air, the AIM-9L Sidewinder air-to-air missile was used with great success by the British Harrier fighters to shoot down Argentinean aircraft and by the Israeli fighters against Syrian aircraft. It represented a triumph for infrared technology. The ability of the AIM-9L version to hit an enemy aircraft from any direction (All-Aspect Capability – ALASCA), and not only from behind, as was the case with early AIM-9 versions, gave the British and Israeli pilots an enormous advantage which no amount of maneuvering by some enemy ace could match.

However, as was shown by the shooting down of the US A-6E and A-7E by the Syrians over Lebanon, the growing use of IR technology has also become the most insidious threat for the pilots of attack of close air support aircraft. The pilot of an aircraft on a penetration mission must be equipped with an IRWR (Infrared Warning Receiver) able to detect a missile not at the last moment but at the very moment of launch in order to give the pilot enough time to actuate appropriate countermeasures or commence an immediate evasive maneuver.

It is more difficult for a ship to detect an anti-ship missile because these are often launched from much greater distances than air-to-air missiles. Consequently, a ship must have an IRWR able to detect an approaching anti-ship missile flying at an extremely low altitude and which, due to its limited radar surface and the fact that its radar and navigation system may not emit, may completely escape detection by radar and ESM.

It seems likely that "stealth" techniques will be used in the future to make aircraft and missiles invisible, or almost invisible, to radar. When this happens, search radar will necessarily have to be integrated with other systems such as IRWRs and other sensors using new techniques.[755]

"Stealth" techniques are based upon several elements. In regard to the physical aircraft itself, it is essential to reduce its radar and IR signatures. Its radar reflectivity, including its scattering and diffraction properties, is a measure of its efficiency in intercepting and returning a radar signal–its radar signature–and depends upon the aircraft's shape, size, aspect and the dielectric properties at its surfaces.[756] Using radar-absorbent materials (RAM) and appropriate geometries (shapes and configurations) can reduce it. As an instance of the dramatic advances in the field, using these techniques the Rockwell B-1B, the US strategic "stealth" bomber and ASM platform due to enter service in 1987, has a radar cross-section one hundredth that of the comparably-sized Boeing B-52 and one tenth that of the B-1A prototypes of the 1960-70![757] An aircraft or missile's IR signature–that is, the heat emitted by the engine and jet-pipe–can be reduced by greater thermal efficiency and insulation, but is impossible to eliminate. In the field of equipment, use can be made of bi-static radar equipment, special radar whose receiver is installed in the "stealth" aircraft, but whose transmitter is located elsewhere, either on other aircraft or on the ground. Terrain-following radar, permitting very low-level, contour-hugging flight below radar cover to and from a target area, taking advantage of ground clutter, is standard "stealth" equipment, in use on, for instance, the RAF's Phantom FGR.2 (F-4M) tactical aircraft in the early 1970s, and its successors, the Anglo-French SEPECAT Jaguar GR.1, purpose-designed for low-level operations. In operational terms, a great deal can be done to protect aircraft by "stealth" techniques, notably using terrain-following radars and selecting the most suitable mission profiles to propagation conditions i.e. those pertaining to sending out radiation such as infrared and radar.[758]

Again, regarding air operations, it must be observed that air losses in the Falklands, especially on the Argentinean side, and in Lebanon, particularly by the Syrians, were far too high in proportion to the number of aircraft employed. This can be explained mainly by the fact that nearly all Argentinean and Syrian aircraft–and quite a few aircraft–lacked active ECMs–jammers and electronic and IR deceivers–which made it extremely difficult for them to escape the numerous types of anti-aircraft missiles used in these conflicts, such as Sea Dart, Sea Wolf, Sea Cat, Rapier, Roland and Sidewinder.

All these considerations confirm, as we seen in previous conflicts, that electronic and IR systems are essential factors in reducing air losses.

Conclusion

In conclusion, the conflicts in the Falklands and Lebanon represent an important turning point in the history of war because they demonstrate that Electronic Warfare is an irreplaceable instrument of success both in offensive and defensive operations. In particular, the battles fought in Lebanon have proved beyond any shadow of a doubt that the result of future battles will depend much less on the quantity of the aircraft, ships or tanks used than on their quality, which naturally includes new developments in the field of electronic technology.

However, Electronic Warfare is not static: the mere possession of a certain number of ESM or ECM devices is not enough to ensure success. In Electronic Warfare, what works today may not work tomorrow, and developments in EW systems must always closely and appropriately follow developments in the threat. With the endless evolution of applied military technology, electronically guided weapons are coming closer and closer to perfection and thus constant up dating and refinement of EW equipment is required.

The extremely dynamic and evolutionary character of EW also, unfortunately, demands constant, heavy financial expenditure. If a potential enemy changes the frequency of the his radars, develops a new anti-jamming device or makes some important change in the IR guidance system of missile then the potential opponent has to modify or even completely renew his own EW equipment. However, from any point of view, this is certainly the most worthwhile investment for armed forces.

When the red light of an RWR or IRWR illuminates in the cockpit of a warplane or the CIC of a warship on a mission, it means that, within seconds, a missile will hit that aircraft or ship if nothing is done. In those instants, the lives of the entire crew, the survival of the aircraft or ship and the success of the mission itself depend almost entirely on immediate identification of the missile and actuation of appropriate countermeasures. Only if the EW and IR devices can completely and immediately deal with the imminent threat, will the crew's survival and the mission's success be largely ensured.

If providing aircraft and ships with the electronic means to greatly improve their chances of survival and success appears to be an arduous and costly task, one must bear in mind that the cost of a modern warplane, warship, tank or, even more so, trained crew is very much greater than the cost of providing them with EW equipment. This investment must be made in peacetime because the price to be paid once an unexpected war has broken out will be extremely heavy.

It is, therefore, vital that intelligence is gathered continuously in peacetime by SIGINT and IRINT operations and by other means in order to acquire information regarding the parameters of new weapons systems deployed or under development by potential enemies. Finally, emphasis must be placed upon providing national facilities for technical and scientific research in order to develop the technology necessary to achieve and maintain superiority in Electronic Warfare, which has now become an obligatory route to success and the survival of a country's armed forces.

Chapter 21

Electronic Warfare in the Gulf War

"The next war will be won by the side that best exploit the electronic spectrum."

Introduction

When Admiral Sergel Gorshkov made his now famous, prediction, did he realize and anticipate that the main factor to coalesce the entire out put of the electronic medium into a worthwhile comprehensive war fighting entity would be the computer? Considering that the Soviet Union lagged behind the West in computer technology, the answer is, possibly not. Could that, then, be the cause of Iraq's [which was equipped chiefly by the Soviets] impotence?

With the advent of the radio in the beginning of the twentieth century, the electromagnetic spectrum became a determinative new war fighting media, with a direct force multiplying effect on existing weapon systems and the management of forces. Since then it has slowly but surely broadened its scope to the extent that it is now equivalent if not predominant to commonly recognizable war fighting tools.

Some systems, such as radar, radio jammers and direction finding equipment, were developed and utilized during World War II. However, it was not till much later that the evolution in this field stepped up to the point where Electronic Warfare has become an intrinsic and inescapable part of the weapon systems deployed to wage war. It substantially enhances the destructive potential of ground, air and naval forces–and is commonly referred to as "*force multiplier*". Experience in more recent years in the Falklands, Bekaa valley and the US-Libyan confrontation, accentuates the dynamic and revolutionary nature of electronic combat as well as its impact.

The Gulf War can be termed the first full-scale electronic war since World War II ended in 1945. These electronic systems form part of every single activity on the field, some embedded, others supportive, some stand alone, some active, some passive. The point to be registered is that the electromagnetic spectrum has pervaded the entire infrastructure that constitutes a war fighting potential. The need to incorporate electronic "state of the art" technology in its offensive and defensive forms has a direct bearing on future security imperatives.

A study of the application of electronic force multipliers in combat in the Gulf and other recent conflagrations, points to numerous lessons that under developed countries should be loath to have to relearn at the expense of their national security and economic well being. What should the under developing world have learned from all this? And how can they avoid having to relearn the same painful lessons at high costs in men and material and potentially high risk to the survivability of the nation in future conflicts? To ensure a viable security environment for the future, under developed countries, must endeavor to stay abreast of developments in the electronic field, their military applications, be sensitive to the potential threat and generate the means to reliably predict associated technological trends that will be critical in providing suitable countermeasures. It is probably safe to state that any future combat operations on land, in the air or over the seas, and even in space, are going to be critically dependent on electronic systems, both passive and active, with a direct bearing on the outcome of future battles. This leads us to the conclusion that capability in electronic combat is a distinctive element in the future survival of all states--more so the under developed world.

What the United States demonstrated during the Gulf War was the current "state of the art". The contemporary growth index of electronics is indicative of greater sophistication in future hardware and their application, vis-à-vis current electronic combat capabilities and concepts. Whereas in 1980s we envisaged operating against singular threats, the Gulf War demonstrated the effective application of tightly integrated electronic warfare operations in support of a wide variety of weapon systems, in unexceptionally large numbers, in a multiple threat environment on land, sea and air, with future possibilities in space. There is necessity to develop concepts to exercise passive and active techniques across the entire spectrum, and incorporating sophisticated countermeasures both on board weapon platforms and supported by resources external to those platforms.

Analysis of the Electronic Components of the Gulf War

One of the prime ingredients of the Gulf War was the electronic warfare aspect. Its occurrence was all pervading–used as it was for surveillance and target acquisition; identification of friend or foe; damage assessment; command and control in force management; communications for decision making and passing of decisions; planning operations; communicating real time information; navigation of third generation weapon systems; degrading hostile electronic devices and command structures; locate mobile missile launchers and directing friendly fires; integrated computerized fire control systems; night fighting devices compatible to weapon platform and mission; deception and so on.

Colonel M. Ponomarev of the Soviet forces has this to say historically, "American forces are all well equipped with new types of arms and combat equipment. The above is all reflected in the use of radio electronic combat, which for the first time in the history of warfare is being used on such a wide scale and has seriously complicated the conduct of air defense, aviation and Iraqi command, control and communications."[759] Considering the scale at which such warfare was conducted, and the unqualified defeat imposed on a force as potent as that of Iraq; we shall analyze the systems employed, endeavor to reconstruct their employment individually and in their totally, and finally, draw lessons that are relevant for the future military well being of Under Developed countries.

Electronic War in the Gulf Conflict

While neither of the antagonists have released any information on the electronic war aspects that went with the Gulf crisis; an analysis, based on known combat features; availability of electronic equipment; and published war fighting doctrines; has been carried out and a possible scenario worked out.

The conduct of Electronic Warfare operations by the coalition forces seemed to have achieved considerable success in the areas of Electronic Countermeasures [more specifically jamming], C^3I, target designation and accuracy of weapon systems, navigation etc. However, the performance in the ESM sphere appears to have been more than disappointing.

Concept of Operations

The concept of electromagnetic operations hinged on need to generate a suitable force ratio against Iraq by degrading hostile systems while substantially increasing the Allies combat potential by an appropriate mix of force multipliers at all levels of the operations.

The electronic policy aims could be surmised as follows:

- Neutralization of the enemy's ability to direct operations at the higher echelons and degradation of combat cohesion at formation and unit level, to prevent the possibility of a coherent resistance.
- Suppression of the entire range of surveillance devices deployed by Iraq so that the military hierarchy was devoid of battle field intelligence inputs on which to base their plans, and at the same time secure freedom of movement of coalition resources.

- Degradation of the enemy's kill potential by neutralization of all active electronic emissions designed to assist in target designation.
- Acquisition of electronic intelligence before during and after the battle to provide inputs critical for planning and conduct of the war and each engagement.
- Enhancement of the kill potential of all friendly weapon systems.
- Provision of real time and secure communications and data collation to allow for smooth operations management.
- Enhancement of resources to ensure maintenance of momentum by the field force and round the clock operations.
- Isolation of the theater of war against external electronic interference.

To execute this policy, the United States had a wide array of electronic and electronically enhanced systems deployed throughout the Middle East. The major applications of electronic warfare doctrines employed by the coalition forces are outlined below.

Penetration of Hostile Air Space

By increasing the chances of penetrating Iraq's air space without being shot down or intercepted meant a greater bomb load to target ratio and reduced attrition allowing for sustenance of the air effort at its peak levels. A host of systems were employed to cover the complete range of systems to be neutralized. Early warning radar systems were jammed by airborne jammers; air defense radars were suppressed by high speed anti radar missiles; hostile jammers were located and then destroyed from the air or by special operations groups; Air Defense guns and missile launchers were detected by Satellite reconnaissance JSTARS or visual reconnaissance; radio communications between ground control interceptors and aircraft was jammed; individual ECM packages were provided to all aircraft on missions over Iraq; stealth techniques were employed on the F-117; and deception techniques such as generating false radar noises. There must have been a number of other classified techniques, which are unknown to the rest of the world, unless detected by the Soviet Union. The coalition forces achieved remarkable successes in this sphere, proving that penetration of hostile air space is now chiefly a function of electronic warfare.

Enhancement of Weapon Lethality

The explosive content of all modern munitions is configured to destroy the entire range of weapon systems that can be fielded, provided a direct hit is scored. Electronic have played a major role in substantially upgrading hit probabilities thereby directly increasing the kill coefficient of all munitions. This high-technology increment of weapon lethality provided the coalition forces with a clear superiority of force ratio despite their claims to the contrary. Some of the more prominent techniques used were:

- Laser and radar designators, and installation of miniature computers with terrain discerning capability, responsive to Global Positioning System, delivered warheads to pin point targets even beyond the line of sight [over the horizon].
- Low light television, thermal images, image intensifiers and infrared devices provided the ability to execute accurate night engagements as also to operate in poor battle field visibility with the same efficiency as by day.
- Gyro stabilization of weapon platform and sighting devices allowed for accurate application of fire from moving platforms.
- Built in electronic interception and lock on devices generated adequate lead-time to engage targets even before they were aware of a hostile presence.

- Computerized fire control systems allowed for nearly instantaneous reaction by coalition weapon systems.

Maintenance of Momentum

Extraordinary night vision devices accurate and manageable navigation systems, fail safe communications and real time surveillance devices all enhanced the capability of the ground, air and naval elements to prosecute a relentless war by day and night. This factor, in itself imbalances Iraq's combat cohesion to a great degree and precluded timely and meaningful reactions.

Deception

The electromagnetic spectrum was used extensively to deceive Iraq's military commanders at both the strategic and tactical levels. Electronic countermeasures were used to degrade the adversary's surveillance devices; ghost electronic emissions were created to depict forces in areas where they did and exist; secrecy devices secured the coalition's C^3I infrastructure; false radar noises were generated to deceive hostile missiles; and so on. Iraq's commanders were denuded of the means to assess the enemy's intentions and, therefore, were unable to plan or execute their defensive operations in keeping with the developing threat.

Although it is getting increasingly difficult to conceal plans and deployment, the value of deception has paradoxically increased. This is because electronic sensors can only pick up tangibles leading to a one-dimensional view. Iraq is ignominious defeat notwithstanding, demonstrated, that despite the technological superiority at the disposal of the coalition forces, deception is possible if the battlefield environment is understood and a suitable response provided. Some of the more significant cases of deception resorted to by either side during the Gulf War that are worthy of note are:

- During the war, Iraq put together a substantial force to launch an attack on Khafji and other border areas. Despite reconnaissance satellites, JSTARS aircraft and absolute air supremacy allowing for round the clock surveillance of the battle area, the attack actually developed.
- In the pre-war period Coalition Air Forces would simulate attacks on Iraqi positions in Kuwait. The Iraqi sensors deployed to support the air defense systems were activated to detect and warn against these seemingly hostile aircraft. In doing so, the Americans would monitor the electronic emissions of the surveillance devices [radars] thus being able to develop suitable hardware for ECM realization dawned on the Iraqis in November 1990 when they switched off all active surveillance devices. This had its backlash on 17 January 1991 when the lack of active surveillance left the initial air attacks to be mounted undetected and unannounced.
- Iraq on the other hand was able to deceive the Americans about the locations of their missile sites, gun areas, armor concentrations, air field damage and communication centers. This was done by the intelligent use of paint, deployment of dummies, creation of positive response to electronic, thermal imaging and photographic surveillance devices, in areas that these assets did not exist or were not deployed. Consequently, Iraq was able to deceive the Americans during the initial stages of the air war. The latter claimed to have destroyed all communication systems, damaged all airfields and destroyed Iraq's surface missile facilities. Yet, Iraqi aircraft were airborne throughout the war period indicating serviceability of airfields; Saddam Hussein continued to have the means to communicate with troops in the field right up to the declaration of truce; and Scud missiles continued

their relentless attack on Saudi Arabia and Israel up to 27 February 1991. This deception cost the Americans a substantial amount in terms of additional air effort and was directly responsible for the prolongation of the conflict and increasingly the cost penalties.

- Likewise, the coalition forces engineered a complex deception plan to fix Iraq's military effort to Kuwait. While we have substantial evidence on the physical aspects of this deception plan, information on the electronic activity are not forthcoming. By General Schwarzkopf's own admission, while VII and XVIII corps were being repositioned to the West, a corps sized radio net continued to operate in the original concentration areas. An active electronic emission policy becomes essential to create a credible deception in an environment where passive electronic surveillance exists. Therefore, we can assume that electronics played an important part in this deception plan.

A striking feature of the deception thrust by the two antagonists is that whereas the coalition forces combined deception with mobility, Iraq's deceptive policy hinged on enhancing the survivability of static assets. Both concepts achieved considerable success.

It is important for the military in the developing world take cognizance of this facet of the conflict in deriving doctrinal lessons and future equipping policies. Without comparable technological wherewithal Iraq opted for a cheaper and effective approach. If they had the technological capacity to bolster their operation with offensive electronic surveillance devices, however primitive, the nature of the conflict could have been radically altered. Deception plans may be taxing and appear futile in the short run, but once resources are developed, they more than pay for themselves by limiting damage and preserving assets.

Management of Logistics

For the Gulf War the most critical and complex function was the management of inventory, maintenance of forces, replenishment of war wastage rates, and transportation of stores from different parts of the globe to specific destinations in the theater of operations within specific time parameters. The entire operation was electronically controlled by means of a wide and powerful array of computers coupled with real time data processing and communication facilities. If it were not for the electronic wherewithal, the logistics effort to support the coalition forces in Iraq would have capsized with disastrous effects on the conduct of battle.

Damage Assessment

The coalition was dependent [more or less entirely] on electronic surveillance systems to carry out bomb damage assessment. For their purpose they fielded, surveillance devices based on satellites, aircraft, helicopters, mobile, ground stations and on board ships. These were deployed to cover Iraq and its peripheral areas entirely. Even the human intelligence portion of the surveillance plan was dependent on sophisticated and miniaturized electronic navigation and communication devices.

The United States had placed a lot of confidence in the electronic spectrum to provide critical information on damage inflicted on hostile targets. This was directly linked with the development of plans and resource allocation to achieve the task most efficiently. For this purpose the United States had developed and deployed a wide range of exotic and expensive equipment. Throughout the war, damage assessment proved to be the greatest problem area; as a matter of fact, it was one area in which an over dependence on the electromagnetic spectrum proved to be a failure. To balance this discrepancy, the coalition forces had to project a large effort in the form of Special Operations Groups, into the battle zone.

Most weapon systems were fitted with devices to record and report the effectiveness of each target engagement; post attack photographs were a dedicated part of all missions; and satellites were tasked to over view the damage. Despite these efforts, the United States soon realized and acknowledged that the inputs on damage assessment were quite often inaccurate. The upshot was that decision-making at higher levels became difficult and frequently faulty. Some glaring examples in this area:

- From 20 January onward the coalition Air Force reported that all Iraqi airfields were rendered operationally unfit. Yet, the Iraqi Air Force was able to take off throughout the war–if they had the will to do so!
- The United States went onto record that they had destroyed the entire nuclear and chemical weapons facilities, in the first few days of the conflict. Later while combining Iraq under the auspices of the United Nations, only three nuclear establishments were proven destroyed while Iraq actually had many more facilities.
- In early February the United States made a downward revision of its claims on the destruction of Iraq's tanks and artillery. This flowed from an inaccurate bomb damage assessments and forced General Schwarzkopf to postpone the ground offensive till the desired attrition had been achieved.
- The optimistic reports that all Scud launchers had been destroyed on the first night of the air offensive needs no elaboration.
- Claims of neutralization of all command, control and communications facilities were belied by the ability of Iraq to continue to direct hostilities to the end of the war.
- The same is true of other vulnerable targets such as roads, bridges and industrial complexes.

The under developed countries should analyze all released war reports against the actual damage inflicted on Iraq. From this they can derive a meaningful policy on defensive measure to reduce damage by passive means, carry out selective hardening and create an infrastructure to deny accurate bomb damage assessment within a tactically realistic time frame. This accentuates the significance of appropriate censoring, media control and manipulation of news and views of the affected population.

The Nature of Electronic Warfare of the Gulf War

During the Gulf War, the Coalition's electronic warfare (EW) systems, operations, and tactics may have lacked drama and media attention, but were vital to the success of the entire war effort.[760] The war demonstrated lessons and reflected valuable experiences in all the elements of EW: electronic support measures (ESM), electronic counter measures (ECM), and electronic counter-counter measures (ECCM) with a scope and sophistication that far exceeded anything seen before. The EW investment made in the 1980s defense build-up was intended for a Soviet-NATO conflict in central Europe. Refined in exercises such as the U.S. "Green Flag" series against a postulated formidable Soviet threat, allied EW triumphed against the much weaker Iraqis.

The Impact of Electronic Warfare on the Gulf War

The Coalition's EW completely disrupted Iraq's command, control, communications and intelligence (C^3I) system. EW served the command links from Baghdad to field forces, which led directly to the spectacular collapse of the Iraqi Army as soon as the ground offensive began. In the air war, EW increased the impact of Coalition air power, which quickly defeated Iraqi air defenses, and lowered losses in Coalition aircraft. As one pilot said, "If it had not been for ECM....50% of our aircraft would not have returned.[761] EW also allowed the Coalition to look deep into the Iraqi operational and strategic depths, while denying them the same advantage, and the deception that accompanied the ground offensive was made possible by EW superiority.[762]

EW resulted in a low loss of Coalition aircraft despite the Iraqi air defense system, composed of 17,000 SAMs (surface-to-air-missile) nearly 10,000 AAA pieces, and a wide variety of sophisticate communications links. A major factor in this imbalance was the fact that the Iraqis were weakened by a limited EW investment. Iraq never faced a technically sophisticated air threat from Iran, and it was confident that it could deal with the threat posed by its other Arab neighbors. Thus, it had made limited investment in air defense system modernization.[763] Maintaining what some have described as the world's fourth largest war machine with a GNP about equal to Portugal's le economy in EW: much was sacrificed to achieve and maintain the force structure. The vast force structure was built on a Third World economy, which meant that there were far too few technical personnel to support the military and its associated industries. To compensate, it relied on foreign advisors and technicians, particularly Soviet advisors, and when these were withdrawn, the military's EW capabilities were weakened.

Chapter 22

The Beginning of the Gulf War

The Invasion of Kuwait

At about 2 A.M. (Baghdad time) on August 2, 1990, three Iraqi Republican Guard divisions invaded Kuwait. One proceeded down a coastal road to Kuwait City, a second seized the inland oil fields, and the third proceeded to the Saudi Arabian border. Kuwaiti A-4 aircraft and Chieftan tanks fought for three days until their fuel and ammunition were exhausted. The small Kuwaiti Navy also made a valiant showing, with the last two fast attack craft escaping while firing at pursuing Iraqi tanks.[764]

The Roots of Invasion

The reasons for the invasion dated back to the creation of present-day Kuwait. In 1889, Great Britain and Kuwait signed a treaty in which Britain assumed control of Kuwait's foreign affairs. This was done in order to thwart German imperialist designs in the region, and after World War I began, London established a protectorate over Kuwait. World War I also led to the collapse of the Ottoman Khilafah and the creation by the European powers of Iraq and a number of other countries. These events and decisions, reflected the European balance of power and did not consider the region's culture or politics, they still reverberate, and the discovery of oil and, later, in the 1970s, its greatly enhanced value, aggravated troubled, at times tribal, situations. Kuwait was an artificial creation imposed by the West, and it both denied Iraq a considerable amount of oil and restricted its access to the seas. This arrangement was never accepted, and when Kuwait received its independence on June 19, 1961, Baghdad almost immediately claimed it, basing this on the facts that Kuwait had been a part of the Ottoman Khilafah, that it was an artificial British creation, and it threatened Iraq's access to the sea. Threatened by invasion, Kuwait appealed to the British, whose military reaction in July 1961 was enough to thwart Iraq. Kuwait was admitted to the United Nations and the Arab League, but Iraq, did not renounce its claim and, would often resurrect it, and would cite it to justify the August invasion.[765]

The Iran-Iraq War

There were other reasons arising from events in the 1970s and 1980s that would prompt the invasion, and one of the most significant was the Iran-Iraq War. The cause of Iraq's invasion of Iran on September 22, 1980 was that the new Irani Shiite State was messianic and wished to expand its influence throughout the Islamic world. In doing so, it began to interfere significantly in Iraqi affairs, attempting to influence Iraq's sizeable Shiite faction.[766]

Iraq failed to defeat Iran decisively, and after a year, Irani forces went on the offensive and, regained almost all of their lost territory, and approached Basra. Here the offensive failed, and the war became a stationary battle of attrition. Meanwhile, Iraq began to develop nuclear and chemical warfare capabilities that would profoundly influence subsequent events. The nuclear capability was seen as such a danger to the Israelis that they conducted a preemptive air attack and destroyed Iraq's primary nuclear facility. The chemical warfare capability was also significant, and Baghdad used it against Iranian forces in 1984, 1985, and 1986, and on its own rebellious Kurdish population.[767]

These capabilities alarmed the West. The United States developed policy that was intended to halt both the Iran-Iraq War and the development of the Iraqi chemical and nuclear warfare capabilities. The military aspects of this policy provided the United States with considerable resources. In January 1983, a new unified command, Central Command (CENTCOM), was established and assigned responsibility for a huge geographic area, including the Arabian and Persian Gulf. It was given over 800 people, and the forces assigned to the Rapid Deployment Force also were increased. As a result, CENTCOM was given seven Air Force tactical fighter wings, two strategic bomber squadrons, five Army divisions, a Marine Corps Expeditionary Force, three carrier battle groups, a surface action group, and five maritime patrol squadrons. U.S. military positions throughout the Middle East were also expanded to handle the deployment of large numbers of U.S. troops. $523 million was spent to build an airfield in southern Egypt, while supplies were propositioned in Oman and Diego Garcia.[768]

Why Iraq Invaded Kuwait?

There were five reasons for Iraq's decision to invade Kuwait. Iraq could not repay about $80 billion that had been borrowed to finance the Iran-Iraq War.[769] It could argue that the war was in Kuwaiti and Saudi interests since the enemy was Iranian messianic. Shiite fundamentalism, which potentially threatened them. Kuwait's decision to not forgive Iraq's $65 billion debt provided economic and emotional justification for the Iraqi invasion.[770] Second, the Kuwaitis were incredibly rich and had huge investments abroad. Access to this wealth could resolve Iraq's financial problems. The third reason was alleged Kuwaiti oil drilling in the Rumailah oil field, which lay in disputed border territory, and the fourth was Kuwaiti overproduction of oil. Gulf revenues were depressed as a result of an oil glut on the spot market in the late 1980s, and on July 17, 1990, President Saddam Hussein threatened to use force as retribution for Kuwaiti overproduction and underpricing. He claimed that Kuwait and the United Arab Emirates had cost Iraq $14 billion in oil revenue. When Saddam suggested peace talks, the Amir of Kuwait provided the final justification for the invasion when he failed to consent to face-to-face talks, preferring Arab League mediation instead. Thus, as Baghdad prepared to assault Kuwait militarily, Saddam concealed these preparations by misinforming the United States and by agreeing to allow the Egyptians and Saudis to mediate an end to the quarrel. President Bush sent the U.S. Ambassador to Iraq, April Glaspie, to meet with President Saddam, who told her to convey to President Bush that he had peaceful intentions and was not seeking a U.S.-Iraqi confrontation.[771] Meanwhile, on July 31, 1990, Iraqi and Kuwaiti spokesmen met in Jidda, Saudi Arabia for negotiations concerning oil and territorial disputes, but the Iraqis walked out of the meetings on August 1st.[772] Many nations of the world, with the United States and Great Britain in the forefront, could not accept the annexation of what had been a peaceful nation, and a countdown to war commenced.

The Western Response to the Invasion of Kuwait

Great Britain and the United States led the effort to create a Coalition to force Iraq to leave Kuwait. Political factors and intense diplomacy delayed the Coalition's military operations as the United Nations first tried sanctions and then resorted to military operations when it saw the sanctions were not working.[773]

All the Coalition's members were crucial to its success, and each came to it with its own problems and perspectives. America had strengths and weaknesses. One weakness was the specter of its great defeat in Vietnam. Second, there existed a Presidential-congressional dispute as to which branch of government controlled U.S. foreign policy. Congress had set limits on the time a President could deploy troops without its approval, and this could play any lengthy troop deployment to Saudi Arabia. Third, an overriding U.S.-Soviet rivalry had been resolved. Now America was the only superpower, and while others might look to it for protection, it might not be willing to assume the role of world's policeman. On the plus side, after several difficult years, America had regained its confidence under President Reagan and this was continued under President Bush. Bush also had more foreign policy and national defense experience than any previous President. He had served as UN Ambassador, Ambassador to China, CIA Director, and Vice President, and his intellect and this experience were strong asserts. These factors were present when the Iraqi invasion occurred and would influence U.S. policy in the Gulf War.[774]

Great Britain was naturally disposed to rescue Kuwait by its long association with Gulf. Even after withdrawing from east of Suez in 1971, she maintained an informal security relationship with some of the Emirates and Oman.[775] In 1990, she had a large officer contingent attached to the Omani armed forces, many important military liaison teams in the region, civilian working in Kuwait and the Armilla Patrol in the Gulf. Her response to the invasion reflected Mrs. Thatcher's belief that aggression must be reversed and international law vigorously upheld. She felt that these principles ran in tandem with U.S. decisiveness and against the cautious indecision of her European allies, and chided other NATO members, saying, "It is sad that at this critical time, Europe has not fully measured up to expectations."[776]

Although at the outbreak of the Gulf War French public and political opinion would be firmly behind the French contingent-Operation *Daguet*, the political decision to join the Coalition created problems. Frances's ties with the Arab world and large Muslim-Arab population were concerns, although during the war opinion polls of Arab immigrants were surprising 24% were pro-Saddam 24% were against, and 52% had no opinion. These quelled French fears of internal problems, and opinions polls taken during the war showed that 70% of the public favored France's participation. Parliamentary support was strong, with only the Communists and the National Front opposing. Because most of the Italian public supported the Andreotti government, Italy joined the Coalition without any insurmountable political difficulties and maintained her pro-UN position during the war.[777]

It is difficult to discuss a pan-European response, given its diverse political, social, and cultural themes. While the European public was outraged with the Iraqi invasion (84 percent of British and Dutch, 70 percent of French, 66 percent of German, and 62 percent of Belgian voters supported the war's aims in February 1991), Europe's erratic diplomatic reaction posed its governments against each other, giving rise to name-calling. Britain's Minister of State for Defense Procurement Alan Clarke accused the allies of running for their cellars at the first sign of trouble, and the British press accused Europeans of cowardice, selfishness, and appeasement. The strain of the crisis made the fault lines running through Europe embarrassingly clear.[778]

Although Saudi Arabia enjoyed warm relationships with America and Great Britain, allowing the deployment of thousands of troops was tantamount to a cultural invasion. In this conservative Islamic nation that was the home of some Islam's holiest sites, this was a significant act, and was approved only after great deliberation. Conversely, Riyadh had no Alternative, since to not accept such aid would leave it defenseless against an Iraqi invasion. Egypt had a different agenda. President Hosni Mubarak had been embarrassed greatly by President Saddam, who let him believe that he had been instrumental in resolving Iraqi-Kuwaiti differences, while President Saddam intended to invade Kuwait all along. President Saddam and President Mubarak were also competing for leadership of a progressive Islamic national block, and Iraq's chemical, nuclear, and biological warfare programs threatened Middle East peace, and with it, Egyptian security. Syria must have had apprehensions when it entered the Coalition in that its extreme anti-Israeli stance. However, President Assad's great hatred for Saddam and fear of growing Iraqi power were sufficient to convince him to join the Coalition.

Chapter 23

Building the Coalition

The United States

President Bush froze all Iraqi assets in the United States soon after the invasion occurred, and Secretary of State Baker and Soviet Foreign Minister Shevardnadze issued a statement condemning the invasion from Moscow.[779] This was important because it set an initial U.S.-Soviet position on the invasion, and at a minimum, meant that there would probably not be a U.S.-Soviet confrontation.

President Bush then met Thatcher in Aspen, Colorado. At the time, he did not believe that Iraq would invade Saudi Arabia and was leaning against a military response. However, Thatcher argued that Iraq would invade and that the only option was to send troops to the region. This established an Anglo-American cooperation that would be the core of the Coalition. Given their reticence concerning the presence of foreign troops in Saudi Arabia, the Saudis were approached cautiously. Cheney and Powell discussed a Coalition force with the Saudi Ambassador, and when Bush learned that the Saudis were not going to permit the deployments, he let them see satellite photographs of Iraqi forces amassing for an invasion along their border. The king reversed his stand and accepted the troop deployment.[780] Support was solicited from other Arab nations, and the Soviets agreed to honor the sanctions against Baghdad and to halt further arms sales. Japan, and China agreed to boycott Iraqi and Kuwaiti oil. Turkey, given its proximity to Iraq, faced a difficult situation, but with firm assurance, it joined the Coalition and closed the oil pipeline to Iraq on August 7th.[781]

In January, the United States still had not resolved the issue of whether the President or Congress controlled foreign policy. President Bush had sent U.S. forces to

Saudi Arabia and had committed the nation to support UN actions if Iraq did not withdraw, and there was great public approval for his policy. Thus Congress was faced with either supporting Bush, thereby conceding considerable power, or of opposing his commitment. The latter option was so unpalatable that Congress delayed taking action, and then approved Bush's actions just days before the war.

Great Britain

From August until the war's end, the ruling Conservative party did not waiver in its determination to defeat Saddam, despite the trauma of a change of leadership from Margaret Thatcher to John Major and low ratings in opinion polls due the disastrous introduction of the new and unpopular poll tax. Having learned, from its lukewarm support for the Falklands War, that less than wholeheartedly supporting British troops was costly in elections, the opposition Labor Party was firm in its support for Operation Granby and two senior official opposition spokes men who were at odds with the deployment were relieved of their portfolios. However, Labor stressed that British and U.S. actions should be clearly sanctioned by the United Nations and that they not be seen as an Anglo-American action at King Fahd's behest. Opposition to the use of force was slight if vocal, involving some 30 MPs on Labor's left out of a total of 650 MPs. Innate anti-Americanism was combined with the belief that "Desert Shield" was for the benefit of U.S. oil companies and that the sudden U.S. reverence for international law and the United Nations was hypocritical considering U.S. actions in Grenada and Panama. A final exception to the broad consensus was former Conservative Prime Minister Edward Heath, who went to Iraq in an effort to secure the release of British Hostages. He warned that a conflict would result if U.S. and European troops occupied a hostile and devastated nation and urged a negotiated solution under which Iraqi forces would withdraw and Arab League would provide a buffer force between Kuwait and Iraq.[782]

France

France was criticized at home for its ambiguous stance. Political wavering, the Defense Minister's resignation, and last ditch attempts at peace did not make her popular with her allies. In this respect, France pursued an independent policy in her long held wish not to be under America's shadow. Alternatively, since she did not want to give her Arab friends the impression that she had abandoned them, she pursued every possibility for peace. After a week of what the British Press called "dithering," France supported removing Saddam from Kuwait. While it took six weeks and the violation of the French Embassy in Kuwait before she began Operation *Daguet*, her historic and economic ties with the Middle East were not ones that she wished to lose. Thus, while she was under severe criticism from the beginning of the conflict, she played, fully, every role and function asked of her by the United Nations and the Western European Union (WEU).[783]

Italy

In Italy, there was relevant political opposition to the Coalition despite overwhelming popular support. This was not spawned by the "Democratic Party of the Left," a coalition of communists and a multifarious array of small leftist parties, but from a right-wing "catholic" front that claimed to be inspired by the Pope's pronouncement against war. Despite the fact that the Pope later made a distinction between peace with justice that was to be sought, and peace at any price that was not, fundamentalist catholic groups, represented primarily by the right-wing group "Communion and Liberation" and the reactionary weekly *Il Sabato*, spoke with a vengeance against both the United States and any Italian part in the Coalition. It even proclaimed that Italian soldiers should desert. The communists, ignoring their atheistic tradition, immediately allied themselves with these reactionary groups. Although they refused to declare solidarity with Italian troops deploying the Gulf, there were some responsible politicians, such as Sr. Napolitano in the "Democratic Party of the Left", who refused to take such absurd positions.[784]

The major problem was not from this alliance's mass rallies and propaganda, but unprecedented opposition from inside Christian Democratic Party. While this was not supported by the Pope, it appeared to be supported by some Vatican figures, such as the editor of the *Observatore Romano*, the Holy See Paper. The Christian Democrats in the government held firm, although they may have had some misgivings. Solid support from Socialist Party ministers, especially Foreign Secretary de Michelis, who adamantly supported the intervention, and from other minor lay parties, Liberals, Republicans, and Social-Democrats, helped the Christian-Democrats to preserve, and the government majority was compact, firm, and never wavered. The "declaration" from an under-secretary that approved a Soviet peace plan was a personal one, and met with an immediate rebuttal from the government.[785]

The Italian military could offer only a limited response because it was under reorganization from a large conscript army into a smaller, professional one. In the interim, a conscript's service obligation was reduced to ten months. This was simply not enough time to prepare the desert warfare, and the training he did receive prepared him for emergencies on Italian borders that were topographically very different from the sands of Kuwait. Nonetheless, since Italy was very vulnerable to international terrorism, the Army had to be mobilized to provide protection against anticipated terrorist attacks.[786] Since there were about 1,500 targets to be protected, the Army was almost completely mobilized and 96% of the trained personnel, totaling 90,000 men, served in two groups of 45,000 troops.[787] Italy was also a main U.S. supply route and the U.S. Air Force established a major logistical facility for large tanker aircraft at Milan's Malpensa International Airport to refuel B-52 bombers flying from British bases to Iraqi targets.

She also sent several Stinger missile batteries to help protect Turkey, and two Italian first-rate brigades of paratroops and naval infantry (marines) were placed on alert, ready to respond to a NATO defense of Turkey, should it be attacked by Iraq.

The European Community and NATO

Twelve European states froze Iraqi and Kuwaiti assets and embargoed Iraqi oil, while the EC supported the UN resolutions, vowing to maintain its embassies in Kuwait for as long as possible. However, even the EC's greatest supporters had to admit that in terms of a military commitment, the crisis had deflated the Community's image as a forceful actor on the world stage. The West European Union (WEU) could coordinate a European military response because the obstacles to a NATO role "out-of-area" did not apply to it. Established to strengthen the European defense identity, it acted as linchpin of a European mine hunting operation in the Gulf during the Iran-Iraq War, when WEU naval forces protected their own nations' maritime traffic and acted jointly against the mine threat. However, the members' command and control, foreign policies, and rules of engagement differed greatly and the idea of a unified command was seen as unrealistic. Six WEU nations–Great Britain, Italy, France, Belgium, the Netherlands, and Spain–agreed on August 21st to send naval ships to the Gulf in a coordinated operation, but these were under national control because their nations had different views on the crisis and on the WEU's role as the executor of EC's security policy.[788]

A concern was the Iraqi threat to Turkey. On September 10th, the United States requested that the operations of NATO's ACE (Allied Command Europe) Mobile Force and Naval on-Call Force for the Mediterranean (NAVOCFORMED) be extended eastward to show support for Turkey and fill the gaps left by U.S. ships deploying to the Gulf. By January 10th, 42 fighter aircraft (18 Belgian Mirage-5s, and 18 German Alpha ground attack aircraft) and German and Dutch Patriot, Roland, and Hawk air defense devising resolutions for restoring peace and security in the Gulf and introducing punitive sanctions enforced by a naval embargo. Both she and America convinced the United Nations to delegate the conduct of military operations to them and both resisted Soviet efforts to revive the UN Security Council Military Staff Committee. In Saudi Arabia, there also was close cooperation. Britain subordinated her forces to CENTCOM, but made it clear that if problems developed they could be referred to the commander of British forces, the Defense Secretary, and the "War Cabinet." The overall British commander. Air Chief Marshall Sir Patrick Hine was based at Headquarters Royal Air Force Strike Command at High Wycombe outside London. As a result of these efforts, Resolution 660, demanding that Iraq withdraw from Kuwait, passed unanimously on August 2nd, followed on the 6th by Resolution 661, which imposed the embargo.[791]

Two factors, that the embargo be complete and that the issue of Iraqi aggression remain divorced from the traditional Arab-Israeli issue, created problems. The embargo placed tremendous pressure on Jordan, which did not completely seal off Aqaba and its borders to Iraqi commerce. Likewise, Israeli's killing Palestinians during the October 8th Jerusalem riots, gave Iraq a chance to link the Occupied Territories issue to its invasion. The Coalition weathered both of these problems, but a third was more enduring: the embargo was not immediately effective. Sanctions and blockades have poor records of success, and as the embargo's effects were assessed, it was concluded that it if it were to succeed (and this was a question in itself), then it would take a long time, certainly at least a year, to force Iraq to withdraw. The fact that months-long military presence would be costly and would mean a lengthy disruption in oil production with serious economic effects; Saudi concern over a Western presence in their country during the pilgrimage season; the possibility that the war would be fought in the summer's brutal heat; intense pressure on king Hussein; and the chance of another incident in the Occupied Territories were all factors that weighed against such a delay when success was so uncertain. Also, London and Washington believed that war was necessary, because if Saddam withdrew, then they have to commit to a costly long-term peacekeeping force, and Saddam would be free to continue his nuclear, chemical, and biological warfare programs. Thus, while the sanctions kept the military pressure on, by November it was obvious that they were not enough to force a withdrawal from Kuwait, and Washington and London began actively advocating the use of force. France, China, and the USSR all opposed this, but British and U.S. efforts culminated in Resolution 678, which approved the use of force to expel Iraq if the latter did not leave Kuwait by January 15th [792]. The threat of war prompted many initiatives to prevent it. Working to sustain the Coalition's resolve, America and Great Britain responded to these proposals, while continuing to demand an unconditional withdrawal from Kuwait. At times, London took the lead in sustaining the pose; on one occasion Thatcher was rumored to have advised Bush that "now is not the time to become wobbly, George."

While there was agreement within the European Community on political and economic measures against Iraq, Britain was appointed that the WEU did not act more decisively. The WEU agreed to coordinate naval affairs through a working group of military commanders, but they did not consider a unified military command or uniform rules of engagement. Thatcher had already asserted that NATO should be ready to act beyond its historical area, and after the invasion, she called for a revision of the NATO treaty to allow "out-of-area" interventions.

Conclusion

The Coalition experience of the Gulf War was that America benefited because in its leadership role. It showed great consideration for foreign sensitivities. President Bush's personal approach was very successful, and America emerged from the war with greater prestige, which could be valuable as he worked for the new world approach. Whether this could be sustained in the postwar period was problematic, but at war's end guarded optimism was warranted. Finally, the White House had regained control of U.S. foreign policy, and this might figure prominently in future U.S. commitments overseas.

For Great Britain, the crisis showed that her longstanding" special relationship" with the United States was still there, and it was Mrs. Thatcher who initially seemed to lead the way, notwithstanding those who said Britain's future role lay wholly within the European Community. The leadership changed with her departure, but there was no change in substance and the British collaboration with the United States was unwavering. The wide ranging and indecisive European response served to support those who have argued that the nation should delay a greater European Community commitment; others argued that the crisis occurred too soon in what may be a lengthy process to create a political and militarily united European unit, and London should have been, and now be, fully committed and involved.

For France, while the Coalition improved Franco-American relations ‹France had pursued an independent course, reflecting considerable disparity between her views and those of others. For Italy, the war was a success. Despite political tumult, she faced her duties and successfully projected her power into the Gulf, in this, her first combat endeavor in over 40 years. For Turkey, the war meant a decision between NATO and the Muslim world, and Ankara opted for NATO. It was also showed that NATO would honor its commitment to that nation, and Ankara should have felt more confident concerning her security at war's end. For the Saudis, the Coalition meant security from Iraq, for Egypt, it meant a greater regional leadership role, and for Syria, it offered the chance of better future relations with London and Washington. For the European Community, the Coalition showed that it was far from united, and that there was a lot of work to do before unity is achieved. At minimum, the Community must address how to establish a coherent military defense of its political, economic, and strategic interests.

Chapter 24

The Iraqi Diplomatic Efforts

Iraq's diplomacy was hallmarked by failure. It failed to prevent U.N. resolutions and embargoes; halt the deployment of Coalition forces to Saudi Arabia; secure an active commitment from any nation to support it against the Coalition; link its occupation of Kuwait to Israel's occupation of the West Bank and Gaza; convince the Arab world that the Coalition deployments were an intrusion of infidels into the Islamic world; and prevent the war. Having said this, we must also note that there was some imaginative creativity in Saddam's policy and that it caused problems for the Coalition.

Failure to Justify the Invasion

Iraq invaded Kuwait to retaliate for what it saw as Kuwaiti injustices and because it could not pay its huge Iran-Iraq War debt. When Kuwait would not renegotiate Iraq's debt it gave Iraq economic cause for invading, since its undefended wealth offered an easy solution to Saddam's financial worries. Kuwait's drilling in the disputed Rumailah oil field and its overproduction of oil that depressed oil prices were additional provocations.

The fact that other nations might not accept these reasons as legitimate grounds for the invasion under international law meant that they might oppose Saddam's aggression, and duplicity in his policy assured it. Before the war, Saddam told the U.S. Ambassador to Iraq that he did not want a U.S.-Iraq dispute, and he led Egyptian President Hosni Mubarak to believe that he would not invade Kuwait, Mubarak was furious at being deceived by Saddam. He had set up the mediation conference in July, and immediately stated in public that war had been averted. These moves and Iraq's bullying of delegates at Arab meetings caused many to question Iraq's integrity. This was critical, because the Saudis later said they asked for U.S. aid because they felt that the Iraqis tried to deceive them during discussions after the Kuwaiti invasion, leading them to conclude that Iraq was about to invade them. It should also have led everyone to conclude that, if Iraq invaded Saudi Arabia then an invasion of the United Arab Emirates would soon follow. If these moves were successful, then Saddam would have a major influence over the world's oil.

The Constituents Policy of Iraq

Hostages as Human Shields

When Saddam announced on August 9, 1990, that he intended to detain the hostages, he elicited world criticism, which became condemnation when one of the hostages, James Worthington, died of heart attack. This became a major and prolonged issue and while parties were often successful when they went to Baghdad to ask for the release of hostages, Saddam never seemed to realize that most of these people, Edward Heath, Willy Brandt, Jesse Jackson, and others, did not represent their governments. Inn sum, Saddam was never able to use this issue to dissolve the Coalition, and he finally announced that all the hostages would be released on December 5th.[793]

The Overture to Iran

Saddam also attempted reconciliation with Iran. On August 15th, he said he would release all Iranian prisoners of war and return virtually all the territory taken during the Iran-Iraq War (1980-1988). This totaled some 164 square miles in the Ilam region, including the strategic Shatt al Arab waterway. This theme was pursued further on September 9th, when Foreign Minister Tariq Aziz met Iranian Foreign Minister Ali Akbar Valyati to convince Iran to break the blockade. Although the two nations restored diplomatic relations, Iraq never convinced Iran to take any military action against the Coalition. While Tehran did provide small scale aid by allowing humanitarian truck convoys to proceed to Iraq, it remained neutral in the war. In the end, while some Iranian extremist fundamentalist groups supported Saddam, the government was not prepared to do so for several reasons, including the costly Iran-Iraq War, traditional enmity toward Iraq, Saddam's duplicity, the strength of Coalition forces to which Iran was very inferior militarily, and the economic need to improve relations with the West.[794]

The Holy War

Saddam also tried to discredit the Coalition by depicting it as an infidel intrusion into the Islamic world, and on August 10th, he called for a jihad or holy war, to expel Coalition forces. In doing so, he posed as a devout disciple of Islam, a role that he had assumed on prior occasions.

In previous years in contrasting traditional and progressive cultures of the Islamic world, Saddam's actions characterized him as a progressive, but as the Iran-Iraq War dragged on he tried to align himself with Islam to appeal to Islam's traditionalists by showing that he was not secularist. A report was published that that traced his heritage back to Fatima and Ali, Muhammad's (peace be upon him) daughter and son-in-law, who are loved by Shiite Muslims. Saddam, in Muslim attire, was seen on television on pilgrimages to Mecca, and posters of him praying were posted. This was not completely successful because it did not accord with the Ba'ath Party's essentially secular nature.

A jihad is holy war. Only leaders who are caliphs or successors of Prophet Muhammad (peace be upon him) can call jihads, and no successor has been proclaimed since 1924.[795] Saddam hoped to establish himself as a caliph through his connection to Ali, Muhammad's (peace be upon him) son-in-law, but his call for jihad failed to convince the majority of Muslims. The most significant response was from the Palestinians, many of whom signed up to fight the Coalition. However, they were probably more interested in Saddam's support for their cause than in a jihad, per se. at any rate, none ever reached the front lines and their protest was limited to influencing King Hussein of Jordan. Elsewhere, there was some popular support for Iraq, but this failed to influence national policies.

Contrasting these modest and politically insignificant gains were major defeats. On August 10th, members of the Arab League in Cairo voted to send troops to Saudi Arabia and demanded that Iraq withdraw from Kuwait. Also, when 400 leading Islamic figures met in Mecca on September 13th, they not only refused to support Saddam's jihad, but also authorized Kuwait to proclaim a holy war against Iraq. Thus, Saddam's attempt to mobilize the Islamic world failed because he attempted to stretch reality too far, and his credibility suffered accordingly.[796]

Free Oil

As the embargo began to affect Iraq, Saddam tried to combat it. The price of oil had risen by 50 percent because of Iraq's invasion, reaching $30.00 a barrel in September. Saddam used this to attempt to break the embargo by offering free oil to Third World nations that were suffering because of the embargo, he cast the situation in anti-imperialist rhetoric. He said he was prepared to supply Third World nations with oil free of charge because in this time of oil shortage, the United States, Israel, and the "procolonist" nations would ensure that they had the oil that they needed and that other nations would get only that which remained. The offer was open to all nations regardless of their positions in the ongoing crisis, but the nations had to arrange for their own transportation. Thus, Saddam was inviting them to test the embargo.[797]

The game failed for several reasons. First, it was met with disbelief and mockery, because it appeared transparent in light of Iraq's unwarranted seizure of Kuwait. Second, the Coalition had greater credibility since it took measures to help those nations hurt most by the embargo. Finally, the coalition said that even if the oil were free it violated the embargo, and ships would not be allowed into Iraqi ports to collect it.

Involving Israel

A major weakness in the Coalition's cohesion was Israel. A traditional ally of the United States, it relied on U.S. support whenever its anti-Palestinian policies alienated Arab nations or evoked U.N. condemnation. Saddam attempted to link his seizure of Kuwait with the Israeli Occupied Territories. On August 12th, he said that he was prepared to resolve the crisis if Israel withdrew from the Occupied Territories. Reacting to the slaying of Palestinians by Israeli police on October 8th, Saddam said that he would attack Israel if it continued to occupy Arab lands. This bid to link the Iraqi invasion to the Occupied Territories was a continuation of a diplomatic theme he had begun earlier, but skillful Coalition diplomacy kept the two themes apart and considerable pressure on Israel to temper its treatment of the Palestinians defeated his tactics.[798]

Iraq's Diplomatic Dialogue and Coalitions Partners

A major issue in the Iraqi-Coalition diplomatic dialogue was the embassies in Kuwait .Iraq demanded that they close, as Kuwait was now the 19th Province of Iraq whereas the Coalition defined Kuwait's seizure as illegal and kept them open. On August 22nd, President Bush said that he would defy Iraqi orders to close the U.S. embassy by August 24th, and Saddam quickly labeled this as an act of aggression. Iraq turned off the water to embassies on the 26th, and on September 14th, Iraqi troops entered the Canadian, Dutch, and Belgian embassies, as well as the French ambassador's residence, where they removed four French citizens, who were later released. This pressure backfired, since an enraged Mitterrand responded by ordering several thousand French soldiers and dozens of planes and tanks to Saudi Arabia in response for this illegal intrusion. The embassies gradually were closed, with the U.S. and British embassies closing on December 13th and

16th, respectively, after all the British and U.S. hostages in Iraq had been freed and those in hiding had left Kuwait.[799]

An uncompromising Iraqi diplomatic stance scuttled many opportunities for peaceful solution to the crisis. When talks with Jordan and U.N. Secretary General Perez de Cuellar in August both failed, Iraq proposed that he and Bush publicly address each other's nations. Their taped broadcasts had no effect on the impasse. King Hussein's October peace initiative failed, and in November, the United States worked to convince the United Nations to authorize military action. To win such approval and possibly out of a desire to exhaust all peaceful opinions before resorting to war, Bush insisted that Iraq fully understand the Coalition's resolve. On November 30th, he invited Foreign Minister Tariq Aziz to Washington and said he wished to send Secretary Baker to Iraq. While Iraq accepted this offer, it believed if it delayed the talks, then Bush would delay combat action beyond the January 15th deadline. Thus, Iraq wasted the time it had left. On December 9th, Saddam said that his schedule prevented him from meeting Baker before January 12th, and Bush promptly accused him of stalling. Both agreed to an Aziz meeting in Washington on December 17th, but could not agree on a date for baker's visit to Baghdad. When Bush threatened to suspend the talks unless Saddam agreed o see baker no later than January 3rd, Iraq suspended them. After Algerian and European attempts at peace failed, U.S.-Iraqi talks were resumed on December 26th in Baghdad. Bush finally directed Baker to meet Aziz in Geneva and, if these went well, to proceed to Baghdad for meetings with Saddam. When criticized for independent diplomacy after the United Nations had approved a deadline, Bush said that the Baker mission was merely to ensure the that Iraq understood the Coalition's resolve to act after January 15th. The Baker-Aziz meeting failed to move Iraq. Subsequently, in a last minute attempt to avert war, Secretary General Perez de Cuellar met Saddam. He also failed to move Saddam.

Believing that it had exhausted all other options, the Coalition began its air campaign on the 17th. Iraq believed that it could at least part of Kuwait through talks and could avert war through stalling. Both believe grossly miscalculated the Coalition's resolve, with dire consequences.[800]

The Scud Missile Attacks

After the war began, Iraq launched 40 Scud missiles at Israeli cities in hopes of bringing Israel into the war, thereby forcing some Coalition Arab members to leave, and possibly bringing other Arab nations into the war on Iraq's side. This tactic failed because Washington and London convinced Israel to remain neutral, and provided protection through Patriot missile deployments.[801]

The Soviet Gambit, February 1991

On February 11, 1991 Soviet envoy Yevgeny Primakov went to Baghdad to pursue a Soviet initiative that might have saved Iraq from further destruction. This created a problem for Bush in that the Soviet were hopeful about a settlement and possibly that the Soviet Union would support Iraq might have thwarted the Coalition's military operations. From a rational perspective, given the existing military situation, Saddam should have accepted the Soviet proposal immediately and without reservation. However, he tentatively agreed, and then kept retracting certain stipulations and adding more of his own. The final result was an offer that the Soviet passed to the Coalition but one it could not actively support.[802]

Conclusion

Some lessons can be gleaned from Iraqi diplomacy are old one. First, military power is linked to political power, and nations should rarely undertake political actions unless they have enough military power to defend them. Second, military action, such as Iraq's invasion, must be politically credible–it must be viewed as justified by others. Iraq convinced almost no one of its right to invade Kuwait. Third, when attempting to break an enemy alliance, as Saddam tried to break the Coalition, one must determine and then focus one's efforts on the pact's weakest point (Clausewitz called this center of gravity). Saddam's attack against the Coalition correctly identified the U.S.-Israeli relationship as the weakness, but rather than focus his efforts here, he diffused his effort by assailing many aspects of the Coalition. This detracted from the alliance's greatest weakness and diminished Saddam's credibility when some of his efforts were clearly ill founded.

Other lessons reflect the recent changes in regional power relationships. The Soviet-American rapprochement and critical Soviet domestic problems were not completely understood by President Saddam. Thus, when the Coalition acted against Iraq, a Soviet military response was not forthcoming, and the Coalition was free to pursue its goal without fear of a superpower confrontation.

President Saddam never seemed to realize this. There were chances to resolve the crisis, and in each he chose he most assertive, least compromising option. At several junctures in the Fall of 1990, he could as a concession probably have withdrawn from Kuwait City but retained significant benefit from his invasion by staying in the Bubiyan and Warba Islands and Rumailah oil fields. Had he done so, it is doubtful that the Coalition would have held together. In the end, his inability to compromise brought all negotiations to unsuccessful ends, and Iraq not only lost all it had seized, but also suffered great destruction.

Chapter 25

The Soviet Role

Any discussion of contemporary Soviet foreign policy must consider the Soviet reconciliation then occurring with West. This posture was a stark change from the Soviet stance of the past. Beginning with its first significant crisis response, which occurred during the June 1967 Arab-Israeli War, through its very significant military response to the Jordanian Crisis of 1970, the Indo-Pakistani War of 1971, the October 1973 Arab-Israeli War, the Cyprus Crisis of 1974 and 1975, the Angolan Civil war in 1976, the invasion of Afghanistan in 1978, and the Ethiopian-Somali War, to the Sino-Vietnamese War of 1979, Moscow had used its military and political power skillfully in a series of responses that supported its clients. In these encounters, U.S.-Soviet military standoff often occurred, and Soviet clients, supported by Soviet power, were often successful. However, these days ended when the U.S.-Soviet rivalry reached a climax in the 1980 and the Soviet Union and Warsaw Pact subsequently began to collapse. If Saddam had expected the Soviet Union to come to his aid as it had done with other clients in the past, he was sorely mistaken.[803]

President Mikhail Gorbachev's goals were to: preserve the integrity of as much of the USSR as was possible; to transform the economy; to gain technological help from the West; to recast the military into one that offered strategic defense and a strong regional capability; to insure that newly united Germany was so integrated into Europe that it did not again pose a military threat to Russia; to associate, even ally itself with the new European political-economic structure; and to play a significant role in that structure. In this context, the situation in 1991 was transitional, one in which Soviet foreign policy was evolving from a worldview to one that focused on regional events and interests. Soviet actions in the war reflected this transition, combining diplomatic neutrality that reflected the new policy with limited military assistance to Iraq. A trapping of the old.[804]

Gorbachev's foreign policy of national self-determination was a renunciation of Moscow's earlier policy of actively influencing the world to advance communism. Implicit in the repudiation was the understanding that old allies, old radical regimes, would no longer be assisted. However, since immediately setting these allies adrift would impact critically on Moscow's credibility, there was a transition period in which Moscow was providing less support before it ceased all helps. In the interim, Soviet involvement was curtailed and the clients were expected to measures to insure self-reliance.[805]

From this vantage point, one can understand what appeared to be conflicting Soviet actions in the Gulf war. Iraq had been an important Soviet client, one that offered a balance to Iranian theocratic messianism. In September 1990, many observers said Moscow was at a crossroads, to choose between its old confrontational policy and its cooperative posture. In reality, there was no choice. The changes in the USSR had so weakened the military's power that, short of a strategic confrontation, Moscow could not have stopped the Coalition. Thus, while it is plausible that the Soviet Union knew of the invasion before August 2nd, it is also likely that warned against such a course of action. Thenceforth, its diplomacy was to convince Saddam to withdraw from Kuwait while it continued to provide low-level assistance to him.[806]

Soviet Diplomacy

Soviet-American diplomatic cooperation was evident at the start of the crisis. Secretary of State James Baker and Soviet Foreign Minister Eduard Shevardnadze, in the midst of the talks when the invasion occurred, issued a joint statement condemning the "brutal and illegal invasion" of Kuwait, and the Soviets stated that they would immediately suspend Iraqi arms deliveries. Having said this, it remained for the Soviet

Union to define precisely its role in the crisis. Baker urged it to play an active role in the Coalition, but Moscow opted to not to be involved militarily. Admitting that there were Soviet military advisors in Iraq, it said later it would withdraw all of them except those who remained voluntarily or those with valid "contracts" with Iraq. Soviet policy was to provide minor aid to both the Coalition and Iraq. During Secretary Dick Cheney's October visit to Moscow, he was told of Iraq's military posture, the types of Soviet weapons that they had, and about Iraq's chemical warfare capability. Thenceforth, the Soviet tried to convince Iraq to withdraw from Kuwait, while U.S. policy was to gain Soviet support, or at least its neutrality in the crisis. It appears that the USSR was willing to acquiesce because this cooperation not only coincided with Gorbachev's policy, but also could be traded for substantial aid. Still Soviet policy remained independent. Gorbachev said that while the USSR and the United States were partners, "we are prepared to cooperate, but we will not be led."[807]

While the Soviet response reflected Gorbachev's foreign policy, it was also to Soviet economics advantage in that there were so many economic and diplomatic concessions made to Moscow in this period that it appears that it was trading its support for aid. During a late-October diplomatic trip, Gorbachev signed several trade agreements with Spain and France, and just before the vote on the U.N. resolution to authorize force against Iraq. Saudi Arabia agreed to lend the Soviet Union $ 1 billion. Other loans included $ 1 billion from France, $ 1.5 billion from Spain, $ 6.3 billion from Italy, over $ 10 billion from Germany, possibly $ 1 billion from Kuwait, and $ 5 Billion from other Gulf States. On the diplomatic front, several nations, including Saudi Arabia, Iran, Japan, and Israel re-established relations with Moscow.[808]

Soviet policy changed after December, after Shevardnadze resigned in protest when Moscow repressed dissent in the Baltics and the USSR, Soviet policy was far less clear, creating problems for the Coalition. On February 11, 1991, Soviet envoy Yevgeny Primakov went to Baghdad to persuade Saddam to withdraw his forces from Kuwait. Saddam agreed to cooperate in "finding a peaceful, political, equitable honorable solution to the region's central issues, including the situation in the Gulf."[809] This was far from an unconditional withdrawal from Kuwait.

The Coalition continued the dialogue with Moscow but made no concessions concerning its demand that Iraqi forces withdraw from Kuwait. However, the Soviet continued their diplomacy as the Coalition made final preparations for the ground war. Bush had serious concerns, but agreed with Gorbachev that it might be possible to end the war. The Soviets negotiated intensely but Iraq still demanded several concessions, saying that it would free all POWs immediately after a cease-fire. Would begin withdrawing from Kuwait under U.N. supervision 24 hours after hostilities ceased, and would complete its pull out in a fixed time, if a cancellation of all sanctions against it were tied to its withdrawal, and if there were guarantees that debate would be held on the Palestinian issue. Bush called this initial Iraqi acceptance and then the long list of demands a "cruel hoax."[810]

Several accounts for these Soviet diplomatic efforts. After Shevardnadze's departure Soviet policy was much less purposeful, reflecting the great influence he had exerted. Another reason for Moscow's actions was the Baltic repression itself. It was as serious as the Hungarian Revolution of 1956 and the Czechoslovakian action of 1968 in terms of political repression and physical brutality, and while it never approached the slaughter of 1956, it certainly was bloodier than Prague in 1968. Had the Gulf War not occurred, it would have been a major incident adversely affecting Soviet-Western relations. However, by working to keep the West preoccupied with Iraq, Moscow probably hoped to minimize the reaction to the Baltics. The third reason pertained to the

Soviet military relationship with Iraq. The huge destruction of the Soviet equipped and trained Iraqi Army could not have been pleasing, and the Kremlin may have been desperately seeking a way to avert Iraq's total defeat in a ground war, even if this meant pursuing a policy that was not completely to Washington's liking. Finally, Soviet prestige also influenced their actions. While Gorbachev's foreign policy indicated the USSR might play a more regional role in world affairs, recognizing that one's would influence is declining truth for a nation to accept.[811] Although Great Britain did this gracefully when she granted India and other Commonwealth countries their independence, there are a host of other powers in history that could not accept a new reality and acted accordingly. Soviet statements reflect that this was the case.

The Military Role

While Soviet foreign policy reflected neutrality, its military policy was one of low-level assistance to Baghdad. The evidence indicated that the Soviet Union indicated early on that there would be no major military posturing in Iraq's defense. Rather, Moscow recommended withdrawal, but if Iraq did not withdraw, then it would provide limited assistance to its former client. Many rumors, most emanating in the early weeks of the crisis and some based in fact, persisted concerning Soviet involvement in Iraq during the war. Moscow was said to have foreknowledge of the invasion of Kuwait and quite possibly planned the major details of the assault, Soviet General Albert Makashov went to Baghdad on July 17th, two weeks before the invasion, and remained there until August 13th. He reportedly assured the Iraqis of Soviet military support in their endeavors. Unsubstantiated repots said that the Soviet Union continued its arms shipments until the air war began. Some were airlifted, and most came overland through Jordan. In late October, there were unconfirmed reports that Soviet Spetsnaz troops were guarding Saddam against coup attempts or assassination. In mid-January, 1991, the CIA purportedly identified as many as 400 Soviet trucks believed to contain munitions moving from the USSR through Iran to Iraq. This assistance purportedly was continued into the war. Soviet military advisors were initially kept in Iraq pending completion of their contracts, and some allegedly helped the Iraqis aim and target Scud missiles. The Soviets launched four strategic imaging reconnaissance satellites to monitor the region. Iraq was said to have access to :real time" satellite images and was informed by the Soviets of U.S. satellite over flight schedules so that the secret Scud launching locations would not be revealed. Soviet advisors allegedly participated in military operations against \coalition forces in the Kuwait and Iraqi theaters of war, manning antiaircraft batteries and servicing intelligence needs. U.S. intelligence was said to have heard Russian on Iraq's army tactical radio network, and the transmissions were traced to Iraqi tank battalions and regiments. One intelligence source was to have concluded that the tank units were being commanded by Soviets.[812]

While most of the above assertion remains unsubstantiated and some will prove to be incorrect, we can reasonably conclude that there was some Soviet assistance to Iraq. Additionally, while the Soviet military is restructuring and there are continued good relations with the West, it is prudent for the Soviet military to continue assessing Western military power. The War produced such an ideal opportunity for intelligence collection that Soviet surveillance, by satellites and other means, should and was expected. In sum, Soviet military involvement reflected a policy in transition from one that had supported Saddam to another that stopped such support. During the war, Moscow's most significant action was to not block Coalition efforts either diplomatically or militarily. In this context, the relatively little assistance provided to Iraq. While it cannot be quantified exactly, nonetheless was inconsequential to the extent that it did not impede substantially Coalition diplomatic or military activities.[813]

Conclusion

Soviet policy during the war reflected Moscow's independent and an accurate view of the existing international situation. In desperate need of aid from the West, it successfully traded moderation for assistance. Militarily, it provided some help to Iraq, but this was so limited that Moscow was not directly implicated. Gone was the intense Soviet-American standoff and horrendous escalation that had characterized so many crises in the past. Now Moscow declined a massive military response, while pursuing an independent policy that sought to limit the war's dimensions. Of greatest significance was the fact that now wars were again possible, as one of the two powers that had kept peace was no longer willing to play that role.

Chapter 26

The Air Power

Deployment of Forces

Great Britain, the United States, and nine other nations responded to Saudi Arabia's request for aid in August 1990, in the most extensive projection of air power in history (see Appendix A). On the 7th, the Coalition had 323-fixed wing combat and support aircraft. This strength rose to 501 aircraft on the 12th; 1,220 on September 11th; 2,430 on January 17th, and finally 2,790 aircraft by February 24th.[814]

In terms of distance and time, the projection of U.S. air power from America and Europe to west Asia was the largest in history. The Air Force deployed 46 percent of its total combat force in the United States, a force equal to 10.4 tactical fighter wings. Twelve reserve squadrons with five C-5 and seven C-141 heavy lift transport aircraft established a U.S.-West Asia air bridge. On August 18th, the Civil Reserve Air Fleet (CRAF) was activated for the first time in its 38-year history; it had 95 passenger and 63 cargo planes. The airlift amounted to a Berlin Airlift every six weeks and sent 482,000 people and 513,000 tons of cargo to West Asia, "the equivalent of moving Oklahoma City–all of its people, vehicles, food, and household goods halfway around the world". Within theater, the 317th Tactical Airlift Wing (provisional) transported over 209,000 tons of cargo.[815]

U.S. air power was deployed in two phases. The first began with an Air Force fighter squadron that flew non-stop for 15 hours 7,000 miles from the U.S. east coast to Saudi Arabia, and was aerially refueled seven times by Strategic Air Command (SAC) KC-135 tanker aircraft.[816] It was in Saudi Arabia and ready for combat less than 34 hours after the deployment order was issued by Washington, and joined those Coalition forces already there: the Royal Saudi Air Force and remnants of Kuwait's Air Force that had fled to Saudi Arabia when Iraq invaded. However, within four days, five fighter squadrons and an AWACS element were present, and by August 12th, there were reinforced by Royal Air Force aircraft and fighter embarked aboard U.S. Navy carriers. The first phase lasted five weeks and when finished, the Coalition outnumbered Iraq in both defensive and offensive aircraft. The second phase, from November 8th to January 15th doubled the Coalition's aircraft.[817]

Concurrently, her Majesty's Government ordered forces to the Gulf on August 9th, and within 48 hours, a squadron of twelve Tornado F3 fighters was operational at Dhahran Air Force Base. Two hours after their arrival, two were airborne on an operational mission. Within the next 48 hours, a squadron of twelve-ground attack Jaguars, with VC10K tanker support, were Thumrait Air Base in southern Oman, and by the 16th, three Nimrod maritime patrol aircraft were further north at Seeb. A squadron of Tornado GR1s at Muharraq, Tornado F3s (with Rapiers and Light Armored Squadron from RAF Regiment to provide airfield defense) later reinforced these deterrent forces at Dhahran, and Tornado GR1s (some equipped with ALARM for defense suppression of enemy radars) at Tabuk. After Desert Storm had begun six Buccaneers equipped with Pavespike laser designators, followed later by a further six, were deployed. Also, Tornado GR1s in theater were modified to take the Thermal Imaging Airborne Laser Designator (TIALD) equipment. The Jaguars moved forward from Thumrait to Muharraq, and Puma Chinook helicopter were deployed to Al-Jubail for logistic support and casualty evacuation by mid-January. The Royal Air Force had deployed 96 aircraft, 14 percent of its total force, including: 24 Tornado IDS aircraft from RAF Germany to Bahrain; 18 Tornado F3 (with Foxhunter A- 124 radar) from RAF Lemming to Bahrain; a squadron of Tornado GR1s to Tabuk; a squadron of 12 Jaguar GR-1As from RAF Cottishall to

Bahrain; six TR-1A early warning and reconnaissance aircraft from RAF Alconbury deployed to an undisclosed site; a detachment of C-130s; a squadron of 17 Chinook and a squadron of 19 Puma support helicopters from RAF Odiham and RAF Gutersloh; a detachment of VC-10 tanker aircraft to Seeb; four Nimrod MR2s RAF Kinloss to Seeb, and RAF Rapier and ground defense squadron.[818]

The Air Transport Force (ATF) flew around 14 million miles to support Operation Granby and moved some 50,000 tons of freight. This peaked at some 600 tons per day, more than six times the RAF's normal worldwide peacetime average. Within theater, Chinook helicopters flew some 500 sorties and some 1,350 hours carrying over one million kilograms of freight and over 8,000 troops, and Pumas flew some 1,200 sorties and 2,200 hours carrying over 68,000 kilograms of freight, over 4,000 troops, and 161 casualties. During the war, the tanker force offloaded some 13,000 tons of fuel.[819]

France contributed about 850 men and 43 combat aircraft, including five Mirage F1-CRs, 24 Jaguars, 12 Mirage 2000-2 D1s, four C 160 transports and two C135 FR refueling aircraft. In addition, operation *Metell* involved sending eight Mirage F1-Cs to Qatar, whilst 4,000 men and a squadron of ten Mirage F1–Cs WERE propositioned in Djibouti. An air base was established at Ad Ahsa from which 2,472 sorties, including 1,387 combat sorties, were flown. The airborne division of operation *Daguet* arrived on October 3rd. For ten weeks before the start of the air campaign, French Mirage 2000s flew air defense missions over Saudi Arabia, and Mirage F1–CRs DC8 Sarigues, and C160 Gabriels conducted reconnaissance against Iraq.[820]

The Air Force and Navy organized Italy's force to the Gulf. A squadron of ten Tornado bombers, reserve teams, repair groups, and a group of engineers were sent to set up *Locust*, a base at Abu Dhabi, while the 46th Air Brigade provided two Hercules C-110 aircraft to transport men and supplies to and from Italy. The Canadians deployed 24 CF-

18 aircraft, and several Arab nation contributed to the Coalition Air force: Bahrain sent 12 F-16s; Kuwait, 18 A-4s; Oman, 20 Jaguars; Qatar, 12 Mirages; Saudi Arabia, 48 Tornadoes, 85 F-5s, and 42 F-15s; and the United Arab Emirates 50 Mirages.[821]

The Air Campaign

The air campaign had four phases. The goal of phase I was to destroy Iraq's vital centers of gravity–its offensive and defensive air capabilities, including the entire Air Force and its integrated ground-based air defense system; its national communications, including television, radio and land lines; its nuclear, biological, and chemical weapons research and production capabilities; and its war production potential and transportation system including railroads and bridges, and oil distribution and transportation capabilities. The goal of phases II and III was to neutralize the Iraqi Army in the Kuwaiti theater of Operation (KTO) by cutting bridges and lines of communications to disrupt its supply, destroying its armor and artillery, and killing and demoralizing its personnel. The goal of Phase IV was to win the air/ground campaign by providing intelligence, massive firepower as needed, and protective air cover for friendly ground forces.[822]

Before the air campaign began flying routine E-3A AWACS flights near the border, which conditioned Iraqi personnel to consider such activity as normal, waged deception operations.[823] However, on the night of January 17, Coalition strike aircraft were aerially refueled just beyond Iraqi radar range, and when the air campaign began at 3 a.m., the AWACS vectored the strike aircraft to their targets and surprise was achieved. The campaign began with Stealth F-117A and Tomahawk cruise missile strikes. Tomahawks reduced pilot exposure over heavily defended targets, especially during daylight hours, and the F-117As flew virtually undetected. Although the F-117As amounted to only 2.5 percent of all U.S. air power, they struck 31 percent of all Iraqi targets hit on the campaign's first day and opened corridors for strikes by other aircraft.

RAF Tornado GR1 aircraft were involved in the first wave of attacks on Iraqi airfields using JP 233 airfield denial weapons, some 6,000 1,000-pound bombs (of which over 1,000 were laser guided), over 100 anti-radar missiles, and nearly 700 air-to-ground rockets. At dawn on the 17th, French Jaguars bombed Al-Jaber air base and Scud missile silos. French Mirage 2000s flew defensive missions over Saudi Arabia and strikes on munitions depots, naval bases, and other targets. Italian aircraft also struck targets and a Tornado was lost when it was hit by Iraqi 23-mm four-barreled machine gun fire. In the first 14 hours of the campaign, over 1,000 sorties were flown against Iraq's early warning system, fighter defense direction system, command and control structure, communications, air defenses, Scud missile sites, electrical power, and other related targets. Eighty percent of the sorties were effective, meaning that 80 percent of the aircraft reached their targets, delivered their ordnance, and returned. The others did not because of mechanical or weather problems that prevented the pilots from positively identifying their targets, which was required under the rules of engagement so that civilian damage was absolutely minimal. Having been surprised in the initial attacks, the Iraqi Air Force and air defenses were never able to recover. By the end of the first 24 hours, the Coalition had flown 2,107 combat sorties, fired 196 Tomahawk missiles, and lost a U.S. Navy F/A-18A, two U.S. Navy A-6Es, a U.S. Air Force F-15E, a U.S. Marine Corps OV-10A, an Italian and British Tornadoes and a Kuwaiti A-4. A U.S. Air Force F-4G crashed with mechanical problems. Iraq lost four MiG-29s, three F-1 Mirages, and a MiG-25.[824]

The French intensified their activities on the 23rd as part of a Coalition strategy that called for two daily raids, one that delivered 250-kilogram bombs, and a second that that involved AS 0 missile attacks. Mirage F1 CR fighter bombers were committed to combat on the 26th, and by February 12th, French FATAC (*Force Aerinne Tactique*) had delivered its thousandth 250-kilogram bomb. By the 18th, the Mirage 2000s had completed their thousandth hour of flight operations. Meanwhile, the Italian Air Force contingent conducted bombing missions and flew defensive air missions to protect Italian naval ships. The defensive mission required 2,100 more, amounting to a total of 226 missions against Iraqi targets in the vicinity of Basra, the Iraqi-Kuwaiti border, and inside Kuwait. Canadian operations were also notable; Canadian CF-18 aircraft flew a heavy schedule of sorties.[825]

The Royal and U.S. Air Forces were the backbone of the Coalition's air campaign. The Royal Air Force made a significant contribution, flying 6,000 sorties, including 2,000 offensive sorties by Tornado GR1 and Jaguar aircraft, between January 17th and February 28th. RAF missions involved air defense, offensive counter air/air interdiction, tactical reconnaissance, and Nimrod maritime reconnaissance operations. In air defense, Tornado F3s flew more than 2,500 operational combat air patrol sorties, of which over 700 were flown during the war. In offensive counter air/air interdiction (OCA/AI) operations, about 1,500 Tornado GR1 operational sorties were flown of which about half were flown against OCA targets and half against AI targets in three phases: a one week night low-level OCA phase with JP233 and 1,000-pound lofted bombs; a two three week period of night/day medium level AI, with some OCA operations using ballistic free-fall 1,000-pound bombs; and a final three-week phase involving a concentrated day/night medium level OCA/IA campaign delivering exclusively 1,000-pound laser guided bombs (LGBs) designated by Buccaneer/Pavespike (day only) or Tornado/TIALD (day/night). Due to their night and all-weather penetration capability and their unique JP233 airfield denial weapons, the Tornado GR1s were well suited to offensive counter-air attacks against Iraqi airfields and were used intensively for that purpose in the early days. Initially, the RAF were tasked to harass enemy airfield operations rather than attempt to close a selected few accurate trajectory, the Jaguar proved extremely effective in attacks against Iraqi naval targets, destroying patrol boats and landing craft. Over 600 Jaguar sorties were flown.[827]

The RAF also fulfilled a vital tactical reconnaissance mission. The Tornado GR1A reconnaissance variant with its Vinten Line-scan/computing Devices integrated system was deployed just before the outbreak of the war. It is the first reconnaissance aircraft to be equipped with video recording sensors and provides a day night reconnaissance capability. Some 140 Tornado TR1A operational sorties were flown on tactical reconnaissance missions. They operated mainly in pairs at night and at low level and for extended periods over enemy territory against Scud missile launchers, enemy positions, supply routes, and bridges for damage assessment after laser guided bomb raids.[828]

Naval Air Operations

Located much closer to some targets in Kuwait and Iraq than land-based Coalition aircraft, carrier-based aircraft were also used for strikes. EA-6B Prowlers disrupted Iraqi radar and communications, while A-6E Intruders bombed military command and control centers and ground troops, and F/A-18 Hornet and F-14 Tomcats flew combat air patrols to defend against enemy fighters. The F/A-18s, accompanied by Prowler jamming and Intruder attack aircraft, also flew into Iraq's fire control radar. The Hornets had anti-radiation bombs and missiles, such as HARM, that were designed to lock-on to radar beams and destroy targets.[829]

The Carrier-based aircraft also were invaluable in covering friendly combatant ships in the Gulf area. In mid-January, they flew against Iraqi-held islands and oil platforms that were being used to spy on Coalition ships and to ire at Coalition aircraft. A unique combined attack was waged against Kura Island. Army helicopters and the frigate *Nicholas* launched precision-guided rocket at Iraqi positions on nine oil platforms, including the Dorra oilfield platform about 40 miles from occupied Kuwait. Navy Special Forces then seized the platforms. At the same time the frigate *Curls* and A-6 aircraft from *Roosevelt* attacked Iraqi positions on Kura Island.[830] After naval aircraft attacked the naval base at Umm Qasr on January 25th, hitting four Iraqi naval vessels., and hit two others in the Gulf, Iraq had lost at least 18 boats.[831]

Meanwhile, two Nimrod sorties were flown daily in support of the *Midway* group in the northern Gulf. Tasked with locating and identifying Iraqi Navy ships and aircraft, they were very successful in making many of the initial detections and then directing attack aircraft, particularly Royal Navy Lynx helicopters, onto their targets. Nimrod also played on important role as Airborne Command Center, acting as Scene of Search Commander as part of the search and rescue (SAR) organization.[832]

U.S. naval aircraft focused on destroying Iraq's Silkworm anti-ship missiles that were a serious threat. The Chinese-made Silkworm is a short – to medium-range cruise anti-ship missile designed for shipboard and coastal defense. It has a maximum range of 62 miles and cruises at 100 feet above the water, dropping to about 50 feet for the attack. On January 27th and 28th, British and American aircraft hit two Silkworm launchers at Umm Qasr naval base while attacking patrol boats at Umm Qasr, two Iraqi naval ships in Bubiyan channel, and a patrol boat in Kuwait harbor. On the 29th, A-6s destroyed two Silkworm sites on Iraq's Faw Peninsula, just north of Kuwait, while also attacking an oil storage facility near Kuwait International Airport. On February 9th, a three-launcher Silkworm system and control center were attacked and destroyed. This occurred after a missile narrowly missed the guided missile frigate USS *Nicholas* and exploded about 50 yards off her starboard bow. Shrapnel struck the ship's superstructure but caused no injuries or serious damage. The Iraqis then fired two Silkworms at Coalition ships operating in the northern Gulf. One fell into the sea, and sea Dart rockets fired by the

HMS Gloucester, which was escorting the battleship USS Missouri, intercepted the other.[833]

The naval air campaign was continued; three Iraqi ships were damaged or destroyed in the Shatt-al-Arab and northern Persian Gulf, and three patrol boats were struck near Umm Qasr. On the 30th, attacks were continued on Umm Qasr, a patrol boat was hit and left burning near Mina al Bakr, and 15 prisoners were taken from the oil terminal at Khor al-Amaya. By now, 46 Iraqi naval vessels had been sunk or disabled and 74 Iraqi naval personnel had been taken prisoner. At least three patrol boats were hit on February 1st, thereby eliminating the Iraqi Navy's Exocet missile capability. A-6 attack aircraft relentlessly struck Iraqi convoys. As Iraqi troops retreated from Kuwait, the pace of air strikes from carriers was so feverish that pilots said they took whatever bombs happened to be closest to the flight deck. By war's end 18, F-117 sorties had been flown from six carriers, of which 16,899 were combat direct combat support missions.[834]

Chapter 27

Aspects of the Air Campaign

The Iraqi Air Force and Air Defense Threats

Before the war, Iraq had the world's sixth largest Air Force, and had Soviet-made MiG-21 Fishbeds, MiG-23 Floggers, MiG-25 Foxbats, MiG-29 Fulcrums, Su-24 Fencers, Chinese-made MiG-21s, and French-built Mirage F-1s in its inventory. Although the Coalition estimated that it had about 1,000 fixed-wing aircraft, including about 750 combat aircraft, the actual numbers may have been slightly higher. It also had an impressive air defense system, including as many as 17,000 surface-to-air missiles and between 9,000 and 10,00 anti-aircraft artillery pieces. The system's modern radar systems were fiber optically connected to integrate the computer data link system, and its command and control links were located throughout the country. For greater survivability, many primary command and control nodes were buried and concrete covered to create hardened facilities.[835]

During the two weeks before the war, the Iraqi Air Force flew about 100 sorties daily, including about 60 combat aircraft sorties. It sustained a good effort for the first several days of the war, considering the state of its air defense command and control and the damaged airfields. On the first day, it flew 96 sorties, including 53 combat sorties, and on the second day, its sorties surged to 118, although combat sorties dropped to 23. The number of combat sorties remained the same on the third day, but the total number to 42. On the fourth day, combat sorties accounted for 58 out of the 60 sorties flown. Thenceforth, the number of sorties fluctuated remained low until the sixteenth day, when the flying stopped. During the war, Iraq lost 35 aircraft in air-to-air combat, while the Coalition suffered no losses. The first half of these was lost early in the war and by

January 21st, Iraq had lost 17 fighters (eight MiG-29s, six Mirages, two MiG-25s, and a MiG-23) in aerial engagements. The other 18 were lost as Iraqi fighters fled to Iran. Besides these, it is estimated that a further 227 Iraqi aircraft were destroyed on the ground.[836]

The Coalition gained total air superiority within a week, and it was almost suicidal to fly against Coalition aircraft. In order to protect their planes, Iraqi placed them in residential areas, close to religious shrines and historic sites, and in hardened aircraft shelters. When the Coalition began to destroy the shelters, Baghdad decided to fly them to Iran and other nations to protect them. Thus, about 115-148 combat aircraft (twenty-four Su-24s, forty Su-22s, four Su-20s, seven Su-25s, twenty-four F-1 Mirages, twelve MiG-23s, and four MiG-29s) and 33 civil transport aircraft (two Boeing 747s, a Boeing 707, two Boeing 737s, a Boeing 727, five Airbus 310As, an Airbus 300, fifteen Il-76 Candids, two Falcon 20s, three Falcon 50s, and a Jetstar aircraft) were flown to Iran. Units of the Iraqi Airways fleet also may have been flown to other nations.[837]

Command and Control

To be prepared for Exigencies, the U.S. military has several joint headquarters. Coinciding with geographic areas, each plans and coordinates military operations, including battle planning, use of facilities, deployment, and training areas, logistics support, and contractual support, with U.S. allies in its area. Southwest Asia, including the eastern Mediterranean nations and the Persian Gulf, is under the aegis of U.S. Central Command (USCENTCOM), headquartered at MacDill Air Force Base, Florida. When the Coalition deployed forces, USCENTCOM deployed rapidly to a forward headquarters in Riyadh and established the initial command and control structure for deploying U.S. forces. It later became the multinational Coalition headquarters.

The Coalition's forces operated under both administrative and operational or war fighting chains of command, and General Schwarzkopf, Commander-in-Chief, USCENTCOM commanded both. The administrative chain of command was organized with the various national forces under national command, but subordinate to USCENTCOM. It coordinated administrative and logistics plans, procedures, and actions. Forces with specialized logistical missions, such as the Czechoslovakian chemical decontamination unit, the Polish field hospital, and the South Korean Air Force transportation squadron, were included in the administrative chain of command. More streamlined and flexible, the operational chain of command was designed to coordinate rapidly battle plans, orders, and actions.

Headquarters, Joint Forces USCENTOM had seven subordinate headquarters: 3d U.S. Army in Riyadh; Joint Forces Command (JFC) in Riyadh and Hafr al Batin; U.S. Marines, CENTCOM (MARCENT) in Khafji; Special Operations Command, CENTCOM (SOCCENT) in Dharhan; Joint Air Forces, CENTCOM (CENTAF) in Riyadh: Joint Naval Forces, CENTCOM (NAVCENT) in Dharhan; and 1st U.S. Cavalry Division in King Khalid Military City. Initially a theater reserve directly subordinated to CENTCOM, 1st Cavalry Division was resubordinated to 3d Army, commanded initially by Lieutenant General (Lt. Gen.) John Yeosock and later by Lt. Gen. Calvin Waller, was primarily composed of U.S. XVIII Airborne and VII Corps. They were supported by III Corps Artillery, 11th Air Defense Artillery Brigade, 12th Aviation Brigade (Combat), 7th Medical Command and 13th and 1st Support Commands. Also, the French 6th Light Armor Division was operationally subordinate to XVIII Airborne Corps, and the British 1st Armored Division to VII Corps. These subordinations are excellent examples of how the administrative and operational chains of command differed. Under the administrative chain of command, the 1st Armored Division and the 6th Light Armored Division were subordinate to Lt. Gen. Sir Peter de la Billiere and Michel Roquejeoffre, who were subordinate to Schwarzkopf.

Joint Forces Command was commanded by Prince Khalid Ibn Sultan, a member of the Saudi Arabian Royal Family. Its subordinate headquarters were the Egyptian II Corps, Joint Forces Command North, Joint Forces Command East and the Forward Forces Command. It had the most complex organization because there were so many different national forces. Egyptian II Corps had only Egyptian troops, JFC North and Kuwaiti, Syrian, and Saudi forces, and JFC East had Saudi, Kuwaiti, Moroccan, Omani, and Senegalese forces. Forward Forces Command had Saudi and Pakistani forces, and its operations were complicated by distrust among the Arab Coalition partners. Further complicating the command and control issue were the partners' differing national agenda that affected the operations of their military units. In one case, the Syrian 9th Armor Division was given an operational reserve mission within the JFC because the Syrian leadership would not commit to participating in an offensive to liberate Kuwait. The Pakistani contingent was even more restricted than the Syrians, being tasked with merely guarding Islamic shrines.

CENTCOM's U.S. Marine Corps component (MARCENT), commanded by Lt. Gen. Walter Boomer, consisted of 1st Marine Expeditionary Force (MEF). This MEF was composed of 1st and 2d Marine Divisions (MARDIVs), 3d Marine Aircraft Wing (MAW), and 1st Force Services Support Group (FSSG). The 1st (Tiger) Brigade of the U.S. Army's 2d Armor Division was attached to 2d MARDIV. Information on the organizational structure of SOCCENT is scarce due to the sensitive and classified nature of its missions and operations. The headquarters subordinated to SOCCENT were: 5th Special Forces Group, 75th Ranger Regiment, a U.S. Air Force Special Operations element, U.S. Navy SEAL (sea, air, land) forces, and British Special Forces (Special Air Service and Special

Boat Squadron). SOCCENT units may have participated in joint operations with Egyptian, Saudi, and Kuwaiti units. Joint Naval Forces, CENTCOM (NAVCENT), was commanded by Vice Admiral Stanley Arthur. Joint Air Forces, CENTCOM (CENTAF), commanded by Lt. Gen. Charles Horner, had 1,820 combat aircraft from 11 different nations. Air missions were centrally directed by CENTAF, but were executed by various components. However, U.S. Marine air operations were primarily in support of MARCENT ground force operations.

The nub of coalition warfare is balancing national interest with sound military war fighting strategy. Each nation had a link to its government and could object when displeased. In order to avoid this, major strategic decisions were not implemented until the White House had cleared them with other governments. Washington then issued military directives to CENTCOM.

Conclusion

Overall, the administrative and operational chains of command effectively ensured the necessary unity of command while accounting for national differences. The exception to this was the Joint Forces Command. However, its command and control problems were unavoidable given the diversity of nationalities in its composition and the lack of any formalized collective security arrangements. The Arab partners were not familiar as their European and U.S. allies with coalition warfare procedures. No doubt, if they had a collective security structure of some sort to the war, they would have had significantly fewer command and control problems. Clearly, in light of the problems encountered by the Joint Forces Command, forming a Middle East collective security organization should be an imperative for them. Their experiences may enable them to establish a coalition agenda vice their various national agendas in order to better ensure their collective security in the future.

Desert Storm was a vindication of the Air Force doctrine of unity of theater air control and [up to a point] its strategic concept of air operations separate from ground operations. Circumstances of geography, base infrastructure, and the type of enemy worked to the Air Force's advantage, giving it the opportunity to use its state of the art weapons against an ideal opponent in a nearly ideal scenario. One need not dwell on the unique nature of the Gulf War to observe that the Air Force was well prepared in its strategic concept, its doctrine, and its hardware for the war that occurred. The Air force command and control system became the theater air command and control system, and the other services had to adjust their practices to match it. A single air command was designated, that an Air Force officer filled position, and he was in close proximity to the CINC. Moreover, there is little evidence that CINC did insist on the establishment of a Joint Targeting Board to insure that the needs of all service components were addressed.[838]

The JFACC staff was at its core an Air Force staff. It was joint only to the extent that liaison officers from the other services and the Coalition air forces were assigned to it on a temporary basis.[839] The old USCENTAF [Ninth Air Force] staff was expanded by an infusion of officers and enlisted personnel from commands all over the Air Force. For situations in which little or no joint doctrine was in place, Air Force doctrine and organizational practices were used by default, if not preference. JFACC functions were folded into the USCENTAF organization. Officers of other services were seconded to JFACC. Note that the commander of the 14th Air Division–a USCENTAF subordinate command–was second to serve as the chief planner for JAFCC.[840]

The Air Force was equally well supported in hardware and weapons. It is only a slight exaggeration to say that the Air Force had the only stealth, theater air-to-air refueling, state of the art battlefield air surveillance, and deep penetrator bomb capabilities in theater. It also had an adequate number of fighter aircraft. But it did not have enough tankers to support itself and the other services, or enough SEAD, reconnaissance, and PGM designator and delivery aircraft.

The Navy Role in Command and Control

During the Reagan defense buildup the Navy had expanded toward a goal of six hundred ships built around fifteen carrier battle groups. Its Maritime Strategy emphasized the requirements associated with flank attacks on the Soviet Union in the event of general war. Nevertheless, in the post-Vietnam era the centerpiece of Navy expertise was its experience in showing the flag and in small contingency operations, or CONOPS. Despite the missteps of the Lebanon experience, Navy battle groups performed well in a series of CONOPS–against Libyan forces in 1981 and 1986, in a support role in Granada in 1983, against Iranian naval vessels in 1988, and in a large of less-publicized operations.[841]

Before August 1990 the Navy and the Marine Corps were generally considered to be in a unique position to undertake missions in the Arabian Gulf region because of the problematic status of rapid and adequate base access in the region, and because they maintained substantial forces and equipment nearby. A carrier battle group was rarely far from the Gulf, four to six surface escorts were usually in Gulf or in adjacent waters, and there was equipment for a full Marine expeditionary brigade abroad a maritime propositioning squadron moored at Diego Garcia.[842]

Plans for the use of naval forces were oriented around two general scenarios: defense of shipping and maintenance of access to the Gulf [such as the of reflagged Kuwaiti tankers in 1987], and support of a less likely air-land campaign in the region. In the late 1970s and early 1980s the United States worried about an incursion by the Soviet Union or a client state, in the principal threats became Iran's [and later Iraq's] potential for causing trouble locally and internal instability within a specific Gulf state. In the larger conflict scenarios the Navy and Marine Corps might arrive first, but regional geography and the size of the requisite U.S. force argued for a primary Army-Air Force role.[843]

In August 1990 the larger scenario occurred, bases were made available, and a massive, across the board U.S. military buildup began. The CONOPS paradigm could not prepare the Navy for its new role as part of a large air-ground campaign. As the buildup continued successive battle groups arrived and found themselves plugged into a planning and tasking system and a command structure of which they had little experience–but some degree of suspicion. The connection to JFACC and the ATO system was not a perfect fit. There were setbacks as the Navy's new role as a team player, not team captain, evolved and was gradually accepted.[844]

During initial operations the coordination of naval operations with theater air operations flowed from JFACC through COMUSNAVCENT, Riyadh, to COMUSNAVCENT afloat and then to the Red Sea and Arabian Gulf battle force commanders, the individual battle groups, and finally the carrier air wing commanders. The arrangement was too unwieldy for timely coordination, so a streamlined chain of coordination evolved in which COMUSNAVCENT, Riyadh, worked directly with the commanders afloat, often with the strike cells on individual carriers.[845] In effect COMUSNAVCENT, Riyadh, and his officers at JFACC became COMUSNAVCENT's strike coordinators.[846]

Some consideration was given to moving COMUSNAVCENT himself to Riyadh so that he could discharge his responsibilities as naval component commander more effectively and meet daily with both the CINC and the other component commanders. But powerful institutional voices within the Navy argued that the fleet commander should be afloat. There is merit to that point of view, but in the case of Desert Storm–unlike the

Korean and Vietnamese conflicts – the float commander was also the naval component commander. The Navy's view seemed to be that operational command of the fleet must be exercised by an afloat commander, and that those responsibilities were more important than daily contact with CINC and the other component commanders, including JFACC. There was only one Navy flag officer in Riyadh aside from the one attached to the staff of CINCCENT, while there were as many as ten afloat. COMUSNAVCENT, Riyadh, was the junior battle group commander and a surface warfare officer (an aviator flag officer held this position from August to November 1990). His principal operational duties included conferring daily with the CINC and JFACC on command and control questions involving naval air forces.[847]

In spite of the difficulties over operational paradigms, the unfamiliar command arrangements, and the location of the naval component commander, the Navy commands chain from commander to individual flight crews gradually adapted to the new environment. Adaptation was uneven, perhaps better in Red Sea force than in the Arabian Gulf force (in part because the former was more dependent on Air Force tanker support). Knowledgeable Air Force officers have complimented the performance of naval air units in coordination and integration after a shaky start. Their Navy counterparts have generally supported the JFACC concept and the need for a tool like the ATO. Some have acknowledged that the Navy did not have a command, control, and planning system that could have undertaken the task faced by JFACC in August 1990.[848]

The Navy experienced a series of operational deficiencies during the Desert Storm campaign. Some were the result and policy and program decisions made outside the Navy, but others were the result of service priorities and implicit doctrine:

1. An initial reluctance to deploy carrier battle groups in the Arabian Gulf. This reluctance was of long standing. Arabian Gulf waters are narrow and shallow,

restricting the battle groups' ability to maneuver and to provide defense in depth. The result was some delay and difficulty in integrating the Arabian Gulf carriers with JFACC-controlled operations.

2. A heavy reliance on "inorganic" [i.e., Air Force] tankers for strikes because the carriers were so far from targets. This fact denied the Navy the independent role it had grown accustomed to and became a basis for conflict with JFACC when theater tanker assets were in short supply. The command and control consequence was that tanker availability became an important joint issue, as such service tried to get what it saw as its fair share. The rules used in tanker allocation–rules that call for getting the most ordnance to the target regardless of service–seemed to work against Navy access to tanker resources. But the tanker availability issue is as complex as it is occasionally controversial. At least one carrier battle group commander saw it as a "nonproblem." Some observers have blamed the problem on (a) a lack of airspace in which to set up the number of tanker orbits required, (b) insufficient refueling points on each tanker [such as the KC-135], and (c) Navy–Air Force fuel incompatibilities. The Desert Storm experience suggests that tankers should be the most interoperable of all aircraft, regardless of their parent service.[849]

3. Inadequate installed target identification systems on Navy fighters. In the very dense air traffic environment of Desert Storm, the rules of engagement were designed to require dual phenomenology identification of air contacts before engaging. Air Force fighters designed for the similarly restrictive environment of Central Europe had the necessary equipment; Navy fighters designed and equipped for the less crowded outer air battle in defense of the fleet did not. The absence of such systems on Navy fighters was also an indirect symptom of

its CONOPS mentality. Identification of aircraft is easier during those operations; the requisite systems to support larger-scale operations were on the Navy's acquisition agenda but were given too low a priority to receive funding. The result of this chain of circumstances was that Navy fighters could not be used in some critical CAP stations.[850]

4. A bottom-up strike planning system more attuned to CONOPS than to massive, continuous strike operations. Navy strike planning was somewhat fragmented, interactive process involving the embarked flag's staff, the host carrier, and the air wing commander. It worked in single-carrier operations and deliberately planned strikes, but it was inappropriate for the Desert Storm environment. The command and control consequence was the Navy had a difficult time at first integrating its flight operations with other service and coalition force flying in the Gulf region.[851]
5. A shortage of laser designator platforms and laser-guided bombs. The only designator platform was the venerable A-6 Many other aircraft could drop laser-guided bombs, but few could guide them. Moreover, the Navy lacked the equivalent of the Air Force's deep penetrator bomb (the laser-guided I-2000). For this reason, Navy aircraft were not suitable for some important strike missions.[852]

Balanced against these shortcomings were some Navy advantages that contributed significantly to the outcome of Desert Storm:

1. The land attack Tomahawk missile was not only extremely accurate, but it could also be used in daylight and had weather against strongly defended targets. The Air Force's stealth F-117s operated at night, but the only way to keep key targets under attack the rest of the time without putting aircrews at risk was to use Tomahawk

missiles. There were no comparable standoff weapons in JFACC's arsenal. But they also created a significant coordination problem for JFACC, since the version that was used required a great deal of precursor target planning and programming.

2. The Navy HARM-shooter team put real teeth into the SEAD mission. For many, Navy F/A-18s, A-6s, and EA-6s with HARM were the preferred SEAD package in theater. The command and control consequence was that Navy (and Marine) resources were used to make up for USAF and coalition air force SEAD deficiencies, thus putting a high premium on pre-strike planning and coordination of tactics.
3. The Red Sea carriers provided a useful strike capability in spite of the long distance to most targets. They provided an additional axis of attack and were well suited to striking targets in western Iraq. More generally, the carriers were not particularly vulnerable to the version of Scud missiles Iraq used. While land-based air power carried most of the burden of theater air operations, the experience of Desert Storm demonstrated again the complementary of land–and sea-based air operations under component joint command and control arrangements.

The Marine Role in Command and Control

The Marines were early arrivals in Desert Shield. Advanced elements of the First MEF and the Seventh MEB arrived in Saudi Arabia on 14 August. Ships from Maritime Propositioned Squadron Two began unloading the equipment of the Seven MEB the next day. But Marine air units were slow to arrive–the first fighter squadrons arrived on 22 August–because of shortage of Air Force tanker support for the transit.[853] From the start the Marines were given the task of defending the Gulf coast of Saudi Arabia. Ultimately, their position was translated into an offensive posture intended to retake the coastal route to Kuwait City. Marine air bases were quickly established at Shaikh Isa (Bahrain) and

King Abdul Aziz (near Al Jubail). Some Marine AV-8B Harriers were kept afloat on amphibious units flying missions against Iraqi forces in Kuwait and providing air support for Marine ground units.

Since Vietnam, the Marines' fixed-wing tactical air units had been completely reequipped. F/A-18s and AV-8Bs had replaced F-4s and A-4s, and only a few A-6s remained in their inventory. Senior Marine aviators still remembered Vietnam, including what they perceived as an Air Force attempt to gain control of Marine air at the expense of the MAGTF concept. In spite of the 1986 Omnibus Agreement there remained a wide divergence between Marine and Air Force officers on tasking authority and priorities for Marines saw it, they had responsibility for a specified area in the vicinity of their ground forces. Within that area it was the commander of the MAGTF, not JFACC, who determined missions and priorities. If there were any sorties left over, they would be made available to JFACC. The Marines saw themselves as the only truly combined-arms team, integrated across air-ground lines and not across service lines in the air medium. The Air Force, on the other hand, focused on utilization of all tactical air resources in theater. It recognized the Marines' special ground force support doctrine and the MAGTF concept, but it remained adamant on the need for centralized allocation and tasking authority.[854]

The series of compromises struck between JFACC and Marine Corps commanders put their fixed-wing tactical air under the ATO while Marines retained control and tasking authority over sorties in specified zones near their ground formations. This was the old "route package" in all but name, but it did recognize in principle the tasking authority of JFACC over all air operations in theater. One element of the bargain initially allocated all Marine A-6 and one-half of all F/A-18 sorties to JFACC for tasking as he saw fit, while the reminder of the F/A-18 and all the AV-8B sorties remained effectively under Marine control.[855]

The fundamental tension in this bargain was between the competing demands of a strategic air offensive under JFACC [that is, Air Force] direction and an eventual tactical air operation focused on support of ground forces [including Marines]. During the first five weeks of Desert Storm, from the start of combat air operations on 17 January to the invasion of Kuwait and Iraq on 24 February, JFACC believed that Marine air had a role that went beyond preparing the battlefield for Marine ground operations. Marine commanders agreed but were concerned that when the time came to prepare the battlefield and conduct ground operations, their air units would be diverted to other tasks. It was a quarrel over apportionment and timing. Uneasy compromises were cobbled together, as they had been in Korea and Vietnam, but the fundamental doctrinal issue was not resolved.[856]

There were Marine liaison officers on the JFACC staff who were influential in ensuring that the concerns of their service were accommodated. But Air Force staff officers barely concealed their criticism of alleged Marine attempts to subvert the apportionment and ATO development processes to maintain control of Marine tactical air forces.

The Role of the Allied Air Force

Insofar as the numbers of sorties flown are concerned, allied air forces played nearly as a big role in the Gulf War as naval air forces. The air forces of the United Kingdom (RAF), France, Italy, Canada, Saudi Arabia, Kuwait, Bahrain, and United Arab Emirates, and Qatar were all involved to some degree. Moreover, these air forces were important politically as an expression of international backing for Desert storm.

The allied air forces were under the JFACC and ATO system of control. Since they lacked certain C^3 and other important combat support capabilities, they were critically dependent on US in-flight and mission planning aid. Of interest to this exploration command and control issues is the fact that they represented one more layer of complexity, JFACC tried to broker various national and service interests and develop ATOs that fulfilled both his responsibilities and those external requirements.

The Coalition was successful in integrating and coordinating all air power in mission planning, identifying ground targets for air strikes, and all the other details and requirements of the war. The Joint Force Air Component Commander (JFACC), who used an air tasking order (ATO) to assign targets to specific units and direct the weapons used, controlled air operations. He also provided "deconfliction mission data," to prevent coordination problems that could occur when such a large force operated in such a lucrative target environment. The ATO ideally maximized the effectiveness of Coalition air power.[857]

Satellites provided surveillance, weather data, and navigation support of unprecedented accuracy, threat warnings, and timely and secure communications. The Defense Metrological Support Program provided near real-time accurate target weather data, and Global Positioning System (GPS) was invaluable in guiding forces to target areas with unprecedented accuracy, while the GPS will not be completed until fiscal year 1993, it provided three-dimensional coverage for 18 hours and two-dimensional coverage for 24 hours daily. The navigational data it provided made strike mission much easier to accomplish.[858]

There were communication problems. At first there was a shortage of satellite communications, and civilian and commercial satellites provided up to half of the satellite communications because the Defense Satellite Communications System (DSCS) was swamped. However, the Air Force Space Command shifted the orbit of DSCS satellite from the Pacific to the Indian Ocean area, where it supplemented two other DSCS satellites. By the war's end, there were 128 DSCS terminals in theater, and a Joint Chiefs of Staff spokesman said, "In the first ninety days, we put in more communications connectivity than we have had in Europe over the past forty years,"[859] However, the communications traffic load was horrendous, because super high-frequency communications were not only used for links between Washington and the theater, but also between military units in theater. Additional capability, ultra-high frequency communications, was provided by six Navy fleet satellite communications satellites. The nine satellites provided over 1,400 land and sea satellite terminals with secure communications. While communications requirements increased by a factor of 30 and DSCS continually provided tactical commanders with communications, Air Force Space Command's commander, Lieutenant General Thomas Moorman, said that, "space officials were unable to respond as quickly as needed because of the lack of advanced planning," and believed that "we need to work on integrating space into operations plans." It was concluded that the Air Force must develop a more detailed space doctrine to provide principles governing the use of space systems in war so that these became an integral part of all battle force resources.[860]

Conclusion

Operations Desert Shield and Desert Storm were a major victory for American and Coalition arms. In part the result was made possible by a greater degree of jointness in air operations. But the success masked continuing difficulties.

Gen. Merrill McPeak, Chief of Staff of the Air Force, is quoted as saying:

> We don't really know the command structure was tough enough, durable enough, to really survive difficult combat

> conditions. Unhappily, complex and confusing command arrangements exist not only in situations like Desert Storm but are also a feature of our day-to-day existence.[861]

Moreover, there remain important unresolved doctrinal as well as controversies over roles and missions. The abundance of resources available made it possible to avoid some difficult apportionment and allocation decisions. Jointness too often is used as a façade to cover single-service command structures and procedures. In many ways jointness still stops at the headquarters of the CINCs: they are the lowest levels at which joint staffs exist in most theaters. We believe that Desert Storm points to the usefulness of cadre joint air staffs, and the capacity to fill them out very rapidly.

What was achieved in Desert Storm was unity of control of air operations, not unity of command. Indeed, unity of control may be all that is needed. Unity of command for tactical air forces may be needlessly abrasive and overarching term to describe what is actually meant by tactical control. We can rejoice in the progress made since Vietnam in achieving a high degree of jointness in the command and control of air operations, but it is too soon to say that the services have done all [or even most] of what they need to do.

Air Intelligence

Intelligence was criticized for overestimating the number of Iraqi Army troops in the Kuwaiti Theater of Operations (KTO) there were a number of reasons for this. Realizing that it was very difficult to estimate Iraqi troops strength in the KTO, General Schwarzkopf asked for a "worst case" intelligence estimate, one that qualified as the worst situation that he would encounter. Second, normal procedure is to base estimates by identifying enemy units, since are more easily identifiable, and each has a standard level of manpower and equipment. However, there was no accurate way determining if Iraqi units in the KTO were over or under strength. Thus the intelligence estimate assumed that all units were up to strength. After the war, it was learned that many were not, accounting for the overestimation of troop strength.[862]

Theater reconnaissance systems supplemented these satellites. Unmanned aerial vehicles (UAVs), including Pioneers and Pointers, JSTARS aircraft with synthetic aperture radar, and RF-4C aircraft that have both a conventional imagery and an infrared capability for day and night operations were used. The best theater support was by the U.S. Air Force's TR-1 squadron that deployed from RAF Alconbury, England. It had a ground station (a mobile version of the Ford Aerospace tactical reconnaissance exploitation demonstration system [TREDS] that is reportedly part of Loral) that allowed down linking intelligence in near real time. It also may have had the Ford Aerospace TRIGS system that has a secure automated processing and dissemination capability. Video imagery was provided by F-117As and F-111s, while RC-135 Rivet Joint aircraft provided electronic intelligence (ELINT).[863]

The Mission Support System (MSS) allowed planners to prepare a pilot for a mission in four hours, instead of the days that were needed for a Vietnam mission. MSS was used to integrate charts map, enemy threats, and other data in mission planning. However, despite the overwhelming success of these systems, there were problems with untimely intelligence support; there were excessive delays as the unit level and a shortage of tactical reconnaissance assets.[864]

The most sensitive targets were Iraq's nuclear, chemical, and biological facilities. Coalition Air Forces seriously damaged the nuclear research facility by destroying two of its operating reactors, and seriously damaged their biological warfare and chemical warfare production facilities.[865] By January 30th, aircraft and Tomahawks had attacked 31 nuclear, biological or chemical warfare targets, and had either severely damaged or totally destroyed at least half of them. CENTCOM had absolute confirmation that eleven biological and chemical storage areas were destroyed and that three other production facilities were destroyed or heavily damaged.

The goal of Phase II was to destroy the air defense radars and missiles in the KTO; achieved undisputed control of the air; sever KTO supply lines and isolate the KTO; and continue attacks on the Republican Guard. CENTCOM said that 26 leadership targets had been struck, with 60 percent of them severely damaged or destroyed. Telecommunications centers and electrical generating facilities were attacked, leaving 25 percent of the electrical facilities completely inoperative and another 50 percent with degraded outputs. The goal was not to destroy all electrical power because the Coalition wanted to leave Iraq's civilian population with some electricity. Seventy-five percent of Iraq's command, control, and communications facilities were struck, with 33 percent completely destroyed or inoperative. More than 800 strike sorties were flown to attack 29 Iraqi Air Defense "nerve system" targets, which forced Iraq to use less effective and more easily targeted backup systems. Thirty-six bridges were targeted to destroy supply lines to southern Iraq and the KTO and by January 30th, 790 sorties had been flown against 33 of them. This reduced the rate of supply by about 90 percent, from about 20,000 tons daily. The Republican Guards were struck by about 300 sorties daily and were hit very heavily. For example, on January 29th, 21 B-52s dropped 315 tons of bombs on them, and on the 30th, 28 B-52s dropped 470 tons of munitions, while F-15Es, F-16s, and A-6s also attacked. Strike damage on an ammunition storage area in northern Kuwait was sp large that a secondary explosion destroyed 125 storage revetments and reportedly surpassed an exploding volcano.[866] Forty-four airfields (16 primary and 28 dispersal fields) were originally targeted. Thirty-eight were struck simultaneously, and collectively, they were the target of 1,200 strike sorties. Many were hit at least four times an nine were rendered unoperational. These multiple strikes over necessary because it is relatively easy to repair damaged runways and to insure that airfields remained inoperable, it was necessary to strike them repeatedly at approximately 48 hour intervals.[867]

The Iraqi Scuds

The worst intelligence failure was the gross underestimation of the number of mobile Scud missile launchers. Intelligence was not aware that Iraq had converted trucks into launchers and there is still no accurate estimate of the total number of these converted launchers. The 36 fixed sites were easily targeted, but the mobile launchers proved to be nightmare, because the Iraqis simply launched missiles from them and then immediately moved them to hiding places, such as buildings, aircraft shelters, culverts along highways, and in other structures.[868] Besides Soviet-supplied mobile launchers, Iraq had built its own launchers by adding missile rails to trucks designed for hauling equipment, and there was no way to determine how many had been made. To further complicate matters, Iraq used decoys. The Coalition conducted armed road reconnaissance with A-10s and placed F-15Es on airborne combat patrol missions over areas, designated as Scud boxes, where Scuds were operating. The F-15Es worked with the Grumman E-8A Joint Surveillance Attack Radar System (JSTARS) ground surveillance aircraft, which was still in its developmental test and evaluation stages. In synthetic aperture radar provided images of fortifications and bomb damage assessments out to 93 nautical miles, and it would identify "suspicious" ground vehicles and divert the F-15Es to attack them.[869] Their success against the mobile launchers forced Iraq to move the Scuds to areas that severely restricted their ability to launch against Tel Aviv and Riyadh.

The Scud's inability to hit a defined target precluded its use as a military threat and it has been described best as a long-range terrorist weapon. The United States shared intelligence and provided warning of Scud attacks to Israel in an arrangement agreed upon before the war. Besides sending U.S. manned Patriot units to Israel at its government's request, America trained Israeli crews on the Patriot system. The first battery was airlifted to Israel within eleven hours of Israel's request for missiles. During the first ten days of the air campaign, Iraq fired am average of five Scuds per day. However, as air strikes and British and American Special forces teams struck and took their toll, this rate fell sharply, to one day for the war's last 33 days.[870]

The Baghdad Baby Milk Factory and the Amiriya Bunker

The destruction of the Baghdad baby milk factory and the Amiriya command and control bunker caused significant reactions [871]. The Coalition said that intelligence had confirmed that the factory was a biological weapons plant and that assessing the bunker as a command and control bunker was valid. The Amiriya reaction was so strong that Washington controlled targeting thenceforth. Retired U.S. Air Force Lieutenant General Leonard Perrots, former director of the Defense Intelligence Agency and a special consultant to that Agency during the war, said "...the American intelligence community had got it wrong when bombers attacked the baby milk factory outside Baghdad at the beginning of the allied air campaign," and "...admitted that intelligence information that led to the bombing of the reinforced bunker at Amiriya in Baghdad, killing 300 civilians, had not been accurate. It was not the most current information." Since Washington never recanted its story or provided the media access to the intelligence used to determine the status of two targets before they were attacked, serious questions persist

Bomb Damage Assessments

In his testimony to Congress in June 1991, General Schwarzkopf said bomb damage assessment (BDA–(the analytical examination of targets that were struck to determine the amount of damage they sustained–was abysmal. BDA was critical because from it, planners would determine if a target had been destroyed or if additional strikes were required. While BDA in itself is difficult, two problems made it worse. The weather in the region was the worst it had been in 14 years, and video tape recorders in many fighters did not have sufficient quality for accurate BDA. Analysts confirmed less than one-half of the aerial kills with the recorders but believed that better recorders would solve the BDA problems.[872]

Weapons

Both precision guided and unguided weapons were used in the air war. Some precision guided munitions (PGMs) glide while others are self-propelled, and all have guidance systems to lead them to their targets. In laser-guided munitions, a target is illuminated with a laser and the weapon homes in one a spot of interest light. Of the U.S. aircraft, only the Air Force's F-15E, F-111, F-117A, and Navy's A-6E could laser their targets. Equally impressive was the electro-optically guided bomb (EOGB) that had either a television camera (GBU-15V1/B) or a might attack infrared sensor (GBU-15V2/b). Only the F-111 and F-15E had this system, which required a weapon system operator to steer the EOGB onto the target. F-15E aircraft were extremely effective with their Low Altitude Night Infrared Navigation System (LANIRN) that was used with JSTARS.[873]

Despite the subsequent criticism, the initial acclaim for the Patriot missile was deserved. Patriot has been designed to destroy aircraft, nor missiles, and thus did not have the pinpoint accuracy needed to guarantee destroying a Scud warhead in the air. Its innovative use against Scud, while it did not completely destroy them, intercepted the majority of them, saving many lives and property.

In laser guided bombs (LGBs), the GBU-15 EOGB and GBU-10 Paveway II were patterned after the standard MK-84 2,000-pound general-purpose bomb. (GBU-15 is a precision modular glide bomb for use against heavily defended targets.) Probably the most effective of the PGMs was the GLU-109/B, a 2,000-pound bomb with a hardened steel case. Built like a large armor-piercing round, it could penetrate 28.8 feet of reinforced concrete before exploding. It could be fitted with the GBU-10 Paveway II LBG kit and possibly the GBU-15 EOGB. Mk-82 and M118 demolition bombs were also adapted with laser guidance kits.[874] Use of PGMs minimized collateral bomb damage.

The Royal Air Force deployed half a squadron of Pave Spike-equipped Buccaneers to enhance their LGB capability. Pave Spike enabled the RAF to switch from low altitude attacks where anti-aircraft artillery fire was especially deadly, to safer medium altitude standoff deliveries. Each Pave Spike Buccaneer could carry four LGBs, could conduct strikes alone, could act as a target (laser) designator for Tornado GR1s and Jaguar GR1 As, or could deliver Anglo-French television-guided anti-radiation Martel missiles. The RAF's JP233 Low Altitude Airfield Attack System was used effectively against Iraqi airfields by cratering runways and lying down area denial weapons (delayed explosives) that were a continuing threat to Iraqi repair crews and vehicles. The JP233 has 30 SG357 catering weapons and 215 HB876 denial weapons in each weapon dispenser, and each Tornado carried two JP233s mounted in tandem on shoulder pylons.[875]

Among the tactical weapons the Coalition used cluster bombs (CBUs) that were effective on close-air-support missions where targets were well spread out on the battlefield. CEMs (Combined Effect Munitions), patterned after a 1,000-pound tactical munitions dispenser (TDM) that releases a variety of sub munitions, were also used. Each contained 202 three-pound BLU-97/Bs that could penetrate 118 millimeters of armor. One B-52 with its 40,000-pound bomb load capacity could deliver over 8,000 BLU-97/Bs. For the most part, the B-52s focused on bombing Iraqi Republican Guard Divisions.[876]

Coalition aircraft obtain" catastrophic kills" 80 percent of the time with their air-to-ground Maverick missiles, about 100 of which Raytheon AGM-65D/G infrared imaging version. F-15E, F-16, and A-10 aircraft had LAU-88 triple missile rail launchers that enabled them to carry six Mavericks.[877]

Conclusion

The first is lesson is a reaffirmation of the traditional belief that good leadership, training, discipline, and morale are vital to a war effort. The best weapons are of questionable value when these qualities are absent. General Schwarzkopf stated this admirably when he said that the Coalition would have won even if the sides were reversed, even if the Coalition had Iraq's manpower and equipment and Iraq had the Coalition's. The heart of the matter, he said, that "the Coalition came to play, and Iraq didn't." in this context the war reaffirmed the importance of rapidly gaining air superiority and ultimately, air supremacy, in a combat theater. This gave the Coalition freedom to maneuver on the land, sea, and air.[878]

The air campaign completely devastated Iraq's Army. Despite the outcome of World War II, before Vietnam, some still believed that air power could be enough to win wars. This theory was discredited in that war, but it must be considered again. Indeed, for the first time in history, air power was the major determinant in a large-scale war between two formidable forces with field-deployed armies. Had the ground war been delayed and air war continued the deadly air strikes would have decimated Iraq's Army. This view will be argued at length by military strategists and historians in the future and is not meant to lessen the significant contributions of Coalition ground and naval forces. However, the inescapable conclusion is that air power virtually brought Iraq to its knees, and the air war showed that air power might be enough to win some conflicts.

The third lesson is that, working with a single concept of operations and clear and concise objectives that made best use of the unique capabilities of the component air forces, the Joint Force Air Component Commander (JFACC) afforded the needed command and control of the disparate component air forces. The result was both a unity of purpose and flexibility in execution that would not have been possible otherwise.[879]

The Gulf War demonstrated undeniably the value of the F-117A Stealth fighter. It continually struck Iraqi targets with lethality never before known in warfare, while never being hit despite heavy Iraqi anti-aircraft artillery and surface-to-air missile defenses.[880] The value of conventional precision-guided munitions (PGMs) was shown. Their striking hardened targets without causing collateral damage to civilian property was remarkable, proving that PGMs can surgically provide awesome destructive power in conventional air strikes. The B-52 bombers showed that despite their age, they can successfully deliver high conventional munitions tonnage against targets over long distances on very short notice and an important part of the U.S. Air Force's global reach capability.

The Coalition's ability to conduct nighttime operations was successful in denying Iraq's forces respites after sundown. The systems used demonstrated that air forces can now operate in a nighttime combat environment with almost as much accuracy as in daylight. The high overall mission capable rates sustained during the war reflected excellent training and maintenance. It ensured mission capable rates during the war that exceeded those in peacetime. Finally, new high-tech systems such as JSTARS, space systems, AWACS, and the like were of immense value in providing information on the battlefield situation.[881]

Finally, as in any war, there were problems. Many complained of the excessive time needed to get intelligence to their units and that there were not enough theater reconnaissance systems to provide all the necessary intelligence. Second, the U.S. Air

Force deployed to the West Asia without enough training munitions. This precluded them from taking full advantage of the training time afforded during Desert Shield. Finally, the U.S. military space commands were not able to respond promptly to the crisis because of an obvious absence of advanced planning. More comprehensive space doctrine and principles governing the use of space systems during wartime must be developed.[882]

Chapter 28

Command, Control Communication, and Intelligence (C^3I)

Modern C^3I, as its called, is the most important contribution that the electromagnetic spectrum has made to the conduct of modern warfare. These assets are designed to create optimum efficiency in force management in fast and fluid combat scenario. The total volume of data that needs to be acquired and processed for meaningful decision-making cannot be handled in consonance with the speed of application of modern weapon systems. Thereafter there is a need to direct combat forces, combat support elements and combat logistic services to meet plan imperatives. The electronic media suitably reinforced by data processing computers has been harnessed to meet the C^3I needs of the modern military machine. The United States has, over the last two decades created the most complex and user-friendly C^3I systems, which are totally the realm of electronics. Iraq too had a fairly formidable infrastructure to meet its C^3I requirements.

The elements of the system comprise intelligence collecting entities, means of communicating this data to the relevant headquarters/weapon system for decision making and plan formulation; transmission of directions to all agencies concerned with the execution of the plans, including a return feedback. The cycle is repetitive thus continually developing the battle situation to its conclusion. The system cannot survive in the basic from, as it is dependent on electronics, which are vulnerable to interference and interception, it is essential that a good C^3I system is endowed with the following characteristics:

- *Reliability* providing exceptionally high assurance levels for prompt development and direction of operations.

- Should be able to *survive natural* and man made denigration.
- Have the *flexibility* to meet the needs of a fast moving multiple faceted battle situations.
- Be designed to pass *real time communications to meet the imperatives of the modern battlefield.*

During the Gulf conflict both the antagonists had viable C^3I systems. However, the status was asymmetrical because:

- Iraq did not have access to the wide array of satellite imagery and other sophisticated airborne surveillance devices that were available to the United States. Even the limited number of AEW IL-76 aircraft in her inventory was not put to any use, as their very survivability under the existing air imbalance would be suspect.
- Redundancy of Iraqi systems was limited to the numbers fielded at the time the confrontation started with no scope for replacements. On the other hand, the United States had the resources of NATO and other theaters around the globe.
- The sophistication levels of Western equipment surpassed that of the equipment supplied to Iraq by the Soviets. Besides the technological edge of Western equipment, the Soviet's obviously did not provide top of the draw systems that are currently being fielded by their forces.
- Western firms provided a fair amount of Iraq's C^3I infrastructure. This meant that those specific systems were already compromised. According to Neil Munro the allies could easily crack scrambling systems supplied by RACAL electronics [UK].[883]

- Electronic counter-counter measures, with the coalition, to defend systems against hostile electronic offensive devices, was way above anything fielded by Iraq.

The C^3I infrastructure with the United States has strategic and tactical imperatives in a nuclear war-fighting environment. It comprises of technology that will not be readily available to Under Developed countries in the near future. Even if technological hurdles were overcome, the economics would make a similar structure beyond their reach. Therefore, while appreciating the criticality of C^3I for peace and war time security environmental management, developing countries must create the wherewithal in keeping with their specific threat perceptions, rationalize the technological and economic problems and adopt those measures that are attainable, analyze the American development experience and reduce overheads by avoiding those areas of friction that the latter encountered. In the light of this, the Under Developed World needs to consider the following:

- In the first decade and a half of development of C^3I systems, the three Services in the United States pursued independent programs. This duplicated the R&D costs and they arrived at systems that were not necessarily compatible for integration of forces in operations. In the mid 1980s, large amounts of funds had to be appropriated to make the entire system compatible. Under Developed countries cannot afford to spend $ 100 billion, as was the case in the United States. They would be well advised to ruthlessly curtail inter-service rivalries and create a C^3I system as an integrated national asset within which all aspects of crisis management fall– they be on the diplomatic, strategic or tactical level. A common approach would greatly reduce the cost penalties.

- While developing the different components the R&D should include all aspects of survivability to ensure that the systems provide minimum inescapable operational functions even under asymmetrical conditions as experienced by Iraq. Passive measures within our economic and technological reach should be given a higher priority. Active measures to degrade attacking electronic systems should be cost effective and simple. For example, the most sophisticated system such as that of the United States, could be totally disrupted by the projection of suitable virus that would automatically find their way back into the computers on which the systems are dependent. Cheap, simple and effective avenues must be exploited on a priority.
- The vulnerability to interference and interception of systems fielded by Iraq, needs to be taken serious note of. While developing the software, the users need to be incorporated to evolve compatible doctrines so that the system and its application are both geared to battlefield survivability.
- All the hard and software that goes into the planned C^3I system should be indigenously created. This has a number of advantages as illustrated by the Iraq conflict. Initial security of the systems is enhanced; technological skills would be at hand to modify or upgrade systems once they are compromised or for their upgrade to meet future battlefield requirements; redundancy would be unaffected even if the developed countries placed an embargo at the time of crisis.
- Simple and effective electronic countermeasures also electronic counter-counter measures must be considered and incorporated within the whole system.

- Finally, the system is workable only if intelligence inputs are made available to provide the necessary fuel to drive the system. Therefore, Under Developed countries will have to review their existing cumbersome and questionable intelligence collecting systems and redefine, reorganize and restructure them to fit the potential of modern C^3I systems. This would require the existing human intelligence sources to be provided with secure, reliable and real time communication facilities; the generation of electronic surveillance and signal intelligence facilities; and automation of data collation and processing.

The Technical Challenges to the Developed World

Of the multitude of challenges in the field of electronic warfare, the first hurdle that developing nations face is the creation of a sufficiently broad, flexible and accessible technology base to draw from in response to the rapidly evolving electronic threat. The complete suppression of air defense systems in the Bekaa valley and the unequivocal degradation of the entire command, control, communication and surveillance means of Iraq's armed forces, make it quite evident that the Developed World can ill afford to ignore this crucial ingredient to their security structure. Developed World countries need to constitute a viable development and acquisition cycle that would provide, to start with, adequate defensive measures, to be subsequently upgraded to include "state of the art" offensive systems [technological know how and resources permitting]. As in the case of Iraq, lack of such an indigenous program or infrastructure led to their dependence on the developed world for their electronic warfare assets. Under the circumstances, these were immediately compromised as supplier nations were aligned them. Consequently the coalition forces were able to neutralize these systems without much difficulty.

Technological Asymmetry

The Gulf War clearly demonstrated that technology works. Technological superiority the wherewithal to accomplish a military mission with considerably reduced force levels. The war in the Falklands and Israeli sojourn into Lebanon in 1982 were precursors of this phenomenon. Both these as well as the Gulf conflict demonstrated two basic asymmetries–one in force levels and the other in technology. In all cases, the winning side had a disadvantage in numbers while retaining massive technological superiority. A state of technological asymmetry was the underlying factor for success. The operative word is "asymmetry". This is quite distinct from a "technological edge" which may manifest itself as being superior in some restricted areas of technology. Such an edge does not constitute technological asymmetry. The latter embraces the entire gamut of warfare from weapon systems to weapons support and is not confined o C^3I as commonly believed.

With the *Technological Giant* – the United States having willy nilly and progressively conducted offensive military operations against Libya, Granada, Panama and now Iraq, developing countries, especially the threshold powers, need to review their threat perceptions. Most developing countries tend to limit the evaluation of the threat to the immediate environment by focusing their entire attention on hostile neighbors thus losing sight of larger and removed global developments. While we do not advocate a hostile stance be taken by developing countries toward a super power, it would be prudent to objectively appreciate the possibilities of future friction areas and generate adequate means to ensure their particular security environment.

Therefore, emerging power centers in the Under Developed World, such as China, need to assess their strategic environment in keeping with the technological capacity of other global powers that may, at some future date, wish to impose their will on lesser developed countries.

Under developed states need to carry out a pragmatic evaluation of their technological base to include existing potential of Research and Development, industrial infrastructure and development of suitable resources to create and operate a high-technology military complex. In keeping with the futuristic security environment. This analysis would provide a comparative technological gradation of their own status vis-à-vis inimical countries, and the thrust for doctrinal and organizational development to ensure a state of technological symmetry or superiority. In so far as the developed world goes, evaluation of their assets will establish future technological objectives to ensure minimum levels of security for which suitable development programs will need to be instituted.

Re-usability of High-Tech

Yet another area of concern is the *re-usability of high-tech systems in war and the abnormally high redundancy of these systems.*

The electronic media can be easily penetrated provided the technological know how is available and the frequency bands are identified. This leaves them vulnerable to reactive countermeasures – electronic countermeasures [ECM]. Having once applied these systems in Iraq within range of electronic intelligence [ELINT] means of the USSR, all systems have definitely been compromised. Colonel General Shaposhnikov, Chief of Soviet Air Forces, observed that, "As the war continues we will be able to draw conclusions about new methods of warfare".[884] The Soviet developed suitable ECM pods, and within the next three years could offset the offensive electronic capacity of the United States. Therefore, the latter has no options but to upgrade and redesign a large portion of the electronic component of their arsenal if they wish to retain technological asymmetry.

The obsolescence rate of advanced technology currently stands at approximately five years in the developed countries. This suggests that existing military equipment should be turned over every five years. Commercial civil applications can be rapidly changed as modernization generates greater out put thus offsetting the costs. However, military appliances are exorbitantly expensive and the lead-time for introducing new technologies is considerable. Therefore, by the time a system can be put into production, it has been overtaken by at least one if not more generation of the same equipment. Even an affluent country like the United States has budgetary constraints, which compel it to field modern weapon systems and support equipment for a full and cost effective life cycle. Consequently, electronic warfare assets in the United States are running approximately five generations behind their civilian counter parts.

The dilemma for the developing world is even more perplexing. The question that arise are:

- The intelligence on existing systems is inadequate. While we can extrapolate the General Staff Qualitative Requirement of some of the systems fielded during the Gulf War, the developing world needs to generate its own operational requirements. However, without access to the technological details of such equipment, defensive ECM is difficult to develop.
- The existing infrastructure limits their technological capability to systems that are far behind those fielded by the coalition forces during the Gulf War.
- As the systems that were fielded by the United States were compromised, these will be replaced within the next 2 to 3 years with "state of the art" components thus further increasing the technological gap in the armed forces of the developed and developing world.

- While conducting their indigenous development programs, at what stage must design freezes be implemented to ensure meaningful production? This is a critical issue. If design freezes are not incorporated, the qualitative operational parameters of weapon systems would be obliged to change during the development stage thus increasing the lead time for introduction into service and inflicting serious cost penalties. If designs are frozen prematurely and full scale production undertaken, there is a danger of fielding technically inferior equipment.
- Considering the large initial investment that would be necessitated how would the developed world cope with the factor of redundancy? The limitation of resources would have a direct bearing on the long-term efficacy of weapon systems in the armed forces.

With the expected upgrade of American armories, the United States is bound to underwrite the costs by making available considerable out dated technology. Besides being obsolete in terms of modern armed forces, induction of foreign electronic equipment would generate susceptibility to ECM equipment imported by an inimical state.

In view of this, a possible option with a developed world, emerging power like China would be to:

- Acquire electronic technology, even if it is comparatively vintage, to stabilize the existing technological base.
- Consolidate existing expertise and increase the allocation of funds for Research & Development in both military and civil institution to establish a secure indigenous capability.

- Create covert assets to identify, and where possible acquire, "state of the art" technology.
- Establish the military thrust that needs to be developed and institute policy including design freeze.
- Enhance the civil growth of electronic technology to provide drive and resources to meet the military requirement.
- Put together a meaningful technological edifice and compete for a larger share of the world market to off set the costs of one's own military requirements.

Research and Development

Developed world countries see the effect of high-tech around them and aspire to induct the "state of the art" equipment. The attempts at going high-tech are usually accompanied by a lack of in depth expertise that flows from a holistic growth pattern. Consequently, research and development policy tends to lack direction. R&D scientists are given very broad areas to include a large variety of parameters, which would tax even the developed world. The dissipation of effort generates high frustration levels and the entire effort ends up in an exercise in reverse engineering. Ipso facto reverse engineering in the developing countries must not be summarily dispensed with. Japan is a good example where they followed this route. But their intentions were quite clear; reserve engineering was a step to technology generation and not an attempt to seek technology. Each of the Developed World countries would need to identify the specific areas for technological increments and formulate a national strategy to meet their ends.

The reliance on high-tech in the West flowed from the need to overcome manpower shortages. The same is not driving force in a majority of the developed world as they have large manpower resources. However, high-tech developments in the area of military application have received their drive from the increased speed of operations; necessity for a robust and meaningful decision making apparatus to avert the increasing costs of mistakes; exponential increases in lethality and accuracy and so on. As is so aptly demonstrated by the United States in the Gulf conflict, future wars are going to bank so heavily on the electromagnetic spectrum, those not keeping pace will meet the same fate as Iraq.

Policy for development in high-tech electronic war fighting systems needs careful consideration. The minimum inescapable requirement rather than the whole bag of the tricks needs to be identified, specific parameters to meet these requirements worked out, and the R&D effort prioritized to meet these goals. A haphazard, we want it all, attitude must be ruthlessly curbed.

Specific Areas for Development

A number of specific technology areas will be critical to armed forces, irrespective of the country they belong to. While a large number of these are beyond the technological and economic reach of Developed World countries, research in critical fields must be initiated at the earliest.

Technology in the field of lasers has made prolific strides in battlefield applications primarily in the field of enhancing kill potential of weapon systems by providing accurate ranges; designating targets; or even direct destruction of targets by its own power. It also has applications for surveillance, provision of communications, degrading hostile electronic systems, position locators, small arms sights, and so on.

Development of avionics with low observable aircraft presents a major technological challenge. The integrated electronic warfare system, integrated communications, navigation and identification avionics systems form the basis for comprehensive futuristic avionics that will give pilots situational awareness needed to complete their missions while maintaining levels of survivability anticipated for "stealth" type aircraft. The degree of difficulty of each individual component is exacerbated by the problems of integration and critically of reliability.

The saturation of the electromagnetic spectrum suggests that passive means for acquisition and fire control systems need to be exploited. The concept hinges on the ability to optimize on hostile electronic support measures to increase the kill potential of own weapon systems. It involves integrating weapon platforms with sophisticated signal intercept, recognition and direction finding facilities rather than making active emissions to achieve target destruction,

Unmanned aerial vehicles (UAV) have come of age. The United States deployed 40 in support of their operations in the Gulf. They are a cheaper substitute for the more hazardous tasks over the combat zone such as reconnaissance, immediate battlefield intelligence, as jamming and intercept platforms to degrade the enemy's electronic systems in support of specific operations, and provision of precise navigational directions in the absence of satellite dependent systems.

Thermal imaging has proved its worth during the Gulf War. These optronics proved battle winners for the ground forces, which joined tactical combat under severely reduced conditions of visibility. Thermal imagers can see through total darkness, rain, dust, light foliage, smoke and haze; and proved ideal for weapon sighting and combat observation tasks. Considering the wide range of possible applications, thermal imaging systems will play a vital role in both special operations and low intensity conflicts.

Most current night vision devices are based on passive *image intensifying* technology. It magnifies ambient light thereby allowing visibility even on dark nights. Besides enhancing weapon performance at night, it provides adequate observation for crew served weapons and pilots' perspective of the immediate engagement area, something that other systems have not been able to overcome.

Missile guidance technology was the ultimate battle winner during the Gulf War. Modern missiles incorporate guidance systems of various levels of sophistication. The more effective ones have several types of guidance systems included in the missile, for use in different stages of missile flight so as to minimize the circular error of probability. Nearly all elements of the electromagnetic spectrum go into the creation of guidance systems. These include infrared homing, laser radar, radar homing, radar sensing, television and terrain contour matching. Miniaturized computers play a critical role in integrating all these systems.

Intelligence

Indications and Warning (I&W)

Was the Gulf War preventable or foreseeable? Kuwaiti Army Colonel Said Matar, military attaché to Iraq before the war, recounted subsequently that as early as April 1990 he warned in his reports of an Iraqi military operation, and on July 2nd, he pinpointed August 2nd as the invasion date, based on data from several sources confirmed independently by informants in the Republican Guard. No one in Kuwait heeded his warnings, and Kuwaiti army officers and the minister of planning silenced him while talking to the press, illustrating the common syndrome that those with intelligence prescience are seldom rewarded by their superiors. The invasion also caught virtually everyone in Western intelligence community by surprise. That community documented the Iraqi buildup, but completely missed Baghdad's real intentions until August 1st. Walter P. Lang, the U.S. national intelligence officer for the Middle East and South Asia, warned of the Iraqi invasion. But his alert was ignored.[885]

Indications and warning, or I&W, are "successful" only if no shots are fired, if war is prevented altogether. The Coalition's impressive success should not obscure this basic I&W sine qua non. The evidence suggests that strategic I&W, from both Iraqi and Coalition perspectives, were far from "optimal."

The Policy Context

Referring to post-1980 U.S. policy toward Iraq as the "great controversies," international relations expert Professor Paul Gigot avers that decade of consistent U.S. misjudgment could be traced back to Washington's reaction to Israel bombing of Iraq's Osirak nuclear facility, which involved condemning Israel, while failing to see that the threat from Iraq's potential nuclear capability.[886] The climax of this policy was the August invasion.

As Robert Wohlstter, an I&W expert, noted, it is very hard to separate genuine policy "signals" from the backdrop of "noise" in which they are embedded. Saddam's aggressive signals were intentions. It was simply assumed that his threats, designed to concessions from Kuwait, did not constitute a precursor to (and *indicators* of) invasion. This led to the second mistake, failing to signal U.S. intentions. In fact, the pattern on mixed messages could plausibly be seen as appeasing Saddam.

The roots of this U.S. policy were anchored in the 1979 Iranian revolution that sparked a tilt toward Iraq. Pentagon analyst and National Security Council staffer Howard Teicher warned of the dangers of this and forecasted Iraq's invasion of Iran. During that war, Washington was a "silent ally," sharing intelligence with Iraq. Several years later, a 1985 memorandum by Teicher and the CIA's Graham Fuller stated that concerning Iraq's domestic terror, "change" might very well cosmetic. No sanctions were imposed in 1988 in response to Saddam's chemical attacks on the Kurds, although Iraq had replaced Iran as the primary threat to U.S. regional interests, since Iran, weakened severely by its war with Iraq, could no longer offer a balance.

The Bush Administration explicitly rejected making overtures to Iran and issued a directive favoring détente with Iraq in mid-1989. From late-1989 to July 1990, Saddam issued many threats and hostile actions toward both Washington and various Arab states. His April 1989 threat to use chemical weapons on Israel sparked a reevaluation of U.S. policy. Limited sanctions emerged as an opinion, but this was never pursued seriously. Consistency characterized the messages during 1990. There was no threat to break relations and U.S. strategy clearly was one of placating Iraq. However, the infamous July 25th meeting between Saddam and Ambassador Glaspie culminated in the statement that "we have no opinion on the Arab-Arab conflict, like border dispute with Kuwait."[887] Washington never provided even the most basic signal that might have served to deter Iraq.

All of this demonstrates those policy preconceptions (and underlying state concepts, leader images, regional security frameworks, and other theoretical framework, and other theoretical frameworks) shaped decision-makers' perceptions. This, of course, is natural and inevitable. However, when policy becomes the driver and controlling lens through which intelligence is processed and interpreted, failing to respect norms of analytical pluralism may lead to an egregious situation in which "policy without intelligence" dictates actual choices as well as assessing stimuli from the environment. This is one of several "models" for interpreting I&W performance.

Models for I&W Performance Assessment

All major I&W case studies that have accrued in strategic studies literature share a common trait in that military attacks typically generated many warning signals that were embedded in a maze of both noise and deception.[888] There often were several previous alerts that turned out to be false alarms. The Pearl Harbor case provides a dramatic example of this syndrome; after June 1940; there had been three distinct periods of huge tension and alerts in U.S.-Japanese relations, including the month of November 1941, a month prior to the attack.

It can be argued that the Gulf War fits this pattern, since warning signals of Iraq's attack existed. Such post hoc minority "prescience," it must be conceded, often turns to be a false alarm. From Iraq's perspective, signals of Coalition intentions were potentially clear, although there was a failure to recognize them for what they were, and as is usual in such cases, noise and potential deception pervaded the environment. For example, the West's preoccupation with the end of the Cold War may have resulted in failing to heed the warning signals. A list of prior alerts was at least theoretically available; and as was the case with most Arab-Arab conflicts, the Iraqi claim on Kuwait had a lengthy history, as Iraq had threatened to seize Kuwait as early as 1961, when the latter became independent.

The Falklands case shows the central role of strategic *assumptions* in the matrix of precrisis/prewar political and strategic intelligence indicators and analytical frame- works. Faulty Argentine and British strategic assumptions imply that the war may have been avoided that more rational, better-articulated strategic concepts may well have prevented it. Notably, finished intelligence data available to British decision-makers was much less alarmist than the raw material, giving at least indirect support for the belief that indicators and data were filtered through a particular strategic assumptions lens.

The logic of the British strategic concept was abysmal. Underlying the baseline assumption that Argentine simply would not go to war was a higher order set of factors contained in London's fundamental defense strategy. A truism in strategic thinking is that a nation's political goals must be achievable with available military forces and strategy.

Related to this is transparent fashion in the deterrent value of forces on the spot. Only a token force was present in the region, signaling to Buenos Aires that Britain was not serious about defending the Falklands. Thus, from Argentine's vantagepoint, the base assumption was that the British would not fight but would indulge in posturing and harassment. This was a valid assumption, given the empirical signals and indications that she would neither make a long-term military commitment nor diplomatically resolve the issue.

From the British perspective, Falklands was a decision or policy failure. Decision-makers rely on and extrapolate from preconceptions in the form of "facts" about their own potential, their opponent's capabilities, political and military intentions, and inferred or perceived risk calculations. Preconceptions or strategic assumptions obviously have a potential for extensive variation on the dimensions of quality, rigor, and validity. In more basic terms, Falklands also can be seen as an intelligence analysis failure, since there was compelling evidence of flawed analysis and key miscalculations on both sides and better analysis could have prevented the war.

Analogously, the Gulf War was perhaps not a failure of data (collection) but of interpretation and assessment (analysis). But before embracing this conclusion prematurely, the insidious nature of "hindsight bias" must be recognized. Wars often begin with surprise attacks, the pattern of August 1990. Postmortems in such in such contexts lead to the conclusion that an "intelligence failure" had occurred. However, the hindsight bias, a powerful and pervasive fallacy ("I knew it would happen all along"), leads to the facile and dangerous assumption that what we know after the fact could realistically have been foreseen. This almost universal human cognitive bias can held to unwarranted inferences of intelligence or analysis failure. Hence a note of strong caution about premature or suspiciously enthusiastic assignments of "blame" for the war.

Grenada provides a textbook example of poor intelligence, since it was weak in both volume and quality. U.S. forces met more resistance than expected, the Cuban presence was severely underestimated, and there were few data on military hardware. Concerning capabilities and intentions, there was no defensible evidence to sustain the rationale that Grenada was being transformed into a base for exporting terrorism. Both pre-attack and tactical intelligence were deficient and there even was uncertainty about exactly who was in charge on the island.

Two somewhat contrasting models can be juxtaposed to explain inadequate performance. The first *foolish intelligence* occurs when estimates are flawed and other analytical errors and biases intrude. An example of this is the consistent underestimation of Soviet force sand intentions in strategic weapons. The second model introduces the notion of *policy without intelligence*, when decision-making occurs without the benefit of intelligence input. The U.S. decision to declare a Defense Condition 3 alert in response to perceived Soviet actions during the Arab-Israeli War in 1973, when extreme secrecy precluded intelligence involvement, is a good example of this pernicious syndrome. In direct and striking contrast, the Cuban missile crisis illuminates the value of close cooperation between the intelligence and policy communities. There is undeniable evidence of foolish intelligence with respect to Grenada. Political intelligence, concerned with elite analysis (analyzing the actions and beliefs of leaders), bureaucratic politics interpretations, and internal social trends, can increase lead-time dramatically. The most noteworthy characteristic of political intelligence in this instance was its obviously poor quality, due to both the lack of HUMINT (human intelligence) and the paucity of genuine, rigorous analysis.

Even more evidence supports a policy without intelligence interpretation. Developments in Grenada were viewed in the context of overall Central

American/Caribbean regional patterns as seen through a Cold War prism. This theoretical framework provided a constraining lens, analogous to the casual role of strategic assumptions in the Falklands case. The theoretical prism maximize the role of external Cuban and Soviet influence, despite the convincing evidence that the Grenadian revolutionary process was unfolding in line with a purely domestic trajectory. There is no support for the belief that alternative hypotheses were identified and considered, reinforcing the validity of the applicability of the policy without intelligence model. The case and models surveyed here offer a basis for formulating some conclusions about the war. The pervasive hindsight bias warns against prematurely accepting any hypotheses relating to I&W shortcomings. With this, we now turn a consideration of specific evidence about prewar intelligence and analysis.

Policy emerges as the driving primordial variable from the U.S. perspective. Offensive military planning began in September 1990.[889] On October 30th, Bush approved a timetable to launch an air war in mid-January and a large-scale ground offensive in February. The war led to victory, but prior to these officials lacked insight into Saddam's intentions, and no options to halt the invasion were seriously considered in summer of 1990.

Was the Gulf War avoidable? Hindsight is always perfect but the evidence and plausible reasoning suggest that war could have been avoided. America tilted considerably toward Saddam's regime, while completely misjudging his designs on Kuwait and allowing its addiction to cheap oil to distort its view of regional events. While satellite photos clearly showed Iraqi troops amassing on the border, the assessment was that Saddam was bluffing or at worst would make a limited grab for oil rich islands off Kuwait.[890] This policy posture, which governed the intelligence analysis and estimation processes, was reinforced by the belief that Iran was the key regional threat (and, as is known in alliance research in international relations, "the enemy of my enemy is my friend"). Thus, U.S. intelligence and policy leaders ignored human rights abuse, shared intelligence during the war with Iran, and sold grain and large amounts of military equipment. All of this converges in a portrait in which America's "actor concept" of this regime was as inaccurate and misleading as Britain's strategic concept in the Falklands War.

The raw data were there, but interpretation was very deficient. Just as a dominant theoretical framework served as a lens which obscured events in Grenada, failing to inject nuances and subtleties into this process reflected deeper analytical problems. Specifically, a greater awareness of the region's complexities was needed. Grenada was refracted through an arbitrarily imposed Cold War/external environment prism. Like wise, in respect to the Middle East, two conflicting schools currently compete for hegemony. The first sees all events in terms of their impact on Israel; the second, "Arabist" perspective, says that a tilt toward \Israel and neglect of the Palestinian problem will result in permanent unrest.

Neither premise explained the Gulf War's alliance patterns, with "moderate" the Jordan linked to Baghdad and "hard-liners" like Syria active partners in the Coalition. The "Arab world" is not as monolithic and predictable as is assumed. Cross cutting cleavages complex shared interest patterns, and many historical Arab-Arab conflict axes and fissures (many unrelated to Israel) imply that intelligence analysis should be less framework-driven and that explicit analytical pluralism, with developing and juxtaposing multiple alternative hypotheses, is essential. The data were potentially available but interpreting and the intervention of theoretical framework "biased" the assessments. Intelligence perspectives are always biased, although the term bias is used here to refer to a predisposing prejudgment, not in the more commonplace pejorative sense. The danger is not the intrusion of frameworks (all of which constitute "biases"), but the dominance of one particular theoretical perspective.

If we briefly shift from I&W to intelligence during the war, the picture is less bleak. There was certainly to breakdown in technical intelligence; during battles satellite photography was of such high quality that planes were capable of dropping leaflets, which identified Iraqi brigades and divisions by name. Conversely, in other intelligence areas, there were problems. For example, since the war the Director of CIA has retired, which may indicate displeasure with the CIA's performance in the war. Specific problems concerning intelligence are just coming to light, but on 13 June, General Schwarzkopf testified before the U.S. Congress that intelligence reporting on bomb damage assessments was abysmal. There are rumors that Schwarzkopf was very dissatisfied with the intelligence support that he received from Washington's Intelligence Community, particularly the Defense Intelligence Agency, and that he eventually relied on Army Intelligence organization for intelligence inputs.[891]

Before the air war was launched, the reconnaissance focus was the strategic question: how large were Iraq's forced and where were they deployed? [892] When the war began, the need shifted to tactical intelligence or specifics and information was frequently delayed in "clogged circuits" between Washington and Riyadh. Photographic capabilities were good, but photos reached fighter squadrons within one or two hours, while media, in contrast, moved pictures in only seconds. Due to intelligence shortcomings. There was a change of air tactics. F-16s patrolled individual 20x20 mile grids of terrain, instead of set targets. As the republican Guard shifted equipment, a new problem arose: reconnaissance photos became outdated too fast. This led to the use of "Fast FAC's" (fast forward air controllers). F-16s stripped of weapons except for phosphorous rockets led the attacks looking for enemy equipment in new location.

High technology space-based reconnaissance systems "proved their value in warning, communications, surveillance, and navigation, but the Gulf War strongly suggested that improvements in collecting and disturbing surveillance data are needed."[893] Satellites warned of Scud launched and cued Patriot systems, but their dated architecture, involving a small number of ground stations that passed warnings manually to commanders in the field, should be upgraded to a system in which data are delivered to users automatically, perhaps directly from satellites.

Tactical intelligence recorded a number of successes and several failures. In I&W, the best interpretation of the failure to warn of Iraq's invasion (again, taking into account the inescapable impact of the hindsight bias and recognizing that warning is so extraordinarily difficult, in part because the events per se are so rare and noise is so pervasive), emphasizes a policy or decision failure as the culprit and, secondarily, an analysis failure. The same holds for the other I&W evaluation task of Saddam's estimate that the Coalition simply would dissolve and that there would be no U.N. offensive at all.

From the U.S. view, the policy failure can be attributed to the national security bureaucracy; including the President Bush's immediate reaction to the invasion was anger; he had personally invested in the idea that Saddam's behavior could be moderated.[894] It was *assumed* all along that Iraq's saber rattling should be seen as using threats to force concessions from Kuwait, a case of coercive diplomacy rather than the unfolding of a trajectory leading to war. This assessment led to a second key mistake: the failure to signal U.S. intentions.

Saddam ignored all of the warnings of a coalition military response. Iraqi Foreign Minister Tariq Aziz told Secretary Baker at the January 9th Geneva meeting: "Your Arab allies will desert you. They will not kill other Arabs. Your alliance will crumble and you will be left lost in the desert. You don't know the desert because you have never ridden on a horse or camel."[895]

Simplistic strategic assumptions thus account for I&W policy " failures" on both sides. The data offered an empirical basis consistent with a hypothesis into the equation. Saddam's failure to see warning signals in the noise of the environment can be intercepted in a straightforward fashion. A dictator in a totalitarian state easily becomes immune to external signals because of his own unchallenged beliefs and the complete absence of analysis and policy pluralism in the decision-making process; there are no devil's advocates or institutionalized dissenters in Baghdad.[896] In a totalitarian regime ruled by an egomaniacal (albeit pragmatic, but opportunistic) dictator, the price of dissent–or even rigorous reality testing, is too high to pay.

Dissenters in the U.S. intelligence and policy processes do not pay the price of death, but dissenters are still disturbingly rare. The evidence suggests that the Bush national security policy process unfolds along two tracks; the official bureaucracy such as the National Security Council, and a small coterie of advisors surrounding Secretary of State Baker. Concepts like devil's advocacy or multiple advocacies are alien to this process.

It should also be noted that there were some failure symptomatic of " foolish intelligence." The most dramatic occurred during the war, leading to the bombing of the Amiriya bunker in a Baghdad suburb, killing 400 civilians. As a result, the Pentagon reassumed some control over targets. Air Force General Dugan notes in an assessment of lessons of the war some favor the use of space systems for almost all reconnaissance requirements.[897] However, rapidly unfolding tactics virtually dictate continuous intelligence updates; daily passes over the Baghdad bunker were insufficient to prevent the dynamic assessment/reassessment of the situation.

There were at least three major intelligence blunders. First, U.S. planners were told Iraq had moved 540,000 troops into the Kuwait Theater, with more than one-half in Kuwait. The actual totals were 250,000 and 150,000, respectively. Iraq was estimated to have only 35 Scud missile launchers; the actual number was up to 200. Finally, intelligence reported that Iraq had moved chemical weapons into the Kuwaiti theater, setting off major efforts to discover and destroy them; none were found.

This implies sub optimal intelligence performance especially when other problems (such as the proliferation of technical data with a concomitant failure to conduct high quality *analysis*, the lack of HUMINT, and the obsolete architecture of the system for disseminating satellite-based warnings) were present. Very basic capabilities were misestimated dramatically, and intelligence performance was far from acceptable. The strategic and tactical intelligence processes and products were not quite as deficient as those for Grenada, but they were distant from any reasonable standard of success. Compared to Grenada and many previous I&W "failures," this situation lacked many of the typical ambiguities of collection and analysis barriers, suggesting that intelligence should have been of appreciably higher quality.

Conclusion

The future of the Middle East will be debated extensively, and consequences and antecedents of the war are obviously multidimensional. America is in need of a long-term strategy In the Gulf region with respect to Iraq. Systematic analysis of the lessons learned and strategic policy planning will require high quality current, I&W, and estimative intelligence. Central to this is the indisputable need for more sophisticated intelligence analysis and analytical pluralism. Theoretical perspectives and policy assumptions can easily become analytical straitjackets. The hope (and expectation) is that warning (and other forms of) intelligence inputs to the policy process can be analytically grounded and sensitive to underlying casual forces in the gulf region and to nuances and subtleties operating below the surface.

Chapter 29

Electronic Intelligence

Introduction

The most lethal and some of the most expensive weapons systems used in the Gulf War in the seven months from the Iraqi invasion of Kuwait on 2 August 1990 and the cease fire on 28 February 1991 were not the missiles, the fighter aircraft, the tanks, or even the ships (apart from the aircraft carriers and some of the other major naval surface combatants). Rather, they were the plethora of electronic intelligence and electronic warfare systems, which had been deployed or directed to the area since the Iraqi invasion of Kuwait on 2 August 1990. Theses systems range from billion dollar, 37,300 pounds intelligence satellites to vehicle-mounted electronic intercepted and direction-finding (DF) systems.

Beginning in August 1990, photographic and signals intelligence (SIGINT) satellites, surveillance aircraft, and SIGINT ground stations were used to map the locations of Iraqi military forces–including missile sites, air defense sites, command and control stations, and political and military headquarters. Those, which were mobile, were continuously tracked. Those which emitted electronic signals (such as early warning and air defense radar stations and communications facilities) were continuously monitored. Electronic order of battle (EOB) tables were compiled to support the development of electronic counter-measures (ECMs).

SIGINT provided the US intelligence community with the first substantive warning that an Iraqi invasion of Kuwait was likely. On 29 July, four days before the invasion, SIGINT systems detected the activation of Soviet-built *Tall King* radar in southern Iraq. (The 350-mile-range radar had previously been used to monitor Iranian air movements, but had been deactivated in 1989.)[898]

Photographic intelligence, SIGINT, and other technical intelligence activities were critical to the preparation of plans for military operations in the Gulf. And in both the Allied air campaign and the 100-hour ground battle, the intelligence and electronic warfare systems provided a "force multiplier" which enhanced the military effectiveness of the forces several-fold. Ordnance was delivered with extraordinary accuracy against precisely located and generally well-identified targets. Rapid bomb damage assessment (BDA) allowed optimal employment of the Allied air forces against the Iraqi target set. As US Secretary of Defense, Richard Cheney, stated on 21 January 1991:

> We have a ...bomb-damage assessment process that let us go and martial our assets, our intelligence assets, look at targets, determine whether or not they've been struck, whether or not we've done sufficient damage. If we think they need to be hit again, then we put them back in the strike plan and they get a second or third mission assigned to them.[899]

The density of the electronic activity in the region greatly exceeded that in any previous theater of operations. It was impossible for President Saddam Hussein to make any significant military movement without it being detected and monitored by US technical intelligence capabilities. As a retired US Air Force general stated a month after the Iraqi invasion of 2 August, perhaps with some hyperbole, US electronic surveillance of Iraq was already so intense that US intelligence analysts "can probably tell when a [Iraqi Air Force] pilot turns on his electric razor in the squadron ready room".[900]

US and Allied Technical Intelligence Capabilities

On the US side, the intelligence systems included various types of satellites, airborne systems, ship-based systems, and fixed and mobile ground-based systems.

In order to process, analyze and determine the enormous volume of intelligence collected, two Joint Intelligence Center (JICs) were established–one in the basement of the Pentagon, organized by the Defense intelligence Agency (DIA) but also including personnel from the Central Intelligence Agency (CIA), the National Security Agency (NSA), the National Reconnaissance Office (NRO) and the Service intelligence agencies; and the other at the headquarters of the US Central Command (CENTCOM) in Riyadh in Saudi Arabia. By mid-February 1991, there were more than 700 intelligence personnel supporting CENTCOM in Riyadh–including more than 300 at the JIC and another 300 at a large imagery interpretation and photographic reproduction center supporting the theater with respect to target planning and bomb damage assessment (BDA).[901] The in-theater complex in Riyadh seems to have functioned very effectively. Its structure has been described by a senior US intelligence official as follows:

> Out of whole cloth we had to build the structure in-theater for [intelligence] collection, processing and analysis. If you had a chance to go through the dictionary of resources related to the theater for collection, processing and analysis, it would take an hour to an hour-and-a-half worth of reading. It's a very impressive array of virtually everything that exists in the inventory. To a substantial degree, all of it is performing well; not only collection resources, but also analytical resources, information-handling display systems, and the like...In terms of tactical collectors, there is a wide diversity of virtually every kind of

tactical collector that exists in the inventory. All [intelligence] services are in theater. There is a very strong national [intelligence] overly on top of those tactical collectors.[902]

According to Brigadier General John Stewart, Chief of Intelligence at CENTCOM in Riyadh, numerous communication links were established between the JIC in Riyadh and the US national and service intelligence agencies. As between the JIC and the field commanders. For example, a communication network code named *Trojan* was established during the war to enable intelligence to be provided by the JIC to "the fast-moving VII Corps".[903]

Satellites

In the seven-month period from 2 August 1990, the US launched several types of intelligence satellites and maneuvered others into different orbits specifically to monitor events in the Gulf. These included SIGINT satellites, infrared missile launch detection satellites, photographic or imaging satellites, and a radar imaging satellite.

1. Geostationary SIGINT Satellites

The US National Reconnaissance Office (NRO) maintained two types of geostationary SIGINT satellites–code named *Vortex* and *Magnum*–stationed over the western Indian Ocean to intercept Iraqi communications and other electronic signals. There were *Vortex* satellites (previous versions of which were code named *Chalet*), launched on 4 September 1989, and which are primarily designed to collect communications intelligence (COMINT); and there *Magnum* satellites (also known as *Mentor*, previous versions of which were code named *Rhyolite* and *Aquacade*), launched on 24 January 1985, 23 November 1989 and 16 November 1990, which were originally designed for telemetry collection but which are also capable of intercepting a wide range of communications and other electronic emissions.[904] These satellites were concerned with monitoring the most critical communications channels within Iraq, including those used by President Hussein himself, the senior commanders of the Presidential or Republican Guard, and the command networks of other Iraqi military units. The geostationary SIGINT satellites are controlled from ground stations at Pine Gap in central Australia, Bad Aibling in West Germany, and Menwith Hill in Yorkshire, England. The intelligence collected by these satellites was provided in real-time not just to the national intelligence agencies and defense planners in Washington, but also directly to US commanders in the Gulf itself. As *US News & World Report* reported in September 1990:

> Spy satellites lofted primarily to keep tabs on the soviets are eavesdropping on Iraqi communications and constantly updating the picture on the region available to American field commanders.[905]

2. Missile Launch Detection Satellites

The US Defense Support Program (DSP) satellites positioned in geostationary orbits over the equator at about 69° E and 75° E longitude and controlled from Nurrungar in South Australia were responsible for detecting launches of Iraqi ballistic missiles.[906] Iraq launched 81 *Scud*-B and longer-range *Al Hussein* and *Al Abbas* missiles (both modifications of the *Scud*-Bs) during the war. The infrared sensors abroad the DSP satellites are designed to detect the intense heat emitted by ballistic missile exhausts and provide early warning of missile launches within seconds of take-off. During the war between Iran and Iraq, DSP satellites detected some 166 missile attacks.[907] In a speech on 17 August 1990, Brigadier General Donald Hard, Director of US Air Force Space and Strategic Defense Initiative programs in the Office of the Assistant Secretary of the Air Force Acquisition, confirmed that DSP satellites were already watching for any missile launches from Iraq.[908] On 12 November 1990, an advanced DSP satellite was launched to provide additional coverage of Iraqi missile launch sites.[909] In addition to transmitting the early warning intelligence to the ground control station at Nurrungar and a Simplified Processing Station at Kapaun in West Germany, the new DSP satellite was able to broadcast the intelligence directly to mobile receiving stations in Saudi Arabia.[910]

The DSP satellites, together with other sensor systems in the Middle East, detected five Iraqi missile test launches in December 1990. On 2 December, three *Al Hussein* were launched from a base near Basra in southeast Iraq and flew some 418 miles, impacting about 60 miles from a military field airfield in western Iraq known as H-3, close to the border with Jordan. (These were the first Iraqi missile launches since April 1990.) US and Allied forces in the Gulf were placed on alert as soon as the first launch was reported.[911] Further launches took place on 26 and 28 December, the last of which caused a 90-minute alert of US and Allied forces.[912]

These five test launches provided DSP system controllers with an unexpected and well used opportunity to recalibrate the satellite sensors and install multiple data links to expedite and extend the distribution of DSP warning data.[913] According to one account:

> Iraqi President Saddam Hussein "blundered" when he launched ...test Scuds before the war began. The tests enabled the U.S. to ascertain the improvements needed to lengthen the warning time of a Scud attack.[914]

The DSP system not only provided a warning service. It also provided intelligence on the location of the *Scud* launch sites for rapid reaction search-and-destroy air attacks, as well as trajectory data for US anti-missile systems. Of the 81 Iraqi missiles launched between 17 January and 28 February 1991, nearly half (39) were launched from around the H-2 and H-3 bases near Rutbah against Israel and slightly more than half (42) from outside Baghdad and elsewhere in eastern Iraq against Saudi Arabia.[915] The precise ability of the DSP system to determine the *Scud* launch points has never been publicly stated, but it is probably around ± three nautical miles.[916] By the end of the first week of the war, Allied planners had developed procedures whereby DSP launch locational data was relayed directly to one of two E-8A Joint Surveillance Target Attack Radar System (JSTARS) aircraft which was always airborne, and which then directed attack aircraft on airborne alert against the launch areas.[917]

The DSP system also provided data on the general "impact" points of the *Scud* missiles, which was relayed directly to the Information Coordination Central (ICC) facilities at the battalion control stations for the *Patriot* anti-missile batteries deployed outside Riyadh and Tel Aviv.[918] A secure communications system code named *Hammer Rick* was also established for the transmission of DSP warning intelligence directly to Israeli authorities in Tel Aviv.[919] (In addition, a Dutch *Patriot* battery was deployed to Jerusalem on 23 February to protect the city from *Scud* attacks. Although one of the Dutch officers stated that it, too, would receive warning intelligence from the US launch detection satellites, Iraqi *Scud* launches had ceased by the time the battery was deployed.)[920] The advance warning and impact prediction data provided by the DSP system was a major factor in the extraordinary success of the *Patriot* against the *Scuds*.[921]

In summary, according to Henry Cooper, Director of the Strategic Defense Initiative Organization (SDIO):

> This was the first war in which space played a central part, and DSP was a very important part of it.[922]

3. Keyhole (KH) Imaging Reconnaissance Satellites

During the period from August 1990 through February 1991, the Gulf region was observed by more US imaging reconnaissance satellites than the US has ever had before in orbit at any one time.[923] At least five and possibly seven KH-11 *Kennan* and 37,300 pounds Advanced KH-11 satellites (also variously known as KH-12 *Ikon, Crystal* or the

Strategic Response satellite) provided imagery of the Saudi Arabia/Iraq/Kuwait area. These include two or three KH-11s – KH-11-6, launched on 4 December 1984, which may still have some operational capability; KH-11-7, launched on 26 October 1987; and KH-11-8 launched on 6 November 1988.[924] Since August 1989, there have been four advanced KH-11 or KH-12 launches, although not all of these may have been deployed successfully–KH-12-1, launched on 8 August 1989, KH-12-2, launched on 22 February 1990; KH-12-3, launched on 8 June 1990; and KH-12-4, launched on 16 November 1990 with the specific mission of focusing on the Persian Gulf area.[925]

The satellites are maintained in orbits about 500 km above the earth's surface, from which altitude they are able to provide visual images with a resolution of better than 1-foot. These images are transmitted in real-time via data relay satellites to the main *keyhole* ground station at Fort Belvoir in Maryland as well as various other ground terminals. In addition to its visible light imaging system, the KH-12 satellites have an infrared imaging capability, which enables them to produce images during nighttime as well as daytime.[926]

In addition to these imaging capabilities, the KH-12 satellites are also equipped with a variety of SIGINT receivers to monitor telephone conversations, microwave signals, and secure video transmissions.[927]

In order to provide this *Keyhole* intelligence to US commanders in the Gulf as rapidly as possible, the US instituted a program designated *Constant Source*. Transportable ground stations were deployed in the Gulf which could "be used with the KH-11 digital imaging spacecraft, with advanced versions of the KH-11 and with the Lacrosse imaging radar spacecraft," and which transmitted the resulting data "directly to field commanders."[928]

According to one report in late February, *Keyhole* images were routinely shown to US and Allied pilots preparing to attack targets in Iraq and Kuwait as part of their pre-flight briefings. The images included the targets themselves, enemy air defense sites, and civilian areas to be avoided in the attacks.[929]

4. The *Lacrosse* Radar Satellites

On 2 December 1988, the US launched the first of a new type of surveillance satellite; code named *Lacrosse*, which uses synthetic aperture radar to produce "images" in all weather conditions. It is able to "see" through clouds, darkness and even some foliage. It has sufficient resolution to discern tanks, mobile missile launchers, etc. In the Gulf, the dry, sandy terrain provides an ideal background for the radar images. Extensive radar imagery was provided to US commanders in the Gulf during both day and night through the *Constant Source* program.[930]

5. Meteorological Satellites

The US Air Force Space Command's Defense Meteorological Satellite Program (DMSP) satellites were also used to support both US military planning and the imaging satellite activity.[931] The DMPS satellites orbit at an altitude of about 825 km, and provide images of cloud cover, local weather systems, and ground features down to a resolution of 0.34 nautical miles. DMSP data was used to determine the times and routes for air strikes against Iraqi targets, to organize aerial refueling operations, to plan the 100-hour Allied ground offensive, and to program the orbits of US *Keyhole* satellites for maximum cloud-free coverage of the Gulf region.

Airborne Systems

The US and its allies used a sophisticated array of airborne intelligence collection systems to observe Iraqi military deployments and operations, including Airborne Warning and Control System (AWACS) aircraft, U-2 and TR-1 high-altitude reconnaissance aircraft, RC-135 strategic reconnaissance aircraft, and tactical reconnaissance aircraft such as EF-111s and RF-4Cs.[932]

A significant proportion of the 110,000 sorties flown by US and Allied aircraft over Iraq during the war–perhaps more than 10 percent or more than 11,000 sorties–were concerned with intelligence collection, bomb damage assessment and electronic warfare operations.[933]

From the point of view of continuous surveillance of Iraqi airspace, the most capable airborne warning and surveillance systems are the US and Saudi Arabian Boeing E-3A AWACS. Saudi Arabia acquired five of these aircraft in 1986-87 under a program known as *Peace Sentinel*.[934] The main operating base for these Saudi AWACS aircraft is at Al Kharj, southeast of Riyadh, but they have also operated from the airfield at Riyadh, Dhahran (which also serves as a Saudi Air Force Sector Control Center), and the King Khalid Military City (KKMC) at Wadi al-Batin just 60 miles southwest of Kuwait. The US also now has eight AWACS aircraft deployed in Saudi Arabia, and maintains an AWACS Message Processing Center at Riyadh, which receives, processes and distributes AWACS data collected by both US Air Force and Saudi Air Force aircraft. In addition, the US has deployed AWACS aircraft at Konya in Turkey since October 1983.[935] (Three NATO E-3A AWACS were also deployed to Konya).[936]

The E-3A normally operates at an altitude of 29,000 feet and a cruise speed of Mach 0.72. It can fly for approximately 11 hours without in-flight refueling, and up to 22 hours with refueling and an augmented crew. At the normal mission altitude, the radar range is 175 nautical miles (nm) for low-flying (200 feet) small fighter aircraft; 240 nm for medium-size targets; and 360 nm for high-altitude bomber-size aircraft.[937] In addition to the radar systems, the US Air Force's AWACS are also equipped with various SIGINT systems. Between early August 1990 and the end of February 1991, the US AWACS aircraft flew more than 375 missions for a total of nearly 5,000 flying hours.[938]

The AWACS aircraft worked at an extraordinary tempo during the air campaign over Iraq and Kuwait. Nearly all of the 110,000 sorties flown by the Allied air forces were monitored and provided with air traffic control and flight vectoring services by the AWACS aircraft, which also maintained continuous electronic monitoring of Iraqi air defense activity.[939] The AWACS aircraft also tracked *Scud* missiles, searched electronically for *Scud* launch sites, and directed attack aircraft to the designated launch sites.[940] According to US and Allied pilots, the AWACS aircraft were also a "key factor" in air-to-air operations, guiding fighter aircraft to optimal intercept positions.[941] According to one fighter pilot involved in air-to-air engagements in Operation *Desert Storm*:

> AWACS is all seeing, all-knowing. It gives us the "big Picture" and it can guide us right to the point where we can begin our engagement.[942]

The TR-1s, successor to the U-2 high-altitude reconnaissance aircraft, deployed from RAF Alconbury in England to bases in Saudi Arabia and Turkey, from which they conducted surveillance flights along Iraqi borders as well as over flights of Iraq itself. The TR-1s are equipped with a synthetic aperture side-looking radar (SLAR), various ELINT systems, and photographic or infrared cameras. During a single high-altitude flight, the cameras and ELINT receivers can scan and record activity across a 180 km strip more than 5,000 km long.[943] A mobile version of the Ford Aerospace tactical reconnaissance exploitation demonstration system (TREDS) was deployed to Saudi Arabia to serve as a ground station for receiving ELINT and imagery from the TR-1s in near real time and disseminating the data to air and ground commanders "within minutes".[944]

Two prototype E-8A Joint Surveillance and Target Attack Radar System (JSTARS) aircraft were deployed to Saudi Arabia ob 12 January at the specific request of General Norman Schwarzkopf.[945] The JSTARS has been described as follows:

> JSTARS is the most powerful flying eye ever conceived, capable of tracking the moves made by every Iraqi tank, gun or vehicle, predicting its course, relaying information instantaneously to ground and air commanders and aiming the artillery and surface-to-surface missiles to destroy them.
>
> Flying a random patrol between 80 and 120 km behind the front Line, out of range of enemy missiles at around 30,000 ft, the E-8A searches out targets over more than 30,00 square miles while AWACS aircraft watch for enemy aircraft.[946]

The central sensor abroad the JSTARS aircraft is multi-mode, high-resolution, synthetic aperture phases-array radar carried in a 24 ft radome located below the nose of the aircraft.[947] Six truck-mounted ground station modules (GSMs) were deployed in Saudi Arabia as part of the system.[948] Each of the two aircraft flew a 12-hour sortie each day to provide continuous real-time coverage of activity within Iraq.[949] By the end of the first week of Operation *Desert Storm*, the E-8A JSTARS aircraft were being supplied with DSP data on Iraqi missile launches and used to direct attack aircraft against the launch sites.[950] During the course of their seven-week deployment in the Gulf, the two JSTARS aircraft (flying as the 4411th JSTARS Squadron) flew 54 missions and logged more than 600 combat hours.[951] Both aircraft were based at Riyadh Air base in the Saudi Arabian capital.[952]

According to Colonel George Muellner, USAF, Commander of the 4411th JSTARS system provided ground commanders with near real-time wide area imagery intelligence on a scale and in such comprehensive detail as to be unprecedented.[953] According to Muellner:

> JSTARS brought to the ground commander what AWACS does for the air commander.[954]

The US Air Force EF-111A *Ravens* from the 390th Electronic Combat Squadron were the first US aircraft to penetrate Iraqi airspace at the start of Operation *Desert Storm*. The aircraft jammed Iraqi anti-aircraft gun and missile radars and ground control intercept (GCI) communications "to open the air war against Iraq".[955]

The US Air Force's EC-130H *Compass Call* electronic warfare and communications jamming aircraft also saw "heavy use" in the Gulf War. Along with the EF-111 *Ravens* and F-4G *Wild Weasels*, eight *Compass Call* aircraft were used to jam Iraqi air defense radars and GCI communications as well as perform other tactical command, control and communications countermeasures (C^3CM). The *Compass Call* are designed to conduct "spot" jamming of particular frequencies rather than "barrage" jamming. The essential piece of hardware is a computer-controlled system, which receives, and process enemy signals and then disrupts selected targets. The antenna systems include several blade antennas, large radomes mounted on the fuselage and under the wings, and trailing wire antennas, which are extended to a length of several hundred feet while the aircraft is in fight.[956]

The US Marine Corps also used specially equipped C-130 transport aircraft, *Senior Warrior*, for SIGINT collection. An Air Force computerized SIGINT system code named *Senior Scout* was installed in the aircraft, and the system used to monitor Iraqi radio communications and other electronic emissions in Kuwait and southern Iraq.[957]

US Army airborne SIGINT and electronic warfare aircraft used in the war included the RC-12D *Guardrail*, OV-ID and RV-1D *Mohawks*, and RU-21H *Ute* systems. The *Guardrail* aircraft are equipped with multiple SIGINT interception and DF antenna systems, as well as microwave data links for transmitting the SIGINT data to ground processing and dissemination facilities deployed in Saudi Arabia.[958] The RC-12D *Guardrails* and OV-1D and RV-1D *Mohawk* intelligence aircraft together flew more than 475 combat missions and logged 3,900 flight hours during *Operation Desert Storms.*[959]

Two types of unmanned aerial vehicles (UAVs)–*Pioneer* and *Pointer* – were also used for battlefield reconnaissance. The *Pioneer* has a 5-hour endurance and a data link range of about 120 miles, and is equipped with both a video camera and a forward-looking infrared radar (FLIR) system. Six *Pioneer* units were deployed to the Gulf – there with Marine Corps ground forces, one with the Army's 7th Corps, and one each abroad the battleships *Wisconsin* and *Missouri.* Each unit had about five UAVs. The *Pioneer* logged some 1,011 hours during 307 flights in *Operation Desert Storm.*[960] According to General Alfred Gray, Commander of the Marine Corps, the *Pioneers* were extraordinarily successful.[961] During the ground offensive at the end of February, for example, the commander of the Marine task force driving north into Kuwait received *Pioneer* video imagery directly on a console in his command vehicle as he approached Kuwait City, enabling him to monitor for Iraqi reaction to the Marine movements and operations.[962] The *Pioneers* were also used to provide route reconnaissance for Army helicopters, and real-time targeting information for Marine Corps aviation.[963] The *Pioneer* is a much shorter (3.5 mile) range system equipped with a video camera "to allow ground troops to look over a ridge".[964] Five *Pointer* systems, each consisting of four UAVs and two ground stations, were deployed to the Gulf.[965]

In addition to these US airborne systems, other Allied air forces also operated SIGINT and PHOTINT aircraft during the war. For example, the Royal Air Force (RAF) deployed six *Jaguar* reconnaissance aircraft, several *Tornado* GRIAs, and two detachments of *Nimrod* R-1 and MR-2 aircraft; the French Air Force deployed a single C-160 *Gabriel* aircraft to Al Hasa in eastern Saudi Arabia; and an Israeli SIGINT-equipped Boeing 707 was used to patrol the Israeli-Jordan border.[966]

Ship-Based Systems

All US major surface combatants are equipped with a variety of signals intercept, DF, and Electronic support measures (ESM) systems. These systems include, for example, the AN/SLQ-30 Threat Reactive Update Modernization Program (TRUMP) with a broadband intercept receiver and a special purpose electronic threat processor; the AN/SLQ-32 series of signal intercept and ESM suites; and the AN/SSQ-72 *Classic Outboard* system, composed of SRD-19 *Diamond* HF/VHF DF system and SLR-16 communications intercept and analysis receiver. These enabled US naval commanders to monitor all electronic activity in the Persian Gulf as well as any activity by the Iraqi Navy's patrol vessels, fast attack missile boats and mine warfare craft based at Basra and Umm Qasr.

SIGINT Ground Stations

Surrounding Iraq are several dozen US and Allied SIGINT stations in Turkey, Saudi Arabia, Oman and the United Arab Emirates (UAE).

There are some 17 US SIGINT stations in Turkey.[967] Most of these are designed and equipped for the interception of missile telemetry or other particular signals emanating from the southwest USSR. However, at least some of these were reportedly reoriented to monitor Iraqi signals.[968]

There are some 18 SIGINT stations in Saudi Arabia, including a facility in Jeddah code named *Briscoe Cat*. Most of these were established in the late 1970s under the *Saudi Ibex* program, which involved an investment of more than a billion dollars.[969] Two particular stations designed to monitor Iraqi communications and other signals are located at Khafji and Araz.[970] (It is interesting to note that Iraq's single attempt at offense during the war was the attack on Khafji on 30-31 January.)

A dozen SIGINT sites were established in the UAE in the late 1970s. these are located along the borders with Saudi Arabia and Oman as well as on four islands in Persian Gulf (Dalma, Az Zarqa, Sir Abu Nubyr and Abu Musa).[971]

There are also several SIGINT stations in Oman. The largest of these is a joint US National Security Agency (NSA)/British Government Communications Headquarters (GCHQ) station on Masirah Island off the East Coast of Oman.[972] GCHQ also has a SIGINT station at the Abut Sovereign Base.[973] The NSA also maintains SIGINT sites at Al Khasab, at the southern tip of the Strait of Hormuz, and at Al Khoud near Rusayl and on Um Al-Ranam Island.[974]

Locating the Scuds

Although the fixed Iraqi missile launch facilities were all destroyed during the first several days of the air campaign, locating and destroying the mobile launchers proved to be quite difficult.

Almost all–about 95 per cent–of the missile launchers took place at night; on the few occasions when launches were conducted in daylight hours, it was during the early morning and under heavy cloud conditions.[975]

All relevant US and Allied intelligence collection systems were applied to the task, but each had important deficiencies. In the case of the *Keyhole* photographic satellites, for example, there were intervals of two of three hours between each pass over Iraq, and more than half the passes took place at night or when cloud cover or smoke from oil fires blocked the satellites' vision. Although the *Lacrosse* radar satellite was unaffected by light or cloud conditions, only one of these satellites was operational, and it passed over Iraq only twice a day; the resolution of the *Lacrosse* radar imagery was relatively poor, making it difficult to distinguish *Scud* mobile launchers from trucks and other large vehicles; and the time required to down-link and process the *Lacrosse* data meant that at least 15-20 minutes generally elapsed between the satellite pass and the availability of the data in the field. Data from the DSP warning satellites was provided much more rapidly, but the DSP system can determine the actual launch point only to an area of some 30 square miles, and several minutes still elapsed between the launched of a missile and the receipt of the DSP data by US and Allied aircraft waiting to attack the launch systems; by the time the attack aircraft arrived over the launch area, the mobile launchers could have moved several miles in any direction to shelters, road underpasses or other camouflaged sites.

SIGINT systems were also used to locate the *Scud* launchers. Preparation of the missiles for launch involved considerable electronic activity. Makeshift command and control nets had to be constructed and activated; the missiles fueled, erected and checked to ensure that all components were functioning; and the guidance data inserted. Each missile launcher was accompanied by van-mounted *End Tray* meteorological radar, which was activated prior to a missile launch to track weather balloons in order to obtain ballistic trajectory data for navigation/guidance of the missile to the target.[976] Monitoring of *End Tray* radar missions frequently provided warning that a missile launch was imminent, and airborne direction finding (DF) systems were frequently able to determine the location of the missile facilities some minutes before missiles were launched. However, the *End Tray* data was not conclusive. As John Pike, the Director of Space Policy for the Federation of American Scientists, has noted:

> The problem is that you can turn on these meteorological radars without there being a Scud launch, or you can have a weather radar van just driving around by itself.[977]

Iraqi SIGINT units also provided intelligence to the *Scud* commanders, warning them of incoming US/Allied air attacks and enabling them to take evasive action.

Army CEWI Operations

At the tactical level, each US Army Division deployed to the Gulf included a Combat Electronic Warfare and Intelligence (CEWI) battalion responsible for collecting intelligence and conducting electronic warfare in direct support of field commanders. The purpose of the CEWIs is to find targets for artillery and tactical aircraft, deceive enemy commanders, and disrupt enemy C^3 networks. The battalions include long-range reconnaissance troops as well as radio monitoring, radio direction finding, and electronic jamming vehicles, and three jamming helicopters.[978] Although the operations of the CEWI battalions were hampered by the extensive use of radio silence by the Iraqi forces, were still integral to the US Army's ground campaign at the end of the war.

Special Operation Units

Numerous US and Allied special operations units also operated within Kuwait and Iraq from the 1990 through February 1991–including the US Delta Force, Green Berets, Rangers and Navy Seals (sea, Air and Land teams) as well as the British Special Air Service (SAS) and Special Boat Squadron (SBS). According to General Schwarzkopf, these Special Forces units "were the eyes that were out there" to Allied commanders and US both during the "weeks before the ground war began" and during the ground war itself.[979] These units were equipped, *inter alia*, with hand-held devices "to eavesdrop on radio transmissions of nearby units".[980] They also carried portable communications systems, which enabled them to transmit short bursts of information over secure satellite links from hiding places deep in Iraq and Kuwait.[981] In addition to SIGINT collection, these Special Forces destroyed Iraqi communications centers, microwave towers and landlines, thus "forcing the Iraqis to use conventional radio which was intercepted by the

Allies".[982] In cases where they did not destroy the communications facilities, they left small battery-operated jamming devices to jam the communications.[983]

Decrypting Iraqi Communications

At the outset of Operation Desert Shield in August 1990, the National Security Agency (NSA) and the associated Service Cryptological Authorities (SCA) were not well placed for the decryption of Iraqi communications. The NSA/SCA was frustrated by the Iraqi investment in sophisticated Soviet, British and French encryption systems; the widespread use of landlines and optical fiber cables; the high standard of discipline exercised by Iraqi radio operators; and a scarcity of Iraqi linguists in the US intelligence community.

As Operation *Desert Storm* progressed through January-February 1991, however, the Iraqi communications became increasingly susceptible to decryption. There were several reasons for this development. To begin with, once the full weight of US satellite, airborne and ground-based SIGINT systems was brought to bear against Iraqi communications, the volume of intercepted signals available for the cryptological agencies to work on increased enormously, thus greatly improving the chances of decryption. It is also possible that some of the suppliers of the Iraqi encryption systems, such as Racal Electronics, assisted the Allied decryption effort.[984] More importantly, as the air war wreaked havoc on the Iraqi C^3I system destroying or incapacitating communications centers, landlines and optical fiber cables, Iraqi communicators were forced to use increasingly insecure communications systems. Indeed, by early February 1991, the combination of electronic warfare aircraft and Special Forces operations against the Iraqi C^3I network had reached the point where the Allies were essentially able to tailor the Iraqi use of communications to modes, which were known to be insecure and easily intercepted. At this point, the dearth of skilled translators available to read the decrypted traffic became a bottleneck.[985]

On the other hand, even when Iraqi communications remained unencrypted or unread because of the dearth of translators, much intelligence was still gleaned about the location of Iraqi units, their internal organization and the chains of command, by analyzing the patterns of communications between various units.[986]

The success of the NSA/SCA SIGINT activity during Operation *Desert Storm* was acknowledged by President George Bush on 1 May 1991 when he visited NSA Headquarters at Fort Meade in Maryland to honor the contributions of the "unsung heroes" to the Allied victory in the Gulf.[987]

Chapter 30

Iraq's Electronics Intelligence Capabilities

Although Iraq's electronics intelligence capabilities are dwarfed by the enormous complex of sophisticated US Systems, they are nevertheless able to provide the Iraqi political and military leadership with a fairly comprehensive coverage of communications and electronic activity around Iraq's borders. According to a report in February 1991, for example, "the Iraqis...have a sophisticated network of radio-listening equipment".[988]

Iraq's capabilities consisted essentially of three Ilyushin Il-76 *Adnan* airborne early warning (AEW) aircraft, more than a dozen reconnaissance aircraft, some dozen and half SIGINT ground stations, and various sorts of truck-mounted mobile intercept, DF and jamming systems. Much of this capability was provided by the Soviet KGB and GRU under liaison and assistance agreements concluded in the mid-1970s. According to some reports, Soviet advisors and technicians continued to assist with the operation of some Iraqi SIGINT and electronic warfare facilities throughout Operation *Desert Storm*.[989]

The three Il-76 *Adnan* AEW aircraft (one *Adnan*-1 and two *Adnan*-2s) provided only a very limited airborne warning and surveillance capability. The *Adnans* are derivations of the Soviet Il-76 *Mainstay* AWACS, but have inferior electronic systems, and the *Mainstay* themselves are less capable than the Boeing E-3A AWACS. (There are, for example, major 'blind spots' caused by the placement of the rotodome forward of the wing trailing edge and by the tall tail fin of the Il-76.) The aircraft only achieved an initial operational capability (IOC) in 1989, and crew skills and operating techniques were yet to be brought to full proficiency. In August 1990, it was reported that Iraq had signed a military cooperation agreement with Jordan, which allowed Iraq to fly both high-altitude photographic reconnaissance and ELINT missions over Jordanian airspace to monitor much of central Israel.[990] At the same time, it was reported that the *Adnan*-1 AEW aircraft had monitored aircraft in Israeli airspace while flying over Iraq.[991] However, the Iraqi Air Force was reluctant to fly the *Adnans* after 2 August for fear of comprising their operating frequencies and other electronic characteristics as well as their control and reporting links. Soon after the Allied air bombardment of Iraq was launched on 17 January, the *Adnan*-1 was damaged severely during an attack on the Al Taqaddum airfield.[992] The two *Adnan*-2s flew to Iran in late January to escape destruction.[993]

The Iraqi Air Force also operated three types of reconnaissance aircraft- eight MiG-21 *Fishbeds*, and several Mirage F-1EQ aircraft.[994]

The great weight of the Iraqi technical intelligence capability resided in the SIGINT ground stations. Major SIGINT stations were established around Baghdad, along the southern border with Saudi Arabia, near Basra in the southeast of the country, west of Rutbah near the border with Jordan, northwest of Mosul near the border with Turkey, along the Northeast Highlands from Mosul to Kirkuk, along the border with Iran, and at two sites southeast and southwest of Baghdad where they were co-located with major command centers. The main Iraqi defense electronic center at Al-Dour, northeast of Baghdad, also had an extensive range of SIGINT and other electronic warfare systems which could have been utilized for operational purposes.

In 1978, Iraq also acquired several tactical communications intercept and jamming systems from France, which were deployed along its borders with Iran and Saudi Arabia, under a program known as *Qari*.[995]

Both the Iraqi military and the security organizations–the General Intelligence Department (Mukhabrat) and the State Internal Security (Amn al-Amn) – also possess various sorts of mobile SIGINT, DF and jamming equipment. For example, units of the Presidential or Republican Guard operated mobile intercept and DF systems in Kuwait in a fairly successful effort to locate and stop illicit Kuwait communications. (In addition, a major radio monitoring and jamming station was established near Kuwait City to jam Radio Kuwait, a clandestine broadcast station that was initially operated in Kuwait and later moved to eastern Saudi Arabia. The Iraqi station was destroyed by Allied aircraft in late January.)[996]

Soviet-supplied van-mounted intercept and jamming systems, code named *Paint Can*, were also deployed at several places inside Kuwait (including the Iraqi military headquarters in Kuwait), along the Iraq/Saudi Arabia border.[997] These systems were used to jam US and Saudi AWACS aircraft flying surveillance missions along the Iraq/Saudi Arabia border and over the Persian Gulf near Kuwait.[998] The *Paint Can* systems were prime targets for US air strikes after 17 January.[999]

Iraqi forces also used tactical SIGINT equipment to monitor the communications nets of US troops based in Saudi Arabia about 50 miles south of the Kuwaiti border. By studying US frequencies, call signs and the names of signals personnel, the Iraqis were able to engage in "imitative deception" involving "coming on U.S. frequencies, using names of Marines they have picked up, and getting the patrols to bite on a phony message".[1000]

The poor communications security (COMSEC) practices of the US and Allied forces would have allowed Iraqi SIGINT units to collect valuable intelligence on their deployments and operations. The Saudi Arabian forces were particularly lax, both before and during the war. According to a US advisor to the Saudi forces, they "have no idea of operational security" and regularly "talk in the open" about sensitive subjects.[1001] Further:

> After the first two weeks of the war, [other U.S. units] stopped talking to us...because the Saudis were spreading intelligence we gave them as gossip...[Communications]

discipline was very weak.[1002]

Poor COMSEC practices were also common among US personnel. For example, during the airlift to Saudi Arabia in August/September 1990, when Iraqi SIGINT capabilities were all intact and subject to minimal electronic countermeasures, "most aircraft gave out home bases, identified their units, and one cheerfully revealed his tail number".[1003] Poor communications discipline caused frequent re-transmission of orders and other messages. The air-to-air refueling tankers even used their peacetime color identification codes.[1004]

Even during Operation *Desert Storm*, when most of the major Iraqi SIGINT facilities were destroyed or incapacitated, special SIGINT units with Soviet-made electronic equipment operated close to the front lines and collected extremely valuable intelligence. For example, the Iraqi units monitored the communications between Allied airborne forward air controllers and incoming attack aircraft, including those directing the attack aircraft, including those directing the attack aircraft to specific targets in the area. On one occasion, US SIGINT personnel heard a radio conversation between the commander of a mobile *Scud* launcher and his immediate superior in which the commander reported that he was moving position because an F-16 attack was imminent – foreknowledge derived from monitoring the communications and breaking the target coding system used by the forward air controllers and the attack aircraft.[1005]

The Iraqis also used tactical SIGINT to counter certain maneuvers by Allied attack aircraft. According to one account, for example:

> The Iraqis used information obtained from radio intercepts to lay ambushes for low-flying attack aircraft. They listened in as U.S. pilots talked among themselves about tactics to avoid various types of air defense missiles. After some study, "the Iraqis

> knew how we reacted to the SA-8" surface-to-air, radar-guided missile, for example, a U.S. official said. The usual response was a hard left or right turn into a flight path at right angles to the flight of the missile. This maneuver would be followed by a hard turn toward the missile when it got close enough. Often the final turn would cause the missile to break its radar lock because it could not turn quickly enough.
>
> The Iraqis countered this evasive maneuver by deploying shorter-range, infrared-guided missiles–such as the SA-9 or 16–at right angles to an SA-8 battery. When an SA-8 missile battery's radar locked onto an allied aircraft, the pilot rolled away, offering "a big heat plume" from his engine exhaust for heat-seeking SA-9 or SA-16 missile to guide on, an intelligence official said.[1006]

Iraq's non-strategic SIGINT capability proved impossible to completely demolish during Operation *Desert Storm*. According to General Glenn Proffit, USAF, Chief of the US Air Force's electronic combat forces at CENTCOM in Riyadh:

> [The Iraqi] SIGINT network was very robust, [land] had a lot of depth...[SIGINT collection] was probably the most militarily effective thing he [Saddam Hussein] did.[1007]

Overall, however, this "robust" capability did the Iraqis little good. As General John A. Wilkham, former Chief of Staff of the US Army, has observed, the destruction of the Iraqi command and control system meant, "even if intelligence was available, they could not make good use of it".[1008] For example, US pilots downed behind Iraqi lines were probably tracked, together with the rescue attempts, by Iraqi "electronic eavesdroppers", but there was nothing the Iraqis could do about it.[1009]

Iraqi security organizations reportedly monitored all international telephone communications. According to one report, for example:

> Foreigners' telephones are tapped and are instantly
> Disconnected if people talk in a language the eaves-
> Droppers don't understand. When a visiting dentist
> From Zambia called home and started speaking in
> His native tongue to his wife, the line went dead.
> Seems there were no Zambian interpreters in Baghdad.
> On Fridays, the Muslim holy day, international calls
> Are restricted to 10 minutes because there are not enough
> People to tap all the calls.[1010]

Although Iraq lacked any satellite capability of its own, it was able to use other imaging satellite systems for limited intelligence purpose. On 2 May 1990, three months before the invasion of Kuwait, Iraq purchased a set of 10-meter resolution SPOT photographs of Kuwait and Saudi Arabia from Spot-Image, a French company that specializes in satellite imagery.[1011] Iraq also had access to Soviet satellite imagery, including imagery of Kuwait and Saudi Arabia taken with the KFA-1000 camera with a 5-meter resolution; imagery from the 5-10 meter resolution MKF-6M camera used by the *Mir* crew; and imagery taken by another camera with a 10-12 meter resolution.[1012] Iraq also had access to real-time wide-area imagery from three US weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA), which provided it with images of the region six times a day–at least for as long as the Iraqi receiving facilities continued to operate. The NOAA spacecraft provide images with a resolution of 0.6 to 2.4miles in visible and infrared wavelengths. Imagery of cloud cover over Iraq was used by the Iraqis to schedule *Scud* launches when clouds made it more difficult for US and Allied aircraft to locate and destroy the mobile launchers.[1013]

Finally, it should be noted that an important Iraqi intelligence asset was some familiarity with advanced US intelligence systems. In mid-1984, during the course of Iran-Iraq war, Baghdad and Washington established a secret intelligence cooperation agreement whereby Iraq "was given information gleaned from satellite photo of Iranian troop positions that helped it plan and wage its campaigns".[1014] In August 1986, the CIA reportedly "established a top-secret Washington-Baghdad link to provide the Iraqis with better and faster intelligence from U.S. satellites".[1015] In addition to satellite photography, Iraq was also provided with some US SIGINT concerning Iran. Hence, as a senior US intelligence official stated in February 1991:

> Iraq...has had about four years or more worth of US delivering intelligence to it with regard to Iran's conduct of the war. So they had a substantial knowledge and sensitivity of our capabilities in the area of imaging and other intelligence collection methods such as signals intelligence (SIGINT). If you go back to the fundamental, we had already failed on the first count. That is, that our security had been penetrated because we were dealing with this target [i.e. Iraq] to whom we had spent so many years displaying what our intelligence capabilities were.[1016]

Iraq used this knowledge of US photographic satellite and SIGINT capabilities to camouflage some of its military activities (such as the mobile *Scud* deployments), to conduct electronic deception operations, and to enforce strict radio silence and other operational security (OPSEC) measures at the battlefield level. (In addition, the defection of a Saudi Arabian F-15 pilot to Sudan on 11 November 1990provided Iraqi intelligence with tactical information about Saudi communications frequencies as well as the capabilities of Saudi electronic warning and electronic countermeasures systems.)[1017]

Conclusion

Electronic intelligence and electronic warfare capabilities were critical to the course and outcome of the war in the Gulf. As Admiral Sergei G. Gorshkov, the late commander of the Soviet Navy, once said, "The next war will be won by the side that best exploit the electromagnetic spectrum".[1018] And as Norman Augustine, former Under Secretary of the US Army, stated more recently, "the side who wins the next war will be the side with the last antenna standing".[1019]

On 15 January, the US began jamming radio frequencies in Iraq as a prelude to the air attack, which began on 17 January.[1020] Iraqi command, control, communications and intelligence (C^3I) centers and facilities figured as the priority target set at the outset of the air campaign. Massive and repeated air strikes were directed at the Defense Ministry headquarters, Iraqi Air Force headquarters, Iraqi Air Defense headquarters, the Presidential compound, the headquarters of the Baath Party, telephone exchanges, and other command bunkers and communications facilities in and around Baghdad; at Iraq's regional sector air defense command sector air defense command centers at Kirkuk, Nasiriyah and Rutbah; and other major command and intelligence centers such as Baiji, Karbala and Al Kut; at the bridges across the Tigris River carrying communications cables; at the Iraqi SIGINT and jamming stations; and at other command posts and communications facilities throughout Iraq. According to General H. Norman Schwarzkopf, the commander-in-chief of the Allied forces in the Gulf, some 75 per cent of Iraq's command, control and communications facilities were attacked during the first 14 days of the air campaign, with about one-third of them destroyed or incapacitated.[1021] In addition to the air strikes, elite commandos of the US, British and French special forces operated inside Iraq to destroy underground communications cable links between Baghdad and Iraqi forces in the Kuwaiti theater of operations.[1022]

The principal objectives of these attacks against Iraqi networks were to serve the connections between the Iraqi high command in Baghdad and the Iraqi forces, and to curtail the flow of intelligence to the Iraqi high command. The attacks against the Iraqi air defense headquarters, sector command posts and radar and communications sites proved especially effective in decapitating the Iraqi air defense operations and paralyzing the air defense units.[1023] More generally, the attacks on Iraqi communications systems so severely disrupted them that within 3-4 weeks of the air campaign it was taking President Hussein some 24 hours to get messages to the front by reasonably secure means.[1024] By mid-February, the Iraqi leadership was even dispatching messengers on motorcycles to disseminate orders and intelligence.[1025] Otherwise, it was dependent upon improvised, unsecured HF radio communications no more sophisticated than walkie-talkies for communications with field commanders. By mid-February, Hussein still retained an ability to communicate with corps-level commanders, but the links were too rudimentary to coordinate corps-level operations, let alone multi-corps operations; and it had become too difficult for Baghdad to keep in touch with commanders at the division level or below.[1026] And with the destruction of the Iraqi intelligence collection system, Hussein was "stripped...of his electronic eyes and ears".[1027]

As General John A. Wilkham, former Chief of Staff of the US Army, has noted:

> Before the air war, Iraq possessed sophisticated intelligence capabilities. aircraft, including helicopters, could gather visual and electronic intelligence...Ground-based signals intelligence [SIGINT] systems could yield electronic intelligence from non-secure transmissions...

> The air war destroyed almost all of Iraq's intelligence eyes and ears, and particularly their command and control systems, so that even if intelligence was available, they could not make good use of it.[1028]

On the other hand, the US and Allied forces did not attempt to completely destroy the Iraqi communications systems. Forcing the Iraqi leadership and field commanders to use unsecured HF radio transmissions provided the US and Allied forces with valuable SIGINT concerning Iraqi plans, preparations and morale. Leaving some Iraqi radios operational also allowed the Allies to deceive Iraqi defenses by propagating fake orders.[1029] Most importantly, some Iraqi communications systems were left intact so as to provide a means of monitoring communications between Saddam Hussein and his military commanders in an effort to pinpoint the location of the Iraqi leader. As one Pentagon official stated in mid-February, "We have adopted a strategy of leaving Saddam with some communications so that we can track him".[1030] According to Secretary of Defense Cheney, however, in an interview on 27 January, Hussein was not being targeted as an individual, but as the principal element of the Iraqi national command authority. When asked why the US was not attempting to target Hussein himself, Cheney stated:

> We clearly are interested in destroying their national command authority. That means specifically those elements that command the forces that have been used to take Kuwait and continue to occupy it–its communications, its facilities, it's the command headquarters of the divisions in the field as well as back in Baghdad.
>
> We've not gotten to the business of trying to truck him [i.e. Saddam Hussein] down to an individual location and then

> strike that location. But we obviously are interested in working to make certain that they can no longer command the forces. And that means that, in that context, as the commander of those forces, as part of the national command authority, he might be well affected. We're not in the business of targeting specific individual.[1031]

It is clear that, within a week of the start of the war, a concerted effort was underway to use SIGINT to track and locate the Iraqi leader.[1032] It was reported on 25 January, for example, that:

> A Central Intelligence Agency task force ha coordinated an Intensive effort to identify and locate Saddam's electronic "fingerprints", or the characteristics patterns of movement and communication that accompany his travel around Iraq.[1033]

There was certainly no inhibition on targeting other Iraqi military and political leaders. Indeed, the last major aerial bombardment of the war, on 27 February, involved attacks on a military command bunker at Abu Ghurab outside Baghdad and on the Baath Party headquarters. The attack on the bunker at Abu Ghurab involved two F-111s, each fitted with a specifically designed laser-guided 5,000 lb "bunker buster" bomb.[1034] "Pentagon sources" commented on these attacks as follows:

> We wanted to totally wipe out all those closest to Saddam... We are confident that [at Abu Ghurab] we killed most of the Iraqi military leadership.[1035]

In the end, the overwhelming superiority of the US and Allied forces with respect to electronic intelligence and electronic warfare capabilities was a major factor in the

US/Allied victory. As General John Galvin, the NATO Supreme Allied Commander, stated in an interview on 6 March 1991:

> Saddam had some pretty good stuff. He had some good fighters, T-72 tanks, [etc.], but he couldn't put it together because he lost the electromagnetic spectrum, all the radars down, all the radio antenna down, and so forth.[1036]

Iraq was, in effect, left with no antennas standing!

Chapter 31

Operation Desert Shield

Introduction

During the early morning darkness of 2 August 1990, Iraqi President Saddam Hussein implemented his long-standing plan to invade and annex the small neighboring state of Kuwait. Beforehand, Iraqi military commanders had paid particular attention to concealing their troop movements from reconnaissance satellites and radio listening services. Consequently, Western intelligence services were unaware of the extent of Iraqi intentions until a few hours before the leading units crossed the border into Kuwait. Once over the border, the Iraqi units advanced rapidly. Pockets of Kuwaiti troops were quickly isolated and neutralized. The Emir of Kuwait and large numbers of his countrymen fled to Saudi Arabia. Later that day,[1037] the United Nations Security Council passed Resolution 660, which condemned the invasion and demanded immediate and unconditional withdrawal by Iraqi forces.[1038]

The Early EW Response to the Iraqi Invasion

As is usual in such circumstances, the first U.S. plane from outside to reach the area was an RC-135 Rivet Joint aircraft from the 55th Strategic Reconnaissance Wing. At the time of the invasion, it had been on detachment at Hellenikon, Greece. The plane took off, passed over Egypt and Saudi Arabia, and flew to a point south of Kuwait where it spent several hours monitoring radio traffic from advancing Iraqi troop units. At the end of its mission the RC-135 returned to Hellenikon.[1039]

The invasion sparked off a flurry of diplomatic activity. On 6 August 1990, President Bush ordered the implementation of Operation "Desert Shield," the movement of forces into the area to counter a feared invasion of Saudi Arabia. Thus began the largest military airlift, ever, to carry combat units, equipment and supplies to the Arabian Gulf area.[1040]

On August 7, 1990, the 1st Tactical Fighter Wing, with fort-eight F-15s, flew non-stop from Langley Air Force Base (AFB), Virginia, to Dhahran (Saudi Arabia). It was the longest operational fighter deployment so far, involving non-stop flights of between 14-17 hours with six or seven in-flight refuelings along the route. In the days to follow, twenty more squadrons of U.S. combat planes would move to bases in Saudi Arabia. On August 10, 1990, a Rivet Joint aircraft landed at Riyadh (the capital of Saudi Arabia) to provide COMINT (communication intelligence) support in the area.[1041]

At the time of the invasion, Brigadier General Larry Henry had been Inspector General of Tactical Air Command. He was soon on his way to the Air Force Command Center at Riyadh to join the staff of General Chuck Horner, the U.S. air commander. Soon after arrival, he assembled a small team of staff officers to plan SEAD (Suppression of Enemy Air Defense) operations to support U.S. strikes, should the Iraqis resume their advance. There was plenty to worry about:[1042]

"When I got to Riyadh we had just two squadrons of F-15s in theater, with just over forty planes, and a similar number of F-16s. I did not have any Wild Weasels; they were sitting on the ground in North Carolina waiting in line for tanker support.[1043]

"My first job was to put together some sort of defense suppression effort, to support air operations aimed at slowing a possible invasion by the Iraqi forces. At that time we were worried, big time, about the Iraqi army continuing its advance into Saudi Arabia. The Iraqis had seventeen divisions sitting in Kuwait, looking south. Even if they were incompetent, they could still have advanced through Saudi Arabia at a rate of about 10 km a day."[1044]

In the days to follow, the required specialized SEAD units–EF-111 Ravens, Wild Weasels F-4Gs and EC-130 Compass Call aircraft–began to reach the theater. Several of the newly arrived units found themselves living in conditions that verged on the squalid. Captain David Long, an EC-130H Compass Call crewman with the 41st Electronic Combat squadron, deployed to Bateen airfield in the United Arab Emirates:[1045]

"Within twenty-four hours of our arrival, the planes and the crews were ready to go war. But we had no hard billets, no base infrastructure. For the first three days, we slept on cardboard boxes in an aircraft hangar. The daytime temperatures were in excess of 100° F, with humidity in excess of 90 percent. We ate in-flight meals provided by the local airline, but by the time the food reached us it was usually cold and unappetizing. Had the war started then, life would have been very difficult. But we would have flown. It took about three weeks to get us into tents with air conditioning, with a proper chow hall and basic latrine and shower facilities.

"During August we took three aircraft to Riyadh and flew sorties near the Iraqi border from there. By trade. we do not gather information for intelligence purpose, but we do gather information to make better jamming decisions. We took advantage of Desert Shield to fly training sorties and gather information how Iraqi communications systems worked."[1046]

Major Mike Kemerer, a staff officer transferred from the 65th Air Division headquarters at Wiesbaden, Germany, arrived in Riyadh and was told to assemble an up-to-date order of battle for Iraqi air defense missile system. The previous listing, he recalled, was based on old data "kept in a notebook." He too had to work in primitive conditions at first. The main item of furniture in his office was a table made from boards placed on empty meal boxes. As computers and other specialized items equipment arrived, things improved rapidly. An important step was the arrival of a constant source data relay terminal, which correlated and displayed data inputs from all the U.S. national surveillance systems. With numerous different ELINT sources now focusing their attention on the Iraqi air defense system, Mike Kemerer and his team quickly updated their order of battle on the Iraqi missile system.[1047]

Electronic Support Measures (ESM)

Electronic support measures (ESM) involve collecting and analyzing electronic emissions. The Coalition's ESM effort was extensive and yielded a comprehensive intelligence picture. Among its specialized ESM aircraft were three U.S. Air Force RC-135s, including RC-135V/W Rivet Joint models. U-2Rs were used to collect COMINT (communication intelligence), and some could relay intercept data in real time through a wideband satellite link. British RAF Nimrod R.2s deployed; and the French had a DC-8 Sarigue, EW combat aircraft, such as the U.S. Navy's EA-6B and Air Force's F-4G, EF-111A, and possibly RF-4Cs were used to refine the electronic order of battle before the war began. The U.S. Navy's EP-3E and EA-3B forces also reportedly had aircraft in the Gulf, and the Air Force's TR-1As were also used for COMINT collection and radar surveillance. These were supplemented by U.S. Army ESM aircraft, both fixed wing (including RC-12s and RV-1D Quick Looks) and helicopters (including EH-60A Quick Fix IIBs) that provided intelligence vital to the rapid outflanking movements of the ground campaign. At sea, eight U.S. submarines conducted surveillance and reconnaissance operations, presumably using ESM, and also provided indications and warning for carrier battle groups. Besides the ESM capabilities on its surface combatants and submarines, the Navy used "bolt-on" ELINT (electronics intelligence) and COMINT systems. The French electronic research ship *Berry* reportedly configured for ESM duties was also used against Iraq.[1048]

The Gulf War was a space-age war in its unprecedented use of satellites for communications, navigation, and intelligence. Geostationary U.S. ELINT satellites–two Magnum and a Vortex–were stationed over the western Indian Ocean to provide information on Iraq. KH-12 imaging satellites also reportedly had a secondary ELINT capability. The ELINT satellites provided information to field commanders promptly because improved connectivity between U.S.-based processing facilities and theater headquarters had been provided by the mid-1980s Constant Source and TENCAP (Tactical Exploration of National Capabilities) programs that had expedited the intelligence flow considerably. Ground-based strategic ELINT sites that probably were used in the intelligence effort against Iraq included US stations in Turkey, Saudi Arabia, the United Arab Emirates, and Oman, British stations in Cyprus and Oman, and French facilities in Djibouti.[1049]

The Coalition's ground force's ESM capability was enhanced considerably by the U.S. Army's Combat Electronic Warfare and broad range of EW capabilities and worked closely with corps-level military intelligence brigades. This integration of ESM with offensive EW, hard-kill weapons, and intelligence gathering seen in the CEWI battalions was constant throughout the war. Iraq had offensive landline communications, including fiber-optic systems, to provide secure communications, and extensive back-up systems, including buried telephone lines and troposcatter radios. Landlines were targeted by special operations forces, forcing the Iraqis to use radio links that were intercepted by COMINT forces and were destroyed by hard-kill weapons.[1050]

The most common ESM systems used were the radar homing and warning (RHAW) receivers carried by all tactical aircraft (with the possible exception of some A-4KV and Jaguar fighter bombers) and many helicopters. The ESM problem seen in earlier conflicts–adapting systems and threat libraries of electronic signatures originally designed against Soviet threats to include Western-designed threats–did not re-occur. During the 1979 Iran Hostage crisis and the Falklands War, US and British forces initially were unprepared to counter threats from Western-designed gear, but in 1991 there were equipment and tactics to counter systems such as captured HAWK SAMs and Exocet ASM and SSMs. This was due in large measure to the five months between the force deployments and the beginning of the war. In this respect, General Dugan said, "It's not clear that the US will have time in future to train against friendly equipment and the lessons learned to others is don't give the US five months to train."[1051]

Iraqi ESM, consisting of Soviet–and Western-designed systems, proved difficult to totally destroy during the air campaign. Although the attacks rendered the Iraqi high command blind and deaf and unable to move forces in response to information, the residual Iraqi ESM capability required an extensive deception plan to cover the shift of Coalition forces westward before opening the ground offensive, Coalition forces were redeployed in radio silence, while bogus radio transmissions in the original assembly areas provided a flow of radio traffic that would indicate to Iraq that the units had not moved.[1052]

Iraq used COMINT information to move its mobile Scud missile systems away from incoming air strikes, to turn off radars from defense suppression strikes, and to ambush low-flying attack aircraft came over their targets, alerting AAA to open fire. This led the Coalition to cease jamming support for some F-117 strikes so that the aircraft remained largely undetected; while on other occasion jamming was used to trigger fruitless Iraqi AAA barrage firing. Iraqi also monitored the rescues of downed Coalition aircrews, but was unable to use this intelligence to thwart these operations. Iraqi internal security forces also used ESM equipment against Kuwaiti resistance.[1053]

Many sources noted that the Coalition was able to monitor Iraqi communications throughout the war and that this provided much valuable intelligence. This suggests that orders for using chemical weapons would have been have intercepted had they been given and that such intercepts led to post-war Coalition warnings against the use of chemical weapons against the Shiite rebels.[1054]

The Development of SEAD (Suppression of Enemy Air Defense)

As the allied buildup accelerated, Larry Henry and his staff began work on a SEAD plan to support offensive air strikes on targets in Iraq itself. Now their primary intelligence target was the Iraqi integrated air defense system entitled Kari (Iraq in French, Irak, spelled backwards). Created at great expense by French engineers during the 1980s, the system had become operational just too late to play a significant part in Iraq's war against Iran. Now, with France numbered among the Coalition allies, the planners at Riyadh had rare insights into the operation of the enemy control system.[1055]

The hub of Kari was the National Air Defense Operations Center located at Baghdad. This directed the air defenses for the entire country. Subordinated to it were sector operations centers, which together covered the airspace above Iraq and Kuwait. They directed the activities of interceptor fighters, and missile and gun batteries, within their assigned geographic area. Each sector, in its turn, controlled a number of intercept operations centers responsible for directing local air defense in their assigned areas.[1056] These operations centers were housed in buildings with reinforced concrete shells, hardened to withstand anything except a direct hit from a moderately large warhead.[1057]

Kari employed a wide range of radars types, giving it a high degree of frequency diversity and redundancy. The communications system linking the various operations centers employed parallel links with UHF, VHF and HF radio, data link and landlines. That afforded further frequency diversity and redundancy.[1058]

Kari controlled formidable assemblies of air defense weaponry. U.S. intelligence sources estimated the Iraqi night and all-weather interceptor force comprised about 160 fighters; MiG-23s, MiG-25s, MiG-29s and Mirage F-1s. The defenses around Baghdad, the most heavily defended part of the country, included some 550 SA-2, SA-3, SA-6, SA-8 and Ronald missile launchers. The AAA defenses in that area comprised more than 1,200 guns of calibers between 23 mm to 85 mm.[1059] other important areas, notably the H-2 and H-3 military bases and the cities of Mosul. Talil/Jabilah and Basra possessed less strong but still menacing SAM and AAA defenses.[1060]

To expose the weaknesses in the Iraqi air defense system, the Coalition sent fighters to fly "needling" missions close to the Iraqi border. As they did so, RC-135s and other intelligence collectors observed the Iraqi response. These operations soon revealed a weak link in Kari, as Larry Henry explained:

"During Desert Shield we sent aircraft in close to the border–real close–and watched what the Iraqis did. I wanted to see the timeliness of their reaction, and track the way they passed on the information. I wanted to see their sector operations centers and intercepts operations centers would operate if we actually went in. would they act independently, or would they just pass the data up the chain of command? We found that in most sectors the passage of information was pretty good, it was passed up the chain of command and also to the adjacent sectors. They alerted each other.

"Then we found one intercept operations center where the information went only up the chain of command, never sideways. It seemed that those guys did not talk to their counterparts on either side. That was the weak point in the system we had been looking for. What surprised me, was that this was the same sector the Israeli planes had flown through, when they bombed the Iraqi nuclear reactor at Osirak back in 1981. now it was a good place for us to blast a hole through the defenses, through which to run our planes to attack Baghdad. If that center went down, those on either side of it wouldn't be alarmed if they heard nothing. They did not expect to hear from them anyway.

"Once we had the Kari system figured out, we began working on ways to kill the heart and soul of it. We had the luxury of planning a pre-emptive strike, we had the luxury of an inept enemy and we had the luxury of an enemy who decided to squat for five months. We even had the luxury of being able to feint at him several times and watch his reaction."[1061]

During this period F-117A stealth fighters also took part in needling missions near the border to test the Iraqi reaction; there was none.

The intelligence attack revealed other weaknesses of Kari. The infrastructure and some surveillance radars had come from France, but the great majority of surveillance and missile and gun control radars had come from the Soviet Union. That had had produced integration problems and there were weaknesses in the data processing and software systems. The interception training exercises flown by Iraqi fighter pilots were simplistic by NATO standards, with no attempt at large-scale co-coordinated defense operations and relatively little activity at night.[1062]

The plan to reduce the effectiveness of Kari would open with precision attacks on the national air defense center and a number of sector and interceptions operations center buildings. These structures required direct hits from precision weapons to put them out of action; in the attack plan, that was what they would get.

Simultaneously, there was to be an elaborately choreographed attack to neutralize missile batteries in the heavily defended area around Baghdad. Earlier in his career, while studying at he National War College, Larry Henry had made a detailed study of the June 1982 Israeli attack on Syrian missile batteries in the Bekaa region of Lebanon. The operation had fired his imagination, and would now serve as a model for his own larger-scale SEAD action against the Iraqi air defense missile batteries.[1063]

The plan to neutralize the Baghdad missile defenses would replicate the Bekaa action in four essential respects. First, all intelligence sources were to be used to assemble a highly detailed picture of the layout and composition of the enemy defense. Intelligence officers would catalog the locations of the various control centers, missile batteries and radars, note their operating frequencies and other parameters, and determine their operating patterns.

Secondly, on the night of the initial air attack, Larry Henry planned his so-called "Puba's Party" to provoke a reaction from the defenders. As in the Bekaa action, drones, masquerading forces, would cruise over the defenses and lure the missile batteries into action. It was hoped the batteries would launch expensive (and, for the Iraqis, irreplaceable) long-range missiles at the pilotless planes. It was also hoped that some batteries might expend the missiles on their launches, which would effectively put them out of the fight. Larry Henry commented:

"I was working to get inside their reload cycle. Depending on the type of missile, it might take between ten and twenty minutes to reload the launchers after the missiles had been fired. But those times were taken in daylight with no enemy planes around. I figured it would take longer in the middle of the night when we had attack planes about."[1064]

Thirdly, jamming of the missile acquisition radars from EF-111As and EA-6bs would force the missile batteries to use their narrow-beam target tracking radars to locate the drones and engage them. That would extend the radars' time on air, increasing their vulnerability to attack from anti-radiation missiles. Fourthly and finally, Wild Weasel F-

4Gs and Navy and Marine WA-6Bs and F/A-18s would deliver a concerted attack on the missile control radars with HARMs (High Speed Anti-Radiation Missiles).[1065]

It was a good plan, clever without being over complicated. While it might not fool a well-trained and skillfully manned air defense system, Larry Henry felt confident that the Iraqi system was not in that category.

Kari controlled the air defense of Iraq, but in Kuwait there was a quite separate system. There the attackers would face mobile radar-guided SAM system like the SA-6, the SA-8 and the Ronald. Larry Henry continued:

"Those were pop-up systems, they were very mobile. We didn't know how many there were, so we could not plan against them. Those missile batteries were scattered around the desert; they were difficult to kill. The guys were autonomous, they were not part of a permanent air defense system, and they were not hooked up to any big communications web. But fortunately for us the Iraqis used the SA-6s and similar systems more like the Syrians than the Soviets, they did not keep moving them around with army units, they squatted down to protect the Republican Guard."[1066]

By early October Larry Henry finished work on his imaginative plan. Unfortunately he would not remain in the theater to bring it to fruition; he was required to return to the U.S. to take up another appointment. Brigadier General Glen Profitt took over the defense suppression command cell, but Henry's plan remained in place with few changes.[1067]

Electronic Warfare in Army Aviation

During the build-up of forces in Saudi Arabia, Army Aviation suddenly discovered that it had urgent need of an organization to perform the same function as John Corder's Electronic Warfare Aggressor Squadron. For in this area, the Army's problems were even worse than those that had afflicted the Air Force.[1068]

On August 4, 1990, two days after the invasion of Kuwait, Army Colonel Tom Reinkober moved into his new assignment as Program Manager for Aircraft Survivability Equipment (ASE). From his St Louis office, he and a staff of some fifty officers and technicians oversaw the self-protection EW systems fitted to Army helicopters and fixed wing aircraft. In time of peace the front line aviation units made few demands on his office, but all that changed, as Army aviation units learned they were earmarked to leave for the Middle East and might have to go to war. Suddenly the demands for assistance to bring the various items of EW equipment to operational status became more numerous and more strident.[1069]

Reinkober visited several of the aviation units preparing to move to the Middle East. As we observed earlier, Army helicopters and light aircraft intended to operate in the combat zone carried suites of lightweight EW equipment for protection against missiles and radar laid AAA. On paper they appeared to have a formidable electronic warfare capability. Yet, as Tom Reinkober soon discovered, the truth was rather different:

"When *Desert Shield* began, if you were to categorize the level of knowledge of electronic warfare in the Army Aviation unit between one and ten, ten being good, I would say that generally the knowledge of EW was about in the two range. Very few Colonels really took EW to heart. That was something they didn't train for. They didn't use their jammers; they didn't use their radar warning receivers. Most of them thought those things were too complicated to have in their aircraft. Systems like the ALQ-144[1070] were classified, which meant that when the helicopter was on the ground it had to be kept under guard. So many units flew without ASE equipment.

"Once they were notified that their unit was going to the Persian Gulf, everybody got religion. Of the first 790 aircraft that we checked, only about 150 had fully operable ASE systems. Most of the faults were not with the B kit (the black boxes). The faults were usually with the A kit fixed to the aircraft, the wires and the connectors. There were wires hanging loose, wires not connected. We found many cases of corrosion. They had big time problems, people had not being paying attention to those things."[1071]

In the short term, Reinkober's men could do little to put things right. Usually when they arrived at a unit, its personnel were busily engaged in packing equipment ready for shipment to the Gulf. Had they known when the land battle would start, the ASE teams could have concentrated on fitting out the last of the aircraft to be shipped out. But with the war likely to begin at any time, that option was not available:

"There was no way that would could get to everybody, to get all their equipment up and running, before they left the US But once units got religion, I became their best friend. I told them 'If we don't get to you before you go the Gulf, we will meet you when your aircraft arrive there on the boat.' We were even fixing aircraft while they were in the hold of ship, while it was being loaded."[1072]

Tom Reinkober dispatched a 15-man ASE team to Saudi Arabia commanded by Lieutenant Colonel Pete McGrew, a Marine Corps officer attached to his staff. The team met each Army helicopter unit as it arrived in Saudi Arabia and brought its aircraft to a battle-worthy condition. Included in the team were field representative from each of the contractors that had built the ASE system. The ASE team was totally self-sufficient in the theater. It flew its UH-1 helicopter from unit to unit, carrying the necessary replacement cables, connectors and EW equipments. In addition to supporting Army units, the ASE team provided assistance to USAF units operating MH-60 Pave Hawk and HH-3 Jolly Green Giant helicopters and Marine Corps KC-130 transports, which also carried the Army-type EW systems. Throughout this period of the civilian Logistics Avionics Representatives attached to Army units provided valuable logistical and administrative preparatory back up, enabling the ASE team to begin work as soon as it arrived.

As important as getting the various systems to function properly, the ASE team found it necessary to run crash-course to increase EW awareness on units and show how the various equipment functioned. A signal generator enabled flight crews to see the symbology that would appear on their screens when the aircraft was observed by specific Iraqi systems. The ASE team also carried out essential reprogramming work on the APR-39 (V) 2 and the ALQ-136 equipment, to take into account new intelligence information as it was received.

Meanwhile, in the U.S. the various contractor companies were working hard to produce the replacement components and cabling to bring the Army aircraft to a battle worthy condition. As these items came off the production lines there remained a further hurdle to surmount: how to move them to the Gulf in time to fit out the helicopters as soon as they arrived. At that time everybody had mountains of top priority equipment and supplies they needed moved immediately to the theater.

Tom Reinkober devised an imaginative method to get transportation priority for his shipments. Now retired from the Army, he is willing to share his secret with others who might find themselves in a similar situation in the future. Surprisingly, he bypassed the official priority delivery system:

"Much of my equipment was classified. I had my contractors consolidate their equipment, including the unclassified bits, on classified pallets were then driven to the main loading airfields at Dover or Charleston. My loads arrived already palletized, so the loading guys didn't have to do anything to them. I worked inn the contract administration area; I know how those people think. When they received a classified pallet that was all ready to go, they would put it on the next airplane. They wanted to get rid of it as soon as they could, or they have to guard it.

got permission to put the ALQ-144A into production even before it got through its testing. Everybody knew that against the newer types of IR missile the ALQ-144A was better than the ALQ-144, we didn't need to go though all the wickets to find out how much better it was. Fortunately, Saddam Hussein co-operate immensely by not starting the war early. By the time Desert Storm began., two-thirds of the apaches in the theater had ALQ-144As fitted."[1074]

The new jammer was also installed in a large proportion of the OH-58D Kiowa Warriors and UH-60 Black hawks before the ground war began.

In many studies of the conflict, the sheer size of the U.S. Army's aviation commitment has passed without comment. It is worth pointing out that in terms of the number of machines destined to operate "in harm's way" over the combat zone, the Army's deployment exceeded that of Air Force. On the eve of the main land campaign the Army contingent comprised:[1075]

- 274 McDonnell AH-64 Apache attack helicopters
- 465 UH-60 Black Hawk utility helicopters
- 24 EH-60 Quick Fix helicopters
- 132 Bell OH-58 Kiowa scout helicopters
- 163 Boeing CH-47 Chinook medium lift helicopters

In addition there were numerous UH-1 Huey helicopters, OV-1D Mohawks, RC-12 Guardrails and C-23 Sherpas that were not intended to operate within range of enemy air defense systems, but which might have to do so if the war took an unexpected turn.

For the first time, helicopters carrying suites of electronic warfare equipment were about to go into action in large numbers. Only after battle had been joined would their proponents learn whether they were effective.

The Electronic Intelligence (ELINT) Before the Storm

During the months before the start of hostilities there was a large-scale reconnaissance effort, using every type of sensor, to determine the positions and identities of Iraqi combat units in the likely battle area. The RC-135 Rivet Joint aircraft, for example, maintained a continuous 24-hour listening watch over Kuwait and the southern part of Iraq from August 11 until 10 December 2001. Then came a ten-day period when coverage was reduced to 12 hours per day, to allow the ground crews to prepare the aircraft for wartime pacing. On 20 December 2001, the 24-hour coverage resumed. From January 16, 2001, as the air war was about to begin. Rivet Joint aircraft flew four missions per day on two orbit patterns.[1076]

The value of the intelligence thus gained can scarcely be exaggerated. Army Colonel Charles Thomas, deputy commander of the Joint Intelligence Center at Riyadh, explained:

"The ELINT collected from the Iraqi Army air defense units helped us to understand, on the basis of which types of radar lit up, what type of gun or missile battery they belong to. For example, signals from Straight Flush radar meant an SA-6 missile battery was present. We knew that certain types of air defense unit were co-located with certain echelon of command. Thus, an SA-6 battery indicated that a division or higher echelon headquarters was positioned nearby. The next step was to figure what kind of division it might be associated with, and which elements of the division or the corps the SA-6 unit might be positioned to defend.

"Guardrail did a good job, it was our primary tactical intercept collector. It was invaluable because of its capability for line of sight intercept. Once the Iraqis came on the air, Guardrail's "vacuum cleaner" was an excellent tool. Its airborne DF (direction fonder) capability was such that it would at least put us in the ballpark of where the signals were coming from, within 5 or 10 miles. If an infantry division was hunkered down somewhere, Guardrail would confirm its tight and left limits.

"That intelligence became part of the larger all-source fusion process. We took what we got from Guardrail, and collated that with information from other sensors to reduce the aria of uncertainty. Then we would send reconnaissance aircraft to see what was there. We knew the way the Iraqis deployed their troops, the way they dug their entrenchments. That gave us a feel for the kind of unit in there. We would not have known to look there, if Guardrail had not given us the initial indication."[1077]

Electronic Warfare Simulators

During this period of preparation for war the major U.S. electronic warfare simulators, REDCAP and AFEWES, were programmed with a detailed picture of the Iraqi air defense system. Each U.S. electronic warfare equipment and tactic was then tested against it to gauge its effectiveness. Glen Miller, working with the REDCAP simulator at Buffalo, New York, was one of those heavily involved with this project:

"Typically, countries like Iraq have very structured command and control systems. Decisions have to be made as a very high level; there is little or no autonomy or delegation. The U.S. had to put together this big composite and see how effective we were against that. To counter a system like that you work against the radars, so that they have only sketchy information. You also jam or destroy the radio communications link to compound their problems."[1078]

Most of the radars used in the Iraqi system were Soviet types and the effectiveness of EW against these had been investigated over many years. In addition, however, there were several radars bought from western nations. The vulnerability of these, and their influence on the system as a whole, was less certain until the REDCAP and AFEWES simulations started to provide answers.

The Final Stage of Desert Shield

In mid-November 1990 Major General John Corder arrived at Riyadh to take up the post of Director of Operations to his old friend Lieutenant General Chuck Horner. Given John Corder's background, it was to be expected that high on his list of priorities would be a check on the operability of aircraft electronic warfare systems. As he explained, a start had already been made:

"As soon as the planes deployed to Saudi Arabia, while I was still in the US, we had the EW Aggressor Squadron go out there to check over the jamming systems. The fighter units had all been through the program earlier, but some Special Operations units had not we picked those up first. We found that in the interval between checks the performance of some systems had deteriorated a little, but not much.

"By about the second week in December it was clear that we were going to have a fight, it was just a matter of time. The EW Aggressor guys had returned to the US, so I got them back to run the checks again. I knew which units were going to bear the brunt of the operations around Baghdad, and I had their systems checked every day. So when the guys taxied out to go into combat on the first night, I knew with a very high ninety percent probability that all the EW gear in those planes was combat ready. That was good feeling."[1079]

During the later stages of Desert Shield, Coalition aircraft regularly flew training exercises in full view of the Iraqi air defense radars. Usually taking place on Wednesday nights, these involved E-3 AWACS, RC-135 Rivet Joint, EC-130 ABCCC aircraft and varying numbers of fighters. As well as providing useful in-theater training, the exercises accustomed the Iraqi air defense operators to seeing such operations and treating them as routine. When the real attack came it was going to look no different.[1080]

US Air Force, Navy and Marine Corps Electronic Warfare

Note: although the table below gives the figures for January 20, 1991, the number of planes available was little different on the night of January 17, 1991, when the air offensive began. The table does not include the strength of RC-135 contingent. Which was not included in the published list.

Aircraft deployed in the Persian Gulf Area, January 20, 1991[1081]

Location	Service	Type	No.
At Taif, Saudi Arabia	USAF	EF-111A	18
Incirlik, Turkey	USAF	EF-111A	6
Aircraft Carriers	USN	EA-6B	27
Shaikh Isa, Bahrain	USMC	EA-6B	12
Saudi Arabia various bases	USAF	EC-130H	15
Incirlik, Turkey	USAF	EC-130H	3
Shaikh Isa, Bahrain	USAF	F-4G Wild Weasel	48
Incirlik, Turkey	USAF	F-4G Wild Weasel	12
Incirlik, Turkey	USAF	F-16C (HARM carriers)	13
Jeddah, Saudi Arabia	USN	EA-3B	2
Bahrain Itnl	USN	EP-3E, P-3B	3
Masirah, Oman	USN	EP-3E	1
Total			160

Chapter 32

The Electronic Warfare in Desert Storm

Introduction

United Nations Security Council Resolution 678 had stated that unless Iraq withdrew her military forces from Kuwait by January 15, 1991, member states would be permitted to use "all necessary means" to dislodge them. That deadline had passed without any move from the Baghdad government, apart from the usual bout of rhetoric. Diplomacy having failed so obviously and publicly, it would be left to force of arms to decide the issue.[1082]

Throughout Desert Shield, E-3 Sentry and E-2 Hawkeye radar surveillance planes, usually backed by RC-135 Rivet Joint and Ep-3 aircraft, had flown around-the-clock patrols to observe any activity by Iraqi aircraft. Backing these were standing patrols by fighter planes, F-14s, F-15s, F/A-18s, Tornado F-3s, Mirage 2000s. As the deadline passed, these planes continued to operate exactly as before. It important that the Iraqis should not detect anything unusual in the offing. Moreover, if the Iraqis attempted a pre-emptive air strike, those fighters were in position to meet it.[1083]

The Beginning of the Storm

The Coalition headquarters in Riyadh, Saudi Arabia, preparations were well advanced for the long-planned aerial onslaught on targets in Iraq and Kuwait. H-hour for Operation Desert Strom, the start of the coordinated series of attacks, was 02:30 hours on 17 January. Supporting the first night's action would be the most powerful and elaborate air defense suppression operation ever attempted.[1084]

The first of the attacking planes took off from Barksdale AFB, Louisiana, at 0635 hours (U.S. Central Standard time) on the 16th (H hour minus 11 hours 25 minutes).

Seven B-52 Stratofortresses from the 2nd Bomb Wing set out to strike at targets more than 7,000 miles away in northern Iraq. Each heavy bomber carried seven AGM-86 air launched cruise missiles fired with high explosive warheads.[1085] It was to be a potent demonstration of the reach of modern air power, for the bombers were scheduled to make direct return flight to Barksdale after the mission.

Next, at 0100 (H minus 2 hours), the slowest aircraft in the attack force lifted off from Al Jouf airfield in Saudi Arabia near the Iraqi border. This force comprised eight AH-64 Apache attack helicopters of Task Force Normandy, 1st Attack Helicopter Battalion, 101st Airborne Division. Leading the force were two Air Force MH-53J Pave Low helicopters serving as navigation "mother ships." A further AH-64 and an UH-60 provided backup command and control and rescue facilities, should these be needed. The blacked-out helicopters hugged the desert floor as they clattered away to the north at 120 knots.[1086]

The helicopters' targets were two early warning/ground controlled intercept (EW/GCI) radar stations positioned some 50 miles inside Iraq and about 70 miles apart. These radars were subordinated to the intercept operations center at Nukhayb; the one, which General Larry Henry had determined, was the weak link in the Iraqi system. By putting these radars out of action, the helicopters would strike the first blow to open a corridor through which Coalition attack planes could pass unseen on their way to targets in the Baghdad area.[1087]

Thus the night's activities were to open with a "hard kill" electronic warfare operation. Apache helicopters had been chosen for important mission, over fixed-winged planes, because they had the better chance of reaching their targets undetected. Moreover, thy alone had the ability to deliver repeated attacks and observe that each one had been successful before moving on to the next target. The armed helicopters offered the highest level of assurance that every required item of equipment at each radar site would indeed be destroyed.

At 0131 hours (H minus 1hour 29 minutes), the first Tomahawk cruise missile roared away from its launcher aboard the cruiser USS *San Jacinto* in the Red Sea.[1088] In the Persian Gulf the battleships *Wisconsin* and *Missouri* and the cruiser *Bunker Hill* began launching their Tomahawks soon afterwards. The warships unleashed fifty-two of the snub-nosed missiles during the initial wave of the attack.

As the warships' missiles sped along their pre-programmed routes, the seven B-52s from Barksdale reached their designated launch points over Saudi Arabia. The heavy bombers launched thirty-five cruise missiles at eight separate targets. Then they turned around to begin their long return flights to Barksdale. (The flight would involve about 34 hours airborne, making this by far the longest operational bomber mission ever flown.[1089]) By 0215 hours (H minus 45) the waves of shorter range attack planes were formed up and heading towards the Iraqi border: F-117As, F-111s, F-15Es. A-6s and Tornado GR 1s. With them came the F-14s, F-15s, and F/A-18s that would escort them past the expected swarms of defending fighters. Each jet aircraft scheduled to penetrate Iraqi airspace carried its own self-protection electronic defense suite: a radar-warning receiver, active jamming equipment and Chaff and IR decoy dispensers. To add to the radar trickery, EF-111 and EA-6B stand off jamming support planes accompanied the raiding forces. EA-6B Prowlers, F-4G phantoms, F/A-18 Hornets and A-7 Corsair carrying AGM-88 HARMs (High speed Anti-Radiation Missiles) also moved in, ready to engage any enemy battery which lit up its radar as a prelude to engaging the attack planes.[1090]

Electronic Countermeasures

The most dynamic element of electronic warfare, electronic countermeasures (ECM), are intended to affect enemy electronic emitters. ECM consists of active countermeasures that involve radiating electromagnetic energy, and passive countermeasures that do not. Both were used in the war.

Active jamming was extremely heavy. With the possible exception of some non-Saudi Arab forces, every fixed-wing tactical aircraft that crossed the front lines had either an internal or podded jammer. This let them operate largely at medium altitude, above the reach of visually directed AAA and heat-seeking Sam's thereby reducing aircraft losses. Many helicopters also carried on-board self-protection ECM gear.[1091]

The most formidable ECM aircraft were the U.S. Air Force's EF-111A and the Navy-Marine Corps EA-6B. Both had the powerful ALQ-99 jamming system and were used throughout the war to escort air strikes, providing jamming support that enabled tactical aircraft to penetrate to their targets. The Navy and Marine Corps did not launch strikes without EA-6B support, and this prevented Iraqi SAMs from lock-on against strike aircraft.[1092]

Air communications jamming was the mission of about eight U.S. Air Force EC-130H Compass Call aircraft (which also have a "spoofing" capability able to invade enemy communications nets) supported by U.S. Army RU-21 Cefire Tigers. These aircraft, surface-based jammers such as those in the CEWI battalions, and accurate air strikes served the control links from Saddam's centralized national command authority to his troops. At the tactical level, air defense radars did not receive target data when they were jammed and had to light up and search, making them vulnerable to HARM missile attacks. This communications severance was very complete. The captured diary of one

Iraqi air defense battery commander revealed that he had not heard from his superiors for the last three weeks of the war![1093]

Iraq's active jamming was focused mainly on ground-based systems. It deployed a range of Soviet-designed and 1970 vintage French-designed ground-based jammers that had little effect. Also, its "Paint Can" van-mounted jammers were reportedly countered when it tried to jam E-3A AWACS radars before the war. Both AWACS and tactical aircraft overcame Iraqi jamming during the war itself.[1094]

To defeat Iraqi C^3I and air defense, the Coalition used ESM, hard-kill weapons, and ECM judiciously, so that each complemented the other's effects. Hard-kill weapons were vital, and the Israeli general who said, "the most effective ECM is a bomb on a radar station" was proven correct. Hard-kill systems included U.S. Air Force F-4G "Wild Weasel," as well as F-117 and F-16s. U.S. Navy-Marine Corps EA-6Ba and F/A-18s also made extensive use of anti radiation missiles (ARMs). During first ten days of the air campaign, U.S. forces alone flew over 1,000 sorties against Iraqi air defenses, expending about 600 HARM anti-radiation missiles (over 1,000 were throughout the war) that supplemented Paveway laser-guided bombs. Royal Air Force Tornado GR1s fired over 100 ALARM ARMs. Attacks on the key nodes of the Iraqi C^3 system in the first hours of the war were so destructive that Iraq never recovered. In the very first strike of the air campaign eight U.S. Army AH-64 Apache helicopters destroyed two Iraqi radars, opening strike corridors for fixed-wing aircraft going to repeat the process throughout Iraq. This was followed by many similar tactical aircraft strikes, led by U.S. Navy Tomahawk cruise missiles and Air Force F-117s and F-4G.[1095]

The Coalition's passive countermeasures went far beyond the near-universal use of chaff (and their active-infrared countermeasures counterpart, flares) seen in earlier conflicts. U.S. Navy and Marine Corps tactical aircraft made extensive use of TALD air-launched decoys, and efforts were made to reduce the radar cross-section of a wide range of ships and aircraft.[1096]

The U.S. Air Force F-117 Stealth fighter does not use passive countermeasures. It is a passive countermeasure and is the best example of how ECM has progressed from a peripheral "and-on" to an integral part of a system. While the F-117s represented only 2.5 percent of the Coalition's tactical air power, they struck 31 percent of the targets hit in the first day of the war and were assigned more than 40 percent of all targets. While they were not invulnerable to detection, they showed the increased importance of passive countermeasures in the face of modern weapons.[1097]

The Role of Decoys & Drones: Electronic Deception

Before the leading attack planes entered the SAM defended areas, the key part of Larry Henry's bequest to the night's activities, "Puba's Part," was approaching its climax. Thirty-eight Northrop BQM-74 decoy drones, launched from ground sites just over the border in Saudi Arabia, headed for Baghdad flying in fighter-type formations at medium altitude. At the same time Navy A-6s launched scores of Tactical Air Launched Decoys (TALD), which began heading toward areas around the country.[1098]

Iraqi surveillance radars observed the incoming drones and decoys. As they came within range, the missile batteries received the order to engage. Missile control radars began tracking the intruders, then the batteries launched salvo after salvo of SAMs in their direction. Not to be outdone, AAA units at several points opened fire, sending colorful but unaimed tracer rounds into darkness.[1099]

The first indication to the outside world that Desert Storm had begun came at 0237 hours, when CNN broadcast its now-famous television pictures showing tracer rounds arcing across the night sky over Baghdad. That was 23 minutes before H-hour, however, well before the attack on targets around the capital was scheduled to begin.

Almost certainly, that famous television coverage depicted the Iraqis' reaction to the decoy "attack on the city by drones.[1100]

As the Iraqi missile batteries began picking off the decoys there was great excitement at the launch sites. This was just like swatting flies. But, unfortunately for those doing the swatting, these particular "flies" had not come alone. Once the SAM batteries had been drawn into a full-scale action, the second phase of the attack opened.[1101]

Flying behind and somewhat lower than the decoys came several attack forces. One such force, heading into Baghdad air defense zone, followed hard on the heels of six BQM-74 drones and thirty-two TALD decoy gliders. This follow-up force comprised twelve F-4G Wild Weasels, two EA-6Bs, ten F/A-18s and eight A-7s, all laden with AGM-88 HARMs. Three EF-111As and the two EA-Bs provided standoff jamming protection for the package.[1102]

Having swallowed the bait, the ecstatic Iraqi missile-control radar operators ignored the fast approaching nemesis in its wake. As Larry Henry's plan had required, the special receivers in the HARM-carrying planes now displayed a plethora of signals from SAM control radars. Calmly the planes' crews locked their HARMs on individual radars and sent the deadly weapons on their way. According to report, for a brief period that night no fewer than two hundred HARMs were in flight and heading for active enemy radars.[1103] At the end of their flights a large proportion of the weapons detonated on or near enemy missile control radars, causing mayhem and destruction at the firing sites.[1104]

The Role of Apache

The next act of the carefully choreographed operation on time at 0238 hours, H minus 22. The Apache helicopters of Task force Normandy reached firing positions beside the two radar sites they were to attack (and which had been left alone long enough to report the approaching decoys). Each Apache carried eight hellfire laser guided missiles and a pod with nineteen 70mm unguided rockets, to supplement the built-in 30-mm cannon in the nose turret. Marking their targets with laser designators, the crews launched their hellcat missiles from ranges around 3 miles. Then they closed to 1.5 miles to attack with unguided rockets. The helicopter crews had orders to demolish the equipment at each target in strict order of priority: first the electrical generators, then the communications facilities, then the radars themselves, then other targets.[1105] Army Lieutenant Tom Drew, leading one of the Apache attack teams, later wrote:

"There were people running around the site. They all seemed to pick the wrong places to go. As my missiles neared impact, two people ran inside. Direct hit! My next target was an anti-aircraft position. I checked it only to find a guy running from it. He never made it back to the site. As the team leader, I was responsible for ensuring that all the targets were destroyed. I surveyed the site. All the primary targets were destroyed and burning."[1106]

In less than two minutes the Apaches fired twenty-seven Hellfire missiles, about a hundred 70 mm rockets and thousand rounds of 30 mm ammunition.[1107] The attacks wrecked both radar stations.

Tomahawk Missiles and the Destruction of Electrical Power Plants

As the leading Tomahawk missiles closed unerringly on their programmed targets, there was more trickery afoot. As mentioned earlier, it was known that the Iraqi air operations centers normally ran on power from the Iraqi national electricity grid. Several Tomahawks were targeted selected electrical power generating plants and switching stations. In the payload bay of each missile were large numbers of spools, each measuring ½ - inch by ¾ - inch, wound with long lengths of carbon fiber.[1108] The cruise missiles passed low over their targets and the spools were ejected. As the spools fell, the carbon fibers unwound to produce serpentine trails that descended slowly to the ground. When a length of fiber fell across high voltage electrical transmission lines, the resultant short circuit tripped out the protective circuit breakers.[1109] That severed electrical power to the surrounding area, including the air defense control centers whose computers duly "crushed." The centers were out of action until the back-up electrical generators were started and brought on line. While the centers were down, vital information on the air action had been lost. Contrasting sharply with some of the sophisticated electronic warfare methods used that might, this simple "electrical attack measure" proved its worth.

The Role of Stealth Fighters F-117A

In further moves to prepare a safe path for the main attack forces, F-117A Nighthawk stealth fighters from the 37th Tactical Fighter Wing (TFW) headed for key targets in the most heavily defended areas of Iraq. Tonight this novel and ungainly combat plane was to face the first real test of its combat capability. If there was a sizeable chink in the plane's cloak of radar near-invisibility, the pilots of the 37th might pay for that failing with their lives.[1110]

During their ingress the Nighthawks made frequent changes of heading. That complicated tracking by any radar that chanced to be in the right place to pick up the plane's minuscule radar echoes. Flying radar echoes. Flying at the head of the stream, Major Gregory Feest of the 415th Tactical Fighter Squadron (TFS) headed into Iraq. His initial target was the interceptor operations center at Nukhayb, the one that General Larry Henry had selected as being the weak link in the enemy defensive chain. Thirteen minutes earlier the helicopters of Task Force Normandy had wrecked two radar stations controlled from this center itself were about to pay a heavy price for their previous reticence.[1111]

At 0251 hours (H minus 9 minutes) Feest commenced his bomb run. Although he could see some guns firing into the air, no rounds came in his direction. Once he had the "in range" symbology on his screen he made a quick check of his position relative to the target. Then, satisfied with the indications, he depressed the bomb- release button. The weapons bay doors snapped open, there was a "clunk" as the bomb released, and then the doors snapped shut. As he held the laser marker on the target, Feest watched the infrared screen intently. He just made out the final few seconds of the bomb's fall, and then it penetrated the concrete roof of the bunker and detonated. Fascinated, he watched as a dense column of hot smoke spurted out the entry hole. Moments later the heavy steel entrance doors tumbled away from the side of the building, as if kicked by some enormous boot. It was clear that this particular bunker was not going to do much controlling for some time to come. After the doors came to rest there was a brief pause, then the defense came to life wit a vigorous barrage of tracer rounds that came streaking past the stealth fighter. It was the first time Feest had been shot at and he felt vulnerable. Yet as he moved away from the target the tracers did not follow; obviously the gunners were spraying the sky blindly. Feest turned on to the heading for his next target, the sector operations center at H2 airfield in western Iraq, and soon left behind the scene of commotion.[1112]

In the minutes that followed the Nighthawks attacked thirty-seven other targets. In this first real test in combat, the facetted fighter demonstrated its ability to punch well above its weight. Two minutes after H-hour, 0302 hours, an F-117 planted its bombs on the central telephone exchange in Baghdad. The success of that particular strike was confirmed in real time in the operations center at Riyadh, where officers watching the live CNN transmission from the Iraq capital saw the speaker break off in mid-sentence as the picture dissolved into "snow." [1113]

At 0306 hours the first of the Tomahawk cruise missiles reached Baghdad. Missiles with high explosive warhead smashed into the Presidential Palace, others hit the ruling Ba'ath Party headquarters complex and the sprawling missile storage complex at Jaji.[1114] At about the same time, the AGM-86 air-launched cruise missiles from the B-52s began exploding on communications, air defense and airfield targets around Mosul in northern Iraq.[1115]

In the Absence of Radar

With the Nukhayb intercept operations center and two of its subordinated radar stations out of action, a safe corridor had been gouged through the Iraqi control and reporting system. Like sand streaming through an egg timer, conventional attack planes sped through that corridor making for their assigned targets. Of the SAM sites positioned to engage the planes, several remained silent after their control radars had been wrecked or damaged in the HARM onslaught. As other sites, where the radar had escaped damage, the missile launchers were empty and crews were toiling in the darkness to re-load them.

Following the disruption of important sections of the Iraqi control and reporting system, it was almost impossible to track the many attacking forces sweeping across the country. Lieutenant Dave Giachetti, Weapons System Officer in one of eight F-111Fs of the 48th TFW bound for chemical weapons storage bunkers at Ad Diwaniyah near Baghdad, remembered:

"I thought it was kind of eerie, because outside everything was so calm and so quiet. We went in at low level on TFR. In the built up areas, everyone had their lights on, the streetlights were on. On the way in we flew parallel to a road for some time, there were cars moving with their lights on. We were at flying at 400 feet at 540 knots towards our target and I thought, Man, they don't even know we're coming!"[1116]

At several targets the defenders had no warning of the raiders' approach. Wing Commander Ian Travers Smith, leading three Royal Air Force Tornados running in for a low altitude attack on the taxiways at Al Sad airfield, had dramatic proof that his approach had not been observed:

"I had a few problems with my autopilot so I had to fly the aircraft manually. I was head-down in the cockpit as we turned on the IP [initial point] for the target run, which was almost along the line of a valley. Then I looked up and I couldn't believe my eyes: all the runway and taxiway lights were on, the entire airfield was lit up. We really had caught them by surprise."[1117]

The moment the planes' airfield denial munitions detonated, the airfield's lights suddenly extinguished. By the time the defenses went into action the Tornados were speeding clear of the airfield.

Elsewhere, attack planes had to pass through areas where the alerted defenses put on displays similar to that over Baghdad. Lieutenant Colonel Tommy Crawford led six F-111Fs of the 48th TFW to attack Ali Al Salem airfield in Kuwait. The planes' route took them over deployed Iraqi army units in the desert, which hosed the sky with their automatic weapons. Like many others that night, Crawford found the strings of rising tracers thoroughly disconcerting at first.

"We made a low level attack because of the SAM threat, there were several SA-6 launchers in the area. Our intention was to run in at 1,000 feet until SA-6 signals on the radar-warning receiver forced us down. But there was so much AAA; I couldn't believe how much there was. We crossed the border at 2,000 feet and that was where we stayed until we delivered the bombs. It seemed like every 50 yards a guy with a gun was shooting at us, it was the damnedest 4th of July show you ever saw. As we approached the border it looked like a solid wall of fire, but you had no perception of depth so it looked a lot worse than it really was. Once we had crossed the border, it seemed the flak opened up in front of us as we flew along. Then it seemed as if was worse to the sides and behind than it was in front."[1118]

Nobody enjoys being shot at, but it had soon become clear that the visual display was far less dangerous than it had appeared.

The First Electronic Combat (EC)

Captain Brent Brandon, an EWO (electronic warfare officer (Air Force)) with the 390th Electronic Combat Squadron, was aboard the second of two EF-111 Raven leading nineteen F-15E Strike Eagles flying in trail towards Scud launching sites in western Iraq. After completing his refueling. Captain Jim Denton, the EF-111's pilot, cased the aircraft down to low altitude. The plane crossed the Iraqi border flying at 540 knots at 400 feet. Brandon takes up the story:

About four to five minutes before we popped [climbed to medium altitude to begin jamming] I detected radar that was watching us. Normally, we don't want to jam as it gives away our protection, but this guy was out away from the target area so we powered on. That was the first electronic combat of the war, our jet powering out there against that lone emitter. We were a little early, but we did it to protect the package.

"With five minutes to go [before the F-15Es started their attacks] we popped up to a medium altitude and I started our ten directional jammers, blinding the guys...As soon as we jammed on, AAA started to come off the right wing. It was very intense, bright orange flashes all the way around. I can remember being riveted to the picture–it was so beautiful. I was supposed to be checking my systems, checking six for bad guys, looking out, cross checking Jim's stuff, but it was so pretty that all I could do initially was just look at this AAA going off."[1119]

As the attack package picked its way between the important H2 and H3 airfields and the F-15Es commenced their bomb runs, the first Iraqi interceptors took off and began moving into position to engage. One enemy fighter, believed to have been a Mirage F-1, headed after the lead EF-111. After a brief tussle the EF-111 shook off the Iraqi pilot, but now the latter curved around on the tail of Denton and Brandon's aircraft:

"... this Iraqi fighter swung in behind us and locked us up [on its radar]. The guy swung in right at six [o'clock, behind] and we got cockpit indications that we were locked up...we knew that missile launch was imminent. I said, "Break left! Take it down!" Jim racked it up and we sliced back down. I punched off Chaff and flares by the dozen."[1120]

With the AWACS aircraft broadcasting the bandit's position and U.S. fighters streaking in to engage. Denton sped out at full throttle towards the safety of the Saudi border. Brandon continued:

"We were booking along now at low altitude. Jim was doing an awesome job. I was checking six, looking for this guy that had locked us up. We were just below the Mach. We were off the TF [terrain following radar], wallowing around at 200 to 500 feet, just flying off the altimeter and sucking seat cushion. It was hairy just moving around that low. I looked back at five o'clock, and saw an orange glow come off the bandit. It started to corkscrew toward our jet. We broke right. We took it up from low altitude into a last ditch maneuver, pulled into the missile, dispensed Chaff, watched the missile shoot behind us, waited for the second shot, and then saw a big fireball right behind us–a big explosion."[1121]

As the EF-111A sped from the scene, its crew thought that their pursuer might have hit the ground as it tried to line up for a second shot at them. Later, following investigation of the available evidence, the shoot down of the Iraqi fighter was credited to an escorting F-15C.[1122]

The Search for the Scuds

Late on the afternoon of 17 January, within hours of the first air strikes, his troops launched two modified Scud ballistic missiles at targets in Israel. Others soon followed. Later, Scuds were also launched against targets in Saudi Arabia. These missiles carried a warhead weighing around pounds and its poor accuracy made it unsuitable for attacks on military targets. Yet, for the Iraqi leader, any military effect from these attacks would be a bonus. His aim was to secure political effect.

Locating the mobile Scud launchers and their support vehicles would prove a needle-in-a-haystack problem, however, the majority of missile firing took place at night. Between firings, the missile crews dispersed their vehicles and camouflaged them skillfully. When a launch was imminent, the vehicles concentrated rapidly at a pre-surveyed site. Within as little as ten minutes from the arrival of the last vehicle, the Scud had been fired and the vehicles were moving out to their hiding places.[1123] Decoy vehicles were laid out invitingly, complete with dummy missiles. Signal troops assigned to the missile firing units practiced excellent emitter control to avoid betraying setting-up or launching signatures that an enemy might detect.[1124]

As well as various space and other classified systems, a platoon from the Army's 201st Military Intelligence Battalion joined in the work of collecting intelligence on Scud launchings. The platoon operated three TLQ-17A high frequency receiving/jamming equipment nicknamed "Sand crabs." Each system employed a gigantic collapsible directional antenna measuring about 320 feet long, 300 feet wide and 60 feet high, resembling a huge fish trap with a triangular opening. Only the receiver was used in this operation. The three TLQ-17 sites in Saudi Arabia were positioned to triangulate signals emanating from potential Scud launching areas in Iraq.[1125]

Although the "Sand crabs" and other sources reported frequent success in locating the Scud launch signatures and Coalition aircrews submitted numerous reports of destruction inflicted on launchers and associated vehicles, subsequent analysis has revealed that these claims were greatly exaggerated. As one official source later admitted:

"The Scud hunt unfolded in a way that tended to make this problem in intelligence from intelligence analysis, strike planners and commanders alike. The first ten days of the air campaign saw numerous claims of mobile Scud kills by aircrews, backed in some cases by cockpit videos, and the lull in launches during the third and fourth weeks seemed at first to subordinate pilot reports. In retrospect, however, many of the Coalition aircraft had struck decoys, other short-rage missiles, or traffic such as fuel trucks. Intelligence had not understood the full scope of Baghdad's Scud decoy program, and exploitation of 'low signature' firing location.'"[1176]

The Nature of Electronic Warfare Support

At the Air Headquarters at Riyadh, Major General John Corder held overall responsibility for issuing and executing the huge Air Tasking Order put out each day. Part of this dealt with coordinating the activities of the electronic warfare support aircraft and the attack forces.

"We had a rule, we would put the best airplanes in the best places to do the job. When it came to providing EW support, that put the EF-111s in certain places and it put the EA-6Bs in certain places. If we wanted to make a very high speed, very deep penetration, we used EF-111As for the support. If we wanted a long time on station, in an area not too heavily defended, and there was no need to keep up with a high-speed force, that meant using the EA-6Bs.

"I have often been asked whether I provided direct support for the F-117s during Desert Storm. The answer is, most time, yes. We supported everybody. During the first couple of weeks we played about 70 percent zone defense and 30 percent what we called man-to-man. Zone defense meant the jammer flew out to a given zone, and everybody in the area got the benefit. Man-to-man there was a strike force that needed to be protected on this axis at this time, and the jammer had to be in exactly the right place. We used that tactic when sent forces into the heavily defended areas around areas around Basra and Baghdad. As the war progressed and we got a better grip on things, the proportion of zone defense missions increased further."[1127]

The Wild Weasel

The Wild Weasel force in the Persian Gulf area comprised forty-eight F-4G Phantom of the 35th TFW (Provisional) based at Shaikh Isa AB, Bahrain. In the north, operating out of Incirlik in Turkey, the 23rd TFS operated twelve F-4Gs with a similar number of F-16s able to carry and launch, but not target, anti-radiation missiles.[1128]

Since the end of the Vietnam War, the Wild Weasel units' equipment had been much improved. The F-4G Phantom was a considerably better fighter than the F-105G, and its new APR-47 receiver suite made it far more effective as a radar hunter than its predecessor. Moreover, the Weasel's primary weapon was now the HARM, longer ranging and considerably more lethal than the AGM-45 Shrikes and AGM-78 Standard ARMs it replaced. HARM weighed 790 pounds, which included a 145-pound pre-fragmented high explosive warhead.[1129]

Lieutenant Colonel Ed Ballanco flew his first operational Wild Weasel mission from Shaikh Isa on the morning of 17 January. Piloting one of a dozen F-4Gs, he took off soon after dawn to support a large "Gorilla" of F-16s attacking the military airfields at Ali Al Salem and Ahmed Al Jaber in Kuwait. Also present were F-15s flying top cover and EF-111s providing standoff jamming support. The F-16s ran in at altitudes around 20,000 feet, the Wild Weasel at 28,000 feet with the EF-111s and F-15 top cover above them.[1130]

Because the distance to the target was relatively short, each F-4G carried a centerline fuel tank and no underwing tanks. That meant they could carry their maximum weapon load of four HARMs plus two AIM-7 Sparrow missiles for self-defense.

That day the Wild Weasel force ran into difficulties during the refueling phase of their mission. A tanker malfunctioned; so two F-4Gs were unable to take fuel and had to abort. Then the presence of thunderstorms in the refueling area forced the planes to take a new route around the area of turbulence. Consequently, when Ed Ballanco and his flight leader finally rolled out on target heading, they were a couple of minutes late.[1131]

"As we left the tanker we pushed up the speed to as fast as we could go. But, heavyweight and with a full load of munitions, we were not that fast. As we ingressed at about 28,000 feet in amongst the 'puffies,' I could see the F-16 flights below me to my right and left, about ten miles in front. We swept the target area with our APR-47 gear and saw that some missile sites were active.[1132]

"To avoid having to deconfliction our targeting, we targeted the SAMs by type of missile and by airplane. So we had one aircraft going after SA-6s, another engaging SA-3s, somebody else looking for SA-2s. I was after SA-6s. I launched a long range HARM into the target area and I think it was a good shot.[1133]

"Then other missile sites in the area become active, suddenly we found ourselves in a target-rich environment. I fired HARMs at two separate radars as the F-16 flights were coming off the target. Then we got an indication of a missile launch directed at somebody else. We turned to point directly at the site and got off our shot within a few seconds. The missile's time of flight was short, about 25 seconds, then the radar went off the air. We reckoned we killed that one too.

"In a space of about a minute and a half we had fired all four HARMs, each targeted at an individual radar. We still had gobs of gas left, and our flight plan was to head north and attacks other SAM sites that came up. I had gone a little way on my planned track when it dawned on me; OK dummy, the flights you were sent to cover have gone home, you are separated from your flight leader and you have no missiles left. Just why are you going deeper into enemy territory? I turned around and went home."[1134] Other Weasel crews returning from the engagement had similar stories of apparently successful HARM attacks. That pace of fighting between the Iraqi missile batteries and the Wild Weasels was too fast and too furious to continue for long, and it did not.

On the evening on 17 January, just eighteen hours into the conflict, a Weasel Flight from Shaikh Isa flew across Kuwait in company with an attack force. Although the F-4Gs flew over an area where several Republican Guard SAM units were known to be present, the latters' radars remained frustratingly silent. It was the clearest indication that the Iraqi missile control radars had been hit hard, and those that survived had orders to stay off the air.[1135]

The Electronic Order of Battle (EOB)

The reports that the Iraqi target tracking radars were silent posed an unexpected problem for Major General John Corder:

"After about the fourth day of the war the Iraqi Electronic Order of Battle (EOB)–our understanding of the disposition of their forces–was in a shambles. We did not know how many radars we had destroyed, we did not know how many were sitting there not emitting, we didn't know where the systems were that were worth going after, we didn't know if they were waiting out there in the weeds.

"I put some of my people on the Rivet Joint aircraft, I wanted to know what was going on electronically. We fussed around with that for two or three days trying to figure it out and we never got a good grip on it. After a few days, I gave up trying the normal collection way of doing business on Iraqi EOB. Then I thought, who are the best people with best air vehicle to know what the enemy EOB is? It was the F-4G Wild Weasel guys, with their excellent receivers and combat recording capability. At Shaikh Isa my good buddy Lieutenant Colonel Brad Elico was working in the tactics cell. I called him and said 'Brad, what's going on? What are you guys seeing?' He told me that the number of signals from Iraqi missile control radars had fallen almost to zero. From then on, he gave me regular updates to confirm that picture.

"The big bosses like General Schwarzkopf and Chuck Horner, they wanted to see briefing charts showing the locations of all the active SAM sites. I said to them 'Look, we don't know where they are. But let me tell you this, if I was able to tell you the positions of all their active SAM sites at this stage and we had not been able to knock them out, it would probably mean we were losing. We're not losing many airplanes. We've got a grip on things. This is what it feels like when we're winning!'"[1136]

Both Chuck Horner and John Corder had haunting memories of friends lost during the air war over Vietnam, and strong views about the danger of over-using the low altitude penetration tactic. Now the Iraqi fighter and long-range missile defenses were in tatters, with little remaining capability against targets flying at 15,000 feet and above. Accordingly, from now on, Coalition and U.S. aircraft sent over heavily defended parts of Iraq would do so at medium altitude.[1137]

Major General Corder had the clout to shrug off embarrassing questions concerning the number of Iraqi radars remaining. Those lower down in "the food chain" could not. Mike Kemerer, now a Lieutenant Colonel was still at the Intelligence Office at Riyadh trying to make sense of the enemy EOB (electronic order of battle). He outlined his problem:

"The Constant Source [secure data relay terminal] screen gave near real-time updates on Iraqi radar emissions. During the first couple of days of the war, I saw lots of the war, I saw lots of radar activity. Then I could see that our guys were tearing down the Iraqi integrated air defense system, and by the end of the war I saw very little radar activity.

"We knew the Wild Weasels were very effective, because we had SIGINT collection taking place at times when the Weasels were up. Radar would be up and emitting, tracking an airplane. A HARM would be fired and several seconds later the radar would go down. And it would not come back up again. So we had good SIGINT indications that radar had been put out of action."[1138]

As any good cop will testify, knowing a thing to be sure is quite different from being able to prove it. While there were clear signs that HARMs had destroyed a significant proportion of the Iraqi missile control radars, finding evidence that was "admissible in court" was a very difficult matter. Mike Kemerer continued:

"Our EOB data was based primarily on SIGINT. At the start of Desert Storm, there were about two hundred radars in the Iraqi EOB. As the war progressed, there was a major problem because we had no good way of doing EOB deletions. Guys would go out and bomb radar or shoot a HARM at it. But unless there was imagery confirmation, that radar could not be deleted from the official list. Also, when the Iraqis moved radar from on place to another, SIGINT would plot the radar in the new location and report it as new radar. So the official EOB just kept growing, it never got smaller.

"In the office we had a big map with different colored pins representing the different types of radar. We pulled out pins when we judged that radar had been killed. If the evidence was believable, we pulled the pin. So as the war progressed, our manual board showed less radar. But we kept getting SIGINT collection data that added emitters to the official EOB. There was a disconnect between the official computer database, and what we really believed the EOB to be.

"We begged for imagery confirmation of the attacked radar sites. But imagery collection assets were limited and they were prioritized to go after troops, guns, and tanks, not SAM sites that might or might not be operational. Only occasionally did we get imagery confirmation that a radar had been knocked out."[1139]

The intelligence office at Riyadh also kept tabs on the Iraqi efforts to resuscitate parts of the beleaguered Kari system and bring them back into action:

"We could see the Iraqis doing significant repair work. They would take undamaged items from two or three bombed operations centers, and reconstitute a new one at a different location. They did a good job reconstituting some sites in the Baghdad area, those had priority. Usually the reconstituted sites had less capability than the originals. Instead of the five separate communications at the original site, the reconstituted one might have just HF radio and data link. When a new site was running well enough to be effective, we would retarget it. It was a continuing process."[1140]

By the time the land battle had begun, Major General John Corder was no longer interested in the Iraqi EOB his intelligence officers had put together. That was just as well, because by that stage in the war the accounting system had collapsed. Mike Kemerer explained:

"When there was just the air campaign, we had a clear field of fire. But once the ground war started, the Coalition forces moved so fast that it really complicated our efforts. There was no continuous front line, so we could not say with certainty who owned this or that piece of territory. Once the ground war started, the official EOB showed Iraqi radars and SAM sites well behind our forward positions. And without confirming information, they could not be deleted from the list. Another complicating factor was that the Coalition ground forces brought their radars with them as they moved forward, and in some cases those radars were types used by the Iraqis."[1141]

Whit General Schwarzkopf's mighty Blitzkrieg thrust running at full tilt, such intelligence was largely irrelevant. Had that advance been slowed or halted these factors might again have come into play, but neither of those things happened.

The conflict had witnessed the most intensive and successful radar-wrecking campaign in history. Despite that, when the fighting ended the official U.S. estimate of the Iraqi EOB listed more radars than it had at the beginning of Desert Storm.[1142]

The Wild Weasel Adopts A New Posture

With the change in penetration altitudes came a major change in the posture adopted by the Wild Weasel force. Ed Ballanco explained:

"After the first few days we gave up flying regular direct support missions, going in with or ahead of a particular strike force. Instead, we flew mainly indirect support missions, nick-named the 'Weasel Police.' Beforehand we would go through the frag [the operational order for the day] and mark down the kill boxes where attack planes were going to be active. Then we positioned our Flights in the optimum locations to support those forces. The 'Weasel Police' had free reign to support attack missions as we thought best.

"The exception was when B-52s came over Kuwait. Then we transitioned from the indirect support mode to the direct support mode, to cover them. They had the highest priority. The attack fighters could usually look after themselves, but the B-52s were much less maneuverable and they needed our help."[1143]

For missions supporting forces attacking the more distant targets in Iraq, the Weasel F-4Gs needed to carry three external fuel tanks, one under each wing and one on the centerline. This cut their offensive load to just two HARMs, representing a significant reduction if firepower. Fortunately, by that time the Iraqis had few SAM batteries operational on any one-day.

Attack forces were always pleased to have F-4Gs as company. Not only would the Weasel protect them from missile attack, but their APR-47 receiving system provided useful tactical ELINT. The F-4G served as a "mini Rivet Joint." Sharing the information with the rest of the force. False alarms on radar warning receivers dogged attack crews in this conflict, as in those earlier. The Rasit artillery counter-battery radar operated by the Iraqi Army was a frequent culprit, giving indications similar to one of the SAM control radars. Using the APR-47, the EWO could tell the difference between Rasit and the SAM radar. A brief call of "Ground picture clear" from the Weasel plane, always trusted, set minds at rest. If Weasel planes were on their way home with unused HARMs, the Rasits became a favored target.[1144]

On 24 January there was another example of the APR-47's utility, when an F-4G on "Weasel Police" duty picked up signals from Cyrano IV radars. It was a clear indication that Iraqi Mirage F-1 fighter-bombers were airborne and bent on attacking someone. A warning was flashed to the AWACS plane controlling the area. That initiated a train of events, which ended a few minutes later when a Saudi F-15 was vectored on the enemy planes and shot down two in rapid succession.[1145]

Certainly, the Weasel had been successful in their task of suppressing, depressing and destroying the enemy missile batteries. As a major contributory factor making this possible, Ed Ballanco paid tribute to the training he had received earlier:

"The Red Flag and Green Flag training we had all gone through gave us a tremendous advantage. It was invaluable in getting everyone's situational awareness up to speed, and having some feel as to what to expect. In fact, aside from getting shot at for real, most the Wild Weasel combat missions I flew were far easier than the Red Flag and Green Flag missions."[1146]

It had taken more than a quarter of a century for these training programs to prove their worth. Now, in terms of aircraft and crews saved, they had done so in no uncertain manner.

The Role of High Speed Anti-Radiation Missile (HARM)

Us aircraft carriers operating in the Red Sea and the Persian Gulf carried a total of twenty-seven Grumman EA-6B Prowlers jamming support planes. A further twelve of these planes, from the Marine Corps, flew from Shaikh Isa, Bahrain.

Lieutenant Commander Rick Morgan flew as an ECM Officer with VAQ-141 aboard the USS *Theodore Roosevelt* in the Persian Gulf. During combat missions these aircraft normally flew with one ALQ-99 pod under each wing and one under the fuselage, a HARM on the port inboard station and a fuel tank on the starboard inner station. Morgan outlined their usual mode of operation:

"With their self-defense jammers, Chaff, flares, and evasive maneuvers, the attack planes could handle the terminal threats. We in the Prowlers were there to jam the early warning and missile acquisition radars. That made it harder for missile control radars to find their targets, so they had to spend longer on air doing it. And that made them more vulnerable to attack from HARMs."[1147]

Rick Morgan flew his most memorable mission on 24 January. His Prowler, and another from *Midway's* VAQ-136, was tasked to support a daylight strike on Al Jaber airfield in Kuwait. The raiding force comprised sixteen F-16s of the 401st TFW from Doha and four Royal Air Force Jaguars from Bahrain. Of the four HARMs Morgan would fire during the campaign, this was the only occasion he launched without first acquiring a specific enemy radar:

"We got into position about 10 miles off the coast and started our orbit at about 15,000 feet. We looked down and, lo and behold, there were two wagon wheels of F-16s orbiting. It was our strike group; they had come off their tankers a little early and were waiting at their IP (initial point). We heard the AWACS tell the strike leader Wolf Zero-One that all the players were in position, and then we saw them go in. On that occasion, we fired our HARM preemptively, timed to get to the target to support the F-16s. The missile went out in front of us leaving a big white smoke trail. To one side, we saw a couple of SA-2s going up, two white fingers going up in a straight for the moon without any guidance."[1148]

A few moments later Morgan heard a panic call on the strike force's frequency: "Lead's been hit, Lead's been hit!" There was a lot more chatter as the fighters came off the target, covering the leaders badly damaged F-16 as he headed for the relative safety of the sea. Shortly after crossing the coast he ejected and was picked up by a helicopter from one of the frigates.[1149]

"As we headed back to our ship we discussed what had happened. I remember saying 'Oh my God, what did we miss? What didn't we see on our system, what was if we failed to knock down electronically, so they could bag this guy?' I hadn't heard or seen any radar signals that looked threatening. That bugged me."

"I would not discover what really happened until after the war, when some F-16 pilots from Doha paid a social visit to our carrier. We asked what had bagged that F-16. What had we missed? They said 'It wasn't your fault, the guy had a premature detonation of a VT [radar] fused bomb, soon after it came off the rack it exploded.'"[1150]

When he learned that he was in no way responsible for the F-16 loss, Morgan felt "a lot whole better."

As well as the EA-6B Prowlers, Navy and Marine A-7s and F/A-18 attack fighters were equipped to launch HARMs in action. (That was in contrast to the Air Force, where these missiles were carried only by planes belonging to dedicated Wild Weasel units.)

Later in Desert Storm, the EA-6B became the primary Navy and Marine HARM shooter. In Morgan's view, it was for more effective in this role than any of the other Navy planes:

"The EA-6Bs were a lot better equipped to use HARM than the regular attack planes, and we were much more selective in delivering attacks. The Prowler has two EW trained aircrew in the back seats able to recognize radar signals, listen to their audio and then decide whether or not to shoot.

"The F/A-18 and A-7 guys did not have those options, and they certainly flew with us and if a radar signal came up they would shoot at it. Afterwards, if you asked them what they had shot at, they would say 'I don't know.' They shot off so many HARMs that we had to start conserving them, or we might run out. Those are expensive missiles; the guys should not have been using them like popcorn.

"Like all anti-radiation missiles, HARM is an equal opportunity weapon. If it sees something that matches the parameters it is looking for, it is going to home in it. And you are talking about a missile with a humongous footprint area."[1151]

Less-than-careful targeting with HARMs led to instances of "HARM Fratricide," On two occasions, these missiles homed on non-U.S. Coalition warships operating in the Persian Gulf, causing damage to each. Fortunately, nobody was injured. Another weapon went off close to a frigate without inflicting damage. On land, HARMs destroyed two U.S. counter-battery radars, in one case killing a marine. HARM also demolished a TACAN (Tactical Air Navigator) beacon in northwest Saudi Arabia, which marked the orbit point for tankers supporting planes operating over Iraq; its loss was sorely felt.[1152]

The Role of VAQ-137

Compared with the dense electronic environment in central and eastern areas of Iraq, that in the west of the country was relatively sparse. Commander Ken Krech was executive officer of VAQ-137, the EA-6B squadron aboard USS *America* in the Red Sea.

After a few days, his unit too had almost run of missile control radars to engage with its HARMs. Krech now sought permission to go after the other types of radar in the area:[1153]

"After the first three or four nights, there weren't many missile-type targets left for us to shoot at. But the Iraqi IADS (integrated air defense system) was still alive and that was frustrating. They had their early warning and GCI (ground controlled intercept) radars up, and they seemed confident that we would not shoot at them. I went to see the CAG (Commander Air Group) and suggested that we ought to attack those radars too. I said 'Why carry these 800-pound missiles all the way into Iraq and back, when we could shoot at one of their radars?"[1154]

The CAG agreed to the suggestion. The Prowlers could engage the Iraqi surveillance radars; provided the raiding force had cleared the target area and no missile-control radars were operating. Ken Krech continued:

"On the carrier we had a secure system to pick up the national intelligence broadcast in our ready room. We could see in-near-real-time which Iraqi radars were up, based on the information from the national sensors. When I knew I could use any HARMs I had left during my egress, I picked my secondary target. I noted the location of the radar, a Flat Face, its exact parameters and the positions of other radars nearby. So when I walked out to the airplane I had all the information I needed to attack that radar.[1155]

"We took off, and when we were on the tanker I called the EA-3 Whale of VQ-1 which was monitoring Iraqi radar emissions in the area. On the secure radio, I told him that I was looking for Flat Face radar at this co-ordinate with these parameters. I said 'Have you guys seen it?' He said 'Yea, in fact its up right now!' So even before we left the tanker, I had my system ready to go after that Flat Face. We went over the border and as we came over the radar horizon, I picked up its signals.

"We flew the mission, and the Iraqi missile control radars were very quite. As we headed away from the target area I called the EA-3 on the secure circuit and told them I was ready to attack the radar, and gave him the details. The guy came back and said 'OK, we're watching'. My pilot pulled the trigger and I called the launch on the secure radio. It was early morning, the sun was up. It was on over-the-shoulder shot. The missile came off the launcher leaving a trail of smoke, headed out in front, then arched way over to the left for a thirty-something mile shot. I counted down the time to impact on my clock. When I got to 4 seconds to impact I turned off my jammers, so I could watch the radar's signals on my screen. Suddenly the signals disappeared. The EA-3 and an RC-135 on the EW circuit came up one after the other and said 'He's stopped, he's stopped, you got him!'"[1156]

Every day VAQ-137 supported three air strikes, each with two EA-6Bs, both of which carried two HARMs. So on the day in question the Prowlers took off carrying twelve missiles. They fired most of them at the enemy surveillance radars. Post flight analysis produced evidence to suggest that the missiles might have damaged or destroyed about six enemy radars. The day's attack had a greater effect on the enemy than Ken Krech could have imagined:

"The word got around the Iraqi radar sites real quick. Next day, we noticed a big change in attitude at the radar stations in the H3 area. They had a rough idea of the range of HARM, they knew which radars were out of reach and they left those on. But if an EA-6B turned on its jammer, and it was within HARM range of radar, that set immediately went off the air. They waited until we left the area before they turned those radars back on. So, by using HARMs against these radars on just one day, we influenced the way they used their radars for the rest of the war. It meant there were a lot less radar for us to jam.

For me it was a big lesson. Some people will say that was not a proper way to use HARM, but I would argue it was a great way to use the weapons."[1157]

The Compass Call EC-130H

The force of EC-130H Compass Call aircraft in the Persian Gulf area comprised of fifteen aircraft based at King Khalid International Airport, Riyadh, and there at Incirlik in Turkey. The communications jamming support plane carried a crew of thirteen: a flight crew comprising two pilots, navigator and flight engineer; and a mission crew consisting of the mission commander, two operators, five linguists and an airborne maintenance technician.[1158]

The Rivet Fire communications jamming system fitted to the EC-130H jammed VHF (very high frequency), UHF (ultra high frequency) and higher bands used by special command and control systems. The system could be programmed to employ specific types of modulation to counter enemy signals, depending on their characteristics. Lieutenant Chris Bakke, an EWO (electronic warfare officer) with the 41st TEWS (tactical electronic warfare squadron), described the way it operated:

"The system received signals, it searched for and filtered through those that met the criteria we had set. Then the operators got the signals, they filtered them further and designated the targets. Once a signal had been designated as a target, it is routed to the mission commander for jamming. The linguists assisted the mission commander to classify targets by the type of weapon system they were associated with, by their location, by whatever other criteria we wanted to use."[1159]

When on station, each EC-130 was allocated a box-shaped area in which to operate, flying racetrack patterns at altitudes around 20,000 feet. The jamming could be radiated either to port or to starboard, by switching the antennas. When they were jamming, the planes flew straight runs about 15 minutes (75 miles) long, running perpendicular to the threat axis.[1160]

If Compass Call aircraft were to be used to their full potential during these operations, much depended on having effective control over the jamming. It will be remembered that for much of the Vietnam War, absence of such effective control had led to the NSA exercising its veto on communications jamming. Captain David Long, another EWO with the 41st, explained how this was achieved during Desert Storm:

"It was a co-operative effort between NSA, the Air Force and the intelligence community. Do our folks jam it, or do we exploit it and gather the information? That is a major dilemma that had to be worked on before we could use our system. During Desert Storm we had an electronic combat (EC) communications net with an EC controller who controlled us using a secure voice link. If there was a departure from the Frag order, he decided whether or not we could jam. Also we had an electronic combat co-ordination officer on board the AWACS plane, he would provide liaison between Compass Call, the RC-135s and other planes.[1161]

"The system in our airplane could differentiate automatically between enemy and friendly communications. Working with a joint frequency restricted list, we programmed is not to jam those frequencies used by friendly forces. Before Desert Storm there was a major effort to go through the entire primary, secondary and tertiary frequencies used by all friendly forces. During Desert Storm, if we found significant enemy activity on a frequency used by friendly forces, we would call our controller indicating the type of enemy activity and request permission to jam it. My experience in Desert Storm was that 100 percent of the time when we said had found important enemy activity on a frequency used by our forces, the friendlies were moved off that frequency and we were able to jam it."[1162]

Orbiting in the "dress circle" over Saudi Arabia, the Compass Call crews were much concerned about the amount of traffic coming past them in both directions. Although the jamming planes had their allocated band of altitudes, other planes were also routed through those areas. When an EC-130 flew on combat mission, normally it would have its navigation lights extinguished. However, with the risk of a mid-air collision being far greater than the risk from Iraqi fighters, the lights stayed on.[1163]

On the night of 27 January Iraqi troops pushed into Saudi Arabia and seized the small town at Khafji. Chris Bakke war airborne abroad an EC-130 when it happened:

"We had been on station for about four hours. The aircraft was fitted with the Integrated Work Station, a new system still with some minor problems. After a few hours, it didn't want to work any more. About that time I got a call over the command and control net, telling us to re-orient from east-west orbit to a north-south orbit. Over the radio I could hear the JSTARS (Joint Surveillance Target Attack Radar System) working. It was clear that a ground battle was in progress and some Marines were in trouble. We had been told to jam a couple of specific frequencies, but the system wanted to die. We worked hard to try to keep it running, it was a flight! Our experienced maintenance technician did an outstanding job; he worked furiously to keep the system up. The options were to run a quick reset of the system, or shut it down and start up from the beginning– which was very time consuming. We tried all the quick options, to keep pumping out jamming and help the Marines in their time of need. One of the inherent characteristics of electronic warfare is that you never really realize how effective you have been, unless you hear the enemy complain or if they are slow to react. Only then do you realize you have achieved the desired results."[1164]

In time of war fratricide can take many forms. Chris Bakke described a rare, possibly unique, instance of electronic warfare–Psyops (psychological operations) fratricide:

"On one occasion I was on orbit conducting jamming operations, and we knew an EC-130E Commando Solo aircraft was in the area putting out Psyops broadcasts to Iraqi troops. But we didn't know the frequencies or the times when it was operating. A linguist misidentified a broadcast, we targeted it and we ended up jamming it. We discovered the mistake only after we landed."[1165]

Following this discovery, there was a general tightening of procedures to prevent a recurrence. Those aboard the Compass Call plane only hope they had not done a good job on that occasion.

The Rivet Joint RC-135

During Desert Storm the Rivet Joint RC-135Vs and RC-135Ws played a vitally important role collecting SIGINT (signal intelligence) intelligence on what their enemy was doing. These big slow planes did not control air battles; their forte was to collect and analyze the information. They then reported their findings by secure link to the Air Force Operations Center in Riyadh and other recipients.[1166] One of the latter was the Air Force Operations Center in the basement of the Pentagon, from which point Major Bill Strandberg was able to watch the proceeding:

"E-System had just developed a new system called TIBS (Tactical Information Broadcast Service). This allowed Rivet Joint planes to transmit a graphic-based 'picture' of the Iraqi battle space, via satellite, to ground stations. E-Systems, with the only receiver in the U.S. at their plant at Greenville, Texas, passed the picture to Washington, DC, by landline.

"In the Air Force Operations Center in the Pentagon we had a 35-in TV screen. We could watch the TIBS display coming from a Rivet Joint RC-135 over Saudi Arabia. The display showed the airborne tracks from the AWACS, with Rivet Joint Information added. Occasionally you would see a hostile aircraft symbol disappears off the screen, as an Iraqi plane was shot down. The pictures were recorded on data disk, and we replayed them during briefings of senior officers and people like the Secretary of the Air Force, Assistant Secretaries of Defense and their staffs." [1167]

For the most part the Rivet Joint aircraft kept clear of Iraqi territory and so avoided any direct communication with the enemy. Nevertheless, an RC-135 did suffer combat damage on one occasion. On 25 January the plane had been on the ground at Riyadh AB when it was hit by fragments from a Scud missile that exploded high above. The damage was minor and the repairs did not remove it from the planned operational program.[1168]

Conclusion

Having examined the part played by electronic warfare in its various forms in support of the air actions during Desert Storm, it remains to assess what they achieved. First, though, let us look at the losses suffered by Air Force, Navy and Marine fixed wing planes during the conflict due to enemy action.

In total, twenty-seven Air Force, Navy and Marine fixed wing planes were lost in combat during Desert Storm. The breakdown of those losses is given in the table below. It will be seen that the losses during Desert Storm approximated to a relatively quiet month over North Vietnam in 1966.

AF and Navy fixed wing planes lost to enemy action during Desert Storm[1169]

Cause of Loss	Air Force	Navy/Marine
Fighter	0	1
AAA	3	4
SAM (Radar)	3	2
SAM (IR)	7	5
Other	1	0
Unknown	0	1
Total	14	13

The significant difference between the two conflicts, however, lay in diverse range of SAM systems deployed by the Iraqis. For most of the Vietnam War, U.S. combat pilots had only one type of SAM to worry about. They never had more than two. In contrast, the Iraqis fielded at least ten different SAM systems.[1170] Those should have been sufficient to make the skies at medium and high altitude a dangerous place for any plane passing within range.

The fact that they did not must be credited to successful employment of the various electronic warfare systems. As recounted earlier, Desert Storm was the first major conflict during which the self-protection EW systems carried by U.S. planes were regarded as a go/no go item for a combat mission.

The table shows the relative lethality of the threats facing the modern combat aircraft, and that their order of importance has changed markedly during the past two decades. Until the final year of the Vietnam War, AAA had been the main cause of losses, SAMs came a long way down in second place and enemy fighters were even further down in third place.

In Desert Storm the pattern was rather different, with SAMs responsible for the destruction of seventy (70 percent) of the twenty-seven U.S. fixed winged planes lost. Splitting those losses between the IR guided and the radar guided weapons put the nature of the modern threat into sharper focus. Over Vietnam, it will be remembered, the SA-7 IR guided missile accounted for relatively few aircraft. Twenty years later, the newer generation Soviet IR weapons were far more dangerous. During Desert Storm these accounted for twelve (44 percent) of U.S. fixed wing losses. IR homing missile like SA-9 Gaskin and the SA-13 Gopher, and the shoulder-launched SA-14 Gremlin and the SA-16 Gimlet, were the main culprits. These weapons gave little or no indication of their presence until they were launched. Once in flight they were difficult to detect, particularly in daytime. They were invulnerable to any normal type of SEAD effort.

During the powerful defense suppression effort mounted during the first few days of Desert Storm, a significant number of Iraqi missiles control radar were destroyed or damaged. The survivors rarely came on the air. Consequently, the radar guided missile systems achieved far less than their IR counterparts. The radar guided missiles accounted for five (18 percent) of the U.S. planes destroyed. In fairness it should be pointed out that the long range systems used by Iraqis, the SA-2, SA-3 and SA-6, were more than twenty years old and employed elderly technology radars that were relatively easy to jam. These systems could not engage planes without emitting signals that betrayed both their intent, and made them vulnerable to attack from anti-radiation missiles. Moreover, the fighters' electronic jammers and Chaff dispensing systems could counter these systems. The short range, the SA-8 Gecko and the French-built Roland, were on a different and higher plane of effectiveness, but neither system was fielded in large numbers during the conflict.

It is interesting to note that two of the planes lost–an F-14 and an F-15E[1171]–fell to the venerable SA-2E system dating from the mid 1960s. Although it had been overshadowed by later designs, the SA-2E had gone through several modifications and improvements. It could still be dangerous if ignored, as appears to have been the case.

AAA (including small arms fire), for the most part optically aimed or unaimed barrage fire, accounted for seven (26 percent) losses. It was a poor showing, considering the vast numbers of automatic weapons fielded by the Iraqis. The main reason for the low figure was that over the combat zone Coalition fixed-wing planes usually kept above 10,000 feet, unless they needed to descend below that altitude to deliver their weapons.[1172]

Only one U.S. plane was lost in air-to-air combat, the F/A-18 that fell to a MiG-25 on the first night of the conflict.[1173] The 32:1 victory score achieved by U.S. fighters during *Desert Storm* confirmed the superiority of U.S. fighter pilot training and equipment. It also showed the value of the enhanced situational awareness given to fighter pilots, when directed from AWACS aircraft with indirect assistance from RC-135 Rivet Joint aircraft. Their enemy counterparts received little or no reliable assistance from their battered and jammed air defense infrastructure.

Certainly, there were failing and glitches in the U.S. electronic warfare efforts to support air operations during Desert Storm–perfection is impossible to achieve in war. Overall, however, that effort succeeded brilliantly. The minutely planned "spoof and punch" operation on the first night of the war inflicted a blow on the Iraqi integrated air defense system from which it never recovered. Thereafter the Coalition forces owned the night, they owned the skies over Iraq above 10,000 feet and they owned the effective use of the radio frequency spectrum. In the weeks that followed the Iraqis were unable to challenge ownership of any these.

Electronic Counter-Counter Measures (ECCM)

The most basic tactic is emission control (EMCON) that reduces the radiation of electromagnetic energy that is vulnerable to ESM or ECM. Radio or radar silence is its most intense application. Maintaining effective electronic discipline in the Coalition was sometimes difficult. While U.S., British, French, and NATO forces have spent years trying to minimize those lax operational communications security practices commonplace in the past, some Coalition forces, particularly the Saudis, did not have such discipline.[1174]

Iraq made extensive use of EMCON. Before the war, the Iraqis minimized the use of their radios and air defense radars, thereby reducing the ELINT available to the Coalition. When hostilities began, Iraqi defense radars were activated but were quickly silenced by Coalition attacks. There was 95 percent less radar activity on January 23rd than on the 17th. Frank Kendall, U.S. Undersecretary of Defense for tactical warfare programs was correct when he said, "the willingness to turn on your radars and fight did not seem to be there."[1175]

The Iraqis also practiced tactical EMCON and were quite good at controlling radar emissions from their missile sites until the last moment. Iraqi actions were similar to other Arab and Vietnamese users of Soviet-made air defense systems in that they switched to the less accurate back-up optical guidance mode for their SAMs and AAA. The low number of aircraft lost to SAMs, mainly heat seekers, shows this method is less effective.[1176]

ECCM also was a factor in the success of secure, reliable Coalition communications and resolved interoperability problems that initially seemed insurmountable. Systems such as the U.S. Army's SINCGARS radio system, the Air Force's have Quick radio and the Navy's Link 11 data link had integral ECCM capabilities. The Iraqis had first and second generation secure radios with ECCM capability, but they were not used effectively.[1177]

Chapter 33

The Electronic Aspects Of The Land and Naval Operations Of The Gulf War

The Element of Surprise

Surprise is an essential ingredient in the success of a military operation. Since the dawn of history, imaginative commanders have sought to present their adversary with an erroneous impression of their strengths, their weaknesses and their dispositions. A successful deception operation rests on the twin pillars of tight security regarding one's own plans and good intelligence on the strengths, the intentions and the fears of the enemy. During the ground battle to eject Iraqi forces from Kuwait the Coalition forces were in a fortunate position regarding all of these aspects.

One factor that greatly assisted the security of the Coalition's plans was the paucity of the intelligence channels available to the Iraqis. Any time after 17 February, a single successful reconnaissance flight along the border with Saudi Arabia would reveal the huge force massed for General Schwarzkopf's left hook to outflank the entire Iraqi defensive line. Yet, the skies belonged to the Coalition Air Forces, and from the Iraqi dispositions it is clear they had no inkling of what was afoot.

Lacking reliable sources of information the Iraqis had to rely on more fallible sources. Much would depend on what was seen or heard, or thought to have been seen or heard, by the troops in front-line positions, backing this would be whatever intelligence could be learned from interceptions of the Coalition forces' radio traffic, from real or apparent sympathizers in foreign countries, and from the brutal interrogation of prisoners. There was the vast quantity of information to be gleaned from the foreign media, though much of that was conflicting. Apart from the unfortunate prisoners of all those sources

- A large scale amphibious landing operation at some point on the coast of Kuwait, and/or
- A move northwards toward Baghdad through the Euphrates Valley, or
- A large-scale direct assault across Kuwait's southern border with a thrust toward Kuwait City.[1179]

The bulk of the Coalition armored units moved to their start point along the Iraqi border one week before the ground offensive opened. Those units that remained in place along Kuwait's southern border then began deception operation to draw attention upon themselves. A fake military headquarters created a volume of spurious message traffic aimed at convincing the Iraqi high command that the main body of the attack force had not moved at all.[1180] U.S. troops created their mythical "Task Force Troy," which radiated spoof communications from dummy headquarters. They also communicated small-scale raids against Iraqi forces in Al-Wafrah to draw attention to that area. Navy Seabees and Army psychological warfare experts employed a range of tricks to make these forces appear far larger than was the case. There is reason to believe that these deception activities kept as many as five Iraqi infantry divisions and one armored division tied down and safely clear of the main attack.[1181]

Psychological Warfare

Troops that are well motivated and supplied, in no immediate danger and confidant of their cause, make poor targets for psychological operations. When Desert Storm began the Iraqi troops deployed across the desert fulfilled these conditions. They were proud of their country's status as a regional power. They accepted the official government statements that Kuwait was really part of their country and for many years the Kuwaitis had stolen oil from "their" Rumailah field. They believed their cause to be just. Most of their units were reasonably well equipped and their troops knew how to use their weapons effectively. Morale was good and the troops were unimpressed by the size of the Coalition arrayed against them. Had not their leaders assured them that the polyglot alliance would collapse as soon as its troops began shedding their blood?

Yet, within a period of less than six weeks, the fighting spirit in most main-force Iraqi Army units had disintegrated. How did it happen?

Over Vietnam the B-52 had gained a fearsome reputation for its ability to put down huge quantities of high explosive on troop positions. That capability was well known to the Iraqis, and the fear of it formed a central plank of the Coalition psychological operations campaign. Colonel Jones, commander of the U.S. Army's 4th Psychological Operations Group, explained:

"Most of the alternating leafleting and bombing was done inside Kuwait. We did drop leaflets on the Republican guards with B-52s, but the massive leafleting of specific divisions was really along the front in Kuwait and it was designed to do several things. First, to let them know that our intelligence system was good enough to target specific divisions by number. But we did not just leaflet that particular division. We dropped a million and a half leaflets each time, all along the front over every single division and told them that tomorrow we are going to bomb the 20th Division or whatever. We also announced it on the radio. And then we did exactly what we told them we were going to do. We scheduled with the Air Force, generally sending in flights of 4 or 6 B-52s, each carrying 72 x 750 lb bombs apiece. We dropped leaflets in the dark, so that when the Iraqi soldiers woke up in the morning the leaflets were all over the ground to tell them that there was an alternative. It wasn't just that we were going to bomb them but the alternative was to get away from their equipment, to desert, to come across the border. There was an alternative to death and that was an important message to get across. It was in fact a leadership substitute, and it was a warning. We alternated leafleting them (giving them 24 hours to think about it), bombing them, leafleting them again, saying that we told you so, that we are going to do it again tomorrow and those of you who are left who didn't pay heed to our warnings before, had better watch out next time, and then bombing them again."[1182]

Broadcast from EC-130E Volant Solo aircraft of the 193rd Special Operations Wing strengthened the message. These planes transmitted the U.S. produced "Voice of the Gulf" broadcasts on the HF and VHF bands. The planes flew mission lasting up to fourteen hours, orbiting at altitudes around 20,000 feet over friendly territory.[1183]

As well as dropping several million leaflets across Iraqi troops positions, MC-130E Combat Talon aircraft delivered a more immediate type of" wake-up call ". Sleep termination was achieved by 15,000 pound BLU-82 fuel-air blast bombs, released from the plane's hold by running them out of the rear on the cargo roller conveyor.

Meanwhile, to compound the miseries of the Iraqi troops holed up in the desert, the Allied bombing campaign made it harder to move food and other supplies to these units. Rumors of deserters being summarily shot by Iraqi death squads in the rear areas did nothing to raise the plummeting morale of the sorely tried front-line units.[1184]

The Signal Intelligence (SIGINT) Works

Even before the ground fighting began, it was clear that Iraqi military leaders had greatly exaggerated the capabilities of the U.S. SIGINT exploitation systems. Iraqi units passed the vast majority of their signals traffic by landline, using radio as little as of possible. Certainly, the maintenance of radio silence denied much useful information to the Coalition. However, such a policy needed to be handled with knowledge and understanding of the risks it entailed. The Iraqi commanders applied their policy with neither. Their approach fell apart once Iraqi troop units had to move. As they abandoned their landlines and were forced to use radio to communicate, their luck of familiarity with this form of communication immediately became evident. Colonel John Black, Intelligence Operation Officer with the U.S. 3rd Army, commented:

"We were amazed as the extent of their EMCON (electronic emission control). They hardly used their radios. Later we asked Iraqi senior officers taken prisoner why they had not used their radios more .They said that if they passed their talk button, they expected to have enemy artillery shells bursting round their heads within a couple of minutes. They greatly overestimated our capability to intercept their signals, take and plot bearings and bring immediate artillery fire down on them. They must have read our press releases and believed every word!"[1185]

On 29 January an Iraqi brigade delivered a surprise-armored thrust which captured the small town of Khafji just inside Saudi Arabia. Iraqi troops assigned to the follow-up forces moved into concentration points close to the border, but once their purpose was clear these units came under heavy bombardment from the air. That caused considerable disruption of the Iraqi attack plan. The Iraqi troops experienced other difficulties when they used radio to communicate while on the move. Army Colonel Charles Thomas at the Joint Intelligence Center at Riyadh observed:

"The Iraqi had not used their radios for so long, the untrained reservists on the sets did not know how to use them properly. Also, because the radios had not been used, they had not been maintained. So when the troops needed to use their radios, they were incapable of communicating effectively."

"SIGINT indicated that the Iraqis tried to orchestrate a multi-brigade attack against Coalition forces and around Khafji. They tried to co-ordinate an attack by five brigades from three divisions from two different Corps. They tried for two or three days, then gave up. I was waiting for the other shoe to drop, for the other brigades to appear. But they never did. The Iraqis just could command and control all those elements and bring them into action as a unified force. Clearly they had not trained, at brigade level and above, to do that efficiently. It was our first real indication of the Iraqi weakness in this respect."[1186]

Guardrail Operations

As part of the final preparations for Desert Storm, three Military Intelligence (Aerial Exploitation) Battalions had deployed into the theater with their Guardrail and RV-1D Quick Look Mohawk companies. The 1st Military Intelligence Battalion, from Germany, was assigned to support VVIII Corps, which would attack in the west. The 2nd MI Battalion, also from Germany was to support VII Corps in mounting the most powerful thrust in the center of the front. The 15th MI Battalion, from Fort Hood, was to support the Marines and other IIIrd Corps units in the east scheduled to make the slower advance into Kuwait from the south. The 1st and 2nd Battalion operated the Improved Guardrail V with RU-12 aircraft; the 15th operated the older Guardrail V with lower-performance RU-21s.

Guardrail operations began in mid-January and units flew at maximum effort from 23 February, the day before the main Coalition offensive opened the Surge in air activity led to planes flying missions round the clock and placed heavy demands on both men and machines. This was particularly so for the 1st MI Battalion as Captain Lee Ilse, one of the pilots, explained:

"Our Guardrail ground station was located at Rafha, out west close to XVIII Corps headquarters. But because the airfield at Rafha was overcrowded, we weren't allowed to base our aircraft there. We had to use King Fahd airport at Dhahran as our main base. Our standard mission profile was to take off from King Fahd, fly to Rafha about two hours to the west, refuel, then take off and do five hours on track. Then we landed at Rafha to refuel and take a nap. Then we took off again and did another five hours on track. When the second mission of the day was over, being at altitude and with the prevailing westerly wind pushing us, we could go home to king Fahd. I don't think it was ever les than 20 hours from mission brief to mission debrief, and sometimes it was 26 hours."[1187]

Also on 23 February, tactical aircraft and long-range artillery carried out destructive attacks on ten out of the fourteen Iraqi communications centers located in and near Kuwait. The remaining four, all in the northern sectors with Republican Guard, were left intact to see if they would yield useful intelligence.[1188]

On morning of 24 February, as Coalition armored columns streamed through the breech in the Iraqi defensive line in Kuwait, U.S. amphibious forces staged a major demonstration of the coast south of Kuwait City. During the early morning darkness, the battleship *Missouri* mounted a destructive bombardment of coastal targets with her mighty 16-in guns. Soon after dawn, the helicopter carrier *Okinawa* conspicuously launched a number of CH-53E troop carriers, which clattered towards the coast as if running in to land troops. Then, about three miles short of their apparent objective, they turned around and returned to their carrier.[1189]

Early the next day there was a similar feint in the area, to reinforce the threat. At mid-day there were feint operations near Al-Far and Faylaka, and on the night of 26 February Navy A-6s carried out a feint operation near Bubiyan.[1190]

The high drama of the land battle was lost on the Army Guardrail and Mohawk crew flying their monotonous orbit patterns high over the desert. Their planes were the smallest and the slowest of those operating in the" dress circle" over Saudi Arabia and those aboard felt distinctly vulnerable. Lee Ilse recalled:

"When on station we flew in pairs at 31,000 feet, at our loitering speed of 120 knots. From up there we didn't see much of the ground war. The most memorable thing I saw a night firing of multiple launch rocket system. The ripple firing of the roman candles, and the carpet of explosions as the rockets detonated round the target, was very impressive in the dark desert night. But we paid much more attention on what was happening in the air than on the ground. There were a lot of other aircraft operating in the same area as we were, JSTARS, AWACS, Compass Call, ABCCC and strike planes going back and forth. We were under procedural control, flying at different altitudes with a certain amount of separation. But when you are in a little Beech King Air and you see an AWACS coming towards you only a thousand feet above, that really gets your attention!"[1191]

The Guardrail units maintained a round-the-clock watch on Iraqi signals activity, but for the two more westerly of the units there was relatively little signals activity to tap into. Only when the land battle started did their missions yield results, and even then the haul was far less than had been hoped. Major Gary Long, commander of the Guardrail Company, 1st MI Battalion, explained:

"There was never the density of communications that we had expected. But some key things did had happen. But some key things did happen. We picked up indications that some Iraqi units were thinking of doing something different instead of retreating. They had stopped and were talking in plain language. We got low-level chatter between individual tanks and units. Things like 'I think the Americans are over there,' 'We need help over here' or 'I'm short of gas.'

"Because the Army was short of Arab linguists, we had Kuwaiti nationals working in the Guardrail ground stations. My senior Kuwaiti had been finance minister in the government. Others had been students at Harvard and Princeton, summoned back by the Emir to play their part in the war. These were educated and sophisticated guys, and they were very highly motivated."[1192]

The Exiled Kuwaiti proved particularly valuable for their ability to recognize and understand the various regional dialects and slang terms used by the Iraqi troops.

Ironically it was the 15th Military Intelligence Battalion, positioned furthest east and operating the older Guardrail V system that had the most opportunities and achieved the best results with the system. Lee Ilse continued:

"The 15th MI Battalion, with its 12 year old Guardrail Vs, supported the Marines in the east. Although it was an old rinky-dink system, they picked up a fair number of signals particularly when the Iraqis started to retreat out of Kuwait City. They flew tracks up along the Kuwaiti border and then out over the Gulf. So they were uniquely positioned and had a good geometry for their DF [direction finding] operations to cover the evacuation and also look up towards Basra."[1193]

For the reasons already given, overall the Guardrail aircraft picked up for fewer enemy signals than had been hoped. Yet they did a lot better than the ground collection sites, as John Black explained:

"Guardrail provided much useful information for constructing the Iraqi Army order of battle. The ground based SIGINT units were far less effective. As part of the deception plan, the divisions that were to take part in the main armored thrusts kept back from the border, and unfortunately that included all their intelligence collection assets. I think that was a mistake–and it may hurt our ground SIGINT capability in the future. After the war commanders said 'my organic SIGINT didn't tell me anything. Well, that's true. But it didn't tell them anything because they didn't let them [the collection units] go close to the border. In my opinion we should have put the collection sites right along the berm, they would not have made a significant signature. We could at least have been trying to collect, prior to the ground war."[1194]

When the land battle began the ground collection units continued to achieve little, but for a quite different reason. Susan Browning, now a Colonel, was executive officer of the 533rd MI battalion. The unit was part of the 3rd Armored Division. One of the spearhead formations taking part in General Schwarzkopf's famous "Hail Mary" thrust to outflank the entire Iraqi border defense system. The battalion and its intercept and jamming equipment were carried in M-113 armored personnel carriers and wheeled trucks. The MI battalion had no chance to perform its normal tasks, as Susan Browning explained:

"Once the advance began, we were moving forward so fast. For security, the MI battalion had to stay tucked in close behind the leading tank brigade in the division. We had to keep up with the lead brigades because as we advanced, we saw Iraqi troops we had bypassed on either side. When our leading tank battalions stopped to engage in firefights with Iraqi tanks, we were about 3 km behind them. We could see the flashes from their guns as they fired.

"The MI battalion commander took the decision not to deploy the Trailblazer antennas when we stopped. It was just too dangerous. To get an acceptable bearing on an enemy emitter, the antenna baseline needs to be about as wide as the target is deep. Typically ‹that would mean setting out antenna baseline 15 to 20 km wide. That was out of the question when we simply had no idea what was on our left flank, what was on our right flank. So, no, we were not able to provide useful intelligence for the division during its rapid advance.

"But as long as we kept moving, we knew we had to be doing something right. And when we moved through what had been Iraqi positions we could see the death and destruction we were inflicting on the enemy. So long as we maintained our momentum we knew the war was not going to last long.[1195]

Had Iraqi troops brought a Coalition armored thrust to a halt at any point, the intelligence troops would have come into their own. Their task would then have been to establish the composition and location of the enemy forces. During the advance the division's MI battalion was rather like an insurance policy–something that is reassuring to have, though if things went well there would be no need to make a claim.

No claim was necessary. Once the Coalition Blitzkrieg got into its stride, no force at the Iraqi command could impose more than a temporary pause in its progress. Charles Thomas commented:

"By and large our ground intercept systems were ineffective once the ground war got going. These systems had been designed for operations in Central Europe, where the guys could stop, set up their antennas and listen. But once the land battle started in the Gulf, the U.S. forces never stopped. They just kept going. Consequently, there was no time for the ground stations to stop, set up their antennas and perform routine intercept operations some commanders complained that they were not getting SIGINT information. I told them 'the reason you're not getting SIGINT is that you are moving so fast. Count yourself lucky!'"[1196]

The Army Helicopters

The U.S. Army's plan of attack called for large numbers of combat helicopters to operate over the battle zone. Often these would fly through areas where only a cursory search for Iraqi anti-aircraft systems had been possible. For the first time in a major engagement, helicopters would go into action relying on suites of EW equipment to protect them from enemy short-range IR and Radar guided missiles and radar controlled AAA.

As mentioned earlier, APR-39A(V)1 warning receiver carried by Army helicopters was a relatively cheap item of equipment (it cost and weighed about one-tenth as much as an equivalent warning receiver fitted in a fighter plane). Yet, the receiver proved invaluable for warning helicopter crews of their proximity to the enemy, enabling them to take evasive action or deliver attacks. During after-action conversation with Army helicopter crews, Colonel Tom Reinkober collected these comments on the value of the EW equipment:[1197]

- ZSU-23/4 radar controlled track mounted AAA system engaging AH-64s, 27 February, midmorning, vicinity AO. All aircraft in the fight received" ZSU, ZSU, Tracking" on the warning receiver. Position of ZSU confirmed through AH-64 sight system, 3,500 m off the nose. Engaged with Hellfire missiles, ZSU destroyed.
- ZSU engaged AH-64 as part of a flight of three AH-64s on a screen mission. ZSU radar was on and picked up by APR-39A(V) at least 10km away. AH-64 less than 50 feet AGL [above ground level]. APR-39A(V)1 gave" Guns Tracking" just as ZSU round on horizon stretch towards AH-64. Evasive action taken. One hour later, OH-58D saw ZSU-23/4 in the same

area. APR-39A(V)1 alerted on ZSU. Evasive taken. OH-58 called in artillery barrage on target area. Several destroyed ZSU's confirmed.

- Missile engagement ‹OH-58D, 30 miles inside Iraq, 24 February. Pilot reported hearing" Radar Track, radar Lock" 2-3 times and then "Missile Launch" 2-3 times. Following descent to 10 feet AGL the warning from the RWR ceased.
- AH-64 Missile/Guns engagement: (Armed Recon–Iraq) 350 feet AGL, APR-39A(V)1 picked up "SA-8 Tracking. SA-8 Searching" at 5:00 [o'clock] position. A/C descended to break lock, then wingman descended to defilade position. Crew also received "Guns, Tracking" at 350 feet AGL in same vicinity. Broke lock when A/C descended to 50-150 feet AGL. Confidence level in APR-39A(V)1 is extremely high. Crew never once felt threatened by Iraqi SAM–and were able to fully concentrate on target engagement.[1198]
- Late night, early AM, APR-39(V)1 had a strobe, locked on. Evasive maneuver taken–no missile alert light; to enemy fire. After unmasking, another strobe (2:00 position) was steady. Remasked in place–unmasked after one minute–strobe was gone.

Inevitably, there was a crop of complaints concerning misleading indications from the warning receivers :

- Patriot Batteries did cause problems. Patriot gave off symbols of "Fixed Wing," "ZSU‹" "SA-6," Pilots could visually see the Patriot batteries, so they knew the APR-39A(V)1 was describing a Patriot.
- The APR-39A(V)1 would be ideal RWR, if a ZSU was ZSU and a Patriot really was a Patriot.

- APR-39A(V)1 works as advertised, but Patriots drove us crazy with false alarms.

U.S. Army helicopter combat losses during Desert Storm amounted to just one AH-64 Apache, two UH-60 Black Hawks and one UH-1. The AH-64 fell to an IR missile; the other three helicopters succumbed to small arms fire. Seven AH-64s were damaged. In five cases this cases this was due to small arms fire, in one case to a missile fragment, and in the remaining case the hit was either a small arms or AAA round.[1199] Given the huge number of sorties flown in the battle area by Army helicopters and their aggressive handling, their minimal loss rate is little short of astounding.

The AH-64 lost fell to an SA-14 Gremlin man-portable IR weapon. During a daylight action on 25 February, a force of Apaches had been engaging Iraqi vehicles from the hover about 25 feet above the desert. Subsequent examination of gun camera tapes showed an Iraqi soldier pop up from foxhole about 1,500 yards in front of the helicopters. There was a flash and a back blast, followed 3-4 seconds later by a radio call from the Apache: "We're hit, we're hit!" The missile struck the AH-64 in the engine compartment, and the warhead detonation and subsequent crash wrecked the helicopter crew was not aware they were under attack until the missile impacted. That particular AH-64 was one of the few sent into action without an ALQ-144 (V) infrared jammer fitted in place of the earlier ALQ-144 (V).[1200] The two crewmen suffered minor injuries and were rescued soon afterwards. Other AH-64s then strafed the wrecked helicopter to prevent the Iraqis gaining access to the classified items of equipment it carried.

U.S. Army helicopter crews reported having been engaged by Iraqi short-range missiles on only eight occasions, with total of seventeen missiles, during the entire war. of the missiles fired, nine were believed to have been IR guided while the remaining eight were radar-guided weapons.[1201]

The ubiquitous man-portable IR homing missile–SA-7 Grail, SA-14 Gremlin and SA-16 Gimlet–were marginally the more effective. Only one attack on an Army helicopter was successful. During the other eight attacks the missiles missed their target, probably due to a combination of IR jamming from the ALQ-144 (V) or ALQ-144A (V), the use of IR decoys and the presence of effective IR signature suppression methods.

The much-feared radar-guided missiles, and the equally formidable ZSU-23/4 radar-laid AAA system, failed to down a single Army helicopter. The combination of map of the earth flying tactics, timely warning from APR-39(V)1 warning receivers and the development of Chaff, coupled with jamming from ALQ-136 or ALQ-162 equipment defeated that threat on every occasion.

At first glance the crews' reports of only seventeen short-range missiles launched in their direction, during the entire land battle, suggests that the threat must have been negligible. That was certainly not the case. However, before they could be launched, the guided missiles needed to achieve an IR or radar lock-on. Undoubtedly there were numerous occasions when the missile crews tried to achieve lock-on, but the helicopters' active countermeasures systems prevented it. As a result, the missiles failed to leave their launchers. Also there were occasions when the radar-warning receiver provided timely indication of a threat, allowing the helicopter pilot to reach a place of safety behind a fold in the ground or some other obstacle.[1202]

A further important factor in keeping helicopters out of harm's way was the accurate picture assembled on the Iraqi air defense units' electronic order of battle (EOB). Much of the information came from the ever-present RV-1D Mohawk ELINT planes, relentlessly flying their orbit patterns. Forewarned of the more dangerous defensive concentrations, the helicopters could be routed safely round them.

All in all, Army Aviation has reason to be extremely pleased with the performance of its electronic warfare systems during Desert Storm. The ghost of the disastrous Lam Son 719 operation over Laos, two decades earlier, had been exorcised. Having spurred the Army into devoting resources to improve the survivability of its helicopters, those losses had not been in vain.

Communications' Jamming

During the land battle U.S. Army and Marine units deployed several TLQ-17 communications jamming equipment, carried in light trucks and in a couple of dozen Eh-60 Quick Fix helicopters. When Iraqi units started using their radios, on the U.S. side there was the now familiar conflict between those who wished to jam and those who wished to listen, but now, with a proper control mechanism in place there was room for both. Jamming was permitted against high-level digitally encrypted signal, which could not be read easily or quickly. These were more vulnerable to jamming than voice communications and sometimes-Iraqi commander resorted to transmitting important messages "in clear." Those messages were left unjammed and sometimes provided a rich harvest for the U.S. eavesdroppers.[1203]

On 25 February, for the first time in several months, the commander of the Republican Guard Tawalkana Division came on the air. His FM radiobroadcast to his subordinates ordered them to begin forming a defensive line against the allied onslaught. As the division struggled to move into position early on 26th, a Republican Guard commander warned the Tawalkana that they were violating communication security. To that the irate Tawalkana commander angrily replied that the American attack was well under way and he had little security left to protect.[1204]

The National Security Agency followed the squabble from afar and relayed the messages to Riyadh. Other gems followed and Charles Thomas described how the same source provided the first hard evidence of an intended Iraqi withdrawal from Kuwait:

"Once the Coalition forces were committed, we needed to know whether the Iraqis would stand the fight. The initial elements of U.S. forces were closing on locations where Republican Guard units were known to be in position. Then SIGINT gave the first clear indication that the Republican Guard did not intend to stay and fight. There were indicators that they were moving forward their big Steyr artillery tractors, used to tow their high value artillery. We knew that only the Republican Guard units were issued with that artillery. Soon afterwards, we got indications that they were moving forward tank transporters too. It seemed clear to us the Nebukedneza division and the rest of the Tawalkana division were polling back."[1205]

Those reports coupled with the analysis of radar pictures from Boeing E-8 JSTARS aircraft, confirmed the pattern of the Iraqi withdrawal and later rout

Conclusion

Electronic warfare made two major contributions to the success of the land battle. The first was that it allowed U.S. Army helicopters to operate over the combat zone with minimal losses; only one machine was lost to a missile and three fell to small arms fire. The second major success was the enforcement of the culture of "EMCON suicide" on Iraqi military commanders. That was neither intended nor expected, but was nonetheless welcome. Charles Thomas commented:

"In my view a most significant electronic warfare success was on the first day of the land battle, when we breached the Iraqi lines without suffering casualties. We had eight or nine very narrow breach lines. A division with 5,000 vehicles flowing through three breach lanes took the better part of eighteen hours to push through. Although many of the vehicles were armored, most were not. For every ten Abrams tanks there needed to be a 5,000-gallon tanker close by, to keep them supplied with fuel. There were never better targets for the Iraqi artillery, our casualties could have been horrendous."

"It was obvious where the breaches were, there were huge dust clouds. The Iraqis had both rocket and tube artillery within range. Although there were futile attempts to do so, their forward observers failed to direct accurate artillery fire on those breach lanes.

"By ordering their troops to avoid using the Iraqi leadership committed EMCON suicide. Their soldiers were so afraid of our perceived capability to locate transmitters accurately, and deliver counterstrikes immediately they came up on the nets, that they stayed off the air. I hold that up as a major success for our electronic warfare troops."[1206]

In the related fields of deception and psychological operations, U.S. forces scored other major successes. The feint operations mounted by the Navy and Marines off the coast of Kuwait achieved their aim of padlocking the Iraqi army units in place. Up to the time that Saddam Hussein ordered all of his forces to pull out of Kuwait, there had been no attempt to move units away from the coastal areas threatened by the feints.

The attack on Iraqi troop morale produced spectacular results. About 400,000 Iraqi troops were deployed in Kuwait and adjacent areas in Iraq. Estimates vary the number killed, the most plausible being somewhere between 10,000 and 25,000,[1207] that is, between 2.5 and 6.25 percent of the total.

Yet, carefully exploited, that relatively small percentage loss would lead to a collapse of fighting spirit in many army units. Rarely in modern times has a well-equipped army broken and fled after suffering so low a casualty rate. The collapse of resistance is all the more remarkable if one considers the Iraqi troops' confident mood just a few weeks earlier.

The air attacks did not deal out death and destruction uniformly among the Iraqi Army units. A few ill-fated divisions suffered far more heavily than the average, while others suffered a great deal less. Thanks to the Coalition propaganda campaign and the lack of alternative sources of information, all knew the worst effects of the aerial pounding. Significantly, when the collapse came, it affected the entire force and not just those units hardest hit.

Chapter 34

Aftermath

In September 1991, President George Bush delivered a historic address to mark a major shift in the U.S. military posture. Following the end of "The Cold War," he ordered that U.S. strategic bomber; tanker and ICBM units were to cease their alert status. Strategic Air Command (SAC) was to disband as a separate force and its much-reduced fleet of aircraft was to merge with those of Tactical Air Command (TAC) to form the new Air Combat Command (ACC). The newly formed U.S. Strategic Command would have no assets of its own, but it would control all nuclear forces should the nation came under serious threat.

The spirit of co-operation with the countries in the one-time Communist bloc quickly took hold, with some of them applying to join NATO. That led to a further change in the balance of power in Europe. The stage was set for the military equivalent of a harsh stock market "correction". With the military budget as a whole slashed by nearly 60 percent, and the procurement budget by over 70 percent, all the U.S. armed services took savage cuts.

By December 1998 the Army's combat power had been reduced by half, losing eight standing army divisions and 293,000 reserve troops. The Navy's strength in fighting ships was reduced from 605 to 353, with four aircraft carriers and thirteen ballistic missile submarines retired. The number of fighter wings in the Air Force fell from 34 to 21, with the loss of some 2,000 combat planes including 232 strategic bombers.[1208] By June 2000, the U.S. long-range bomber force comprises 95 B-1B Lancers, 21 B-2 Spirits and 71 B-52Hs, a total of 187 planes.

Those reductions in expenditure forced the entire U.S. armament industry into a brutal process of rationalization, mergers and downsizing. Nowhere would those changes cause deeper upsets than in the electronic warfare community. In 1987, twenty-four U.S. companies were named as producers of electronic warfare systems in service. Within less than a decade, only about one-third of those companies still operated under the same name. Most of the remainder was absorbed into larger companies, with sizeable layoffs as a result. The rest of the companies ceased their involvement with electronic warfare.

After Desert Storm

Following the end of Desert Storm, the plan to disband the dedicated Wild Weasel units went ahead despite the efforts of many people to get the decision reversed. Major General John Corder outlined the case he put before the Chief of Staff of the Air Force and Secretary of the Air Force Donald B. Rice.

"I told them, if you gather up all the air-to-air combat capability in the U.S. it amounts to something like eighty squadrons of planes–F-14s, F-15s, F-16s, F-18s. All I am asking for is two squadrons of Wild Weasels. Now let us look at the balance of the threat. You ask what the balance is between radar-guided SAMs and enemy fighters, and most anybody will tell you it is 70 to 30 in favor of the radar-guided SAMs. Now, surely our country can get by on 78 squadrons of air-to-air combat capability, in order to have two squadrons to work 70 percent of the problem?"[1209]

As he left the meeting John Corder thought his eloquence might carry the day, but it did not. The last F-4G Wild Weasel was phased out of service in 1995.[1210]

The airplane chosen to replace the F-4G in the defense suppression role was the F-16CJ Fighting Falcon carrying the HARM Targeting System in a pod. The consensus was that the single-place general-purpose fighter, flying this as one of its several roles, would be far less effective than a two-seat plane dedicated to the task. The crucial question however, was whether the new machine would prove *effective enough* in combat?

The EF-111A did not long outlive the F-4G. Ken Krech described how the Raven finally met its demise.

"In 1995 the Navy had a total of about 130 Prowlers. Under the planned fleet run-down, the EA-6B force was to stabilize at eighty flyable planes. So twenty-five Prowlers were scheduled to go the bone yard [the aircraft storage facility at Davis Monthan AFB, Arizona]. Then somebody in the Department of Defense said 'The Air Force has said it needs a minimum of twenty-four EF-111 Ravens. The Navy is about to send twenty-five EA-6Bsto the bone yard. Instead of sending twenty-five EA-6Bs to the bone yard and keeping twenty-four EF-111s, for the American taxpayer it makes more sense to replace the Raven force with Prowlers.' It purely a monetary decision, nothing to do with which airplane was the more capable or anything like that."[1211]

So it was that the Navy picked up the mission to provide jamming support for Air Force strike forces.

In the Air Force the sole electronic warfare support plane remaining in the inventory was the EC-130H Compass Call communications jamming aircraft. And, as mentioned earlier, the fleet of those was reduced from thirteen to ten.[1212]

From his position as Chief of the Electronic Warfare Division in the Pentagon, Air Force Colonel Andy Vittoria summed up a major problem he now faced:

"After Desert Storm people were saying, "Why do you guys want money for research and new Electronic Warfare equipment? Everything worked great and you did great We had difficulty getting them to realize that we learned how to counter those systems during the Vietnam War and we had built our equipment over several years. And we now needed new systems to counter the new defensive weaponry coming in."[1213]

The abolition of so many electronic posts seriously affected the level, expertise and understanding of this subject in the Air Force. The pool of operational experience, painstakingly built up and nurtured during the Cold War, was rapidly ebbing away. In one of these moves, the operational Electronic Warfare Branch in the Air Staff was abolished. From then on officers who lacked specialized training in the electronic warfare and had little understanding of the issues involved made many day-to-day decisions.[1214]

The B-2: Very Low Observable Strategic Bomber:

The long-running and extensive problems with the B-1B Lancer, its ALQ-161A countermeasures system, and the ALQ-165 ASPJ system did enormous damage to the Armed Forces' credibility in Congress. They left a reservoir of resentment at the falsehoods that had been issued and accepted. From now on there would be a festering skepticism regarding future military procurement programs.

Given that climate of opinion, the B-2 program was almost guaranteed a bumpy ride from the politicians. Under the original plan 132 of these very low observable strategic bombers would be procured. Production of the plane was to begin in 1988-1989 and the type would attain its full operational capability in 1994-1995. Both those numbers and those dates were to prove wildly optimistic.

Had Mikhail Gorbachev been able to hold together the tottering Soviet empire for a few months longer, the B-2s service career might have been quite different. But in 1989, with the Soviet threat receding month by month, Congress was in no mood to fund a new and very expensive strategic bomber fleet for the Air Force. The Northrop B-2 was one of several major development programs in the political firing line.

Taking its lead from the influential House Armed Services Committee, in 1989 Congress refused the request to fund full production of the B-2. Instead, it insisted that the plane should first complete its first stage flight-testing and establish that it met the demanding radar cross-section requirements.[1215]

The decision marked the crossroads for the B-2 program, which afterwards faced progressively greater difficulties. It took until the middle of 1991 to complete the required tests. And, since it took about five years to build a B-2, the plane could not reach operational status before 1996 at the earliest. In the meantime, the rapidly changing world situation forced further cutbacks. In the spring of 1990, a further review of U.S. military aircraft production programs reduced the planned B-2 buy from 132 planes to 75.[1216]

Even that program did not survive long as mentioned earlier; in September 1991 President Bush had ordered U.S. strategic bomber, tanker and ICBM units to cease their alert status. In the following month, the Warsaw Pact was dissolved. Congress responded by voting to limit production of the B-2 to just sixteen planes–the six test aircraft and five production machines under construction, plus a further five B-2s for which long-lead items had been purchased. Early the following year President Bush was able to squeeze out of the Congress the money to buy another five B-2s. That brought the total production run of the bomber to twenty-one planes, including the test aircraft.[1217] There would be no further increase beyond that.

In December 1993, the first production Northrop B-2 Spirit arrived at Whiteman AFB, Missouri, to join the 509th Bomb Wing. In the wake of the Cold War, production was slow. Two years elapsed before the unit possessed its first eight bombers. The early B-2s were Block 10 aircraft, suitable only to provide training for the pilots and maintenance crews. They were not cleared to operate at full flight loads, they carried no terrain-following radar or precision weapon attack capability, and had only a limited defensive system.[1218]

The first Block 20 aircraft, the variant with a limited operational capability, arrived at Whiteman in July 1996. Later new-build planes arrived in this configuration and the Block 10 planes returned to the makers for conversion to that standard. In January 1997 the Block 20 was declared operational for conventional attack missions. In the following May, after nuclear certification tests, the 509th attained initial operating capability.[1219]

The first bomber with the definitive Block 30 configuration reached Whiteman in November 1997. This carried a number of changes including a further reduction in the radar signature and improvements to the attack system. In the year that followed a succession of Block 30 modified planes arrived at Whiteman and by the end of 1998 the unit possessed eight. Once the Block 10 and Block 20 planes had been brought to Block 30 standard, it was planned to do the same with the six development aircraft.[1220]

The APQ-181 navigation and attack radar fitted to the B-2 is a low-probability-of-intercept system developed by Hughes Electronics (now Raytheon Systems). The radar operates in the J band and employs electronically scanned antennas fitted beneath the leading edge of the wing. The radar can operate in the synthetic aperture mode and has a ground moving target indicator feature for the detection of surface vehicles.[1221]

The B-2 carries a defensive management sub-system tailored to the plane's capabilities, details of which are classified. However, it is known that the system derives much of its real-time intelligence from a Lockheed Martin APR-50 warning receiver.[1222]

Towed Decoy ALE-50

The Navy towed decoy system had undergone more than a decade of research and development before the ALE-50 was passed to Raytheon and the company could ready the system into production. As originally conceived, the ALE-50 was to have been carried internally by the A-6 Intruder. The space available in the plane's rear fuselage determined the decoy's size. That gave rise to problems as Fred Paxton, Raytheon's Program Manager for the system, explained:

"The Navy wanted the launcher assembly to be internal in the aft end of the A-6. That limited the length of the decoy. But the length of the decoy was critical, because it determined the level of isolation we could achieve between the receiver and the transmitter antennas. In any system of this kind, you get only as much effective gain as you have isolation. That was the challenge in designing the radio frequency part of the decoy. If there is insufficient gain, the decoy will not give as large a radar return as the airplane.

"The heart of the decoy is the traveling wave tube, on the end of a power cable. There is a radio frequency chain with a receiver antenna, some solid-state amplification and a modulation capability, a traveling-wave-tube and a transmitter antenna. There is hardly any signal processing. The advantage of the basic repeater system used in the ALE-50 is its simplicity. You just bring in the signal, amplify it and chuck it back."[1223]

Yet, with an electronic system, the simple solution was not always so simple. Fred Paxton again:

The disadvantage that goes with simplicity is that you process all the radio frequency signals in the environment. So any emitter on the airplane operating in the band of frequencies covered by the decoy, you are going to repeat. The frequency range of the plane's onboard radar is within the frequency range of the decoy, because many target radars also operate in that range.

"On all the platforms the towed decoys have gone on, we had to work with the airframer and the other system houses to do an electro-magnetic compatibility analysis. In the case of the radars, we found that with the physical distances and sensitivities, there was not much of a problem. Radar is directional and if it looks forwards, the decoy is pretty far down in the radar's back lobes. So unusually, we do not interfere with the radar."[1224]

Following the decision to phase the A-6 out of service, the Navy targeted the ALE-50 for installation on its new F/A-18E/F attack fighter. But the type is some years away from operational service. Meanwhile, the Air Force had begun to take a great deal of interest in using decoys to protect its planes. During the latter half of the 1990s, that service carried out operational evaluations of the ALE-50 aboard the F-16 and the B-1B. the decoy demonstrated its effectiveness against a range of modern threat systems and the Air Force ordered it into full production.[1225]

Among the first units to receive the system were those operating F-16s in Italy. The plane's decoy installation comprised a combined launcher and control unit, which fitted inside a weapons pylon on each side of the plane. It was a neat installation; there was one decoy mounted on each side of each pylon, giving a total of four decoys, yet those pylons could still carry the same about of ordnance or fuel.

The Debut of B-1B

At the end of 1998, there was a resurgence of air strikes on targets in Iraq, in furtherance of the long-running dispute concerning the policing of the no-fly zones in the north and the south of the country. The significant feature of the action was that it saw the combat debut of the B-1B Lancer, some fourteen years after the plane first entered service. Two Lancers from the 20th Bomb Wing, fitted with the latest modifications to their electronic warfare suites and with installations for ALE-50 towed decoys, took part in an attack on the Republican Guard barracks at Al Kut near Baghdad. Navy F-14s, F/A-18s and EA-6Bs supported the heavy bombers.[1226]

The ALE-50 installation in the Lancer consisted of a four-decoy dispenser unit on either side of the rear fuselage, beneath the horizontal stabilizer. The importance of the decoy system for the B-1B, in providing it with a more effective self-protection capability, can scarcely be exaggerated. It meant that for the first time since it entered service the bomber was able to operate over medium-threat areas in the non-nuclear attack role, without undue risk of suffering losses.

The fact that the Lancer could receive protection from the towed decoy system originally intended for the much smaller A-6 Intruder points out the success of the signature-reduction modifications applied to the B-1B. as stated earlier, for such reduction in an aircraft's radar signature, there is a proportionate reduction in the jamming power needed to screen it. On this subject, Stan Alterman commented:

"Stealth features largely in all modern military planes, even those where it was not a primary aspect of the design. So while the B-1B is nowhere near as stealthy as the B-2, it still has a head-on radar cross-section to rival that of the much older F-4 Phantom. Thus, countermeasures systems developing power levels previously thought sufficient only to protect fighter-type planes will suffice to protect the B-1B. That argument also applies to the towed decoy systems."[1227]

The installation of the state-of-art ALR-56M warning receiver and the towed decoy installation has, metaphorically speaking, patched the holes in the protection of the B-1B given by its ALQ-161A countermeasures suite. Thus, after more than a decade in limbo, the long-range bomber has at last assumed its rightful place in the U.S. combat inventory.

Advanced Self Protection Jammer (ASPJ) ALQ-165

In 1993, following the Congressional declaration that the ALQ-165 system was "neither operationally effective nor suitable." No further funding was allocated for production and the majority of the 136 systems delivered to the Navy had gone straight into storage.

Although the U.S. government had lost interest in the ALQ-165, it raised no objection when the companies requested permission to offer the system for export. Korea bought it to equip some of its F-16 Fighting Falcons; Finland and Switzerland purchased it for their F-18 Hornet. Those orders would keep the ALQ-165 production lines going for a bit longer.[1228]

That was not the end of the ALQ-165 story, however, the next conflict to see serious U.S. air involvement was that in Bosnia in 1995. On 2 June a Bosnian Serb SA-6 missile battery shot down Captain Scott O'Grady's F-16. The Pilot ejected and, after six days in the woods evading Serbian troops and civilian, a U.S. Marine rescue team picked him up. Elevated to the status of media hero, O'Grady was immediately whisked back to Washington to receive a formal welcome home from President Clinton.

Prompted by that incident, the Marine Corps air commander in the area made an official request to have ALQ-165 jammers installed in his planes. In the U.S. a few of these systems had their software updated to include additional countermeasures techniques and the latest information on threat systems. The jammers then went through a brief re-evaluation process, flying against a range of threat systems at medium altitude. The ALQ-165 passed the test with flying colors.[1229] Following that result, the stigma of being labeled "neither operationally effective nor suitable" was lifted from the jammer.

The ALQ-165 now became the jammer of choice for F/A-18 C/D and F-14D units operating over Bosnia and for those engaged in later airspace policing duties over Iraq. The system's ignominious sojourn in storage was at an end. Since they re-entered service the 136 production systems have been in almost continual demand, with units leaving the conflict zones passing their jammers to those that replaced them.[1230]

It now seems likely that every existing ALQ-165 will be in almost continual use for much of the decade to come. While the ASPJ story cannot be said to have a happy outcome, the serendipitous chain of events had saved it from an otherwise inglorious ending. Hopefully the lessons learned from the ASPJ program will save its planned successor, the ALQ-214 Integrated Defensive Electronic Countermeasures system, from a similar grueling struggle for survival.

Radar Homing Anti-Ship Missiles Nulka

The latest addition to Navy countermeasures to protect warships from radar homing anti-ship missiles is Nulka. This decoy round is about 6-in in diameter, 7 feet long and weighs about 100 pounds at launch. It employs a hovering rocket system developed in Australia. Frank Klemm, from the Naval Research Laboratory, described how it works:

"Nulka is an active decoy seduction system. It has some distraction capability, but because of its short endurance it is not very effective in this mode. A solid fuel rocket powers the decoy. For control there are three metal tabs at 120-degree intervals around the periphery at the base that can be extended into the efflux of the rocket. When a tab enters the efflux it spoils the thrust on that side, allowing the decoy's height and direction of flight to be controlled. Pull all the tab out, there is an excess of thrust over weight and Nulka goes up. Push all the tabs in, there is less thrust than weight, and Nulka goes down. Push in one tab, and Nulka tilts over and heads in that direction."

A drawback of Chaff, "Rubber Duck" and most other naval decoy systems is that the wind carries them away from the warship in a predictable and often undesirable way. Nulka is different; it can be programmed to head in any direction. Usually that ability will be used to remove the effect of the wind component. Frank Klemm continued:

The best description of Nulka is that it is a 'solid fuel rocket propelled helicopter.' And that is how it behaves. The autopilot can be programmed to fly it anywhere we want relative to the ship, within certain limits."[1231]

Frank Klemm went on describing how the system would be employed in an operational scenario:

"The SLQ-32 [radar warning receiver system] passes the Nulka fire control processor the information that there is a threat, gives its type, and provides a line of bearing on it. The fire control processor then works out the best trajectory for the Nulka to defeat that threat, and feeds this into the decoy's autopilot before launch. The system takes into account the movement of the ship and the wind speed and direction."[1232]

Nulka is an end-game system. With its short flight endurance, it needs to be launched when the missile is nearing the warship. After launch the decoy climbs to a few hundred feet to a pre-set altitude, then it radiates as it moves away from the ship. Nulka is gyro-stabilized, enabling its autopilot to align the directional antenna on the incoming missile. Frank Klemm again:

"For the seduction mode the decoy needs to start from a position adjacent to the ship, then it moves away at a predetermined speed. The separation speed and angle are optimized to minimize decoy discrimination based on its flight path."[1233]

Navy warships being modified for Nulka carry two additional launching tubes mounted near the Super RBOC launchers.

Guardrail Common Sensor

In the mid-1990s the Army field a further major variant of Guardrail, Guardrail Common Sensor. The advances in microelectronics during the previous decade had made it possible to build far more capable receivers, for a given size and weight. That allowed the new system to include the capabilities of the Quick Look ELINT system previously carried in RVID Mohawk aircraft. Also, Guardrail Common Sensor used the CHAALS (Communications High Accuracy Airborne Location System) to exploit time-difference-of-arrival and differential Doppler techniques, to produce highly accurate bearings on signal sources.

The Beechcraft RC-12K aircraft carrying the new system had more powerful engines than its predecessor, enabling it to cruise at altitudes up to 35,000 feet. To make full use of these new capabilities, the Guardrail Common Sensor aircraft flew in three-plane teams rather than in two-plane units as before. With the appearance of Guardrail Common Sensor, the RVID Mohawk has passed out of service.[1234]

Major Gary Long served at the Guardrail program office at Fort Monmouth, New Jersey, during the early part of the decade, overseeing development of the new system. A series of briefing charts in his office illustrated the spectacular improvements Guardrail has made during its long evolution:

"The first graphic showed a map of Washington, DC. With early Guardrail, we could determine the location of an enemy transmitter to within an area about the size of that city. With the improved Guardrail V, we could narrow the location to an area about the size of the White House grounds. With Guardrail Common Sensor we can say the source of the signals is somewhere in an area about the size of the East Wing of the White House."[1235]

Colonel "Butch" Erickson, serving at the Army's Intelligence and Security Command School at Fort Huachuca, Arizona, made much the same point in a different way:

> "The Guardrail systems I through V had a DF capability, but there was no great precision. With Guardrail V you could say that a transmitter lay somewhere inside a 1000 meter grid square. If you put an A-10 or an F-16 over that grid square and the pilot knew what the target was, he should be able to find it. The Air Force has eyes on its bullets–they are called fighter pilots!

"That degree of accuracy was not good enough to direct an artillery engagement, unless one was willing to waste a lot of ammunition. But whereas with Guardrail V we were playing inside a 1000-meter grid square, with CHAALS we are in the precision location business. Guardrail Common Sensor can determine the position of a transmitter to within a 100-meter grid square. If a target emits communications signals or radar signals, we will find it.

"Once the target is found we can engage with the MLRS (Multiple Launch Rocket System) out to 32 km, or ATACMS (Army Tactical Missile System) out to a maximum range of about 85 km. In either case, there would be a very high chance of scoring a hit with the first missile launched.

"Using Guardrail Common Sensor in conjunction with MLRS or ATACMS, if an enemy air defense radar or missile battery comes on the air and is within range, we can engage it. We can achieve a greater certainty of destruction than a Wild Weasel type aircraft launching an anti-radiation missile. And we can do it without putting a pilot's life at risk."[1236]

Finally, the U.S. Army has a signals location system to measure up to the Iraqis' assessment of its abilities prior to the Gulf War!

Airborne Reconnaissance

By the early 1990s the Army's Crazy Horse RC-12G aircraft, used in low-intensity operations in Central and South America, needed replacement. They were replaced for Airborne Reconnaissance Low (ARL) altitude mission, by the four-turboprop RC-7. This plane uses the same airframe as the Bombardier Dash 7 airliner, with a large fuselage designed to house fifty passengers. In its intelligence-collection role the RC-7 carries a range of sensors tailored to the particular operation it is engaged in. the suite might include optical cameras, an infrared line scan equipment, a moving-target indicator radar, a SIGINT collection system, an electro-optical video system, or a mixture of any of these. And instead of the two operators carried in the Crazy Horse RC-12 the ARL aircraft carries up to four.[1237]

New Developments In Electronic Warfare Systems

Throughout the 1990s the inexorable march of technology produced a raft of new possibilities for electronic warfare systems. These innovations will be addressed under the headings of power sources, digital signal processors, and digital radio-frequency memories.

The power source in radar or a jamming system converts high voltage electrically into a high-powered output at the required radio frequency. In other words, it is the heart of the system. If the heart fails, the system dies. Before we look at some modern systems, let us consider some earlier power production devices

In the mid-1960s microwave countermeasures systems employed magnetron, backward-wave oscillators (carcinotrons) or traveling wave tubes (TWTs). These power sources gave efficiency levels of around 10 percent. That is to say, of the power fed into the device, 90 percent remained behind in the form of heat. It required a heavy duty cooling system to remove that heat and dissipate it. A failure of the cooling system could cause the transmitter to overheat and burn out, so there had to be safety cutouts to prevent this resultant thermal stresses were a major cause of failure of vacuum tubes and other components.[1238]

At the end of the 1970s the new-generation TWTs gave higher gain, greater bandwidth, greater power output and much higher efficiency levels than previous systems. That process has continued. Paul Westcott, at the Air Force Research Laboratory at Wright Patterson AFB, described some of the more recent systems:

"Since the mid-1990s a family of mini-TWTs has appeared. These new systems are much smaller than their predecessors. Instead of a package the size of a small suitcase or a shoebox, a microwave power module would fit into a lady's small evening handbag. Current devices provide in excess of an octave of bandwidth, have output powers in excess of 150 watts, and have efficiencies in excess of 35 percent."[1239]

This rise in efficiency from 10 percent to 35 percent might not seem a lot, but it significantly reduced the problem of retained heat. That in turn led to a significant increase in TWT reliability. Paul Westcott continued:

> "With the small air-cooled microwave power modules, we can pack several of them side-by-side. We configure them in a linear antenna array and, we can steer the beam in azimuth to direct the power where we want it to go. For most applications azimuth beam steering is enough, most modern jamming systems are configured that way. But if necessary we could mount the microwave power modules in a planner array, and steer the beam in both azimuth and elevation. We can even divide the power so that the jammer radiates multiple beams simultaneously. It is merely a matter of having the right control circuitry."[1240]

Modern countermeasures systems employ digital computer control and power management systems. The only interface for the pilot with the jammer is a simple control unit with switch marked Off, Standby, Receive and Transmit. Once the switch selection is made, the system functions automatically. When a plane is under threat from modern weaponry, the workload on the pilot is far too great for it to be otherwise.

Next, let us turn to digital signal processors. Radar warning receivers, to provide both threat warning and power management, have made startling progress over recent decades. A continual succession of incremental improvements has produced a massive

Finally, let us turn to the digital radio-frequency memory (DRFM), a vital part in the newest deception countermeasures systems. The DRFM replaced the older Random Range Program (Ranrap). The DRFM memorizes the incoming signals and recalls them as required. Paul Westcott described some of the advantages this brings:

"With the DRFM we can do transponder jamming and not just signal repeating. The DRFM memorizes the incoming signal and we can put out that exact signal, as many times we want, we can produce a picket fence of these targets. We can put in any amount of delay we want or no delay at all. We can arrange for our signal to arrive in advance of the returning radar pulse, even id the pulse repetition frequency [PRF] is jittered or staggered. Modern signal processors have enough power to determine the rate of PRF jitter or stagger."[1242]

Technology in Warfare: The Electronic Dimension, The Role of Electronic Warfare since its Inception into a Central Aspect of the Gulf War in 1991

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Volume III

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Chapter 35

Reflections Of The Gulf War On The Conflict In Kosovo

By the late 1990s, the break-up of the former state of Yugoslavia was almost complete. Four out of the original six states–Croatia, Slovenia, Bosnia and Macedonia–had split away and formed their own governments. Two states–Serbia and Montenegro–remained together and constituted the Federal Republic of Yugoslavia (FRY). Yet the inter-racial sectarian enmities built up over several hundreds of years continued to plague the Balkan area.[1243]

In the westerly Serbian province of Kosovo, the Belgrade government used all means used all means at its disposal to maintain Serbian dominance over the ethnic Albanians that comprised nine-tenths of the population. That heavy-handed oppression led to calls for independence there, too. Following a series of provocative attacks by Kosovar guerilla fighters, FRY military and special police units moved into the province to suppress the rebellion. Police supported by army tanks and artillery launched several one–sided actions against the guerillas. Albanian civilians caught up in the fighting, or suspected of sympathizing with the rebels, received harsh treatment.[1244]

The crisis and killings dragged on into the early part of 1999, while NATO governments became increasingly vocal in their condemnation of the Serbian atrocities. Protracted negotiations failed to secure the withdrawal of Serbian military and paramilitary forces from Kosovo, so NATO threatened to mount an aerial offensive against targets in the FRY. The Serbian President, Slobodan Milosevic, refused to relent. When the talks broke down, NATO air force units were ordered into action.[1245]

The conflict that followed, and its outcome, has been the subject of heated debate. It is not intended to re-run the arguments on these pages. Rather, as has been the case throughout this study, we shall look at those aspects of the action that are relevant to the subject of electronic warfare.

The FRY Air Defense System

For the most part, the FRY air defense system and weaponry had been manufactured in the Soviet Union during the Cold War period. The mix of radar guided surface-to-air missiles comprised "the usual suspects" long known to NATO: the SA-2 Guideline, the SA-3 Goa, the SA-6 Gainful and the SA-8 Gecko. In some cases, these had undergone local modifications to increase their effectiveness. There were also large numbers of short-range IR missiles, the man-portable SA-7 Grail, the SA-14 and SA-16 Gremlin and SA-16 Gimlet, and the vehicle-borne SA-9 Gaskin. The air defense fighter force comprised fourteen MiG-29 Fulcrums and about sixty obsolescent MiG-21 Fishbeds. The Federation possessed the usual range of Soviet AAA weapons and their associated gun control radars, as well as some locally manufactured 20 mm and 30 mm weapons.[1246] Most of the radars used in the FRY had come from the Soviet Union, though there were also a few TPS-63 and TPS-70 surveillance sets purchased from the US.[1247]

A part from the locally produced weapons and modifications to Soviet-built equipment, US and NATO planes had encountered every one of weapon systems during operations over Iraq. Examples of each system had been examined and tested by intelligence teams. Their capabilities, their limitations and their vulnerabilities were well known. It remained to be seen whether the FRY forces would make better use of their equipment than had the Iraqi had before them.

Operation Allied Force

Operation "Allied Force," the action against the FRY, began on the night of 24/25 March 1999. Spearheading the attack was a salvo of Tomahawk Land Attack missiles launched from US warships and a Royal Navy submarine and targeted at parts of the FRY air defense system.[1248] Planes from thirteen NATO nations then delivered a series of coordinated follow-up attacks.

The purpose of Phase I of the operation was to establish air superiority over Kosovo, create a no-fly zone south of latitude 44 degrees north (which covered a large swath of the FRY but not the capital Belgrade), and degrade the integrated air defense system with the FRY.[1249]

To keep NATO planes out of reach of the dangerous man-portable IR weapons, it was decided that attacks would be delivered from an altitude above 15,000 feet. Aircraft above that altitude would remain vulnerable to radar guided missiles. To contain that danger, the raiding forces would rely heavily on support from teams of defense suppression aircraft.[1250] Each attack force entering enemy territory was to have its own dedicated covering force, usually comprising four air superiority fighters (F-14s, F-15Cs, F-16s, F/A-18 or Mirage 2000s), two EA-6b jamming support planes, at least two F-16CJs or German Air Force Tornados carrying HARM missiles, and EC-130H Compass Call communications jamming aircraft.[1251]

During that first night, Lt. Col. Bill MacLure of the 493rd Fighter Squadron, 48th Tactical Fighter Wing, was flying as Number 3 in an F-15C four ship covering one of the force packages. Each F-15C carried the regular air superiority armament load of four AIM-120C Advanced Medium Range Air to Air Missiles (AMRAAM) active radar guided missiles, two AIM-7M Sparrow radar semi-active missiles, two AIM-9M Sidewinder Infrared missiles, and a 20 mm cannon. MacLure recalled:

> "That first night was perfectly clear, with very little moon. When we were still on the tankers we could see red flashes, as the first cruise missiles hit their targets. So, we could see there was a war going on, about 30 or 40 miles south of the tanker tracks.

"On that first night we thought the biggest threat would be the SAMs. They had a pretty good array of SA-3s and SA-6s up around the Belgrade area, where the targets were. We thought the SAMs would be active. We did not expect MiGs to come up, considering the level of their pilot training, that it was night, and the size of our force package."[1252]

Bill MacLure and those flying with him were mistaken in that assumption, however. Without doubt, FRY officers had studied General Larry Henry's "spoof and punch" mounted against the Baghdad missile defenses several years earlier. Warned that there might be an attempt to repeat those tactics, the SAM batteries were ordered to stay off the air.

Instead, the FRY Air Force scrambled several MiG-29s in the hope of engaging and perhaps shooting down some of the raiders. On this occasion, the E-3 AWACS plane that should have supported MacLure's formation had to abort the mission. If it came to air-to-air combat, the F-15Cs would be on their own. MacLure continued:

"The F-15Cs had to go into the target area first, make sure there were no enemy aircraft about. We would attempt to fly our CAPs [combat air patrols] outside the SAM coverage. At the same time, the F-16CJs would engage any SAM batteries that turned on their radars. Shortly after we pushed in, we heard that a MiG-29 had splashed in the south, an Eagle from our squadron had got the first kill of the war."[1253]

A few minutes later, Maclure's flight leader detected a MiG-29 as it took off from an airfield near Belgrade. He tracked it and then, having completed the necessary identification procedures, engaged it. The spunky MiG pilot evaded an AIM-120, then an AIM-7, but succumbed to a second AIM-120.[1254] Later that night a Dutch-manned F-16 brought down one more MiG-29. The opening gambit by the FRY Air Defense Corps' had been costly failure.[1255]

The Smart Weapons

While that action was in progress over Serbia, several flights of F-15E attack fighters headed for targets in Kosovo. Each Strike Eagle carried an offensive armament of two GBU-10 2,000-pound laser guided bombs and a defensive armament of two AIM-120Cs, two AIM-9Ms and a 20-mm cannon.[1256]

Weapon System Officer Captain Don Jones of the 494th Fighter Squadron, 48th Tactical Fighter Wing, was aboard one of the attack fighters. His flight was part of a package attacking the airfield just outside the capital, Pristina, and other targets in the area. He recalled:

> "There was not a lot to see, it was night and we had our lights off. There was not a lot of light on the ground, though we did see scattered fires where villages were burning. Our targets were a tunnel built into a hillside to house airplanes, and a barracks. We attacked these with our LGBs.
>
> "The mission was a lot easier than we had expected, no missiles came up at us that first night. We had expected a lot more reaction from the defenses. My guess is that perhaps they thought we would send in a whole lot of target drones, we had against Iraq. Maybe they thought we were drones and that was why didn't shoot at us."[1257]

The Compass Call: EC-130H

Supporting the attack packages were EC-130 Compass Call aircraft of the 43rd Electronic Combat Squadron. The converted transport planes flew their designated orbit pattern well clear of the defenses, at altitudes, around 24,000 feet.

One of those airborne on that first night was Captain Kathy Maloney, the only female Compass Call mission crew commander. Like many others that night, she was excited at the prospect of going into action for the first time.

"I had been looking forward to doing the job for real. We arrived on station in time to support the first allied air strike going in. the AWACS was reporting details of unfriendly fighters that had taken off, but I did not feel particularly threatened. There was a big air strike going in, there were a lot of planes between the good guys and the bad guys. Any enemy fighter that got airborne had too much to deal with, to think about attacking our plane."[1258]

Normally the Compass Call operational missions lasted between twelve and fourteen hours. That included the transit to the orbit line and back lasting up to two hours, and an in-flight refueling about half way through the mission. Such missions, flown three days out of every four during the weeks to follow, imposed considerable wear on both the aircraft and their crews.

Major Chris Bakke, another Compass Call mission crew commander with the 43rd, had flown in this type of aircraft eight years earlier during *Desert Storm*. From his viewpoint, what were the main differences between the two conflicts?

"Professionally, the biggest difference between the two campaigns was the density of the signal environment. The Yugoslavs had a more sophisticated network than the Iraqis, and they were very much smarter in the way they used it. They had a more extensive radio network in a smaller geographic area, than the Iraqis. As a result, there were many more signals up and we did a lot more jamming.

"The other big difference with Desert Storm was that the airspace around Yugoslavia was more confined than in the Middle East. The available airspace was a lot smaller, and the strike and support planes were packed in more closely throughout the conflict.

"We jammed their AAA and SAM systems as much as possible, to protect the NATO strikes aircraft. If Yugoslav fighters took off, we also jammed their communications. As a result of the various countermeasures, and the aggressive combat air patrols, the Yugoslav air defenses were no more effective than those over Iraq."[1259]

The B-2 and JDAM in the Theater

The first night of Allied Force saw the conflict debut of two important US systems. The first was Northrop B-2 Spirit. Two of these bombers from the 509th Bomb Wing took from Whiteman AFB, Missouri, to strike at targets in FRY. After delivering their attacks, the B-2s returned nonstop to Whiteman completing missions lasting around 31 hours.[1260]

The second of the new systems making its debut was the 2,000-pound Joint Directed Attack Munitions (JDAM) weapons. Each B-2 carried sixteen of these free-fall weapons. Equipped with GPS-guidance, the near-precision JDAM was able to hit its targets regardless of weather conditions.[1261]

The ALE-50 towed decoy system, which had previously seen combat aboard a few B-1Bs, now also went into action in large numbers aboard the F-16 attack fighter. Major Dennis Millsap was the ALE-50 Program Manager at Wright Patterson AFB, Ohio. That post brought him into close contact with front-line units operating F-16s fitted with decoys. At times he had been made to feel like a salesman trying to push some dubious product on to reluctant customer. Yet as soon as the conflict began, all that changed. Denis Millsap recounted:

"In peace time electronic warfare system start to slip. Fighter pilots think;

'You just give me more bombs and more bullets, and I'll make it happen.'

Then, as soon as they saw one of those smoking telephone poles go by, guys realized that maybe they were not as invincible as they had thought. Immediately the shooting started over Kosovo, people were calling us about the [towed]decoys saying 'Hey! We want more of these things!'

"One pilot said 'The ALE-50 is like the American Express card – we don't leave home without it.' That comment soon got to the ears of people at 4-Star level. And they said 'If the guys won't leave home it, how many do we have? and how many missions can we fly?' That put new emphasis on EW system, now there is a huge push for them. That had not been the case over the previous few years."[1262]

During the conflict there was grave concern that with not many ALE-50 decoys being jettisoned that none fall into unfriendly hands. Denis Millsap continue:

"The decoy was classified secret, we don't want to fall into the wrong hands. So, pilots were told to jettison them in places where they would not fall into enemy hands, for example into the sea.

"Had the bad guys captured a decoy and tried to reverse engineer it, they would still have lacked the important software. The decoy had been designed with a volatile memory, so that if power was disconnected it forgot what it had been programmed to do."[1263]

The Response of FRY

The FRY government's reaction to the NATO air attacks was swift and brutal. In pursuit of a "final solution" to its Kosovo problem, it ordered Army and special police units to expel the entire ethnic Albanian population from the state. Tens of thousands of refugees began pouring across Kosovo's borders with Albania and Macedonia. Many came on foot, carrying the pitifully few belongings they had been allowed to take with them. TV news broadcasts round the world showed heart-rending scenes of people of all ages who had been uprooted, herded out a gunpoint and dumped on barren hillsides without food, water, sanitation or shelter. With the refugees came horrific stories of random killings to force people to leave their homes, which were then looted and in many cases burned. Eventually the number of expellees would top the 800,000 mark. The enforced exodus led to a massive international aid program to move food, medical supplies and tents into the area to keep the refugees alive.

At the same time there was harsh international condemnation of the actions of the Belgrade government. Yet, by themselves, the NATO air attacks could do little to ease the suffering of the refugees or hinder their oppressors. The most they could achieve was a disruption of daily life in the FRY, so that its leaders and their supporters would come to realize there was a heavy economic price to pay for their chosen course of action.

The Role of AWACS: E-3

During Allied Force there were fears that the Yugoslav Air Force might attempt to retaliate with attacks on NATO troop positions in Bosnia or aircraft flying there. To meet that potential threat, throughout the conflict NATO fighters maintained round-the-clock standing patrols over the republic.

On the afternoon of 26 March, three days into Allied Force, a pair of F-15C fighters, Dirk Flight from the 493rd Fighter Squadron 48th Tactical Fighter Wing, arrived over Bosnia on patrol. Just over an hour later, as dusk was falling, Dirk Flight was near the city of Tusla. The F-15Cs were flying at 28,000 feet at Mach 0.85 when the Flight Leader, Captain Jeff Hwang, observed a contact on radar about 40 miles to the east. That put the contact inside Serbia. His wingman, Captain Joey McMurry, notice the contact at about the same time.[1264]

Hwang reported the contact to the supporting E-3 AWACS aircraft, but the later had not seen it. From the start, it was clear that the plane he was watching on radar was not on any sort of pleasure flight. Hwang recalled:

> "The contact was doing over 600 knots at about 6,000 feet, which was much faster than I expect any non-fighter type aircraft to be going. At the time we were close to the Bosnia/Serbia border, it didn't make sense to continue heading east. For one thing, it would have taken us over enemy territory and too far from our supporting assets."[1265]

Hwang now did something any trained fighter pilot would be loath to do. Ordering his wingman to follow, he turned his back on the potentially hostile plane. If there was to be an engagement, Hwang was determined to run it on his terms. To do that, he needed to put more distance between himself and the approaching plane. As the F-15Cs headed west, they accelerated to supersonic speed. At about that time, the AWACS reported that it now had radar contact on the unidentified plane. When he had the spacing he needed, Hwang turned his F-15Cs to face the possible enemy. As they rolled out of their turns the two US pilots regained contact on radar. Jeff Hwang continued:

> "He was heading west, directly toward us. We were running at way above supersonic speed, and the indications [on the F-15C's classified air-to-air identification] were that the contact was a MiG-29 and it was flying supersonic too. We were closing at more than 20 miles per minute. The sun was setting in the west. I had not planned it that way, but the sun was on our backs and I have the MiG pilot would have the sun in his eyes. I think maybe his ground control had told him where we were, or perhaps he was going after one of the tankers."[1266]

Under the strict rules of engagement, pilots had to obtain clearance from the AWACS before engaging a plane they had not identified visually. The F-15C pilots were still awaiting that clearance when events removed the need for it. The contact was closing fast and it would soon reach a position from which it could launch missiles at the F-15Cs. Now Hwang and his wingman were threatened and under their Rules of Engagement they were permitted to strike the first blow:

> "I directed our formation to combat jettison, to punch off the wing tanks and arm up the weapon systems. Our basic tactical employment with radar is that if there is only one hostile group or contact, both pilots should not lock our radars on the same group. I put my radar back into search to look for additional contact, you have to assume there is more than one enemy plane present. I told my wingman he was primary shooter, and cleared him to shoot."[1267]

Hwang watched the AIM-120 streak out in front of his wingman, then the AWACS called to say the radar contact had split: there was not one plane but two. Then Hwang's radar screen also showed the two contacts.

> "I locked up on the leader, then went to narrow scan. That enabled me to engage multiple targets with AIM-120s. I was able to target both contacts, but I could not tell which one my wingman had fired at. At that time both planes were in the mid teens altitude. they turned toward the northeast back towards us."[1268]

Flying just below 30,000 feet, Hwang was 16 miles from his target when he launched his AIM-120. The two second wait for the weapon to fire after he pressed the button felt like an eternity. Once that missile was on its way, Hwang shifted the marker to the second contact on his screen and pressed the firing button a second time. Again, there was the heart-stopping delay before the second missile surged out in front of the fighter.

Although it felt much longer at the time, only about ten seconds separated the two missile launches.

Now there were three AIM-120s heading through the twilight somewhere out in front of the US fighters. But it seemed as if nothing much was happening. As the F-15Cs came within 10 miles of the contacts, Hwang asked his wingman to check his radar-warning receiver for signs that the approaching planes might be trying to target them.

"I called 'Naked!' [not being targeted], my wingman called 'Naked!' also. So we continued with the attack, descending rapidly to try to get a visual on the MiGs. Then against a broken cloud deck, just below the horizon, I picked up black dot ahead but a fair way off my nose, about 8 miles away. It was the MiG, which I assess to be the trailer. Still there had not been any explosions, the missiles launched earlier had not 'timed out.' I was starting to think about engaging with Sidewinders when, just outside my heads-up display, I saw an explosion. It looked just like a torch being swung through the air at a Hawaiian Luau party. That was not the plane I had seen, but another that I assessed was the leader. I returned my attention to the trailer, and a couple of seconds later he exploded into flame in the same way as the first."[1269]

Hwang gave a quick call to the AWACS to report the kills, "Dirk I, Splash two MiG-29s." From the time of the initial radar contact until the second MiG went down was just four minutes, including the initial turn away from the MiG to open the range.

After the shootdowns, the F-15Cs continued heading east to make sure no other planes were following the first pair. The US pilots saw no further contacts, nor did their AWACS controller. Then, the two F-15Cs had to return to the CAP line. They still had weapons left, and their replacements were not due to arrive for another 2 ½ hours. Before the two F-15Cs returned to their base at Aviano in Italy, news of their shootdowns was broadcast on CNN.[1270]

The wreckage of the two MiG-29s fell on open ground a few miles inside Bosnia, close to the border with Serbia. Both pilots had ejected and it is believed they reached the ground safely and escaped into Serbia.[1271]

The Shootdown of the Stealth Fighter F-117A

On the night following Jeff Hwang's shootdowns, 27 March, the NATO air forces initiated phase 2 of the air campaign. This expanded the list of targets to include military objectives in Kosovo and also in the area south of latitude 44 degrees through which reinforcements might pass on their way to Kosovo.[1272]

At the opening of the new phase the defenders enjoyed a rare taste of success when they brought down an F-117A stealth fighter. According to one source,[1273] the aircraft was leaving the target after completing its attack when it was engaged by three or four SA-3 Goa missiles. Fragments from at least one missile struck the plane and it fell out of control. The pilot ejected and the plane crashed in a field about 25 miles northwest of Belgrade. The source attributed the loss to a combination of factors: a flight route similar to that used four nights in a row, the nearest EA-6B jamming aircraft being at an orbit station too far from the F-117A to give it effective cover, and clever operational procedures and a large slice of luck on the part of the SA-3 battery crew.[1274]

It appears likely that the Low Blow missile control radar was cued to search in the correct part of the sky by one or more long wavelength acquisition radars. The most probable candidate was the Spoon Rest B (P-18). That equipment would have a good chance of getting glimpses of the F-117A during its approach. The source mentioned that some time earlier one or more SA-3 batteries had been moved into positions that were under known F-117A flight routes. To conceal their arrival, the radars made either no test transmissions or the bare minimum necessary for calibration.[1275] Given the huge propaganda value of an F-117A shootdown, it is almost certain that the missile crews involved were the best trained and most experienced available. The flat undersurface of the F-117A, when seen from directly below, constituted the most discernible aspect of the low observable aircraft, if the Low Blow radar crew when the stealth fighter was approaching its overhead and turned on their equipment as the plane came past, that would have given the SA-3 site optimum conditions for a missile engagement.

The F-117A pilot reached the ground safely and was soon picked up in a daring combat rescue operation. Although, the F-117A shootdown caused shock waves in some quarters, others argued that it was bound to happen sooner or later. Nobody had advertised that combat plane, or any other, as being completely invulnerable to attack. By the time of the shootdown, F-117A had flown about 1,400 combat missions over Iraq and FRY without incurring a single loss or instance of battle damage. Given that the stealth fighters' targets usually lay in the most heavily defended areas, even after the loss its combat record was substantially better than that of any other attack fighter.[1276]

After the loss of the F-117A came the process of locking the stable door after the horse had been stolen. Later F-117A operations apparently used more varied routing and enjoyed more effective screening from the EA-6Bs. The moves appear to have been successful, for during the remainder of the conflict no further stealth fighter would be lost in action.

Celebration over the Wreckage of F-117A

Following the F-117A shootdown, jubilant FRY officials took coach-loads of reporters to the crash site to clamber over the wreckage. The remains were then collected and, no doubt, pieces found their way to Russia or China or perhaps to both countries. That raises the questions of how valuable the wreckage of the F-117A might be to its recipients. Might a foreign design team reverse engineer the plane and build one of their own? After all, in the late 1940s engineers at the Tupolev plant in Russia had reverse engineered the B-29 Superfortress bomber and produced several hundred copies.

In fact any team of engineers attempting to replicate the F-117A design would face something akin to a Catch-22 Situation. If the team lacked a detailed understanding of stealth principles, it stood no chance of reproducing the plane's low observable features and getting them to work properly. On the other hand, if the team possessed such understanding it would not want to copy the outdated facetted shape, dominated by the limits of computer technology two decades earlier. The knowledgeable team would want to build a better stealth design of their own. (Not that copying the older plane would present an easy option.) Few people are better qualified to discuss this than Sherm Mullin, onetime Program Manager for the F-117A:

> "They [anyone trying to reverse engineer the F-117A] would have many problems, but I think the biggest problem would be the fundamental one of developing the automatic flight control system. Even if they could build and airplane to the tolerances of the F-117–I don't believe they could, but let us assume they could–they would have to replicate this very complex automatic flight control system. It is a four-channel redundant system with automatic voting. So anyone trying to copy the F-117 would have to come up with a computer, and all the equations to go in that computer. That would give them one heck of a design problem."[1277]

Although aspects of the plane would be of considerable interest to anyone working on a similar program, some of them would defy analysis. Sherm Mullin continued:

"Even if an F-117 was captured intact, it would be very difficult to reverse engineer the plane. Probably the most complex component on the airplane, from the very low observable viewpoint, is the edges. The total periphery of the wings, the total periphery of the tails, the total periphery of the flight control surfaces on the wings, those are all radar absorbing structures. These are critically important at all radar frequencies. To make them, we had to develop a very complex manufacturing and testing process. If you had one of those sections and took it part, it is not at all obvious how it functions. It is extremely sophisticated. You are talking about a mechanical part whose electromagnetic properties, over a full radar frequency range from very low to very high, are extremely complex. Building a part that looks the same and should bolt on the airplane is not a big deal. But getting the same electromagnetic properties that are required to get the radar signature you want, that is a very tough problem."[1278]

Passive Deception: Chaff

After the first week of the conflict, FRY missile batteries became more determined to engage the attackers. One of those who noticed the difference was Major McGovern of the 494th Fighter Squadron, 48th TFW, part of an F-15E force carrying out a daylight attack on an army barracks near Obrava in the south of Serbia.

> "We dropped our bombs, two GBU-10s [2,000 pound LGBs]. The back seater was designating for the bombs, when missile control radar illuminated us. On the ALR-56 missile launch warning receiver, we could see it was an SA-3 tracking radar. We dropped Chaff and commenced an evasive maneuver. That forced the WSO [weapon system officer (Air Force)] to stop designating the target. We evaded the first missile. Then I rolled out to get a visual on the second missile, and saw it was well clear. The [laser designating] pod gave us a countdown to impact. We needed between 8 and 12 seconds of level flight to correct the final part of the bomb's trajectory. As we rolled out I looked at the clock, and there happened to be 12 seconds left before impact.

Fortunately my WSO was thinking exactly the same thing as we rolled out. He resumed designating. I held the plane straight and level, looking out to see that no more missiles were coming for us. He guided in the weapons and shacked [scored a direct hit on] the target. Then we resumed our evasive maneuvers in that area."[1279]

B-1B Lancer Bomber and ALE-50 Decoy System

From 1 April, five B-1B Lancer bombers joined in the attacks on FRY from their bases at Fairford in England. Like the F-16s, these aircraft carried an ALE-50 towed decoy system.

The B-1B flew more than fifty missions during the Kosovo conflict, many of them against defended targets. According to one report these aircraft had an estimated thirty missiles fired at them. Of that thirty, it is believed ten locked on to the bomber/decoy combination before they were seduced by the decoys.[1280]

Throughout this period the Raytheon plant at Goleta, California, had been busy turning out ALE-50 decoys to replace the large number being used by the B-1Bs and F-16s. As mentioned earlier, each plane deployed at least one decoy per incursion into enemy territory. As it returned from the mission, the streamed decoy had to be jettisoned. Dan Feldhaus, working on the decoy production line at Goleta, described the change in mood at the plant during the conflict:

"Working behind closed doors in an assembly lab can be awfully repetitive. Although I've enjoyed working on the decoy program, inevitably the day-to-day monotony begins to wear on you–especially when you're not quite sure if your efforts are really being recognized. The only target we got to aim at is the monthly shipping date, when we sent our product to some unknown military base, not knowing if it is even being used or appreciated–not knowing, that is, until a situation known as 'Kosovo' occurred.

Once the problems in Kosovo began to heat up, the atmosphere changed. We started shipping product faster, two to three times each week to an Air Force base in Europe. All of a sudden we were working harder, faster, with The understanding that the decoy was not only being used but that pilots 'didn't want to fly without it.' Could all the 'boring repetitive tasks' actually be quite a bit more important than we thought? And, most importantly, were our contributions really helping to save the lives of our warfighters?"[1281]

As stories began to filters back from the air war over Yugoslavia, the workers learned they were having a major impact on events taking place thousands of miles away:

"Then, to our surprise, came word from overseas that an ALE-50 had taken a direct hit–probably saving both pilot and aircraft. Wow! Talk about making a difference!

"Work became a little more fun again, more urgent. More meaningful. Near the end of the Kosovo Conflict we received a packet of pilot-generated Thank-you notes, for what they referred to as their 'little buddy' (the ALE-50).[1282]

Phase III of Operation Allied Force

When Phase II of the air campaign failed to bring the FRY government into meaningful negotiations, Phase III was launch. This expanded the target list to take in high-value military and security related targets throughout the territory of the FRY.

On 3 April cruise missiles struck Belgrade for the first time, hitting interior ministry buildings. during the days to follow there were cruise missile attacks on a number of similar targets. On 5 April NATO bombers began attacking fuel storage depots and oil refineries, quickly halting operations at all of the latter. On 23 April the Serbian state television building in Belgrade, long used to dispense government propaganda, was heavily damaged in an air attack.

During the early morning darkness of 2 May an F-16 Fighting Falcon was shot down over FRY. Once again the culprit was an SA-3 missile battery. The aircraft fell to earth near Metic. The pilot landed by parachute and was rescued soon after he reached the ground. No information has been released on whether the aircraft had its ALE-50 decoy deployed at the time it was hit.

Electricity Grid and the Cluster Munitions

On 3 May F-117As opened the attack on parts of the FRY electricity grid. The weapon used was the CBU-94 cluster munition, a refined variant of the carbon-fiber-wire device used to disrupt the Iraqi electricity supply system nearly a decade earlier. Like its predecessor, the CBU-94 was designed to cause a temporary stoppage in the electricity supply, but no lasting damage. The individual submunitions, each about the size of two soda drink cans stacked one on top of the other, were carried in a tactical munitions dispenser dropped from the aircraft. At low altitude the dispenser opened and the submunitions spilled out, each one stabilized in its fall by a small parachute. Then small explosive charges in each submunitions expelled the reels of specially treated wire in succession. The latter unwound in the air to produce long lengths of wire, which fell slowly to drape themselves across high voltage power lines in their path. The wires shorted out the power lines, producing showers of sparks and huge power surges that caused the circuit breakers to pop out. That section of the electricity supply system was when unusable until all of the offending wires had been removed.[1283]

EA-6B Prowler: The Jamming Station

Like the other supporting systems, the EA-6B Prowler force was worked hard during Allied actions. To look at their work in detail let us follow a typical action on the night of 7 June. The composite Navy and Marine EA-6B Wing at Aviano sent two Prowlers to support a strike force attacking the main power plant in Belgrade. The pair took off around midnight.

Each Prowler carried the standard external stores layout employed during Allied Force: one jamming pod under each wing and one under the fuselage, a fuel tank on the right inboard station and a HARM on the left inboard station. The Air Tasking Order called for each EA-6B to launch its HARM preemptively at a set time and from a set point, to suppress the missile defenses as the main strike force ran in. once it had fired its HARM, each EA-6B moved to its assigned orbit station and provided jamming to support the main attack. Each EA-6B had a separate orbit station, one on the eastern side of FRY and the other on the western side.

Air Force Captain Jeff Fischer, an EWO on an exchange tour with Navy squadron VAQ-138, flew in an EA-6B that night:

> "The Yugoslavs had imposed a blackout throughout the country. As we ran in, we knew Belgrade was about 50 miles away on the nose, but we could see no lights from the city or from the countryside. It was very serene, very quiet. The EA-6B is a pig at altitude; we were at 20,000 feet because above that height it cannot pull much G in maneuvers. Given the choice we would have liked to have been higher, that would have given our HARM a better range. The strike force went in higher than we did.
>
> "As we neared the designated firing point we began the countdown for the HARM launch. The missile came off the rail and lit up the sky like a beacon. After the launch, we turned away. When we looked down, we saw that three AAA sites were firing traces at us. It was the first time I knew I had been shot at, and for the pilot it was the first time she knew she had been shot at.

The airplane was not hit, but it was very uncomfortable until we got clear. As we were driving outbound, with our jamming antennas pointed aft, we looked back and saw SAMs coming up and exploding in the sky.

"Suddenly the sky above Belgrade lit up as if it was daytime. I looked at my watch I saw it was the TOT [time on target], somebody's bombs were exploding on the power plant. When the flash died down there was a warm yellow glow in the sky, with flashes from secondary explosions. We remained on station for about ten minutes, until the last of the attacking planes had left danger area. Then we went home."[1284]

RC-12K Guardrail Common Sensor Aircraft

Since 1995 the 1st Aerial Exploitation Battalion had operated its RC-12K Guardrail Common Sensor aircraft from Taszar in Hungry, supporting the US forces in Bosnia. The Battalion was still there at the end of 1998, when the situation in Kosovo came to the boil. The 1st AEB was part of 205th Military Intelligence Brigade attached to 5th Corps in Germany. Colonel Susan Browning described the relocation of her Guardrail unit and its mode of operation:

"I was told to look at ways of supporting possible US operations in Kosovo, as well as those in Bosnia. We looked at several options, and decided we could support both operations from bases in Italy. At short notice we re deployed the Guardrail aircraft to Naples, and moved the Integrated Processing Facility (IPF) to Brindisi in the south of the country. Ideally, we would have liked to put the Guardrail planes at Brindisi too, but the Italian government would not let us do that. That move was completed in March 1991, just before the air war began.

"During each mission the planes had first to make a one-hour flight to

Brindisi, where the crews received their briefings. Then they flew to their Orbit stations over Albania. With the flights out and back via Brindisi, the Guardrail planes had only about two hours on station for each mission. Normally the unit would have eight RC-12Ks, but it had lost one during a training exercise in 1998. With only seven planes, and having to fly so many missions, we could only afford to put up only two planes up at a time [instead of the preferred three]. So, we lost a bit of accuracy. Even so, Guardrail was the most prolific collector of intelligence available to the Army in the theater."[1285]

The RC-12Ks established their base line over Albania close to the border with Kosovo, a distance of about 160 miles from their ground processing facility. Operating at altitudes close to their limit of 35,000 feet, the RC-12Ks were able to intercept and locate the sources of signals originating from Kosovo and a large segment of the FRY.[1286]

Unmanned Air Vehicle (UAV)

One further type of operation employed during Allied Force needs to be mentioned at this point, that of unmanned air vehicles (UAVs). It was not the first time US forces had employed such systems in combat, but this conflict saw them being used more intensively than ever before.

US forces employed three UAV systems during Allied Force: the Air Force's Predator, the Navy's Pioneer and the Army's Hunter. Predator, the largest of the three, carried a synthetic aperture radar as well as optical and infrared imagery gathering systems. Pioneer and Hunter carried only optical and infrared imagery systems. The missions assigned to the UAVs were general surveillance and reconnaissance, real-time targeting and bomb damage assessment, and providing cueing for other reconnaissance and surveillance systems.[1287]

Purists might argue that the above tasks are not relevant to electronic warfare. such operations certainly come under the umbrella of Information Warfare, however, and on those grounds a description of them merits inclusion in this study. There is another reason for including them. During the next couple of decades there is little doubt that UAVs will take over part of the SIGINT collection task. Readers might therefore be interested in some examples of operations by the Hunter UAV, to illustrate the strength and the weakness of this vehicle.

The Hunter, manufactured by TRW, employed a twin boom layout, had a wingspan of just over 29 feet and was just less than 23 feet long. Power came from two flat-twin motorcycle piston engines each developing 64 hp, mounted in a push-pull arrangement. The UAV's maximum take off weight was just under 1,600 pounds. Its maximum speed was 106 knots, its usual loiter speed was 65 knots, its ceiling was 15,000 feet and as operated over Kosovo it had an endurance of about 8 hours. The vehicle carried an optical TV camera and a forward-looking infrared (FLIR) sensor, permitting day and night operations. With mission equipment, the unit cost of the vehicle was about $1.5 million.[1288]

The Hunter took off from a runway in the conventional manner using its fixed wheeled gear. It landed conventionally, but used an arrester hook to pick up a cable to bring it smoothly to a halt. An external pilot standing beside the runaway controlled the take-off and landing.[1289]

For the operational part of its mission, the Hunter was controlled from a separate ground station clear of the airfield. During this phase of the flight, two operators controlled the system. The internal Pilot (IP), controlled the UAV's flight path by feeding corrections into autopilot. The IP's task was to guide the UAV along the planned route and position the sensors to secure the required imagery. Beside the IP sat the mission payload operator (MOP). The MPO's task was to select the optimum sensor for each target, train it on the objective and adjust the zoom lens to get the required amount of detail.[1290]

The Hunter carried global positioning system receiver to determine its position at any time during the flight. It passed this and other flight information, together with the video picture from the selected sensor, to its ground station by data link.[1291]

In April 1999, shortly after the start of Allied Force, Alpha Company of the 15th Military Intelligence Battalion deployed to Petrovic airfield near Skopje in Macedonia. When operations began Alpha Company flew between four and six sorties per day, each lasting up to eight hours. The small relatively simple UAV possessed a unique and formidable reconnaissance capability, during a single sortie, a Hunter could spend up to seven hours over enemy territory. It could fly from target, or it could loiter over areas of interest, or it could combine both in a single mission.

The UAVs provided capabilities that no other reconnaissance system could match. On the other hand, its operators had to particularly careful to keep them separate from regular air traffic. A UAV could not "see" other planes, so it could not turn to avoid them. The Hunter's systems could, however, see objects on the ground in remarkable detail.[1292]

Army Sergeant Antonio Mitchell served as a hunter Internal Pilot with Alpha Company during the conflict. Discussing the UAV's value in providing real-time targeting air strike and real-time damage assessment, he cited a nighttime mission that he controlled almost at the end of the conflict:

> "We were told to check a factory building in Kosovo for activity, and get accurate target coordinates for an attack. When the UAV arrived in the area, I flew it around the building so we could look it over. We could see there was a security fence around the building, and it was guarded. On the FLIR, we could

even see which guards were smoking. Over the course of the next few minutes we saw several trucks pull up to the building, and later drive away. Obviously, it was some sort of supply depot.

"Then I was told to move the UAV to a standoff position about five miles away, but to keep the building under observation. I was told that a B-52 was coming in. After a wait we suddenly saw little fires dotted all over the building, cluster Munitions going off The first quickly took hold and we saw people running out of the building. The UAV left the area, but the next day I sent one back to look at the building. It was just a burned-out shell, with the roof collapsed."[1293]

The ability to loiter over a single point in enemy territory for hours on end and observe what transpired is virtually unique to the UAV. Unless there were exceptional circumstances, that tactic would be considered too dangerous for a manned aircraft.

Being able to loiter in one area was also useful to cue other reconnaissance and surveillance systems. During one mission in the early hours of the morning. Antonio Mitchell was ordered to search a large wooded area suspected to certain troops. The FRY troops were skilled at camouflage and there were no signs of troops in the area. Then something unusual occurred:

"We saw a truck driving along the road by itself, at about 3 miles per hour. It looked like it might be a military vehicle, so we followed it to see where it went. From time to time the truck stopped, the driver and passenger got out and walked into the woods. About ten minutes later they came back, got into the truck and drove on. But after about half a mile, it stopped again. That process was repeated several times, we followed that truck for over an hour."[1294]

It was not the sort of behavior one would expect from a civilian vehicle at such an hour of the night, and afterward the area came under close scrutiny from other sensors.

Probably the truck was delivering orders, mail or hot food to troops in the field. The point of the story, however, is that no other type of reconnaissance vehicle could have followed the movements of a single vehicle deep inside enemy territory in that way. Such a loiter capability will also be valuable for some aspects of the SIGINT collection role.

Even in the daytime, the UAV's small size and light gray color made it difficult to see from the ground when it was above 10,000 feet. Its small engines were difficult to hear on the ground if there was any wind or background noise. When optically laid guns engaged a Hunter, its low 65-knot loitering speed was often an asset. AAA gunners are taught to aim their rounds well in front of the target when they engage a fixed-winged aircraft. In the case of the Hunter, rounds fired at them passed safely clear in front.[1295]

Late in May, Antonio Mitchell encountered an "out of body experience" when the Hunter was controlling was shot down. He recalled:

> "The first sign I had of anything amiss was when one engine suddenly stopped. That was unexpected–usually we had some warning if an engine was about to fail. Then I lost the downlink signal and the video picture. I repositioned the antenna to re-align it on the UAV, and the downlink came back for three or four seconds. During that time, the instruments showed about fifty failure aboard the UAV. Then I lost the downlink again and never regained it."[1296]

A level of attrition had to be expected and accepted when UAVs were employed on combat operations. During its two-month period in operations, Alpha Company lost seven Hunters. Four were either definitely or probably lost to enemy action, two crashed following technical failure and one flew into the side of a mountain.[1297]

Petrovic airfield where the Hunters were based was a busy international airport. As well as civil airliners there were military transport and helicopters from the NATO air forces arriving and taking off at frequent intervals. Integrating the UAV operations into the normal pattern of flight traffic presented some difficult problems, as Antonio Mitchell explained:

> "The airliners were carrying passengers, so our operations were not allowed to impose any delays to their flights. A lot of times we would be ready to launch, but the airport was not ready for us. So, we had to wait before we could set up our equipment. We needed the runway to ourselves for about 5 minutes before the UAV take off, to position the arresting gear across the runway–if a UAV had to abort the take-off, it dropped its hook and picked up the arrester cabie. Because it was sometimes hard to get a launch slot, we usually sent off a pair of UAVs each time, one behind the other."[1298]

Recovering a UAV to the airport at the end of its mission presented other problems. While manned aircraft were taking off or landing at Petrovic, the unmanned vehicles had to hold over a point well clear of the airfield. Sometimes vehicles had to orbit for more than half an hour. Thus, with reserves, the UAVs needed to arrive at their holding area with fuel for at least one hour's flight at loitering speed.[1299]

Conclusion

The air war over the FRY provides a ringing endorsement of the potency of modern air power and, when carefully applied and supported, its near invulnerability. The action lasted 78 days and cost no NATO lives and only two manned planes in combat. Much has been written about the failure to inflict significant damage on Serbian military and paramilitary forces operating in Kosovo. Yet overall the bombing campaign inflicted sufficient damage on the FRY and its economy to force President Milosovic to accede to NATO demands without the need for a costly land campaign. With hindsight several aspects of the conflict could have been handled better, but that can be said for any war.

The loss of only two aircraft, both apparently to radar-guided missiles, was too few to allow any meaningful statistical analysis. It is certain, however, that the decision to remain above 15,000 feet whenever possible over hostile territory was effective in neutralizing the otherwise dangerous IR missile systems.

Although the Kosovo conflict is too recent for detailed conclusions on the effectiveness of the various electronic warfare systems to appear in any unclassified account, there is no question that the various EW systems were resoundingly successful in holding aircraft losses to such a low figure. Since the losses were so light, there can be no doubt that the missions by F-16CJs, EA-6Bs and EC-130H Compass Call aircraft were effective in suppressing the enemy defenses. Although much of the FRY air defense equipment was elderly, it included several effective systems, which NATO aircrews would have ignored at their peril.

Chapter 36

The Role of Infrared Rays: The Invisible Rays

Introduction

The various ECMs methods introduced by the Americans in the Gulf War and of the long war in Vietnam almost managed to neutralize the effectiveness of radar as a means of detection and guidance. The *Fansong* radar used to guide SAM-2 missiles was often completely jammed or deceived by ECMs, while some of the Soviet air-to-air missiles arming MiGs were impotent against U.S. aircraft equipped with "smart" or deception jammers. In consequence new missile-guidance system exploiting infrared (IR) energy were researched and developed.

The Discovery of Infrared

The use of the infrared energy was not new. The British astronomer Sir William Herschel, who was already famous for his discovery of the planet Uranus, had discovered it by chance, in the year 1800.[1300] He was experimenting with various colored glass filters to protect his eyes from the sun's rays, which caused him considerable discomfort during his astronomical observations. During these experiments, he noticed that heat reduction was not equivalent to light reduction. Therefore, he devised an experiment in which the solar spectrum was projected onto a screen by passing light through a glass prism. When he passed a thermometer over each of the projected colors, he noted that the temperature increased as the thermometer passed from blue to red. He further noted, with some surprise, that, after passing through the red and into the "empty" zone, the thermometer continued to show an increase in heat; this area has since become known as the infrared spectrum. He had, in effect, discovered that the solar spectrum contained rays other than those, which could be seen by the naked eye, and he therefore called these "invisible rays." Herschel did not fully appreciate the importance of his discovery, however, and many years passed before it was followed up by further experiments; this time lapse can also be attributed to the lack of instruments for measuring heat, apart from the common thermometer.[1301]

During World War I, considerable progress was made in developing practical applications of infrared rays. Both sides were quick to realize the military importance of infrared radiation as a means of seeing in the dark without being seen, of detecting targets by their heat emissions and conducting secure communications which were very difficult to intercept. A signaling system using infrared pulses with a range of 2 miles, and vision device capable of detecting an aircraft at an altitude of 5,000 feet, or a person at a distance of 900 feet were developed in those years, although only to the experimental stage.[1302]

Research in the infrared field really gained momentum during World Word II. It is interesting to note that this momentum was set off by an error by the Germans during the Battle of the Atlantic between Allied convoys and German submarines. Allied anti-submarines forces stopped using search radar operating in the L-band because these emissions were so easily intercepted by German submarines that, thus alerted, crash-dived and escaped. They introduced radars operating on a higher frequency, in the X-band, and this had of course, immediately resulted in an increase in German submarine losses that the Germans could not understand. The German secret service was called in to find an explanation and they erroneously concluded that the Allies were using infrared ray detectors.[1303]

This mistaken conclusion caused the Germans to waste a lot of time and, no doubt, contributed to the final defeat of their submarines in the Battle of the Atlantic. On the other hand, German efforts devoted to the study of infrared radiation led to important advances being made in this field. Many people in Germany still remember the fear and amazement they experienced when huge armored vehicles roared past them at night, with no lights! These vehicles were transporting the famous V-1 flying bombs and their launchers to the French coast of the English Channel. To avoid being detected by enemy aircraft, they were using a device comprising an infrared emitter and an image converter, to enable the drivers to see in the dark. This phenomenon took place towards the end of the war when Germany was suffering constant air raids.[1304]

The Germans also used infrared rays in ship-to-ship, ship-to-shore, and, on the Libyan Front, tank-to-tank signal communication systems. However, during the Battle of El Alamein in 1942, one of these systems was captured by the British and, thereafter, the Allies also began research into the use of infrared radiation for military purpose.[1305]

The Americans used an infrared ray device for aiming rifles in the dark: it afforded sufficient accuracy to hit a man at range of approximately 80 yards. American soldiers first used this weapon, called a Sniperscope, during beach landings in the Pacific, casing greater terror among the Japanese soldiers.[1306]

In Italy, the navy first evaluated infrared ray devices, experimentally, in 1941-42 for the purpose of determining the distance at which a target could be detected in conditions of darkness or fog. The device used a receiver consisting of a parabolic mirror with a diameter of 50 centimeters incorporating a thermo-electric detector cell. Night experiments demonstrated that a person could be observed at a distance of about 100 yards and a vehicle with its engine running at about 500 yards; the cruiser *Taranto* was sighted at a distance of 5000 meters even though she was not using full engine power at the time.[1307]

Research on infrared systems continued after the war, its value as a means of detection, which could not itself be detected, now being fully appreciated. Continual progress in this field has brought about a long series of inventions for military use.

In the field of aeronautics, an IR tracking device able to signal the elevation and azimuth (bearing) of any heat-emitting target, in the air, on the ground and on or under water, was developed, it could also be used as an aid for instrument landing systems (ILS) for aircraft and in hydrographic surveys along coasts. Another important invention was Forward Looking Infrared (FLIR). This equipment enables a pilot flying in cloud or total darkness to "see" all objects on the ground or below the clouds having a different radiometric temperature from their immediate environment. IR systems have proved to be extremely useful in the field of missiles and strategic surveillance; installed on satellites, they give immediate warning if an Intercontinental Ballistic Missile is launched from any point on earth. Devices able to detect the presence of noxious or poisonous gases in the atmosphere have been developed as surveillance aids. IR sensors have been added to radar antennas to improve their performance, especially when radar silence has to be observed.[1308]

Military demand for IR devices led to accelerate technological progress in this field and the development of ever more sophisticated devices, such as power sensors, radiometers and other IR measuring instruments.

The applications of IR in the purely scientific field, in industry and in medicine are too numerous to mention here. IR systems are used for widely different purposes from testing the asphalt surface of roads to early diagnosis of tumors and many other diseases, particularly vascular illnesses, from infrared ovens for cooking food to systems in chicken incubators, from spray painting of cars to measuring the temperature of stars. One of its best known uses is certainly in photography, the first experiments with IR being made in the 1930s, since which time there has been a whole series of innovations in this field. For example, good photographs can be taken, using IR techniques from a distance of over 1000 Kilometers on a day when visibility is only 10 Kilometers; this particularly useful in the field of geodesy. IR photography is also useful in checking the health of plants by the color of their leaves which shows up clearly in IR photographs, enabling one to distinguish sick plants or trees from healthy ones.[1309]

In geology, IR photographs of the stratographic layers of the earth reveal its geological age since the presence of fossils in the rock shows up clearly, because fossils and the earth covering them have different radiometric temperatures. Analogous techniques can be used to detect underground operational centers and ammunition stores as well as archeological objects and the remains of buried cities. IR techniques are extremely useful in detecting counterfeit letters and documents since IR rays reveal some types of ink while others are not. Applications of IR in the field of communications are very interesting; research is aimed at developing systems whereby signals are transmitted by electromagnetic waves (EMW) in the infrared spectrum via optical fibers. These applications are of particular interest to all sectors of telecommunications such the telephone, videophone, cable television and data transmission.[1310]

In order to examine further the applications of infrared energy, it will be useful first to recall certain notions, which belong to the field of physics.

It is known that the retina of the human eye is sensitive to only a small sector, i.e. the visible sector, of the electromagnetic spectrum; furthermore, the eye's sensitivity is not constant but varies according to the chromatic scale of light. For example, the stimulating effect of yellow light is almost 100,000 times greater than that of red light, which is one of the weakest colors in this respect. The wavelength of yellow light is approximately 0,0005 millimeters; with both longer and shorter wavelengths, the eye's sensitivity drops gradually. At the longer wavelength end of the spectrum, the eye is still able to pick up wavelength of about 0.0008 millimeters but, beyond this point, darkness reigns since the stimulus of such radiation is too weak to produce a response in our visual organs. We than 0.0008 millimeters are in the infrared region and, if they are of sufficient intensity, perceive waves longer as heat. The main factor, which distinguishes infrared from light radiation, is, therefore, the wavelength. The infrared region extends from the point where the red end of the visible spectrum ends to the microwave band used for high-resolution radars (EHF). The infrared region is itself divided into four parts: near, medium, far, and extreme. The main factors involved in an infrared system are the sources, transmission of IR energy and detectors or sensors.[1311]

All bodies that have a temperature above absolute zero (-273 degrees Celsius) spontaneously emit IR energy. The process is set off by atomic oscillations in the molecules composing the bodies and is therefore closely related to their temperature.

A prototype infrared detector is to be found in nature, in the animal kingdom. The last of the snake families to evolve, the highly poisonous pit viper family, found in North and Central America and South-East Asia in particular, has two small dimples between the eyes and nostrils containing two perfect IR sensors which enable it to detect and locate all things which are either hotter or colder than the immediate environment sensitive and can detect minute variations in temperature. They are composed of a membrane, full of special nerve fibers, which react to heat, stretched over a small air-filled cavity. The snake, which usually hides in holes dug in the ground, is thus able, in total darkness, to detect the presence of a frog, mouse or any other unfortunate creature, which has come within its sphere of action, and kill it.[1312]

Being a from of electromagnetic energy, IR radiation can be absorbed and transformed into heat or processed in such a way as to make it observable; for example, it can be transformed into electric current or projected onto photographic film susceptible to infrared rays. From a military point of view, IR energy detectors demonstrated their practical usefulness towards the end of World War II when they were first used to detect aircraft and follow their route. IR devices used in World War II were nearly all of the active type, a beam of infrared radiation being focused on the target. However, the German did also experiment with a completely passive system, which did not emit IR energy itself but, instead, detected the IR energy emitted by the target itself–like the rattlesnake. This system was designed to detect aircraft at a distance of 12 Kilometers but was never actually put into operation, probably because IR technology was not yet sufficiently advanced to permit actual production of such a system.[1313]

After the war the major world powers continued their research on infrared rays, concentrating on passive systems for the guidance of weapons. These systems had the advantages of not revealing the presence of the guided weapon, of affording a high degree of accuracy and, above all, of being immune to ECM. In 1950, this research led to the development of the first passive IR missile-guidance systems. Missiles guided by such systems are the American AIM-9 Sidewinder, the first, and AIM-4 Falcon, the British Firestreak and the French Matra R-550 Magic.[1314]

The best known of these missiles is the AIM-9 Sidewinder which gave proof of its great accuracy in the very first tests carried out. The radio-guided target drones used in the tests were systematically destroyed by the missile which homed right into the exhaust nozzle of the targets jet engine: to reduce the replacement costs of the expensive drones used in these trials, strong IR sources were fixed to the wings, which were much cheaper to repair. Further confirmation of the accuracy of the Sidewinder was provided by a tragic incident, which took place during a training exercise in the United States in 1961. A B-52 Stratofortress was shot down by a Sidewinder missile accidentally launched from a USAF

F-100 fighter-bomber; the missile homed onto the exhaust of one of the jet engines causing an explosion which tore off a wing and set the bomber hurtling on the ground. Most of the crew was killed.[1315]

Several years later, a Sidewinder missile was involved in an incredible espionage affair, many aspects of which are still unclear. An enterprising Soviet agent somewhat managed to steal an entire Sidewinder missile with an IR guidance seeker head from an airbase in West Germany and smuggled it to Moscow. He traveled half way across Germany with the missile rolled up in a carpet in his car and then sent it across the border by train as unaccompanied baggage "of no commercial value"! The Russians, soon thereafter, produced an IR guided missile of their own, the AA-2 *Atoll*, which was almost identical to the American Sidewinder.[1316]

Atoll missiles carried by MiGs and Sidewinder carried by various U.S. fighters were the main air-to-air weapons used during the Vietnam War. A Sidewinder was responsible for shooting down the first North Vietnam MiG-21 in 1966.[1317]

In 1973, a few months before war broke out in the Middle East, about a dozen Syrian aircraft were shot down by Israeli Shafrir IR guided missiles, which are based on the Sidewinder. In October 1973, the Israelis themselves suffered heavy losses on the Egyptian front caused by the Soviet-built SAM-7 *Strela* IR-guided missiles. The *Strela* missiles were equipped with filters which eliminated, to a certain extent, one of the main defects of IR guiding systems: the high percentage of the false alarms resulting from distraction by other heat sources. They were very easy to handle and could be carried by a single soldier on his shoulder. They proved to be a deadly weapon against Israeli aircraft, which were forced to fly low to avoid search radars and SAM-6 missile-guiding radars. Fortunately for the Israeli, the explosive power of the Strela was limited due to the small size of its warhead; otherwise, there would have been a real massacre of Israeli aircraft.[1318]

However, IR-guided missiles had several shortcomings. The most serious defect of the Sidewinder was that, instead of homing in on the target, it would often head for stronger sources of heat such as the sun itself, sunlight reflected by clouds, heat-producing bodies on the ground or even, in some cases, nearby friendly aircraft. There was also the serious limitation of having to attack the enemy aircraft from virtually dead astern in order to present the missile with the hottest area of the target, the jet pipe.[1319]

These serious shortcomings arose from the fact that the IR-sensors fitted to the missile seeker head were not sensitive to the right IR wavelengths. For example, they had to attack enemy aircraft from behind because the lead-sulfur sensors used on the first Sidewinder missiles only reacted to wavelengths corresponding to the hot metal of exhaust nozzles of the jet engines. An IR sensor, which would react to the whole jet stream coming from the engine, was needed so that the missile could be launched regardless of the position or direction of the enemy aircraft. In technical terms, it was necessary to devise an IR sensor, in which would react not to wavelengths of 2.5 micrometers (corresponding to sunrays reflected by clouds or emissions from the incandescent metal of the jet exhaust nozzle), but rather to wavelengths of 5 micrometers, corresponding to exhaust gases. This was done by freezing the detector itself to temperatures referred to as cryogenic (from the Greek word Krios intense cold), such temperatures being much lower than those obtained by normal freezing units.[1320]

Most of the original defects of IR-guided missile have now been overcome by various means, such as the use of filters, and they are now a vital weapon in the arsenals of many countries. Combined guidance systems are now often used in which radar is used to measure distance while IR is used for direction finding or as a secondary system in case the radar is neutralized by ECMs. IR is also used to distinguish a "hot" target (for example, a ship or an aircraft) from one that does not emit heat (for example, chaff).[1321]

Looking back at the past few decades, we can note that every time a new weapons system entered the picture, parallel countermeasures were devised to neutralize or reduce its effectiveness. This happened first with radar systems and is now happening with IR systems. Information regarding IR countermeasures (IRCM) is difficult to come by however, as such developments are kept top secret. Nevertheless, it is certain that many nations are devoting a considerable intellectual and financial effort to developing countermeasures to IR-guided arms systems.

IR Warning Systems, which have exactly the same function as RWRs, are already in existence. When installed on aircraft, they warn the pilot of the approach of a missile: the IR sensor either picks up the heat (IR energy) emitted by the missile on launch or during its thrust phase, or picks up the friction produced as the missile passes through the atmosphere. Such early warning enables the pilot to make an appropriate evasive maneuver, launch flares or activate IR devices to interfere with missile flight path, should it be IR-guided. Such devices for jamming or deceiving IR seekers are based on new concepts, such as laser beams that can damage or even burn-up the IR sensor of an enemy weapons system. Another IRCM involves burning combustible material in combustion chambers to heat a special membrane that radiates especially modulated IR energy. Other systems use propane gas burnt in special containers, or arc lamps to produce IR energy that interferes with enemy missile-guidance systems.[1322]

During the Arab-Israeli War 1973, IR deception was used with considerable success. Pyrotechnic devices, such as IR flares and decoys, which emitted greater heat than the targets they were defining, but with the same IR characteristics, were deployed or dispensed to lure IR-guided missiles off-course. A whole new field of electronic warfare had opened up.

Infrared in the Gulf War: Penetrating the Night

Night vision devices, principally infrared detectors, gave the Coalition air forces a tremendous advantage in night fighting. (Forward Look Infrared) FLIR-equipped aircraft and helicopters operated almost as freely at night as in the daylight and attacked Iraq's war machine twenty-four hours a day.

The 48th Tactical Fight Wing (TFW) aircrews flying F-111Fs with Pave Track II pod mounted in the weapons bay, capitalizing on the aircraft's long range and excellent ground mapping radar, could hit a wide range of targets. F-111Fs employed guided bombs against high-value targets such as airfield facilities and manifolds.[1323]

The system that, more than any other, gave the US Air Force control of the night was LANTIRN (Low-Altitude Navigation and Targeting Infrared for Night). Forty-eight F-15Es from the 4th TFW, Seymour Johnson AFB, NC flew out of Al Kharj, Saudi Arabia, equipped with Martin Marietta LANTIRN pod.[1324]

The LANTIRN navigation pod has terrain-following radar. The F-15E can be flown manually, or the TFR can be coupled to the F-15E autopilot. There is also a FLIR sensor that provides a wide field-of-view for the pilot's head-up display.

The targeting pod contains a FLIR tailored for target detection and look on, as well as a target tracker, and a laser designator and range finder. It also includes a device called a bore sight correlator for missile.[1325]

F-16 pilots also employed the LANTIRN navigation pod. The FLIR was a boon to pilots flying at night. "It was like driving down a deserted highway in the middle of West Texas at two in the morning and then all of a sudden seeing the biggest Fourth of July fireworks demonstration that you've ever seen in your life all at once." Lt Col. Tom Rackley, commander of the 421st TF, said. "And that's what it was."[1326]

"In fact, one of the starkest contrasts that will always stick with me is going out there and taking off, going to the tanker, and on clear nights, just sitting there and looking at the beautiful stars and having it very calm, peaceful, and relaxing."[1327]

"Then you go and get your gas and you go into Kuwait or Iraq and your whole world lights up. You're watching all those missiles go by and all AAA going off and you're trying to find your targets, you're trying to avoid other airplanes and everything is just one thing after another."[1328]

"And then, after about twenty minutes of that, you're back in the peaceful night sky again. Coming out of there and climbing up to a very high altitude to come home, putting the autopilot on, turning all the lights off, and just sitting there and allowing yourself to calm down and relax and behold the beauty of the universe. That's what I'll always remember."[1329]

LANTIRN was the key to F-15E effectiveness in night combat. For example, when Joint STARS found what it believed to be a Scud missile site, the F-15E crew, with their synthetic aperture radar, could locate the missile/launcher precisely, even if it was camouflaged, then use LANTIRN to acquire the target visually and illuminate it for the LGB.

FLIR, low-light-level TV, and night vision goggles were extremely important for Air Force Special Forces aircrews. For example, they relied on them for employing the MC-130E Combat Talon on low-level operations deep in Iraq.

The crews of AC-130H Spectre gunships, and HC-130N/P Combat Shadow in-flight refueling birds, were equipped with them. Crews of MH-53J Pave Low night attack helicopters and the HH-3E Jolly Green Giant as well as Marine HH-53 Super Jolly rescue helicopters had them. Night vision goggles were also essential and effective for Army aviators and ground troops.

The ANVIS-6 night vision goggles were the newest in a series of NVGs and was issued to US aviators in Desert Storm. They amplify limited visible or infrared light reflected from the surface of the object.

Chapter 37

The Role of Laser: The Smart Weapons

Death Ray

In the middle of the twentieth century, a physicist named Nikola Tesla[1330] was born in Croatia in 1857. He immigrated to the United States in 1884 and worked for a short time for Thomas Edison. He invented a transformer (named after him) that had an extremely high ratio of transformation and was capable of producing extremely high tension in the region of hundreds of thousands of volts. Tesla made many discoveries and inventions of lasting value to the development of radio transmission and electricity, one of the most famous of which was the power system at Niagara Falls. Military authority from all over the world showed great interest in his discoveries since, according to Tesla he had invented a kind of "death ray" capable of causing the disintegration of whole formations of aircraft at distance of 300-400 km. He died in 1943.[1331]

At first, it was thought that the much longed-for "absolute weapon" which could win all wars had finally been invented. But the initial enthusiasm soon died down when the brilliant but eccentric physicist failed to furnish details of his revolutionary weapon. Nevertheless, the military commanders of major world powers were unwilling to let go of the idea of a "death ray" and waited year after year for their dream to come true.

On 26 February 1935, leading figures from the British War Ministry were invited to one of the main military radio stations near London to watch the physicist Robert Watson-Watt give a demonstration of radar. This event caused great excitement since Her Britannic Majesty's General Staff had placed a very specific request; they explicitly asked whether radar could produce "death rays" which would guarantee the supremacy of British armed forces over all potential enemies. Although they had before them a great invention, which was to revolutionize traditional warfare, those present were somewhat disappointed when the demonstration fell short of their expectations.[1332]

Many years later, in 1960, the research laboratories of the American Hughes Company produced the first laser (for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation) generator machine, developed by the physicist Theodore Maiman. Again there was talk of "death ray" and many journalists really went to town on the subject.[1333]

However, one of the first uses of a laser was in the field of medicine–in microsurgery, where laser beams were used to perform extremely delicate operations, such as in brain surgery, eye surgery for repairing detached retina, in the treatment of certain forms of cancer by destroying the malignant tissue, in stomatology and endoscopy. Laser have also proved to be of great importance in science and technology–in the fields of spectroscopy, microanalysis, high-speed photography, microphotography, micro welding and precision engraving, to give just a few examples.[1334]

Of course, lasers also have many important applications in the military field, which exploit characteristics of the laser beam different from those exploited in civilian fields. One important military application of the laser is in very high precision weapons guidance: guidance of "smart" bombs, or Laser Guided Bombs (LGB), such as the U.S. Texas Instrument Paveway LGB, and missiles, such as, for example, the U.S.-Hughes AGM-65 Maverick. These are fitted with trackers which home on to radiations emitted by a target, which is being illuminated by another laser beam, called a laser-designator. The tactic generally used to launch a smart bomb is the following: two aircraft are used, one equipped with a coded laser beam, while the other releases a pre-programmed bomb which homes on to the laser energy reflected by the "illuminated" target, hitting it with near perfect precision. Alternatively, the laser-designator can be carried by helicopter or by front-line observers or infantry. "Coded", in reference to the laser beam, means that impulses are generated, differing in length and/or spacing, according to a program suitable for the particular type of operation. In the case of AGM-65, a unique coder to only one air or ground designator, thus allowing several to be launched independently in one vicinity, can tie each missile.[1335]

This type of bomb was used during the last years of the Vietnam War. The destruction of the Thanh Hoa Bridge, a hundred kilometers from Hanoi, furnished proof of its great precision. This bridge was in a key position and repeated attacks had been made on it by U.S. aircraft using conventional bombs without any success: it was destroyed on 12 May 1972 by a single laser-guided bomb. On 8 June of the same year, the Americans announced that laser bombs had destroyed fifteen strategically important bridges, thus considerably slowing down the passage of over 3000 North Vietnamese trucks taking supplies to the Vietcong.[1336]

Laser has also been used in missile guidance, endowing the missile with unprecedented accuracy. Another application of laser is in LADAR (Laser Detection and Ranging), a union of laser and radar which is now used for many different purposes: to guide projectiles, including artillery shells, to position satellites, for accurate navigation–in short, in all operations where radar alone cannot give sufficient accuracy. Recently, the U.S. Navy and Marines have carried out numerous experiments using laser to guide Naval artillery shells during amphibious operations. With this new system, every round fired hits its target, resulting in great savings on costly ammunition. It is an innovation, which will certainly bring a new dimension to maritime warfare.[1337]

Low-Light-Level Television

It is well known that acquiring information on the target to be attacked, and if possible, examining it and its surroundings, is a basic requirement in military operations. Since time immemorial all sorts of means have been used to achieve such an important goal. Radar reveals the presence of an object but does not tell us what it is or what it is made of. We have already seen that infrared devices give us an idea of the nature of the target even in total darkness. Nowadays, with modern night vision techniques, it is possible to see almost as clearly in darkness as in daylight.

The most common technique used to improve human vision during periods of limited visibility is by image intensifiers used in Low-Light-Level Television (LLL-TV). Image intensifiers work by amplifying ambient particles of light, such as the weak reflections of the moon and stars, which are always present in the atmosphere. The first image intensifiers were developed at the end of the 1950s but they were rather cumbersome devices and impractical for military use. However, astronauts for making observations during space flights sustained interest in them due to their use.[1338]

Image intensifiers were first used for military purposes in 1965, since which time continuous improvements have been made to them. With modern versions, it is possible to see the light from a cigarette at a distance of 2 kms.[1339]

A further step forward was made in night vision techniques by combining television and image intensifiers, which led to the development of Low-Light-Level TV. This has the dual advantages of both intensifying the light level by a factor of at least six and also of separating the viewer from the image's source, thus making it unnecessary for the viewer to get used to the dark. In effect, with an LLLTV system, it is possible to intensify the weak light emitted by the stars so that one can see an area almost as clearly at night as in daylight. LLLTV is now widely used in aircraft and helicopter giving the pilot adequate night vision for night flying–including take off and landing as well as for navigation and in tactical operations at night or in poor visibility. Image intensifiers are also used in modern submarine periscopes.[1340]

Another system in widespread use is the airborne TV-aiming system also used at normal light levels whose design is very simple. These use special and very powerful zoom lenses, which enable the operator to distinguish very clearly people walking down a street from an altitude of thousands of meters. The operator is able to view the target from the most appropriate altitude, depending on AA defenses: as soon as the target has been framed in the screen, the operator launches the bomb or missile which, using the TV-camera to keep the target in view, is guided by radio-directed signals. Widespread use was made of TV-guided bombs during the last few years of the Vietnam War. in particular, aircraft operating from U.S. aircraft carriers were equipped with the AGM-62 Walleye TV-guided glide-bomb which was particularly suitable for the destruction of targets which are difficult to hit, such as road and railway bridges.[1341]

Traditional artillery has also benefited from electro-optical inventions and, today, it is possible to correct the trajectory of a shell while it is in flight.

Electro-Optical Countermeasures

As had been the case with radar and infrared radiation, the widespread use of lasers and LLLTV led to the development of appropriate countermeasures and counter-countermeasures. Since laser and LLLTV come within the field of electro-optics, such countermeasures are referred to as (EOCM). The subject is also called "optoelectronics" but there has been a tendency recently to distinguish the two, limiting "optoelectronics" to communications and information and "electro-optics" to weapons systems and related countermeasures.[1342]

A laser beam is very highly directional and thus difficult to intercept. On the other hand, it can be easily deceived since it can even operate only very limited frequency bands. The most common deceptive technique is to use another laser, which has similar characteristics but is much more powerful. This laser is beamed onto a point sustained at a safe distance from the target to be protected. The "laser searcher" fitted to the bomb or missile is thus deceived by the more powerful laser and directs the weapon towards this source rather than to the real target with the result that the bomb or missile impacts in a zone where it cannot do appreciable damage.[1343]

Passive countermeasures can also be used to counter lasers. These include reducing the effectiveness of the laser emission by using aerosol, smoke, chemical additives or other chemical substances, which absorbs or disperse its energy.[1344]

The problem of devising EOCMs to counter LLLTV and optical systems in general, including the human eye, is more complicated. One passive EOCM is "optical-chaff" which works on the same principle as the tin foil strips used against radar during World War II and thereafter. Huge quantities of tiny sequins (palettes) can be launched from an aircraft or ship under attack that, by reflection, can dazzle the TV camera of the enemy electro-optical search system.[1345]

It is worth mentioning countermeasures to the human eye, which, in the conflicts in the Middle and Far East, has proved to be still one of the most effective aiming systems. One such system, exploiting the phenomenon of reflection, directs luminous energy towards the eye (through the same focusing lenses used for aiming), which interferes with the eye's vision, confusing or deceiving it, regards the position of the target. It is also possible to direct laser beams as the eye of the man aiming the weapon so that, by exploiting the lens through which the man looking, the retina of the eye is damaged.[1346]

High Energy Laser Weapons

Although the laser nas proved to be an effective guidance system for arms and munitions, efforts to develop a lethal laser weapon, a kind of "death ray", have so far been unsuccessful; the superpowers still doggedly pursue this aim.

In all probability, a portable anti-personnel laser "death ray" weapon could be developed without much difficulty and would no doubt be lethal. However, the fact remains that no one has yet come up with such a weapon: the reasons for this probably lie in the fact that it would be too easy to devise appropriate countermeasures which would neutralize the effectiveness of the weapon. Besides, it would be too expensive to use as an individual weapon: in theory, an ordinary mirror could be used to reflect the beam back to the sender, or by the use of aerosol systems; even better, clouds of dust or smoke could be created by throwing hand grenades, thereby blinding the optical aiming system and neutralizing the effectiveness of the weapon.

In recent times, that two superpower have been directing their efforts towards the development of a "high energy" laser, with a power of 5-10 megawatts, much more powerful than any laser now in existence. This weapon should, in practice, be able to produce and transmit high rates of energy through the atmosphere and concentrate them on high-speed targets such as missiles and supersonic aircraft, boring through them or damaging their guidance systems as a result of thermal effect.[1347]

Air forces are particularly interested in the development of such weapons as a means of protecting bombers from air-to-air and surface-to-air missiles, especially in cases where traditional ECMs are unable to afford protection during penetration of enemy air space. Naval forces, on the other hand, see a high energy laser weapon as a previous means of countering anti-ship missiles, including cruise missiles, and sea-skimmers which travel at very low altitudes. Finally, for ground forces, such a weapon could provide close AA defense against any type of attacker.

However, there are enormous problems to be overcome before such a weapon becomes a reality. The first problem involves transferring the high-energy laser device from the gentle environment of the laboratory to the severe conditions of military vehicles or other platforms with the attendant constraints of power requirements, weight and space. Another obstacle to be overcome is atmospheric dispersion, which is very strong at laser beam wavelength. As with infrared radiation, the atmosphere greatly reduces the propagation and consequently the range of any laser, even high-energy lasers. These problems could be partially solved by using the laser weapons at high altitudes or, better still, in outer space where there would be no absorption of energy.

In the United States several Boeing C-135 Stratolifter aircraft were converted for use as flying laser laboratories to conduct research on the use and installation of laser-weapons at high altitudes. These aircraft are equipped with high-energy lasers and special aiming and tracking systems. One such aircraft disintegrated in flight on 6 May 1981, over Maryland while conducting secret experiments. Meanwhile, various testbed lasers have successfully shot down drones on several occasions, using several different types of laser-generator. Tests are carried out at the White Sands Missile Range where research is also done into the problems of the damage caused by laser to the metals (steel, aluminum, etc.) of which targets are made.[1348]

The development of a high-energy laser weapon by the us defense industry will take a long time and possession of such weapon by only one of the Superpowers would weigh heavily in the present balance of power. For these reasons, the Americans have already set aside increasingly large sums of money for the research and development of appropriate countermeasures to protect themselves, should a lethal laser-weapon eventually appear on the scene.

Very Low Frequency (VLF) Weapons

After the death of Nicola Tesla in 1943, the United States, underestimating the technical and military value of his discoveries, allowed all his papers to be sent to Yugoslavia, which had requested their return. As soon as the papers arrived in

Yugoslavia, Soviet intelligence specialists who immediately took possession of the most important studies and projects secretly examined them.[1349]

The Soviets were extremely interested in Tesla's research and, in recent years, have continued his research into the possibility of developing a new type of deadly weapons; a weapon which would no doubt have devastating effects but would be extremely difficult to develop at a practical level.

During his work on inductive coils, Tesla had also studied the possibility of transmitting electric energy from a distance without using normal conductors. He held that the Earth itself could be used as a conductor, as though it were a gigantic diapason able to emit vibration on a particular wavelength. According to his theory, it was possible to make extremely low frequency (ELF) (6-8 Hz) transmissions through the Earth, using vertical-type waves emitted by the Earth itself.[1350]

In 1899, at Colorado Springs, U.S.A., Tesla unveiled an inductive coil larger than any previously constructed and with it managed to light hundreds of lamps, at a distance of about 40 kms, by transmitting electrical energy through the Earth without using any electrical conductors.[1351]

He further developed his theory that a signal close to the frequency of basic resonance, which he estimated to be 8 Hz, could pass through the Earth and be picked up on the other side, the reason from this being that the propagation of the signal itself would be effected by vertical waves. Some U.S. experts maintain that such a system could have been used by the Soviets to provoke seismic phenomena such as the earthquake which occurred in Peking at the beginning of 1977.[1352]

However, it must be pointed out that vast power and an enormous antenna would be necessary to provoke the Earth in such a way. In fact, to provoke seismic activity of the magnitude of the 1977 Peking earthquake, the Soviets would have to use an antenna consisting of a 20 km copper plate that would surely not have escaped the notice of U.S. reconnaissance![1353]

The hypothesis that the Russians might have developed a low frequency weapon on the basis of Tesla's theories is rather more feasible. Such a weapon would operate on frequency of 8 Hz, which is very close to that of the human brain[1354], and might therefore interfere with the workings of the mind just as ECMs interfere with radio and radar. It seems that impulse emissions on such a frequency can cause effects, which range from drowsiness to aggressiveness. It has been reported that two special transmitters operating on this very frequency have already been built by the Soviets at Riga and Gomel. This resonance is also presently being studied in the United States for use in communications with submerged submarines.[1355]

This weapon, however, has characteristics with Tesla did not foresee: it exploits a different type of resonance, which is formed in the space between the surface of the Earth and the lower layer of the ionosphere. With such a system, Tesla's beam, besides being transmitted through the Earth, can also be transmitted around it.

The efforts of electromagnetic fields on the human body have also been studied in the West. Thanks to the extremely sensitive measuring instruments now in existence, it has been discovered that the human brain and heart have magnetic activity. In the field of medicine, this discovery has given rise to magneto-encephalogram and magneto-cardiograms.[1356]

A great deal of interest has recently been shown in the biological effects of electromagnetic fields in the hand of extremely low frequencies (ELF)–3 Hz – 3 kHz. It is interesting to note that many electromagnetic atmospherical disturbances come within this frequency band and that these ELFs are similar to biological rhythms. Certain sensitivity to these frequencies has also been demonstrated by some animals. Reduced motor activity in birds has been noticed in the presence of electromagnetic field of 1.75 and 5 Hz and an increase in such activity in the fields of around 10 Hz. Also, many fish are sensitive to frequencies between 0.1 and 10 Hz.[1357]

Wewer and Altmann report that electromagnetic fields in this band affect man's behavior. The physiological basis for these observations involves the autonomous nervous system and endocrinic system. In short, an ELF weapon could conceivably be used to influence thought and thereby control the whole of mankind.[1358]

However, assuming for the sake of argument that such a weapon might one day be developed, it would not be difficult, given the low frequency and power, to devise effective ECCMs to protect our brains from this insidious danger that lurks behind the electromagnetic spectrum.

The Smart Weapons in the Gulf War

Laser-and electro-optically guided "smart" weapons were, one of the most dramatic weapons used in the Gulf War. Pictures of bombs flying through bunkers doors, elevator shafts, and hitting individual tanks stunned viewers.[1359] What the vast majority of viewers did not realize, of course, was that the smart bomb was not a new weapon, but rather one that had appeared in Vietnam and been constantly refined since. Here is the great irony "smart bomb" history–heralded as a weapon of the Gulf War, it actually demonstrated almost equally impressive performance nearly 20 years before in a conflict a third of a world away–and its antecedents, indeed, stretched to crude predecessors in Second World War.[1360]

The challenge of attacking North Vietnamese bridges led directly to smart bomb development. (Ironically, difficulties dropping North Korean bridges led the Navy to develop the first mass-produced air-to-ground guided missile, the Bullpup.) Since ballistic-drop weapons–that is, they follow a mathematically predictable course once they are released–a guided bomb would have to have some sort of aerodynamic control surfaces and sophisticated guidance system to effectively change it into a high-speed homing weapon that could seek out a target. In the early 1950s, largely at the instigation of Gen. Gordon Saville, the Air Force examined technologies necessary for producing guided bombs under the "Zero CEP" study effort. As early as 1958, a study group of the National Academy of Sciences recommended looking to the new technology of lasers for weapon guidance. As Air Force interest in developing precision conventional munitions increased with thee onset of Vietnam, the potentiality of laser guidance became increasingly apparent within weapons community. The Air Force maintained a small weapons research staff at Eglin AFB, Florida, and this group received reports from Vietnam indicating that the Bullpup, when used on Vietnamese bridges, tended either to bounce off or break up, without doing too much damage. Worse, it required a pilot to steer it into the bridge using small hand controller in his cockpit, and thus made the attacking plane very vulnerable to anti-aircraft fire.[1361]

In 1965, the Air Force launched a laser-guided bomb (LGB) development effort called Paveway. Col. Joseph Short and Weldon Wood of Texas Instruments. Very quickly feasibility studies determined that the best technical approach combined modular guidance units and stabilizing fins with range-extending winglets that could be added to existing weapons such as the Mk-84 2,000-pound bombs. In 1967, the Navy placed its own electro-optically guided smart bomb in service, the AGM-62 Walleye, which used a television guidance system so that a crew could steer it to a point where they could lock it onto the target and then turn away. Walleye was an impressive weapon, but its warhead–450-pound–was still too small to do a decent job on a bridge. The next year, the first Air Force LGBs went to Vietnam for operational testing. The results were mixed, in part because of the newness of the weapon, inexperience of the operators (particularly the laser designators, firing a small laser "gun" at the target from the backseat of an F-4, and then holding the spot of laser light on the target for up to thirty seconds), and difficulty in finding appropriate targets (a bombing halt was in progress).

Yet more than half those dropped scored direct hits–far more impressive than conventional bombs–and analysts concluded that 2,000-pound LGBs could consistently hit within 20 feet of an aiming point, a revolutionary breakthrough in accuracy. back at Eglin, developers refined the concept, and created a family of modular components to convert conventional dumb bombs into smart ones called Paveway I. Mk-84-based 2,000-pound GBU-10 LGB was ideal for bridge busting, and the smaller MK-82-based 500-pound GBU-12 LGB perfect for trucks and vehicles. To get away from the vulnerability of operating two aircraft in high-threat areas, one a designator, one a dropper (although the British did just that in the Gulf War, with the Buccaneer designating for the Tornado), the Air Force developed Pave Knife, a laser designator boresighted to a television set so that a F-4 crew could "self-designate" a target, keep maneuvering if necessary, and drop an LGB on it. For more permissive environments there was Pave Neil, a laser designator developed for OV-10 FACs to use when working with strike aircraft dropping LGBs. Both systems were in place for Linebacker I and II.[1362]

The performance of the LGB during 1972 North Vietnamese invasion of South Vietnam and the subsequent Linebacker campaigns was impressive. The 2,000-pound Mk-84s demonstrated accuracies within six feet of their aiming point when used against bridges and other targets. In one notable case, an OV-10 illuminated a Communist tank overrunning a Special Forces camp and an F-4 destroyed it with a direct hit by an LGB without injuring or killing any of the friendly defenders. In another case, three artillery pieces and five trucks were destroyed. Another time, two F-4s using the older "buddy" designation system destroyed two tanks with two bombs in three minutes.[1363]

Developing even more sophisticated and capable LGBs in the post-Vietnam years assumed a high priority, for they offered the kind of desirable "one bomb, one kill" potential that post-Vietnam air-to-air missiles were reaching toward themselves. The next major advance came with the introduction of the GBU-16 Paveway II in the early 1970s. Unlike Paveway I, the Paveway II had folding wings so that more could be carried by strike aircraft, structural improvements, and improved guidance ability; it eventually went into service with over thirty nations, and a variant based on British 1,000-pound bomb design served with the British in the Falklands, and later in the Gulf War. Incredibly, given the potential and value of the LGB, Congressional cutbacks in the fiscal year 1974 budget request forced the Air Force to scrounge money from other programs to keep the Paveway program going. Developmental testing of the Paveway II went smoothly, and in 1976,Texas Instruments received a contract to manufacture nearly 7,800 kits to convert conventional bombs in the Paveway II configuration; TI delivered all the kits by the end of the next year. (The U.S. Navy subsequently developed a powered variant of the Paveway II, using a solid-fuel rocket booster from the Shrike anti-radar missile, and designated it the Skipper II; it gave Navy airplanes improved standoff range when attacking heavily defended vessels, and was first used in combat in 1988, sinking an Iranian frigate in the Persian Gulf.[1364]

Good as Paveway II was, it still required a strike aircraft to bomb from medium altitudes, where a plane might be vulnerable to dense Warsaw Pact–type air defenses, or above cloud. Thus, in 1976, the Air Force issued a requirements statement for a new low-level LGB. Out of this came the GBU-24 Paveway III, a very different stand-off weapon that, if not "brilliant," was at least "intelligent." It had on-board autopilot stabilization so that the bomb could "cruise" toward its target, a scanning seeker to find the spot of laser light illuminating the target, and the ability to be dropped outside the target "basket," and then maneuver itself inside it. Initial testing went but one failure in thirty-one drops, but operational testing of the Paveway III using the 500-pound Mk-82 bomb shape revealed serious control sensitivity problems–problems that Paveway III using the heavier 2,000-pound Mk-84 shape did not have. Paveway III eventually completed follow-on testing and evaluation in March 1986, demonstrating forty-four successful drops out of forty-seven attempts, a success rate of almost 94 percent. The Paveway III kit could be fitted to either the Mk-84 conventional 2,000-pound bomb, or, with some software changes to its control system, the BLU-109 2,000-pound hard target earth penetrator bomb. Carried by F-15Es, F-111s, and F-16s, the GBU-24 would not get its chance to demonstrate what it could do in combat until the Gulf War. An advanced derivative, the GBU-27, was carried to the F-117s. During the war, the Air Force and Texas Instruments developed the massive 4,700-pound GBU-28 hardened penetrator using Paveway III guidance coupled to a new bomb shape based upon discarded cannon barrels. Altogether, approximately 9,000 Paveway II and III bombs were dropped in the Gulf War, constituting approximately 47 percent of all the precision-guided munitions used by American forces.[1365]

Although the best known and generally most useful of the smart bombs. LGBs were not the only such weapons. The Air Force had earlier used an electro-optically guided bomb in Southeast Asia (the GBU-7), though it did not achieve the same kind pf precision, as did the LGB. One of the major Air Force development efforts of the 1970s was the GBU-15. A cruciform-wing glide bomb built around the proven Mk-84 or hardened BLU-109 bomb shapes, the GBU-15 offered greater standoff range than a conventional LGB, ideal for attacking heavily defended targets, air defense systems, or ships. Unlike the LGB-15 utilized either television guidance (the GBU-15 [V]1/B model) or a Maverick-like imaging infrared (IIR) system (the GBU-15{V}2/B model). In the

Direct Attack mode, the GBU-15 locked onto the target before being released from the launch aircraft, and thus flew an essentially line-o-sight approach to it. In the indirect attack mode, a weapons system officer in a F-111 or F-15E could fly the weapon into the target using guidance updates transmitted via a data link to the bomb, or he or she could lock the seeker onto the target after launch. Further, it could attack in weather conditions preventing laser-weapon attacks, for the bomb could "break out" under the overcast, and then acquire a target on its viewing system. Begun in 1974, the TV GBU-15 took nearly a decade to enter service, and the IIR version did not enter service until 1987. As with the Navy's Skipper program, the Air Force developed a rocket-boosted version of the GBU-15, the AGM-130, to achieve even greater standoff. But it experienced developmental difficulties (one Air Force general stated, "If ever there was a snake-bit development program, this is it") and was not available for service in the Gulf.[1366] A large and, indeed, awkward-appearing weapon, the GBU-15 helped stem the flow of Iraqi oil into the Persian Gulf after President Saddam Hussein launched his campaign of eco-terrorism. GBU-15s also hit mine entrances, chemical plants, missile sites, bridges, bunkers, building complexes, and command facilities. Altogether, seventy-nine or eighty TV and IIR versions of the GBU-15 dropped in the Gulf War hit their aiming points, a success rate of over 98 percent.[1367]

Chapter 38

The Electronic Warfare in Space

The Birth of Satellite

Man's conquest of space has brought a new dimension to arms technology, communications systems and methods of surveillance with consequent innovations in the field of EW.

The use of satellites for military purposes began in 1958 when the United States launched the communications satellites Score which simply transmitted pre-recorded messages from space.[1368] Ever increasing number of satellites, initially experimental and later operational, was launched in the following years with the intention of establishing a comprehensive communications system in space. To solve the complex problems of command and communications which might arise in the event of a world war, the United States set up a truly world-wide satellite communications network providing secure and effective radio communications, between central commands and military units deployed in any, even the most remote, part of the world. The system would have to be immune to atmospheric disturbance, local interference and, above all, jamming and deception (ECMs).

At distance of 36,000 kilometers, each satellite in this communications net is in geostationary orbit, that is, it is apparently motionless above a fixed point on the Earth's surface. Each covers an area equal to a third of the Earth's and special techniques are employed to reduce the susceptibility of the signals transmitted to all forms of interference and jamming. Today, this system ensures immediate radio contact between two military commands separated by thousands of miles with the same clarity and efficiency as radio contact between two ships a few miles apart. It has also solved the problem of transmission of orders to submarines armed with Submarine Launched Ballistic Missiles (SLBM) with nuclear warheads, such as "Trident" and "Poseidon"; these from a vital part of the U.S. nuclear reprisal "triad", the other two "prongs" being Inter Continental Ballistic Missiles (ICBM) and manned bombers. The problem, for which traditional communications had been unable to offer a stationary solution, was to ensure that these submarines would receive their nuclear orders with absolute certainty but without themselves having to transmit radio signals, which carried the inherent risk of interception.[1369]

Since launching ballistic missiles from submarines requires extremely accurate knowledge of the pieces launch position, which no navigation system then in existence was able to provide, the Americans decided to use satellites to provide precision navigational information. The first satellite of this type, called Navy Navigation Satellite System (NNSS-Transit) was sent into orbit in 1960 and fulfilled most the requirements of U.S. nuclear submarines.[1370]

The United States has recently been deploying a navigation system called NAVSTAR Global Positioning System (GPS) consisting of twenty four satellites in orbit at a distance of about 20,000 km from Earth which continuously emit special signals enabling ships, aircraft, or even infantry equipped with special receivers to fix their position with amazing accuracy–a margin of error of about ten meters![1371]

It is, however, in the fields of photographic and electronic reconnaissance and Early Warning that artificial satellites have proven most useful for military purposes. The Americans sent the first reconnaissance satellite, Discoverer, into orbit in February 1959. It represented a completely new way of conducting reconnaissance since aerial photographs of enemy territory were taken without direct human intervention and from a distance far beyond the range of any weapon on Earth.[1372]

The serious episode of shooting down of Captain Francis Powers' U-2 spy-plane over the Soviet Union in 1960 was largely responsible for convincing the U.S. administration of the need to speed up development and production of this type of satellite in order to be able to proceed in safety with the task of gathering precious and indispensable information for EW which had previously been accomplished by means of missions such as that being carried out by Powers.[1373]

Since then, thousands of increasingly sophisticated and varied reconnaissance satellites, commonly known as spy-satellites, have been launched, mainly by the Americans and the Soviets. In May 1972, in the course SALT 1 (Strategic Arms Limitation Treaty) negotiations, a special agreement was reached between the Russians and the Americans–the so called "open space" agreement–so that, today, reconnaissance satellites are one of the few internationally accepted means of acquiring information. Such use is accepted for "verification" of the SALT and START treaty provisions.[1374]

Spy-satellites have similar functions to those of U-2 spy-planes. Both carry high-resolution photographic cameras as well as equipment for intercepting and recording electromagnetic emissions present in the skies of potentially hostile countries i.e. all communications and radar signals emitted by the electronic devices of these countries. The difference lies in the fact that, while the U-2 brings the films and rape recordings back to Earth, the satellites transmit the pertinent data, duly coded, directly and instantaneously back to the receiving stations for immediate analysis, facilitating "real-time" appreciation of the information.[1375]

Reconnaissance satellites are placed into various types of orbit, the duration of which depends on the type of reconnaissance to be carried out. When their particular mission comes to an end, they disintegrate and burn-up on re-entry to the Earth's atmosphere.[1376]

For improved coverage, two satellites are often launched simultaneously into parallel orbits but at different heights, the satellite in the lower orbit photographing an enemy radar installation, which the one in the higher orbit had discovered, by interception of its electromagnetic emissions. Spy-satellites have also been launched which, after having picked up the signal of a hitherto unknown radar, are able to reposition themselves lower during later orbits to the optimum altitude for taking photographs.[1377]

In recent years, the series of U.S. reconnaissance satellites has shown continuing technological and operation progress. One of the first reconnaissance satellites used by the United Sates was the Satellite and Missile Observation System (SAMOS). Until a few years ago, SAMOS satellites were launched in great secrecy by an Atlas rocket at monthly intervals into orbits, which crisis-crossed the skies over the Soviet Union. At set time, the satellite containing exposed film and the tapes of EMG signals, which had been recorded, expelled special capsules. Slowed by deployment of little parachutes, these fell in a preselected zone in the Pacific Ocean where they picked by the numerous U.S. warships standing by to pick them up. However, there were always large numbers of Soviet "fishing travelers" (i.e. spy ships) also waiting in the same zone where the capsules were to be dropped and so the Soviets sometimes managed to get their hands on the material before the Americans! For this reason, aircraft were adapted for aerial pick-up of the cassettes for more secure recovery of the material.[1378]

Besides the SAMOS satellites, the Americans also used MIDAS (Missile Detection Alarm System) satellites, which were fitted with numerous IR sensors for IR surveillance of the Soviet Union. Every time the Soviets launched an experimental ballistic missile, the MIDAS satellites automatically picked up the IR energy emitted by its engines.[1379]

Later, an even-more sophisticated satellite was developed, called Big Bird, which weighs over 11-tons. Big Bird's incredible operational performance has enabled the United States to keep track of the latest technical and operational developments of a military nature in the USSR and other potential enemies. The Big Bird is able to take exceptionally clear photographs, develop them and transmit them to Earth in code. It can also carry small electronic reconnaissance satellites, which are expelled and placed in independent orbits to record the emissions of any new radar, which are discovered.[1380]

On May 11 1982, a Big Bird was launched from Vandenberg Air Force Base in the U.S. into an elliptical orbit of 169-257 km and a polar inclination of 94.4 degrees. This provided vital information, which was passed to the British during the Falklands conflict. Observation of Argentine troop movements, tracking of Argentine naval units and surveying via high resolution camera of possible sites for a British landing (including the actual site at San Carlos) were all undertaken, and the results passed to the U.K. where the data was transmitted in "real time" to the British Task Force via satellite link to their Shipborne Scot Skynet terminals. [1381]

The Americans have stationed an ELINT reconnaissance satellite of type Ryolite in geostationary orbit at an altitude of about 36,000 km and directly above the Soviet missile test range which runs from the launching complex at Tyuratam to the landing area in the region of the Kamchatka Peninsula.[1382] Its IR sensors are alerted to a launch by the heat emitted. They also operate "listening posts", installed under agreement with people's Republic of China, at Korla and Qitai in mountainous region of Xinkiang in Northwest China, as well as their stations at Shemya and Adak in the Aleutian Islands. All of these are intended to gather telemetry signals on Soviet missiles tests; such signals contain data on missile performance, warhead or multiple warheads, and Circular Error Probable (CEP) i.e. accuracy.[1383]

In another category in the U.S. inventory are Early Warning Satellites whose main task is to prevent the possibility of surprise attacks. To this end, they carry a variety of ultra-sensitive sensors capable of discovering nuclear explosions in any part of the world, detecting the launching of ICBMs, undertaking passive IR surveillance of any source of IR energy, including explosions, fires and new, sometimes disguised industrial plants, and carrying out oceanic surveillance. The latter activity consists of keeping track, even in peacetime, of the movements of hostile or potentially hostile ships and submarines all over the world. Ocean surveillance satellites use IR detectors and other types of sensors.[1384]

The Soviets Union also carried out similar missions in space, their undertaking the same activities as those of the American's. Nearly all those for military use were named Cosmos, their exact functions and purposes not being specified. The Soviets have launched over one thousand Cosmos satellites in the last four decades. They are of widely differing sizes and cover a wide range of functions: some have also been used for scientific research such as exploration of the high strata of the atmosphere and outer space and measurements of the Earth's magnetic field, and solar radiation. However, most Cosmos satellites are for scientific military purposes. Those for reconnaissance are sent into orbit from the missile ranges of Tyuratam, Kapustin Yar and Pelsetsk and usually carry small capsules, which are ejected after a few days. Some of these satellites are fitted with a motor, which enables them to maneuver over objectives to be explored and move in, or away as necessary.[1385]

The Russians, like the Americans, make sure that precious little information regarding their military satellites leaks out. Nevertheless, it is possible to deduce the target zone of their reconnaissance from their orbital inclination (i.e. the angle between the plane on which the satellite's orbit lies and the plane of equator). It is also possible, by statistical analysis of the number of satellites launched, their launch dates and other features which cannot be kept secret, to make valid predictions about their tasks and equally valid inferences of a political and military nature.[1386]

Nearly all satellites launched by the Soviets flew over the United States and USSR. It can therefore be presumed that, besides photographic equipment, they are also equipped with receivers, which pick up all electromagnetic signals held to be of interest.

During the Indo-Pakistani war in 1971, the Soviets launched two Cosmos reconnaissance satellites to follow operations in that part of Asia. During the Arab-Israeli War in October 1973, they launched two Cosmos satellites to carry out photographic and electronic reconnaissance for the Egyptians and later launched another five to check that the cease-fire conditions were being observed and Israeli forces were being progressively withdrawn.[1387]

At least a hundred of the Cosmos satellites launched so far have been for electronic reconnaissance in general and to gather electronic information on NATO radars in particular. Like the Americans, the Russians use some of their Cosmos satellites to maintain a constant watch on the various U.S. fleet (the seventh in the Pacific, the sixth in Mediterranean, the second in the Atlantic, etc.) and to monitor their positions in order to be able to guide their destructive weapons against them in the event of war. These satellites often have nuclear-powered radar as proved to be the case when fragments of Cosmos 954 fell in Canada, causing great alarm at the prospect of nuclear contamination.[1388]

Both during and after the Russian intervention in Afghanistan and the U.S. raid in Iran to free the hostages, the Soviets launched numerous reconnaissance satellites, the last ones being Cosmos 1179 and 1180, sent into orbit in May 1980. Cosmos 1180, unlike its predecessor, which were obviously for reconnaissance over the Middle East, aroused considerable curiosity and suspicion as its parameters (e.g. inclination of orbit) were unlike anything seen before.'[389]

Soviet activity in this field was extremely varied and has included the most amazing missions of electronic espionage. For example, a Cosmos satellite was kept in orbit over Iran for a few years before the Islamic revolution, receiving information transmitted by undercover agents in Iran regarding troop movements and upon defensive installations along the border with the Soviet Union. This activity was brought to a halt when the Iranian counter-espionage service arrested a Soviet agent who was caught red-handed transmitting such information via radio directly to the Cosmos satellite.[1390]

According to U.S. sources, there was a similar case in San Francisco, California in a zone where the EW industry flourishes. Since the companies operating there are forever coming up with new sophisticated equipment, the Soviets decided that it would be a good idea to send a Cosmos satellite into orbit over California to get information regarding such developments directly from source. They were caught after all. [1391]

On the roof of their consulate building in San Francisco, the Soviets installed extremely sophisticated electronic devices capable of picking up even the weakest radio signals. In the southern part of the city several miles away from the Consulate building, is the so-called "Microwave Tower" where a radio repeater system is installed. This is used by the various local electronics companies to exchange communications regarding research, development, production and testing of new special microwave components, such as semi-conductors, and TWTs (Traveling Wave Tubes), which, in their respective technological fields, are the most advanced in the world. Technicians at the Soviet Consulate recorded all these communications, with their precious information on the construction of EW components and equipment. The data was prepared and then passed on to a KGB agent who, using a special portable transmitter, transmitted this information, analysis from locations a good distance away from San Francisco, directly to the satellite, at pre-arranged times. The electronic companies finally discovered the "leak" and applied a series of ECMs to prevent further Soviet interception.[1392]

There have been many cases of industrial espionage, a common activity nowadays thanks to satellites and their EW equipment. The "computer war" or "information warfare" is another example, although little is said about it as few people realize how vulnerable computers are to ECMs. Many large industries use computer centers to solve design problems; satellites are often used as data-links between companies and distant computer centers, often internationally. By intercepting these communications, which are often inadequately coded, it is possible to gain access to an incredible quantity of data regarding plans, which are often secret, for the research and development of defense systems in various countries.[1393]

Of course, every type of U.S. satellite has its Soviet counterpart. There are also Soviet satellites whose functions are totally unknown in spite of being kept under constant observation by the Americans. However, the Soviet satellites are, on the whole, less technologically and operationally advanced than the American satellites and have so far had a shorter "operational life".

Soviet military leaders decided to circumvent the obstacle of U.S. satellite superiority, which would have given the Americans a decided strategic advantage in the event of war, by embarking on an intensive program to develop anti-satellite weapons. Bearing in mind the natural vulnerability of space vehicle, the Soviets designed and developed a new type of satellite capable of attacking and destroying any hostile vehicle in space. Special techniques were also devised for rapid interception, neutralization, or destruction of enemy military satellites, especially the USA's "Early warning" satellites which are responsible for detecting ICBM launchings.[1394]

The first Soviet experiments in this field took place in 1968. On October 10, Cosmos 248 was sent into orbit, followed ten days later by Cosmos 249, launched from the Soviet missile range at Tyuratam. Under full ground control, Cosmos 249 was launched into an orbit to intercept Cosmos 248 and then maneuvered close up to its target, at which moment it was exploded, gravely damaging Cosmos 24. Thus the first "satellite-killer" or "anti-satellite" was born.[1395]

After that, the Soviets have made at least another fifteen test interception in space, all closely monitored by U.S. space command and control stations. As soon as the Americans realized that the Soviets were in the process of devising a satellite-killer system capable of eliminating their surveillance and communications satellites and thus putting at risk the U.S. nuclear deterrent, they immediately set about trying to remedy the situation. First, they built satellites with a special protective armor to defend them from the fragments produced by the explosion of Soviet satellite-killers. They also sent satellites into much higher orbits, which the Soviet satellite-killers were unable to reach.[1396]

For a few years the Soviets made no further experiments, perhaps to evaluate the results of tests, which had been carried out; when they recommenced their test program, a new technique was used. The interceptor-satellite, after making a few orbits, was brought in close to the" victim-satellite", which it would track, traveling at the same speed but in a slightly lower orbit. Over a long period of time, the victim satellite was kept under observation in order to find out and transmits to Earth details of its function and main characteristics. Then, the interceptor would be guided towards the lower strata of the atmosphere where it would disintegrate. This new method, which the Soviets began to adopt in 1976 and which obviously did not have the aim of destroying the victim satellite, was probably connected with experiments on new laser weapons.[1397]

At first, Soviet satellite-killers only intercepted other Soviet satellites, such as Cosmos 803, which was intercepted by Cosmos 604 on 16 February 1976 and by Cosmos 814 on 13 April of the same year. It is almost certain that another satellite-killer, Cosmos 843, sent into orbit in 1976, failed to intercept its target, Cosmos 839. On 27 December 1976, Cosmos 866 was clearly observed approaching its target, Cosmos 880, up to distance of less than 2 km.[1398]

However, the following year there was growing concern in the United States over the fact that the IR sensors of two USAF satellites, used for retransmission of data required for wartime operations by Strategic Air Command's bomber force, were often temporarily blinded, especially when flying over Russia. On two occasions, 18 October and 17 November 1977, these two satellites, as well as other U.S. Early Warning satellites, were put out of action for almost four hours. CIA experts suspected that this black-out was due to deliberate jamming by the Soviets using a laser, either based on the ground or on a killer-satellite which they were testing.[1399]

The Russians continued their anti-satellite test in 1977, using increasingly sophisticated techniques. The target-satellite Cosmos 909, established in an orbit nearly 2000 km high, was intercepted first by the satellite-killer Cosmos 910 on 23 May and then by the Cosmos 918 On 17 June. The latter, launched on17 June 1977 from the Tyuratam range, was first placed in a very low orbit but subsequently maneuvered into a much higher orbit to intercept the target-satellite Cosmos 909 at the same altitude as many U.S. navigation and reconnaissance satellites. After interpreting, both Soviet satellites, the interceptor and the target, flew closer together for a while and then headed downwards to disintegrate in the denser strata of the atmosphere.[1400]

Also in 1977, sixteen Soviet Cosmos satellites were launched as part of a space program officially intended to measure the dimensions of the Earth and to make a more accurate study of the movements of the Poles and the so-called continental-drift phenomenon. However, according to U.S. experts who observed the orbits of these satellites, their real functions were quite different. It would seem that the aim of most of these missions was to acquire precise data regarding the position of important targets in the United States and Europe so that, in the event of war, similar Cosmos satellites could be used to guide Soviet ICBMs to these targets.[1401]

Other missions were set up to test new techniques for intercepting, approaching and destroying the enemy satellite and then effecting re-entry. The technique of detonating the satellite-killer itself to destroy the enemy satellite was abandoned by the Soviets, perhaps because it was necessary to maneuver the interceptor-satellite into very close proximity to its target and in very few of the experiments did they manage to get closer than 1 km. Given the total lack of atmosphere, an explosion in space causes no shock-wave effect which is what causes the most damage in explosions within the atmosphere. Consequently, the Soviets changed the direction of their research to "soft-kill" methods of satellite neutralization. ECMs were tried out to ground command transmissions to satellites essential for keeping them in the desired orbit or to deceive the satellites by giving them false commands to descend into low atmosphere where they would burn up. However, it would seem that these systems have now also been abandoned because the Americans have equipped their satellites with ECCMs, including coding of commands and incorporating anti-jamming and anti-deception devices.[1402]

In the belief that, for certain purposes neutralization is just as effective as destruction, the Soviets have developed new methods to be used after the satellite-killer has approached its victim, possibly in that part of the orbit which cannot be observed from enemy Earth stations. One such method involves the use of manned-spacecraft, whose crew actually boards the enemy satellite. The astronauts leave their spacecraft and render vital parts of the satellite inoperative, either directly or by remote control, using various types of radiation or corrosive chemical substances, or even removing vital parts without which the satellite's functional efficiency would be greatly degraded. Finally, small rockets can be attached to the satellite either to accelerate it and thus send it into a more distant orbit or to slow it down and thus allow the Earth's gravity to drag it into the lower strata of the atmosphere where it will burn up.[1403]

Fearing that Soviets, in the event of an impending conflict, would neutralize enemy satellites in orbit, the Americans, initially, developed a series of jammers to counter an electronic attack. However, the task of jamming satellites in orbit is fraught with technical problems, which cannot easily be solved, and so they finally opted for passive ECMs such as chaff and false IR targets capable of deceiving a killer satellite.[1404]

The sphere of ECMs in space is not limited to anti-satellite operations; however, it has also begun to embrace the study of possible actions against ballistic missiles. Generally speaking, it can be assumed that many EW actions carried out in the atmosphere against radar and IR guidance systems would also function in space against the sensors of a ballistic missile, or, more precisely, against its nuclear warheads which, in the last phase of the trajectory, separate from the missile carrier. Deception has become a factor of growing importance in ICBM tactics for both offensive and defensive purposes. Experiments have been carried out using IR-guided missiles against ICBMs in the phase when the ICBM is still under rocket propulsion. The anti-missile, by homing onto the heat produced by combustion of the ICBM's "booster", may cause it to explode permanently. In the United States, anti-ICBM experiments have already been carried out in the atmosphere.[1405]

IR decoys have proved to be particularly effective for protection against ICBMs. By creating powerful sources of IR energy of the same wavelength as that sought by the powerful lasers against U.S. satellites and ballistic missiles in space. to avoid the degrading effect that the atmosphere has on the laser-beam, small lightweight laser-weapons were under development for use on board spacecraft against enemy satellites.[1409]

In the light of this new information concerning Soviet progress in the field of applied high-energy physics, the Americans concluded that the temporary black-outs of their satellites in October and November 1977 has been caused by Soviet experiments with high-energy laser weapons in space. This confirmed their fears that the Russians had, in fact, acquired the ability to temporarily neutralize their satellites. Moreover, U.S. industry had not yet managed to develop any valid electro-optical countermeasure (EOCM) capable of intercepting and neutralizing even a normal laser beam, mainly because of the high directionality of the beam itself.[1410]

As if this was not enough, U.S. satellites then confirmed that tests had actually been carried out using a compact hydrogen-fluoride laser, capable of neutralizing an enemy satellite at a distance of 1 km, at the large research center of Krasnaja Pahka, 50 km south of Moscow. Moreover, preparations were being made to launch a similar laser-weapon on board a spacecraft. According to U.S. officials, one such experiment had already been carried out from the manned Soyuz spacecraft.[1411]

Faced with such evidence, the Americans realized that they were at least ten years behind the Russians in the field of killer satellites. Pentagon leaders came to the conclusion that the United States could not allow the Soviets to acquire and maintain a dominant position in space or use their superior anti-satellite capabilities during an international crisis or in a direct confrontation to prevent the United States from using that vital element in their military system consisting of satellite for surveillance, early warning, navigation and communications.[1412]

In an attempt to gain time needed to complete their own research and development program in this field, the Americans proposed negotiations with the Russians to suspend test, on anti-satellite weapons. Thus, on June 8, 1978, representation of the two Superpowers sat around a table in Helsinki to discuss the problems of satellite warfare in space.[1413]

However, whereas the Americans came to the negotiating table full of proposals and good intentions, the Soviets, on the other hand, arrived strong in the knowledge that their experiments with satellite-killers were proceeding successfully and that they were in the advanced stages of researching–in addition to high energy lasers–an extremely powerful and fantastic new weapon called a Charged Particle Beam (CPB). Of course, under these circumstances, no agreements were reached and the negotiations were postponed indefinitely.[1414]

Soviet experimentation on the various systems for destroying or neutralizing enemy satellites went on uninterrupted throughout 1979 and 1980 with great success. However, the Russians did not announce the news of this success. According to U.S. intelligence sources, in mid-March 1981, a Russian Cosmos satellite-killer had managed to completely neutralize the photographic, IR and electronic equipment of a U.S. target-satellite, probably by means of a high-energy laser. The U.S. report also suggested that the satellite-killer had employed special IR sensors to home onto its victim.[1415]

The Russians have never issued any information about experiments on their new CPB weapon either but numerous significant events related to such experiments were revealed by U.S. spy-satellites orbiting over the areas where the experiments were carried out. It would seem that the new weapon, based on the principles of charged particles physics, is even more powerful than the high-energy laser. The difference between the two lies in the fact that whereas laser users photons, which do not have mass, the CPB weapon emits a stream of relatively heavy sub-atomic charges, such as electrons, with a negative electrical charge, and protons, with a positive electrical charge, at a speed close to that of light. These jets of energy do not melt the target as a laser but smash it to smithereens. In other words, the CPB weapon works by thrusting the basic atomic particles of which matter consists–protons and electrons–at extremely high speeds against the target, which is destroyed by the kinetic energy concentration and connected thermal effects. In effect, it is a kind of electronic gun, of unprecedented power and rather unusual shape, which emits pulses of jets of energy of the order of hundreds of billions of electron volts.[1416]

A CPB weapon is built by means of an" accelerator" plant, a power generator, particle injectors and extremely high capacity condensers capable of storing very high power levels. Such machinery is generally very large and exceedingly complex.[1417]

On the ground, such a weapon would have a range of only 5 to 10 km due to atmospheric absorption but, if it could be installed on an artificial satellite and operated in space, its range would be increased to many hundreds of kilometers. The Russians probably first tested electron beam-emitting devices in space during the missions of Cosmos 728, launched in April 1975, and Cosmos 780, launched in November 1975.[1418]

News of the Soviet development of these weapons first reached the rest of the world in 1975 when a U.S. surveillance satellite detected the presence of large quantities of gaseous hydrogen containing traces of tritium in the higher strata of the atmosphere over Semipalatinsk in central Asia. This element is one of the necessary ingredients for creating charged particle beams.[1419]

U.S. satellites also revealed that the Russians had transported a new, more powerful magneto-hydrodynamic generator to their research center at Azgir in Kazakhstan near Caspian Sea for testing. This pulse-function generator would be able to supply the necessary power to operate a CPB weapon. A U.S. electronic surveillance satellite orbiting over the Indian Ocean further revealed that a prototype of the weapon had been tested in a desert in the Azgir area.[1420]

The Americans have so far detected at least eight experiments on the propagation of particle beams in the ionosphere and outer space from manned space vehicles such as the Soyuz and unmanned Cosmos satellites. Observations have also been made of a series of experiments connected with the propagation of CPB against targets at the missile range of Sarrova, near Gorki, to determine the effects of such propagation. Experts consider such tests to be the prelude to the development of a CPB weapon for use against ballistic missiles. Sarova, with its ultra-modern equipment for accelerating electrons, is held to be the headquarters of this research and development program, which is directed by Professor M. S. Rabonovich of the Lebedev Institute in Moscow. A new accelerator has recently been built at Sarova and its extremely high power may eventually be used for the development of a proton beam weapon. The construction and testing of this accelerator were carried out under the direction of the physicist A. J. Pavlovskij.[1421]

Following these revelations, another discovery has been made regarding Soviet activity in the field of radiation arms. In early 1978, high levels of thermal radiation and the presence of nuclear waste discharges were noticed coming from the experimental plants at Semipalatinsk. These factors would seem to indicate that experiments to perfect the power sources for CPB weapons were being carried out. It has also been confirmed that an enormously powerful pulse generator has been built in a top-secret zone near Sary Shagan to be used as a source of energy for such weapons.[1422]

The technical difficulties connected with the development and installation of a weapon this kind on a space vehicle are so great that considerable perplexity has been expressed by U.S. authorities about the usefulness of spending so much money on a weapon which would seem to be so difficult, if not impossible, to develop. Nevertheless, the report by the Chinese authorities, mentioned previously, according to which many Chinese soldiers had been hospitalized for eye and brain lesions during the war with Vietnam, could be considered indirect proof that the Russians had already reached the stage of testing radiation arms in a real conflict while the Americans were still talking about them. Alarmed by such information concerning Soviet progress in the field of arms based on "non-conventional" technology, the Americans overcome their initial skepticism and stepped up research, both in the field of high energy physics and in the field of charged particles, so as not to lose this particular race in which so much is at stake: the ultimate objectives go way beyond battles between satellites and could even be said to be part of a design for world hegemony.[1423]

Both CPB and high-energy laser weapons could theoretically be used to intercept ground-launched ICBMs, or SLBMs (Submarine Launched Ballistic Missiles), with nuclear warheads, and destroy them in space.[1424]

A further development in the technology of particle physics involves an even more powerful device, which could be used to generate particle beams from spacecraft and transmit extremely high levels of radiation to Earth with effects similar to those produced by neutron bombs. In other words, with suitable power levels, charged particles could be propagated through the atmosphere to produce a radiation cone, which would have lethal effects on populated areas.[1425]

On the basis of experience acquired in the meanwhile, the Americans decided to carry out a crash program in an attempt to make up for lost time. Plans drawn up by each of the armed forces have been examined on the basis of which a unified plan has been laid down, which has two main directions: one, conventional weapons, and the other, newly-conceived systems.

Regarding the former, satellite-killer are to be developed with similar capabilities to those tested by the Russians. One such system involves a series of small self-propelled semi-satellites, ejected from another spacecraft and guided onto their targets by an on-board IR seeker, which would exploit the difference in temperature between the metal of the satellite and surrounding space. Another development for self-defense from space attacks would be to increase the maneuverability of satellites or ICBMs to enable them to avoid interception (MRV: Maneuverable Re-entry Vehicles).[1426]

Weapons of new conception are those, which utilize new, very advanced technology related to high-energy physics and particle physics. High-energy laser weapons and CPB weapons are grouped together under the heading of "radiation arms" or directed-energy arms'. The ultimate objective of the U.S. program for the development of such weapons, called "Talon Gold Program", is to create a defense against ballistic missiles in space using high-energy lasers which would be installed on spacecraft or space stations, Research in this new field is carried out at the Livermore Laboratories in California and at Los Alamos in New Mexico.[1427]

In the summer of 1977, it was officially announced in the United States that a high-energy laser weapon had for the first time destroyed a missile-target (a NIKE-Hercules) in flight. The weapon used a fluoride deuterium laser emitting very high power IR energy at a wavelength of 3.8 microns. Nevertheless, the Americans were well aware that the Soviets were about ten years ahead of them also in the use of high-energy laser weapons in space. in an attempt to bridge this dangerous gap, they embarked on a program of research and development of suitable electronic and electro-optical countermeasures capable of neutralizing these new radiation weapons, the mere possession of which was enough to upset the balance of military power, both strategic and tactical.[1428]

Plans for the development of radiation weapons drawn up by the U.S. armed forces followed different paths according to the specific sector of possible military applications of such weapons. Beside their potential use against ICBMs and satellites, plans have also been made for their use against landmines, torpedoes, attack and strike aircraft and tanks. The CPB must concentrate enough energy on its target to detonate the high explosive in a nuclear warhead, torpedo warhead or landmine; against metal targets, such as aircraft, spacecraft, satellites and tanks, the Americans aim to develop a CPB which would produce enough heat to destroy all electronic equipment on board immediately, and then, as the weapon closed up to the target, also seriously damage the metallic structure itself.[1429]

While the Americans were struggling against the many bureaucratic difficulties, which hindered the development of their program, the Soviet Union reached a milestone in its work on radiation weapons. In September 1979, an electron beam was tried out against various military targets, including an ICBM, solid materials and high explosive, with complete success. These tests, which were carried out near Leningrad, may turn out to have been the prelude to operational use on the battlefield of the prototype of a weapon exploiting such a beam.[1430]

Besides the technical and industrial difficulties involved in developing these new, unconventional weapons, there is also the problem of transporting them into space, given their huge dimensions and enormous weight. With the launching and subsequent re-entry of the U.S. Space Shuttle *Columbia* in mid-April 1981, the Americans took a giant step forwards in solving this problem in particular, as well as, more generally, in the "space race" with the Soviet Union.[1431]

Re-usable spacecraft like the *Columbia* have a great load capacity and, besides being able to transport laboratories, telescope and satellites of all kinds, they can also carry out several military functions. They can be used to transport heavy radiation weapons, such as high-energy lasers and CPBs, intended to destroy enemy satellites or ballistic missiles, and powerful EW equipment such as jammers and deception jammers, capable of blinding enemy surveillance satellites or deviating enemy ICBM in the event of war. Confirmation of the potential military use of the Space Shuttle by the Americans is provided by the fact that at least twenty-one of the sixty-eight missions scheduled for these spacecraft have been classified by the Pentagon as top secret.[1432]

In March 1983, the U.S. President, Ronald Reagan, in his famous "Star Wars" speech, officially announced a new Defense doctrine based on space-age weaponry. He said that the United States would abandon the old strategy of détente achieved through the threat of massive nuclear retaliation and would pursue a new strategy based on the ability to prevent nuclear war. It would be a defensive strategy employing weapons designed to intercept and destroy incoming enemy missiles. These weapons would be "directed-energy" weapons–high-energy lasers in particular. Since the technology needed for such a strategy does not yet exist, he appealed to the North American scientific community to dedicate their efforts to the creation of an anti-missile defense system, which would render nuclear weapons impotent and obsolete.[1433]

According to experts, this project will involve deploying eighteen space stations into orbit, each equipped with high-energy lasers and revolving in three polar orbits; it could, they opined, be put into operation during the 1990s. If successful, this project would provide the means to neutralize a mass attack of enemy ICBMs launched from any point on Earth. The designed operational range would be 5,000 miles. Each station would be able to direct approximately 1,000 laser-pulses on as many targets and would comprise a sophisticated target detection and acquisition system, a very high power laser, a large mirror to focus the laser beam onto the targets and a target aiming and tracking system However, the project has failed.[1434]

For each shot, the laser will emit a power of approximately to MW (Megawatts) for a period of only to seconds. Lasers developed so far have achieved a MW and projects for 5 MW are underway. In the next twenty years, when new lasers and powerful electronic beams pass from the research to the developmental stage, it seems likely that powers of the order of 10 MW will be feasible. However, the major problem is aiming and focusing the beam on target, as the accuracy required is 1 meter from range of 10,000 kms. This laser beam would require orbiting mirrors 10 meters in diameter and the development of sophisticated microwave search systems and laser aiming systems. A high technology program is already underway in the United States with the purpose of solving this problem.[1435]

In April 1983, the Space Shuttle *Challenger*, the second of four operational "Orbiters" was sent into orbit. It transported a TDRS-A (Tracking and Data Relay Satellite) which was launched some days later. During the mission, two members of the crew carried out extravehicular activity lasting 3.5 hours on the fourth day.[1436]

In February 1984, *Challenger*'s crew gave a successful demonstration of NASA's Manned Maneuvering Unit (MMU). The untethered spacewalks made by U.S. astronauts Bruce McCandless and Bob Steward, who each used the MMU on two separate occasions, demonstrated that it is possible for men to approach enemy surveillance satellites for the purpose of destroying them or degrading their performance. The fantastic achievement of the two U.S. astronauts has opened a new frontier in what human kind can do in space and paved the way for many important operations in future space Electronic Warfare.[1437]

NASA has stated that they plan to have a permanent space station operating by 1991. This manned base will have a crew of six to eight persons, with computers controlling each task. It would evolve over many years and see many cycles of technology and utilization. One such utilization will be the setting up of an Electronic Warfare Command and Control.

For most of us, space stations belong to the realm of science fiction exemplified; perhaps, by memorable sequences from the film *Star Wars*, but such fantastic things are fast becoming a reality. The Superpowers are already studying future electronic combat in space and 1991 is not far away. The era of space fiction is over; it has become a reality and a sort of electronic "star wars" could be what the future holds in store–a Space Shuttle fleet, fitted with high-energy laser weapon systems patrolling the "skies" ready to intercept and destroy enemy ICBMs still in their booster phase. The Russians, as has been devoting great efforts to developing technology related to "directed-energy" weapons and recent U.S. secret intelligence report on the Soviet laser program stated that the Soviet Union would be able to deploy a space-based high-energy laser weapon station as early as 1988.

The biggest drawback to orbiting laser weapons seems to be their vulnerability to countermeasures. It is fairly easy to envisage how to jam a space acquisition or aiming system even with today's technology. A couple of stations put out of action either by failure of their equipment or enemy action would nullify the effectiveness of the whole system and remove the "space-umbrella", allowing enemy ICBM to rain down.

There are two kinds of countermeasures applicable in space warfare countermeasures against the platforms or space-stations (Shuttle, Soyuz, satellites, etc.) and countermeasures against "directed-energy" weapons. Both require threat-warning receivers for immediate detection of enemy radar, laser or IR source (booster, exhaust, etc.). Against the platforms, similar ECM equipment to that used on Earth could be employed: on board jammeis and expendable jammers, chaff, IR flares, radar absorbing shields, and so on. Against the laser decoys, mirrors and space mines could be used–or any other electro-optical countermeasures (EOCM), which may emerge from technological progress. Thus, a sophisticated laser antimissile system of astronomical cost could be put out of action by countermeasures costing much less. However, it is likely that, to compensate for this inherent weakness in electro-optical (EO) weapons, their vulnerability to EOCM, efforts will be devoted to finding effective EO counter-countermeasures (EOCCM).

It is not now so farfetched to suppose that one Superpower, were it to acquire the ability to destroy enemy satellites and ICBMs in space before the other and thus become virtually invulnerable to a preemptive nuclear strike, might be induced to launch a nuclear attack against the other and destroy him.

Apart from this pessimistic hypothesis, it is, nevertheless, likely that, in future theoretical crises, space will provide the perfect arena for a show of strength by the most technologically advanced Superpowers in these new fields of military art and the connected branches of applied science. In other words, a challenge could initiated in space between spacecraft, satellites, ICBMs and "radiation-weapons" in which the Superpower in possession of the more effective "radiation-weapons" could destroy all enemy weapons and equipment, thus proving their potential to destroy the enemy on Earth also. In this way, without killing people or violating territorial borders, a crisis could be resolved in favor of the Superpower in possession of what many people today consider to be the "absolute weapon", capable of winning any conflict.

However, it is unlikely that either the high-energy laser or the CPB weapon will prove to be the" absolute weapon". The idea of an "absolute weapon" has always been a myth and is likely to remain so since, as the events described in this book have shown, as soon as a new weapon is developed, appropriate countermeasures are immediately devised to engage it and neutralize its effectiveness.

The classic struggle between the lance and shield, the gun and armor, the missile and electronic countermeasures will no doubt continue between radiation weapons and radiation countermeasures and between these countermeasures and relative counter-countermeasures and so on ad infinitum. Such is the nature of Electronic Warfare.

From Star Wars to the Gulf War:

Consolidated and crisis marked the decade of the 1980s for the Air Force in the space arena. On the one hand, the newly-created Space Command led the development of an operational focus that involved the shift from consolidating control over space systems to making space systems central to the needs of the warfighter. On the other hand, the space launch crisis at mid-decade led to reexamination of the Space Shuttle's promise and the future military agenda in space. Both developments contributed to the growth and maturity of the operational mindset needed to apply space assets effectively under wartime conditions. By the end of the decade, champions of space could, with justice, point to what they termed the new "operationalization" of space. War in the desert would provide the test.

Buoyed by the new Reagan administration's emphasis on building a strong defense, Air Force leaders anticipated a major effort to develop and apply space systems to meet operational requirements. The Air Force's Space Command would chart the course. Created in late summer 1982, the fledgling command would face a difficult path over the next decade. Although designated the focal point for operational space issues, its experience proved that traditional interests and a fragmented space community could not be overcome immediately. Research and development authorities were especially reluctant to relinquish management responsibility for space systems that they considered best operated by their own more experienced units. Establishing consensus on proper space roles and missions both within and outside the Air Force presented a challenge for space operators – one they had yet to completely achieve by decade's end. The victory of the operators in 1982 provided only an initial achievement in the struggle to move space out of the shadow of research and development and into the realm of the warfighter.

Space Command Sets an Operational Agenda

The formation of Space Command on 1 September 1982, the first major command created by the Air Force in thirty years, represented both an end and a beginning. At long last space advocates had convinced the Air Force community that space deserved representation among the operational commands. In an increasingly complex arena, the ad hoc management methods that had resulted in a fragmented space community could no longer be justified. On the other hand, establishing a space command proved only a point of departure.[1438]

Space Command began auspiciously with the transfer from the Strategic Air Command (SAC) in 1983 of fifty space and missile warning systems, bases, units, and upgrade projects. The initial list included Peterson Air Force Base, Colorado, location of the command's headquarters, as well as Thule and Sonderstorm Air Base in Greenland and Clear Air Force Station in Alaska. Space Command also would own Falcon Air Force Station, located near Peterson and designated the future home of the Consolidated Space Operations Center (CSOC). By early 1984 SAC also had relinquished four major space systems, two operational – the Defense Meteorological Satellite Program (DMSP) and Defense Support Program (DSP) – and two in the development and acquisition phase – the Military Strategic and Tactical Relay System (Milstar) and Navstar Global Positioning System (GPS).[1439]

DMSP. The transfer of the Defense Meteorological Satellite Program from Strategic Air Command to Space Command in 1983 in itself represented an evolutionary shift from strategic to tactical operational applications.

DSP. Space Command also gained operational control of the Defense Support Program, the central element in the nation's space-based early warning system that monitored missile launches and nuclear detonations.

Milstar. In 1983, Space Command received management responsibility from SAC for the extremely high frequency (EHF) joint-service Military Strategic and Tactical Relay System (Milstar) program, then in the early stages of satellite concept definition and communications terminal development. Defense Department officials planned for Milstar to provide world wide jam-resistant voice communications for the National Command Authorities and, ultimately, to serve as the main element in the Military Satellite Communications System (MILSATCOM), replacing the Navy's Fleet Satellite Communications System (FLTSATCOM), the Air Force Satellite Communications System (AFSATCOM), and multiuser Defense Satellite Communications System (DSCS) networks.

Navstar GPS. When turned over to Space Command in early 1984, the Navstar Global Positioning System project was nearing the end of its successful validation phase, during which a limited constellation of five to seven prototype Block I satellite, orbiting at an altitude of 10,900 nautical miles, provided navigation signals transmitted from atomic clocks through a 12-element antenna array to various types of user equipment. The GPS control segment consisted of several monitor stations, a master control station, and ground antennas. Improved Block II satellites for the operational system would have unclear-protective hardness, longer and more accurate navigation signals, and measures to prohibit unauthorized use.

The Challenger Disaster

NASA had expected a triumphant but routine mission of the orbiter *Challenger* on 28 January 1986 in celebration of the Space Shuttle's twenty-fifth flight. Initiating use of the nation's second Shuttle pad at the Kennedy Space Center, Mission 51-L was to launch the "first teacher in space," Christa McAuliffe, perform unprecedented observation of Halley's Comet, and deploy one of the space agency's Tracking and Data Relay Satellites. After cold weather delayed the flight for several days, the *Challenger* rose from its launch site that January morning at 11:39 a.m. Eastern Standard Time. Just 73 seconds after liftoff, a massive explosion destroyed the spacecraft, killing all seven crew members and plunging the nation's space program into the greatest crisis in its young history.[1440]

The *Challenger* accident proved to be a watershed in the nation's space program. The moratorium on Shuttle flights, which extended for 31 months, forced civilian and military leaders to investigate not only the future of space launch but the nation's entire space program. During the hiatus Air Force officials led the way in reassessing the military space program. By the time the Shuttle resumed operations on 29 September 1988, the Defense Department's relationship with NASA had been transformed and the Air Force had immersed itself in a searching self-examination of its commitment to space.

The Decade in Retrospect

By the end of the 1980s the Air Force was well on its way toward achieving the institutionalization of space that enthusiasts had long envisioned. Space activity no longer seemed primarily developmental in nature but, rather, an operational element whose systems could fulfill Air Force missions in a manner comparable to the service's traditional activities. Over the course of the decade the space launch issue remained central to every aspect of the space program. Without assured access to space there could be no space program. In the atmosphere of self-examination following the *Challenger* tragedy and the Titan booster failures, the Air Force at the highest levels moved to reassess not only its investment in the Shuttle but its entire commitment to space.

The *Challenger*'s shock waves generated a variety of space studies that attempted to understand the present and chart the future. Of course, the Blue Ribbon Panel far and away provided a realistic sense of potential of space through its policy analysis, and its examination of the Air Force role in space and the role of space in the Air Force. It called on the Air Force to undertake sober leadership, and it set the stage for the Space Roadmap. The Blue Ribbon Panel's recommendations served as the linchpin for the broad process of "normalizing" space within the Air Force that gained momentum in the late 1980s.

To be sure, much remained incomplete at decade's end. While the return to expandable boosters enabled the service to continue launching communications, weather, navigation, and early warning satellites, it would be 1992 before the three-year Shuttle delay would be overcome. At the same time, roles-and-missions issues continued to demand accommodation between the United States Space Command and its component Air Force Space Command, as well as among the latter and other Air Force and Defense Department organization with space responsibilities. Likewise, the future of space launch also persisted unresolved. A return to the diversity of reliable space boosters did not alleviate troublesome questions about the feasibility and necessity of developing a standardized launch vehicle for the new century.

Nevertheless, the end of the decade offered more hope than pessimism. Through the entire turmoil surrounding space launch in the movement away from the Shuttle, the focus remained centered on operational requirements and the needs of the warfighter. In this regard, Air Force Space Command provided the focus as it moved to consolidate operational responsibilities. Its victory in garnering the space launch mission represented a final shift in the long struggle to move Air Force space from the research, development, and acquisition community to the operational arena.

The Role of Space Systems in the Gulf War

The Gulf War fought under the operational name Desert Storm, represented the first major trial by fire for space forces, whereby military space systems could fulfill their promise as crucial "force multipliers."[1441] By all accounts, space forces provided a support that contributed to the victory of the U.N. Coalition. Their contribution proved more impressive because of the difficulties that had to be overcome. Space systems, up to this point, had focused primarily on strategic rather than tactical requirements. Some embryonic planning and testing of tactical uses of space capabilities had emerged by the late 1980s; however, ensuring nuclear warning and monitoring arms control agreements had been more important than supporting tactical operations. As a result, Coalition planners had to make important adjustments in both the satellite and ground segments of their space in order to meet tactical contingencies. Although remarkably successful, a number of persistent deficiencies could only be minimized, never overcome. In their many postwar assessments of space performance, military authorities attempted to use the lessons learned from the desert conflict to ensure that space systems would better support the tactical warfighters in the future. The Air Force saw in the Gulf War experience a springboard for charting the future of the nation's military space program and assuring its own leadership role in space for the century ahead.[1442]

To be sure, military space systems had provided important operational wartime support long before the Gulf War.[1443] As early as the Vietnam conflict, weather and communications satellites furnished data and imagery to commanders in Southeast Asia and linked them with Washington, D.C. More recently, satellite communications had proven important in the British Falkland Islands campaign and in Urgent Fury, the

Grenada invasion of 1983. In 1986, during Operation Eldorado Canyon on Libya, space systems provided a vital communications link and supplied important mission planning data to aircrews that bombed targets in Libya. In 1988, Operation Earnest Will witnessed the first use of the GPS test satellites to support ships and helicopters during mine sweeping operations in the Persian Gulf. During Operation Just Cause in Panama in 1989, DSCS satellites provided long-haul communications links and DMSP supplied important weather data.[1444]

These operations, however, involved only portions of the military space community for relatively brief period of time, and the contribution of space systems was not widely understood or appreciated. Desert Storm, by contrast, involved the full arsenal of military space systems. Nearly sixty military and civilian satellites influenced the course of the war and helped save lives. Communications satellites established inter-and intra-theater links to support command and control requirements for an army of nearly 500,000 troops. Weather satellites enabled mission planners to keep abreast of constantly changing atmospheric conditions, while early warning spacecraft supplied crucial data on enemy missile launchers, Navigation satellites furnished precise positional information to all elements of the armed forces. Then, too, commercial satellites not only assisted in filling coverage and system gaps, but also broadcast the war over television to a worldwide audience. Desert Storm was, indeed, the first large-scale integration of space systems in support of warfighting.[1445]

Conclusion

Military analysts concluded that, in Desert Storm, space systems contributed to victory in the political battle, ensured effective command and control, and helped make the war a short conflict, which saved lives.

The Gulf War convinced commanders of the importance of satellite reconnaissance and the need to deny it to potential enemies. General Charles A. Horner, commander-in-chief of U.S. Space Command of Air Force Space Command after Desert Storm repeatedly argued for the capability to destroy foreign satellites, even those belonging to allies if they were aiding an enemy. Other Air Force leaders agreed on the need to control space. Air Force Secretary Sheila Widnall asserted in the fall of 1994, "Part of the Air Force mission is control of space, our ability to deny the use of space if necessary." Despite the pleas from Desert Storm leaders, the antisatellite program was confined at mid-decade to a research effort by all three services.[1446]

In the aftermath of Operation Desert Storm, the Air Force played the central role in evaluating the capabilities of space systems to meet the needs of the warfighter. Air Force leaders realized that they must provide the necessary leadership if military space were to benefit from infrastructure modernization and new technological initiatives and, ultimately, achieve "normalization" of space within the Air Force and throughout the military community. But the momentum for change represented by performance of space assets in the Gulf war diminished considerably when confronted by the challenges of developing a new generation of space systems and an effective launch capability, continued fragmentation of the nation's space community in an of budget austerity severely hampered efforts to make the changes Air Force leaders deemed essential. The situation called for strong, central direction, and the Air force responded with another initiative, one designed to chart the course of military space into the Post-Cold war future of the 21st century.

Chapter 39

The Impact of Stealth Aircraft on Air Warfare

Introduction

Air power is about the exploitation of the third dimension above the land and sea by man, but not necessarily "with" him. The advent of surface-to-surface and ground-to-air missiles, as well as the use of unmanned vehicles in the sky and space above it, offers ways to project military force above the earth's surface without dependence on manned aircraft. But for the foreseeable future air power will continue to be largely the responsibility of the airplane. Any study of the interaction of air power and technology must therefore begin with a survey of military aircraft themselves. Even that definition can be ambiguous, because at one end of the spectrum is an aircraft designed specifically for offensive or defensive combat operations possesses characteristics which set it apart from those regularly arriving at and departing from the world's airports, but airplanes designed for other military activities, such as reconnaissance, transport or in-flight refueling, may resemble their civilian counterpart quite closely.

Stealth Technology

In their quest for aerodynamic perfection, however, aircraft designers cannot lose sight of the fact that they are not designing an aerobatics display aircraft, but one, which must survive in combat. Weapon technology has approached the point where an aircraft, which is detected by an enemy, is an aircraft in imminent danger. There are several sources and kinds of threat, and several corresponding defensive ripostes, but increasingly the airframe itself must be a factor in the reduction of its own vulnerability. In military history, an enemy has been detected by either sight or sound. Countermeasures were primarily camouflage and stealthy movement. In modern air warfare, "stealth" is the term associated with a variety of technologies, which seeks to reduce detection of an aircraft not now primarily by visual and audible sensors, but along the entire electromagnetic spectrum, and especially in the microwave frequencies. Aircraft shape, size and materials used in structure are all areas in which the search goes on to reduce "radar cross-section", a phrase, which is freely used to denote not just reduction in size, but in electromagnetic reflectivity generally. Stealth technologies seek to reduce an aircraft's "signature", by making it more difficult to be detected by radar, more difficult to be located by the heat which it radiates and, now of lesser significance, more difficult to be seen. Because of the relatively short attenuated radius of audible sound, the noise generated by a modern military aircraft is now only of concern to civilians below the flight of paths in peacetime. The Rockwell B-1B strategic bomber which incorporates many Stealth features is reported to present a radar cross-section 10 percent of the B-1A and 1 percent of the B-52. Three companies Boeing, Vought, and Northrop, have been commissioned by the US Department of Defense (DoD) to build up an advanced technology bomber, to fly in 1987. In view of previous Northrop experience with aircraft in 1946 and 1947, speculation in the press suggested that its design would be a flying wing, which would not only offer minimum radar reflection but would be aerodynamically extremely efficient. Hitherto, such an aircraft would have been aerodynamically unstable. However, in the 1980s, the interaction of electronic and airframe made the concept operationally feasible.[1447]

The Early Approach of Stealth

Down the ages, fighting man has sought to exploit the element of surprise. Concealment and disguise were early forms of deception; and ambush, a commonly used tactic. Today, the impressive capabilities of surveillance and detection systems combine with sophisticated means of communication and information display to ensure that almost every movement of an enemy, actual or potential, is prey to observation-in the piping times of peace every bit as much as in those increasingly nervy days which would presage any future war; and, very much more so, during the course of war itself.[1448]

The speed of modern air-fighting machines is such as to allow aircraft (combat or support, fixed-or rotary-wing, manned or unmanned, tactical or strategic) to exploit to the full those innate characteristics of air power-flexibility and surprise; to apply force or to proffer assistance at long range, over a wide and diverse area and, above all, in timely fashion. By comparison with war in any other environment, speed is the very essence of air operations. But, of itself, speed is not enough. Once a prime element of surprise, speed per se no longer confers on the aircraft the degree of invulnerability it once did. Defenses have it come too sophisticated for that, and ways must be found to reduce or degrade the efficiency of defensive systems if the air power of today is to be applied as effectively as it was. Surprise is a characteristic now vested as much in the aircraft designer as in the tactician.[1449]

Over the years, military aviation has recognized the need for concealment and deception. Aircraft have long been camouflaged in an arresting variety of paint schemes, to reduce the capability of enemy detection by visual means. Decoy and spoof raids have been frequently used to conceal a true objective or target. In their efforts to escape detection, combat aircraft have been flown ever higher to combat the capabilities, successively, of guns, fighters and missiles. But, as Gary Powers proved as long ago as 1960 with his U-2 spy plane, high might have to be very high indeed. They have also been flown very low, to allow flight under the radar lobe and to take every advantage of terrain masking and of the enemy's known blind spots. But very low, particularly at night or in bad weather, may demand the assistance of terrain-following radar-which can itself be something of a give- away to alert enemy defenses. Electro-optical and infrared systems, however promising for the future, are only now beginning to give the same degree of confidence to aircrew flying in indifferent weather, at the ultra-low levels required to defeat the most advanced detection and tracking radars. As we have already seen, the age of increasing sophistication in aids to navigation and target acquisition (radio, radar, infra-red etc.) has spawned a whole industry of countermeasures and counter-countermeasures; which make the waging of modern war in the air a game of mind-boggling complexity, in which only the most skilled and highly trained can hope to survive alone succeed.[1450]

More recently, science and technology have been able to offer the air force personnel yet further aids to the concealment of their intent and, indeed, of their very presence. With appropriate flair, the several different technologies currently being applied to this activity have been given the dramatic (if slightly sinister) sobriquet of "stealth". So, stealth technology is actually a mix of several different technologies. Between them they seek to reduce the observability of an aircraft (or indeed drone missile, tank or submarine). As applied to aircraft, stealth must increase the difficulty of detection-whether that is by eye, ear, radar receiver, thermal image intensifier or any other sensor. The range of technologies involved covers the suppression of engine exhaust smoke to the masking of on-board electro- magnetic emissions; taking in, on the way, aircraft design, engine noise suppression and camouflage schemes.[1451]

Camouflage

The susceptibility of aircraft to detection by human eye (supplemented, as may be, by image magnifiers and intensifiers) may still be reduced by careful camouflage and by the suppression of engine smoke and contrails, and flight at very high or very low level. Let us first look at the avoidance of aircraft detection by paint and by the use of clean engines. The types of camouflage that have been used on fighting aircraft are almost as varied as the types of aircraft themselves. In large part, success depends on allowing the aircraft to merge with the background, though of course in practice this is very difficult to achieve. Not only does the background against which an aircraft may be seen vary immensely with route, height, time of the day, position of the sun or phase of moon: but those aircraft on occasion have to be seen-not least by friendly aircraft and by ground observers. The truly "invisible" aircraft (if such could be created) might be rather safer over the heart of the enemy homeland than it would be on the approach to its home base. Anti-collision and formation lights may do something to alleviate the problems-particularly in peacetime training, but such training can then less realistically simulate the conditions of war. However, the fact is that no combination of known finishes can make an aircraft even moderately invisible in all conditions of geography and light: and, anyway, hard high-gloss paints carry their own penalties in increased weight and frictional drag. For example, the weight of paint on a Vulcan medium-bomber, flying in the low-level role in the early 1980s, was some 174 pounds. In the right conditions, it could make that very large and distinctive aircraft extremely difficult to spot from a fighter at higher altitude. However, paint schemes became irrelevant to the very low-flying interceptor-or, indeed, the SAM or gun crew-because the Vulcan was just too big and could not be flown low enough to escape such detection. Nor was its disruptive-pattern camouflage of much value over the sea or desert terrain across which, parts of its planned operational profiles might well have caused it to fly. In other words, in the absence of readily available "chameleon paint", camouflage can only be a matter of compromise-at best, valuable during only certain phases of flight.[1452]

It is generally accepted that the most promising compromise, offering relative protection from view for longer periods, lies in a basic gray tone, with counter-shading to compensate for areas of highlighting or shadow. In this, the attempt is made to reduce the visually attractive differences between an aircraft's background and its own color and luminance (or brightness)-which latter property becomes more important with increasing range, when the scattering of light by the atmosphere tends to merge colors. So-called "active camouflage" has been trailed, with various lights and sensors constantly adjusting the luminance of individual aircraft components so that the whole is, as far as possible at all times matching its background.[1453]

The texture of an aircraft's coating is also relevant to visual perception. Gloss paint can offer increased protection against the elements, but its reflectivity is also increased as against that of a dull mat finish. In an attempt to overcome the problem, radar ablative paints have been used for example on the Lockheed SR-71 Blackbird. Rather than absorbing radiation, this type of paint tends to conduct it over the skin, avoiding some of the electro-magnetic hot spots that occur, in flight, on any aerodynamic surface. A still better degree of conductivity can be achieved by blending microscopic particles of metal (normally, iron) into the paint itself, to produce what is known as iron ball paint. Yet further advanced paints, of extremely complex manufacture, may be developed to enhance radar or infrared absorbency. However, their efficiency has yet to be proven and the results of such proof made available as a matter of public record.[1454]

Elimination of Trails

As for engines, the two obvious visual give-away are from exhaust smoke and condensation trails (contrails). The latter are the trails of ice crystals, formed by the freezing of water vapor expelled with the products of engine combustion. Although all aircraft engines run at high temperature, they also extract large quantities of water from the fuels on which they run. In conditions of extreme ambient cold (from about -240 and sea level to -450 at a height of 50,000 ft) the air in the wake of an engine will reach saturation point-the local heating effect of the engine exhaust being insufficient to overcome the increase in relative humidity caused by the addition of water to the cold ambient air. The resultant cloud of ice crystals appears as a trail, which broadens as it is diffused in the surrounding air. If that air is already at or near saturation, the contrail will be slow to evaporate-and is in fact described as "persistent", military pilots have long understood the dangers of contrails in assisting the visual detection of the aircraft, and they are usually well briefed on the heights to fly and on engine-handling techniques to adopt it contrails are to be avoided. Given that the preponderance of military aviation in combat aircraft is now carried out at low level, the problem of contrails is less acute than it once was. But, bear in mind that they can actually form as low as ground level. It is not by any means certain that low-level flight will continue, for all the time, to offer an attacking aircraft quite the relative advantages it now enjoys.[1455]

Less easy to avoid (though less easy to detect and track when they do occur) are wing-tip trails or vortices. These thin and transient trails are formed by a reduction in pressure, usually at the wing extremities of a maneuvering aircraft. Unlike contrails they need milder, but damp air for their formation and they occur invariably at the lower altitudes. Similar effects may be observed over the upper surfaces of wings and (though now only academic interest to the majority of modern military pilots) at the tips of propeller blades in other words, anywhere a rapid reduction of pressure leads to expansion and temperature reduction below the dew-point of the surrounding air. As already suggested, the phenomenon is scarcely one to concern the crew of a large aircraft such as a strategic bomber, though it is of some immediate relevance to pilots engaged in hard visual combat.[1456]

The suppression of engine exhaust smoke is a different matter, and one that can be wholly desirable of military aircrew. The smoke trails from a whole generation of military jet engines have made the aircraft they power very much more easily detected by the eye, either directly or by the shadows they produce on the ground beneath the aircraft's flight path. The truly smokeless engine has not been designed-modern military aircraft if it is to be operated as flexibly and at such potentially high power ratings as requires certainly. However, research and experiment have combined to reduce smoke emission from many engines, though often at some cost in reduced performance.[1457]

Noise Suppression

The aircraft engine is, of course, also a prime cause of another aid to aircraft detection noise. Less immediately relevant to the air combat situation, noise can be useful in the early detection of an aircraft's approach and, as such, needs to be minimized. It is a bonus that noise suppression also helps overcome, at least in part, some of the environment problems of peacetime low-level operation training; and useful again that, unlike many developments in military aviation, it does have a direct relevance to civil aircraft operations. Indeed, it has been primarily the demands of the general public that have maintained the pressure on aero- engine manufacturers to reduce the noise of their products. And noise regulations as applied to civil airlines have become steadily more stringent. As an example, the British Aerospace 146, generally accepted as the quietest of current pure jet airlines-is being considered for yet further noise reduction as later and heavier variant demand greater thrust from its Avco Lycoming ALF 502 engines.[1458]

That said, it is the aero-engine that generates the most obvious problem of aircraft noise. In the context of stealth, it is important to point out that that aircraft with propellers not only bum less fuel (with consequent reduction in infra-red signature); they can also be comparatively quiet, the trick being to silence the noise of the propellers themselves. However, propeller-driven aircraft have inherent limitations on the speed at which they can be flown. Such systems as advanced prop-fans, ducted and unducted contra-fans used in conjunction with ultra high by-pass (UHB) ratio engines will be able to power aircraft at speeds considerably in excess of those attainable with earlier-generation turbo-props. However, one of the problems of engines such as these is in the high levels of external noise they produce. As we shall see, propellers are also rather bad news when it comes to the reduction of an aircraft's RCS.[1459]

One of the keys to progress in the reduction both of engine noise and RCS will lie in the speeds at which future military aircraft require to fly, particularly when they are in range of enemy early-warning, detection or defensive systems. If flight in those areas could be restricted to below (as a ball-park figure) about 500 mph, it would be theoretically possible to sustain it with propellers buried deep inside the aircraft body, with a sandwich skin construction enclosing sound-baffles; with engine inlets so designed as to be virtually invisible to radar; and with jet effluxes which are, by present-day standards, comparatively slow, cool and silent.[1460]

Infra-Red

The mention of "cool" leads us to one of the two other characteristics of aero-engines, which must be addressed if they are to play their part in achieving a genuinely stealthy aircraft. As I have already indicated, all engines produce heat; and aero-engines work consistently at temperatures far higher than those found in most other propulsion systems. Not only does the emission of Infrared (IR) radiation simplify the task of aircraft detection: but many anti-aircraft missiles are, and will undoubtedly continue to be, of the heat-seeking variety. And whereas earlier generations of such missiles needed to home in on large hot targets, technology has now developed to the point at which heat differentials can be very much more accurately measured, and heat-seeking missiles made capable thereby of discriminating and engaging relatively cool targets. Designers can begin to attack the problem by the clever shielding of jet-pipes; but there is no perfect solution in that. Far more effective in reducing emitted engine heat is to enhance the effectiveness of the engine itself, i.e. by ensuring that as little fuel as possible is burnt for a given power output. Pressures on aero-engine designers to increase the Specific Fuel Consumption (SFC) of their products have, until recent years, stemmed *from* the need to reduce aircraft weight (or size) and running costs. Now these pressures are reinforced by the requirements to "stay cool". There may be some relief in the careful direction of cooling air to and around the hotter parts of engines: but practical considerations (and the efficiency of the engine as a means of propulsion) limit what can be achieved in this area. Flight in a reheat is, of course, to be avoided in all circumstances short of desperation when an aircraft is over hostile territory.[1461]

Design

The final problem for stealth, as presented by the aero-engine, relates to its installation, and here we move on to the realm of the airframe designer and address the important role he has to play in the search for the "invisible aircraft". A basic measurement of an object's detectability is held to be its RCS-usually measured in square meters (m^2) and to which passing reference has been made. Calculating the amount of radar energy reflected by a target back to the observer (or radar receiver); and then calculating the size of sphere that would reflect the same amount of radar energy measure RCS. The area of a disc of the same diameter is called the RCS. The two factors held to be of greatest significance in the determination of RCS are shape and material used in the object's construction. It should be noted that RCS is not so markedly a function of the size of an object. To give one rather exaggerated example: let us assume, for argument's sake, that the RCS of a B-52 bomber to given radar wave band was 100 m^2. A fire engine, illuminated by the same radar, might well have a RCS at least double that value. The reason for this is that an aircraft (even a comparatively ungainly aircraft like the B-52) has been designed for maximum aerodynamic efficiency. As far as is possible within the limits set by its role, aerodynamically efficient shapes have been incorporated in its design; and streamlining has been featured to ensure its smooth (and, hence, efficient) passage through the air. The same principles have little application to the fire engine. For the role for which it was designed, strength and solidity are virtues together with space and load-carrying capacity; the large extendable ladder and its associated turntable have no place on our B-52. The result is that the fire engine is all square sides, sharp edges and right-angles which would reflect back any incoming radar signal; and holes, comers and open box-constructions which may even enhance that return. Fortunately, fire engines are not normally threatened by radar illumination, even, in their case, for the purposes of law enforcement.[1462]

However, smooth and contoured an aircraft, does it not also have right angles, box-like constructions and holes? Indeed it does, and in otherwise excellent military aircraft like the B-52, the F-4 Phantom and the MiG-25 Foxbat, those features are found in plenty. Up to the end of the 1970s, they were of less importance in aircraft design than were the often conflicting requirements of strength, weight, speed and load-carrying capacity. Now the accent is on smoothness, curves, embedded engines and obtuse angles. The RCS of an aircraft varies with the angle of interception as well as with the frequency of the threat radar. Against the types of radars in the 1990s and beyond, RCSs of rather less than 1m2 will be the order of the day; and these are probably capable of achievement by such modem strategic bombers as the USAF's B-IB. Interestingly, they would not have been achieved with its predecessor, the B-IA; and a comparison of the two aircraft reveals the sharp spine and high angular intakes of the earlier aircraft as being two of the features which have been lost in the design of the stealthier B-IB.[1463]

RCS is a Function of Four Major Factors:

Size, Shape, Material and Aspect.

Size

Although it would appear that the size of an object should have a marked effect on its RCS this is not necessarily so as is evidenced by the comparison of B-52 and the engine. For a simple example, let us take a plate, of 1 m^2, viewed in a normal plane, e.g. as in mirror. Illuminated by radar operating at, say, 3 Giga-Hertz (GHz), its RCS would be about 12 m^2. However, for another radar operating at 10 GHz, the RCS of that same plate might have increased more than tenfold-to 150 m^2, at least. Hence, the indecency of any bold statement about an aircraft's RCS: it depends on the frequency of the radar being used against it. Another example of the effect of size on RCS can be seen in the decoy. As we have seen, for many years the trusty old B-52 carried small-unmanned aircraft-like decoys called Quails, with RCS specifically designed to equate to that of the B-52 from which they were launched. This feature was built into the Quail by a series of measures to enhance its radar reflectivity. One such device is known as a Luneberg lens-in effect, a specifically constructed reflection designed to optimize the electro-magnetic energy returned to the transmitting radar. Consider, also, three aircraft of roughly the same size-the B-52, B-1A and B-1B. Readily available information suggests their respective RCSs as being in the ratio of 100: 10: 1.[1464]

However, in the future it could be that size comes to assume greater relative importance in the detection of aircraft. One development, under consideration by several nations, is that of early warning by high-frequency (HF) radars. Operating at a frequency of, say 10 mega-hertz (MHz) HF radar have a wavelength of 30 meters (m) and, at the same frequency; the ideal half-wave dipole length for re-radiation would be 15m-or roughly the span of a typical fighter-bomber of the 1980s. This suggest that if HF radar were to be deployed (and there are many practical problems to be overcome in so doing), a whole range of future combat aircraft would have to be either very much larger or considerably smaller than they are now.[1465]

Shape

Let us now consider shape as a factor in the calculation of RCS. In general terms, any flat shape will reflect energy and sharp irregularities will enhance RCS. It is for that reason that tri-hedral comer reflectors often calibrate radars. The junction of two planes at 90° gives rise to a sort of double bounce of energy, which serves to enhance the radar return. Conversely, the reduction of right angle between plates, by as little as a couple of degrees, can serve to reduce the RCS of those plates by a factor of 10.[1466]

Translating that to an aircraft/engine combination: the principal reflection points of a typical fuselage lie in those flat surfaces which are normal (i.e. at right angles) to the transmitter. It is thus important to avoid any 90° angles, which might face the illuminating source; and as the angle between aircraft surface and radar can obviously vary with aircraft height, altitude and flight-path, the designer's task RCS can never be reduced to zero. That said, our designer could do a great deal to reduce it. He can ensure that tailplanes slope in from the vertical and that wings blend into fuselage-features that are already evident on present-generation combat aircraft such as the MiG-29 Fulcrum and F/A 18. Taken to the extreme with 1960s technology, such a shape would have been impossible to control because of its inherent aerodynamic instability. Now that fly-by-wire has made instability the order of the day, by harnessing it in the cause of agility such shapes may well come into their own in the design of stealthy combat aircraft.[1467]

Back to engines (again) and the inherently complex problem of inlet design. Traditional jet engine intakes have, naturally enough, been designed for efficiency in terms of adequate air mass flow into the engine at any likely combination of aircraft speed, Mach number, height, angle of attack or configuration-indeed, across the whole of the aircraft' s flight envelope. They have also had to take into account the demands of easy access on the ground for inspection or repair, when time and aircraft exposure might well be at a premium. Although they vary greatly in size, shape and position on the aircraft, engine intakes can generally be said to offer a direct path for radar energy to pass into the very noisy area (in terms both of radar and of fact) of the low-pressure (LP) compressor-an area stiff very unstealthy comer reflectors. If the engine is to remain outside the airframe, the designer must attempt to block that direct path of radar energy into the LP compressor-a difficult task if he is to guarantee the requisite air mass flow. A better solution would be to mount the engine (or engines) deep inside the aircraft's fuselage or wing structure, with an intake of zig-zig design, heavily coated with radar-absorbent material. Shock-cones, incorporated on some high-performance aircraft (primarily to decrease airflow to sub-sonic speed on entry into the engine), actually serve to reduce the RCS of the inlets they control by restricting the path of radar energy (that doyen of stealthy aircraft, the SR-71). However, as previously suggested, high supersonic flight may not be a pre-requisite of future manned combat aircraft-certainly for the strategic offensive role.[1468]

Aspects

Moving on to another function of aircraft design, let us now look at the question of aspect. In the context of RCS the shaping of an aircraft must be considered from every direction. This is particularly true of the more maneuverable, agile aircraft now in the inventories of many nations as air superiority fighters, fighter-bombers or ground-attack aircraft. In the future, there is no reason against (and every advantage in) making the longer-range manned bomber as maneuverable as it can be, for it will have to face many of the same threats as its smaller cousins; and it may, in the next generation, develop into a smaller variant of itself.[1469]

Although technically difficult to achieve, it is important that the RCS of a modem aircraft is measured from all aspects-ideally, during the design phase when impending errors can be rectified. The methods by which this can be done are complex and deserving of more detailed attention, but they are beyond the scope of this paper. Eager students without access to one of the specialist (and rather highly classified) research establishment may have recourse to a decided second best-and study Maxwell's Linearity Equation, which has an application in the technique of Radar Scaled Modeling.[1470]

Let us take one large bomber as an example of the way in which several of its components affect the overall RCS of the aircraft. The Avro (later, British Aerospace) Vulcan was originally designed in 1947 to Air Ministry Specification B35/46. Known then only as the Avro 698, it was a futuristic design for its day. A large tailless delta aircraft of Aspect Ratio 3, the Vulcan was one of six original designs to meet a tight and, for the time, very demanding specification for an aircraft to carry a 10,000 pound bomb-load over a still- air range of 3,350 miles by day or night from bases throughout the world. It had to be capable of carrying a wide range of conventional weapons and of being modified for reconnaissance duties. An initial all-up weight limit of 100,000 pound was later extended to 115,000 pound; but the Spec insisted on a 45,000 ft cruising altitude after 1 hour in flight, 50,000 ft, after 2 *Y2* hours and as far beyond that as was achievable. The cruising speed was to be 500 knots (Mach 0.875) at continuous power over a target 1,500 mile from base. All that had to be achieved in an elapsed period of less than five years, with scientists, designers and engineers working beyond the boundaries of anyone's experience in areas positively alive with aerodynamic and structural uncertainties. And it had to be done without the benefit of experience of large jet engines or high-speed aerodynamics, without the advanced research facilities and wind tunnels, computers, sophisticated test equipment or exotic materials available to their successors.[1471]

The fact that not one, but three designs to Spec 35/46 eventually entered frontline service with the RAF (one of the them still there in the AAR role) is the greatest possible tribute to Britain's post-war aircraft industry. The Vulcan was designed ahead of its time- not least in the matter of design for stealth, a concept undreamed of at the time. Least beneficial from the point of view were, in fact, the massive tail and the exhaust ports from the large engines. However, those engines were deeply buried in a large and relatively smooth "flying wing" from which there were remarkably few protuberances. The large (eventually, 21,000 pound) bomb-load being internally carried and the body of the aircraft having adequate space for all the special-to-role equipment which, on a smaller aircraft, would have had to be wing-mounted. The large (and potentially radar-resonant) cockpit in fact gave little reflection. The smooth at high altitude, gold-film heating was incorporated to prevent misting. Although transparent at very high light frequencies, this film behaved as if it were all-metal when illuminated by the lower frequencies of radar.[1472]

A modem variant of the gold-film treatment for cockpit transparencies might be to coat them with substances such as indium-tin oxide. The effects of this would be twofold; firstly, in retaining the purpose of the transparency by allowing a very high percentage of light (possibly in the high nineties of per cent) to pass unhindered into the cockpit; secondly (and more important from the point of view of the aircraft's illumination by threat radars), in greatly restricting the passage from the aircraft of the electronic emissions from equipment within the cockpit itself.[1473]

Material

As we have already noted, the ideal invisible aircraft would be transparent to the beams of all threat radars: we have also seen that this is an impossible specification. The aim of the designers and manufacturers of future combat aircraft will be to use, as far as possible, materials whose impedance is close to that of the surrounding air. A few such materials do exist-notably in the range of fiber composites; but those best suited to the reduction of an aircraft's electronic signature may not be sufficiently strong, sufficiently flexible or sufficiently easy to work as to make them suitable for the construction of combat aircraft-certainly, as regards some of the primary structures of those aircraft. For example: glass fiber has for some time been used in the manufacture of dielectric panels, such as those protecting much airborne radar. A glass-fiber aircraft would have a very low RCS and, indeed, small general aviation aircraft such as the Learfan have been largely so constructed-albeit for reasons of weight saving rather than invisibility. It is reported that the "paint" of such aircraft on air traffic control radars was too thin for comfort and that the civil aviation authorities insisted on their carrying two on-board transponders for reliable identification.[1474]

Other fiber materials for example, composites or carbon or boron-are actually conductive and, used in sufficient concentration for strength, may reflect almost as well as metal. One solution has long been understood and, indeed, applied to ships, submarines and tanks as well as to aircraft. This is the coating of metal or other surfaces with any of a range of radar-absorbent materials (RAM). There are two principal families of such materials: so- called "broad-band absorbers" and resonant materials.[1475]

Simply stated, broadband RAM absorbs radar energy over a wide frequency band by rapid attenuation over a short distance. As indicated (for illustrative purposes only) in Figure 38-1, materials coated with thick foam-like substances, cut in the shape of successive pyramids, can greatly attenuate incoming energy. Such coatings, resembling the construction of egg-boxes, are in fact used successfully on shower-moving and stationary objects-for example, in anechoic chambers used for the testing of radars.

Claims have been made for polyurethane foams effective against frequencies as high as 100GHz and, depending critically on the profile of the pyramidal indentations, down as low as the 100- MHz range. The low-density foam, usually carbon-impregnated, ensures dielectric loss; whilst the gradual transition of reflected energy, from that pertaining in free space to total absorption in the material, is affected by its pyramidal profile. The snag is that such facings are hardly conductive to optimum aerodynamic performance. They could only sensibly be used when faced by a radar-transparent skin.[1476]

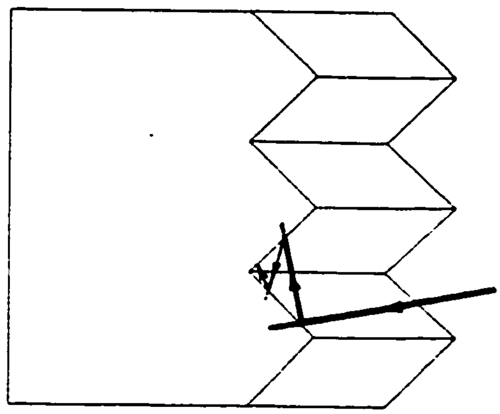

Figure 38-1. The Principle of Broadband RAM.

A more general practical application of RAM for an aircraft's skin is narrow-band RAM or resonant frequency absorption Figure 38-2. This works on the "Salisbury principal". In simple terms, the front face of the material reflects half the radiated energy whilst the next travels a quarter of a wavelength to the fully reflective back-plate; and back another quarter wavelength to combine with 50% reflected from the front face. As a result, half of the emitted energy is returned 1800 out of phase with the rest-and the result is destructive interference. Ideally, there would be no resonant radar reflection; and were it possible to obtain this ideal effect over the whole of an aircraft's surface, such an aircraft would be invisible to radar. However, that would be true only for the radar frequency at which the distance between the front and rear faces of the aircraft's skin was exactly one quarter the wavelength of that frequency. The elimination of one specific threat, at any given time, would thus be achieved without any degradation of reflectivity from other radars and, as we know, single-frequency transmissions are not a feature of modern air defense systems. That said, narrow-band absorption could induce low levels of reflectivity over a modest frequency range.[1477]

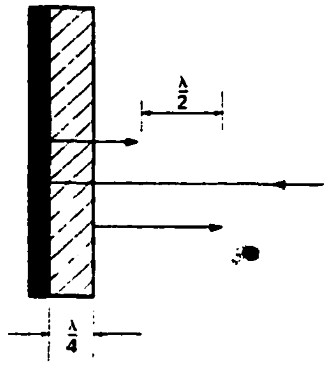

Figure 38-2. The Principle of Narrow-band RAM or "Resonant Frequency Absorption".

Other types of RAM include some in which small metal spheres have been impregnated into the material itself, causing incoming radar signals to scatter and dissipate. The problem here is that widespread use of such material could give rise to unacceptable weight penalties on the aircraft; and the technique is therefore of more general application in the "noisiest" areas of an aircraft's RCS, i.e. in engine intakes and around wing roots.[1478]

Of course, the effectiveness of any radar reflector is proportional to the rate of change of impedance between surfaces. As one obvious example: metal is a good reflector because, at its surface, the impedance of the air changes abruptly from an approximate 377 ohms in free space to conductivity at the metal itself. If this abrupt change in impedance could somehow be graduated, the resultant reflectivity would be reduced-perhaps quite markedly. In the search forever-lower values of RCS, points of transition on an aircraft's surface assume increasing significance. Discontinuities of all sorts have to be avoided. Thus, replenishment and inspection panels need to be as flush and as close-fitting as possible; and joints between differing materials must be virtually invisible to the eye and to the feel, if they are to escape detection by powerful and sophisticated modem radars. All such interfaces or discontinuities would also need to be electronically bonded to obviate sudden detectable changes in impedance-and, here, the use of gold film for sealing is an attractive (though expensive) option. Interesting-and not merely in reducing an aircraft's observability-is the potential of so-called "smart skins" for future combat aircraft. Experimental composites may be developed actually to conduct electricity to the point at which conventional antennae and threat detection sensors could be incorporated in the aircraft's own skin.[1479]

Figure 38-3 is a simplified listing of the target areas on which future aircraft designers will have to concentrate if they are effectively to reduce the RCS of their designs. The values of RCS depicted in that table are purely illustrative, but designs showing overall values greater than 0.1 m^2 are already well out of the race for stealth. And, as has already been indicated, that race will be an increasingly expensive one for its contestants. Not only are the techniques of combat aircraft design and manufacture likely to be an order of magnitude more sophisticated than those which have stood the hitherto conventional test of strength, fatigue-resistance, lightness and reparability; but they will be worthless if they are to carry the sort of operational equipment which can themselves be easily detected by ground sensors. Thus, conventional radios, radars and transponders will have to be dispatched to the museum. Future combat aircraft sensors will require very low probabilities of interception and will employ such complex and advanced techniques as spread-spectrum, passive or multi-static with, in the latter case, the relegation of all transmissions to a stand-off vehicle (or even a satellite) which must itself then be heavily protected. Certainly future technology will promise much, but always at a price.[1480]

RCS (m^2)	FORWARD ASPECT	SIDE-ON	REAR ASPECT
1.0	-	*Main structural areas* - Fuselage - Wings - Tailplane	
1	- Main structural areas, plus - engine inlets	As above	Same, but including engine exhaust nozzles
0.1	- Control surfaces - Antennae - Aircraft nose	Same	Same (less noise)
0.01	- Protuberances	Same	Same
0.001	- Surface skins - Joint lines - Surface interfaces - Connectors - Ports - Material interfaces and transitions	Same	Same

Figure 38-3. Aircraft Design Targets for the Reduction of Radar Cross-Section.

Low Observable Avionics

The next generation of combat aircraft used for most of the roles available to air power will therefore be designed and manufactured to minimize their visual, aural thermal and radar signatures. They must not put these achievements at risk by failing to reduce the potential give-away of their own high-power on-board electronic systems. This requirement will apply to the future manned strategic bomber, and to any stand-off missiles that it might carry. Indeed, the longer flight times involved in strategic operations and their likely exposure to advanced, layered air defense systems positively demand that systems designed for navigation, target acquisition, defense suppression and penetration do not, in themselves, invite or assist enemy detection.[1481]

For future strategic operations it is probable that ever greater recourse will be made to penetration and escape by night or in poor weather. Developments in night-attack aids have been dramatic in recent years and show potential for even greater refinement. As will be well known to any student of air power, the ability to operate effectively by night can treble the time available for air operations in a typical central European winter.

To take advantage of this potential, forward-looking infrared (FLIR) systems are being developed in conjunction with state-of-the-art image intensifiers and advanced wide-angle head-up cockpit displays, to offer the combat pilot the ability to see by night almost as well as he or she can see by day. The added load that would otherwise not be sustainable in the high-threat environment of offensive operations can now be greatly reduced by the automation of tasks and the presentation of information in easily assimilable fashion. There exist already many examples of comparatively low-complexity displays which can, on the one hand, offer the combat pilot a very high-quality remotely generated continuous map of his or her route, target areas, obstructions and enemy defenses; and, at the same time, a FLIR picture of the outside world-with resolution at least as good as that hitherto achieved only by monochromic display. And there is potential for yet further refinement and development in the technology of the beam-indexed cathode ray tube (CRT).[1482]

Another problem area being actively addressed (and with scope for much future development) is that of disseminating to the combat aircrew, in evaluated and usable form, the great mass of information that will be available to assist the successful completion of his task. Here we can see scope for exciting developments in the further miniaturization of mass-memory equipment and dramatic reductions in time of access. Such equipment will also be free of some of the environmental constraints, which currently inhibit their effective use in the harsher regimes of military aviation.[1483]

For now let us recall that in the ceaseless advance of technology there are relatively few instances in which something is gained for nothing. There are many examples where a less effective solution has to be accepted because the optimum is either unobtainable or unusable and others in which the advantages continue to outweigh the disadvantages. As rather over-simplified examples of each: the demands of long-range, heavy-payload, survivable offensive weapons systems preclude the benefits which can be enjoyed by small highly agile manned combat aircraft. Until such time as machines can be designed to think like men (and, despite impressive advances in the technology of Artificial Intelligence, it is unlikely that the full requirement will ever be met) the many applications of air power, more expensive, more complex and more demanding though they may be, will continue to need aircrew. To which all military aviators will echo a resounding "hear hear"-possibly, even recalling the words attributed to one of their more distinguished colleagues on the comparative advantage of man over machine. Scott Crossfield, a famous American post-war test pilot, is reported to have asked:

"Where else would you get a non-lineal computer weighing only 160 pound, having a million precision elements, that can be mass-produced by unskilled labor?"[1484]

Modern avionics systems cannot be produced (or, at least, developed) quickly-and, certainly, never by unskilled labor. That development often enough involves a compromise between conflicting requirements. For instance, IR imaging systems find favor by reason of their low observability. However, certain unchanging laws of physics limit the effectiveness of any IR equipment. It transpires that the amount of IR radiation emitted by any object is proportional to the fourth power of that object's absolute temperature. Obviously, the cooler a target or navigational feature, the less its IR emission and the greater the sensitivity required of the airborne sensor engaged in its acquisition. In consequence, the designer of the IR sensor must restrict himself to the wavelengths at which peak radiation will occur; and must also try to ensure that each of his sensor's component cells be given as much as possible to "see" the object to be acquired. The ideal IR sensor would involve a very large number of detector cells (in the high thousands, it has been suggested), so arrayed as to ensure virtually continuous cover of individual elements of the target. And that poses a significant challenge for equipment which are being carried, at speed, by combat aircraft-themselves subject to the many stresses of flight in a high- threat environment, the designer of airborne radar has a rather easier time of it; but, as we have seen, radar emissions do not meet the need for low observability. With IR systems, the conflicting requirements of sensitivity, stability, uniformity and yield make it necessary for the designer to experiment with chemistry and metallurgy to produce the most effective substances for the construction of his sensor's components. Mercury-cadmium-telluride has, for some time, been favored in FLIR applications, but indium antimonide, gallium and silicon are also candidates for consideration.[1485]

The Role of Stealth in the Gulf War

There are a number of more specific opinions and charges that have surfaced since the Gulf War, and it is worth examining some of them as they reflect current interests and interpretations of the war.

Did stealth prove its value? After the war, defense critics (mostly "low-tech" supporters) noted that while stealth worked, so did everything else.[1486] They suggested that the use of stealth aircraft was unnecessary (and, by extension, therefore, stealth aircraft are unnecessary), since all other aircraft systems-the F-111 Is, and F-15 E's, for example-had high survival rates. In fact, all other aircraft survived only after (and because the stealth fighters-the F -117 As-had destroyed Iraqis air defense headquarters, sector air defense centers, and key air defense infrastructure targets.

With this war, stealth technology-under development, off and on, for the last three decades-came of age. The F-117 first entered service in 1983, over seven years before it went to war. Since that time and for the foreseeable future there is no equivalent system elsewhere in the world. This itself is remarkable by the standards of twentieth-century military technology, for previous weapons have stimulated the introduction of rival systems of near-identical or superior performance in at most a few years, if not months. (Consider, for example, the introduction of steam turbine propulsion, the submarine, the tank, the fighter airplane, radar, the jet engine, the atomic bomb, the sweptwing, the hydrogen bomb, earth satellites, and manned spacecraft.) Critics often allege that some new or improved system will render stealth "visible." In fact, proponents have never said that stealth is invisible, only that it is so difficult to detect and track that engagement would be unlikely. (Similar allegations of vulnerability have been made repeatedly against submarines, which are the only comparable military system that approximates the stealth airplane, and yet, nearly 90 years after their introduction in combat, the submarine continues to resist easy detection.)

During the Gulf war, many telling examples of the value of stealth occurred one attack against one airfield, four A-6Es and four Tornadoes striking the airfield were protected by F-4G Wild Weasels, five EA-6B radar jammers, and twenty-one F/A-I8C Hornets carrying radar-homing missiles. This package of thirty-eight aircraft (and sixty-five men was needed to ensure that eight aircraft could hit one target with a good expectation of survival, a ratio of support aircraft to strike aircraft of almost 5 to 1, and an aircraft-to- target ratio of 38 to 1. At the same time, twenty-one F -117s were striking thirty-seven-targets, by themselves.[1487] In another example, eight F-117s with eight pilots hitting sixteen different aimpoints could accomplish the same at much less risk than a strike package composed of sixty nonstealthy aircraft-thirty two F-16 bomb droppers, sixteen F-15 escorts, four EF-111 jammers, and eight F-4 Wild Weasels-crewed by seventy-two air crew.[1488] Stealth represents a genuine revolution in warfare and, like the submarine, aircraft making use of it will prove very difficult to defeat, the ideal attribute for a high-leverage weapon.

Conclusion

It is clear that the search for low observability or stealth is taking the designers of combat aircraft, their components and their equipment down many a fascinating, but often confusing avenue. Whilst it is a fact that no aircraft can ever be truly invisible, we already know enough to declare that very significant measures can be taken to reduce its visibility to all detection means-visual, aural, electronic, electromagnetic, thermal and radiated.

Furthermore, the comparatively straightforward retrofitting with RAM of existing aircraft, whose radar signature is unacceptably high, would be both an attractive and relatively cost-effective option. It has been reliably calculated that, spread over a fleet of 100 typical modern combat aircraft, such a program would amount to about 0.1% of their procurement cost. Were the end result to be the survival of just one aircraft in war, the return on investment in hardware (to say nothing of the aircrew involved) would, as a conservative minimum, be tenfold.

The air power reliance on technology was perhaps inherent in the very science of flight itself. Also research and development were essential element for continued success of air power always remained.

The F -117 will not always possess the status of combat invulnerability that has characterized its progress so far, but it is most likely to stay ahead of its opposition for a long time yet. With the improved of an all-weather navigation and attack capability it will become an even more formidable weapon system.

Chapter 40

Conclusions, Lessons, and Findings

Introduction

It is now almost twelve years since the war began. In the interim, the after-action reports were written, and those concerned reviewed the performance of each weapon and made modifications to ensure even greater equipment success in the future. In sum, the Coalition's nations began to put the war behind them as they looked to the future. However, many are still attempting to grasp the war's significance.

What was this war, and what lesson does it provide? It helps to begin putting it in perspective. In comparison to history's earlier conflicts, the war was rather small in that it was not a very long one, lasting only weeks instead of months or years, and it was not an extremely violent one. However, the war's contribution lies elsewhere. Its significance is in its profound political, economic, scientific-technical, and military impact, which makes it of the greatest importance to us all. If we can fathom its significance and the lessons it offers, then we can learn and profit from the experience.

Conclusions

A Unique War

In drawing lessons from the Gulf War regarding the impact of modern technology on battlefield in other future arenas, caution is required – for several reasons. For one, the characteristics of the adversaries, the balance of power between them and the way they conducted the war all unique. Of particular note in this regard is the passive Iraqi approach. Thus this was really a one-sided war. It was completely different from most and perhaps all wars in that it featured a lengthy air campaign followed by a very short and easy land campaign. Then too, it was fought in an open desert arena, where air forces, intelligence and precision weapons can achieve best results. Finally, a long period of time, nearly half a year, was available to the coalition forces for thorough preparations and detailed planning of the campaign. Moreover, still limited information is available and many unknowns remained.

The distinctiveness of the Gulf War places severe constraints on our ability to draw lessons. All wars are unique, but this war its enemy, its terrain, and a host of other features was even more distinctive than most. Attempts to identify "lessons" from previous conflicts for application to future ones are fraught with danger. If they are rigidly applied, the theorist is accused of preparing to fight the earlier war all over again. If they are ignored, he or she has "learned nothing from history". Even if the "correct" lessons are shrewdly and objectively extracted, they may prove quite inappropriate to a future conflict elsewhere. The most difficult task for the analysts is therefore to distinguish those features of a conflict which are transient and unique in time and place from those which are likely to recur elsewhere in the future.

Only the future will confirm which aspects of the Gulf War were unique; but certainly the combination of circumstances and features were unusually, interactive and to a great extent they had a synergistic impact on the application of air power. Indeed, as the combined impact was so favorable for the application of air power it is necessary to reflect that on many occasions in military history defeat has been snatched from the jaws of victory. The Gulf War fought by the Coalition was distinguished by skilful diplomacy, intelligent planning, clear identification and pursuit of objectives, imaginative and inspiring leadership and executed with comprehensive professionalism and dedication. But even if on this occasion air power did win the war, or at least dominate and determine its outcome, it does not automatically follow that the face of warfare will be changed everywhere else. An examination of this war's circumstances and features, together with an alternative scenario, induce caution about any predictions.

The interactive factors on this occasion which facilitated such an overwhelming impact by air power included an unusual degree of international consensus about the justification of Coalition action; favorable geography, topography and climate; massive Coalition technological superiority; considerable numerical superiority; Iraqi strategic ineptitude; and unprecedented Coalition supremacy in the quality of the combatants. From the outset, these features were identified and exploited by Coalition commanders to an extent rarely seen in the history of warfare.

The Contribution of Technology to the Gulf War

The role of technology in the Gulf war can be summarized with reference to the following dimensions:

1. **The Depth Dimension**. The capability to destroy point targets anywhere in enemy territory;
2. **The Vertical Dimension**. For intelligence and air assault;
3. **The Night Dimension**. The 24-hour battle; and
4. **The Electronic Dimension**. For command and control, and electronic warfare.

In all these dimensions, with the exception of field intelligence, results were very impressive.

Many systems and weapons were used in large-scale warfare for the first time. The Iraq-Kuwait theater provided a vast test range in which western strategy, based on qualitative technological superiority, was successfully proven, albeit in an easy scenario. Systems used for the first time in the ground battle included the Apache helicopter, the M1A1 tank, the Bradley fighting vehicle and the MLRS – all with superior equipment and armaments; in the air, the F-117A stealth bomber, the Tomahawk cruise missile, laser guided bombs, various air-to-ground missiles and diverse electronic warfare systems. This is of course a very partial list. In addition some systems, still in development, were introduced successfully on a small scale. These included the ATACMS missile, used to attack deep high value targets, and the J-STARS, which was successful in locating Iraqi forces on the move and directing attack aircraft against them.

The Gulf War has and will intensify the technological arms race. New systems, as well as countermeasures, are being developed. The lethality of precision fire will in particular spur development in real-time intelligence and countermeasures.

Summary of General Lessons

I stress again that these 'lessons' are based on partial information, and are appropriate to the particular conditions of the Gulf War. The extent to which they are relevant to a different arena and conditions requires careful, case-by-case examination. With this in mind, the main lessons may be summarized as follows:

1. Precision munitions played a decisive role by day and night. They are becoming the main weapon against ground targets.
2. The wide diffusion of high quality night vision equipment mounted on fighting platforms and weapons has generated a significant increase in night battles.
3. The target intelligence and damage assessment loop, which relied mainly on air photography, was in general quite slow. Optimal use of precision weapons to obtain a high attrition rate requires a short, fast, intelligence loop.
4. Under conditions of air superiority, the air arm provides a decisive contribution to success in war. However, to terminate the war a ground maneuver is still necessary.
5. In the long duel between aircraft and air defense we have returned, under conditions prevailing in the Gulf War, to the aircraft superiority that characterized the 1967 Six-

Day War. In future, development efforts to improve defenses against aircraft and missiles will probably be intensified.

6. The heavy damage inflicted on the Iraqi civilian infrastructure by air bombardment apparently did not affect the course of the war. The air effort expended on these missions could have been used in a better way.
7. The massive attrition of the Iraqi ground forces from the air, which included the destruction of thousands of tanks and artillery pieces, brought about their rapid collapse in the land campaign. A massive, lengthy attrition stage as the opening step of a war should be considered under appropriate conditions.
8. Attack helicopters played an important role in the land campaign.
9. The heavy impact of surface-to-surface missiles on the rear requires a specific response.

Electronic Warfare: New Concept and Role

From the birth of electronic warfare in the Trafalgar War to World War I, World War II, the Korean War, the Vietnamese War, Arab-Israeli Wars, Falklands War, Gulf War, and most recently the war over Yugoslavia, the various electronic systems have saved countless of US and Allied aircraft, Had US Navy and Allied warships ever engaged in sustained action against an enemy employing radar-bombing missiles it is likely that the electronic warfare systems would have saved numerous ships, too.

Electronic warfare is no longer just the "wizard war." Rather it is now so integral to effective war making that it is difficult to isolate and analyze it as a separate entity. Sophisticated technology is a part of daily life, and fears that any level of technology higher than that of the mid-1960s would prove unsupportable in sustained combat were proven invalid in the Gulf War. The war showed that, if it is supported by quality people and good training, EW works.[1489]

The war showed once again that having hardware and manpower does not translate directly into a militarily effective force, especially in the under developed world. The Coalition's air Campaign and EW turned the Iraqi military into ineffective rabble.

There is the question of the role EW will play in the force structuring and thinking of both the United States and "medium" forces, such as those of Great Britain and France, who saw EW's importance in the war, but are unlikely to have the resources in the 1990s to afford many of the new technologies, considering the deep defense cuts that are currently looming.

Finally, while EW did not win the war and may not have been used to its optimum advantage, the lessons remain clear. The Soviet saw the power of Western electronic war fighting and the uselessness of many of their own systems in the hands of the hapless Iraqis; certainly disarming news in Moscow. The West saw that control of the battlefield means control of the electromagnetic spectrum.

The Dynamic Nature of Electronic Warfare

Electronic warfare is a dynamic field of endeavor and no method or tactic will remain effective indefinitely. Chaff worked brilliantly when first used during World War II, but when radar operators became accustomed to seeing it, the effect was much reduced. Although the material still has its uses today, when it is employed alone it has little effectiveness against a modern radar.

Over North Vietnam, the special formation flown by aircraft carrying noise jamming pods was an important factor in countering the SA-2 missile system used in that conflict. Yet that tactic would be completely ineffective against almost every other type of missile.

The tactic of flying decoy drones above the enemy missile defense system, to lure the SAM control radars into action so they can be engaged with air launched anti-radiation missiles, caused severe damage when it was used against the Syrian and Iraqi missile defense systems. Attempts to use the same method against the more savvy Yugoslavs failed to draw any useful reaction, however.

Maintenance of Electronic Warfare Systems and Equipment

Electronic warfare systems that are not run regularly do not reveal their faults and so do not get fixed. Moreover, if personnel do not train with equipment they are expected to use in war, they cannot be expected to have confidence in it.

Carrying such EW systems in peacetime will sometimes be an inconvenience. For example, if a system is secret it may be necessary to post armed sentries to guard the plane. However, if these systems are to be effective in combat, it is essential that in peacetime they be installed in the airplanes, ships or other vehicles that could carry them in war.

History shows the pitfalls when this course is not adopted. In the early 1960s the QRC-160 jamming pods assigned to Pacific Air Forces were stored in the open at Kadena AFB, Okinawa. When they were required in Vietnam, most were unusable and required major refurbishment by the maker.

In 1990 during the preparations for the Gulf War, a large proportion of the electronic warfare system fitted to Army combat helicopters were found inoperable. It required a major refurbishment process to bring these systems back into operation. During that conflict, fortunately, there was time to complete the task before the ground battle opened. This will not always be the case.

Misconceptions of Electronic Warfare

Those who lack detailed knowledge of electronic warfare will often tend to exaggerate its capabilities. Since it is almost impossible to establish boundaries to that technological superiority, people on the technologically inferior side make a guess. If they get that guess seriously wrong this can make a serious consequences to the way the fight. We saw an example of this in 1991, as the Iraqi Army prepared to do battle with the US and Coalition forces. Iraqi commanders believed the US emitter location systems were so capable that they could pin-point the Iraqi transmitters and bring down accurate artillery fire, within minutes of their going on air. As a result Iraqi Army signals personnel were reluctant to use radio to communicate in front areas. For want of practice, the Iraqi troops had quickly lost any proficiency they had had with their radios. Malfunctioning set went unnoticed, unreported and therefore unrepaired. When the war of movement parted Iraqi units from their landlines, their commanders were unable to use radio effectively to assemble forces to mount counter-attacks. Forward observers were unable to call down fire from Iraqi long-range artillery batteries, on targets they had located. Yet ironically the Iraqi original fears had been groundless. The US signals location systems were not as capable as the Iraqis had imagined and the feared accurate deluge of shells after a single transmission would never have occurred.

Tests and Simulations are insufficient to assess the Accuracy and Effectiveness of EW Systems

Despite the efforts of many clever and imaginative people and the use of complex analysis, simulation and modeling techniques, no consistently accurate and reliable method has yet emerged to assess the effectiveness of an EW system from tests. All too often such clinical analyses underestimate the effects of countermeasures on victim equipment. Yet this history has shown instances in combat where a countermeasure achieved more than tests had suggested. During the Vietnam War the controversies over the use of deceptive countermeasures systems, downlink jamming and Chaff trails were cases in point. Although the value of each was questioned, there is little doubt that collectively they helped reduce aircraft losses.

There are several reasons why a test assessment will fail to match the EW system's performance in combat. Perhaps a football analogy will serve to illustrate the point. In a computer-generated game, the players suffer no distractions and perform to their prescribed levels of skill. Yet in the real game, distractions abound. There might be a swirling crosswind; a crowd hostile to one side or the stadium might lie on the landing approach to a major airport. Such things will affect the teams' performances during the game, to a degree that can never be accurately measured.

Essentially the purpose of countermeasures is to provide an enemy with distractions that will impair his performance and, from the attacker's point of view, the more distractions the better. Consider the problem in relation to an air defense missile system like the SA-15 Gauntlet. Even if the electronic capabilities of the countermeasures and the missile system are reproduced faithfully in the test, in combat there will be human factors that superimpose huge variable on the results. War by its nature is a series of missed opportunities. The missile system's effectiveness will vary considerably, depending on the aptitude, level of training and bravery of the operators. Russian regular troops can be expected to make a better job of it than, say, Iraqi conscripts. Yet on what basis can one insert numbers into the test equation to show accurately the difference between the two? How does one build into that simulation the fear engendered by the presence of HARM-carrying aircraft? How should one allow for the enemy's learning curve? Its nadir will probably be during the shock, and panic engendered by the initial surprise air strike. A couple of weeks later, with more experience, those same operators might handle their equipment with commendable skill despite the jamming.

Test of electronic warfare systems in the laboratory and elsewhere have their place. The information they provide is the best available without committing the system in combat, but the margins of error are wide and the findings often fall far short of absolute truth.

Research & Development

It takes a long time to build the high-quality forces and systems that gave U.S. success. Americans should take from the Gulf conflict how long it takes to build a high-quality military force. A general who is capable of commanding a division in combat is the result of more than 20 years' training. To train a senior noncommissioned officer in Marine Corps to the high level of performance we expect today takes 10 to 15 years.

F-111 bombers first introduced into the force in 1967 dropped the precision weapons that everyone watched on television. The cruise missiles that people watched fly down the streets of Baghdad were first developed in the mid-1970s. The F-117 stealth fighter bomber that flew so many missions so successfully (not one of them was ever struck) was developed in the late 1970s. About half of the aircraft carriers we had in the Gulf were over 20 years old.

Development and production of major weapons system today remains a long process. From the time we make a decision to start a new aircraft system until the times it is first fielded in the force average roughly 13 years, and double that before most of the planes are fielded. The work of creating military forces takes a very long time.

As the Department of Defense reduces the armed forces over the next coming years, two special challenges confront Americans, both of which were highlighted by Operation Desert Storm. The first is to the American technological edge out into the future. The second is to be ready for any conflict–like contingency that comes along. Just as the high technology systems the U.S. used in the Gulf War reflect conceptions and commitments of 15, 20, or 25 years ago, so the decisions Americans make today will affect their forces 15, 20, or 25 years from now. Americans want their forces of the year

2015 to have the same high quality and the same technological edge their forces had in the Gulf War.

To provide that high quality force of the future, Americans must keep up their investment in Research and Development (R&D), personnel and crucial systems. But they should also cut unneeded production, reduce their active and reserve forces, and close unneeded bases. F-16 aircraft and M1A1 tanks are superb systems. They can better use the money saved by investing in systems of the future. Reserve forces are valuable, but as they cut the active forces they should cut the Reserves and National Guard units assigned the mission of supporting them. Their declining defense budgets need to sustain the high level of training their remaining forces need. And as they cut forces, they should cut base structure. Common sense dictates that smaller forces require fewer bases.

Lessons

There are both general and specific military lessons to be gleaned from the war. The air campaign virtually won the war in that it so devastated Iraq that the ground campaign was over in hours. This means that we must reconsider the conventional wisdom that air power is not enough to win wars. It may be that we will conclude that air power is sufficient to win some confrontations.

The ground campaign reaffirmed what strategists since Sun Tzu have stressed concerning the importance of good strategy, daring, good discipline, and training. Those trained and led well performed well; those who were not, did not.

In the maritime scene, the war reaffirmed the belief that blockades are of limited military value and often are not sufficient to force a nation to submit within a reasonable amount of time. Additionally, mine warfare remains as a very great naval problem. Mines are now so sophisticated that great sums are needed for systems to defeat them effectively. Finally, there is still a great need for battleships; missiles have not replaced their massive destructiveness.

Concerning specific military lessons, the use of electronic warfare (EW) in the war was unprecedented and proved that EW investment had been well worth the money. EW contributed greatly, and the war showed that EW could be successfully integrated into many weapon systems. Likewise, the war showed that the spending in high tech weapons had been worthwhile. JSTARS was an overwhelming success, Stealth proved its worth, the Stand-off Land Attack Missile (SLAM) and precision guided munitions were tremendously successful, as was Tomahawk, although it was found that Tomahawk needs identifiable terrain on its approach route if it is to hit its target. Night vision devices were a great success, reaffirming what the U.S. military had learned in Panama. A second lesson is that while EW and high tech are highly significant militarily, they are very expensive. While there is pressure to perfect even more advanced systems, current US defense cutbacks are limiting this progress. Turning to command and control, the US military's current unified and specified command system is a successful approach in that it worked well in Panama and Kuwait. The war showed that if unified command can be expanded successfully into a multinational Coalition. Logistics was a success story, reaffirming the common beliefs concerning protecting one's lines of communication and attacking one's opponent's supply structure. A lesson of the war was that in multi-national warfare, it is best if one nation controls logistics and supports all other participants.

There were many intelligence problems, and, while the following emphasizes US intelligence, it assumes that, while others have said little about their intelligence performance, there were inputs from British, French, and other intelligence groups to Coalition intelligence and that these did not resolve the following problems.

Operational/tactical intelligence centers, particularly the military service intelligence organizations, performed well. Here the major complaints were that the intelligence was not delivered quickly enough, and that larger intelligence groups are needed. Turning to national intelligence organizations, the National Security Agency appears to have done well in providing timely signals intelligence on all command levels. The performance of Central Intelligence Agency and the Defense Intelligence Agency appears to have been less adequate. The Coalition never located Saddam, the number of Scud launchers was severely underestimated, striking the Amiriya bunker was an embarrassment, bomb damage assessment was abysmal, and while chemical warfare was expected Iraq never deployed such weapons. The Bush administration was unhappy with the US intelligence performance. While publicly he resigned, Judge Webster may have been asked to CIA. He subsequently said that perhaps the Agency should place greater stress on intelligence accuracy. It seems certain that the White House will now emphasize intelligence quality instead of guarding against intelligence abuses. If past patterns prevail, then there will be a slackening of controls, a resulting spate of intelligence abuses, and another round of scandals and investigations, possibly before the turn of the century. The lesson of the war, then, is that America still has not found the ideal balance between control and performance when it comes to managing its intelligence community.

The Technological Dimension

The uniqueness of a war is partly reflected in its characteristic technologies and equipment. Gen. Dwight D. Eisenhower and his staff identified what they believed were the five most important pieces of equipment contributing to success in Africa and Europe. Eisenhower speaks of them in his memories:

...the "duck," an amphibious vehicle...proved to be one of the most valuable pieces of equipment produced by the United States during the war...four other pieces of equipment...that came to be regarded as among the most vital to our success...were the bulldozer, the jeep, the 21/2 ton truck and the C-47 airplane. Curiously enough, none of these is designed for combat.[1490]

The uniqueness of the Gulf War can be approached in a similar way by looking at ten kinds of technology–not always single pieces of equipment–that seem to best characterize the air campaign. The number ten is of course arbitrary and was chosen simply to limit the discussion and, in part, to mirror the Eisenhower example. I selected ten capabilities and technologies from a longer list of candidates, anyone of which could arguably have been included in the top ten. Unlike Eisenhower's list, however, the Gulf War listing focuses solely on the execution of the air campaign, not on the many worthy logistical and support elements that could have been cited. Note, too, that my selections are not intended to suggest that these technologies are the best or most important items of U.S. air power but only that they worked best in the Gulf War. The ten topics chosen for discussion are Stealth/Low Observability, The Fourth Dimension, Laser-Guided/Precision Weapons, Aerial Refueling, the high-speed anti-radiation missile (HARM), and the STU-III, a secure telephone, Topography, The Technology Gap, Airborne Early Warning and Control (AWACS), and Space System.

1. Stealth/Low Observability

Stealthy, low-observable platforms were the keystones of Coalition attacks against the Iraqi air defense system, leadership, and communications targets early on the first day of the war, even in heavily defended areas. Throughout the war, they attacked with complete surprise and were nearly impervious to Iraqi air defenses. Stealthy platforms needed minimal support from other aircraft but were able to provide stealth to a much larger force by disabling the enemy's air defense system, thus making all Coalition aircraft harder to detect ana attack. Stealth thus not only restored a measure of surprise to air warfare, it provided air forces some freedom of action that otherwise would not have been attainable.

U.S. forces used three platforms during the Gulf War that were in the stealth/low-observability category: the F-117 stealth fighter[1491] and two long-range cruise missiles, the Tomahawk Land Attack Missile (TLAM) and the Conventional Air-Launched Cruise Missile (CALCM). Neither cruise missile nor the stealth fighter figured in the deployment plans envisioned in pre-Desert Shield of Operations plan 1002-90, but they became vital parts of the strategic air campaign. The F-117, which flew only two percent of the total attack sorties struck nearly forty percent of the strategic targets and remained the centerpiece of the strategic air campaign for the entire war. Two hundred and eighty-eight TLAMs were launched during the war, sixty-four percent in the first two days of the air war and none after 1 February. Only thirty-five CALCMs were employed, all launched from B-52 on the first day of the war.

Low observability made possible direct strikes at the heart of the Iraqi air defense system at the very outset of the war. In the past, air forces fought through elaborate defense and accepted losses on their way to the target or rolled those defenses back. In the Gulf War, the Coalition could strike Iraqi air defenses immediately, and they never recovered from these initials, stunning blows. With the combination of stealth and accuracy possessed by the F-117 and cruise missiles, these two platforms carried out all attacks against downtown Baghdad; the F-117 operated at night, and the TLAMs during the day. Given American sensitivity to casualties–our own and Iraqi civilians–they were ideal weapon systems for attacking targets in the heart of the heavily defended, heavily populated city. Moreover, the F-117 had a psychological utility that was probably shared only by the B-52. Both were aircraft of a kind that only a superpower could have, and both could deliver destruction with no advanced warning–small wonder, then, that both figured prominently in psychological operations pamphlets that were showered upon Iraqi troops.

On the other hand, the F-117 and long-range cruise missiles also had limitations: both were less flexible and considerably more expensive than most conventional systems. The F-11, a subsonic, light bomber, had to operate at night to maximize stealthiness, and nearly nineteen percent of the strikes attempted by f-117s were adversely affected by weather (misses or no drops). While not as sensitive to weather conditions as the F-117, cruise missiles had a smaller payload, required a lengthy targeting process, and could not be retargeted after launch. Even without the flexibility of other aircraft, however, these platforms were able to set the terms for air operations over Iraq and to bring the reality of the war home to the residents of Baghdad.

2. The Fourth Dimension

In complementary manner, F-117 and E-3 illustrate the Coalition's domination of the electromagnetic spectrum in *Desert Storm*. F-117 exposed the limitations of relevant Iraqi technology. E-3's uninterrupted activities illustrated the Coalition's mastery of what one neutral commentator has labeled "the fourth dimension" of warfare.[1492] In the first hours of *Desert Storm*, Iraqi air defenses were blinded, paralyzed and decimated by an electronic and firepower offensive unparalleled for scale and intensity in the history of warfare, while Baghdad's attempts at counter-EW were totally ineffectual. There were about 100 specialists Coalition EW aircraft in-theater, together with defense suppression F-4G *Wild Weasels* and USN EA-6B jammers and Weapon carriers. During *Desert Storm*, Iraqi communications and radars were monitored by USAF, USN, USMC, RAF and French signals-intelligence gatherers. Alert to, but powerless to avoid the dangers of conceding SIGINT, the IQAF switched off several of its air defenses radars, but to no avail. Indeed, Coalition surprise was so complete on 17 January that several of the radars were still switched off.

The overwhelming electronic combat achievement laid the basis for all subsequent Coalition military success, Stand-off, barrage and escort jamming of Iraqi radar and fighter control communications by EF-111A, EA-6Bs and EC-130 blinded and paralyzed Iraq's air defense system. When US Army and Navy unmanned decoys stimulated SAM radars, they were attacked by F-4Gs and EA-6Bs carrying HARM anti-radiation missiles. Subsequently, RAF *Tornados* contributed to defense suppression with the parachute loitering ALARM missiles. The destruction or jamming of long-range surveillance and early warning radar allowed the attackers to approach undetected. Ground intercept and control radars, together with missile-guidance and acquisition radars were jammed simultaneously or subsequently. IQAF interceptors could not hear their ground controller and could not see their opponents. SAMs and AAA either fired autonomously or without guidance, or both. Meanwhile continuous Coalition monitoring of the remaining Iraqi frequencies provided target information for defense suppression aircraft within 10 minutes.

Supremacy in electronic combat permitted the swift seizure of command of the air. That in turn made possible the systematic destruction of strategic and tactical targets, the isolation, destruction and demoralization of the Iraqi ground forces, the denial of any Iraqi aerial reconnaissance and the uninterrupted, undetected deployment, build up and redeployment of Coalition ground forces.

Like stealth and AWACS, electronic combat was not an innovation in the Gulf War. Steady evolution since World War II had erupted dramatically over the Bekaa Valley in 1982, including the destruction of 84 Syrian aircraft without any Israeli loss. Then, one or two Israeli ELINT aircraft, a handful of jammers and superior fighters and weapons were confronted by brave, but obviously uncomprehending Syrian aircrew. In 1991 the scene was repeated, but on many times the scale, and the IQAF was much quicker to recognize the inevitable, seeking refuge first in its hardened aircraft shelters (HAS) and then across the border in Iran.

3. Laser-Guided/Precision Weapons

Few scenes were as vivid on television as the picture of guided bomb going through a ventilation shaft in an Iraqi office building. From all appearance, a new age of bombing had supplanted years of employing less accurate, unguided bombs. In fact, the new age had only partly arrived: laser-guided bombs (LGBs) achieved dramatic success in the war, in some measure because of the early neutralization of Iraqi air defenses, but overall, laser-guided bombs comprised only a small fraction of the munitions expanded in the war.

Laser-guided bombs are simply general-purpose bombs with guidance kits added: computer control and guidance canards in the front to detect laser energy and give steering commands and a wing assembly in the near to provide lift. Laser-guided bombs are part of a larger family of precision-guided munitions (PGMs), many of which (air-to-air missiles, for instance) have been around for over 30 years. Radio-guided bombs were used in World War II and Korea, and the Air Force dropped over 4,000 LGBs on North Vietnam during the period April 1972 to January 1973, targeted almost exclusively against bridges.[1493] In the Gulf War, more than 17,000 PGMs were expended, of which 9,342 were LGBs; 5,448 were air-to-surface missiles (predominantly Mavericks); 2,039 were anti-radiation missiles (HARMs); and 333 were cruise missiles. By way of comparison, approximately 210,000 unguided bombs were dropped in the Gulf War.[1494]

What, then explains the wartime prominence of LGBs, which is not a new weapon that comprised less than five percent of the total weapons employed? There are three reasons, one of which has been noted: the marriage of LGBs and imaging infrared target sensors with stealth in the F-117. The stealth characteristics of the F-117 made the normally high-risk tactic of directing the path of an LGB while flying in a heavily defended area a much more routine affair. Any target in Iraq became open to destruction by the F-117's GBU-27; a 2000-pound bomb designed to penetrate hardened facilities. A second reason for the importance of LGBs was Iraq's extensive system of hardened bunkers and aircraft shelters that were vulnerable only to a precision bomb with a penetrating warhead; it was vital that these targets be destroyed, and the LGBs were the only option for doing so. And third, LGB attacks were needed to attain attrition of the heavily revetted Iraqi armor in the Kuwait Theater.

Laser-guided bombs were particularly effective because their employment came as something of a surprise to the Iraqis. Their reaction is understandable, because the LGB performance also surprised the United States. The one new U.S. weapon system prepared to drop LGBs was the F-117, an aircraft whose existence had been kept secret until just a year or two before the Gulf crisis and whose capabilities were largely unknown. Its one publicized employment had been in the Just Cause operation in Panama; in that conflict, the F-117's main notoriety came from a dispute on whether its LGBs, deliberately aimed to miss a building, missed by the correct amount. The US fighter-bombers designed in the 1970s, the F-16 and F/A-18, could not laser designate, and the first squadron of F-15Es received laser-designating equipment only after deploying to the theater, as did the RAF Tornados.[1495]

Laser-guided bombs carried principally by F-117s and F-111s were planned for precision air attacks on nearly the entire Iraqi target structure: air defense operations centers; national leadership and military headquarters; communications nodes; nuclear, chemical and biological weapons research and storage facilities; and bridges were the most prominent. Beyond this planned use, much of the LGB employment was unplanned, growing instead out of adaptations made in the midst of the air campaign. Originally, the Coalition intended to destroy the Iraqi Air Force when its aircraft rose to meet the Coalition attacks. When the Iraqi aircraft instead remained on the ground in hardened shelters, Coalition aircraft shifted the attacks on the nearly 600 shelters themselves. Only weapons with the accuracy of LGBs and with hardened warheads, often dropped two at a time, were able to penetrate the reinforced concrete of these shelters. The results of these attacks were the flight of much of the Iraqi Air Force to Iran and the dispersal or destruction of the rest.

In the Kuwait Theater, CENTAF turned to the use of LGBs when the planned air attacks on Iraqi armor with cluster munitions or unguided bombs proved to be largely ineffective. Iraqi revetted armor was simply less vulnerable to these munitions, particularly at the bombing altitudes used by the Coalition. The use of F-111s, F-15Es, and A-6s carrying 500-pound LGBs against the dug-in Iraqi armor was one of the major innovations of the war and marked a major turning point in the attrition operations against the Iraqi Army. This episode was an excellent example of the flexibility of the weapon, the aircraft, and the organization in dealing with the unexpected.

Laser-guided bomb employment also had limitations. Laser designation was not possible through overcast skies, fog, or smoke. The designating aircraft also had to remain in the target area and within line of sight of the target until bomb detonation. On the one hand, LGBs opened up new targeting possibilities. Without them, systematic attacks on a communications system would have been unlikely simply because the probability of disabling a telephone switch or an antenna would have been too low without an excessive number of sorties; on the other hand, targets that would have been considered lucrative and vulnerable but too costly to attack were now open to assault.

Still, LGBs were of less value against large area targets, such as supply depots or deployed forces, without a single key node to attack. Against the key Iraqi targets in this war, LGBs were as devastating to the Iraqis as they were unexpected.

4. Air Refueling

Air refueling between aircraft took place well before World War II and has been a part of normal U.S. air operations since the 1950s. During the Gulf crisis, it was absolutely essential both to the deployment and to the war itself. Some aircraft required as many as 17 refueling to deploy from the United States to the Gulf region. More than 100 tankers operated the Atlantic and Pacific air refueling bridges, permitting the rapid deployment of some 1,000 fighters, bombers, and support aircraft. During the war, Air Force tankers alone flew almost 17,000 sorties, usually with multiple receiver aircraft per tanker sortie.[1496]

Nearly 60 percent of the wartime sorties by aircraft capable of being refueled in the air actually required tanker support. An elaborate network of air refueling trucks and anchors extended from the Red Sea across the Arabian Peninsula and into the Persian Gulf to support these requirements. This complex arrangement produced more than 60 air refueling trucks in which 275 tanker sorties per day operated, responding to the changing demands of the receiver aircraft. Liaison officers placed on board the E-3 airborne warning and control aircraft managed the dynamic air refueling process, changing tankers from track to track to fill gaps as plans changed or emergencies developed.

The distances between Coalition air bases and targets meant that aircraft attacking deep into Iraq frequently had to refuel at least twice-once en route to the target and again on the return to home base. In some cases, refueling was conducted over Iraqi territory, an indication of the extent to which the Coalition controlled the air. Coalition air forces also relied on refueling to help them control the skies over the battlefield.

In addition to supporting Coalition attack aircraft, aerial tankers refueled combat air patrol aircraft and an entire array of airborne warning, reconnaissance, targeting, and control aircraft that had to provide 24-hour coverage during both Desert Shield and Desert Storm. Only aircraft such as A-10s and AV-8Bs, flying from the more forward operating bases and attacking targets in the Kuwait Theater, could fly back and forth without in-flight refueling.

Air operations without the extensive support of aerial tankers would have changed the character of the war; by how much can only be guessed. Initial deployments to the theater would have been delayed, making more use of en route bases and requiring considerable logistical support at these bases. Because of the ranges to the targets, all dimensions of the air campaign would have been alerted: the number of sorties a day as well as operating bases used. In short, the air campaign was designed with the assumption that all necessary tanking would be available, and a change in that assumption would mean a change in the design. Aerial tankers facilitated the speed and mass of the attacks and provided a margin of safety in air operations. Moreover, against an enemy capable of attacking air bases close to the border, the ability to refuel extensively permitted operations from distant, secure bases and provided a buffer of inestimable worth.[1497]

5. High-Speed Anti-Radiation Missile (HARM)

Several air power weapons contributed to the Coalition's command of the air over Iraq and the Kuwait Theater, but no single weapon was as significant as the high-speed anti-radiation missile (HARM). The use of HARMs effectively neutralized both elements of Iraqi ground-based defenses–anti-aircraft artillery (AAA) and surface-to-air missiles (SAMs)–by suppressing the SAMs and thereby allowing Coalition aircraft to fly above the lethal range of AAA. Other forms of countermeasures to Iraqi radars (jamming, in particular) were important, but the HARM was the chief lethal component of the effort to suppress enemy air defenses.[1498] The HARM homed in on Iraqi radar emissions and destroyed the emitter, and it was launched from a variety of platforms, most notably the F-4G "Wild Weasel" aircraft. The U.S. Air Force fired some 1,067 HARMs, and the U.S. Navy and the Marine Corps fired 894. Combined with the destruction of Iraqi air defense control centers and of Iraqi aircraft in the air and on the ground, overall air defense suppression resulted in an attrition rate for Coalition aircraft of less than a tenth of that incurred by the United States operating over North Vietnam during the Linebacker II campaign of 18 to 29 December 1972.[1499]

Although most of the HARMs were fired during the first week of the war–200 on the first night–they continued their influence throughout the war. On the first night of the air war, an elaborately choreographed combination of stealth aircraft, specialized electronic warfare aircraft, decoys, cruise missiles, and attack aircraft delivered a sudden, paralyzing blow to the integrated air defense system from which the Iraqis never recovered. The HARM's role was to take out the Iraqi SAM radars, activated by the decoys and attack aircraft. As important as the ability of HARM to actually destroy Iraqi radars was its deterrent effect: after the first day of the war, Iraqi radar activity declined precipitously because of the unwillingness of operators to turn on their radars for anything more than brief periods of time. Iraqi operators would, in fact, turn off their radars if they knew a HARM-carrying aircraft was in the vicinity. This was a classically indirect effect of a weapon; a measure of HARM's physical destruction of enemy targets tells only part of the story. By the third day of the war, the radar threat had been so reduced by Iraqi fear of HARMs that the Coalition could fly at altitudes of 10,000 feet or higher, where normally radar-guided SAMs would have posed an unacceptable threat.

The experience of the 35th Tactical Fighter Wing (Provisional), whose F-4G aircraft were the main employers of HARM, indicates how the dominance over SAMs came about. The 35th Wing fired 905 HARMs and recorded 254 radars destroyed, for a 28 percent success rate. More significant, however, was that the radars, if not destroyed, had virtually ceased to operate. The F-4Gs that accompanied strike packages invariably fired all their missiles during the first week of the war; later, some of these aircraft returned with all of their missiles. In the Kuwait Theater, the F-4Gs began a patrol, the "Weasel Police," so that they no longer accompanied each strike package, but each element of the F-4Gs could cover thirty to forty attack formations. Later in the war, the dominance became so complete that ιanker aircraft could accompany the F-4Gs further north, allowing them to remain on-station even longer. During the entire war, only five Coalition aircraft were lost to Iraqi radar-guided SAMs, and four of those five did not have F-4G support.

6. Secure Telephone Unit (STU-III)

The Secure Telephone Unit (STU-III) was an essential item of support equipment for the units that deployed to the Persian Gulf region. Over 350 STU-IIIs were used in the area of operations alone. This unit and the associated family of secure facsimile machines and field phones enabled air campaign planners and staffs to preserve operational secrecy and still establish the informal and ad hoc organizations that sprang up to conduct the campaign.[1500]

Campaign planners communicated regularly with agencies in Washington and with deployed wings, frequently bypassing intermediate theater-level organizations. The STU-III and secure fax created the potential for a tremendous volume of communication between parallel groups in the theater and the united States, dealing with everything from the selection of targets to the status of various spare parts or key munitions. Traditional hierarchies and cumbersome procedures were bypassed, leading to improvisation and creativity on the one hand and confusion on the other hand.

Targeting and sortie production were affected in many ways. On numerous occasions, the Checkmate organization in the Pentagon worked with Washington intelligence organizations to develop prospective targets, then called or faxed the target identification, often including building or site diagrams, to the strategic planning cell in Riyadh. If the target was a high priority one, General Glosson might call a fighter unit on the same day and divert aircraft to this new target. A day later, another call from Washington could bring the first information on target damage. Significantly, the entire intelligence organization in Riyadh could be unaware of these actions until later, if at all. Similarly, adequate coordination with tanker, electronic countermeasures, and reconnaissance aircraft was at times omitted in these late targeting changes, with a resulting loss in sorties and effectiveness.[1501]

Conditions in the theater made extensive use of secure telephones a necessity. In the early days of the deployment, the STU-III tied into the local commercial telephone system since it was one of the few communications capabilities available. Later, permission communications by a mission commander with elements of an attack package at distant bases still took place by secure telephone; so too did subsequent coordination on changes to call signs, times, radio frequencies, and so forth.

The daily air tasking order (ATO) which grew to hundreds of pages was laboriously transmitted over the Computer Assisted Force Management System (CAFMS), but most units had already received the ATO information that pertained to them via secure telephone from Riyadh long before the ATO was sent electronically. Some units avoided CAFMS entirely by arranging for electronic transmission of the ATO from personal computer to personal computer over the voice network through STU-IIIs. The Black Hole also used this technique to transmit master attack plans to Checkmate.

The down side of using STU-IIIs for data communications was the pressure put on voice circuits.[1502]

Although callers (who would have liked more secure phones and lines) often had trouble "going secure," the STU-III came to symbolize the aspects of computers and telecommunications that worked best. The great promise of these intertwined technologies was only partly realized in this war. CAFMS was by no means the only computer-communications system to prove inadequate under the demands of Desert Shield and Desert Storm. While the American military led other armed forces in its use of computers, the rapidly of technical change had left many of its systems out of date even before they were fully developed. Other mainframe systems were only beginning to acquire the hardware and software necessary for integrated databases and distributed processing.

Problems with mainframe systems, exposed immediately at the beginning of the crisis in August 1990, required even more extensive use of secure phones to overcome efficiency breakdowns. Because the Iraqi invasion came while CENTCOM was still developing an operations plan for that contingency, the Joint Operation Planning and Execution System (JOPES) did not have the necessary data to help commanders schedule the deployment. JOPES was itself undergoing hardware and software development and was not ready to manipulate rapidly changing deployment data fast enough to meet CENTCOM's demands. JOPES ran on the Worldwide Military Command and Control System's old Honeywell mainframe computers acquired in the 1970s; it was supposed to integrate separate databases for peacetime planning and crisis planning. JOPES' problems, however, extended beyond its transitional condition to a shortage of personnel trained to operate in this evolving system. For weeks, manual calculations, personal computers, and telephones had to work around JOPES to get American forces deployed to southwest Asia.[1503]

Computer system after computer system followed the sorry pattern of JOPES' performance. Military Airlift Command did not have enough time to schedule missions using its Flow Generation (FLOGEN) model and resorted to personal computer spreadsheet.[1504] The Combat Ammunition System was still under development, and the version used by Tactical Air Command, U.S. Air Forces in Europe, and Pacific Air Forces did not have sufficiently accurate data to be helpful. As for the larger problem of tracking supplies in general, the interim solution of having each deployed unit linked to the supply computer at its host base in the United States never worked well. The precrisis plan to deploy mainframes to the theater for supply accounting gave way eventually to linking as many deployed units as possible to Tactical Air Command's Unisys computer at Langley Air Force Base, Virginia. Achieving that arrangement, however, took the better part of Desert Shield's five months and innumerable STU-III calls.[1505]

The STU-III, like the other four technologies featured in this chapter, hit its stride in the Gulf War. For the most part, these technologies were not really new and were available in less sophisticated forms during the Vietnam War. Thousands of laser-guided bombs were dropped on North Vietnam, together with even more numerous radar-seeking missiles; bombing missions from Thailand depended on air refueling to reach the Hanoi-Haiphong region; and the bases scattered around Thailand coordinated strike packages over the telephone. Some other technologies went through more dramatic changes after the Vietnam War. Airborne radar, for example, came into its own first with the Airborne Warning and Control System and then (just in time for the Gulf War) with the Joint Surveillance Target Attack Radar System. If Iraq's air force and army had been more active, these radar systems would have played a more central role. All of which raises the question: how revolutionary was the air campaign against Iraq?

A revolutionary new generation of high-technology weapons, combined with innovative and effective doctrine, gave the American forces the edge. The war was the first to exploit the new technological possibilities of what has been called the "military-technological revolution." This technological revolution encompasses several broad areas: Stand-off precision weaponry and the sensors and reconnaissance capabilities to make their targeting effective; stealth for surprise and survivability; and the development of missile defenses in response to the expanding proliferation of tactical ballistic missiles and weapons of mass destruction. In large part this revolution tracks the development of new technologies, such as the microprocessing of information that has become familiar in our daily lives, sophisticated sensors, and new materials and design, that substantially reduce radar signature. The exploitation of these new technologies will change warfare as significantly as did the advent of tanks, airplanes and aircraft carriers.

The war tested an entire generation of new weapons at the forefront of this revolution. It represented the coming of age of precision-guided munitions, which made possible a bombing campaign that could achieve strategic results in days rather than months or years, and the use of stealth technology and cruise missiles to achieve strategic surprise and to reduce aircraft losses dramatically. The war also saw the first combat use of the Patriot (or, indeed, of any weapon) in an anti-ballistic missile defense role. Battlefield combat systems, like the M1A1 tank, AV-8jet, and the Apache helicopter, and critical subsystems, like advanced fire control, Global Positioning System (GPS), and thermal and night vision devices, gave us maneuverability and reach our opponents could not match.

The war showed that America must work to maintain the tremendous advantages that accrue from being a generation ahead in weapon technology. A continued and substantial research and development effort, along with renewed efforts to prevent or at least constrain the spread of advanced technologies, will be required to maintain this advantage against what potential adversaries will be able to obtain from the world arms market. In today's budget debate the U.S. needs the high technology advantages offered to their future forces by the B-2 stealth bomber, the F-22 Stealth fighter, and the anti-ballistic missile defense program known as Global Protection Against Limited Strikes (GPALS).

The Gulf War was not the first in which ballistic missiles were used, and there is no reason to think that it will the last. Indeed, ballistic missiles were the only weapon system with which Iraq was able to take significant offensive action against U.S. forces and allies. Americans must expect that even more countries will acquire ballistic missiles and will be prepared to use in future conflicts. Therefore, American planning calls for a more robust defense against ballistic missiles that one day soon will be found in a number of third world arsenals, perhaps armed unconventional warheads. Patriot missiles cannot handle these advanced threats, or any threats actually.

7. Topography

If the topography in the Gulf area was to be compared with that elsewhere in the world, further constraints would be considered. Southern Iraq and the Kuwait region are largely arid or semi-arid desert on low undulating terrain. Major cities and conurbations are few, major roads and rail links limited and Iraqi ground forces were mainly deployed away from civilian populations. Consequently, radar returns from ground targets were usually sharp and free of clutter, epitomized by the widely illustrated JSTARS "picture" of barbed wire twisting in the wind. When acquisition systems were in range, moving targets, such as convoys or armored columns, could be readily detected. In the air, the lowest flying aircraft and helicopters were visible to AWACS. There were no radar shadows in which to seek concealment, unlike, for example, in Bosnia. Iraqi artillery and armor, even when dug in, presented sharp IR images to "tank plinking" aircraft, especially in the evening when sand and metal cooled at different rates.

Behind the Kuwait Theater the Tigris and Euphrates rivers and the Hawr al Hammar mashes were crossed by a number of bridges essential for the resupply and potential withdrawal of Iraqi ground forces. They were visible, vulnerable and valuable interdiction targets. Although the dug-in Iraqi forces were consuming little ammunition and required little maintenance resupply, day-to-day supplies were gradually choked, despite the adept construction of pontoon bridges and bypasses. By the cease-fire, 37 road bridges and nine rail bridges had been destroyed and another nine road bridges severely damaged.[1506] While some units, especially among the Republican Guards were subsequently found to have ample food and water supplies, general patterns emerged of malnutrition and poor health among front-line troops and those captured at Al Khafji. It appears that the deep interdiction attacks reduced the flow of supplies below the level necessary for the entire army, and that they were monopolized by the politically elite formations in the Iraqi mobile reserve.

This regional geography may be contrasted with that of jungle-canopied Malaysia or Vietnam, or mountainous Afghanistan, or forest-covered, mountainous Bosnia. Warfare on any scale in such region would offer different challenges to air power planners from those faced by the Gulf Coalition.

8. The Technology Gap

Those political and environmental advantages were exploited by superior Coalition technology. It is, however, not so much technology which conveys an advantage in warfare but its intellectual mastery. This was demonstrated to a remarkable extent and, subject to the qualifications included by the examination of other, interactive characteristics of this conflict, several technological factors are likely to have a significant impact on future conflicts elsewhere. Three aspects, among many, merit more detailed analysis.

The first is Stealth by the F-117: the product of at least 20 years of research and development (R&D). It is probable that in due course defensive countermeasures will be developed to deprive the F-117 of its relative immunity. It will, however, require the resources of a superpower to develop, produce and deploy the counter-technology on such a scale as to impose major constraints on F-117 operations.

The F-117 undoubtedly has shortcomings. It is not supersonic; it does not carry defensive weapons; it is not an agile aircraft by F-15 or SU-27 standards; it requires several hours to program its offensive systems; it does not possess a particularly long range and it cannot operate in bad weather. Yet, no previous aircraft, or any other conventional weapon or weapon-carrier has had such a dramatic impact on the course of a conflict, nor one embodied a concept with such far-reaching implications for future combat.

The statistics of its performance in the Gulf War have been well publicized. Forty-two F-117 bombers were deployed to the theater, all stationed at King Khalid Airbase near Khamis Mushait in southwest Saudi Arabia, in deep sanctuary from either prying eyes or hostile activity. They flew 1,271 sorties; approximately 2 percent of all Coalition attacks but struck nearly 40 percent of strategic targets without loss or damage.

F-117 has adapted two ancient military attributes, concealment and surprise, to a third dimension enshrouded in electronic warfare. At the USAF Electronic Security Command and Electronic Warfare Center at Kelly Air Force Base in Texas, digital maps of the theater were over laced with US signals intelligence data, which showed the locations, frequencies and effective radius of Iraqi defense radars. For good measure, this achievement was announced to the world two months before *Desert Storm* was launched.[1507]

The F-117 was never invisible, but the combination intrinsic technologies considerably reduced its radar, infrared and optical signature and hence its detection range. The information from Kelly AFB was fed into its navigational computers before each attack and it flew with impunity, and without any support, to achieve complete surprise over Baghdad. It is this attribute, rather than its much-publicized bombing accuracy shared with several other precision-guided munitions (PGM) carriers, which is of longer-term significance. In previous air campaign it had been necessary to roll air defenses back, or fight one's way to the target. It was the F-117 more than any other aircraft, in conjunction with cruise missiles, which enabled the simultaneous attacks to be made on the first night. On a later occasion, a composite force of 75 aircraft, including 32 fighters-bombers carrying PGMs, tankers, defense-suppression and fighter cover, attacked a nuclear construction plan. The force reached and target without loss, but the Iraqi defenders had been warned of its approach and fired smoke pots, which completely obscured the target and thwarted the attack. The following night eight F-117s reached the same target undetected, and placed 16 2,000-pound bombs across it.

Several comparisons of bombing criteria from World War II, Vietnam and the Gulf have been made. General Michael Dugan's was of 4,500 B-17, 95 F-105 and one F-117 sorties to achieve equivalent target destruction.[1508] A US Department of Defense (DoD) summary compared the accuracy probability figures of the B-17: 3,300 ft, the F-105: 400 ft, the F-16: 200 ft, and the F-117: less than 10 ft.[1509] Again, it is not just the reduced CEP, but how many aircraft are going to be required to ensure that at least one gets over the target?

The F-117 will not always enjoy the combat invulnerability, which has marked its progress so far, but it is likely to remain ahead of its opposition for a long time yet. With the addition of an all-weather navigation and attack capability it will become an even more formidable weapon system. Sustained by air-to-air refueling it will become an international instrument with global reach.

9. Airborne Early Warning and Control (AWACS)

One intriguing but unanswered question in air war was, "Could Coalition AWACS aircraft locate the F-117?" supplemented by, "If so, how?" and, "If not, how were F-117 missions deconflicted from other, non-stealthy flight profiles?" Perhaps in time the security wrap will be lifted. Clearly deconfliction was achieved, whether by discrete routing/airspace/time allocation or by intermittent "squawks" or, the achievement of air supremacy, by direct secure communication. Somehow the stealthy F-117 was incorporated in the average of 2,240 sorties coordinated daily by the E-3s in-theater. If any one aircraft may be said to be the linchpin, the center of gravity, of the Coalition's application of air power, it was the E-3, supported on the flanks by USN E-2C *Hawkeyes*. The E-3s flew 448 sorties, the *Hawkeyes* 1,183. E-3s, however, were airborne for 5,546 hours while the *Hawkeyes*, despite flying many more sorties, had less capacity and endurance, total of 4,790 hours. The greater technological superiority lay with the E-3.

The first five USAF E-3s arrived in Riyadh on 8 August, alongside USAF and RAF interceptors. Thereafter they monitored IQAF activity, coordinated the defensive CAPs (combat air patrol) along the Saudi Arabian-Iraqi border and ultimately rehearsed the large-scale control, which was to be applied from 17 January onwards. Without

AWACS there would have been much les confidence in protecting the build-up of ground forces in *Desert Storm* and hence no application of the Air Tasking Order (ATO).

By 17 January 11 USAF E-3s were available from Riyadh and three other flew from Incerlik in Turkey. For most of *Desert Storm* four USAF E-3s were airborne continuously over Saudi Arabia and over southeastern Turkey. In addition, NATO E-3s patrolled the Mediterranean and RSAF (Royal Saudi Air Force) E-3s operated in southern Saudi Arabia primarily for communications relay. The achievements of the E-3s are quantifiable: possibly just one Coalition aircraft shot down by an IQAF interceptor, no Coalition aircraft lost to friendly fire, no mid-air collisions, no AWACS damage, and no AWACS personnel injured.[1510] By the end of the war the Coalition had lost 33 aircraft, and 16 of those were destroyed by "beyond visual range" missile kills. This was the highest proportion of safe sorties in air warfare and is directly attributable to AWACS aerospace surveillance and control which allowed Coalition aircraft to exploit their longer-range missiles to hit an opponent without having to close within visual identification range.

The IQAF had three AWACS aircraft of their own: Soviet: IL-76 airframe with French radar, known as *Adnan*. There was little similarity with E-3. *Adnan* lacked computers and data links. It could control only control only a handful of fighters, by voice and does not have been integrated with the ground-defense system.[1511] It made no contribution to the air war except to the Coalition's target list.

The massive contribution of the E-3 to *Desert Storm* should have come as no surprise. It had been identified as the most important single air power innovation by Western analysts since its development had revolutionized air warfare two decades previously. It had consistently exceeded its specific performance requirement, despite operations in widely differing climatic conditions. By 1991 its contribution was enhanced still further by secure voice communications, the Joint Tactical Information Display System (J-TIDS), which linked it with many other air defense and C^3 structures, IFF radar and the NAVSTAR Global Positioning System (GPS).

The Coalition E-3s, like other high-value assets such as JSTARS, were constantly protected by a defensive interceptor screen. Their pivotal contribution to air warfare had already been noted by the Soviet Air Force and there were reports in western Europe before 1990 that counter-AWACS tactics were being developed by the Soviet Air Force using MiG-25s equipped with anti-radiation missile. The E-3 will, however, remain difficult target, able to see and identify its own attacker well beyond missile-launch range. It has the space and capacity to carry its own ECM defensive screen. Its relative vulnerability, compared with static, ground-based air defense and control systems, is likely to remain slight for the foreseeable future.

10. Space System

Space systems supported Coalition military operations in a wide variety of ways from detection to battle management. Global positioning system (GPS) satellites provided real-time navigational data to land, sea, and air units, which used over 5,000 GPS receivers. Communication satellites handled a good deal of the voice and data transmissions. Meteorological satellites offered critical weather data for planning military operations. And space-warning systems gave indications of Iraqi missile launches. Desert Storm has been called the United States' first comprehensive space war, and it should serve as a catalyst for accelerating the development of tactical space applications.

It is important that the U.S. military recognize the extent of its vulnerability as well: Iraq had no anti-satellite weapons, nor even primitive communications or surveillance satellites. Not all future adversaries will lack this equipment, and as U.S. forces become dependent upon satellites, they will become increasingly vulnerable to an adversary with rudimentary satellite communications and observation capabilities, and even to primitive anti-satellites weapons.

Findings

The Decisive Factor

The decisive factor in the war with Iraq was the air campaign, but ground forces were necessary to eject the Iraqis from Kuwait.

- The mass and precision of the air campaign stunned the Iraqi leadership and military from the war's outset, and stopped most logistic support and ground movement in selected area.
- Early and complete supremacy allowed allied forces flexibility in the conduct of the air campaign and denied Iraqi commanders the intelligence they needed from aerial reconnaissance.
- Centralized control of fixed-wing aircraft in the theater contributed to the effectiveness of the air campaign.
- The air campaign against ground targets was effective with greatly reduced collateral damage compared to earlier campaigns.
- U.S. Army and Marine forces skillfully executed an ambitious ground campaign while a Marine force afloat pinned down Iraqi forces with the threat of an amphibious landing in Kuwait.

The Effectiveness of High Technology

The effective use of high technology was a key reason for both the high level of performance of air and ground forces, and the minimization of allied casualties.

- A new precision in the delivery of weapons made them more effective than in the past and reduced collateral damage.

- Survivability of aircraft and aircrews was enhanced by stealth, defense suppression, and the increased use of pilotless weapons and stand-off range weapons. High availability rates for aircraft were promoted by maintainability in new systems. These factors, in turn, increased sorties rates and allowed the air campaign in particular to develop and sustain a devastating momentum.
- Greater target acquisition ranges and more effective fire enabled ground forces to engage enemy forces at distances beyond the range of enemy sensors.
- Night vision devices enabled around-the-clock operations for Army ground forces, but Marines lacked this capability.
- Land navigation through the use of the Global Positioning System enabled commanders to execute the so-called "Left Hook" through open, nearly featureless desert with unprecedented speed and precision.

Technology Related-Problems

The war with Iraq also demonstrated technology-related problems.

- U.S. forces, particularly in the air campaign, could have been more effective had there been a greater ability to process and disseminate target and other information target and other information, especially in the assessment of damage done by allied air strikes.
- One-target, one-round precision, coupled with long ranges and inadequate ability to distinguish between friend and foe, produced one of the most distressing problems of the war: casualties of friendly fire. U.S. forces lack effective means to distinguish between enemy targets and friendly forces in the midst of battle.

- In many instances, the readiness rates and operating tempos of primary platforms such as aircraft, tanks and fighting vehicles outpaced the ability of support structures and equipment. For instance, aerial tankers became a limiting factor in air operations.
- Communications are still plagued by incompatibilities between services, inadequacies between levels of command, as well as by technical limitations.
- The military effectiveness of U.S. existing defense against tactical ballistic missiles has been questioned. The Patriot anti missile system performed below its intended role of point defense of installations such as ports and airfields.
- U.S. forces on land and sea continue to be woefully unprepared from mine clearing and breaching operations.

U.S. Military Dependence

The Gulf War demonstrated beyond reasonable doubt that the U.S. military is both politically and logistically dependent upon its friends and allies. The United States will be unable to perform any major contingency operation without a substantial degree of assistance from other nations. The option of "doing it alone" simply does exist except in minor operations, and all foreign and defense policy decisions must be made with this realization.

Politically, the Bush administration depended upon its friends and allies, particularly the Arab members of the Coalition, for both international and domestic legitimacy. Internationally, support from the United Nations granted the Coalition military operations almost unprecedented legitimacy; participation of major Arab states in the Coalition may have been the unique precondition for such world support. U.S. public support for President Bush's policies benefited greatly from the creation of an international Coalition and the knowledge that, if blood were ultimately to be spilled, it would not be that of the United States alone.

The economic contributions of allies also had very significant political effects. In the strictest sense, the United States could have conducted its military operations without foreign economic support, but justifying those operations to a skeptical U.S. public would have been much more difficult if Washington alone were footing the entire bill. This lesson has not been lost on either the U.S. Congress or the public. In the future, growing constraints on U.S. defense resources will make this sort of multilateral burden sharing even more necessary for the granting of U.S. public support.

U.S. dependence also has an important logistical aspect. Both in moving to the Gulf and in operating there. U.S. military forces were dependent on Coalition logistical support to a degree that is not widely appreciated. For example, the movement of the Seventh U.S. Corps out of central Germany required 465 trains, 312 barges, and 119 convoys of ships. This logistical operation was orchestrated primarily by four NATO nations using both military and civilian agencies, in essence reversing well-rehearsed NATO plans for the reinforcement of Europe. It took another 578 aircraft and 140 ships to complete the strategic movement to Saudi Arabia. These movements would have been beyond the capability of U.S. transportation assets. At the time already fully occupied with movements from the continental United States.[1512]

The issue of logistical dependence is a pressing one and not isolated to inter-theater operations. Without Arab oil, Saudi trucks, heavy tank transporters from Germany and East European countries and without the Coalition's effort–with the economic embargo–to deny Iraq its requirements, the U.S. military campaign would have been a vastly more difficult proposition. Within the theater, the Saudis alone provided 800 transport trucks for general use and 5,000 tankers and trucks for distribution of 20.4

million barrel of Saudi fuel, as well as water, additional spare parts, communication facilities, and other crucial logistical elements.[1513]

Recognition of dependence and interdependence also calls for renewed efforts to develop and deploy interoperable military equipment, particularly command, control, communications, and intelligence (C^3I) systems. If Americans work with friends and allies in most future contingencies, it makes sense to develop in peacetime not only procedures and understandings, but also the equipment to make that cooperation as smooth as possible. Because of declining worldwide defense budgets, national arms industries are struggling to stay alive, and the process of multilateral arms cooperation has been greatly complicated. But the Gulf War proves that the issue is as important as it is challenging.

At Last!

The coalescence of so many circumstances, which occurred in the Gulf War, may be repeated elsewhere, but history suggests it is unlikely. Air power determined the outcome, but that is not to say that it will do so elsewhere next time. Technology came closer than ever before to matching the dreams and forecasts of the air power theorists, but may not do so in different environments nor, in the longer term, against the swing of the technological pendulum from the offence to defensive countermeasures.

Air power proved that it could substitute for land power. It proved that even if it could not hold ground it could deny it to hostile ground forces. It demonstrated that it could now reach into the strategic heart of a country to threaten any known static political, economic or military target with the maximum precision and the minimum collateral damage and casualties. Ominously, it demonstrated that strategic surprise could be achieved and the most advantageous. It confirmed the fatal consequences of conceding command of the air to an enemy. That conclusion suggests that wherever air power can applied, it is likely to dominate, or strongly influence the outcome of conflict on the surface.

Whether and how far it may be applied is itself likely to be influenced by the presence or absence of the features discussed above. There is indeed, a strong presumption in favor of air power as the instrument of choice for shaping the complexion of war in most circumstances, by those countries able to apply it. The world, however, has not yet seen a conflict in which air power was opposed by well-marshaled forces trained and motivated to exploit its comparative weakness, nor since World War II a war in which one well-equipped, high-quality air force faced another. In view of the dominance of air power by the USA in the foreseeable future, the former is much more likely than the latter. Meanwhile, the remaining skeptics among ground and naval forces should reappraise the implications of hostile command of the air for their activities, while air power ideologues should reflect at length on all the circumstances, which contributed to its apotheosis in1991.

In summary, the conclusion that high technology won the Gulf War, and the corollary that U.S. technology will allow the United States and its allies to dominate battlefields around the world, are flawed. Smart weapons worked well and the U.S. investment in them was justified, but the victory in the Gulf is equally attributable to a number of other vital factors. The implications for defense spending are clear: America needs smart weapons, but she also needs smart, well-trained troops.

Epilogue

Technology in Warfare: The Electronic Dimension

Only the dead have seen the end of war

Plato

Impact of Technology on Warfare

So what is the role of technology in warfare and where do we go from here? Warfare is foremost a sociological matter. Technology provides the means through which scientific knowledge is applied to an artificial process – an engine of destruction and casualties. All technology in warfare either directly provides for or supports this objective function and its detailed development falls into a tried and true process. Engines of warfare fit the organization; needs for warfare and the state of the technical art determine the structure of that organization. Technology provides a means for conducting and resolving conflict. It has a long history in casualty production and increasingly efficient methods for the destruction of material and social assets. Most programs for advancing technology in warfare focus on increasing such performance.

Explosive and tubes for propulsion of those explosive or kill mechanism led to the infantry squad (members close enough to shout to each other and carrying tubes called rifles), the tank (large protected tubes to damage defended positions to help the infantry seize them), artillery (unprotected tubes to hurl explosive shells indirectly from defilade into the defended positions or attacking infantry), the tubes of jet engines, the tube of missiles for defense and attack, and so on. The force structures required large numbers of people to operate in WWI and WWII and would have used only a fraction of these numbers for a WWIII nuclear exchange: dealing with the casualties from that exchange would have been a different story, involving much of the populations of western civilization.

The nature of warfare has already changed, but it is difficult to tell by looking at today's force structures, which are designed around tubes for a warfare we no longer expect to experience but whose memories we still fear and for which we are "prepared." Today's force structure use better and better tubes – they do not easily replace tubes nor can they easily retain the tube holders or change the way that many people directly or indirectly support those who hold tubes.

Before technology of future conflict is best defined we therefore need to understand what its purpose might be and how difficult it might be to realize that purpose. The progress of innovation in industry provides a directly relevant model from which lessons can be learned and new ideas proposed. Existing institutions cannot easily innovate, even though they use technology. The reason are cultural and economic – fear of change and the cost of change.

The Electronic Dimension

Even while the shadow of nuclear weapons remains dominant over international politics and military affairs, electronic warfare is continuing to change the conduct of warfare and political conflict.

It is clear that electronic warfare is becoming more important than ever. But we cannot be sure how electronic warfare would affect warfare, largely because there have been such revolutionary technological changes since Hiroshima.

Some things are obvious. Electronic warfare has created its own technology, such as antiradiation missiles, and its own tactics, such as jamming. Electronic warfare is also continuing to change the nature of any future campaigns and theater offensives. Electronic warfare, or more broadly, the struggle over the collection, manipulation and distribution of information, may also yet change the nature of warfare. Will the manipulation of national or international public opinion by satellite television be more important than several aircraft carriers? Will U.S. national security depend less on military power, and depenu even more on the government's psychological economic, political and military powers?

The nature of changes wrought by electronic warfare are uncertain, and serve to compound the normal uncertainty of war. The uncertainty is a danger and an opportunity– a danger because unexpected failures may cause disaster, an opportunity because the nation or alliance that best understands electronic warfare will have a major advantage in conflict.

Electronic warfare changes more than the techniques, technology and tactics of warfare; it changes higher levels of warfare, including military organization, operational campaigns and strategies. The increased role of electronic warfare first effects offensive and defensive technology.

Radios must be upgraded to include features designed to defeat enemy interception, jamming and eavesdropping. Sensor must be combined to defeat enemy jamming. Identification systems must be designed to allow earlier identification of approaching targets. But improved jamming devices must be built and combined by C^3I networks with other jamming devices to defeat or deceive a wide range of sensors and communications systems.

Electronic systems must be hardened against powerful electromagnetic pulses or lasers, while scientists must pursue the development of more powerful directed energy weapons.

Computerized weapons need to be protected against viruses, even as more effective viruses need to be produced to damage enemy computerized systems.

This cornucopia of electronic warfare systems also changes tactics in high-and-low-intensity warfare. At the tactical level, radio-direction finders and unmanned robot aircraft can be used to find targets for increasingly large-range weapons. Sensors can be blinded by laser weapons. Soldiers must disperse over more ground than ever, yet combine their strength faster with the aid of C^3I networks.

Mobility, dispersion, stealth, and electronic countermeasures become the keys to survival. For example, when threatened by missiles carrying infrared, radar, and passive guidance systems of unknown technical design, a wise course is to forgo reliance on a single defense, but to combine electronic countermeasures and stealth to blind the enemy, high mobility to sidestep attacks, and aggressive physical and electronic attacks to destroy enemy weapons and C^3I networks.

In aircraft to aircraft combat, the very high quality of infrared technology will allow missiles to strike home despite the escape maneuvers of their targets. Thus the dog fighting skills of individual pilots decline further in importance, while cooperation, speed, passive surveillance range, and long-range identification capability become vital. Such desiderata argue for close linkage between fighters and radars, identification systems, and ground-based long-range antiaircraft missiles. Indeed, this C^3I integration was precisely the techniques used by the Israelis in their lopsided 84 to 0 air battle with the Syrian Air Force in 1982. But organized networks of flying machines only increase further the role of electronic warfare and the expense of military preparations.

Control of the air and space will be more important than ever because it greatly determines the ability of warning armies to find targets and transfer information. If one side can prevent reconnaissance by the other, but gather information for itself using aircraft and satellites, then it will have won an advantage that can be used to help destroy targets, including the enemy's vital C^3I networks. But against well armed opponents, the price of aircraft survivability is becoming too great to bear, and is forcing greater use of unmanned space satellites, unmanned reconnaissance drones, and unmanned cruise missiles.

The role of manned aircraft is being restricted to fighter aircraft and various forms of electronic warfare aircraft, whose well-trained pilots cannot be replaced by relatively inflexible computers, no matter how powerful. Such changes in technology and tactics will combine to cause changes in military operations. For example, the high ground of space will become increasingly important for gathering and distributing information.

At sea, modern weaponry in making surface ships less survivable, while the price of defensive system is driving the cost of ships to great heights. It seems clear the U.S. Navy is heading for a major reduction in size during the 2000s – ensuring the remaining ships will have to cooperate even more through the use of advanced C^3I networks.

Moreover, the threat of electronic warfare will force ship designers to build stealthier ships, and ultimately, to seek the safety granted by water's absorption of radio and infrared signals. This trend may drive naval aircraft ashore and funnel more money into construction of submarines able to cooperatively control huge volumes of air and sea by the use of long-range missiles, unmanned minisubs, and unmanned robot aircraft. In effect, large submarines could become underwater versions of aircraft carriers, complete with the carrier's former ability to avoid attack and its good C^3I that allows the concentration of coordinated firepower.

Despite the growing role of submarines, carriers have many years of useful service yet as midocean defensive airbases for relatively short-legged fighters and surveillance aircraft. Carriers are also an excellent means of bringing tactical airpower close to distant low-technology enemies and useful as majestic big sticks in "show the flag" exercises.

Electronic warfare can cause similar changes in the nature of land warfare. The last time a new military revolution was in 1940. The next revolution will become obvious over the next few years as the new technologies are combined in unexpected, powerful, complex, and unfamiliar ways. For example, indirect-fire weapons such as artillery and long-range rockets carrying bomblets and smart missiles will become more important because of their ability to reach out and kill at 40 km (25 mi)or more. The better these long-range weapons are tied to long-range sensors by good communications, the swifter they can reach out and destroy someone. Moreover, instead of forcing their way through the thick defense of the front line into the enemy's rear area, modern weapons allow invaders to attack frontline, rear-area, and enemy homeland simultaneously, so increasing the chance for a quick victory.

The new technology that created long-range sensors and fast-flying missiles is extending the depth of combat. Just as each war has been limited by the distance that the participants could see, shoot and talk to each other, so will high-technology war expand until what was formerly the frontline will eventually expand to hundreds of kilometers width – the range of airborne sensors and long-range missiles. Thus military effectiveness rests ever more on the effective use of electronic warfare to preserve one's own sight, reach and organization, while blinding, limiting and disrupting the enemy.

The advent of long-range conventional weapons and sensors, especially spy satellites, also blurs the distinction between offensive and defensive forces. Now, both defenders and attackers do not even need to leave their bases in order to mass destructive fire onto enemy units. Indeed, the defender can seize the initiative by striking first. But who is the attacker if both armies commence destroying and disrupting each other while still parked on their separate exercise ground? The increased importance of long-range concentrated firepower over massive tank armies means that the attacker can now concentrate firepower for his onslaught even while remaining in what were formerly regarded as dispersed, defensive positions.

Moreover, because the initial effect of electronic combat attacks on enemy networks and organizations is their temporary disruption, military logic calls for a complementary mechanized offensive to take advantage of enemy's confusion and paralysis. As in all military affairs, the combination of different weapons creates much greater power than the sum of the parts. Without an offensive to destroy or capture what has been disorganized, the enemy will simply repair himself and return to the attack. Thus the trend toward attack – and the advantage of surprise – is strengthened by electronic combat. Sadly, this logic will only increase the chance of a crisis escalating to war, and also will make control of wars more difficult.

The power of the new weaponry undermines arguments for schemes intended to ensure adequate defenses without appearing to create an offensive capability. Proponents of such defensive schemes envisage light infantry militia forces equipped with powerful antitank weapons and antiaircraft weapons, backed up by minefield and bunkers and possibly by a small mechanized force. Additionally, these defensive forces would have much electronic warfare capability to blind, jam, an deceive the new long-range sensors and weapons. The scheme's lack of offensive capability is expected to reassure the other side that no attack is possible, helping prevent political crises from escalating into war.

Unfortunately, the growing importance of reconnaissance – strike complexes and fast-moving forces united by extensive C^3I systems helps the attackers concentrate their strength into sudden narrow thrust at critical points. Also, the attacker's electronic warfare would hinder the defender's attempts to mass defensive forces in front of the rapidly moving attackers. Moreover, reconnaissance – strike weapons can simply fly over the infantry, much as the B-29 bomber sailed over the Japanese infantry on the way to drop its nuclear bomb on Hiroshima.

It might be argued that adoption of the new technology will strengthen the defender more than the attacker, because the defender can concentrate his long-range firepower as the enemy concentrates for an attack. Also, the survivability of the defender's C^3I systems might be helped by remaining on the defensive because he can use extensive and well-prepared networks of military and civilian communications.

The importance of electronic warfare means that if soldiers want to win, they must take the offensive to wreck the enemy networks as fast as possible, and before the enemy wrecks their own networks. Like Machiavellian diplomats disassemble the enemy's organization by wrecking his C^3I networks.

War is a two-sided business, so both sides will be racing to wreck each other's C^3I networks. This means that each side has less and less time to wreck the enemy before they are wrecked themselves. Where in the past soldiers, commanders, armies, and even nations had time to recover from enemy surprise attacks, now frontline troops and small nations will not have a second chance to recover from defeat by fast-flying missiles, swift helicopters, and rapidly moving mechanized corps.

The best possible use of time is more crucial than ever because the tempo of war is faster. According to Sun Tzu, "The value of time – that is, being a little ahead of your opponent – has counted for more than their numerical superiority or the nicest calculations with regard to [logistic] commissariat."[1514]

The uncertain effect of the new weapons and electronic warfare on the nature of future war may increase or decrease the chances of war, depending on whether leaders think they add to the certainty of victory or add to the uncertainty of war. The complexity of the tactics and technology of electronic warfare, and the potentially very broad impact it can have on battle might cause some leaders to hesitate before placing faith in the ability of their force to win a quick victory. But if leaders trust the military's confident claims that electronic warfare will help them win quick, bloodless victory, they might be more willing to risk war in a crisis. Thus while the unpredictability of electronic warfare has the happy effect of making war more risky, it also leaves room for political and military miscalculations.

Some observers argue that effectiveness use of electronic warfare would reduce casualties and the cost of war, much as the Panzer divisions captured France at minimal cost in World War II compared to the bloody casualties of inconclusive battles in World War I. However, this would be true only if electronic warfare can be waged effectively – despite the uncertainties – and actually helps to win the war, not just a single campaign in a long war.

Would electronic warfare help achieve lopsided victories in battles and campaigns? Perhaps so, but only when used by skilled soldiers in high-technology mechanized warfare. for example, the Israeli army has several times achieved lopsided results against Arabs, although it has not been able to create a permanent political solution.

Perhaps electronic warfare will bolster the arguments of the maneuver school who suggest that Blitzkrieg warfare can allow inferior forces to beat superior forces and that military skill can prevent wars from degenerating into bloody tests of endurance by attrition. Perhaps so, but only if the political aims of the war can be achieved in a single leap by virtue of incompetent and politically weak opponents or limited war aims. Otherwise, the immense resources of modern states will be harnessed for war and bled away into the mud.

Electronic warfare cannot be seen as a cheap war-winner an enemy has the great benefit of strong political support at home or abroad, or when the enemy is armed with ballistic missiles capable of carrying nuclear, chemical, and biological warheads back to friendly cities. Nonetheless, trying to fight such an enemy without the advantage of soldiers skilled in electronic warfare would be courting disaster.

The technology and tactics needed to fight a low-intensity war differ greatly from those needed in a high-technology war, forcing armies to create, train, and equip two distinct types of ground and air forces. Electronic combat and modern technology have only limited uses in low-intensity wars between insurgents and governments. Spy satellites are not very useful for tracking urban guerrillas. But more than ever, rebel forces need the technological gifts of a friendly government to win – unless they are fighting such a corrupt and unpopular power that it can be kicked down like a rotten door. For example, the revolts in Romania and the Philippines succeeded not just because of popular demonstrations, but because they helped or even prompted local military and political leaders to stage a coup d'etat

After all, the nature of technology is very different from the nature of war. Technology is rational and predictable, while war combines emotion, intellect, responsiveness, and chaos. Therefore, to get the best use from technology, soldiers must not try to twist war into a shape that suits the technology, but must twist the technology to suit the needs of combat. When cutting wood, it is always better to go with the grain than against it.[1515]

Ground, air, and naval forces must be welded together by a common goal, a shared theater wide strategy for winning a war, which must match publicly supported political aims. This strategy must use the strength of each military arm to complement the others, and must use them as efficiently as possible to generate the maximum effective firepower and disruption as quickly as possible.

The same trends that call for increasing cooperation between the various services also call for increasing cooperation between the various national security arms of a state or an alliance.

Political agreement on the goal of a conflict must be forged between various nations and the arms of each government, and must match the wishes of the people.

Military, economic, and political intelligence must be quickly shared throughout government, so that threats can be deterred before they are answered with bloody and uncertain force.

Most importantly, there will be greatly increased efforts to wreck an enemy's will, determination and internal strength. The goal is "collapsing the enemy internally rather than physically destroying him. Targets will include such things as the populations' support for the war. Correct identification of enemy strategic center of gravity will highly important."[1516]

As countries in the developing world acquire more and more powerful weapons dependent on internal electronic systems and overall C^3I networks, the value of such nonlethal weaponry increases. Thus an attack being prepared by the reasonably sophisticated armed forces of a developing country could be crippled in its tracks by several blasts of a defender's radio frequency weapons. And if bloody combat did continue, then the defenders would be better able to resist the attack.

A critical peacetime task for soldiers is to develop new technology and to learn how it is best used. Even a brief look at military history will show many military organizations that have failed to adapt to new technology. The Saxon Housecarls could not adapt to the offensive power of the Norman knights and bowmen in the eleventh century, the French knights could not adapt to the defensive power of the English bowmen and infantry in the fourteenth century. Equally, the Allies could neither understand the offensive power of submarines nor the defensive power of trenches, machine guns and artillery in World War I. Nor could the Allies understand the offensive power of the Panzer divisions in World War II. The Germans did not understand the defensive power of the British radar network during the Battle of Britain, and also failed to understand the immense defensive power of Soviet industry and society.

With such a record of military failures during periods of relatively slow technological change, it would be very surprising if any of the world's militaries fully understood the impact of electronic warfare and the new weapons of today.

Is there a gleam of light to end this dark tale of military uncertainty and effort? It is possible that the technology that brings us C^3I systems may also bring the world together in a global village, tolerant of other's wishes.

There is today a great deal of discussion on the subject of using our present-day technology, knowledge of psychology, sociology, and other social science to prevent war, and various action programs are attempting to put this knowledge to practical use. Common sense, as well as our scientific training, would seem to indicate that if we wish to limit a recurrent phenomenon, we need first to define the cause or causes that phenomenon. It is no longer, for example, regarded as legitimate or intelligent medicine to try to cure a symptom without dealing with its cause. When this *is* done, the same or a related symptom generally breaks out again, sometimes in a worse form.

Notes

Chapter 1

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Chapter 2

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[6] James T. Shipman, Jerry L. Adams, and Jerry D. Wilson, *Introduction to Physical Science* (Lexington, MA: D.C. Heath and Co., 1987), p. 121.
[7] *Ibid.*
[8] *Ibid.*
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[10] *Ibid.*
[11] *Ibid.*, pp. 121-122.
[12] John E. William, Frederick E. Trinklein, and H. Clark Mrtcalfe, *Modern Physics* (New York, NY: Holt, Rinehart and Winston, Publishers, 1984), p. 286.
[13] Bureau of Naval Personnel, *Basic Electricity* (Washington, DC: GPO, 1960), p.1.
[14] David C. Knight, *Eavesdropping on Space: The Quest of Radio Astronomy* (New York, NY: William Morrow and Co., 1975), pp. 9-10.
[15] William H. Nebergall, Frederic C. Schmidt, and Henry F. Holtzclaw, Jr., *College Chemistry* (Lexington, MA: D.C. Heath and Co., 1976), pp. 815-816.
[16] *Ibid.*, p. 817.
[17] Eugene Hecht, *Physics Calculus* (New York, NY: Books/Cole Publishing Co., 1996), pp. 922-923.
[18] *Ibid.*, pp. 924-925.
[19] Gerrit L. Verschuur, *The Invisible Universe Revealed* (New York, NY: Springer-Verlag, 1987), p. 9.
[20] David C. Knight, *Eavesdropping on Space: The Quest of Radio Astronomy* (New York, NY: William Morrow and Co., 1975), pp. 17-18.
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[22] *Ibid.*, p. 19.
[23] *Ibid.*
[24] Gerrit L. Verschuur, *The Invisible Universe Revealed* (New York, NY: Springer-Verlag, 1987), p. 181.
[25] David C. Knight, *Eavesdropping on Space: The Quest of Radio Astronomy* (New York, NY: William Morrow and Co., 1975), pp. 19-20.
[26] *Ibid.*, pp. 21-22.

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[27] D. Lawrence, "Soviet Radioelectronic Combat," *Air Force Magazine*, March 1982.
[28] P. Collins, "The Enervating Weapons – A Basic Look at Electronic Warfare," *NATO's Fifteen Nations Special*, 2/1980.

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[32] D. Curtis Schleher, *Introduction to Electronic Warfare* (Boston, MA: Artech House, 1986), pp. 4-5.
[33] Winston S. Churchill, *Their Finest Hour* (Boston, MA: Houghton Mifflin Company, 1949), pp. 381-2.
[34] *Aviation Week and Space Technology* (hereafter referred to as AW&T) April 22, 1991, pp. 68-69.
[35] Eric Schmitt, Why Iraqi Battle Threat Fizzled: Allied Strength and Enemy Weaknesses, *The New York Times*, March 4, 1991, p. A-9.
[36] Barbara Opell, McPeak Says Iraqi Air Force in Ruins, *Defense News*, April 18, 1991, p. 36; Kernan Chaisson, U.S. Must Refine EW Systems, Tactics, *Defense News*, March 11, 1991, pp. 29-30; and F-117 Joint STARS are Winners in Gen. Storm Scorecard, Inside the Pentagon, March 7, 1991, pp. 6-7.
[37] Air Commodore J. Singh, *Air Power in Modern Warfare* (New Delhi, India: Lancer International, 1988), p. 122.

[38] George Leopold, Maintenance of Vital EW Gear in Gulf Worriers U.S., *Defense News*, January 28, 1991, p. 31.

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[39] Daniel Roselle, *A World History: A Cultural Approach* (Lexington, MA: Ginn and Co., 1976), p. 419. In 1805 Lord Nelson and the British fleet had defeated the French fleet at the Battle of Trafalgar, off the southwest coast of Spain.
[40] John D. Kraus, *Antennas* (New York, NY: McGraw-Hill International Edition, 1988), p. 2. By 1800 Alessandro Volta of Italy had invented the Voltaic cell and, connecting several in series, the electric battery. With batteries, electric currents could be produced.
[41] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 1
[42] Ibid., p.2.
[43] Paddington to West Dayton in 1837 and Washington to Baltimore in 1844.
[44] Captain L. S. Howeth, *History of Communications – Electronics in the United States Navy* (Washington, D.C: U.S. Government Printing Office, 1963), p. 15.
[45]Daniel Roselle, *A World History: A Cultural Approach* (Lexington, MA: Ginn and Co., 1976), p. 504. In 1854, France joined Britain against Russia in the Crimean War. A victory in this war enabled France to regain some of the prestige.
[46] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 7.
[47] *Ibid.*, p. 8.
[48] Notably the attack with fire ships by the English on the Spanish Armada at anchor off Calais in 1588; the pursuit of du Casse by Benbow in the West Indies in 1702 and the action between Saumarez and Linois in the Straits of Gibraltar in 1801.
[49] Ten times as bright as an arc light using current supplied by primary batteries and able to stay alight four times as long.
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[51] Ibid., p. 130.
[52] Henry Newbolt, *Naval Operations*, Vols. 4 and 5 (London, UK: Longmans Green, 1928-31), vol. 4, p. 175.
[53] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), pp. 26-27.
[54] *Ibid.*, pp. 38-39.
[55] *Ibid.*, p. 40.

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[57] *Ibid.*, pp. 55-60
[58] *Ibid.*, pp. 68-70.
[59] Radio transmitter using as its radio frequency source the oscillatory discharge of a capacitor across a coil and a spinterometer.

[60] Eugene S. Politovski, *From Libau to Tsushima*. Trans. by Major F. R. Godfrey (London, UK: John Murray, 1906), pp. 79-85.
[61] *Ibid.*, pp. 87-92.
[62] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 44.
[63] *Ibid.*, p. 45.
[64] *Ibid.*, pp. 45-46
[65] *Ibid.*, p. 46.
[66] Eugene S. Politovski, *From Libau to Tsushima*. Trans. by Major F. R. Godfrey (London, UK: John Murray, 1906), pp. 90-92.
[67] *Ibid.* pp. 93-95.
[68] *Ibid.*, pp. 97-98.
[69] *Ibid.*, p. 100.
[70] *Ibid.*, p. 105.

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[71] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 59
[72] Captain L. S. Howeth, *History of Communications – Electronics in the United States Navy* (Washington, D.C: U.S. Government Printing Office, 1963), p. 27.
[73] *Ibid.*, p. 32.
[74] *Ibid.*, p.33.
[75] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 72.
[76] *Ibid.*, pp. 72-73.
[77] Captain L. S. Howeth, *History of Communications – Electronics in the United States Navy* (Washington, D.C: U.S. Government Printing Office, 1963), p. 57.

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[78] David Kahn, *The Code Breakers* (New York, NY: Scribner, 1996), p. 298.
[79] *Ibid.*, p299.
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[82] *Ibid.*, p. 263.
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[84] John M. Carroll, *Secret of Electronic Espionage* (New York, NY: E. P. Dutton & Co., 1966), p.16-17.
[85] *Ibid.*
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[87] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 87.
[88] David Kahn, *The Code Breakers* (New York, NY: Scribner, 1996), p. 300.
[89] John M. Carroll, *Secret of Electronic Espionage* (New York, NY: E. P. Dutton & Co., 1966), p. 23
[90] *Ibid.*, p. 25.
[91] *Ibid.*, p. 26.
[92] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p. 88.
[93] John M. Carroll, *Secret of Electronic Espionage* (New York, NY: E. P. Dutton & Co., 1966), p. 29.
[94] *Ibid.*, p. 32.
[95] *Ibid.*, p. 32.
[96] *Ibid.*, pp. 32-33.
[97] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), pp. 111-112
[98] *Ibid.*, p. 113
[99] *Ibid.*, p. 125.
[100] *Ibid.*, p. 130
[101] *Ibid.*, p. 132.
[102] *Ibid.* p. 133.
[103] *Ibid.* p. 106.

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[105] *Ibid.*, p. 160.

[106] Alfred Price, *Instruments of Darkness: The History of Electronic Warfare* (New York, NY: Charles Scribner's Sons, 1977), pp. 55-56.
[107] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), pp. 168-169.
[108] *Ibid.*
[109] Alfred Price, *Instruments of Darkness: The History of Electronic Warfare* (New York, NY: Charles Scribner's Sons, 1977), pp. 56-58.
[110] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p.169.
[111] Mario De Archangelis, *Electronic Warfare* (Poole-Dorset, UK: Blandford Press, 1985), p.
[112] *Ibid.*, p.
[113] Alfred Price, *Instruments of Darkness: The History of Electronic Warfare* (New York, NY: Charles Scribner's Sons, 1977), p. 58.
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[115] Arthur Hezlet, *Electronics and Sea Power* (New York, NY: Stein and Day, 1975), p.170.
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[122] R. J. Overy, *The Air War: 1939-1945* (New York, NY: Stein and Day, 1981), p.58.
[123] Alfred Price, *Instrument of Darkness* (New York, NY: Charles Scribner's sons, 1977), p. 61.
[124] *Ibid.*, p. 62.
[125] *Ibid.*, p.48.
[126] David Kahn, *The Code Breaker* (New York, NY: Scribner, 1996), p. 447.
[127] Alfred Price, *Instrument of Darkness* (New York, NY: Charles Scribner's sons, 1977), p. 72.
[128] R. V. Jones, *Most Secret War* (London, UK: Coronet Books, Hodder and Stoughton, 1978), p. 239.
[129] R. J. Overy, *The Air War: 1939-1945* (New York, NY: Stein and Day, 1981), p.57.
[130] *Ibid.*, p. 258.
[131] R. J. Overy, *The Air War: 1939-1945* (New York, NY: Stein and Day, 1981), p. 41.
[132] Haywood S. Hansell, Jr., *The Strategic Air War Against Germany and Japan: A Memoir* (Washington, D.C: Office of Air Force History, 1986), p. 50.
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[499] *Ibid.*, p. 250
[500]Anthony Pearson, *Conspiracy of Silence: The Attack on the U.S.S. Liberty* (London, UK: Quartet Books, 1978), pp. 15-21.
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[525] *Ibid.*, pp. 225-227.
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[555] Mario de Arcangelis, *Electronic Warfare* (Poole, UK: Blandford Press, 1985), p. 191.
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[559] Chaim Herzog, *The Arab Israeli Wars* (New York, NY: Random House, 1982), pp. 345.

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[564] *Ibid.*, p. 158.
[565] Mario de Arcangelis, *Electronic Warfare* (Poole, UK: Blandford Press, 1985), p. 194.
[566] Chaim Herzog, *The Arab Israeli Wars* (New York, NY: Random House, 1982), pp. 348.
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[569] Chaim Herzog, *The Arab Israeli Wars* (New York, NY: Random House, 1982), p. 350.
[570] Merrill Skolnik, *Radar Handbook* (New York, NY: McGraw-Hill, 1990), pp. 11-46, 11-51.
[571] Chaim Herzog, *The Arab Israeli Wars* (New York, NY: Random House, 1982), p. 316.
[572] *Ibid.*, p. 318.
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[576] Mario de Arcangelis, *Electronic Warfare* (Poole, UK: Blandford Press, 1985), p. 199.
[577] Chaim Herzog, *The Arab Israeli Wars* (New York, NY: Random House, 1982), p. 326.
[578] *Ibid.*, p. 349.
[579] Ibid., p. 349.
[580] *Ibid.*, p. 351.
[581] Ibid., p. 352.
[582] *Ibid.*, p. 353.
[583] *Ibid.*, p. 354.
[584] *Ibid.*, p. 410.
[585] *Ibid.*, p. 410.
[586] *Ibid.*, p. 411.
[587] *Ibid.*, pp. 404-405.

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[589] *Ibid.*, p. 374.
[590] *Ibid.*, p' 375.
[591] Mario de Arcangelis, *Electronic Warfare* (Poole, UK: Blandford Press, 1985), pp.224-226.
[592] Christopher Andrew, *For the President's Eyes Only* (New York, NY: HarperPerennial, 1996), p. 435.
[593] *Ibid.*, pp. 436-437.
[594] *Ibid.*, pp. 438-439.
[595] *Ibid.*, pp. 440-441.
[596] The TERCOM (Terrain Contour Matching) guidance system of the AGM-cruise missile is based on correlating the terrain-mapping data stored in the system itself with the terrain being over flown to locate the point fixes along the route to the target. In other words, the missile follows a pre-programmed flight path down to the target. The TERCOM's sole function is to compensate for course errors by comparing the terrain program contour characteristics, stored as digital data in the computer "library" of the guidance system, with the actual terrain contour characteristics as measured during flight by the radar altimeter. The maps are programmed using measurements collected by reconnaissance aircraft and satellites.
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[598] *Ibid.*, p. 444.
[599] *Ibid.*, p. 445.
[600] *Ibid.*, pp. 446-447.
[601] *Ibid.*, p. 448.
[602] Rhodri Jefferys-Jones, *The CIA & American Democracy* (New Haven, CT: Yale University Press, 1989), p. 223.
[603] *Ibid.*, 224.
[604] *Ibid.*, pp. 225-226.
[605] Christopher Andrew, *For the President's Eyes Only* (New York, NY: HarperPerennial, 1996), p. 449.
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[608] *Ibid.*, p. 228.
[609] Loch K. Johnson, *America's Secret Power: The CIA in a Democratic Society* (New York, NY: Oxford University Press, 1989), p. 117.
[610] *Ibid.*, p. 118.
[611] *Ibid.*, p. 419.
[612]Christopher Andrew, *For the President's Eyes Only* (New York, NY: HarperPerennial, 1996), p. 451.
[613] *Ibid.*, p. 451.
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[619] *Ibid.*, p. 453.
[620] *Ibid.*, p. 454.
[621] *Ibid.*, p. 454.
[622] *Ibid.*, p. 455.
[623] *Ibid.*, p. 455.
[624] Loch K. Johnson, *America's Secret Power: The CIA in a Democratic Society* (New York, NY: Oxford University Press, 1989), p. 120.
[625] *Ibid.*, p. 120.
[626] *Ibid.*, p. 121.
[627] Rhodri Jefferys-Jones, *The CIA & American Democracy* (New Haven, CT: Yale University Press, 1989), p. 216.
[628] *Ibid.*, p. 217.
[629] Tony Mason, *Air Power: A Centennial Appraisal* (London, UK: Brassey's, 1994), p. 93.
[630] *Ibid.*, p. 94.
[631] Rhodri Jefferys-Jones, *The CIA & American Democracy* (New Haven, CT: Yale University Press, 1989), p. 248.
[632] Tony Mason, *Air Power: A Centennial Appraisal* (London, UK: Brassey's, 1994), pp. 114-121.
[633] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), pp. 72-75.
[634] *Ibid.*, pp. 72-75.
[635] *Ibid.*, pp. 82-83.
[636] *Ibid.*, p. 254.
[637] Christopher Andrew, *For the President's Eyes Only* (New York, NY: HarperPerennial, 1996), p. 469
[638] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 242.
[639] *Ibid.*, p. 242.
[640] *Ibid.*, p. 242.
[641] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), pp. 148-149.
[642] *Ibid.*, p. 150.
[643] *Ibid.*, p. 152.
[644]*Ibid.*, p. 153.
[645] *Ibid.*, p. 155.
[646] Tony Mason, *Air Power: A Centennial Appraisal* (London, UK: Brassey's, 1994), p.65.
[647] *Ibid.*, p. 66.
[648] *Ibid.*, p. 76.
[649] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), p.156.
[650]Type 42 destroyers were equipped with terminals for the" Scot Skynet" system for communications via satellite.
[651]It has been suggested that the ship's ESM equipment was also switched off to facilitate radio communications via satellite (see Defense Electronics, November 1983: Falklands). However, it is inconceivable that a ship acting as a radar picket would have had both its radar and ESM equipment switched off simultaneously.

[652] James F. Dunnigan, *How to Make War: A Comprehensive Guide to Modern Warfare* (New York, NY: William Morrow, 1988), p. 151.
[653] *Ibid.*, pp. 152-153.
[654] *Ibid.*, p. 154.
[655] There are new generation weapons, such as Seaguard, Goalkeeper, Phalanx, etc., that have very high rates of fire–up to 4,000 rounds per minute. Their ammunition is also of an extremely advanced "kinetic" type, guaranteeing destruction of a missile by one round.
[656]A few weeks previously, Argentinean naval aviation had begun intensive operational testing for the employment of the Super Etendard-Exocet combination. The British-designed and built Type-42 destroyers *Hercules* and *Santissima Trinidad* were used for this purpose. It was concluded that it was possible to get close enough to Type - 42s, to which class *Sheffield* belonged, to launch missiles by low flying to avoid detection by their radar. The missiles could be launched from a distance outside the range of Sea Dart missiles and, once the missiles had been launched, the Super Etendards had nothing more to do than return to base.
[657] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), p.157.
[658] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 248.
[659] The "warmers" of most NATO ships are, generally, programmed only for Soviet radars. Moreover, the Abbey Hill equipment had an extremely limited capacity for pre-programmed warnings. It should also be noted that the surface-to-surface (MM-36) version of the Exocet is installed on many ships of the Royal Navy.
[660]James F. Dunnigan, *How to Make War: A Comprehensive Guide to Modern Warfare* (New York, NY: William Morrow, 1988), p. 155.
[661]Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 250.
[662]Agave is a light; multi-purpose monopulse radar installed on French Super Etendard and Jaguar aircraft. Its main modes are air-to-surface and air-to-air search and tracking, data feed to the missile's radar guidance system, ranging (distance measuring) and navigation. It operates in the I-band (8-10 GHz).
[663] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), pp. 250-251.
[664] *Ibid.*, pp. 251-252.
[665] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), p.158.
[666] *Ibid.*
[667] *Ibid.*, pp. 159-160.
[668]Tony Mason, *Air Power: A Centennial Appraisal* (London, UK: Brassey's, 1994), p. 125.
[669] *Ibid.*, p, 126.
[670] David Baker, *The Shape of Wars to Come* (New York, NY: Stein and Day, 1984), p. 167.
[671] *Ibid.*, p. 185-186.
[672] *Ibid.*, p. 182.
[673] *Ibid.*, pp. 190-191.
[674] *Ibid.*, p. 208.
[675] Ibid., p. 215.
[676] *Ibid.*, pp. 215-216.
[677] *Ibid.*, p. 217.
[678]Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 257.
[679] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), pp. 218-219.
[680] *Ibid.*, p. 220.
[681] *Ibid.*, p. 231.
[682] *Ibid.*, p. 249.
[683] *Ibid.*, p. 250.
[684] *Ibid.*, p. 251.
[685] *Ibid.*, p. 252.
[686] *Ibid.*, p. 262.
[687] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 260.
[688] *Ibid.*
[689] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), p. 274.
[690] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), pp. 260-261.

[691] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), pp. 282-284.
[692] *Ibid.*
[693] *Ibid.*, pp. 292-293.
[694] *Ibid.*, p. 300.
[695] Built by Texas Instrument during the Vietnam War, this family of smart, or laser-guided bombs (LGBs) includes various types, all equipped with the same type of guidance unit, fitted to the nose.
[696] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 262.
[697] *Ibid.*
[698] Max Hasting and Simon Jenkins, *The Battle for the Falklands* (New York, NY: W. W. Norton & Co., 1983), p. 300.
[699]The British also declared that they had lost only twelve aircraft, of which nine were Harriers and Sea Harriers.
[700]The ALQ-101 is the head of a family of pod-contained jammers. It was installed on attack aircraft used in Vietnam. Various technical improvements were made, culminating in the production of a new version, the ALQ-119, which has been sold to many countries. In the Falklands, it was installed on Vulcan bombers to neutralize the radars used to guide Argentinean Roland missiles.
[701] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 263.
[702] Bob Woodward, Veil: *The Secret Wars of the CIA 1981-1987* (New York, NY: Simon and Schuster, 1987), p. 217.
[703] Thomas Friedman, *From Beirut to Jerusalem* (New York, NY: Farrar Straus Giroux, 1989), p. 126.
[704] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 265.
[705] *Ibid.*, pp. 265-266.
[706] EHJ Pallet, Aircraft Instruments & Integrated Systems (London, UK: Longman, 1992), pp. 17-18.
[707] Aviation Week & Space Technology, *Military Aircraft Pilot Reports* (New York, NY: McGraw-Hill, 1996), pp. 113-125.
[708] Col. Trevor N. Dupuy, *Future Wars: The World's Most Dangerous Flashpoints* (New York, NY: Warner Books, 1993), p. 34.
[709] Fillipo Neri, *Introduction to Electronic Defense Systems* (Boston, MA: Artech House, 1991), p. 274.
[710] Ibid., 204.
[711] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), p. 268.
[712] Patrick Seale, *Asad of Syria: The Struggle for the Middle East* (London, UK: I. B. Tauris, 1988), p. 383.
[713] Helena Cobban, *The Superpowers and the Syrian-Israeli Conflict* (New York, NY: Praeger, 1991), p. 35.
[714] Fillipo Neri, *Introduction to Electronic Defense Systems* (Boston, MA: Artech House, 1991), p. 218.
[715] Mario de Arcangelis, *Electronic Warfare* (Pool, UK: Blandford Press, 1985), pp. 268-269.
[716] D. Curtis Schleher, *Introduction to Electronic Warfare* (Boston, MA: Artech House, 1986), p. 179.
[717]Fillipo Neri, *Introduction to Electronic Defense Systems* (Boston, MA: Artech House, 1991), p. 212.
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Acronyms & Glossary

AA	Anti Aircraft
AAA	Anti Aircraft Artillery
ABM	Anti Ballistic Missile
ADF	Automatic Direction-Finder
AEW	Airborne Early Warning
AI	Airborne Intercept (radar)
AIM	Air Intercept Missile
AJ	Anti Jamming
ARM	Anti Radiation Missile
ARP	Antenna Rotation Period
ATO	Air Tasking Order
AWACS	Airborne Warning and Control System
BDA	Battle Damage Assessment
C^3 I	Command, Control, Communication and Intelligence
C^3CM	C^3 Countermeasures
CENTCOM	US Central Command
CEP	Circular Error Probable
Chaff	Metal foil or metal coated fiberglass dipoles, intended to produce spurious echoes on enemy radars or break lock-on.
CIA	Central Intelligence Agency
COMINT	Communication Intelligence
Compass Call	Lockheed EC-130 fitted with equipment to transmit radio TV broadcasts while airborne, usually used to pass propaganda messages to unfriendly forces.
CPB	Charged Particle Beam
CPS	Cycle Per Second (c/s)
CW	Continuous
DF	Direction Finder
DIA	Defense Intelligence Agency
DJ	Deception Jamming
DME	Distance Measuring Equipment
DoD	US Department of defense
ECM	Electronic Countermeasures
ECCM	Electronic Counter-Countermeasures
EHF	Extremely High Frequency
ELF	Extremely Low Frequency
ELINT	Electronic Intelligence
EOB	Electronic Order of Battle
EOCCM	Electro-Optic Counter-Countermeasures
EOCM	Electro-Optic Countermeasures
ESM	Electronic Support Measures
EW	Electronic Warfare
EWO	Electronic Warfare Officer
FLIR	Forward Looking Infrared
FM	Frequency Modulation
GCI	Ground Controlled Intercept (radar)
GHz	Giga Hertz 1 GHz = 1000 MHz
GPS	Global Positioning System

GWAPS	Gulf War Air Power Survey
HARM	High Speed Anti-Radiation Missile
HAS	Hardened Aircraft Shelter
HF	High Frequency
HOJ	Home-on-Jam
Hz	Hertz (cycle per second).
HUD	Head-Up Display
ICBM	Inter-Continental Ballistic Missile
IFF	Identification Friend or Foe
ILS	Instrument Landing System
INS	Inertial Navigation System
IP	Initial point. Final navigational check point, before commencing attack run.
IR	Infra Red
IRBM	Intermediate Range Ballistic Missile
IRCM	Infra Red Countermeasures
IRSM	Infrared Support Measures
IRWR	Infrared Warning Receiver
JCS	Joint Chiefs of Staff
JSTARS	Joint Surveillance Target Attack Radar System
JTIDS	Joint Tactical Information Display System
Kc/s	Kilocycles per second
Km; km/h	Kilometer; Kilometer per hour
KTO	Kuwait Theater of Operations
LADAR	Laser Detection and Ranging
LF	Low Frequency
LGB	Laser Guided Bomb
LLTV	Low-Light-Level Television
LORAN	Long-range navigation
LORO	Lobe-on-Receive Only
m; mm	meter; millimeter
Mc/s	Megacycle per second
MF	Medium Frequency
MHz	Megahertz
mph	miles per hour
MLRS	Multiple Rocket Launcher System
MRBM	Medium Range Ballistic Missile
MW	Megawatts (10^6W)
NATO	North Atlantic Treaty Organization
NAVSTAR	Navigational Satellite System
NDB	Non-Directional Radio Beacon
nm	nanometer (10^{-9}m)
NM	Nautical mile
NSA	National Security Agency
PGM	Precision Guided Munitions
RAF	Royal Air Force
R&D	Research & Development
RSAF	Royal Saudi Air Force
RWR	Radar Warning Receiver
SAC	Strategic Air Command

SAM	Surface-to-Air Missile
SCUD	Soviet designed medium range surface to surface ballistic missile
SEAD	Suppression Electronic Air Defense
SIGINT	Signal Intelligence
TALD	Thermal Imaging and Laser Designating
TFS	Tactical Fighter Squadron
TFW	Tactical Fighter Wing
TLAM	Tomahawk Land Attack Missile
UAE	United Arab Emirates
UAV	Unmanned Aerial Vehicle
USA or US	United States of America
USAAF	United States Army Air Force
USAF	United States Air force
USN	United States Navy
Wild Weasel	Code name for dedicated Air Force units sent to attack enemy SAM sites
WSO	Weapon System Officer

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AFHRA

On 19 August 1991, the Secretary of Air Force directed the formation of the Gulf War Air Power Survey (GWAPS) to collect, integrate, and evaluate all observations, after action reports, and other data from operations Desert Shield and Desert Storm. The Air Force Historical Research Agency (AFHRA) was selected as the repository for all documents collected to support the survey.

The Gulf War holdings at the AFHRA were collected over a three-year period and include a compilation of several individual collections of Gulf War documents, the first of which arrived in the fall of 1991. Other small collections followed throughout 1992 and 1993. In April 1993, at the completion of research for the Gulf War Air Power Survey, the SAF/OSG (Office of the Secretary of Air Force, Gulf Air Power Survey) collection was transferred from Washington D.C. to the AFHRA. This major collection is divided into the SAF/OSG central collection, the Task Force Collection and New Acquisitions.

The Air Force Historical Research Agency (AFHRA) at Maxwell AFB, Alabama. Formerly known as the Albert F. Simpson Historical Research Center, the agency holds an enormous amount of documentary material on the USAF, dating back to World War I and before. When combined with the holdings of the Air University Library, Maxwell AFB's "academic circle" probably has the world's most extensive collection of material relating to military air power.

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