MASTER'S THESIS M-604

CROSS, Dalton Harvey Erikson. THE ADMINISTRATION OF GOVERNMENT SPONSORED AERONAUTICAL RESEARCH AND DEVELOPMENT IN CANADA.

Carleton University, M. A., 1964
Political Science, Public Administration

University Microfilms, Inc., Ann Arbor, Michigan

THE ADMINISTRATION OF GOVERNMENT SPONSORED AERONAUTICAL RESEARCH AND DEVELOPMENT IN CANADA

BY

D. H. E. CROSS

A Thesis submitted to Carleton University
in partial fulfillment of the requirements
for the degree of Master of Arts in
Public Administration

School of Public Administration,
Carleton University,
Ottawa, Canada.
February, 1964.

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1. THE AIRCRAFT AND ENGINE INDUSTRY

1.1 Introduction

This study of government sponsored research and development in Canada covers mainly the administration of those aspects of aeronautical research and development on which depend advances in the state-of-the-art of aircraft, and aero engines. Excluded are those aspects of engineering and science which lay the basis for improved navigation, communication and electrical systems for aircraft or missiles.[1] Also excluded is the administration of related sciences such as meteorology or aviation medicine. This definition is narrower than is sometimes understood by the term aeronautics.[2] However, it is a convenient definition since it is descriptive of the work of a large number of government agencies in Canada whose aeronautical activities as defined are inter-related. It is with the problems of the planning and coordination of the activities of these various agencies that this thesis is largely concerned.

In order that this study of the administration of government sponsored aeronautical research and development can be viewed in proper perspective, a brief survey of the industry is necessary. This is because the majority of government spending for aeronautical research and development is directed to industry. As well, the organization of government agencies and their respective responsibilities for aeronautical research and development has been strongly

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1) Such systems are commonly known in the trade as Avionics equipment. The term Avionics is derived from the two words AVIation electrONICS.

2) The concise Oxford Dictionary defines aeronautics as "the science, art, or practice of aerial navigation".

influenced by the degree to which government support of the industry has been deemed necessary or desirable.

Following an historical outline of the growth of the main assembly plants and their subcontractors, industry statistics are given. To the extent that this thesis is concerned with industry-government relationships, the period of historical interest is that following the outbreak of the Korean war in 1950. It is in this period that the industry acquired a full research and development capability in addition to the manufacturing capability which was the legacy of the second World War.

The tremendous growth sparked by the Korean War came to an abrupt end with the cancellation of the ARROW interceptor development program on the "Black Friday" of February 20, 1959. Since 1959, no new aircraft or engine developments have been undertaken by the Canadian Armed Services. Defence requirements have been filled by purchases abroad, or by the licenced production of foreign designs as was the practice prior to the Korean War. As a result, an industry maintained at a high level of activity by defence development and follow-on procurement contracts has been replaced by one in which the primary objective of government support of development is to maintain a technology and to make defence sales abroad rather than to meet the requirements of the Canadian Services.

1.2 World War II (1939-45)

At the end of World War II, Canada had produced more aircraft per capita than any other Allied country. Her aircraft plants had supplied over 18,000 aircraft of 30 different types ranging from primary trainers to fighters, light and heavy bombers and flying boats. Over 100,000 people were employed in 45 different plants.[1] She had at the peak strength an Air Force of 78 squadrons of which 46 were overseas. The personnel strength was 215,000. With the destruction of the Air Forces of the Axis powers complete in 1945, Canada was the world's fourth ranking air power. Under the arrangements of the British Commonwealth Air Training plan, 130,000 air crew, including 73,000 for the RCAF, were trained in the 97 technical and flying training schools established across the country. More than 80% of the total trained were Canadians.

The magnitude of this accomplishment may be appreciated by comparison with the country's Air Force at the outbreak of war in September, 1939. The RCAF at that time had in service 210 aircraft distributed through 8 squadrons. Of these, only 19 Hawker Hurricanes could be considered a modern type. The total personnel strength was 4,061 officers and men, of whom about 75% were regulars. The industry employed in 1939, about 1,000 people, producing an average of 100 aircraft of a dozen different types each year. The size and versatility of the war production effort can be seen from Table I, Appendix I. None of these aircraft were of Canadian design and all of the engines were imported. This dependence on outside sources for engines caused considerable difficulties and many delays. The United Kingdom stopped all shipments of engines following the invasion of Norway in 1940, and it was not until Packard began to produce the ubiquitous Merlin in the United States in early 1941 that a precarious situation was overcome. Commenting in an

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1) J.H. Parkin, <u>Unpublished Notes</u>; in the possession of the author.

article in Saturday Night[1] "Aeronautical Engineers" observed that:

> .. ...It has been stated that this very important question (of engine manufacture in Canada) has been considered by business men active in the Ministries of Air and Munitions. This brings to light the ever amazing fact that there are no qualified engineers in these Ministries directing policy on technical matters....

Further, they hoped that:

> ...the future of Canada's Aircraft Industry does not rest upon a government that is not noted for its progressive policy, and which is advised by business men not noted for either their foresight or aggressiveness...

The war effort concentrated with conspicuous success on production of aircraft designs conceived and developed elsewhere. Research and development capability was meagre. Its objective was the ironing out of flaws which came to light in these designs as a result of operational experience. Even here, the Canadian research and development contribution was limited largely to improvement of the training aircraft which high spirited young pilots flew under the bridges of Ontario's Grand River or between the grain elevators of small prairie towns. For engines, the industry was dependent on the largesse of its allies and this dependence extended also to a wide range of aircraft components and parts. The industry was, therefore, far from being self-sufficient.

To the young men who came to high places during the war, both in the RCAF and in the Ministry of Aircraft and Munitions, this dependence on others brought frustrations not to be borne with equanimity. Events of the post war years gave these men opportunity to put right what was to them an intolerable situation which prevented Canada from shaping her own destiny insofar as it was affected by the deployment of air power.

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1) "In Total War Canada Needs Plane Engines" by "Aeronautical Engineers", <u>Saturday Night</u>, Nov. 30, 1940, Vol. 56, No. 12, Page 14.

1.3 Post War Readjustment (1944-49)

At the end of the war RCAF strength shrunk nearly twenty fold to 12,735 officers and men. In 1947 ten regular squadrons were authorized. They flew Hurricanes, Mustangs and eventually their first jet aircraft, the de Havilland Vampire which was ordered from the U.K. and began to arrive in 1948. In addition 16 Merlin engined conversions of Douglas DC-4/6's, the "North Star", were ordered from the Canadair Company.[1)]

In the period to 1948, apart from repair and overhaul work, there was little defence business for Canadian industry. The aircraft and parts industry's annual sales dropped from the wartime peak of more than $425 millions annually to $36 millions in 1946, and employment from 100,000 to less than 10,000. The number of plants shrunk from the wartime peak of 45 to 16 [2)] in 1946 and eventually to 11 by 1948.

Many old names in the industry disappeared, and new ones took their place. In 1944, the aircraft division of Canadian Vickers was split off as a separate entity called Canadair Limited. The company was later acquired by the Electric Boat Company, which was in turn bought out by General Dynamics of which Canadair is now a subsidiary. The plants of the Crown owned Victory Aircraft at Malton were sold to the great United Kingdom combine of Hawker Siddeley which formed for their operation a Canadian company named A.V. Roe Canada Limited.

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1) Ultimately a total of 25 were supplied to the RCAF, a further 24 to TCA and 22 to BOAC.
2) Canada. Air Industries and Transport Association, <u>Annual Reports</u>.

During the five year period after the war, the dreams of those who looked to the day of a self-sufficient aircraft industry began to take shape. A.V. Roe Canada was selected to provide the stuff of which dreams are made and began to stuff the dreams with a will. In October, 1946, a RCAF contract was awarded to the company for the manufacture of two prototype CF-100 Canuck all-weather interceptors.

On the engine side the advent of the gas turbine gave Canada an opportunity to compete with well established engine manufacturers on an equal footing. Following preliminary studies by the National Research Council in 1943, a Crown Company, Turbo Research Limited was established at Leaside in March, 1944. The company was acquired by A.V. Roe Canada in 1946. In 1945 design studies were begun which culminated in the construction of the TR3 Chinook experimental turbine which ran successfully in March, 1948 at 2600 lbs. thrust. An order for a new engine called the "Orenda" of 6350 lbs. thrust was placed in 1947. It also ran in 1948. With the placing of a production contract in 1949 for this engine, Canada was on the way to having an aero engine industry.

During this period, de Havilland turned to civil markets. In 1945, the company began production of the DH-83, a version of the pre-war Fox Moth. A two seat trainer the DHC-1 Chipmunk flew in May, 1946. This was followed in 1947 by the DHC-2 Beaver which became world renowned for its rugged reliability and rough field capability.

1.4 Korea to the Arrow (1949-59)

During this period the U.S.S.R. pressures in Europe which led to the formation of NATO in 1949, brought in turn Canadian commitments to the NATO forces. A 1949 Defence White Paper anticipated that the most likely kind of attack from outside Canada would be launched by sea or air. The paper concluded that an attack from the air would be met best by jet interceptors and anti-aircraft guns and the necessary radar equipment and communications system. The RCAF were to provide both home defence forces and an Air Division in Europe.

In partial fulfilment of these commitments, the Canadian designed CF-100 fitted with Rolls Royce Avon turbojets made its first flight in 1950, and the first production machine fitted with Orenda engines was delivered to the RCAF in 1951. The first squadron became operational in 1953.[1)] To meet the NATO commitment, Canadair began production in 1949 of F-86 Sabres, under licence from the North American Aviation of the United States. These aircraft were also powered by the "Orenda". The first Sabre squadron became operational in 1951 and by the end of 1953 there were 12 squadrons in service in Europe. By 1958 more than 1800 Sabres had been produced by Canadair. Of these 225 were sold to West Germany and 60 went to the United States Air Force to enable the rapid replacement of Sabre squadron losses in Korea in 1952.

The outbreak of war in Korea drove home to the Western nations the fact that they must prepare themselves to meet the pressures of a long "cold war" which might on occasion become rather hot.

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1) The skills of the design team necessary for the design and development of the CF-100 were acquired during the design of the Avro Jetliner, which first flew on August 10, 1949, just two weeks after the flight of the de Havilland Comet. The Jetliner just missed, therefore, the honour of being the world's first civil jet airliner.

The Defence White paper of 1951-52 reiterated the air defence commitments in Europe and North America and added a further objective. This was to build up the air defence organization, both military and industrial, so that it would be capable of rapid expansion in the event of total war. The new Department of Defence Production under C.D. Howe was established in 1951 and Canada undertook a three-year five billion dollar defence build-up of which more than one half was programmed for the development and procurement of aircraft.

The new department immediately embarked on a program to bring new industries to Canada. Capital assistance for the building of factories and procurement of machine tools was given. To further encourage this establishment, very generous special depreciation allowances were given. During the period to 1953 such firms as Sperry, SKF, Lucas Rotax, Canadian Steel Improvements, Frigidaire, Light Alloys, Deloro, Fischer, and Shawinigan Chemicals were either newly established or expanded to make items never produced before in Canada such as instruments, bearings, fuel systems, precision forgings, turbine blades, high temperature sheet metal components and stainless steel and magnesium castings to meet the needs of the Sabre, CF-100 and Orenda engine production program. The industry thus moved rapidly to the goal of self-sufficiency.

Also during this period, Canadair began, under licence, the production of T-33 Silver Star Jet trainers of which 656 were built by December, 1958 and de Havilland began to produce the Otter, a somewhat larger successor of the Beaver.

The RCAF in 1953 issued a specification for a twin jet supersonic successor to the CF-100 which was later named the Arrow. The original program called for the delivery of two prototypes at a cost of $20 millions in 1957. Instead of relying on engines and armament under development elsewhere, decisions were taken subsequently to develop a new engine, a new armament fire control system, and a new missile, as well as the new airframe. Costs grew rapidly as a result. The first aircraft flew early in 1958. By 1959, development and tooling and prototype costs had reached $370,000,000.

Intelligence assessments of Soviet aircraft programs which indicated a declining bomber threat together with the further heavy expenditures which would have been required to equip the RCAF with production aircraft led the new Conservative government to question the desirability of completing the program planned. Though an indication that the development would be reviewed the following spring was given in October, 1958, without warning all work was stopped abruptly on February 20, 1959, before any industry or government plans had been made to ease the blow. A technical design and development competence which had taken nearly 15 years to acquire was destroyed overnight.

The Arrow cancellation fell doubly hard because the major production programs for the CF-100 and its Orenda engine at A.V. Roe and for the F-86 and the T-33 trainer at Canadair had also just been completed in the latter part of 1958. The effects reverberated through the plants of the subcontractors established expressly in support of these programs, many of whom had little or no business except for these defence contracts. More than 10,000 persons lost their jobs immediately. A further 5,000 jobs were lost in the austere time which followed.

1.5 Post Arrow Period to Present (1959-53)

The years from 1958 to the present have been difficult for the industry. As has been mentioned, immediately prior to this period several major production programs came to an end. As well, by the end of 1959, Canadair had completed nearly half of the RCAF order for the anti-submarine maritime reconnaissance Argus, and was well into its deliveries to the RCAF Transport Command of the CL-44, a "stretched" transport turbine powered version of the Argus. Two attempts were made by Canadair to penetrate the civil market, first with a turbine version of the Convair 440, called the Metropolitan, of which the RCAF bought the only 10 produced, and second with a swing tail cargo transport version of the CL-44 which has had limited sales. After two lean years, prospects were brightened in 1960 by an order from the RCAF for the production under licence of the CF-104 strike reconnaissance aircraft which have just begun to replace the RCAF Air Division's Sabres in Europe. Following the order for the CF-104, the RCAF also placed in 1962 an order for the CL-41, a small side by side jet basic trainer which Canadair developed initially as a private venture. More recently, the development of a small vertical take-off aircraft has commenced at Canadair.

Avro Aircraft was dealt a mortal blow by the cancellation of the Arrow. Nearly all of the most experienced members of the technical team were dispersed, largely to the United States.[1] The

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1) Many of the former Avro employees now hold senior positions in the United States' National Aeronautics and Space Administration. They have made major contributions to the Project Mercury orbital flights and are now working on Project Apollo, the United States' man to the moon program.

company lingered on with attempts being made to fill the great assembly bays with the construction of vending machines and aluminum boats. These efforts were largely unsuccessful. The Avrocar "flying saucer" program was also a failure. Finally, in 1962, the assets of the company were acquired by de Havilland.

Orenda Engines Limited, which had been developing the Iroquois engine, was also badly hurt by the Arrow cancellation, particularly since a production run of more than 3800 Orenda turbojets had just been completed in 1958. The Company was however able to retain key technical staff. Production orders for the J-79 now being produced under licence from the General Electric Company of the U.S. for the CF-104 were received in 1961. As a result of a 1962 order the company is now producing J-85 engines, also under licence from General Electric for the Canadair CL-41. With this "bread and butter line" as a cushion, the talents of the technical team have been directed to the design of a line of industrial gas turbines which is having considerable success. One of these programs, for an advanced regenerative engine for marine, vehicular and power generation applications is being jointly sponsored by the U.S. Bureau of Ships and the Department of Defence Production.

De Havilland, the only company not heavily dependent on Canadian defence orders since the war, has been relatively unaffected by the sharp change in development policy. The Otter was followed in 1958 by the DHC-4 Caribou freighter which placed a very heavy strain on the Company's resources. It was not until U.S. Army orders were received for the machine in 1960 that the success of the aircraft was assured. More recently, it has been announced that the company will produce major sub-assemblies of the Douglas DC-9 in return for sharing with Douglas, a portion of the development cost of this new civil passenger jet intended as a replacement for the Viscount. This imaginative cooperative arrangement may well be the beginning of a future pattern which will provide a suitable means of redressing Canada's serious imbalance of trade in larger civil aircraft. The agreement with Douglas represents an important departure for de Havilland from what has come to be a very heavy dependence on one customer, the U.S. Army, which has been far the major purchaser of the company's Beaver, Otter and Caribou aircraft. Late in 1962 it was announced that de Havilland had begun the development of the Caribou II, a larger twin turbine engined short take-off and landing transport intended as a successor to the present Caribou I. The company has also recently received a development contract from the Royal Canadian Navy for a prototype hydrofoil boat, intended for anti-submarine duties.

Since 1958, an additional development capability for aero engines has been established in Montreal. Canadian Pratt and Whitney, which until that time had been engaged in the overhaul and production of the engines designed and developed by Pratt and Whitney in the United States, began as a private venture the design of a small jet engine, the JT-12, which was eventually developed and is now in production by the U.S. company. In 1959 the technical team assembled for the design of the JT-12 began work on the PT-6, a small 500 horsepower turboprop which is just reaching the production stage. The major portion of the piston engine spare parts and overhaul business of the parent company has also been transferred to the Canadian company.

It is worth emphasizing that although support of development by the Canadian services has virtually ceased since 1959, an attempt to keep a development capability alive is being made by the Department of Defence Production which has been funding the development of aircraft and engines to meet U.S. service and NATO requirements. At present there are five aircraft and engine programs under way with Department of Defence Production support. These are the Caribou II at de Havilland, the 600 Horsepower OT-4 marine and vehicular gas turbine at Orenda, the United Aircraft of Canada 500 Horsepower PT-6 turboprop/turboshaft engine which is aimed at the light aircraft and helicopter market, the CL-84 vertical take-off aircraft and the CL-89 drone at Canadair. In the case of the Caribou II and OT-4 "development sharing" arrangements with the U.S. Army and Navy respectively have been made and U.S. funds are being contributed to these two programs. In the case of the CL-89, British support has been announced.

All of these developments which are in their early stages are, compared to the Arrow interceptor and Iroquois engine developments, relatively small programs, and it is too early to judge their success. Since, for example, the two engine projects should have civil applications, it would be fair to say that while the health of the industry is still vitally dependent on defence procurement, there is some trend away from this dependence. Military business still provides, however, the "bread and butter" line of all our major companies, as will be evident from the section on statistics which follows.

1.6 Industry Statistics

The industry in Canada today is dominated by four major prime contractors, two of which are airframe manufacturers, and two of which are makers of engines. These are the de Havilland Aircraft of Canada Ltd., Canadair Limited, the Orenda Engines Division of Hawker Siddeley Canada Ltd.[1)] and United Aircraft of Canada Ltd.[2)] All are controlled by foreign capital, but have largely Canadian managements. There is a supporting web of subcontractors, many of whom are also controlled by foreign capital. The majority of these were established with government assistance in the period which began with the Korean War in 1950 and ended with the cancellation of the Arrow interceptor aircraft in 1959. With the exception of de Havilland, none publish company statements separate from their parent company, but it is estimated that between them the four prime contractors accounted for 75%[3)] of the industry's sales of $325 million in 1961.[4)] The position of the aircraft and parts industry relative to other secondary industry in Canada is shown in Appendix I, Table II for the year 1959. Employment, sales and other statistics for the industry are given in Appendix I, Table III for the years 1949-1959. In 1959 the industry ranked 15th in terms of sales

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1) A.V. Roe Canada Ltd. was renamed Hawker Siddeley Canada Ltd. in 1962.

2) Canadian Pratt and Whitney was renamed United Aircraft of Canada Ltd. in 1963.

3) Discussions with officials of the Department of Defence Production.

4) Dominion Bureau of Statistics, Aircraft and Parts Industry Annual Report, 1961.

and 12th in terms of value added to manufacture. Employment, which reached a peak of 42,000 during the height of the Arrow program, has been of the order of 28,000 since 1959, which ranks the industry 11th in terms of total employees. Thus, the industry forms an important segment of Canadian secondary industry.

The aircraft and engine industry is the major element of the defence industry. Table IV, Appendix I shows the expenditure on defence contracts placed by the Department of Defence Production in Canada each year since 1956. Aircraft and related items have accounted for not less than 34% of the defence development and procurement expenditures in this period, and as much as 46% of the total in 1958, the peak year for the Arrow program. In Table V, Appendix I, the industry's total sales are compared with figures for defence sales. It is apparent that the industry is vitally dependent on defence procurement. In the years 1956 through 1961, defence sales represented 83% of the industry's total sales. Since the industry was established largely on defence grounds, this is not surprising. Table VI summarizes sales statistics at home and abroad, both civil and defence. The statistics have obvious flaws, but better data would require extensive data gathering and analysis beyond the scope of this thesis. In Table VII, Appendix I, Export and Import Statistics for the industry are examined. It will be seen that over the past several years defence procurement has resulted in imports valued between $15 to $40 millions per annum. Depending on the year, these figures represent between 5% and 15%

of total aircraft and parts expenditures by the Department of National Defence. It may be concluded therefore that Canadian industry has been the recipient of between 85% and 95% of the defence funds expended for aircraft equipments.

It will also be noted that the figures for imports have jumped sharply the past two years. By far the larger fraction of these sums results from the equippage of our airlines with aircraft built in the United States and Britain, but a part also results from the import of aircraft to meet the demands of the sporting and executive market. It is also worth noting that in the last several years, amongst all the commodities Canada imports[1)] aircraft and engines and parts have ranked between 4th and 7th in dollar value. Imports of aircraft and associated products represent therefore, one of the major pressures on our holdings of foreign exchange. Since the drain is primarily for commercial imports, it is apparent that the industry and government might well give serious consideration to what steps should be taken to enable a larger share of the commercial market to be supplied successfully by Canadian companies, or to find a means of redressing the balance by increased aircraft and engine exports.

It is also obvious that much better statistical data than is currently available is required if an accurate appraisal of the industry is to be made.

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1) Dominion Bureau of Statistics. Canada Year Book, 1962, Page 965.

In summary, it will be evident that the industry was created by defence needs, and in spite of the dislocations which resulted from the cancellation of the Arrow program, the industry is still overwhelmingly dependent on military procurement, with the Canadian armed services being the major customers. It might be expected, therefore, that the Canadian services, in particular the R.C.A.F., would play the major role in planning, financing and coordinating government sponsored aeronautical research and development. For various reasons, many of which have an historical basis, this is not the case. This historical background, and the role other agencies play will be examined in the succeeding sections.

2. GOVERNMENT SPONSORED RESEARCH AND DEVELOPMENT

2.1 Introduction

From the previous historical and statistical information, it is apparent that the primary market for aeronautical equipment developed or produced in Canada has been the armed forces of our own, or other countries. It has become the practice of modern governments to control the profits of the armaments industry, and these controls have been applied to the defence sales of the aircraft and parts industry in Canada. Except for smaller projects or where development costs have been previously borne by a military development, the strictness of these controls has made it impossible or rare for the industry to finance the whole cost of a new development out of profits. The government has therefore assumed the greater share or all of the cost of development of new products. Although the bulk of development activities is carried out by industry, research in the aeronautical field is carried out in industry, the universities and in government research laboratories.

In Canada, government support for aeronautical research in the universities is given by the Defence Research Board and the National Research Council[1] by means of research grants to staff members, mainly at the Universities of Toronto, McGill and Laval. Aeronautical research is carried out by the Defence Research Board at the Canadian Armament Research and Development Establishment (CARDE), by the Division of Mechanical Engineering of the NRC and the National Aeronautical Establishment (NAE), which is also a Division of the NRC. The Defence Research Board has been the major source of financing for research in industry, initially by the means of contracts financed out of Headquarters' allotments, and more recently through the Defence Industrial Research Vote. The recently established National Research Council Industrial Research Assistance Program is also a potential source of funds for industry research. Development may be financed by the Department of National Defence to meet Canadian service requirements, and by the Department of Defence Production to meet United States or NATO requirements.

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1) Hereafter, the abbreviation DRB will be used for the Defence Research Board, and NRC for the National Research Council.

An organization chart indicating the lines of authority for these various agencies is shown in Figure I, Appendix II. It will be evident from this organization chart that these agencies enjoy varying degrees of independence and because of this and the number of agencies involved, the achievement of research, development and production policies, and programs responsive to defence and civil requirements, and economic capability is not an easy task. Although there is one hierarchy of advisory committees terminating in the National Aeronautical Research Committee, shown in Figure I, Appendix II, which draws its membership from these various government agencies, industry, and the universities, and which on the surface would appear to be playing the part of coordinating and planning bodies, it has been ineffective in the past. It is proposed to discuss the function of these committees following a description of the responsibilities, organization and history of those agencies with aeronautical research and development interests, and an analysis of the effort, in terms of money and manpower which each agency applies to aeronautical research and development.

2.2 The National Research Council Division of Mechanical Engineering

In June, 1919 the Canadian Air Board was established for the purpose of regulating civil aviation, conducting civil government air operations, and to be responsible for the air defence of Canada including the organization and administration of a Canadian Air Force. The Board was also authorized to undertake aeronautical research and to cooperate with other organizations for this purpose.[1] The Board requested the National Research Council to assume responsibilities for research. An Associate Air Research Committee was formed by the Council in 1920 to coordinate and sponsor aeronautical research in Canada. This took the form of financial support for individuals, and the universities, including tunnel facilities at the University of Toronto. In 1928 the Associate Air Research Committee recommended that aeronautical research laboratories should be included amongst the laboratories which the NRC began to establish in 1928. By the end of 1933, the aeronautical laboratories included a nine foot diameter open jet wind tunnel, an engine test laboratory, an aircraft and allied instrument laboratory and supporting wood and metal working shops. These were situated on John Street in Ottawa under the direction of the Division of Mechanical Engineering. During the next few years:

> ...the projects were, because of the limited resources available, in general,those of direct and immediate interest to Canadian Aviation, or for which Canadian conditions were particularly favourable...[2]

Almost all the research was aimed at the solution of operational problems.

In 1938 a major expansion of facilities intended to meet the anticipated needs of the RCAF and industry was undertaken at the present Montreal Road site. By 1941 this

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1) J.H. Parkin, Unpublished Notes.
2) Ibid.

was complete and the Council's aeronautical research activities were transferred to this new location. The new facilities continued to be the responsibility of the now much expanded Division of Mechanical Engineering, under the direction of Mr. J.H. Parkin. The aeronautical facilities at the new site included aerodynamics, instruments, power plant, fuels and lubricants, and structures laboratories as well as the necessary supporting shops. The use of these new facilities was determined mainly by the needs of the RCAF which expanded rapidly following the outbreak of war in 1939. During the war little research was possible due to the pressure of work for immediate specific problems.[1)] This work was connected mainly with the solution of problems encountered in adapting foreign designed aircraft employed in the Commonwealth Air Training Plan[2)] to Canadian conditions and eliminating design and structural faults in these aircraft.

Following the war years in 1946, the RCAF agreed to participate jointly with NRC in manning a Flight Research Section. The RCAF supplied, flew, and maintained the necessary aircraft, while the NRC scientific staff designed and carried out the experimental programs, flying where necessary as observers. The Section was stationed at Arnprior, under the control of the Division of Mechanical Engineering. In

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1) Ibid.

2) J.J. Green, "The Growth of Aeronautical Research in Canada During the Post-War Decade." Journal of the Royal Aeronautical Society, Vol. 59, No. 540, Dec. 1955, page 793.

1948 additional buildings housing low temperature and gas dynamic laboratories were constructed at the Montreal Road site. Although improvements and additions have been made to the various laboratories since that date, with the exception of the addition of a propulsion wind tunnel now being commissioned, the character of the aeronautical facilities at Montreal Road has changed little to this day.

As will be elaborated on in the succeeding section, control of the Flight Research Section passed to the National Aeronautical Establishment in 1951. The fact that from 1951 to 1959, the Director of the Division of Mechanical Engineering and the Director of the National Aeronautical Establishment were one and the same person made the change a formality.[1] Control of the Aerodynamics and Structures Section at Montreal Road was passed to the National Aeronautical Establishment when it was given divisional status in 1959. The Mechanical Engineering Division is now comprised of Analysis, Instrument and Control Systems, Engineering, Hydraulics, Ship, Fuels and Lubricants, Low Temperature, Gas Dynamics and Engine Laboratories. Of these, only the latter three are engaged in aeronautical research and development

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1) The National Aeronautical Establishment (NAE) and the Division of Mechanical Engineering (DME) came under the direction of Mr. J.H. Parkin until 1957. On his retirement, Dr. D.C. MacPhail who had been head of the Gas Dynamics Section succeeded to the dual post. In 1959, the NAE became a separate division. Dr. MacPhail retained the direction of the DME, while Mr. F.R. Thurston was appointed head of the NAE.

to any extent, and only these are examined in detail. Table 2.1 shows the breakdown of staff between the various sections.

Table 2.1 Division of Mechanical Engineering Professional and Technical Staff

Section	1961-62 Professional	1962-1963 Professional	1962-1963 Technical	Total
Engine	9	10	29	39
Gas Dynamics	12	11	13	24
Low Temperature	7	7 1)	14 1)	21
Others	41	40 1)	80 1)	120
Totals	69	68	136	274

It will be seen that approximately 40% of the division's professional staff are employed in sections which are engaged to some extent in aeronautical research. A further breakdown has been attempted in Table 2.2 which gives the estimated effort actually devoted to aeronautical and to non-aeronautical activities and also the division between applied and basic research, and the supply of services to outside agencies.[2)]

1) Figures are estimated.

2) The breakdown has been derived from Quarterly Bulletins of the NRC Division of Mechanical Engineering and the National Aeronautical Establishment, and from conversations with officials of these agencies. The estimate given by officials in the various sections checks closely with the estimates calculated from the Quarterly Bulletins.

Table 2.2 Division of Mechanical Engineering Professional Man Effort Devoted to Aeronautical Research and to Non-Aeronautical Research 1962-63

		Aeronautical			Non-Aeronautical		
Laboratory	Total	Basic Research	Applied R & D	Services	Basic	Applied	Services
Engine	10	1	6	1	-	1	1
Gas Dynamics	11	1	4	-	3	3	-
Low Temperature	7	1	1	2	-	3	-
Others	40	1	2	4	4	15	14
Total	68	4	13	7	7	22	15

It will be seen that of the total professional staff of 68, a total man effort of 24, or about 35% is devoted to aeronautical activities. Of this aeronautical effort, about one-third is devoted to supplying services to industry. The rest of the effort is on the various internal research programs. Within the three laboratories where the aeronautical effort of the division is concentrated, 60% of the staff is so engaged. In the case of the Engine Laboratory, 80% of the work is aeronautical. This 80% figure is made up of 55% vertical take-off and landing propulsion studies and experiments, 15% miscellaneous, and 10% turbine engine anti-icing work. The vertical take-off work is concentrated on the lifting fan concept in which the exhaust from a jet engine is used to drive turbine blades fixed to the fan blade tips. Lift is generated by the reaction resulting from increase in velocity of the air sucked through the fans which may be wing or fuselage mounted.

In the Gas Dynamics Laboratory, about 45% of the work is aeronautical. This is almost entirely on lifting fan propulsion schemes. In the Low Temperature Laboratory, about 55% of the work is aeronautical. This is concentrated on various aircraft and helicopter anti-icing and de-icing work. Total annual operating and capital budgets for the Division are not available. A rough estimate indicates that, excluding the cost of operation of the Central Workshops, expenditures are of the order of $1,240,000 for salaries, $1,000,000 for operating costs and $500,000 for capital works. Of these sums, total operating costs of $790,000 and capital costs of $200,000 can be attributed to aeronautical work.[1] Including an estimate for aeronautical work in the workshops would raise the total operating costs for aeronautics to $1,050,000.[2]

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1) Estimates of cost of various activities in the Division of Mechanical Engineering is made difficult by the fact that a charge to the various laboratories for work done in the Central Workshops is made for materials but not for labour.

2) The cost of operation of the workshops is probably $750,000 per annum, making a total operating budget of about $3,000,000 for the Division. If the costs of the aeronautical work in the workshops is in proportion to the number of professionals engaged in aeronautical work, an additional $260,000 should be attributed to aeronautics.

2.3 National Aeronautical Establishment

In June, 1950, Canada went to war in Korea. As a result of this, and commitments made both for North American Defence and in Europe, a vastly expanded military effort was undertaken and nearly one-half of this effort, as measured by the funds expended, was to be directed to the development and procurement of aircraft and equipment for the RCAF.

It was clear that a substantial expansion in government aeronautical research and development facilities would be required, to support the efforts of industry. Although this need was foreseen by those in the NRC who had a responsibility for aeronautical research matters, it became apparent that the necessary funds could not be obtained without diverting a major portion of the NRC's operating and capital budget for several years to come. This could only be done at the expense of the Council's non-aeronautical activities. The Council's senior management were therefore reluctant to assume the responsibility for the necessary expansion.

Since the need was imposed by the increased defence effort, defence estimates appeared to be the proper source of financing. It appeared logical as well that the financial burden for the new facilities should be borne largely by the Defence Research Board which, in 1947, had assumed control of those NRC laboratories across the country which continued to be engaged in defence research after the end of World War II.

It was agreed, therefore, between the Department of Defence Production, DRB, the RCAF and the NRC that a separate establishment, to be named the National Aeronautical Establishment, should be set up, and in December, 1950 the Cabinet authorized its formation. It was agreed by the National Aeronautical Research Committee, also established at that time, that for an interim period the NRC would assume administrative responsibility for the new establishment, and that funds for the construction of new facilities would be provided out of Department of National Defence estimates.[1] In the longer term, it was anticipated that the new facilities would be transferred to the control of the Defence Research Board when they were essentially complete. At the time of the National Aeronautical Establishment's formation, the aerodynamics, engine, structures, gas dynamics, low temperature and icing facilities, and aircraft instrument laboratories of the Division of Mechanical Engineering were designated portions of the National Aeronautical Establishment, i.e. almost the entire Montreal Road Facilities of the Division.[2] The Director of the Mechanical Engineering Division, J.H. Parkin, also assumed the duties of Director, National Aeronautical Establishment.

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1) DND press release, P.M. Editions, Wednesday, April 6, 1955.

2) The sole exception was the Hydraulics and Ship Laboratory.

In 1953, the Flight Research Section of the NRC moved into a new hangar built on a 344 acre site adjoining RCAF station Uplands. A runway extension to 8,000 feet, power-plant, cafeteria, storage and garage buildings to support the future planned expansion were also provided at this time, for a total cost of $3.5 million provided out of Department of National Defence estimates. The NRC provided the operating funds for the new facilities.

In 1952, the Technical Advisory Panel (TAP), which met for the first time on May 25, 1951, and which was set up by the National Aeronautical Research Committee to advise the Director of the National Aeronautical Establishment on technical matters, recommended to the National Aeronautical Research Committee the construction of a trisonic tunnel on the Uplands site. However, it was not until 1954, when it was obvious that existing tunnels would be inadequate to support the development of the Arrow aircraft and projected air defence missiles, that approval for its construction could be obtained. Preliminary estimates indicated costs of $3.68 millions over a three year period to be met by the RCAF and DRB. The NRC and DRB managements also at this time concluded that control of the Uplands site, including the Flight Research Section and the operating costs thereof, should be passed to DRB at the expected completion date of the tunnel in 1957.

The NRC management hoped that the Montreal Road aeronautical facilities could concentrate on basic research, while the Uplands facilities, under DRB control, would assume the responsibility for applied research and development testing in support of the design and development of aircraft and missiles for the RCAF.

Preparation of the necessary specifications was not complete until 1957. By this time design changes, inflation, and a decision to manufacture many of the components of the tunnel in Canada resulted in an increase in costs, and early in 1957 approval was obtained from the Cabinet Defence Committee for an increase in capital expenditure to $6.0 millions to be provided from defence estimates. At the same time, the transfer of the Uplands site facilities to the DRB was authorized, to be effective on a date to be decided by the National Aeronautical Research Committee.

Early in 1958, presumably because of mounting pressure on defence estimates, the Department of National Defence sought, and obtained, an agreement from the NRC to share the cost of construction. In September, 1958, in a speech in the House of Commons, the Prime Minister indicated that the future of the Arrow Aircraft was uncertain. The National Aeronautical Research Committee, on its own initiative, ordered a review of the need for the trisonic wind tunnel, and following consultation between the Technical Advisory Panel and representatives of the industry, it was concluded in November that even if the industry would not in the future be involved in the development of high speed aircraft, the tunnel would be required to support the industry in production sharing programs with the United States, and to solve problems arising in RCAF aircraft acquired either by purchase abroad or by production under licence. Further, since it had a subsonic, transonic, supersonic speed capability, it would be useful regardless of the direction that aircraft development in Canada took in the future.

In November, 1958, the National Aeronautical Research Committee also concluded that further expansion of the National Aeronautical Establishment was unlikely, and that it was no longer logical to proceed with the authorized separation of the Montreal Road and Uplands site and transfer of the latter to DRB. The NRC and DRB agreed and the National Aeronautical Research Committee confirmed that a new division of NRC should be formed. This was to comprise the aerodynamics and structures facilities at Montreal Road and the high speed tunnel, flight research and other facilities at the Uplands site. Propulsion, instrument, gas dynamics, icing and fuel laboratories reverted to the Division of Mechanical Engineering, which they really had never left, but remained under the direction of Dr. D.C. MacPhail, who succeeded Mr. Parkin in 1957 as Director of the Division of Mechanical Engineering and as Director of the National Aeronautical Establishment, Mr. F.R. Thurston, then section head of the Structures Laboratory, was appointed Acting Director of the new division which came into being on January 1, 1959. For want of a better name, the new division remained the "National Aeronautical Establishment".

Since 1959, capital expenditures have been applied mainly to the modernization of the Montreal Road low speed tunnel facilities, and completion of the trisonic tunnel, which is now in use.[1)2)] The DRB has continued to contribute to the cost of construction of the trisonic tunnel, the final cost of which has approached $9.0 million.[3)]

The present organization of the National Aeronautical Establishment is shown in Figure 2, Appendix 2.[4)] The three section heads of the Aerodynamics, Flight Research and Structures and Materials Section report to the Director of the Establishment, who is in turn responsible to the Vice-President (Scientific) of the National Research Council. The Director is appointed by the President of the NRC, following consultation with the National Aeronautical Research Committee.

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1) Disucssions with an official of the DRB. At the time approval for the trisonic tunnel was sought in 1954, plans for the construction of hypersonic and low speed tunnels, engine test beds and structural facilities were also being made. The total capital expenditures projected were of the order of $14 millions. The subsequent growth of the high speed tunnel costs, and decreases in defence estimates prevented a start being made on these other facilities.

2) Discussions with National Aeronautical Establishment officials. A proposal put forward in 1960 to the National Aeronautical Research Committee for construction of a heated air hypersonic test facility was not approved. Presently, the construction of a large low speed tunnel suitable for testing large scale models of vertical and short take-off landing aircraft is under discussion.

3) The Royal Commission on Government Organization, Volume 4, page 278.

4) Discussions with NAE officials.

Table 2.3 - National Aeronautical Establishment
Scientific and Technical Staff

	Total Scientific & Technical 1960-61	Total Scientific & Technical 1961-62	1962-63 Scientific	1962-63 Technical	1962-63 Total
Aerodynamics	69	79	30	50	80
Flight Research	43	49	14	35	49
Structures	37	41	20	22	42

The professional and technical staff for the past three years are shown in Table 2.3 above.

Of the 30 scientific personnel in the Aerodynamics Section, an equivalent of 16 are employed on the operation of tunnels and the development of tunnel equipment. The efforts of the remaining 14 are distributed equally between basic and applied research programs.[1] Nearly 55% of the professional effort at present then is employed in the provision of high and low speed tunnel test facilities, the majority of the operating time of which is taken up by industry.

The efforts of the Flight Research Section are augmented by a staff of approximately 30 maintenance technicians and test

1) Discussions with National Aeronautical Establishment officials. Of the total staff of 80, no less than 36 are employed in support of the tunnels. Of these approximately 10 have been occupied with bringing the high speed tunnel into operation.

pilots attached to the National Aeronautical Establishment from the RCAF Central Experimental and Proving Establishment which is also located at Uplands. These RCAF personnel maintain and fly the RCAF aircraft on loan to the Flight Research Section.

Table 2.4 - National Aeronautical Establishment Expenditures

Dollars

Year	Salaries	Operations and Travel	Total Operating	Capital	Overall Total
1960-61	1,002,000	344,000	1,346,000	1,693,000	3,039,000
1961-62	1,105,000[1]	428,000[1]	1,533,000[1]	740,000[2]	2,274,000
1962-63[3]	1,140,000	485,000	1,635,000	166,000	1,801,000

Figures for the NAE's budget are given in Table 2.4. Excluding capital expenditure the total operating cost of the establishment is of the order of $25,000 per professional employee, which is considerably below the NRC's average of $34,500.[4]

1) Report of Royal Commission on Government Organization. Volume IV, page 278. Figures are estimated.

2) Review of the National Research Council 1962. NRC No. 6816, page 18. Capital expenditures were $166,000 on Low Speed Facilities, and $574,953 on the High Speed Tunnel.

3) Discussions with National Aeronautical Establishment officials. Figures are estimated.

4) Report of Royal Commission on Government Organization. Volume IV, Appendix, page 314.

The deficiency is mainly in the Aerodynamics Section where the average is about $20,000 per professional. This may be explained, at least in part, by the fact that more than 80% of the Low Speed Aerodynamics staff, and 55% of the total aerodynamics staff are providing wind tunnel services rather than carrying out research. The Structures and Materials and Flight Research Sections' operating costs per professional approach the NRC average closely. Provision of services to others does not absorb such a high proportion of these two sections' efforts as occurs in the case of the Aerodynamics Section.

The construction and commissioning of the Trisonic Tunnel, the modernization of the Low Speed Facilities, and the present very heavy utilization of the latter by industry has imposed a heavy work load on professional staff who had previously been accustomed to spending the majority of their time on research. The low operating budget and this work load extends the research work that is attempted over such long periods that morale and enthusiasm suffer. Over the past three or four years, this combination of circumstances has resulted in the loss of some of the section's most competent personnel. Both the quantity and quality of the section's research output has therefore suffered,[1] and as a

1) Over the five year period since 1958 when the tunnel modernization program began, the Aerodynamics Section personnel have averaged 0.2 published papers per year per professional as compared to 0.5 papers per year per professional for the rest of the National Aeronautical Establishment.

further consequence it has become increasingly difficult for the section to attract qualified staff to replace those who have left.[1] Insufficient delegation of authority to section heads on budget and personnel matters has also contributed to the present situation in the Aerodynamics Section.[2]

It is not proposed to discuss the programs of the various sections in detail, but some analysis of the distribution of effort is required, since it relates to the problem of co-ordination which is discussed elsewhere.

Table 2.5 gives a breakdown of professional effort between basic and applied research and the provision of services to other government departments and industry. In this latter class is included the effort required to develop and support test facilities such as tunnels and structural test rigs. Also included is the provision of technical advice to industry.

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1) Discussions with National Aeronautical Establishment officials and professional staff.

2) Ibid. This lack of delegation is not peculiar to the National Aeronautical Establishment by any means. It is common to a varying degree in many government research laboratories. Funds which are earmarked at the section level at the beginning of the year have a way of being diverted to other uses before year end. Personnel departments are often singularly slow in following up a section head's recommendation to approach suitable personnel who through professional contacts are known to be looking for a change of employment.

3) These are described in such publications as the NRC Annual Review, and in the Quarterly Bulletin of the Division of Mechanical Engineering and the National Aeronautical Establishment.

Advantage of this is taken in the main by smaller companies whose small engineering staffs may encounter a problem requiring specialized knowledge outside their own experience. This type of service is usually provided as an adjunct to the solution of a problem requiring the use of the National Aeronautical Establishment's test facilities. A third type of service activity is that undertaken at the request of other government agencies. In the case of all these services, charges are made where a substantial effort is involved. These charges are usually the direct salaries of the National Aeronautical Establishment personnel involved, plus a 100% overhead allowance. For the provision of low speed tunnel services, a charge of $50.00 per occupancy hour is made.

Table 2.5 - Distribution of National Aeronautical Establishment Professional Manpower Effort.1)

Section	Professional Man Effort		
	Basic Research	Applied Research	Services
Structures	5	8	7
Aerodynamics	7	7	16
Flight Research	-	10	4

1) The figures have been derived from discussion with National Aeronautical Establishment officials and from an analysis of the Quarterly Bulletins of the Division of Mechanical Engineering, and National Aeronautical Establishment, for the years 1961 and 1962. Accuracy of this breakdown is probably of the order of ±10% of the man efforts shown.

As has already been noted, about 55% of the Aerodynamics Section effort is devoted to the provision of tunnel test services to other agencies. In the case of the Structures and Flight Research Section, the activity represents about 35% of the effort. For the Establishment as a whole about 40% of the effort is devoted to the service function.

Discussions with National Aeronautical Establishment officials and personnel indicate that for the remaining 60% of the effort, which is devoted to basic and applied research, projects arise in a number of ways. In the case of basic research, which represents less than 20% of the total effort, the choice is determined largely on the basis of the competence, enthusiasm and interest of the individual researcher and a judgement as to the scientific value of the proposed work. In the case of applied research, projects arise usually as a result of informal discussions with workers in industry and other government agencies. Whether or not an applied research project is started depends on whether suitable equipment and competent staff are available, whether in the judgement of the section heads it is likely to prove useful to some outside agency, whether or not it looks like an interesting piece of work to do, and whether there is money available.

If, as is generally agreed, the individual researcher should be given considerable leeway in choosing his activity in the basic research area and it is considered that in providing a service function, the National Aeronautical Establishment generally accedes to a request to provide such services, it follows that the applied research program is the only portion of the establishment's program which might be considered subject to change as a result of stimuli from external influences. This represents 40% of the establishment's man effort.

Two points are worthy of note. None of the persons interviewed in the National Aeronautical Establishment or the Division of Mechanical Engineering considered that the Advisory Committee system terminating in the National Aeronautical Research Committee exerted any significant influence on the choice of research programs. Secondly, it will be evident from the previous historical background, that the National Aeronautical Establishment and the Division of Mechanical Engineering research facilities and internal research programs were established in support of the industry's development and production programs. There is general agreement among officials of the defence agencies and industry who were interviewed that NRC tends to forget this fact and that the internal programs of the Division of Mechanical Engineering and the National Aeronautical Establishment seldom reflect the real needs of the industry. These critics class many of these programs as providing only "fun and games" for the individual scientists working on them.

More will be said on these two points in the chapter dealing with planning and coordination. Having examined the roles of the two civil agencies, an analysis of the part the Defence Research Board and other defence agencies play in aeronautical research and development will be undertaken next.

2.4 The Defence Research Board

The Defence Research Board (DRB), which is a civilian agency of the Department of National Defence, was formed in April, 1947.[1] The Chairman of DRB is a member of the Chiefs of Staff Committee. Among other duties, DRB assumed responsibility for those laboratories of the National Research Council which continued to be employed in Defence Research after World War II. Some aeronautical research and development is carried out in the Board's Canadian Armament Research and Development Establishment (CARDE) at Valcartier, Quebec. The major CARDE effort is research directed at the problems of defence against the ballistic missile, and on explosives and propellants for small rocket engines. For security reasons no analysis of the aerodynamic research portion of these programs can be given. The Board has no laboratories of its own engaged in more conventional aerodynamics research, although as has been indicated, it was at one time intended that the National Aeronautical Establishment would be a DRB laboratory.

With the exception of the CARDE programs, the Board's influence on the course of aeronautical research and development in Canada has, until 1963, been exercised through one of its headquarters directorates, the Directorate of Engineering Research (D Eng R). Following a recent reorganization, responsi-

1) The complete powers and duties of the Board may be found at Section 53 of The National Defence Act; 14 Geo. V, Ch. 43. Part III, King's Printer, 1950.

bilities for aeronautical matters have been assigned to the Directorate of Industrial Research (DIR). Until 1963, the Board financed substantial aeronautical research programs in industry by contract. This industry support has been concentrated in the four major firms; de Havilland, Canadair, Orenda, and United Aircraft of Canada Limited. These programs were monitored by four professionals in the Aeronautical Section of the Directorate of Engineering Research. In the past few years, the major portion of the research program has been concentrated on gas turbine engines, materials and on vertical and short take-off and landing aircraft. In 1961 the government approved the establishment of a Defence Industrial Research Program,[1] the objective of which is to increase the ability of Canadian defence industry to undertake the development of equipment to meet North American and NATO requirements. The Directorate of Industrial Research was established within the DRB to assume the responsibility for this program.[2] Members of the Aeronautical Section of the Directorate of Engineering Research have been transferred to this directorate, and funding of aeronautical research in industry has continued through the medium of the Defence Industrial Research vote. The level of support for aeronautical

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1) Canada. Defence Research Board. The Defence Industrial Research Program. Issued by Chairman, D.R.B. National Defence Headquarters, Ottawa, November 28, 1962.

2) The Board's organization is given in Fig.3, Appendix II.

research in industry has been increasing sharply as a result of the much larger funds which have been made available through this new vote. Table 2.6 shows the research funds spent by the Board in industry over the past several years.

Table 2.6 - Defence Research Board Aeronautical Research Expenditures in Industry

$ Dollars

	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64[1]
Directorate of Engineering Research	262,160	119,866	199,935	266,738	53,448	
Directorate of Industrial Research					713,045	1,200,000
Total	262,160	119,866	199,935	266,738	766,493	1,2[illegible],000

These expenditures have all been directed to applied research, or to studies to outline the direction and emphasis that subsequent applied research should take. Since most of these programs have been or are on a cost-shared, no profit basis, the choice and content of programs have been determined in close consultation with the firms involved. No major experimental program involving novel aircraft configurations is undertaken prior to the completion of thorough design

1) Estimated.

studies by the firm concerned. These studies help to ensure that research follows profitable lines. In this there has been a high degree of success achieved, if success be measured by whether or not the research results are applied to and result in novel or improved company products. Recent programs supported by the Board have culminated in the CL-84 vertical take-off aircraft now under development by Canadair, and in major improvements to the short take-off and landing capabilities of the de Havilland Caribou aircraft.

Until the establishment of the Defence Industrial Research Program, the Board's support of aeronautical, as well as other industry research programs, has been predicated on relevance to Canadian defence commitments. Approval for a particular program was given if it was related either to an armed service requirement, or made a contribution to NATO fields of interest, or to North American defence.[1] Since only the most unimaginative staff officer could fail to build a case on at least one of these grounds, in practice the choice of programs resulted from the interplay between the company concerned and the Directorate of Engineering Research staff, and the enthusiasm and persistence with which the case for support of particular programs was put to the Board's management. Suggestions for programs therefore went up the line, rather than down and provided

1) Conversations with a senior official of the DRB.

funds were available management generally accepted the recommendations of the Directorate. There is no evidence that the deliberations of the National Aeronautical Research Committee or the Technical Advisory Panel affected program content, and both bodies are considered by members of the Board's staff to have been ineffective in formulating policy within which research programs could be fitted.[1)]

With the establishment of the Directorate of Industrial Research, the method of the selection of programs is largely unchanged, with the exception that Canadian service requirements no longer figure, since the primary objective to to build up the technological competence of Canadian defence industry. Program approval is given by the Advisory Committee on Defence Industrial Research.

Members of the Directorate of Industrial Research staff have appointments to NRC Advisory Committees on Propulsion, and Aerodynamics. The staff also provides the Secretary of the DRB Advisory Committee on Plasma and Gas Dynamics Research and the DRB Advisory Committee on Materials Research, which review university grant applications for research in fields related to aeronautics. The Director is a member of the Department of Defence Production Advisory Group on Aeronautics and the DRB Advisory Committee on Defence Industrial Research.

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1) Conversations with officials and staff of the DRB.

International contacts are maintained through participation by Directorate of Industrial Research staff in the activities of the NATO Advisory Group for Aeronautical Research and Development (AGARD), and with United States and British military organisations through the DRB liaison members in London and Washington, and by personal visits to United States and British military establishments and companies. These contacts with the military organizations of other countries provide access to classified information concerning recent state-of-the-art advances, and to the forward planning and requirements of the armed services of these other countries. Such contacts are of particular importance in the case of the United States, where the armed services play a prominent role in funding and monitoring aeronautical research and development. Knowledge of the content and progress of these foreign military research programs enables the Directorate of Industrial Research staff to assist Canadian companies to avoid both unnecessary duplication of effort and unprofitable lines of approach, but also helps to ensure that the research is concentrated in areas which will pay off when the time comes for development of a specific product to meet a specific military requirement.

In theory, the DRB has the responsibility for making recommendations to the Minister concerning service development programs. The Chairman, DRB, approves the Services' Development Estimates[1] prior to their being passed to the Minister and these estimates are included in the estimates of the Board. In practice, the substantial influence inherent in this approval power is rarely exercised. This has been particularly true in the case of aeronautical development, especially in the period which has followed the "Arrow" cancellation when RCAF development spending has been sharply reduced.

In fact, contact between the Directorate of Engineering Research/Directorate of Industrial Research staff and the RCAF headquarters directorates responsible for RCAF development programs has tended to zero so far as RCAF programs are concerned. This is the result of a number of factors, among which is the decrease in DRB laboratory participation in RCAF aeronautical development which followed the demise of the Arrow. As well, present RCAF aeronautical developments are concentrated on product adaptation or improvement programs, rather than major new developments involving advances in the state-of-the-art, and therefore of little interest to research oriented staff. Most importantly however, the interests and energies of the Directorate of Industrial Research staff have been fully absorbed in their industrial research programs, and in the monitoring of Department of Defence Production Development Fund projects.

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1) The DRB screening takes place in June and July.

2.5 The Armed Services

The responsibility for the management of Royal Canadian Air Force research and development programs vests in the Air Member for Technical Services. The organization for aeronautical research and development is shown in Figure 4, Appendix II.

The aeronautical development programs of the RCAF are almost wholly concerned with remedying aircraft defects or deficiencies which show up in service. These problems may be resolved in conjunction with the firm concerned or through an ad hoc investigation carried out by the NRC Division of Mechanical Engineering or the National Aeronautical Establishment. Programs of this type are under the technical direction of the Directorate of Aircraft Engineering.

The 20 members of the Directorate are career officers with professional qualifications. As is the normal practice with RCAF personnel, the majority of the junior staff are posted in and out of the Directorate, usually after a two or three year tour of duty. Because of this, most officers have a general grounding in many aspects of aeronautical engineering, but few achieve in depth the specialist knowledge of any particular aspect of aeronautical engineering which will be acquired by industrial or government research and development personnel.

The Directorate had, at one time, the responsibility for monitoring the development of aircraft such as the A.V. Roe

Company's CF 100 and Arrow which were newly designed to meet a requirement established by the RCAF. With the lack of new developments of this type, the Directorate's responsibilities are now somewhat different. It assists in the preparation of specifications for modifications to aircraft purchased abroad, and is responsible for the technical supervision of the production of aircraft built under licence in Canada. In cooperation with the National Aeronautical Establishment, it also establishes airworthiness criteria, such as the fatigue life of aircraft in service. As well, at the request of the Chief of Operational Requirements, the Directorate analyses the characteristics of existing aircraft, or aircraft under development elsewhere which are being considered for procurement to meet an "Operational Characteristic" (OCH) established by the Chief of Operational Requirements. While it may make recommendations through its Air Member to the Chief of the Air Staff as to the best aircraft for a given role, it has no responsibility for formulation of the Operational Characteristic and may not see it in final form until it has been approved.

Since the "Operational Characteristic" is the prerequisite of a decision to develop or buy, and may not only result in a heavy expenditure of Crown funds but have considerable consequences for the Canadian aircraft industry, the process of its formulation is of interest.

Following the assignment of a role to the RCAF by the Minister, the Cabinet Defence Committee, or the Chiefs of Staff, implications of the role are defined by the Chief of Plans and Intelligence in terms of the class and strength of the threat which may have to be met, and the assistance which can be expected from other services or allies in meeting the threat. The Chief of Operations in consultation with the Chief of Operational Requirements will then prepare an "Operational Concept" which defines in broad terms the means which will be employed choosing, for example, between guided missiles or interceptors to meet a bomber threat. The Chief of Operational Requirements then prepares in detail the specifications of a system to meet the operational concept. This is the "Operational Characteristic", and might define the range, weapon load, speed, and other characteristics of an interceptor.

The Chief of Operational Requirements consults with the Directorates of the Air Member for Technical Services in the choice of an end item, which may be available "off the shelf" or may require development. Following the preparation by the Chief of Plans and Intelligence of a plan showing how this selected item will meet the role originally specified, approval of the Air Council, or for major programs the Chiefs of Staff Committee, and the Cabinet Defence Committee is obtained.

It will be noted that the participants in the preparation of the Operational Characteristic are part of the Vice

Chief of the Air Staff's Division (Figure 4, Appendix II). The definition is mainly in the hands of officers with operations rather than scientific or engineering backgrounds.

Once a program is approved, it is implemented by the Air Member for Technical Services. If only procurement is required, the program is referred to the Chief of Materiel who implements the procedures requesting the Department of Defence Production to place a procurement contract. If development is required, a program will be established under the direction of the Chief of Aeronautical Engineering, and development contracts let, again through the Department of Defence Production.

The procedures employed in the preparation of the Operational Characteristic were criticized by both industry and Department of Defence Production personnel who were interviewed. In recent years the Operational Characteristic tends to be established too late to enable a Canadian development to be undertaken and completed in time to meet the delivery dates required. As well the specifications often seem to preclude the purchase of a system already under development under the provisions of the Department of Defence Production Development Fund. The lack of RCAF interest in the Caribou aircraft is frequently cited in this latter regard. Very often the Operational Characteristic seems so written that only one particular system can possibly meet the requirement -

and this is often of United States origin. It is natural that the RCAF should resist any attempt to force it to choose inferior equipment to fulfill the role specified. However, DRB staff seldom, DDP staff never, and industry rarely plays any part in the formulation of the Operational Characteristic leading to an aircraft requirement. As a result, the RCAF is sometimes accused of being deliberately and unnecessarily secretive, or perverse, or obtuse, or all three. Obstruction, rather than cooperation, between industry, the RCAF, and other government agencies with a voice in aeronautical research and development results all too often as a consequence.

One other function fulfilled by the RCAF is of importance in the context of aeronautical research and development. The North Atlantic Treaty Organization has, in the past, held competitions to select an item for development or procurement against a requirement agreed jointly by its member countries. Technical teams from each country participate in joint evaluations of industry proposals. When Canada enters a competition, a small team consisting of technical, operation, and production experts chosen from DRB, NRC, the RCAF and Department of Defence Production personnel is sent. This team is led by an RCAF officer from the Chief of Operational Requirements office, even though an RCAF development program is not involved. In the case of aircraft programs, the stakes are extremely high, and although in theory the technical teams are expected to take a dispassionate view, in practice the evaluations take place in an atmosphere of unbridled competition, with the experts in a given field, such as performance, or stability and control, doing their best to obtain the highest possible evaluation for the entries of their own country and to seek out the deficiencies in the entries of other countries.

The Canadian teams seldom number more than half a dozen, and any one expert is expected to cover a number of fields. They find themselves opposed by teams of as many as 15 or 20 from each of the larger countries such as Great Britain, France and the United States. These teams from other countries are well prepared. They are selected well in advance of the evaluations, and receive intensive briefings from industry and the government laboratories of their own country. Their tactics and objectives are carefully thought out in advance, and their preparations are coordinated at a sufficiently exalted level that both military and civilian members of the teams work to the same goal.

Because of the different interests of the relatively independent agencies involved in Canada in aeronautical research and development, the members of the Canadian teams take different attitudes to the job of evaluation and are not nearly so well rehearsed, nor so effectively supported, as the teams of other countries.

For example, the R.C.A.F., unlike the military representation of other countries, receives no direction from civil authority on the position it is to take in support of Canadian entries. Its attitude is that it is there to make its experience available to all and to deal fairly with all entries. The Department of Defence Production, as a consequence of its mandate to sustain a defence industry, is a staunch supporter of Canadian entries. DRB representatives also tend to be somewhat partisan since the Canadian entries often have their origin in DRB supported research. National Aeronautical Establishment representation is not so numerically strong as would be possible if support of such competitions were given a high priority.

In spite of these disadvantages, in a recent competition, two Canadian entries were among the five chosen for a further round of evaluations. This result speaks well for the quality of both the industrial entries, and the abilities of the Canadian teams, but it is clear that if Canada expects to win competitions of this sort, much closer coordination of Canadian agency efforts must be achieved.

Royal Canadian Navy and Canadian Army development is limited compared to the RCAF whose development funds were curtailed sharply early in 1959. The individual expenditures of the three services on aeronautical development are not published, so no financial comparison can be made. Since fiscal 1958-59 when Canadian Service development expenditures in industry were $45.2 million, service expenditures in industry have been at a level of about $8.0 million per year for all development. The sharp drop is accounted for by the cancellation of the Arrow interceptor program. The expenditure on airframe, engine and accessory development is substantially less than this $8.0 million figure. In 1962-63 it was approximately $525,000.[1)] As has already been noted, this is a far cry from the $40 millions per year being spent in industry in the hey day of the Arrow.

The RCAF is the major buyer of aircraft, and where a large dollar value is involved, arrangements have been made to build these aircraft in Canada. The quantities of aircraft procured for both the Army and Navy have been small, and with few exceptions have been purchased abroad.[2)]

The Army's organization for aeronautical matters is shown in Figure 5, Appendix II. Under the Deputy Quarter Master General (Equipment Engineering) is the Chief Superintendent, Army Equipment Engineering Establishment (CS/AEEE)

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1) Conversations with officials of Canadian industry, DND and DDP. Some development costs are "buried" in production contracts, and the cost cannot be isolated. The estimate of a $525,000 level of expenditure is based on an examination of Department of Defence Production monthly contract award lists. These lists do not include "classified" contracts.

2) The Army has purchased a few Beaver aircraft from de Havilland and recently the RCN has ordered S-61 helicopters which will be assembled under licence from the Sikorsky Company of the U.S.A. by United Aircraft of Canada at Montreal.

responsible for 14 divisions, one of which is an aeronautical division headed by a service officer.[1] The Aeronautical Division has an Aeronautical Section and an Airborne Section. The Aeronautical Section is comprised of two civilians, one a professional engineer and the other a technical officer. It is responsible for carrying out evaluations of aircraft against requirements specified by Army Headquarters, and with RCAF assistance, prepares specifications for the aircraft which the Director of Equipment Policy finally selects for purchase.[2] Aircraft development is limited to minor modifications of existing aircraft and is carried out under the aeronautical section's cognizance, usually at the Joint Air Training Centre operated by the Army and the RCAF at Rivers, Manitoba.

Also reporting to the Deputy Quarter Master General (Equipment Engineering) is the Directorate of Equipment Engineering (DEE) which is part of the Army Headquarters staff. Under the Directorate of Equipment Engineering are 6 Divisions, among them an Aeronautical and Construction Equipment Division. This Division has one serving officer who acts as the Headquarters link between the users as represented by the Directorates under the Vice Chief of the General Staff and the Aeronautical Division in the Army Equipment Engineering Establishment. The

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1) The AEEE's organization is situated in Ottawa, but is not part of the Headquarters' staff.

2) Aircraft purchases are made for the Army by the RCAF. Specifications for these aircraft are approved both by the Quarter Master General for the Army and by the Air Member for Technical Services for the RCAF.

Aviation Section in the Directorate of Land/Air Warfare reconciles the requirements of the Artillery, Armoured and Service Corps for aircraft insofar as possible, and in conjunction with the Director of Equipment Policy establishes the requirements against which aircraft purchases are made.

The Royal Canadian Navy's organization for aeronautical matters is shown in Figure 6, Appendix II. Reporting to the Chief of Naval Technical Services, who is a member of the Naval Board, is the Director General Aircraft (DGA). Reporting to the Director General Aircraft is a Director of Aircraft Design and Production responsible for three sections, Design, Experimental Projects, and Production. The Directorate carries out evaluations of existing aircraft which are being considered for purchase to fill requirements established by the Directorate of Naval Aircraft Requirements. It also monitors production programs of aircraft being produced for the RCN, either under licence in Canada or abroad. Again, as for the Canadian Army, aircraft development is limited to minor modifications of existing aircraft.

The Director General sits on the Department of Defence Production's Advisory Group (Aeronautics) and members of his staff sit on the various project review groups which monitor Department of Defence Production programs. The activities of these groups are elaborated on in the succeeding section on the Department of Defence Production.

2.6 Department of Defence Production

The Department of Defence Production was created in February, 1951.[1] The new Department was made responsible for the procurement of defence equipment on behalf of the Department of National Defence and for ensuring that the necessary production capacity and materials are available to support defence production programs.[2] The Department has been responsible for encouraging the establishment since 1950 of a large number of subcontractors capable of meeting the diverse needs of aircraft and engine procurement programs. Since 1958, following a series of agreements between the governments of Canada and the United States, the Department has assumed a major role in defence development.

Since the Hyde Park agreement of 1941, the problem of defence of the United States and Canada has been treated as one of the joint defence of the North American continent. In 1950, the two governments issued a Statement for Principles of Economic Cooperation which extended the joint military planning resulting from the Hyde Park agreement into the economic sphere. This was followed in 1958 by a production sharing agreement, the objective of which is:

> ...the integration of the defence production capabilities of Canada and the United States to bring about the most economical and efficient development and manufacture of military weapons for the defence of North America...[3]

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1) Defence Production Act, R.S.C. 1952, King's Printer, Ottawa.
2) Ibid, Chapter 62.
3) Canada Year Book, 1959, page 1175. Queen's Printer.

Procedures to implement this agreement have been worked out under the aegis of the Canada - United States Ministerial Committee on Joint Defence by a Senior Policy Committee consisting of senior Canadian officials from the Departments of Defence Production, National Defence, External Affairs and Finance, and the United States Department of Defense. Under a Steering Group operating at the Branch Head level a number of Working Groups have been established to make detailed arrangements for the production sharing of specific projects of mutual interest.[1] The earliest example of a production sharing program was in the aeronautical field and resulted in orders for components of the Bomarc anti-aircraft missile being placed in Canada at Canadair.

The Department has made strenuous efforts to achieve equal opportunity in the United States for Canadian suppliers in bidding for prime production contracts and sub-contracts. Canadian companies are expected to compete with their American counterparts on the basis of technical competence, price, and delivery dates and to mount adequate sales efforts. In the early days of the production sharing program, because of the urgency of finding business as a result of the Arrow cancellation, the Department provided financial assistance to Canadian firms by

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1) Department of Defence Production. Production Sharing Handbook, Catalogue P21-1262 Queen's Printer. This reference gives details of the procedures and regulations which apply to production sharing contracts.

absorbing part of the pre-production and tooling costs where they were bidders against American contractors who had been able to write off such costs under previous contracts.

It soon became apparent that technological capability was of great importance in winning production contracts because the firm which develops a product and is therefore familiar with it, has a substantial advantage over an outsider when requests for bids on production are issued by the U.S. Services. Since there was a lack of new developments under way to meet the requirements of the Department of National Defence, the Department of Defence Production pressed for, and was given in 1960, the authority and funds "To sustain technological capability in Canadian industry by supporting selected defence development programs on terms and conditions approved by the Treasury Board".[1)]

The executive responsibility for the Development Sharing Program devolves upon the Branch Directors with the duty for overall coordination being assigned to one of the Assistant Deputy Ministers. A system of interdepartmental committees consisting of representatives from the Department of National Defence, the Armed Services and DRB, the Department of Defence Production and Treasury Board staff recommends the approval of

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1) Department of Defence Production. Defence Development Sharing. Queen's Printer, Catalogue P.21-1562, Ottawa, 1962.

and reviews the programs supported in industry. To date, as will be apparent from Appendix I, Table VIII, the majority of the programs have been concentrated in the electronics and aeronautical field.

The Organization of the Department is shown in Figure 7, Appendix II. Within the Aircraft Division, Number 6 Division, which is comprised of a Production Section and a Development Section is responsible for the Production and Development Sharing Programs respectively. The Development Section consists of 6 persons who are each responsible for a number of development projects. When a proposal is received from a company requesting financial support, an officer of the section prepares a brief for the Advisory Group Aeronautics (AGA)[1] which is mainly concerned with the technical aspects of the proposal, and its likelihood of meeting a probable or actual United States Armed Service requirement. On receipt of the blessing of the Advisory Group Aeronautics, the project is referred to the Interdepartmental Committee, DDP Development[2] which considers the financial arrangements and whether the proposed project is suitable within the overall policies and framework of the

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1) The Advisory Group Aeronautics membership is as follows: Assistant Superintendent Equipment Requirements DND; Chief of No. 6 Division, Aircraft Branch DDP; Director of Industrial Research DRB; Director of Aircraft Engineering RCAF; Director General Aircraft RCN; Director of Equipment Engineering Canadian Army; Treasury Board Observer.

2) The membership is: Asst. Deputy Minister DDP; Vice Chairman DRB; Assistant Deputy Minister, Requirements DND; Director General, Program Analysis, Treasury Board Observer.

Development Program. On receipt of this senior committee's approval, Treasury Board approval is obtained. A Project Review Group, consisting of a DDP officer from the Development Section as Chairman and technical specialists from DRB and the three Services, is then established and follows the program by means of at least quarterly meetings at the contractor's plant, and by review of progress and technical reports.

Before any project can be supported, it must be demonstrated that there is either a United States requirement[1)] for the end product of the development, or that there is a strong likelihood that such a requirement will develop, either because the project will result in a substantial improvement in the state-of-the-art and is likely to create a demand as a result of its excellence, or because there are good indications that the program will fill a United States need which for reasons of priority and financial shortages has not yet reached the requirement stage.

As a result of these criteria, three types of development programs may be distinguished.[2)] The first of these is where there is a United States requirement and the United States is prepared to finance it. Canadian companies who have previously established their competence and are listed with the United States Procurement Agency concerned may bid competitively

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1) In the last year a NATO interest has become justification for support by the Development Fund.

2) Dept. of Defence Production, Defence Development Sharing. April, 1962, Catalogue P21-1562, Queen's Printer, pages 6-7.

against United States contractors. To ensure that the bid is not lost on account of price,[1] the Department will sometimes agree to finance a portion of the cost, usually 25-50%, thus reducing the bid to the U.S. Service having the requirement. An example of this type of program is the 600 HP marine and vehicular turbine development at Orenda, and the Caribou II program at de Havilland.

The second kind of program is that where there is a United States requirement and the Canadian government and the company bear the full cost. This type of program results where there is known to be a need, but for reasons of priority and funding shortages, the United States requirement has not been formally stated. An example of this type of program is the 500 HP turboprop/turboshaft engine development program at United Aircraft of Canada. This engine fills a gap in the spectrum of U.S. Army turbine engine developments.

The third type of project is one which can be classed as a unique concept. On the basis of prior research a Canadian company may be able to show that a follow on development will result in an important advance in the state-of-the-art. If the end product is likely to match a future United States requirement, the Department of Defence Production will share

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1) This may be necessary where it appears likely that some of the U.S. bidders will "buy in" to the program, i.e. make a low bid and absorb part of the costs themselves because of the potential of a project in the long term.

the cost of development with the company. An example of this type of project is the CL-84 tilt wing vertical take-off aircraft under development by Canadair.

As will be evident from the foregoing, it is essential to the program that the Department of Defence Production be fully informed of actual and prospective United States requirements. This information is obtained through the Department's liaison officers posted to Washington and to the various United States service agencies with research and development responsibilities. Liaison with the Canadian Services and DRB provides additional information on requirements. Insofar as technical advice is concerned, the Department relies most heavily on DRB and to a lesser extent on the Canadian Services.

The level of the Department of Defence Production development funding is compared to expenditures on development by the Canadian Services in Table 2.7.

Table 2.7 - Comparison of DDP and Canadian Armed Service Expenditures for Development by Industry

$ Thousands

	1958-59	1959-60	1960-61	1961-62	1962-63
DDP Development 1)	—	1,851	2,902	4,420	8,000 2)
Total Aeronautics	—	—	2,270	2,810	3,400
Canadian Service Development 3)	45,238	8,561	8,193	7,476	8,000

1) Public Accounts, Details of Expenditures and Revenues.
2) Conversation with an official of DDP.
3) Royal Commission on Government Organization. Vol. IV, page 316.

It can be seen that in 1962-63, the DDP development program approached that of the Armed Services.

In the aeronautics field, it appears likely that DDP has replaced the RCAF as the primary source of funds for the support of industrial defence developments. This has had both desirable and undesirable effects. Although it is too early to judge, in the longer term, the dependence of the industry on Canadian defence procurement could be reduced. It remains to be seen however whether the political difficulties of selling into other countries, in particular the United States, can be resolved sufficiently that these external defence markets will achieve reasonable stability. It may well be that the industry will find it has only acquired a fickle customer who will more often than not turn up a nose after both the company and the Department of Defence Production have expended considerable funds on a particular development.

One Department of Defence Production officer who was interviewed felt that the program had had the undesirable effect of continuing the "spoon feeding" of the industry which commenced during the Korean War and criticized some elements of the industry for their lack of aggressiveness in seeking external markets. Industrial executives counter by pointing out the difficulties of selling to foreign armed services which have their own home industries and political lobbies to contend with. They also cite the difficulty of trying to stay equal in technology to foreign firms who are not required to cost share, but which have their research and development costs paid in full by government contracts.

Some RCAF officers resent what they feel has been the usurpation by the Department of Defence Production of an activity which properly belongs to them. They feel that the funds which the Department has been given for aeronautical development have been obtained at the expense of their own Development Estimates which have dwindled year by year since 1959. They consider that the Department officers concerned are amateurs who will eventually discover that there is more to running a development program than promoting its approval and getting out a contract. They feel that the Project Review Groups are not a suitable means for exercising control over the projects. In particular they feel that inadequate technical supervision results. Department officials tend to feel that the requirement for cost sharing keeps the firms "honest" and that since most of the development contracts require the firm to share all or a substantial portion of any cost over runs, there is a considerable incentive for the firm to meet cost, time, and performance requirements. The firm is the design authority and there is therefore no need to have a multitude of government project officers exercising supervision on a day to day basis.

Whatever the merits of these various viewpoints it will be apparent that they are not conducive to mutual confidence and respect between the Department of Defence Production and at least some quarters of the RCAF. One very important disadvantage results. The lack of strong RCAF support for the Department's attempts to sell into NATO markets has already been mentioned. More importantly, serving officers of other countries tend to be suspicious of Canadian products which are not being developed for the RCAF. This is because the RCAF will not in these circumstances be familiar in detail with the equipment, and there is no guarantee that the foreign buyer will not have to bear substantial costs in the future to rectify faults that may only show up after considerable flying time has accumulated. It has been suggested that this problem could be solved by "making" the RCAF buy these products. However, the RCAF objection here is that within the framework of present defence policy, none of their commitments lead to a need for many of the equipment developments the Department of Defence Production is sponsoring. Not to be outdone, the industry suggests that our defence policy should be changed so that the commitments of our services will lead to requirements for equipment that we can afford to develop and produce in Canada.

It is obvious, however, that the lack of a home market for Department of Defence Production supported developments puts the industry at a disadvantage in the very export market that the Department is trying to develop. Canada is unique in trying to sell abroad equipment whose production tooling and development costs have not been absorbed in part by home defence orders.

Before turning to the problems of coordination resulting from the activities of so many agencies with so many different objectives, and so many different programs, a brief outline of the administration of university research in the aeronautical field will be given.

2.8 University Research

As well as supporting aeronautical research and development in the laboratories of its own agencies and departments, and in industry, the Canadian government administers programs of grants-in-aid of research to staff members at Canadian universities. As well, awards of scholarships and fellowships are made to students carrying out post graduate research.

Most of the aeronautical research in Canadian universities is being done at the Institute of Aerophysics of the University of Toronto and the Mechanical Engineering Department of the University of McGill at Montreal. Although Toronto's interest in aeronautics extends back to 1917 when a four foot wind tunnel was constructed, Canadian university aeronautical research on a large scale began in 1949. In that year the Defence Research Board entered into an agreement with the University of Toronto for the construction and operation of the Institute of Aerophysics. The objective was to train personnel for research and development in the basic physics of gases, applied aerodynamics and ballistics with special emphasis on supersonic flight.

Also in 1949, McGill began the construction of a gas dynamics laboratory which concentrated on research in the fields of combustion, internal aerodynamics and turbo machinery.[1] During the past five years the emphasis at McGill has been on subsonic aerodynamics and hypersonics. More recently research laboratories at Laval University have been carrying out investigations in subsonic and supersonic aerodynamics. As well, a small amount of work is underway at the Universities of McMaster, Waterloo and British Columbia.

The research is supported by the National Research Council and the Defence Research Board. Applicants for DRB support submit their requests in November. The following January, the applications are reviewed by the DRB Advisory Committee on Plasma and Gas Dynamics[2] which is composed of technical specialists from industry, government laboratories and the universities. This committee is concerned mainly with the technical merit of the application. In March applications approved by this Committee are forwarded with the recommendations of the Director of Industrial Research to the Chief Scientist. The Chief Scientist submits the applications to the DRB Standing Committee on Extramural Research which considers the grants from all fields. This Committee which is

1) J.J. Green, "Aeronautical Research in Canada," pages 795 and 800.

2) Grants for research in the materials field come before an Advisory Committee on Materials Research.

a subcommittee of the Defence Research Board is concerned mainly with overall grants policy. However, it may increase or reduce a grant or override a recommendation of the advisory committee to award or cancel a grant. The Standing Committee is chaired by the Chief Scientist. The Chairman, DRB, who is a member of the Standing Committee submits the program as a whole for the approval of the Minister of National Defence early in March, following which the grants are paid to the credit of the university, to be drawn on by the applicant as required.

Apart from technical merit, the research supported must have relevance to the DRB's own laboratory programs, to a Canadian Armed Service or North American defence requirement, or to a NATO requirement. Apart from these criteria in the aeronautical field, DRB encourages at a few universities the establishment of strong research groups, each made up of a number of individuals working in various aeronautical fields. This is done to ensure continuity and because the necessary facilities such as wind tunnels are expensive, and it would not be economical to duplicate them at every university.[1)]

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1) Conversations with an official of the DRB.

The expenditures of the DRB for university research in aeronautics are shown in Table 2.8.

Table 2.8 - Defence Research Board University Grants for Aeronautical Research

	$ Dollars			
	1960-61	1961-62	1962-63	1963-64
Gas Dynamics	280,280	290,115	277,915	273,715
Materials[1]	69,000	69,000	75,000	75,000
Total	349,280	359,115	352,915	348,715

It can be seen that the level of expenditure has remained fairly constant over the past four years. This reflects the nearly constant level of DRB's total expenditures on grants, which has in turn been influenced by the ceiling on defence expenditures.[2]

While the funds allocated by DRB may be used at the discretion of the grantee to pay salaries to research students and technical assistants, or to buy equipment and

1) The sums shown are for materials grants relevant to the aeronautical structures and materials field. Total grants for materials are about $165,000 per year. The data is based on conversations with DRB officials.

2) Conversations with an official of the DRB.

materials and pay other operating costs, the National Research Council makes separate awards for student support in the form of scholarships and fellowships, and for operating costs, major items of capital equipment, major installations and travel. Scholarships and Fellowships are awarded by a Scholarship Selection Committee consisting of members from the senior staff of various universities. Eight grant selection committees review applications for operating grants in various fields of research.

Aeronautical research applications are reviewed by the Engineering Grant Selection Committee which is chaired by a senior official of the NRC's engineering staff. The recommendations of the Grant Selection Committees are reviewed by a Standing Committee on Scholarships, Fellowships and Assisted Researches. This Committee which consists of the members of the National Research Council is concerned mainly with overall policy and administrative considerations with respect to grants and scholarships. However, it alone considers applications for travel assistance, major equipment and major installations. As for the Defence Research Board, grants are awarded in March of each year.

Table 2.9 shows the total of the support awarded in aeronautical fields.

Table 2.9 - National Research Council Grants for Aeronautical Research at Universities[1)]

	$ Dollars			
	1959-60	1960-61	1961-62	1962-63
Scholarships, Fellowships	7,600	12,000	16,400	N.A.
Operating Grants	8,000[2)]	8,000[2)]	9,400	N.A.
Major Equipment Grants	—	—	—	—
Total	15,600	20,000	25,800	55,800[3)]

It will be apparent by comparison with the DRB figures, that with the exception of the most recent year, 1962-63, NRC provides less than 10% of those government funds directed to the support of aeronautical research in Canadian universities.[4)] In 1962, by agreement between NRC and DRB, the support of low speed work at the Institute of Aerophysics was transferred to NRC.

From the viewpoint of DRB, and certainly industry, one of the most valuable benefits of university research in the aeronautical field is that it results in the supply of well-

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1) Canada - National Research Council - Report on Unisity Support 1959-60, 1960-61, 1961-62.
2) Estimated.
3) Estimated.
4) The awards are a very small proportion of the NRC's total awards for grants and scholarships, the total of which was about $12 million in 1961-62.

trained personnel for government laboratory or industrial research and development. This is more important from the practical point of view than the results of the research, for while the research may make a contribution to the general fund of knowledge, it is rare that it makes any but the most indirect contribution to the solution of a government or industrial research or development problem. Since this is so, it would appear anomalous that DRB, which carries out little aeronautical research in its own laboratories should be the prime sponsor of university aeronautical research, and even more anomalous that the Board should attempt to apply criteria of defence relevance to basic research programs whose utility cannot be predicted in advance. The anomaly can be explained partly by resorting to history. It was during the defence build up of the 1950's that university aeronautical research was sharply expanded, and on the government's part the justification was the need for trained personnel to support the aircraft and engine development programs of the period. Since the need for personnel arose from defence requirements, it was considered that DRB should bear the responsibility for the necessary university support.

The analysis of the functions and level of effort of the various government agencies involved in the administration of aeronautical research and development is now complete, and the problems of planning and coordinating these various efforts will be examined in the Chapter which follows.

3.0 THE PLANNING AND COORDINATION OF AERONAUTICAL RESEARCH AND DEVELOPMENT

3.1 The Pattern of Research and Development

From the previous description of the aeronautical research and development activities of the various agencies concerned, it will be apparent that responsibility is widely decentralized. In theory, four agencies, that is the Department of Defence Production, and each of the three Services, can support industrial developments. Of these four the RCAF formerly had, and the Department of Defence Production now has, substantial funds available for industrial work. Defence need has been, and still is, the primary justification for government development support of the industry. In the review of industrial statistics in Chapter One, it was indicated that the industry was very dependent on defence procurement for its sales. Both development and procurement are therefore primarily defence oriented. It has been noted that aeronautical propulsion research is underway in the Division of Mechanical Engineering of NRC and the Canadian Armament Research and Development Establishment of DRB, with the former being justified on civil grounds and the latter tied to defence research programs. The National Aeronautical Establishment of the NRC has programs in flight research, structures and materials and aerodynamics. It has been noted that 40% of this effort in terms of manpower is taken up in the provision of services to industry or other government agencies. Because this service function stems largely from programs of research and development funded directly by the defence agencies, via the industry, it too is almost entirely defence oriented. It has also been indicated that DRB, through the Directorate of Industrial Research, is the major government source of money for aeronautical research in industry.[1] We have also seen that both DRB and NRC support university research in aeronautics.

The expenditures of all these agencies for the fiscal year 1962-63 have been collected in Table IX, Appendix I. It can be seen that of the total expenditure of $8.1 millions, the various defence agencies provided $5.0 millions, or 62%. Of this $5.0 millions, $4.7 millions or 59% of all expenditures went for industrial research and development and 5% to the universities. With the exception of $56,000 going to the universities, the civilian agencies expenditures were entirely in support of in-house programs. These amounted to $3.0 millions or 37% of the total. Since the expenditures of DRB and the Department of Defence Production for industry research and development are increasing steadily, and will more than double in 1963-64[2] the portion of the total funds

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1) To date, the NRC Industrial Research Assistance funds have not been used for aeronautical research support.

2) Discussions with officials of DDP and DRB. aeronautical development and research expenditures by DDP and DRB in industry will amount to $9.5 millions and $1.2 millions respectively in 1963-64.

spent by the NRC is steadily decreasing. By the end of fiscal 1963-64, NRC expenditure will be about 20% of the total and will be further reduced in 1964-65. Thus, on the basis of 1963-64 estimates, about 80% of the government's expenditures for aeronautical research and development are being directed to industry or the universities and are predicated on defence needs. Therefore, while NRC expenditures approached a peak of about 50% of the total expenditures in 1959-60 as a result of the cancellation of the Arrow program, it would appear that the pattern of 1950 to 1958 in which defence expenditures were dominant is now being re-established. However, NRC in-house expenditures still make up 65% of the funds spent by the government for aeronautical research.

Certain trends in these figures should be noted. First, during the fiscal year 1963-64 the expenditures by government for aeronautical research and development in industry have begun to approach the 3:1 multiple of government in-house spending that is prevalent in other countries such as the United States and Great Britain. Secondly, the estimated total $10.7 million expenditure by government in 1963-64 for industrial research and development, while less than that of the Arrow program peak, is once again a substantial sum of money. Because the Department of Defence Production and Defence Industrial Research programs require cost sharing, the total expenditure in industry may be inferred to be about \$15 - \$18 millions per annum at present. This would represent between 4% and 5% of sales. In comparison, the development costs for the aircraft and parts industry in the United States are of the order of 20% of sales.[1] Because the Canadian industry must, on economic grounds, always be dependent on licencing and production sharing arrangements for a large proportion of its home sales, it would not be reasonable to expect that the United States' figure should be equalled. It is likely, however, that if the studies proposed in the final chapter of this Thesis are undertaken, that it could be shown that development support of the order of twice that currently given will be required to generate the level of export sales necessary on balance of payment considerations alone.[2] Tentatively,

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1) United States National Science Foundation. Funds for Research and Development in Industry, 1959; NSF 62-3. See also Research and Development in the Aircraft and Missiles Industry (1956-61), NSF 63-19, May 1963.

2) The reasoning is as follows - An examination of the high growth industries in the United States indicates that research and development expenditures of 20% of sales are required. Thus the present level of expenditure of \$18 million per annum is laying the basis for future sales of the order of \$100 million per annum which, hopefully, will be in the export market. To meet a target of \$200 million in export sales, above the present level, within the next 10 years, research and development expenditures double the present level will be required. Of this, about one-half or \$20 millions must come from the government, and the other one-half from the industry and from development sharing arrangements.

it might be suggested therefore that total government spending for aeronautical research and development in industry must, in the next five years, approach $20 millions per annum. Of this sum, about one-fifth to one-quarter, or $4 - $5 millions per annum should go to support industrial research.[1)] On the assumption that in-house spending by government should be about one-quarter to one-third of its expenditures in industry, it might also be tentatively concluded that the expenditures in-house should be increased from the current level of $3.0 millions to about between $5 - $7 millions per annum, including capital expenditures for new facilities. Thus, the total expenditure by industry, by government, and from development sharing sources should be about $35 - $40 millions per annum in five years' time.

Having indicated the pattern of research and development expenditures for the years since 1950, and made a tentative projection of these for the future, the means by which the efforts of the various agencies and industry are coordinated can be examined. Canada's aeronautical industries and laboratories are concentrated in the Toronto, Ottawa and Montreal areas. Many of the senior workers in research and development know each other personally. Many of them have worked with one another in government laboratories or in another

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1) A division of expenditures of 20% for applied research and 80% for development is appropriate to the "science based" aircraft industry.

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segment of the industry at an earlier stage of their careers. There is a flow of workers from the universities to industry and to government laboratories and from the laboratories to industry and university teaching posts. Because the concentration of facilities results in small travel distances, personal contacts can be maintained readily and result in a general awareness among research personnel of what others are doing. As well, because the level of effort is small compared to other countries, there have been, and probably would be even without the existence of more formal means of communications, few instances of duplication of effort in research.

The achievement of adequate concentration of effort is more difficult. In the case of development concentration of effort is essential. This is because funds are always limited and because timing is of fundamental importance. If the development must compete with the developments of other countries, it must be completed in the same or a superior time scale and be technically comparable as well. If the end product of the development is intended for a home military market, it is in constant danger of being overtaken by changes in political climate or by advances in technology which may offer reduced cost or increased effectiveness compared to the particular development and to all other developments of its class.

This was the fate which overtook the Arrow program. Here a lack of sophistication in weapons system management techniques resulted in gross underestimates of the time and cost to complete the development. Although very substantial sums were spent, they were inadequate to complete the program before technological developments elsewhere, and decisions at the political level resulted in the program first being questioned and then cancelled. It is clear therefore that in selecting development projects, the responsible agencies must weigh carefully the full implications of the total cost of the program and assure themselves that it is both economically and technically feasible to complete the program in a time scale that will result in a successful end product.[1)]

In the case of research, a distinction must be drawn between fundamental or basic research, and applied research. In the case of basic research very little can be done to ensure that worthwhile work is done[2)] beyond providing a climate in which creative and curious engineers and scientists can work and giving them adequate financial support. It is generally agreed that about 10% to 20% of the research budget should be set aside for basic research. Provided they

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1) See for example Tucker, Robert S. "Management of Defence R & D." American Society of Mechanical Engineers, Paper 63, EMGT-4, 1963.

2) Unless of course, one is prepared to hire only scientists whose interests are known to coincide with some pre-determined research policy of the organization, and to encourage the transfer of such persons to other agencies or the universities where their interests diverge from the organization's interests. This is the technique adopted by the very successful Bell Telephone Laboratories.

are suitably qualified and experienced, the people doing such work can be left to set their own goals and their own timing. Work of this kind belongs in the universities and to a limited extent in government laboratories. In the latter case, some control is required to ensure that the work covers a reasonably broad spectrum because it is necessary that there be informed opinion available within the government agencies over as much as practical of the range of disciplines which the field of aeronautics encompasses. This is necessary to ensure that advice is available to enable the government to be a discriminating buyer.

In the case of applied research, more control over the selection of projects is required. This is because they invariably take more time and effort to reach a successful conclusion than is initially estimated and if they are not compatible with the funds and manpower available, events may also pass them by. Unlike basic research which seeks new knowledge, applied research seeks to derive practical uses of new knowledge, with the objective of improving existing processes and mechanisms. Applied research achieves its fulfilment when an improved end product is successfully marketed. If the applied research does not result in an improved end product, and the end product is not successfully marketed, beyond giving training and experience to the workers carrying out the applied research, the work will have fallen short of success.

The wise selection of suitable applied research projects is extremely difficult. All the considerations involved in selecting suitable developments must be projected even further into the future. The selection process requires looking ahead 5 to 10 years in time and envisaging both the type of product that buyers will want, and foreseeing what the performance of alternatives may be. It requires therefore an ability to project and interpret technological trends. It requires also an appreciation of what may be economically possible end products.

Because the end markets for Canadian developed aeronautical products are overwhelmingly military, it is reasonable to expect that the defence agencies would be in a better position to predict the needs of five to ten years hence than an agency such as NRC, and that the defence agencies in their selection of applied research tasks would be more likely to display a greater degree of prescience.[1] Even if they are not more prescient, the fact that advanced developments must be based on previously completed applied research means that developments funded by the military are likely to be based on research funded by military agencies, for the people concerned are bound to have more faith in their own concepts than those

1) For comment on the need for "prescience", see Tucker, Robert S., "The Management of Defense R & D." American Society of Mechanical Engineers, Paper 63-EMGT-4, 1963.

of outside agencies such as NRC. They are in fact in a strong position to influence the future.

NRC management, being divorced from the military milieu in recent years, justify their applied research programs on the basis of likely civil applications. In the absence of government expenditure for civil developments, and because of the close relationship between the defence agencies and the industry, very few of the results of the research are used by the industry. As a result, the industry and the defence agencies are generally critical of the applied research done by NRC.[1] In an effort to improve its communications, NRC has supported, in the aeronautics field, the establishment of associate committees whose membership is drawn from industry, the universities and the defence agencies. At the same time many officials of both the Division of Mechanical Engineering and the National Aeronautical Establishment emphasize the non-aeronautical application of much of the work they do.[2] There has in fact been in the years since 1958

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1) Conversations with industrial officials and officials of DDP, the DRB and the RCAF. This criticism is not directed to the quality, but to the selection of the applied research tasks.

2) One official of the NAE who was interviewed stated that it was becoming increasingly difficult to justify programs on aeronautical grounds because of the parlous state of the industry. An official of the DME felt that it was not possible to draw a distinction between their aeronautical and non-aeronautical work since the results would be applicable in many industries.

in both the Division of Mechanical Engineering and the National Aeronautical Establishment a gradual shift in program emphasis from aeronautical to non-aeronautical work.[1)]

It will be apparent that there is an unfortunate schism in philosophy between the defence agencies and industry on the one hand and the NRC on the other on what constitutes useful aeronautical applied research. It is against the preceding background that the Committee structures which have been set up in an attempt to achieve a coordinated effort must be examined.

3.2 The National Aeronautical Research Committee and the Technical Advisory Panel and the Associate Committees

The influence of the National Aeronautical Research Committee (NARC) on the affairs of the National Aeronautical Establishment (NAE) has been mentioned briefly in the section dealing with the Establishment. The National Aeronautical Research Committee, its subsidiary Technical Advisory Panel, and Associate Committees are the only government committee hierarchy concerned solely with aeronautical research. The Committees are representative of all of the bodies in Canada with aeronautical interests, including industry and the universities. It might be expected therefore that they would play a considerable part in coordinating

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1) A 1958 estimate shows 47% of the DME effort was in aeronautics, as opposed to 35% of the effort in 1962. The NAE figures are 1958 - 94%, 1962 - 80%.

aeronautical research activities in Canada. The general view is that they have not been effective[1] and it is necessary to examine their origins and history to see why this has been so.

The National Aeronautical Research Committee was established on December 28, 1950 by the authority of the Cabinet, at the same time as the formation of the National Aeronautical Establishment was approved. The Committee is responsible to a sub-committee of the Privy Council Committee on Scientific and Industrial Research consisting of the Chairman of the Privy Council Committee and the Ministers of Transport, Defence Production,[2] and National Defence. On matters relating to defence, it also reports to the Cabinet Defence Committee. Under its initial terms of reference, dated December 28, 1950, the National Aeronautical Research Committee[3] was:

> ...responsible for all matters of broad policy concerning the functioning of the NAE and in these matters the Director would be guided by the decisions of the Committee. Detailed administration, however, of the NAE will be the responsibility of the President, NRC. The Director of the NAE will be appointed by the President of NRC after consultation with the NARC...[4]

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1) Not one of the persons interviewed in industry, government or the universities considered that they were effective.

2) The DDP Minister was named to the Committee in 1952.

3) Hereafter the abbreviation NARC is used interchangeably with the full name of the National Aeronautical Research Committee, and the abbreviation TAP used for the Technical Advisory Panel. NAE is an abbreviation of the National Aeronautical Establishment.

4) From a communication with the Secretary of the NARC.

The members of the National Aeronautical Research Committee are the Chairman of DRB, the President of NRC, the Chief of the Air Staff, the Deputy Minister of Transport, and the Deputy Minister of Defence Production.[1] The Chairman of the Committee is appointed by the Privy Council Sub-Committee. The formation of a Technical Advisory Panel (TAP) was also authorized at this time. Its terms of reference were as follows:

> ...The TAP will consider and advise the National Aeronautical Research Committee on all technical matters involving policy and will serve as a scientific and technical advisory panel to the Director of the Establishment...[2]

The original members of the Technical Advisory Panel were the Director of the National Aeronautical Establishment; the Deputy Director General (B) of the Defence Research Board; the Air Member for Technical Services, RCAF; the Controller of Civil Aviation, Department of Transport; and the Director of the Aircraft Division, Department of Defence Production.[2] The Technical Advisory Panel members were the senior officials responsible for aeronautical matters in the various organizations represented on the National Aeronautical Research Committee.

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1) The Deputy Minister of Defence Production was added in 1952.

2) The Director of the Aircraft Division, DDP, was also added in 1952.

It is clear therefore that initially the National Aeronautical Research Committee and the Technical Advisory Panel were not intended to coordinate the activities of all government agencies with aeronautical interests, but were to concern themselves with the National Aeronautical Establishment which was to comprise "the laboratories and flight test facilities for the conduct of research and experiments required for the development and operation of military and civil aircraft in Canada".[1] Further, the National Aeronautical Research Committee was not authorized to receive appropriations from parliament, but was to be the means by which the various participating agencies were to ensure that the programs of the National Aeronautical Establishment reflected their own particular interests whether civil or defence.[2] By virtue of the terms of reference of the NARC and the TAP, the Director of the National Aeronautical Establishment was, from an administrative point of view, put in a curious position. He was responsible to the President of NRC for "detailed administration", to the NARC for "all matters of broad policy" and was as well subjected to the "scientific and technical" advice of the TAP.[3]

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1) See Canada, Royal Commission on Government Organization, Vol. IV, Special Areas of Administration, Queen's Printer, page 275.

2) One other very practical reason for the NARC's formation was to keep under control a very considerable row which was developing between DND and NRC aeronautical personnel concerning the control of the substantial new facilities which were planned.

3) Conversations with former officials of the NRC and the DRB. Personality conflicts and the ill feelings generated by the struggles for control of the NAE operation made what was an administratively cumbersome arrangement completely unworkable in practice.

Since the senior management of the NRC had supported the arrangements, the Director was obliged to make the best of them. Under his Chairmanship, ten meetings of the Technical Advisory Panel were held.[1] From 1951 through 1953, these were at approximately semi-annual intervals. Four meetings were held in 1954, and none thereafter until the Panel was reconstituted in 1958.[2] These meetings were concerned mainly with the plans for the construction of the new hangar and the operation of the Flight Research Section at Uplands. In 1952 plans for the construction of other facilities were considered. Among these were a 6' x 6' trisonic wind tunnel.[3] Two recommendations of the Technical Advisory Panel to the National Aeronautical Research Committee during this period are of interest. The Panel recommended that research and large scale test facilities should not be provided using government funds at the industry plants without proposals to do so being referred for the consideration of the Technical Advisory Panel.[4] At a meeting in 1953 the Panel

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1) This account of the Panel's operations is based on conversations with present and former officials of the NRC and DRB.

2) Meetings were at the call of the Chairman. There were no calls after 1954.

3) The history of the tunnel has been given in the section on the National Aeronautical Establishment.

4) This did not prevent the construction at Malton of an expensive engine pressurized test facility. Later events, i.e. the Arrow cancellation, proved the wisdom of the TAP's recommendation. The facility has been unused since 1958.

recommended that they be authorized to set up technical sub-panels in fields such as aerodynamics, power plants and structures and in other aeronautical areas as seemed from time to time desirable. The membership, it was suggested, should be drawn from working level staff from the industry, universities, airlines, other civil and military government agencies and the National Aeronautical Establishment.[1)]

The Technical Advisory Panel was reconstituted in October, 1958[2)] to advise the National Aeronautical Research Committee whether or not the five foot trisonic tunnel should be completed in view of the likely reduction in aeronautical research and development activity presaged by the Prime Minister's speech, on the Arrow program, in the House of Commons on September 23, 1958. The Panel reviewed briefs submitted by the industry to the National Aeronautical Research Committee on the tunnel question, and following a series of six meetings concluded in late November that the tunnel should be completed. The NARC accepted the recommendation and DRB withdrew stop work orders which had been placed on Defence Construction Limited late in September.

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1) The TAP members, it should be noted, were technical administrators rather than specialists. It was felt that they could improve their effectiveness if they had the advice and support of technical sub-committees.

2) By 1958 retirements, re-organizations and staff changes resulted in all of the original members, except one, of the TAP no longer being on the scene.

During the period to 1958, the National Aeronautical Research Committee concerned itself mainly, like the Technical Advisory Panel, with the plans for the National Aeronautical Establishment. In 1954 it confirmed the agreements made by DRB and NRC managements that control of NAE Uplands should pass to DRB on the completion of the trisonic tunnel, which it was expected would occur in 1957. Also in 1954, approximately 18 months after the Panel had made its first suggestion,[1)] the National Aeronautical Research Committee empowered the Panel to constitute technical sub-panels. During the period from 1951 to 1954 twelve meetings were held. The next meeting occurred two years later in 1956. At this and subsequent meetings further discussions were held on the question of whether DRB or NRC should control the National Aeronautical Establishment, whether each should control a part, or whether the Establishment should be an autonomous agency, independent of both. Finally in 1957, the NARC approved a submission to the Cabinet Defence Committee which recommended the transfer of the Uplands facilities, i.e. the Flight Research and the Trisonic Tunnel to DRB. The Cabinet accepted the recommendation of the NARC and empowered the NARC to decide on "an early date" for the transfer. Also in 1957 various means for coordinating the work of the separated

1) The TAP repeated its recommendation that sub-panels be formed in mid 1954.

facilities were considered by the NARC among which were a revitalized Technical Advisory Panel and a Scientific Advisory Committee on Aeronautical Research on which industry would be represented. Nothing concrete was implemented however, and the NARC neither decided on an effective date of transfer, nor on the machinery for coordination. No further meetings were held until the period October to December, 1958. The four meetings of this period, like the meetings of the reconstituted Panel were concerned with the future of the trisonic tunnel. During this period the senior management of NRC and DRB bilaterally agreed that the transfer of the Uplands facilities should not be proceeded with and that the National Aeronautical Establishment should be given divisional status within NRC.

The National Aeronautical Research Committee gave its blessing to this arrangement which represented a complete reversal of all its previous decisions and its plans for the Establishment. The decision was predicated on the assumption that Canada would no longer be involved in large scale aeronautical research and development. The reasoning was as follows : Since a growing Research and Development effort was no longer likely, the concept of an expanding National Aeronautical Establishment should be abandoned. Therefore, since it had assumed substantial expansion of the Uplands plant the concept of separate DRB and NRC control of the Uplands and Montreal Road facilities was no longer sound.

Since separate control was no longer logical, the Uplands facilities should be administered as a unit together with the NRC Montreal Road facilities.

As indicated earlier NRC then gave divisional status to a National Aeronautical Establishment which included the Uplands facilities and the aerodynamics and structures facilities at Montreal Road. Excluded were the Fuels, Gas Dynamics and Engine Laboratories which had been part of the original Establishment.

In making this decision, the National Aeronautical Research Committee agreed that the Technical Advisory Panel with the new director of the National Aeronautical Establishment as Chairman, should meet regularly and continue to follow the work of the Establishment. The Panel was to remain a creature of the Senior Committee, but was not to consider itself responsible for directing the affairs of the Establishment. The Panel also was to draw up for itself revised terms of reference for the NARC's approval. It was also agreed that the NARC should continue to meet regularly, and that it would still be desirable that any further aeronautical research facilities should be placed on the Uplands site. It was obvious of course that the original relationship of the National Aeronautical Research Committee and the Technical Advisory Panel to the National Aeronautical Establishment would need to be altered and during the next two years both the NARC and the TAP sought to determine what this should be.

The NARC subsequently met in mid 1959, early in 1960 and again at the end of 1960. During this period it agreed that TAP and its associate committees would have to be advisory in function. It authorized the formation of associate committees in aerodynamics and structures. A suggestion during this period by the National Aeronautical Establishment that consideration should be given to the construction of a hypersonic heated air facility was rejected by both the TAP and the NARC. By common consent the NARC and the TAP continued to consider themselves responsible for the Establishment's policy with respect to facilities growth. That they were also concerned about the problems of coordinating research effort is evidenced by the support given to the formation of the technical committees and by their subsequent deliberations. Their concern for coordination of effort represented a change in philosophy and took them beyond their original terms of reference.

During the latter part of 1959, members of the Technical Advisory Panel learned that the Division of Mechanical Engineering had included in its estimates for subsequent years provision for the construction of a 20' x 12' working section low speed wind tunnel for testing lifting fan engines. The Panel at a mid-1960 meeting instructed the Chairman to draw this fact to the attention of the Chairman of the National Aeronautical Research Committee, and express their concern about it since the provision of aeronautical facilities was

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One other event of significance occurred late in 1960. The aircraft and engine industry had become increasingly concerned about its exclusion from senior government committees on aeronautical research and wrote DRB recommending that a body should be formed to enable industry's views to be made known to the government. This request and the Division of Mechanical Engineering wind tunnel question gave rise to further discussions in the National Aeronautical Research Committee on what their and the Technical Advisory Panel function should be. It was agreed that the terms of reference of both the NARC and the TAP would have to be revised.

The first step taken was to revise the terms of reference and membership of the Panel. These changes were approved by the NARC in April, 1961. The revised membership added to the already existing membership[1] the names of the Vice President, Scientific, (NRC); the Chief Scientist (DRB); the Director of the Division of Mechanical Engineering (NRC); and a member of the DRB Canadian Armament Research and Development Establishment. Thus all government laboratories carrying out aeronautical research were represented. The addition of the Vice President, Scientific, NRC and the Chief Scientist, DRB, provided representation which could speak on matters of technical policy for their respective organisations. As well two industrial representatives named by the Air Industries and Transport Association[2] were added, as was the Director of the Institute of Aerophysics of the University of Toronto. Thus all the Canadian interests were represented on the new Technical Advisory Panel.

The terms of reference were made more specific than the original terms. The Panel was empowered to establish advisory committees, to review at least annually the research

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1) The membership prior to April, 1961 was the Director, National Aeronautical Establishment; the Chief Aeronautical Engineer, Department of Transport; the Air Member for Technical Services, RCAF; Director, Aircraft Branch, Department of Defence Production; and the Director of Engineering Research, DRB Headquarters.

2) In 1963 the membership was modified to give representation from the Air Industries Association of Canada and one member from the Air Transport Association. This change was consequent to the establishment of two industry associations in place of one in 1963. As well, the term of the Chairman was limited to two years.

programs already in existence or sponsored by the agencies participating in the NARC as well as programs in existence elsewhere in Canada. It was also authorized to review annually the reports submitted by its advisory committees, and the requirements for aeronautical research as advanced by the various agencies. Following these reviews, the Panel was required to recommend to the National Aeronautical Research Committee programs to overcome deficiencies between the requirements and existing programs. Figure 8, Appendix II gives the terms of reference of the Panel in full.

In April, 1963, the NARC adopted revised terms of reference.[1] The original powers of being "responsible for all matters of broad policy concerning the functioning of the NAE" were revised to make the NARC responsible for the overall advice on government policy on aeronautical research in Canada.

As a result of revising its own terms of reference, the National Aeronautical Research Committee now is to consider the reports and recommendations of the Technical Advisory Panel with regard to Canadian research requirements and facilities, to consider Canadian research programs and their relation to national need, and to endorse the implementation

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1) These are given in full in Figure 9, Appendix II. Since the proposal for the formation of the NARC and its original terms of reference were submitted to and approved by Cabinet, the NARC's power to amend its own terms of reference is open to question. Nevertheless, it was done by common consent of its members.

of approved proposals for new or re-oriented research programs, for new research facilities and for industrial participation of appropriate kind. It will also review research programs inside and outside the Government Service with a view to achieving the best possible coordination.

It may now be understood why, until 1961, when the Technical Advisory Panel was given broader powers, the National Aeronautical Research Committee structure has not been effective in coordinating research activity. Except for the National Aeronautical Establishment, the participating members, in accordance with the original terms of reference, have never considered themselves obliged to submit their own programs for the review of the NARC and TAP.[1] The Division of Mechanical Engineering propulsion research programs did not come under the Panel's review after 1958 by virtue of the separation of the Engine and Gas Dynamics, Fuels and Instruments Laboratory from the National Aeronautical Establishment.

It seems doubtful that there would have been any real improvement in the situation even if the NARC had assumed earlier the powers it took unto itself in 1963. The National Aeronautical Research Committee members do not

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1) Even the National Aeronautical Establishment has not always been cooperative in this respect.

have aeronautical backgrounds, and the sense of urgency and frustration that those concerned with aeronautical research have felt because of the widespread decentralization, and the lack of national goals does not seem to have communicated itself to the NARC. This is apparent from their infrequent meetings, and the time taken to reach decisions on, in particular the relationships between the National Aeronautical Establishment, DRB and the Division of Mechanical Engineering, and even on what their own responsibilities should be.

For example, on the basis of the past account, it may be noted that although the suggestion for the formation of technical sub-panels was first made by the Technical Advisory Panel in 1953, they were not authorized until late in 1954, and none were actually formed until 1960. Further, although the trisonic wind tunnel was authorized in 1954, it is still, nearly ten years later, not fully in operation. It seems likely that it would have been completed more speedily if it had been the responsibility of a single agency not required to seek the National Aeronautical Research Committee's approval. Again, although in 1958, it was apparent to many that aeronautical research and development would continue to be of importance to Canada, the NARC considered that it would not be at a level sufficient to justify the continued growth of aeronautical research facilities and the transfer of the National Aeronautical Establishment to DRB. Within a year of this decision the Establishment had proposed the construction of a hypersonic test facility at a cost of $2 millions, and the Division of Mechanical Engineering, regardless of the National Aeronautical Research Committee's decision that major new facilities should be placed at Uplands, had laid plans for, and shortly began, the construction of a major new tunnel for propulsion studies at Montreal Road. More recently, a new low speed tunnel has been proposed. In fact, most of the NARC's decisions merely reflected agreements already reached by its NRC and DRB members.

In spite of their broader terms of reference, neither the Technical Advisory Panel nor the National Aeronautical Research Committee has been given an opportunity to review the aeronautical programs of the Division of Mechanical Engineering. It may be concluded that the National Aeronautical Research Committee has often been dilatory, and where it has not been dilatory, it has often been ineffective. Whether the more comprehensive terms of reference will give it greater vitality remains to be seen. Its past history gives little grounds for expecting that it would be effective in the field of aeronautics if it were to "assume the responsibility for coordinating the programs of the Defence Research Board, the RCAF and the Department of Defence Production in this field", as the recent Royal Commission on Government Organization suggests.[1]

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1) Canada. Royal Commission on Government Organization, Vol. IV, page 280.

The lack of success of the NARC and the TAP in achieving coordinated research programs indicates the futility of delegating to committees the job of solving problems of jurisdiction and coordination where none of the organizations concerned are seriously interested in seeing an effective overall program achieved at the expense of their own prerogatives.[1] The historical rivalries have been too strong.

Although it has been possible on the basis of a review of some ten years of history to come to a conclusion concerning the effectiveness of the National Aeronautical Research Committee and the Technical Advisory Panel, it is too early to make a judgement concerning the effectiveness of the Associate Committees which the NARC authorized in 1954, and which were formed in 1960 and 1961.

The three NRC Associate Committees on Structures and Materials, Aerodynamics and Propulsion are responsible to the Technical Advisory Panel. Although this fact is not appreciated by most of the membership of the various committees, the committees are NRC Associate Committees for administrative convenience only.[2] The terms of reference

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1) This ineffectiveness would have been predicted by Urwick, <u>The Elements of Administration</u>, Pitman and Sons 1943, reprinted in Canadian Public Administration, MacMillan Company, 1960, page 74.

2) Cloaking the Committees with the title "NRC Associate Committee" provides a mechanism for paying travelling expenses of industrial and university members.

of the Associate Committees are given in Appendix II, Figure 10. In the Terms of Reference the Committees have been invited to consider Canadian pure and applied research needs and to make recommendations to the Technical Advisory Panel for appropriate programs and facilities. They are also invited to make recommendations to the Panel for appropriate action with respect to Canadian participation in the programs of the Commonwealth Aeronautical Advisory Research Council (CAARC) and the Advisory Group for Aeronautical Research and Development (AGARD) which is a scientific body of the North Atlantic Treaty Organization.

The Committees have all been active since their formation. All have met at least four times per year, and some more frequently. Some have formed ad hoc sub-committees to consider and recommend to the full committee appropriate action in various fields within their purview. The Aerodynamics Committee has, at the request of the Technical Advisory Panel carried out a detailed review of existing aeronautical research programs in Canada and made recommendations to the Technical Advisory Panel concerning areas which should receive emphasis in Canada. It has also recommended the construction of a new low speed wind tunnel. The Structures and Materials Committee has arranged an industry - National Aeronautical Establishment cooperative test program on refractory metals and coatings for very high temperature materials.

The Propulsion Committee has been less successful. Like the Structures and Materials Committee, the Propulsion Committee has not carried out the review of research in its field in Canada requested by the Technical Advisory Panel, and partly because of a lack of response from the industry,[1] has been able to start relatively small hares only. The Aerodynamics Committee's sterling efforts have elicited little response from the Technical Advisory Panel or the National Aeronautical Research Committee. It would appear that the Committees' most useful function is to bring working level representatives of industry, government, and the universities together at frequent intervals. Since the members of the committee are technical specialists, more concerned with the practice of engineering science than the politics of scientific organizations, they are able to accomplish useful work when the work can be done within existing resources. Where appeals must be made to higher authority through the TAP-NARC committee hierarchy for increased support, or a redistribution of effort, bureaucracy begins to interfere with science and the protection of vested interests begins.

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1) Engine firms traditionally do their own research and development and rarely make use of government facilities or of government personnel for advice.

4.0 RECOMMENDATIONS FOR IMPROVING THE PLANNING AND EASING THE PROBLEMS OF EFFECTIVE CONTROL AND COORDINATION

It will be apparent that there is in Canada no single agency nor any effective coordinating mechanism which ensures that government funds for aeronautical research and development are allocated in a logical manner.[1] As might be expected, both in industry and government laboratories, the result is a hodge-podge of research and development programs which, because of their number, are often financed inadequately. Such widely decentralized responsibilities for aeronautical research and development are, with the exception of the United States, unique to Canada. Even in the United States strong centralized control exists in each of the major agencies such as the Army, the Navy and the Air Force, and in the National Aeronautics and Space Administration. This control extends to the full range of university, government laboratory and industrial research, and through the development and procurement cycle. Further, the various programs of the three U.S. Services are subject to the overall scrutiny of the Department of Defence. The organizations of other countries, whose efforts are not so large as that of the United States are strongly centralized. In Great Britain, the Ministry of Aviation is responsible for the government aeronautical laboratories and manages the

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1) Discussions with officials of the Treasury Board staff indicate that no attempt is made to consider as a whole the aeronautical research and development efforts of the various agencies.

aeronautical development programs of the Armed Services.[1] It is also responsible for the support of civil research and development. In Sweden, which has a gross national product and population comparable to Canada, control of aeronautical research and development funds vests in the Swedish Air Board, an agency of the Royal Swedish Air Force.[2] In France, overall coordination and control is exerted through Secretary of State for Air and the Ministry of Defence, which has also played a leading part in assisting the industry to build up export sales.[3]

There is no evidence that the large number of agencies has been of benefit to the well being of the Canadian industry, to the quality of the management of government supported industrial research and development, or the quality and usefulness of government laboratory research in aeronautics. On the basis of the previous analysis, there is good reason to suggest that a more centralized organization would be desirable. The situation can be summarized as follows:

Aeronautical research and development programs in Canada are a mirror of the highly decentralized organization. There is no single policy making body, and therefore no national goals.

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1) Monteith, G. Stuart. "Organization of Research and Development in Government Establishments and Nationalized Industries." British Communications and Electronics, December, 1962.

2) Lofkvist, H.E. "Aeronautical Research and Development in Sweden, Financial Background and Organization," Aeronautical Engineering Review, December, 1954.

3) Bonté, General Lewis. "The French Aeronautical Industry. Its Current Situation and Future Prospects." Interavia, Vol. VI, page 787, 1963.

Consequently, each agency sets its own goals and establishes research or development programs according to an interpretation of its own needs or the national need. There is no centralized long range planning which results in lack of coordination of industry, government laboratory and armed service programs.[1] No one agency has the responsibility for the full cycle of research, development and procurement. In the research field no one agency has the power to establish a coordinated program.

DRB finances aeronautical research in industry, but does very little aeronautical work in its own laboratories. The Division of Mechanical Engineering, and the National Aeronautical Establishment of the NRC carry out the majority of the aeronautical research in Canada, but do not finance work in industry. The internal programs of the two NRC agencies have, in the past, rarely been useful to industrial programs, and where they have been related, it is too often a case of too little and too late.[2] The internal propulsion research programs of the Division of Mechanical Engineering have seldom been related to the flight and aerodynamics research programs of the NAE or the industry.

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1) This fact was recognized by nearly every person interviewed. See also Canada, Royal Commission on Government Organization, Volume IV, page 232.

2) NRC officials dispute this, but the statement reflects the consensus of industrial officials who were interviewed.

The RCAF, which is the prime customer for Canadian industry's aeronautical products has meagre development funds. While DRB theoretically has had the power to exert a strong influence on RCAF development programs by virtue of its power to review RCAF development estimates, this power is not now exercised and was not exercised even when the RCAF was spending very substantial sums. The Department of Defence Production, now the major source of development funds, has no power to ensure that development programs have an adequate research base. Further, it is resolutely attempting to keep a development capability alive by funding development programs aimed at export sales. Few, if any, of the Department's programs to date can expect to achieve the substantial home market, which the experience of other countries would indicate, is the sine qua non of a successful aeronautical export program. The RCAF's roles, as determined by national defence policy, have not for the past several years required aircraft or engines which Canada could develop for politically acceptable costs. The RCAF does not participate fully in the export sales efforts of the industry and the Department of Defence Production as the air forces of other countries are required to do.

The multiplicity of agencies results as well in imbalances between the effort on research and development, and between government laboratory and industrial programs. It results also in considerable frustrations for government personnel at the working level who must frequently work with inadequate funds, facilities or manpower within their own agency.

The result of these fragmented responsibilities has all too often been research and development programs which are too little and too late to be of value to the industry, to the agency concerned, or even to make a worthwhile contribution to the general fund of knowledge.

In many ways, the problems resulting from the decentralized aeronautical research and development organization are typical of the problems of the whole of non-departmental government research and development administration in Canada. Any suggestions for improved planning, coordination and control of aeronautical research and development must be compatible with the whole picture, which following the report of the Royal Commission on Government Organization is under extensive review.

It would appear from the Commissioners' report, however, that no major changes were contemplated in the allocation of program responsibilities insofar as aeronautical research and development is concerned.[1] The Commissioners noted the lack of coordination between the programs of the various agencies, and the absence of a single body for the coordination of aeronautical research and development,[2] and suggested that the National Aeronautical Research Committee assume the responsibility for

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1) Royal Commission on Government Organization, Scientific Research and Development, Vol. IV, Section 23, pages 275 to 280 inclusive.

2) Ibid. Sections 45 and 46, page 279.

the coordination of research programs. By virtue of the change in the Committee's Terms of Reference made in 1963, assumption of this responsibility is feasible, but as has already been noted, it is considered that it is unlikely to discharge such a responsibility effectively, because of the historical rivalries between the various agencies concerned. However, if, as the Commissioners suggest, the Defence Research Board were to become a Defence Research and Development Board responsible for the management of Armed Service development programs, a considerable improvement in planning, and coordination of aeronautical research and development would be feasible.

A Defence Research and Development Board would automatically bring into day to day contact those directorates of the DRB and of the RCAF which now have only a nodding acquaintance with each other. Close integration of Defence Industrial Research programs with RCAF development programs would be facilitated.

Since by far the majority of the end products stemming from aeronautical applied research in Canada are, and will continue to be, for military purposes, both a greater sense of purpose among the National Aeronautical Establishment staff and more useful research programs would result if the NAE were brought under the control of the proposed Defence Research and Development Board. One organization would then be responsible for government laboratory, industrial and university aeronautical research and for the developments of the three Services who are the major users of aeronautical equipment produced in Canada. As well, a more effective use of manpower, both Armed Service and civilian, should be possible.

The National Aeronautical Research Committee with a membership revised to include industry representatives should become responsible for advising any Central Scientific Bureau set up within the Privy Council or under the proposed President of the Treasury Board.[1] Otherwise, both the Committee and the Technical Advisory Panel could be abolished without being missed.

This would leave two control centres, one in the Defence Research and Development Board, and a second in the Department of Defence Production, responsible for the full range of aeronautical research and development. Until the Department of National Defence begins to support aeronautical development again on a larger scale and shows a greater willingness to assist the industry to achieve export markets, separation of the responsibility for development between the proposed Defence Research and Development Board and the Department of Defence Production is essential. If, as some of the recent pronouncements of the Minister of Defence indicate, more funds will become available for development within the Department of National Defence, the argument for a large Department of Defence Production program for military aeronautical development will be less compelling.

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1) Canada. Royal Commission on Government Organization, Vol. IV, pages 223-224.

Until that time the existing, or slightly modified, Department of Defence Production Interdepartmental Committee on Development and its Advisory Group, Aeronautics, which has both DRB and Armed Services' membership could provide the necessary coordination between the two agencies.

Closer integration of the propulsion research programs of the NRC Division of Mechanical Engineering with those of the National Aeronautical Establishment and industry research could be achieved in the short term by a policy of having DRB place research contracts with NRC for specific programs of research in the Gas Dynamics and Engine Laboratories in particular. In the longer term, the transfer of aeronautical propulsion research to National Aeronautical Establishment control at the Uplands site would be desirable. This would ensure effective coordination of structures, propulsion, aerodynamics and flight research.

Within the National Aeronautical Establishment itself, an internal reorganization is required to separate the functions of wind tunnel design and support from those of aerodynamics research. A Tunnels Group should be formed to design, operate and maintain the tunnels and a budget for this activity established separately from that for aerodynamics research.[1] In this way, the true

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1) See for example, "The Organization of the Swedish Aeronautical Research Institute" by Velandu, Ely. Research Establishments in Sweden; Royal Swedish Academy of Engineering Sciences, Stockholm, 1951.

effort being applied to aerodynamics research could be distinguished and an adequate level of effort established.

These adjustments in the existing institutions could be made with relatively little strain and dislocation, and are to be preferred to the more drastic solution of a separate Ministry of Aviation responsible for all aeronautical research and development and the regulation of air transport. This latter solution is impractical because the scale of activity in Canada is too low to justify a separate department.

The Department of Defence Production and its twin sister Department of Industry, the Defence Research and Development Board, together with the Armed Services, the industry and the airlines should then establish suitable policies and fields of concentration for aeronautical developments in Canada. The initiative for this undertaking should come from the Department of Industry and the Defence Research and Development Board.

To establish these policies and fields of concentration, projections of civil and defence equipment needs for three to ten years ahead should be made so as to determine the probable size of the home market. Taking into account foreign sales possibilities, foreign research and development trends, desirable levels of employment in the Canadian industry, balance of payment trends in aeronautical products, production sharing possibilities and the effect on these factors of buying abroad, or licencing for Canadian production, a desirable level of sales from new Canadian developments could be established. Then, following an analysis of the Canadian industry's technological capabilities and the development sharing possibilities with other countries, suitable areas of concentration and particular development projects could be selected and the necessary level of government financing established. As is done in Sweden, commitment authority for this level of financing for a five to seven year period should be obtained.

For the short term projections, say three to five years, licence, or buy, or develop decisions would be firm. The five to seven year projections would enable the need for development decisions and development sharing arrangements to be anticipated and made as and when appropriate.

Projections for the seven to ten year period would not only help to indicate suitable development fields, but would also provide a valuable guide to future required levels of financial support and to suitable programs of research, both in the universities, government laboratories, and in industry. Technological projections for these periods should also be undertaken to assist in the selection of applied research tasks.

Within the overall levels of research and development financing established, care would have to be taken that there is sufficient flexibility to enable support of the unusually gifted individual, or the man with a bright idea, or to enable advantage to be taken of unexpected opportunities.

Worthwhile studies of the type described are difficult, but there is a need for them if sound policies are to be established. The results of the studies having established research and development policies and levels of financing would enable those responsible, both in industry and government, for the management of research and development, to make long range plans. Such planning is essential if the 10 to 12 year period of research, design, development and initiation of production for major aeronautical products is to be fruitful.

Insofar as its research and development expenditures are concerned, government, no more than a large corporation "is not offered the choice of planning or not planning. The only choice is whether the planning will be orderly and effective, or whether it will be haphazard, fragmented and practically useless."[1)]

The present Canadian organization for aeronautical research and development results in the ineffective implementation of haphazard, fragmented and too frequently useless planning and a consequent wastage of money, manpower and facilities.

Appropriate policies and plans could be determined by the procedures and forecasting methods proposed. Those policies and plans could be formulated and implemented effectively by the proposed organization which gives the authority for planning, control and coordination of aeronautical research and development to the

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1) Werner, Jesse. "Effective Planning for Research." American Management Association Report Number 69, 1962.

defence agencies who are, and are likely to remain, the major government influence on the industry.

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Most of this Thesis is based on personal interviews with government, industry and university personnel. These interviews took place during the period December 1962 to June 1963. Where possible, statements made were checked against published information, and where this could not be done the statements of one person were checked against those of another.

I am particularly indebted to Mr. J. H. Parkin for permission to make use of his unpublished notes on the history of the Canadian aircraft industry.

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Appendix I

Table I - Total Production of Aircraft as of 30 June 1944*

Manufacturer	Type of Aircraft	Ordered	Accepted	Balance
Boeing	Shark	15	15	—
	PBY	300	233	47
Associated Aircraft	Hampden	160	160	—
Canadian Car and Foundry	Grumman	15	15	—
	Hurricane	1451	1451	—
	SBW 1	1000	196	804
	SBW 1 mod	30	24	6
Canadian Vickers	Delta	8	8	—
	Stranraer	32	32	—
	PBY Canso	389	212	157
De Havilland Aircraft	Tiger Moth	1384	1384	—
	Menasco Moth	136	136	—
	DH 98 Mosquito	670	276	394
	DH 98 (F Bomber)	773	1	772
	DH 98 Trainer	57	—	57
Fairchild Aircraft	Bolingbroke	626	626	—
	SBF 1	300	50	250
	SBF 2	280	—	280
	SB2C mod.	125	125	—
Federal Aircraft	Anson II	1832	1832	—
	Anson V	1300	742	558
Fleet Aircraft	Fleet Trainer	431	431	—
	Fleet 60 Fort	101	101	—
	Cornell	500	500	—
	PT 23	93	93	—
	PT 26A	1142	1142	—
Noorduyn Aviation	Norseman	1146	539	607
	Harvard	3120	2278	842
Victory Aircraft	Lysander	225	225	—
	Lancaster	600	81	519
Total		18301	12908	5393

* Report of Special Committee on War Expenditures, 12 August, 1944. Taken from J. H. Parkin, Unpublished Notes.

Appendix I

Table II – Secondary Industry Statistics – 1959

Salaried Employees		Production Workers		Total Employed	Total Wages	Fuel & Power	Cost of Material	Value Added	Gross Value Production	Industry
Number	Salaries	Number	Salaries							
	$ 000		$ 000		$ 000	$ 000	$ 000	$ 000	$ 000	
121,461	641,924	364,489	1,457,256	485,950	2,099,180	138,678	3,793,328	3,756,035	7,571,640	Durable Goods
11,350	68,393	35,996	163,762	47,346	232,152	10,429	764,840	505,261	1,252,370	Motor Vehicle Parts
24,863	133,813	49,020	183,264	73,883	316,857	10,177	501,800	566,293	1,047,462	Electrical Apparatus and Supplies
13,992	66,650	94,678	213,050	108,670	279,700	5,013	499,791	457,973	955,086	Clothing
15,424	77,851	22,437	80,954	37,860	158,805	15,921	391,731	474,558	880,912	Chemicals
13,041	62,617	50,538	140,286	63,579	202,903	15,076	429,641	363,536	802,517	Textiles
5,739	35,723	29,203	147,188	34,942	182,911	36,076	354,160	393,908	782,494	Primary Iron and Steel
13,227	63,647	28,215	112,605	41,442	176,252	5,996	245,746	320,002	563,307	Industrial Machinery
6,458	32,250	22,745	75,803	29,203	108,053	4,692	307,060	219,543	527,714	Paper Products
7,525	36,176	29,786	113,450	37,311	149,626	30,136	209,870	317,085	521,233	Non Metallic Metal Products
6,813	34,569	17,466	64,932	24,279	99,501	6,697	260,263	170,982	432,456	Non Ferrous Metal Products
10,041	4,879	27,845	82,662	37,886	131,383	4,910	185,235	246,239	432,429	Miscellaneous Manufacturing
5,342	26,450	15,751	60,409	21,093	86,859	5,420	160,397	188,179	347,680	Rubber Products
6,051	27,026	26,448	79,378	32,499	106,404	3,603	161,033	167,221	329,846	Furniture
10,337	60,257	18,179	82,228	28,514	142,485	3,685	127,937	195,912	327,534	Aircraft and Parts

Appendix I

Table III - Aircraft and Parts Industry - Statistics - 1949-59

Year	Salaried Employees: Number	Salaried Employees: Salaries $ 000	Production Workers: Number	Production Workers: Salaries $ 000	Total Employees	Total Salaries & Wages $ 000	Total Fuel $ 000	Cost Material $ 000	Value Added by Mfg. $ 000	Value $ 000
1949	3,243	9,497	7,482	17,947	10,725	27,443	1,070	24,315	35,714	61,099
1950	3,580	11,448	7,029	18,727	10,549	30,175	1,209	18,150	35,816	55,175
1951	5,485	19,417	13,713	40,141	19,198	59,558	1,493	36,292	79,404	117,188
1952	9,730	34,533	23,626	74,134	33,356	108,667	2,024	115,286	127,297	244,607
1953	10,949	45,574	27,099	96,802	38,048	142,376	2,439	135,757	260,548	398,744
1954	10,776	46,068	24,319	89,795	35,095	135,863	2,735	158,893	181,382	343,011
1955	11,714	52,199	21,332	78,070	33,036	130,269	4,684	140,831	208,800	354,315
1956	13,076	60,861	22,487	85,567	35,563	146,428	4,085	138,156	212,270	354,510
1957	14,956	74,218	26,660	105,481	41,616	179,699	4,832	148,547	271,064	424,443
1958	15,050	78,897	24,882	103,380	39,932	182,277	4,661	176,539	281,132	462,331
1959	10,337	60,257	18,179	82,228	28,516	142,485	3,685	127,937	195,912	327,534

Appendix I

Table IV – Expenditures on Canadian Government Defence Contracts Placed in Canada by the Department of Defence Production and Defence Construction (1951) Limited on Behalf of the Department of National Defence.

$ Thousands

Program	1956	1957	1958	1959	1960	1961	1962
Aircraft	302,140	324,869	324,645	248,221	225,417	193,953	171,536
Electronics and Communication Equipment	117,400	85,534	73,749	83,264	73,307	101,452	97,127
Armament	54,775	39,962	36,656	41,178	21,174	17,028	13,163
Tank-Automotive	20,241	11,462	9,554	6,946	7,829	7,590	8,133
Ships	73,384	76,587	49,379	34,089	29,632	44,835	52,347
Fuels and Lubricants	46,330	47,449	46,139	40,208	38,759	37,695	37,261
Clothing and Equipage	15,821	10,515	6,999	20,562	4,082	7,049	10,615
Construction	156,561	102,432	46,871	66,277	63,374	67,123	79,646
Other	102,647	110,215	105,520	87,258	86,734	80,470	87,782
Total	889,299	809,026	699,513	628,003	550,309	557,195	557,612

Source: Department of Defence Production, Annual Reports, 1958, 1961, 1962. The term "Aircraft" includes complete aircraft and items of aircraft such as air frames, engines, propeller, navigation and flight instruments, electrical systems and components. Government Furnished Equipment (GFE) for aircraft and repair and overhaul of aircraft is also included. Excluded are accessories such as armament, communications and photographic equipment, training devices and ground equipment.

Appendix I

Table V - Comparison of Military and Commercial Sales - Aircraft and Parts Industry

$ Millions

	1958	1959	1960	1961	1962
Military Sales:[1)]					
To Canadian Services	324.7	248.2	225.4	193.9	171.5
To U.S. Services	37.0	51.9	47.4	71.8	102.8
To Other Countries	92.3	19.0	23.9	32.9	49.9
Total	454.0	319.1	296.7	298.6	324.2
Commercial Sales[2)]	8.0	8.4	11.4	30.6	31.9
Total Sales[3)]	462.0	327.5	308.1	329.2	356.1

1) Department of Defence Production, Annual Reports, 1958, 1959, 1962. Aviation Trade 1962. Aircraft, June, 1963, page 12. Sales to the U.S. Services after 1959 are adjusted to include sub-contracts. Value of military sales to other countries assumes all sales to these countries are military.

2) Commercial sales are derived by taking the difference between total sales and military sales. Accuracy of figures is questionable. The Department of Defence Production figures are for aeronautical items, while the Dominion Bureau of Statistics figures are based on the value of production of companies in the aircraft and parts classification. Some of these companies sell other than aircraft and parts products. Improved data would require a survey of the industry on a company by company basis. Higher values in 1961 and 1962 are sales of CL-44 aircraft to U.S. airlines.

3) Dominion Bureau of Statistics. The Aircraft and Parts Industry. Catalogue 42-203, Published annually. Figures for 1961 and 1962 are preliminary estimates.

Appendix I

Table VI - Aircraft and Parts Industry - Military and Commercial Sales, Home and Export

$ Millions

	1958	1959	1960	1961	1962
Military Sales:					
Export	129.3	70.9	71.3	104.7	152.7
Home	324.7	248.2	225.4	193.9	171.5
Commercial Sales:					
Export	—	—	—	30.6	31.9
Home	8.0	8.4	11.4	—	—
Total Sales	462.0	327.5	308.1	329.2	356.1

Note: Military export figure for 1958 has been adjusted to include aircraft engines and parts. Figures obtained from data given in Table V.

Appendix I

Table VII - Aircraft, Aircraft Engines and Parts - Canadian Imports and Exports

$ Millions

		1958	1959	1960	1961	1962
IMPORTS:	Defence Purposes					
	By DND from U.S.	12.3	10.4	37.0	24.7	17.7
	from U.K.	4.0	5.1	4.3	3.0	1.6
	By Industry	90.6	63.7	59.4	59.9	65.0
	Total	106.9	79.2	100.7	87.6	84.3
	Commercial Purposes	33.0	35.7	66.3	225.0	174.7
	Product Breakdown					
	Aircraft Engines & Parts	45.1	37.3	50.5	95.6	57.3
	Aircraft & Parts	94.8	77.6	116.5	217.0	201.7
	Total	139.9	114.9	167.0	312.6	259.0
EXPORTS:	Defence Purposes	129.3	70.9	71.3	104.7	152.7
	Commercial Purposes	—	—	—	30.6	31.9
	Total	129.3	70.9	71.3	135.3	184.6

Sources as for Table V. Imports by industry for defence products derived by assuming Canadian content of industry's defence sales is 80%. Aviation gasoline not included in import figures.

Appendix I

Table VIII - Department of Defence Production - Expenditures to Sustain Technological Capability in Canadian Defence Industry.[1]

$ Dollars

	1959-60	1960-61	1961-62	1962-63[2]	1963-64[2]
Aircraft and Parts					
Avro Aircraft	—	300,000	90,000		
Bristol Aero Industries	—	86,777	251,301		
Canadair	216,000	65,000	962,074		
De Havilland Aircraft	341,300	604,788	465,441		
Fleet Manufacturing	—	—	4,243		
Jarry Hydraulics	—	21,585	19,307		
Lucas Rotax	—	14,442	129		
Orenda Engines	—	—	286,304		
United Aircraft	1,200,000	1,182,079	731,566		
Total	1,757,300	2,274,671	2,810,865	3,400,000	9,500,000
Electronics					
Total	93,800	626,996	1,542,279	N.A.	N.A.
Other Industries					
Total	—	—	67,779	N.A.	N.A.
GRAND TOTAL[3]	1,850,500	2,901,666	4,420,423	8,000,000	13,500,000

1) Public Accounts of Canada - Details of Expenditures and Revenues.
2) Department of Defence Production - Figures are estimated.
3) Commitment authority was as follows: 1959-60 $4 million, 1960-61 $7 million, 1961-62 $20.5 million, 1962-63 $25 million, 1963-64 $40 million.

Appendix I

Table IX - Total Government Expenditures on Aeronautical Research and Development (1962-63)[1)]

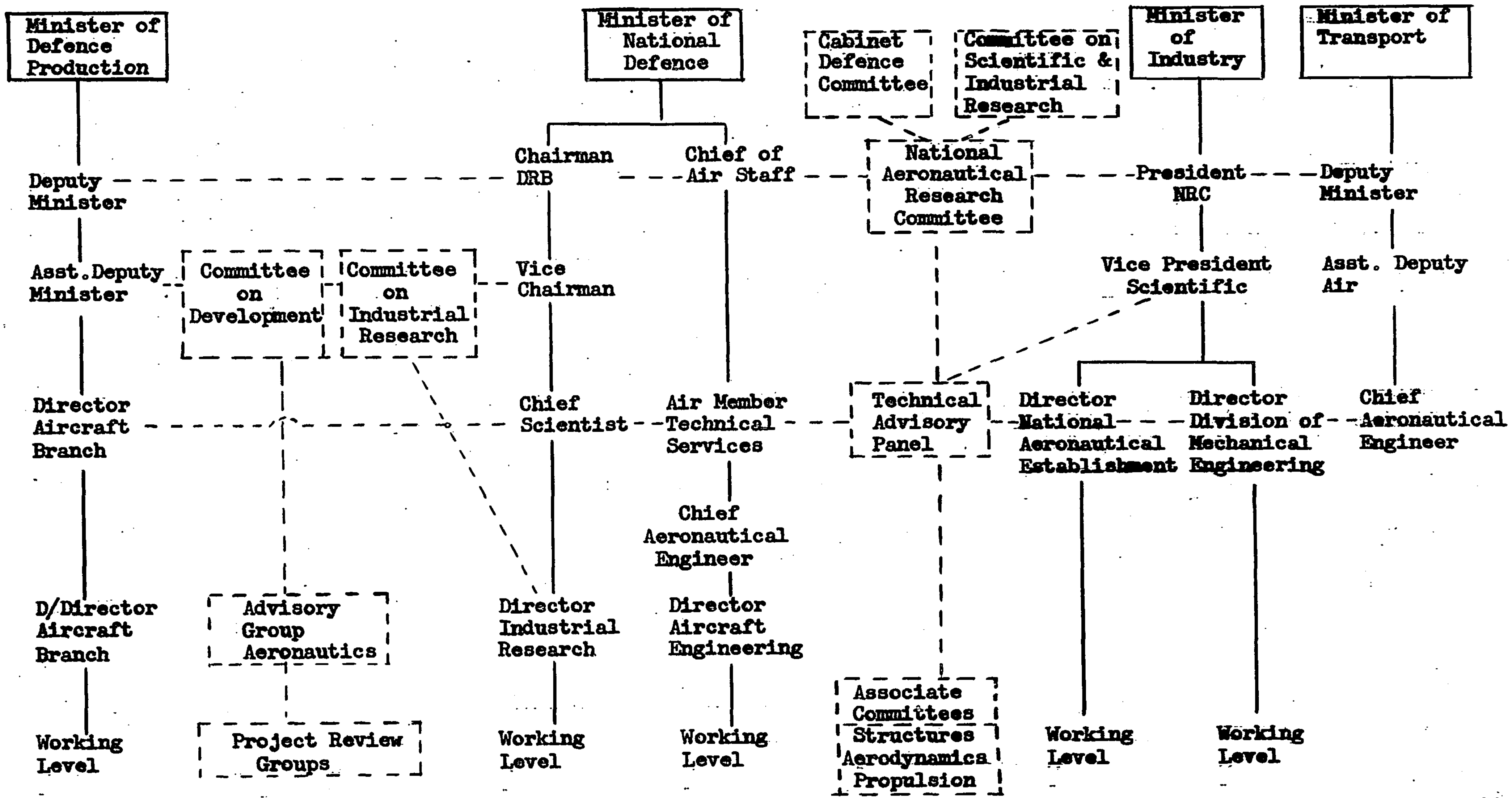
$ Dollars

Agency	In-House Research		Extramural Research & Development			Total Expenditures
	Provision of Services	Other Operating and Capital	Industrial Research	Industrial Development	University Research	
Department of National Defence (excluding DRB)				525,000		525,000
Defence Research Board			766,000		349,000	1,115,000
Department of Defence Production				3,400,000		3,400,000
Defence Agencies - Total			766,000	3,925,000	349,000	5,040,000
National Research Council					55,800	55,800
Division Mechanical Engineering	300,000	950,000				1,250,000
National Aeronautical Estab.	540,000	1,255,000				1,795,000
Civil Agencies - Total	840,000	2,205,000			55,800	3,100,800
GRAND TOTAL	$3,045,000		$4,691,000		404,800	8,140,800

1) An estimate for 1963-64 would give the following: DRB, Industrial Research $1.2 million, DDP, Industrial Development $9.5 million. NRC in-house and university grant expenditures will be about the same, giving a grand total of $14.2 million which is nearly double the 1962-63 figure.

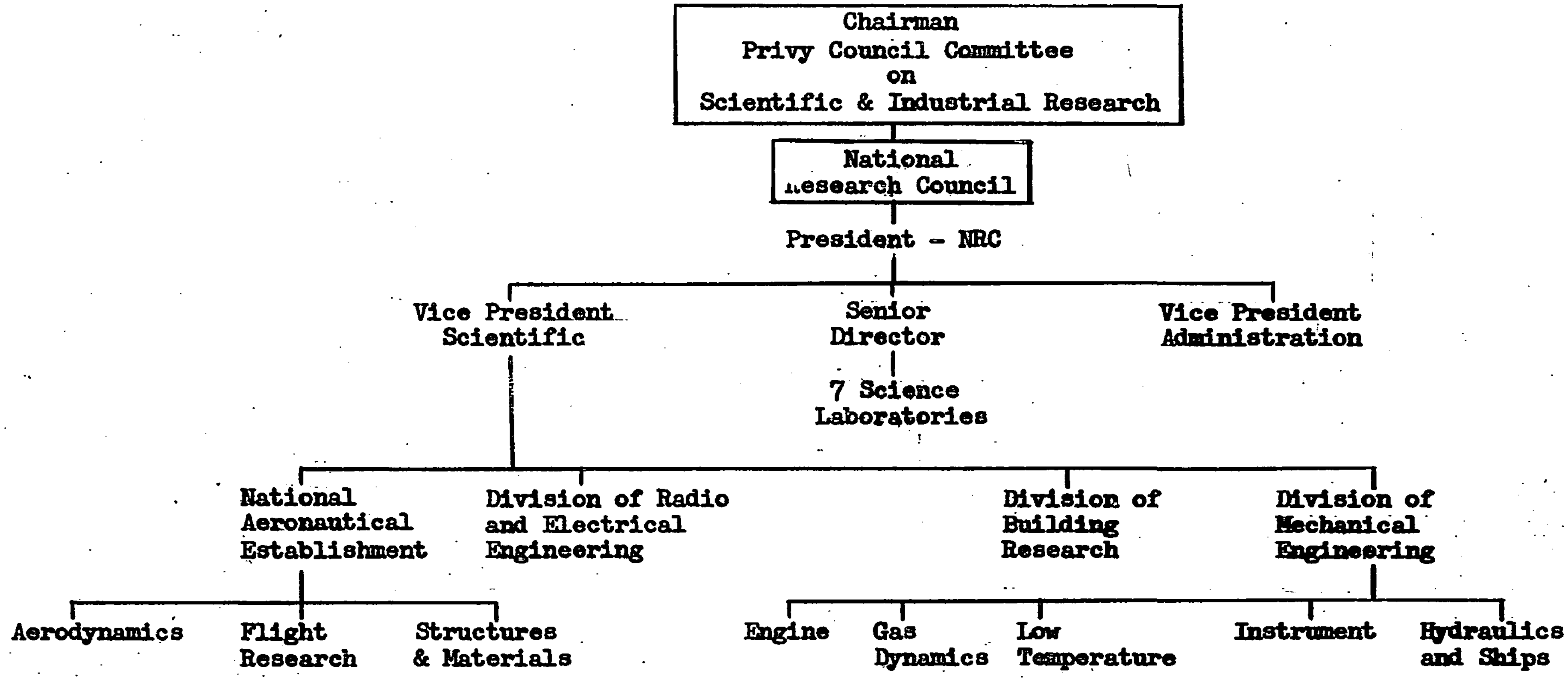
Appendix II

Figure 1 - Organization of Government Departments and Agencies - Aeronautical R & D



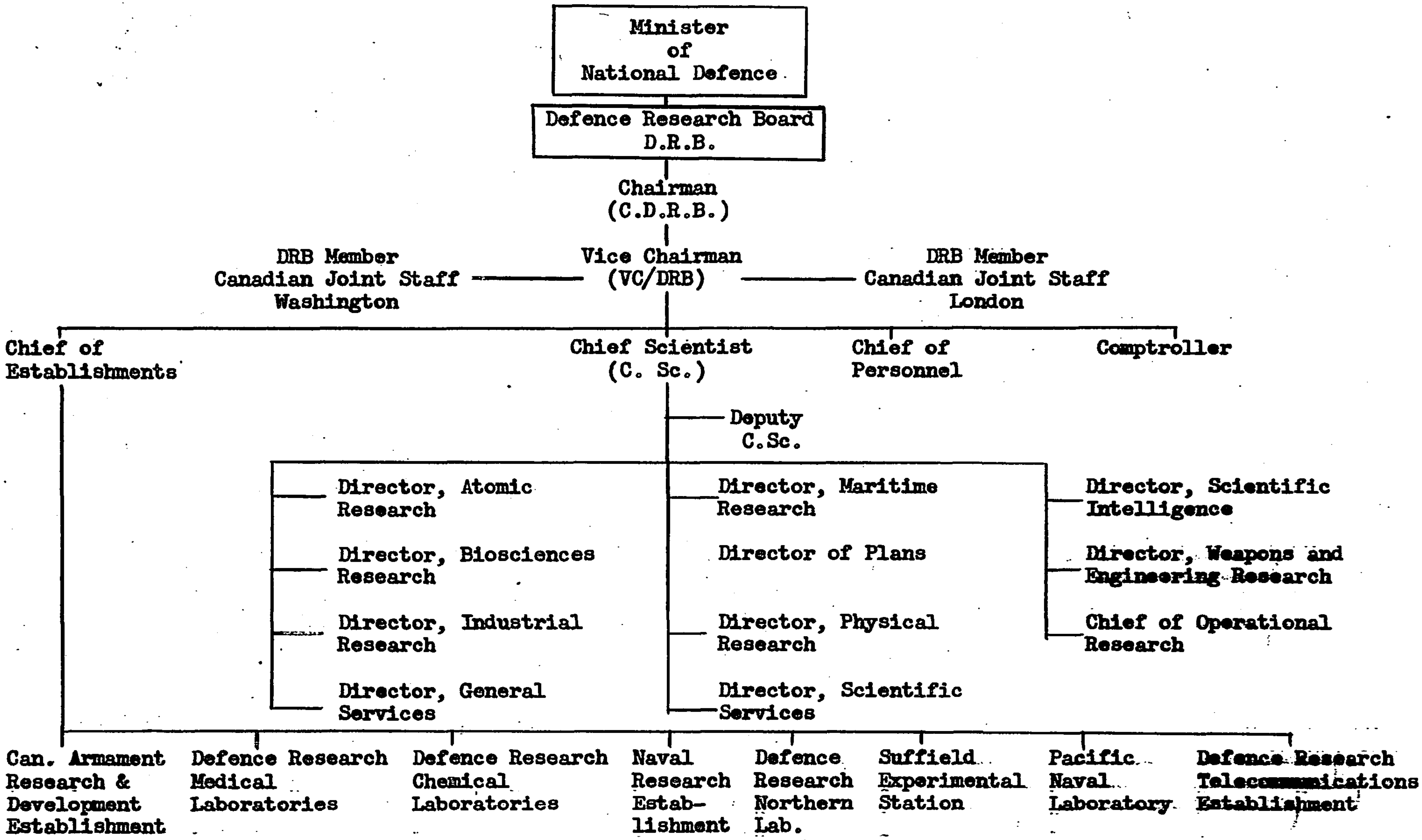
Appendix II

Figure 2 - NRC Division of Mechanical Engineering and National Aeronautical Establishment Organization



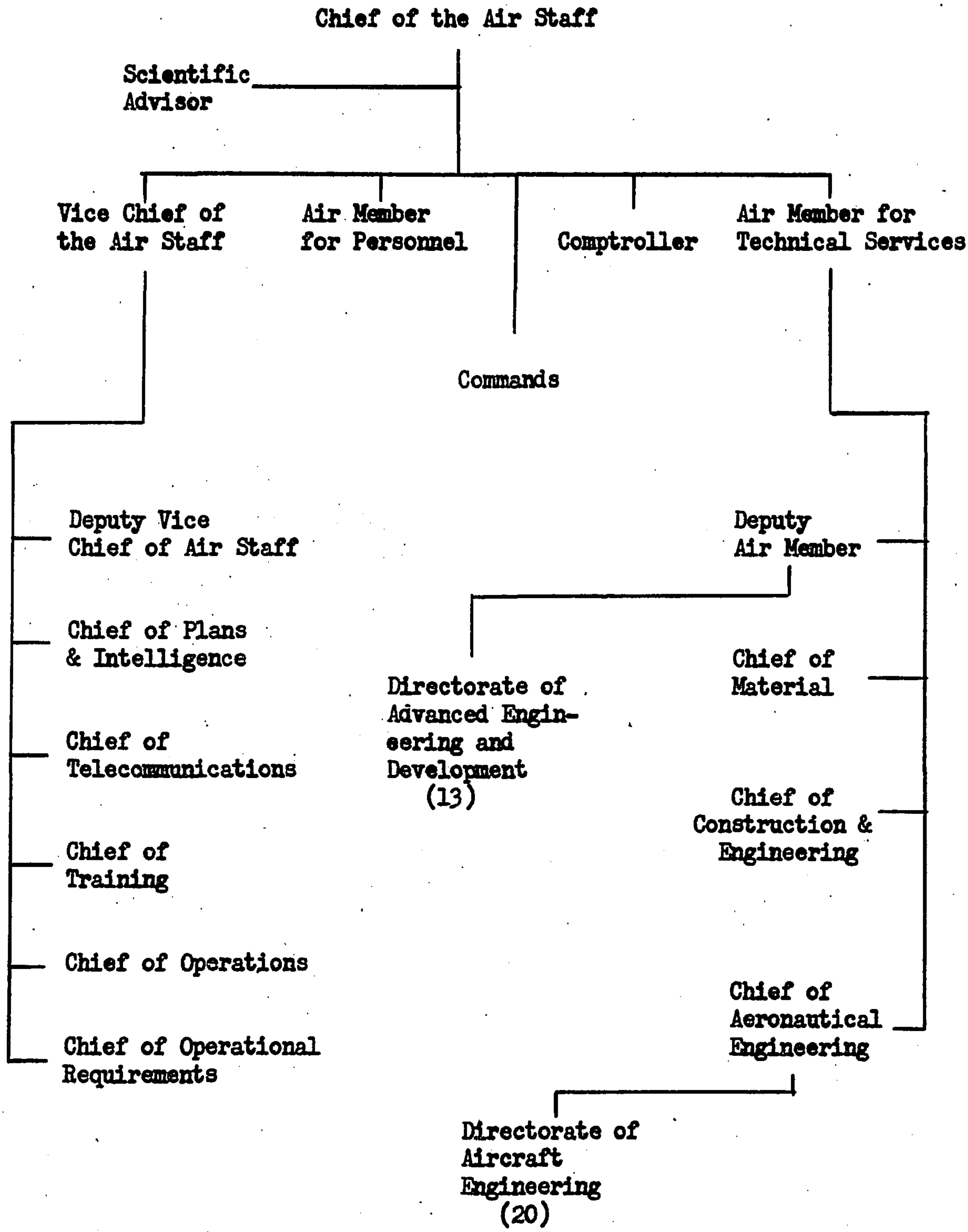
Appendix II

Figure 3 - Organization of the Defence Research Board



Appendix II

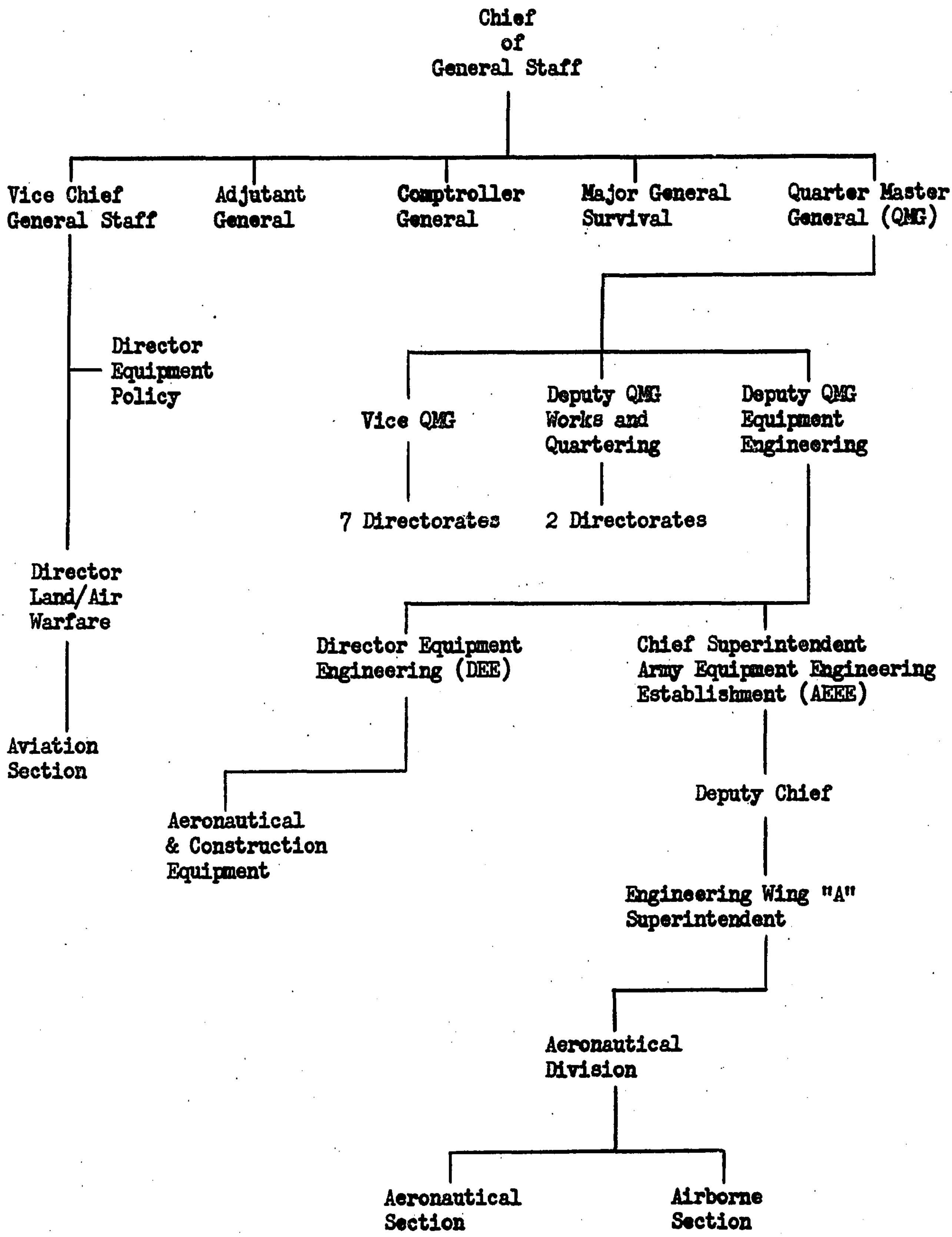
Figure 4 - Royal Canadian Air Force Organization



Note: Numbers in brackets indicate number of professionals engaged in aeronautical programs.

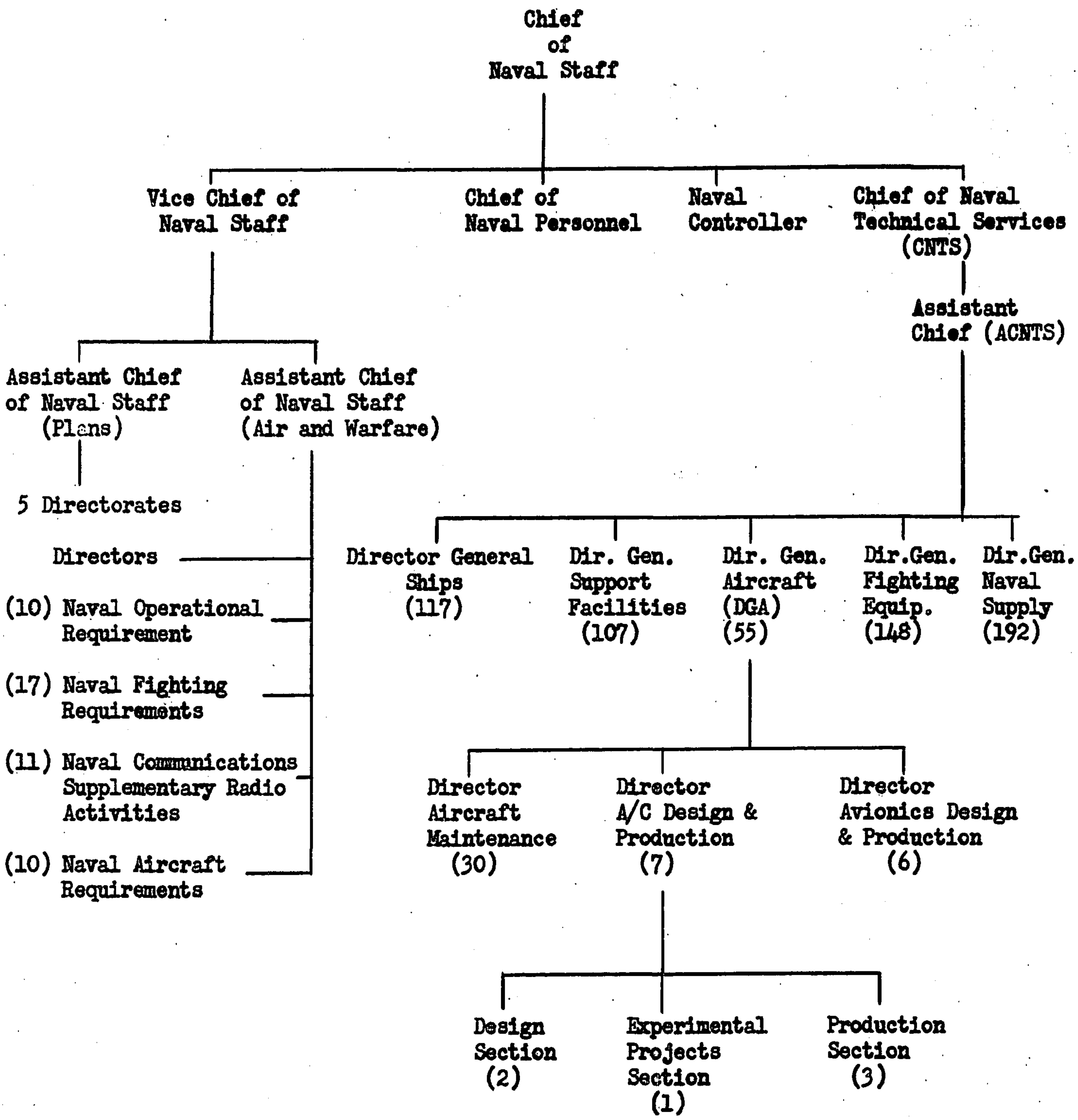
Appendix II

Figure 5 - Organization of Canadian Army Headquarters



Appendix II

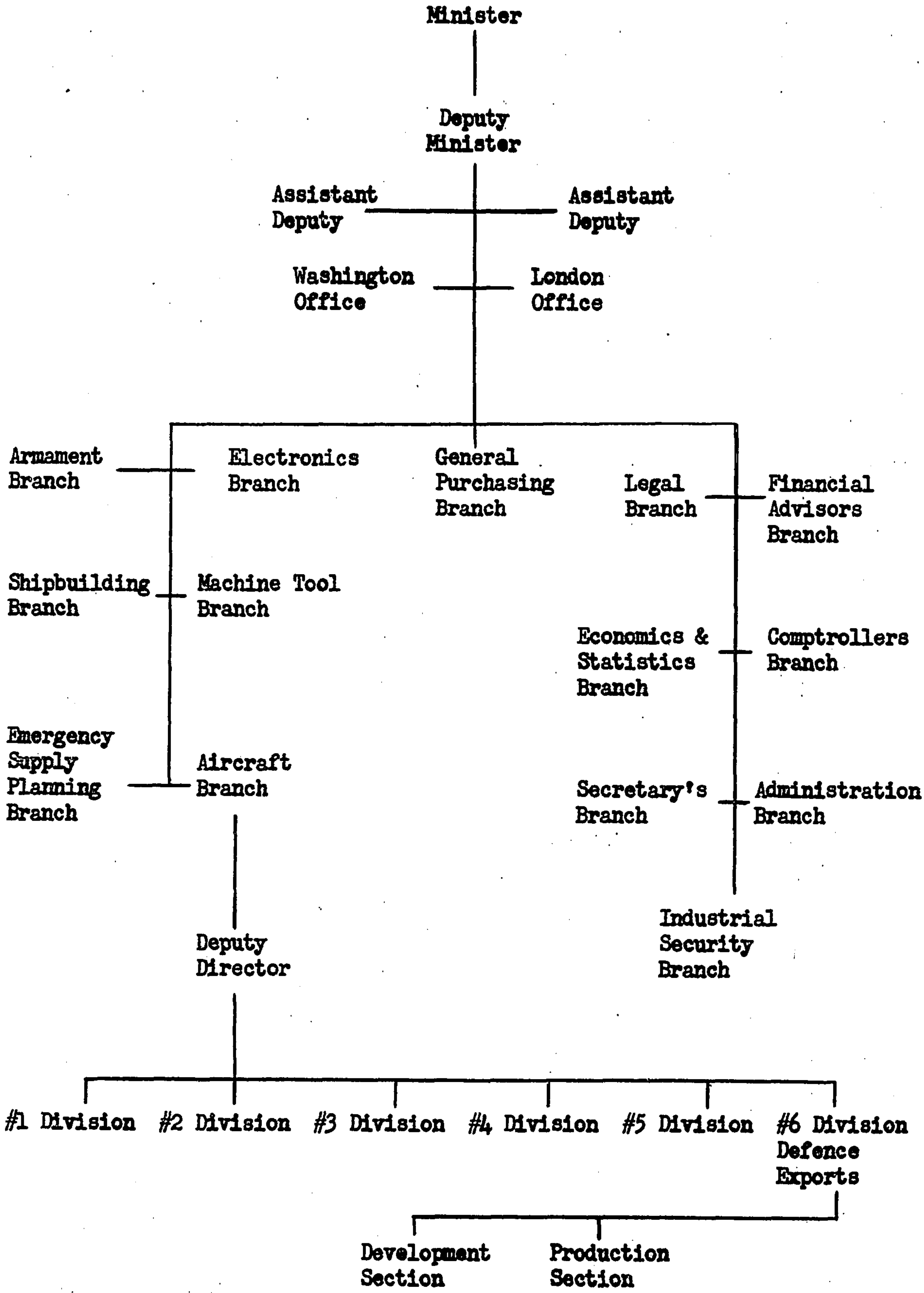
Figure 6 - Headquarters Organization of Royal Canadian Navy



Note: Numbers in brackets give number of engineering and technical personnel.

Appendix II

Figure 7 - Organization of the Department of Defence Production



Appendix II

Figure 8 - Technical Advisory Panel

Constitution

1. Name

A Panel is hereby constituted, to be known as the Technical Advisory Panel of the National Aeronautical Research Committee.

2. Terms of Reference

The Technical Advisory Panel will advise the National Aeronautical Research Committee on all technical matters involving policy and will serve as a scientific and technical advisory panel to the Director of the National Aeronautical Establishment. Among other duties which might be assigned by the National Aeronautical Research Committee, the Technical Advisory Panel will be required:

(a) To establish or recommend the establishment of such advisory committees as may seem desirable.

(b) To review at least annually the aeronautical research programs already in existence in or sponsored by the agencies participating in NARC as well as those programs in existence elsewhere in Canada. Account will also be taken of programs active in other countries.

(c) To review the reports submitted by the advisory committees.

(d) To review at least annually the requirements for aeronautical research.

(e) Following the above reviews, to recommend to NARC programs which will help to overcome the deficiencies between the research requirements and research in existence or which may seem desirable for some other purpose.

3. Membership

The membership of the Technical Advisory Panel shall consist of:

Vice-President (Scientific), National Research Council
Chief Scientist, Defence Research Board
Chief Aeronautical Engineer, Department of Transport
Air Member for Technical Services, Royal Canadian Air Force
Director, Aircraft Branch, Department of Defence Production
Director of the National Aeronautical Establishment
Director of Engineering Research, Defence Research Board
Director, Division of Mechanical Engineering, NRC
Director, Institute of Aerophysics, University of Toronto
One member, appointed by Canadian Armament Research and Development Establishment
Two members, appointed by Air Industries Association of Canada
One member, appointed by Air Transport Association of Canada.

Cont'd next page

4. Chairman

The Chairman shall be appointed for a period of two years from the membership of the Panel by the National Aeronautical Research Committee.

5. Secretary

The Secretary of the Panel shall be provided from the staff of the National Aeronautical Establishment.

6. Meetings

The Panel shall meet at the call of the Chairman, and there shall be at least one meeting annually.

18 April, 1963.

Appendix II

Figure 9 - National Aeronautical Research Committee

Constitution

1. Name

The formation of the National Aeronautical Research Committee was authorized by Cabinet directive in December 1950. The Committee shall report to the Privy Council Committee on Scientific and Industrial Research, except that on matters relating to defence, it shall report also the Cabinet Defence Committee.

2. Terms of Reference

(a) The NARC shall be responsible for the overall advice on Government policy on Aeronautical Research in Canada.

(b) The NARC shall

(1) Consider the reports and recommendations of the Technical Advisory Panel with regard to Canadian research requirements and facilities.

(2) Consider Canadian research programs and their relation to the national need.

(3) Endorse the implementation of approved proposals for new or reoriented research programs, for new research facilities, or for industrial participation of appropriate kind.

(c) The NARC will also review research programs inside and outside the Government Service with a view to achieving the best possible coordination.

3. Membership

The membership of the National Aeronautical Research Committee shall consist of:

President, National Research Council
Chairman, Defence Research Board
Chief of the Air Staff, RCAF
Deputy Minister, Department of Defence Production
Deputy Minister, Department of Transport

4. Chairman

The Committee shall choose one of its members to act as Chairman. The term of office of the Chairman will be two years.

5. The Secretary of the Committee will be provided from the staff of the Defence Research Board or the National Research Council.

6. Meetings

The Committee shall meet at the call of the Chairman, and there shall be at least one meeting annually.

Appendix II

Figure 10 - Terms of Reference of Associate Committees

Within the commonly accepted bounds of the subject connoted by the title of the Associate Committee and with respect to both aeronautical and astronautical national interests, the Committee is invited

1. To consider Canadian pure and applied research needs and to make recommendations to the Technical Advisory Panel of the National Aeronautical Research Committee for appropriate programs.

2. To consider the provision of facilities for the proper support of Canadian research and to make appropriate recommendations to the Technical Advisory Panel and to create and maintain these facilities.

3. To consider the work of the Commonwealth Advisory Aeronautical Research Council and the Advisory Group for Aeronautical Research and Development of the North Atlantic Treaty Organization and to recommend to the Technical Advisory Panel appropriate policy and action.

It is also proposed:

A. That the Associate Committees shall meet not less than twice per year.

B. That appointments to the Committees shall be for a term of 2 years subject to reappointment.