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ABSTRACT

This report is the first of two volumes which document the Instructor Support Feature (ISF) Guidelines for aircrew training. Designed to provide a communication vehicle among personnel involved in the acquisition process for new aircrew training devices (ATDs), these guidelines focus on the development of specifications for the instructional component within the total simulation system. This report is divided into four sections. The introduction presents background information on the project as well as the major conclusions reached through research and development activities. In the second section, the description of project activities that were conducted to develop the ISF guidelines provides a general overview followed by a detailed description of the major activities. The third section presents the findings of the investigations and analyses for each feature. The fourth section presents eight major conclusions and recommendations. A list of 14 references and a 26-item bibliography are also included, as well as a glossary of terms and a list of abbreviations and acronyms. Six appendices include a list of training sites visited, an interview guide used to collect data, a list of course documentation for various ATDs, an annotated listing of systems with advanced instructor support capabilities, a list of documentation on these systems, and a detailed comparison of internal ISS features among these four systems. (DJR)

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AIR FORCE HUMAN RESOURCES LABORATORY

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This report documents the development of specification guidelines for aircrew training device (ATD) Instructor Support Feature (ISF) requirements. Thirteen advanced instructional systems and ATDs provided data for identification and definition of ISFs. These operational definitions and a recommended specification procedure were written to aid operational users from the major commands, SimSPO procurement personnel, and contractors. One conclusion reached as a result of the specification procedure development is that both student training and instructor requirements be analyzed comprehensively. Other study results point to the need for instructor training in the use of ISFs. The data, methods, and analysis used to reach these conclusions and others are reported. Volume I documents the research and development effort and presents methodology, results, conclusions, and recommendations. Volume II contains the ISF Guidelines. The ISF Guidelines is a "living" document. The current version of the Guidelines can be obtained from the Simulator Systems Program Office, ASD/YWEE, Wright-Patterson AFB, OH.

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SUMMARY

This report documents the research and analysis project that resulted in the development of Instructor Support Feature (ISF) Guidelines. The guidelines are intended to aid operational users from the Air Force major commands, Simulator Systems Program Office procurement personnel, and contractors in the development and procurement of instructor support systems for future aircrew training devices (ATDs). During the 12-month technical effort, the Guidelines content and format were defined, data were collected and analyzed for inclusion within the Guidelines, and the Guidelines document was written. Thirteen advanced instructional systems and ATDs provided data for identification and definition of ISF requirements. Volume I documents the research and development effort and presents methodology, results, conclusions, and recommendations. Volume II contains the ISF Guidelines. The ISF Guidelines is a "living" document. The current version of the Guidelines can be obtained from the Simulator Systems Program Office, ASD/YWEE, Wright-Patterson AFB, OH.

PREFACE

This document is the final report of the Performance Measurement System (PMS) Guidelines for Aircrew Training Devices (ATDs) project conducted under Contract Number F33615-84-C-0054, sponsored by the Air Force Human Resources Laboratory (AFHRL). The project focused on the development of the Instructor Support Feature (ISF) Guidelines to aid in the specification of requirements for ATD acquisitions. The Guidelines are published as Volume II of this report.

Drs. Wayne Waag and Gary Thomas of AFHRL/OT provided technical direction during the course of the study. Mr. Craig McLean and his staff at the Simulator Systems Program Office made valuable contributions to the contents of the ISF Guidelines.

The authors wish to express their gratitude to the many operational personnel at the training sites visited for their time and assistance. Their input greatly added to the operational validity of this report.

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I. INTRODUCTION

This report supplements the Instructor Support Feature (ISF) Guidelines. The purpose of the ISF Guidelines is to provide a communications vehicle among those personnel involved in the acquisition process for a new training device. These personnel include operational users at the Air Force Major Commands (MAJCOMs) who initially state training requirements, Simulator Systems Program Office (SimSPO) procurement personnel involved in the final specification definition, and contracting personnel involved in system development. The Guidelines specifically provide guidance in the development of specifications for the "instructional component" within the total simulation system. The research and development activities conducted in support of the development of the Guidelines revealed several interesting and notable results and findings with respect to the use of aircrew training devices. The purpose of this report is to document these conclusions and present the methods used to reach them.

The following major conclusions were reached:

1. A comprehensive front-end analysis of both student training tasks <u>and</u> instructor requirements is required in order to ensure that the instructional system is designed to meet user needs.

2. Instructor training in the use of instructor support features is needed.

3. The concept of the "task module" has successfully been used to ensure that operational data are provided so that the resulting instructional system supports user needs.

4. Instructional system data (e.g., maneuvers and procedures, displays, and performance measurement criteria) must be kept current with changes in training requirements and flight procedures. Provision for economic update and revision is crucial.

5. The instructional system should provide for level(s) of automated control that support the specific training objectives.

6. The Automated Performance Measurement feature should be designed as an aid, not as a replacement, to support the instructor in an evaluation of the student's performance of the training objective.

7. The specification of instructional features should be based on functionality and performance from a user's perspective rather than on the latest technology. Current technological advances and current standards can then be incorporated to properly support these specified functional requirements.

8. These Guidelines should be continually updated so that lessons learned and proven technology from advanced instructional systems can be effectively transitioned into the operational training environment.

These conclusions are addressed in greater detail in Section IV.

Background

In 1981, the SimSPO of the Air Force Aeronautical Systems Division (ASD) stated a need for enhancing the instructor's capability to assess student performance in ATDs. The need for improved student performance measurement capabilities within ATDs was also clearly identified by the Defense Science Board 1982 Summer Panel Study on Training and Training Technology.

Prototype systems, incorporating state-of-the-art performance measurement technology, have been successfully implemented in research and development environments and have provided valuable lessons. A means was sought for capitalizing on this information for application in the operational training environment. Development of a set of guidelines addressing the design, development, and incorporation of Performance Measurement System (PMS) capabilities within ATDs was the proposed solution. By providing guidelines for personnel who are tasked with specifying these requirements in Prime Item Development Specifications, proven and current technology could be effectively transitioned into the operational setting.

The scope of the guidelines was defined to include performance measurement requirements such as parameters measurement, associated scores, and start-stop logic and also instructor support requirements such as scenario control, briefing, display of information, and debriefing. Associated computer hardware and software considerations were included as well. Instructor support considerations were identified early on in the project as essential to instructor acceptance and utilization of the PMS within an ATD. Thus it became apparent that the guidelines must feature all instructor support requirements, with performance measurement as one of these requirements. The guidelines were therefore renamed "Instructor Support Feature (ISF) Guidelines." The term "instructor support feature" is used to describe those capabilities of the ATD that are specifically designed to aid instructional activity. The term "instructor support system" (ISS) is used in this document to refer to computer-based systems which support instructor support features.

Prototype training systems have demonstrated that an ISS can provide the instructor with greater ability to control and monitor student activity and therefore to make the simulator a more effective training system. These systems have much to offer insofar as lessons learned during their development, test and evaluation, and operation. The lessons learned from these systems as well as from other ATDs can contribute dramatically to the improvement of the specification of ATD requirements.

If a single guidelines document could be used by the spectrum of individuals involved in specifying ATD requirements, it would serve as a common basis for communication of need and would promote a greater degree of mutual understanding. Current ATD acquisitions utilize specifications for instructor support requirements which are rudimentary at best. This has resulted in the design and implementation of aircrew training devices with features which are either too difficult for instructors to use or do not fulfill the training needs. These deficiencies result in low utilization rates by instructors, loss of productive training time, and ineffective training.

In summary, the major goal of the effort was the development of a set of clear, usable guidelines for instructor support feature requirements in future ATD acquisitions. These guidelines are intended to be used by MAJCOM requirements personnel, SimSPO specification writers, ATD users, and contractors alike. It is anticipated that use of these guidelines will result in well defined specifications that lead to the provision of useful instructional support capabilities within ATDs. Secondary goals include the provision of data which facilitate the further definition of mission tasks and instructional support functions and the promotion of more effective ISS designs.

The remainder of the report is divided by section. Section II, Method, describes how the study activities were accomplished. Section III, Results, documents the findings of the investigations and analyses. Section IV, Conclusions and Recommendations, discusses overall conclusions derived as a result of these activities and offers recommendations for the future.

II. METHOD

This section describes the project activities that were conducted to develop the ISF Guidelines. A general overview is followed by a detailed description of the major activities. The results of these efforts are described in Section III. The categories in Sections II (Methods) and III (Results) are presented in parallel order.

General Overview

The project goals were achieved using a three-phased study approach:

1. Definition of design guidelines content and format.

2. Review of simulator training requirements across a spectrum of Air Force Commands, and review of the state-of-the-art capabilities of four systems which utilize advanced instructor support features.

3. Development of the ISF Guidelines and a sample specification.

Figure 1 presents the overall "roadmap" of the approach. The three phases of the study were, for the most part, time-phased, with some overlap in activities.

The project began during Phase I with the identification of prospective content and format for the guidelines. In order to accomplish this, the specification process and relevant sections of specifications from recent ATD acquisitions were reviewed. In addition, a meeting with SimSPO and MAJCOM personnel was held to determine needs. A library of materials, including course documents, systems documentation, and ISF-related information, was also used to determine appropriate content and potential formats.

Phase II encompassed a review of simulator training across a spectrum of Air Force Commands and a review of the state-of-the-art capabilities of four systems which utilize advanced instructor support features. The review of these systems included both data collection during site visits and the review of course documents collected during Phase I. During each site visit, ATD training requirements, including aircrew training objectives, simulator characteristics, and instructor control and informational requirements were collected and assessed.

Simulator training was observed at the following MAJCOMs.

1. Tactical Air Command (TAC): A-10, F-15, F-16 aircraft
2. Military Airlift Command (MAC): C-130, C-141 aircraft
3. Strategic Air Command (SAC): B-52, KC-135 aircraft
4. Air Training Command (ATC): T-37, T-38 aircraft

Locations and dates of these visits are identified in Appendix A. The interview guide utilized during these visits is included in Appendix B.

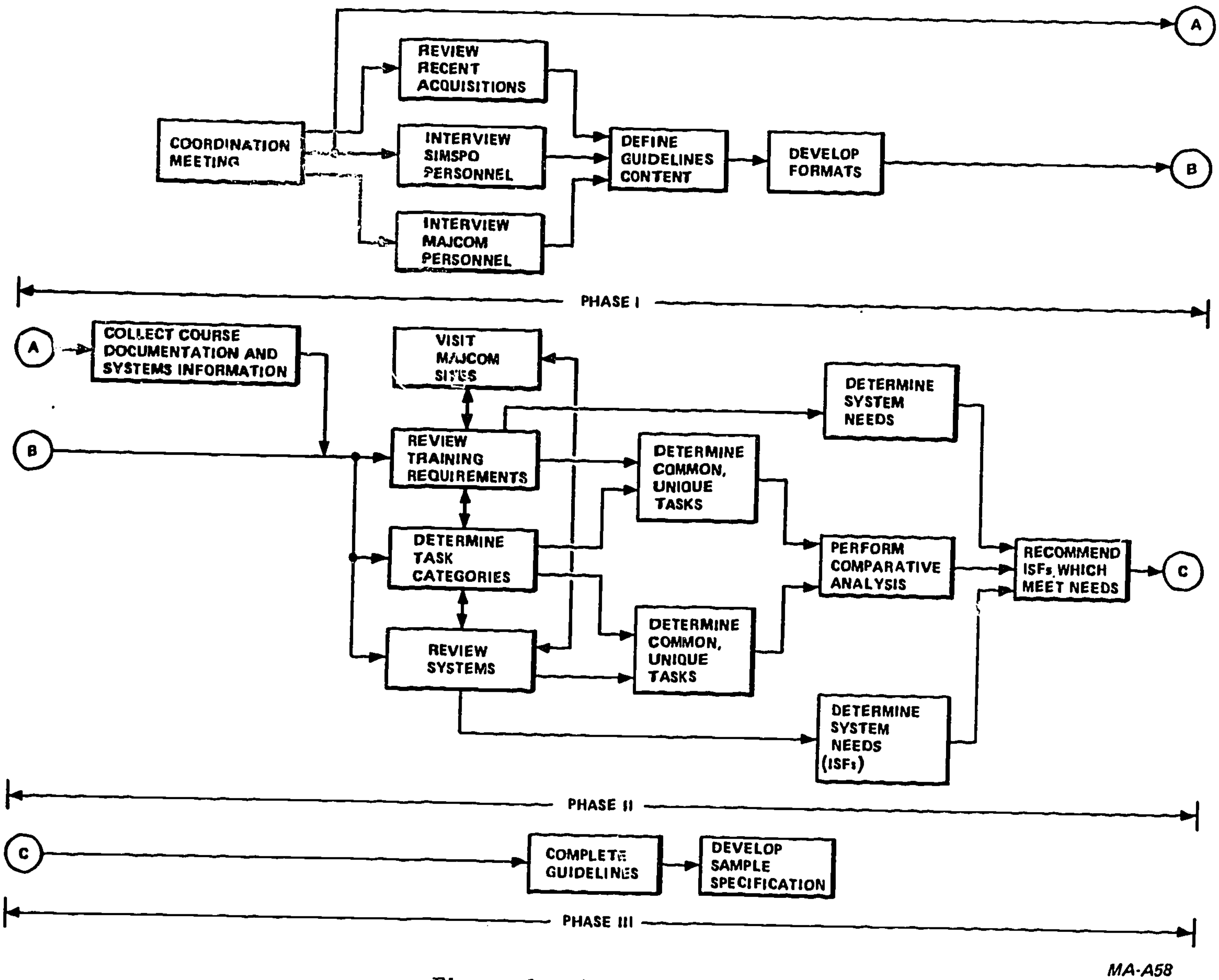

Figure 1. Approach Roadmap.

Training documentation including course syllabi, task and objectives documents, instructor guides, and simulator manuals was collected. Complete documentation was difficult to obtain. Over 30 documents were reviewed for information regarding aircrew training objectives, simulator characteristics, and instructor control and informational requirements. A listing of course documentation acquired and reviewed is included as Appendix C.

Four additional training systems have been built as modifications to existing ATDs and were included in this review. These systems were designed to specifically provide advanced instructor support capabilities and include:

1. Automated Flight Training System (AFTS®) for F-4E and A-7D aircrews.
2. C-5A Performance Measurement System (C-5A PMS).
3. F-14 Instructor Support System (F-14 ISS).
4. Air Refueling Part Task Trainer Instructor Support System (ARPTT ISS) for B-52 aircrews.

A brief description of each of these systems is provided in Appendix D.

Descriptive data on these systems were collected and reviewed. These included functional specifications, design documents, operation manuals, and program source listings. Test and evaluation data were also reviewed. Appendix E provides a listing of the documentation reviewed.

Interviews were conducted with personnel who were directly involved in the development of the systems. The purpose was to verify the information contained in the documentation and to derive lessons learned regarding system functions and hardware and software implementation. Visits were made to selected MAJCOM sites to observe training and to determine user attitudes regarding the design and implementation of the advanced instructor support features. These visits are included in the Appendix A listing.

The third phase culminated in the writing and production of the actual guidelines, including a sample specification and procedure by which the specification was generated.

Data management was a major concern throughout this project. Preliminary information and data obtained as a result of the review of training and systems documentation were entered into computer-based files. These files contained data describing each ATD, the aircraft, instructor support features, tasks trained, performance measurement, and scoring and information sources. After site visit information was obtained, these data were reworked into data files which describe each ATD in terms of training objectives, instructor/operator station (IOS) type, IOS control, IOS displays, performance evaluation, ISFs, and comments regarding lessons learned.

Project notebooks for internal use were utilized to organize correspondence and data relating to the project. A project library that was maintained included over 100 references, including recent research publications that address the issues of ISF design and use. These sources are identified in Appendices A and D and in the References and Bibliography sections. A glossary of ISF-related terms and acronyms were compiled and updated periodically throughout the course of the project. The resulting glossary and acronym listing are included in the back of this report.

Investigation of the ATD/Specification Process

Before the guidelines content could be developed, an investigation of the ATD acquisition/specification process was necessary to identify the type of information needed by SimSPO in order to properly specify ISS requirements. This investigation also provided insight about Guidelines user needs and helped to determine where the Guidelines would apply in the acquisition/specification process.

This investigation focused specifically on the part of the acquisition/specification process from the initial identification of need by the MAJCOM user, to the communication of need to the SimSPO specification writer, and to expression of these requirements in the actual Prime Item Development specification.

Several Air Force regulations and other publications that describe this process were reviewed. These sources are noted in the References and Bibliography. A fact-finding meeting was held with SimSPO and MAJCOM personnel in order to document the current specification process and to further establish the content and format needs of the guidelines users. Concept papers were prepared prior to the meeting in order to generate discussion and obtain feedback as to the direction of the study. These papers addressed such topics as state-of-the-art instru[illegible] support capabilities, automated performance measurement of simulator [illegible]ks, system hardware and software design and implementation considerations, alternative guideline formats, and the ATD acquisition process. These papers proved a useful communication tool in that their content, as well as the feedback obtained from meeting participants, helped shape the ultimate content and format of the guidelines.

A sampling of past ATD specifications (including those for the A-10, F-15, F-16, and C-130 aircraft) was also acquired and examined to gain familiarity with current specification practices and to see if a generic computer system architecture for the support of ISFs was currently applied or implied.

Instructor Support Feature (ISF) Analysis

An analysis compared ISF utilization and effectiveness among the representative ATDs and for the four systems with advanced instructor support capabilities. This analysis provided data for the Lessons Learned section of the ISF definitions included in Section II of the ISF Guidelines.

Task Commonality Analysis

The purpose of the task commonality analysis was to determine whether a commonality exists among tasks trained at the ATDs selected as representative from the four MAJCOMs and the four systems with advanced instructor capabilities. If it was demonstrated that there are common tasks taught in most ATDs and that the four systems address the monitoring of these tasks, then it could be reasoned that the ISS technology which has already been developed could be applied to meet current and future ATD training requirements.

Because five of the nine ATDs investigated conduct pilot training only, the scope of the analysis included a comparison of pilot flight station tasks only. A detailed review of training documentation, including the simulator training syllabi and instructor guides, was made in order to identify tasks trained on each ATD. This documentation describes the general training scenario and the specific training objectives for each event. In many cases, however, a description of the training events on a task-by-task basis is not provided. Extensive interviews with instructors were conducted to obtain further information about which specific tasks were monitored during simulator training sessions.

A listing of training tasks by phase of flight was compiled for each ATD. The tasks were then grouped by type into the following categories: Normal Flight, Normal Procedures, Emergency Flight, Emergency Procedures, Tactical Flight, and Tactical Procedures. The tasks which are monitored in the four systems were then identified from existing documentation and grouped into the previously defined task listing. To facilitate comparison and analysis of these training tasks, a task-listing matrix was generated; this matrix has been included in Appendix E of the ISF Guidelines.

Comparison of Internal ISS Characteristics

The four systems representative of the current capabilities were compared on their ability to monitor, to compute performance measures and score, and to trigger other instructional support actions. Common and effective functional characteristics were identified to provide guidance for future ISS design.

ISS Hardware/Software Implications

The ISF requirements of these four systems were then analyzed from a systems engineering, hardware, and software perspective. This analysis provides reference for future implementations.

Definition of Guidelines Format

Several alternative guideline formats were considered for presentation of the guidelines information. A literature search of format types used in other design guides/handbooks was conducted so that an effective framework for presentation of the content of the guidelines could be designed. Three basic format types were considered and are briefly described as follows:

1. Checklist. This format type is used in the AFSC Design Handbook (1977). Checklists are provided to use for establishing design requirements and for verifying that the requirements have been met. The intent is to ensure that all applicable design factors have been examined and that all problems were resolved or otherwise determined unimportant to the design. Each checklist item in the handbook cross-references to another section entitled "Design Notes" which provides coverage of a specific topic.

2. Narrative. The particular format type under consideration was one used in Caro, Pohlmann, and Isley (1979). This format was intended to communicate information on instructional features to engineering and other simulator design personnel. It consisted of the following elements:

Feature
Definition
Purpose and Intended Use
Function Description
Concurrent Events Description
Feature Diagram

3. <u>Model Specification with Accompanying Handbook</u>. This format style was used in Hritz and Purifoy (1980). The accompanying handbook provides a set of instructions on how to apply the model specification to a specific application. For each paragraph and subparagraph of the specification, the following sections are addressed in the handbook:

Rationale and Guidance
Performance Parameters
Background and Sources
Lessons Learned

Two alternative format layouts were considered for the Guidelines: the standard header/paragraph layout that is used in most documents, and the Information Mapping® writing style described in Horn (1983) that offers a more unique visual presentation. The Information Mapping® style provides a structured format using labeled blocks to organize the material. These labels highlight the structure of the information, making it easy for the reader to locate relevant detail. Because information is presented in modular units, changes and updates can be easily accommodated.

Guidelines samples were prepared in these two alternative layouts and then presented to IOS Working Group members who, as representative of Guidelines users, selected the Information Mapping® style as the preferred layout.

The feasibility of on-line computer format alternatives for ease of update was also considered. Final delivery of the Guidelines included IBM personnel computer compatible diskettes that contained word processing files and software, in addition to the hardcopy.

Guidelines Development

The development of Guidelines content was a iterative process. During the course of the project, its content outline was revised several times to meet the needs of the Guidelines users. The document is organized into four sections; each section is intended to be read by different users at different times in the ATD procurement process:

I. Overview
II. Instructor Support Features
III. Selecting Instructor Support Features
IV. Providing Operational Information

Development of ISF Definitions (Section II, Instructor Support Features)

Based on an extensive survey of research publications which address the subject of ISFs, specifically Caro, Pohlmann, & Isley, 1979; Semple, Cotton, & Sullivan, 1981; Polzella, 1983; Leaf, Fitzpatrick, & Gunzburger, 1983; and the present analyses, sixteen instructor support features were identified for inclusion in Section II of the Guidelines. Originally, only "advanced instructional features" (e.g., performance measurement, scenario control) were intended to be addressed. Advanced instructional features are those features which increase the instructor's efficiency and effectiveness by reducing the workload and providing support in the total instructional process of simulator training. However, it was felt that more basic ISFs (e.g., record/replay, freeze) should also be included. It should be noted that the term "instructor support feature (ISF)" was specifically selected for use because it so closely describes the purpose of these features. An attempt was made to provide a concise definition for each feature, describe its instructional value, list additional considerations to be examined when fine-tuning the specification, note related features, and provide examples and lessons learned based on past experience. The content of the ISF definitions is based on the analyses results and a review of the research material cited.

Drafts of the definitions were discussed at a working meeting held in April 1985 at Luke AFB. The meeting was attended by personnel from the 4444th Operational Squadron, as well as from AFHRL and SimSPO. Feedback was sought to determine whether they met the typical user's needs. Initial response by this representative group of operational users was positive and suggestions for improvement were incorporated into the Guidelines.

The "Task Module" Concept

A control mechanism successfully implemented in the four systems with advanced instructor support capabilities was that of mapping training tasks into modular data files referred to as "task modules." In these systems, task modules have successfully served as the means by which ISFs are implemented. Because of this success, the task module concept has been introduced in the Guidelines (Section IV, Providing Operational Information) as one approach to implementing a data-driven instructor support system.

Task modules are presented as tools to be used by operational users which provide a framework for specifying ISS requirements so that required training support functions will be provided by the ATD. For example, task modules identify the conditions triggering or terminating a training objective, and define the appropriate aircrew performance measurement procedures and information displays with respect to that objective. Refinement of information contained in task modules continues as training requirements are defined more explicitly. Ultimately, this information is translated into data files and modular software programs by contractors. Thus task modules are the bases of an approach to modular software architecture from which an ISS could be built, which would control the operation of the system.

ISF Guidelines Appendices

The following appendices were also developed to be included in the ISF Guidelines document.

Appendix A. Aircrew Training Documentation. This appendix lists the training documents and syllabi from thirteen aircrew training programs which were collected and reviewed.

Appendix B. Bibliography. This appendix lists the informational literature relating to the subject of instructor support features which was reviewed.

Appendix C. Sample Specification. To illustrate the use of the Guidelines, a sample specification for a future ATD acquisition of interest to SimSPO was developed. This provided not only an opportunity to validate the Guidelines but also an opportunity to positively affect a procurement as well. In addition, by engaging in this process, a procedure for analyzing instructor support requirements for future ATD procurements was derived.

It was hoped that the ATD for which the sample specification was to be generated would be identified during Phase I. The system initially designated by the Air Force was the C-130. The selection was then changed to the F-15E Dual Role Fighter (DRF). Final selection of the F-16 upgrade was not made until the end of Phase II. The delay in the identification of the system did, however, have a positive impact. It enabled the sample specification to serve a useful purpose by making it a working document that would potentially affect an actual procurement, rather than merely provide a hypothetical sample that would simply demonstrate the application of the Guidelines.

Two meetings with the TAC Instructional Systems Development (ISD) Squadron's F-16 training program upgrade representatives were held at Luke AFB in order to identify training tasks and instructor support system requirements. Based on their inputs, a listing of F-16 training objectives was compiled, similar in format to the descriptions found in the task commonality matrices. Identification of each training objective enabled further definition of requirements in terms of briefing, initialization, control, instruction, monitoring, and debriefing. Constructing these tasks sequentially into hypothetical training events, and examining them in the context of a total training exercise, enabled instructor support requirements to be defined even further.

Various specifications were reviewed for content and format structure as well. These included MIL-STD-490 (1968) and the draft specification by Leaf et al. (1983). The basic format structure of the sample specification remains unchanged from previous specifications; the content, however, is entirely different. Using the procedure described in Section III of the Guidelines, the sample specification was generated. Functional definitions of the required instructor support features, written by SimSPO staff based on the ISF definitions, were tailored and included to meet the needs of operational users.

Appendix D. Training Sites Visited. This appendix lists the data collection trips that were made to operational ATD and prototype ISS sites.

Appendix E. Task Commonality Analysis. The matrices contained in this appendix provide a listing of general tasks currently trained at nine ATD sites. Although this table is provided to show commonality of tasks across several different training sites, it may provide guidance in the development of a list of task modules for future ATDs.

Appendix F. ISS Implementation Considerations. ISS cost and implementation guidelines have been presented as appendix material for SimSPO personnel who have technical backgrounds but limited experience with ISS implementation.

Appendix G. Sample Task Modules. Representative samples of specific task modules were developed to provide specific cases for reference by those involved in the specification process.

III. RESULTS

This section presents the findings of the investigations and analyses efforts. These results are described under the following headings and are presented in the same order as described in Methods (Section II) immediately above:

1. Current ATD Acquisition/Specification Process
2. Instructor Support Feature Analysis
3. Task Commonality Analysis
4. Internal ISS Analysis
5. Hardware/Software Implications
6. Guidelines Format Selection
7. The Final Product -- The ISF Guidelines

Current ATD Acquisition/Specification Process

Acquisition of ATDs is handled by the Deputy for Simulators, SimSPO, of the Aeronautical Systems Division, Air Force Systems Command (AFSC/ASD/YW). SimSPO is involved in specifications for acquisitions that range from training programs to products and equipment. Some of these acquisitions have included ISSs for ATDs. The SimSPO follows established procedures from ATD project inception, through contract award, and to final transfer of the ATD to the using Command and the Air Force Logistics Command (AFLC). These procedures are mandated by Air Force Regulation (AFR) 800-2 (1982), Acquisition Program Management.

The SimSPO, however, is not always involved with acquisitions. For example, simulator "refurbishments," which may include changes to the simulator, can be procured through the AFLC. AFLC, with Ogden Air Logistics Center acting as the implementing agency, is responsible for simulator modifications and maintenance after the initial acquisition. The regulation governing Modification Program Approval and Management is AFR 57-4 (1983).

Need Identification

Training requirements are initially identified by the MAJCOMs using the ISD process, an approach to the analysis of training requirements and development of training systems. This includes performance of a task analysis of the missions to be trained and media selection. Relevant regulations include AFR 50-8 which requires that the ISD process be utilized in the identification of training requirements, and AFR 50-11 (1977) which requires that all training equipment be designed according to ISD methodology.

Acquisition of a new ATD is formally initiated by a Statement of Operational Need (SON), a statement of training requirements generated by one of the MAJCOMs. It is a formal document which identifies an operational deficiency and states the need for a new or improved capability. In a SON for acquisition of a new weapon system, the statement of requirements may be stated very generally, usually amounting to a single statement that an ATD will be required. A SON specific to the ATD, on the other hand, usually provides more substantial detail, such as operator control and ISF requirements. Therefore, the level of detail varies substantially among SONs. In the case of the acquisition of a major system, and when approval by the Secretary of the Air Force is required, the preparation of a Mission Element Needs Statement (MENS) is necessary. The Air Force Regulation which addresses the preparation of the SON and MENS is AFR 57-1, Statement of Operational Need (SON).

Concept Development

The using Command issues a draft SON document and distributes it to the other implementing and participating Commands (e.g., AFLC, AFSC, HQ USAF and ATC) for comment. These Commands in turn contribute data and experience on the technical base, logistics costs, human factors, training, etc. The using Command notes their input to refine and update the SON. During this time, SimSPO and the using Command begin to work together to define user needs more specifically. After suggested changes are incorporated and cost estimates included, the final version of the SON is sent to HQ USAF for evaluation and validation.

HQ USAF assesses the technology and constraints and identifies the estimated resources to satisfy the need and requests review by the other Commands so a recommended course of action can be provided as well as a determination of priority ranking for the SON or MENS. The issuance of the Program Management Directive (PMD) by HQ USAF notifies all concerned as to whether the SON or MENS has been validated or approved, in whole or in part, or disapproved. It is at this point, upon issuance of the PMD and AFSC Form 56, that the program is assigned to SimSPO. The SimSPO assigns a Program Manager (PM) whose role is to guide the program toward achieving the program objectives. The PM prepares a Program Management Plan (PMP) that lays out the acquisition strategy and defines the support requirements of the participating organizations. The PMP is submitted with the revised PMD to influence the directives.

The PMD is the official management directive that provides direction to the implementing and participating commands and authorizes the commitment of resources to satisfy the operational need. As directed by the PMD, the SimSPO works with subject matter experts from the using command to fully evaluate the operational and supporting implications of various alternative design approaches. The SimSPO relies heavily on the operating, supporting, Operational Test and Evaluation (OT&E) and other participating commands to participate actively in the acquisition life cycle. All participants coordinate to ensure system design, operational, and support concept development.

Advisory resources are available to the SimSPO as well. The ASD engineering directorates provide experienced engineering personnel who perform front-end analysis and rough costing support. Training equipment specialists participate early in the definition phase through the validation of device functional requirements. From the Air Force Human Resources Laboratory, training psychologists and engineering personnel specializing in simulation research may make contributions during all phases of the acquisition process.

Generation of Specification

A team composed of personnel from SimSPO and also operational training, management and engineering personnel from the using Command is tasked with developing the actual ATD Prime Item Development Specification (PIDS). SimSPO personnel meet with user representatives via site visits to determine how the system will be used, facilities requirements, etc. A draft specification is prepared in accordance with MIL-STD-490. This draft is reviewed in detail by the users as well as by the Director of Requirements (DR) and Director of Operations (DO) at the MAJCOM. In some cases, a draft of the specification is sent to industry for comment. After modifications have been made, the final version of the specification is published.

Problem Areas Identified

The investigation of the ATD acquisition/specification process and discussion with MAJCOM and SIMSPO personnel pointed to several problem areas relating to ATD acquisition. Identification of these problems enabled the definition of a guidelines content that would meet user requirements.

Because equipment and training requirements are often developed concurrently, front-end analysis does not always precede procurement. Typically, the simulator is procured first, and then the training is defined. ISD goes on during the acquisition process but, unfortunately, does not always drive the requirements. This has led to the design and implementation of systems that often do not support the intended training objectives or meet instructor needs. If, instead, the operational users would clearly identify their requirements and communicate them to the specification writers at the outset, specifications could be generated that would more accurately reflect their needs.

In an effort to reverse the process of procuring simulators first and then defining training, the SimSPO is attempting to move towards contractor-provided training programs. In the future, a contractor may be responsible for the entire process, including the front-end analysis, development of necessary media, and the operation and maintenance of the resulting program. The SimSPO's role will be to oversee the process. This trend has significant implications to the development of ISSs in ATDs. Specific guidelines for specifying requirements based on past procurements would provide a repository for lessons learned to benefit all future participants and would promote sharing of information.

Another problem area is the lack of personnel who are properly trained in identifying ATD training and ISF requirements. This is partly due to personnel turnover, unfamiliarity with state-of-the-art technology, and the lack of adequate guidelines for selecting ISFs of new procurements. Unfortunately, what happens too often is that an ATD procurement is based on the dictates of an individual, who is only familiar with one particular device, rather than a result of an effort based on "corporate" knowledge. In other cases, there is a tendency to over-acquire "just in case." The resulting ATDs, then, are either insufficiently equipped with features or are too complex to utilize fully.

It was also noted that the terminology used to define ISFs is used very loosely and, in some cases, leads to the design and development of features that do not fulfill user requirements. At times, there is a basic misunderstanding as to what these features are to provide, what they are to be used for, and what benefits are to be gained. It is important, therefore, that requirements personnel, specification writers, users, and contractors alike be thoroughly familiar with the terminology used in defining ISFs and have an understanding as to each feature's purpose and intended use.

For the most part, previous specifications have not provided enough direction to the contractor in regards to user training and instructor support feature requirements. In many cases, the description of required capabilities is unclear. This has resulted in the design and implementation of ATDs that have not completely satisfied user needs. For example, specifications that simply list desired ATD functions without regard to how an instructor must exercise those functions and without regard to their purpose and intended use may produce a "feature-rich" ATD with unusable features.

ISF Guidelines Intended Audience and Use

As a result of this investigation of the ATD acquisition process, it became clear that a vehicle for providing common vocabulary for the communication of instructor support requirements would alleviate some of these problems. By standardizing the terminology used in describing ISS requirements, the Guidelines would facilitate communication among the MAJCOM personnel who identify initial training requirements and needs, the SimSPO specification writers/procurers who are tasked with specifying requirements in the PIDS, and the contractors who build ATDs.

The ISF Guidelines provide procedures for analyzing training and instructor support requirements to specify ISSs, provide descriptions of ISFs, and educate the reader about current system capabilities. These Guidelines can assist MAJCOM operational personnel in identifying their requirements and help SimSPO personnel express those requirements accurately in procurement specifications.

Figure 2 illustrates the anticipated points, within the acquisition process, where the Guidelines are expected to be utilized. As a guide to the SON, the Guidelines would provide assistance to operational personnel in selecting ISFs to include in a future procurement. As a guide to the PIDS, they would provide a functional description of ISFs in specification terminology. Finally, during Prime Item Development, the Guidelines would provide operational personnel with assistance in developing the task modules that would ultimately be used by the system developers.

Instructor Support Feature Analysis Results

The purpose of the ISF analysis was to compare ISF utilization and effectiveness for the representative MAJCOM ATDs and the four systems with advanced ISFs. Results of the data gathering and site visits are described in this section. Tables 1 and 2 contain supplementary information. Refer to Section II of the ISF Guidelines for complete definitions of each ISF and additional lessons learned.

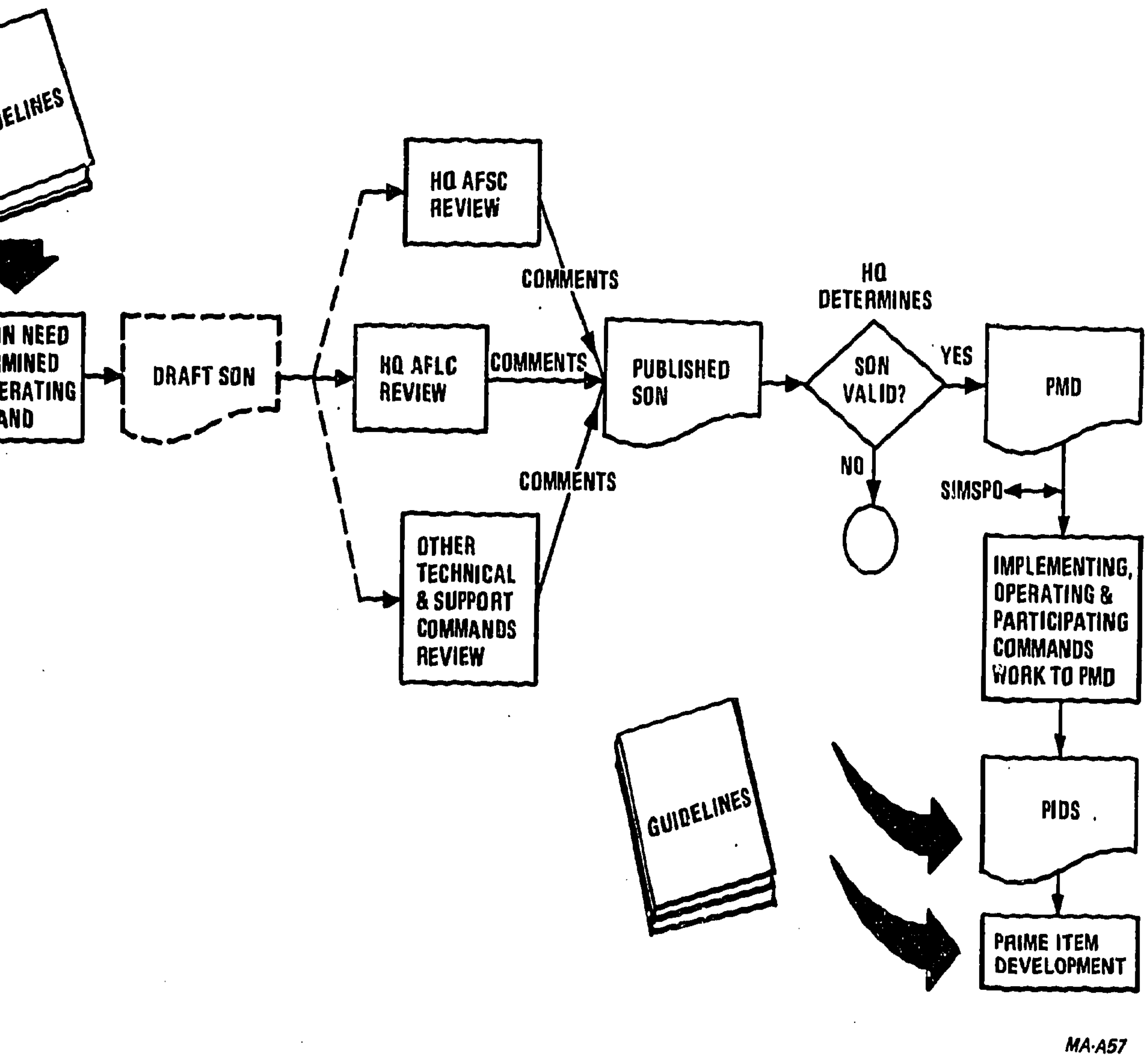

Figure 2. ISF Guidelines Use in the ATD Acquisition Process.

Table 1. ATDs IOS Characteristics/Features

SIMULATOR	A-10	F-15	F-16	B-52	C-130		T-50 (T-37)	T-51 (T-38)
R COMMAND	TAC	TAC	TAC	SAC	MAC		ATC	ATC
'E	OFT	WST	OFT	WST	WST	OFT	OFT	OFT
UAL	Yes	No	Yes	Yes	Yes	No	Yes	Yes
TION	No	Yes/Not Used	No	Yes	Yes	Yes	Yes	Yes
RACTOR	Reflectone	Goodyear	Singer/Link	Singer/Link	Singer/Link		Singer/Link	Singer/Link
ISSION	Day Visual Ground Attack	Fighter	Fighter/Attack	Strategic Bomber	Freight, assault transport		Trainer	Trainer
'RNG OBJECTIVES	Normal/Emergency Procedures Normal/Emergency Flight Radar Warning Receiver System Procedures	Normal/Emergency Procedures Normal/Emerg. Flight Tactics Flight Weapon Systems Procedures	Normal/Emergency Procedures Normal/Emerg. Flight Tactics Flight Weapon Systems Procedures	Normal/Emergency Procedures Normal/Emerg. Flight Tactics Flight Weapon Systems Procedures	Normal/Emergency Procedures Normal/Emergency Flight Tactics Flight		Normal/Emergency Procedures Normal/Emergency Flight Basic Instrument Flight	Normal/Emergency Procedures Normal/Emergency Flight Basic Instrument Flight
SORTIES	6	18	11	10	10		25	26
'H OF SESSIONS	2 hours	1.5 hours	1.5 hours	4 to 6 hours	3.5 hours		1.3 hours	1.3 hours
ESCRIPTION CATION	Offboard	Offboard	Offboard	3 offboard console operator stations	Onboard instructor operator station		Offboard console operator station	Offboard console operator station
UT DEVICE	Lightpen/keyboard	Keyboard w/edit line	Function keyboard and light pen	Function keyboard	2 function keyboards		1 keyboard	1 keyboard
'PUT DEVICE	3 CRTs	3 CRTs	3 CRTs	2 CRTs SECU display/keyboard for onboard instructor	3 CRTs MCU for over-the-shoulder use		1 CRT Control box for onboard instructor who sits next to student	1 CRT Control box for onboard instructor who sits in rear cockpit
RIO CONTROL	Manual	Manual	Automated Manual	Automated (Mission) Manual (Non-mission)	Automated (Programmed); Manual		Manual	Manual
	Yes	Yes	Yes	Yes	Yes		Yes	Yes
ATION VARIABLES ROL	Can make runtime changes	Can make limited runtime changes	Can make runtime changes	Can make runtime changes in non-mission mode	Can make runtime changes		No runtime changes	No runtime changes
	Environmental conditions Aircraft position Weapons load	Environmental conditions Aircraft position Tactics set Weapons stores	Environmental consitions Aircraft position Target	Environmental conditions Aircraft position (non-mission mode) Airfields Tactical environment	Environmental conditions Aircraft position Cargo loading		Environmental conditions Aircraft position Airfield layout Aircraft systems	Environmental conditions Aircraft position Airfield layout Aircraft systems

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Table 1. Concluded

SIMULATOR	A-10	F-15	F-16	B-52	C-130	T-50 (T-37)	T-51 (T-38)
ALFUNCTION ONTROL	Automated Manual	Automated Manual	Automated Manual	Automated Manual	Automated Manual	Automated Manual	Automated Manual
S DISPLAYS ample Types)	Plot Displays Approach Ground Controlled Approach (GCA) X-Country Weapons score Programming	Selectable profile God's eye Status Control pages	Concept Instrumentation A/R & intercept Map pages Approach/departure plates Instrument Landing System (ILS) GCA page Weapons scoring	Plot Displays Approach/Departure (ILS/Precision Approach Radar (PAR) X-Country Rendezvous Weapons Delivery Instruments Programming Training Status: Mission Weapons Nav/Comm Proc. & Malf.	Plot Displays X-Country (30 min. historical track) Approach/Departure Drop/Extract Zones Out of tolerance Drop Score	Plot Displays Programming	Plot Displays Programming
TOMATED RFORMANCE ASUREMENT	YES, auto or manual Parameters Maneuvers Weapons scoring	YES Parameters Weapons scoring	YES Parameters Weapons scoring	YES Parameters Maneuvers Weapons scoring	YES, auto or manual Parameters variables Maneuvers (10 for crew)	NONE (Parameters monitoring*)	NONE (Parameters monitoring*)
OCEDURES MONITORING	YES	NONE	YES	YES	YES	NONE	NONE
TA STORAGE & ANALYSIS	NONE	NONE	NONE	NONE	NONE	NONE	NONE
MONSTRATION	YES	NONE	YES	YES	YES		
EFING UTILITIES	For student Instructor Pilot (IP) as part of sim checkout	NONE	NONE	NONE	NONE	NONE	NONE
ORIAL	NONE	NONE	Help function	NONE	NONE	NONE	NONE
EEZE/TOTAL EEZE/PARTIAL	YES Position Parameter Flight System	YES Flight System Parameter	YES Parameter	YES Parameter Attitude Flight Path Position	YES Parameter Position	YES Parameter Attitude Position Heading	YES Parameter Attitude Position Heading
ULATOR ORO/REPLAY	YES, up to 10 min.	NONE	YES, up to 5 min.	YES, up to 15 min.	YES, up to 7.5 min. or point of problem freeze	YES	YES
RIEF rdcopy/Printout	YES Any CRT display	YES of any CRT display Tactics Scoring Summary	YES of any CRT display Parameters Monitoring	YES Post flight, off-line of any CRT display Mission perf. history Post mission performance history	YES Post flight, off-line of any CRT display Procedures monitoring printout Out-of-tolerance printout	NONE	NONE
OTE GRAPHICS AY	NONE	NONE	NONE	NONE	NONE	NONE	NONE

Polzella (1983).

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Table 2. Characteristics/Features of Four Systems

	AFTS	C-5A PMS	F-14 ISS	B-52 ARPTT ISS
R COMMAND	TAC (F-4E) Air Nat'l Guard (A-7D)	MAC	N/A NAVY	SAC
RAFT	A-7D & F-4E	C-5A	F-14	B-52
MISSION	Tactical Fighter	Transport	Maritime Air Superiority Fighter	Strategic Bomber
ATO	ISS Strap-on to A-7D & F-4E MTs	ISS Strap-on to C-5A MT	ISS Strap-on to F-14 OFT	Part-task Trainer
TRAINING CTIVES	Normal Flight Tactical Flight	Normal/Emergency Procedures Normal/Emergency Flight	Normal/Emergency Procedures Normal/Emergency Flight	Inflight refueling
TH OF SESSIONS	20-30 min. per run; 1.5 hr sessions	4 hours	1.5 hours	1.5 hours
ESCRIPTION CATION PUT DEVICE TPUT DEVICE	Offboard IP station Function keyboard CRT Remote Terminal Function keyboard CRT	IP & Instructor Flight Engineer (IFE) onboard stations w/special function keyboard and display System control; offboard station w/2 CRT/keyboard terminals	IP offboard station Touchpad on display 2 19" graphics displays Remote Terminal Touchpad on display 2 19" graphic displays	2 onboard stations w/PEP panel 9" b/w monitor 1 offboard station PEP panel 19" color monitor Remote offboard station Touchpanel 19" color monitor
	YES	YES	YES	YES
ARIO ROL	Fully Automated	Fully Automated Semi Automated	Fully Automated Semi Automated/By Objective	Fully Automated Semi Automated/By Objective
LATION VARIABLES ROL	No runtime changes; operator input restricted to system control only. Modes vary by complexity and variable changes.	Can make runtime changes Environmental conditions, etc.	Can make runtime changes Wind direction and velocity Air turbulence Carrier speed Sea state	Can make runtime changes A/C model and positions Tanker offload Tanker/receiver (T/R) flight parameters Visual eyepoint Gross weight, etc.
UNCTION ROL	Automated	Automated Manual	Automated Manual	Manual only
ISPLAYS le Types)	Realtime performance data Exercise geometry Performance Summary Ground Attack Radar (GAR) Ground Attack Tactical (GAT) Standard Instrument Departure (SID) TACAN Penetration ILS, GCA Air-to-Air Intercept (AAI)	Mission Sequence Mission Plot Checklist/Procedures Error Alert Monitored parameter values, Active and Available malfunctions	Operating areas, approach/dep plates GCAs and Carrier Controlled Approaches A/C historic and present position	T/R position: overhead, vertical, envelope views Runtime graphics Altitude, Azimuth, Speed, Throttle, Total Fuel Flow Profiles
MATED ORMANCE UREMENT	Run scores after each run; these calculated into single score Adaptive scheduling. User can change predefined scoring values	Parameters and maintenance of parameters values within windows Crew member assessment Crew coordination assessment Mission assessment	Scores task modules in realtime. Can make realtime change. Total grade calculated; instructor can override grade	Scores task modules proficient/nonproficient Evaluation Template (minimum proficiency and actual) Instructor can override grade

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Table 2. Concluded

	AFTS	C-5A PMS	F-14 ISS	B-52 ARPTT ISS
OCEDURES)NITORING	NONE	YES	YES	YES
TA STORAGE & ALYSIS	Values of each performance measure saved; Historical records of training and performance; Interrogate feature	Data Retrieval Data Analysis	Samples, processes and records aircraft parameters; Performance Summary Training Session Description	Class Summary Comparative Mission Data Analysis
IEFING UTILITIES	Replay used for pre-mission brief	NONE	Can call up aircraft system description and procedures	Training Summary available
TORIAL	NONE	22 pages of help displays	Tutorial to review ISS functions and features	Help information: ISS system operation, syllabus, training summaries
EEZE	YES	YES	YES	YES
BRIEF Hardcopy/Printout	YES Offline CRT display Performance Summary at end of exercise	YES Offline/runtime CRT display Crew Performance Assessment	YES Offline/runtime CRT display Performance Summary Exercise Summary	NONE
MOTE GRAPHICS PLAY	YES	NONE	YES	YES
ULATOR ORO/REPLAY	NONE	NONE	NONE	NONE

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Summary of Analysis by Feature

The following is a summary by feature.

Scenario Control. The systems which had fully automated scenario control included the B-52 Weapon Systems Trainer (WST), the F-16 Operational Flight Trainer (OFT), C-130 OFT/WST, and the four systems. One of the differences in the operation of these systems is how the missions are generated. For the ATDs, generation of mission scenarios requires users to have data entry and programming skills. For the four systems that have advanced ISFs, the training objectives have been preprogrammed into a database and allow for easy selection of preprogrammed scenarios by the instructor during the briefing or the initialization process.

Realtime Simulation Variables Control. It was observed that the manual selection is best suited for informal training (e.g., continuation training, instructorless practice, and review). Simulation variables were available on all of the systems visited. The amount of usage depended on the accessibility of the variable and whether a device technician was available during training.

The selection of variables by re-initializing the simulator seemed to break the flow of training and detracted from the realism of flight. It was used most for instrument navigation training where approaches to different airfields are practiced.

Variables are preprogrammed in the B-52 WST when operating in the "mission mode." This system also provides for manual control of certain variables and allows flexible instructor interaction.

Malfunction Control. The automatic feature is rarely used. The main reason given was that it did not allow the instructor to tailor training to student response and needs. In some cases, the malfunction activation and deletion did not correspond to the desired scenario. In particular, the A-10's preprogrammed malfunctions do not correspond to the syllabus being trained.

The B-52 ARPTT and the F-14 ISS provide a feature whereby the instructor may select a set of malfunctions during the initialization process. These malfunctions are then grouped together on a special menu and may be readily accessed during the exercise for actuation and deletion. This feature is being used on the B-52 ARPTT ISS.

Reposition. Repositioning the simulator to a specific location was used on all devices visited and was mostly used for repetitive training (e.g., approaches). This feature is accomplished in many different ways and in varying degrees. The most versatile method was seen on the A-10 ATD where the simulator can be positioned anywhere within the active geographic graphics display by identifying the position with a light pen. Repositioning in the A-10 simulator may also be accomplished by bearing and distance from a fix, latitude/longitude, or by identifying a previous position by a "snapshot Initial Condition (I.C.)". The most common way to reposition was accomplished via an I.C. reset. The A-10 may be over-designed for the training requirement, however. The I.C. reset may be somewhat restrictive, time consuming, and difficult to access.

The B-52 ARPTT and F-14 ISS have a feature whereby the trainer may be repositioned to the beginning of any flight-training objective (e.g. pre-contact position, initial approach fix). This feature is currently used in the ARPTT.

The repositioning feature on the F-14 OFT was somewhat user unfriendly in that repositioning to the end of a runway would cause a crash condition if the landing gear were not down.

IOS Display Control and Formatting. Selection of displays was observed to be both by instructor selection or by automated actuation. In most cases, where the aircraft was geographically referenced on a display, an automated feature would provide the correct reference. For example, in all cases when the simulator was repositioned to the beginning of an approach, an approach display would automatically come up. In all cases when a geographic plot was being displayed and when the aircraft flight path approached the edge, the display would change to the next appropriate display.

With respect to displays other than geographic referencing, the instructor has to manually select any display associated with procedures and or cockpit activity. In some cases, the cockpit controls were separated by relative position in the cockpit. In other cases, display of controls was by aircraft system. This separation does not necessarily provide total feedback with respect to certain procedures so instructors had to use some other "work around" method to evaluate performance. An exception to this is the ISS systems that automatically select displays appropriate to the current training objective.

Those systems that provided checklists and procedures on special displays were not often used because the checklists and procedures were outdated.

Total System Freeze. All systems observed have this feature, and it was used in varying degrees depending on the type of training. At the Undergraduate Pilot Training (UPT) level, freeze was used extensively by the instructor while providing direct feedback and corrective action. It is rarely used in total mission training.

The Crash Override feature was found on all devices and, in all cases observed, was always left on.

Partial Freeze. Partial/parameter freeze was found on many of the devices but was only used at the UPT level. Instructors expressed that there is little training value for this feature at the MAC/SAC/TAC sites.

Automated Simulator Demonstration. This feature was found on many of the devices but was only used at the UPT level, and then not very often. Instructors expressed that this feature may have some value, but that they would rather use the simulator time for "hands-on" training.

Simulator Record/Replay. This feature was found on many of the devices but was mostly used at the UPT level and then only by certain instructors. Other instructors expressed that this feature may have some value, but again, they would rather use the simulator time for "hands-on" training. This was especially true at the MAC/SAC/TAC sites.

<u>Hardcopy/Printout</u>. This feature was found on [illegible] devices. Some of the systems required that the system be taken down from the runtime programs prior to providing the hardcopy output. This was observed to be restrictive to actual training, and by the time the copy is made, the instructor has already debriefed the student. Some of the devices required that the display being hardcopied be frozen while the output was produced. This may be disruptive with respect to real-time feedback. In most cases, this feature was not used often by instructors. The reasons varied from not knowing that it existed to not knowing what to use it for.

<u>Procedures Monitoring</u>. Some of the systems, including all those that utilize advanced ISFs, have this feature. However, it is not used much because the procedures are quickly outdated due to the many changes (e.g., aircraft configuration, local course rules, and ATC procedures).

<u>Automated Performance Measurement</u>. Some of the systems have a parameters monitoring feature, but it is rarely used. Among the reasons given were that it is to difficult to set up and that the results have little relevance to the objective being evaluated.

Some of the WSTs have a feature called automated performance measurement where bomb drops and missile shots are scored. This feature is not used in the A-10 nor F-16 because instructors feel that the basic simulation does not provide the cues necessary to properly launch the weapon. The F-15 missile scoring is used for basic intercept procedures and shots made beyond visual range (BVR).

The four advanced instructional systems have a more comprehensive automated performance measurement feature that evaluates performance by training objective. The B-52 ARPTT ISS has just recently installed this feature; however, there has not been enough feedback with respect to operational usage. The AFTS® scoring has either been used or not used depending on Command support and physical location (e.g., GCAs are used frequently in Alaska where the weather is bad and pilot proficiency in instrument flying is critical to safety of flight; GCAs are not used very much at Davis-Monthan where there may be 1 day in the year when an instrument approach is required and probably never to the field minimums).

The C-5A PMS and F-14 ISS were designed primarily for R&D purposes, and no operational data were evaluated in this effort.

<u>Data Storage and Analysis</u>. The C-5A PMS has the capability to store and analyze scoring data. Operational evaluation data are not yet available. Because this feature was only recently installed on the B-52 ARPTT ISS, no data have been collected with respect to operational usage.

<u>Remote Graphics Replay</u>. Systems which provide this feature are the F-14 and B-52 ARPTT ISSs. The F-14 ISS was an R&D development system and the operational usage was minimal. The ARPTT Briefing/Debriefing console has just recently been installed. However, the operational feedback thus far has been very enthusiastic with respect to the remote graphics replay capability.

The AFTS® also provided for viewing of replay of exercise geometry and controller voice messages for pre-mission briefing or post-training critique purposes in an adjacent briefing area.

Tutorial. The only system which has this feature is the F-14 ISS. Not enough data were collected from either the user or from a research perspective because this feature was installed just prior to re-hosting the main computer of the simulator. Unfortunately, this re-configuration made the ISS inoperative.

The B-52 ARPTT has a HELP function which provides the user with system usage information which may be accessed upon request during briefing or debriefing. The C-5A PMS supports HELP pages. Not enough information has been gathered to make any comments on this feature.

Conclusions

A Scenario Control feature would be of value to all of the devices visited in that it would reduce the instructor workload during instruction. A fully automated Scenario Control feature (programmed mission scenarios) would be of greater value to long sessions, as in MAC/SAC, and to a lesser extent in ATC where a console operator, because of the design of the system, would provide the support. Programmed mission scenarios are most appropriate for evaluating progress (e.g., checkrides) where standardization is important or for total mission training practice, but during normal training sessions, they do not allow for instructor flexibility and therefore limit training effectiveness.

During many of the training events, the instructor should have the capability to tailor training to the needs of the individual student. Semi-automated scenario control allows the instructor to create a tailored mission to meet student needs and provides support to aid the instructor during training. Flexibility (e.g., instructor interaction with the system) during training is also essential. The instructor should be able to modify variables, insert and remove malfunctions, and move forward or backward in the profile to satisfy basic instruction and student progress.

The instructor wants flexibility and therefore resists automated malfunctions that cannot be changed and automated performance measurement that is rudimentary or inaccurate. Unfortunately, the operational deficiencies of some of these features have alienated instructors. Improvements in ISF design and instructor education as to their purpose and intended use should lead toward instructor acceptance.

Software in the simulator should be up-to-date with respect to the aircraft. Data relating to aircraft procedures, for example, must be easily modifiable by an on-site maintenance activity if the procedures monitoring feature is going to be utilized and appreciated by instructors.

Most of the ATDs reviewed provide automated performance measurement of simulator variables and display raw performance data. The ISSs provide automated performance measurement by training objectives. The focus on measurement of objectives rather than parameters was observed to provide more meaningful information. A score override feature would help diminish instructor resistance to the idea of automated performance measurement.

Because of other demands on instructor time, months can pass without any time on the ATD, making it difficult for the instructor to maintain his skills. A user-friendly interface design that allows the instructor to operate the system with minimal training or a tutorial built in the system for refresher training would help solve this problem.

Instruction on utilization of ISFs is usually informal and on the job. While discussing ISFs with instructors, it was noted that many of them were not aware that certain features existed. In some cases, they did not know how to operate them, and in other cases, they did not know how the feature could be applied to training. Some instructors viewed the simulator as a substitute for the aircraft on the flight line only and do not take advantage of the ATD as part of a total training system. The maximum potential of ATDs will only be attained when instructors are provided with the proper training in the usage of the simulator and its instructor support features.

Task Commonality Analysis Results

The task-listing matrix that was generated for the task commonality analysis presents a listing of tasks that are trained on the ATDs investigated and those incorporated in the four systems with advanced ISFs. This matrix has been included in Appendix E of the ISF Guidelines.

A strong commonality was seen among simulator training tasks grouped in the normal flight, normal procedures, emergency flight, and emergency procedures categories, and this commonality is consistent across the Air Force MAJCOMs. This is not surprising, since these types of tasks reflect the objective of the basic flight training philosophy, which includes ensuring that the student has a firm understanding of procedures and limitations of the aircraft and can demonstrate this knowledge, as well as the motor skill ability, to safely operate the aircraft under normal and abnormal conditions prior to the first flight.

The task-listing matrix indicates that conversion training-task requirements encompass all UPT training-task requirements. In conversion training, the student is familiarized with the new systems and utilizes them to perform the same kinds of tasks that are covered in UPT. Primary emphasis is on safety of flight and on the student's ability to safely operate the system within the procedures and guidelines set forth. This includes starts, takeoffs, landings, instrument and basic airwork skills, navigation, use of checklists and abnormal situations. Once this performance has been demonstrated, the student is introduced to basic tactical skills.

Because most tasks that fall into the categories of tactical flight and tactical procedures are unique to each tactical mission, a strong commonality among training tasks was not observed. Some common tasks, however, are applicable to all major operational commands. Such mission-related tasks are encompassed in Air-to-Ground Attack and Electronic Warfare. These tasks, as taught in conversion training, provide the basic foundation for continuation training in the operational squadrons. The AFTS® for the A-7D and F-4E is the only system designed to monitor tactical training. These systems provide air-to-air and air-to-ground training that could meet the needs of conversion training in these areas.

Nearly all conversion training tasks in the first four task categories (normal flight, normal procedures, emergency flight, and emergency procedures) have already been incorporated into the four systems. Tasks which have not been identified as ones monitored by an ISS were not done so by design. The ISS systems for the F-14, B-52 ARPTT, and C-5A could be easily modified to monitor any additional conversion training-task requirements.

Internal ISS Analysis Results

This section describes the capabilities that allow systems to monitor, compute performance measures and score, and trigger other instructional support actions. Refer to Appendix F for a detailed comparison of ISS capabilities of the four systems which feature advanced instructor support. It should be noted that these systems were all modifications to existing ATDs and that the system design was dictated by what existed.

Conceptual View

A conceptual view of the ISS is presented in Figure 3. The ISS is viewed as a device that may monitor any variable present in the simulation (e.g., variables for flight, navigation, controls, environment) and take action when specified criteria are met (e.g., altitude = 1000 ft). The variables to be monitored and the actions to be taken are dictated by a stored script; also, a new script can be initiated when specified criteria are met. In this view, the ISS is a controller of the instructional process, and much depends on its ability to monitor, interpret, and diagnose ongoing performance and to take action based on complex statements of performance conditions.

Task Module Definition. The concept of a task module is used in two of the four systems examined in this analysis (F-14 ISS and ARPTT); however, it has been applied to the entire discussion, since it provides a functional description that includes training relevance and some independence of specific methods of engineering implementation. Task modules are instructional building blocks that describe the training objectives at a level which has meaning to instructors and that can be used by the machine to monitor and control in a manner appropriate to the instructional objectives. Thus, if a training objective is to execute a standard instrument departure with malfunctions inserted under specified conditions and to measure flight, navigational, and procedural performance, all such information would be included in the task module definitions corresponding to the training objectives. Upon completion, new task modules can be referenced by the ISS until all objectives for a given mission are included. The task module, then, is a control file or a script which drives the ISS and which can be interpreted by instructional personnel and related to training requirements.

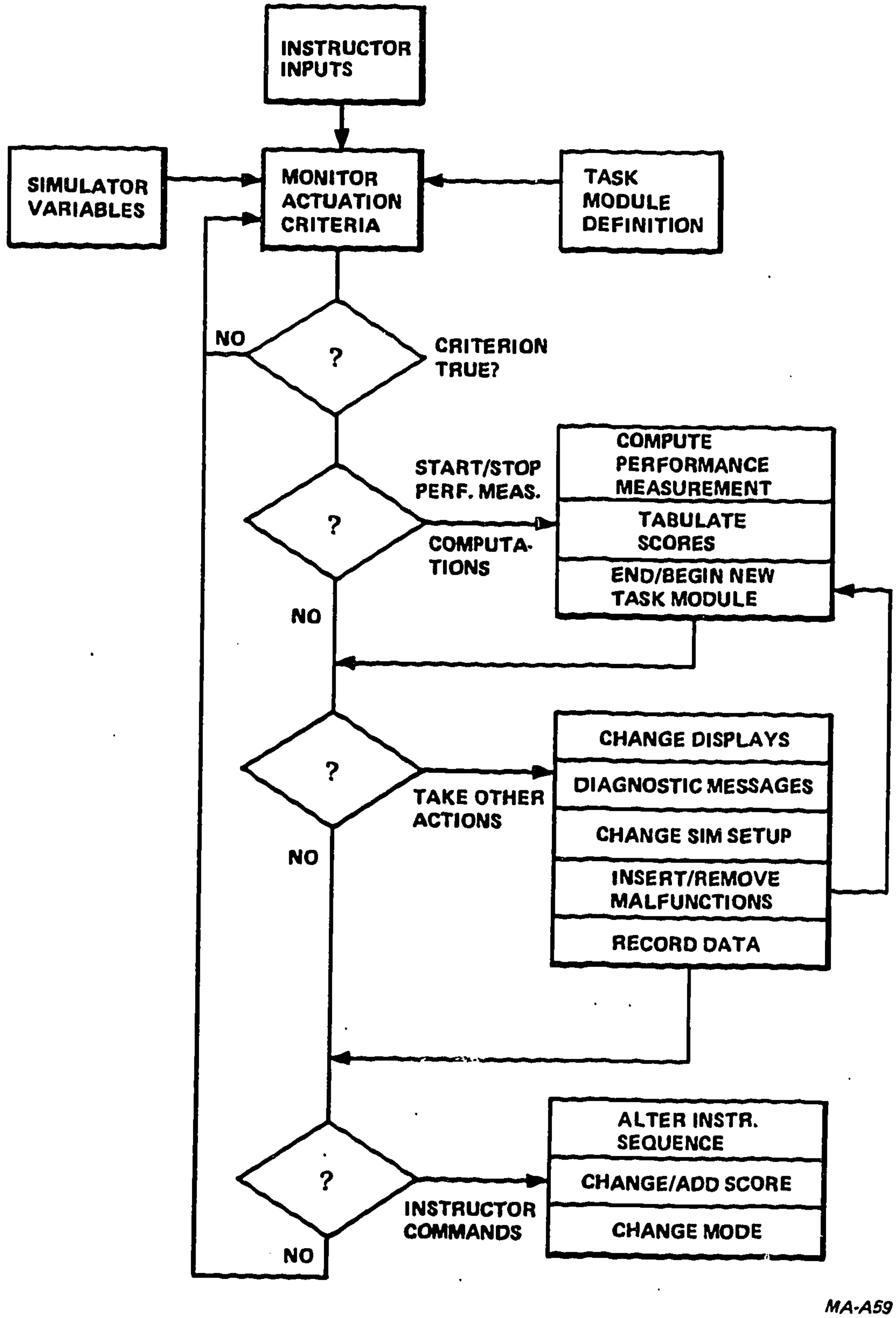

Figure 3. Conceptual Model for ISS Control and Processing.

Start and Stop of Computations. An important feature of the ISS is the ability to recognize conditions and to start and stop ISS processes; for example, to start a new task module when a complex combination of events occurs and then to end it later and to start/stop measuring performance (e.g., measure average heading error when between two NAVAIDS). This match-a-pattern-take-an-action characteristic can permit "smart" behavior on the part of the ISS, and if the ISS is truly to support the instructor and avoid inadvertent actions, very complex recognition may be necessary. The actuation criteria that can be specified for a given ISS was therefore a fundamental determiner of ISS performance. It should be noted that start-and-stop conditions are often difficult to describe precisely enough for computer recognition. Therefore this remains one of the primary challenges in developing a "smart" ISS.

Performance Measurement. Performance measurement is an ISF of an ISS, and in fact, such systems are often called Performance Measurement Systems. Of course, performance measurement is important for scoring and grading, but is also important as an adjunct to normally available simulator variables for the purposes of control of ISS instructor support features.

Instructor Support Actions. An ISS may incorporate a number of ISFs which require direct control of the simulator and setup conditions, instructor console displays, insertion and removal of malfunctions, display of diagnostic messages, and the recording of detailed data for post-simulator use. Appendix F describes the comparison of instructor support actions among the four systems in greater detail.

Instructor/ISS Interaction. Although an ISS derives much of its effectiveness from automatic functions, it must also support an instructor in a flexible manner, allowing the instructor to override and re-direct its actions. For example, the instructor may wish to vary the sequence of task modules, skip a task module, or alter the conditions under which a malfunction is inserted. The ability for flexible interaction between instructor and ISS was examined during comparisons among the selected systems and is discussed in greater detail in Appendix F.

Conclusions

A view has been taken that the ISS is a programmable controller and a generator of information, and although the four representative ISSs vary in the way they are implemented, all fit the same general model. The method of specifying the program for the ISSs varies, but the task module concept can be used for initial specification for any ISS. This implies a data-driven system, but specification in this manner still permits a large degree of design freedom. The types of actuation criteria included in an ISS determined how "smart" the ISS can be in behaving "intelligently" in controlling instuctional events and features. The ISS can be the generator of a large amount of different types of information, and this capability depends on the manner in which performance measurement is implemented and the types of data recorded and displayed. Although all four systems provide a preprogrammed automatic mode, each provides some manner for instructor control and override, allowing a degree of flexibility in use of the ISS for tailored instruction. All provide instructional support through the control of performance measurement, scoring, displays, malfunctions, communications and data recording. These four systems provide a range of examples that characterize the current technology and provide a basis for the generation of future specifications.

Hardware and Software Implications

The purpose of this section is to present findings on the hardware and software implications of ISS functional requirements. The four systems were studied from the systems engineering, hardware, and software perspective, and an attempt was made to correlate the resulting ISS characteristics with the requirements and to note commonalities among the four. Cost was also examined. However, it was difficult to break down for meaningful comparison.

All four systems were developed as adjuncts to existing ATDs. The information collected reflects the final hardware and software configurations used for the AFTS® F-4E and A-7D operational production systems, the F-14 ISS research and development system, the C-5A PMS research and development system, and the B-52 ARPTT operational system.

Hardware and Software Components

Table 3 contains the data that characterize the capability of the hardware and software of the four systems. The implications of each characteristic or associated group of characteristics are described further below.

Stations. The number of instructor support stations, their location, and functions provided at each station were noted as being functions of the existing ATD configuration and instructional requirements. For example, for the B-52 ARPTT ISS, existing, non-functional displays were replaced with CRTs and touch pad devices to allow instructor control and monitoring from either the left or right seat on board; the need for better instructor control of the simulator was identified as a priority item during the IOT&E of the ARPTT prototype. Concurrency of off-line activity, such as debriefing using off-line replay with real-time monitoring, is also a consideration.

Man-Machine Interface. The selection of input and output devices which constitute the instructor interface with the ISS is driven by easily used input devices and easy to understand, uncluttered displays within the constraints of space availability and the state of current technology. Special function keyboards, coupled with functionally grouped menus in the older systems, led to touch-activated devices and color CRTs in the B-52 ARPTT ISS. In the AFTS® and F-14 ISS, speech generation devices provided for the natural replay and provision of controller advisories. Speech understanding within the AFTS® facilitated automation of the controller role for air-to-air intercept training.

Simulation Interface. In two of the four systems (AFTS® and C-5A) a data acquisition unit was used to examine data that flowed between the simulation computer and the simulated cockpit devices. In the C-5A PMS, additional data were obtained by tying-in between the IP station and the ATD's input processing computer. In the F-14 ISS, the switch unit was interposed between the simulation input/output (I/O) processor and the simulation computer's shared memory. The data acquisition unit utilized on the AFTS® and C-5A PMS was designed to accommodate 2000 channels and burst rates of at least 750,000 24-bit words per second. The F-14 ISS dealt with 32-bit words sent over a 2-Mbit serial stream. The B-52 ARPTT ISS was unique in that it shared memory with the simulation computer. All interfaces were designed to capture and send information on ATD parameters necessary to monitor and control the ATD on a non-interference basis. Tradeoff studies were performed to identify the means considered most cost-effective for the existing ATD configuration.

Computational System. All four systems were implemented as stand-alone systems that utilized their own processors and storage. Design tradeoff studies performed on the C-5 ATD and ARPTT ATD considered the possibility of utilizing existing spare capacity within the ATD host, but it was decided that the system could be best developed by using additional processors to minimize impacts on the existing ATD. All computers were commercially available. Their computing capacity is expressed in terms of Data General Nova instruction execution and FORTRAN Whetstone benchmarks as points of reference in Table 3. Three of the four systems distributed the computing task further, utilizing more than one minicomputer.

For the most part, the processors chosen to perform the ISS control were minicomputers. When the first prototype AFTS® was developed, one of the goals was to show that the system could be built using minicomputer technology, rather than mainframes. Proven effective in AFTS®, similar (but of the technology commercially available at the time of their procurement) minicomputers were applied to the F-14 ISS and the C-5A PMS.

The Perkin-Elmer 32/D was a departure from the above in that the ISS was procured as part of an upgrade of the entire ATD to meet a 15-year life cycle. The 32/D was a cost-effective, vendor-supported upgrade for the existing ATD; the selection of an additional 32/D and a shared memory interface was a good logistical choice for the ARPTT ISS, as shown in the life cycle cost study performed as part of the ARPTT upgrade study.

System Performance. System performance takes into account whether the capacity of the computational system adequately supported the functional demands upon the system, such as monitoring cycle time, number of simulation variables, expected task module concurrency, and the software architecture.

In all four systems graphics computation was to some extent off-loaded onto the graphics device. In the F-14 ISS and C-5A PMS systems, a dedicated minicomputer was allocated for graphics processing. It should be noted that the processor used for graphics on the C-5A PMS proved to be inadequate due to demands on its capability to load files off disk.

The F-14 ISS computer performed adequately for a single, off-line or real-time activity; the disk file management demands of the software architecture precluded effective concurrent activity. The C-5A PMS computer effectively handled all activity except for the monitoring of momentary switches. An attempt at increasing the cycle time to 200 milliseconds from 800 milliseconds was thwarted by the lack of sufficient spare computing power.

Table 3. Hardware and Software Characteristics

CHARACTERISTIC	SYSTEMS			
	AFTS	B-52 ARPTT ISS	F-14 ISS	C-5A PMS
Stations	2	4	2	3
Location	Offboard	Left and right seat onboard (replaced Electro-optical Visual System displays, tight fit) 2 offboard (one in place of previous operator console)	Offboard	Instructor pilot onboard station (station mod.) Instructor flight engineer onboard station 1 offboard
Functions	1 for monitoring and replay 1 for just replay	Onboard – all but debrief 1 offboard – all but debrief 1 offboard – all but runtime	1 for primary control, monitoring 1 for brief/debrief, setup, and tutorial	Real-time mission monitoring and control onboard Startup, generation, and data analysis offboard
Concurrency	Runtime, & replay or hardcopy	Runtime and any one offline	Runtime & brief/debrief & hardcopy	Runtime and debrief reports hardcopy (graphics hardcopy directly off IP display)
Input Devices	Keyboard and function keys Speech input	Touch pad device	Touch pad over 19" monochrome CRT	Special function keyboard Keyboards offboard
Output Devices	CRT displays, synthetic voice Printer/plotter	Onboard 9" monochrome CRTs Offboard 19" color CRTs	2 cantilevered 19" monochrome CRTs Printer/plotter Synthetic voice	Instructor pilot display with graphics hardcopy unit 9" monochrome CRT for IFE, 15" monochrome CRT, 2 CRT terminals Line printer
Simulation Interface	Switch unit diverts data flow between sim computer and sim cockpit. Concern for information flow rate.	128 Kb shared memory with sim computer	Switch unit diverts data flow between I/O computer and ATD's shared memory.	Switch unit diverts data flow between sim computer and cockpit. Also intercepts IP key inputs/responses between IP station and sim computer.
Computational System	Data General Nova 3 Speech processor (SUS-Nova 3) Graphics processor in display device	Perkin-Elmer 8/32D (ISS and graphics control)	Data General S-250 (ISS control) Data General S-130 (for graphics control)	Data General S-130 Data General Nova 4S (display and communications)
Computing Capacity				
Data General Nova instructions MIPS	1.15		S-250 – 1.23 S-130 – 1.2[illegible]	S-130 – 1.23 Nova 4S – 1.8
KWhets (FORTRAN)		901	S-250 – 3[illegible] [illegible]imate) S-130 – [illegible]	S-130 – 240 Nova 4 – 185
Storage (in bytes)	96 K main memory (SUS – 32K) 10 M disk	896 K main memory 80 M disk	S-250 – 1.0 [illegible] S-130 – 384 K 96 M disk 10 M disk	S-130 – 512 K Nova 4S – 64 K 10 M disk each

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Table 3. Concluded

CHARACTERISTIC	SYSTEMS: AFTS	B-52 ARPTT ISS	F-14 ISS	C-5A PMS
System Performance	Good performance with spare capacity, slowing of replay when concurrent with runtime	Good performance during concurrent activity, slowing of simulator variable processing	Good performance for single activity, S-250 not adequate for concurrent activity control, S-130 adequate	Good monitoring performance except fo momentary switches, Nova 4S not adequ for display processing
Monitoring Cycle	200 ms 800 ms	100 ms	200 ms	800 ms (slow for momentary switches)
Variables	10-30 for a given task	664 (about half monitored)	165 (about 280 items)	About 2400
Task Module Concurrency	N/A	2	4	10 (8 checklists + navigational profile + monitoring parameters)
Software Architecture	Task modules embodied in code Parameters for scoring, airfield, and curriculum redefinable via editors Software scheduler brings in blocks of code and data for mission segments (Airfield Procedures (APR), GAR/GAT, AAI) based on curriculum definition and algorithm for adaptive curriculum	Task modules embodied in data read in via disk files Monitoring separated into continuous measurement done synchronously and procedural events done asynchronously. Task modules identified for mission are read in and acted upon Editor for module definition	Task modules embodied in data read in via disk files Monitoring done by asynchronous event detection (event detector is synchronous), messages are passed on to activate response to the event as defined within the task modules Macro assembler used for module definition	Task modules represented as a navigation profile and mission segments read in as data from one precompiled disk file, all values converted. Monitoring separated into continuous measurement and procedural events monitoring, all done synchronously. Language provided for module definition
Simulation Variable Processing	Values of interest for the active task are evaluated	Values of interest evaluated whenever required	All simulation variables evaluated synchronously	All simulation variables evaluated synchronously
Software (Source Lines of Code (SLOC))				
Control	Executive control and display drivers – 58,000 SLOC* Display – 50,000 SLOC*	Real-time instructor control, menu management – 7200 SLOC Display – 4000 SLOC	Real-time instructor control menu management – 5670 SLOC Display – 1550 SLOC	Real-time instructor control 12,500 SLOC Display – 6000 SLOC
Measurement	Air-to-air, ground attack, and airfield procedures control, and display – 26,500 SLOC* Editors for curriculum, airfield, and scoring – 26,000 SLOC*	Procedures/event monitoring, and data recording – 2700 SLOC Exercise definition – 1000 SLOC Interactive task module editor – 3400 SLOC	Procedures monitoring, performance measurement, scoring – 1550 SLOC Exercise definition – 1020 SLOC	Mission profile generation – 18,565 SLOC
Brief/Debrief	Geometry, voice replay – 6800 SLOC*	Logon and debrief – 2000 SLOC (graphic replay)	Logon and debrief – 1800 SLOC (graphic replay)	PMS research utilities – scoring, reportin data retrieval/analysis – 7710 SLOC
Tutorial	None	None	Tutorial on ISS – 1020 SLOC	
Training Management	Student records handling – 4000 SLOC	Mission data analysis – 810 SLOC Registration – 1000 SLOC		
Other	Systems confidence tests, speech recognition utilities – 5000 SLOC Diagnostics Land mass calibration	Picture generation, menu creator – 1600 SLOC Test driver – large	Controller models – 1080 SLOC Test driver	Confidence program, diagnostics – 10,716 SLOC*

*Includes significant amounts of assembly language source lines of code

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The higher performance capacity of the B-52 ARPTT ISS 32/D allowed all ISS control and graphics to be hosted in one computer. AFTS® and ARPTT perform adequately given the required functionality, but with little spare computing and memory capacity.

Software Architecture. In all four systems, an attempt was made to allow for changes in training tasks to be accomplished without requiring reprogramming of system software. This was accomplished via use of disk-based data files which were predefinable off-line using editors and preprocessors and, in all systems except the AFTS®, via runtime control actions. It is of interest to note that more than just parameter editing is necessary to accommodate changes expected in procedural tasks, i.e., checklists, as shown especially in C-5A PMS in which a language was developed.

As discussed in the previous section, task modules were embodied in code in the AFTS® and in data files in the other three systems. The latter three systems were data-driven in the sense that the task module definition provided data which described events that initiated activity on the part of the ISS. In the C-5A PMS, the activity was hardcoded. In the B-52 ARPTT and F-14 ISSs, some of the parameters, e.g., diagnostic feedback messages or measurement algorithm, were identified by data within the task module definition.

The C-5A PMS and AFTS® used fixed (synchronous) execution cycles with code being scheduled and executed on one of two available cycles, 200 or 800 milliseconds. The F-14 ISS and B-52 ARPTT ISS had synchronous and asynchronous (on request) components. The synchronous components took care of graphic updates, event detection (processing of simulator variables of interest to see if an action was required), and, in the case of the ARPTT ISS, the processing of continuous flight task requirements. The asynchronous components performed activities as required, when required. Thus, instructor control requests or student actions could be acted upon when the trigger (start, stop, procedural step, out-of-tolerance, etc.) event was sensed. Activity priorities could be adjusted to match user requirements.

Software Components. The procurement of an ISS can address needs and budgetary tradeoffs for a minimal to an all-encompassing ISS. Each ISS configuration can address a different set of major functions. Major functional areas identified through the study of training requirements include: display and control, measurement, brief/debrief, tutorial, and training management. These five areas map to ISFs in the following manner:

1. Display and control -- IOS Display Control and Formatting, Initial Conditions, Real-time Simulation Variables Control, Malfunction Control, Freeze

2. Measurement -- Automated Performance Measurement, Procedures Monitoring, Scenario Control

3. Brief/Debrief -- Briefing utilities, Hardcopy/Printout, Remote Graphics Replay

4. Tutorial -- Tutorial

5. Training Management -- Data Storage and Analysis

At a minimum, an ISS requires display and control functions that allow the control of the ATD and the real-time monitoring of the student. Given this core capability measurement, then brief/debrief, tutorial, and training management can be added as required to procure a system that meets the needs of the user community. Table 3 presents information on software components implemented for the four systems, broken down by functional area to give a frame of reference for future procurements.

The software for each of the systems was written using combinations of assembly language and available high level languages, such as FORTRAN and Data General Corporation's ALGOL (DG/L). Note that source lines of code (SLOC) numbers identified in Table 3 include extensive assembly language lines, resulting in much higher numbers for the AFTS®. Operating systems and utilities commercially available for the hardware were adopted for both the development and runtime operation of the systems. All operating systems were multitasking, able to keep track of more than one system activity at a given time. Also, the F-14 ISS took advantage of its multiprogramming operating system's messaging capability to implement asynchronous system control.

Common Characteristics

Given the collected data just discussed, major characteristics common among the four ISS systems lead to the definition of a stand-alone system for ISSs which can be added to existing ATDs. This stand-alone, modular ISS has the following features:

1. All ISS processing is isolated from the simulation processing.

2. Data are passively shared with the simulator.

3. The ISS can be added with minimal modification to an existing ATD.

4. The system does not require large, i.e., mainframe, computers.

5. The system attempts to provide user stations that are tailored for effective instructor use.

6. The training tasks are specifiable and updatable without requiring system reprogramming.

7. Software is functionally modularized.

8. Commercially available software and hardware are utilized to the greatest extent possible.

Hardware and its accompanying software development environment can be specifically selected to support the ISS functions or can be expanded in functionality without impacting the simulation. Additionally, adverse impacts on the existing ATD utilization by ISS development can be minimized. For example, the AFTS® was added to existing F-4E and A-7 ATDs in about a week. The AFTS®, F-14 ISS, and C-5A PMS could also be switched completely off as necessary to allow use of only the pre-existing ATD.

The synchronous rate required for simulation processing is not required for ISS processing. For example, the F-14 ISS was attached to the 2F95 ATD which had a cycle time of 20 Hz. The F-14 ISS successfully performed all display and monitoring functions using a 5-Hz simulation variable monitoring cycle coupled with asynchronous processing of other activity. The B-52 ARPTT ISS was designed in a similar fashion, allowing for monitoring of events of interest, processing of continuous flight variables, and updating the displays at a 10-Hz rate. The application of a small, synchronously executing kernel of software dedicated to the detection of events of interest could possibly have alleviated the problem of detecting momentary switches in C-5A PMS.

Software modularity allows for addition of functionality in phases. For example, a tutorial capability was added to the F-14 ISS after all other functionality was completed. The B-52 ARPTT ISS was delivered in two phases: the first phase provided monitoring and display functions, while the second provided measurement and training management functions. The ISS was operational after delivery of the first phase and down time was minimal for the installation of the second phase.

The above constitutes a baseline description of what fairly hi[illegible] commonalities may be carried forth into a generic architecture for an ISS. The commonalities break down, when going too far past the functional requirements of these systems, to a lower level of implementation detail.

Note that the systems represent a progression from AFTS®, which was architected in 1973 (based on studies performed since 1969), to C-5A PMS and F-14 ISSs, which were developed in 1978, to the B-52 ARPTT ISS, which was designed in 1981 and 1982. The C-5A PMS did indeed reuse pieces of the AFTS® executive control software, and the B-52 ARPTT ISS transferred the F-14 ISS software architectural concepts to a different training problem and hardware suite. These transfers were successfully accomplished but not without a great deal of additional customization and development. This again is evident in the funding required to build the production AFTS® based on work done on the prototype AFTS® (see the following discussion on cost factors).

The development of these systems has capitalized on previous lessons learned and advancements in technology, as well as focusing on the unique requirements of each of the procurements.

Cost Factors

Historical costs could not be accurately separated into the same cost elements across the four systems, since the work breakdown structure was different in every case. The significant results were in the area of relative contractor development and procurement costs and identification of cost drivers, rather than the absolute value, since only contractor costs were reviewed.

The relative costs for the AFTS® production and C-5A PMS are shown in Table 4 as points of reference. Note that the C-5A PMS and AFTS® costs do not reflect the costs associated with the research and development studies which preceded.

Table 4. Relative Development and Production Costs

Cost Category	Systems: AFTS® A-7D: 1 proto, 4 production F-4E: 1 proto, 15 production	Systems: C-5A PMS 1 research/development system
Management	7 %	9 %
Software Engineering	8 %	47 %
Hardware Engineering	6 %	32 % (engineering and procurement)
Manufacturing/ Procurement	39 %	
per unit	2 %	
Installation	5 %	4 %
Provisioning	18 %	N/A
Data	13 %	7 %
Quality Assurance	2 %	N/A
Final Contract $	9,690,928	1,237,252
Reference Year	1978	1980
Adjusted Amount in 1984 $	17,637,489	1,670,290

Software costs are identifiable as cost drivers and have traditionally been difficult to estimate. Table 5 shows the relative costs of the different software modules implemented in C-5A PMS and F-14 ISS. Estimated source lines of code figures are given to provide a frame of reference for the magnitude of the software development effort. Note that the referenced numbers contain a mix of assembler (both ISSs), FORTRAN (C-5A PMS), and DG/L (both ISSs). Comparable costs are not available for the other programs.

Table 5. Relative Software Costs

Software Category	System					
	C-5A PMS			F-14 ISS		
	SLOC/%		Cost %	SLOC/%		Cost %
Top Level Analysis/Design	N/A		14	N/A		19
Display	6,000	13	4	2,000	14	12
Real-Time Monitoring/Control	13,000	28	50	9,000	64	62
Off-line Analysis/Debrief	8,000	17	3	3,000	21	6
Scenario Generation	19,000	41	28	N/A		N/A

Life cycle costs were addressed in the B-52 ARPTT ISS. The elimination of a console operator by adding the ISS, and provision of computers supportable for a 15-year life cycle were major factors. Again, these costs reflect the objective of the ARPTT upgrade study, to upgrade an existing prototype ATD for a 15-year life cycle.

Selection of Guidelines Format

As specified in the contracted Statement of Work, selection of the Guidelines format was to be made by the Air Force. Suggested criteria for selection of a format were that it provide condensed yet comprehensive information and that it be easy to use and reference.

The Guidelines are intended to educate the reader about the instructor support capabilities, as well as to supplement other current specification guides. For this reason, the narrative format style was recommended because it can present a deeper layer of information. This format was subsequently selected. The IOS Working Group members selected the Information Mapping® layout for the visual presentation of the Guidelines.

It was felt that a single guidelines document to be used by the spectrum of individuals involved in specifying ATDs, rather than several volumes geared to separate audiences, would promote a greater degree of mutual understanding of ATD requirement specifications. To facilitate information access, tabs and an index have been included.

Computer-readable diskettes containing the Guidelines were provided to SimSPO upon submittal of the final deliverable of the ISF Guidelines. With regular on-line update, the Guidelines can serve as a repository for lessons learned to benefit all users.

The Final Product -- The ISF Guidelines

The ISF Guidelines were developed as a result of all of the efforts described. The review of ATD acquisition/specification process and instructor support feature analysis provided valuable insight into user requirements. The internal ISS comparison and the examination of hardware/software implications provided important lessons learned about the development and utilization of state-of-the-art systems. It is hoped that use of these Guidelines, written and formatted with the readers in mind, will lead to better written specifications for ISS capabilities of future aircrew training devices.

IV. CONCLUSIONS AND RECOMMENDATIONS

Front-end analysis for both student and instructor requirements is needed

To ensure instructional system performance fully supportive of the specific requirements, a comprehensive front-end analysis of instructor requirements, as well as student training tasks, must be completed. Requirements for instructional systems which are copied from seemingly similar recent procurements may at best be approximations of what is actually required. Efforts committed to proper planning, analysis, and specification of the instructional system will prevent specifications that do not meet user needs.

Instructor training is needed

There have been several documented studies, including the one conducted during Phase II of this project, which point out that instructors are not properly trained in the use of ATDs, especially in the area of instructional features. A well designed instructional system for the ATD greatly improves the potential for simulator training in many ways that are not available when using the actual aircraft. This potential will not be realized (and the features will be ignored) if minimal time has been allocated for training the instructor in the use of the instructor support features, or if the instructor infrequently uses the simulator.

The ISF Guidelines have been carefully written in user-specific terms to provide operational definitions and lessons learned. These guidelines would be a valuable tool during initial formal training to introduce the instructor to instructional features and their intended use.

Ongoing instructor effectiveness would also benefit from automated instructor support system capabilities specific to a particular ATD if they were better understood with respect to specific training objectives. Therefore, the design should include provisions for built-in instructor tutorials and help features specific to the device.

Task modules provide operational data required for the instructional system to support user needs

In order to provide user-oriented and meaningful "on-line" support, an instructional system must "know" where the student is in a training mission and to take preprogrammed action under appropriate circumstances. The <u>task module</u> (user-oriented building blocks which have been transformed into software data files) has evolved as a central concept in this regard, containing the logic, performance algorithms and criteria, displays, data recording and other actions to be taken. The task module provides a means for communication between the operational personnel and the contractor: it provides the means for operational personnel to specify precisely to what extent the

ISS is going to support the achievement of each instructional objective; and it provides the system developers with the means for controlling the system to achieve efficient and effective training.

It is important for preliminary design of an instructional system that the training objectives of a device be clearly defined early on. These objectives may be directly correlated with a list of task modules (as described above) which may then be used as part of the design criteria.

The instructional system should be kept current

An ISS uses a great deal of information specific to the training to be administered. This information includes definitions for each mission profile in the syllabus, information for each flight maneuver and procedure, together with performance measurement criteria, and definitions of each computer-generated display (including navigation, approach, and departure templates). These data must be kept current with changes in training requirements and flight procedures; otherwise, the instructional system becomes unusable or ineffective in the areas of change. This is one of the important lessons learned from the systems that have been tested in operational environments.

Consequently, instructional system design should include provision for economic and efficient update and revision. This has been successfully accomplished using the task module concept (database-driven architecture). The dynamically changing data described above are transcribed into computer files and contained in a database. The files are then used by a database-driven software while the system is in operation.

Transcribing operational data into the database files would best be accomplished by a software utility, thus preventing dependence on system specific software skills and expertise that is both costly and time-consuming. This update could then be accomplished at the field activity in parallel with any operational objective/procedure change.

Levels of automation should depend on the training objective

The state of the art in instructional systems is fully capable of providing complete automation of a training scenario, including the preprogramming of all required inputs during a session. This type of ATD control may be very effective when the instructor's presence is primarily to monitor (e.g., standardization/evaluation events or total mission-oriented events). This type of automation and control enhances standardization for evaluation purposes and relieves the instructor of non-instructional tasks during mission-type training.

However, total automation may be totally undesirable for training where the instructor should be actively involved in the training process (e.g., UPT training where motor skills are learned and reinforced). In these cases, total automation restricts the instructor's capability to tailor the session to the student's needs.

The design of the instructional system should be especially sensitive to the automated control features and provide the levels required by the training objectives specific to that device. Providing varying levels of automation that can be selected by the instructor as part of the exercise definition process provides the flexibility to cover a broad spectrum of training objectives of many ATDs.

Automated performance measurement should be designed as an aid to the instructor

In the past, performance measurement was too inflexible and rudimentary to provide meaningful feedback. For example, some performance measurement systems provide single aircraft parameters that have no meaning when presented in isolation. Such parameters should be presented in combination with other parameters and student actions to present a more complete, and therefore more accurate, evaluation of the student's performance on an objective. In other cases, performance measurement systems have provided a single score for a maneuver without any supporting data. This type of measurement is also usually ignored by instructors and students because it provides no information with respect to how the score was obtained.

State-of-the-art, automated, performance measurement technology evaluates performance by objective, taking into account all of the actions required to perform the maneuver. A review of the measurement of each action, along with the evaluation criteria, should be made available such that the student and the instructor can determine both whether a criterion was met and how it was performed.

Automated performance measurement should be designed to aid, not replace, the instructor in his evaluation of student performance.

Requirements should not be overspecified

The specification of instructional features should be based on functionality rather than technology. Within the basic instructional system architecture, use of available technology is to be encouraged by not over-specifying hardware or software components. Technology changes daily: computer hardware costs are decreasing as performance continually increases; new input and display devices are continually being introduced; software technology is on the verge of making major advances with Ada as a programming language; and artificial intelligence and other approaches are emerging. Therefore, specification of functionality and performance from a user's perspective is imperative. This will allow contractor latitude in providing SimSPO with a spectrum of alternatives that will maximize the application of current technological advances and current standards.

The Guidelines should be maintained as a dynamic document

The product of this project, the ISF Guidelines, is intended to effectively transition lessons learned and proven technology from advanced instructional systems into the operational training environment. As rapid advances in weapon systems technology occur, progress in instructional systems technology is expected. With the introduction of software-driven cockpits, tactics and procedures required to overcome new threats and adversaries cannot be predicted. Instructional systems technology will meet this challenge with innovations in hardware, software, and yet undiscovered technologies. The guidelines, too, should accommodate these changes with continued update and revision.

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Hagin, W.V., Osborne, S.R., Hockenberger, R.L., Smith, J.P., & Gray, T.H. (1982). Operational test and evaluation handbook for aircrew training devices: Operational suitability evaluation (AFHRL-TR-81-44(III), AD-A112569). Williams AFB, AZ: Operations Training Division, Air Force Human Resources Laboratory.

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APPENDIX A

TRAINING SITES VISITED

Training Device	Location	Date
AFTS A-7D	Davis-Monthan AFB	12/7/84
A-10	Davis-Monthan AFB	12/7/84, 1/30/85
ARPTT ISS	Castle AFB	1/15/85
B-52	Castle AFB	1/15/85
C-5A PMS	Altus AFB	12/12/84
C-130	Little Rock AFB	12/11/84
F-15	Luke AFB	11/15/84, 1/29/85
F-16	Luke AFB	11/15/84, 1/29/85
T-37 (T-50)	Williams AFB	11/13/84
T-38 (T-51)	Williams AFB	11/13/84

APPENDIX B

INTERVIEW GUIDE

This interview guide was used merely to guide the interview to bring out the issues and not to collect data. Because the number of instructor support features incorporated into each system varied significantly from one ATD to the next, this form was used as a general guide. The resulting data has been summarized in Section III, Results, Instructor Support Feature Analysis.

INTERVIEW GUIDE

SYSTEM LEVEL CONSIDERATIONS

Contact: ____________________ Phone: (   ) ______

Position: ______________________________

Site: ____________ ATD: ______________

1. What are the training objectives?

2. What are the specific tasks?

3. What is the performance criteria?

4. Can you provide any grade sheets or records of accomplishment?

5. Does the simulator capabilities match the stated requirements?
   a. Does it train to the objectives? ___ yes ___ no
   b. If not, what the are shortfalls? Is it because the simulator can't do it, or is it because it is not used?

6. Are there advanced instructor support features?
   If yes, do they accomplish the intended purpose?
   If not, why not?

	Yes	No
Scenario Generation	___	___
Preprogrammed Missions	___	___
ISS CONTROL FUNCTIONS		
Simulation Variables Control	___	___
Malfunction Control	___	___
Repositioning	___	___
Display Control	___	___

	Yes	No
INSTRUCTOR CONTROL OPTIONS		
Display	___	___
Scenario Changes	___	___
Mode Changes	___	___
Tutorial	___	___
Algorithms/Assessments	___	___
Grading Criteria	___	___
Data Storage & Analysis	___	___
Brief	___	___
Debrief	___	___

7. Does the course syllabus match what is actually taught?

INTERVIEW GUIDE

TASK LEVEL CONSIDERATIONS

ATTEMPT TO AUGMENT OUR COLLECTION OF REPORTS

Task listing for Simulator Training

Material for the training of instructors, Instructor Guides

Stan/Eval documents

Student guides, handouts

OBSERVE SOME TRAINING IN EACH SIMULATOR

PERFORMANCE MEASUREMENT DISCUSSIONS

In the context of the following matrix (as appropriate to the training)

	FLIGHT	PROCEDURES
NORMAL		
EMERGENCY		
TACTICAL		

Walkthrough a selected task in each category

1. Looking at fine-grained performance? End results?
2. Common errors?
3. Standards of performance?
4. Scoring/grading criteria? Forms?
5. What is included in the debrief of the task?
6. Accessibility of Performance Measurement information

Listen for:

1. Instructor workload level
2. Information not detectable by machine
3. Difficult-to-define or to-evaluate task factors
4. Uncertain, complex task sequencing
5. Out-of-the-ordinary performance measurement algorithms

COLLECT CONTACTS FOR FOLLOWUP IF NEEDED

APPENDIX C

COURSE DOCUMENTATION

A-10

IOS Manual, Upgrade Training Course (not dated)
Flight Objectives Pamphlet (8/84)
TAC Syllabus (8/84)
Gradesheet

B-52

Training Program WST Coursebook (not dated)
Console Familiarization Course (1984)
WST OIS Console Operations Guide Vol. I and II (8/84)
WST DDS Console Operations Guide (8/84)
Test Option 5 Scenario Description (not dated)

C-130

Pilot Study Guide Part I, Pilot Initial Qualification Course (10/82)
Student Study Guide Part II, Tactical Mission Qualification Training (12/82)
Instructor Guide Part II, Pilot Requalification/Upgrade Course (1/83)
Instructor Guide, Navigator Mission Qualification (12/82)
Mission Profiles I - V (not dated)
Nullmeyer, R.T., and Rockway, M.R. Effectiveness of Weapon System Trainers for Tactical Aircrew Training. In Proceedings of Interservice/Industry Training Equipment Conference and Exhibition, October 1984.
P[illegible]d Preliminary Simulator Instructor Guide for Tactical Mission Qualification Training (12/82)
Flight Simulator Operating Instructions (10/82)

C-141

SIM/CPT Instructor Guide, Pilot Initial Qualification Course (11/82)
Flight Instructor Guide, Pilot Initial Qualification Course (1/81)
Instructor Guide, Pilot Airdrop Qualification Course (11/83)
Instructor Malfunction Guide, Flight Engineer Initial Qualification Course (3/84)
Flight Instructor Guide, Navigator Airdrop Mission Qualification Course (3/83)
Task and Objectives Document, Loadmaster Airdrop Qualification Course (10/81)

F-15

Operational Training Course (10/81)
Simulator Instructor Pilot Upgrade Procedures (7/83)
Instructor Operator Guide, F-15 Simulator (7/83)

F-16

Basic Operational Training Course (1/84)
Wordstar Lesson Plans (1984)
Gradesheets
Instructor Handbook (3/82)

KC-135

Pilot WST Coursebook (1/84)
Navigator WST Coursebook (1/84)

T-37

Instrument Program (3/83 and 9/84)
Syllabus of Instruction for Undergraduate Pilot Training (T-37/T-38) (8/83)
T-50 IFS Mission Guide (3/83)

T-38

Syllabus of Instruction for Undergraduate Pilot Training (T-37/T-38) (8/83)

APPENDIX D

SYSTEMS WITH ADVANCED INSTRUCTOR SUPPORT CAPABILITIES

Automated Flight Training System (AFTS®). Developed in the late 1970's, the Automated Flight Training System (AFTS®) was installed on the Air Force F-4E and A-7D flight simulators for use by the Tactical Air Command (TAC) and the Air National Guard. This system provides the capability to run preplanned automated training sequences without interfering with existing trainer performance and allows a set of training courses to be run through with minimal instructor intervention. The AFTS® scores the aircrew on task performance, and on satisfactory score achievement; the system automatically advances the student to more difficult tasks. This automated adaptive training is provided for the following exercises: instrument maneuvers, instrument penetration/approaches, instrument departures, radar navigation, normal and emergency procedures, ground attack radar, air-to-air intercept, and weapon scoring.

F-14 Instructor Support System (ISS). The F-14 ISS was an R&D prototype developed in 1981 which "strapped on" to the F-14 Operational Flight Trainer at Miramar Naval Air Station. This system was designed to provide state-of-the-art instructor support functions in the areas of procedural monitoring, performance measurement, briefing, debriefing, graphics replay, record keeping, and instructor training via a built-in tutorial. In addition, this system provides instructor-oriented simulation control according to the training objective. The ISS was developed and tested on site in the operational environment to provide direct user feedback.

C-5A Performance Measurement System (PMS). Developed in 1982, the C-5A PMS was an R&D prototype developed to "strap on" the C-5A flight simulator. It provided such additional training capabilities as preprogrammed mission scenario design, real-time aircrew performance measurement and instructor feedback, and post-mission data retrieval and analysis. Various levels of statistical performance data were generated and recorded by the C-5A PMS during a mission. These data could then be retrieved by research personnel at any time for the purpose of performing statistical analysis.

Aerial Refueling Part Task Trainer Instructor Support System (ARPTT ISS). The Air Refueling Part Task Trainer Instructor Support System (ARPTT ISS), installed on the ARPTT simulator at Castle AFB in 1984, is an instructor support system that allows the instructor to operate the simulator with greater ease and more flexibility. Much of the technology used in the F-14 ISS design was applied in the ARPTT, including performance measurement, procedures monitoring, and record keeping. An additional feature provided curriculum managers with trainer utilization and training effectiveness data.

APPENDIX E

SYSTEMS DOCUMENTATION

AFTS®

Training Specification for AFTS for A-7D (6/77)
Training Specification for AFTS for F-4E (7/78)
Performance Specification for AFTS for A-7D (6/78)
Performance Specification for AFTS for F-4E (6/78)
Software Users Guide for AFTS for F-4E (4/79)
Program Source Listings
Grunzke, P. Evaluation of the Automated Adaptive Flight Training System's Air-to-Air Intercept Performance Measurement. AFHRL-TR-78-23. Air Force Human Resources Laboratory, Williams Air Force Base, AZ. July 1978.
AFT Program Description, 5/72
Automated Weapon System Trainer, 6/70

B-52 ARPTT ISS

Study on the Refurbishment of Aerial Refueling Part Task Trainer (ARPTT) to Extend its Life Expectancy - Technical Report (10/30/81)
Functional Design Document - ARPTT ISS (11/30/84)
Instructor Guide, B-52 Training Program Pilot BPAT (not dated)
ARPTT Training Program 5/84
Program Source Listings

C-5A PMS

C-5 Course Summary Document, Pilot Initial Qualification Course (1/82)
CPT/SIM/FLT Student Guide, Pilot Initial Qualification Course (2/81)
CPT/SIM/FLT Instructor Guide, Pilot Initial Qualification Course (1/83)
C-5 Pilot Master Task Listing (3/83)
Operations Manual - PMS for the C-5A Simulator (9/83)
System Specification (Parts I, II and III) (12/82)
Program Source Listings
Swink, T.R., Butler, E.A., Lankford, H.E., Miller, R.M., Watkins, H., and Waag, W.L. Definition of Requirements for a Performance Measurement System for C-5 Aircrew Members. AFHRL-TR-78-54. Air Force Human Resources Laboratory, Williams Air Force Base, AZ. October 1978.
Waag, Wayne L. and Hubbard, David C. The Measurement of C-5A Performance. In Proceedings of Psychology DOD Symposium, U.S. Air Force Academy, April 1984.

F-14 ISS

F-14 Instructional Support System (ISS) Final Technical Report (6/30/82)
F-14 ISS Operational Design (not dated)
F-14 ISS System Development Notebook Vol. I (not dated)
Program Source Listings
Semple, C.A., Vreuls, D., Cotton, J.C., Durfee, D.R., Hooks, J.T., and

Butler, E.A. The Functional Design of an Automated Instructional Support System for Operational Flight Trainers. NAVTRAEQUIPCEN 76-C-0096-1. Naval Training Equipment Center, Orlando, FL. January 1979.

Osborne, S.R., Semple, C.A., and Obermayer, R.W. Three Reviews of the Instructional Support System (ISS) Concept. NAVTRAEQUIPCEN 81-C-0081-1. Naval Training Equipment Center, Orlando, FL. March 1983.

Bosworth, L.K., Kryway, J.T., and Seidensticker, S.S. F-14 Instructional Support System (ISS) Weapons System Training (WST). NAVTRAEQUIPCEN 80-C-0056-1. Naval Training Equipment Center, Orlando, FL. March 1981.

APPENDIX F

INTERNAL ISS COMPARISON

This appendix presents a detailed comparison of internal ISS features among the four systems (AFTS®, C-5A PMS, F-14 ISS and ARPTT ISS). These systems were reviewed and examined under each of the following topics:

1. Task module definition
2. Actuation criteria
3. Performance measurement
4. Scoring schemes
5. Instructional support actions
6. Instructor/ISS interaction

This discussion does not compare the instructor support feature implementation of these systems; rather, it describes how training objectives were utilized as controllers and generators of information.

Task Module Definition

Although the concept of a task module is used formally with only some of these systems under investigation, it can be generalized to all of the systems by grouping together system functions which collectively meet a training objective. This has been done for each of the selected systems and the resulting sets of task modules are provided in the task commonality listing.

Format

The four systems differ in the manner of implementation: The AFTS® "task modules" are embedded in Fortran code; F-14 ISS and ARPTT ISS are data-driven by formal task modules; and, the C-5A PMS has some functions defined in a fill-in-a-form manner but many other functions are expressed as an elegant general-purpose authoring language. In each case, however, there is some means to control the decisions and actions of the ISS.

The general form of the F-14 ISS and ARPTT ISS task modules is that of (a) a header that includes identifying information, start/stop logic, and scoring factors applying to the entire task module, followed by (b) logic, algorithms and diagnostic feedback appropriate to each step or event in the task module. These shall be further amplified in a subsequent paragraph. The C-5A PMS treats specification of navigational profiles (i.e., instrument departure, enroute, holding pattern, initial approach, and ILS) with a form that resembles the task module form, but treats the remainder of specification with a block-structured language with many control and action options; the overall result resembles multiple nested subroutines which give the author detailed control over the ISS.

Flight Tasks

The flight task modules for the F-14 ISS use the following format for header information:

1. Type: normal, emergency, tactical (approach, departure,..)
2. Name: operational name for the specific module (HI TACAN ...)
3. Description: a concise summary
4. Start Conditions: the conditions which start the module
5. Stop Conditions: the conditions which stop the module
6. Performance Measurement/Scoring: a listing of the steps in the task module and weighting/scoring factors.

Each task module is further broken down into steps (measurable events) of the following format:

1. Step no.: a unique sequence number
2. Description: statement of performance requirements
3. Start Conditions: the conditions which start measurement of the step.
4. Stop Conditions: the conditions which stop the step
5. Diagnostics: immediate feedback of performance, or other instructional actions, based on measurement within the step.

Consequently, the total task module is composed of the header and any number of steps or events, and in this manner, quite general flight task modules can be specified.

For comparison, an After Takeoff Climb Task Module for the C-5A PMS consists of the following statements:

```
AFTER TAKE OFF CLIMB
    MONITOR "AFTER TAKEOFF/CLIMB" CHECKLIST
    MONITOR "ABQ-NORTON ENROUTE" ENROUTE PROFILE
    WHEN ALTITUDE > 10000
        OR MANUAL-CABIN-PRESS < -10
        OR MANUAL-CABIN-PRESS > 10 THEN
            AFTER 120 SECONDS
            ENTER MALFUNCTION 950
            MALFUNCTION TEXT: "WHEN ALTITUDE EXCEEDS 10000 FT
            MALFUNCTION TEXT: "OR MANUAL CABIN PRESS IS NOT NORM"
            MALFUNCTION TEXT: "THEN AFTER 2 MINUTES"
            MALFUNCTION TEXT: "  ENTER MALFUNCTION 950"
        WHEN M950 = "ACTIVE" THEN
            AFTER 60 SECONDS
            CLEAR MALFUNCTION 950
            MALFUNCTION TEXT: "WHEN MALFUNCTION 950 IS SET IN"
            MALFUNCTION TEXT: "THEN AFTER 1 MINUTE "
            MALFUNCTION TEXT: "  CLEAR MALFUNCTION 950"
```

The enroute profile referenced in the above would be defined through the use of a form shown in Figure F-1; the referenced checklist will be described later.

```
1234567890123456789012345678901234567890123456789012345678901234567890123

001          ENROUTE SPECIFICATION
002
003 FILENAME: [       ]$EN.NP  (UP TO 7 CHAR. RIGHT JUSTIFIED     .
004
005 ----------ENROUTE PROFILE DEFINITION---------
006
007 ENROUTE NAME: "[                    ]"  (20 CHAR)               .
008 TO - FROM DESCRIPTION: "[                              ]"  30.
009 CRUISE TEMP DEVIATION: [  ] DEG C  (-29:+29 OR "DEF")           .
010 GROUND TEMPERATURE:    [  ] DEG C  (-79:+79 OR "DEF")           .
011
012
013
014 ***********LEG DESCRIPTION TABLE***********
015
016   THERE ARE TWO PARTS TO THIS TABLE.  EACH LOOKS LIKE
017   A SEPARATE TABLE. BUT THEY EACH DESCRIBE THE SAME NUMBER
018   OF LEGS.  THE FIRST PART DEFINES THE NAVIGATION POINTS.
019   THE SECOND PART SPECIFIES ALTITUDES AND ENVIRONMENT.
020   LEGS ARE NAMED BY THEIR END POINTS.  A SINGLE START
021   POINT FOR THE FIRST LEG IS ALSO REQUIRED.
022

1234567890123456789012345678901234567890123456789012345678901234567890123
```

Figure F-1. Enroute Route Structure Definition Form Sheets (Sheet 1 of 5).

```
023   THERE ARE 5 LEG TYPES POSSIBLE IN THE FIRST PART OF THE
024   TABLE:
025
026       TYP   DESCRIPTION
027
028         1   DIRECT TO INS WAYPOINT
029         2   RADIAL TO AN OMNI NAVAID
030         3   RADIAL FROM AN OMNI NAVAID
031         4   TO AN NDB NAVAID
032         5   FROM AN NDB NAVAID
033
034   THERE ARE 4 MUTUALLY EXCLUSIVE SETS OF DATA THAT CAN BE
035   USED TO DESCRIBE THE ENDPOINT OF A LEG.  ONLY CERTAIN
036   SETS MAY BE USED FOR CERTAIN LEG TYPES:
037
038       SET   LEG TYPES       DEFINITION OF ENDPOINT
039
040         1       1           LATITUDE AND LONGITUDE
041         2   2 OR 4          NAVAID ITSELF
042         3   2 OR 3          RADIAL & DME FROM TACAN/VORTAC NAVAID
043         4   2,3,4 OR 5      INTERSECTION OF TWO RADIALS/BEARINGS
044                             FROM DIFFERENT NAVAIDS.
045
```

Figure F-1. Enroute Route Structure Definition Form Sheets (Sheet 2 of 5).

```
1234567890123456789012345678901234567890123456789012345678901234567890123

046   THE FOLLOWING SHOWS WHAT FIELDS MUST BE USED FOR EACH
047   SET, WHERE "N" REPRESENTS A DIGIT AND "X" REPRESENTS A
048   NON-DIGIT CHARACTER. "#" IN UNUSED FIELDS MAY REMAIN.
049
050 PT   SET    RADIAL     NAVAID      LATITUDE
051   TYP  NAVAID      DME       RADIAL            LONGITUDE
052
053 NN 1  1                            NN NN NN.NX NNN NN NN.NX
054 NN N  2 XXX/X
055 NN N  3 XXX/X NNN NNN.N
056 NN N  4 XXX/X NNN       XXX/X NNN
057
058 LOWER AND UPPER BOUNDS:
059
060 01 1  1       001 000.1       001 70 00 00.0S 180 00 00.0E
061 10 5  4       360 200.0       360 70 00 00.0N 180 00 00.0W
062
063 UNITS: DME IN NM, RADIALS IN DEG, LAT/LONG IN DEG MIN SEC.
064
065 NUMBER OF LEGS: [  ]  (01:10)
066




1234567890123456789012345678901234567890123456789012345678901234567890123
```

Figure F-1. Enroute Route Structure Definition Form Sheets (Sheet 3 of 5).

```
1234567890123456789012345678901234567890123456789012345678901234567890123456789012

067 PT    SET   RADIAL      NAVAID       LATITUDE
068   TYP  NAVAID      DME        RADIAL
069                                                 LONGITUDE
070 START     /         .     /              .           .
071 01        /         .     /              .           .
072           /         .     /              .           .
073           /         .     /              .           .
074           /         .     /              .           .
075           /         .     /              .           .
076           /         .     /              .           .
077           /         .     /              .           .
078           /         .     /              .           .
079           /         .     /              .           .
080           /         .     /              .           .
081                                          .           .
082 ********* LEG DESCRIPTION TABLE - SECOND PART *********
083
084   ENDPOINT NUMBERS MUST MATCH THOSE IN FIRST PART.
085   "DEFAU" IS ALLOWED IN BAROM PRESS, MEANING CARRYOVER
086   FROM PREVIOUS PROFILE. EITHER UPPER ALT LIM OR LOWER
087   ALT LIM MAY BE "NONE". BUT ONE VALUE MUST BE PRESENT.
088

12345678901234567890123456789012345678901234567890123456789012345678901234567890123
```

Figure F-1. Enroute Route Structure Definition Form Sheets (Sheet 4 of 5).

089	END	ASSIGNED	UPPER	LOWER	--WIND-		BAROM	TRANSITION	
090	PT	ALTITUDE	ALT LIM	ALT LIM	DIR	VEL	PRESS	ALTITUDE	
091									LIMIT
092	01	00000	00000	00000	001	000	28.00	00000	*LOWER*
093	10	50000	50000	50000	360	300	32.99	30000	*UPPER*
094	--	FT	FT	FT	DEG	KTS	IN HG	FT	*UNITS*
095	START								
096	01								
097									
098									
099									
100									
101									
102									
103									
104									
105									
106									

107 ABBREVIATIONS: KTS=KNOTS, PM=PERFORMANCE MEASURE

108

109 HSI COURSE SET ERROR LIMIT -PM2: [ ] DEG (00:20)

110 CDI DEVIATION LIMIT -PM3: [.] DOTS (0.01:2.00)

111 GROUND TRACK ERROR LIMIT -PM4: [.] NM (00.01:50.00)

112

Figure F-1. Enroute Route Structure Definition Form Sheets (Sheet 5 of 5).

Procedural Tasks

The F-14 ISS procedural task modules are of the following form for header information:

1. Type: Procedures task module (normal, emergency, weapons)
2. Name: Specific name (e.g, takeoff checklist)
3. Start conditions: conditions for starting the task module
4. Stop conditions: conditions for stopping the task module
5. Scoring: Measurement and scoring is done at the task module level rather that at the step level. Measurement consists of critical event measures (e.g., errors of omission or commission), mandatory measures (specific important switches or events), optional measures, and sequence measures.

The remaining parts of the task module describe the steps as follows:

1. Step no.: unique sequence number
2. Description: statement of the procedural activity
3. Contingencies: the events which must have taken place prior to the initiation of this step.
4. Events: a list of events appropriate to this step, including steps which are "correct" and those which are "incorrect"
5. Diagnostics: feedback to the instructor indicating incorrect actions

In comparison, the procedural modules definition form for the C-5A PMS is shown in Figure F-2, and a sample procedural specification for the Cruise Checklist is shown in Figure F-3. The two methods of task module specification are quite similar, although the C-5 PMS method provides a method for crew/individual measurement, and a different scheme for specifying sequences of actions. In that scheme, steps are grouped into blocks identified by BEGIN and END labels. Blocks may be nested within other blocks, and each block is delimited BEGIN SEQ ... END or BEGIN NSQ ... END to indicate whether the included steps are to be performed sequentially or in arbitrary order. When this scheme is used, one does not have to explicitly identify specific actions which must precede a specific event.

Concurrent Modules

In practice, task modules may occur in sequence, one after the other, as TAKEOFF follows TAXI, etc. However, task modules, or steps within them, may occur concurrently, in parallel or overlapping fashion. In particular, it may be desirable to define an "umbrella" task module that is active during an entire training mission; this module would continuously test for abnormal conditions which might occur at any time (e.g, crash, over-g of aircraft, navigation outside the defined gaming area).

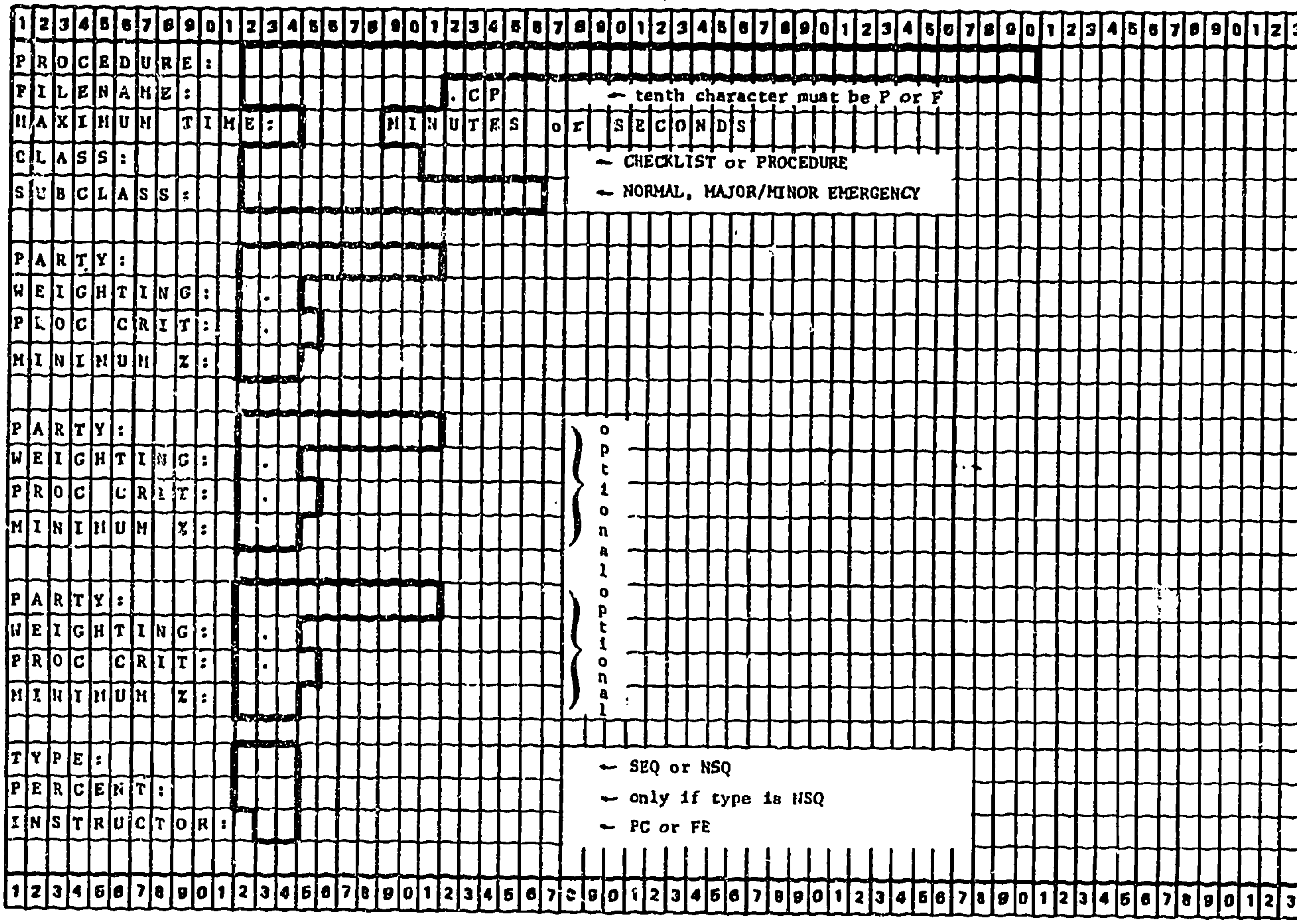

Figure F-2. Procedural Modules Definition Form (Sheet 1 of 5).

1234567890123456789012345678901234567890123456789012345678901234567890123

TO-1 PAGE:

LINK:

Up to 5 lines may be used.

DEF-STRT-1:
DEF-STRT-2:
DEF-STRT-3:
DEF-STRT-4:

STRT-TXT-1:
STRT-TXT-2:
STRT-TXT-3:
STRT-TXT-4:

DEF-STOP-1:
DEF-STOP-2:
DEF-STOP-3:
DEF-STOP-4:

AFTER: SECONDS - optional

STOP-TXT-1:
STOP-TXT-2:
STOP-TXT-3:
STOP-TXT-4:

1234567890123456789012345678901234567890123456789012345678901234567890123

Figure F-2. Procedural Modules Definition Form (Sheet 2 of 5).

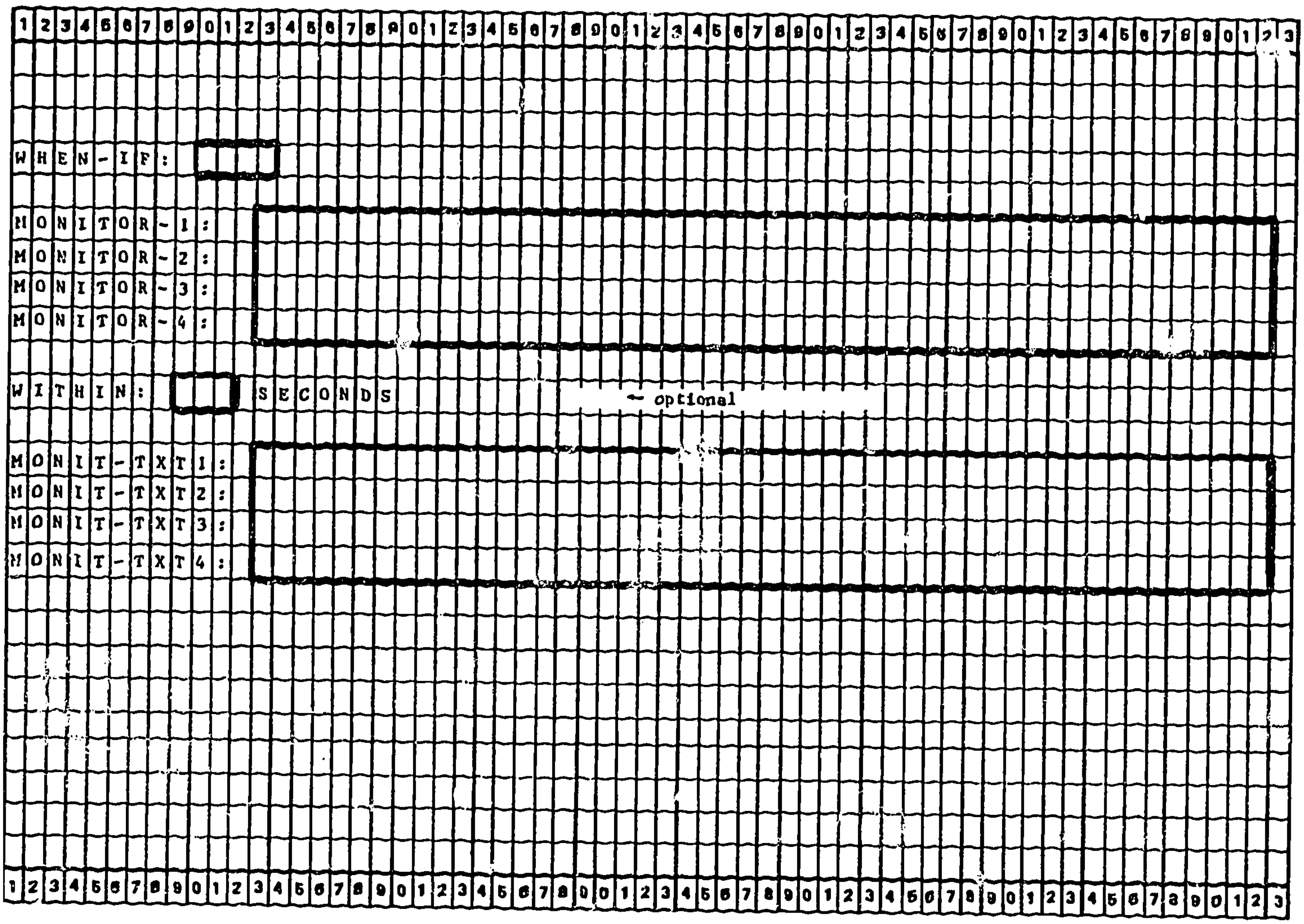

Figure F-2. Procedural Modules Definition Form (Sheet 3 of 5).

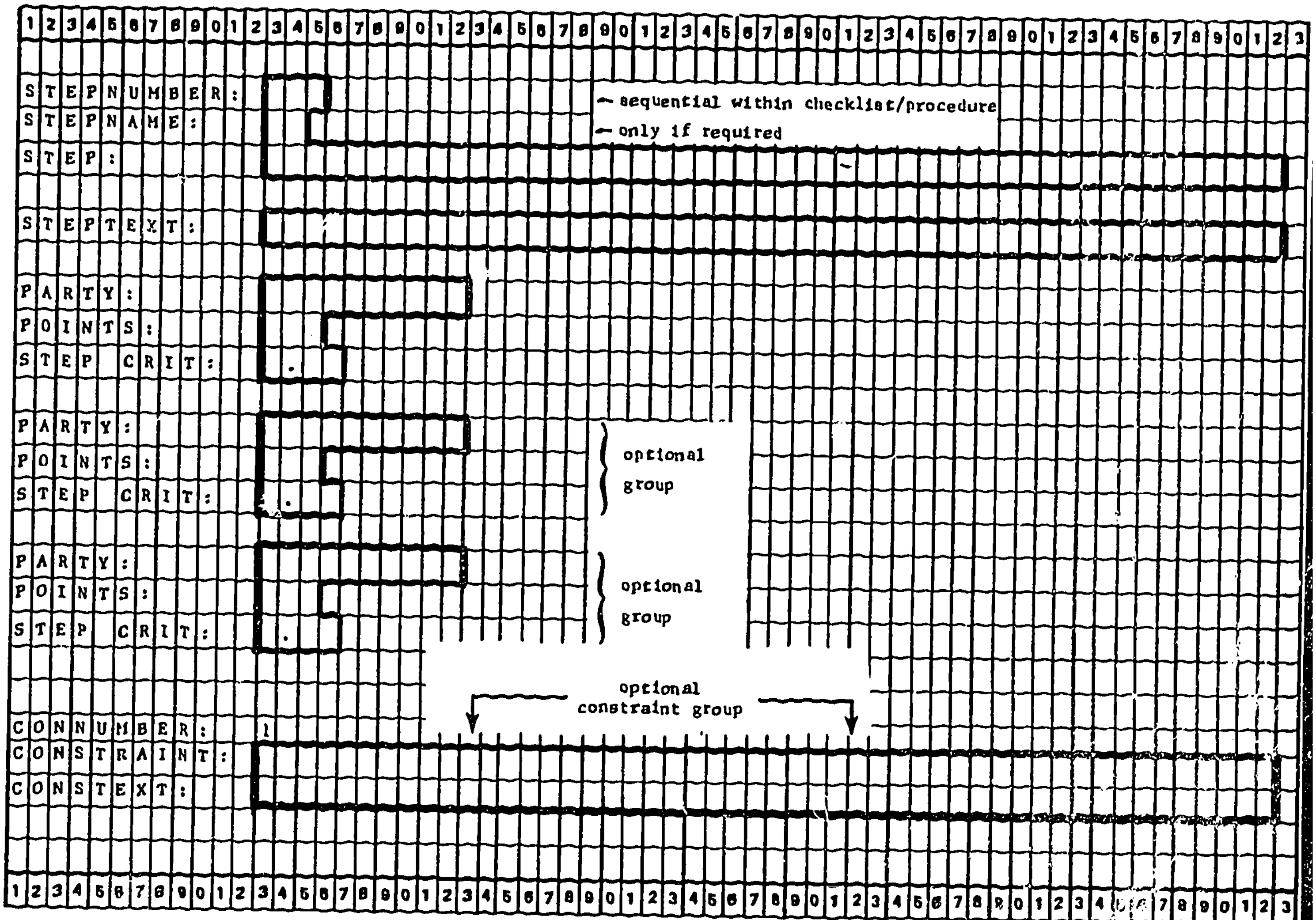

Figure F-2. Procedural Modules Definition Form (Sheet 4 of 5).

CONNUMBER: 2
CONSTRAINT:
CONSTEXT:
CONNUMBER: 3
CONSTRAINT:
CONSTEXT:
CONNUMBER: 4
CONSTRAINT:
CONSTEXT:
CONNUMBER: 5
CONSTRAINT:
CONSTEXT:
CONNUMBER: 6
CONSTRAINT:
CONSTEXT:
CONNUMBER: 7
CONSTRAINT:
CONSTEXT:
CONNUMBER: 8
CONSTRAINT:
CONSTEXT:

Figure F-2. Procedural Modules Definition Form (Sheet 5 of 5).

PILOT CHECKLIST "CRUISE   FILENAME: NC110V00\#P.CP   5/5/82 12:30:47 PAGE 1

```
PROCEDURE:     "CRUISE"
FILENAME:      NC110V00#P.CP
MAXIMUM TIME:  20 MINUTES
CLASS:         CHECKLIST
SUBCLASS:      NORMAL
PARTY:         PILOT
WEIGHTING:     1.0
PROC CRIT:     1.00
MINIMUM %:     70
PARTY:         COPILOT
WEIGHTING:     1.0
PROC CRIT:     1.00
MINIMUM %:     70
PARTY:         CREW-COORD
WEIGHTING:     1.0
PROC CRIT:     1.00
MINIMUM %:     70
TYPE:          SEQ
INSTRUCTOR:    PC
TO-1 PAGE:     2-96
DEF-STRT-1:    LINK; FROM "AFTER T/O CLIMB"
STRT-TXT-1:    "AFTER T/O CLIMB" CHECKLIST COMPLETED
DEF-STOP-1:    P-RADAR-ALT-SW="OFF"
AFTER:         300 SECONDS
STOP-TXT-1:    PILOTS RADAR ALTIMETER OFF + 5 MINUTES

STEPNUMBER:    01
STEP:          "BEGIN NSQ"
STEPTEXT:      BEGIN NSQ LANDING LIGHTS OFF

STEPNUMBER:    02 ; (LEVEL 1 )
STEP:          L-LANDING-LIGHT-SW="OFF"
STEPTEXT:      LEFT LANDING LIGHT OFF
PARTY:         PILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         COPILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         CREW-COORD
POINTS:        3
STEP CRIT:     1.00

STEPNUMBER:    03 ; (LEVEL 1 )
STEP:          NOSE-LANDING-LIGHT-SW="OFF"
STEPTEXT:      NOSE LANDING AND TAXI LIGHTS OFF
PARTY:         PILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         COPILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         CREW-COORD
POINTS:        3
STEP CRIT:     1.00

STEPNUMBER:    04 ; (LEVEL 1 )
STEP:          R-LANDING-LIGHT-SW="OFF"
STEPTEXT:      RIGHT LANDING LIGHT OFF
PARTY:         PILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         COPILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         CREW-COORD
POINTS:        3
STEP CRIT:     1.00

STEPNUMBER:    05 ; (LEVEL 1 )
STEP:          "END"
STEPTEXT:      END LANDING LIGHTS OFF

STEPNUMBER:    06
STEP:          "LEADING EDGE, AND FUSELAGE LIGHTS OFF"
STEPTEXT:      LEADING EDGE, AND FUSELAGE LIGHTS OFF

STEPNUMBER:    07
STEP:          "SEAT BELT LIGHTS: AS REQUIRED"
STEPTEXT:      SEAT BELT LIGHTS: AS REQUIRED

STEPNUMBER:    08
STEP:          "ALTIMETERS: STATE SETTINGS"
STEPTEXT:      ALTIMETERS: STATE SETTINGS

WHEN-IF:       IF
MONITOR-1:     ALTITUDE-AGL>4800
MONIT-TXT1:    IF CRUISING ABOVE 5000 FT AGL

STEPNUMBER:    09
STEP:          P-RADAR-ALT-SW="OFF"
STEPTEXT:      PILOTS RADAR ALTITUDE OFF
PARTY:         PILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         COPILOT
POINTS:        3
STEP CRIT:     1.0
PARTY:         CREW-COORD
POINTS:        3
STEP CRIT:     1.00

WHEN-IF:       IF
MONITOR-1:     MP0125
```

Figure F-3. Sample Procedure Specification.

Other Modules

Flight task modules and Procedural task modules are two examples of the task module concept, and depending on their definition, can be sufficient to define modules for training. However, the implementer may wish to create other categories of task modules to suit the purposes of a specific design. For example, in the C-5A PMS implementation, a distinction is made between checklists, procedures, navigational profiles, and aircraft parameter envelopes. Additionally, a format is specified for malfunction insertion as shown in Figure F-4.

Many of these distinctions appear to be implementation-specific and should be made at the discretion of the designer; however, at the time of specification, it may be wise to maintain independence from design details. It may be desirable, therefore, to use a simpler task module format at the time of initial specification. The following format was used in this analysis in the attempt to derive a common basis for comparison between the four selected systems:

1. Step: a unique sequence number (zero for the header, 1.. for individual steps in the task module
2. Description: text describing the task or step to be performed
3. Start logic: a concise description of the logic which can be used to identify the starting point for the task or step
4. Stop logic: a concise description of the logic which can be used to identify the stopping point
5. Measurement: specific measures to be computed
6. Scoring: a method for scoring/grading performance
7. Action: actions to be taken during the task/step (e.g., diagnostic messages to be sent to the instructor, malfunctions to be inserted
8. Comment: any comments on the above

For purposes of initial specification, the above format can be filled-in with liberal use of text which can allow a single form to suffice; whereas, later in design, a number of specific forms may be required. In fact the same form can even be used for procedural task modules by using the BEGIN SEQ - BEGIN NSQ convention of nested blocks.

Actuation Criteria

Since the basic function of the kernel ISS is to monitor and take action, the ability to respond based on criteria specified by the task module definition is of central importance. The actuation criteria for all four systems appears to be similar.

```
MALFUNCTION SPECIFICATION :=: WHEN <CHECK> THEN

                    [AFTER <number> SECONDS]

                    { <SIMPLE MALFUNCTION> }
                    { <MALFUNCTION BLOCK>  }

                    [<MALFUNCTION TEXT>]

CHECK :=: Arbitrary Boolean expression of up to four <STATE>s

MALFUNCTION BLOCK :=: BEGIN <SIMPLE MALFUNCTION>

     [WHEN <CHECK> THEN [AFTER <number> SECONDS]] <SIMPLE MALFUNCTION>

     END

SIMPLE MALFUNCTION :=:  ( {ENTER} MALFUNCTION <number>                       )
                        ( {CLEAR}                                            )
                        (                                                    )
                        ( SET MALFUNCTION <malfunction variable name>        )
                        (                                                    )
                        (    TO <value>                                      )
                        (                                                    )
                        ( FLUCTUATE MALFUNCTION <malfunction variable name>  )
                        (                                                    )
                        (    BETWEEN <value>  AND <value>                    )
                        (                                                    )
                        (    EVERY <number> SECONDS                          )
                        (                                                    )
                        ( RELEASE MALFUNCTION <malfunction variable name>    )

MALFUNCTION TEXT :=: MALFUNCTION TEXT:  text enclosed in quotes
```

Figure F-4. Malfunction Specification.

The basic structure for actuation criteria is of the form:

<simulator variable> <relational operator> <particular value>

where relational operators include equal, not equal, greater than, greater than or equal to, less than, less than or equal to, within range X,Y, outside range X,Y. More complex actuation criteria can be formed by combining such relationships into more complex logical expressions using AND, OR, NOT. Ordinarily any simulator variable can be included in such relations, including communications when the simulation includes speech generation equipment.

These actuation criteria can be thought of as the nucleus of an authoring language for the generation of task modules. Additional refinements to the basic actuation criteria structure to allow implementation of a wide range of task modules include:

1. Latch time: Latch time is the length of time a state must exist for it to be recognized. It is particularly useful for testing switch actions, to ignore intermediate positions of a rotary switch when moving from one position to another.

2. Monitor time: Monitor time is the maximum allowable time for a task module step. After the specified time,the action is taken to be incomplete.

3. WHEN and IF: A WHEN criterion causes subsequent criteria to be evaluated continuously as long as the criteria are true; the IF criterion is evaluated only once.

4. Closest point of approach: Particularly useful for navigational task modules, passage of a navigational aid (e.g. TACAN) is taken to occur when the distance to the NAVAID is at a minimum.

The author of a task module must specify actuation criteria in sufficient detail that ISS actions are triggered whenever a specific instructional situation occurs and no other. It is quite easy, for example, for a deviation and correction during straight-and-level flight to be taken as the turning segment which is to follow it. It is also difficult to anticipate all of the odd actions a student might take. Consequently, the author must define each task module with care, and the specifier of the ISS must provide for a sufficiently rich set of actuation criteria. Otherwise, unfortunate actions such as premature triggering of a task module, instructor display, or malfunction insertion may occur.

Performance Measurement

One of the instructor support features that can be triggered based on specific actuation criteria is automated performance measurement. Performance measurement can be useful to the instructors to supplement their observations when they are busy or unable to observe. It may be the instant-by-instant graphic display of a flight profile plotted against a nominal profile which is otherwise unavailable. It can also be useful to provide feedback to the student during unsupervised practice or trial ch[illegible]ides. Performance measurement can be used by the Training Manager to assess the instructional process. It can provide normative data to permit comparison of a student's performance with other previous students at the same stage of training. Performance measurement can also be used for the purposes of training research. Further, it can be used within the ISS/ATD for instructional control. Consequently, there are a number of reasons for including performance measurement in an ISS.

Flight Task Measurement

The measurement of flight tasks, as it is included in the four representative systems, depends on whether performance is to be measured over a period of time, or at a specific instant of time. If performance is to be measured over a period of time, the following should be considered:

1. Average value (an ordinary average, may use an absolute value of a parameter to treat +/- variations the same)

2. Root-mean-squared value (based on a squared value so +/- values are treated the same, an indication of variability)

3. Tolerance bands (within or outside of a specified range)

If performance is to be measured at an instant of time, then a "snapshot" is taken of the value of flight task parameters at the designated time.

Performance criteria, to be presented along with student performance, may be based on the performance of previous students. This requires that data are accumulated with each student, statistical analyses are performed, and normative performance criteria are updated at intervals.

For example, the C-5A PMS makes the following measurements during an instrument departure:

1. Correct NAVAID selected? (correctness of frequency selection)
2. Correct HSI course selected? (correctness of course on HSI with the correct NAVAID selected)
3. Centered CDI? (RMS course deviation in dots)
4. Specified ground track? (RMS ground track error in NM)
5. Specified DME arc track? (Average arc deviation error in NM)
6. Within altitude restriction? (Altitude error at checkpoint)

Procedural Task Measurement

Procedural measurement for the representative systems incorporates the following:

1. Errors of omission -- events not performed
2. Errors of commission -- unwanted events were performed
3. Constraint errors -- at specified events, flight parameters were out of tolerance (e.g., airspeed at flaps down)

Sequence errors -- events out of sequence

rcent of mandatory actions completed

6. Percent of optional actions completed
7. Time to first event -- e.g, beginning of checklist

Note that procedural performance measurement occurs largely at the task module level, and that little measurement is possible (except for errors of commission or constraint errors) at the point of each step in the procedure. Note also that flight task modules and procedural task modules, and the corresponding measurement, are not necessarily mutually exclusive; they can be intermixed, and flight tasks can constitute a step in a procedure. Further, an option to calculation of quantitative measures is the display of appropriate information for diagnosis and assessment by the instructor.

Two notational schemes have been used to denote the order in which events should occur in a procedure:

1. Grouping items into nested blocks to indicate whether the events within a block must occur in the designated order or whether order is unimportant

2. Listing items which should occur before and after each item in a procedure

It is also possible to specify constraints for each item in a procedure, i.e., conditions which must be met at the time of the event (e.g., airspeed when flaps are lowered).

Scoring

Since a large number of performance measures may be generated for various types of tasks, a number of crewmembers, many task modules, and multiple simulator sessions, a means for summarizing and scoring performance may be desired. No standard method for doing this is known; however, the methods used for some of the representative ISSs are presented in the following paragraphs.

AFTS®

The training provided by the AFTS® consisted of a series of user-defined and preprogrammed training problems with increasing levels of task difficulty. Progression in training proceeded from the simple to the complex. Difficulty was a combination of inherent operational complexity and variables such as wind and equipment malfunctions. Each task module included a point structure for determining the points to be awarded for a specified band of performance. The points awarded were then differentially weighted in accordance with assigned weights to produce a proficiency score at the end of an exercise. Based on the derived score, the AFTS® would then adapt the training so that the next exercise was at an appropriate level of difficulty and, thereby, provide individualized, self-paced aircrew training.

F-14 ISS

For each flight task or procedural task measurement, a score was assigned (in the range 2.5 to 4.0), then each score was multiplied by a weighting factor, and all weighted scores were summed to produce a score for each task module. A matrix was produced for each task module, for viewing by the instructor, the rows of which corresponded to each performance measure in the task module, and the columns included the following information:

1. Nominal Value
2. 4.0 Range (upper and lower measurement limits for this score)
3. 3.5 Range (upper and lower measurement limits for this score)
4. 3.0 Range (upper and lower measurement limits for this score)
5. 2.5 Range (upper and lower measurement limits for this score)
6. Measured Value
7. Number of Measures
8. Grade
9. Weight Factor

Using this output, the instructor could see the desired value of a specific performance measure (nominal value), the range of performance that would yield a specific grade, the measured or actual value of performance, the grade which this algorithm produced, and the weighting factor for combining each measure grade into a grade for the entire task module. An advantage of this approach is that the grading algorithm is clearly displayed, and the instructors are permitted to change Range definitions or Weight Factors to agree with their subjective standards.

C-5A PMS

The task module definitions for the C-5A PMS include the assignment of points to each step in a procedure, each parameter envelope, and each navigational profile; further, provision is made to assign the resulting performance measures to one or more crewmembers. For example, a procedure may yield all "possible points" if performed correctly, half of the "possible points" if there is a sequence violation, and no points if an omission or constraint violation occurs. Further, the earned points are multiplied by a criticality factor for each step to reflect differences in the seriousness of errors.

Based on the points produced by the previous method, five levels of proficiency assessment are derived:

1. Performance Monitorable Task Assessment -- Combination of individual scores into a single score for the performance monitorable task. There will be a separate score for each crew member/crew coordination associated with the task.

2. Performance Monitorable Task Group Assessment -- Combination of scores for all tasks belonging to the same group (procedure, navigational profile, parameter). There will be a separate score for each session.

3. Crew Member/Crew Coordination Assessment -- Combination of the summary performance scores from Level 2 for a crew member or for crew coordination.

4. Session Assessment -- Combination of the pilot, copilot, flight engineer, and crew coordination proficiency assessment score into a single score for the session.

5. Mission Assessment -- Combination of the proficiency assessment scores for both sessions.

Note that each mission of C-5A training is divided into two similar sessions; ordinarily, one student flies as pilot and the other copilot on one session, and then they reverse roles on the second session.

ARPTT ISS

Minimum proficiency levels were defined for each of the ARPTT training objectives and stored as part of the task module definitions. The ISS was then capable of assigning a grade of proficient/non-proficient. These grades could then be reviewed with the instructor during an evaluation of objectives. The instructor then had the capability to change the grade if desired. The completion of these objectives will be kept in the student's training summary and used as a reference of the student's progress. Overall class statistics were also maintained for review by curriculum managers of standardization requirements of the syllabus.

Instructional Support Actions

The ISS has a basic capability for recognizing conditions and triggering actions. Among the actions which can be triggered by the ISS are malfunction insertion/removal, initiation of displays, set-up of simulator initial conditions, communications, and recording of data. Each of the representative ISSs has this capability which differs in accordance with the specific application and not in any substantial way. Some of these features are briefly summarized below without attempt to contrast the four systems.

Malfunction Control

A number of malfunctions are ordinarily possible in a modern flight simulator, and the ISS may be required to control any of them. These include malfunctions that are controlled (in the C-5A simulator) by digital entry, control pots, pot selectors, switches, circuit breakers, and environmental inputs. Malfunction insertion and removal may be based on specific combinations of flight, environmental conditions, and time. During the time that a malfunction is active, it may also be desired to vary (gradually increase/decrease, or fluctuate) the level of specific parameters. Control of malfunctions by the ISS offers the potential of reducing the complexity of malfunction control by the instructor and the potential for freeing the instructor for other instructional duties.

Initiation of Displays

Based on actuation criteria stored as part of the task module definition, the ISS can trigger the generation of displays without direct action by any personnel. This also offers the potential for unburdening instructional personnel of operator duties and freedom for instruction. Among the types of displays that can be produced are:

1. Mission sequence displays (sequences of tasks)
2. Mission plot displays (ground-referenced graphics)
3. Route charts (displays for departure, enroute, approach plates)
4. Checklist/procedure displays (displays of predefined sequences together with time-stamped crew actions)
5. Error alert displays (messages alerting instructor to errors)
6. Proficiency assessment displays (scores/grades for specific tasks and total mission)
7. Debriefing report (data to support the debriefing period)

Recording

The ISS may be viewed as an information generator, of which some information is generated to support training-in-progress, and other information is generated to support external training processes. Among the external needs that may be supported are debriefing, development of performance norms, training management data analysis, and training research data analysis. An example of statistics accumulated by the ARPTT is shown in Table F-1. Data for these needs will depend on the specific overall training system, but will certainly include all recording of all events in a manner appropriate for debriefing, and will include all basic data used in developing grades for proficiency assessment. Specific research requirements may dictate that even greater performance measurement detail be recorded.

Table F-1. Precontact Statistics

		STUDENT TYPE			
	REQUIRE	IQP	PUP	REQUAL	TOTAL
NUMBER OF STUDENTS	XXXXXXX	3	0	0	3
AVG. TIME TO PROF.	XXXXXXX	198.7	0.0	0.0	198.7
% TIME OUT IN ALT.	0	0.0	0.0	0.0	0.0
% TIME OUT IN AZI.	0	0.0	0.0	0.0	0.0
% TIME OUT IN DIST.	0	0.0	0.0	0.0	0.0

Instructor ISS Interaction

Much of the foregoing discussion is based on preprogrammed automatic operation of the ISS. Although this mode has a number of advantages, it could provide an inflexible environment for instruction unless options for instructor interaction and override are provided. Furthermore, not all crew actions (e.g., communications, out-of-cockpit visual objects) can be automatically sensed; in such cases, the instructor must provide the needed information. Each of the four systems provides some means for deviation from fully preprogrammed and automatic operation.

AFTS®

The automated-adaptive mode is the normal mode for AFTS®; however, it does allow the instructor to control the sequence of training. Adaptive training can be modified by beginning a training session with a selection from a menu of initial conditions. For a given set of initial conditions, AFTS® can be paused with a FREEZE command, and either CONTINUE or RESET to the start for rerun.

ARPTT AND F14 ISS

Both the ARPTT and F14 ISS provide options for selecting a fully preprogrammed mode (CANNED mode), part-task training (PTT) mode, or instructor constructed sessions produced from a menu of task modules (ISSM or ISEL modes). Preprogrammed insertion of malfunctions can be modified through use of ACTIVATE/ REMOVE MALFUNCTION switches. Control of task module sequencing can be modified by selection of reposition options to SLEW TO or RADAR VECTOR TO, allowing training to begin from a new position.

C-5A PMS

The C-5A PMS provides the instructor with the capability to intervene in the pre-defined sequence of events and allows modification of the selection of checklists, procedures and malfunctions, and alteration of the selection of displays of mission information. During training, the instructor may exercise controls to STOP PMS, START, SUSPEND, CONTINUE, and SCORE. ENTER, CLEAR, START, and TERMINATE controls are provided to control the insertion and removal of malfunctions.

The preceding discussion is only exemplary and does not give a full presentation of the options for control provided for each system. It is however intended to be suggestive of types of control which the instructor may need and to be suggestive of the interaction that must be specified for each new ISS. The ISS must unburden the instructor, and may do this through the use of automation; nevertheless, the instructor must be able to conveniently override and re-direct the system.

Conclusions

A view has been taken that the ISS is a programmable controller and a generator of information, and although the four representative ISSs vary in the way they are implemented, all fit the same general model. The method of specifying the program for the ISSs varies, but the task module concept can be used for initial specification for any ISS. This implies a data-driven system, but specification in this manner still permits a large degree of design freedom. The types of actuation criteria included in an ISS determines how "smart" the ISS can be in behaving "intelligently" in controlling instructional events and features. The ISS can be the generator of a large amount of different types of information, and this capability depends on the manner in which performance measurement is implemented and the types of data recorded and displayed. Although all four of the systems provide a preprogrammed automatic mode, each provides some manner for instructor control and override, providing a degree of flexibility in use of the ISS for tailored instruction. All provide instructional support through the control of performance measurement, scoring, displays, malfunctions, communications and data recording. These four systems provide a range of examples that characterize the current technology and provide a basis for the generation of future specifications.

GLOSSARY OF TERMS

AIRCREW TRAINING DEVICE (ATD): A term that refers to synthetic training devices (simulators) used in support of aircrew training programs. These devices range from simple procedures trainers to more complex training systems.

ALGORITHM: A precise characterization of a method for solving a problem or achieving a goal, e.g., a sequence of actions terminating in a solution.

BRIEF: Review of events, objectives and procedures with aircrew and instructional staff prior to simulator session.

CHECKLIST: A series of distinct actions to be performed at discrete times.

CHECKRIDE: A mission or profile in which the computer monitors the student performance, usually from takeoff to final landing, without intervention by the instructor.

CONTINUATION TRAINING: Training conducted routinely in operational squadrons, or proficiency training conducted periodically.

CONVERSION TRAINING: Initial qualifying training for a particular type of weapon system.

DATA-DRIVEN: A system that relies on general software which acts upon a database, such that a change to the database would not affect a change to the software.

DEBRIEF: Review of event results with aircrew and instructors subsequent to simulator session.

INITIAL CONDITIONS (I.C.s): A set of conditions or starting points for each training scenario. These include variables such as airspeed, altitude, fuel load, etc.

INITIALIZATION: Initialization involves specifying, usually from the instructor/operator console, the parameters of interest and their values for positioning and configuring an ATD within a gaming area.

INSTRUCTOR SUPPORT FEATURE (ISF): Features provided by the Instructional Support System (IS) to aid the ATD instructor in conducting the training exercise.

INSTRUCTIONAL SYSTEMS DEVELOPMENT (ISD): Procedural approach to the analysis of training requirements and the development of training programs and systems.

INSTRUCTOR/OPERATOR STATION (IOS): The aircrew training device man-machine interface where active control and monitoring of training events occurs.

INSTRUCTOR SUPPORT SYSTEM (ISS): Automated system within the ATD designed to aid the instructor in performing the training function.

MISSION ESSENTIAL NEEDS STATEMENT (MENS): A statement prepared by HQ USAF to identify and support the need for a new or improved mission capability. It is normally based on one or more SONs and is prepared if the Secretary of the Air Force or Secretary of Defense must approve the need and the solution approach.

MODULARITY: Property of a system which allows individual units to be added, deleted, or modified, without affecting remainder of that system.

OFF-BOARD STATION: Instructor/operator station which is outside cockpit.

OFF-LINE: Any action not associated with active training on the simulator.

ON-BOARD STATION: Instructor/operator station which is inside cockpit.

ON-LINE: Controlled directly by a computer, usually in association with active training.

OPERATIONAL FLIGHT TRAINER (OFT): A device that dynamically simulates the flight characteristics of the designated aircraft to train flight crews in cockpit procedures, instrument flight procedures, emergency procedures, communications and navigation procedures, and includes limited mission execution.

PART-TASK TRAINER (PTT): A device which provides selected aspects of a task (fuel system operation, air refueling, radar operations, etc.) to be practiced and a high degree of skill developed independently of other mission tasks.

PERFORMANCE MEASUREMENT SYSTEM (PMS): The computer-based monitoring, recording, processing and displaying of objective, quantitative information for describing and diagnosing student performance.

PROGRAM MANAGEMENT DIRECTIVE (PMD): The official HQ USAF management directive used to provide direction to the implementing and participating commands and to satisfy documentation requirements.

PROGRAMMED MISSION SCENARIOS: Highly structured sets of events that are caused to occur automatically, under computer control.

SAMPLING RATE: The temporal frequency at which a stated variable (parameter) may be recorded or examined by an automated performance measurement system.

SCENARIO: A predefined sequence of training events used to exercise the capabilities of an ATD in a specific area of intended training usage.

SPECIFICATION: Statement describing the device to be built in terms of its functions and characteristics.

STATEMENT OF OPERATIONAL NEED (SON): A general statement of requirements prepared by one of the Air Force Major Commands.

SYLLABUS: Course of study

TASK MODULE: User-oriented building blocks that correspond to the operational training requirements which have a direct correlation to a group of files which make up the data base for a modular data base driven system.

TRAINING OBJECTIVES: Explicit statements of the goals of training including tasks to be performed, the performance standards for each task, and the conditions under which those tasks are to be performed.

TRAINING REQUIREMENTS: General statements of task performance skills required for operational proficiency.

UNDERGRADUATE PILOT TRAINING: Initial pilot flight training.

WEAPON SYSTEM TRAINER (WST): A device which provides a synthetic flight and tactics environment in which aircrews learn, develop, and improve the techniques associated with their crew position in a specific aircraft, and operate individually or as a team in the execution of simulated missions.

ABBREVIATIONS AND ACRONYMS

AAI	air-to-air intercept
AFB	Air Force Base
AFHRL	Air Force Human Resources Laboratory
AFLC	Air Force Logistics Command
AFR	Air Force Regulation
AFSC	Air Force Systems Command
AFTS®	Automated Flight Training System
ARPTT	aerial refueling part-task trainer
ASD	Aeronautical Systems Division
ATC	Air Training Command
ATD	aircrew training device
BVR	beyond visual range
CCA	carrier controlled approach
CDRL	contract data requirements list
CPT	cockpit procedures trainer
CRT	cathode ray tube
DBMS	data base management system
DO	Director of Operations
DR	Director of Requirements
DRF	Dual Role Fighter
ENET	Engineering Equipment and Training
GAR	ground attack radar
GAT	ground attack tactical
GCA	ground controlled approach
HQ USAF	Headquarters, United States Air Force
Hz	hertz
I.C.	initial condition
ILS	Instrument Landing System
I/O	input/output
IOS	instructor/operator station
IOT&E	initial operational test and evaluation
IP	instructor pilot
ISD	instructional system development
ISF	instructor support feature
ISS	Instructor Support System
KB	kilobyte

MAC	Military Airlift Command
MAJCOM	major command
MB	megabyte
MCU	malfunction control unit
MENS	Mission Element Need Statement
MIL-STD	Military Standard
OFT	operational flight trainer
OT&E	operational test & evaluation
PIDS	prime item development specification
PM	program manager
PMD	Program Management Directive
PMP	Program management Plan
PMS	performance measurement system
PTT	part-task trainer
R&D	research and development
SAC	Strategic Air Command
SECU	simulation exercise control unit
SID	standard instrument departure
SIMCERT	Simulator Certification Program
SimSPO	Simulator Systems Program Office
SLOC	source lines of code
SON	Statement of Need
SOW	Statement of Work
TAC	Tactical Air Command
TACAN	tactical air navigation
TM	task module
UPT	Undergraduate Pilot Training
WST	weapon system trainer