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FUNCTIONAL DESIGN OF AN AUTOMATED INSTRUCTIONAL SUPPORT SYSTEM FOR OPERATIONAL FLIGHT TRAINERS

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Functional requirements for a highly automated, flexible, instructional support system for aircrew training simulators are presented. Automated support modes and associated features and capabilities are described. Hardware and software functional requirements for implementing a baseline system in an operational flight training context are presented. The importance of an effective man-machine interface is discussed as it relates instructor acceptance and system utility.

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FOREWORD

This report documents the planning stage of an effort to extend automation for flying training to support for the flight instructor. Feedback is necessary for such development, and the operational training of fleet replacement pilots for the F-14A aircraft at NAS Miramar will be the context for the evaluation of software designed for instructor support. Logicon, Inc. is currently producing the described system and the first stage of implementation should be installed on Device 2F95 in February 1980.

Gilbert L. Ricard

Gilbert L. Ricard
Scientific Officer

PREFACE

The authors wish to acknowledge the assistance and cooperation of the Navy personnel who directly contributed to the study. The success of any study of this type hinges strongly on the efforts of personnel at both the program direction and operational levels who devote time and effort to provide guidance and information required. In particular, the authors wish to acknowledge the efforts of the following:

Mr. Ira Goldstein, who served as the Naval Training Equipment Center Technical Representative for the study and was instrumental in providing both short term and long term direction for the ISS development, including the identification of futher automated instructional research.

Mr. James Bolwerk, who served as Commander Naval Air Force, U. S. Pacific Fleet liaison and provided guidance regarding operational training factors to be considered for the structuring of instructional support capabilities.

LCDR William Gilchrist, LCDR George Cagell, and Mr. Victor Breddell, Jr. of Fleet Aviation Specialized Operational Training Group, Pacific Fleet, whose cooperation facilitated the observation of instruction on Device 2F95 and the interviewing of training device personnel at VF-124, NAS Miramar California.

LT Scott Launey, LT Jeffrey Punches and LCDR John Snyder, together with other Instructional Systems Development personnel and instructors at VF-124 and the authors gratefully acknowledge these individuals for making available their scarce time to answer the myriads of questions asked of them.

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SECTION I

INTRODUCTION

OVERVIEW OF STUDY

This report is the result of a study that:

- Took a global look at Instructional Support Systems (ISS), then
- Created a functional ISS design for a specific flight training simulator (F14A), and
- Tailored the design to fit a realistic budget and schedule.

The need for the study came about by the requirement to minimize the use of advanced Fleet aircraft for training and the need to maintain and preferably improve the quality of aircrew training. In spite of the minimized use of aircraft for training purposes, the current high cost and limited availability of advanced Fleet aircraft for training has greatly increased the Navy's need to rely on training simulators to reduce training costs without sacrificing operational readiness. This then requires more use of flight simulators in such a manner that the flight training standards are achieved in a cost effective manner. These objectives can be realized by the continued application of the instructional system development approach and the enhancement of the instructional capabilities of present future training simulators.

The technology of automated instructional support offers the potential for reducing the instructor's workload while providing a means for further improving the efficiency and quality of training with simulators. In particular, the ISS can be expected to:

- Standardize training
- Measure performance objectively
- Adapt the scheduling of the training tasks
- Advance the student through the curriculum according to proficiency
- Motivate the student
- Aid instructional management

This can be achieved by a system design which:

- o Provides the Instructor Pilots (IP) with automated supports that can relieve them of ancillary instructional tasks.

- o Provides automated auxiliary support by incorporating support capabilities typically not found in training simulator settings.

- o Provides an Instructional Support System (ISS) that will facilitate ongoing refining and testing.

THE AUTOMATED INSTRUCTIONAL SUPPORT SYSTEM SETTING

In any instructional setting, the instructor's primary duty is to teach, i.e., to transmit knowledge and guide the student's learning. Flight simulators offer the potential for very effective instruction because of the control that can be exercised over the training situation. However, instructor tasks that are ancillary or secondary to teaching often reduce the efficient and effective use of flight simulators. It has been estimated that approximately 20 percent of the IP's time during each simulator training session must be devoted to ancillary tasks. Automated instructional support can reduce this time by providing assistance in the performance of such antillar tasks as:

- o System initialization

- o Problem set up

- o Note taking

- o Acting as missing crewmember

- o Mission communications

Automated instructional support technology also offers the potential for enhancing the quality and for standardization of simulator training by providing IP's and training management personnel with auxiliary capabilities not previously available. Auxiliary task support can include:

- o Computer-resident syllabus to facilitate planning and standardization

- o Computer-generated pre-session briefing aids

- o Automated Replacement Pilot (RP) readiness testing

- o Automated performance measurement and scoring

- o Data files for objectively establishing quantitative performance norms

- o Automated prescription of subsequent training
- o Automated maintenance of student progress files
- o Automated performance summaries for debriefing

The general functional flow of an Automated Instructional Support System that would accomplish the foregoing purposes is shown in Figure 1.

Projects leading toward the development of effective instructional support systems have been sponsored by the Naval Training Equipment Center for some time. Early work established the feasibility of automating a syllabus for aircraft weapon system training (Leonard, Doe and Hofer, 1970; and Futas, Butler and Johnson, 1972). The concepts were demonstrated in the laboratory (Charles and Johnson, 1971; Charles, Johnson and Swink, 1972 and 1973), and later implemented in the field at Luke Air Force Base (Swink etal., 1975), and for the Greek Air Force (Butler, Langford and Futas, 1975; and Butler, Barber and Futas, 1975). Parallel automated performance measurement work was performed for the Navy during the same time frame (Vreuls and Obermayer, 1971; Vreuls, Obermayer and Goldstein, 1976; and Wooldridge, Breaux and Weinman, 1976).

Successful demonstrations also have been made of the technical feasibility of computer automated problem set up, performance measurement and control of the next exercise for selected segments of instrument flight training, Ground Controlled Approach (GCA) and TACAN approaches, Air-to-Air Intercept (AAI), and Ground Attack Radar (GAR). Automation of problem briefing, air and ground controller voice messages, problem dynamic replay, and limited instructional coaching also have been achieved. Computerized Speech Understanding Systems (SUS) have been installed in the laboratory and at an operational flying training establishment (Fuege and Grady, 1975).

These demonstrations show that it is possible to use existing hardware and software technology to automate various instructor functions. Initial applications have been shown to offer training benefits (Puig and Gill, 1975; and Brown, Waag and Eddowes, 1975).

SUMMARY

Based on the current state of ISS technology this study achieved the following objectives:

- o Developed an ISS structure and concept that has general aircrew training application to any aircraft type yet is flexible enough to be programmed to meet a specific Fleet requirement.

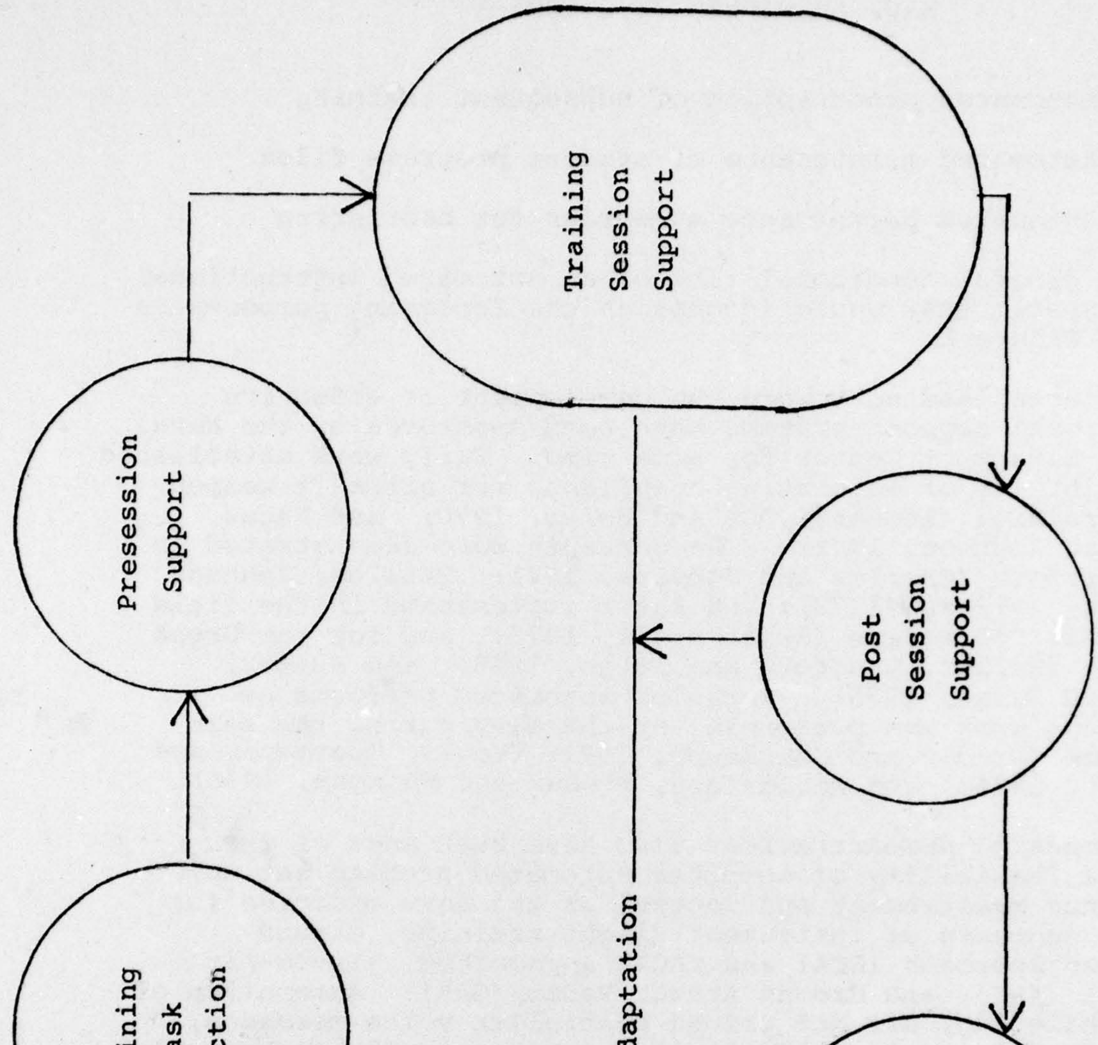


Figure 1. Flight Training Simulator Automated Instructional Support System Functional Flow

- Developed a function design for an automated ISS that could be "strapped onto" an existing F14A Operational Flight Trainer (OFT) (Device 2F95) which will enhance pilot training by more effective use of the IP.

The following definitions amplify program objectives and the type of ISS design that was pursued:

- Instructional support is providing computer assistance, through automation, for the performance of ancillary and auxiliary instructional tasks.

- Ancillary instructional tasks are those routine activities that are required simply to use training devices in present configuration.

- Auxiliary task support is providing instructors and training management with aids and information that can be used to more objectively and comprehensively ensure training quality.

- Stratification of feature automation is the structuring, of supported instructional activities into functional classes so that the classes can be ordered in a hierarchy representing a scale of support wherein each step or level can subsume all levels below it.

- An experimental ISS is one that is capable of contributing to automated instructional research, and is flexible enough to be modified to benefit from it.

- A flexible ISS is one that can be reprogrammed to modify instructional support characteristics. Flexibility also centers on providing the instructor adequate means to tailor the nature and amount of support to match individual instructional needs.

The report of the study that follows is divided into six significant parts as follows:

- A discussion of the methodological approach taken to the problem which covers analysis of the ISS requirements, the development of a specific ISS concept that will fulfill the needs uncovered by the prior analysis and a system design through which the ISS concept can be implemented.

- A description of the training environment which was used as a baseline for the ISS requirements analysis.

- A dissertation on the determining features and operational character of an optimum or "full support" ISS on which the F14A and subsequent system designs can be predicated.

- An operational description of the proposed system to show its compatibility with existing training simulators and training requirements.

- An outline of the hardware and software design which is the basis for subsequent system specifications.

- An implementation and administration plan by which the ISS can be brought into operational use.

Because of the wide ranging disciplines involved in this study it has been difficult and at times impossible to qualify and record the rationale for the numerous decisions that provided its direction. To say the least, much good judgment and experience prevailed, each individual involved realizing that the resultant ISS will require significant flexibility to accommodate tuning, modification and validation of the basic design.

SECTION II

APPROACH TO THE PROBLEM

ISSUES AND CONSIDERATIONS

The approach was intended to ensure that the ISS functional design would be responsive to the needs of both operational training and research. Key elements considered were:

- Instructional support needs, as defined from an operational training reference point, would largely provide the guidance for determining the bandwidth for automated support capabilities to be incorporated in the ISS functional design.

- The ISS design must capitalize on the strengths and compensate for the weaknesses of present instructional support system technologies, including instructional techniques, hardware and software. Therefore, the design must incorporate capabilities that enable it to be used in a research role as well as an instructional role to optimize the capitalization/compensation rationale.

- Support capabilities incorporated into the ISS objectives should not be limited by a-priori judgments of implementation difficulties and constraints. Rather, a full support system should be conceived and then any reasonable subset of capabilities could then be selected for implementation.

- ISS hardware and software designs should be based on state of the art technologies to ensure an efficient and compact system. Technology that is "advanced" state of the art could be used if developmental risks are modest.

- The ISS design should complement, rather than duplicate, instructional features of the host simulator's instructors console.

- System capabilities, as expressed through the man-machine interface, must have user acceptance and require minimal instructor training.

- The design must acknowledge that pilot training and the use of a particular flight simulator to accomplish the training are dynamic and changing. Therefore, certain instructional support capabilities must be modifiable with relative ease.

- o The ISS design must be generalizable to simulator training applications other than those characterizing a particular instructional setting or device.
- o The resulting system design, when implemented, must be transparent to the host simulator, thus not interfering with or requiring modification to the simulator's software.

METHOD

Recognizing that designing such a system was highly innovative, research necessitated venturing beyond what has been tried and proven. The methodology used is shown in simplified form in Figure 2. In the absence of implementation and operational feedback, the design process used was largely open loop and based upon best estimates. As implied in Figure 2, feedback ultimately will be required to optimize features of the system, determine their utility and acceptance, and establish guidelines for generalizing the design features to other applications.

The approach to the problem was divided into three phases:

Phase I. Analysis of Requirements and technologies

Phase II. Development of a Specific Concept

Phase III. System Design

PHASE I - ANALYSIS OF REQUIREMENTS. Figure 3 shows the Phase I tasks. Activities in the phase centered upon determining operational instructional support requirements. Parallel activities examined instructional technology that could be brought to bear on the problem, and hardware and software constraints that could affect ISS design.

Fleet Readiness Squadron (FRS) VF-124, at NAS Miramar, CA., was used as the operational training environment for establishing support requirements. Device 2F95 (F-14A OFT) was established as the candidate host simulator for an ISS implementation.

Initial activities centered upon establishing present and anticipated uses of the OFT in the FRS syllabus. Of the two OFTs at Miramar, the one selected incorporated a VITAL-2 visual system. This visual system uses point light sources to display night visual imagery which is limited to a relatively narrow forward field of view.

Both OFTs are single seat simulators. An instructor's console containing various repeater instruments and annunciators is located remotely from the cockpit.

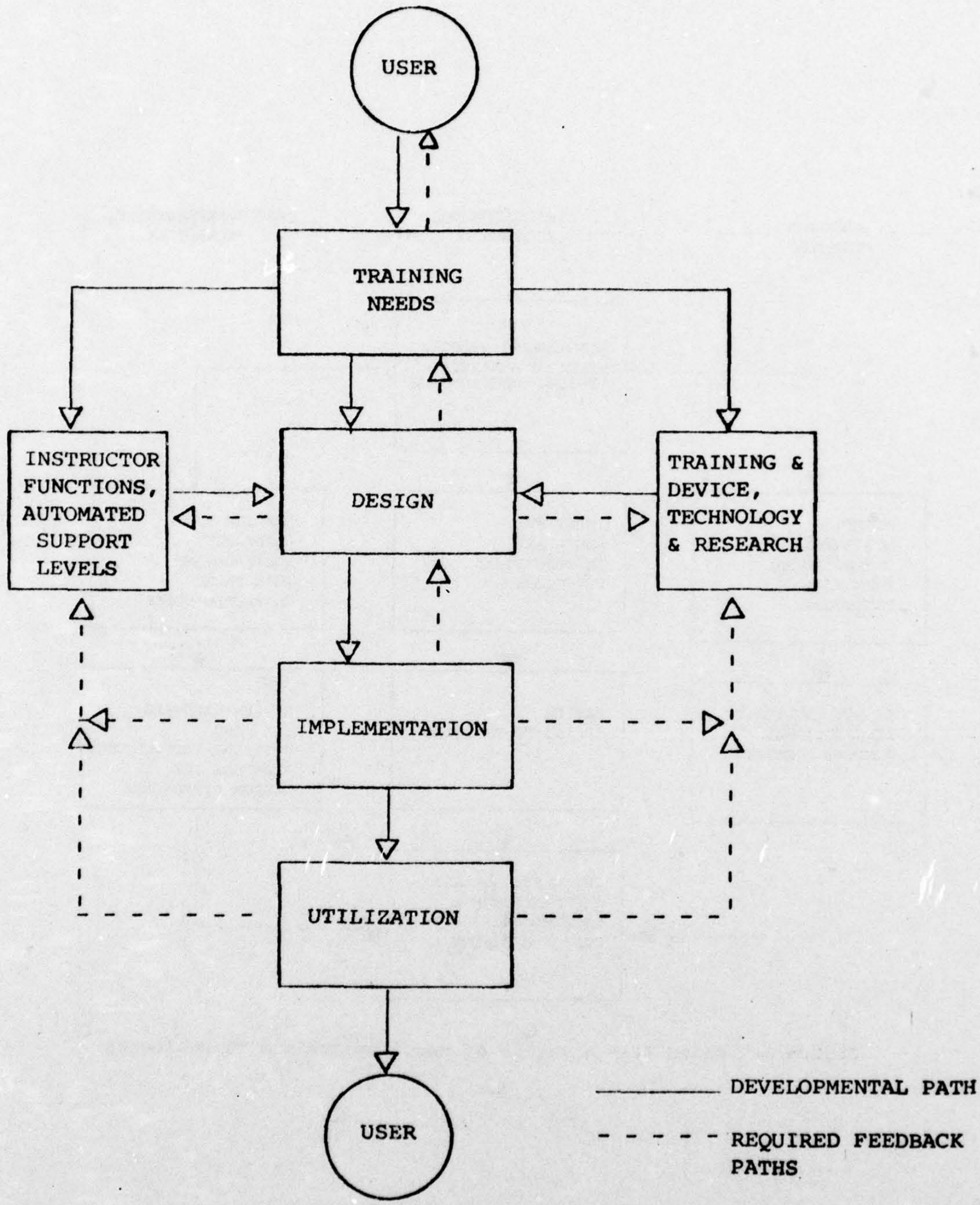


Figure 2. **Methodological Framework for Complete ISS Development and Validation**

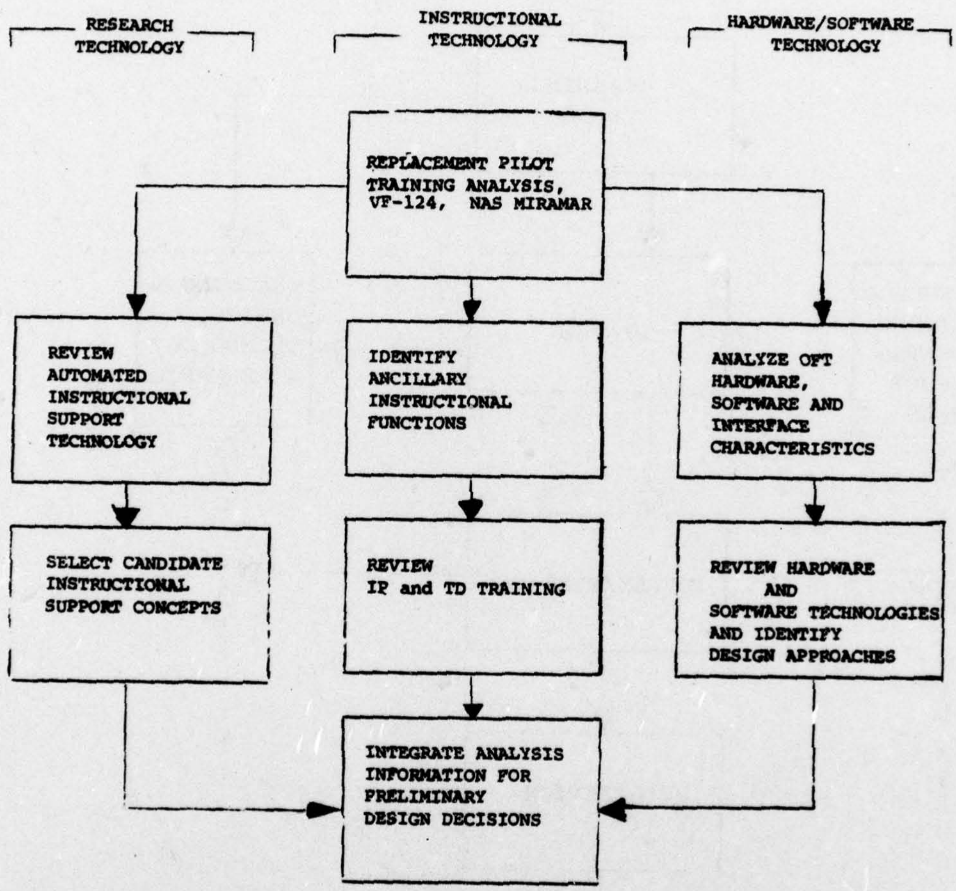


Figure 3. Phase I. - Analysis of Requirements and Technologies

Analysis of the OFT was done for Fleet Squadrons as well as VF-124. Fleet personnel typically use the OFT electronically linked to Device 15C9, the Mission Trainer, for integrated aircrew training and NATOPS checks. The linked mode enables training on tactical problems. This is not possible in a stand-alone OFT. Taken together, analysis of FRS and Fleet usage provided information on a broad sample of weapon system training tasks to which ISS design may ultimately have to be responsive.

Instructor interviews, Training Device Operator (TD) interviews, and training exercise observations were completed to identify ancillary instructional functions and provide a focus for prescribing meaningful automated instructional support.

This part of the analysis phase was concluded with a review of Instructor Under Training (IUT) syllabus materials and practices. This was done to establish the type and amount of training that IPs typically receive on the use of the OFT in the FRS program. This provided a baseline for estimating special training requirements for the effective use of the ISS.

One parallel activity examined on-going and recently completed instructional support research to assess the potential utility of recent advances in:

- Computer-resident syllabus structures
- Automated performance measurement and scoring
- Instructional man-machine interfaces
- Automated adaptive training

The main purpose of the examination was to evaluate the status of these technologies for field application. An adjunct purpose was to examine and, hopefully, benefit from lessons learned in the laboratory and from the field as they relate to system utility and system design for user acceptance.

A second parallel activity involved interviews with OFT maintenance personnel and a review of OFT hardware and software documentation. The primary objective was to establish the feasibility of a strap-on, transparent interface. A second objective was to establish the adequacy of the technical documentation of the OFT for use in later design work.

The culmination of Phase I was the integration of analysis information to establish goals and bounds for Phase II.

PHASE II - DEVELOPMENT OF A SPECIFIC CONCEPT. The goal of Phase II was to draw upon available information and experience, and develop an integrated ISS concept. The tasks involved in this iterative and largely inventive process are shown in Figure 4 and were created to:

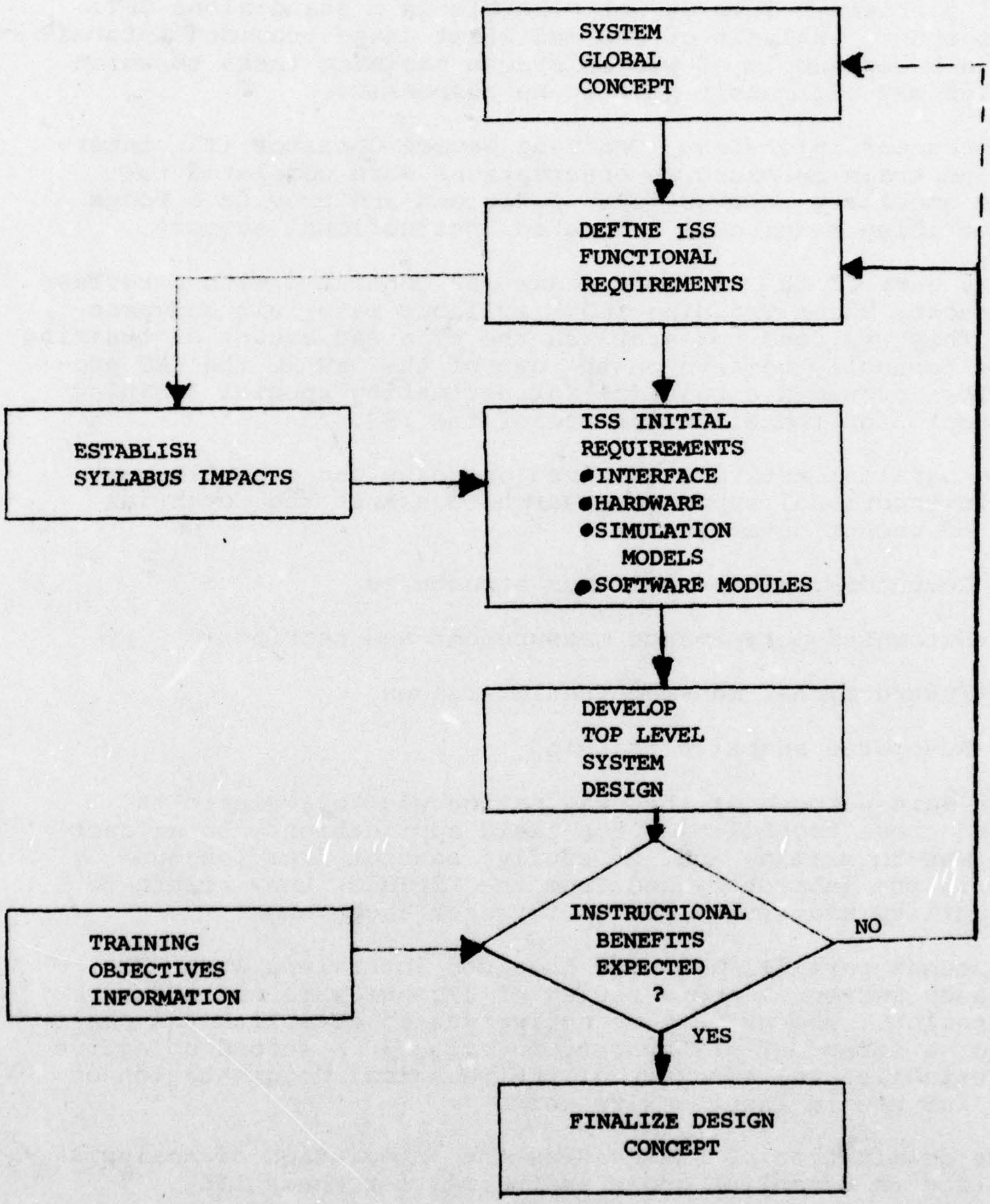


Figure 4. Phase II.-Development of a Specific Concept

- o Refine candidate automated support capabilities into a set of easily understandable modes of operation.
- o Evolve an operational system structure that organizes support capabilities hierarchically.
- o Refine requirements of research as they relate to the anticipated needs of ISS development in the field.
- o Evaluate the requirements of research on hardware and software design.
- o Evaluate alternative man-machine interface designs in terms of system utility, user acceptance, and IUT training.
- o Determine alternative programming methods to accommodate ISS software.
- o Evaluate alternative hardware configurations, considering hardware/software interdependencies and relative costs.
- o Weigh each concept against anticipated instructional support benefits and developmental risk factors.
- o Result in a "full-support" concept that eventually could be implemented.

The foregoing activities were not accomplished independent of those of Phase III. Indeed, several candidate designs had to be examined to evaluate their effectivity as an ISS.

PHASE III - SYSTEM DESIGN: Figure 5 summarizes the activites performed during the design phase. Activities in this phase centered upon translating operational system requirements into a functional system design which is the central subject of the remainder of this report.

Recommendation for the IUT syllabus were also finalized during Phase III. These recommendations could not be finalized earlier because the relative merits of system concepts incorporating resident computer assisted instruction and operator job performance aids had to be resolved first.

Following development of hardware and software requirements, a phasedimplementation plan was developed. The strategy, presented later, was developed to provide a means of obtaining user feedback reasonably early while simultaneously providing a realistic schedule for the production of the more complex software modules. Early feedback was felt to be of particular importance since many of the features of the ISS have not been subjected to the realities of operational training

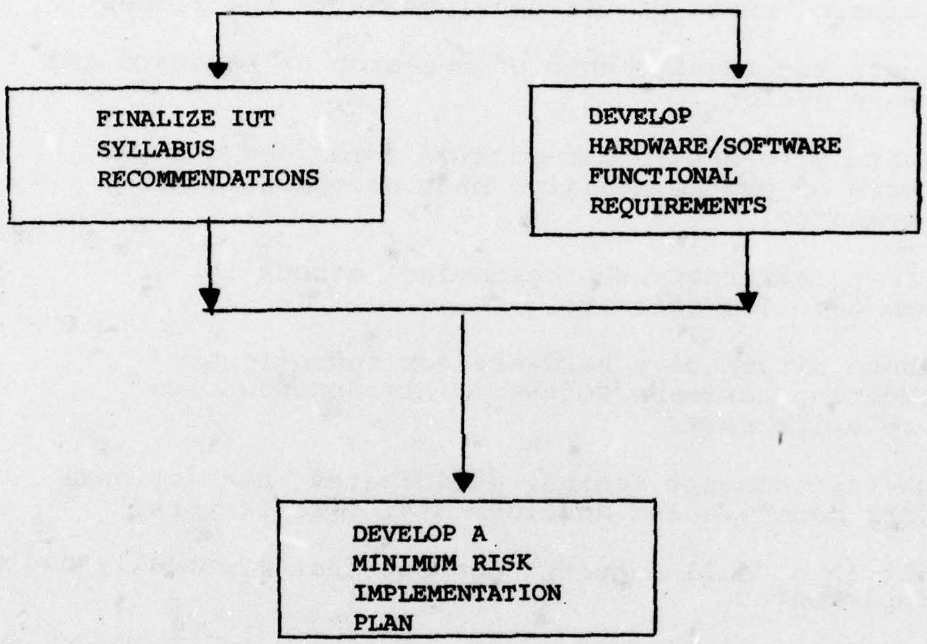


Figure 5. Phase III - System Design

SECTION III

THE TRAINING ENVIRONMENT FOR INSTRUCTIONAL SUPPORT SYSTEMS

OVERVIEW

The purpose of this section is:

- o To briefly describe the instructional environment used as the baseline for the analysis of the requirements for ISS.
- o Provide an understanding of several specific features of the ISS design which were dictated by the assumption that the prototype field implementation would be in the same training environment as that analyzed.

FRS VF-124, NAS Miramar, California, provided the training program analyzed. Replacement Pilots (RP) and Replacement Naval Flight Officer (NFO) training at VF-124 is intended to provide the skills, knowledges and attitudes necessary for an F14A Fleet assignment where aircrew members must perform proficiently in all aspects of aircraft operation, weapon utilization and mission accomplishment. Training toward these goals is provided through a 26-week course of instruction involving academic, simulator and inflight training.

SIMULATOR TRAININING APPLICATIONS

RP simulator training at VF-124 focuses almost exclusively on the use of the OFT. A procedures trainer was not available. The aircrew mission System Trainer (Device 2F112) had not been installed during the analysis timeframe.

The simulator portion of the RP syllabus has three purposes which were addressed in a minimum of eleven structured exercises. The content of each exercise is largely described in the Instructor's Briefing Guide document. Each exercise lasts from one to one and one-half hours. The three purposes are discussed below.

FLIGHT FAMILIARIZATION. This involved performance of normal procedures, takeoff and Standard Instrument Departures (SID's) from NAS Miramar. Simulated flight can be continued to an over-the-water controlled airspace, Whiskey-291. The aircraft (simulator) can then be flown and maneuvered in the warning area to enable the RP to learn aircraft responses, control techniques associated with the F14A, the use of cockpit controls and displays unique to the F14A, and to practice responses to selected failures/emergencies. Upon completion of training within the dedicated area, the aircraft (simulator) is flown to a marshal point, and thence to NAS Miramar, where various instrument approaches, final approaches, missed approaches and landings are practiced. Prescribed voice procedures are required.

AIRWAYS FLIGHT. This involves normal procedures, takeoffs and standard instrument departures from NAS Miramar. Flight is continued on various legs of specially designated airways training routes (India routes). Instrument approaches and missed approaches are performed at intermediate Air Force Bases. Fuel planning is emphasized and upon completion of the last airways leg, various instrument approaches, final approaches, missed approaches and landings are performed at NAS Miramar. A bingo fuel profile flight to MCAS Yuma can also be simulated. This training further enables the RP to learn control techniques unique to the F14A, the use of F14A cockpit controls and displays, and to practice responses to selected failures/emergencies. Prescribed voice procedures are required.

CARRIER OPERATIONS. This training centers upon launch, departure, flight to a marshal point, holding pattern, instrument approach, various final approaches, missed approaches and recovery. Normal procedures and carrier operations procedures are incorporated. Prescribed voice procedures also are required. Failures/emergencies are not incorporated.

The OFT is also used for fleet defense. This involved integrated aircrew team performance, standoff missile and short range missile launches, and tactical and electronic responses to various threats. Prescribed tactical communications are required. This application is almost exclusively for Fleet aircrew refresher training and NATOPS checks, and requires the OFT to be electronically linked with Device 15C9, the rear-seat Mission Trainer. The VF-124 syllabus does not require linked mode Fleet defense training. However, since this is likely to change with the introduction of Device 2F112, the need to incorporate aircrew training exercises into the ISS was taken into account.

OFT USAGE

Each of the two OFTs at NAS Miramar is normally scheduled to be available approximately 50 hours per week for training. A review of six weeks of OFT usage showed a relatively high overall utilization. Significantly:

- 23 percent of OFT simulator sessions were logged as scheduled RP training
- 17 percent of OFT sessions were logged as Fleet use and other miscellaneous uses
- 55 percent were logged as "extra training," wherein RPs use the OFT outside of the normal syllabus.

These findings were of particular importance in terms of incorporating ISS features that could enhance quality and standardization of instruction while making maximum productive use of "extra training" time. Typically, an IP is not present during extra training; however, with the assistance of a training device-man (TD), the RP can practice flight control, navigation, fuel management, some communication procedures, most normal procedures and a plethora of emergency procedures with no formal instruction, and with performance feedback derived almost solely from cockpit cues. It was felt that a "full support" ISS should be capable, to some extent, of compensating for the absence of an IP by providing the RP and TD with information and system control capabilities that would make possible efficient use of the extra time sessions.

RP AND IP ASSIGNMENTS

As in most FRSs, a particular student is not assigned to a particular instructor, even for sub-phases of instruction. This reflected the instructional philosophy of exposing students to both varying instructional styles and different approaches to problem solving.

One consequence of this philosophy is that a heavy administrative burden is placed on the use of simulation grade sheets to ensure continuity of training in all required areas. Although inadvertent, it occasionally happens that continuity of instruction breaks down and an RP does not receive prescribed training or achieve acceptable levels of performance on all objectives. This aspect of the instructional context is not unique to VF-124. It was felt that a full support ISS could provide useful administrative assistance to overcome this problem.

IUT TRAINING

VF-124 is not unique in that IPs generally lack training in both simulator operation and instructional methods (Charles, Willard and Healy, 1975). The training analysis performed as a part of this study showed the following. Instructors Under Training (IUT) receive rather informal training in use of the OFT, consisting largely of flying the simulator missions several times, followed by on-the-job training in console operation. An expanded IUT syllabus recently was developed at VF-124 but, to date of this document, has not been formally implemented. Even when implemented, it can be expected that heavy instructor workloads will limit expansion and formalization of IUT training.

The latter point is important in that it directly affects the conceptualization of the ISS. The assumption is that it is not realistic to count on IP training to compensate for design inadequacies of the ISS. On the contrary, an operational ISS must be designed to maximize ease and orderliness of operation if it is to be used effectively by the IP.

INSTRUCTIONAL FUNCTIONS

A significant aspect of the analysis was to establish IP and TD ancillary and auxiliary instructional functions, and to determine which of these would be candidates for automated support. The following listing summarizes the identifiable functions performed by the IP during training of an RP on the simulator. An asterisk appears by those determined to be candidates for automation.

*Review and evaluate the RP's progress to date.

*Decide upon training content of the simulator training exercise to be undertaken.

*Present a pre-session briefing covering the instructional objectives to be met and the mission plan to be used as the training medium.

*Interrogate the RP on flight control, system and operational knowledges required to enable him to benefit from the simulator exercise.

*Provide instruction in areas of RP pre-exercise knowledge weaknesses.

Provide over the shoulder instruction on cockpit controls, displays, and procedures.

Perform plane captain's role by giving hand and arm signals to RP during performance of engine start and post-start system checks.

*Perform missing crewmember role by reading NFO checklists and monitoring RP responses.

Perform missing (NFO) crewmember role by participating in problem diagnosis following system failures.

*Provide training problem control in keeping with content of the Instructor's Briefing Guide.

*Adjust training problem content in keeping with RP's observed performance.

Communicate system, procedural and operational knowledge to the RP.

*Provide coaching, cueing and performance feedback to the RP.

*Insert and/or remove, or command TD to insert and/or remove system failures.

*Vector the RP within a simulated warning area.

Interrogate the RP on system knowledge, procedures, causes and consequences of failures, flight operations, communication procedures, aircraft operations and operating limits, and NFO tasks during the training exercise.

*Take notes for performance evaluation, grading/scoring, learning problem diagnosis, and post-exercise debriefing of the RP.

*Sample and evaluate the RP's performance in the areas of system knowledge, normal procedures, emergency procedures, flight control, navigation, flight operations and voice communication procedures.

*Complete and annotate grade sheets.

*Perform the following communications:

- Mission communications
  - San Diego departure control
  - San Diego approach control
  - Airport Terminal Information Service (ATIS)
  - Beaver (search and rescue) control
  - NAS Miramar
    - Clearance delivery
    - Ground control
    - Tower
    - Approach control
    - GCA controller
    - Missed approach controller
  - Intermediate landing sites
    - Local area approach control
    - Local area departure control
    - Local area missed approach controller
    - Local area GCA controller
  - Los Angeles Center (appropriate FAA sector controllers)
- Carrier
  - Carrier Air Traffic Control Center controller
  - Marshall controller
  - Carrier controlled approach controller
  - Bolter control
  - Landing Signal Officer controller
- Instructional
  - Cueing
  - Coaching
  - Performance feedback
  - Mission instructions (e.g., NFO "slow to 320 knots.")

*Debrief the RP, summarizing strengths and weaknesses in his performance, and ascribe possible reasons for them.

*Prescribe remedial, extra and next training content.

*Perform post-exercise instructional management record keeping.

The TD assists the IP to operate the device and also performs maintenance as required. TDs do not perform instructional functions, but respond to RP requests for system initializations and failure insertions or removals during "extra time" training exercises. The functions that they perform in operating the device are listed below. An asterisk appears by functions which are candidates for automation.

Set simulator cockpit controls to appropriate positions prior to the RP's accomplishment of checks preceding takeoff.

Activate the OFT's computers, load the program tapes, and perform system readiness and safety checks.

*Complete the system initialization by entering data in keeping with the Instructor's Briefing Guide for the exercise or request by the IP which programs the:

Emergency manual insertion/removal controls
Reset control
Carrier site data
Ground site data
Aircraft environmental data

*Activate and initialize the VITAL-2 visual system.

*Respond to IP and/or RP commands to accomplish:

Ground power on/off
Ground air on/off
Remove/insert (simulated) wheel chocks
Insert/remove emergencies/failures
Operate slewing control to reposition the simulator's geographic position

Close down the simulator following training or perform maintenance.

The asterisked IP and TD functions, in conjunction with previously discussed auxiliary functions, provided the basis for deriving the organization and structure for the design of the ISS.

SECTION IV

INSTRUCTIONAL SUPPORT SYSTEM FEATURES AND CHARACTERISTICS

OVERVIEW

This section covers:

- o the development of the design concept for a "full support" ISS, and
- o the translation of the concept into a F14A OFT ISS design.

OBJECTIVES

Identifying and characterizing features of a full support ISS was not a challenging task. However, developing an integrated ISS conceptual framework to organize and implement support features proved very challenging because several design goals being pursued frequently countered each other.

A primary objective was to provide for instructional flexibility. One need for flexibility centers on being able to modify computer-resident syllabi with relative ease and no major disruption to system software, so as to keep pace with changing instructional requirements. This translated into a requirement to organize the computer-resident syllabus content in a highly modular framework. Such that, syllabus modules could be changed without disruption of the resident syllabus.

A second related objective was to develop a system structure that would accept the broadest possible spectrum of instructional decision making. One end of this continuum is characterized by the highly standardized, or canned check ride. The structure also had to accommodate automated decision making characterizing adaptive training. Finally, IP decision prerogatives at the beginning of each simulator session and during the session had to be accommodated in a manner that would enable IP's to tailor automated instructional support to daily needs as they arise.

Finally, the system structure had to be flexible enough to respond to the total spectrum of training tasks that any RP might specify for extra session training. These could cover the spectrum from canned missions through self-paced automated adaptive training, through practice on particular flight control or procedural tasks.

Concept transportability also had to be taken into account. This required anticipating the extension of ISS applications beyond the analysis reference point established in the training environment. Thus, other mission categories, crew position training devices, anticipated instructional support requirements, and integrated aircrew training applications had to be considered. Feedback will have to provide the extent to which concept transportability will have been achieved.

The requirement that the ISS also support instructional research did not prove difficult conceptually. The need to maintain automatically, data files identifying the utilization (or lack thereof) of ISS features was established to provide one type of measure of user acceptance. It also is anticipated that the utilization files will provide info_mation of value for developing and refining adaptive training logics. This information will be based upon modeling of IP instructional behaviors as reflected through the manners in which IP's call upon ISS in relation to student progress and performance.

The need to support automated performance measurement and scoring research also was recognized. Automated systems can and should measure RP performance at a finer level of task definition and, typically, using a broader spectrum of measures than is practical with a manual measurement and grading system. Creative measure analysis and definition can go a long way toward defining meaningful automated measurement. However, the need was recognized for empirical measurement research to develop minimum measure sets for various tasks, and particularly to develop scoring algorithms for evaluating task performance at finer levels than is commonly practiced in training simulations.

The need for research flexibility in automated training problem development and modification also had to be accommodated in the overall system structure. It is assumed that adaptive logics will have to be developed empirically from logics initially derived by analysis. The impact of this need had to be accounted for in software architecture. It also played a role in defining the scope and character of basic instructional units that comprise the computer resident syllabus.

A paramount goal was to develop system concepts that, hopefully, would be responsive to the previously described needs and would, at the same time, foster user acceptance. This requires that system support features had to have a high likelihood of providing meaningful instructional support in an operational training environment. Thus, the selection of support features and the characteristics of their operation had to consider the IP and the TD as the system user(s). In this content it was obvious that research capability of the ISS, although necessary, could not pace the system's conceptualization.

Finally, evolving a highly straightforward, logically organized, relatively easy to use man-system interface for IP's and TD's was considered absolutely essential for user acceptance and, therefore, ISS utility. It was recognized that the interface would have to enable IP's to obtain the type and amount of instructional support desired with considerable ease. A control-display or procedural wilderness simply had to be avoided. As a result, all candidate features, characteristics and system operational concepts had to be evaluated repeatedly for impacts on the type of man-system interfaces that might be required to exercise them.

A focus was needed from which to initiate development and analytical evaluation of an automated adaptive ISS. One point of focus that proved workable was to define and scope the modules of instruction to be accomplished and supported. The resulting "task modules" are discussed subsequently. A second point of focus was to develop a basic structure within which to organize support features and capabilities in a hierarchical manner. These subsequently became system operating modes, which are discussed below.

TASK MODULES

Task modules (TM) are individual programming units which define the training objectives in the computer-resident syllabus. They are the lowest common denominators with which instructors, system algorithms or adaptive logics can create training exercises.

The TM concept is central to ISS flexibility and growth potential. Training exercises are built by selecting and organizing TM's which represent training objectives that a student has yet to achieve. This provides flexibility for efficient self-pacing. A master listing of all TM's is maintained in a system file. Content of the file can be changed to reflect changing instructional requirements which the system is to support. Existing TM's can be modified to add or delete performance measures, change proficiency standards, or make modifications to any of the elements that define a TM. RP progress in achieving criterion performance on TM's is maintained in the system to allow for identification of objectives yet to be achieved, for planning purposes.

Three types of TM's are required:

- o Flight profile TM's, which are mission flight profile segments.
- o Procedural TM's, which are the various normal and emergency procedures that can be simulated.
- o Tactical TM's, which are tactical engagement training objectives for use in a full mission ISS.

A further characteristic of TM's is that procedural TM's, such as emergency/failure modules, can occur simultaneously with a flight profile TM or tactical TM. This can be done by associating procedural TM's to "hooks" defined in flight or tactical modules. Procedural modules also can be exercised when predetermined initiating conditions have been met. They also may be manually initiated.

Module sizing was a significant consideration. Training objectives can be specified at almost any level, ranging from macro to microscopic. Procedural TM's sized themselves; each procedure comprises a module. Flight profile modules required sizing decisions. It was decided that TM's would be sized in keeping with the manner that pilots typically view a mission. Examples of TM's sized in this manner are: takeoff, departure, individual airways legs, approach, final approach and landing. Separate modules were then established for each type of takeoff, various departures, a spectrum of airways legs, different approaches, final approaches and landings. For training exercise development based on current training practices at VF-124, a total of 88 flight profile modules were defined. Normal procedure and flight profile TM's are presented in Appendix A. Emergency/failure modules are presented in Appendix B.

Tactical modules were not defined. Conceptually, however, each tactical module would consist of an engagement. The modules would define threat types, numbers, altitudes, speeds, and additional information characterizing the threat to be coped with during the engagement. This approach to sizing is ideal for within-session adaptive problem control because subsequent threats can be selected and instituted based upon crew performance in coping with prior threats, within the session as well as during previous sessions.

The approach taken to TM sizing further defined characteristics of the modules. For example, a single module may incorporate more than one performance measure or proficiency standard. This is particularly true of flight modules, because many are made up of more than one flight segment. For example, a Seawolf-Seven standard instrument departure from NAS Miramar contains four discrete flight segments:

- Climbing right turn to 300° magnetic to intercept NKX TACAN Radial 280
- Intercept 280 radial at 2,000 ft.
- Fly outbound 280 radial at 2,000 ft. to Seawolf (NKX DME = 7 mi.)
- Climb outbound on 280 radial to W-291 boundary (NKX DME = 31 mi.)

Certainly, such fine cut flight segments can be construed as performance objectives and, hence, as training objectives. However, doing so would have extracted them from any meaningful operational context. Further, assembling training flight profiles out of such small units would be an unnecessarily burdensome human task as well as a complex machine task.

Furthermore, it was recognized that task modules also could be defined in ways that would make them too encompassing. For example, a flight module could be defined to consist of a particular departure in combination with a particular airways route. If this were the case, IP's and system algorithms could only call upon the "combined" module, even if training was required only on a portion of the module, such as the departure.

Accordingly, the following information elements were established to define a task module. The information elements were derived from an analysis of information the ISS would require to support instruction at the task module level. The resulting elements organize easily within the definition of a training objective, i.e., specification of behaviors to be trained, conditions of performance, and standards of proficiency. The additional category of system information was added to accommodate information requirements unique to automated instruction.

- System Information
  - Module entry conditions
  - Module termination conditions
  - Base data, shore
  - Base data, ship
  - Visual system data
  - Graphic display data
  - Hook definition data, for associating failure modules with flight or tactical modules
  - Controller models to be used
  - Cueing message data
  - Instructor alert message data
- Conditions Information
  - Environmental data, atmospheric and oceanographic
  - Requisite aircraft configuration data
  - Requisite aircraft systems failed
  - Aircraft initialization data
- Task Information
  - Failure module designation
  - Failure insertion conditions
  - Failure removal conditions
  - Procedural steps for coping with failure
  - Normal procedure module designation
  - Normal procedure procedural steps
  - Flight module designation
  - Flight segment(s) definition data
  - Tactical module designation

- Task Information (cont'd.)

  Threat characteristics data
  Mission communication
  Communication originator - ISS, IP or RP
  Communication initiating conditions
  Communication message content
  Communication delivery medium, display for IP or voice generation

- Measurement Information

  Performance dimension designation(s)
  Performance measures - measure start/stop conditions, parameters, desired values, transforms
  Proficiency scoring criteria data - algorithm for converting performance measures to a score consisting of one of five categories
  Algorithm designation for combining scores within a module

ISS MODES

ISS operating modes evolved out of the recognition that total system capabilities had to be organized. Initial attempts to identify ISS modes centered upon clustering various instructional support features into categories. It soon became evident, however, that this strategy was resulting in system operational structures that bore little direct relationship to operational training.

A further strategy resulted in the operating modes that are presented below. This strategy involved definition of system modes that encompassed the continuum of instructional decision making, ranging from detailed planning of the instructional content of a simulator session through relegation of training content decisions to the computer. A second element of the strategy was to conceive of modes in a manner that would provide instructors with considerable latitude to change to modes different from the one selected at the beginning of the simulator session. This was felt necessary to ensure that ISS would be a flexible, responsive support system. The following modes resulted.

COMPUTER ASSISTED MANUAL MODE. The Computer Assisted Manual (CAM) mode will require the greatest instructor involvement in planning the content of a simulator session. As with all modes, instructional content is selected from a computer resident syllabus containing all task modules.

In the CAM mode, the IP (or TD) selects individual task modules for which he desires automated instructional support. This capability allows the IP to draw upon automated support while tailoring the content presented to the RP. CAM is expected to have research utility in that automatic recording IP selection of this (or any other) mode, along with the training content (modules) selected, should provide valuable information for subsequent use in developing and refining adaptive training logics.

From a training standpoint, for example, if an RP is having difficulty adequately performing TACAN approaches, the IP can call various TACAN approach modules resident in the syllabus. This, in turn, would enable him to obtain automated measurement support for use in diagnosing the RP's performance problem.

In a different instance, an RP may wish to practice carrier landings during an "extra session." In this case, the TD could call appropriate approach or final approach modules with related voice controllers and "enable" reset to module entry conditions for repeated trials.

The CAM mode also enables the IP to request automated support in the area of procedures monitoring. For example, the mode enables him to select automated support for monitoring RP performance relative to one or more normal procedure modules. Similarly, it provides him with total flexibility for selecting individual and multiple emergencies/failures to be inserted, monitored and removed.

The CAM mode should have considerable utility for tactical training applications. Tactical engagements usually are relatively brief, and a number of engagements can be incorporated into a unit of simulator training time. The CAM mode provides the instructor with very convenient and responsive means of selecting and initializing subsequent engagements based on student prior performance.

INSTRUCTOR SELECT MODE. The Instructor Select (ISEL) mode is much like the CAM mode in terms of training content decision making. ISEL, however, will allow the IP to select from a list of total mission profiles, each profile consisting of a pre-determined structure of flight modules organized and sequenced into a meaningful mission context. Selection of the ISEL mode allows the IP to quickly and easily draw upon automated support for the flight portion of the mission, while retaining decision prerogative on, for example, emergencies that he wishes to have the student cope with.

ISEL incorporates two ways of inserting or removing emergencies. Firstly, to select emergencies from a computer generated display listing, and to specify the conditions for automatic insertion and removal. Secondly, to manually insert and remove failures via the ISS console.

Similarly, automated support in monitoring and evaluating the performance of normal procedures can be obtained by selecting normal procedure modules from a computer generated display listing.

For training in tactics, the ISEL mode would allow the instructor to select from alternatives, pre-determined sets of tactical scenarios, each scenario consisting of a series of engagements made from tactical task modules.

CANNED MISSION MODE. The CANNED mode will build upon ISEL by providing for totally pre-programmed missions and events. Thus, flight, normal procedure, emergency and tactical modules comprising a total training exercise will be specified in advance as the instructional decisions of this mode center exclusively on selecting the canned mission to be used.

In practice, it is anticipated that two categories of canned missions will be required. The first category will be missions designed to emulate present simulator training exercises and the second category will be NATOPS evaluation missions, which, should be highly standardized and objective.

A canned mission capability is desirable for several reasons as follows:

- It provides instructional personnel with easily accessible full system support to accomplish training in a highly structured version of how simulator training is presently structured.

- It provides instructional users, with a minimum training involvement opportunity, to observe a spectrum of ISS instructional support capabilities and features. This could be particularly beneficial to instructional personnel when they are first learning how to use ISS.

- It enables the RP, with the assistance of a TD, to utilize the spectrum of ISS capabilities during "extra training" sessions.

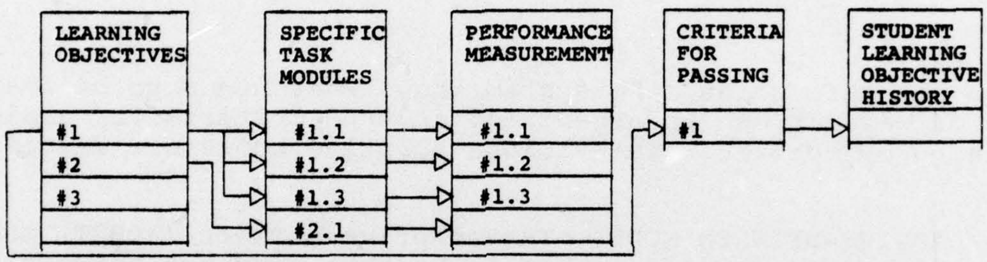
- It provides the student with the opportunity to self-test his performance capabilities, at least within the training content of the mission selected.

- When various adaptive training logics become operational, their effectiveness likely will be enhanced if training is at least started from a standardized baseline.

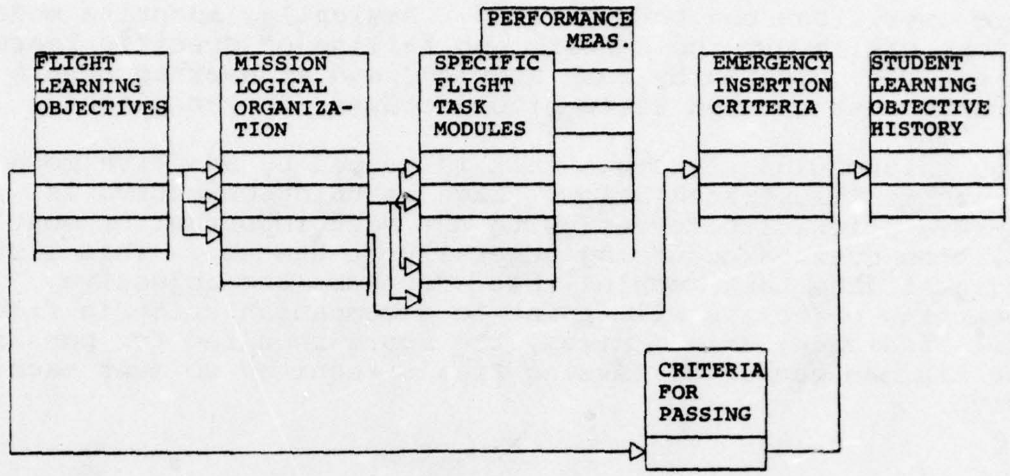
Note that ISS avoids the rigidity often associated with canned mission scenarios by building each mission from computer-resident task modules. As discussed previously, the content of any module can be altered, and new modules can be created . Similarly, algorithms that draw upon the modules to create canned training exercises can be modified. Thus, content of canned missions can be modified with relative ease. Additionally, the capability to create additional canned missions exists.

ADAPTIVE OPERATION MODES. Adaptive operation modes will be developed empirically, after sufficient data and experience have been obtained on all lower order modes. However, at this time, the envisioned functional characteristics of adaptive operations can be described. Basically, adaptive mode operations will audit the passing and failing of specific learning objectives, defined by task modules, and attempt to create missions from structured lists of objectives not yet passed.

The information structure that is needed by adaptive mode operations is illustrated below. Each learning objective is listed in a prioritized order, with the most important or most difficult objectives occurring generally at the top. This list will point to the task modules that addresses the objective. Each learning objective will point to a companion criteria file that will indicate, as a minimum, the score required for passing and the minimum number of passing trials required to meet each objective.



The minimum information set for flight and tactical modules will be similar to procedure modules, except that an additional file that organizes groupings of modules may be required for logical flight continutiy. Also, each mission organization must have associated with it a set of emergency insertion criteria that are permissible. That information set is illustrated as follows:



Thus, at this point, the system knows what needs to be learned, a number of ways it can be organized, and the criteria for achieving the learning objectives. The various adaptive modes are described below:

- ADAPTIVE-BETWEEN MODE. The adaptive-between (ADBET) mode will use adaptive training logic that operates between simulator sessions only. It accesses information identifying which training objectives have and have not been met by each RP. It derives a list of objectives that have not been passed. Next, it constructs a simulator flight profile or series of tactical engagements from lists of logical flight or tactical module organizations which reflect unsatisfied training objectives. Failure modules are attached to the resulting flight events. ADBET is hierarchical: e.g., satisfaction of failure objectives can be made more important than satisfaction of flight objectives, within limits.

  A fairly sophisticated set of rules will be required to optimize the achievement of different categories of objectives and associated task modules. For example, some flight modules (e.g., carrier operations modules) are not amenable to emergency procedure training. Thus, ADBET logic may be required to create "composite missions," such as half of a mission in a simulated warning area, followed by transition to carrier operations. This would be the case, for example, where flight objectives were being met at a rate faster than emergency objectives.

Development of rules to accomplish between session adaptation were not addressed during this study. However, the student's position in the syllabus, the required procedures which precede flight training, the number of objectives passed (or yet to go), and the limits of "normal" student progression will have to be considered in order to determine even a rudimentary set of rules.

ADBET also will require rudimentary algorithms which address alternate training time-optimal pathways through the syllabus. It is possible, for example, that some emergency or flight training objectives may be "postponed" until a later time if achievement of them is impeding student progress.

ADBET logic is not intended to be infinitely adaptive. For example, only logical groups of flight modules will need to be considered for constructing mission profiles. These groups will likely fall into the categories of flights in warning area, India routes, departures, approaches and final approaches, carrier operations and tactical exercises.

- ADAPTIVE-WITHIN MODE. The adaptive within simulator session (ADWIN) mode will do everything the ADBET mode does, only it will operate within a simulator session. Thus, real-time, or very near-real time decisions will be required. ADWIN is conceptualized to re-organize the simulator mission (if necessary) as a function of the performance achieved on the prior completed emergency, flight or tactical module. In reality, it is probable that ADWIN will operate most effectively in relation to emergency procedure and tactical objectives.

  Given prioritized lists of learning objectives, ADWIN initiates a simulator mission using ADBET logics. If a higher priority objective is not passed, it is brought up again in place of a lower priority objective later in the mission. A set of contingencies is required to reasonably distribute objectives of like priority so that one objective does not repeat to the exclusion of everything else.

  Due consideration will have to be given to the within-session change of flight modules. Only limited flight module adaptation should be permitted, within the context of the mission. For example, a substandard take-off and departure may be worthwhile repeating, at least after a certain stage of training. Certainly, approaches may be repeated in favor of some other flight modules that can be postponed until later or the next simulator session. Finally, flight maneuvers that are important for the next aircraft flight may be repeated in favor of less critical maneuvers.

ADWIN's adaptation for tactics appears quite natural, because one may, change the nature of the next tactical exercise, providing the exercise remains within a reasonable mission context.

- SELF-ORGANIZING MODE. The self-organizing (SELFORG) mode is envisioned to be upward compatible with both adaptive modes. SELFORG will perform audit trails on the operations of ADBET and ADWIN, and adjust control algorithms (algorithms which control the selection of exercises) in accordance with the probability of success that has been achieved by students passing through each of the specific exercises or individual modules. SELFORG will eventually preclude unproductive pathways and in essence, it will perform housekeeping, but cannot add new exercises.

  A SELFORG capability will have to be implemented through offline data analyses performed by a training research specialist. However, as a result of current research, ways may emerge to implement controller algorithms that can perform all or part of a normal audit trail operation.

Given the current state of the art in automated instructional support, it is likely that a first generation ISS would incorporate only CAM, ISEL, CANNED and a preliminary ADBET capability. ADWIN and SELFORG mode capabilities require additional development before meaningful operational applications can be made. In particular, methods of joint problem adaptation of flight and procedural task combinations and procedural and tactical task combinations require considerable ISS data collection before models can be developed.

SUPPORT FEATURES

The balance of this section describes other categories of ISS features many of which will be independent of mode, since support capabilities such as performance measurement and scoring, RP cueing, and use of automated voice controllers, are specified at the task module level.

The material herein is intended to simplify the presentation of support feature information and is not intended to dictate software organization of a full support ISS.

DATA FILES. A number of different data files will be required for efficient planning and accomplishment of a simulator training session. These are:

- STUDENT HISTORY FILE. A master computer-resident module file will contain a listing of all task modules that are associated with the learning objectives that RP classes are to accomplish through training in the simulation. It defines the computer-resident syllabus, and can be modified as required. As performance measurement and scoring data indicate that individual RPs have achieved criterion performance on a task module, note is automatically made of this in the master file. What results is an identification of modules on which criterion performance remains to be demonstrated. This information is maintained separately for each RP. Content of the file, when accessed by the instructor or adaptive logics, provides a basis for efficiently structuring the content of simulator sessions by providing an ability to focus on objectives yet to be mastered. The date of achievement of each module by each student also is noted to provide for assessing rate of progress.

- STUDENT AND CLASS FILE. This file will contain individual student background data and is designed to provide instructors with ready access to relevant student background information which can be useful in planning simulator training session content. Content of the file can be accessed and displayed at the class level, in addition. Summarized at the class level, content of the file provides instructional management and researchers with diagnostic information to assist in assessing differential group performance at the class level.

- MEASURES COLLECTION FILE. An automated, adaptive instructional support system will require the use of valid criteria for acceptable and unacceptable levels of student performance. Additionally, valid diagnostic measures that can pinpoint student performance deficiencies in manners that allow for attributing probable causes also are required. These requirements exist both for human interpretation of student proficiency and diagnosis of performance problems, and for automated adaptive training logics designed to accomplish the same goals.

The many advantages previously described for sizing task modules bring with them a requirement for empirical measurement research and development. The various task modules are of a rather precise nature. Each will require measuring a number of performance dimensions. Analytic, or best guess, measure analyses must provide the starting point. Empirical work will be required to modify and validate the initial best guesses, both with respect to proficiency assessment and performance problem diagnosis.

A considerable spectrum of performance standards will be required. For example, some task modules, such as flight TMs, contain more than one *measurement segment*, as described previously. Others, such as procedural TMs, require measurement and assessment of highly different dimensions of performance. The assessment of performance of a procedure, for example, requires measurement and scoring of responses, together with measurement and assessment of the occurrence of required procedural steps and the sequence of occurrence of at least highly critical stages.

The purpose of the ISS measure file is to collect data to establish objective standards of acceptable performance as well as diagnostic information at the task level.

The value of the research and development made possible by the file falls within several areas. One is to replace initial best guess performance standards with empirically derived standards. This should enhance user acceptance of ISS proficiency assessments because the number of scores that instructors or students would question should diminish, at least in theory. Results of the research hopefully should guide measure analyses for aircrew training applications beyond an initial ISS installation. The functioning of automated adaptive training logics should be enhanced through use of data provided by the measures file.

Measures data will be voluminous and will have to be recorded for off-line analyses to develop performance norms and diagnostic measure sets. Each measure will have to be highly qualified, at least in terms of the following dimensions:

- Task module designation
- Task(s) (measure segments) within the module
- Measure source (student or IP Identification)
- Date and time of day, to allow for relating performance to prior executions by the same measure source

o PERFORMANCE NORMS FILE. This file is designed to contain a current listing of performance normative data for use by scoring algorithms in scoring proficiency at the task module level. Initially, the file will contain best guess data. Content of the file can be updated with empirically derived normative data following empirical measurement research and development.

The file will have to contain two classes of normative data. One class will be quantitative breakpoints for scoring individual performance dimensions within a task module. The second class will be quantitative breakpoints for a use in developing an overall module score for use in assessing proficiency at the module level.

An intriguing alternative to developing normative data through off-line analyses and human judgements is automatic generation of norms by system software. Automatic generation of norms often is assumed in higher order, self organizing automated adaptive training structures.

The ISS concepts and functions set forth in this report do not incorporate automated norm generation for two reasons. First, the ability to do so in a system as inherently complex as ISS remains a researchable issue. As automated instructional support system applications in operational settings are in their infancy, initial user acceptance is of primary importance. The technology that can be brought to bear in operational training settings through such systems has yet to be demonstrated to instructional and training management personnel. In this context, incorporating a competitive, computer-based capability with NATOPS or other Navy standards of performance may be premature.

- INSTRUCTOR ACTIONS FILE. Its purpose is designed to automatically record significant instructor actions involving ISS. These are: modes initially selected, mode changes made during the course of a simulator session optional support features selected, and support features that normally would come into use automatically but were de-selected by the instructor. This information is amplified with instructor and student identification information, together with date and time of day. These data will provide the mechanism for relating significant instructor actions to student performance and history information.

  Over time, analysis of significant instruction actions will serve four purposes: firstly, it will objectively identify relative frequencies of ISS feature usage; secondly, it will provide a means for taking instructor actions relative to student performance into account for building or refining adaptive logics; thirdly, it will provide a quantitative source of feedback on the effectiveness of instructor training in ISS usage, and forthly, it will provide a source of feedback on ISS acceptance by instructors.

PRE-SESSION SUPPORT. ISS is conceived to provide both ancillary and auxiliary instructional support in preparation for the conduct of a simulator training session. Pre-session support centers in three areas: firstly, mission planning; secondly, computer-generated pre-session student briefing content that is based on session instructional content identified during planning, and thirdly, computer based pre-session readiness testing. The latter is intended largely to replace the pre-session interrogation of students by instructors, and is expected to have direct application during "extra session" training when an IP may not be present.

- MISSION PLANNING. From the instructional user's standpoint, ISS is organized to provide him with student performance history information, including objectives yet to be met. Displaying a list of modules on which "criterion performance is yet to be achieved" is designed to provide objective focus for session planning.

  Following a review of student performance history information, the next planning decision required will be the selection of an ISS mode of operation, ranging from CAM through various adaptive modes. In CAM, the instructional user selects one or more task modules for which instructional support is required. These are not limited to modules on which criterion performance has not been achieved. They can be any modules. In ISEL, the user selects a total flight profile or series of tactical engagements as a starting point. If he has used available planning information optimally, the selected profile or engagement will maximize opportunities to achieve criterion performance on yet unmastered task modules. The basic ISEL unit can then be amplified with procedural and/or emergency modules at the discretion of the user. CANNED mode exercises are selected in a similar manner to ISEL. If an adaptive mode is selected, system logics select modules to be incorporated into the training session.

  A mission builder function will then be called upon. The mission builder takes mission planning inputs from the instructional user (CAM and ISEL modes), algorithms for the CANNED mission plus adaptive logic which may have been selected, and creates the training exercise from the modules that have been specified.

  A mission editor function is then called upon. The mission editor checks for module-to-module compatibility. In doing so, it determines whether existing conditions for a preceding flight module, such as altitude, heading for speed, are compatible with entry conditions for the next flight module, and any discontinuities are displayed. For example if an airways leg flight module and a final approach flight module were selected, a discontinuity may exist, as the termination of the first would not necessarily have to coincide in time and space with the beginning of the second. In the event of incompatibility, the IP is required either to accept the incompatibility or modify his initial planning to eliminate it.

A second type of mission editor compatiblity check is to assess compatibilities of procedure modules, both normal procedures and emergency procedures, with flight or tactical modules in which they are to occur or which follow them. Logical inconsistencies are identified. For example, it is inconsistent to plan an engine hot-start emergency for occurrence during a flight module when both engines are anticipated to be running normally. Similarly, a no-flaps landing requires prior failing of systems that are used for operating the flaps.

In this respect, it must be noted that flight task modules identified in Appendix A as having instructional meaning in the VF-124 context, incorporate different flight module designations for situations where certain prior emergency conditions exist. Final approach is an example! different final approach modules are identified for flap versus no-flap. This is necessary because standards of acceptable flight control performance may be different for the two types of landings and such standards are contained in individual module definitions. Measurement and scoring research will also require maintaining performance measure data separately for such modules.

The mission editor also can be viewed as a training tool as it will sensitize the new ISS user to potential problems he can create while planning a mission if insufficient attention is not paid to details in the use of CAM, ISEL operating modes.

Furthermore, the mission editor function also will be beneficial in developing CANNED missions which must be completely debugged before they are made available to instructional users on a day-to-day basis. Similarly, adaptive logics may draw upon the power of this editing function.

The planning activity, which identifies the content and the sequence of the planned simulator session, provides the basis for two optional, pre-sesssion instructional supports: a computer generated pre-session briefing, and a computer-generated pre-session readiness test.

- o PRE-SESSION BRIEFING. At the ISS user's option, a computer-generated pre-session mission briefing can be requested. Content of the briefing is patterned after present instructor briefing formats, which outline the mission scenario. The computer-generated briefing identifies the normal procedure, flight and tactical task modules, in sequence, that comprise the mission plan. Emergency modules incorporated into the plan are listed separately and in alphabetical sequence to minimize student anticipation of when they are apt to occur. It is expected that the briefing will be electronically displayed and a hard copy made.

- PRE-SESSION READINESS TEST. It is a common and useful practice for instructors to interrogate students on aircraft operational limits, effects of failures and malfunctions, stimulus patterns associated with various aircraft states, operational rules, and other elements important in the context of the upcoming training session. This can be done following the mission briefing. The intent is to identify mission-critical knowledge weaknesses so that remedial instruction can be given prior to the mission. The full-support ISS incorporates this function with the objectives of standardization and providing for mission readiness testing in the absence of an instructor.

  Following receipt of the mission briefing by the student, ISS can be commanded to draw upon an item pool and develop a pre-mission test based upon the briefed mission that the student is to fly. The test is administered and scored by ISS console. A multiple choice format is anticipated.

  After the test has been taken, the instructor, if present, can review the results and provide necessary remediation prior to commencing the mission demonstration.

  The number of test items and the logic for their selection is not addressed here. It is unlikely, however, that one test item should be administered for each task module that has been planned for a simulator session. The resulting items could be both excessive and redundant.

The question of the utility of providing a pre-session demonstration of planned mission events, either in the cockpit or at an ISS console, should be answered with respect to specific ISS applications. Demonstration capabilities are not common in training simulators presently in use. Thus, there is a dearth of operational feedback on the utility of demonstrations as a function of mission task characteristics and requirements. Additionally, no directly applicable basic research is known to exist.

The utility dimensions of pre-session demonstrations involving an ISS or a training simulator must be questioned. Having a computer operate cockpit controls to demonstrate procedures has little apparent training value and would require controls that could be operated remotely. Furthermore, in the tactical training area, it must be remembered that tactical maneuvering and weapon delivery decisions must be influenced by adversary offensive and defensive actions. Demonstrating one possible way of completing a tactical exercise in a simulation could be of little practical training value. However, a capability to quickly re-set to defined initial conditions, as ISS enables, provides the opportunity to increase the number of missions conducted during a session. For these reasons, a demonstration capability is not recommended for initial ISS applications.

TRAINING SESSION SUPPORT. Many of the features and characteristics of ISS support the conduct of instruction during a simulator training session. They are intended to be of instructional value to both instructors and students. Features and characteristics directly relating to the conduct of training are described below.

- Automatic Problem Initialization. Following the completion of planning activities, the entire training program will automatically initialize. ISS monitors pertinent host simulator systems and data parameters to determine when entry conditions for the first task module have been met. From this point on, system operation can be totally automatic within the design bounds of ISS.

- Automatic Module Sequencing. Sequencing of subsequent task modules will be automatic. As above, module entry conditions data are monitored so that ISS can determine when to begin operating on the module's program. Similarly, module exit conditions are monitored so that an on-going module can be closed out when it has been complteted.

- Instructional Monitoring Information. Two CRT displays will provide the instructor-system interface through which all mission information can be called upon.

Section VI of this document addresses the physical description of ISS, including the man-machine interface. It is important to establish here, that the instructor-system interface will be built around two CRT displays.

One display is a graphics display that allows monitoring, in real time, of the following: cross-country flight path history, flight path history within a simulated warning area, approach and final approach profiles, and tactical flight history. This capability is provided to allow monitoring of mission progress relative to the mission plan. Content of the display is defined largely by the definition of the flight or tactical module that is active at the time.

A touch panel alphanumeric display is provided for instructor command of ISS and for ISS display of instructional monitoring and other information. Using the display, the instructor can review task modules comprising the session plan and receive information regarding which modules have and have not been performed to criterion. Also at his option, he can review performance scores on completed modules, and request more detailed diagnostic measurement information on completed modules.

Instructors also will be able to participate in scoring student performance through the man-machine interface. Scoring of student communication protocols and performance is assumed to be manual, pending further development of computer speech understanding system technology. A scoring format is displayed upon instructor request. He may then identi-y the communication module and enter a score. The instructor-generated score is used to assess the student's achievement of criterion performance.

For research purposes, and to facilitate initial refinement of scoring criteria, instructors also will be provided with the option of overriding computer-generated scores. These data will enter the student's file for the module scored. This feature is intended only for use during the initial period of ISS operation.

A limited inter-instructor memorandum capability also is provided. This uses a fixed format display field. Instructors can designate comments that apply to student performance or attitude. These comments can be called up subsequently only by instructors.

- <u>Synthesized Instructor</u>. The ISS will incorporate a computerized voice generation system. This capability is used in two ways, one of which is to relieve the instructor from many routine instructional communications, as discussed below.

  If enabled from the ISS console, computer-generated evaluation feedback voice messages can be transmitted to the host simulator cockpit and to the ISS console. This relieves the instructor of having to provide feedback. Also, auditory display of the messages at the console capitalizes on the voice generation system as a supplement to the electronic displays. Presenting this feedback to the cockpit also provides the student with knowledge of results information during unsupervised "extra session" training.

  Student prompting messages also are available if the capability is enabled from the console. Prompting messages are initiated by failure to respond within a predetermined time to insertion of an emergency, failure to make major required flight path changes, and similar events.

  A full support ISS will incorporate the option for a <u>brief</u> in-cockpit mission summary <u>briefing</u> using the voice generation system. Its primary <u>purpose</u> is to provide a synopsis of the content of CANNED missions during unsupervised "extra training."

An additional use of computer-generated voice messages is to alert both the student and the instructor to near real time changes in session training content resulting from operation of within-session adaptive training logics (ADWIN). In this case, the task module selected by the computer would be announced shortly prior to initiation. This use of the voice generation system also is selectible from the console. For example, advising the student of an upcoming emergency or the nature of the next tactical threat could prove counterproductive if the voice generation to the pilot was not curtailed.

Use of the voice generation system for delivery of coaching messages was considered but not adopted. Although technologically possible, considerable difficulties can be anticipated in achieving agreement among instructors on content of specific messages that should be associated with specific RP performance events. The position is taken here that coaching is highly individualistic and best left to instructional personnel.

When enabled, computer voice generated messages are not transmitted when other communication channel activity is sensed.

- <u>Synthesized Mission Communications</u>. A practical and demonstrated use for computer-generated voice messages is in the delivery of routine, predictable mission communications. This is particularly true when time is of the essence in delivering the message, such as during a ground controlled approach (GCA). The capability need not be limited to time critical messages, however. The ISS will incorporate computer speech generation capabilities for mission-related controllers identified below, the controller models and voice generation being selectible from the ISS console.

  - Departure controller
  - Vectoring RP within warning areas
  - FAA enroute controllers
  - Approach controller
  - GCA controller
  - Missed approach controller
  - Carrier air traffic controller center

    CCA controller
    LSO controller
    Bolter control

Voice generation capability also has potential for emulation of tactical communications. Applications include direction of air intercepts and direction of ground attacks involving mapping radar. In each case, controller models and computer generated voice messages are used to emulate a missing crewmember. A full support ISS incorporates missing crewmember simulation for cases where adequate crewmember models are practical. Specific ISS application decisions are required for more precise definition of required capabilities in this domain.

o <u>Instructional Intervention</u>. A primary theme through the ISS conceptualization is one of flexibility. A significant aspect of system flexibility is avoiding irreversible instructional decision making. One facet of such an avoidance is to incorporate capabilities allowing for instructional intervention during the course of a simulator training session. It can be argued, and wisely, that allowing too much flexibility may work counter to standardization of instruction. It also can be argued that system flexibility is required to achieve user acceptance. Additionally, instructional intervention flexibility also is viewed as essential for obtaining feedback for use in the design of future ISS-like systems. The following paragraphs briefly summarize additional system characteristics that are incorporated to enhance the flexibility of ISS.

Any ISS-supported training session can be terminated at any point in time. Neither the student nor the instructor is committed to consuming valuable simulator time simply to satisfy a computer-resident plan.

Any ISS-supported session can be stopped temporarily through operation of a freeze function. This capability is required to provide for uninterrupted instructor-student didactic communication.

Within the bounds previously described, instructional users can change from one ISS mode of operation to others, although doing so can involve session replanning.

A reset capability also provides ISS users with the option of establishing simulation parameters at the entry conditions of designated flight or tactical modules during all but NATOPS or other similar check missions. This enables, for example, skipping part of a CANNED exercise as well as resetting to a completed module for repeated trials. Similarly, on-line instructional intervention is allowed for inserting emergencies not initially planned.

o Instructional User Aids. Two types of user aids will be incorporated into ISS to enhance using the system to its full capability to support instructional tasks. One type of aid is alerting messages and the second type is a set of on-line procedural aids designed to provide ready access to decision and procedural requirements for efficiently operating an ISS.

The first category of aids when enabled by the instructor will present alerting messages involving mission centered training events. In addition to the student prompting messages described previously, the ISS can advise the instructor the following typical information:

- Next scheduled task module
- Low fuel
- Exceed flight envelope
- Scheduled training time exhausted
- Occurrence of failure

The second category of aids can be accessed by the instructor (or TD) at any time to provide information on ISS operation. This capability is intended to complement formal IP and TD training in ISS usage by minimizing the need for these users to rely upon long term memory for detiled decision sequences or operating procedures. Specific aids should be tailored to a finalized ISS design. The following categories of aids represent the types that are intended:

- How to select system operating modes
- How to plan a session using each mode
- How to access student history information
- How to modify a session plan during a session
- How to access performance diagnostic information

POST-SESSION SUPPORT. ISS post-session support capabilities fall within two categories: immediate post-session and instructional management (after many sessions) support.

o Debriefing Aids. A three-part debriefing format will be provided. Debriefing information will be displayed at the ISS console; hardcopy can be made.

The first part consists of a graphic presentation of the student's flight path history in relation to flight module boundaries for airways, carrier operations, approaches and final approaches. Where the student has performed the same flight modules more than once, all flight path histories are superimposed on the same profile. Separate graphic outputs are presented for each tactical engagement. Aggressor and defender profiles are displayed.

The second part is a two-column, chronologically-sequenced list of:

- Modules performed (objectives met) within established performance criteria, along with scores achieved.

- Modules attempted but not performed within criterion limits and scores achieved, along with diagnostic summary information (e.g., too slow, below minimum altitude, maximum allowable stimulus recognition time exceeded, procedural sequence error, communication missed). The intent is to provide sufficient detail to allow definition and diagnosis of the performance problem without overly complicating the output or saturating the student or instructor with levels of detail that they will have little time or inclination to use.

For the third part, summary scores also are output for selected performance categories that correspond with (although may not correlate perfectly with) performance categories on Navy grading forms. The intent is to provide a capability that will encourage instructors to continue using performance and proficiency measurement system capabilities and debriefing support capabilities by providing them with information that will be useful to them in completing required grade sheets. Development work is required to derive scoring algorithms that produce summary scores that correlate sufficiently with corresponding instructor-generated grades to this output so that it is perceived as useful and worthwhile. For an F-14A OFT ISS design, the following performance categories should apply.

- Interior cockpit inspection procedures

- Prestart procedures

- Engine start procedures
- Post start procedures
- Takeoff procedures
- Prelanding/descent procedures
- Post landing procedures
- Failure of stimulus recognition: An overall score derived from the response from insertion of the failure until the first valid (measurable) procedural response was observed (aggregated over all failures).
- Procedural responses to failures: An overall score derived with reference to meeting/not meeting performance criteria associated with individual procedures.
- Aircraft performance understanding: An overall score derived from exceeding/not exceeding aircraft performance limits for both normal system operation and degraded system operation.
- Aircraft control sensitivity: An overall score derived from exceeding/not exceeding flight profile criteria.
- Overall GCA performance score
- Overall CCA performance score
- Overall AWCLS performance score
- Overall mission score: An aggregate of the above scores.

Debriefing support may merit expansion to incorporate output from adaptive logic generation of the next mission. This would cue the student on what to anticipate and prepare for. It would also allow the instructor additional time to decide and record whether he would recommend (to another instructor) going along with the plan for the next session.

o <u>Instructional Management Support.</u> A full support ISS will provide two types of management support. One is a summary of ISS utilization and effectiveness and the other is student scheduling.

- A fixed format ISS utilization report will identify, for the period covered, hours of host simulator activation, hours of ISS activation, and a summary of ISS modes of operation support features used.

- A second fixed format report will summarize student performance at a class level. The report addresses proficiency levels achieved by the class for categories of modules (flight, emergency, normal procedures, and tactical). It also summarizes training resources (simulator hours, instructor hours and TD hours) required by each class.

The second type of management support is computer based student scheduling. ISS data files make accessible simulator training status information for students who are legitimate system users. This information, in combination with other scheduling information, makes feasible the use of ISS computers for scheduling subsequent simulator sessions for students. The role of ISS in this regard, however, requires further analysis. The Navy's Versatile Training System (VTS) is a computer based training management system. The question to be resolved is whether VTS fills simulator training scheduling needs.

SUMMARY

A summary of the proposed ISS functional capabilities and modes is shown as a flow diagram in Figure 6.

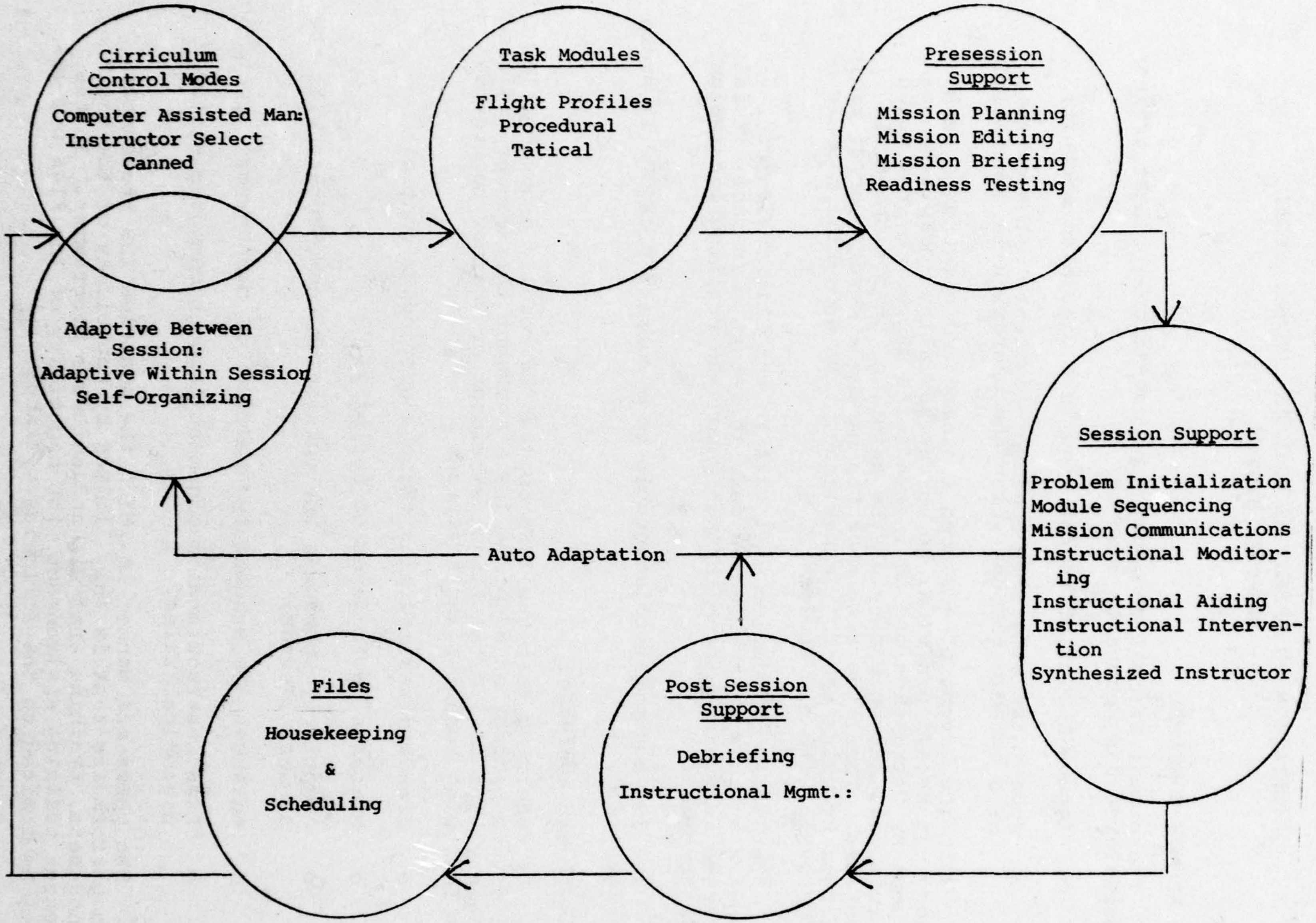


Figure 6. Summary of ISS Functional Capabilities and Modes

SECTION V

ORIENTATION TO OPERATING WITH AN INSTRUCTIONAL SUPPORT SYSTEM

THE ADD-ON CONCEPT

The organizational concept of an operational flight trainer or simulator has generally been to:

- locate the pilot and/or crew in a simulated cockpit;
- locate the simulator operator adjacent to the cockpit at a console through which the operation is controlled.

With the advent of advanced training and electronic technology, it became practical to enhance existing cockpit/console concept by "strapping on" an instructor's support system which in turn will automate many of the existing console operation functions. Thus, the simulator can become a more powerful training tool by using the IP's experience, time and skill more effectively with his student.

The "strap on" device will talk to the flight simulator computer and displays selected data in return. In fact, it is a separate computing system through which the training curriculum is controlled.

The ISS equipment relationship to a current F14A OFT is shown in Figure 7.

OPERATIONAL FEATURES

By requiring that the ISS computer be readily programmable, the device becomes an adaptive ISS attachment that can be utilized with any type of digital flight simulator or trainer to provide the following benefits and features:

- Standardizes training through curriculum control;
- Measures performance objectively;
- Adaptively schedules the curriculum commensurate with the student's needs;
- Advances the student by eliminating unnecessary repetition;
- Aids instructional management through computer stored historical files.

The power and manner in which the adaptive ISS attachment can perform its task is only limited by capability of the training management, training analysis and software programmer. In the present training environment, the capability of the F14A OFT ISS will be limited to the following syllabus:

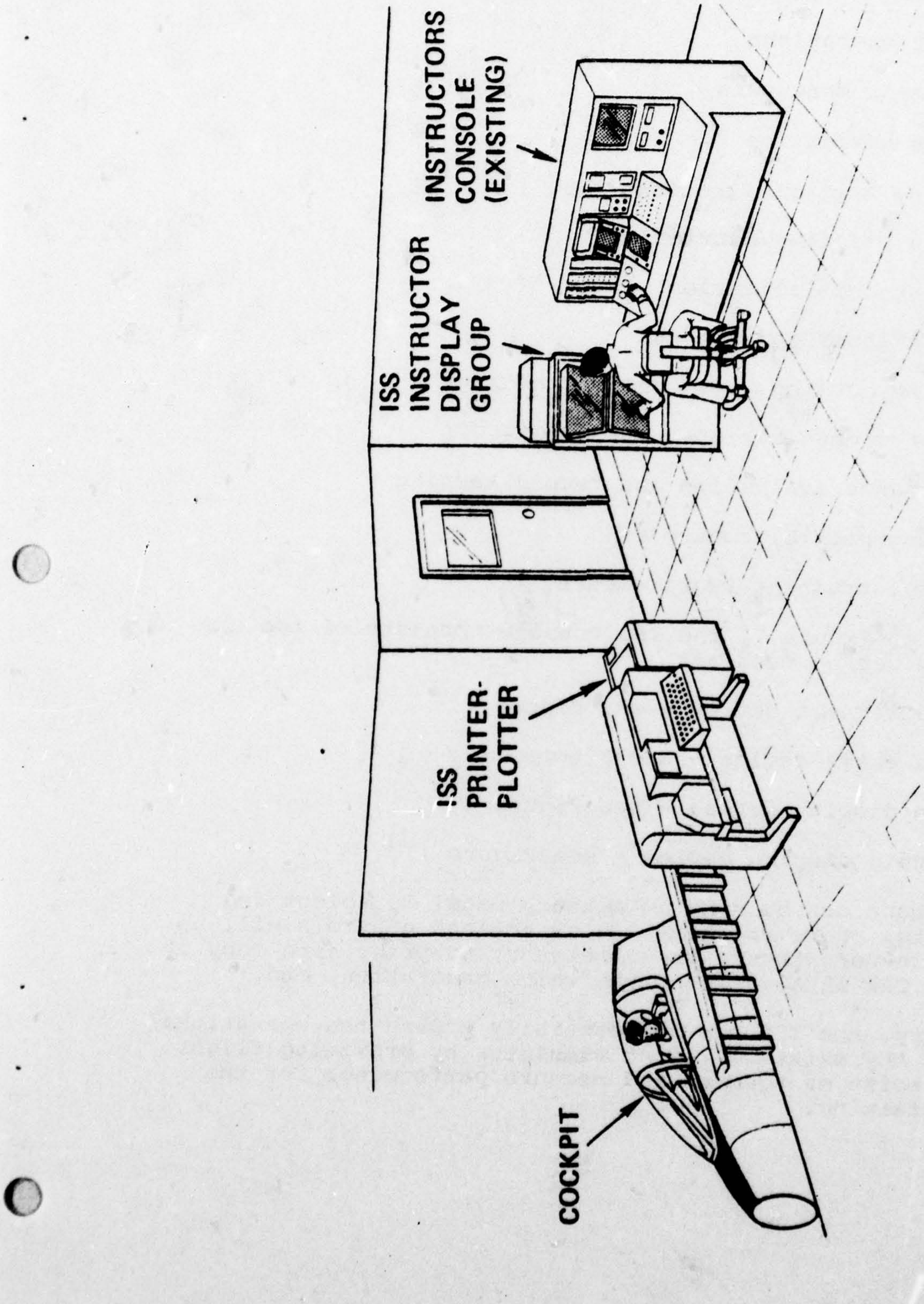


Figure 7. F-14 OFT Training Area with ISS Equipment

- o Normal/emergency procedures
- o Approaches/departuures
- o Carrier operations
- o Instrument maneuvers
- o Airways Navigation

But will provide support functions for:

- o Mission briefing/debriefing
- o Exercise initialization
- o Failure insertion/removal
- o Coaching, cueing, performance feedback
- o Mission communications - NFO, ATC, GCA
- o Performance evaluation and record keeping
- o Training problem control
- o Remedial training requirements

As shown in Figure 7, the ISS console consists of two CRT displays which can be used as:

- o a data request device - see Figure 8;
- o a data entry device - see Figure 9;
- o a data display device - see Figure 10;
- o a graphic display device - see Figure 11.

The CRT face can be used as a touch panel to select and manipulate data. However, some "quick action" controls will be provided to freeze/unfreeze the simulator, to print hard copy of the displayed CRT data, silence the voice generation, etc.

In summary, the ISS can substantially expand the operational capability of any existing flight simulator by providing flight planning, exercise management and measure performance for the pilot under training.

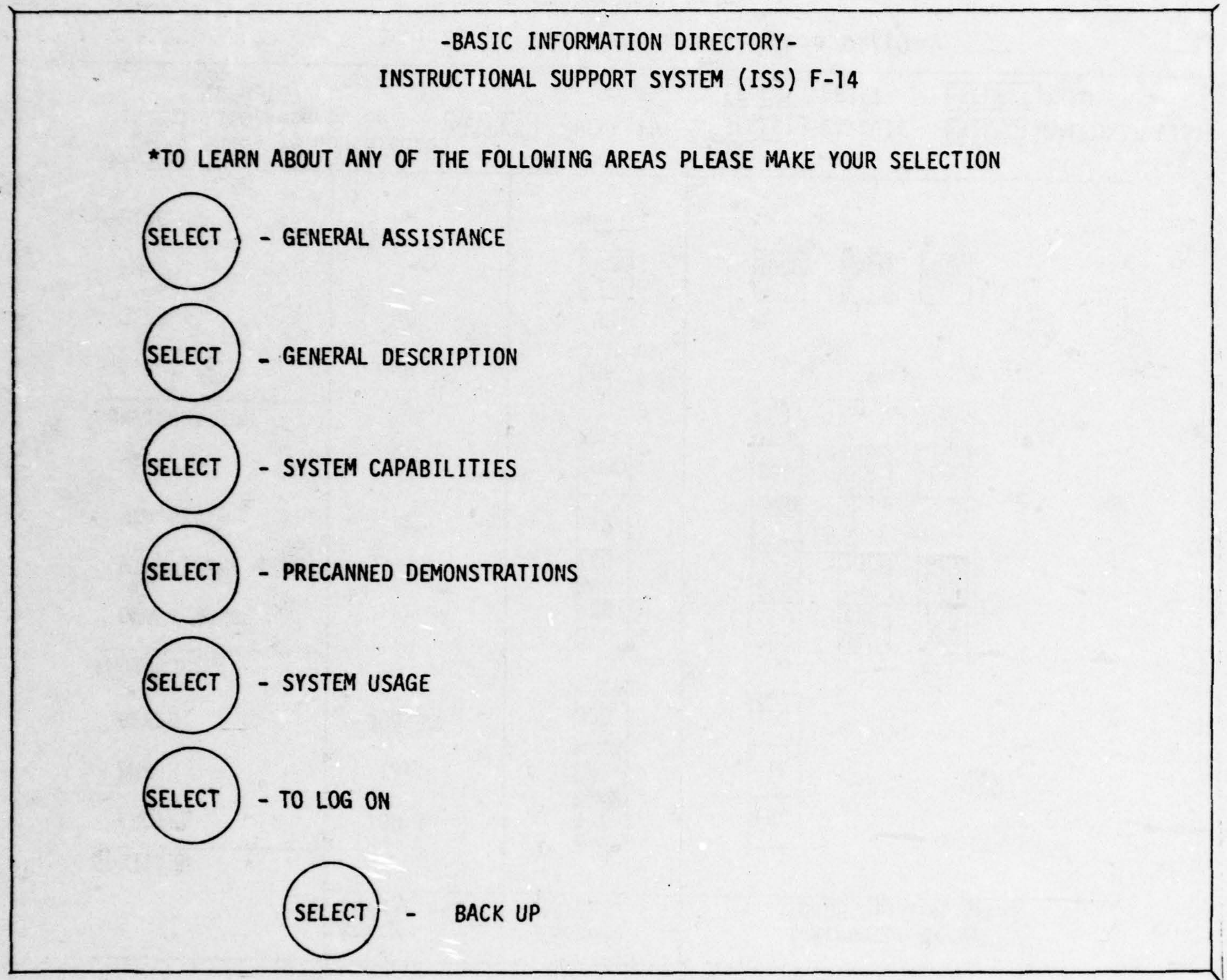


Figure 8. Basic Information Selection Display

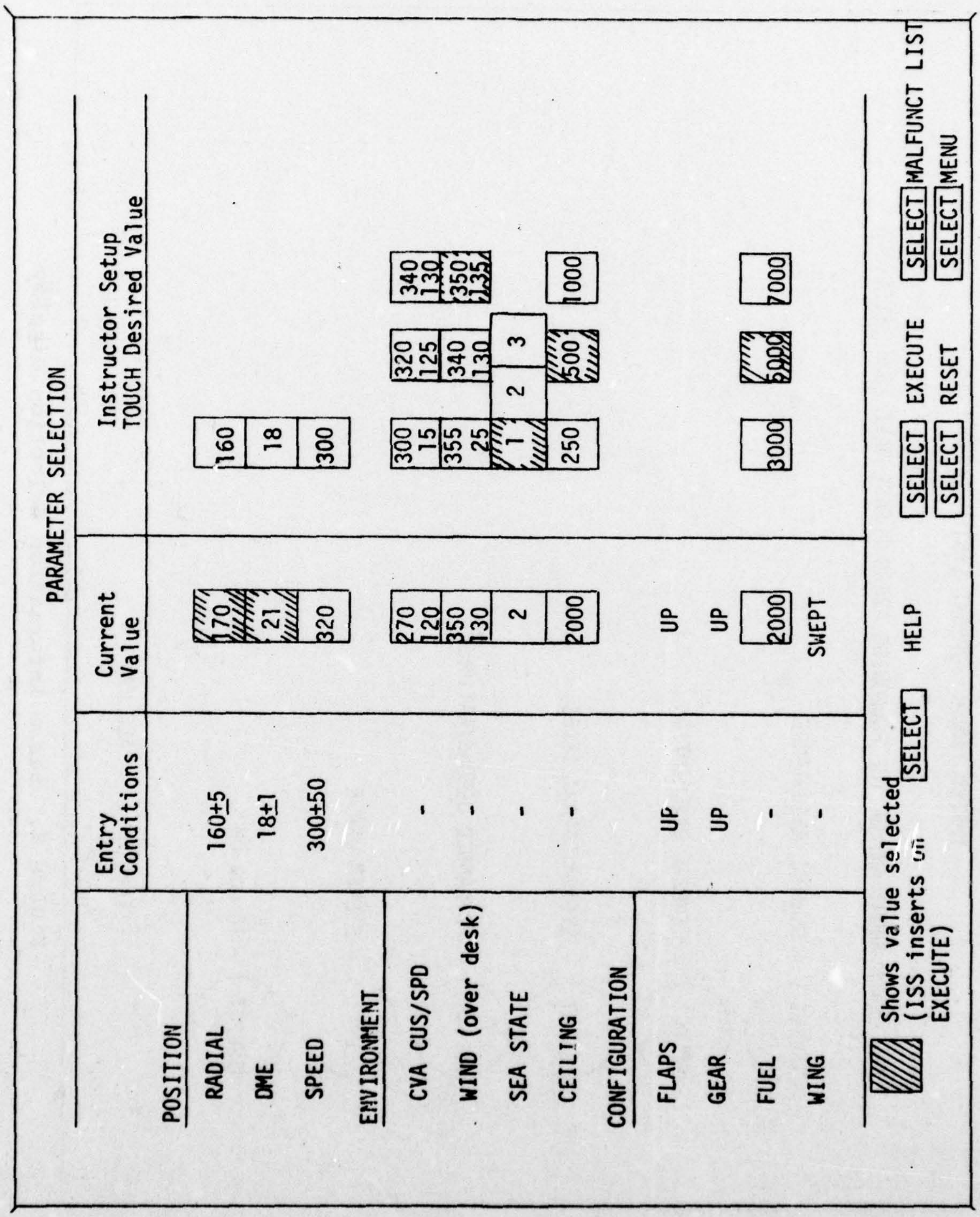


Figure 9. Parameter Selection Display

Abbreviated Check List

Engine Start

1. Crank left engine momentarily observe aux brake pressure gauge increase . . . ☐
2. Start right engine . . . . ☐
   a. ENG CRANK switch-OFF . . . . ☐
      (45 to 48% RPM)
   b. GEN CAUTION light-OUT . . . . ☐
   c. FUEL PRESS lights-OUT . . . . ☐
3. Gnd power - DISCONNECT . . . . ☐
   Hyd transfer pump flt to comb . . . . . ☐
4. Start left engine . . . . ☐
   a. ENG CRANK switch-OFF . . . . ☐
   b. GEN CAUTION light-OUT . . . . ☐
   c. FUEL PRESS lights-OUT . . . . ☐
5.

	Left	Right	Nominal
RPM	0	57	63 to 74
TIT	0	650	500 to 600
F/F	0	950	900 to 1,100
Nozzle	3	5	OPEN(S)

Responses

Time (M-SS)	Event
A. 0-00	ENG. CRANK - LEFT
B. 0-05	AUX. BRANKE PRESS >50
C. 0-06	ENG. CRANK - OFF
D. 0-06	ENG. CRANK - RIGHT
E. 0-10	RIGHT THROTTLE - ON
F. 0-11	RIGHT RPM >22%
G. 0-12	RIGHT THROTTLE - IDLE
H. 0-16	RIGHT TIT >500^{0}
I. 0-17	NOZZLE = 5
J. 0-18	RIGHT RPM >55%
K. 0-20	ENGINE CRANK - OFF

SELECT MENU

Diagnostic Alerts

Time	Step	Event	MSG	Rule
0-10	2	E	Right RPM<22	Throttle - OFF till 22% RPM
0-18	2	J	ENG. CRANK - ON	ENG. CRANK - OFF by 55% RPM

Figure 10. Procedures Monitoring Display

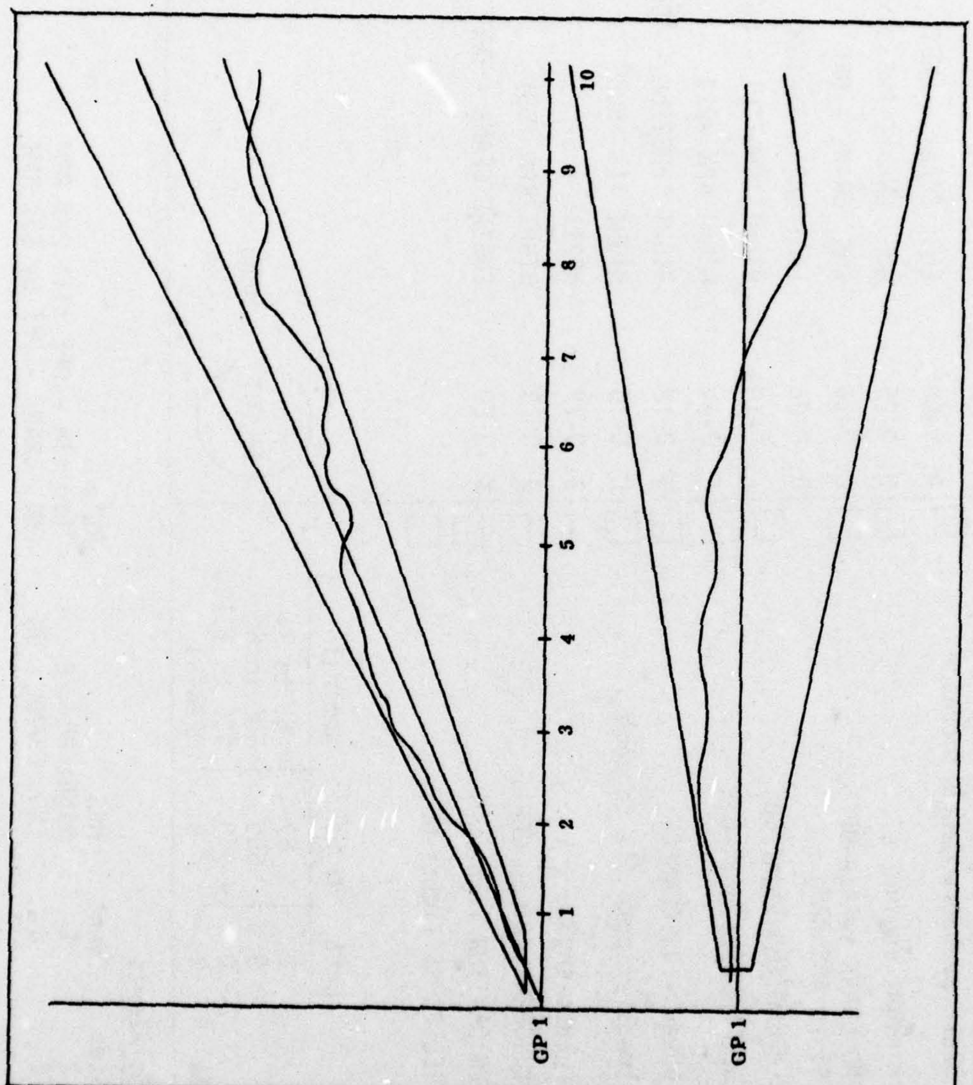


Figure 11. Graphic Display Showing a Final Approach

OPERATING WITH THE ISS

For the F14A OFT at Miramar, the ISS is intended to provide the following support to the instructor during a typical flight training session, once the RP and IP's names have been entered through the ISS touch panel:

a. Review and evaluate the RP's progress to date.

b. Recommend training content of the training exercise to be undertaken.

c. Present a pre-session briefing covering the instructional objectives to be met and the mission plan to be used as the training medium.

d. Provide an interogative for the RP to establish his knowledge on flight control, system and operational knowledges required to enable him to benefit from the exercise.

e. Provide instructional cues to the IP in those areas of RP pre-exercise knowledge weaknesses.

f. Complete the system initialization by entering data in keeping with the Instructor's Briefing Guide for the exercise or requested by the IP, and which programs the:

- Carrier site data
- Ground site data;
- Aircraft environmental data;

g. Perform missing crewmember role by reading NFO checklists and monitoring RP responses.

h. Set up training problems in keeping with content of the Instructor's Briefing Guide.

i. Adjust training problem content in keeping with RP's observed performance.

j. Provide coaching, cueing and performance feedback to the RP.

k. Insert and remove system failures.

l. Vector the RP within a simulated operational area.

m. Make performance evaluation, grading/scoring and learning problem diagnosis, for post-exercise debriefing of the RP.

n. Evaluate the RP's performance in the areas of system knowledge, normal procedures, emergency procedures, flight control, navigation, flight operations and voice communication procedures.

o. Perform the following communications commensurate with the exercise flight plan.

- Mission communications
  - San Diego departure control
  - San Diego approach control
  - Airport Terminal Information Service (ATIS)
  - Beaver (search and rescue) control
  - NAS Miramar
    - Clearance delivery
    - Ground control
    - Tower
    - Approach control
    - GCA controller
    - Missed approach controller
  - Intermediate landing sites
    - Local area approach control
    - Local area departure control
    - Local area missed approach controller
    - Local area GCA controller
  - Los Angeles Center (appropriate FAA sector controllers)
- Carrier and Communications
  - Carrier Air Traffic Control Center controller
  - Marshall controller
  - Carrier controlled approach controller
  - Bolter control
  - Landing Signal Officer controller
- Instructional communications
  - Cueing
  - Coaching
  - Performance feedback
  - Mission instructions

p. Debrief the RP, summarize strengths and weaknesses in his performance, and ascribe possible reasons for them.

q. Prescribe remedial next training content.

r. Perform post-exercise instructional management record keeping.

SECTION VI

SYSTEM DESCRIPTION

OVERVIEW

This section describes the proposed system from a technical standpoint and is partitioned into discussions on:

- o Man-Machine Interface
- o Hardware
- o Software

It should be noted that as the ISS is a strap-on device, a prerequisite of the system design is that it shall not impact the existing hardware and software. Much work has been done by this study to ensure that this requirement can be met; but only time can provide the answer on realizability of the objective.

As the first ISS implementation is anticipated for an F14A OFT, the system design is naturally keyed to Device 2F95 which would be the host simulator.

MAN-MACHINE INTERFACE

It was realized early in the study that the design of the Man-Machine Interface (MMI) was a key factor in the operational acceptability of ISS.

From an organizational aspect, the MMI had to fulfill three primary requirements:

- o It had to provide the IP (or in some instances the TD) with unambiguous procedures such that he could operate the ISS for its intended purpose.
- o It had to display to the IP information that allowed him to control the progress of the exercise.
- o It had to provide the IP with data that enabled him to monitor and assess the performance of the RP.

Commensurate with current display technology, a dual CRT display group was chosen as the means to fulfill the MMI - see Figure 12. The displays are situated to minimize operator movement of head and arms and to reduce light reflected from the display surfaces. The vertical placement of the consoles (one above the other) requires only slight eye movement to view either display. This placement also achieves concentration of ISS and existing OFT equipment (shown in Figure 13) to minize the operator's physical movement between consoles.

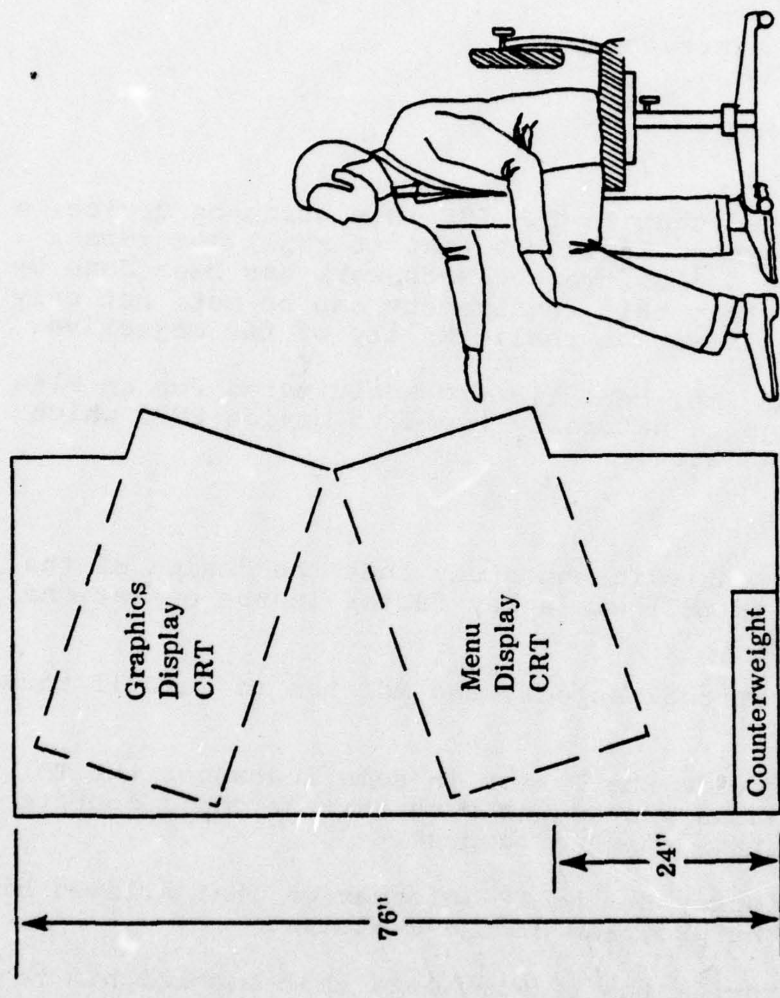


Figure 12. Side View of ISS Display Group

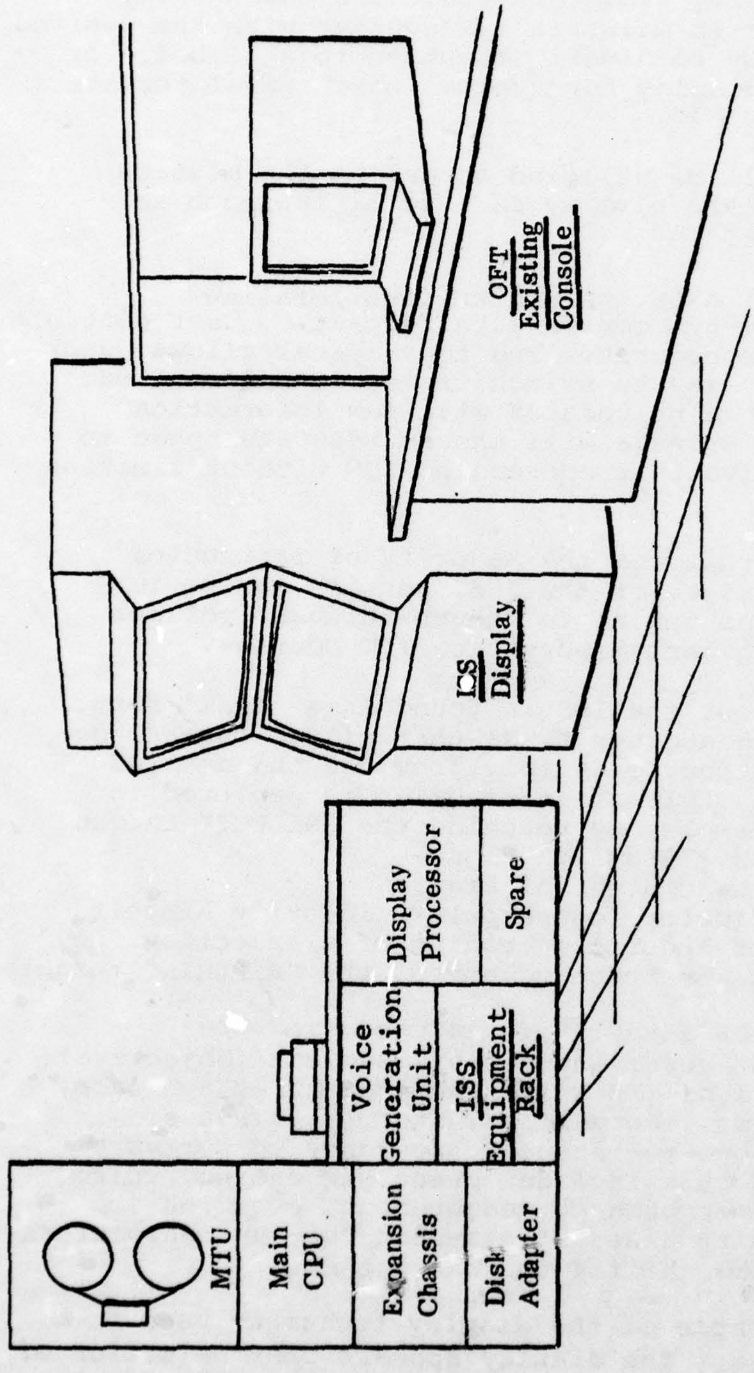


Figure 13. ISS in Relation to a Typical OFT Instructor's Console

The lower display will have an integral touch panel capability which is used by the operator to select options listed in "menu" form on the lower ISS display group console. The touch entry method allows the operator to maintain eye contact with the desired selection and avoids having to divert attention to a keyboard or similar device. The CRT display for typical touch panel formats are shown in Figures 14 and 15.

The upper display will be utilized to depict the mission history. Figure 16 shows the display c- a final approach to recovery on a carrier deck.

INSTRUCTOR PROCEDURAL AIDS. A system incorporating many capabilities can be very complex with respect to user controls, options, data entry and procedures. The touch-panel allows quick selection, thus making it easy to switch frames of information. Furthermore, the display can be updated with new information rapidly, and a large disc storage will ensure adequate space to store sufficient descriptive text concerning ISS without limiting its capabilities.

These features mean that for the majority of instructor questions concerning the usage of the ISS, answers can be immediately available without having to "thumb-through" volumes of manuals or rely on long term memory from IUT courses.

Basic information about the ISS is found in a "menu" form. Each selection can lead to another frame that either further defines the desired information, or simply provides the desired information itself. This style of interaction is depicted in Figures 14 and 15; for example, by touching the "SELECT" target adjacent to "TO LOG ON THE SYSTEM" in Figure presentation changes to the content of Figure display requests the instructor (operator) to identify himself to ISS. If he is in doubt about the meaning of a selection, he may obtain amplifying data by touching any of the "EXPLAIN" targets.

CONTROL AND DISPLAY OF EXERCISES. As discussed previously, Task Modules (TM) represent a basic segment (objective) of a flight training session. TM's include departure, approach, enroute navigation problems, emergencies, etc., as discussed in Section IV. TM's have a one-to-one correspondence to software modules. Each software module includes event sequencing, voice generation, task set-up, performance measurement, etc. While each TM can be executed with a set of standard "set-up" parameters, the instructor is given the ability to change these.

Figure 17 is an example of the display technique used to change "set-up" parameters. The display appears upon selection of an ACLS Mode II-T Final Approach TM in the CAM mode. The display summarizes key parameters relative to this type of approach. The instructor is presented with the standard values indicated by a

-BASIC INFORMATION DIRECTORY-

INSTRUCTIONAL SUPPORT SYSTEM (ISS) F-14

*TO LEARN ABOUT ANY OF THE FOLLOWING AREAS PLEASE MAKE YOUR SELECTION

SELECT - GENERAL ASSISTANCE

SELECT - GENERAL DESCRIPTION

SELECT - SYSTEM CAPABILITIES

SELECT - PRECANNED DEMONSTRATIONS

SELECT - SYSTEM USAGE

SELECT - TO LOG ON

SELECT - BACK UP

Figure 14. Basic Information Directory

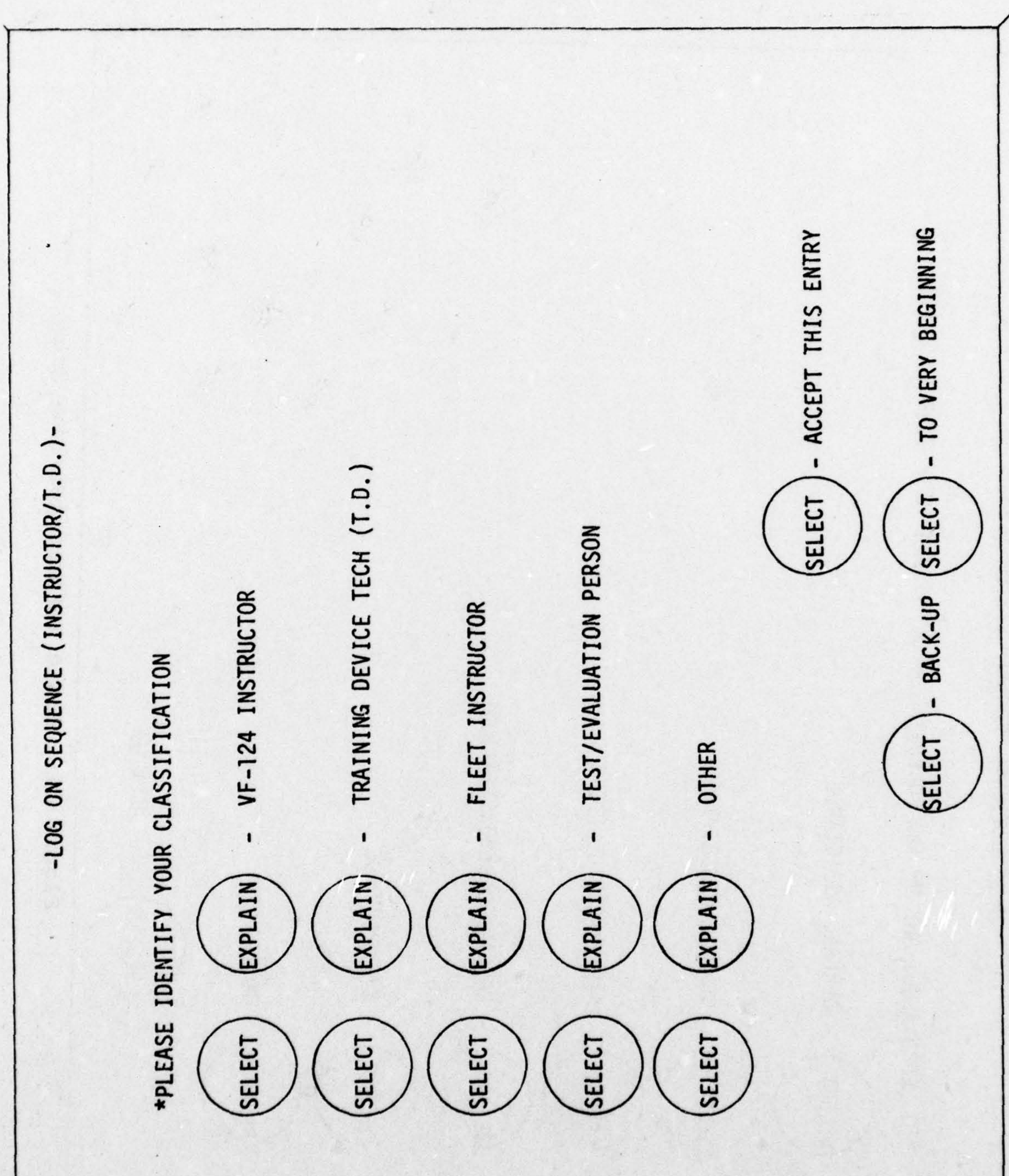


Figure 15. First Display of Log on Sequence

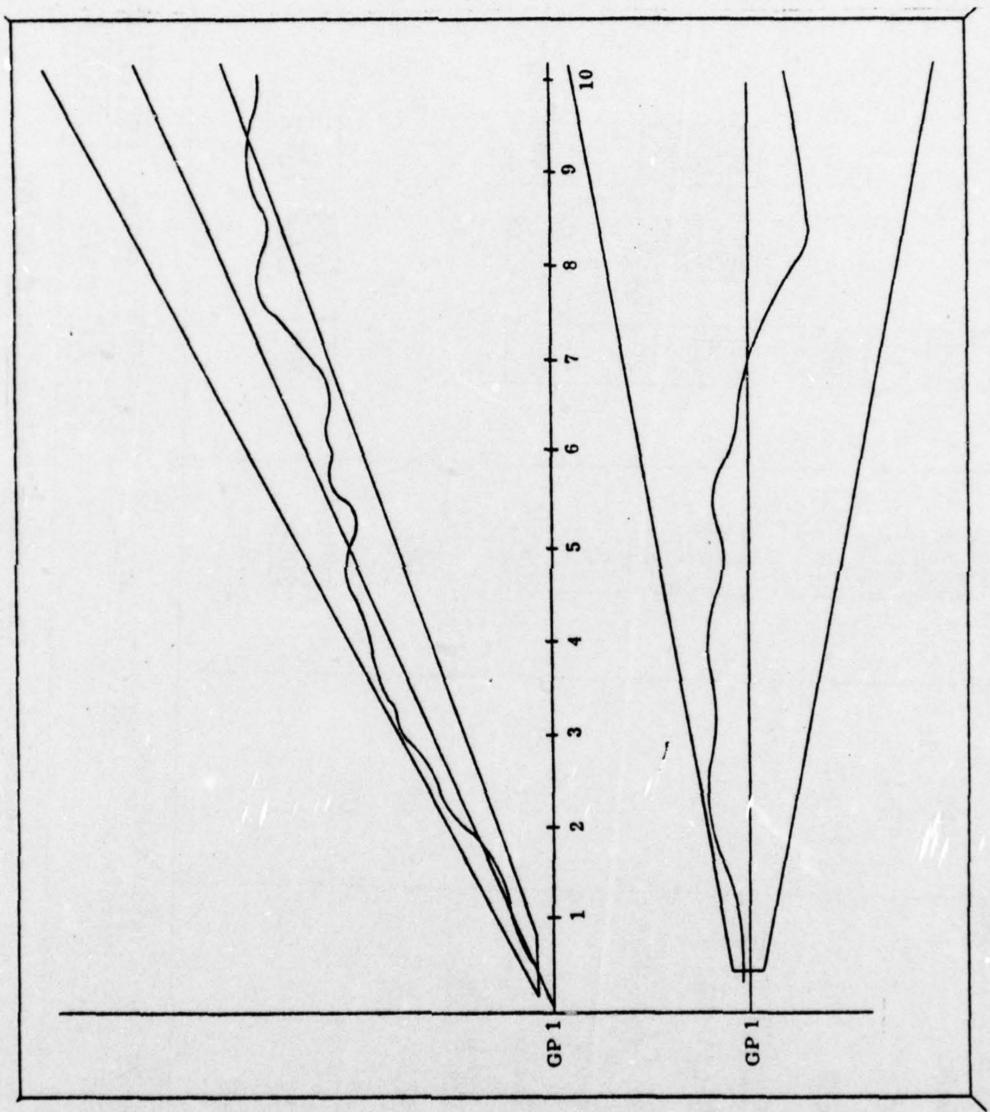


Figure 16. Graphic Display Example Showing Final Approach Format

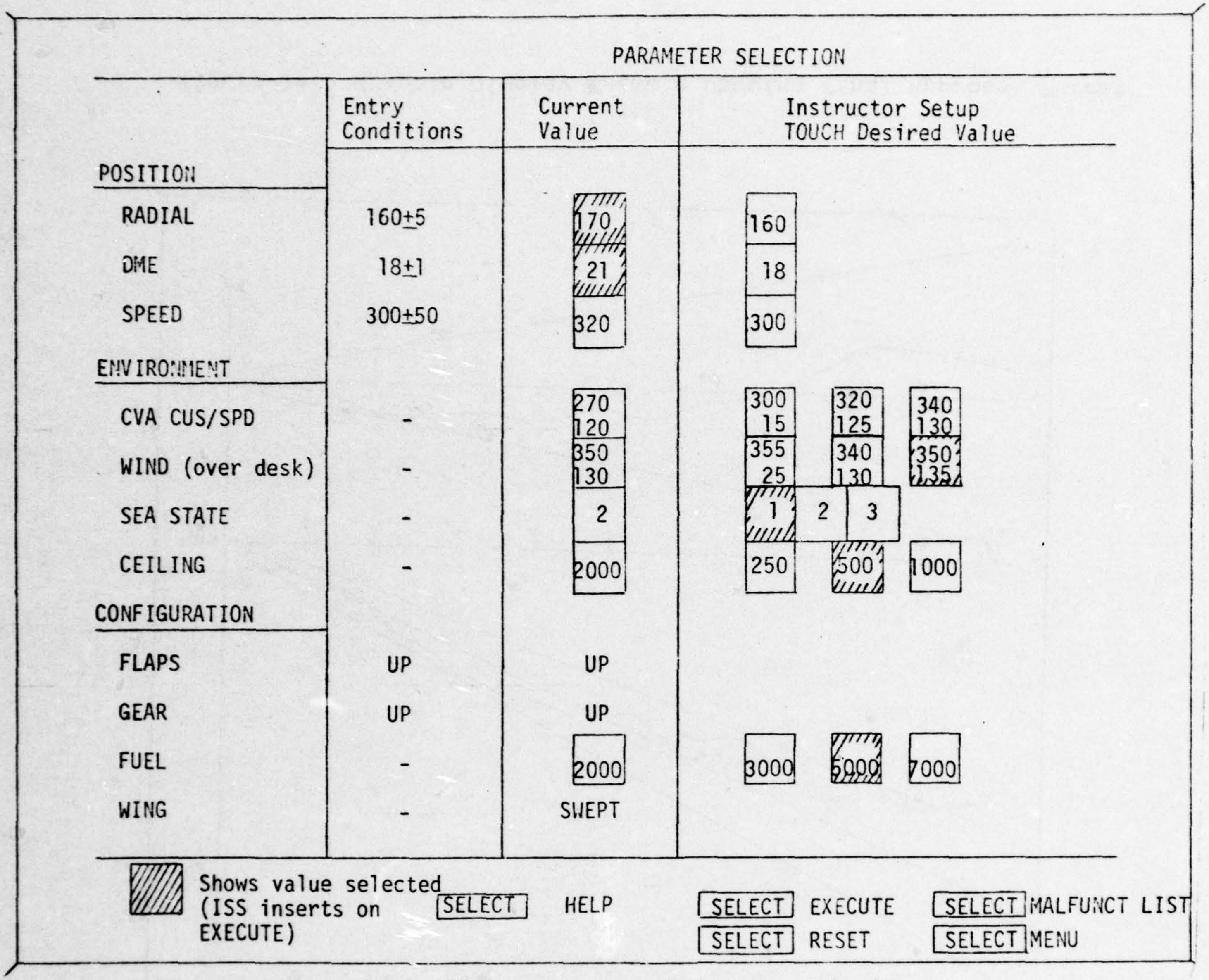


Figure 17. Parameter Selection Display

"hashed-box." For instance, he might select an alternate value by touching the box representing 250 Ft. ceiling. Furthermore, his decision may include opting for the "current" value indicated (5000 lbs). When he touches the "EXECUTE" box, the "hashed" values are entered in the ISS/trainer, and event sequencing begins. (Note: the instructor might simply call up this approach and touch "Execute"; in this case, the student would be given a standard run.)

The great majority of instructor selection and control tasks will be implemented with such interactive touch panel display frames. However, certain significant controls will be implemented by dedicated keys placed adjacent to the displays. These controls are estimated to be less than a dozen and exampled by: hardcopy, freeze, unfreeze, abort, silence voice, etc. Most display frames would be annotated to aid the instructor; in addition, an explanatory frame (HELP, EXPLAIN) would be accessible for further assistance.

PROCEDURES MONITORING. The VF-124 replacement pilot (RP) simulator training curriculum places significant time and emphasis on learning to perform normal and emergency procedures. The instructor, at his console, must pay close attention to repeater instruments and annunciators to verify that various procedures have been performed correctly. However, some relevant information, such as throttle position, is not displayed at the instructor's console. Without knowledge of the throttle position, the instructor is unable to verify correct starting procedures. Automated procedure monitoring capability will provide auxiliary support by detecting and displaying the student's actions that change relevant aircraft states. In addition, it could alert the instructor to probable procedure violations. The instructor could then focus his attention on other aspects of the mission of standard procedures with only occasional reference to a display presenting procedures summaries.

A typical CRT display format for procedures monitoring is shown in Figure 18. Display of such data is a significant software design challenge which results from several factors:

- o Standard abbreviated checklists serve largely as memory aids. What appears as a checklist item often requires many crosschecks, decisions, and actions.
- o There are many ways to do it correctly. There are also many ways a procedure can be violated. It is challenging to encode software to detect the great majority of likely violations and to report the violation in a meaningful way.
- o There are well over a hundred different failure and emergency procedures for the F-14A. In addition, new emergency procedures or alterations to existing procedures occur. A challenge exists to encode procedures monitoring software at low unit cost and yet provide the required flexibility for change.

Abbreviated Check List

Engine Start

1. Crank left engine momentarily observe aux brake pressure gauge increase . . . ☐
2. Start right engine . . . . ☐
   a. ENG CRANK switch-OFF . . . . ☐
      (45 to 48% RPM)
   b. GEN CAUTION light-OUT . . . . ☐
   c. FUEL PRESS lights-OUT . . . . ☐
3. Gnd power - DISCONNECT . . . . ☐
   Hyd transfer pump flt to comb . . . . . ☐
4. Start left engine . . . . ☐
   a. ENG CRANK switch-OFF . . . . ☐
   b. GEN CAUTION light-OUT . . . . ☐
   c. FUEL PRESS lights-OUT . . . . ☐
5.

	Left	Right	Nominal
RPM	0	57	63 to 74
TIT	0	650	500 to 600
F/F	0	950	900 to 1,100
Nozzle	3	5	OPEN(S)

Responses

Time (M-SS)	Event
A. 0-00	ENG. CRANK - LEFT
B. 0-05	AUX. BRANKE PRESS >50
C. 0-06	ENG. CRANK - OFF
D. 0-06	ENG. CRANK - RIGHT
E. 0-10	RIGHT THROTTLE - ON
F. 0-11	RIGHT RPM >22%
G. 0-12	RIGHT THROTTLE - IDLE
H. 0-16	RIGHT TIT >500^{o}
I. 0-17	NOZZLE = 5
J. 0-18	RIGHT RPM >55%
K. 0-20	ENGINE CRANK - OFF

SELECT MENU

Diagnostic Alerts

Time	Step	Event	MSG	Rule
0-10	2	E	Right RPM<22	Throttle - OFF till 22% RPM
0-18	2	J	ENG. CRANK - ON	ENG. CRANK - OFF by 55% RPM

Figure 18. Procedures Monitoring Display

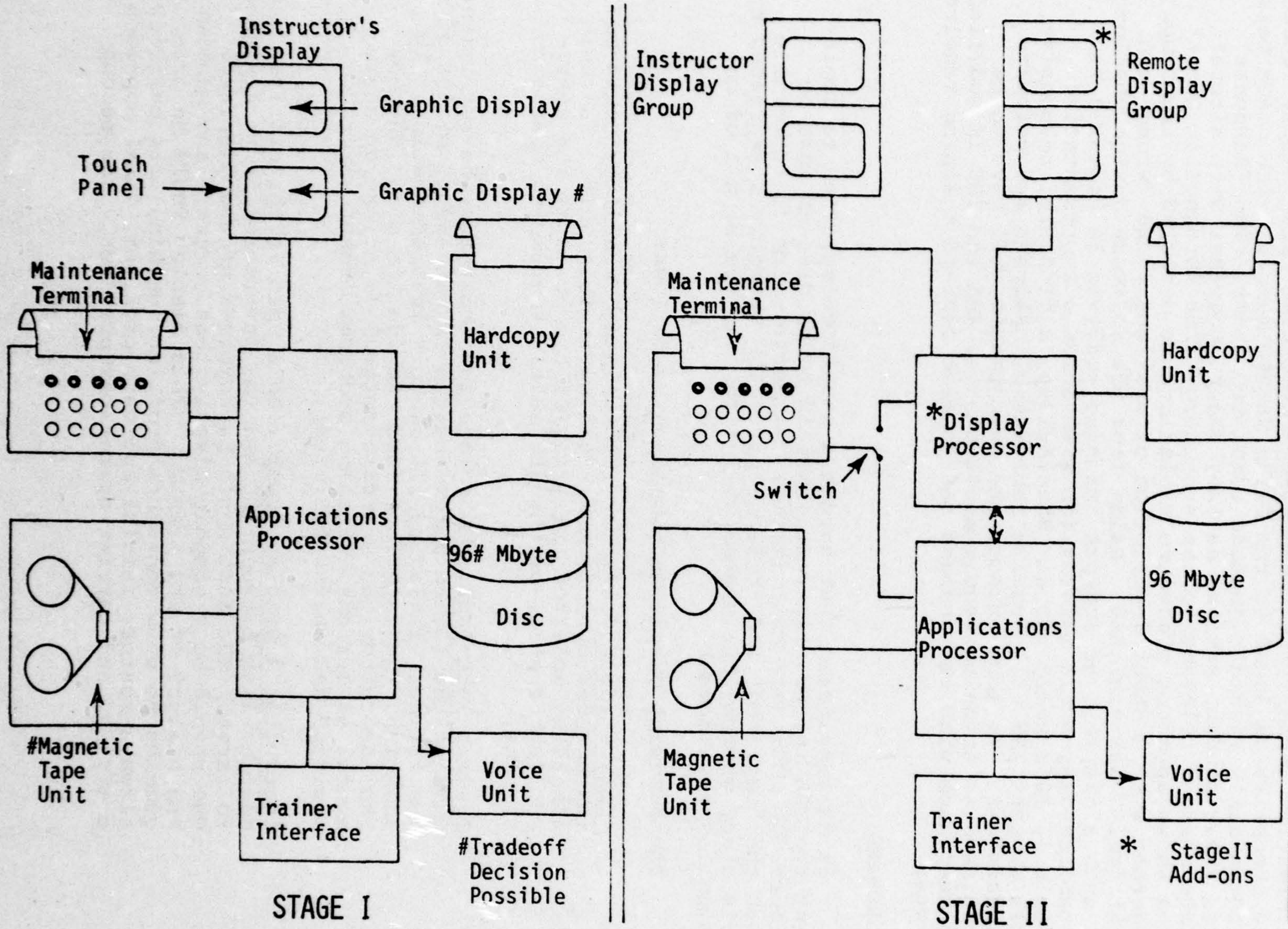


Figure 19. ISS Hardware Organization Assuming a Two-Stage Implementation

Note that the display illustrated in Figure 18 has three information areas. The "Abbreviated Checklist" area simply repeats the checklist as found in the F-14A NATOPS manual, with check marks automatically placed alongside completed items. The "Response" area shows student actions as they occur, together with aircraft state changes relevant to the procedure. The "Diagnostic Alert" area shows apparent procedure violations as detected by the computer together with a short description of what was found "wrong" and what "rule" was violated. Aside from the software design challenge of such a display, an indepth training analysis is required to establish diagnostic information with which a representative sample of IP's would agree. Nonetheless, a flexible, responsive, full support ISS will require substantial analysis and software investments. To some extent, the investments will have to be continued as training requirements change, and the ISS is modified to keep pace with the changes and to meet revised training requirements.

HARDWARE

It is considered that hardware should be selected to implement the ISS in two stages as shown in block diagram form by Figure 19. The two-stage hardware implementation is compatible with the "tailored" and "full support" ISS objectives expressed by this study whereby the system will "grow" as the result of ongoing ISS development.

The hardware complement would be as follows:

Application Processor. ISS training capability would be implemented by software residing in this unit. The unit should be selected primarily on the basis of the availability of state-of-the-art multi-programming operating systems.

Trainer Interface. This interface must provide sufficient data to the ISS to determine the instantaneous status of the trainer, including all cockpit instrumentation. In addition, the interface must provide the means whereby the instructor can exercise control (i.e., setup environmental conditions, training problems, reset aircraft position and insert failures).

Instructor's Display Group. This unit is the critical man-machine link between ISS and the instructor it is designed to serve. The unit would be composed of two displays. One should be a graphic display that portrays the geometry and history of the mission. This display would be programmed to show departure profiles, warning area overview, airways routes, initial approach profiles, final approach profiles, and carrier operations profiles. The second display would be equipped to have a touch entry capability that can be programmed to allow simple control over the ISS modes and features. Available control options would be apparent from the display content.

Disc Drive. This unit would provide storage for the ISS. Stored on the disc would be a complete set of program development software as well as applications programs. In addition, a complete log of ISS training activity should be maintained in files on this disc. These files would allow the instructor to review student performance, and, would provide the training analyst with the basis for objectively recommending improvements of the training sequence, modifications of performance norms, and improvements in design.

Voice Synthesizer. The ISS would automate routine, standardized, predictable voice transmissions. For instance, ISS should provide GCA voice messages as the student flies a simulated approach.

Printer/Plotter. This unit would respond to commands of the IP to the ISS to print either alphanumeric or graphic information. The instructor should be able to obtain a hardcopy image of either of the displays. Using this device items, the ISS would print such information as mission briefing and performance summary data. The unit also would allow users of the system to obtain program listings, statistical reports and graphs.

Maintenance Terminal. A small keyboard/printer would be incorporated for maintenance purposes. Such a unit is necessary to run diagnostic routines for the CPU and its peripheral devices. This unit also would have the means of modifying the ISS's software.

Magnetic Tape Unit. This unit would serve two functions: file preservation and data transportation. It is essential that an ISS data base be preserved. The system data base must be restorable from recent magnetic tape recordings should a loss of disc data occur. In addition, it is considered prudent that performance data collected on the ISS be subjected to analysis. Magnetic tape provides a proven means whereby data files may be transported in a secure manner to other facilities for analysis.

Remote Display Group. This unit is a stage II requirement and would be identical to the instructor's ISS station. Instructors and students could use the station to conduct planning, briefing, and debriefing. The station would be able to be operated simultaneously with a training mission, and it should be located in a briefing room close to the trainer.

DEVICE 2F95 INTERFACE

The access and control of certain information in Device 2F95 are of primary concern to the feasibility of an ISS for the F-14A OFT. Two interfaces are required: both must meet the objective of non-interference with the OFT's internal data transfers.

General descriptions of the two required interfaces are shown in Figure 20 and are described below.

A Direct Memory Access (DMA) is recommended to access the OFT's Signa Five core memory via memory port A. This will allow the extraction of certain initial values prior to the exercise. Less than 50 memory accesses at a rate of 1 per 4 to 10 milliseconds will be required. During the exercise, it may be desirable to read a few (less than 10) memory locations for a total of 200 accesses per second to acquire data available only in the Sigma Five memory.

An interface connected between the Multiplexed I/O Processor (MIOP) and the Device Controllers (DCs) in the OFT cabinet (unit 6A1)is planned. This interface is called a Data Acquisition and Control System (DACS). It is anticipated that it could be similar in concept to DACS used in other trainer installations.

The DACS allows any data flowing over this MIOP-DC link to be acquired and placed via DMA (data channel) into the memory of the ISS CPU. Furthermore, it allows any data destined for the MIOP from these device controllers to be intercepted and modified. This capability allows the ISS CPU to insert instructions which would normally be coming from the instructor's console.

The DACS should require no DMA access to the Sigma Five core memory. It must be designed to have no adverse effects upon the operation of the MIOP-DC bus, or the operation of the input device controllers.

The DACS will acquire approximately 100 different words (less than 400 bytes). It will control (or modify) about 25 input words (100 bytes). These actions will be repeated on every I/O cycle of which there are 5 to 20 per second depending on the device.

The DMA Control and DACS Interface and power supplies can be mounted on a special panel attached to the rear of memory cabinet (unit 6A6). All equipment can be concealed behind the external door to the cabinet. The panel should swing out for maintenance.

Three cables running from the MIOP in unit 6A5 to the device controllers can be routed and intercepted by the DACS located on this panel.

Access to memory port A in unit 6A6 also would have to be established for the DMA interface.

Power can be obtained, up to 10 amperes from the 60Hz, 120V single-phase outlets behind the counter-weight at the bottom of unit 6A6.

Cables to the ISS CPU would be routed under the floor. There will probably be two cables with a total of less than 100 conductors.

The interfaces must function in a manner requiring no changes of the software of the Sigma Five computer. The interfaces would be inactive for any one or more of the following conditions:

- Power-off in ISS CPU
- Following "power up" or reset of the ISS CPU
- Whenever a special switch is in the "bypass" position
- Following a "bypass" command by the ISS CPU

In other words, the interfaces should function only when ISS power is on, a manual switch is in the operational position, and the appropriate ISS CPU commands are in effect. When these conditions do not exist, Device 2F95 would operate without knowledge or benefit of the ISS.

By means of bypass cards and/or other disconnect methods, the interfaces would be easily and completely disconnected from the trainer.

Build-in test equipment should be designed into the interfaces to facilitate off-line maintenance.

Other configurations of DMA/DACS interfaces are feasible and practical, for instance, a single box can be placed in the link between the MIOP and the Sigma Five core memory. This would allow the ISS CPU to read or write into the Sigma Five core memory and, furthermore, would allow acquisition and/or modification of selected data flowing to/from the MIOP. However, the final interface configuration should be a contract review item with the system implementation contractor based on a requirement that the ISS shall not interfere with the operation of Device 2F95 and that the ISS shall fulfill its intended performance. This would give the contractor freedom of choice in optimizing the interface.

SOFTWARE DESCRIPTION

The goal of the design of the ISS is to emphasize modular software. A modular design allows low-cost expansion of system capabilities. All application-level programs should be done using an efficient, easy to understand, higher-order, latest technology

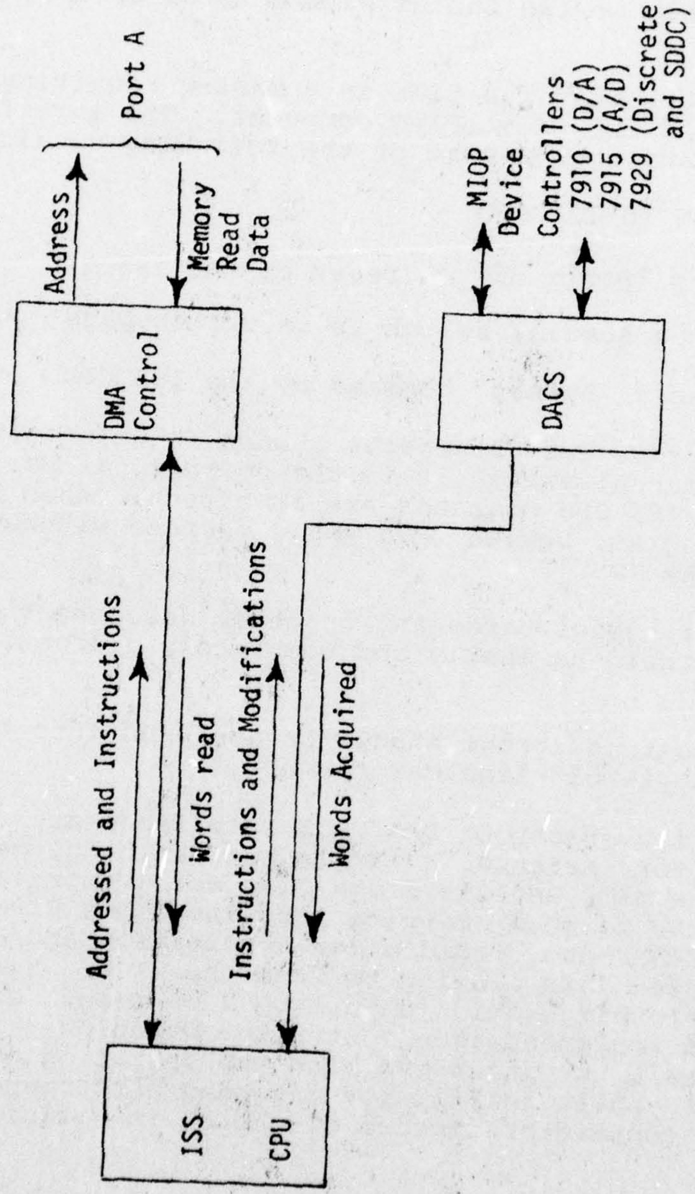


Figure 20. ISS/2F95 Interface

programming language. Inter-module communication and timing control will depend largely on the operating system selected. The ability to provide effective and easy to understand inter-module communication should be a primary factor in operating system selection.

As can be seen by the illustrated hierarchy diagram in Figure 21, the ISS is conceived of as a large collection of program units. The ISS should be designed to be a self-supporting system; that is, using on-line program development to provide the means for application programs to be modified at the source level. The operating control system recommended by the equipment supplier should be utilized for ISS applications and scheduling. This would virtually eliminate the cost of developing costly, real-time executive and I/O control software.

Note that applications software will represent the largest category of development labor and cost.

DATA BASE DESCRIPTION

The following paragraphs describe identified elements of the ISS data and outline their requirements.

<u>Task Module Performance Record</u>. The basic data entity within the file system is the Task Module (TM) performance measurement record. Each record should contain several variables as measured by the TM performance measurement logic. It must be possible to access these data and any related diagnostic and amplifying information relating to the student's prior performance of the specific TM.

<u>Exercise File</u>. This file will be associated with a particular instructor and student. From this file it should be possible to identify which TM's were used during a specific simulator exercise with the relevant amplifying data including: the ISS mode(s) of operation used, instructor overrides, environmental factors, concurrent emergencies, etc.

<u>TM History</u>. It should be possible to determine within the file structure all executions of a TM. All amplifying data relevant to the executing of the TM will likewise be accessible, including: student, student classification, instructor, as well as mode of operation, instructor overrides, environmental factors and the presence or absence of concurrent failures and/or emergencies.

<u>Student History</u>. For a given student it should be possible to determine: prior level of experience, all simulator exercises performed and all mission elements (TM's) performed and to what criterion levels.

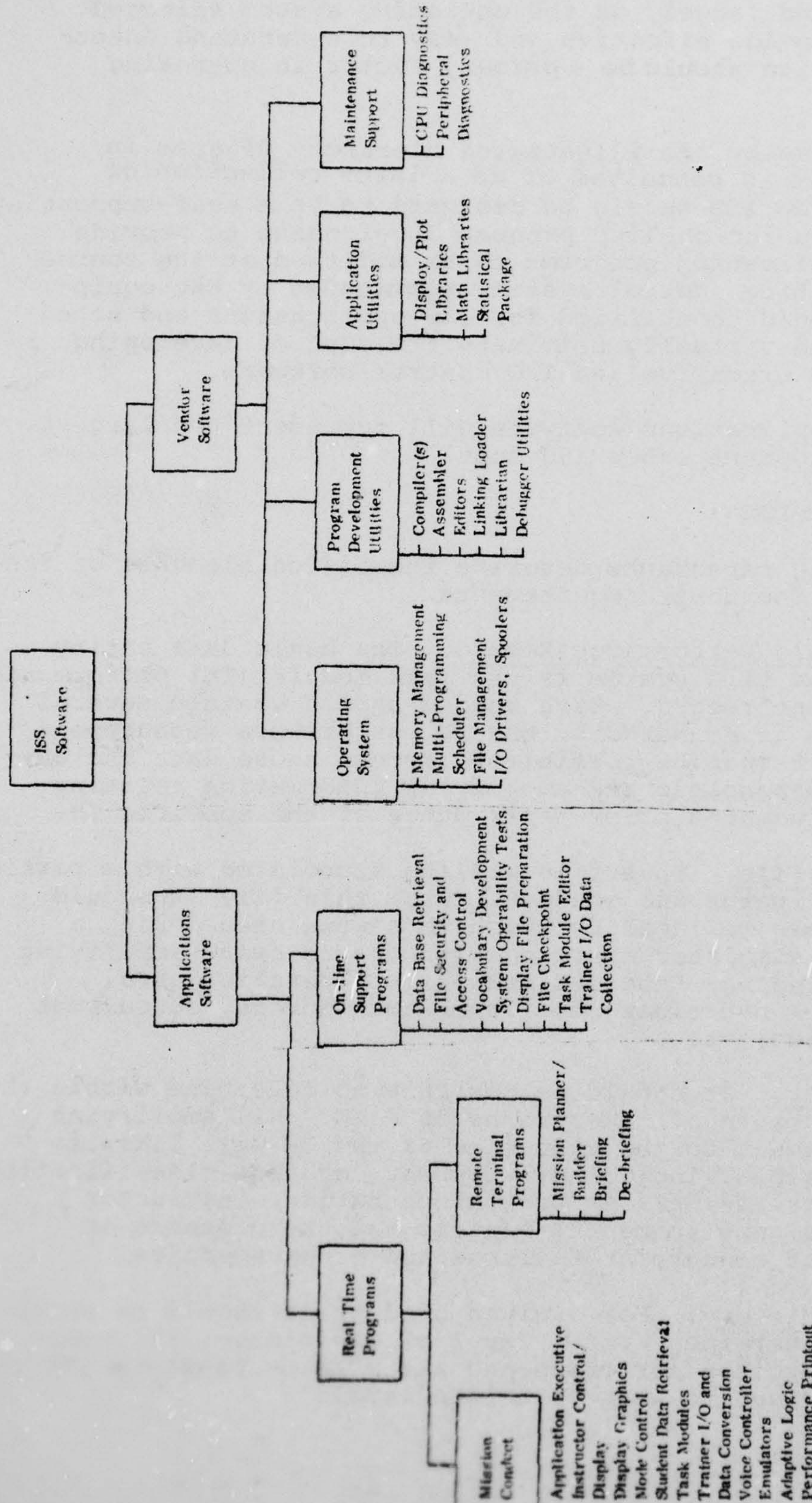


Figure 21. ISS Software Hierarchy

Instructor History. The system, in part, should be designed to determine effective training techniques from the various instructors. Thus, given an instructor, it should be possible to determine the specific exercises he has supervised and, in turn, the modes by which they were executed along with a list of modifications the instructor performed.

Normative Data Files. As a history of the usage of the system builds, normative data should be computed for various-performance parameters. These data could then be used to replace the initial "best-guesses" used for scoring. Normative data files should be organized by the student's time in terms of training, TM, and performance measure.

RP Proficiency Files. In the OFT training program, various criteria for student attainment can be defined. These files should list the number and categories of TMs flown to criterion level. These files should be displayable to the instructor with student achievements "checked off." This provides the IP with an aid for effective and efficient planning and budgeting of his time on the simulator.

DATA RETRIEVAL AND ANALYSIS

A library of programs allowing retrieval of data should be a part of the ISS. These programs would allow a training analyst to:

- determine normative values of performance parameters;
- refine scoring algorithms based on statistical data; and
- correlate instructor technique with student performance data.

The objective of these analyses is to refine and improve the ISS.

Usage of these programs should allow a training analyst to print out the data on all executions of a given TM. The printed data should include the date, instructor's name, the student's name, training level, relevant environmental values, and the presence of failures, as well as values of performance measurements. A more sophisticated use could allow a training analyst to reject certain occurrences and to determine statistical characteristics of specified variables for the remainder.

DATA FILE HOUSEKEEPING

A loss of files due to equipment error, programming error or human error could seriously jeopardize the goals of attaining an automated instructional support device. Means must be provided to preserve the growing data base.

A plan that requires daily recording of changed or new files plus weekly checkpointing of the entire data base is recommended. File audit programs should be provided to the extent practical that will detect errors in the files. The use of a standard magnetic tape unit is recommended for this purpose in anticipation of transporting the ISS's files to a remote facility for analysis.

SECTION VII

IMPLEMENTATION

OVERVIEW

It is considered that the Device 2F95 ISS can be implemented in three stages as discussed herein. It is not intended to imply that other strategies would be inappropriate. The proposed plan does reflect the best judgement of the study team in this regard at the time the report was written.

The proposed strategy provides for user feedback at a reasonably early time, while providing a reasonable development and evaluation schedule for the more complex of the software modules.

Stage I is viewed as an 18 month effort that would focus on an early demonstration of the fundamental features of the ISS. The ISS 2F95 interface would have to be developed during this stage to provide a means for the field demonstration. Preliminary instructor software to provide diagnostic performance feedback on emergency and normal procedures also falls in this category. The capability for the automated support of departure and approach training task modules should be included to allow user feedback on the automation of the flight control and navigation modules. A limited version of the CAM mode should be implemented. The basic system would be delivered at the close of Stage I.

Stage II also is conceived as an 18 month effort. During this stage, a second (remote) instructor control-display console would be added for mission planning, briefing and debriefing instruction. Additional software deliveries would implement the remaining ISS operating modes, including the carrier operations, the airways navigation and additional procedural TM's. IUT training materials should be developed and validated during Stage II.

Stage III is a 12 month effort to refine the ISS modes, automated support features and operations. The logic for adaptive training would be developed and implemented. Computerized voice recognition of RP radio transmissions should be incorporated into the system. A formal evaluation of the ISS should occur during the closing months of Stage III.

Figure 22 graphically depicts the recommended candidate program stages.

STAGE I

The primary Stage I requirement is to focus on developing, demonstrating and evaluating the acceptability of the features and capabilities of the ISS as it presently is conceived. From

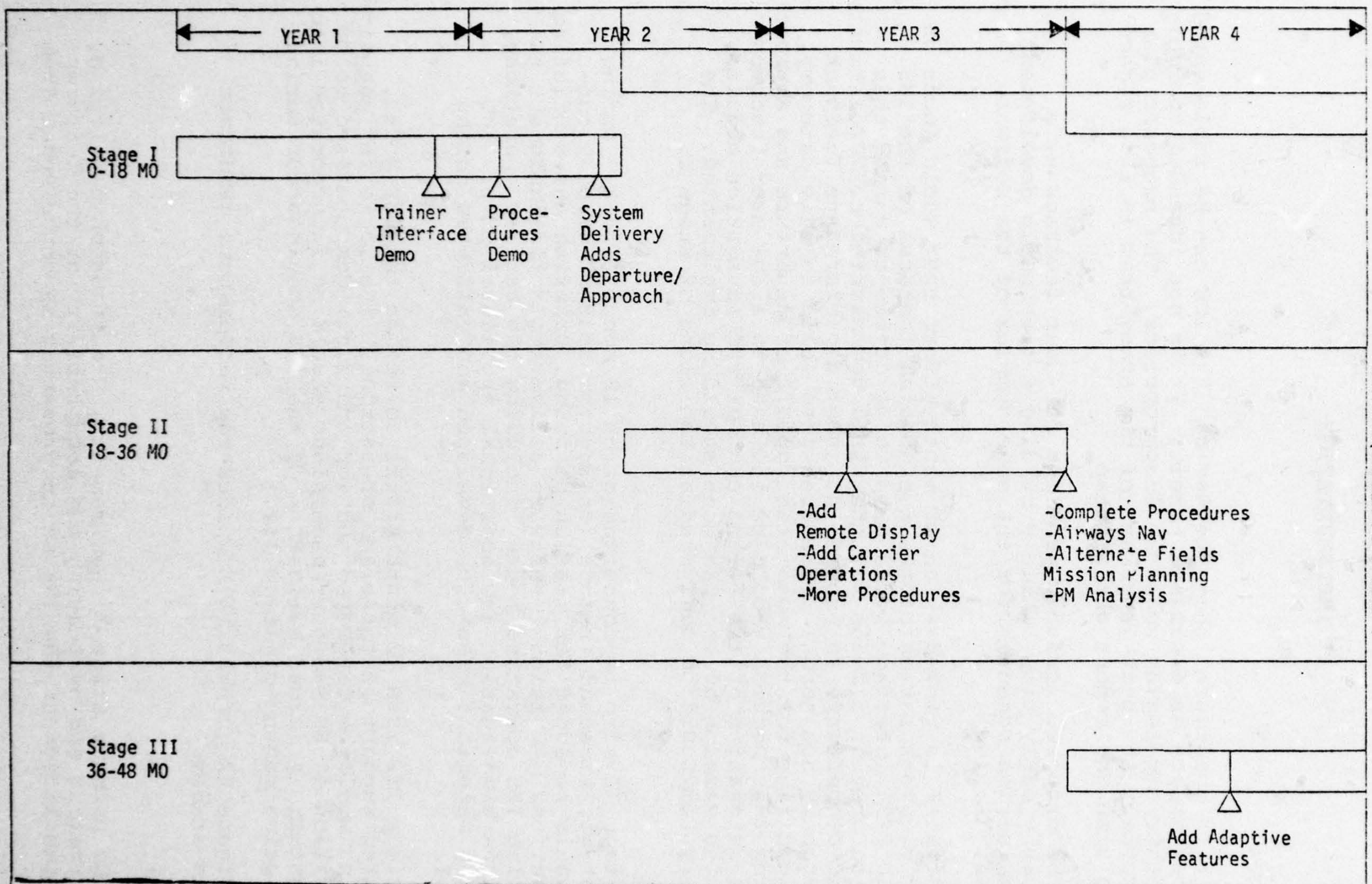


Figure 22. Candidate Staging of ISS Implementation

an instructor-user's point of view, this may be summarized by two questions:

- o Is the ISS man-machine interface easy to use, and does it provide the user with relevant information and the capability for control?
- o Do the ISS's features and capabilities offer meaningful and useful aids that assist IPs in performing their primary function: instructing?

Early answers to these questions are needed to provide guidance for subsequent design and implementation decisions. Positive answers will provide the confidence that the basic design is good. Negative feedback should be useful for redirecting the development activities for their efficient use.

The design recommended for the man-machine interface must be evaluated early. This includes the planned graphics display, the use of a touch panel, the IP's procedural aids, and all the problem control and monitoring display formats. This is felt to be necessary because of the need for instructor acceptance early in the implementation program. A primary ingredient in the instructors' acceptance of the system will be their acceptance of the methods, media and procedures for using the ISS.

Stage I also will serve as a test period for the software as well as for the instructional capabilities. A primary example involves the capabilities to automatically monitor and inform the IP of the pilot's performance of normal and emergency cockpit procedures. As this is a new and undeveloped automated support system, the Stage I ISS should incorporate the software for procedures monitoring, including the diagnostics related to improper execution by the RP. Expanded criteria for the automatic insertion of failures and their removal also should be developed for this stage.

In addition to the monitoring of procedures, the Stage I system also should incorporate the ability to monitor the basic flight profile, the performance measurement and the scoring. This will enable their refinement later. Several departure and approach task modules should be included as these also provide an instructional context for meaningful use of synthetic voice generation. The incorporation of a GCA and ACLS Mode 11-T task module should be a stated objective.

STAGE II

Stage II allows feedback to affect the system's design and commence when the remaining ISS automated features, short of adaptive training, are introduced. Automatic insertion, removal, and monitoring capabilities for the remaining normal and emergency procedures would be implemented in this stage. The flight control and navigation context would be expanded to incorporate additional departures, warning area operations, airways navigation, operations at intermediate landing sites, carrier operations, approaches and final approaches. Thus, the majority of all of the TMs would be implemented in Stage II. Data files for retaining student's performance measures and information on their proficiency would be implemented also. The second (remote) IP control-display console would be delivered, together with mission planning, briefing and debriefing capabilities.

It is considered that a civilian instructional specialist, either Navy or contractor, be resident at the installation throughout Stage II. Such an individual would fill several valuable roles. One role would be to provide on the job training for the initial cadre of IPs to use the nearly completed ISS. In doing so, he could accumulate valuable knowledge on the acceptance and utility of various system capabilities, features and procedures. Additionally, he could use experience gained by working with the cadre of IPs to develop objectives and content for the IUT program. Finally, it is anticipated that he could coordinate the analysis of the growing base of performance measurement and instructor usage data so that the proper adaptive training modes and logics can be established.

STAGE III

Stage III would focus on the development of adaptive training logics for between session problem adaptation, together with preliminary tests of the logics. The conclusion of Stage III should concentrate on a system operability and training effectiveness evaluation of the ISS and the IUT program to provide feedback for future instructional support system development.

HARDWARE STAGING CONSIDERATIONS

Stage I hardware should incorporate the main CPU and disk memory, which are sized for a multi-programming program development and real-time operating system. However, Stage I should be designed to minimize costs until the fundamentals of the design are proven by demonstration and acceptance by the IPs achieved. Some expenditure for hardware could be delayed until Stage II for some reduction of efficiency of the software development. Specifically, a 10M byte disk drive could be substituted for the recommended 96M byte drive and magnetic tape unit. The larger disk, however, is still required in Stage II to provide the capacity for the anticipated performance measurement data.

Configuring both the graphic and menu displays with the same CRTs offers several long range benefits. First, the system would have redundancy; second, the graphic capabilities could prove useful for future display design. However, a less expensive alpha-numeric display that provides the necessary symbology for touch panel interaction for menu manipulation could be selected and lead to deletion of the requirement for a maintenance terminal.

Stage II also adds a second display group and a second CPU for display processing. The second display group, which should be identical to the instructor's display, would be located in a briefing room near the simulator. Its purpose is to enhance the mission planning, briefing, and debriefing functions of the ISS. A dedicated display processor is also added at this stage to remove the load of display processing from the applications processor. This would allow expanded training applications. Depending on the amount of I/O transfers from the disk, it may also be necessary to add a cartridge disk unit to the display processor during this stage.

SECTION VIII

LIFE CYCLE SUPPORT CONSIDERATIONS

MAINTENANCE CONSIDERATIONS

The ISS should be configured mainly from commercial equipment, and, therefore, each equipment vendor should have an effective field maintenance organization in the installation site area. Each hardware unit also should have a significant lifetime. All off-the-shelf hardware used should incorporate diagnostic programs and necessary equipment to isolate failures to an easily replaceable module or unit.

As the Stage I system is viewed as a prototype device, should unexpected technical difficulties arise or should acceptance be unfavorable, it will make little sense to pursue expansion and refinement of the ISS. Because of this possibility, it is recommended that development of maintenance documentation and provisioning parts documents be deferred.

STAFFING CONSIDERATIONS

A need is anticipated for three people in addition to those normally required to operate and maintain Device 2F95. Each new position is discussed below.

Technician support will be required for preventive maintenance trouble shooting, and monitoring of expendables. This should require approximately only four hours per week. A reasonable plan would appear to be to provide TDs with instructions sufficient to enable them to address these requirements. During Stages I and II, it would appear most practical that maintenance be provided by the ISS development contractor.

A data control person also will be required to control the ISS software validity checks. It is anticipated that this should require no more than one-half hour daily and two hours at the end of the week. This role also could be filled by a TD.

An important research role is also anticipated. This should be filled by a full-time, civilian instructional specialist with a background in instruction research. The success of the ISS of the type discussed in this report could depend on this individual. The instructional specialist will have to perform many critical tasks. During initial system operation, he will have to provide IP and TD on-the-job training. From this experience, he could make detailed inputs to the IUT course providing both objectives and content. He also will be the contractor's source of user acceptance and design information. He will also be required to direct or perform data analyses to aid the refining of performance scoring algorithms, as well as the developing and refining of adaptive training logics. Finally, he should ensure that the task modules are refined or developed so that the ISS is kept current with changes to the RP syllabus.

SECTION IX

SOFTWARE SUMMARY

INTRODUCTION

This section provides an overview of ISS information flow during mission conduct. Major real time software processes (modules) are described.

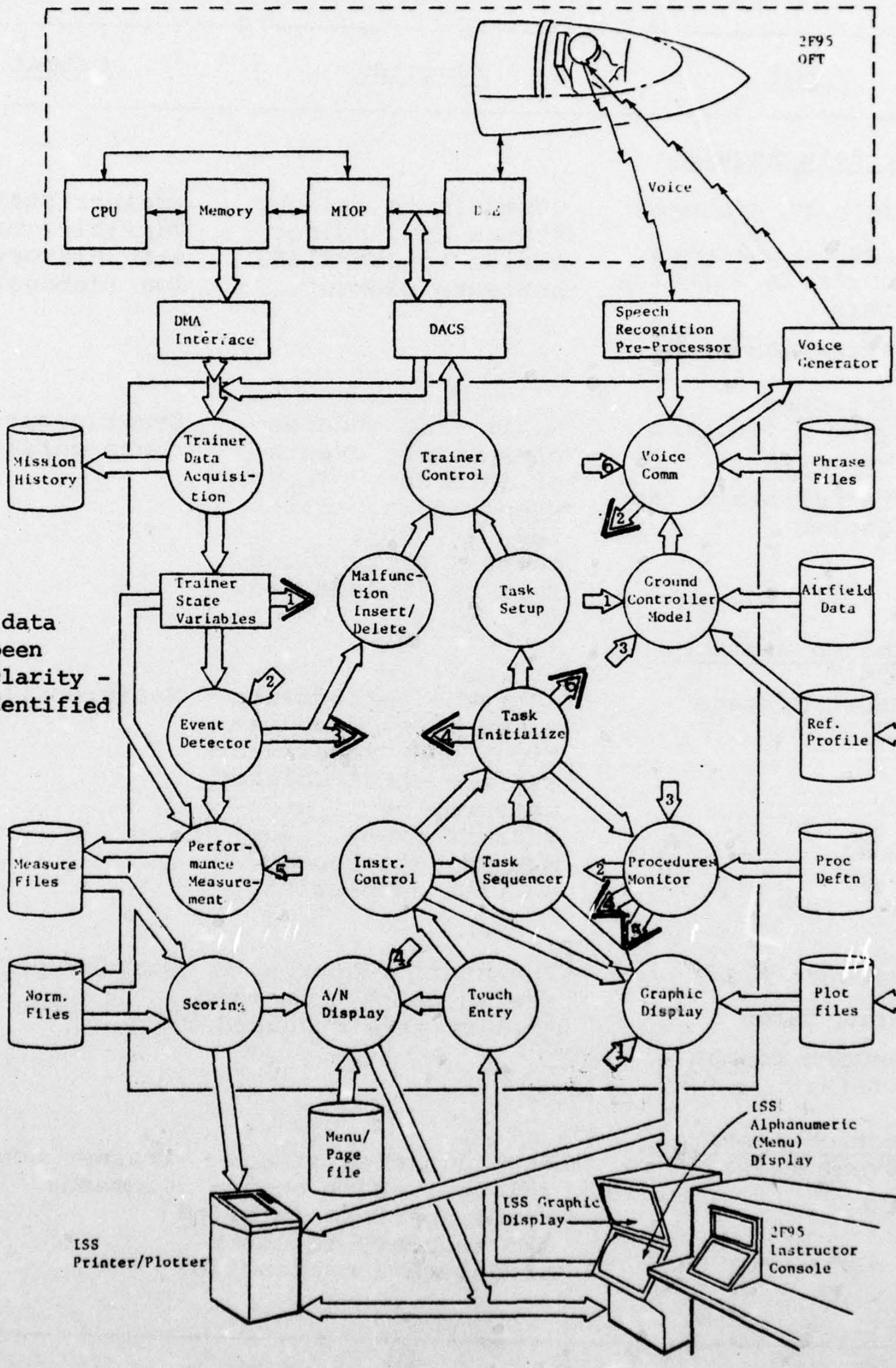
While ISS performs many vital services other than mission conduct, these other functions are designed to support efficient and effective training. The support services include: syllabus maintenance, instructor training, mission planning, and mission briefing and debriefing, as well as training research operations. The support functions are anticipated to be considerably less complex to implement and should be less demanding of computational resources than mission conduct. Thus, only mission conduct operations are described.

INFORMATION PLAN

Figure 23 depicts information flow during the conduct of an ISS mission. The critical interfaces to the OFT computer system, to the trainee in the cockpit, and to the instructor are shown. Each significant ISS software process (module) is depicted as a circle.

MODULE SUMMARY

Table 1 describes, briefly, the ISS software modules depicted in Figure 23.



Note: Some data lines have been broken for clarity - these are identified by numbers.

Figure 23. ISS Data Flow for Mission Conduct

TABLE 1. MISSION CONDUCT SOFTWARE MODULE DESCRIPTIONS

Input	Function	Output
Trainer Data Acquisition		
Aircraft dynamics Cockpit switches controls & indicators Navigation aids	Communicate trainer status and trainer action to other ISS software elements	Trainer state variables mission history log (debugging)
Event Detector		
Event definition messages Trainer state variables	Notify ISS modules of specific events of interest. (e.g., wheels down, altitude 10,000). Complex expressions must be implemented.	Event occurrence messages
Performance Measurement (PM)		
Event message	Activate performance measurement computations upon receipt of start event. Collect measures until stop measure event. Format PM data report on task completion	Measure file
Scoring		
Measure files Norm files Report format files	Transform measures to scores using criterion or normative standards.	Display page Print page
Malfunction Insert		
Event message	When notified of a relevent event occurrence, perform detailed I/C sequence to enter or delete a malfunction	Trainer control commands

TABLE 1. MISSION CONDUCT SOFTWARE MODULE DESCRIPTIONS (continued)

Input	Function	Output
Ground Controller Model		
Trainer state variables Airfield and profile files Event messages Navigation aid parameters Pilot phrase recognition	Emulate the UHF radio transmissions of various ground controllers (e.g., GCA, CCA, Departure).	Phrase selection messages
Voice Communications		
Phrase selections Phrase file Speech recognition: voice patterns	Generate selected phrases via a voice generator. Conform to half-duplex UHF protocol. When speech understanding is added, recognize phrases spoken by the R.P.	Phonemic codes to voice generator Pilot phrase recognition
Touch Entry		
Touch X-Y	Decode touch X-Y into processing requirements	Instructor request messages
A/N-Alphanumeric		
Instructor Request message Display request messages Menu/page file Alert messages	Format alphanumeric (menu) display pages. Respond to "secondary" instructor selections (e.g. help frames)	Display list
Instructor Control		
Instructor request messages	Process "primary" instructor selections. (e.g. sign on, log off, mode selection, abort requests)	Initialization Task termination Mode selection

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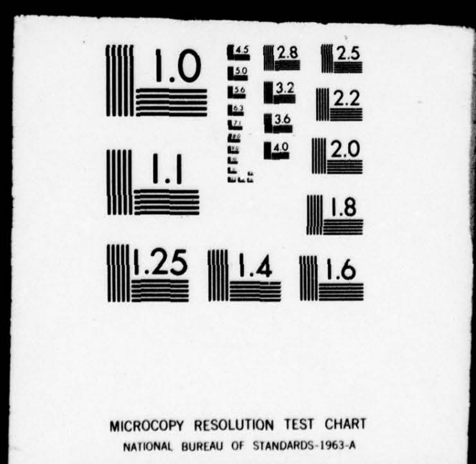

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TABLE 1. MISSION CONDUCT SOFTWARE MODULE DESCRIPTIONS (continued)

Input	Function	Output
Task sequencer	Maintain mission task list. Monitor task completion and close-out; activate next sequential task.	Task selection message Mission task list Task initialization requests
Task Initializer Parameter selection entries	Present task parameter entry display. Command initial trainer setup, as appropriate. Activate performance measures, event description, and procedures logic as appropriate.	Parameter entry display page Trainer setup commands in-cockpit Problem briefing via voice generator
Task Setup Setup commands	Decode setup commands into specific trainer I/O control sequences	Trainer control commands
Procedures Monitor Event messages	Determine conformance of pilot actions with specified procedures. Report relevent events to the instructor display. Classify and report apparrent errors.	Event descriptors Procedures display Performance measures
Graphic Display Task sequence Display control commands	Display mission geometry. Actual track history is plotted against desired profile. A split screen vertical and horizontal plot to be used for final approaches to landing.	Graphic display list Graphic hardcopy snapshots

SECTION X

USER TRAINING

CONSIDERATIONS

Training of the IPs and TDs will be required to assure that the capabilities and features of the ISS are used effectively during routine training. The TDs are included inthe training requirement for three reasons.

- o Some FRS IPs may wish to rely on TDs to operate ISS.
- o TDs will have to operate the ISS during unsupervised "extra training."
- o A skilled TD will likely be required to assist Fleet IPs in ISS procedures.

A short course of instruction also is considered necessary to introduce Fleet instructors to the manners in which ISS can support them in their instruction and evaluation of students.

A number of support features on existing training simulators are not used at all; others are not used as effectively as they could be. This occurs, in part, because IPs and TDs are not aware of them, do not know how to use them, find the features of marginal utility, or find them difficult to use. The ISS design has attempted to minimize these problems through careful organization of the systems, through design of the man-machine interface, and the incorporation of user procedural aids. However, the ISS can be cost-effective and can meaningfully support instruction, only if it is used properly. This will require training of its users.

INITIAL TRAINING

A formal training program will not be needed initially, assuming a phased implementation of ISS. This statement is predicated on the assumption that the developmental contractor and the on-site training analyst will work closely with a limited cadre of IPs and TDs. Thus, instruction of the IPs and TDs could take place on a one-to-one basis. Experience gained from this process should provide information for a course outline, for instructional materials, and the instructional methods to be developed.

FORMAL TRAINING

Ultimately, a formal program for training of the IP's and TD's in the effective use of the ISS must be provided. A logical structure in which to incorporate this training, is the IUT training program. The following is suggested as a syllabus for the required training module.

- Effective use of simulators for flying training
- Training objectives in their structures and purposes
- Training quality control and proficiency advancement
- The instructional support role of the ISS
- Modes of operation of the ISS in relation to its role
- Instructional support features in relation to modes
- Operating procedures for the ISS
- Effective uses of the ISS

It is recommended that the module be self-contained with clear instructional features. This strategy will provide its easy incorporation into an existing IUT syllabus, while enabling IPs and TDs to repeat the instruction as required. It also is recommended that the formal program incorporate hands-on demonstrations by IPs and TDs of their ability to operate the ISS following instruction.

Furthermore, the syllabus should have a closing segment in which instructors experiment with the ISS capabilities. Following an evaluation of this "free-form" instruction, the closing segment could include details of any lessons learned and a summary of possible mistakes made by the instructors.

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APPENDIX A

LISTING OF NORMAL PROCEDURES AND FLIGHT MODULES

NORMAL PROCEDURES MODULES

Interior Inspection Pre-Start
Engine Start
Post-Start Checks
Takeoff Checks
Pre-Launch Setups (carrier only)
Pre-Land/Descent Checks
Landing Checklist Procedures
Post-Landing Checklist Procedures

TAKEOFF/LAUNCH MODULES

Military Power T.O., Miramar
Zone 2 Afterburner T.O., Miramar
Zone 5 Afterburner T.O., Miramar
Aborted T.O., Miramar
Single Engine T.O., Miramar
Carrier Launch, Ship

DEPARTURE MODULES

Miramar, Seawolf-Seven Departure
Miramar, Henshaw-Three Departure to Thermal VORTAC
Miramar, San Pedro-Five Departure
Ship, Tactical Departure

WARNING AREA MODULES

Whiskey 291 (Seawolf-Seven Departure)

AIRWAYS MODULES

India Route 33 (George AFB) (Henshaw-Three Departure)

Thermal VORTAC direct to Needles VORTAC
Needles VORTAC direct to Hector VORTAC
Hector VORTAC direct to Fremont IAF
(From George Missed approach) direct to Los Angeles VORTAC
Los Angeles VORTAC direct to Oceanside VORTAC
Oceanside VORTAC direct to MIRAMAR UHF Radio Beacon

India Route 35 (March AFB) (San Pedro-Five Departure)

Tinny Transition direct to Los Angeles VORTAC
Los Angeles VORTAC direct to Henshaw IAF
(From March missed approach) direct to Ladds IAF (Miramar)

India Route 50 (Norton AFB) (Henshaw-Three Departure)

Thermal VORTAC direct to Needles VORTAC
Needles VORTAC via J-6 to Hector VORTAC

Hector VORTAC direct to Mentone IAF
(from Norton missed approach) direct to March VOR
March VOR direct to Ladds IAF

CARRIER OPERATIONS MODULES

Follow CATCC Vectors to Marshal Point
Navigate to Marshal Point

APPROACH MODULES

Shore Facilities
Hi-TACAN A, Miramar
Hi-TACAN B, Miramar
Random Radar Vector to GCA Pickup, Miramar
Random Radar Vector to Hi-TACAN A IAF, Miramar
Random Radar Vector to Hi-TACAN B IAF, Miramar
Hi-TACAN to Runway 5, Norton AFB
Hi-TACAN to Runway 16, George AFB
Hi-TACAN to Runway 31, March AFB
Random Radar Vector to GCA Pickup, MCAS, Yuma

Ship
Holding Pattern at Marshal Point
Mode I (Automatic) Approach
Mode I-A (Automatic to 0.5 miles) Approach
(DLC Final Approach)
Mode II (Manual) Approach, (ACLS Guidance)
Mode II Approach for APC Final Approach Technique
Mode II Approach for DLC Final Approach Technique
Mode III Approach for Area Surveillance Radar (ASR)
Final Approach
Mode III Approach for Precision Approach Radar (PAR)
Final Approach
Mode III Approach for ASR Final, APC Technique
Mode III Approach for ASR Final, DLC Technique
Mode III Approach for PAR Final, APC Technique
Mode III Approach for PAR Final, DLC Technique

FINAL APPROACH MODULES (Vital ceilings yet to be accounted for.)

Mode I, Ship (Automatic)
Mode I, Miramar (Automatic)
Mode I-A, Ship (Automatic to 0.5 mile)
Mode I-A, Miramar
Mode II, Ship (Steering Needles)
Mode II, Ship, APC (Automatic Power Control Technique)
Mode II, Ship DLC (Direct Lift Control Technique)
Mode II, Miramar
Mode II, Miramar, APC
Mode II, Miramar, DLC
Mode II-T, Ship (Steering Needles plus Voice Controller)
Mode II-T, Ship, APC
Mode II-T, Ship, DLC
Mode II-T, Miramar

Mode II-T, Miramar, APC
Mode II-T, Miramar, DLC
Mode III, Ship CCA
Mode III, Ship CCA, APC
Mode III, Ship CCA, DLC
Mode III, Miramar GCA (Normal Configuration)
Mode III, Miramar GCA (Auxiliary Flap Failure)
Mode III, Miramar GCA (Aft Wing Sweep Landing)
Mode III, Miramar GCA (No Flap/No Slat Landing)
Mode III, Miramar GCA, APC
Mode III, Miramar GCA, DLC
Mode III, George AFB GCA
Mode III, March AFB GCA
Mode III, Norton AFB GCA
Mode III, MCAS, Yuma GCA

LANDING/RECOVERY MODULES

Carrier Recovery
Runway (Rollout) Miramar NAS
Runway (Rollout) Yuma MCAS
Arrested Runway Ldg., Miramar

MISSED APPROACH MODULES

Shore Facilities
- Miramar Runway 24R Missed Approach (Mode II Approach)
- Miramar Runway 24R Missed Approach (Mode III Approach)
- Norton AFB Runway 5 Missed Approach
- George AFB Runway 16 Missed Approach
- March AFB Runway 31 Missed Approach

Ship
- Bolter/Waveoff (Modes I-A and II Approaches)
- Bolter/Waveoff (Mode III CCA Approach)

APPENDIX B

LISTING OF FAILURE (EMERGENCY) TASK MODULES

System/Subsystem	Failures
Air Data Computer	ADC failure
	Approach indexer lights failure
	CADC caution indicator light on
Armament and Stores System	Gun firing failure
	Missile status flag select failure
	Missile/store release failure
Communications/Navigation System	
Communications	Auxiliary UHF failure
	Headphone preamp failure
	ICS filter failure
	Main UHF failure
Navigation	ADF failure
	AHRS advisory indicator light on
	AWCLS AN/SPN-42 failure
	CSDC data freeze
	Data link failure
	ILS failure
	IMU unreliable
	Pilot bdhi failure (TACAN display)
	Radar altimeter unreliable
	Radar failure
	TACAN self test failure
	TACAN serial data failure
Electrical Power System	Dual transformer/rectifier failure
	Emergency generator failure
	HSD electrical power failure
	HUD electrical power failure
	Left ac power generator failure

System/Subsystem	Failures
Electrical Power System (cont)	L GEN caution indicator light on
	Right ac power generator failure
	R GEN caution indicator light on
	TRAN /RECT advisory indicator light on
	VDI electrical power failure
Lighting	CANOPY caution indicator light on
	Interior light failure
	LADDER caution indicator light on
Environmental Control System	BLEED DUCT caution indicator light on
	Bleed duct failure
	Cockpit pressurization leak
	ECS failure
	Main bleed air regulator failure
	OXY LOW caution indicator light on
	Oxygen low
Anti-Ice System	AOA heater circuit breaker failure
	INLET ICE caution indicator light on
	Pitot static heater failure
	WSHLD HOT advisory indicator light on
Fire Detection System	Fire detection short circuit
Flight Control Systems	
Primary Flight Control Systems	Autopilot caution indicator light on
	HZ TAIL AUTH caution indicator light on
	MACH TRIM advisory indicator light on

System/Subsystem	Failures
Primary Flight Control Systems (Cont)	Pitch stabilization channel A failure
	PITCH STAB 1 caution indicator light on
	PITCH STAB 2 caution indicator light on
	Pitch trim motor failure
	Roll stabilization channel A failure
	ROLL STAB 1 caution indicator light on
	ROLL STAB 2 caution indicator light on
	RUDDER AUTH caution indicator light on
	Rudder authority stops failure
	Runway pitch trim
	Runway roll trim
	Yaw stabilization channel B failure
	YAW STAB OP caution indicator light on
	YAW STAB OUT caution indicator light on
Secondary Flight Control Systems	Emergency flap control failure (down)
	Emergency flap control failure (up)
	FLAP caution indicator light on
	Flaps/slats malfunction
	Asymetrical Flaps
	GLOVE VANE caution indicator light on
	Left glove vane servoactuator failure
	Left outboard slat actuator failure
	Main flaps/slats & auxiliary flaps failure
	Right auxiliary flap actuator/relay failure

System/Subsystem	Failures
Secondary Flight Control Systems (Cont)	Right glove vane servoactuator failure
	Right outboard slat actuator failure
	Runaway wing sweep channel 1 control drive servo
	Speed brake switch failure
	SPOILERS caution indicator light on
	WING SWEEP advisory indicator light on
	Wing sweep channel 1 failure
	Wing sweep failure (2 channels)
Fuel System	Aft tank refuel/transfer valve fails closed
	BINGO caution indicator light on
	Forward fuel tank leak
	Fuel quantity indicator failure
	Fuel system imbalance
	Left wing tank leak
	Left wing tank transfer pump failure
	L FUEL LOW caution indicator light on
	L FUEL PRESS caution indicator light on
	No external tank fuel flow
	R FUEL LOW caution indicator light on
	R FUEL PRESS caution indicator light on
	Right engine boost pump inoperative
Hydraulic Power Systems	Combined hydraulic power system failure
	Combined hydraulic power system partial failure

System/Subsystem	Failures
Hydraulic Power Systems (Cont)	Flight control backup module failure
	Flight hydraulic power system failure
	Flight hydraulic power system leak
	HYD PRESS caution indicator light on
	Mid outboard spoiler module failure
Landing Gear Systems	Arresting hook failure
	BRAKE warning indicator light on
	Landing gear down lock solenoid failure
	Landing gear handle relays failure
	Landing gear safety relays failure
	LAUNCH BAR advisory indicator light on
	Left landing gear unsafe
	Low brake accumulator
	Nose landing gear unsafe
	Nosewheel steering failure
	Right landing gear unsafe
	Side brace fails to engage
	Tire blowout
Powerplant and Related Systems	
Afterburner Exhaust Nozzle Control System	Left exhaust nozzle failure
	Right exhaust nozzle failure
Air Inlet Control System	Left AICS malfunction
	L INLET caution indicator light on
	L RAMPS caution indicator light on

System/Subsystem	Failures
Air Inlet Control System (Cont)	Right AICS malfunction
	R INLET caution indicator light on
	R RAMPS caution indicator light on
Engine	Left afterburner blowout
	Left engine compressor stall
	Left engine fire
	Left engine flameout
	Left engine overtemperature
	Left engine seizure
	Left hung engine
	L OVSP/VALVE caution indicator light on
	Right afterburner blowout
	Right engine compressor stall
	Right engine fire
	Right engine flameout
	Right engine overtemperature
	Right engine seizure
	Right hung engine
	R OVSP/VALVE caution indicator light on
Oil System	Left engine oil pressure fluctuation
	Left engine oil pressure low
	L OIL HOT caution indicator light on
	OIL PRESS caution indicator light on
	Right engine oil pressure fluctuation
	Right engine oil pressure low
	R OIL HOT caution indicator light on

System/Subsystem	Failures
Starting and Ignition System	Left engine hot start Left engine ignition failure Right engine hot start Right engine ignition failure
Throttle Control System	Auto throttle failure

APPENDIX C

EXAMPLES OF EXPANDED FLIGHT PROFILE MODULES

Seawolf-Seven Departure, Miramar

Climbing right turn to 300° magnetic to intercept NKX TACAN Radial 280

Intercept 280 radial at 2,000 ft.

Fly outbound 280 radial at 2,000 ft. to Seawolf (NKX DME = 7 mi.)

Climb outbound on 280 radial to 14,000 ft.

Fly outbound on 280 radial to W-291 boundary (NKX DME = 31 mi.)

San Pedro-Five Departure, Miramar

Climbing right turn to 300° magnetic to intercept NKX TACAN radial 280

Intercept 280 radial at 2,000 ft.

Climb outbound on 280 radial to 14,000 ft.

Fly outbound on 280 radial at 14,000 ft. to NKX DME = 20 mi.

Intercept Mission Bay (MZB) VORTAC radial 300

Climb outbound on 300 radial to assigned altitude

Fly outbound on 300 radial to Tinny Intersection (MZB DME = 70 mi.)

Hi-TACAN A, Miramar, ACLS (Mode II) Approach

Descend to 16,000 ft.

Intercept Miramar (NKX) TACAN radial 060 at DME = 27 mi., Alt = 16,000

Descend inbound on radial to 6,600 ft. at DME = 16 mi., 250 KIAS

Descend inbound on radial to 4,300 ft. at DME = 13 mi., 250 KIAS

Descend inbound on radial to 3,400 ft. at DME = 11 mi., 250 KIAS

Descend/decelerate inbound on radial to AOA = ___., Ldg. configuration, at DME = 8 mi., Altitude = 2,800 ft.

Hi-TACAN-A, Miramar, Missed Approach

Arrest descent at DME = 2.5 mi., NKX radial 060 inbound

Level climb to 1,500 ft. ALT, inbound on 060 radial speed = 250 KIAS maximum

Configure aircraft for cruise

Right turn to 360° magnetic, after a beam of NKX TACAN speed = 250 KIAS maximum

Climb on 360 heading to 5,000 ft. by DME = 13 mi., speed = 250 KIAS maximum

Right turn to 13 mile DME ARC, ALT = 5,000, speed = 250 KIAS maximum

Fly 13 mi. DME ARC to intercept NKX TACAN radial 060, DME = 13 mi.

Right turn to intercept 060 radial inbound

Descend inbound to 3,400 ft. at DME = 11 mi., 250 KIAS

Descent/decelerate inbound on radial to AOA = ___, Ldg. configuration, at DME = 8 mi., altitude = 2,800 ft.

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ERRATA NOTICE NO. 1

The following corrections should be made to NAVTRAEQUIPCEN 76-C-0096-1 dated January 1979.

FUNCTIONAL DESIGN OF AN AUTOMATED INSTRUCTIONAL SUPPORT SYSTEM FOR OPERATIONAL FLIGHT TRAINERS

NAVTRAEQUIPCEN 76-C-0096-1 January 1979

1. On the front cover and DD 1473, it was omitted that the last three authors of this report represent Logicon, Inc., 4010 Sorrento Valley Boulevard, San Diego, California 92138.

After corrections are made, this notice is to be inserted at the front of the report for record purposes.

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