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SIMULATOR PILOT CONSOLES FOR NAS
AND ARTS III FACILITIES

Kenneth House
Stephen Karovic
Theodore Rundall

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FINAL REPORT

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

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*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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16. Abstract

This report describes the work effort and results of a feasibility and desirability study of replacing simulator pilot consoles in the field with more cost effective, easier to learn and use devices. Technically, such an action was found to be feasible and could result in a significantly improved simulator pilot operating capability. A touch panel input device using a menu list concept with target to map association, performed by an interface processor, is recommended. As an aid to deciding the desirability of proceeding with such a procurement, the costs of various alternatives were estimated. The costs of the preferred system was found to exceed the budget, unless a reduced number of consoles or sites were equipped, in which case the average cost per console was increased substantially. The information from field input was logically analyzed to arrive at the conclusion that the limited life potential of the system, the operational limits on increased training, and high overall cost make the desirability of the action questionable.

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PREFACE

The conduct of this study and the preparation of this report required the help and assistance of several organizations and individuals. The authors gratefully acknowledge the special contribution of Messrs. R. A. Bales, M. M. Lawrence, and R. H. Watson of MITRE Corporation, Metrek Division, who performed the significant interface analysis portion of the study, contributed major input to the costing analysis, and prepared the portions of the functional specifications required under this project. The authors are also indebted to Messrs. R. M. Johns and R. F. Irwin of the Development Programming Branch, ARD-140, personnel of the National Enroute Data Systems Branch, AAT-540, and National Terminal Data Systems Branch, AAT-550, who provided valuable advice in the software analysis, and Messrs. F. B. Woodson and W. J. Dunn, ANA-230, who acted as engineering consultants on this project.

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INTRODUCTION

BACKGROUND.

The Federal Aviation Administration's (FAA) newly upgraded Air Traffic Control Specialist (ATCS) training program stipulates that after graduation from the academy, the developmental controller will receive advanced environmentally oriented radar training at the Air Traffic Control (ATC) facility. This requirement will be satisfied using the recently improved radar controller training capability in the enroute centers and the Automated Radar Terminal System (ARTS III) facilities. The training function in the enroute centers is provided by a training simulation computer program called Dynamic Simulation (DYSIM) that is an integral part of the operational program in the Central Computer Complex (CCC) of the Air Route Traffic Control Center (ARTCC) system. Simulated targets are generated by the DYSIM subprogram of the CCC. All other automated operational functions, such as tracking and strip printing, for these simulated aircraft, are performed by the operational subprograms of the CCC. The major inputs to DYSIM for controlling the generation of radar target data are provided through the pilot consoles. The simulator pilot responds to the trainee controller's instructions to "fly" the simulated radar targets. The present training capability in the enroute centers uses operational Plan View Displays (PVD) for both the trainee and pilot positions.

The simulator training function in an ARTS III facility is similar to the DYSIM program in the enroute system. The simulation computer program, Enhanced Target Generator (ETG) is an integral part of the operational program in the ARTS III Input/Output Processor (IOP). As in the enroute system, training is performed on operational displays called Data Entry and Display Systems (DEDS). At the ARTS III locations, however, the pilots share the radar display with the ATCS trainee, and a separate keyboard is provided for use by the simulator pilot.

The operational PVD's and DEDS consoles are expensive (in excess of $110,000 each) but provide much more display capability than is needed for the simulator pilot position. The operational need for these consoles is great. The keyboards of these controller consoles are not designed for simulator pilot "flying" and, therefore, a high rate of input errors have been reported. The capability for fast entry is limited until considerable experience is attained.

OBJECTIVE.

The objectives of this project, as stated in the Engineering and Development (E&D) Program Plan (reference 1) are:

1. To investigate the feasibility and desirability of replacing the existing operational consoles (those used at pilot positions in field training) with a more cost effective pilot simulator type console.

2. To provide technical specifications and support during the acquisition of pilot simulator consoles, if required.

SCOPE.

In July 1975, the Associate Administrator for Engineering and Development (AED-1) received a request from the Associate Administrator for Administration (AAD-1) for support in the development of a revised terminal/enroute training program (appendix A), including the development of engineering specifications for simulator pilot consoles. The resulting E&D program plan called for a feasibility and desirability study as stated in the objective and further stated that: "If the study demonstrates the practicality of introducting new pilot positions in either or both systems, then technical specifications for procurement of simulator pilot consoles will be developed as required by the operating services."

As a first effort, an investigation was requested of the possibility of providing a low cost, quick solution, such as using closed-circuit television, or a slaved display, to provide the simulator pilot with a picture of the trainee's display. This was performed and found to be infeasible as reported in NAFEC Letter Report, NA-76-43-LR (appendix B).

Additional guidelines were prepared by the Systems Research and Development Service (SRDS) Program Manager and approved by representatives of the Office of Personnel and Training (OPT), Air Traffic Service (ATS), Airways Facilities Service (AFS), and SRDS (appendix C). In addition, ATS and AFS advised that the fiscal year 1978 budget provided for about $3.7 million for 114 consoles at 20 ARTCC's in the continental United States, NAFEC, and centers external to the continent equipped with Enroute Automated Radar Tracking Systems (EARTS). They also advised that tentative plans were being made for a fiscal year 1979 budget of about $4.6 million for consoles at ARTS III-equipped terminals.

The guidelines required that a functional specification was to be completed by April 1, 1977, in order to make the desired procurement in fical year 1978. This resulted in a change in emphasis from the complete system-wide study originally envisioned (but not possible in the time allowed) to the preparation of the specification and the accumulation of data necessary to support that effort.

The resulting accumulated data, with conclusions and recommendations regarding feasibility and desirability, were presented to a steering group consisting of representatives of OPT, ATS, AFS, and SRDS prior to the delivery of the specifications, as planned, to allow a decision to be made on whether to proceed with the procurement. This report documents the effort as presented to this group on March 9, 1977.

FEASIBILITY AND DESIRABILITY.

The question of the feasibility of replacing simulator pilot consoles is primarily a question regarding ability. That is: Is it technically possible and cost effective to replace the existing operational-type consoles, used in the field at simulator pilot positions, with simpler, lower cost, special purpose devices following the guidelines (appendix C)?

Desirability, on the other hand, is a question of practicality and benefit. That is: Is it practical and sufficiently beneficial to replace the existing operational-type consoles? We will attempt to answer the feasibility question, and provide sufficient information to permit a steering group decision on the desirability of proceeding with a fiscal year 1978 procurement based on the information available.

An answer to the feasibility question can be an absolute Yes or No. However, an answer to the desirability question requires knowledge of the alternatives. The basic alternative, of course, is to leave the system as it is, at least for awhile. The impact of that alternative should start with an understanding of why new consoles were proposed in the first place. The Program Plan (reference 1) states (in reference to the operational controller consoles) that: "The cost of these consoles is high; their keyboards are not designed for simulator pilot flying; and the operational need for consoles is great," implying that new simulator pilot consoles are needed to restore the costly controller consoles to operational use. Upon investigation, we found that this was not really the purpose. First, as stated earlier in the background statement: "At ARTS III locations, the pilots share the radar display with the ATCS trainee." That is (as was verified by observation), in most cases, a separate console is not used by the simulator pilots at ARTS III facilities. Any new consoles would be additions to the system, which would have the benefit of allowing separation of the students and pilots while expanding their capability, but, generally, they will not replace controller consoles.

Further, it was also found that AFS requested that all facilities (ARTS III and enroute) report the total number of operational displays necessary to meet their needs, including training, through 1982. The resulting shortage of enroute consoles is to be relieved by another procurement budgeted in fiscal year 1978. A procurement to meet the ARTS III shortage is also planned. The AFS request and field response did not consider the possibility that simulator pilot consoles used for training might be replaced by new equipment. Therefore, all controller consoles presently used for simulator pilots (plus possibly others for projected needs) are planned to be retained for training purposes. The objective apparently is to permit all of these consoles to be used for students if replacement simulator pilot consoles are purchased as a result of this project. Presently, the largest enroute training capability has four student and four simulator pilot positions. The guidelines (appendix C) require a maximum of eight student positions, thus supporting the assumption that a doubling of enroute training capacity is desired.

We have concluded, therefore, that the actual purpose for obtaining replacement simulator pilot consoles is to enhance and expand the training capability and improve (simplify) entries without the high cost of purchasing additional operational consoles.

The alternative to providing replacement simulator pilot consoles, which we must investigate, is the impact of not providing these improvements. The total impact of that alternative can be fully determined only by a complete study of the present system, its utilization, life, and projected training needs. This type of study was specifically rejected because of insufficient time. We will, however, attempt to answer the desirability question by a logical analysis of the data available, including other factors affecting (and affected by) the significant increase in training capacity indicated. A following project will undertake a full study of the present radar training capabilities in the field, and develop requested improvements to the DYSIM and ETG simulation programs.

TECHNICAL APPROACH OVERVIEW.

As originally planned, the effort was broken into five phases: (1) Functional and Software Analysis, (2) Interface Analysis, (3) Console Design and Human Engineering, (4) Candidate Screening and Reporting, and (5) Specification Documentation. It was quickly recognized that the primary efforts would be the functional analysis portion of Phase 1 and the interface analysis (Phase 2). All other actions would be a support to, or an outgrowth of, the results of these analyses.

The design guidelines were treated as guidelines only, and not as firm restrictions, especially in the area of limitations on any hardware and software modifications. It was recognized that, when a new device is introduced into existing automated systems, some impact on the existing system is unavoidable. Modifications were also anticipated if an interface, different from that used by the replaced devices, is required. Also, in order to take a responsible approach to the problem, it was essential that the requirements be considered against the total combined capabilities of both the existing system and the proposed new subsystem. Tradeoffs were investigated, which could result in more efficient use of the total capability. Other things considered were the future utility of the new subsystem in light of the long-term training needs and anticipated system changes, and the commonality of the new subsystem with other auxiliary displays under development.

Data accumulated from field trips and other contacts with field personnel were used primarily to provide the specific information needed for completing the functional specifications by April 1, 1977. An attempt was made to observe the total training environment and to question users regarding it. Time did not permit an organized study of a sufficient sample size and length to provide statistical support to the general impressions, and the sometimes very subjective information received. The results, therefore, reflect a broad analysis of our observations and information received, as they relate to the questions regarding feasibility, desirability, and to the training systems in general.

As requested, an interim briefing on the preliminary findings was presented midway through the effort. Also, a final oral report on the information contained in this report was presented on March 9, 1977, to allow the interservice steering group to decide on the advisability of proceeding with the fiscal year 1978 procurement.

FUNCTIONAL ANALYSIS

APPROACH.

An analysis of radar simulation training as it is conducted in the field facilities was carried out to obtain a full understanding of the functions required of the simulator pilot. As a first step, current available documentation on DYSIM and ETG was obtained and studied. NAS Change Proposals (NCP) depicting changes to the basic capabilities were analyzed. A function-by-function comparison of DYSIM and ETG was prepared. From this, the common and unique capabilities of the two subprograms were examined and the amount and complexity of button-pushing required for particular entries was determined.

Visits were made to ARTS III and enroute facilities that were actively conducting radar simulation training programs. Radar simulation training sessions were observed, with particular attention paid to the simulator pilot function. In each instance, radar simulation was discussed at length with the facility's Evaluation and Proficiency Development Officers (EPDO) and Specilists (EPDS). Subjects covered in these discussions included: overall utilization of radar simulation and its effectiveness, performance of the pilot function and associated problems, and problems associated with radar simulation in general.

Facilities visited or represented via direct interview with EPDS included: New York, Chicago, Washington, Cleveland, Albuquerque, and Atlanta ARTCC's; and Philadelphia, Baltimore, Chicago, Dallas, Cleveland, Raleigh-Durham and Boston Terminal Radar Approach Control (TRACON) facilities.

Based on the information gathered during field trips, the various clearances and other information received by the simulator pilot were analyzed as to source, resulting actions necessary, methods of accomplishing those actions, and associated problems. This of course led to more discussions and analyses of the training, the training environment, and testing at the various sites.

FIELD TRAINING SYSTEMS.

GENERAL. Preliminary investigations conducted to determine operational requirements, although limited, revealed some findings that were considered to be normative, with variations between facilities and personnel. Although training requirements are well established for all facilities, there appears to be a wide variation between the training needs (space, equipment, and staffing) and their ability to meet those needs.

TRAINING ENVIRONMENT. Radar simulation training laboratories have not yet been established at some facilities; notably terminals, and space for such laboratories is nonexistent at some locations. Training at some terminals is done in the maintenance room using the maintenance display, while other facilities have first-class training environments. Space limitations would prevent any significant expansion of the training laboratories at many facilities (both terminals and centers).

COMMUNICATIONS. One area of concern frequently mentioned was the lack of realism in the communications system used in the training laboratory. The Bell 300 communications system is used in only a few facilities and apparently the cost of including it in others is prohibitive. Terminal training staffs complain that the trainee issues his control instructions "into thin air," robbing significant realism from the simulation. A leased communications package for DYSIM laboratories that do not have the Bell 300 system is being provided to relieve this problem in centers.

STAFFING. Staffing in terminal facilities varies from a single EPDS who acts as pilot, ghost, instructor, and evaluator, to facilities with hired target generator operators, an EPDO, and teams of EPDS's supported by Data Systems Specialists (DSS). As might be expected, variations in the degree to which simulation is used appear to be proportional to the equipment and staffing variations. It is probably highly significant that terminals that are ARTS III assembly sites seem to be the most advanced in ETG implementation. The variance between enroute facilities is not as great as between terminals, yet variances do exist. The most apparent difference is that the larger centers seem to be better staffed, and as a result are more advanced in DYSIM implementation than the smaller centers.

In centers, it is common to use two instructors in one problem. One instructor monitors and evaluates the trainee's performance while the other instructor monitors the problem from the pilot positions and modifies the developing situation as necessary to meet the training requirements. Availability of personnel properly trained and currently proficient in the simulator pilot function influence the training program. In DYSIM, two pilots ordinarily handle a 50 percent traffic sample; three pilots are needed for a higher density traffic sample. In ETG also, up to three pilots may be required to support one controller. If fewer are used, a pilot can fall behind in his data entries and adversely affect the controller's performance. Training staffs are understandably reluctant to administer pass/fail tests under such circumstances.

UTILIZATION. In the centers, DYSIM is viewed enthusiastically and is widely accepted by management, training staff, and controllers alike. These people feel that considerable improvement in the quality of training and significant reduction in the total amount of training required, including on-the-job-training (OJT), has resulted from the use of DYSIM. Measurements of these factors are not available, and judgments as to amounts vary widely. DYSIM is utilized heavily, about 16 hours a day in some facilities, and its use extends well beyond merely training developmental controllers. It is also used for proficiency checks, remedial or refresher training and testing, training for special or unusual situations, staff and region familiarization, and for evaluating new procedures or traffic flow changes. Terminal facilities also are enthusiastic about the benefits of radar simulation for training. It is thought of as an excellent training tool that has reduced the overall amount of training required and has improved the quality of training.

IMPLEMENTING CHANGES. Nearly every facility contacted has a list of proposed changes they would like to see made to the simulation software to ease the simulator pilot burden or to improve realism. A prime complaint was the length of time necessary to implement what appeared to be relatively simple changes. Some of the most significant proposed changes appeared in subsequent program modifications that were not yet in use at the facilities concerned. The priority level for DYSIM or ETG changes is obviously not as high as changes to improve or correct the operational program. Most training staff people contacted feel that they should have the authority to independently modify their training system as they see fit to meet their needs.

Preparation of a new enroute training problem and scenario tape is an excessively tedious, time-consuming, and manpower-consuming process. Many thousands of new cards must be punched. Airway changes, procedure changes, or issuance of a new program tape require that cards be repunched. At the time of our discussions with training staffs, reading the card decks into the central computer often caused program aborts. Changing from card to tape input solved this problem but required even more card punching. (One center required 52,000 cards for its DYSIM problems, and 104,000 cards to convert to tape.)

OPERATIONAL IMPACT OF TRAINING. A problem area that may just be emerging is the saturation of track tables while DYSIM and ETG are running. No one identified any impact on training resulting from this problem. However, it was noted that some centers do not run high density DYSIM problems during peak traffic periods in order to avoid automatic shutdown of DYSIM. (Such an occurrence would affect DYSIM only, not the operational program. See Software Analysis.) Terminals also anticipate having eventually to schedule their training during off-peak hours for similar reasons.

SUMMARY. Some facilities claim to have few of the problems cited. Such facilities are the exception, and, as far as is known, those sites with a well equipped operational facility, a well-equipped laboratory, and a large training staff substantially supported by data systems specialists. A more indepth study of the total field training status, utilization, short-comings, and results will be contained in a subsequent project (216-103-120, Enroute and ARTS III Facility Training Enhancements) planned for completion in February 1978.

SIMULATOR PILOT POSITIONS.

SIMULATOR PILOTS. In many facilities, the simulator pilot is a developmental controller who may be taking instruction in radar, himself. Another facility may use a Full Performance Level (FPL) controller as a pilot. As stated earlier, the EPDS often acts as both pilot and instructor. Some facilities use hired target generator operators. Generally, however, developmental controllers serve as simulator pilots in centers, with the exception that they do not serve as simulator pilots for FPL or supervisory proficiency testing. Ordinarily, the simulator pilot also performs ghost functions appropriate to that position (that is, the functions associated with facilities or positions interfacing with the trainee). Again, a few facilities vary this procedure, assigning other personnel (FPL, developmental, instructor) to perform these functions.

FUNCTIONS. Briefly stated, the functions performed by the simulator pilot are:

1. Monitoring the air-ground "frequency" and initiating and responding to voice communications.

2. Selecting appropriate entry functions and making associated keyboard entries to offset target movement (pilot functions) in response to clearances and instructions received from the controller or the instructor, called for by the script, or required by procedures.

3. Making operational program keyboard entries, usually associated with ghost functions such as handoff, accept handoff, start track, and drop track.

4. Flight strip marking (reminders of future actions to be taken such as holding, altitude changes, etc.).

5. Offsetting data blocks to alleviate display clutter.

6. Checking certain data entries against posted look-up tables (conversion of indicated airspeed to true airspeed, climb/descent rates, etc.).

The simulator pilot's chief problem is that he has too much to do and too little time in which to do it. The keyboard entries he is required to make are lengthy and complex and often several entries are required to be made in quick succession. The operators of the pilot position and the training staffs interviewed indicated that there is a need for a pilot entry device that is more efficient and easier to use.

EQUIPMENT. The equipment provided at the pilot positions in ARTS III and enroute facilities are markedly different. In a typical terminal facility, the only dedicated pilot equipment may be one portable ARTS III keyboard, while in a typical enroute facility, each pilot occupies the equivalent of a center sector, with PVD and associated data entry devices including a Computer Readout Device (CRD), radar controller's alphanumeric keyboard with trackball, Quick-Action Keyboard (QAK), and "D" position alphanumeric keyboard. The alphanumeric keyboards in use in terminals and centers were not designed for use as pilot entry devices and are quite dissimilar.

PROCEDURES. The procedure for making pilot data entries in both ETG and DYSIM are similar; the flight is identified, the function (heading, speed, altitude, or beacon) is specified, and the value entered, in each case using the operational alphanumeric keyboard to make the entries. Ghost functions, consisting primarily of making and accepting handoffs and starting and terminating targets, are executed in the same general ways. Both systems allow the use of scenario tapes for initial entry of training problems.

DYSIM/ETG CAPABILITIES. With minor limitations, all normal aircraft motions or responses to controller clearances, can be accommodated by both simulation systems. The consistency and standardization of the aircraft motions was, however, criticized as being unrealistic and some actions required considerable ingenuity, dexterity, and a good memory on the part of the simulator pilot. A scratch pad and continuous observation of the position of the aircraft was required.

When used for training purposes, the DYSIM and ETG computer programs perform the same basic functions, which are that of generating simulated targets and allowing them to be manipulated by means of commands (simulating pilot response to control instructions) that control heading, speed, altitude, and beacon response.

DYSIM has some target control capabilities that ETG lacks. Conversely, ETG has some capabilities that DYSIM lacks. For example, holding pattern leg length and 360° turns are provided for in DYSIM but not in ETG. On the other hand, ETG has the capability to "freeze" the problem, provides specific no-gyro turn commands, allows direction of turn to be specified, and has its own wind factor, none of which DYSIM has. Other differences between ETG and DYSIM are the result of inherent differences between ARTS III and the enroute system, such as the fact that the enroute system processes primary radar returns and stores and processes flight plan data, while ARTS III does neither.

New capabilities and refinements are gradually being added to DYSIM and ETG. Appendix D compares specific ETG and DYSIM data entry functions that were current at the time of this writing.

PILOT ENTRY LIMITATIONS. The most time consuming or difficult simulator pilot input in the enroute facilities was the target initiation process. This process included a Start Sim message, a Start Track message, a Beacon Mode C message and a Handoff message. These messages were necessary for every target entering the training problem. This problem was alleviated in a subsequent program modification (A3D2.3). Automatic track initiation was provided when a Start Sim message was entered and Beacon Mode C was assumed initially on all flights since this condition was most prevalent. This modification reduced the target initiation process from four messages to two messages.

The following enroute command instructions required improvisation and extraneous entries for pilot conformance.

1. When a new beacon code was entered, mode C capability had to be included or it was dropped. This was changed by A3D2.3.

2. Direction of turn cannot be specified in DYSIM. The target will turn in the direction that requires the least change in heading. No-gyro turns (turns in a specified direction but unspecified amount) were accomplished by determining the present heading and then inputting a heading change of less than 180° consistent with the direction of command turn. Constant surveillance was required by the pilot so that if a "stop turn" command was not received from the controller before the target reached the input heading, a new heading was entered to keep the target in a turn. The pilot response to a "stop turn" command was to check the target's present heading and enter that value as the new command heading.

3. As direction of turn cannot be specified for a heading change, the pilot response to a turn of more than 180° in a specified direction was to enter two separate heading messages. The first heading message would perhaps change the target's present heading by 170° and the second message would be the command value issued in the clearance.

4. The pilot response to a command to climb or descend to an altitude at maximum rate or to expedite climb or descent was to determine the type of aircraft for that particular target, refer to a listing of aircraft types with associated climb/descent rates, determine the type of aircraft that had a higher rate than the type previously determined, move to a non-radar control (D) position and enter a Flight Plan Amendment message to change the type of aircraft to one of higher performance. When this was accomplished the pilot would move back to the simulator pilot position to input the command altitude originally issued. Surveillance of that targets altitude was now necessary so that when the command altitude was reached the pilot would move back to the D position to change the type of aircraft back to the original type so that subsequent altitude changes would be at the normal rate.

5. Speed change commands are issued in indicated airspeed, and the pilot input response is in true airspeed. A conversion listing is used which provides average true airspeeds based on an average altitude with respective indicated airspeeds. The pilot response to a change of speed is to refer to the conversion table for the issued indicated speed, find the comparative true airspeed, and enter that value in the speed change message. If a command is received to "resume normal speed," the pilot determines the filed true airspeed from the flight progress strip and enters that value in the speed change message. Speed is not presently displayed in enroute data blocks.

6. With some variations, DYSIM and ETG basically operate on the principle that the simulator pilot, rather than computer logic, is the initiator of aircraft motions. That is, the target action occurs at the moment of simulator pilot entry and specifically as directed by the entry. A clearance for an aircraft to proceed from present position direct to a fix, for instance, requires that the simulator pilot observe the relative positions of the aircraft and the fix, and mentally compute and enter the appropriate specific heading change required. Also, any clearance requiring compliance at a point or time in the future, such as an altitude change at a fix along the route of flight, requires a notation on the flight progress strip and surveillance of the aircraft target. When the aircraft reaches the fix, the pilot enters the appropriate command and the command action is initiated.

In terminal facilities a number of complex codes must be memorized or looked up for the entry of appropriate turn rates, speed change rates, altitude change rates, beacon code validations, etc.

The complexity of the messages, the notations and referrals for messages containing future action, the lookup tables necessary to perform some actions, and the display scanning to enter a message at the correct time, require very close attention and limit the number of aircraft one pilot can handle. Four or five aircraft simultaneously, and nine or ten per hour, seem to be the average handled by proficient pilots.

ENTRY ERRORS. Despite the above problems, the operators of the present pilot position devices become quite proficient in a relatively short time and can be trained in making almost error-free entries. Although few erroneous entries were observed, the potential was certainly present and once an error is made it is difficult to recover since new messages are being received while attempting to correct the error. Some of the messages are lost and can affect the developmental controllers performance in a pass/fail training situation.

TRAINING BENEFITS TO PILOT. Some training benefit is gained by the pilot console operator in using the operational keyboard and scanning the graphic display of the traffic situation. This benefit, however, is minimal since the pilot is usually too busy performing his function. The consensus of opinion was that a more efficient pilot entry device to help the pilot, and therefore the controller taking the problem, is more important than the familiarity lost by not using the operational devices. The pilot operator should be considered a support position rather than a training position.

DEVICE ANALYSIS

APPROACH.

Experts in the area of entry devices and displays were queried, briefings were received from many vendors in the field; articles, reports, and brochures on various computer systems, entry devices, and displays were read to determine the state-of-the-art and the ability of off-the-shelf devices to meet the needs for a simulator pilot console.

Alternative message entry devices and methods which could provide simpler and quicker entry capability with a minimum of special training were investigated. Currently available keyboard layouts were analyzed, including that used in The National Aviation Facilities Experimental Center (NAFEC) Digital Simulation Facility (DSF). Keyboards and systems designed for United States Air Force (USAF) and Canadian radar controller training were also considered. Recognizing the advantage of having a keyboard which is identical with that proposed for use in the FAA Academy's Radar Training Facility (RTF), the functional similarities and differences between that system and the desired subsystem were analyzed to determine the practicality of that approach. Entry devices other than keyboards, such as touch sensitive displays, were also investigated.

About halfway through the project, as requested by the SRDS program manager, a dynamic model of the entry concept considered most desirable was prepared and demonstrated at NAFEC using available NAFEC equipment and facilities. The lead time required to prepare the model and for the interface analysis effort did not permit an indepth analysis of all entry possibilities. An early decision on the most promising entry device was made primarily on the basis of briefings by various vendors, advertised capabilities, and experience with similar devices and methods.

ENTRY DEVICE INVESTIGATION.

REQUIREMENTS. The guidelines required that we simplify the simulator pilot inputs, interface the new entry device with the current DYSIM and ETG capability (without significant modification), and also provide a device common for both enroute and ARTS III facilities. A device which was quick and easy to learn and which would allow an increase in pilot capability with reduced input errors was desired.

COMPARISON WITH OTHER SIMULATORS. A cursory examination of the simulator pilot entry capabilities in use in the DSF, and planned for the RTF, pointed out some basic conceptual differences between those systems and the DYSIM/ETG systems. In the DSF/RTF concept the simulator pilot is primarily a translator between the controller (oral communications) and the computer (digital data). That is the simulator pilot orally communicates the reports generated by the computer (and portrayed on the display) to the controller, and enters the clearances received from the controller into the computer. Aircraft target status, position and actions are maintained by the computer and the human is merely the medium of information exchange. In the DYSIM/ETG systems, however, simulator pilots must maintain cognizance of the status and position of the aircraft targets and determine the specific aircraft status reports required by the controller, and actions necessary to carry out the received clearances. Also, in the DSF/RTF concept, in order to allow entry of the various possible clearances, a specialized and complex functional keyboard was devised which operates with a software system designed to control the simulator pilot entries. Acceptable message components (aircraft, fixes, etc.) and syntax are maintained by the software. Six to eight weeks of special training is necessary for new simulator pilots to become proficient in operating the keyboard. This, of course, would be less for persons familiar with air traffic control. Nevertheless, proficiency in using such a system would require additional special training and experience not compatible with the guidelines and realities of the field training system.

Other systems did use keyboards more compatible with DYSIM/ETG requirements, but they too were designed to operate with specific target generation systems. Modifications appeared necessary to adapt them to current DYSIM/ETG capabilities.

TOUCH SENSITIVE DEVICE ENTRY. The entry method chosen as most likely to provide a simpler, easier to use entry capability, common to both ETG and DYSIM application, was a touch sensitive display overlay. A number of possible touch entry techniques available off-the-shelf from various vendors were investigated. Some use light pens or sonic devices touching the display to trigger the entry. Others identify any touch (with a finger, for instance) on the face of the tube by interrupted light beams, pressure sensing devices, deflection of overlay surfaces against each other, impedence changes, etc. It was determined that such devices are in use successfully in a number of applications. Experiments by MITRE and NAFEC also have established the feasibility and utility of such devices. For our use it was decided that a system allowing finger touch should be used rather than one requiring an intermediate device like a light pen.

As with the DSF/RTF concept, the method chosen required that acceptable entries and syntax be maintained by the software. The aircraft under the direction of a simulator pilot are listed by the computer on a display along with basic data about the aircraft (speed, heading, altitude, and beacon code), and a list of possible entries (referred to as a menu list). The touch sensitive overlay allows the pilot to select the action he wishes to take, or the reference aircraft and flight condition he wishes to change, by merely touching the appropriate item on the face of the display. The touch on the display face is picked up by the touch system overlaying the display, and is transmitted to the software as an x-y location. The software then identifies the data at that location, not unlike a track ball entry in the operational system. The software then displays a menu of the next acceptable data (message field) dependent on the entry previously identified. Thus, the operator can proceed in proper logical order through all fields of any possible message. Data entry errors are thus eliminated and virtually no training is required as the software controls the entry sequence in essentially the same order as a clearance would normally be received. Software control also allows for the differences in terminal and enroute type of clearances with no differences in the device used or in training method. Translation of the entered message into the appropriate ETG or DYSIM message, or messages (in proper format and sequence), is also accomplished by software, thus eliminating memorizing or looking up special codes and formats.

TOUCH ENTRY CONCEPT EVALUATION.

DISPLAY. Appendix E describes the initial basic display and entry procedure prepared for the model constructed at NAFEC for evaluation of the touch entry/menu list concept. This was only for the concept evaluation and not intended to represent the final display format or procedures recommended.

EQUIPMENT. A PDP-11 driving a GT-44 display system with a 14 inch cathode ray tube was programmed at NAFEC for the evaluation. Instead of the preferred finger touch system, a light pen, available on the GT-44, had to be used. The display was mounted in a console similar to that envisioned for a simulator pilot.

SUBJECTS. Nine controllers from the field with current experience in DYSIM or ETG worked at NAFEC for 2 days participating in the evaluation of this entry concept and also adding to our knowledge of current training capabilities. Four of the controllers were from enroute facilities and five from terminals, from six different regions, representing facilities with a variety of traffic densities. All of them were familiar with simulation training, and all had served as simulator pilots.

METHODS. The concept was first demonstrated to the controllers from terminal facilities and then hands-on time was provided for each. During the hands-on time, air traffic control clearances were issued by project personnel. The controllers, acting as simulator pilots, made appropriate data entries in response to the clearances. Debriefings were held, and questionnaires were completed by the controllers. The same procedures were later followed with the controllers from enroute facilities.

The debriefings permitted a free discussion of the data entry and display concept being evaluated and, incidentally, provided project personnel with specific information on the training requirements peculiar to different facilities.

RESULTS. The personnel involved in the touch entry device evaluation at NAFEC believed the concept to be highly beneficial in reducing pilot workload and reducing error potential. These benefits could then increase the aircraft handling capacity of the pilot and possibly decrease the number of pilots necessary to support a training problem. No measures are available to define the increased capacity but best guess estimates indicate a possible 50 to 100 percent increase in the present capacity. The controller responses to the questionaires are compiled on the sample questionaires in appendix F.

DISPLAY INVESTIGATION.

APPROACH. Six categories of display systems were investigated by MITRE for use as the pilot console displays:

1. Random Position Graphics

2. PPI Shared Mode

3. High Resolution TV, Bit Image Memory

4. High Resolution TV, Scan Converter Memory

5. Plasma Panel

6. Direct View Storage Tube

Table 1 summarizes the comparison of these display systems.

The intent of this investigation was to consider the applicability of a category of display for the pilot console function, and not to recommend a particular manufacturer's display, although an example of a display is shown in each case. Two different kinds of data presentation are involved at the pilot position. One is alphanumeric data in tabular form (tabular display), such as lists of information; the other is data in graphic form (graphic-display), such as a radar display with moving targets, data blocks, maps, and symbols.

RESULTS. The results of this investigation showed that relatively inexpensive display systems, capable of meeting the needs of a simulator pilot position, are available. The type of system most likely to meet the graphic display needs at a reasonable cost (about $10,000) was the high resolution, TV-type system with scan converter memory. If only a tabular display is required, lesser quality is acceptable and such displays, adequate to the needs, can be obtained for about $3,000.

TABLE 1. COMPARISON OF CANDIDATE DISPLAYS FOR SIMULATOR PILOT CONSOLE FUNCTION

	Random Position Graphics	PPI Shared Mode	High Resolution TV Bit Image Memory	High Resolution TV Scan Converter Memory	Plasma Panel	Direct View Storage Tube
Size	19.25 in Circular (Usable)	22 in Circular	14x14 in (25 in diag) (Usable)	12x9 in (17 in diag) (Usable)	8 1/2x8 1/2 in (sq.) (Usable)	7.5x5.6 in (11 in diag) 15x11 in (19 in diag) (Usable)
Resolution	0.009 to 0.021 in line width	0.020 in line width	0.014 in max. spot size (1024x1024)	700 TV lines (8192x8192 raster inits)	60 lines/inch 0.016 in (512x512)	(1024x780 points)
Brightness+Levels	50 F.L. Up to 5 levels	10 F.L. one level	25 F.L. one level (multi-level option)	50 F.L. one level	30 F.L. one level	Unknown (but low) one level
Hardware Blink	Yes	Yes	No	No	No	No
Erase	Line/char. Selective	Line/char. Selective	Yes-but removes overlap	Yes-but removes overlap	Yes-but removes overlap	Page erase only
Refresh Rate	55 Hz.	24 Hz.	None	None	None	None
Cost	\$30 to \$50K	\$15 to \$20K	≈\$30K	≈\$10K	\$5 to 6K	\$3 to \$10K
Advantages	Good graphics In FAA inventory	In FAA inventory	Display processor included Good graphics	Display processor included Good graphics Low cost Low power (≈460W)	Low cost Low power (≈200W)	Good Graphics Low cost Low power (≈105W)
Disadvantages	Requires a display processor with a refresh memory High cost High power (1700W)	Requires a display processor with a refresh memory No graphics High cost High power (1600W) Low brightness	High cost No independent selective erase High power (≈1400W) No hardware blink	No independent selective erase No hardware blink	Poor resolution Poor reliability No hardware blink	Low brightness No selective erase No blink
Vendor	Raytheon (PVD)	Burroughs (ARTS II)	Raytheon (Raycomp)	Hughes (C9	Owens-Illinois	Tektronix

TABULAR VERSUS GRAPHIC REQUIREMENTS.

The determination to use a tabular touch sensitive display for message entry and the relative display cost differences posed a question of the necessity for having a graphic display for the simulator pilot. As described earlier, the DYSIM/ETG concept assumes that the human simulator pilot, rather than the computer, is maintaining cognizance of each aircraft's status and position. Therefore, a graphic display appeared essential. Specifically such a display provides:

1. Flexibility of starting a target anywhere on the display by identifying x-y coordinates with a trackball or touch overlay.

2. A reference for determining target position for handoff and terminate functions.

3. A reference for target position to input actions at future points.

4. Some training value by allowing a trainee acting as simulator pilot to visualize the situation.

The introduction of an interface processor, which would display graphically the map and target data received from the main enroute or ARTS III computer, however, introduced the possibility that it, rather than the human, could maintain aircraft target status and positional relationship to the map. Operational advantages of such a capability were readily apparent. No longer would the simulator pilot have to use memory joggers or mental calculations to carry out required aircraft actions. Clearances could be entered immediately, as received, and the computer would determine the appropriate heading to a fix, and the time to send the appropriate message to DYSIM or ETG based on its maintenance of the target/map association. The pilot's target-handling capability would most certainly be increased, and errors, delayed actions, etc., would be decreased. Programming, of course, would be significantly increased, but this would be a one-time cost.

If the cheaper tabular displays could be used, instead of the graphic displays, the program costs might be offset. However, another use of the graphic displays was uncovered during our investigation which makes their elimination infeasible at present. The instructors, in some facilities, use the graphic displays at simulator pilot positions to visualize, modify, or create desired problem situations. Such a capability is essential, especially during high-density training and testing. At some facilities simulated targets are affected by the winds aloft, resident in the operational system. This could prevent preplanned traffic situations from developing, unless the problem is modified by instructor intervention. Also, instructors attempt to dynamically modify a training situation to best exercise a trainee's weak areas. Some instructors feel that such actions are virtually impossible to accomplish looking over the shoulder at the controller trainee's scope and must be performed at the simulator pilot position.

If graphic display presentation is required, then the touch sensitive entry requirement means that both graphic and tabular presentations are necessary. This could be accomplished by: 1. using a single display switchable between graphic and tabular presentation, 2. providing a single display containing both tabular and graphic data simultaneously at each simulator pilot position, or 3. providing separate graphic and tabular displays.

The first option appears to be unacceptable, as the need for information from both sources is frequently simultaneous. This opinion was supported by a limited survey of ATCS's, EPDS's, and EPDO's.

The second option poses a problem of display size. Dedicated areas for graphic and tabular data would be required which did not infringe upon each other, and the graphic area must be large enough to clearly depict the same data as is presently on the PVD's and DED's. When larger scopes are used, the edge areas (most likely the areas used for the tabular data) would probably have considerable parallax, making it unacceptable for touch entry. Some vendors, however, claim to have larger, virtually flat face displays which could be used as described.

The last option would satisfactorily meet the needs, but obviously at an increased cost. This could be reduced if the graphic displays were considered for instructor use only, in which case one additional graphic display for each controller position (half the number of simulator pilot positions) would be required.

INTERFACE ANALYSIS

APPROACH.

A full report on the interface analysis carried out by MITRE Corporation in support of this project is contained in their report MTR-7437 (reference 2). The analysis examined the technical feasibility of alternative hardware interface approaches, estimated the costs of each approach, and determined the software implications of each approach on the existing operational programs. The constraints on the analysis (appendix C) were: no modifications to existing operational hardware was allowed, only minor modifications to existing operational software was allowed, the same basic hardware for the enroute and terminal approaches must be used, standard off-the-shelf hardware interfaces must be used as much as possible, and the present operational capability of pilot consoles must be maintained, i.e., graphics display with full message input capability (either touch or keyboard). Full tabular displays could be considered as a potential cost saving/enhanced capability option.

The following is a summary of the results of the technical feasibility analysis of various interface approaches. Information on costs and software impacts will be discussed later in the report.

ENROUTE FACILITIES.

Three basic enroute interface approaches were examined as follows:

APPROACH 1. Interface the simulator pilot console with the Computer Display Channel (CDC) or the Display Channel Complex (DCC) display subsystem using the present Radar Keyboard Multiplexers (RKM's). Figure 1 is a block diagram of the hardware interfaces for this approach.

Advantages of this approach are: it would cause no change to the CCC to CDC/DCC interface, the Display Generator (DG)/PVD combination would be released for operational use, a high quality graphics display would be used, and it would require very few, if any, changes to CCC or CDC/DCC software.

Disadvantages are: This interface requires the use of relatively large and expensive displays, touch entry devices are not feasible on this size display, additional RKM's and Refresh Memory Input/Output Control (RMIOC) ports may be required, and this is the most expensive enroute interface approach.

APPROACH 2. Interface the simulator pilot console with the CCC via either the Input/Output Control Element (IOCE) Selector Channels, or through a Peripheral Adapter Module (PAM) using General Purpose Input (GPI) and General Purpose Output (GPO) adapters to interface with the IOCE Multiplexer (MPX) Channels. Figure 2 is a block diagram of the hardware interfaces for this approach.

From a technical standpoint, this approach meets all of the basic requirements such as: no modifications to operational hardware are required, only 2 man-years effort is required for the software interface with the CCC, the same hardware can be used in the preferred terminal approach, standard off-the-shelf hardware interfaces are used, and the present operational capability can be maintained (graphical display).

Other advantages are: the pilot positions will be able to function as ghost positions, the pilot consoles are smaller than PVD's or ARTS III consoles, the hardware/software development will not be difficult, the pilot subsystem can easily be converted to a full stand-alone system when desired, and the interface hardware will be compatible with any replacement subsystems of the enroute or terminal systems.

The negative, or questionable, aspects of this approach are: CCC software changes are required to send only target and full data block information on training target flights to the interface processor, and CCC software changes are required to accept simulator pilot inputs from a different channel than the CDC/DCC.

APPROACH 3. Interface the simulator pilot console with the CCC via the PAM Common Digitizer (CD) adapter. Figure 3 is a block diagram of the hardware interfaces for this approach.

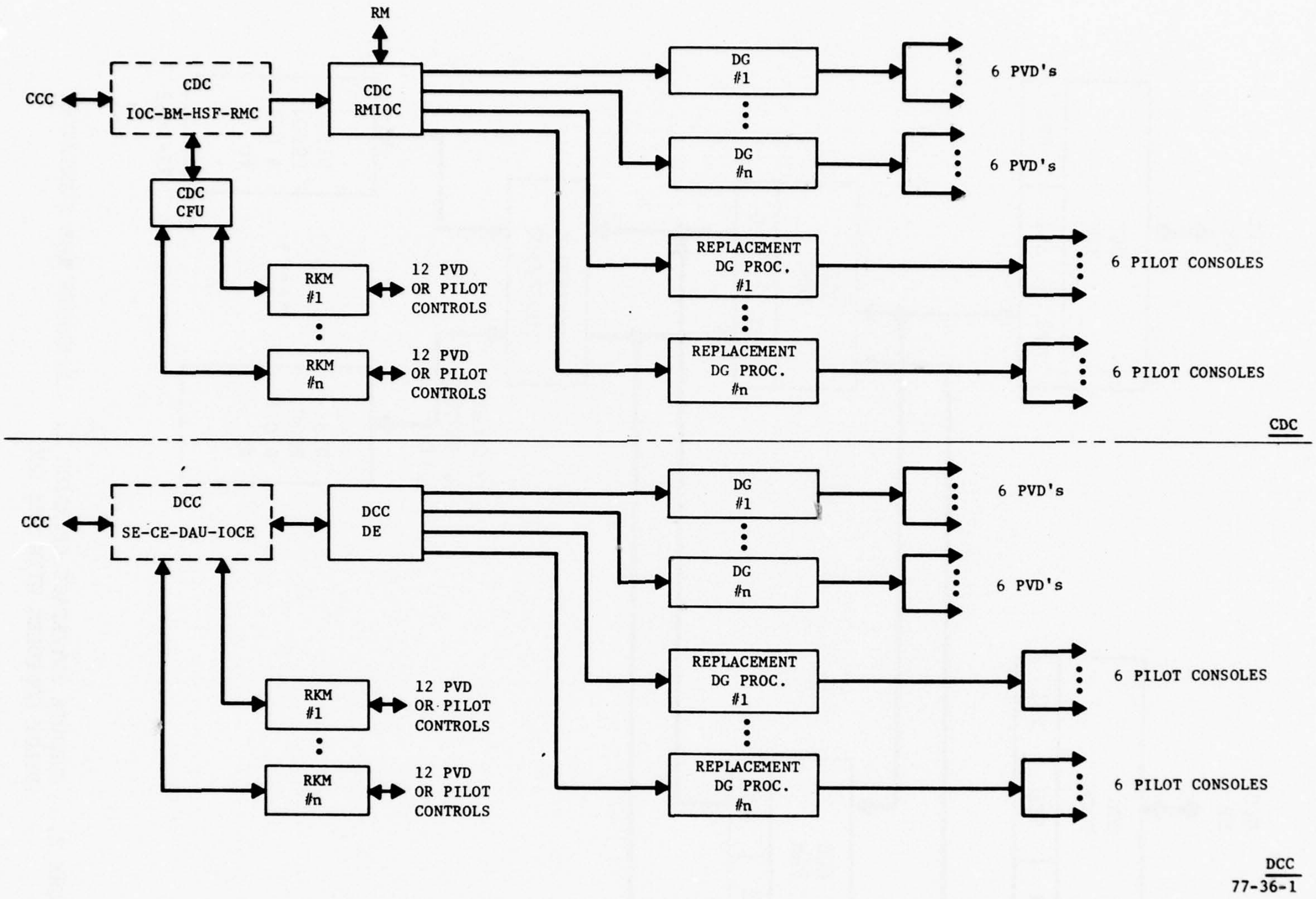

FIGURE 1. ENROUTE INTERFACE APPROACH 1: INTERFACE THE SIMULATOR PILOT CONSOLES WITH THE CDC OR DCC DISPLAY SUBSYSTEMS

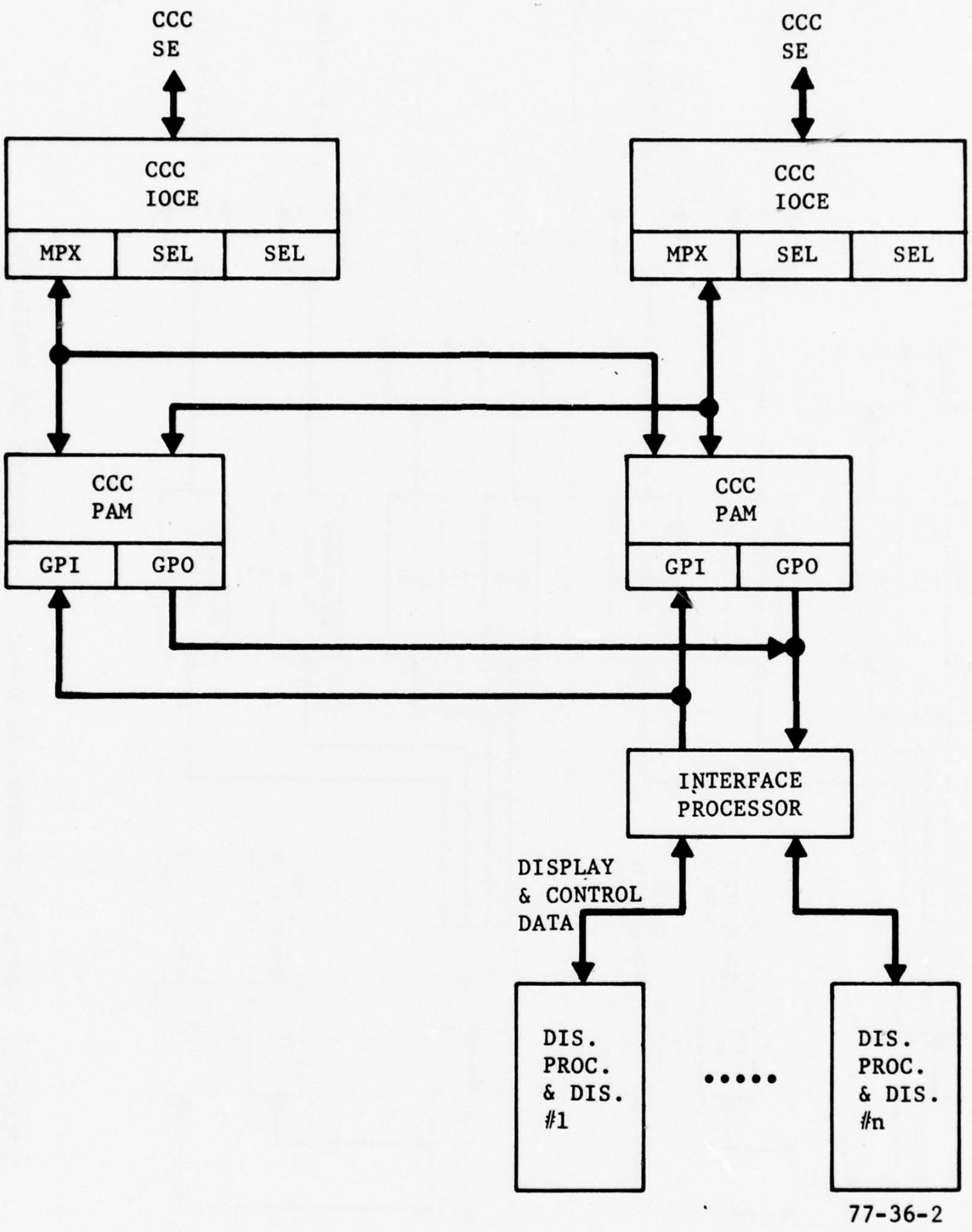

FIGURE 2. ENROUTE INTERFACE APPROACH 2: INTERFACE THE SIMULATOR PILOT CONSOLES WITH THE CCC

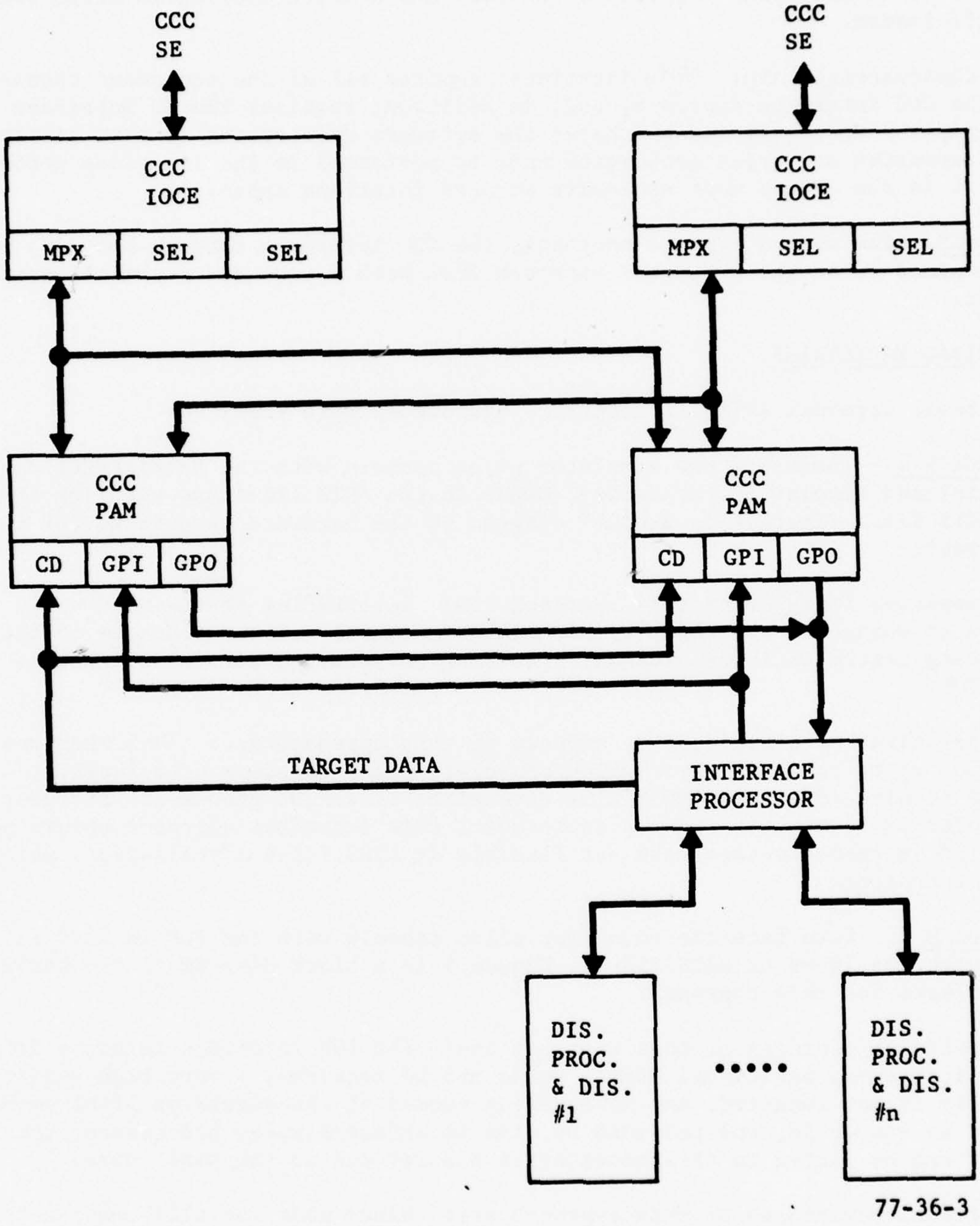

FIGURE 3. ENROUTE INTERFACE APPROACH 3: INTERFACE THE SIMULATOR PILOT CONSOLES WITH THE CD ADAPTER

The positive features of this approach are: The simulation targets would appear as normal radar targets to the CCC, and a major subprogram DYSIM could be off-loaded.

The disadvantages are: This interface requires all of the equipment required by the CCC interface approach, and, in addition, requires the CD interface development and equipment purchase; the software development is more difficult and expensive as target generation must be performed in the interface processor; and it is the second most expensive enroute interface approach.

RESULTS. The second enroute approach, the CCC interface through the PAM, was determined to be the preferred approach from both a cost and technical standpoint.

TERMINAL FACILITIES.

Two basic terminal ARTS III interface approaches were examined:

APPROACH 1. Interface the simulator pilot console with the Multiplexer and Multiplexed Display Buffer Memory (MDBM) in the ARTS III-A and with the IOP in ARTS III. Figure 4 is a block diagram of the hardware interfaces for this approach.

The positive features of this approach are: interfacing at the MDBM would cause no change to the IOP-B to MDBM interface, and software changes to the existing system would be minimal, requiring only normal adaptation changes to the IOP.

The negative, or questionable, aspects of this approach are: Each MDBM would service up to four simulator pilot consoles, eight consoles at a facility would require additional MDBM's at each site; if target generation at the pilot consoles is a possible future requirement, this interface approach should not be used as these features are not feasible at ATRS III-A installations using this approach.

APPROACH 2. Interface the simulator pilot console with the IOP in ARTS III and with the IOP-B in ARTS III-A. Figure 5 is a block diagram of the hardware interfaces for this approach.

The positive features of this approach are: The IOP interface is not a difficult interface, additional MDBM's would not be required, a very high quality display is not required, map information needed at the simulator pilot consoles could be stored in, and provided by, the interface/display processors, touch input can be fitted to this category of display due to the small size.

Additional advantages of this approach are: Since most (or all) components in this system are commercially available off-the-shelf, maintenance problems are reduced, the reliability of most system components can be determined prior to purchase, the same equipment could be used for enroute (using enroute approach 2), ARTS III, and ARTS III-A facilities, thereby reducing provisioning

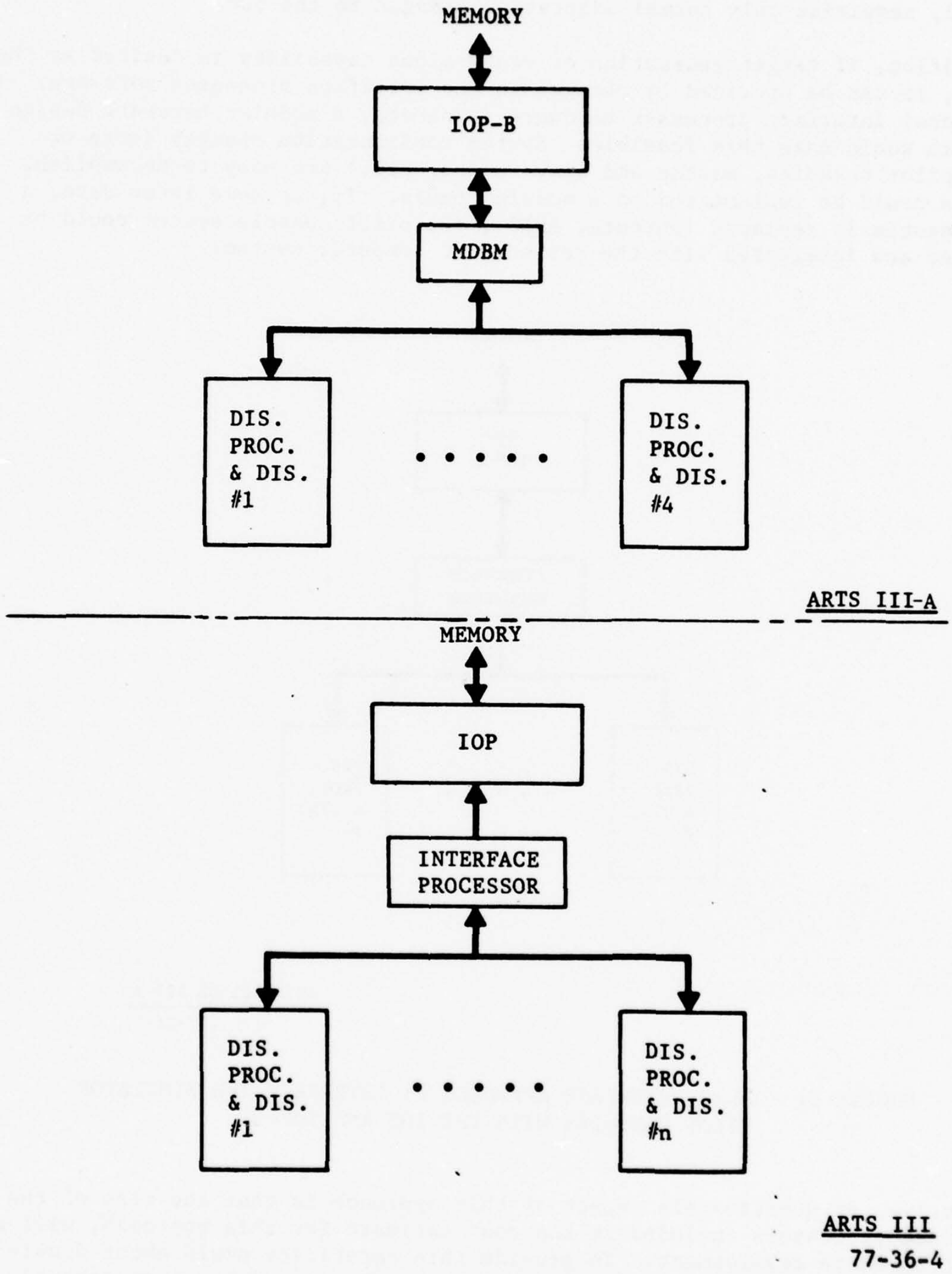

FIGURE 4. ARTS INTERFACE APPROACH 1: INTERFACE THE SIMULATOR PILOT CONSOLE WITH THE MDBM IN ARTS III-A AND WITH THE IOP IN ARTS III

and training problems, and the software change to the existing system would be minimal, requiring only normal adaptation changes to the IOP.

In addition, if target generation or stand-alone capability is desired in the future, it can be provided by changes to the interface processor software. If additional interface processor hardware is needed, a modular hardware design approach would make this feasible. System configuration changes (more or fewer pilot consoles, master and slave units, etc.) are easy to accomplish. Systems could be implemented on a modular basis. If, at some later date, a major system is replaced (enroute, ARTS), the pilot console system could be retained and integrated with the replacement computer system.

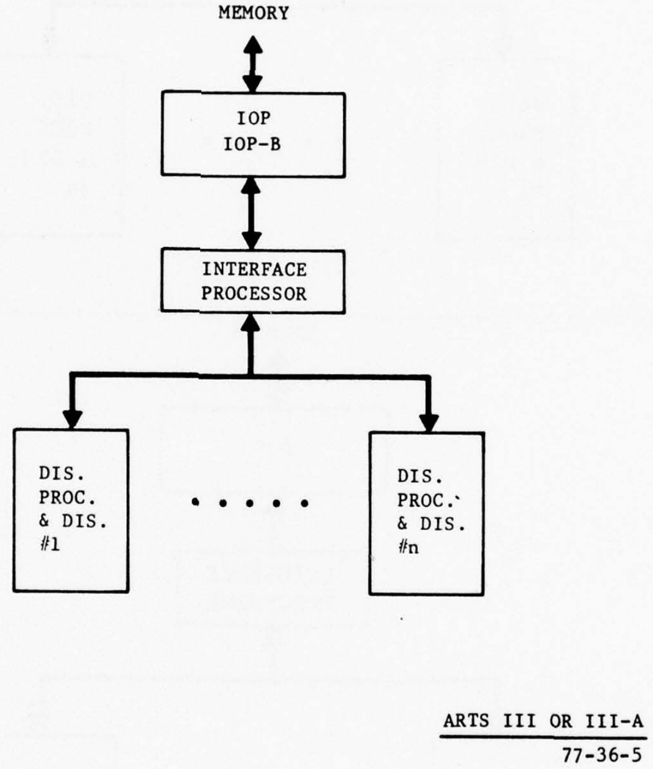

FIGURE 5. ARTS INTERFACE APPROACH 2: INTERFACE THE SIMULATOR PILOT CONSOLES WITH THE IOP AND IOP-B

A negative, or questionable aspect of this approach is that the size of the interface processors included in the cost estimate for this approach, will not permit software development. To provide this capability would about double the cost of the interface processors (mainly to purchase peripheral equipment).

RESULTS. The preferred approach from both a cost and technical standpoint appears to be approach 2, IOP Interface.

OTHER INTERFACE ALTERNATIVES.

In addition to the approaches discussed above, several other alternative approaches using redundant or existing operational equipment were examined, i.e., the use of the redundant CDC or DCC at the enroute centers, the use of the redundant IOCE's at the enroute centers, the use of ARTS II consoles, the use of redundant IOP's in the terminal facilities, and the use of redundant Direct Access Radar Channel (DARC) equipment at the enroute centers.

The most promising of the alternatives is the latter one, the use of DARC equipment, which could reduce the cost of the preferred enroute approach. It would have no effect on the terminal approaches except to establish which interface processor would be used if the same hardware were bought for both the enroute and terminal systems.

SOFTWARE ANALYSIS

APPROACH.

An analysis of the software impact on the existing field automation systems resulting from interfacing the new consoles and increasing the training load was provided by the SRDS Development Programming Branch (ARD-140) at NAFEC, and by MITRE. Advice and consultation was also received from the National Enroute Data Systems Branch (AAT-540) and National Terminal Data Systems Branch (AAT-550) also at NAFEC.

The software impact of the new simulator pilot consoles, as proposed, had several aspects requiring investigation:

1. The magnitude of changes to the operational software to interface a new processor through different channels as proposed by MITRE.

2. The magnitude of the software required in the new processor to perform the desired actions.

3. The additional software impact of doing target to map association in the new processor.

4. The impact on available computer time of the implied increase in training capability.

5. The impact of future proposed changes on the software under development to accommodate the desired system.

Estimates of the magnitude of operational program changes were obtained from AAT-540 and AAT-550 input. Software development estimates (number of instructions) were based on experience from the DSF at NAFEC, and on MITRE experience in the development of the Display Demonstration Capability at MITRE METREK.

Despite the limitations on changes to the existing operational and simulation programs laid down by the guidelines, it was recognized at the outset that any new device interfaced through a new channel to the operating system will incur some changes. The following, for the most part, is a summary of the more complete analysis of this software impact contained in MITRE report MTR-7437 (reference 2).

BASIC ENROUTE SOFTWARE IMPACT.

APPROACH 1. The first of the three candidate approaches for the enroute interface investigated by MITRE (interface pilot console with CDC/DCC) imposed the least impact on operational system software. The changes required were primarily adaptation changes of the type experienced whenever any new display is added to the system. A processor, required to replace the present DG, however, would require new software (about 8,000 instructions) primarily to accept the high data rate from the CDC/DCC, and to provide appropriate data to the pilot display at a lower rate.

APPROACH 2. The preferred second enroute interface approach (interface of the simulator pilot console with the central computer via the PAM using GPI and GPO adapters) would require changes to the existing monitor programs. A new program code would also be required to: accept inputs from a new channel, output appropriate data on the new channel, and provide the logic to route the appropriate data to one of the two channels, in addition to the usual adaptation changes necessary for the addition of any new display to the system. These changes to the operating system are estimated at about 2,500 lines of code.

Under this approach, new software must be developed for both the interface and the display processors to perform functions for the pilot displays similar to that now performed by the CDC/DCC for both the trainee and pilot displays. Those CDC/DCC-like functions for the interface processor would be:

1. Storage and presentation of the map with fixes, as on the PVD, without boundaries or other controller information.

2. Routing of data by display address.

3. Handshake with the CCC and data rate compatibility.

Capability to perform software maintenance should also be included as a necessary function.

The CDC/DCC-like functions that would be performed by the display processor are:

1. Provide storage and display of trail history, pilot selectable (may not be necessary if hardware is prohibitive, and the heading vector or the heading alphanumerics are present).

2. Range scale and offset computations.

3. Trackball processing.

4. Coordinate conversion.

5. Keyboard interpretation and input message processing.

6. Refresh displays.

The following additional software changes, not discussed in the MITRE report, should also be made to the enroute DYSIM program in order to most efficiently utilize the capabilities of the proposed new simulator pilot consoles:

1. The simulator pilot in the enroute system should constantly know what the speed of each target is without looking it up in the flight data on the strips. Presently, however, speed data is not output to the simulator pilot. A change should be made to DYSIM to output this information.

2. As mentioned in the Functional Analysis Section, there is no capability presently in DYSIM to change the rate of ascent or descent of a given target without changing the type of aircraft with a flight plan amendment message, and then restoring the original aircraft type with another amendment, after the ascent or descent is complete. It is possible, but cumbersome, to have the interface processor generate these same false messages to DYSIM when an appropriate change of rate is entered by the simulator pilot. However, DYSIM should be modified to permit this capability without such gimmicks.

3. Similarly, direction of turn and turn without a new heading (No-Gyro turn) cannot now be specified in DYSIM by the simulator pilot, as required occasionally, without multiple messages appropriately timed. Again the interface processor could be programmed to enter the several fake messages at the appropriate time, but this is extremely inefficient. DYSIM should be modified to permit a turn in a specified direction with or without a new heading, and to process a stop turn message.

The magnitude of effort to accomplish these DYSIM changes was not determined.

APPROACH 3. The third enroute interface approach investigated (interface the simulator pilot consoles with the CD adapter) would generate targets outside the central computer, thus eliminating the primary function of DYSIM. Major changes would be required to accomplish this and to develop another software interface to provide flight data to the new interface processor. The software required for the interface processor using this approach, would be on the order of creating a new DYSIM (about 14,000 instructions). In addition, a software interface with the central computer to gain access to flight record files and storage for these data would be required.

BASIC ARTS SOFTWARE IMPACT.

The two candidate approaches for ARTS III interface investigated by MITRE had identical software impact. The IOP software changes would be essentially the same as adding any new displays to the system. The new interface and display processor would require about 8,000 instructions to control the refresh of the display, store and display a map, and transfer data between the IOP and the display and between the display input device and the IOP.

TARGET/MAP ASSOCIATION.

In MITRE's analysis of software, an assumption was made that with graphic displays at the simulator pilot positions, the simulator pilot entries would be limited to the same basic entries as are permitted today into DYSIM and ETG, but using a greatly simplified method (touch panel with the menu list as described earlier). That is, target/map association by the computer (also described earlier) would not be required. The above software estimates were the result of that assumption. They did, however, also estimate the software impact (new interface software development) required, if only tabular displays were available. In that case, the simulator pilot would not be able to visualize the relationship between the aircraft target position and map points, in order to respond to commands such as: "maintain altitude to a fix point and then climb to another altitude." Later, as indicated in Device Analysis, it was determined that target/map association in the interface processor was essential to obtaining the desired improvements to the simulator pilot capability, regardless of the displays used.

An estimate of the magnitude of performing the target/map association function in the interface processor was made based on the number of instructions (26,000) required for the pilot console processing in the DSF at NAFEC. The DSF target generation and controller console processing programs are not included in that figure.

Adding the target/map association function to the interface processor for the enroute facilities does not appear to impact significantly the size of the processor required, In the enroute facilities, the processor must be adequate to handle up to 16 simulator pilot consoles. This would require a processor which could also adequately handle the increased processing of target/map association. This, however, is not true of the smaller interface processor for terminal sites which is required to service only a maximum of eight simulator pilot consoles and normally only four. Adding the target/map association function to those systems will require a larger interface processor.

INCREASED TRAINING CAPABILITY.

REQUIREMENTS. The functional requirements in the guidelines (appendix C) imply the need for a significantly increased field training capability. For instance, whereas the largest enroute training facility in the field today has four student and four simulator pilot consoles, the functional requirements call for a maximum number of eight student consoles and 16 pilot consoles per facility. A similar magnitude of increase is indicated for ARTS III facilities. The maximum number of targets per student console listed in the functional requirements is 25 for enroute facilities and 16 for ARTS III facilities.

ENROUTE IMPACT. Some of these requirements are out of line with the capacities of NAS enroute systems and DYSIM. Some of them exceed the needs expressed by field training people. Presently, the enroute systems can handle a maximum total of 60 simulated targets in the automatic mode. (In automatic mode, the simulated aircraft is associated with a flight plan and will automatically proceed according to that plan unless removed by pilot action. Manual mode requires that the simulated aircraft movements be controlled by the pilot. In that mode, up to 200 targets are acceptable.) It was ascertained that the automatic mode limit was not just a function of the assigned table space. Rather, the limit of 60 is imposed by the fact that the time to process more than 60 simulated targets can exceed the available cycle time. Time-out aborts could occur if more than that number of simulated targets required processing. The National Enroute Data Systems Branch determined that the present method of processing automatic mode simulated targets could be considerably improved in order to reduce the processing time. They estimate that about 9 man-months would be required to make this software improvement. The magnitude of the resulting increase in processing simulated targets, however, is not known.

An associated problem is that the enroute operational program possesses a safety feature that does not permit DYSIM to function when the track tables become filled to 82.5 percent of capability. This 82.5 percent figure includes tracks input from DYSIM. As a result, training staffs at some busier facilities presently avoid running 100 percent training traffic samples during peak "real world" traffic handling periods.

Regarding the doubling of the number of training consoles (from four to eight maximum in ARTCC's) and adding two pilot positions for each training console, it soon became apparent that such an increase would much more than double the present training capability of any center. In the present best equipped laboratories, four pilot positions and four training positions do not permit running four simultaneous training problems unless all four problems are very elementary. For example, if two 50 percent peak load traffic samples were run in this laboratory, only two controllers could be trained, because each controller requires two pilots. This leaves two training positions unutilized during the training run, which is not an uncommon situation. If eight training positions and 16 pilot consoles were provided, the training capacity might well be quadrupled. Personnel from training staffs at the New York and Cleveland Centers stated that the maximum number of consoles required in the foreseeable future for controller trainee positions would be six. (Cleveland would provide four of these consoles for training developmental controllers and two for training full-performance-level controllers). We feel that this same maximum requirement would apply to any center.

ARTS III IMPACT. The ARTS III target generating limit has recently been increased to 64. When track saturation occurs, training track files are automatically pre-empted for operational use as needed.

MAINTAINING SOFTWARE COMPATIBILITY.

The software development mentioned previously will probably be the pacing item in a procurement of new simulator pilot consoles. The decision to include target/map association actions adds to the technical risk for software development and, therefore, the time for obtaining an operational system. A rough estimate of the time to develop the necessary software would be 1 year after the start of the contract. The requirement for a functional specification by April 1, 1977, was established because of the need to let the contract prior to the end of fiscal year 1978 (September 31, 1978). (Lead time of about

18 months is common for a contract of this magnitude.) Therefore, it can be assumed that delivery of the first new simulator pilot console system, ready for use, will not be for at least 2 1/2 to 3 years. This time lag could cause a problem of software compatibility.

As noted in Functional Analysis, most every facility actively using DYSIM or ETG has proposed changes which they feel will improve the realism or reduce the simulator pilot burden. Over the next 2 1/2 years many more such change proposals can be anticipated. ATS has stated that they intend to increase the rate of implementation of such proposals in order to provide needed improvements to the field training capabilities. This, of course, is commendable and must be permitted; however, according to the received guidelines and contract specification requirements, the new simulator pilot consoles must interface with DYSIM and ETG, essentially as they are anticipated to be at the time the contract is let. An attempt was made to include changes now anticipated for future program modifications in the preparation of the functional specification. Other changes processed during the development of the new system will require either continuous modification of the contract during the development, or an immediate software update upon completion of the contract, in order to assure compatibility with DYSIM and ETG as they exist at that time. It is also probable that some changes, made to DYSIM and ETG in the interim, will have to be removed as they will duplicate functions in the new interface processor.

COST ANALYSIS

APPROACH.

The analysis of various interface possibilities conducted by MITRE and fully reported in MTR-7437 (reference 2) included an estimate of the costs of each of the three enroute, and two ARTS III interface approaches investigated by them. These estimates were based on their knowledge of the current components of the field automation systems, off-the-shelf costs of various possible components as received from manufacturers, and experience in the development of other systems. Software development costs were estimated at the rate of $35 per instruction, based on experience with other systems and the assumption that this software would have a relatively low level of documentation and heavy emphasis on assembly language.

When preparing the basic costs, MITRE made an initial assumption that only graphic displays would be used and, with graphic displays, extensive target/map association functions in the interface processor would not be required. In addition, MITRE prepared alternative cost estimates for the preferred enroute interface: (1) using the DARC equipment at the enroute centers as the interface processor, and (2) using only the cheaper tabular displays, with target/map association programming in the interface processors.

Originally, it was estimated by ATS that there would be a requirement for 228 consoles at 23 enroute sites (including NAFEC and two EARTS sites), and

130 consoles at 63 ARTS III sites. Recognizing that EARTS sites could not use the same specifications as other enroute facilities because of their use of ARTS III type of processors, MITRE reduced the number of enroute sites to 21, but otherwise used the above figures for their cost estimates.

Subsequent decisions and information received required the preparation of new cost estimates: 1. AFS determined that the DARC equipment should not be considered for use as the simulator pilot console processor (appendix G), 2. Target/map association programs in the new processor were determined to be essential regardless of the type of display used, 3. There is a strong possibility that both a tabular and a graphic display will be required to adequately perform the desired functions (see Device Analysis), 4. The number of enroute consoles included in the fiscal year 1978 budget was later established as 114, while the number for the fiscal year 1979 ARTS III procurement was left open, and 5. We were asked to determine the number of consoles and sites possible within the $3.7 million fiscal year 1978 budget for enroute facilities and the $4.6 million estimated for ARTS III sites in fiscal year 1979. These new estimates were prepared by combining the basic data provided by MITRE. A very conservative approach was taken, in that the costs of both tabular and graphic displays, and a summation of both software estimates (with and without target/map association) were used.

In all cases, the estimates only reflected initial contract purchase costs and did not attempt to reflect total life cycle costs of the systems, nor do they reflect in-house costs, such as those costs necessary for: changes and adaptation of the basic ARTS III and enroute software, training of in-house personnel, site preparation or new construction, continuing maintenance and adaptation of the delivered software, etc.

In the following sections, the costs are broken into "recurring" (those costs which vary according to the number of units of each item required) and "nonrecurring" (those fixed costs required no matter how many units are purchased). Program management and contingency costs were each computed as 10 percent of the costs of all other contract items; while provisioning, factory inspection, and freight costs were percentages (10, 5, and 3 1/2 percent respectively) of the total hardware costs (i.e., all items under recurring costs, except installation and site test).

BASIC COSTS OF ENROUTE INTERFACE APPROACHES.

Tables 2, 3, and 4 depict MITRE's cost estimates for each of the three enroute interface approaches investigated. Costs were estimated for 228 simulator pilot consoles at 20 ARTCC's and NAFEC. Only graphic display costs are shown and costs of target/map association software in the interface processor are not included.

BASIC COSTS OF ARTS III INTERFACE ALTERNATIVES.

Tables 5 and 6 depict MITRE's cost estimates for 130 simulator pilot consoles at 63 ARTS III facilities for each of the two ARTS III interface approaches investigated. Only graphic display costs are shown, and costs of target/map association software in the interface processor are not included.

TABLE 2. ESTIMATED COSTS OF ENROUTE INTERFACE APPROACH 1: INTERFACE RAYTHEON PILOT CONSOLE WITH THE CDC/DCC

Recurring Costs

Item	Unit Cost	No. Req'd	Enroute Cost
1) Display Station (Processors + Graphics Display)	$30,000	228	$6,840,000
2) Cables	3,600	21	75,600
3) Installation & Site Test	500	21	10,500
Total Recurring Costs			$6,926,100

Nonrecurring Costs

1) Display Station Software Development (8,000 instructions @ $35/instruction)	$ 280,000
2) Hardware Development	250,000
3) Hardware Documentation	70,000
4) Software Documentation	50,000
5) Program Management (10% of Contract cost)	757,600
6) Contingency (10% of Contract cost)	757,600
7) Provisioning (10% of Hardware cost)	692,600
8) Factory Inspection (5% of Hardware cost)	346,300
9) Freight (3½% of Hardware cost)	242,400
Total Nonrecurring Costs	$3,446,500
Total Costs (Recurring and Nonrecurring)	$10,372,600

NOTE: Estimate does not include the cost of additional RKM's or RMIOC's if needed.

Software development estimates (number of instructions) are based on MITRE experience in development of the display demonstration capability at MITRE METREK.

TABLE 3. ESTIMATED COSTS OF ENROUTE INTERFACE APPROACH 2: INTERFACE PILOT CONSOLES WITH THE CCC

Recurring Costs

Item	Unit Cost	No. Req'd.	Enroute Cost
1) Interface Processor	$50,000	21	$1,050,000
2) Display Processor & Graphics Display	10,000	228	2,280,000
3) GPI/GPO Interface Processor Interface	3,400	21	71,400
4) PAM GPI Adapters	1,200	42	50,400
5) PAM GPO Adapters	1,158	42	48,600
6) Cable Driver/Receiver Assembly	400	228	91,200
7) Data Entry Device	1,000	228	228,000
8) Cables	2,700	21	56,700
9) Installation & Site Test	500	21	10,500
Total Recurring Costs			$3,886,800

Nonrecurring Costs

1) Display Station Software Development* (8,000 instructions @ $35/instruction)	$ 280,000
2) GPI/GPO/Interface Processor Interface Development	80,000
3) Data Entry Device Development	10,000
4) Hardware Documentation	50,000
5) Software Documentation	50,000
6) Program Management (10% of Contract cost)	435,700
7) Contingency (10% of Contract cost)	435,700
8) Provisioning (10% of Hardware cost)	388,700
9) Factory Inspection (5% of Hardware cost)	194,300
10) Freight (3½% of Hardware cost)	136,000
Total Nonrecurring Costs	$2,060,400
Total Costs (Recurring and Nonrecurring)	$5,947,200

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* Software development estimate (number of instructions) is based on MITRE experience in development of the display demonstration capability at MITRE METREK.

TABLE 4. ESTIMATED COST OF ENROUTE INTERFACE APPROACH 3: INTERFACE PILOT CONSOLES WITH THE CD ADAPTER TO GENERATE SIMULATED TARGETS EXTERNAL TO THE CCC

Recurring Costs

Item	Unit Cost	No. Req'd.	Enroute Cost
1) Interface Processor	$50,000	21	$1,050,000
2) Display Processor & Graphics Display	10,000	228	2,288,000
3) GPI/GPO/Interface Processor Interface	3,400	21	71,400
4) PAM GPI Adapters	1,200	42	50,400
5) PAM GPO Adapters	1,158	42	48,636
6) PAM CD Adapters	2,910	42	122,220
7) Cable Driver/Receiver Assembly	400	228	91,200
8) Data Entry Device	1,000	228	228,000
9) Cables	2,900	21	60,900
10) Installation & Site Test	700	21	14,700
Total Recurring Costs			$4,017,400

Nonrecurring Costs

Item	Cost
1) Display Station Software Development* (14,000 instructions @ $35/instruction)	$ 490,000
2) GPI/GPO/Interface Processor Interface Development	80,000
3) CD/Interface Processor Interface Development	40,000
4) Data Entry Device Development	10,000
5) Hardware Documentation	65,000
6) Software Documentation	50,000
7) Program Management (10% of Contract cost)	475,200
8) Contingency (10% of Contract cost)	475,200
9) Provisioning (10% of Hardware cost)	401,700
10) Factory Inspection (5% of Hardware cost)	200,900
11) Freight (3½% of Hardware cost)	140,600
Total Nonrecurring Costs	$2,428,800
Total Costs (Recurring & Nonrecurring)	$6,446,200

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* Software development estimate (number of instructions) based on experience from Digital Simulation Facility at NAFEC and the display demonstration capability at MITRE METREK.

TABLE 5. ESTIMATED COSTS OF ARTS INTERFACE APPROACH 1: INTERFACE PILOT CONSOLES WITH THE MDBM IN ARTS III-A AND DIRECTLY WITH THE IOP IN BASIC ARTS III

Recurring Costs

Item	Unit Cost	No. Req'd.	ARTS Cost
1) Interface Processor	$10,000	63	$ 630,000
2) MDBM	75,000	29	2,191,095
3) Display Processor & Graphics Display	10,000	130	1,300,000
4) IOP/MDBM/Interface Processor Interface	4,000	63	252,000
5) Cable Driver/Receiver Assembly	400	130	52,000
6) Data Entry Device	1,000	130	130,000
7) Cables	1,100	63	69,300
8) Installation & Site Test	500	63	31,500
Total Recurring Costs			$4,655,900

Nonrecurring Costs

1) Display Station Software Development* (8,000 instructions @ $35/instruction)	$ 280,000
2) IOP/MDBM/Interface Processor Interface Develop.	100,000
3) Data Entry Device Development (covered under Enroute costs)	
4) Hardware Documentation	50,000
5) Software Documentation	50,000
6) Program Management (10% of Contract cost)	513,600
7) Contingency (10% of Contract cost)	513,600
8) Provisioning (10% of Hardware cost)	465,600
9) Factory Inspection (5% of Hardware cost)	232,800
10) Freight (3½% of Hardware cost)	163,000
Total Nonrecurring Costs	$2,368,600
Total Costs (Recurring & Nonrecurring)	$7,024,500

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* Software development estimate (number of instructions) is based on MITRE experience in development of the display demonstration capability at MITRE.METREK.

TABLE 6. ESTIMATED COSTS OF ARTS INTERFACE APPROACH 2: INTERFACE PILOT CONSOLES DIRECTLY WITH THE IOP IN BOTH ARTS III-A AND BASIC ARTS III

Recurring Costs

Item	Unit Cost	No. Req'd.	ARTS Cost
1) Interface Processor	$10,000	63	$ 630,000
2) Display Processor & Graphics Display	10,000	130	1,300,000
3) IOP/Interface Proc. Interface	4,000	63	252,000
4) Cable Driver/Receiver Assembly	400	130	52,000
5) Data Entry Device	1,000	130	130,000
6) Cables	1,100	63	69,300
7) Installation & Site Test	500	63	31,500
Total Recurring Costs			$2,464,800

Nonrecurring Costs

Item	ARTS Cost
1) Display Station Software Development* (8,000 instructions @ $35/instruction)	$ 280,000
2) IOP/Interface Processor Interface Development	100,000
3) Data Entry Device Development (covered under Enroute Costs)	
4) Hardware Documentation	50,000
5) Software Documentation	50,000
6) Program Management (10% of Contract cost)	294,500
7) Contingency (10% of Contract cost)	294,500
8) Provisioning (10% of Hardware cost)	246,500
9) Factory Inspection (5% of Hardware cost)	123,200
10) Freight (3 1/2% of Hardware cost)	86,300
Total Nonrecurring Costs	$1,525,000
Total Costs (Recurring & Nonrecurring)	$3,989,800

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* Software development estimate (number of instructions) is based on MITRE experience in development of the display demonstration capability at MITRE METREK.

COST SAVINGS USING DARC AND TABULAR DISPLAYS.

Table 7 depicts MITRE's cost comparisons between the preferred basic enroute CCC interface approach using a new interface processor and graphic displays, and the same approach using the DARC processor for the interface and tabular displays.

The major cost saving for the full tabular display option is the difference between the display station costs. A graphics display is estimated to cost $10,000, whereas the cost of an adequate tabular display is estimated to be only $3,000. These savings are somewhat offset by the difference in the estimated cost of software development; i.e., $280,000 for the graphic display approach, without target/map association software, and $910,000 for the tabular display approach, with such software.

For the DARC option, the major cost saving is the $50,000 interface processor and peripheral equipment at each enroute site since the DARC processor would already be installed at each enroute site. The other savings result from the fact that the DARC processor would already be interfaced with the CCC/GPO. The total net savings are estimated to be about $1.4 million. It is important to point out that this total savings could not be attained on either of the other enroute approaches since they involve a different interface with the system. Additional savings would also accrue in reduced maintenence, training, and spare parts. Using the DARC option would have no effect on the ARTS interface approaches except to establish which interface processor would be used if the same hardware were bought for both the enroute and terminal systems.

ADJUSTED FINAL COST ESTIMATES.

ENROUTE. Table 8 uses the basic cost estimates received from MITRE to depict the preferred enroute interface, adjusted to 114 consoles at 21 sites, with both graphic and tabular displays, and with software development costs for target/map association software (the sum of MITRE software estimates used for tabular and graphic displays). Site and console costs are separated to allow easy computation of costs for various numbers of sites and consoles. Table 10 compares some possible combinations of numbers of consoles and sites which could be provided within the fiscal year 1978 budget of $3.7 million. It also shows the total costs for both 114 and 228 consoles at 21 sites and average cost per console in each case.

ARTS III. Table 9 uses the basic cost estimates from MITRE to depict the preferred ARTS III interface, adjusted to the number of consoles and sites possible within the $4.6 million planned for fiscal year 1979, with both graphic and tabular displays and with software development costs for target/map association (the sum of MITRE's software estimates used to support systems using graphic displays and those with tabular displays). In this case, as determined by MITRE, the processor with limited peripherals in the original MITRE estimates would not be able to support the larger requirements of target/map association. Therefore, the processor costs are increased by $15,000 each, in order to provide a larger processor with adequate power. Site and console costs in

TABLE 7.
COST COMPARISONS OF EN ROUTE CCC INTERFACE APPROACH WITH DARC AND TABULAR DISPLAY OPTIONS

		GRAPHIC DISPLAY		GRAPHIC DISPLAY W/DARC		TABULAR DISPLAY		TABULAR DISPLAY W/DARC	
	UNIT COST	NO. REQ'D.	TOTAL COST	NO. REQ'D.	TOTAL COST	NO. REQ'D.	TOTAL COST	NO. REQ'D.	TOTAL COST
Recurring Costs									
1) Interface Processor	$50,000	21	$1,050,000			21	$1,050,000		
2) Display Processor & Graphics Display	10,000	228	2,280,000	228	$2,280,000				
3) Display Processor & Tabular Display	3,000					228	684,000	228	684,000
4) GPI/GPO/Interface Processor Interface	3,400	21	71,400	21	71,400	21	71,400	21	71,400
5) PAM GPI Adapters	1,200	42	50,400	42	50,400	42	50,400	42	50,400
6) PAM GPO Adapters	1,158	42	48,600	42	48,600	42	48,600	42	48,600
7) SSCU Switching Cards & Basket	4,000			21	84,000			21	84,000
8) Cable Driver/Receiver Assembly	400	228	91,200	228	91,200	228	91,200	228	91,200
9) Data Entry Device (Touch Panel)	1,000	228	228,000	228	228,000	228	228,000	228	228,000
10) Cables	2,700	21	56,700	21	56,700	21	56,700	21	56,700
11) Installation & Site Test	500	21	10,500			21	10,500		
12) Installation & Site Test (DARC option)	150			21	3,150			21	3,150
Total Recurring Costs			$3,886,800		$2,913,500		$2,290,800		$1,317,500
Nonrecurring Costs									
1) Display Station Software Development			*280,000		*280,000		**910,000		**910,000
2) GPI/GPO Interface Processor Interface Development			80,000		40,000		80,000		40,000
3) Data Entry Device Development			10,000		10,000		10,000		10,000
4) Hardware Documentation			50,000		30,000		50,000		30,000
5) Software Documentation			50,000		50,000		50,000		50,000
6) Program Management (10% of Contract cost)			435,700		332,400		339,100		235,800
7) Contingency (10% of Contract cost)			435,700		332,400		339,100		235,800
8) Provisioning (10% of Hardware cost)			388,700		291,400		229,100		131,800
9) Factory Inspection (5% of Hardware cost)			194,300		145,700		114,500		65,900
10) Freight (3½% of Hardware cost)			136,000		102,000		80,200		46,100
Total Non-Recurring Costs			$2,060,400		$1,613,900		$2,202,000		$1,755,400
Total Costs (Recurring and Non-Recurring)			$5,947,200		$4,527,400		$4,492,800		$3,072,900

* 8,000 instructions @ $35/instruction.

** 26,000 instructions @ $35/instruction. Based on experience at the Digital Simulation Facility at NAFEC.

TABLE 8. ENROUTE SIM. PILOT CONSOLES CCC INTERFACE - BOTH GRAPHIC AND TABULAR DISPLAYS

	Dev. /Doc. Costs	Site Costs*	Console Costs	21 Sites 114 Consoles	Contract Sub-Costs
Recurring Costs:					
1. Interface Processor		$50,000		$1,050,000	
2. Display Processor & Graphic Display			$10,000	1,140,000	
3. Display Processor & Tabular Display			3,000	342,000	
4. GPI/GPO Interface Proc. Interface		3,400		71,400	
5. PAM GPI Adapters (2/site)		2,400		50,400	
6. PAM GPO Adapters (2/site)		2,316		48,636	
7. Cable Driver/Receiver Assembly			400	45,600	
8. Data Entry Device (Touch Panel)			1,000	114,000	
9. Cables		2,700		56,700	
Hardware Costs		$60,816	$14,400	$2,918,736	
10. Installation & Site Test		500		10,500	
Total Recurring Costs		$61,316	$14,400	$2,929,236	$2,929,236
Nonrecurring Costs:					
1. Display Station Software Dev.	$1,190,000			$1,190,000	
2. GPI/GPO/Interface Proc. Interface Dev.	80,000			80,000	
3. Data Entry Device Development	10,000			10,000	
4. Hardware/Software Documentation	100,000			100,000	
Dev. /Doc. Costs	$1,380,000			$1,380,000	1,380,000
Contract Costs					$4,309,236
5. Program Management (10% Contract)	138,000	$ 6,132	$ 1,440	430,924	
6. Contingency (10% Contract)	138,000	6,132	1,440	430,924	
7. Provisioning (10% Hardware)		6,082	1,440	291,874	
8. Factory Inspection (5% Hardware)		3,041	720	145,937	
9. Freight (3 1/2% Hardware)		2,128	504	102,156	
Total Non-recurring Costs	$1,656,000	$23,515	$ 5,544	$1,401,815	
TOTAL (Recurring & Non-Recurring Costs)	$1,656,000	$84,831	$19,944	$5,771,051	

*Cost per site excluding consoles

TABLE 9. ARTS III & ARTS III-A SIM. PILOT CONSOLES IOP OR IOP-B INTERFACE - BOTH GRAPHIC AND TABULAR DISPLAYS

	Dev. /Doc. Costs	Site Costs*	Console Costs	30 Sites 83 Consoles	Contract Sub-Costs
Recurring Costs:					
1. Interface Processor		$25,000		$ 750,000	
2. Display Processor & Graphic Display			$10,000	830,000	
3. Display Processor & Tabular Display			3,000	249,000	
4. IOP Interface Proc. Interface		4,000		120,000	
5. Cable Driver/Receiver Assembly			400	33,200	
6. Data Entry Device (Touch Panel)			1,000	83,000	
7. Cables		1,100		33,000	
Hardware Costs		$30,100	$14,400	$2,098,200	
8. Installation & Site Test		500		15,000	
Total Recurring Costs		$30,600	$14,400	$2,113,200	$2,113,200
Nonrecurring Costs:					
1. Display Station Software Dev.	$1,190,000			$1,190,000	
2. IOP/Interface Proc. Interface Dev.	100,000			100,000	
3. Data Entry Device Dev.	(Enroute)				
4. Hardware/Software Documentation	100,000			100,000	
Dev. /Doc. Costs	$1,390,000				1,390,000
Contract Costs					$3,503,200
5. Program Management (10% Contract)	139,000	$ 3,060	$ 1,440	350,320	
6. Contingency (10% Contract)	139,000	3,060	1,440	350,320	
7. Provisioning (10% Hardware)		3,010	1,440	209,820	
8. Factory Inspection (5% Hardware)		1,505	720	104,910	
9. Freight (3 1/2% Hardware)		1,054	504	73,437	
Total Non-Recurring Costs	$1,668,000	$11,689	$ 5,544	$2,478,807	
TOTAL (Recurring & Non-Recurring Costs)	$1,668,000	$42,289	$19,944	$4,592,007	

*Cost per site excluding consoles.

TABLE 10. COST COMPARISON OF VARIOUS COMBINATIONS OF SIMULATOR PILOT CONSOLES AND ENROUTE SITES

No. of Consoles	at	No. of Sites	=	Total Cost	Avg./Console
228		21		$7,984,616	$35,020
114		21		$5,711,051	$50,096
38		15		$3,686,337	$97,008
51		12		$3,691,116	$72,374
55		11		$3,686,061	$67,019
60		10		$3,700,950	$61,682

TABLE 11. COST COMPARISON OF VARIOUS COMBINATIONS OF SIMULATOR PILOT CONSOLES AND ARTS III SITES

No. of Consoles	at	No. of Sites	=	Total Cost	Avg./Console
130		63		$6,924,896	$53,268
83		30		$4,592,007	$55,325
89		27		$4,584,819	$51,514
94		25		$4,599,961	$48,935

Table 9 are separated to allow easy computation of costs for various numbers of sites and consoles. Table 11 compares combinations of consoles and sites which could be purchased for the amount planned. It also shows the total cost if 130 consoles were purchased for 63 sites and the average cost per console in each case.

Of special interest, in the case of ARTS III facilities, is the fact that the DEDS equipment now used for this purpose costs approximately $110,000 each; however, each DEDS can accommodate up to three entry positions (or, in this case, three simulator pilots). Average cost per simulator pilot, therefore, would be approximately $33,000.

FUTURE UTILIZATION OF PILOT CONSOLES.

It is anticipated that upgraded third generation programs will introduce heavier storage and processing demands on the enroute and ARTS III computer facilities. Because the storage and processing capabilities of the CCC and the IOP are, practically speaking, finite, eventually a decision may have to be made to abandon the use of DYSIM or ETG or both, in favor of one or more of the upgraded third generation functions. Also, anticipated increases in air traffic will increasingly inhibit the use of DYSIM as the 82.5 percent track table capacity, described in Software Analysis, is reached more routinely. The point being made is that if this occurs, or when it occurs, and simulation capability that is independent from the operational facility is mandated, the simulator pilot console hardware would be salvageable for use in such an independent system.

FUNCTIONAL SPECIFICATION

When sufficient information had been accumulated and analyzed to allow a decision to be made on the feasibility and desirability of using more cost effective, special-purpose, pilot-simulator-type consoles in the field, an oral report was made to the steering group charged with making the final decision. A decision to proceed with the procurement will require a functional specification; but the logistics of such a procurement requires a lead time of approximately 18 months. As the enroute procurement was budgeted for the fiscal year ending September 30, 1978, the specification was requested by April 1, 1977, one month after the oral presentation to the steering group. This was insufficient time for preparation of such a document; therefore, as soon as the best interface was decided upon, and the decision was made on the use of a touch sensitive input device, the specification was started. As agreed, NAFEC and MITRE prepared Part 1 - Scope, Part 2 - Applicable Documents, and Part 3 - Requirements. Airway Facilities Service had the responsibility for Part 4 - Quality Assurance Provisions, and Part 5 - Preparation for Delivery.

Although the hardware portion of the specifications could be written to make them usable for either the enroute or the ARTS III interface, this was not possible for the software portion. That is, there are some differences in the message repertoire between the systems, and there is a total difference in the message formats required to and from the central computer. The effort, therefore, concentrated on the preparation of the specifications for the enroute interface while maintaining knowledge of the future ARTS III requirements.

The oral report was presented to the steering group on March 9, 1976, and the MITRE reports MTR-7521 and MTR-7522 (references 3 and 4) containing information for parts 1, 2, and 3 of the specifications for enroute facilities were delivered in May 1977. On direction from the steering group, specifications for the ARTS III facilities were not prepared.

The specifications were prepared to provide:

1. Interface with the PAM of the CCC. (Enroute approach 2 described earlier.)

This approach is the least expensive and takes maximum advantage of standard interface hardware.

2. A graphic display capability with position selection (For example: trackball, joy stick).

Although this course of action involves potentially higher hardware costs, a graphic display is required as an integral part of the facility training function. The instructors use the display to assess the total traffic situation confronting the student so that appropriate modifications to the traffic can be made to provide special problems in real time. In addition, the graphic presentation represents the least departure from the current training mode and will make the transition easier, as well as providing some training benefits to controllers acting as pilots.

3. Touch panel input.

The touch panel input method has the potential for reduced input error and shortened pilot training time since the memorizing of message composition and format is at a minimum. Since the characteristics of the graphic display such as overall size, display surface curvature and thickness can constrain the application of a touch panel, the specifications do not exclude the possibility of a separate tabular display for the touch function. A standard keyboard for complex inputs and backup will be considered.

4. A message repertoire which will accommodate all messages acceptable to, and received from, the DYSIM program.

The specification does however, assume that additional changes will be made to DYSIM which will output target speed to the interface processor, allow entry of no-gyro turns (with direction of turn specified but without a new heading), allow entry of a specified direction of turn, allow a stop turn entry, and allow entry of a change of rate of ascent or descent for a given aircraft.

5. Association of target position with map positions for selected input messages.

The time when this decision was made did not permit time for specifying all of the possible applications of this capability. For instance, full utilization of the look ahead ability (allowing entry of a message defining action at a future point) is not included, but the capability will be there for future implementation.

CONCLUSIONS

In preparing conclusions and recommendations, it was assumed that although the study could firmly establish the technical feasibility of providing the desired simulator pilot consoles, the decision on desirability of such actions was dependent upon additional factors beyond the scope of this study, and within the purview of the steering group. The conclusions, therefore, are designed to provide as much information as possible, which will aid in that decision-making process.

It is concluded that:

1. It is feasible to develop a more cost effective pilot simulator type console within the guidelines, design objectives, and functional requirements specified by the working group. Operational software changes amounting to about 2 man-years effort are required to interface the new input devices.

2. The functional specifications prepared under this project are adequate for the procurement of replacement simulator pilot consoles for enroute facilities in the continental United States. EARTS equipped ARTCC's, however, cannot be accommodated with the enroute specifications. Specially modified specifications may be required.

3. The simulator pilot's operating capability can be greatly improved, entry errors can be reduced, and simulator pilot training kept to a minimum by use of a touch panel input device, a menu list designed for simulator pilot entries, and with software in the new interface processor which provides target/map association.

4. With target/map association performed by the software, a graphic display is not essential for the simulator pilot. The instructors, however, require a graphic display and an entry capability, similar to the simulator pilot's, in order to visualize and modify the developing situation to meet the individual needs.

5. Simulator pilot consoles, as specified, can provide a means for additional enhancements to the field training capability. They may possibly also act as the base for a future independent training function.

6. The new consoles, as stated, cannot be placed in operation in less than 2 1/2 years. Necessary changes to DYSIM and ETG must be allowed to take place during this time. These changes will cause a continuing divergence between existing capabilities and the specifications, including the crucial interface requirements. Therefore, an immediate update after delivery or continuing changes during development must be assumed; either of which will further delay the field implementation date. At the same time, new operational functions and traffic load increases can be expected to decrease available training time and limit the effective life of the field training capability. The new consoles by themselves will not affect the useful life of the present system.

7. Although the new consoles are apparently desired to accommodate an anticipated large increase in the amount of training, it is not probable that such an increase, with the present operational systems, can ever be achieved. Such an increase requires a significant increase in track processing capacity. Approximately 9 man-months of reprogramming effort can improve the simulated target track processing time, and allow some increase in the number of simulated tracks.

8. Partial preliminary information indicates that the training staff and availability of trainees is not sufficient to support the amount of increased training implied by the guidelines and by the number of pilot consoles desired. That is, the number of people necessary to man the increased number of pilot positions, prepare the training problems, and instruct the increased number of students are not available nor anticipated. Increased staff and specially hired simulator pilots may be necessary.

9. There is not sufficient physical space in many facilities to accommodate the increased number of consoles indicated.

10. The cost of providing 114 consoles at 20 enroute facilities and NAFEC, as specified, is approximately $5.7 million (or about $50,000 per console), not including regional costs for site preparation and other in-house costs. Because of fixed costs, changes to the number of sites or consoles will affect the total cost at the rate of about $85,000 per site plus $20,000 per console. Therefore, variations in the number of consoles and sites are necessary and possible to keep costs within the budget. For instance, 55 consoles at 11 enroute sites would cost approximately $3.7 million.

11. The cost of providing 83 consoles at 30 ARTS III facilities, as specified, is approximately $4.6 million (or about $55,000 per console), not including regional costs for site preparation and other in-house costs. Changes to the number of sites or consoles will affect the total cost at the rate of about $42,000 per site plus $20,000 per console.

12. As one ARTS III horizontal DEDS can accommodate three input keyboards, up to three simulator pilots could support a controller trainee at another display with the present system for about $33,000 per simulator pilot, based on a DEDS cost of about $110,000.

13. A complete study to acquire substantive or quantitative data regarding the present field training system would be most helpful in determining the desirability of the new consoles, but it will take 9 months to 1 year to complete, thus further delaying the procurement and reducing the useful life. Further, it is expected that such a study would only substantiate and quantify the magnitude of the anticipated limitations and additional costs for support, space, and revised software.

RECOMMENDATIONS

Regardless of the decision on procurement of new simulator pilot consoles, it is recommended that:

1. The reprogramming of the enroute track processing software necessary to improve the processing time and relieve the simulation target track capacity problem (for automatic mode targets) be done as soon as possible.

2. Action be taken to insure that the present field training capabilities are enhanced as much, and as soon as possible by reducing the time for processing the pending software National Airspace System (NAS) Change Proposals (NCP) designed to improve DYSIM and ETG. Further, that action be taken to include NAFEC in the process in order to maintain currency, to evaluate the training effectiveness of the NCP and to ensure that consistency is maintained with the ever-evolving training capabilities.

3. The planned study of the present field training capabilities, projected short and long term needs, expected life, and alternative enhancements or replacement systems be started immediately and completed as soon as possible.

4. Upon completion of the study, action should be taken to design and procure a field training capability adequate to meet the total field training needs as envisioned from the study.

REFERENCES

1. DOT, FAA, Office of Systems Engineering Management, Engineering and Development Program Plan - Air Traffic Control Specialist Personnel Support, National Technical Information Service, Springfield, Virginia 22151, Report No. FAA-ED-21-3, December 1975.

2. Bales, R.A., Lawrence, M.M. and Watson, R.H., ATC Controller Training Subsystem: Pilot Simulator Interface Alternatives for Enroute and Terminal Facilities, MITRE Corp., METREK Division, McLean, Virginia 22101, Report No. MTR-7437, January 1977.

3. Bales, R.A., ATC Controller Training Subsystem Specification: Software Functional Requirements for Enroute Simulator Pilot Consoles, MITRE Corp., METREK Division, McLean, Virginia 22101, Report No. MTR-7521, March 1977.

4. Lawrence, M.M., ATC Controller Training Subsystem Specification: Simulator Pilot Consoles, MITRE Corp., METREK Division, McLean, Virginia 22101, Report No. MTR-7522, May 1977.

APPENDIX A

AAD-1 LETTER TO AED-1, ASSISTANCE REQUIRED IN DEVELOPMENT OF ATCS TRAINING, DATED JULY 14, 1975

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20591

DATE: JUL 14 1975

IN REPLY REFER TO:

SUBJECT: Assistance Required in the Development of ATCS Training

FROM: Associate Administrator for Administration, AAD-1

TO: Associate Administrator for Engineering and Development, AED-1

Recent investigations and evaluations have revealed a substantial inadequacy in the Air Traffic Controller Training Program. To correct the identified deficiencies, the Office of Personnel and Training, in concert with the Air Traffic Service, is presently engaged in an effort to develop a revised terminal/enroute training program.

During the development effort, it became apparent that in order to assure successful implementation of the program and meet the stated objectives, additional resources and development actions would be required.

In response to the above and to a need suggested in the IDA study, you established an AED working group on ATCS training which has been exploring areas in which your office could most actively support Personnel and Training in their effort. As a result of their meetings, the group has determined that the areas in which your assistance would provide the most immediate benefit are:

1. Academy Simulation

    a. Development of engineering specifications for Academy radar simulation according to the attached training requirements and schedule.

    b. Providing technical assistance to the Aeronautical Center, which I believe should be the Requiring Activity, in their procurement of the simulation system for the Academy.

2. Identification and development of improvements to field radar simulation which should be completed by January 1, 1976, to provide lead time for FY-78 budget programming. This should include as a minimum.

    a. functional enhancements;
    b. scenario development, tape input and adaption;
    c. engineering specifications for pilot consoles;
    d. future enhancements necessary to provide complete and total simulation of the operational environment.

3. Immediate assistance in the completion of CODE development.

4. Coordination with AAM, CAMI, TSC and NAFEC in the continued development of Controller Performance Measurements (CPM) which would accurately identify controller progress during the various phases of his/her training. The action should be completed by January 1, 1976, as stated in the proposed Air Traffic Controller Training Program completion schedule. (Copy attached).

5. Development of a capability for simulation training at the ARTS II facilities, VFR Towers and Non-NAS centers. In order to prepare this for submission in the FY-78 Budget, I suggest a completion date of January 1, 1976.

While seeking your immediate and active support in the areas enumerated above, I in no way mean to infer that this is the total support you could render. For instance, immediate and on-going expansion of coordination and communication with the Office of Personnel and Training regarding those E&D programs which have a direct impact on operational or maintenance training would be most beneficial. Some areas which should be considered are your developmental and research efforts concerning FSS, DABS, MLS/RNAV/M&S, ICS and WVAS. To accomplish this, I suggest retention of the E&D Working Group as a permanent interoffice activity. Should you, or the working group, determine other methods of assistance, the arrangement for action upon them would be greatly appreciated.

Charles E. Weithoner
CHARLES E. WEITHONER

Enclosure

APPENDIX B

LETTER REPORT, NA-76-43-LR, LOW-COST ATCS TRAINING PILOT SIMULATOR CONSOLE FOR FIELD FACILITIES, DATED AUGUST 26, 1976

August 26, 1976

Letter Report, NA-76-43-LR,
Low-cost ATCS Training Pilot
Simulator Console for Field Facilities

Director, ANA-1

ARD-1

This report was prepared by William Dunn and Kenneth House, ANA-230. It is an interim report on the work underway under project 216-103-010, Simulator Pilot Consoles for NAS Enroute and ARTS III Facilities, in NAFEC Program 21-279, ATCS Personnel Support.

Background

Operational displays costing about $100,000 are presently used in the facility training configuration by both the ATCS trainee and at the pilot simulator position supporting the training. Only the trainee needs an operational unit. NAFEC was requested to investigate the feasibility and desirability of providing a special purpose pilot simulator console to replace the operational consoles now used for that purpose. Alternatives under investigation include: (1) a new cheaper display that could perform all functions of the present operational display, (2) commercially available terminal consoles with a tabular display and keyboard, interfaced with the central computer through a minicomputer, and (3) separate target generation capability for each site or for multiple sites from a central or regional location.

Because of the cost and time implicit in the above alternatives, NAFEC was requested to investigate the possibility of providing a low cost, quick solution, such as using a closed circuit TV, to provide the pilot with a picture of the trainee's display. The TV approach was investigated and found to be infeasible, primarily because of the problems regarding camera location, stability of lighting, etc. The display being monitored is also being used by the trainee and cannot be reasonably screened. The camera must also be at sufficient distance to include the whole display in the picture. This introduces reflections and reduces resolution below adequate levels.

However, on the assumption that such a reproduction of the trainee's display would be adequate for the simulator pilot, and that the simulator pilot display requires no capability of its own, another alternative was investigated. This method incorporates a "slave" display. which would receive all its drives and video from the host display. The details of our study of this quick, low-cost approach are enclosed.

Conclusions:

1. A TV presentation of the trainee's display for use by the simulator pilot is not feasible.

2. Contrary to the original assumptions in the enroute system, the simulator pilot requires a different display than the trainee. Also, the entry capability available to the pilot, after removal of the operational console, is inadequate for the actions desired and will require software changes. The slaved display approach is, therefore, not feasible for enroute facilities.

3. The total cost of implementing the slaved display approach, with a sole-source contract to Orwin, is approximately $20,000 for the enroute and $22,000 for the ARTS III, one-time charges, plus an additional $6,000 per display. If implemented only in the ARTS III system, the sole source accessibility of Orwin Corporation to design the interface and build and install the displays would be questionable. Costs would undoubtedly increase. The slaved display approach is, therefore, not considered as desirable for ARTS III sites.

Recommendation:

It is recommended that we proceed immediately toward determining the feasibility of a pilot simulator subsystem for the field facilities, which is compatible with long-term reqkirements and which will also provide for improvements to training effectiveness, rather than pursuing further a quick, low-cost temporary solution.

If further information on this project is desired, please contact the NAFEC Program Manager for NPD 21-279, Mr. Kenneth House, ANA-230, or Mr. William Dunn, ANA-230.

[illegible] Joseph M. [illegible]

for ROBERT L. FAITH

Enclosure
cc:
ANA-4, ANA-64, ANA-523, ARD-54, ARD-150.
ANA-230:KHouse:lm:x2764:8/16/76

ENCLOSURE

Quick Low-cost Pilot Simulator Study

The Slave Display Characteristics

A slave presentation remoted 50 feet can be provided which would have sufficient resolution and bandwidth to allow reading of alphanumerics without difficulty. The enroute and terminal slave displays would be identical except for tube phosphor. It would use a rectangular tube with a useful area of about 14" x 14". If necessary, compensation can be applied to the remoted video and drive signals to provide for the differences in characteristics between the slave and its host display. The host display will not be degraded by either the presence or absence of a slave display. The failure of a slave display will not affect the performance of the host display.

To obtain a slave display it will be necessary to:

1. Identify the video and deflection circuitry interface points and document them.

2. Build interface and isolation amplifiers.

3. Document the cabling and mounting requirements in sufficient detail that will allow FAA technicians to cable and mount the isolation and/or driver amplifiers. These amplifiers will have their own power supplies and be independent of the host's present circuitry. If the isolation and/or drive amplifiers are mounted outside the FAA host display, their mounting would be the contractor's responsibility, at least, for the first units.

4. Plug in and remote the new display some 50 feet and faithfully reproduce the host picture on the slave display.

5. Build and install the new display.

6. Prepare a description of interface points, cable and plug schematics, isolation and drive amplifiers circuitry and parts in sufficient detail to allow a procurement under competitive bid to be written by FAA for a quantity buy of slave displays.

A Method for Accomplishment

Orwin would be the company we would recommend to perform all the above actions except those items named in Item 3 to be accomplished by FAA technicians. Orwin is a two-man company with a record of production for FAA of like items; e. g., the design of the new deflection system for the Plan View Display (PVD). This system has been successful and demonstrates a 35-percent reduction in the power used by the NAS enroute displays. At the same time, the PVD's excellent performance characteristics were maintained.

Their knowledge of deflection and video circuitry would allow them to transfer their PVD slave solution to the terminal display thus using the same slave display (except for the phosphor) in both areas. The risk of failure to produce an enroute display would be zero. For the terminal display, there is a risk that the task would take longer to accomplish than desired. There is no risk of failure to produce a terminal slave display. However, the deflection and video amplifiers in the terminal area differ from those of the enroute. There is then a risk that an unforeseen problem may arise that will cause some delay in achieving an acceptable solution. Though there is little or no risk of failure, there is still an advantage if this approach is pursued, in solving the logistics of the two cases at NAFEC. This would provide the least upset of an operational environment and yet allow the displays to be transferred to a field site after a successful demonstration. These displays would be solid state and need the absolute minimum of additional display circuitry. Maintenance is at the card substitution level thus requiring little maintenance support.

Cost and Time to Accomplish

On the assumption that "ORWIN" does perform the task, the following costs can be predicted: For the enroute system, $20, 000; for the terminal system, $22, 000. These costs include a display and documentation sufficient for the console modification by an FAA technician as proposed in item 3 and for the documentation to satisfy the other listed items. It also includes a successful system demonstration of the slave display at a location some 50 feet from the host display. The time to accomplish the task is predicted to be 120 days. This is broken down as follows: 90 days to the delivery of the enroute display and the cable change documentation and parts for the modification of a PVD. After the cabling and installation of the display the system would be demonstrated.

An additional 30 days is needed for the delivery of a like package to the terminal. The time of 120 days is, of course, after "Receipt of Contract." The building of the additional displays is estimated to cost $6,000 each based on a 100-display buy. Since the display is a commercially available one and the cabling modifications to the FAA displays are to be done by FAA technicians, then the time to delivery, after contract, would be minimal.

Simulator Pilot Input

In order to keep the cost down and to preclude impact on the present software, the use of present operational input devices was assumed. In the ARTS III system each display is equipped with up to three keyboards, one of which is used by the pilot in the training configuration. Therefore, with this slaved approach the pilot would continue to use one of the keyboards associated with the trainee position.

The enroute area posed different problems. The trainee and pilot use totally separated but identical keyboards, Computer Readout Device's (CRD) and category/function devices. Our contacts with AFS have indicated that, whereas, it is feasible to physically mount these devices separate from the PVD consoles, there are not, in fact, any such devices available for such use. D (manual controller) position CRD's and keyboards are available at each pilot position. In order to use these for simulator pilot input, however, software changes are required. These changes were characterized by IBM as being "relatively minor."

Operational Impact

The ARTS III Enhanced Target Generation (ETG) system presently uses the same display for both the trainee and pilot, therefore, there does not appear to be any operational impact involved in slaving the trainees' display and using one of the keyboards associated with the trainees' display for the pilot. Physically, the pilot and trainees could then be separated by up to 50 feet. The fact that the trainees' display would also contain the pilot's preview area does not appear to be significant. If required, the pilot's preview area could be covered.

In the enroute system, however, other problems exist, in addition to the need for software changes indicated above, which make this approach questionable, if not unacceptable.

1. Operationally, using the D position eliminates the category/function capability available at the R (Radar) position. Even with the software changes the pilots entry requirements will be more lengthy and cumbersome, thus reducing the number of targets he can control effectively. The lack of the trackball, although not considered important, may further decrease his capability.

2. The original assumption that the pilot's display required no capability separate from the trainees' was found to be incorrect. The pilot requires constant heading and altitude information, a special simulator target identification and manual/automatic indicator not displayed at the trainee's position. Thus, if this approach is implemented, the DYSIM software must be further modified to output this information for each simulator target on the appropriate pilot's CRD.

In either case, this approach will use the basic DYSIM and the ARTS III Enhanced Target Generator (ETG) programs as presently planned. No special capabilities will be available for enhancement of these systems beyond those possible at the present time.

APPENDIX C

ARD-152 LETTER TO AAT-14.2, APT-310, AAF-610 AND ANA-230, SIMULATOR PILOT CONSOLES FOR ENROUTE AND ARTS III ATC FACILITIES, DATED AUGUST 24, 1976

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

WASHINGTON, D.C. 20591

DATE: August 24, 1976

IN REPLY REFER TO: ARD-150

SUBJECT: Simulator Pilot Consoles for En Route and ARTS III ATC Facilities

FROM: Acting Chief, Training Requirements and Performance Evaluation Section, ARD-152

TO: AAT-14.2, APT-310, AAF-610, ANA-230

To support the SRDS/NAFEC effort of investigating the feasibility and desirability of replacing En Route and ARTS-III radar displays (currently being used as "target operator positions") with simulator pilot consoles, the enclosed developmental guidance was developed by representatives from AAT, APT, AAF, and ARD. It is recognized that during the course of this developmental activity it may become necessary to modify these design guidelines, functional requirements and design objectives, therefore, it is recommended that this working group be retained as interoffice coordinators.

George A Scott

GEORGE A. SCOTT

Enclosure

SIMULATOR PILOT CONSOLES FOR ENROUTE AND ARTS III ATC FACILITIES
(SRDS SUBPROGRAM 216-103)

BACKGROUND

The FAAs newly upgraded ATCS training program stipulates that after graduation from the Academy, the developmental controller will receive advanced environmentally oriented radar training at the Air Traffic Control facility. This requirement will be satisfied through the use of the ATC facility simulation programs - DYSIM in EnRoute and ETG in ARTS III.

An integral part of the simulation program is the simulator pilots who in response to the controllers instructions "fly" the simulated radar targets. An operational radar console (PVD) is used for each psuedo pilot position in the EnRoute facility while at the ARTS III locations, the pilots share the radar display with the ATCS trainee. In the latter situation, a separate keyboard is provided for use by the simulator pilot. The cost and need of the radar consoles is high and the keyboard which was not designed for simulator pilot inputs is cumbersome and time consuming. The availability of the radar training program, including scheduling and equipment (consoles) is dependent on the real-time operational situation at the facility.

OBJECTIVE

The objective of this effort is to investigate the feasibility and desirability of replacing the existing operational radar displays that are being used for pilot consoles during training exercises. The study will also consider improved techniques for entering pilot messages. If these studies indicate the practicability of introducing new simulator pilot consoles, then SRDS will develop the required functional specifications which, when further developed by AAF, will lead toward the procurement and implementation of the pilot position equipment.

DESIGN GUIDELINES

The FY-78 budget provides a funding item for procurement of the simulator pilot consoles for the EnRoute facilities. It is anticipated that the simulator pilot consoles for the ARTS III facilities will be included in the FY-79 budget. Based on this action, the NAFEC feasibility/cost study and the functional specification development (if deemed necessary) will initially concentrate on the EnRoute pilot console situation with the ARTS III to follow shortly thereafter.

Recognizing the need to provide developmental guidance, a working group, consisting of representatives from AAT, APT, AAF and ARD developed the following design guidelines for the EnRoute and ARTS III pilot consoles.

1. Modifications to the existing operational hardware i.e., PVDs, DEDs, CRDs, keyboards are not acceptable.

2. It is highly desirable that no modification be made to the current operational system software. Minor modifications to the DYSIM and ETG simulation program to accommodate the pilot console and/or to enhance keyboard entries are acceptable.

3. A standard system interface, preferably through the EnRoute GPI/GPO and the ARTS III ESI, should be provided.

4. A separate pilot console recording, in addition to that already provided by the EnRoute SAR/DART and ARTS III data extractor program is not required.

5. During facility training exercises, the pilot position will also function as a ghost position - initiating and accepting both verbal and automated handoffs, coordinating flight plan information, etc.

6. Communications for the pilot/ghost position is not a part of this developmental task. Provisions for mounting of communication selector panels, volume controls and headset jacks should be considered in the design of the pilot console.

7. The overall physical dimensions of the pilot console must not exceed those of the existing operational radar displays.

   a. EnRoute PVD - 51.5" high, 35.5" wide, 54.5" deep.
   b. ARTS III DED - 48" high, 30" wide, 56" deep.

8. A closed circuit television system is not an acceptable design approach for the pilot console.

DESIGN OBJECTIVES

1. The pilot console hardware including the display, keyboard and housing should be common for both EnRoute and ARTS III facilities. The console must be a self supporting unit that can easily and rapidly be replaced. Electrical connectors that are readily accessable and provide a quick change capability is a highly desirable requirement.

2. The application of sound human engineering used in the design of the pilot console i.e., heigth and angle of the display, configuration of the keyboard, display filters, is a manditory design objective.

3. To improve the simulator pilots operating capability the keyboard inputs must be simplified. An analysis of existing DYSIM and ETG input methods and their associated limitations is a prerequisite for the design of the pilot console keyboard.

4. Limited funds for this effort dictates that the cost of the pilot console (hardware and software) remain low.

FUNCTIONAL REQUIREMENTS

Some of the functional requirements that will substantially contribute to the overall analysis, design and development of the pilot console are listed below.

	ARTCC	ARTS III
Desired # of targets per pilot console	10-12	10-12
Maximum # of pilot consoles per facility	16	8
Maximum # of student consoles per facility	8	6
Maximum # of targets per student console	25	16
Ratio of pilot console to student console		
Normal training mode	2:1	2:1
Maximum mode	Flexible	Flexible

Enhancements to the ETG or DYSIM program such as freeze, backup and replay are not considered a part of this task, however, provisions for these capabilities will be considered and incorporated as they apply to the pilot console only. An example of this would be providing a "freeze" key on the pilot console keyboard but not developing the software to provide this capability. Note - ARTS III facilities recently incorporated the "freeze/restart" capabilities into the ETG program which indicates that a freeze key on the pilot console keyboard is a valid requirement.

If after review of the NAFEC feasibility/cost study, a decision is made to proceed with the procurement of a specific simulation pilot console, SRDS/NAFEC will, by April 1, 1977, develop the required functional specification. The FAA Specification for VHF Direction Finders dated August 1, 1975, shall be used by as a representation of the specification that AAF needs by April 1, 1977, if they are to commit FY-78 funds for the EnRoute pilot consoles.

Members of the working group that assisted in the development of these design guidelines, functional requirements and design objectives for the simulation pilot consoles are listed below. It is strongly recommended that this group be retained as an interoffice coordination activity for the duration of this program.

Arnold Corradino Arnold Corradino	**Air Traffic Service**
Willis F. Gee Willis Gee	Office of Personnel and Training
William H. Covell William Covell	Airway Facilities Service
George A. Scott **George A.** Scott	Systems Research and Development Service

APPENDIX D

COMPARISON OF DYSIM AND ETG SIMULATOR PILOT FUNCTIONS

APPENDIX D

COMPARISON OF DYSIM AND ETG SIMULATOR PILOT FUNCTIONS

A comparison of the simulator pilot functions was made as performed using DYSIM and ETG. The functions compared are those data entries that ordinarily are made from the simulator pilot positions, in a training simulation, to manipulate the movement of individual targets. Additional actions are also performed by the simulator pilot in his role as a controller of an adjacent position to the trainee controller's position (ghost controller functions). These functions (hand-off and accept hand-off, primarily) are operational type functions, rather than simulation functions, and are not considered in this comparison. There are also other DYSIM and ETG functions performed by the training staff from their input/output typewriter positions to set up and control the total training environment. These also are not dealt with in this comparison. Detailed functional descriptions of DYSIM and ETG may be found in NAS Model A3d2 and ARTS III specifications and handbooks.

In the following comparison, the specific keyboard entries related to the function are shown first, followed by a comparison analysis of the similarities and differences between DYSIM and ETG for that function. In the DYSIM entries, the first key depressed is the specific function key (START, SPEED, HEADING, etc.) in the simulation category on the enroute category/function keyboard, followed by the appropriate fields of data indicated. The last message field is the simulated aircraft identification (coded below as SAID or SFID in the entries). In ETG entries, the first key depressed is the F15 key, identifying the entry as an ETG message. This is followed by the target identification (TG in the comparison) and the appropriate fields of data indicated. In both cases, an ENTER key depression enters the completed message into DYSIM or ETG for action.

A lower case "d" in the following entries depicts a digit (0-9) and a parenthesis around a field identifies it as an optional field. Upper case letters (or groups of such letters) identify specific keys on the keyboard. Further descriptions of the specific entries are included with the appropriate functions. Commas are used to separate the fields and are not a part of the entry.

DYSIM	ETG
SPEED FUNCTION	
Entry	
SPEED, dddd, SFID, ENTER	(F15), TG, V, ddd, (/ddd), (d), ENTER
Legend	
dddd - Ground speed in knots (kn)	V - Speed Message ddd - Ground speed in knots (/ddd) - Final speed when initiating a target with increasing or decreasing speed. (d) - Rate of change (numeral 0-5)
Analysis	
Four speed digits are required, leading zeros.	Three speed digits are required. Maxi-speed permitted is 500 kns.
Speed changes are made at a uniform, randomly selected, rate of .5, 1.0, or 1.5 kns/s. Speed changes may be automatic, as discussed under Hold Function.	Speed changes are made at 45 kns/minute unless a different rate code is entered: 0 - 45 kns/min 3 - 90 kns/min 1 - 60 kns/min 4 - 120 kns/min 2 - 75 kns/min 5 - 225 kns/min
If a speed instruction is entered while the flight is in a holding pattern, the input will be rejected.	
If a speed instruction is entered while the flight is in a turn, the turn will be completed before the speed change occurs.	
BEACON FUNCTION	
Entry	
BEACON, (dddd), (C), (I), SFID, ENTER	(F15), TG, B, (dddd), (Δd), (W), (I), ENTER
Legend	
dddd - Octal digits C - Turn on/off Mode C	B - Beacon Message dddd - Octal digits

DYSIM	ETG
I - Squawk Ident.	Δd - Key followed by a digit (0-3) to effect Mode 3A validity. W - To effect weak target I - Squawk Ident.
Analysis	
A separate Code Reliability Index (CRI) Function controls Mode 3A validity.	Mode 3A validity is controlled by this function
Mode C may be turned on or off	Mode C emissions are controlled by the Altitude Function
Weak target ability is not available	A weak target may be specified

ALTITUDE FUNCTION

Entry	
ALTITUDE, ddd, SFID, ENTER	(F15), A, ddd, (/ddd), (d), (d), ENTER
Legend	
	A - Altitude Message
ddd - Altitude in hundreds of feet	ddd - Altitude in hundreds of feet
	(/ddd) - Final altitude when initiating a target climbing or descending
	(d) - Change rate (numeral 0-3)
	(d) - Mode C validity (numeral 0-3)
Analysis	
Rate of climb or descent is obtained from the aircraft characteristics table. In order to change the rate, the pilot must move to the D position keyboard and change the type of aircraft by entering a flight plan amendment message.	Rate of climb or descent is at 750 feet per minute (fpm) unless a different rate code is entered: 0-375 fpm 1-750 fpm 2-1500 fpm 3-3000 fpm
Mode C off/on capability is part of the Beacon Function	Mode C validity may be established by entry of the validity code, 0-3, representing mode C through validity level 3, respectively.

DYSIM	ETG
HEADING FUNCTION	
Entry	
HEADING, ddd, (R), SFID, ENTER	(F15), TG, H or HL or HR, ddd, (/ddd), (d), ENTER
Legend	
ddd-Magnetic heading in degrees (R) - Intercept route	H - Heading Message R - Right turn L - Left turn ddd - Magnetic heading in degrees (/ddd) - Final heading when initiating a target turning (d) - Change rate (numeral 0-7)
Analysis	
Direction of turn can not be specified. The target automatically turns in the direction requiring the smallest turn to reach the new heading. When the longer direction of turn is specified by the controller, the pilot must make two heading entries to lead the target around in the desired direction.	Direction of turn may be specified. Target will turn in direction requiring the smallest turn if direction is not specified.
The turn rate is 3°/s if ground speed is 210 kn or less, otherwise the rate is gradually reduced as the ground speed increases.	Turn rates are nominal values based on ground speed, unless a different rate code is entered: 0-1°/s. 4-4°/s. 1-1.5°/s. 5-5°/s. 2-2°/s. 6-6°/s. 3-3°/s. 7-7°/s.
Entry of optional code R will cause the simulation flight to change to the automatic mode when intercepting the converted route.	ETG does not store route-of-flight, and therefore, does not have an automatic mode.
A target cannot be initiated which is in a turn.	A target may be initiated in a turn by entry of two headings (initial and desired).

NO-GYRO TURN

	DYSIM	ETG
Entry	None	(F15), TG, L or R or F or G or T, ENTER
Legend		L - Standard rate, left turn R - Standard rate, right turn F - 1/2 standard rate, left turn G - 1/2 standard rate, right turn T - Stop turn
Analysis	A target cannot be turned without a new heading. Direction of turn is is automatic (Heading Function). This function can be fabricated by using the Heading Function, selecting a nominal heading to cause a turn in the desired direction, entering additional heading changes as required to continue the turn, and stopping the turn by entering a heading change containing the present heading shown in the data block.	This function will initiate a turn at the rate and in the direction defined in the message without final heading. The turn will continue until this message is again entered using the stop turn indicator.

DYSIM	ETG
HOLD FUNCTION	
Entry	
HEADING,H(L),(dd(D)),(*),SFID,ENTER	(F15),TG,HHS or HRHS or HLHS, (d), ENTER or (F15) Y,S
Legend	
H - Hold	HH - Hold Message (No direction specified)
(L) - Left turns (otherwise right turns are made)	
(dd) - Leg length in minutes or	HRH - Hold right turns
(dd(D)) - Leg length in miles	HLH - Hold left turns
	S - Single symbol fix identification
	(d) - Turn change rate (see Heading Function)
(*) - Maintain existing speed. (If * is not entered, maintain current speed only if less than 210 kns, otherwise reduce speed to 210 kns in the hold.)	Y - Automatic descent in hold.
Analysis	
Hold capability is actually a variation of the Heading Function. Holding fix cannot be specified. When message is entered, the target begins holding at its present position.	Hold capability is actually a variation of the Heading Function. Holding fix may be specified by entry of appropriate single symbol fix identifier.
Leg length may be specified in either minutes or miles. 00 in the leg length will result in 360° turns.	Leg length is fixed and is not variable. No single entry will automatically cause 360° turns.
Right turns will occur unless an (L) code is entered.	Direction of turn may be specified. If not specified right turns will occur.
Turn rate is determined as described under Heading Function.	Turn rate is determined as described under Heading Function.

DYSIM	ETG
The speed of the target will be reduced to 210 kns (unless current speed is less), if * is not entered. A speed instruction will be rejected if entered while the aircraft is in a hold.	Speed of the target is not changed in a hold unless a separate speed instruction is entered.
A hold instruction will be rejected if the aircraft is in a turn.	
Altitude of the aircraft will not change in a hold unless a separate altitude instruction is entered.	A second message is available which will cause automatic descent of the aircraft in a holding pattern.

AUTOMATIC FINAL FUNCTION

Entry

DYSIM	ETG
None	(F15),TG,N,aaa,rrr,ENTER *or* (F15),TG,*,ENTER

Legend

DYSIM	ETG
	N - Automatic Final Approach Message aaa - Airport identification rrr - Runway identification * - Inhibit target termination function.

Analysis

DYSIM	ETG
There is no Automatic Final Approach capability in DYSIM.	

BLIP/SCAN FUNCTION

Entry

DYSIM	ETG
BLIP/SCAN,(dd), SFID, ENTER	None

Legend

DYSIM	ETG
(dd) - Two numeric characters identifying the ratio of blips to primary radar scans.	

Analysis

DYSIM	ETG
	ARTS III does not process primary radar, and therefore does not have this function.

DYSIM	ETG

CODE RELIABILITY INDEX (CRI) FUNCTION

Entry

CRI,(dd),SFID,ENTER	None

Legend

(dd) - Two numeric characters identifying the desired index of reliability	

Analysis

	Mode 3A validity is controlled via the Beacon Function in ARTS III

SIM START FUNCTION

Entry

Manual Mode Target	
START,ddd,TRACKBALL, SAID, ENTER or	(F15),TG,ddd,ddd, etc., SLEW
Automatic Mode Target	
START,(ddd),(TRACKBALL),SAID,ENTER	

Legend

ddd - Heading in degrees (Manual Mode) (ddd) - Altitude in hundreds of feet (Automatic Mode)	ddd,ddd,etc. - altitude, speed, etc.
TRACKBALL - Slew trackball to desired position on display for starting this target and enter that position.	Slew - Slew trackball to desired position on display for starting this target and enter that position.

Analysis

Manual mode requires complete target movement control by the pilot; therefore, heading and initial position (trackball) are required. Automatic mode targets will move in accordance with a defined flight plan; and therefore, heading and initial position are not required, but an initial start altitude may be specified.	There are no flight plans in ARTS III, and therefore all target movements are specified by the pilot. Initial altitude, speed, heading, etc. are included in the start message.

	DYSIM	ETG
SIM STOP FUNCTION		
Entry	STOP,SFID,ENTER	(F15),TG,ENTER
Analysis	Sim target is terminated	Sim target is terminated
SIM OFFSET FUNCTION		
Entry	OFFSET,d,SFID,ENTER	None
Legend	d - A digit (1-9)	
Analysis	There are both a Full Data Block and a Simulation Data Block in the enroute system. The Simulation Data Block is offset from the target position with this message in accordance with the entered code: 1 - Northwest 2 - North 3 - Northeast 4 - West 5 - Current Velocity Vector 6 - East 7 - Southwest 8 - South 9 - Southeast	There is no simulation data block in ARTS III and therefore no requirement for this function.

APPENDIX E

DATA ENTRY CONCEPT DISPLAY

APPENDIX E

DATA ENTRY CONCEPT DISPLAY

The format of the displayed data used for the touch-entry/menu list concept evaluation is shown in figure E-1. A list of active aircraft is in the upper left of the screen arranged in ascending alphabetical and numerical order. Along the top of the screen are abbreviated column headings identifying the items required to be continuously available to the simulator pilot (flight identification, beacon code, speed, altitude and heading). A matrix is thus formed which portrays all required information on active aircraft under the pilot's control. Inactive flights, ready for activation, are listed at the lower left. At the middle right is an alphanumeric keyboard which would allow entry of numerical data or data to be spelled out, if necessary. At the lower right is a menu list area for a computer generated list of next acceptable entry data. At the top right two areas were set aside: one is a preview area of the message as it is formed, and under that is an area for computer-generated messages.

Entry of message data starts with a touch on the desired aircraft identification (e.g., Continental 22, in figure E-2). The result is a change in the display to isolate the selected aircraft identification in the preview area and portray a list of possible messages in the menu area (figure E-3). The operator then touches either a message from the menu list or the column heading depicting the function desired. (In the latter case, a single touch of the desired item in the matrix opposite the desired active aircraft identification could replace the above two touches.) Figures E-2 through E-7 depict the sequence of displayed pages which occur as a result of a simulator pilot's entries when he receives the following clearance from a controller trainee: "Continental 22, turn left, heading 290." The circled items show the touch required after the displayed page appears. A touch of CLEAR at any point prior to entering a message deletes the message composed to that point, and returns the display to its original page without any message sent to the main computer. In an operational system the ENTER touch at the end would cause the appropriate DYSIM or ETG message, as translated from the entered data, to be sent to the main computer. The display would then return to its original page. In this case, the heading of Continental 22 (CO22) would then increment from 300 to 290 as the target in the main computer reacts to the input message. For the demonstration model, the display returned to the original page but with the heading of CO22 changed instantly to 290.

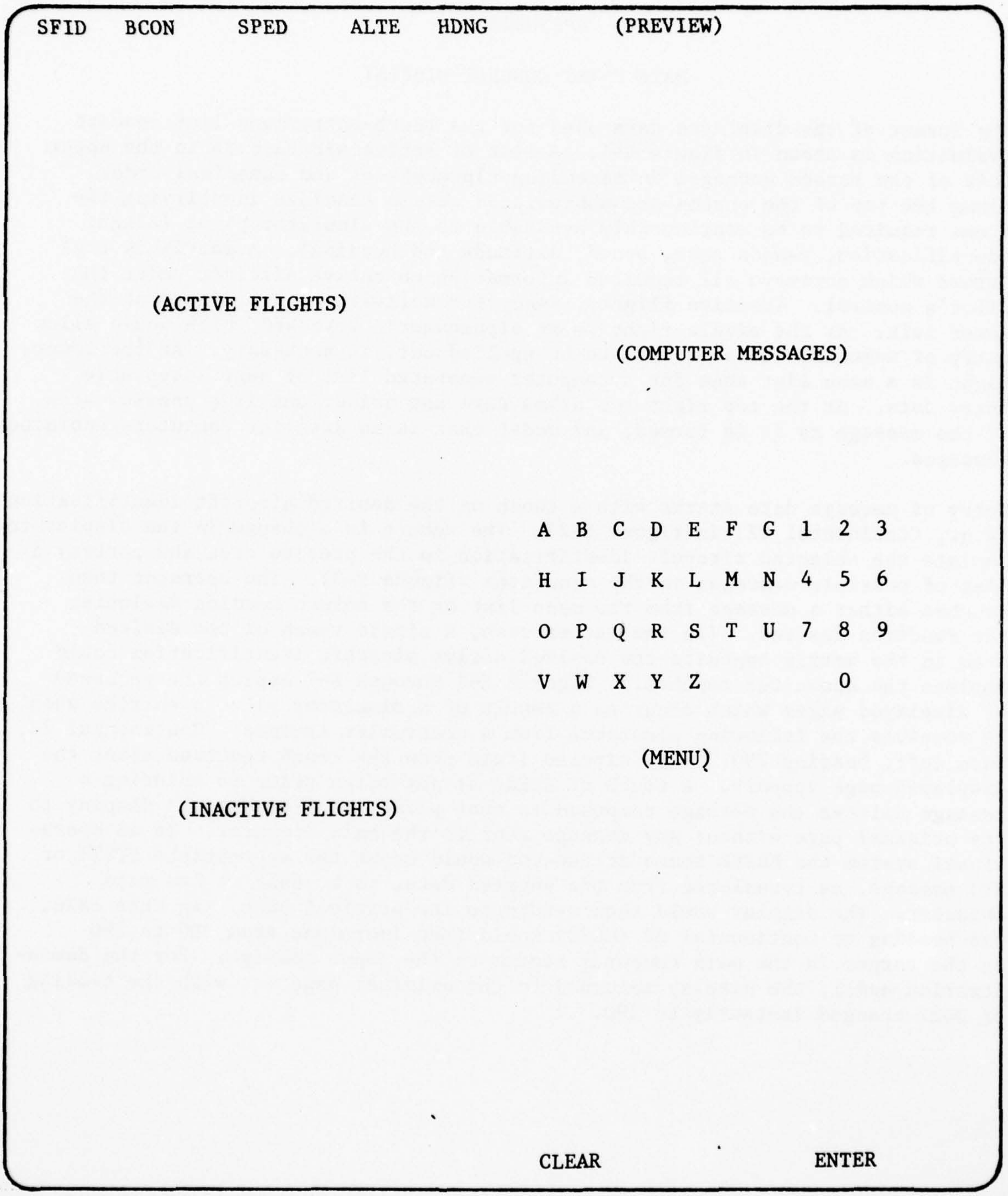
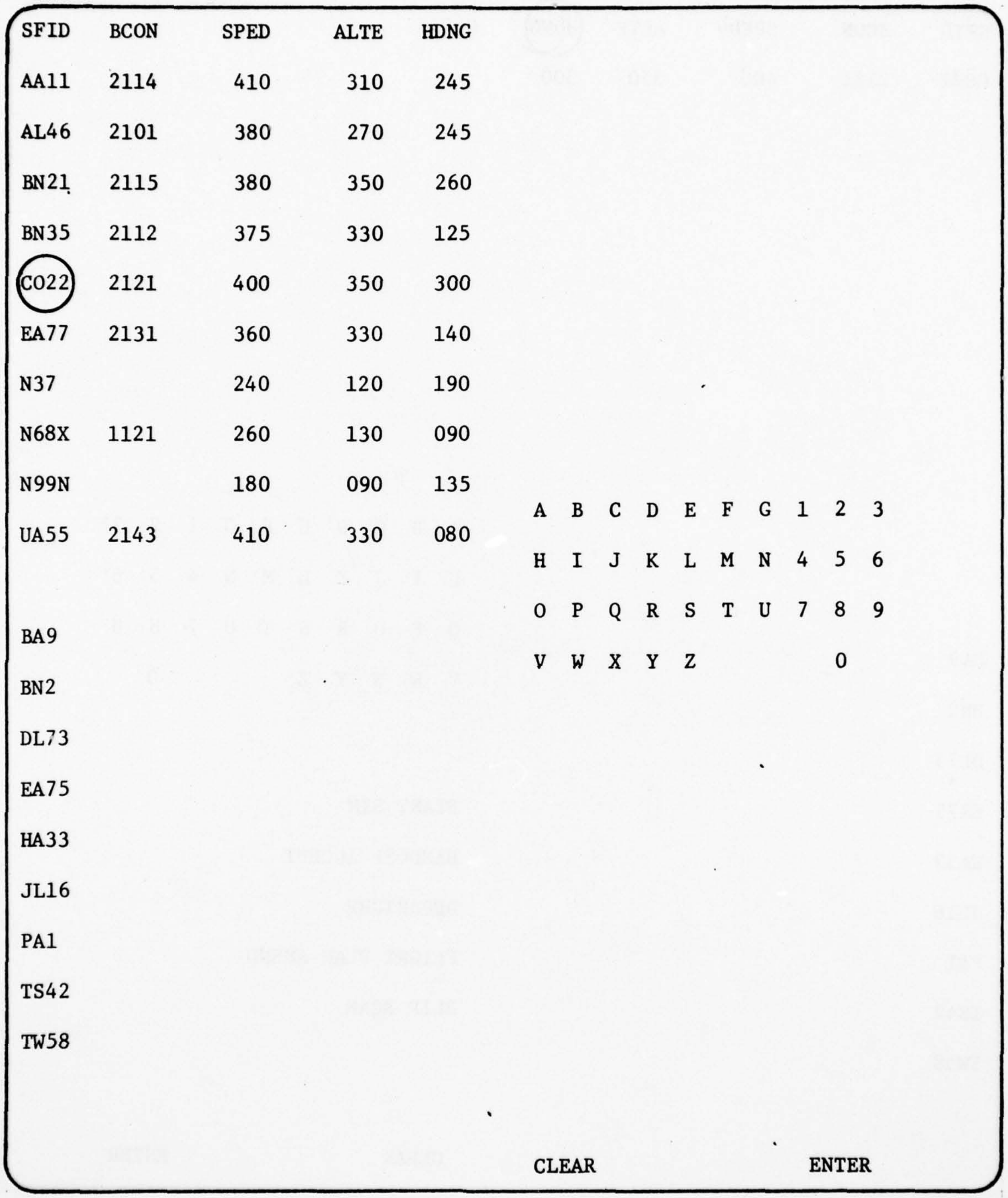


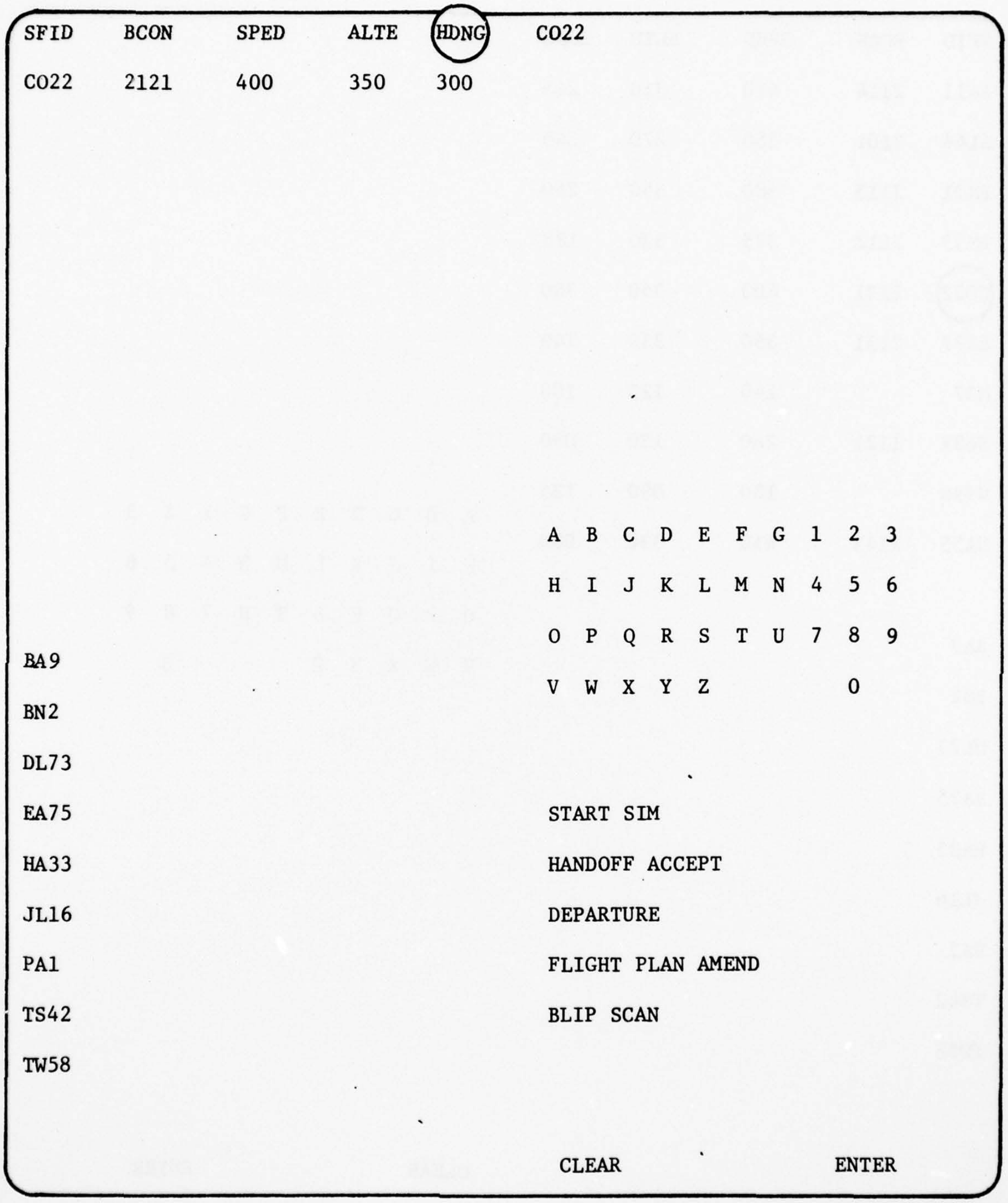
FIGURE E-1. DATA ENTRY CONCEPT DISPLAY FORMAT



SFID	BCON	SPED	ALTE	HDNG
AA11	2114	410	310	245
AL46	2101	380	270	245
BN21	2115	380	350	260
BN35	2112	375	330	125
CO22	2121	400	350	300
EA77	2131	360	330	140
N37		240	120	190
N68X	1121	260	130	090
N99N		180	090	135
UA55	2143	410	330	080

BA9
BN2
DL73
EA75
HA33
JL16
PA1
TS42
TW58

FIGURE E-2. ORIGINAL DISPLAY OF DATA ENTRY CONCEPT EXAMPLE-
TOUCH AIRCRAFT IDENTIFICATION



SFID	BCON	SPED	ALTE	HDNG	CO22
CO22	2121	400	350	300	

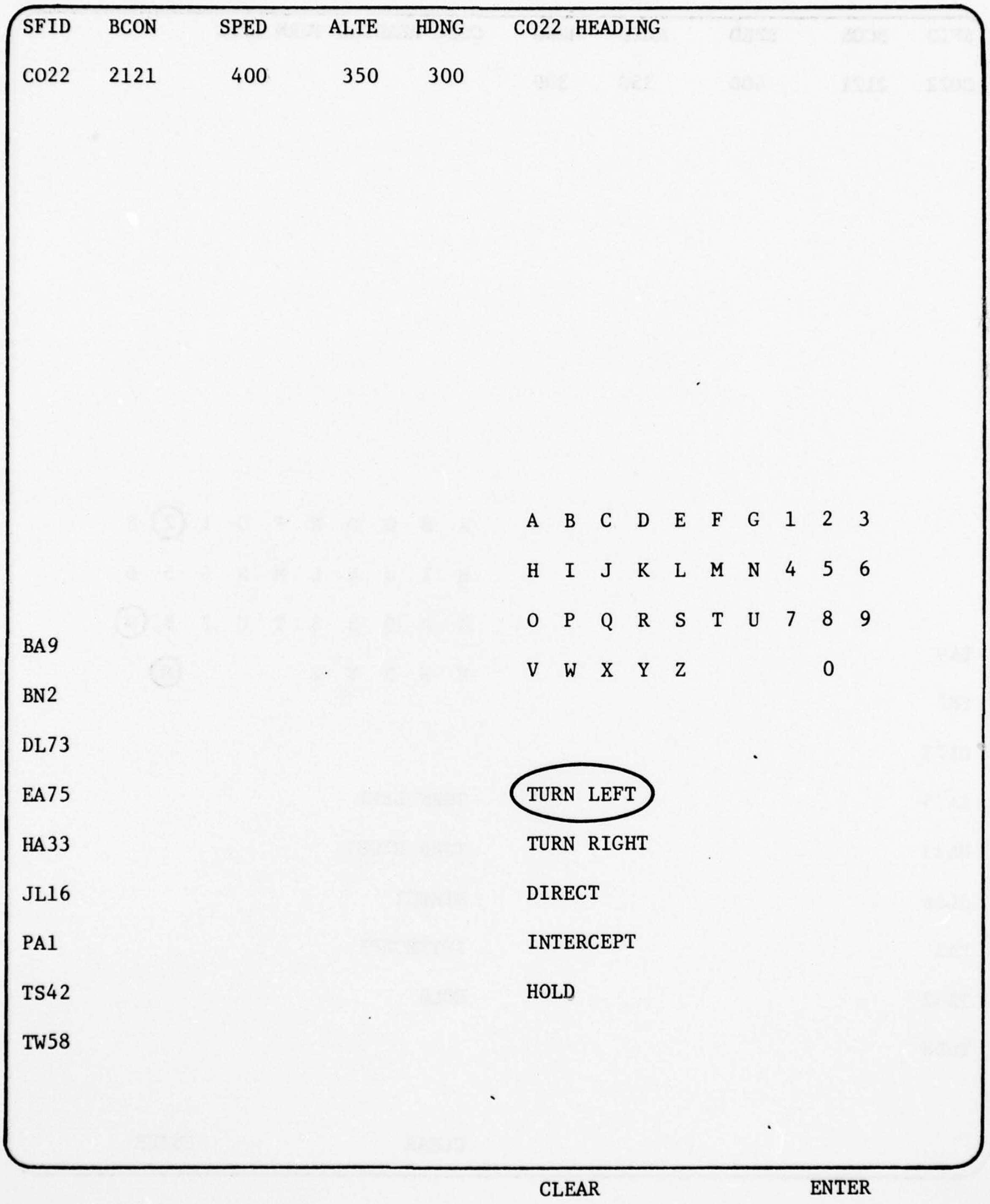
A B C D E F G 1 2 3
H I J K L M N 4 5 6
O P Q R S T U 7 8 9
V W X Y Z 0

BA9
BN2
DL73
EA75
HA33
JL16
PA1
TS42
TW58

START SIM
HANDOFF ACCEPT
DEPARTURE
FLIGHT PLAN AMEND
BLIP SCAN

CLEAR
ENTER

FIGURE E-3. DISPLAY RESULTING FROM TOUCH OF CO22 AIRCRAFT IDENTIFICATION-TOUCH FUNCTION OR MENU LIST ITEM DESIRED



SFID	BCON	SPED	ALTE	HDNG
CO22	2121	400	350	300

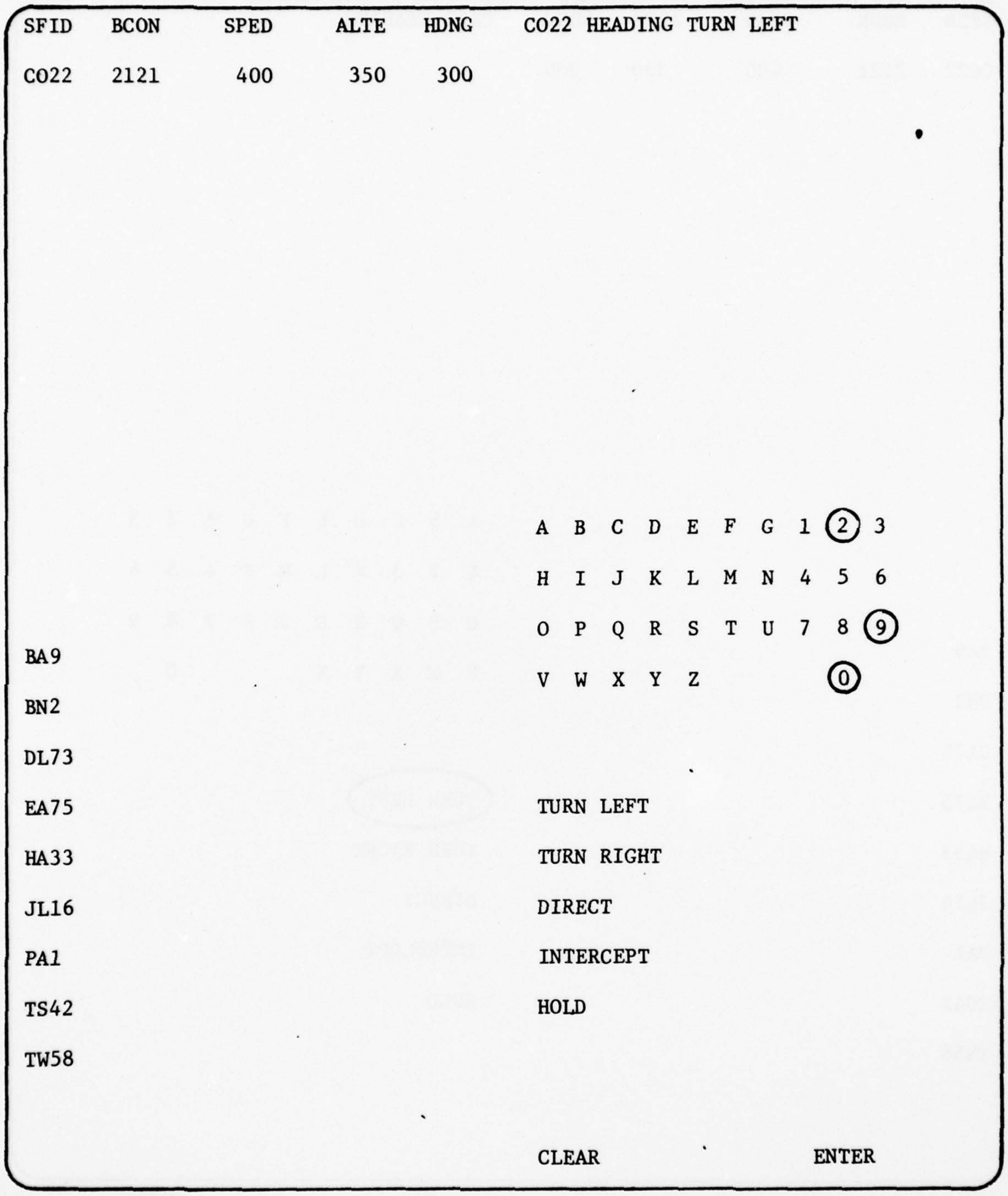
CO22 HEADING

A B C D E F G 1 2 3
H I J K L M N 4 5 6
O P Q R S T U 7 8 9
V W X Y Z 0

- BA9
- BN2
- DL73
- EA75
- HA33
- JL16
- PA1
- TS42
- TW58

- [✓ TURN LEFT]
- TURN RIGHT
- DIRECT
- INTERCEPT
- HOLD

FIGURE E-4. DISPLAY RESULTING FROM TOUCH OF HEADING FUNCTION - TOUCH ACTION DESIRED IN MENU LIST



SFID	BCON	SPED	ALTE	HDNG
CO22	2121	400	350	300

CO22 HEADING TURN LEFT

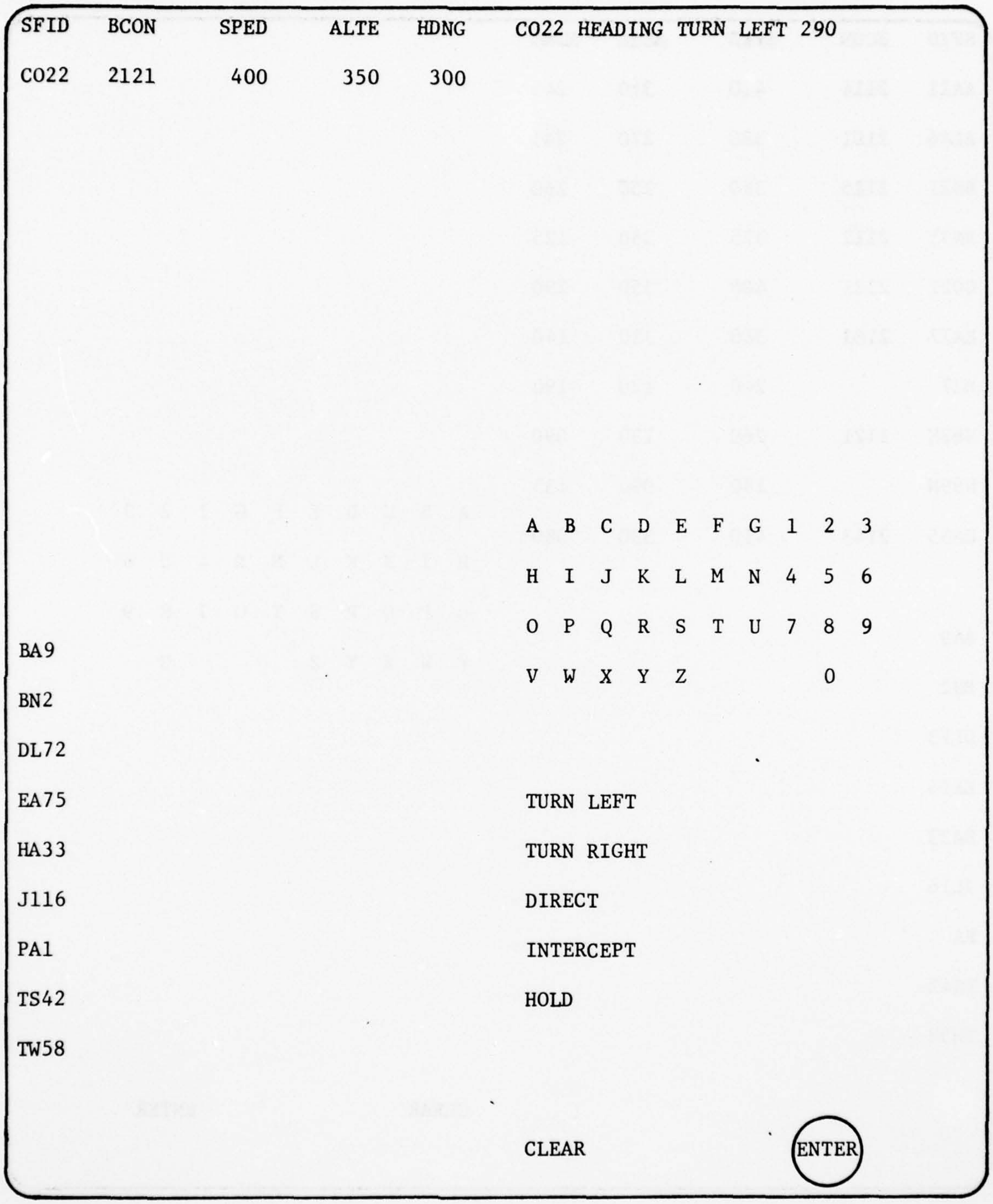
A B C D E F G 1 ② 3
H I J K L M N 4 5 6
O P Q R S T U 7 8 ⑨
V W X Y Z ⓪

BA9
BN2
DL73
EA75
HA33
JL16
PA1
TS42
TW58

TURN LEFT
TURN RIGHT
DIRECT
INTERCEPT
HOLD

CLEAR ENTER

FIGURE E-5. DISPLAY RESULTING FROM TOUCH OF TURN LEFT ACTION-TOUCH LIMITS OF ACTION



SFID	BCON	SPED	ALTE	HDNG
C022	2121	400	350	300

C022 HEADING TURN LEFT 290

A B C D E F G 1 2 3
H I J K L M N 4 5 6
O P Q R S T U 7 8 9
V W X Y Z 0

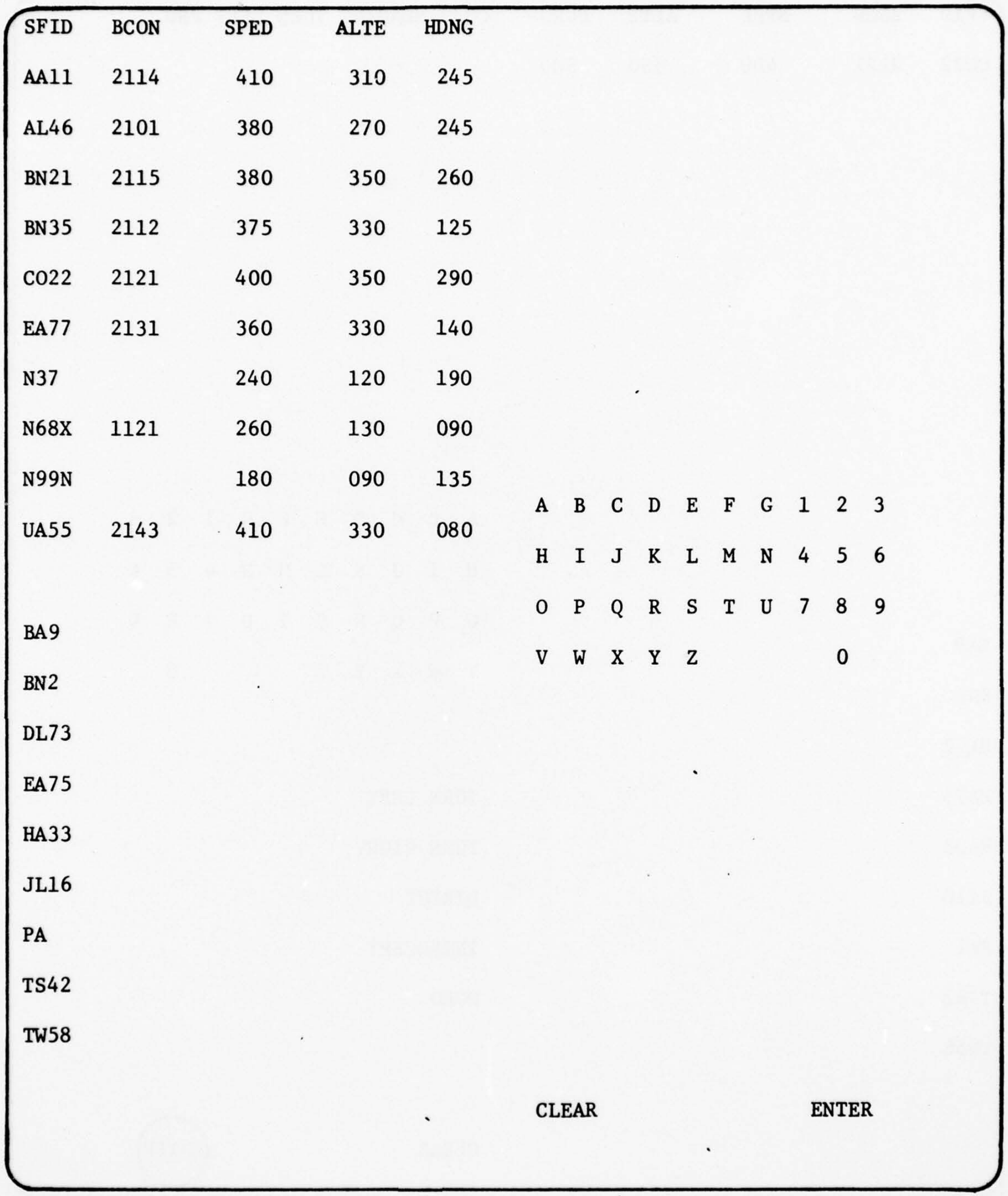
BA9
BN2
DL72
EA75
HA33
J116
PA1
TS42
TW58

TURN LEFT
TURN RIGHT
DIRECT
INTERCEPT
HOLD

CLEAR

ENTER

FIGURE E-6. DISPLAY RESULTING FROM TOUCH OF 290 (DEGREES) - TOUCH ENTER



SFID	BCON	SPED	ALTE	HDNG
AA11	2114	410	310	245
AL46	2101	380	270	245
BN21	2115	380	350	260
BN35	2112	375	330	125
CO22	2121	400	350	290
EA77	2131	360	330	140
N37		240	120	190
N68X	1121	260	130	090
N99N		180	090	135
UA55	2143	410	330	080
BA9				
BN2				
DL73				
EA75				
HA33				
JL16				
PA				
TS42				
TW58				

A	B	C	D	E	F	G	1	2	3
H	I	J	K	L	M	N	4	5	6
O	P	Q	R	S	T	U	7	8	9
V	W	X	Y	Z				0	

FIGURE E-7. DISPLAY RESULTING FROM ENTRY OF MESSAGE AND CONSEQUENT TARGET ACTION - READY FOR NEW MESSAGE

APPENDIX F

ENTRY CONCEPT EVALUATION QUESTIONNAIRE RESPONSES

APPENDIX F
ENTRY CONCEPT EVALUATION QUESTIONNAIRE RESPONSES

QUESTIONNAIRE
ON SIMULATOR PILOT-GHOST CONSOLE

Name ______________________________ Date ____________________

Title ______________________________

How familiar are you with radar simulation training associated with the NAS enroute system?

Not at all 1T Somewhat 3T Very familiar 4E

How familiar are you with radar simulation training associated with the ARTS III system?

Not at all 1E Somewhat 1T, 2E Very familiar 4T, 1E

Have you actually served as a "pilot" in radar simulation training? 5T, 4E

We want to evaluate the concept of data entry by "menu" lists utilizing a message-touch system for use by pilot-ghosts in simulation training. The touch equipment being used here is a light pen, which has some defects. We would use a system which would work by a touch of the finger on the message element desired. In addition, there are limitations in the computer programming done so far. We realize that it is difficult to evaluate a concept without also evaluating the device used to demonstrate that concept, but we ask that you try. Please answer the following questions in order to help us evaluate the concept.

NOTE: T - Number of Terminal ATCS evaluators
E - Number of Enroute ATCS evaluators

2

Three basic measures that we think are important in evaluating any concept are: (1) ease of learning, (2) speed with which entries can be made, and (3) error-proneness in making entries. Please indicate below the response that, in your opinion, is most appropriate regarding pilot entries using the menu-list and message-touch concept in response to clearances, as compared to making the same entries using ARTS III or NAS consoles and keyboards.

	Greatly Degrade	Degrade	Improve	Greatly Improve	No Change
HEADING CHANGE					
Ease of learning			2T, 1E	1T, 3E	2T
Error-proneness			4T, 1E	3E	
Speed			2T	2T, 4E	1T
ALTITUDE CHANGE					
Ease of learning			1T, 2E	1T, 2E	3T
Error-proneness			3T, 2E	2E	1T
Speed			2T, 1E	2T, 3E	1T
SPEED CHANGE					
Ease of learning			2T, 2E	1T, 2E	2T
Error-proneness			3T, 2E	2E	1T
Speed			2T, 1E	2T, 3E	1T

3

	Greatly Improve	Degrade	Improve	Greatly Improve	No Change
BEACON CODE CHANGE					
Ease of learning			2T, 1E	1T, 3E	2T
Error-proneness			1T, 1E	3E	2T
Speed			2T	4E	2T
SQUAWK IDENT					
Ease of learning			3T	3E	2T, 1E
Error-proneness			1T	3E	3T, 1E
Speed		1T	2T	4E	1T
DIRECT TO A FIX					
Ease of learning			1T, 1E	3T, 3E	1T
Error-proneness			3T, 1E	1T, 3E	
Speed			3T	2T, 4E	

COMMENTS ON THE ABOVE:

(The comments emphasized the need for reduced number of touches. Some improvements were suggested. The concept was generally praised.)

AD-A047 567 NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ATL--ETC F/G 5/9
SIMULATOR PILOT CONSOLES FOR NAS ENROUTE AND ARTS III FACILITIE--ETC(U)
NOV 77 K HOUSE, S KAROVIC, T RUNDALL
UNCLASSIFIED FAA-NA-77-36 FAA/RD-77/136 NL

2 OF 2
ADA047567

END
DATE
FILMED
1 -78
DDC

4

Additional Menu Lists

The use of menu lists is being considered for selecting HEADING, ALTITUDE and SPEED, instead of using the numeric keyboard for entering these values. In your opinion, how will this affect:

	Greatly Degrade	Degrade	Improve	Greatly Improve	No Change
Ease of learning?			3T, 1E	2T, 3E	
Error-proneness?			1T, 1E	2T, 3E	1T
Speed?			2T	3T, 4E	

Pilot Capacity

A "pilot" will be able to handle

a greater 3T, 4E

fewer____

the same 2T

number of flights using a menu list device, than using the ARTS III/NAS controller console.

Comment?

(Comments generally were in support of the belief that the pilot capability would be enhanced.)

5

Training Effect

Some of the training benefit gained by a developmental controller in today's system by acting as a pilot may be lost if a special pilot device is implemented. The training benefit that will be lost is

significant 4T, 1E

insignificant 1T, 3E

Comment?

(Comments reflected the mixed feelings indicated in the above tabulation.)

We believe that the pilot position can be operated efficiently without the use of a PPI. Ghost functions (initiating and accepting handoffs, starting and terminating flights, etc.) can be handled with a tabular list. Certain navigational functions that presently require use of the PPI, such as clearance direct to a fix, in NAS, can be accomplished, we believe, by means of software in the pilot mini-computer. Also, we feel that pilot response to traffic calls can be arbitrarily made. Are you aware of any pilot functions that require a PPI that we may not have considered? For example, would it be necessary, even in the future, for a pilot to follow other traffic, as in a visual approach?

Comment?

(Comments indicated a decided majority (8 to 1) felt that a PPI (graphics) display was required at the pilot position.)

6

Can you suggest improvements to the data entry and display concept that you have seen? (Other than in reference to the light pen which we won't be using, anyway)

(Many suggestions for improvement were made orally at the debriefings. As a result, few were made in the questionnaire. Many of the suggestions were later incorporated in the pilot console specifications.)

Please comment on the concept of menu-lists and a message- touch system for a simulator pilot console, particularly with regard to ease of learning, accuracy of data entries, and speed of entries.

(The comments were generally highly favorable towards the concept. The need for portability of the device was suggested by two terminal controllers. One controller suggested that the pilot console be "considered for selected facilities...rather than all facilities.")

APPENDIX G

AAF-600 LETTER TO ARD-100, USE OF THE DARC PROCESSOR WITH PILOT RESPONSE UNITS, DATED JANUARY 24, 1977

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
WASHINGTON, D.C. 20591

DATE: JAN 24 1977

IN REPLY REFER TO: AAF-610

SUBJECT: Use of DARC Processor with Pilot Response Units

FROM: Chief, Automation Engineering Division, AAF-600

TO: ARD-100

As agreed at the briefing on the pilot consoles presented on December 7, 1976, we have investigated the possibility of using the so called "backup" processor in the DARC system as the processor for the pilot consoles. The following items were considered:

1. The DARC system design has not been finalized and we do not know if the standby processor can be used for another purpose without impacting DARC system performance.

2. The Air Traffic Service may change the DARC functional requirements which in turn may change requirements for the DARC standby processor.

3. There are other offline uses which have been proposed for the DARC standby processor, such as, software adaptation and maintenance printed circuit board checking, and DCVG testing. If the processor is available for offline use, these other requirements for its use would have to be considered along with pilot console processing, in terms of priority and time sharing.

4. In addition to using the DARC standby processor for the pilot consoles, all of the DARC peripheral equipment was requested. Again, we could not agree to this condition until the requirements of the DARC system operation are defined.

Since it was indicated that a decision was necessary by January 1, we must take the position at this time that the DARC standby processor should not be considered for use as the pilot console processor.

Jerry
GERALD L. THOMPSON

GLOSSARY

A3d2	NAS Enroute Program Tape Designation
AAD-1	Associate Administrator for Administration
AAF	Airway Facilities Service (mail routing code)
AAM	Office of Aviation Medicine (mail routing code)
AAT	Air Traffic Service (mail routing code)
AED-1	Associate Administrator for Engineering and Development
AFS	Airway Facilities Service
APT	Office of Personnel and Training (mail routing code)
ARD	Systems Research and Development Service (mail routing code)
ARTCC	Air Route Traffic Control Center
ARTS III	Automatic Radar Terminal Service (Model III)
ATC	Air Traffic Control
ATCS	Air Traffic Control Specialist
ATS	Air Traffic Service
CAMI	Civil Aviation Medical Institute
CCC	Central Computer Complex
CD	Common Digitizer
CDC	Computer Display Channel
CODE	Controller Decision Evaluation
CRD	Computer Readout Device
DABS	Discreet Address Beacon System
DARC	Direct Access Radar Channel
DART	Data Analysis and Reduction Tool
DCC	Display Channel Complex
DEDS	Data Entry and Display System
DG	Display Generator
DSF	Digital Simulation Facility
DSS	Data Systems Specialist
DYSIM	Dynamic Simulation
E&D	Engineering and Development
EARTS	Enroute Automatic Radar Tracking System
EPDO	Evaluation and Proviciency Development Officer
EPDS	Evaluation and Proficiency Development Specialist
ESI	Externally Specified Index (Input Control Function of ARTS III)
ETG	Enhanced Target Generation
FAA	Federal Aviation Administration
FPL	Full Performance Level
FSS	Flight Service Station
GPI	General Purpose Input
GPO	General Purpose Output

GLOSSARY (Continued)

ICS	Integrated Communications System
IDA	Institute of Defense Analysis
IOCE	Input/Output Control Element
IOP	Input/Output Processor
M&S	Metering and Spacing
MDBM	Multiplexed Display Buffer Memory
MLS	Microwave Landing System
MPX	Multiplexer
NAS	National Airspace System
NCP	NAS Change Proposal
OJT	On-the-Job Training
OPT	Office of Personnel and Training
PAM	Peripheral Adaptor Module
PPI	Plan Position Indicator
PVD	Plan View Display
QAK	Quick Action Keyboard
RKM	Radar Keyboard Multiplexers
RMIOC	Refresh Memory Input/Output Control
RNAV	Area Navigation
RTF	Radar Training Facility
SAR	System Analysis and Recording
SRDS	System Research and Development Service
TRACON	Terminal Radar Approach Control
TSC	Transportation Systems Center
USAF	United States Air Force
VFR	Visual Flight Rules
VHF	Very High Frequency
WVAS	Wake Vortices Advisory Services