Human Engineering Evaluation of Optional Sector Suite Configurations

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16. Abstract

Concept designs of the future en route sector control suites, fabricated in full-scale, were assessed by Federal Aviation Administration air traffic control specialists with regard to human factors considerations. Potential hardware and software enhancements of the sector control positions were simulated with mockups and used to demonstrate possible sector control operations of the future. Questionnaires and group discussions/interviews were used to obtain controller inputs.

The concept of interactive menu-aided data entry for the radar and flight data positions was highly favored as was the electronic display of reference information. There was almost complete agreement on the location of the data entry device on the shelf at the base of the primary display screens. Preferences for display screen shape for radar traffic display were related to sector geography. A four-console in-line configuration was considered suitable for one to three controllers and a curved configuration, was considered suitable for one to two controllers.

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EXECUTIVE SUMMARY

A study was conducted to generate recommendations for developing the future sector suite and insuring its effective use by air traffic controllers. The recommendations were based upon controller assessments and human engineering analyses of various configuration options and performance enhancement concepts.

Twenty-seven controllers participated in the controller assessment activity. Mockups and dynamic simulations were used to represent and demonstrate the different sector suite configurations and performance enhancement concepts assessed. Questionnaires and open interviews were used to collect the desired data from controllers. Analytic techniques, based upon well documented visibility requirements and military standards, were used to assess the visibility, accessibility, and seating accommodations provided by alternative sector suite configurations.

The study results provided information on several basic design issues essential for early development decisions. It also identified a number of problem areas where further studies will be required to provide information necessary for detail design. Specifically, the study resulted in 21 design recommendations and 13 recommendations for additional studies and evaluations.

INTRODUCTION

PURPOSE.

This report presents the results of a study to generate recommendations for the development of the future "sector suite." The results are based upon an assessment by controllers, and human engineering analyses, of various configuration options and proposed new performance enhancement concepts. A "sector suite" represents the work station and all of the displays, controls, and other equipment required by controllers to control air traffic in a designated geographic area.

SCOPE.

The study, as reported herein, includes three separate but interdependent activities. The first consists of a review and assessment by controllers of several alternate sector suite configurations, and of the utility and usability of various categories of information and a number of new performance enhancement concepts. The second activity involves the use of human engineering analytical techniques to assess the visibility and accessibility of displays and controls associated with the different sector suite configurations. The third activity uses the results from the first two, along with other available information, to develop a list of recommendations for both the design of the future sector suites and the development activities associated therewith. These recommendations facilitate the development of a sector suite design that will most nearly:

(1) Satisfy known controllers' requirements; (2) meet human factors requirements for usability and performance effectiveness; and, (3) facilitate the Federal Aviation Administration's (FAA) recognized requirement for maximum commonality in future equipment design.

BACKGROUND.

The FAA is engaged in a comprehensive engineering, research, and development program to restructure and modernize the National Airspace System (NAS) along more efficient and productive lines. Major steps in the rebuilding process will be the replacement of the air traffic control computers in the en route facilities by the mid-1980's and the transition to new sector control suites and associated computer software by the late 1980's. The new sector suites will accommodate an evolution to much higher levels of air traffic control automation (reference 1). These planned automation enhancements are intended to reduce the highly labor-intensive character of the current en route air traffic control (ATC) operation.

Planned enhancement concepts include the following: Flight data will be displayed electronically, eliminating the present electromechanical paper strip display system. Touch sensitive display/entry devices at the radar and data positions will be used to transfer information from the controller to the computer. Interactive software will provide assistance to the controller in the form of prompts and menu selection lists which will facilitate data entry and eliminate syntax errors involved in message construction. The primary display screens, radar and flight data, will have a touch entry capability to accommodate the most frequently entered control data. Weather information will be enhanced on the radar screen by contour outlines and/or some other similar method of highlighting. Weather information processed and interpreted by meteorological experts may be displayed on a separate television-type monitor at the sector. Hard copy, or static material, such as controller charts, maps, reference manuals, etc., will be displayed at the sector, possibly as computer-generated displays or by a microfiche-based random access rear projection system. Higher level automation enhancements, such as computer-assisted flight route planning, control message generation, and data link transmission will be incorporated into the sector suite as they become available and their effectiveness is demonstrated.

Before the FAA embarks upon full scale developments of such potential enhancements, it is essential that the design requirement necessary for effective use and acceptance by air traffic control specialists be determined. This need for such activities is not only recognized by the FAA as essential to cost effective system development, but has been set forth as a requirement by the House Committee on Science and Technology. This project was initiated at the request of the Systems Research and Development Service to provide information that would assist the Air Traffic Service in defining those requirements.

PROJECT APPROACH.

The approach followed in the study was strongly influenced by the limited availability of controllers resulting from the controller strike which occurred just after the project was initiated. The approach was designed to use the limited time that was available from controllers to obtain that information deemed most critical to the on-going sector suite development effort; i.e., information necessary for design decisions required early in the development procedure and for design decisions most dependent upon controller inputs. It was recognized that additional evaluation efforts, including more extensive controller assessment activities, would be required for the final design of the future sector suite and its various performance enhancement techniques.

In order to use the controllers' time most expeditiously, extensive efforts were directed to the selection of the most promising concepts and the identification of the more critical issues prior to their subjection to controller review. A variety of different concepts for the future sector suites, their configuration and display/control content, were generated. The concepts were based upon information relating to future operational requirements, potential developments to meet those requirements and existing design objectives, such as maximum commonality, stemming from economic and logistic consideration.

Full-scale mockups of a number of these concepts--those that were deemed to offer the greatest potential--were then developed. These mockups were then subjected to a series of design reviews. Participants in these reviews included project personnel, management personnel, and visiting operational personnel. Based upon the results of the reviews, issues relating to configuration, information requirements, and enhancement concept usability considered most essential for immediate controller assessment were identified.

Mockups, display materials, and simulations were then selected to represent and demonstrate these configuration issues and enhancement concepts. This selection included dynamic simulation and experimental devices, currently in use at the Mitre Corporation for the research and development activities directed at some of the enhancement concepts.

In order to insure inputs from all controllers on the identified issues of specific concern, a questionnaire was developed which was directed specifically at those issues. In addition, however, as part of the assessment activity, discussions and open interviews were held with, and comments solicited from, controllers to obtain their inputs on any issue or considerations relating to the sector suite, its design, or operations which they considered important.

The controller assessments were conducted at the Mitre Corporation laboratories in McLean, Virginia, rather than at the Technical Center in Atlantic City, New Jersey, to permit more productive use of available controller time (reduced travel time). It also facilitated use of the Mitre research devices noted above.

Following the above assessment activity, the sector suite configurations that had been assessed by the controllers were subjected to further human engineering evaluations. These evaluations consisted primarily in the use of analytical techniques to determine the visibility and accessibility of controls and displays for the different configurations. These determinations were made for operations using both single and multiple crew members. Any modifications which would be required to provide adequate visibility or accessibility were also identified.

The information obtained from the above two activities, along with other relevant data, known requirements, and/or constraints was then used to derive a list of recommendations for use in development of the future sector suites. These recommendations included both recommendations relating to the actual design of the sector suite, and recommendations for further research or evaluation efforts that should be accomplished in order to achieve the required design.

CONTROLLER ASSESSMENT

The controller assessment activity was considered as the most important element of the present study. It was aimed at obtaining early "operational requirements" type information from controllers on certain basic questions relating to configuration and enhancement concept "usability," to help guide the sector suite development effort. It was not intended as an assessment of the "detailed design" characteristics of the sector suite. That assessment must be conducted after more detailed development activity has been accomplished.

ASSESSMENT APPARATUS/DEVICES.

The information derived from controllers involved two major design concerns: (1) Information concerning the general configuration of the work situation, its size and the orientation of displays, regardless of content; and (2) Information regarding the need for, and usability of, information and performance enhancement concepts and their proposed location in the configuration. While the interrelationship between these two will be highly important and must be carefully considered in detailed design, for the purposes of this study they were addressed independently. Therefore, the mockups used for the assessments for depicting overall configurations, including the primary and secondary display screens, and the material which represented the actual displays and controls were developed as separate units. In accordance with the FAA design objective of maximum commonality in new systems hardware, all primary and all secondary displays for all configurations had the same size and shape, and any display or enhancement concept could be represented on any display screen. Control devices could also be placed in different locations. In addition, devices for dynamically simulating some of the enhancement concepts located in the Mitre labs were also used in assessing these concepts.

The sector suite configuration mockups, the enhancement concepts and the material used to represent them in the mockups, and the devices used for the dynamic simulation, are described below.

SECTOR SUITE CONFIGURATIONS.

Two basic configurations were selected as the primary tools for use in the assessment activity. These configurations are shown in figures 1 and 2. Both configurations incorporated four primary display screens, two secondary display screens, data entry/display devices, and communications modules. The displays represented in the figures are illustrative only since any display could be represented on any screen and control devices located in different positions. The primary difference in the two configurations was the orientation of the primary rectangular display screens. In one configuration the long axis of the screen is vertical to the shelf and in the other configuration the long axis is horizontal. In both configurations, the consoles are positioned in line. Mockups of three other configurations were also used, but only to solict comments on a specific characteristic (in each case) that differed from the basic configurations. These are shown in figures 3, 4 and 5. Two of these configurations, figures 3 and 4, are variations of the basic configuration generated by placing the two 4

FIGURE 1. SECTOR SUITE MODEL — VERTICAL DISPLAYS, IN-LINE CONFIGURATION

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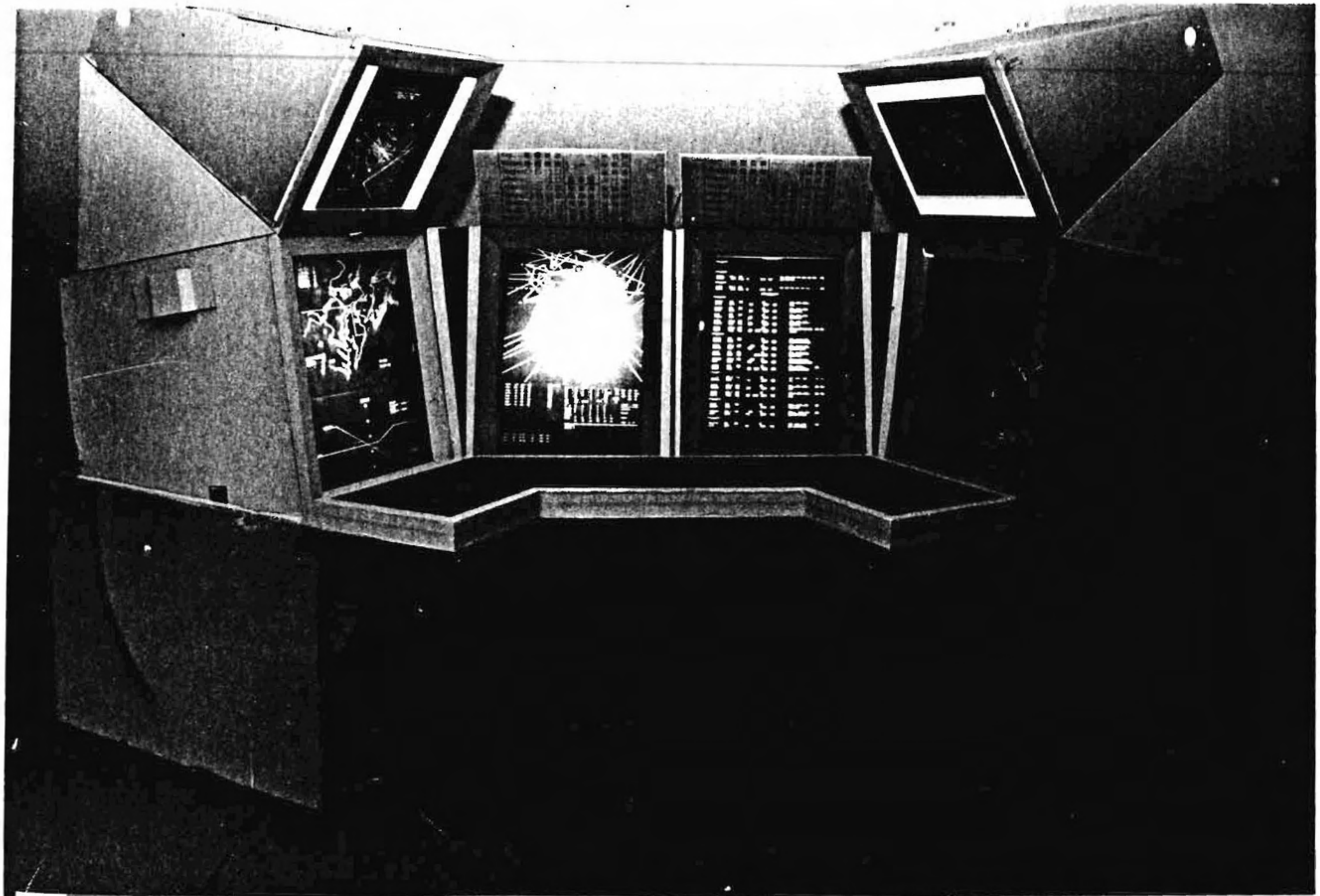
FIGURE 2. SECTOR SUITE MODEL — HORIZONTAL DISPLAYS, IN-LINE CONFIGURATION



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81-3399

FIGURE 3. SECTOR SUITE MODEL — VERTICAL DISPLAY, CURVED CONFIGURATION

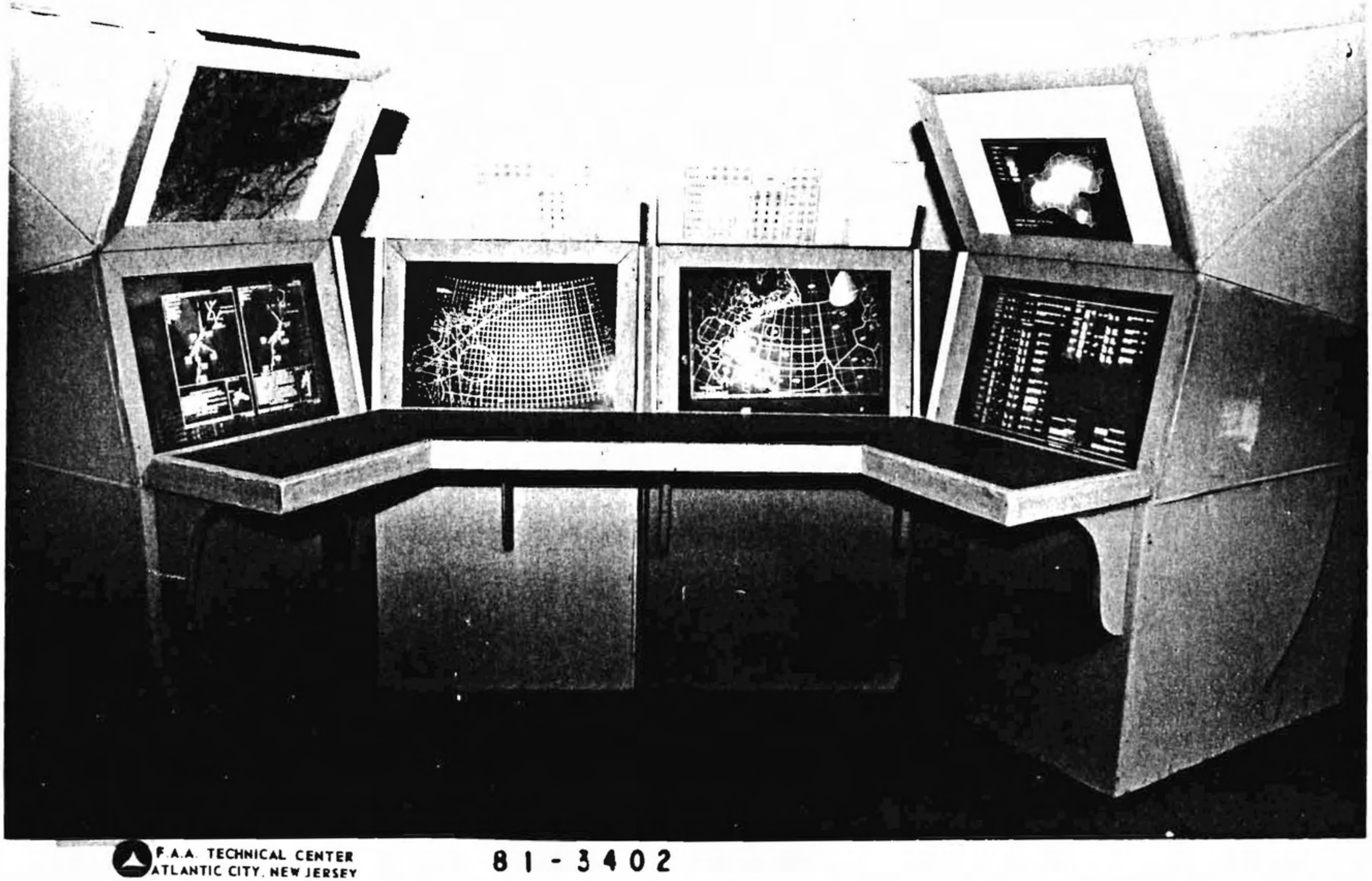


FIGURE 4. SECTOR SUITE MODEL — HORIZONTAL DISPLAY, CURVED CONFIGURATION

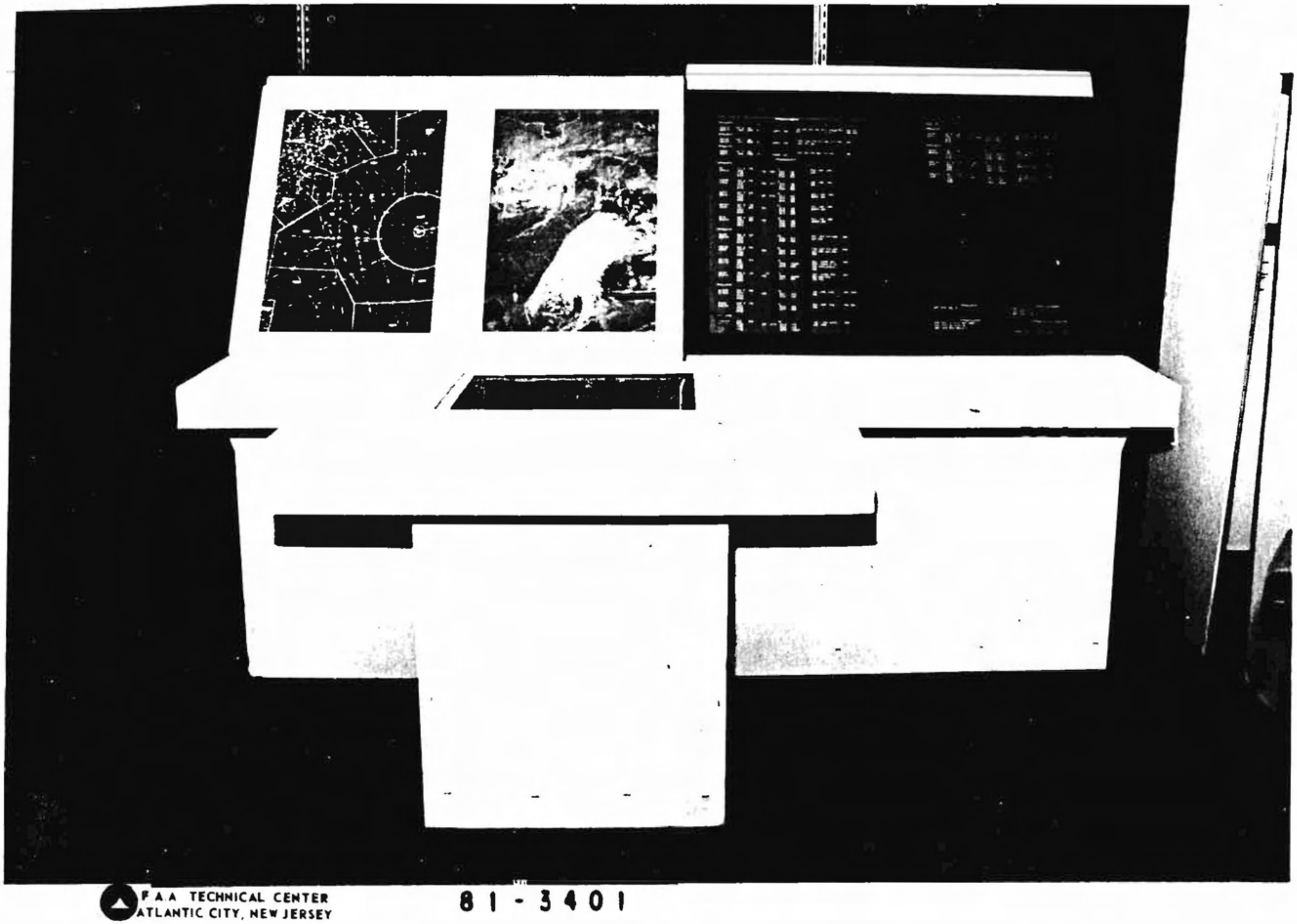


FIGURE 5. SECTOR SUITE MODEL — ISLAND CONFIGURATION

outer consoles at an angle of approximately 45° and replacing the straight shelf with a curved shelf. The fifth configuration, figure 5, was an "island" configuration which includes a table top, surface mounted primary display screen.

In addition to the configurations represented by the mockups, line drawings of two other configurations were used in conjunction with the questionnaire. These represented other variations to the basic configuration generated by placing secondary display or control elements between the primary display screens.

ENHANCEMENT CONCEPT REPRESENTATION

Eleven performance enhancement concepts were selected for assessment by the controllers. These concepts and the material used to represent them are noted below. All primary displays used back-projected 35 mm slides, and all secondary displays used back-lighted photographic transparencies.

Electronic Tabular Display Subsystem. Data formats for the flight data tabular displays and the touch entry data selection displays were taken from the Electronic Tabular Display Subsystem (ETABS) engineering model specifications (reference 4). Visible display area dimensions, the number of display lines and characters, and the size of the touch devices correspond with the ETABS specification.

Radar Position Interactive Device (RAPID). The radar position touch entry display formats were patterned after the concept model developed for the FAA by Mitre Corporation and illustrated in a working paper (reference 5). Radar display controls--e.g., altitude filters, vector length--were included in the menu selections.

Radar Screen Touch Entry. The simulation of the touch entry capability on the radar screen was based on the RAPID menu list formats. This was located on the screen below the radar traffic picture on the vertical display and alongside the radar traffic picture on the horizontal display.

Advanced Weather Displays. Advanced weather display materials were generated from photographs of a system currently under evaluation by the FAA at the Cleveland Air Route Traffic Control Center (ARTCC). It depicts five levels of precipitation on a raster television-type color display.

Weather Contours. This display material consisted of representations of heavy precipitation areas on the radar screen by various types of contour lines, patterned on options being considered by the FAA (reference 6).

Meterological Information. This display consisted of meterological data in a tabular format.

Profile Descent Planning Display. This display was generated from a photograph of the display of an experimental device under development at the Mitre Corp. The display provides a vertical view of the flight route of an aircraft with the capability for a controller to "look ahead" in time and display optional flight routes. This capability permits the controller to plan fuel efficient descents and resolve potential conflicts between aircraft.

Oceanic Sector Displays. This display material was developed from an oceanic air traffic control graphic display performance description (reference 7) prepared by the FAA. The system would provide tracking and data tags on a graphic display of oceanic traffic.

Static Information. This display included selected items from the ATC reference information used at the sector and presently located in folders, notes, on maps displayed overhead, etc. The actual display would also present such items as approach plates, controller charts, ATC procedures, letters of agreement, etc.

Advanced Communications. The representation for this enhancement consisted of a photograph of a concept for an advanced communications system developed at the Technical Center. The concept utilizes electronic switching as planned, by FAA, for the future. For the controllers at the sector, the major change will be a more compact control panel having on display only the frequencies currently in use, and with switching and display of radio frequencies under software control.

ASSESSMENT METHODOLOGY.

The controller assessment activities were conducted over a 2-week period (December 1981) in Mitre Corporation Laboratories at McLean, Virginia. Use of the Mitre facilities reduced the "time away from work" requirements for operational controllers since it permitted use of controllers from the Washington ARTCC in Leesburg, Virginia, with very limited time required for travel.

Subjects. Twenty-seven controllers participated in the assessment activity. Thirteen were journeymen controllers from the Leesburg ARTCC; two were journeymen controllers from the Atlanta ARTCC; one was a journeyman controller from the Baltimore-Washington International Tower; and eleven were from FAA Headquarters. Appendix A details the experience of all twenty-seven controllers.

Assessment Procedures and Data Collection. The assessment sessions required 6 hours from each controller (in groups of 2 to 4), scheduled approximately as follows:

8:45 - 9:00	General Orientation
9:00 - 10:15	Dynamic Simulations: Touch Entry/ETABS/RAPID.
10:30 - 12:00	Sector Suite Mockups: Demonstration and discussion of configurations and enhancement concepts
12:45 - 1:45	Sector Suite Mockups assessments: Questionnaire/Open discussions/interviews
1:45 - 2:15	Briefing of Automated En Route ATC Concepts (AERA)
2:30 - 3:30	Sector Suite Mockups: Open discussion/review/ reevaluation

The assessment sessions were directed by one of two experienced air traffic control specialists from the Technical Center. The session began with a general orientation which described the objectives of the study, what was desired from the controllers, and how the assessment activity would be conducted.

The controllers were then introduced to some of the enhancement concepts through dynamic simulations of those concepts in use at the Mitre Corp. These included menu driven touch entry, PVD touch entry, RAPID and ETABS. The touch entry capabilities for both the D- and the R-controller positions were demonstrated. Controllers used the devices, with a simulated traffic sample, to perform several different functions at each position. To obtain assessment data, open interviews and discussions followed the demonstrations and controllers' use of the devices and simulated concepts.

Following the above demonstrations and assessment sessions, the controllers were taken to the sector suite mockup area. Here the session director first described the various enhancements and how they would be used in the control of air traffic. These concepts were then demonstrated, using the mockups of the two basic configurations (figures 1 and 2), with the simulated display/control materials. During both the description and demonstrations, the controllers were encouraged to ask questions and to discuss the concepts, the sector suite configurations, and their use. Since the mockups, the displays and the controls were only static representations, the controllers were asked to "visualize" controlling traffic with the proposed equipments and to attempt to identify potential advantages and disadvantages. The different displays, of course, could be, and were, represented on different display screens, and simulated control devices placed in different locations. The different configuration for the enhancement concepts and their proposed locations were assessed for single and multiple crew usage. The above demonstrations and discussion sessions were followed by a "lunch break" after which the controllers returned to the mockup area for a further assessment and data collection session. In this session, the controllers completed the questionnaire (described in the next section) and provided both written and oral comments, suggestions and recommendations relative to the future sector suite. The questionnaire was explained, amplified, and discussed while it was being completed, and controllers were encouraged to give reasons for their answers to the questions. The same was true for the comments and suggestions made by the controllers.

The next session was held in the AERA Laboratory at Mitre where a briefing on advanced ATC automation advanced concepts was provided. These included computer-assisted and computer-generated air traffic management, computer-generated metering constraints and computer-generated communications. While these concepts were not included in those for evaluation addressed by the controllers, they were described in order for the controllers to better understand some of the future capabilities to be accommodated by the sector suite and to be given consideration in current design planning.

The controllers then returned to the mockup area for a final review, discussion and reassessment (where appropriate) of the sector suite configurations and enhancement concepts. During this session they were shown three additional mockup configurations not previously discussed. Two of these were "curved" versions of the two basic configurations (figures 3 and 4). The other was the island configuration. (figure 5). They were asked to consider possible advantages offered by these configurations for both single and multiple crew usage. During this final session the controllers were asked to review, and if appropriate, change any of their previous inputs.

RESULTS.

The results from the controller assessment activities are summarized below. They are grouped in accordance with three data collection activities that were accomplished and in the order in which they were conducted: (1) interviews following demonstrations and use of dynamic simulation; (2) completion of questionnaires following demonstration and discussion of mockups; and (3) final interviews and written comments.

DYNAMIC SIMULATION RESULTS. The assessment activity in which dynamic simulation was employed was directed primarily at "touch entry" and its use in different applications. The details relating to these assessments may be found in reference 6, but the major results are summarized below:

Menu-Driven Touch Entry - This was viewed as highly desirable to simplify both message composition and entry. It will reduce work and result in fewer input errors. However, touch areas must be designed to reduce the probability of "bad" touches.

PVD Touch Entry - This was considered particularly useful because it will keep the controller's attention on his scope. Common actions such as handoffs, altitude and vector changes should be included in a PVD touch capability. However, designs must be achieved that will reduce bad touches due to parallax and/or improperly defined touch areas and inadvertent touches that could result in entering unwanted data.

Rapid Touch Entry - This interactive data entry device at the R position was considered desirable but must be designed to complement the touch entry on the PVD. It must also be designed so as not to distract the controller's attention for any length of time, from traffic on the PVD.

ETABS Touch Entry - Touch entry with ETABS was deemed very desirable but design should incorporate the following features: Highlighting should be used to indicate which items were touched. An auditory signal is needed to acknowledge data inputs. Some message updates should require an "acceptance" by the controller before being changed.

QUESTIONNAIRE RESULTS - The questionnaire was used with the mockups and the associated display and control representation to obtain controller inputs on specific design issues. These issues involved configuration, display/control characteristics and location, and information requirements and accessibility. The questionnaire, shown in appendix B, consisted of six items. The six items along with the controllers' responses to each are discussed in turn below.

ITEM 1: Overall Configuration - This item addressed the overall configuration for the sector suite "work station." Controllers were asked to rank, by order of preference, the top three of five configurations depicted by line drawings (figure B-1). Two of these represented the two basic mockup configurations, which differed only in the orientation of the primary rectangular displays. Two others were variations to each of the basic configurations generated by providing space between the primary displays for secondary display/control devices, and thereby also extending the length of the overall configuration. The fifth was an "island" configuration, also represented by a mockup. Rankings were requested for both two-man and three-man sector suite operations. With the exception that the island configuration was selected by very few controllers, the results indicated no clear preference for any single configuration (table C-1(a)). However, most of the controllers from FAA Headquarters indicated a preference for those configurations in which the primary displays were oriented horizontally. Field controllers, on the other hand, selected the horizontal and vertical display orientation equally often (table C-1(b)). For three-man operations there was a decided first rank preference by both field and headquarters controllers for the "extended" configurations (i.e., configurations C and D).

ITEM 2: Display Orientation - This item was intended to separate the question of display screen orientation from that of overall configuration to isolate any interactive effects that might have been present in the first item. The results (table C-2) only confirmed the results obtained from item 1 relative to display orientation. The question of display orientation (or shape) is highly dependent upon display function and usage.

ITEM 3: Display/Control Location - This item addressed the question of locating information, displays, and controls for effective use by controllers. It listed nine general types of displays or controls which were to be "placed" by the controller on a sketch of the sector suite. The listed displays and controls, with various possible locations, had been included in the preceding demonstrations and discussion. Modification to the selected configuration, for use in this item, was solicited. The controllers' location preferences are shown in figure C-1 through C-9.

The results indicated that for those displays/controls where usage was understood by the controller based upon past experience; e.g., radar or flight data, there was general agreement as to location. Radar was placed on the primary display in front of the R controller and flight data on the primary display in front of the D controller. However, for the newer display/control concepts, the controllers apparently did not have adequate understanding of their function and usage to provide inputs usable for design purposes. There was wide variation among the controllers in the placement of different items. The primary conclusion that can be drawn from these results is that more study and much more extensive controller evaluations are required in order to define a sector suite design that will ensure effective controller performance.

There were some trends, or tendencies, to place some items in certain locations more frequently than in others that may be useful in developing design alternatives. These are summarized and included in appendix C along with the actual display/control location data, which has been consolidated for each selected configuration.

ITEM 4. Data Entry Device Location - This item asked the controllers to choose between three possible locations for the data entry (touch entry concept) device: on the shelf, on the displays, or between displays for both R and D controllers. The results (table C-3) indicated that most of the controllers wanted the device placed on the shelf, for both the R and the D positions. In addition, a number of the controllers stated that they preferred the device located on a 45° angled panel at the base of the primary display screen. The controllers who wanted data entry on the display screen also wanted a backup device on the shelf. From the interviews that followed, it would appear that the most effective solution would be to have a dual data entry capability--on the displays and also on the shelf.

ITEM 5. Data Entry Device (Shelf Mounted) Installation - This item assumed the use of shelf-mounted data entry devices (alone, or in conjunction with display mounted devices) and asked for information relative to the preferred installation and orientation of these devices on the shelf. Three options were shown in the questionnaire--flush, angled, or top-mounted and movable. Controller-suggested alternatives were also solicited. The results (table C-4) indicated that the device should be both movable and angled or adjustable for ease of reading and use.

ITEM 6. Information Requirements and Display Accessibility - This item asked the controllers to assess the need for various types of information as "essential," "nice to know," or "not needed" for air traffic control operations. It also asked them to assess the accessibility requirements for that information by indicating whether it should be "constantly displayed," "forced on the display," or "available for callup." Nineteen items of information were listed for assessment. The results from these items are presented in table 1. The table shows the number of controllers who classified the various types of information into the three "need" categories. As will be noted in the table, most of the controllers rated each of the information items as either essential or nice to know.

The results also show that most controllers want the information either constantly displayed or available for callup. Moreover, most of the information, according to the controllers' ratings, should be available for callup. The majority of controllers considered that only four items of information needed to be displayed continuously--video maps, flight progress strips, altimeter setting, and controller charts.

FINAL INTERVIEW RESULTS. Space was provided in the questionnaire, discussed above, for written comments by the controllers. Their comments are given in appendix D. Since these comments were discussed with the controllers during the final interviews, they are included as a part of the results from those interviews. The more significant findings obtained from the final interviews are summarized according to the major topics discussed.

Overall Configuration - The interviews confirmed the questionnaire results indicating that the present assessment activity would not permit the selection of a preferred, or optimum, configuration for the sector suite. The controllers' comments and discussion indicated that the preferred configuration would be dependent upon its usage, number of display/controls included, number of crew members required, and their functional task requirements. For example, for single crew operations, and for certain multi-crew operations, the curved configuration has decided advantages but would be unacceptable for other operations. The island configuration, while not considered acceptable for on-line traffic control operations, was

TABLE 1. RATING DATA FOR ATC INFORMATION ITEMS

ATC Information Items	Information Necessity			Display Preference		
	Essential	Nice to Know	Not Needed	Constantly Displayed	Available on Callup	Forced on Display
Video Maps	27	0		21	6	
Flight Progress Strips	27	0		22	5	
Warning/Restricted Area Status	26	1		8	19	
Altimeter Settings	26	1		19	8	
Controller Charts	24	3		15	12	
NAS Generated Weather Contours	22	5		4	23	
Selected Receiver Trans. Freq.	22	4	1	13	13	1
Approach Plates	21	6		1	26	
Flow Control Information	19	8		11	16	
Navigational Aid Outages	19	8		5	22	
Hourly Observations, PIREP's NOTAM's	18	8	1	3	23	1
List of Facilities Frequencies	17	9	1	8	18	1
Minimum En Route Altitude	16	6	5	6	16	5
Minimum Reception Altitude	13	8	6	3	18	6
Transmitter on Main or Backup	13	11	3	11	14	2
Receiver on Main or Backup	13	11	3	11	14	2
Weather Service Radar	13	14		2	25	1
Letters of Agreement	10	15	2	1	25	1
Winds Aloft	8	18	1	1	25	1

thought to be have considerble potential as a "roll around"/"plug in" unit for use in training. The general consensus was that the sector suite should be modular in design, thus providing the flexibility for variation in configuration to best accommodate the requirements for different operations. The results also emphasize the requirement for additional and more extensive evaluations.

Display Orientation - The interviews also indicated that the controllers preference for orientation of the rectangular primary displays was determined by their preconceived concepts (based on past experience) of the geographical areas to be controlled. Controllers from sectors where the traffic flow was predominantly north-south selected the vertical orientation. Those from sectors with predominantly east-west traffic selected the horizontal orientation. The almost unanimous preference by headquarter controllers for the horizontally oriented displays appeared to be based on the use of displays for flight data presentation. A number of comments indicated that the D position needed a horizontal screen and the R position a vertical screen. In an effort to arrive at an agreement on a common display, the controllers suggested that a square screen would probably best satisfy the requirements for both R and D positions, as well as the requirement imposed by different geographical areas. The results did show that the rectangular display screens used in this assessment would not be satisfactory as a common primary display and that some alteration was required.

Touch Entry Device Location and Use - Touch entry as related to specific application; e.g., ETABS, RAPID, is discussed later with the discussion of these applications. This section addresses general issues common to those different applications. The controllers indicated that the primary data entry device should be located on the shelf. Touch entry on the display should be limited, at least initially, to actions not prone to mistakes through inadvertent touches and where display touches can be shown to significantly increase accuracy and/or speed of data entry. The controllers preferred the shelf-mounted entry devices located at the juncture of the shelf and the base of the display screen, at an angle of approximately 45° and movable to different locations. A portable plug-in device for use by a third person--trainee or handoff controller was also suggested.

ETABS - The controllers indicated that the concept of displaying tabular flight data electronically had advantages, but the specific (ETABS) device represented was not considered as the optimum solution. It was noted that ETABS might be satisfactory for the D controller. The R controller, who must have access to flight data to understand the traffic situation, would prefer that the flight data he needs be presented (or available for presentation) on the primary radar display. Tabular data could be seen by the R controller on the primary screen immediately adjacent to the radar display. On the other display screens, it would be difficult to see using an in-line configuration, and perhaps occluded by the D controller particularly using a curved configuration. The need for a second tabular display was questioned, since having data available for callup is considered preferable to the continuous display of all flight data 17.

The controllers also indicated that the display had to be designed to alert controllers to the occurrence of new flight data (new flight plans).

The capability for the computer to handle the message construction details by presenting only the relevant information (e.g., list of altitudes, list of handoff sectors) in menu lists for selection was highly favored and seen as an aid in reducing data input errors. Controllers also indicated that data entry for the R and the D positions should be compatible and consistent. They noted that the "fields" for data entry on the two interactive display devices should be in the same place. It was further noted that the use of ETABS could result in a reduced need for the controller at the D position, therefore making him available for other duties such as assisting the R position as tracker, handoff man, etc.

RAPID - Menu-driven touch entry for the R position was well accepted by controllers. As was indicated for the ETABS touch entry device, it can reduce data entry formating errors. However, problems of parallax leading to improper touches must be solved. Various suggested solutions included: use of a flat screen display; use of a cursor/marker symbol to show where the finger is pointing; and use of a light pen. Some method is also required to prevent inadvertent touches. Controllers noted that the software logic should make it easy for the controller to correct a wrong selection from the menu list. It should not be necessary to go back more than one step in the menu sequences. One advantage noted for the RAPID/touch system was that it would give the controller a better indication of message rejections than is provided by the computer readout device in the present system.

Radar Screen Touch Entry - Touch entry "on the screen" was considered acceptable by controllers for only the most frequently used entries such as handoff and altitude change. Longer messages should be entered from the shelf-mounted device. However, the controllers indicate that the use of both methods should be further studied to determine the most effective means of using the two in combination and thereby exploiting the advantages of each.

Two additional uses for PVD touch entry were suggested by controllers:

> A latitude/longitude conversion on the PVD whereby the controller could touch a point on the display and get the latitude/longitude coordinates of that point for his use or use of the pilot. This would be particularly useful in the future with the more widespread use of area navigation, or "free flight," in which the pilot selects his own "way points."
>
> A quick-look method of recognizing an aircraft which had been handed off but still required monitoring.

Advanced Weather Information and Display - The controllers showed considerable uncertainty as to how weather information would be used in future traffic control operations. They indicated that if it were to be used for tactical control decisions then it should be on the primary rader display. Since they generally thought that weather information would be of secondary importance it should be placed on a secondary display, to the side, or overhead. At the same time, it was noted that weather information on the secondary screen could be distracting, and when used it would be difficult to equate range and geography on the two screens.

The controllers saw little utility in showing levels of precipitation, through the use of color, but thought that outlining areas of heavy weather (radar returns) on the primary radar display was useful. They indicated that the most useful weather information came from pilot reports. As noted above, the controllers raised a number of questions with reference to the FAA's plans for the use of meteorological information in future traffic control operations. They indicated that information obtained from the National Weather Service or the National Environmental Satellite Service if reduced and interpreted by a qualified meteorologist, and "very recent" would be useful to sector controllers. Less recent data could be used in flow control. But they questioned the use of controllers to interpret meteorological data and use it in decisionmaking. They questioned both the training requirements and the legal implications.

Oceanic Sector Equipment - Controllers considered the sector suite concepts which were assessed as suitable "building blocks" for an oceanic sector when specifically adapted to that purpose. Graphic situation displays were considered highly desirable. The change from the use of computer-generated displays based upon pilot reports to computer-generated displays based upon satellite tracking should be accomplished smoothly and easily. It was noted that the modular components of the sector suite could be readily configured to accommodate altitude reservation scheduling (ALT RVS).

Mode S Uplink/Downlink - The controllers' understanding of this concept was too limited to permit assessment of specific features or configuration requirements. They did offer the following general comments:

With the uplink capability the R controller will require a "preview" area on the primary radar screen.

Capability of locating information on any display screen, or any area on a display screen, should be provided.

Profile Descent Planning - As in the above case, the controllers offered few inputs due to their limited understanding of the concept and its usage.

Static Information - The concept of an overhead display unit capable of providing various static data--controller charts, approach plates, Standard Instrument Departures (SID's), Standard Instrument Arrivals (STAR's), Letters of Agreement, lists of facility frequencies--was well received by the controllers. All of these items are presently available but located in various places at the sector. A computer interfaced system for accessing static data was highly favored. The controllers indicated that the system should provide for instant callups of specific portions of a chart, map, list, etc., rather than provide only a displayed copy of the original. A "zoom-in" capability to enlarge areas of a chart, for example, was recommended. The type of display (CRT, plasma, raster, or other) was not viewed as critical. The location preferred was over the primary viewing area.

Advanced Communications - The locations suggested by controllers for radio communications were about equally divided between an overhead module and one located at the base or side of the screen. However, they did recognize the need to accommodate the arm reach limits of the shorter person, indicating that for this reason locating the communication control at the base of the screen would be preferable. The preferred location for the interphone was also at the base of the display screen. The controllers recognized the advantages of digitally controlled switching of radio frequencies, particularly for combined sector operations. They noted that software controlled display readout would eliminate the need for all frequencies to be displayed continuously.

HUMAN ENGINEERING ANALYSES

The four versions of the basic sector suite configurations that were represented by mockups and used in the controller assessment activity described in the preceding section were subjected to further human engineering analyses. The analyses were conducted to obtain additional data on control/display visibility and accessibility and seating accommodations for the different configurations. Both single and multiple crew usage of the configurations were considered. Both the mockups and analytic techniques, based upon visibility standards drawn from military research data were used in conducting these analyses.

Figure 6, from Military Standard 1472C (reference 9), shows that the optimum visual field subtends an angle 15° from the normal line of sight in either the vertical or horizontal plane. It is the area seen by both eyes without eye or head movement. Areas that can be seen by moving the eyes comfortably in a horizontal direction are included in an angle 35° right and left of center and in a vertical plane 40° upward and 20° downward from the normal line of sight. The head can be moved comfortably 60° right or left of center, 65° upward, and 35° downward. These data were used to assess the visibility of the displays/controls provided by the different configurations.

RESULTS.

Figures 7 through 10 are drawings of the four configurations. Superimposed upon each of these drawings are the relevant visual field limits as noted above. The visibility, accessibility and seating accommodations provided by the different configuration is discussed below.

Configuration Using Vertical Displays - Figure 7 shows the vertical, in-line configuration without the 7-inch wide communication module in the center as it was demonstrated to the controllers. However, even with the additional 7 inches of shelf length, this configuration would be inadequate for a two-person sector operation. The D controller would probably have to sit farther to the right than the centerline of the two right-most displays for a comfortable working arrangement. It would be difficult to add a third person at this sector. The overhead displays are adequate for secondary display areas.

The curved shelf arrangement (figure 8) results in less space for chairs. The arrangement may be adequate for a one-person operation, but is inadequate for two or three persons. Data visibility appears satisfactory for a person sitting in front of the display. However, the 18-inch-wide screen does not appear to take full advantage of the visual area that can be used with eye movement in the left-right direction. For the up-down direction, the visual fields indicate that, for a veiwer normally focusing at a point a little more than halfway up on the screen, head movement would be required to focus on an area at the juncture of the screen and the shelf. This is the area suggested for the data entry/display device. Since the data entry device would receive frequent use, the head movements and eye shifts required could be fatiguing.

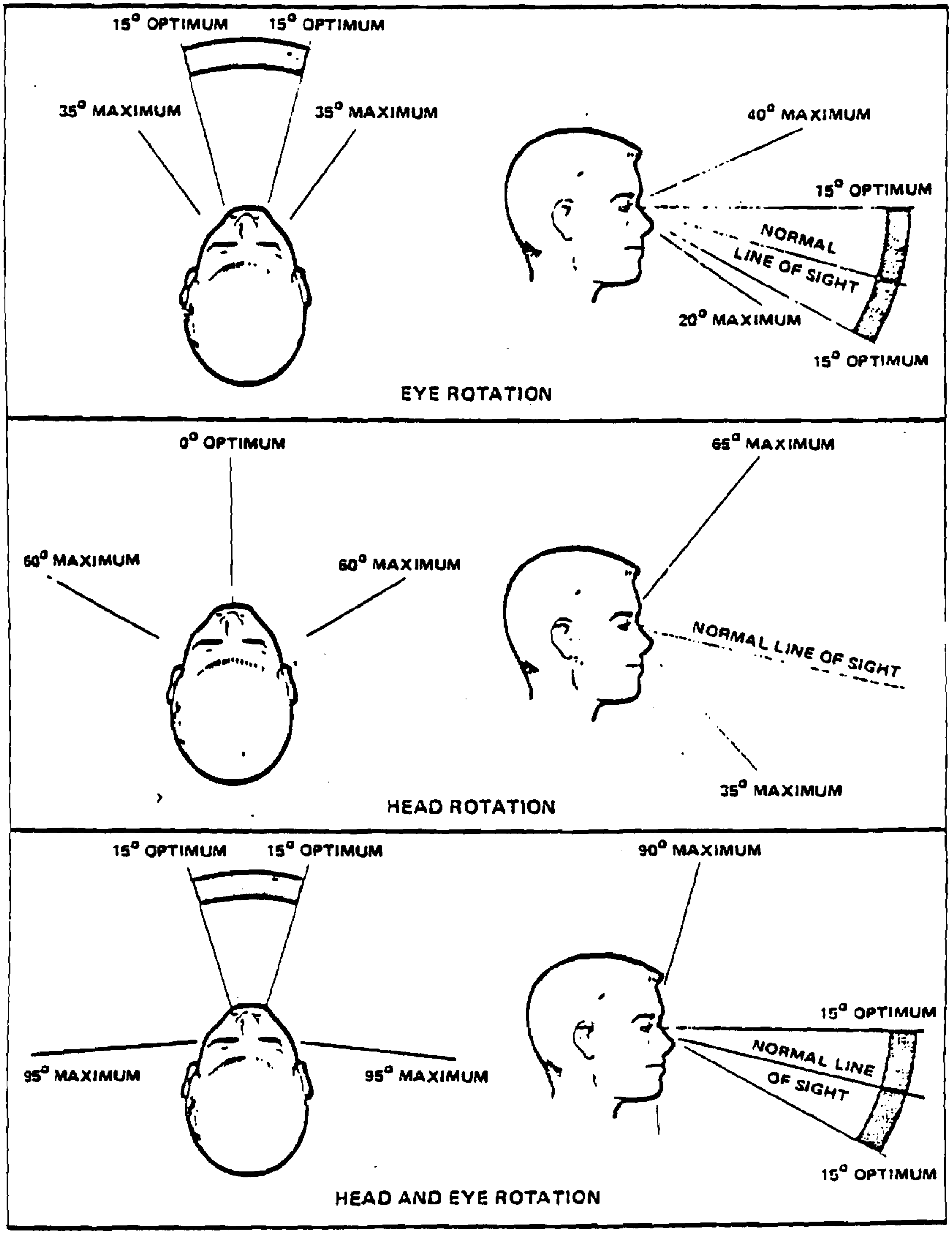


FIGURE 6. VERTICAL AND HORIZONTAL VISUAL FIELD

4 CONSOLE GROUP - VERTICAL POSITION (IN-LINE)

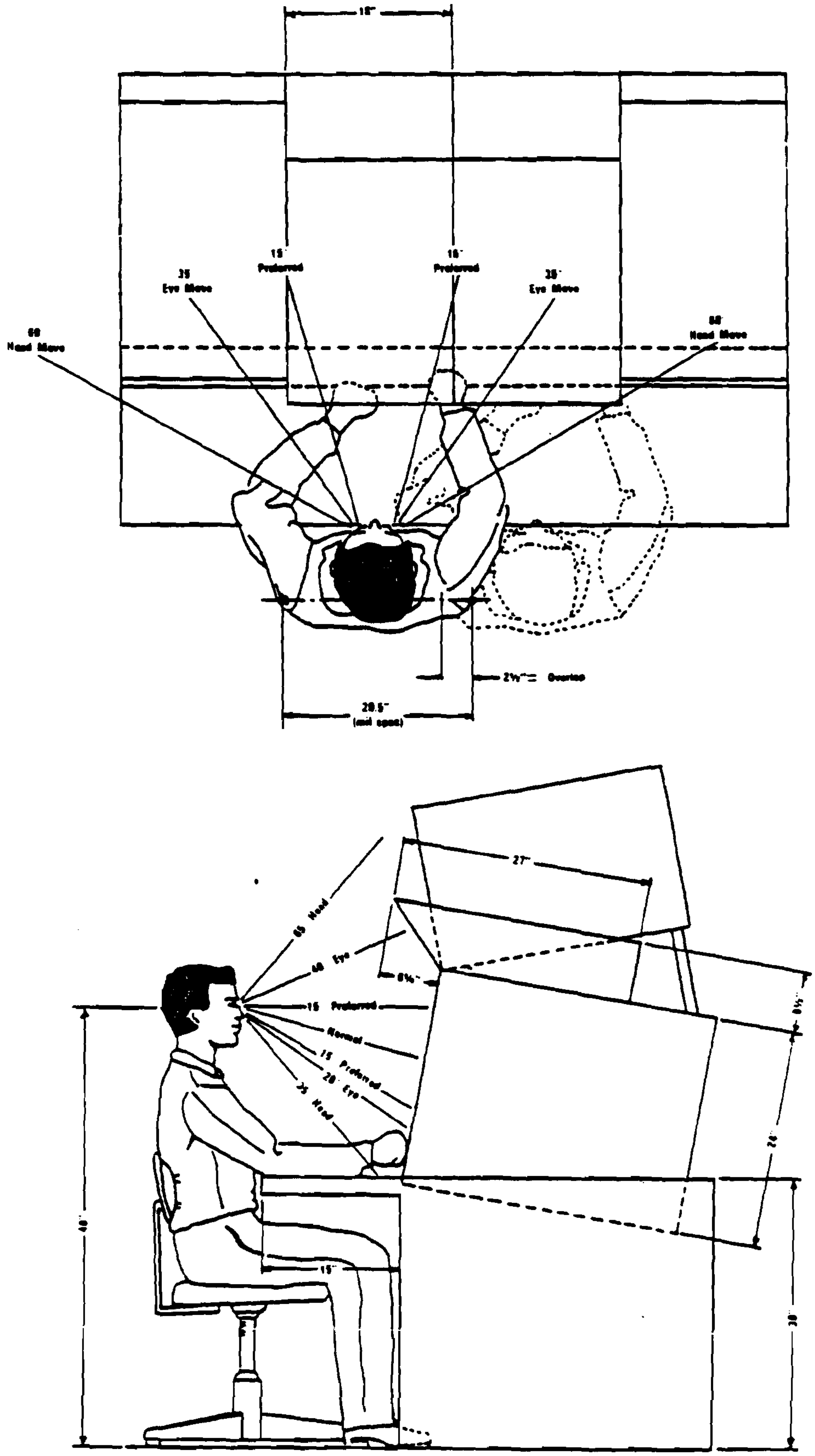


FIGURE 7. VERTICAL DISPLAY SCREENS — IN-LINE CONFIGURATION

4 CONSOLE GROUP - VERTICAL POSITION
(CURVED)

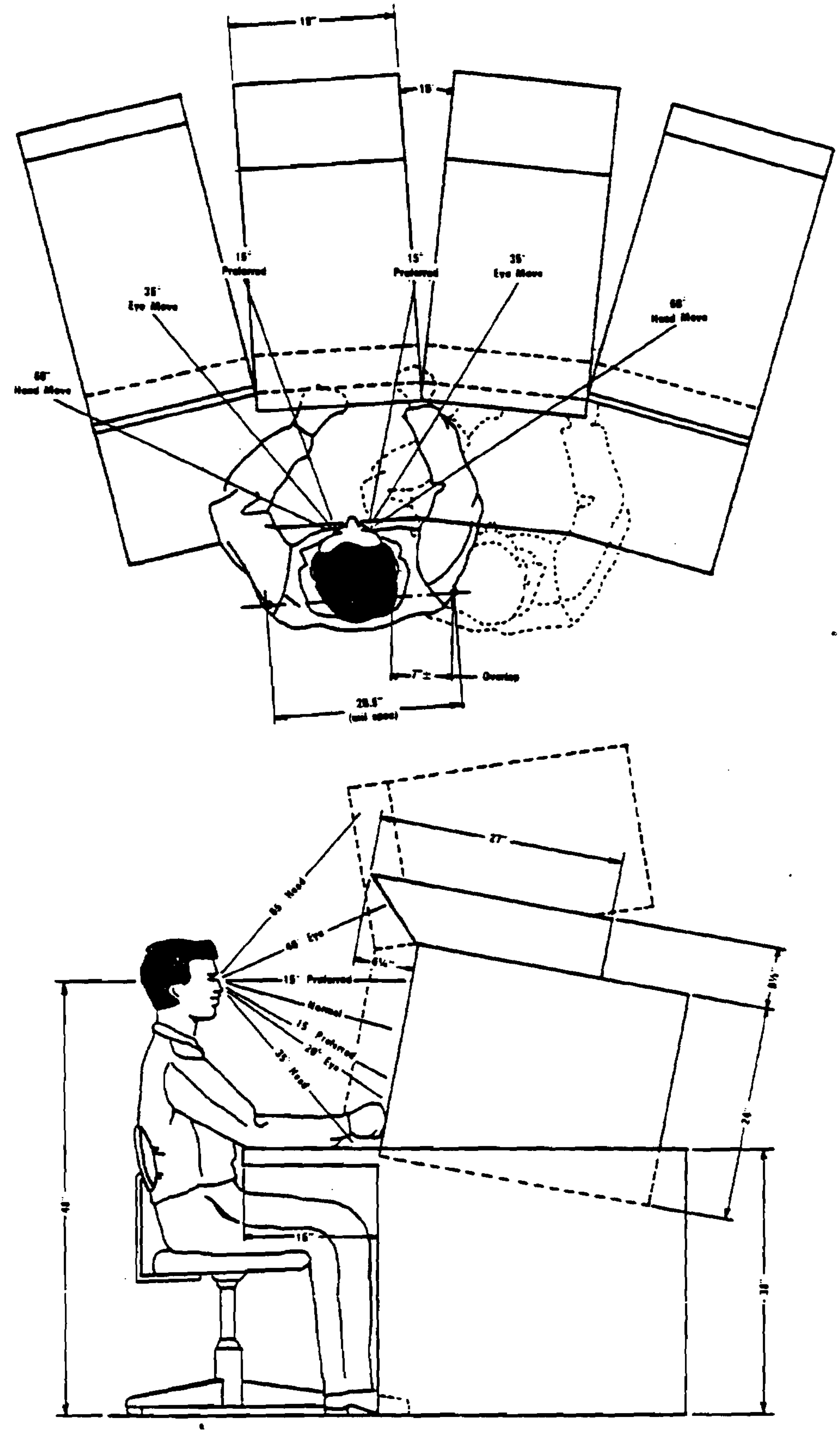


FIGURE 8. VERTICAL DISPLAY — CURVED CONFIGURATION

Configurations Using Horizontal Displays - Figure 9 depicts the 24-inch-wide horizontal display screens. This configuration does not provide adequate workspace for two persons when each is seated in front of one of the two center displays. Human factors standards indicate that at least 30 inches of desk or shelf space is needed for comfort. Curving the shelf as shown in figure 10 provides even less chair space. It appears that data visibility on the 24-inch-wide screens would be efficient for a person seated in front of the display, but only for the left-right direction. The display areas in the up-down direction are inefficient in that the normal line of sight is too high on the screen, causing the optimum visual field to fall on the frame area of the display.

The horizontal screens present the most favorable features. However, in order to accommodate two persons, each would sit off-center but probably not directly in front of the frames between displays. For an R controller sitting off-center, head movement would be required in order to see the right portion of the flight data display. If the controller sat facing toward the D position he could, of course, see the flight data display, but viewing a display to the left of the PVD would require head movement. Head movement to view secondary display areas is generally considered acceptable since it occurs infrequently. Effectiveness of the configuration would depend on how frequently the flight data display would be viewed by the R controller. The 24-inch width is considered unsatisfactory for workspace in a side-by-side arrangement. A minimum of 30 inches and preferably 36 inches in width is needed.

CONCLUSIONS

The primary conclusion that can be drawn from the above human engineering analyses is that not one of the configurations evaluated is satisfactory as a "universal" sector suite design usable for all purposes. The data further support the previously noted contention that the sector suite should be modular in design, with the flexibility to be configured as needed to best meet the unique requirements of each sector operation. It also emphases the need for additional study and evaluation prior to final design.

4 CONSOLE GROUP - HORIZONTAL POSITION
(IN-LINE)

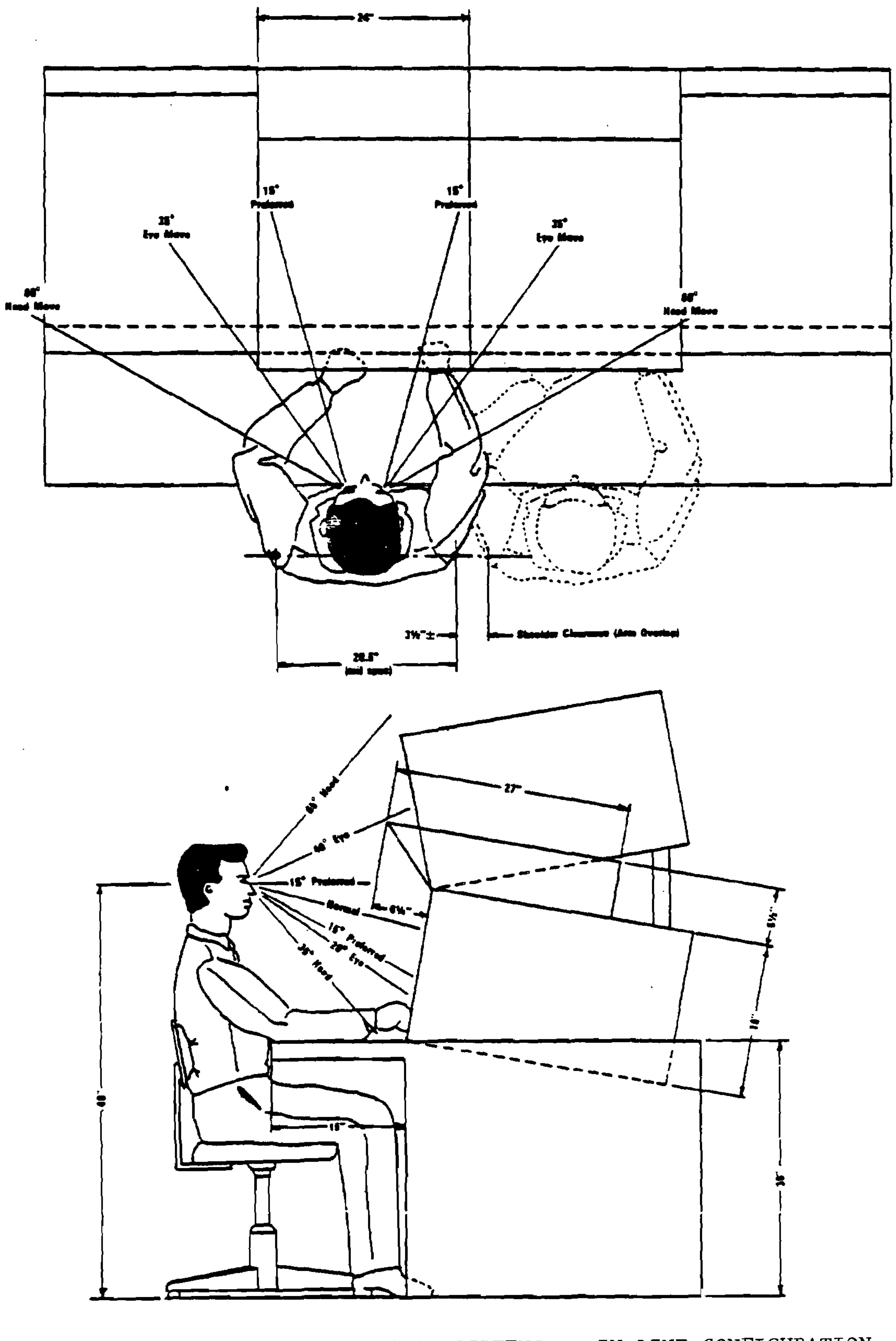


FIGURE 9. HORIZONTAL DISPLAY SCREENS — IN-LINE CONFIGURATION

4 CONSOLE GROUP - HORIZONTAL POSITION (CURVED)

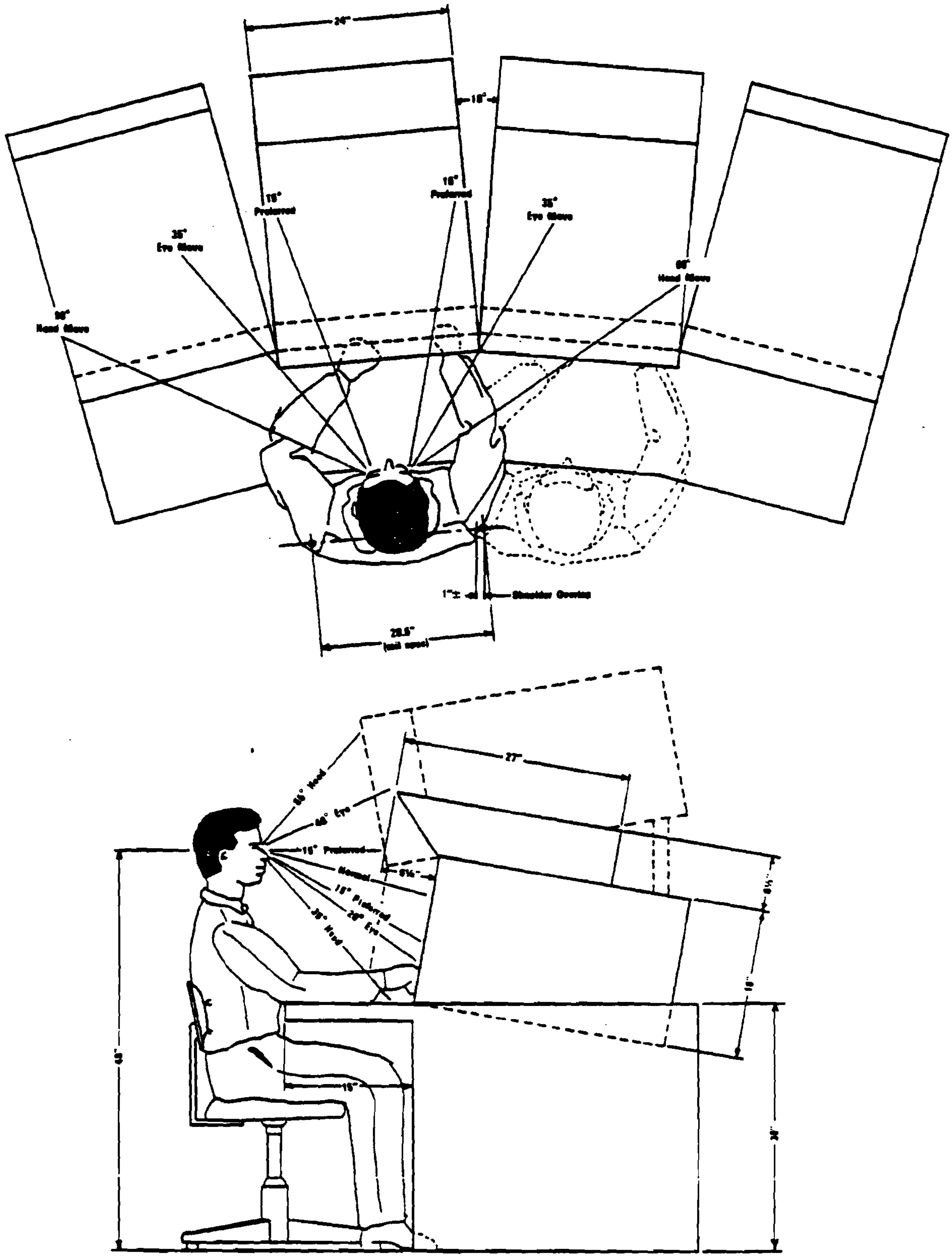


FIGURE 10. HORIZONTAL DISPLAY SCREENS — CURVED CONFIGURATION

RECOMMENDATIONS

As noted in the introduction to this report, the basic purpose of the study was to develop a set of recommendations for use in the design and development of the future sector suite that would enhance the effectiveness of its use by air traffic control specialists. This section presents those recommendations. The recommendations are based, primarily, upon the results obtained from the two activities reported in the preceding sections--the controller assessments, and the human engineering analyses. Two categories of recommendations are provided. The first category relates to specific design issues. The second concerns additional study and evaluation efforts that are necessary in order to insure that the future sector suite is designed so that it can be used effectively by controllers in all air traffic control operations.

DESIGN RECOMMENDATIONS.

This evaluation, conducted early in the development cycle, was intended to obtain information on certain basic concepts to guide design, and not to obtain detail design solutions. The recommendations which follow are categorized according to the basic concepts on which information was obtained.

Sector Suite Configuration

- The sector suite should not be designed as a single fixed configuration.

- The sector suite should be modular in design, using the "building block" concept.

- The sector suite should have the flexibility to use those modules/building blocks that are needed, and to arrange those modules/building blocks into whatever configuration is most effective for each specific sector/air traffic control operation.

- The sector suite should have "shelf" components to accommodate either in-line or curved configurations.

- The sector suite should be designed to provide a separation of at least 30 inches (preferably 36 inches between regularly manned positions).

Display Screen Shape/Orientation

- The primary displays screens should not be rectangular in shape. The primary display should be square or round so that a single orientation will accommodate the geography or primary traffic flow pattern of any sector.

- The primary display screens, if square, should be a minimum of 19 1/2 inches in height and width (i.e., the diameter of the present PVD screen).

Display Characteristics

- Displays should be designed for interchangeability of information; i.e., any display should be able to accommodate any information.

- Displays should be designed so that information can be located or moved to any area on the display.

- Displays should be capable of time sharing, allowing different types of information, primary or secondary to be presented, alternately or simultaneously on a single display; e.g., weather information presented on the traffic surveillance display.

- Displays should be adjustable in angle of tilt to accommodate operators of different stature.

Information Displayed

- Only continuously used information; e.g., traffic surveillance information, should be displayed continuously.

- Most information should be stored in the computer but available for instant call-up.

- Flight data displays should not duplicate current flight strip information.

- Only that communications information which is relevant to the controllers' current task should be displayed continuously.

Data Entry

- The concept of touch entry should be employed in the sector suite.

- Menu driven touch entry should be utilized to the maximum extent possible.

- The primary data entry device should be shelf mounted.

- Display mounted touch entry should also be utilized but its most effective usage must still be determined.

- The shelf mounted data entry device should be movable.

- The shelf mounted data entry device should be tilted to an angle of 45°, or preferably, adjustable in tilt to accommodate different viewing positions.

RECOMMENDATION FOR ADDITIONAL STUDY AND EVALUATION.

The present study has provided much needed information, on certain basic design issues, to help guide the early development effort for the future sector suite. It also served to point out a number of areas where further studies are required in order to provide information that will be essential for detail design. The recommendations listed below include activities required to provide solution to many of the problem areas identified in the study.

Studies should be undertaken to:

- Determine the optimum common display size and shape to accommodate different sector geographies and operations.

- Define the more effective sector suite configuration for different types of sectors/operations. Individual sectors could still change configuration to meet unique requirements and as experience dictates, but these data are needed as a starting point to define initial requirement, and to facilitate transition.

- Determine the most effective location of displays and controls for different sectors/operations. (The same rationale applies here as for the preceding recommendation.)

- Determine the most effective use of display mounted touch entry; and the optimum relationship between display and shelf-mounted entry capability.

- Develop methods or techniques to prevent and/or reduce the impact of improper or inadvertent touches when using the touch entry device.

- Develop methods/techniques for rapid and easy error correction with menu driven touch entry.

- Develop methods/techniques for use with ETABS for highlighting data items entered; and for attracting the controllers' attention to the occurrence of new flight data (new flights).

- Determine the need for, and most effective use of, color for sector suite displays.

- Define functional usage and operational procedures for advanced concepts, such as Mode S uplink/downlink and profile descent planning, and evaluate their use by controllers.

- Define controller usage of advanced weather information and evaluate use and display alternatives.

- Evaluate use of the island configuration as an onsite training device.

- Determine manning requirements for different sector operations.

- Conduct extensive controller performance evaluations of proposed detail designs of the sector suite components, and sector suites as complete operational systems, using dynamic simulations of the components/system in realistic operational environments.

REFERENCES

1. Helms, Lynn J., The Administrator's View — The Best System to be Made Better, FAA World, March 1982.

2. Request for Research and Development Effort from Air Traffic Service to Engineering and Development, 9550-AAT-100-47, dated March 31, 1980.

3. House Calendar No. 61, U.S. House of Representatives, 97th Congress, H. Res 202 (Report No. 97-271), October 14, 1981.

4. System Design Data, Electronic Tabular Display Subsystem, Sanders Associates, Nashua, New Hampshire, April 1979.

5. Radar Position Input and Display (Rapid): Overview and Preliminary Design, the Mitre Corporation, WP-13425, November 1978.

6. Weather Contour Work and Demonstration Briefing, Memorandum, and Technical Illustration, the Mitre Corporation, April 1981.

7. Performance Description for Oceanic Air Traffic Graphic Display, Federal Aviation Administration, February 1970.

8. Results of a Controller Evaluation of a Menu-Driven Sector Suite Design, Mitre Memorandum, W42-M3701, April 1982.

9. Human Engineering Design Criteria for Military Systems, Equipment and Facilities, Military Standard 1472C, May 1981.

APPENDIX A

TEST PARTICIPANTS

TABLE A-1. TEST PARTICIPANTS

(ATC Specialists Who Provided Assessments of the Sector Suite Models)

Subject Number	Facility	ATC Experience: Radar (Years)	ATC Experience: Other (Type)
	Field		
0.	Baltimore Washington International Tower (Planning & Procedures Specialist)	over 5	VFR Tower
1.	Atlanta ARTCC (ATCS)	14	Area Specialist (2 yr)
2.	Atlanta ARTCC (Flow Controller)	over 5	—
3.	Washington ARTCC (Team Supervisor)	over 5	—
4.	Washington ARTCC (Plans & Procedures Specialist)	over 5	—
5.	Washington ARTCC (ATCS)	—	—
6.	Washington ARTCC (ATCS)	over 5	Area Officer
7.	Washington ARTCC Radar Controller (ATCS)	over 5	—
8.	Washington ARTCC (ATC)	over 5	Aree Specialist
9.	Washington ARTCC (Team Supervisor)	over 5	NAFEC, Headquarters
10.	Washington ARTCC (ATCS)	over 5	—
11.	Washington ARTCC (ATCS)	over 5	Supervisor
12.	Washington ARTCC (Operations Officer)	over 5	—
13.	Washington ARTCC (Supervisor)	over 5	Supervisor
14.	Washington ARTCC (ATCS)	over 5	Tower, Military
15.	Washington ARTCC (ATCS)	22	—
	Headquarters		
16.	AAT-110, Planning	1-5	—
17.	Staff Specialist	over 5	—
18.	AAT-120, Staff Specialist	over 5	—
19.	Project Officer	over 5	Oceanic
20.	Specialist	over 15	Team Supervisor Flow Controller
21.	AAT-400, Specialist	1-5	—
22.	Specialist	over 5	—
23.	Specialist	over 5	—
24.	Specialist	over 5	Oceanic, Altitude Reservation
25.	Specialist	1-5	Oceanic, Altitude Reservation
26.	Specialist	over 5	—

APPENDIX B

ASSESSMENT QUESTIONNAIRE

QUESTIONNAIRE

Biographical Data

Name ______________________ Title ______________________

CENTER	REGION	OTHER	DATE

Telephone Number ______________________

Radar Controller

________ 1 yr or less

More than 5 ________

________ 1-5 years

Other specify ________

1. Select three of the following configurations in rank order of preference (1, 2, 3,).

	A	B	C	D	E
A. Two position sector "R" & "D"	___	___	___	___	___

	A	B	C	D	E
B. Three position sector	___	___	___	___	___

2. Please indicate your preference of display shape

A. Upright ______

B. Lengthwise ______

3. Using the configuration you selected in question #1 refer to the table below and place the letter associated with each item in its most preferred location.

A - Radar

F - Flight progress data

D - Data entry (each position)

W - Weather map

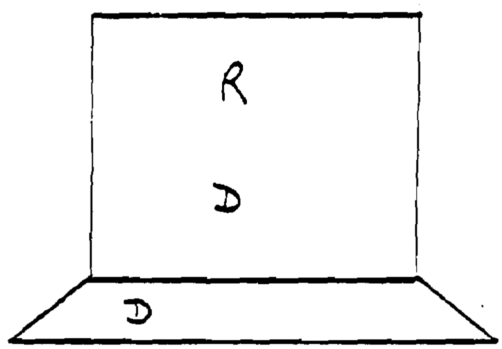
C - Controller charts, sector maps, etc.

TX - Radio

I - Interphone

L - Down-linked data

M - En Route metering info



EXAMPLE

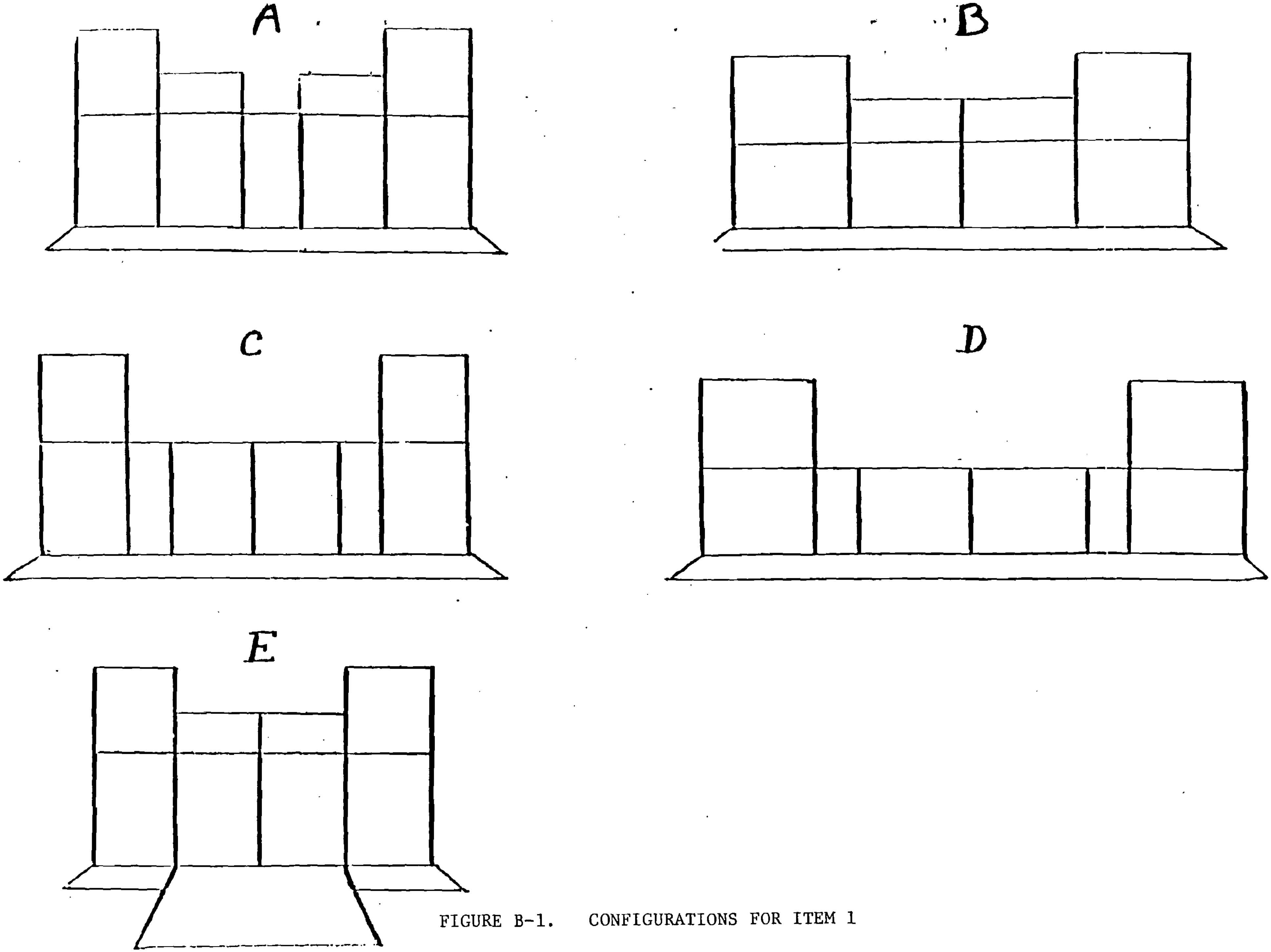


FIGURE B-1. CONFIGURATIONS FOR ITEM 1

4. Regarding the input devices indicate your preference to their location:

"R" position _____ Shelf _____ Display _____ Between Displays

"D" position _____ Shelf _____ Display _____ Between Displays

5. Assuming input devices are placed on the shelf, which of the following do you prefer?

Flush _____ Angled _____

Top Mounted
(Movable) _____

6. Please indicate your opinion as to the necessity of displaying each of the following items for controlling traffic. For each item place a checkmark in one of the 3 spaces to indicate your choice under each heading.

	INFORMATION NECESSITY			DISPLAY PREFERENCE		
	Essential	Nice to Know	Not Needed	Constantly Displayed	Forced Display	Available for Call On Display
1. Weather Service Radar	___	___	___	___	___	___
2. NAS Generated Weather Contours	___	___	___	___	___	___
3. Altimeter Settings	___	___	___	___	___	___
4. Hourly Observations, PIREP's, NOTAM's etc.	___	___	___	___	___	___
5. Winds Aloft	___	___	___	___	___	___
6. Controller Charts (Sector Maps)	___	___	___	___	___	___
7. Video Maps	___	___	___	___	___	___
8. Flight Progress Data (Strips or ETABS)	___	___	___	___	___	___
9. Flow Control Info	___	___	___	___	___	___
10. Warning/Restricted Area Status	___	___	___	___	___	___
11. Letters of Agreement	___	___	___	___	___	___
12. Approach Plates	___	___	___	___	___	___
13. Navigational Aid Outages	___	___	___	___	___	___
14. Transmitter on Main or Backup	___	___	___	___	___	___
15. Receiver on Main or Backup	___	___	___	___	___	___
16. Selected Transmitter/ Receiver Frequency	___	___	___	___	___	___
17. Minimum En Route Altitule	___	___	___	___	___	___
18. Minimum Reception Altitude	___	___	___	___	___	___
19. List of Facilities Frequencies	___	___	___	___	___	___

COMMENTS

Please use the space provided below to give us your ideas, suggestions, and comments regarding the sector suite in which you will be working. You may either improve the design or design your own. Your knowledge and expertise is invaluable and will be given serious consideration. If you wish to refer to a particular question on the questionnaire to expand your answer, please indicate the question number.

Thank you!

APPENDIX C

QUESTIONNAIRE RESULTS

ITEM 1: TABLE C-1. RANK ORDER PREFERENCES FOR SECTOR CONFIGURATIONS

(a)

Subjects	Rank	CONFIGURATION: Two-Man Sector A	B	C	D	E	No Response	Three-Man Sector A	B	C	D	E	No Response
Headquarters N=11	1	1	4	1	4	1		0	2	0	5	2	(2)
	2	1	4	2	1	1	(2)	1	4	2	1	0	(3)
	3	2	2	3	0	0	(4)	2	1	3	1	0	(4)
Field N=16	1	4	4	4	3	1		1	3	6	4	2	
	2	3	4	5	2	1	(1)	4	2	4	4	1	(1)
	3	1	2	4	4	1	(4)	2	4	2	3	1	(4)

(b)
DATA SUMMARIZED FOR DISPLAY ORIENTATION

Subjects	Rank	Two-Man Horizontal B + D	Two-Man Vertical A + C	Three-Man Horizontal B + D	Three-Man Vertical A + C
Headquarters N=11	1	8	2	7	0
	2	5	3	5	3
	3	2	5	2	5
Field N=16	1	7	8	7	7
	2	6	3	6	8
	3	6	5	7	4

ITEM 2: TABLE C-2. DISPLAY SCREEN ORIENTATION PREFERENCES

Subjects	Display Orientation: Upright	Lengthwise
Headquarters N=11	1	10
Field N=16	8	8 (2)*

*"D" upright, "R" lengthwise depending on sector orientation.

ITEM 3: DISPLAY/CONTROL LOCATION - RESULTS

In order to compile the data, the controllers' sketches were first grouped by configuration; then, the letter codes were transferred to a composite sketch for that configuration. These composites are shown in figure C-1 through C-8. Study of the design composites reveal several points related to the original issues of concern. First, it is clear that no subjects suggested new location for the basic ATC data; e.g., radar, flight data, weather, static information. On the other hand, the newer, less familiar data, such as en route metering information and down-linked data were placed at various locations--on the overhead display, on the radar screen, and on the data entry panel. A number of subject drew touch entry devices on a 45° panel below the display. Touch entry on the cathode-ray tube (CRT) was selected by several subjects both for the radar (R) and flight data (D) positions.

In summary, preferred positions for the primary data (radar and flight strip information) were always on the centrally located displays, often with weather, metering data, sometimes with down-link data sharing, or superimposed on the display. Controller charts, plates, etc., were placed about twice as often on the overhead as on the side display while weather data were placed about twice as often on the tower displays as on the overhead.

These data can be interpreted to suggest that the necessity for four display screens plus two overheads are questionable. About a third of the controllers indicated multiple use of the side displays; e.g., for charts and weather. Some controllers indicated the side display next to the R position for profile descent planning. Although this automation aid was not one of the items listed, it had been demonstrated in the AERA briefing. The controllers' use of it for their designs is one indication of the applicability of the model configuration for the future system.

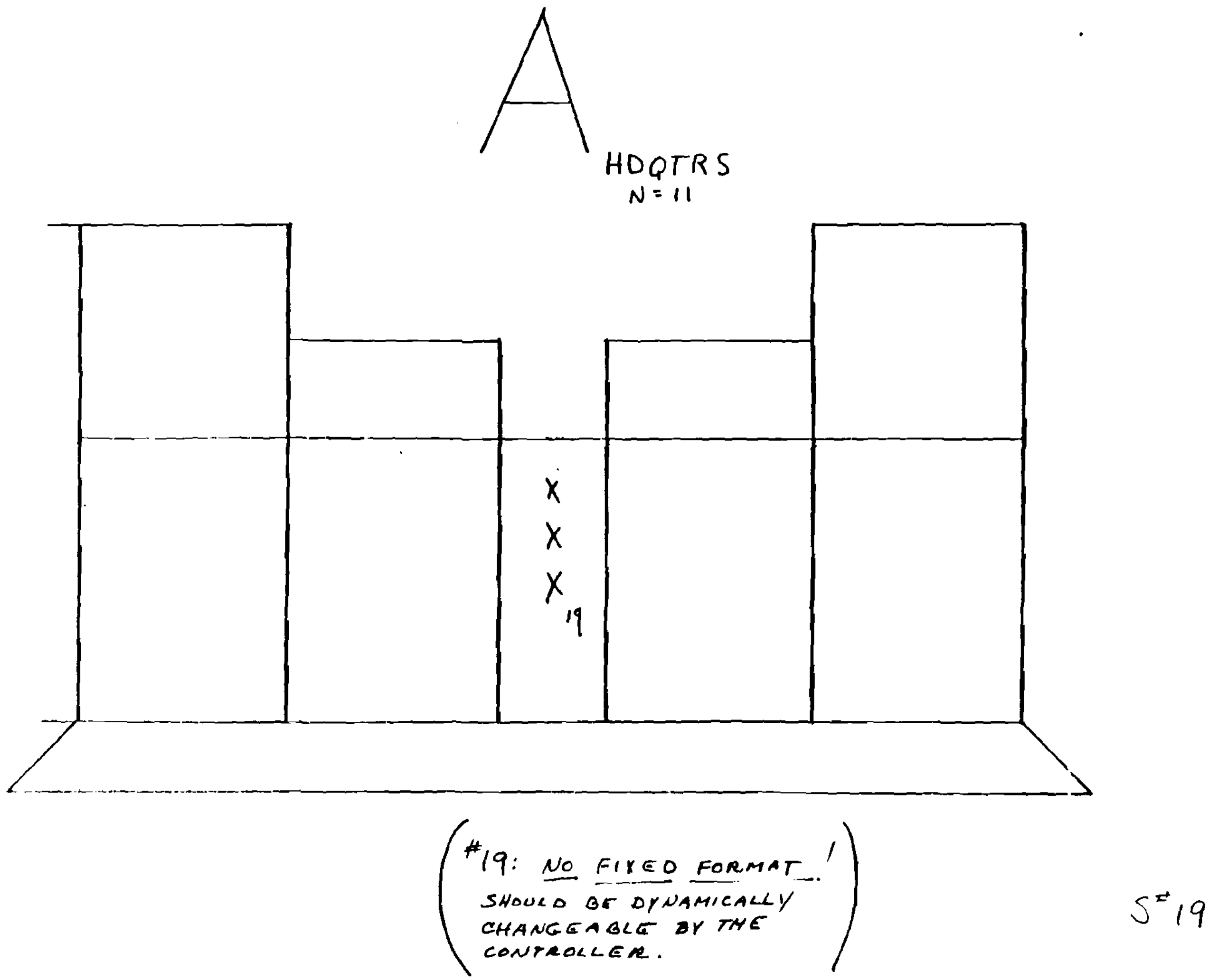


FIGURE C-1. HEADQUARTERS CONTROLLER'S DESIGN FOR CONFIGURATION A (SUBJECT 19)

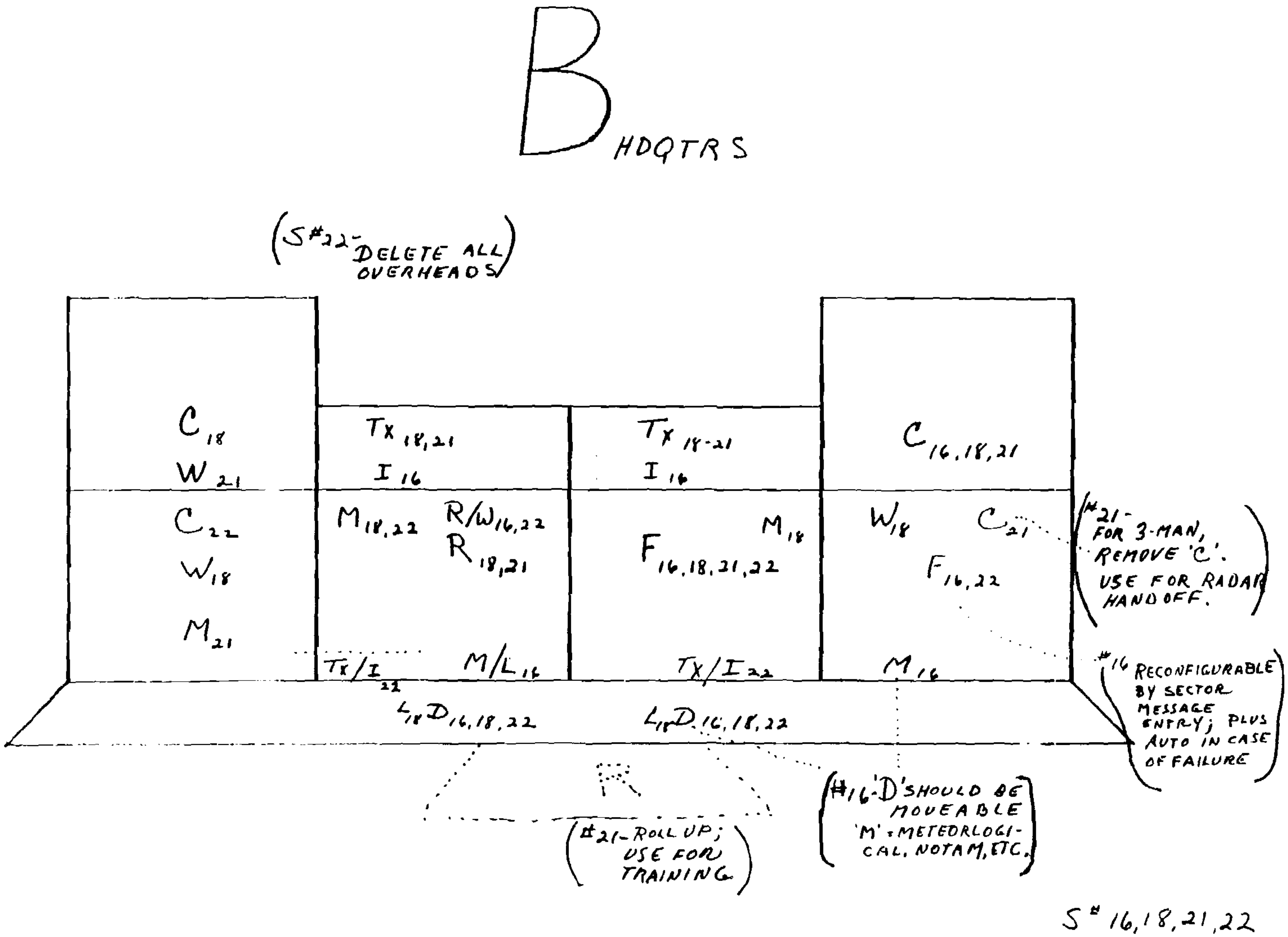


FIGURE C-2. HEADQUARTERS CONTROLLERS' DESIGNS FOR CONFIGURATION B (SUBJECTS 16, 18, 21, 22)

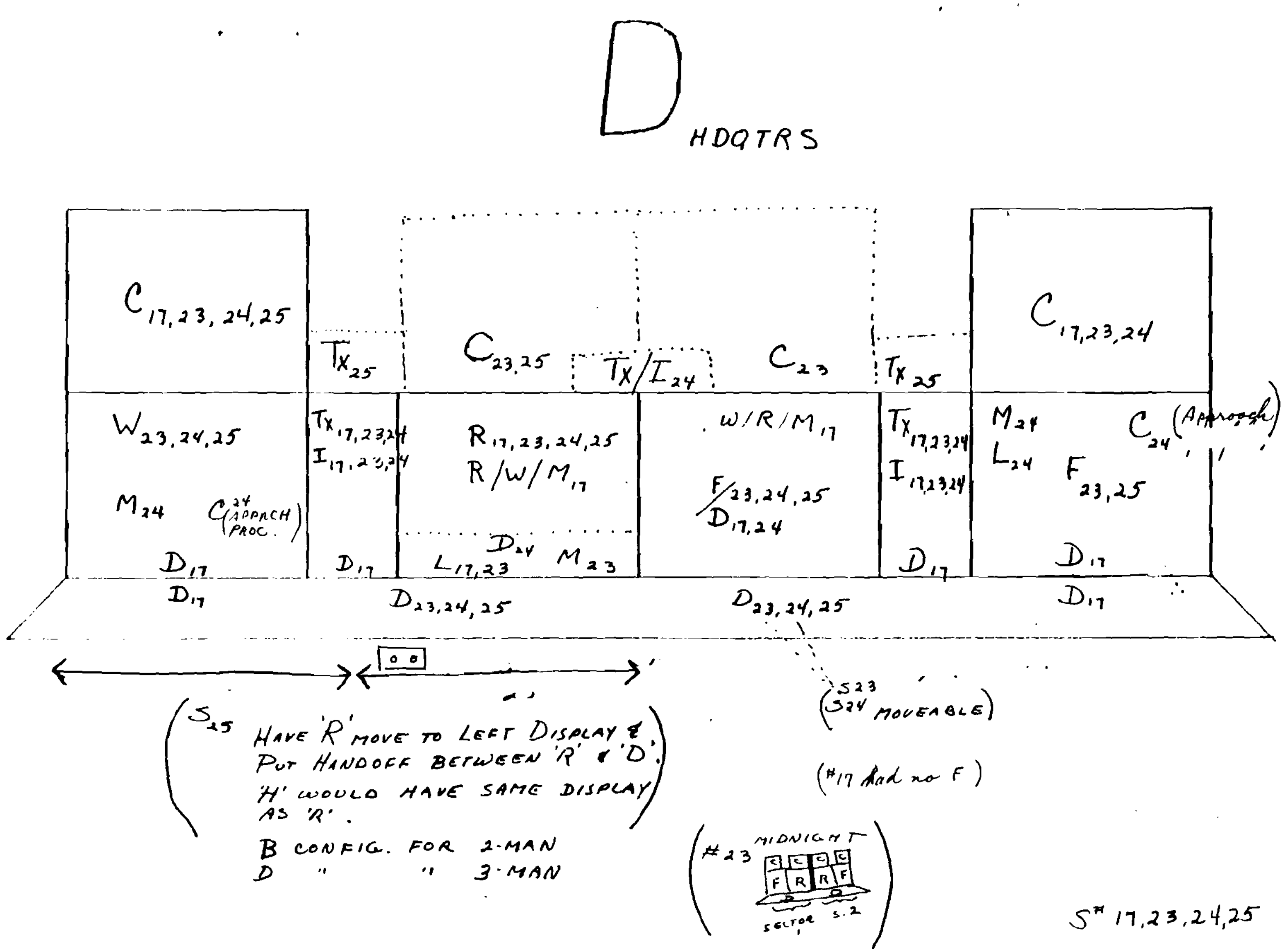


FIGURE C-3. HEADQUARTERS CONTROLLERS' DESIGNS FOR CONFIGURATION D (SUBJECTS 17, 23, 24, 25)

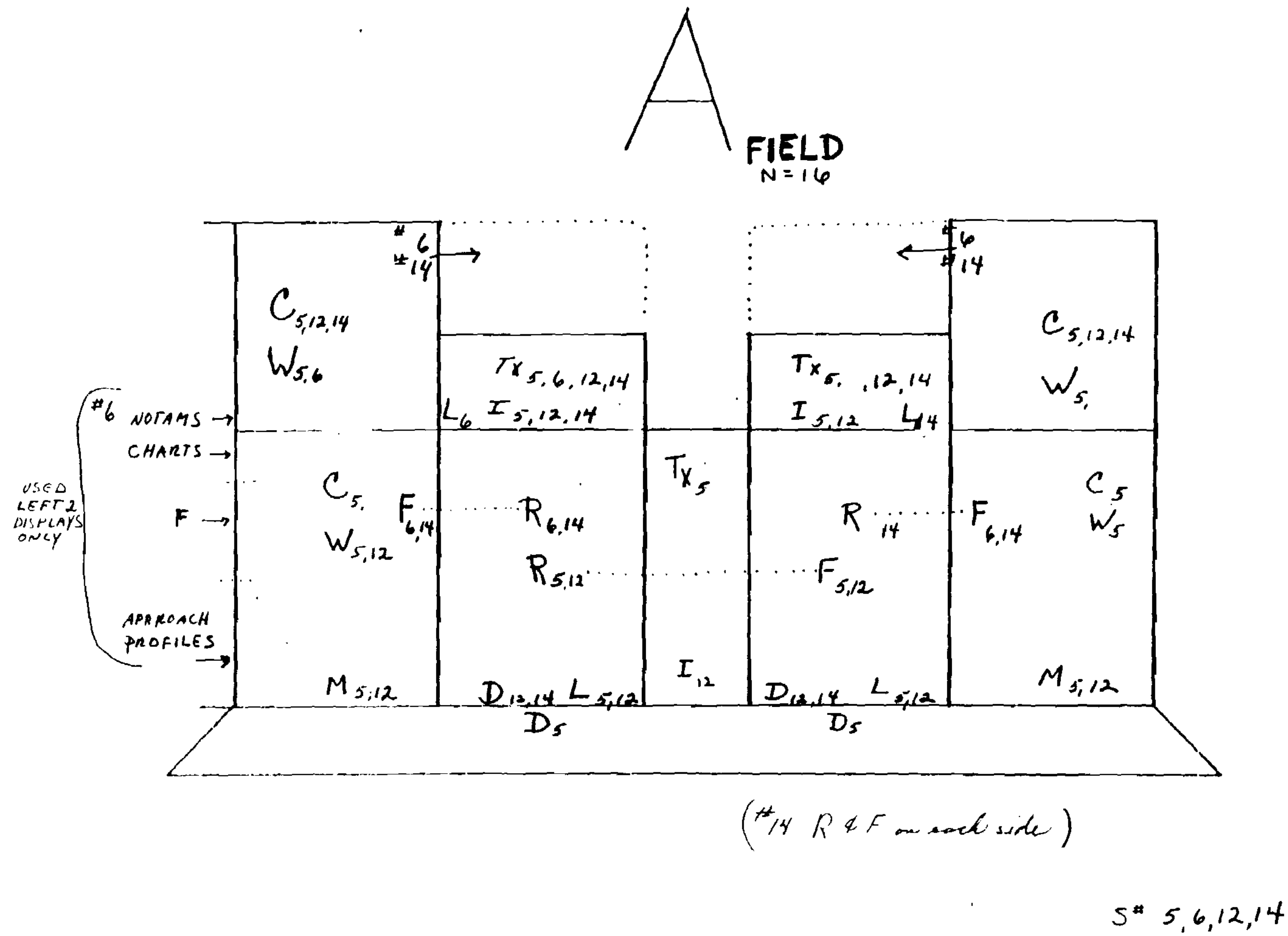


FIGURE C-4. FIELD CONTROLLERS' DESIGNS FOR CONFIGURATION A (SUBJECTS 5, 6, 12, 14)

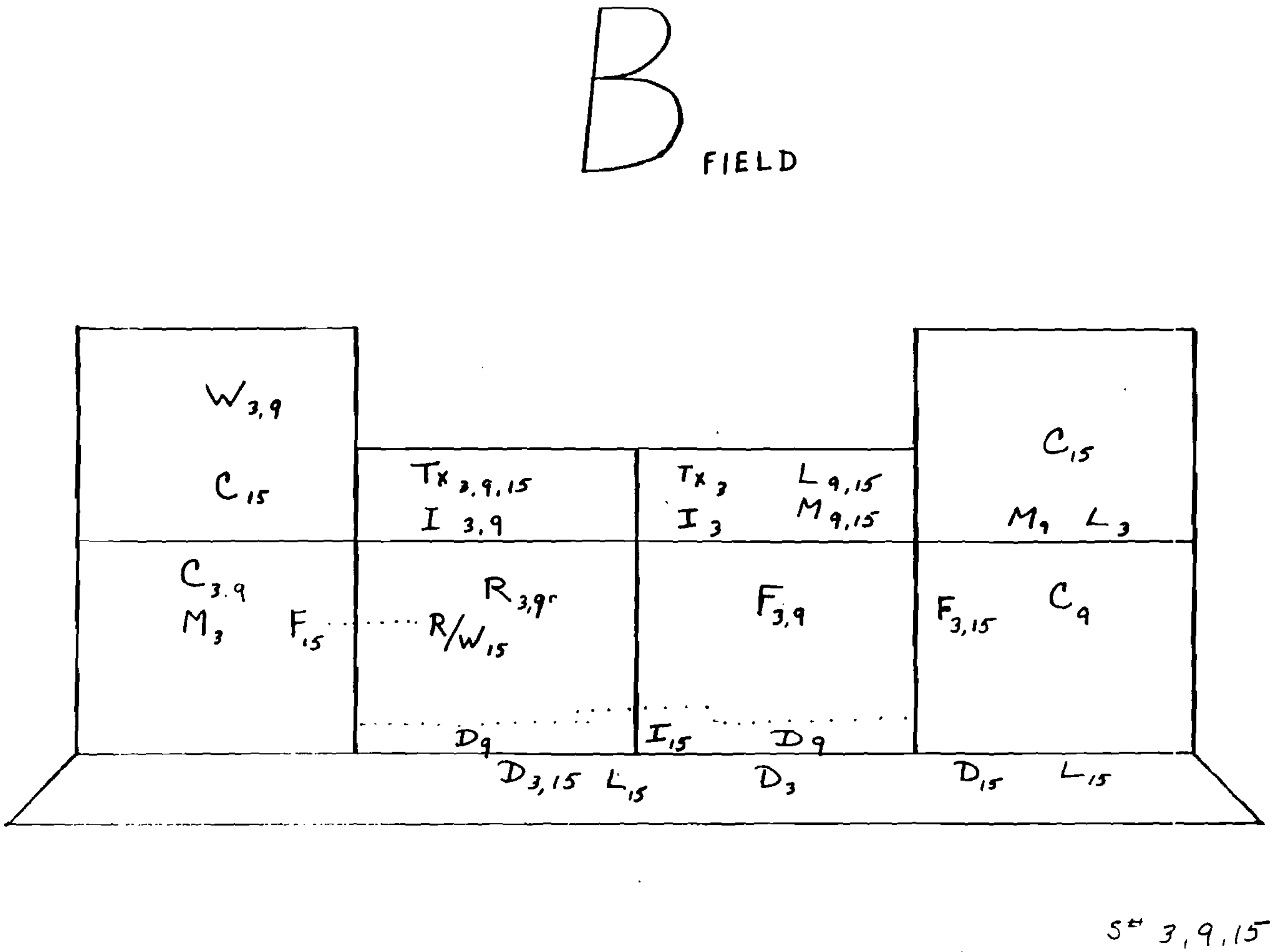


FIGURE C-5. FIELD CONTROLLERS' DESIGNS FOR CONFIGURATION B (SUBJECTS 3, 9, 15)

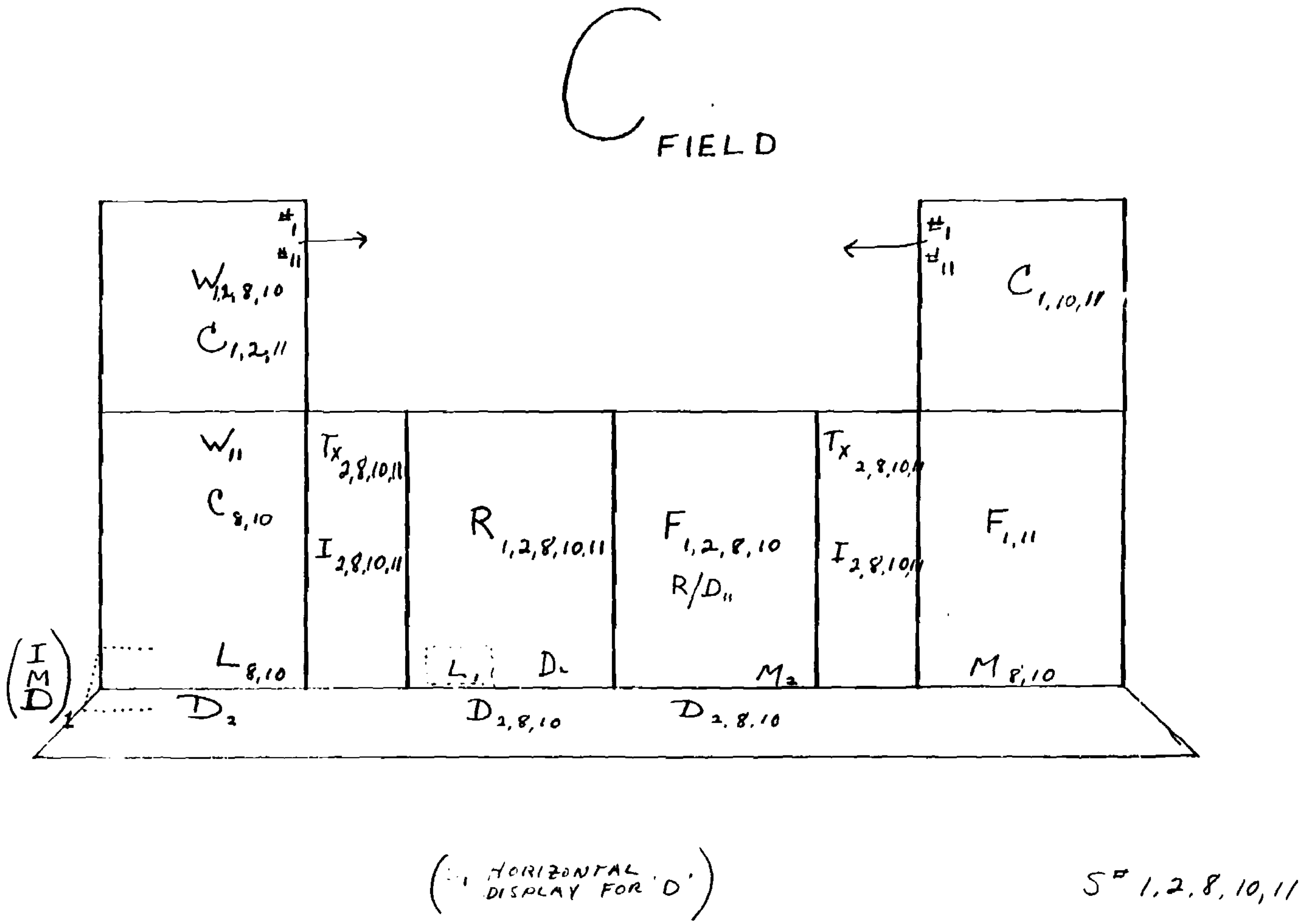


FIGURE C-6. FIELD CONTROLLERS' DESIGNS FOR CONFIGURATION C (SUBJECTS 1, 2, 8, 10, 11)

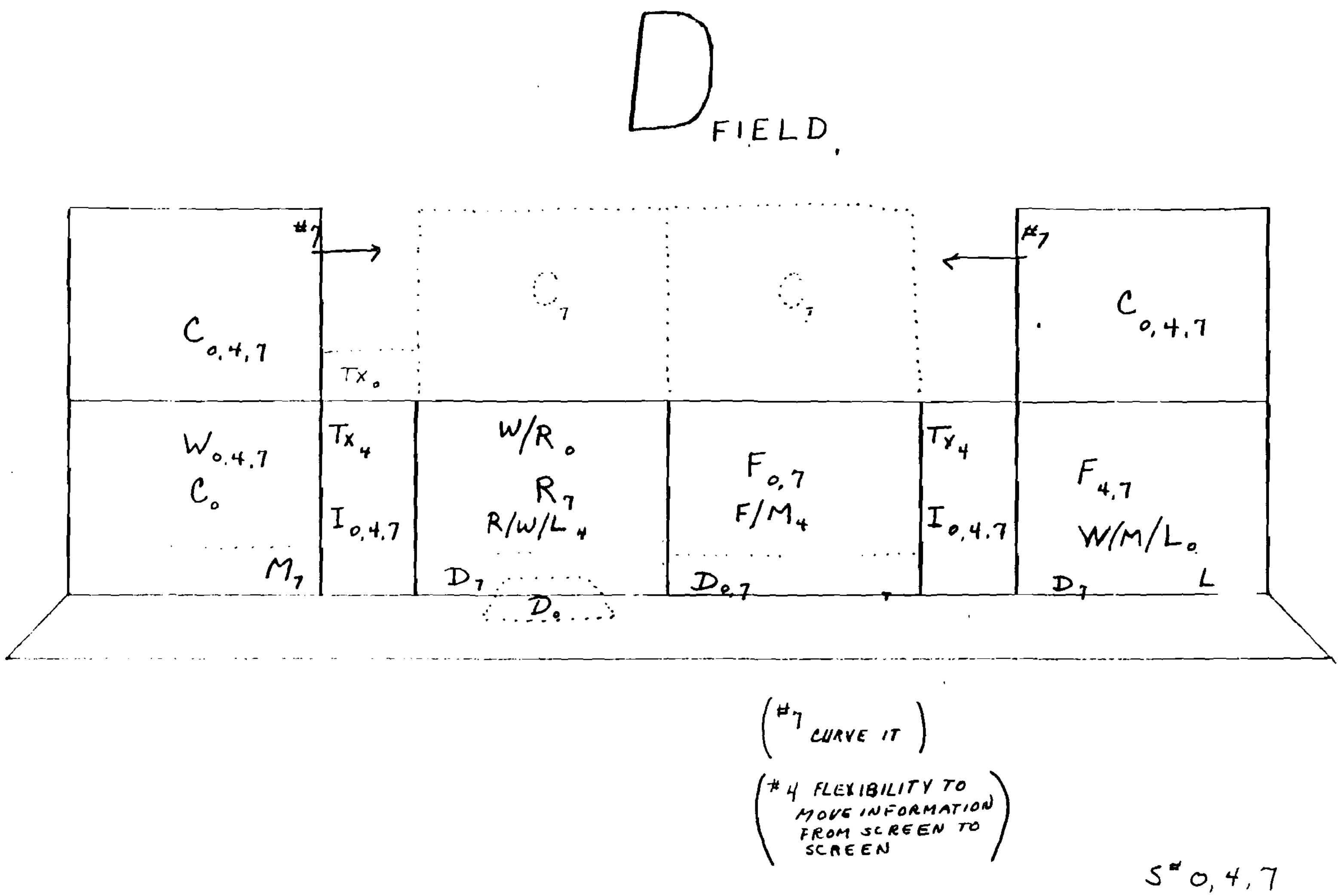


FIGURE C-7. FIELD CONTROLLERS' DESIGNS FOR CONFIGURATION D (SUBJECTS 0, 4, 7)

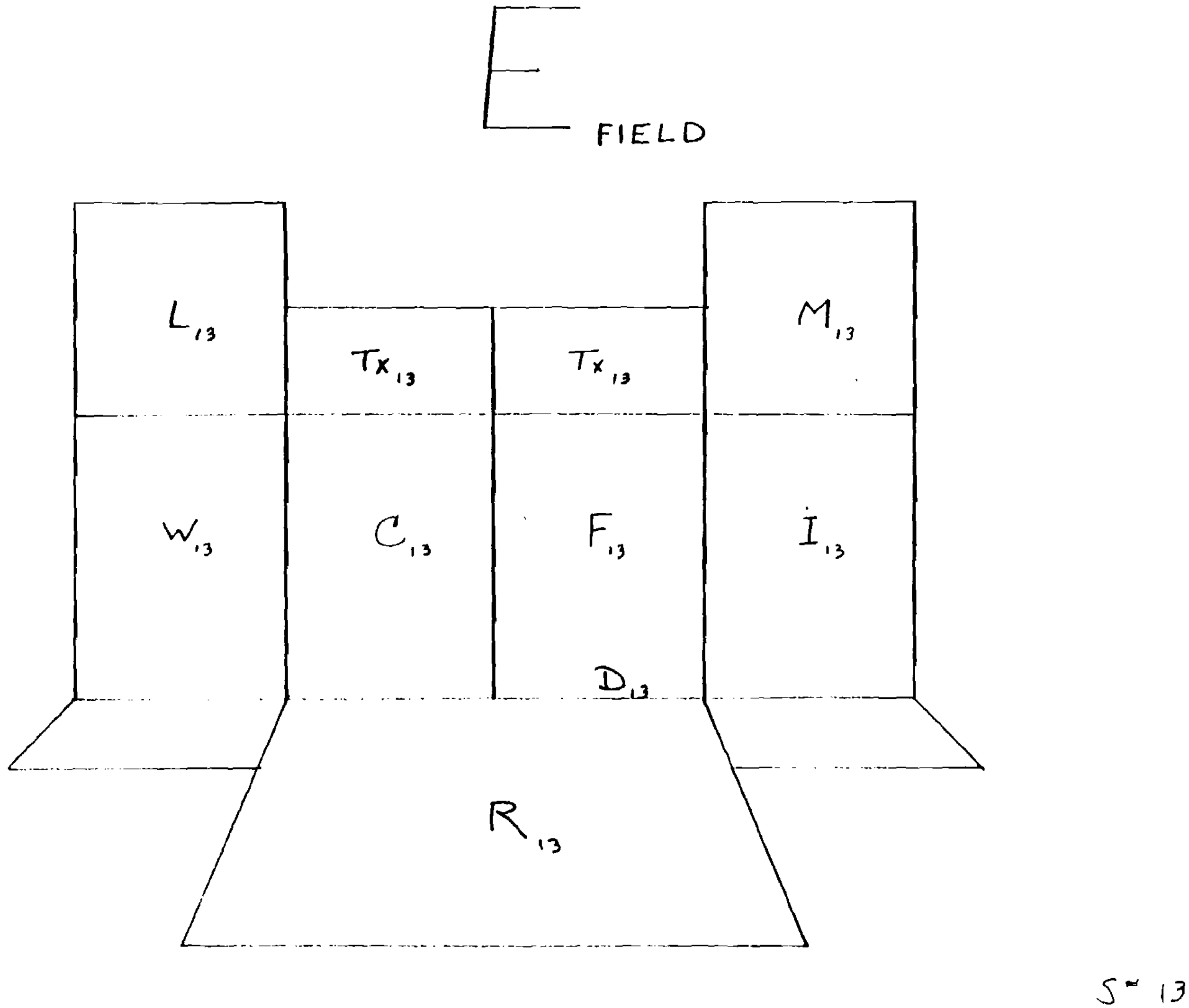
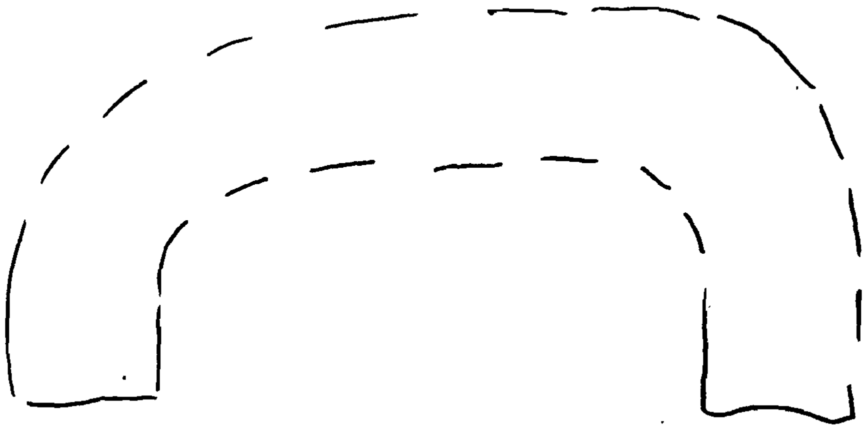
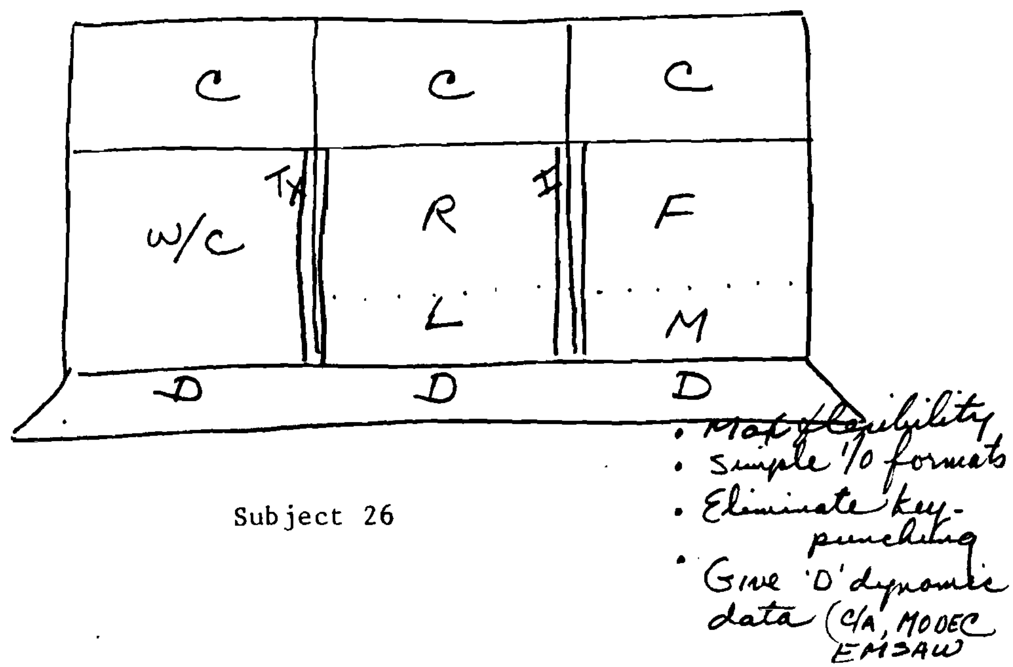


FIGURE C-8. FIELD CONTROLLER'S DESIGN FOR CONFIGURATION E (SUBJECT 13)



Subject 20



Subject 26

FIGURE C-9. ORIGINAL DESIGNS BY FIELD CONTROLLERS' (SUBJECTS 20, 26)

ITEM 4: TABLE C-3. PREFERRED LOCATIONS FOR TOUCH SENSITIVE DATA ENTRY DEVICES

Subjects	For Position	Location Preference		
		Shelf	On Display	Between Displays
Headquarters	R	8	3	-
Subjects N=11	D	8	3	-
Field	R	11(6)*	3	2
Subjects N=16	D	12(5)	3	1

*6 of 11 also wanted the display on a 45° angle at the juncture of the display screen and shelf.

ITEM 5: TABLE C-4. PREFERENCES FOR PACKAGING OF SHELF-MOUNTED INPUT DEVICES

Subjects	Options			
	Flush	Top-Mounted (moveable)	Angled	45°
Headquarters N=11	0	7(4)*	4(1)*	0
Field N=16	2	6(4)*	5(3)*	3*

*Indicatesthe number of subjects who wrote in further requirements (i.e., wanted the device both "Moveable" and "Angled").

ITEM 6: TABLE C-5. RATING DATA FOR ATC INFORMATION ITEMS

ATC Information Items	Information Necessity			Display Preference		
	Essential	Nice to Know	Not Needed	Constantly Displayed	Available on Callup	Forced on Display
Video Maps	27	0		21	6	
Flight Progress Strips	27	0		22	5	
Warning/Restricted Area Status	26	1		8	19	
Altimeter Settings	26	1		19	8	
Controller Charts	24	3		15	12	
NAS Generated Weather Contours	22	5		4	23	
Selected Receiver Trans. Freq.	22	4	1	13	13	1
Approach Plates	21	6		1	26	
Flow Control Information	19	8		11	16	
Navigational Aid Outages	19	8		5	22	
Hourly Observations, PIREP's NOTAM's	18	8	1	3	23	1
List of Facilities Frequencies	17	9	1	8	18	1
Minimum En Route Altitude	16	6	5	6	16	5
Minimum Reception Altitude	13	8	6	3	18	6
Transmitter on Main or Backup	13	11	3	11	14	2
Receiver on Main or Backup	13	11	3	11	14	2
Weather Service Radar	13	14		2	25	
Letters of Agreement	10	15	2	1	25	1
Winds Aloft	8	18	1	1	25	1

APPENDIX D

CONTROLLERS' WRITTEN COMMENTS

HEADQUARTERS ATC SPECIALISTS

1. The sector suite is also planned to replace DYSIM/ETA labs. Provision must be made for providing pilot input/output devices using the same or different equipment which interfaces with each controller's suite. (S18)

2. Sector suite displays should be totally flexible! (e.g., controller should be able to determine and change the information he requires on each display device. He should have capability to superimpose info on any display. (S19)

3. Controllers should be able to convert from in-line to semicircular configuration. (S19)

4. Airway Facilities Service should be able to convert from horizontal display to vertical and vice versa at any display position. (S19)

5. All information should be available for display on the PVD; i.e., weather, approaches, etc. (S20)

6. ETABS should have a failsoft that is capable of being displayed on the PVD. (S20)

7. Like the application to oceanic control and ALTREV. AlTREV capability would be good for supervisors so that they can project two or more ALTREV's and not possible conflicts before approval. The controller would not be left to note the conflicts when the ALTREV's are off and running. (S25)

8. Simple input/output formats and devices are a must. Eliminate all possible key punching. As much dynamic data as possible to "D" (Mode C, C/A, EMSAW). (S26)

9. Maximum flexibility! (26)

ACTIVE FIELD CONTROLLERS

1. Arrange Telco/Interphone line to prevent reaching across displays. (SO)

2. Place seldom used functions above displays. (SO)

3. Retain aircraft on initial display when entering/modifying data. (SO)

4. Have capability to superimpose data all displays. Retain range conformity. (SO)

5. Change of comment. Curve the sector displays. (S1)

6. The sector suite must be compact to where distance will not cause a problem in seeing all information. I would prefer seeing a semicircular layout to alleviate the need to move to view data. (S3)

7. The radar should have the option of using the rapid or a remote entry device. I believe that the remote entry device should be movable, as well as tiltable. (S3)

8. The ETABS must be easily readible from the RADAR position. A color option is needed to point out some information. On ETABS, all of the current information is required. Also, revised information needs to be accented to get the controllers' attention. (S3)

9. I am very much in favor of the concept (of touch entry), however, I have serious doubts about having the touch capability on the radar screen. This leaves too much room for error. (S4)

10. The possibilities of flexibility would be a great advantage and should be retained to the maximum extent. (S4)

11. After seeing curved concept of suite, this is the preference. (S8)

12. Utilize color in displays. (S8)

13. Use the same suite in later applications of "state-of-the-art" replacement. (S8)

14. Expansion capability, such as the island, would appear beneficial if it could be a "plug-in" supplement. This would allow flexibility in the number of controllers versus workload demand. (S9)

15. In some cases, menus have insufficient flexibility; e.g., altitudes. (S10)

16. ETABS: Great possibilities for clerical expediency. Suggest D ETABS print be same size as R side. Also, both in color. Touch zones in ETABS should be larger. (S10)

17. RADAR scopes should be square or circular. "L" position should have a time-sharing radar scope adjacent to R side. OJT can be performed from the "L" position. (S11)

18. Suite concept is an overall improvement to present configuration. (S11)

19. Static and dynamic displays should be angular or winged. (S11)

20. Radar scopes should have weather callup capabilities. (S11)

21. I do like the island display although I have not worked it. Also, I like the lengthwise display rather than vertical. If I have to pick between the two displays (vertical or lengthwise), I prefer lengthwise with static displays immediately over the dynamic displays. (S13)

22. My first impression is to have computer entries made by an entry device in lieu of "touching" the scope itself. (S15)

23. I like the concept of "calling-up" information on the radar scope on demand, but I have trouble with the concept of changing data base information by simply touching the scope. (S15)