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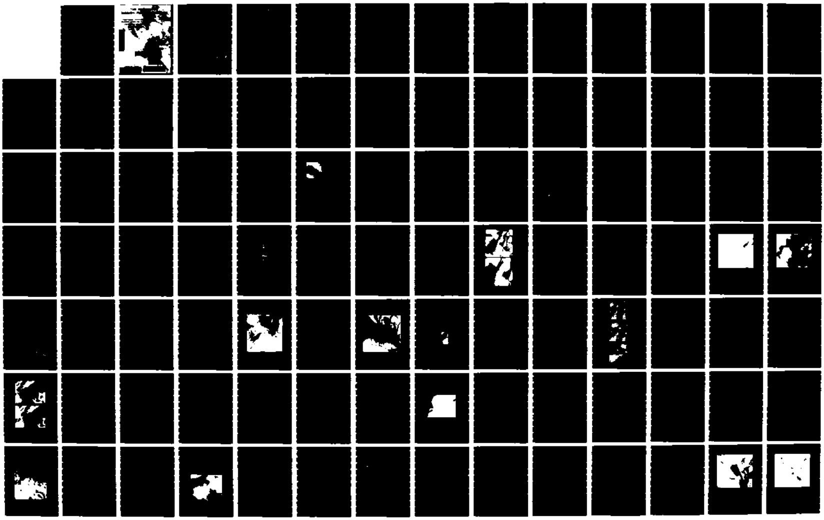

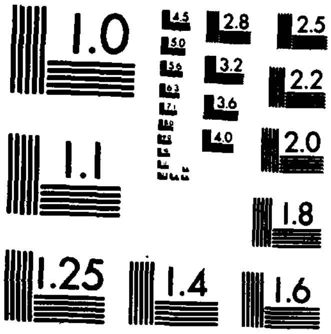
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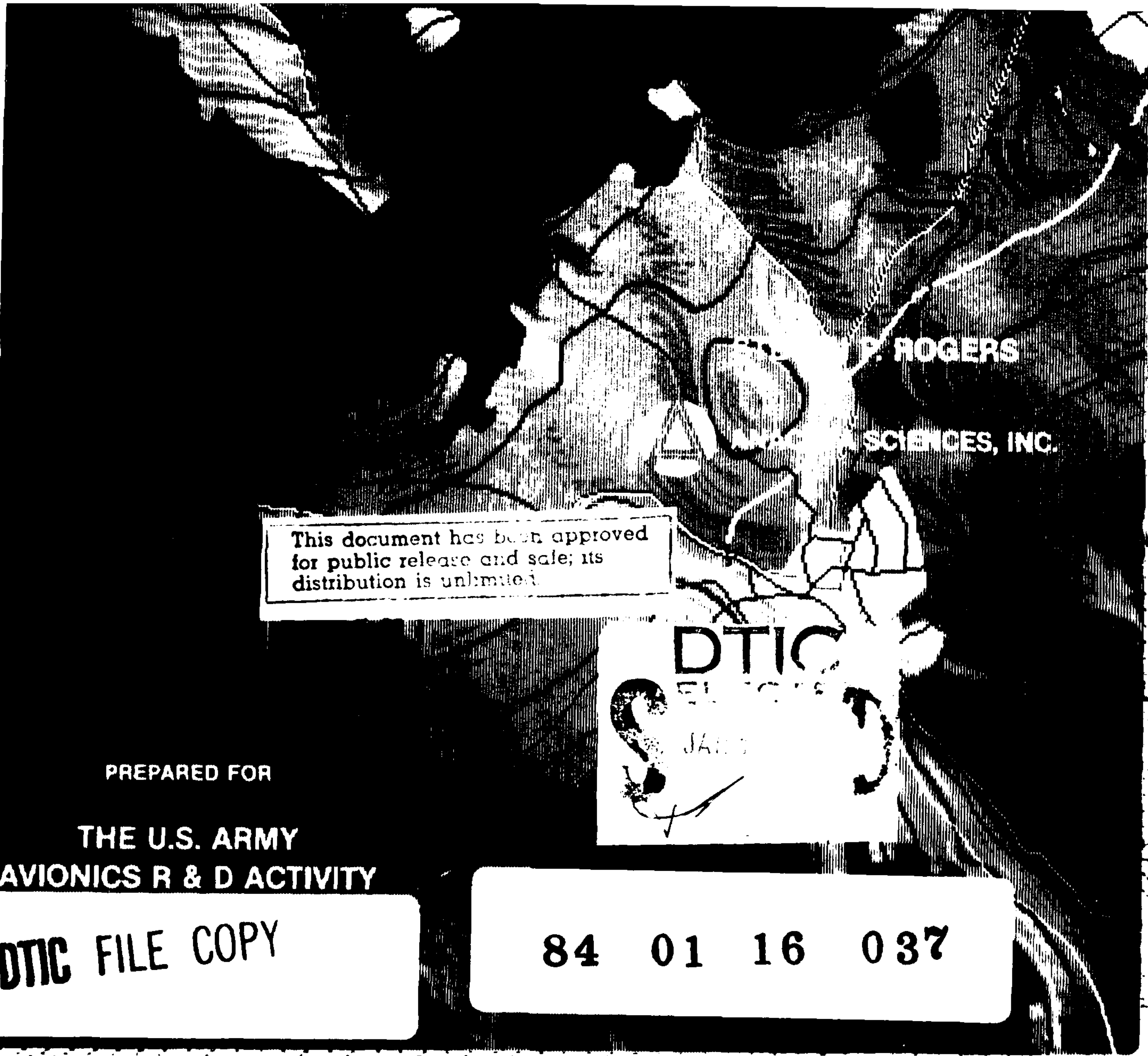

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THE U.S. ARMY
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THE INTEGRATED MISSION-PLANNING STATION

FUNCTIONAL REQUIREMENTS, AVIATOR-COMPUTER DIALOGUE, AND HUMAN ENGINEERING DESIGN CRITERIA

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Submitted to:

RESEARCH AND TECHNOLOGY DIVISION
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The Integrated Mission-Planning Station (IMPS), under development by the U.S. Army Avionics R&D Activity, is a computer-generated topographic display system. The IMPS will provide not only a greatly enhanced navigation capability, but also a combination of dramatic improvements in cartographic support, map information content, and aviator-map interactions. The powerful computational capability of the IMPS can be used to present a shaded "relief map," to display areas marked from visual or radar observation, to construct

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perspective views of key terrain, to support a self-contained terrain correlation navigation system, and to permit rapid solutions to problems of previously forbidding complexity.

This report describes the tasks conducted to provide detailed human factors engineering specifications for the construction and programming of the IMPS and the results of these tasks. The specific project objectives were to define IMPS functional requirements, design IMPS airborne hardware, design IMPS ground-based hardware, and to maximize the aviator-computer compatibility of the IMPS system. The project approach included a literature review, observation of the aviator task performances, interviews with subject matter experts, surveys, perceptual studies, human engineering analyses, detail design specification studies, and dialogue development analyses. The outcome of these efforts is described in terms of an overview of system components and functions, and detailed descriptions of operation of the airborne and ground-based portions of the IMPS system. Each of the major functions of the IMPS system is discussed, and the operational requirements, present deficiencies, IMPS capabilities, and IMPS operating procedures are identified. Appendices to the report provide hardware design criteria and a complete specification of the interactive dialogue system.

FOREWORD

This report presents the results of the Human Engineering Program for the Integrated Mission Planning Station, sponsored by the Research and Technology Division of the Army Avionics Research and Development Activity at Fort Monmouth, New Jersey, under contract DAAK80-81-C-0190.

In fact, the human engineering studies in direct support of the digital map concept began in 1977 with the issuing of the "Memorandum on the utility of a computer-generated topographic display," by Dr. Kenneth D. Cross of Anacapa Sciences, Inc. Subsequent human engineering and behavioral studies explored the Army aviators' accuracy of geographic orientation and recovery from disorientation during nap-of-the-earth (NOE) flight (Rogers and Cross; 1978, 1980); identified the topographic information requirements and applicable computer-graphic display techniques for NOE flight (Rogers and Cross, 1979); and provided a conceptual design of a computer-generated topographic display system to aid mission planning and mission conduct (Rogers, 1981).

The present report represents the culmination of human engineering efforts in providing explicit display, control, and functional requirements for the Integrated Mission Planning Station, and is based upon rigorous analyses of mission task requirements, verified by Army aviation experts, as well as upon thorough consideration of human engineering criteria for equipment design and procedure development.

The system described in this report will be constructed by the Harris Corporation Government Information Systems Division, and installed in the AVRADA facilities at Fort Monmouth for extensive simulation and testing programs.

ACKNOWLEDGEMENTS

A project as revolutionary as the Integrated Mission Planning Station is rarely successful without a key figure who has the commitment and vision to set extraordinary goals, and the perseverance and analytical abilities to achieve them. The author gratefully acknowledges Dr. Norman Shupe, Chief of the Research and Technology Division of the U.S. Army Avionics Research and Development Activity, who has provided these critical leadership qualities.

Translation of functional requirements into a workable IMPS system demanded the development of staggering amounts of software with seemingly unending iterations. Directing these complex activities were Mr. Norman Colten of the Systems Integration Branch of the Research and Technology Division of AVRADA, and Dr. Luen Chan of the Harris Corporation Government Aerospace Systems Division. The GASD software team for IMPS also included S. Dikshit, M. Glenn, T. Norris, J. Palmer-Smith, and D. Thaker. The guidance, ingenuity, and teamwork of these individuals helped to provide resolutions to the thorniest problems, and were instrumental in development of many valuable system capabilities. Thanks are also due to Mr. B.G. Asbury, GASD Business Development Manager, who provided the color plates enlivening the pages of this report.

One of the most important elements of IMPS development was an in-depth understanding of the ultimate users' requirements. The author is deeply indebted to aviators from the 101st Airborne Division, the 2nd Armored Division, the 7th Cavalry Brigade, and the Army Aviation Center Career Training Division, for their contributions of time and expertise.

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INTRODUCTION

In order to clarify the factors determining the design of the Integrated Mission Planning Station (IMPS), this introductory section briefly describes the background of the project, the project objectives, the methodological approach, and the organization of the report.

BACKGROUND

Army Aviation Tasks

Only a few years ago, the Army used helicopters for little more than medical evacuation. Today helicopters are an integral component of the combined arms team and perform a great variety of tasks. Army aviators must be prepared to enhance the ground commander's capabilities in one or more of the five functions of land combat: firepower, mobility, intelligence, command and control, and combat service support.

- **Firepower.** Army aviation units assist the commander in exploitation of firepower by delivering area and point target fire, by observing and adjusting artillery fire, by transporting artillery and antitank teams, and by providing ammunition resupply.

- **Mobility.** Helicopters are ideally suited for rapid movement over obstacles in order to concentrate forces for decisive combat power, and to promptly disperse these forces and permit their redeployment in other critical sectors. This rapid mobility also permits the commander to surprise the enemy and exploit the enemy's lack of preparedness.

- **Intelligence.** Army aircraft have an unequaled capability to perform reconnaissance over a wide area, providing current intelligence regarding weather, terrain, and enemy disposition. Where vegetation limits aerial observation, ground reconnaissance teams may be transported by helicopter to collect the required information.

- **Command and Control.** Army aviation assists in commanding and controlling highly mobile forces operating over broad areas by permitting commanders to study the terrain while maintaining contact with superior and subordinate commanders, and by permitting the commander to move rapidly to the places he is most urgently needed.

- **Combat Service Support.** Army helicopters provide logistical lifelines for friendly elements dispersed across vast areas, often providing the only possible means of resupply of fuel, ordnance, and repair parts, as well as evacuation of critical weapons and systems to repair facilities.

The functions of Army aviation described above require the performance of an impressive array of diverse missions. The missions required depend upon the aviation unit type, the combat arm that the aviation unit serves, the aircraft type, and the specific tactical situation. Thus, the potential missions of Army aviation are countless. A common theme in nearly all of these missions, however, is the requirement for terrain flight.

Terrain Flight

Terrain flight is the tactic of degrading the enemy's ability to detect the aircraft by using landforms and vegetation for cover and concealment. This tactic requires flight close to the earth's surface and includes low-level, contour, and nap-of-the-earth (NOE) techniques. Low-level flight generally employs a constant heading, altitude, and airspeed. Contour flight is conducted in very close proximity to the ground and requires altitude changes to conform to the contour of the earth, while maintaining a generally constant heading. NOE flight is flight as close to the earth's surface as vegetation and obstacles will permit, varying course, airspeed, and altitude in order to take maximum advantage of the cover and concealment offered by terrain, vegetation, and man-made features. In practice, the aviator may use a combination of these three techniques during a single mission. The most important determinants of flight techniques are the enemy situation and the availability of masking terrain. It is critical that the aviator be aware of the positions and altitudes at which masking is or is not available. Flying unmasked sharply reduces survival probability in the high-threat environment. On the other hand, unnecessary NOE flight is inefficient because more sorties can be flown or greater distances covered in a given period using contour or low-level flight. Furthermore, high altitudes offer a greater margin of safety in dealing with aircraft emergencies and hazard avoidance.

Geographic Orientation

Whatever the combat task or flight technique, the Army aviator must be able to maintain his geographic orientation at all times. Aviators must be able to plan and execute their missions precisely in both time and space and relate their momentary position to their planned route and to the movements of other friendly ground and air forces. In the critical timing of events on the modern battlefield, disorientation is tantamount to mission failure. As a minimum standard, Army aviators are expected to navigate to an accuracy of 100 meters at all times (FM 1-1). Furthermore, aviators are expected to navigate in unfamiliar terrain, around the clock, and in adverse weather conditions.

Descent to NOE flight levels greatly increases the likelihood of geographic disorientation due to the aviator's limited view of checkpoint features useful in navigation. While NOE flight serves to mask the enemy's view of the helicopter, it often masks the aviator's view of potential checkpoints. The view of the surrounding terrain may be limited to features within 100 meters of the aircraft. Features often cannot be seen in their entirety, and the extremely low angle of view increases the difficulty of determining the contours of visible landforms.

Both anecdotal evidence and controlled field tests have indicated that the percentage of NOE sorties in which the aviators experience no navigation problems and remain well oriented throughout the flight is exceedingly small. In an early study by Thomas (1963), aviators were able to navigate a 6-km course only 48% of the time without becoming disoriented. In a Canadian test (Lewis & de la Riviere, 1962), aviators were able to reach the designated end points of short courses only 61% of the time. In a more recent experiment (USACDEC, 1972), major course deviations (500-2000 meters) occurred in half of the 12 30-km course attempts by Cobras, and only two crews navigated the entire course without missing checkpoints, circling, doubling back, or experiencing other navigational difficulties. In another recent test (Fineberg, Meister, & Farrell, 1975), 35 Army aviators flew NOE missions in a series of 279 test flights. The results of this eperiment indicated that the probability of successfully acquiring both the initial point (IP) and a subsequent landing zone (LZ) was .65.

Mission Planning

The results of laboratory studies of the accuracy of geographic orientation by Army aviators (Rogers and Cross, 1978, 1980) are in agreement with the field tests, and suggest that the navigation problems are rooted in the difficulty of the map interpretation and terrain analysis tasks. Such findings suggest that the aviators must also experience great difficulty in the extensive mission-planning tasks required for each mission. The successful accomplishment of many of these tasks depends heavily upon the aviator's ability to extract voluminous information from maps. For example, the aviator must study and visualize the overall situation and topography; select engagement points, observation points, or landing zones; determine primary and alternate (masked) routes of flight; select air control points, checkpoints, and barrier features; and determine flight modes, altitudes, speeds, and durations. Each of these activities places an onerous information compilation and processing burden upon the aviator, and omissions or errors might well prove to be disastrous. Although previous map display systems have been designed primarily for assisting in navigation, it would appear that the potential contribution of a map display might well be greatest in aiding the performance of mission-planning and tactical decision-making tasks.

PREVIOUS MAP DISPLAY SYSTEMS

Early attempts to overcome navigation problems included a number of display devices--primarily moving map displays--driven by the navigation sensors available in aircraft. Taylor (1975) listed six potential advantages of moving-map displays:

- They may reduce navigation workload and head-down time in the cockpit by monitoring geographical position
- They may provide a method for cross-checking navigation systems (INS, doppler, radar, etc.)
- They may offer a compatible means of interacting with navigation computer systems
- They may permit storage of large areas of mapping at a variety of scales

- They may be able to display navigation information (e.g., distance, time, and bearing to destination) as well as topographic information

- They may assist the aviator in anticipating and recognizing checkpoints

The earliest moving map displays developed were "direct view" displays employing strip maps which moved on rollers. An indicator was displaced to show present position on the cross-track axis. Related developments employed moving cross-wires to indicate the aircraft's position on stationary maps. The primary disadvantages of direct view displays are: their map storage capacities are small, an impractical amount of time is required to prepare the strip charts, they do not display heading information, and the orientation of the charts is fixed. Futhermore, Army aviators very seldom fly in the limited corridors suited to the use of strip charts, and rapidly fly across areas portrayable on fixed charts of the size suitable for direct view displays given the large map scale required for NOE flight.

Another form of moving map device is the projected map display (PMD), which optically projects photographs of existing paper maps onto a viewing screen. PMDs have a number of advantages over hand-held maps and direct-view map displays, but unlike either of these aids, they cannot be annotated. The importance of map annotations to the Army aviator cannot be overstated. It must be possible to mark route plans and tactical information on the map if a display is to be acceptable for use in Army aviation. A second disadvantage of the PMD is its dependence upon the availability of conventional maps. The large-scale maps required for use in Army aviation are not available for large areas of the world.

A COMPUTER-GENERATED SYSTEM

The IMPS computer-generated topographic display system can provide all of the advantages of the earlier moving map displays and add some revolutionary capabilities. The IMPS system will provide not only an enhanced navigation capability, but also a combination of dramatic improvements in cartographic support, map information content, map-orientation computations, and aviator-map interactions. Some of the potential advantages of the IMPS system are discussed below.

The single most important advantage of the IMPS system over paper maps or projected maps displays is its potential for truly comprehensive and rapid response cartographic support. NOE flight requires the use of large-scale maps (1:50,000 or larger). The smaller scale maps (such as 1:250,000 and 1:500,000), which are designed for conventional flight, do not portray sufficient detail for NOE navigation. Only a very small percentage of the earth's surface is currently mapped in large scale, and in the event that a conflict arose in an unmapped area, it could take more than a year to develop conventional topographic maps. Even photo-base maps could require a month or more for preparation. In contrast, it is feasible to obtain the data required to support computer-generated display systems in a matter of hours.

A second advantage of the IMPS system is its capability for providing operator control of the content of the displayed information. Many of the problems in using contemporary 1:50,000-scale topographic maps stem from the fact that maps were designed to fulfill the requirements of all branches of the Army. The result is a compromise product that is densely packed with data but is not optimal for any single user. The Army aviator, because of his variety of roles, may need many different types of information on different missions or in different phases of a single mission, yet map clutter must be avoided to the greatest extent possible. Aviators using a computer-generated system can select the information that is needed to provide a map optimal for the momentary situation. Aviators can control the classes of information that are displayed (vegetation, hydrography, etc.) and the specific features of a given class to be portrayed (deciduous trees, perennial streams, etc.) In addition, map scale and control interval can be changed at will to tailor the map to the aviator's changing requirements.

A third advantage of the IMPS over conventional map products is its powerful computational capability. For example, the IMPS can be used to:

- Show the general lay of the land by use of shaded elevation bands to indicate high and low areas
- Present a shaded "relief map" enhanced by contour lines
- Display the areas masked from visual or radar observation given known or likely enemy positions

- Construct oblique, perspective views of terrain to familiarize the aviator with the landforms as they will be seen during the mission
- Perform navigational computations pertaining to airspeed, elapsed time, or wind vector considerations over a given flight route
- Interact with a terrain correlation navigation system similar to that used in the cruise missile, which is small, lightweight, accurate in all weather, self-contained, and essentially invulnerable to countermeasures

A fourth advantage of the IMPS is that it offers a truly interactive system. An aviator can enter information such as map annotations, coordinates of objectives, planned routes, and so forth. These items of information can then be selected at will, and used in the computations described above. Furthermore, the "intelligent" nature of the system can permit its interrogation by the aviator to determine certain characteristics of the portrayed features, such as tree height and crown cover. The interactive nature of the IMPS can remove some of the natural limits to the aviator's decision-making capabilities and permit him to rapidly solve problems of previously unthinkable complexity.

PROJECT OBJECTIVES

The overall goal of this project was to provide detailed specifications for the construction and programming of the IMPS system. The specific objectives and sub-objectives were the following:

1. **Define IMPS functional requirements**
   - Identify map-use requirements and other spatial-geographic data requirements for mission planning, navigation, and tactical decision-making in the spectrum of Army aviation tasks
   - Identify special computer-graphic techniques potentially applicable to Army aviation tasks and evaluate the feasibility and practicality of these potential solutions
   - Specify the IMPS functional requirements in terms of their basic purposes, selectable options, aviator inputs, system outputs, and special features
2. **Design IMPS airborne hardware**
   - Identify general display and control characteristics to meet airborne functional requirements
   - Select and integrate specific display and control devices to form a map display, a control-display unit (CDU) and an airborne hand controller (AHC) device
3. **Design IMPS ground-based hardware**
   - Identify display and control characteristics to meet mission-planning functional requirements
   - Select specific displays, controls, and other input-output devices optimal for interacting with the data base
4. **Maximize aviator-computer compatibility**
   - Construct an aviator-computer dialogue system that is smooth and natural in order to avoid delays, errors, and excessive training requirements
   - Provide a map symbology system appropriate to the CRT display as well as to the cognitive and perceptual capabilities of the aviator
   - Identify special system features such as perspective views, terrain avoidance aids, radar masking diagrams, and other capabilities of critical importance to the aviator

PROJECT APPROACH

The approach employed to meet the project objectives included a series of overlapping and iterative information-gathering and system design activities. The activities of greatest importance are briefly discussed below.

LITERATURE REVIEW

Documents related to Army aviation tasks were reviewed to identify functional requirements for the IMPS system. Examples of such documents include Gainer and Sullivan (1974), Garlichs, Cox, Hockenberger, and Smith (1979), Rogers and Cross (1979), Rogers (1981), FM 1-1 (1976), FM 21-26 (1969), FM 17-50 (1977), FM 90-1 (1976), FM 17-47 (1977), FM 100-5 (1977), and FM 101-5-1 (1980). In addition, recent publications pertaining to computer graphics (e.g, Newman & Sproull, 1979) and man-computer interactions (e.g., Engel and Granda, 1975; Smith and Aucella, 1983) were reviewed and principles applicable to the IMPS system were extracted.

OBSERVATIONS

Aviators were observed during the conduct of mission-planning activities performed to meet the requirements of hypothetical missions selected by the author. Aviators of a broad range of ranks and responsibilities were requested to participate in these exercises in order to study the flow of mission-planning information and determine its development and refinement at various echelons in air assault, assault support, attack, and air cavalry units. Aviators were also observed performing navigation tasks during NOE flight in a variety of terrain types.

INTERVIEWS

During the course of a previous project (Rogers, 1981), formal interviews were scheduled with aviators of the 101st Division to aid in determining the optimal aviator-computer interactions for the processing, storage, and display of topographic and tactical data. Additionally, interviews took place with aviators of the 2nd Armored Division, the 6th Cavalry Brigade, and the Career Training

Division of the Army Aviation Center, in order to evaluate specific characteristics of the preliminary conceptual designs. During these interviews, mission scenarios and simulated control and display surfaces were employed to graphically portray the capabilities of the system and encourage comments and suggestions from the aviators.

Subsequently, during the conduct of the present project, many of these aviators were informally interviewed in order to ensure the utility of candidate IMPS features and to provide information needed for specifying IMPS performance requirements.

SURVEYS

During the conduct of the formal interviews discussed above, aviators of the 101st Division completed a questionnaire designed to identify current practices with paper maps that might influence the IMPS system design, to examine opinions of aviators regarding the basic requirements for such a system, and to determine aviators' assessments of various IMPS special features. Subsequently, over 100 aviators completed an extensive survey by *rating the importance of* topographic and tactical features used in meeting Army aviation mission requirements (Rogers, 1982). These data were incorporated in IMPS feature-selection and symbology requirements.

PERCEPTUAL STUDIES

Concurrent investigations at Anacapa Sciences include a basic research program exploring the effects of various display variables on the perception of topographic symbology. Although the basic research program has broader application and interest than the IMPS project, many of the interim research findings were useful in defining the characteristics of the IMPS displays, as well as the sizes, shapes, and colors of the displayed symbology (e.g., Rogers, Gutmann, and Ralstin, 1982; McCallum and Rogers, 1982; and Jarosz and Rogers, 1982).

HUMAN ENGINEERING ANALYSES

Mission analyses were developed from baseline scenarios (e.g., Gainer and Sullivan, 1974; Millard, 1981; APS, 1981) to identify required system functions. The functions were analyzed to determine the best allocation to personnel, equipment, and software. The functions were further dissected to define the specific tasks needed to accomplish the functions. The specific tasks were then analyzed to determine human performance parameters, hardware/software capabilities, and the tactical environmental conditions under which the tasks are conducted. Specific controls, displays, and procedures evolved from the tasks analysis.

DETAIL DESIGN SPECIFICATIONS

All appropriate military design specifications were examined to identify IMPS design requirements. Of greatest importance were MIL-STD-1472C, Human Engineering Design Criteria for Military Systems, Equipment, and Facilities, and MIL-C-81774A, General Requirements for Aircraft Control Panel. Certain sections of these specifications were of particular importance in defining the requirements for the IMPS controls and displays and are described in more detail in Appendices 1 and 3.

DIALOGUE DEVELOPMENT ANALYSES

Given the dialogue purpose and the user capabilities, a menu-selection dialogue was judged most appropriate for the IMPS system. The initial dialogue structure was based on the human engineering analyses described above. Subsequent analyses were conducted to ensure that feedback of system status was continuously provided to the operator, that event sequences were consistent from one mode to another, that consistency was tempered by flexibility and that special prompting and assistance messages were provided to aid the operator in the prevention, detection, and correction of errors. Finally, the dialogue was smoothed and "debugged" by a real-time simulation employing the VAX computer at the AVRADA facility and a computer terminal and modem at the Anacapa Offices in Santa Barbara.

SYSTEM COMPONENTS AND THEIR FUNCTIONS

The IMPS is composed of two major systems: the airborne system and the ground-based system. The ground-based system includes all of the features of the airborne system and has additional capabilities for mission planning and data-base editing. The various components of the system, their purposes, and some of their characteristics are described in the following paragraphs. This overview includes only the basic configurations and functions of components with which aviators interact--subsequent portions of this report represent complete specifications for system operation. A description of the engineering solutions for the realization of this system will be the subject of a separate report.

THE AIRBORNE IMPS COMPONENTS

Figure 1 presents a simplified block diagram of the airborne IMPS components. The aviator interacts directly with four of these components: the color CRT map display, the magnetic tape loader-copier, the control-display unit (CDU), and a joystick-type control called the airborne hand controller (AHC). The physical appearance of these components is shown in Figure 2.

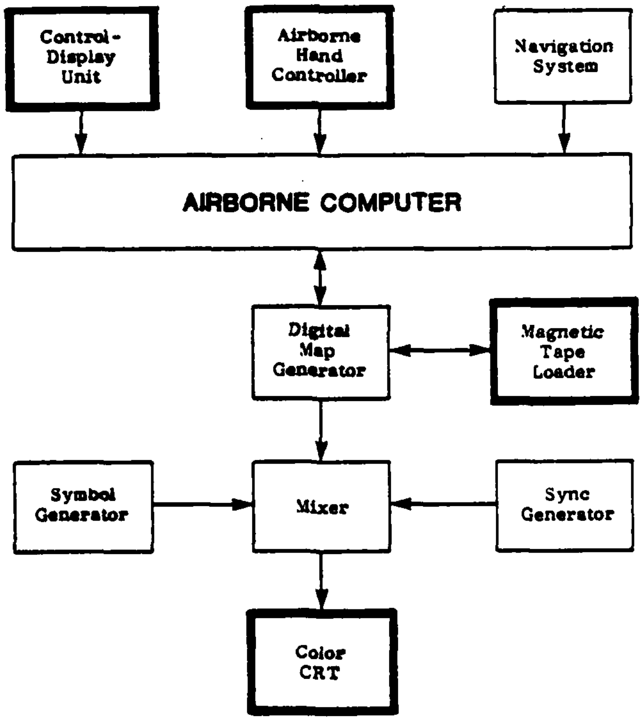
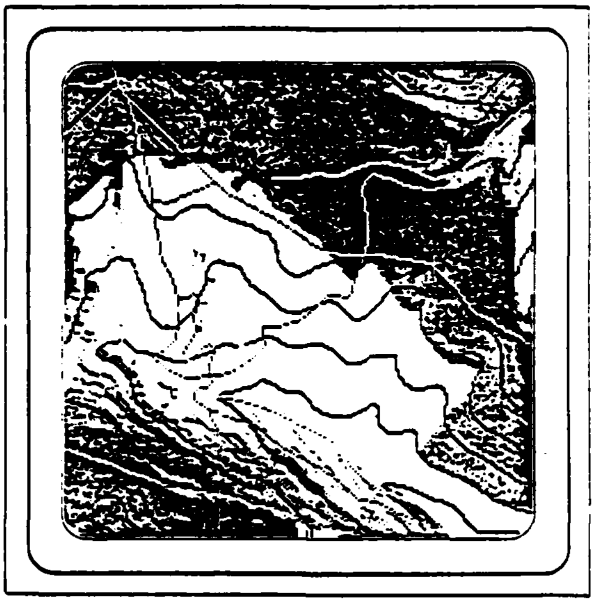
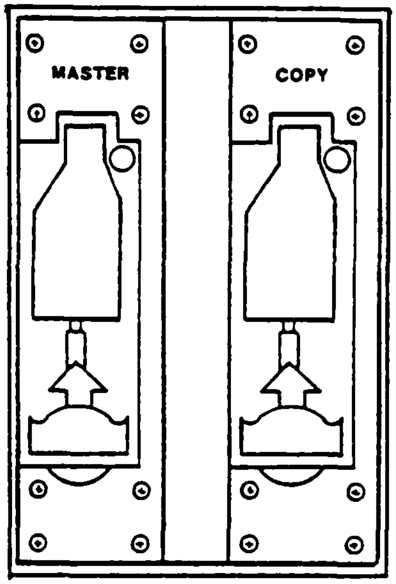


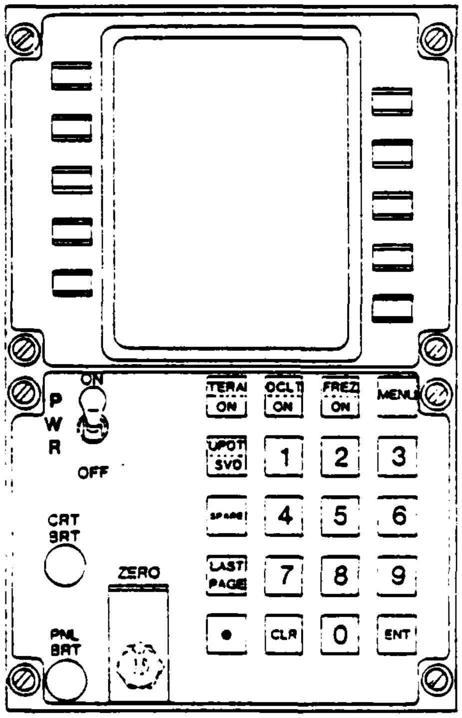
Figure 1. Simplified block diagram of the Airborne IMPS System. The bold surround indicates components with a man-machine interface.



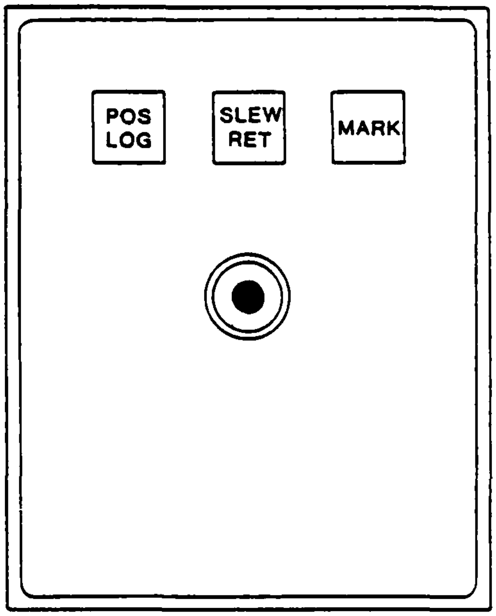
COLOR MAP DISPLAY



TAPE LOADER-COPIER



CONTROL-DISPLAY UNIT



AIRBORNE HAND CONTROLLER

Figure 2. Appearance of the airborne IMPS components.

Color Map Display

A multi-color map display is necessary to meet the extensive visual search and feature coding requirements of Army aviation. Reviews of the literature (Rogers, 1979; McCallum and Rogers, 1982) have revealed that color codes are nearly always extremely beneficial in search and identification tasks. This is an important finding because NOE navigation requires continuous orientation through searching for and identifying topographic features on the map, and correlating them with features seen in the real world. The finding that color codes are of increasing value with increasing map complexity (Dyer and Christman, 1965) is particularly applicable to the densely packed feature on a topographic map.

An additional requirement for a color display stems from the resolution limitations of electronic display mediums. The tiny shape codings possible on paper maps (such as the cross-hatched railroad track symbol) are not currently achievable in a pixel-matrix format, and must be replaced by color codes.

Although many emerging display technologies (electro-luminescent, light-emitting diode, plasma, etc.) offer specific advantages, at the present time only the cathode ray tube (CRT) can meet the multi-color map display requirement. The CRT to be used in the aircraft cockpit is assumed to be approximately 6 to 8 inches in width. It will employ a 512 x 512 pixel matrix to display topographic and tactical data selected by the aviator. Navigation sensor data, augmented by a terrain correlation technique, are used to identify the aircraft's current position on the map display. The map display translates and rotates (in real time) in response to aircraft motion. The aviator has control over a large selection of display formats and capabilities, as described later in this section.

Magnetic Tape Loader and Copier

The magnetic tape loader and copier consists of a small electronics unit and removable hermetically-sealed cassettes. The four-track cassette provides storage for elevation data (Track 1); vegetation, hydrographic, and cultural data (Track 2); intelligence and operations data (Track 3); and mission-planning and in-flight annotation data (Track 4). The geographic area storable on the cassette depends upon the resolution or grid-point interval of the data. The high-resolution data desired for Army aviation use will permit the geographic area stored on a single cassette to be 100 x 100 kilometers--approximately 16 times the area shown on a standard 1:50,000 scale paper map.

The provision of a tape copier greatly simplifies the logistics of map distribution and tactical data exchange. Upon arrival at a new area of operations, the aviator can simply borrow the required cassette and copy the data on a blank or previously used cassette. The distribution of tactical overlay data from higher headquarters can be handled in the same efficient manner.

Airborne Control-Display Unit

The airborne control-display unit (CDU), shown in Figure 3, is an integrated, multi-purpose module which provides the aviator with his primary means of exercising the extraordinary flexibility built into the IMPS system. The uppor portion of the CDU is composed of a small monochrome CRT that displays 12 (16-character) lines of data. The top line is reserved for advisory data, and the bottom line is used as a "scratch pad" to echo keypad entries. The central 10 lines may be used for data display, prompting messages, or labels for the adjacent line select keys. The labels change to indicate the current function of each line select key because the functions of any given line select key will differ depending upon the type of transaction in progress. The versatility of this display-control concept is demonstrated in subsequent pages of this section. Not only does it provide an easily understandable method for leading the user through operational sequences, it also eliminates the need for scores of single-purpose control and display elements.

The lower panel of the CDU provides several different types of controls. On the left side of this panel are the power on-off switch, the CRT and panel brightness knobs, and a "zero" switch to erase secure information in the event of an emergency. The right side of the lower CDU panel is devoted to a numeric keypad and ENTER button for data input, as well as several special-purpose pushbutton controls. The CLEAR button, when pressed once, clears the last digit shown on the scratch pad. A second press clears the scratch pad completely. The MENU button is used to call the display page that presents the function initiation points for all transactions with the IMPS. The LAST PAGE button may be used to display the CDU page presented immediately before the page currently displayed, in order to correct errors or accommodate special strategies for employment of the IMPS

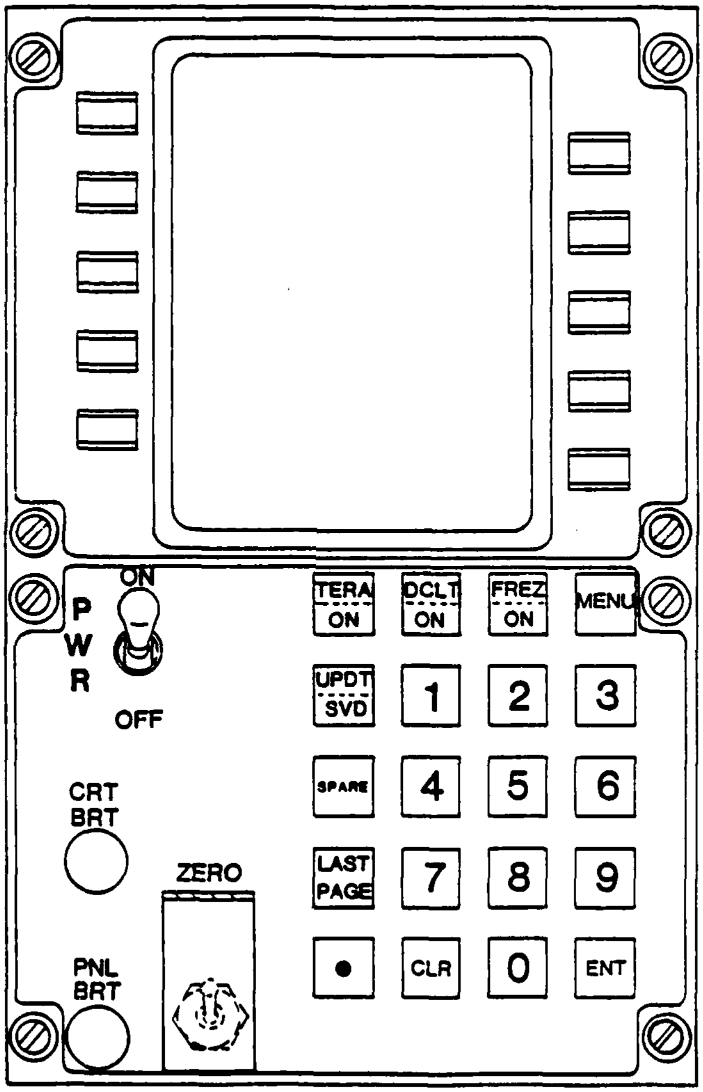


Figure 3. The airborne control-display unit (approximately two-thirds scale).

dialogue. The other special-purpose buttons, TERRAIN AVOIDANCE, SAVED UPDATE, DECLUTTER, and MAP FREEZE are discussed in subsequent portions of this section. The complete human engineering specifications for the CDU hardware are provided in Appendix 1. The design of the display font for the CDU is described in Appendix 2.

Airborne Hand Controller

The airborne hand controller (AHC) is composed of a miniature joystick and three adjacent push buttons. The configuration of this device is shown in Figure 4. The joystick is used by the aviator to slew the map (the windowed portion of scene memory) in order to expand the viewable area, to update the navigation system, and to perform other special tasks described later in this section.

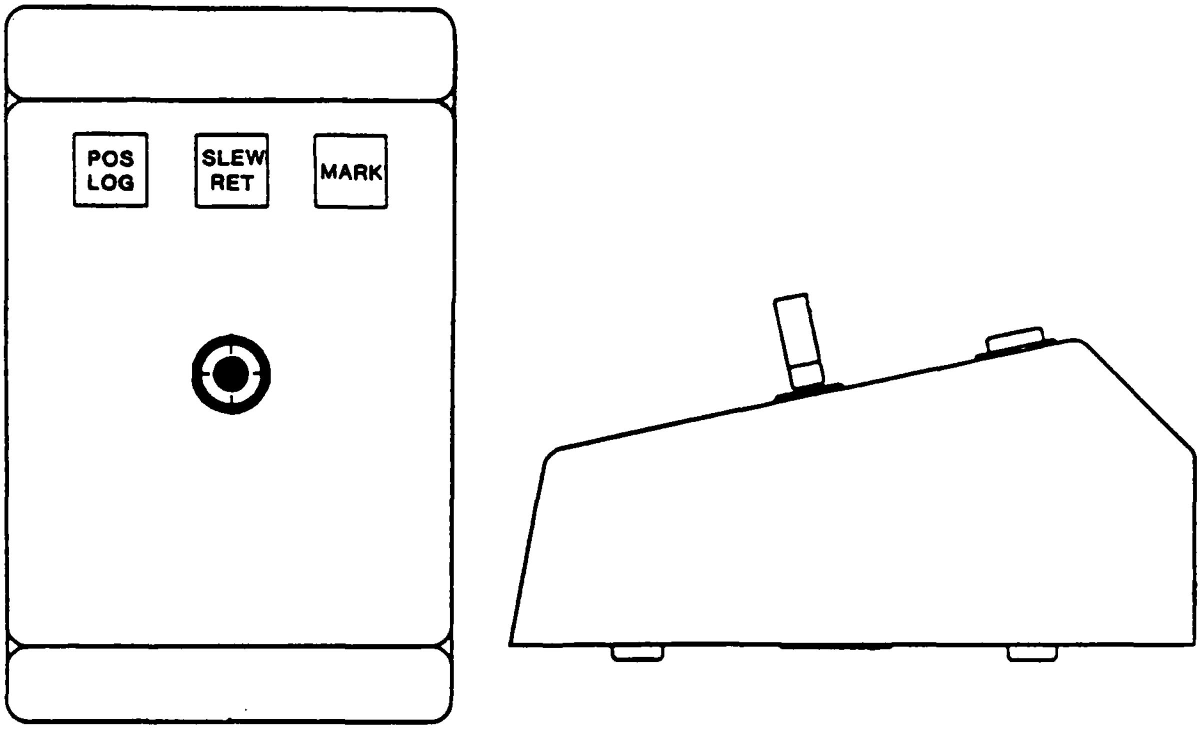


Figure 4. Configuration of the AHC (approximately half scale).

The AHC is also used to move a cursor across the map display in order to designate points in the terrain. In this manner the aviator can obtain range, bearing, coordinate and elevation information regarding the designated points. The cursor may also be used for map annotation and other position-indication tasks.

The joystick is a force-oriented, first-order control device such that the harder the stick is pressed, the faster the motion of the controlled element. This type of control device offers the dual advantages of rapid movement and fine positioning capabilities.

There are three pushbuttons located on the AHC. The position log (POS LOG) button causes a symbol to be recorded on the map indicating the aircraft's present position. Although the IMPS provides much more sophisticated methods of annotating the map, the dedicated-purpose position log button can be used quickly in emergency situations such as coming under enemy ground fire. The uses of the slew return (SLEW RET) button and the MARK button will be described later in this section. The complete human engineering specifications for the AHC hardware are provided in Appendix 3.

THE GROUND-BASED IMPS COMPONENTS

The ground-based IMPS components include the airborne equipment described above. In addition, the IMPS also provides a pressure-sensitive screen over the color CRT, an alphanumeric keyboard, and map overlay digitizing equipment, as shown in Figure 5. The CDU employed by the ground-based system is identical to that employed in the aircraft except that additional software is provided for special IMPS tasks performed at the Tactical Operations Center (TOC).

Touch-Sensitive Screen

Because aviators are accustomed to drawing lines and symbols on paper maps prior to flight, it is important to enable the analogous "drawing" on a CRT map display. This activity is permitted through the provision of a touch-sensitive screen.

A transparent, pressure-sensitive screen over the map display acts as a position sensor. This sensor can be used to edit and annotate the digital data base

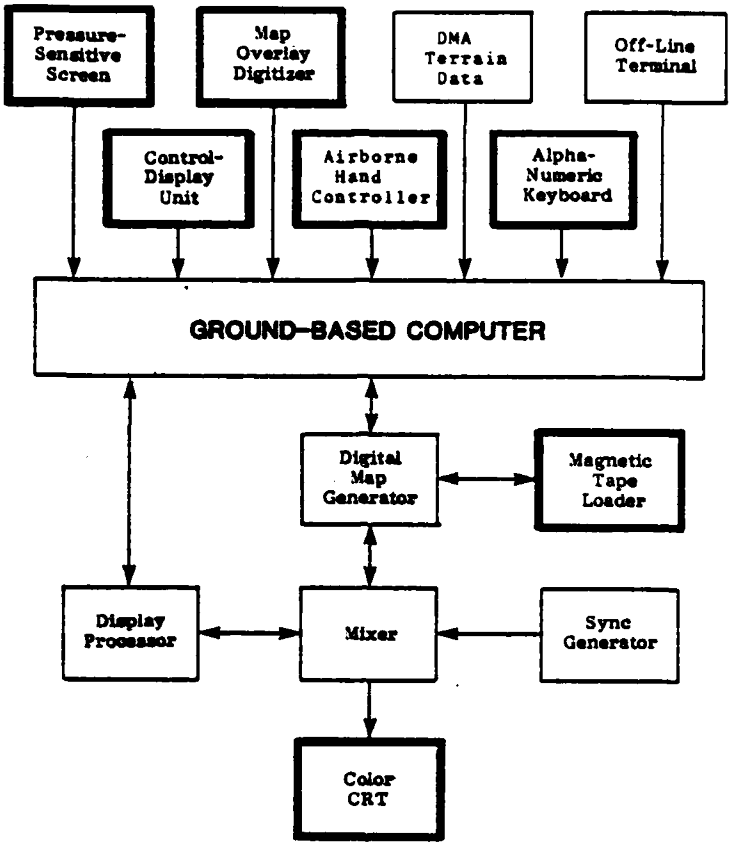


Figure 5. Simplified block diagram of the Ground-Based IMPS System. The bold surround indicates components with a man-machine interface.

by touching the screen with any pointed object. A major advantage of the touch-sensitive screen is that the hand-eye coordination employed is the same as that used when drawing with a pencil.

Alphanumeric Keyboard

Although most map editing and annotation will use point, line, and area symbols, the use of words to perform editing operations or to insert text on the display will be required on certain occasions. A standard alphanumeric keyboard is provided for such entries.

Map Overlay Digitizing Equipment (MODE)

The function of the MODE is to digitize acetate overlays corresponding to standard paper topographic maps. This capability is necessary because the transmittal of geographical information by way of overlays is a standard procedure in Army operations. Furthermore, the revision of acetate overlays on a situation board, and the periodic digitization of these overlays, may provide the most efficient means of updating the data base after a rapid series of after-action debriefings. In addition, the MODE can be used directly with paper maps to create digital "overlay" data without the intervening step of an acetate overlay.

The MODE consists of a square tablet approximately 24 inches on a side and a pen-type stylus that can be used either with or without ink. Like the pressure-sensitive screen, use of the MODE is natural, quickly learned, and unlikely to cause fatigue. The MODE may also be used with its own menu system, thus speeding the entry of data. The use of the MODE is described subsequently in this section of the report.

OPERATION OF THE AIRBORNE SYSTEM

This section of the report describes the procedures employed in operation of the airborne IMPS system. The procedures are defined for eleven sets of functions performed by the system. The requirements for each set of functions, and the present deficiencies in providing these functions, are briefly described, followed by a short discussion of the capabilities of the IMPS system for meeting the requirements and overcoming the deficiencies.

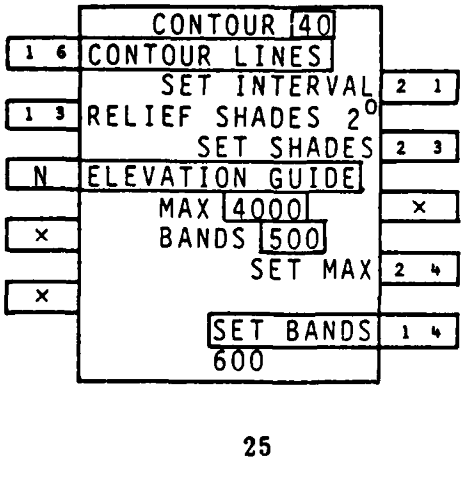
The specific procedures for operation of the system are presented by showing the changing display "pages" on the CDU and examples of changes in the map display resulting from inputs to the CDU or the AHC. The complete set of dialogue pages is presented in Appendix 4.

DIALOGUE STRUCTURE

Dialogue Interpretation

The list of CDU pages provides the primary description of the IMPS dialogue. The CDU pages and operations are depicted as shown in the example below. The page number (2-5) is presented above the page. The numbers on the ten buttons beside the page indicate the numbers of the CDU pages that will appear if the buttons are pressed. Buttons marked with an X have no function on that particular page. The purpose of buttons marked with an N are described in the text of this document. A small rectangle beneath a page, such as E 3 2, indicates that pressing the ENTER key, or other special-purpose control, will lead to another page. Other letters used in the rectangle are M, S, and K, for Mark, Stylus, and Keyboard. A box around information on the CDU page symbolizes the use of "reverse video" as a highlighting technique.

2-5



Use of Reverse Video

The IMPS dialogue makes extensive use of reverse video highlighting in order to provide feedback to the operator. Reverse video is most often used to indicate system status as a result of prior entries. For example, reverse video is used to indicate which of several discrete alternatives have been selected (map scale, orientation, etc.) and to display previous numeric settings (such as contour interval or elevation guide settings). Reverse video is also used as a type of cursor, to step through potential selections as in label definition or feature set storage. In addition, reverse video is employed to indicate that the system is ready for data entry, as in the case of SET INTERVAL, SET SHADES, and other simple entries not requiring more explicit prompting messages. Finally, reverse video is used to highlight error messages in the scratch pad.

IMPS Error Control

The IMPS dialogue is designed to minimize error probability through smooth and natural sequencing and continual feedback of system status, through prompting messages leading the operator to make appropriate responses, and through a display permitting the operator to check numeric data before its entry. Nevertheless, even the best trained operators will sometimes make errors. Where possible, the IMPS system will detect these errors, and indicate them to the operator.

In addition to entry errors, some procedural errors are to be expected in system operation. The operator can always escape from the erroneous sequence by pressing the MENU button and beginning anew. In some cases, however, the operator is likely to realize his error immediately upon display of the called page and wish to return to the page upon which the error was committed. The LAST PAGE button on the lower portion of the CDU will permit exactly this operation. The LAST PAGE button will not reverse any effects on the map display caused by the previous actuation, but will aid in rapid correction of the error.

Ease of Use

The list of CDU pages and the associated notes provided in this document present a great deal of information in a relatively concise manner. A casual scanning of these pages may result in the impression that the operation of the IMPS system is somewhat complex. However, scrutiny of individual functions reveals that the CDU pages carefully guide the aviator through the procedures, yet permit him a comfortable margin of flexibility so that the dialogue is smooth and natural. Pages are designed to fulfill functional requirements with a minimum number of control activations, but do not place a significant memory burden on the aviator. Furthermore, the system is designed so that frequent manipulations are not required—the aviator sets up the system for optimal performance of required tasks and periodically exercises IMPS special functions as desired.

THE AIRBORNE MENU PAGE

A single CDU page is used for initiating all procedures. This page, called the MENU page, is shown below.

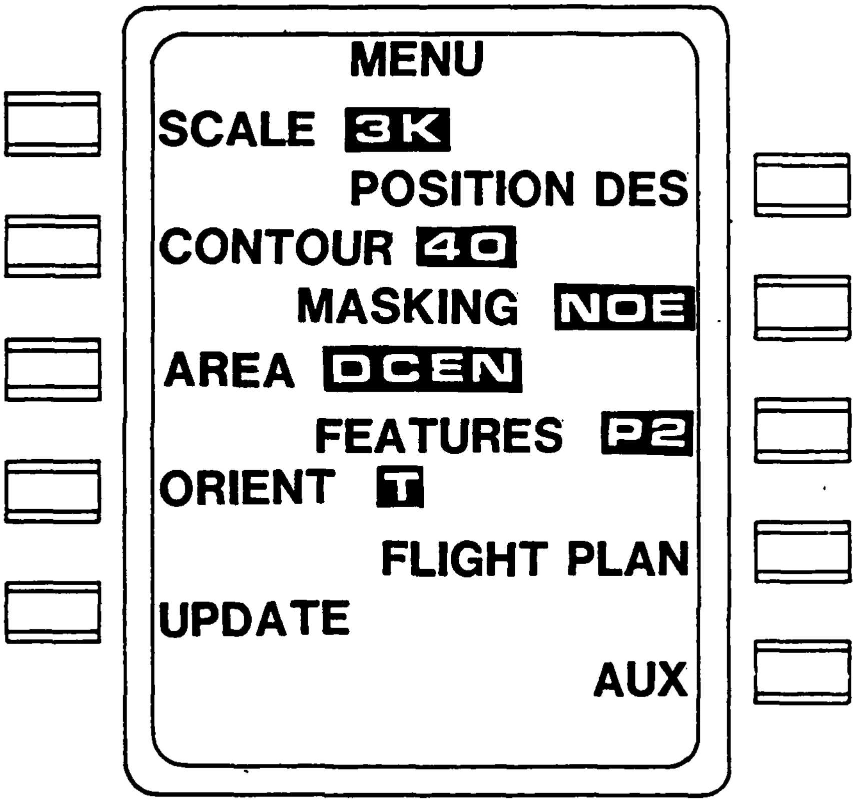


Figure 6. Airborne menu page 1-1 (approximately actual size).

The line labels on the MENU page identify nine sets of related functions performed by the airborne system. Pressing the line select key adjacent to one of the labels initiates the procedural sequence required for performance of that function. An additional two sets of functions, tape copying and flight simulation, can be initiated through the auxiliary (AUX) functions button.

In addition to its role in initiating functions, the MENU page also provides a status display, using reverse video to indicate current IMPS settings pertaining to map scale, contour interval, displayed area, map orientation, masking portrayal, and feature selection rules. The menu page is accessed through the MENU button on the lower portion of the CDU and can be called at any time, regardless of the transaction in progress.

In the subsequent paragraphs, operational procedures are described for the following eleven sets of functions:

Map Scale
Map Contour
Map Area
Map Orientation
Position Update
Position Designation
Masking and Intervisibility
Feature Selection
Flight Plan
Flight Simulation
Tape Copying

MAP SCALE

Requirements

Aviators attempt to obtain maps of several different scales for use in the planning and conduct of missions. Maps in 1:250,000 scale, valued for their wide area coverage, are useful in depicting the overall battlefield situations. Maps in 1:25,000 scale show small areas, but provide fine detail for study of the objective or features along the flight route. Maps in 1:50,000 scale are typically used for navigation at NOE altitudes because they provide the minimum required detail for correlation of map and terrain features.

Present Deficiencies

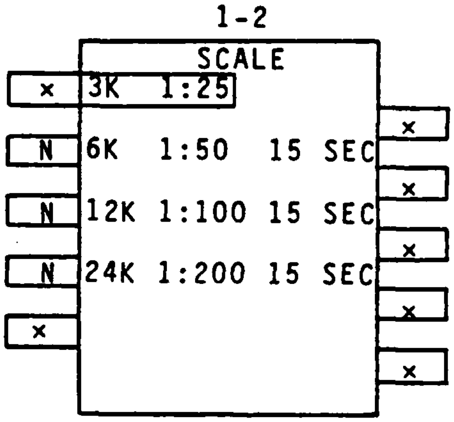
Although NOE flight requires the use of large-scale maps (1:50,000 or larger), only a small percentage of the earth's surface is currently mapped in large scale. Attempting to use small-scale maps (1:250,000 and 1:500,000) is almost certain to lead to disorientation during NOE flight. Even where large-scale maps are available, however, their use in the cockpit is often awkward because many different map sheets may be required for a single mission.

IMPS Capabilities

The IMPS data base may be employed to portray the terrain in any of four scales selectable by the aviator. During mission planning, small-scale portrayal can be used for overall route selection, alternated with large-scale portrayal for scrutiny of specific terrain features. During mission conduct, the map scale can be changed for greatest utility given the aircraft speed, the view of surrounding terrain, the information necessary for orientation, and the desired look-ahead distance. The size of the data base (100 x 100 km) is independent of map scale, so that "flying off the map" is no longer a drawback to large-scale map use.

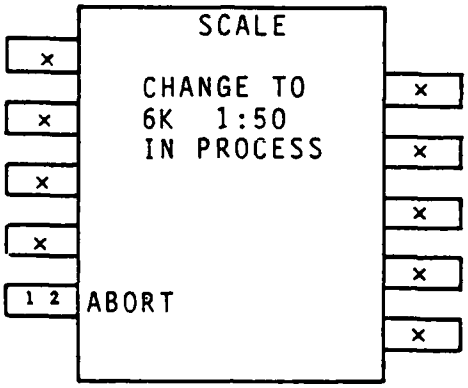
CDU Operation

When the MENU page is displayed, pressing the line select key labeled SCALE calls the scale selection page (1-2) shown below. Pressing any of the four labeled keys on the scale selection page causes the map display to change to the selected scale.



The scale options are labeled in two ways. At left, the scale distance (in kilometers) across the map display is shown. Adjacent to this label is the abbreviated scale fraction, for reference. Reverse video shows the currently displayed scale. The selected scale is also displayed beside the SCALE label on the MENU page. Advisories are provided to indicate the total elapsed time required for a map in another scale to be completely configured (central portions of the maps will be visible much earlier). The 15-second period shown here is an estimate. During this map construction period advisory page 1-7 is shown, indicating the change in progress, and providing an ABORT button to recall page 1-2 and reselect the desired scale.

1-7



The aviator may continue to change scales until he elects to return to the MENU page. The scale last selected will then be maintained on the display. Figure 7 provides an example of change from 1:50,000 scale to 1:25,000 scale. A 1,000-meter grid indicator at the left margin of the map provides a supplementary method for aiding the aviator in making rapid judgments of distance. The grid indicator consists of 1-kilometer tic marks. At 1:200,000 scale (24 kilometers) the tic marks are accentuated every fifth kilometer. Scale changes will cause a proportionate change of contour interval and the new interval will be shown on page 1-1. Feature display rules will also change with scale changes if a preset is selected on page 8-1 (discussed subsequently in this report).

MAP CONTOUR

Requirements

For Army aviators, terrain relief--the shape and height of landforms--is probably the most important class of information on a map. Landforms are stable over long periods of time, are often unique in appearance, and are nearly always discernible. These considerations make landforms the primary reference for

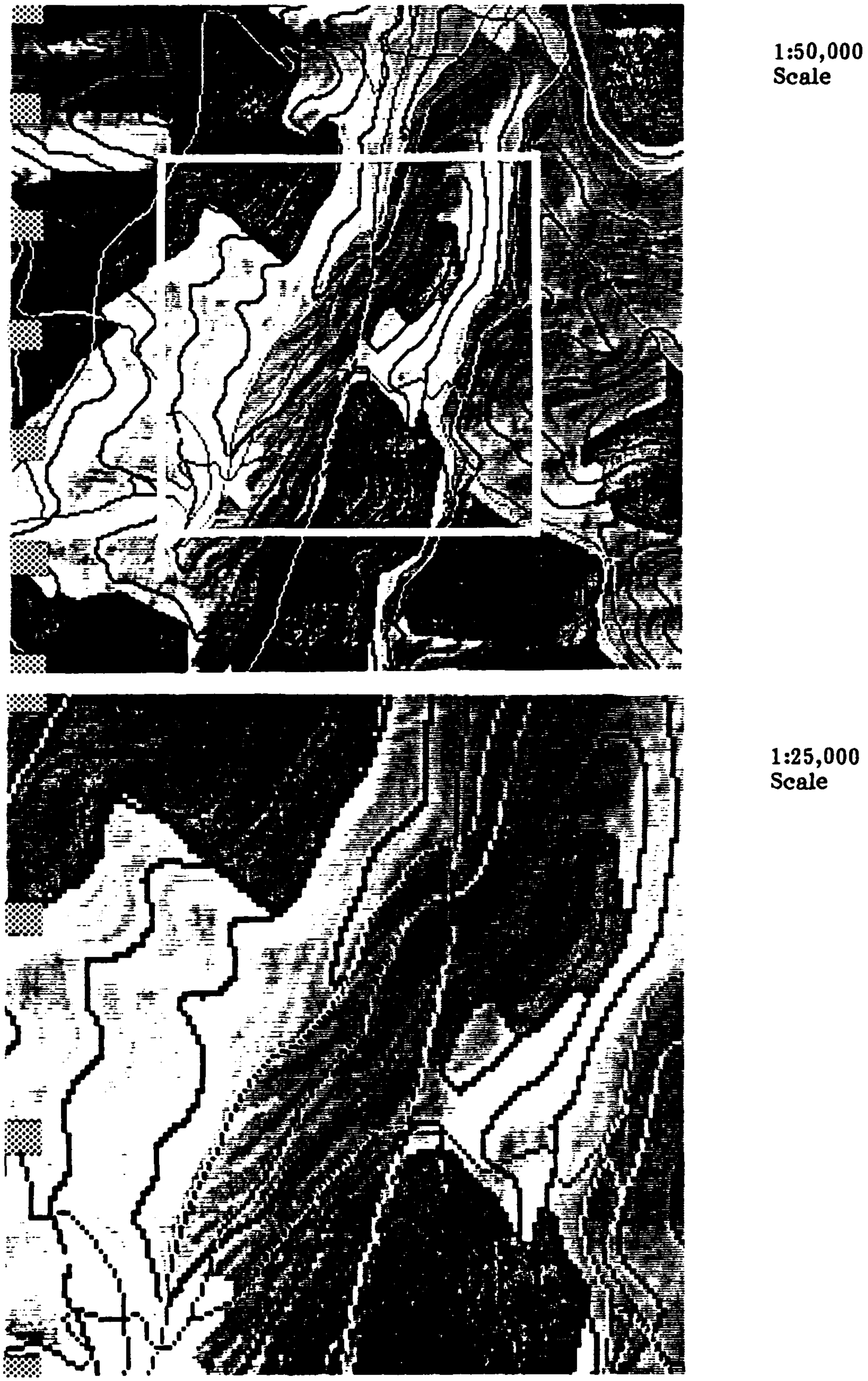


Figure 7. Example of IMPS scale change. The inset box in the top section shows the area covered in the bottom section.

geographic orientation. Furthermore, terrain relief has great tactical significance for military operations in general, and NOE flight in particular. It is essential for all types of missions that aviators be able to extract terrain relief information from contour data presented on maps. Terrain relief is depicted on most topographic maps through the use of contour lines.* The contour line technique is the only terrain encodement scheme which meets the severe requirements of NOE navigation: depicting very large elevation ranges while maintaining the precision required for referencing relatively small terrain features.

Present Deficiencies

Unfortunately, the perceptual task of relating contour lines on a map to the terrain relief on the ground is the most difficult aspect of map interpretation during NOE flight. Even experienced Army aviators commonly encounter difficulty in performing contour interpretation (Rogers & Cross, 1978, 1980). This difficulty tends to result in geographic disorientation and limits the ability of aviators to become reoriented.

The ideal contour interval for landform portrayal depends upon the dimensions of the features, the steepness of their slopes, and the precision required by the aviator. A small contour interval is useful for defining relatively small, flat terrain features. The same contour interval cannot be used for steep terrain features because the lines would abut and form dark areas devoid of information. The contour interval on paper maps, however, is fixed. The cartographer must select a compromise interval (although supplementary contours are sometimes added).

To aid the interpretation of contour lines, some topographic maps have added shaded relief (see Figure 8). This shading, however, is usually manually rendered with an airbrush and reflects a simplified version of the cartographer's interpretation of the relief. The accuracy and precision of this technique is questionable, and the time required for its application is considerable. Furthermore, it is possible that such shading may adversely affect map legibility.

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*For a complete discussion of the characteristics of contour lines and other terrain-relief encodement schemes, see Cross, 1977, pp 26-41.

Another attempt at aiding the aviator's visualization of the terrain is the "elevation guide" (see Figure 9). The elevation guide is a very small-scale map (found in the margin of most topographic maps) that uses three or four unique shades of gray to define the layers between selected elevation contours. The elevation guide, however, is provided only to indicate the overall high and low terrain of the mapped area and cannot be used as a precise navigational earth reference.

Figure 8. Sample of airbrushed shading of a topographic map.

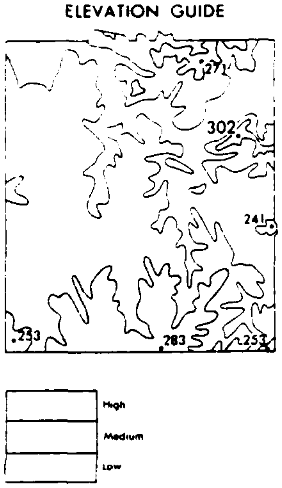


Figure 9. Sample elevation guide from a standard 1:50,000 scale map sheet.

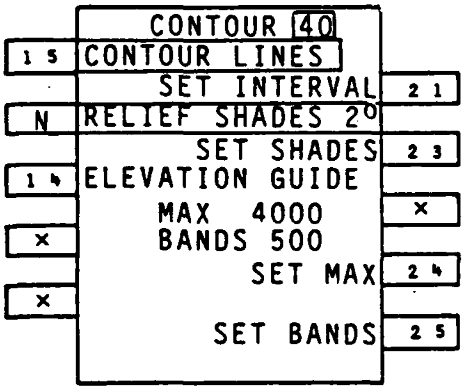
IMPS Capabilities

The IMPS system is capable of displaying any contour interval selected by the aviator. The contour interval can be quickly shifted to meet the changing requirements for precision and to improve the ease of contour interpretation. The general lay-of-the-land, or the configuration of specific landforms, may be carefully examined by selection of the appropriate map scale and variation of the contour interval. The IMPS may also be employed to produce extremely precise relief shading without incorporating human errors of interpretation. The shading algorithm developed at AVRADA (Shupe, 1981) produces an extremely realistic representation of a three-dimensional landform from elevation data, and will greatly reduce the information processing burden imposed upon the aviator by the contour interpretation task. In addition, the IMPS provides the aviator with an elevation guide capability. Rather than employing a separate small-scale depiction, the entire map area is used to display the gray-shaded contour bands so that the guide may be used in conjunction with data providing precise navigational reference points. Furthermore, the aviator can adjust the guide bands in order to optimize the utility of this feature

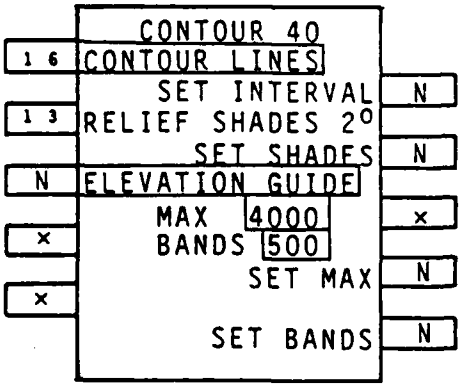
CDU Operation

When the MENU page is displayed, pressing the line select key labeled CONTOUR calls the contour selection page (1-3) shown below. Line select keys on the contour page permit the selection of several topography presentations. The color plates following this page show examples of the enhancement of contour interval relief portrayal by the shaded relief and the elevation guide options. The aviator can select contour lines and choose between relief shading or the elevation guide presentation. The latter two features are mutually exclusive so that selection of one automatically deletes the other. Reverse video indicates the current selection (pages 1-4 to 1-6) and settings.

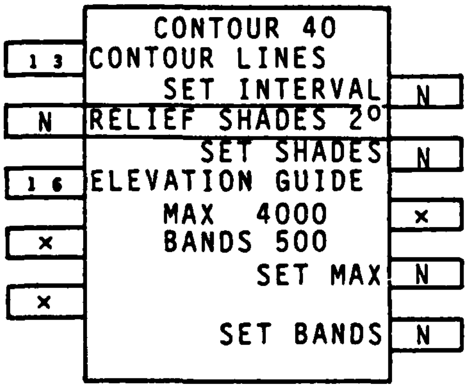
1-3



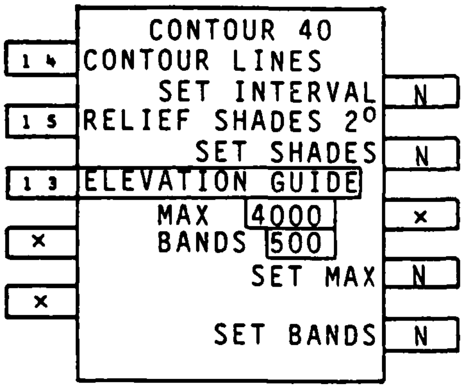
1-4



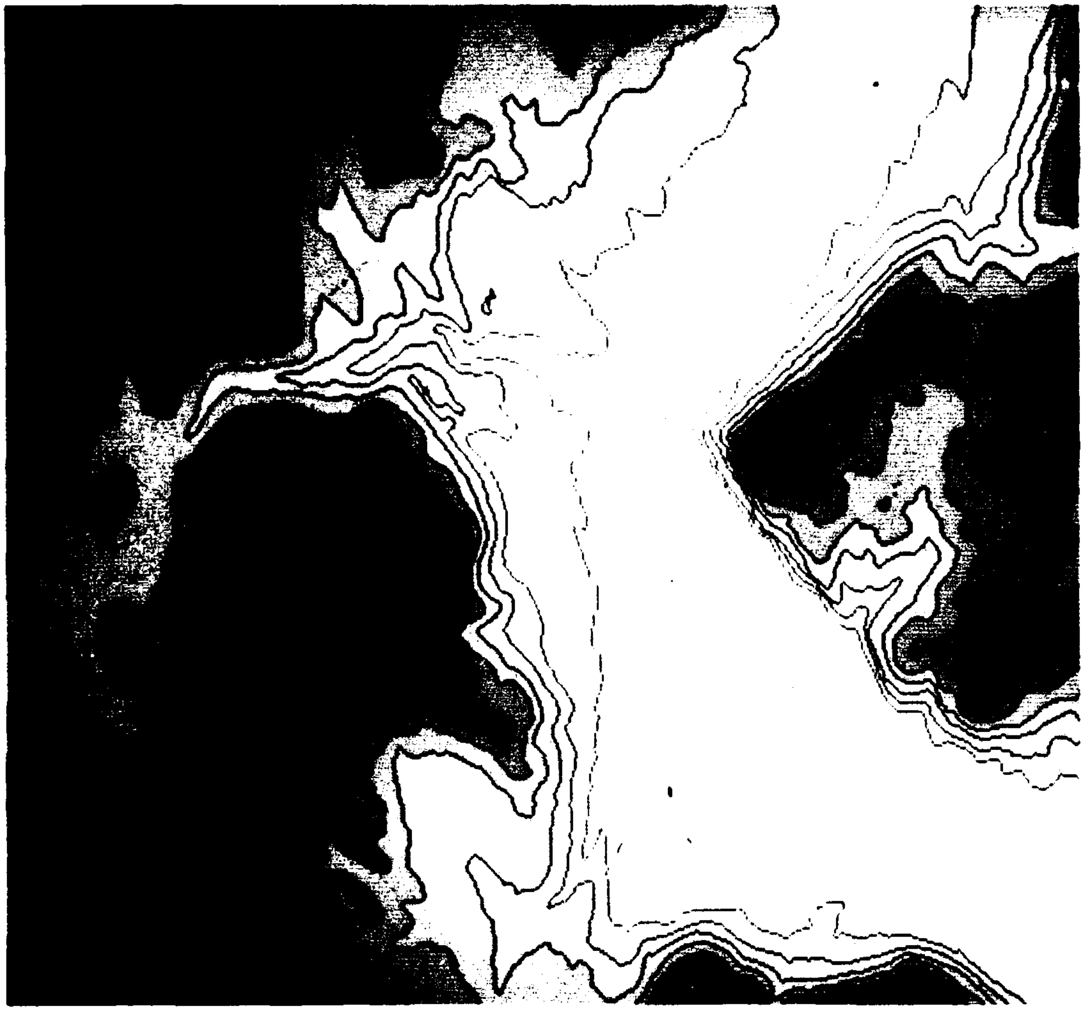
1-5



1-6



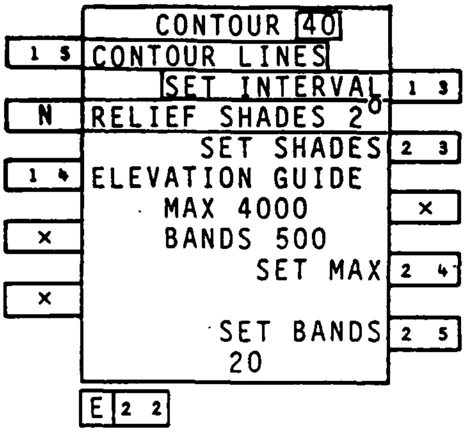
Slope-Shaded Terrain Plan View



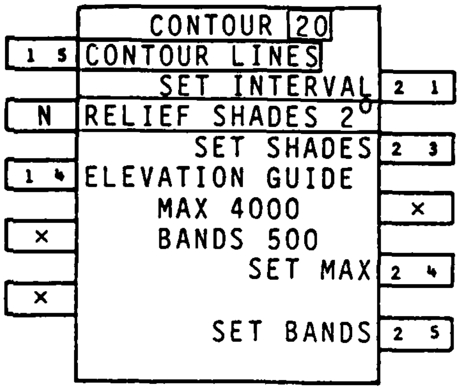
Elevation-Shaded Terrain Plan View

To set the contour line interval, the aviator presses the SET INTERVAL button on page 1-3. The SET INTERVAL label is then shown in reverse video (as on page 2-1) to indicate system readiness for the setting. The new interval is input via the numeric keypad and appears in the scratch pad area for verification. When the ENTER button is pressed, the map contour interval is changed (as shown in Figure 10), the SET INTERVAL label returns to normal video, and the new interval is shown at the top of the page (2-2)

2-1



2-2



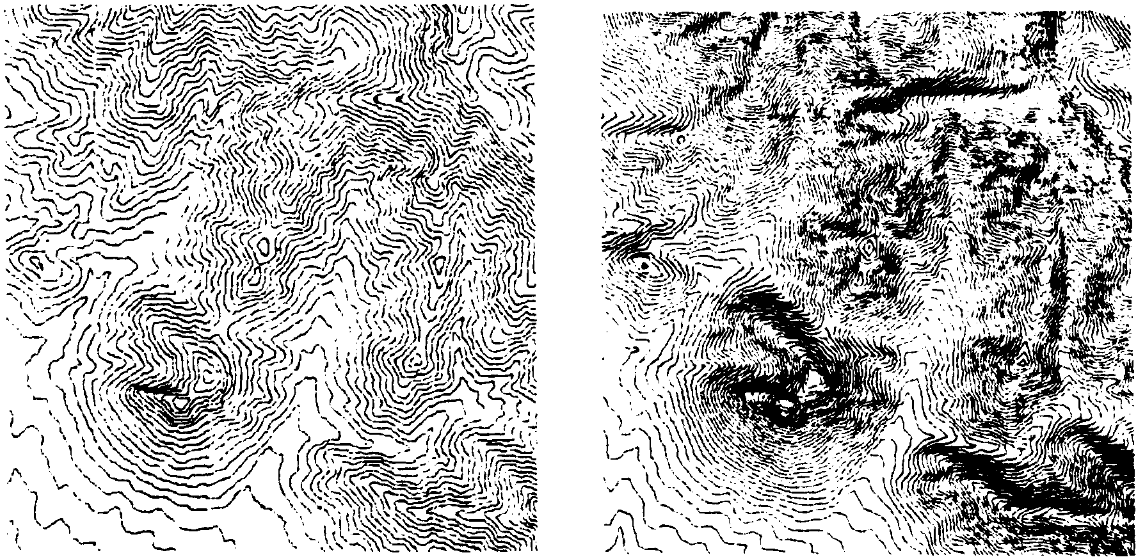
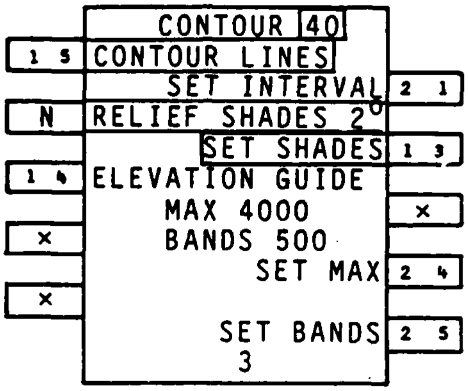


Figure 10. Examples of terrain portrayed by 120-foot and 40-foot contour intervals.

The relief shading technique is based upon terrain slope, and the depiction may be varied by altering the slope-shade relationship. The relief shading factor is set in a manner similar to contour interval setting. The factor advisory (here, 2°) is shown adjacent to the relief shades selection button. Page 2-3 shows that the factor is about to be changed to 3°, whereupon the advisory will also change.

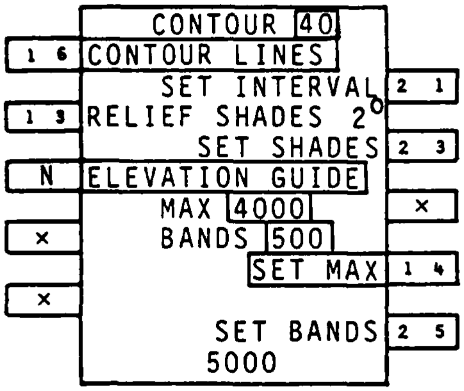
2-3



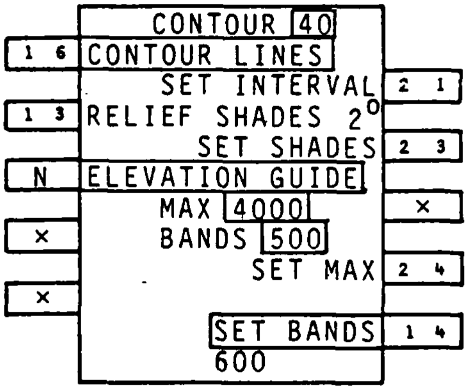
Use of the elevation guide is somewhat more complex because the aviator is permitted to set both the maximum terrain elevation to be included, and the elevation range (bandwidth) of the gray bands. These two settings provide the aviator with considerable flexibility in use of the elevation guide. Up to eight shades of gray may be employed--distributed over the entire elevation range, or limited to any particular range of interest.

The maximum elevation and width of elevation bands of the elevation guide function are entered in the same manner as the contour interval and relief shading factor (pages 2-4 and 2-5). Depending upon the selections made, it is possible that less than eight bands will be displayed. The MAX and BANDS advisories will change to reflect the entries. The relief shading factors and elevation guide settings are maintained in system memory and are specific to each map scale.

2-4



2-5



A special case of the elevation guide is the terrain avoidance mode, called by a special purpose button (TERA) on the lower portion of the CDU. The terrain avoidance mode clearly identifies terrain above and below aircraft attitude through the use of a color-coding scheme. The terrain above aircraft altitude will be depicted in amber, and the terrain below will be shown in gray. The only other features shown in this mode are enemy activity and flight hazards (red). The terrain avoidance mode will be of particular importance when the view of the terrain is obscured by smoke or other atmospheric attenuation, or at night when the use of night vision goggles may be inappropriate.

MAP AREA

Requirements

The aviator is concerned not only with the position of his aircraft on the map, but with the positions of the surrounding military units, obstacles, checkpoints, and landforms. Although the primary area of interest is usually forward of the aircraft, the aviator must also be able to examine mapped data to the sides and to the rear of the aircraft in order to annotate the map with positions of bypassed targets, downed friendly aircraft, or other tactical data. In addition, it is sometimes necessary to study sites at some distance from the aircraft's present position--for example, the area surrounding the mission objective.

Present Deficiencies

Paper maps provide good flexibility for examination of areas adjacent to, or distant from, the aircraft. In the cockpit, however, the required folding, unfolding, and refolding of maps often becomes awkward.

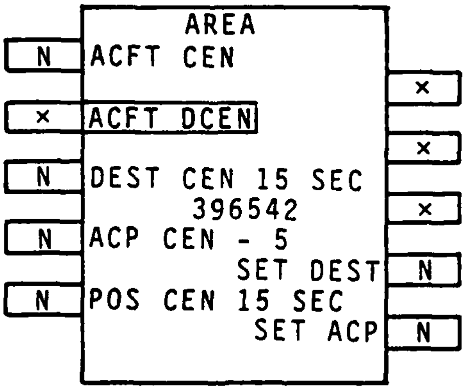
IMPS Capabilities

The IMPS incorporates several features that enable the aviator to conveniently study portions of the data base near to or distant from the aircraft's present position. First, the aviator may select the location of the aircraft's present position indicator--either centered on the display screen to permit portrayal of the terrain surrounding the aircraft, or decentered to provide maximum look-ahead distance. Second, the IMPS system will display the area surrounding any position in the data base designated by the aviator. Third, the displayed area may be changed by slewing the windowed area to increase the viewing distance in any direction.

CDU Operation

When the MENU page is displayed, pressing the line select key labeled AREA calls the AREA selection page, shown on page 2-6.

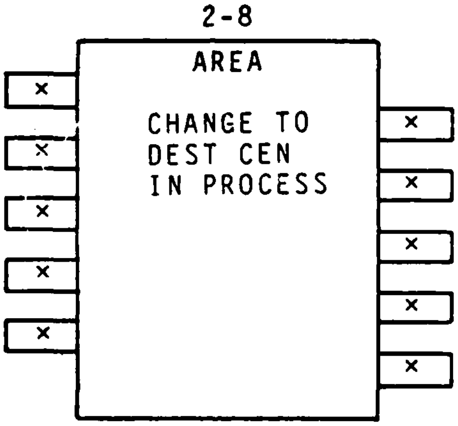
2-6



By pressing one of the upper two buttons on the AREA page, the aviator may chose to position the map such that the aircraft is centered or decentered in the displayed area, as shown in Figure 11.

Figure 11. Alternative portions of the aircraft present position indicator on the map display with selection of the centered or decentered mode.

A predesignated destination (DEST) air control point (ACP), and position (POS) can also be centered by pressing the appropriate buttons. The DEST option shows the coordinates of the destination last entered and the ACP option shows the number of the ACP currently set. Destination coordinates (four, six, or eight digits) and ACP numbers (0-19) are entered just as were contour intervals and other features described above, although the ACP may also be entered through page 10-1. It is not necessary to be in the DEST or ACP modes to set them. The position centered mode pertains to the site last designated on page 5-3 or 5-9. If area changes to display DEST, ACP, or POS on the color CRT require more than two seconds, warnings are presented on page 2-6 and an advisory page such as 2-8 is displayed during the processing of the new area.



In the destination-, ACP-, or position-centered modes, the map is stabilized. If the aircraft is operating within the displayed area, the present position indicator will translate and rotate to reflect geographic position and heading.

In any of the area depictions described in this section, it is possible to increase the viewing distance in any direction by slewing the map. The total viewable area at any moment (the scene memory) is expected to be approximately four times that presented in the display window. For example, in Figure 13, the cross-hatched lines show the viewable area and the terrain depiction shows the windowed area, which may be slewed anywhere within the viewable area.

Slewing is achieved by activation of the Airborne Hand Controller (AHC) joystick. The AHC joystick may always be used to slew the map within the scene

Figure 12. Effect on the display of selecting the destination-centered mode.

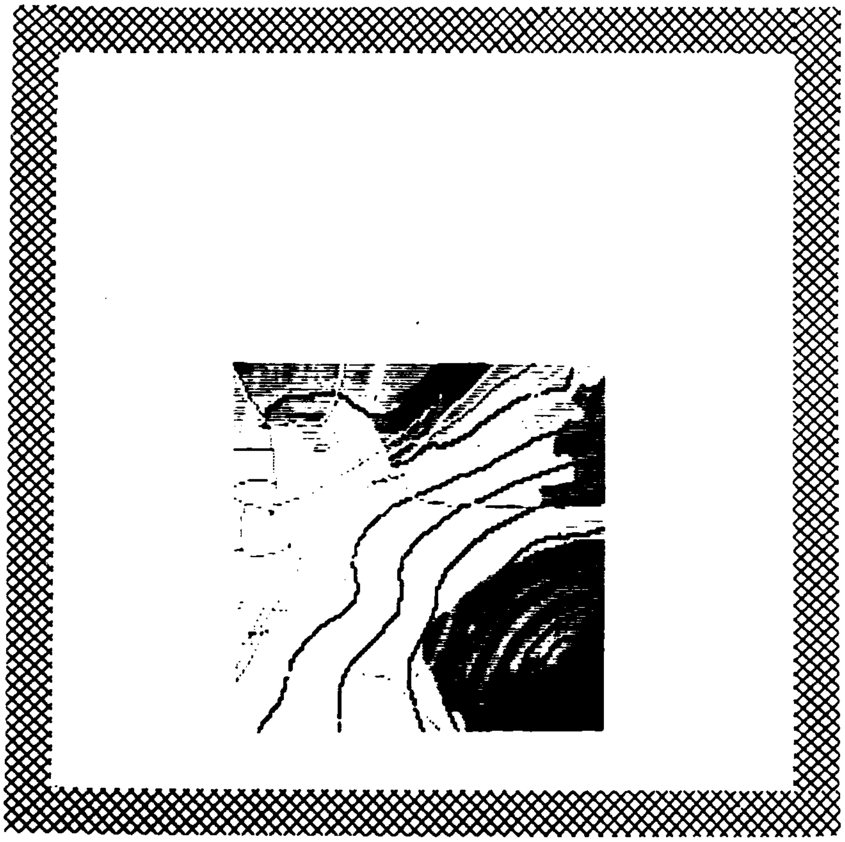


Figure 13. The windowed area and viewable area at a given moment.

memory (unless it is performing some other special requirement), thus providing an immediate method for expanding the viewable area. By pressing the SLEW RETURN button, the aviator causes the map to slew directly back to the centered or decentered mode previously in effect.

MAP ORIENTATION

Requirements

The majority of aviators prefer to orient the map so that the spatial arrangement of the map features is congruent with the arrangement of topographic features on the ground. This map orientation simplifies navigation by terrain referencing because it minimizes left-right confusions. A small proportion of aviators, however, prefer to maintain the map in a constant orientation and mentally transpose the spatial relationships of map and ground features. Still others prefer to turn the map to the cardinal direction nearest the aircraft's planned or actual flight heading.

Present Deficiencies

Although paper maps are easily turned to any orientation, determining their correct orientation can be confusing when the aircraft is following a sinuous course--as is often required for NOE flight. Because all of the alphanumeric information on a map (place names, spot elevations, grid line numbers, etc.) is oriented to be read when the map is north-up, some aviators attempt to alternate between north-up and heading-up map orientations, risking momentary disorientation with each change of map position. Others elect to maintain the north-up mode to reduce this source of confusion, even though the spatial relationships of map and terrain features are not optimal.

IMPS Capabilities

The IMPS system is capable of providing any desired map orientation, and alternating among orientations at will, whether the aircraft is on the ground or in flight. The terrain correlation subsystem continues to function during any map orientation.

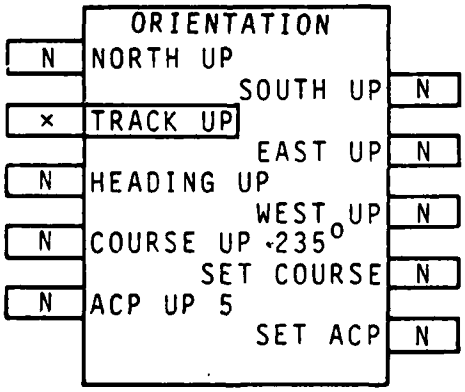
The map orientation can be set at any cardinal direction up, or at track, heading, course, or ACP up. These settings are, of course, mutually exclusive. The track-up model is based on prior movement over the ground and is essentially a wind-corrected course upward display. In helicopters, a stable track can be computed only when the aircraft is proceeding at some given forward speed, probably about 10 knots (McGrath, 1976), so a heading-up capability must also be provided for use during hovering. Heading up is simply the direction the aircraft is currently pointed. Course up is based on an aviator entry of any desired direction. Figure 14 graphically depicts apparent map motion with three examples of map orientation.

The ACP-up mode sets the top center of the display at the current compass bearing to the selected ACP. In the ACP-up mode, the map translates (ACFT CEN or DCEN) and rotates around the ACP selected as up. The aircraft symbol rotates to show heading. If DEST, ACP, or POS are centered, the map is fixed and the aircraft symbol translates and rotates. A map "freeze" capability is also provided to temporarily halt map motion for the cases in which a stabilized image may aid in examination of map details.

CDU Operation

When the MENU page is displayed, pressing the line select key labeled ORIENT calls the map orientation page (2-7).

2-7



Pressing one of the buttons labeled, NORTH, SOUTH, EAST, or WEST will cause the map to be oriented with the selected cardinal direction upward. The

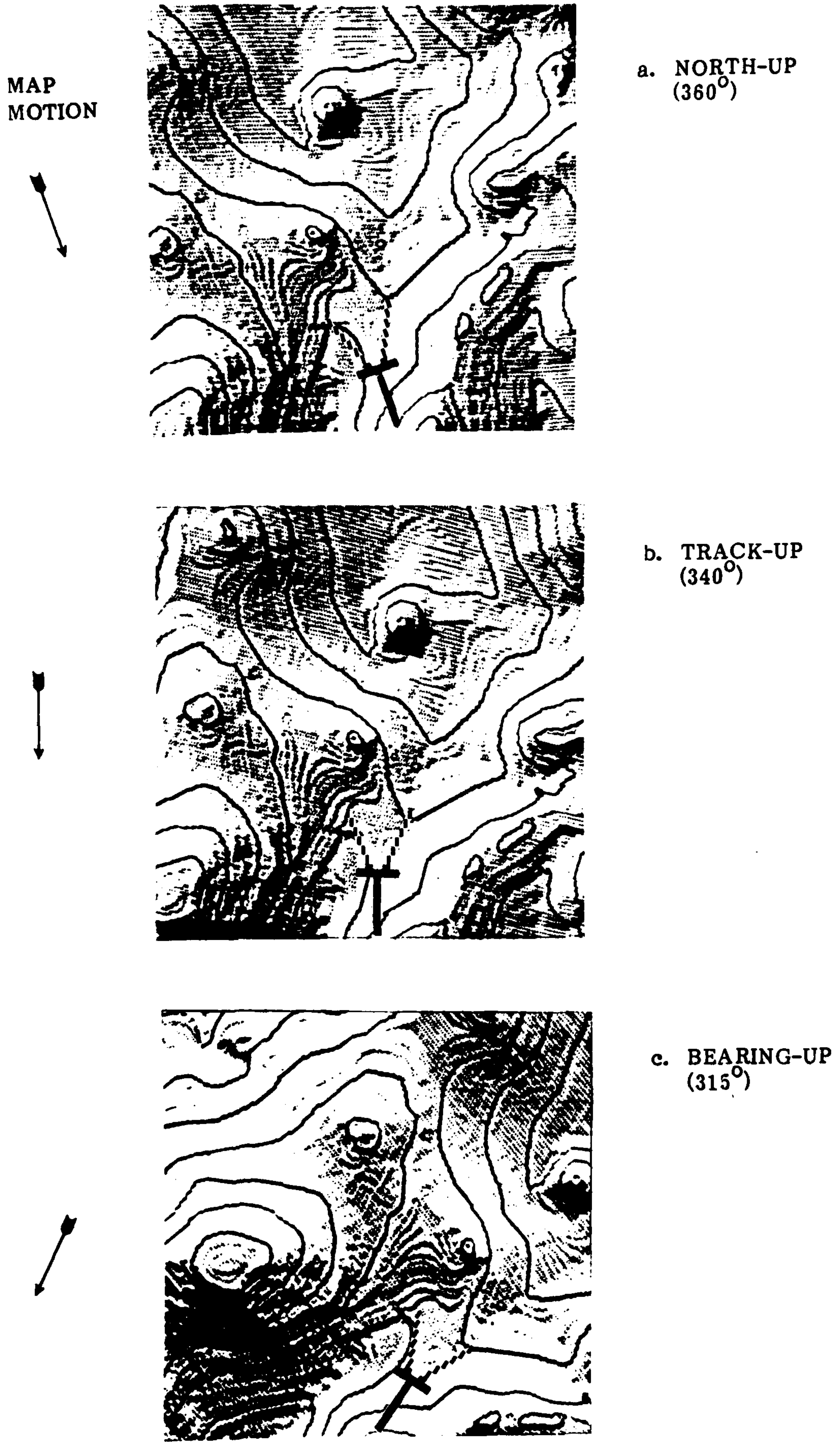


Figure 14. Examples of three different map orientations and the resulting direction of map motion.

results of pressing the TRACK UP, HEADING UP, COURSE UP, or ACP UP buttons have been described above. The SET COURSE and SET ACP buttons operate in the same manner as the SET INTERVAL button, previously described. Current course and ACP settings are indicated next to their respective buttons. The FREEZE button on the lower portion of the CDU stops map motion and initiates motion of the aircraft symbol across the map. A second depression of the FREEZE button causes map motion to resume and the present position indicator to return to the last selection (centered or decentered).

POSITION UPDATE

Requirements

Navigation at NOE altitudes requires continuous maintenance of orientation by identifying terrain features along the route and correlating them with features depicted on the map. Because of the aviator's limited view of the terrain, extremely reliable checkpoints may be available only intermittently. At these checkpoints, the aviator must "update" his estimated position on the map, reducing any accumulated error to a minimum. Although navigation during NOE flight is one of the most demanding tasks ever required of an aviator, there is no substitute for accurate position updating.

The most direct method of updating is recognition of specific terrain features on the ground near the aircraft and identification of their referents on the map. In the absence of such correlation, or because flying near recognizable features may be tactically inadvisable, aviators must be able to update their position by knowledge of the range and/or bearings of distant objects.

Present Deficiencies

Both anecdotal evidence and experimental data indicate that the average Army aviator is unable to consistently perform NOE navigation to the required level of accuracy. Furthermore, in Scout aircraft, navigation is often the responsibility of a crew chief who is insufficiently trained for this difficult task and may be unable to do more than recognize the most obvious man-made terrain features.

IMPS Capabilities

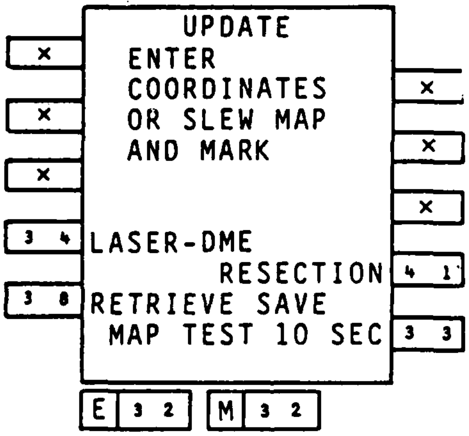
The IMPS system incorporates the most recent development in automated navigation--terrain correlation technology, such as that employed by "cruise missile" weapons. The system uses the digital elevation data, the ground clearance (determined by a radar altimeter), and doppler data to continuously update the navigation display. The system is expected to present the aircraft position with great accuracy. The aviator will have only to set the initial position of the aircraft, and (possibly) to make occasional corrections enroute.

Regardless of the sophistication of the IMPS navigation system, however, the aviator will be required to periodically initialize the system. For this reason, and as a back-up for contingencies, the IMPS system provides several methods of updating aircraft position on the map.

CDU Operation

When the MENU page is displayed, pressing the line select key labeled UPDATE calls the update page (3-1) as shown below.

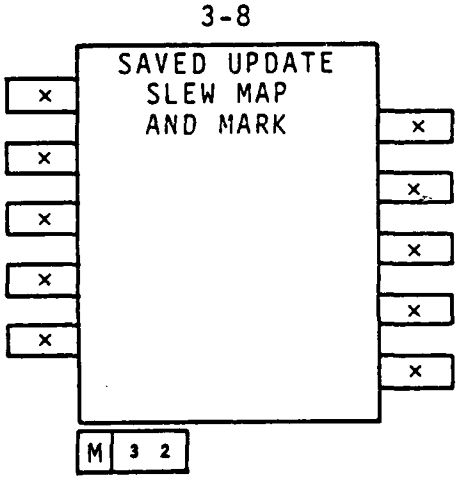
3-1



The update page is used both for initializing and for correcting the navigation system. The aviator can enter the correct coordinates of his position (4, 6, or 8 digits), or slew the map under the present position indicator in accord with his geographic position. In the slewing method, the MARK button is pressed to indicate correspondence of the aircraft position over the terrain and the present position indicator over the map display.

An example is provided in Figure 15. In the upper section of the figure, an arrow indicates the intersection of a road and a stream which the aviator recognizes as the actual aircraft position. Using the AHC, he slews the map so that the present position indicator is correctly placed, and presses the MARK button. An update at high speed may be simplified by pressing the FREEZE button on the CDU, slewing an upcoming feature under the present position indicator, and pressing the MARK button as the feature is overflown. In this case, the map will resume motion when the MARK button is pressed.

In NOE flight, checkpoints are often not seen until moments before they are overflown. Because the checkpoints can appear suddenly, aviators may not have time to use the normal update procedure described above. In these cases, the aviator may press the update save (UPDT) button on the lower portion of the CDU. This action causes an aircraft position marker to be stored. The aviator may then, at his convenience, use pages 3-1 and 3-8 to return to the saved spatial situation on the map display and perform the update by slewing the map to its correct position (at the time of pressing the UPDT button) with reference to the saved position symbol.

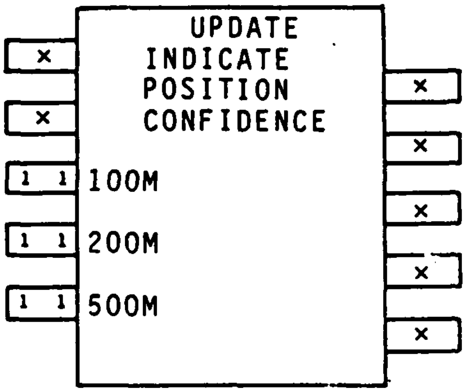


It is likely that the computations performed by the terrain correlation subsystem can be optimized if the probable accuracy of the update is entered. For

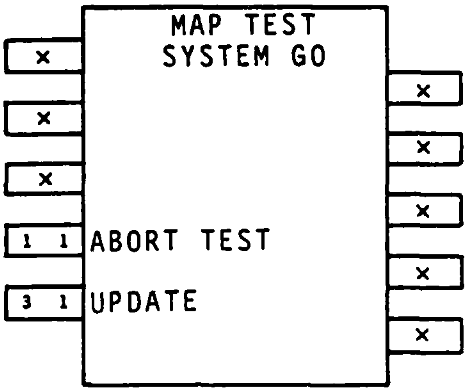
Figure 15. Slewing the map to update the aircraft position.

this reason, a position confidence page (3-2) appears on the CDU after an update by coordinates or map slewing. The aviator indicates the confidence he has in the update by pressing the key on this page that is labeled with the error range best associated with the update.

3-2



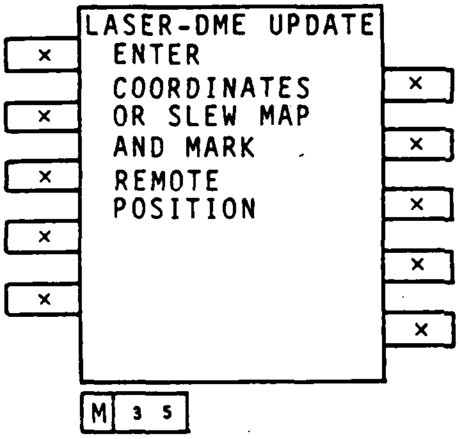
3-3



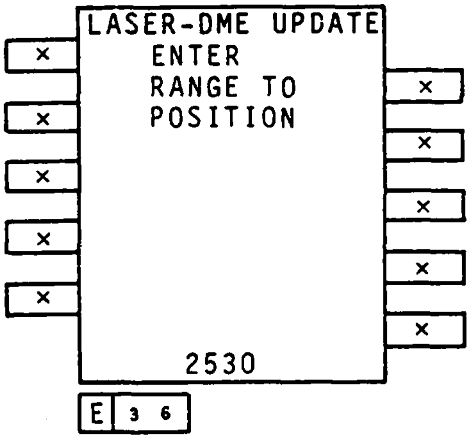
Also shown on the update page is the MAP TEST feature. Pressing the line select key beside this label initiates a series of computer self-checks that conclude with a GO or NO-GO message, as shown on page 3-3. The time required for the test is shown on the update page (10 seconds is hypothetical) to forewarn the aviator. Following test initiation, an "in-process" advisory is presented (instead of the "system go" message) and a test abort button is provided to allow resumption of normal operations should they be urgently required.

The LASER-DME page (3-4) permits the aviator to determine his position by specifying the range and bearing to a position that can be identified both on the map and in the terrain. Although an aviator could determine the bearing to a remote position and estimate its range for this type of update, range estimates are rarely accurate enough for this purpose. In aircraft equipped with a laser rangefinder, however, this type of update will be extremely precise. In non-threatening environments, aircraft with distance measuring equipment (DME) can achieve similar results with radio navigation aids. When the data are entered, a symbol appears on the screen to indicate the computed aircraft position. The aviator then has the option of updating his navigation system in accordance with this computation (page 3-7), or repeating the operation with another remote position to confirm the aircraft present position.

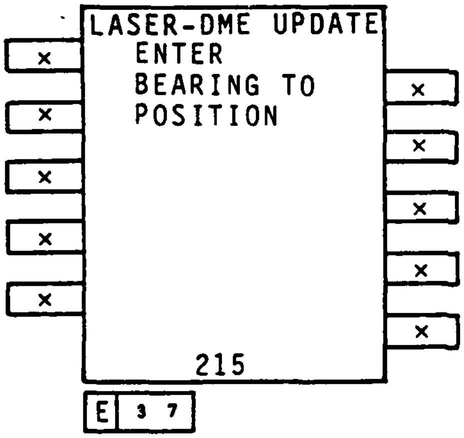
3-4



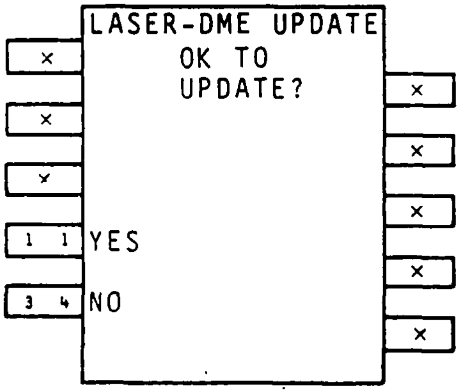
3-5



3-6

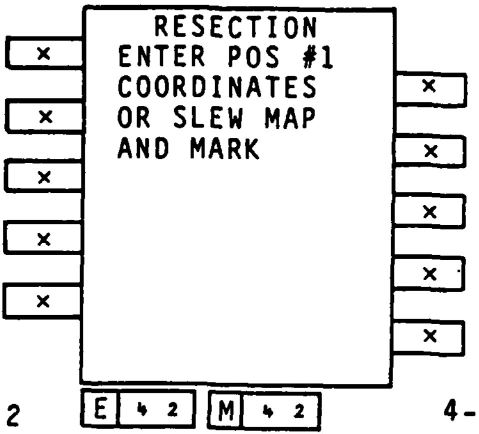


3-7

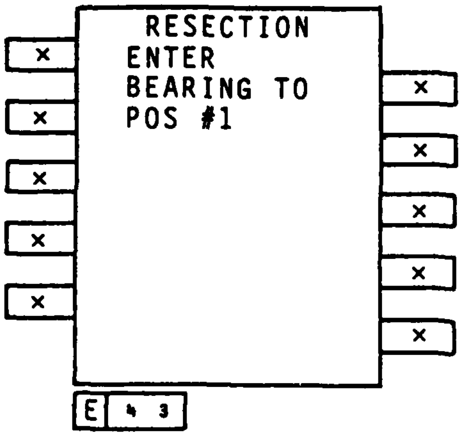


RESECTION is the location of one's own position by sighting on two known features. In this method of updating, the range to the remote positions is not required. After the required information is entered, a symbol appears on the map, as in the LASER-DME function.

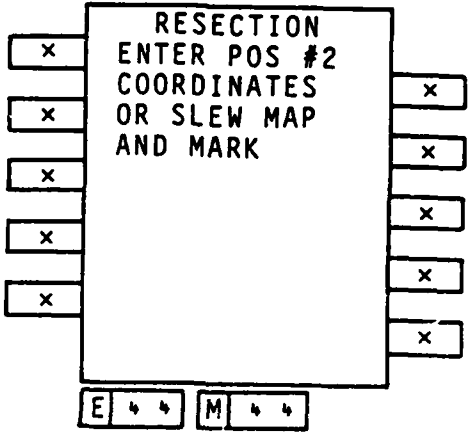
4-1



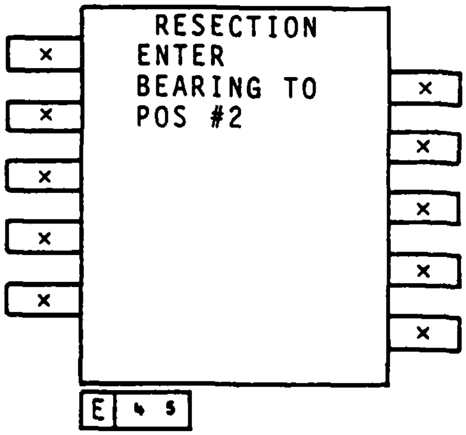
4-2



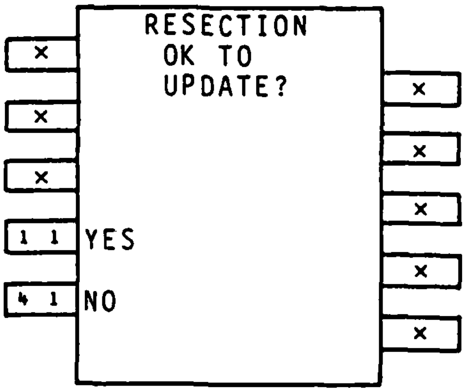
4-3



4-4



4-5



POSITION DESIGNATION

Requirements

All military activities are dependent upon the rapid and accurate transmission of geographic data. The determination, recording, and communication of position designations are continually recurring requirements for Army aviators. Examples include handing off targets, calling for artillery support, requesting tactical air strikes, gathering battlefield intelligence data, specifying rendezvous points, coordinating battle team operations, performing resection for navigation checks, and identifying LZs. Positional information is transmitted by simple grid coordinates, coded coordinates, preselected position code names, and range and bearing from known positions. Latitude and longitude is used for communicating positions to supporting tactical aircraft.

Another type of data often required regarding specific geographic positions is that of elevation. A primary use of elevation data is for terrain avoidance during conditions of limited visibility. Elevation data are also useful for navigation by terrain association through provisions of relative heights of groups of features seen in the terrain, and absolute heights of features near the aircraft. In addition, elevation data are useful in increasing the effectiveness of supporting artillery fire.

Position designation often includes the requirement for a graphic record of specific positions of features on the ground. These annotations serve as readily recognizable cues for mission activities, as well as a method of summarizing intelligence data in a concise manner. Although numerous annotations are provided prior to flight, many must be entered in the aircraft during performance of the mission.

Present Deficiencies

Present procedures for position designation are often awkward and inaccurate. For example, although the military grid reference system permits the location of a point within 10 meters, use of the system to this level of accuracy requires that a plastic coordinate scale be overlayed on the map. The recipient of these coordinates also must use the coordinate scale in order to plot the designated point on the map. Army aviators have found that the coordinate scale is unsuitable for use in flight, and almost never attempt to designate positions closer than the nearest 100 meters (six-digit grid coordinates). Even at this level of accuracy, it is commonly acknowledged that errors are made in determining the coordinates, communicating these coordinates, and in applying them to locate a point on the map. Similarly, without the use of a protractor and distance-scaled straight edge, it is difficult to determine or apply range and bearing information to designation positions on a map. Because these devices are also unsuitable for cockpit use, aviators simply make rough estimates of range and bearing--even in such critical applications as target hand-offs.

The use of the data on 1:50,000-scale topographic maps to convert between grid coordinates and latitude-longitude figures is difficult under any circumstances. In the helicopter cockpit, it is nearly impossible. Determination of elevations at specific positions requires that the aviator count up or down to the nearest index contour line and follow this line to a point where its elevation is given--an awkward and error-prone procedure.

IMPS Capabilities

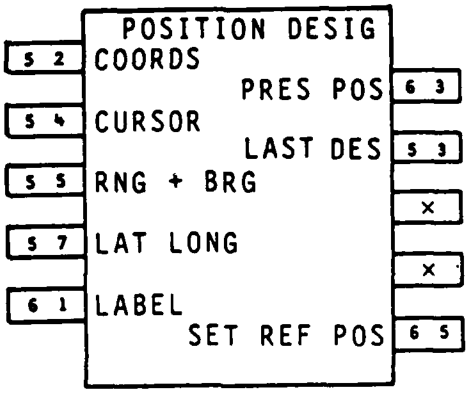
The IMPS computer is capable of speeding point designation, while improving accuracy and precision. Coordinates and elevation of any location on the display may be determined simply by positioning a cursor; or, keying in coordinates will result in a symbol appearing at the designated position. The designation of positions may also be achieved by entering range and bearing data or preselecting code names. The CDU also has provisions for annotating the map display, converting UTM coordinates to latitude and longitude, and computing range and bearing of positions from any site on the map display.

CDU Operation

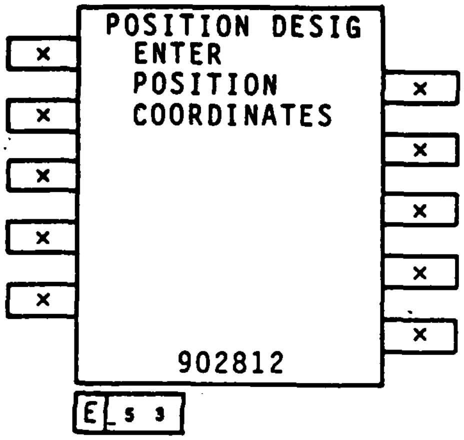
When the MENU page is displayed, pressing the line select key labeled POSITION DES calls the position designation page (5-1). The position designation page provides six options for the specification of positions: by coordinates, by cursor, by range and bearing, by latitude longitude, by label, and by present position. These options are selected by pressing the line select key beside the labels COORDS, CURSOR, RNG+BRG, LAT LONG, LABEL, or PRES POS, respectively.

When the COORDS button is pressed, the CDU provides a prompting message to "enter position coordinates" on the keyboard. The CDU will accept keypad entries of four, six, or eight digits. Page 5-2 shows that the aviator has keyed in the coordinates 902812. When the ENTER button is pressed, the position data page (5-3) appears. The position data page displays the grid zone designation (16S) and the 100,000-meter square identification (ES), information that is often required for communication with map users on the ground. Adjacent to these data are the grid coordinates, to six digits.

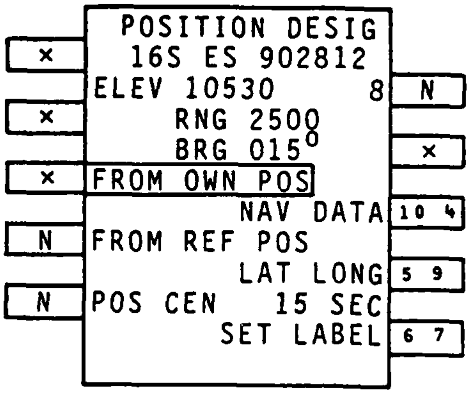
5-1



5-2



5-3



Eight digit coordinates may be obtained by pressing the button labeled "8". If this option is selected, the digit "6" replaces the "8" and the button can be used to recall the six-digit coordinates. Six-digit coordinates are produced through rounding rather than dropping digits.

Beneath the grid position data, the CDU shows the elevation of the position in meters, and the range and bearing of the position from the present position of the aircraft. Range and bearing are updated in real time. Numbers shall follow each other not faster than two per second. The position data on page 5-3 is extremely useful and may be referred to several times, interspersed with other CDU activities. To simplify the reacquisition of data on the most recently designated position, the LAST DES button on page 5-1 may be used to return to this data without repeating the position designation task.

If the aviator has previously entered a reference position (such as a gunship firing position), pressing the line select key labeled FROM REF POS will cause the

CDU to display range and bearing from the reference position, instead of from the aircraft's present position. Selection of this mode is indicated by reverse video of the FROM REF POS label. Entry of reference positions is discussed later in this section of the report. Use of the NAV DATA button on page 5-3 is also discussed later in the report. As the above information appears on the CDU, a position designation symbol appears on the map display, as shown in Figure 16.

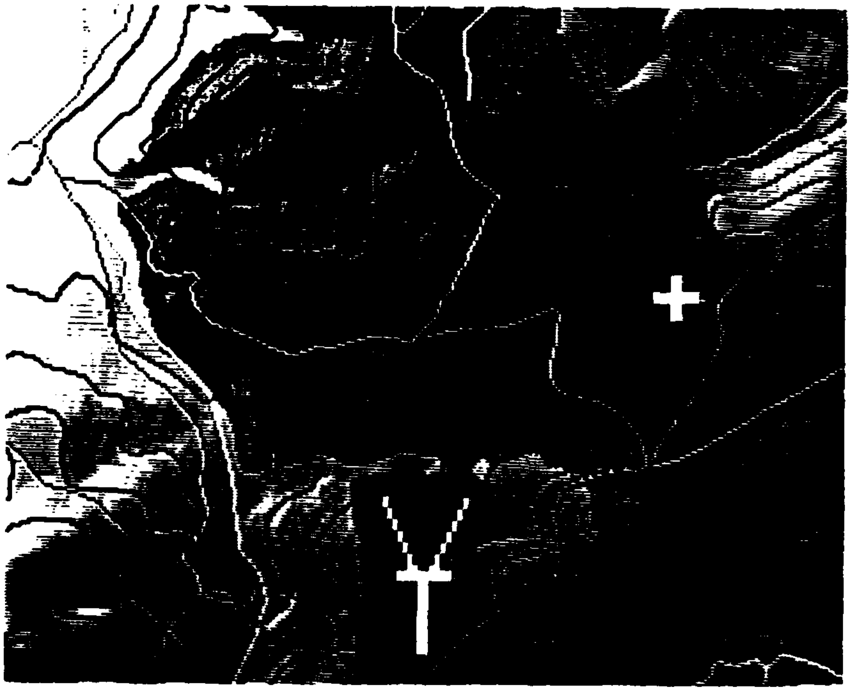
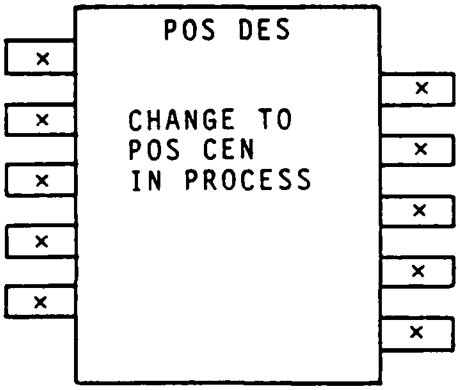


Figure 16. Position designation on the map display.

If the symbol is not present in the visible portion of the map display, the AHC may be used to slew the map as indicated by the range and bearing information on the CDU. Another alternative is to press the line select key labeled POS CEN (position center) to bring the selected position to the center of the display. This option functions in the same manner as the destination center feature described earlier in this report.

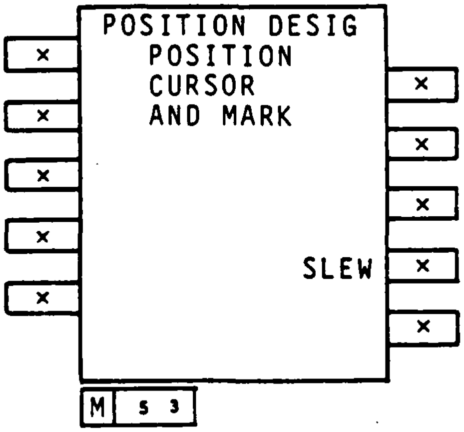
If use of the position center option will entail a time delay, an appropriate warning will accompany the POS CEN label, and an "in process" page (6-8) will be displayed during the delay.

6-8



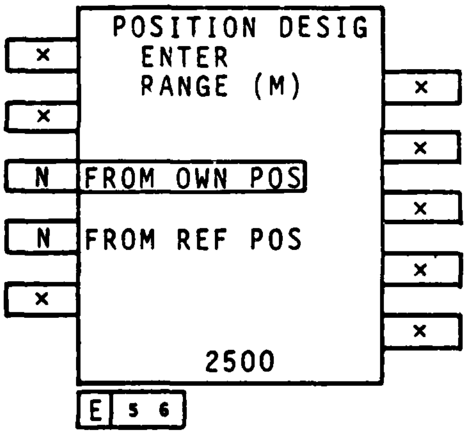
The second method of position designation is that of entry by cursor. This method is employed when the position of interest is visible on the map display, but its coordinates are unknown. When the line select key labeled CURSOR is pressed (5-1), the CDU provides the prompting message "position cursor and mark" (5-4). The aviator uses the AHC to move a cursor from the present position indicator to the position of interest. Pressing the SLEW button permits the AHC to move the map, rather than the cursor. A second press of the SLEW button reinstates cursor movement with the AHC. Pressing the MARK button causes the cursor to stabilize on the designated position (as in Figure 16) and the position data page to appear on the CDU.

5-4

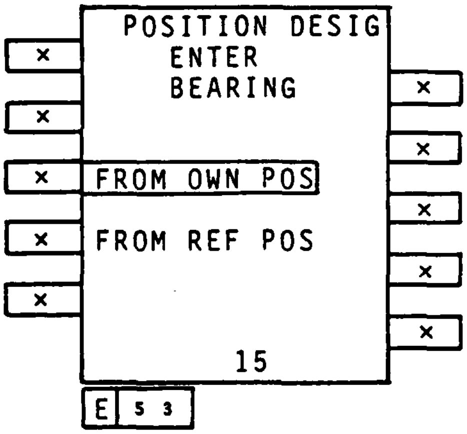


The third method of position designation is that of range and bearing entry, as shown on pages 5-5 and 5-6. This method may be used whenever the transmission of coordinates is undesirable, and may employ any reference position as the origin of the range and bearing data. Pressing the key labeled RNG+BRG causes the prompting message "enter range" to appear on the CDU. The system assumes that the range and bearing to be entered are from the aircraft's present position, as indicated by reverse video of the FROM OWN POS label. However, should the aviator receive (or wish to transmit) range and bearing information based on another reference position, he may press the key labeled FROM REF POS to enter the data. Entering the reference position is discussed subsequently in this section of the report. Once the range is entered, a prompting message requests entry of the bearing. Upon entry of the bearing, the position data page appears, just as in the previous two methods of position designation.

5-5

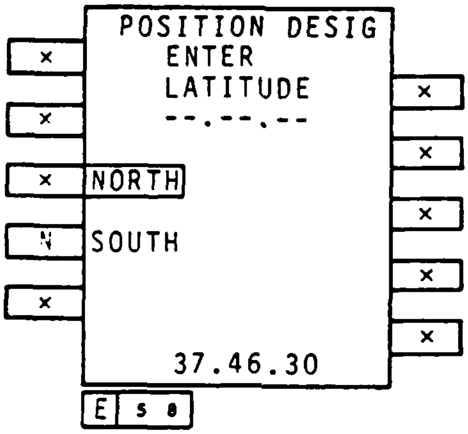


5-6

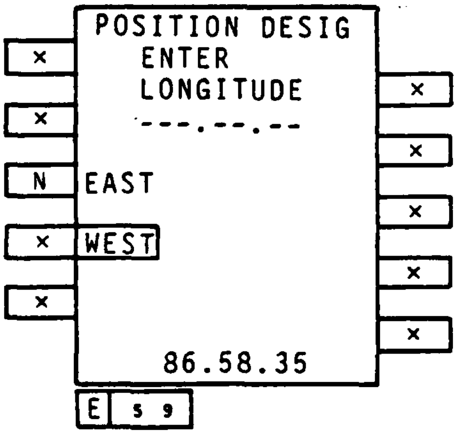


The fourth method of position designation is that of entry by latitude and longitude. When the LAT LONG button is pressed, on page 5-1, a prompting message (5-7) requests the aviator to enter latitude. The north-south selection is made by pressing the appropriate line select key and the degrees, minutes, and seconds (separated by decimal points) are entered by keypad. When the ENTER button is pressed, another prompting message (5-8) requests the longitude, which is entered in a manner similar to that of latitude entry. In order to reduce the number of required operations, settings for north or south and east or west remain unchanged from the last entry, unless the aviator selects such a change. Upon pressing the ENTER button, the position data page appears, just as in the previous five modes, except that UTM coordinates are replaced by latitude and longitude. Pressing the GRID button on page 5-9 converts the position data to UTM coordinates (5-3). Conversely, pressing the LAT LONG button on page 5-3 converts the position data to latitude and longitude.

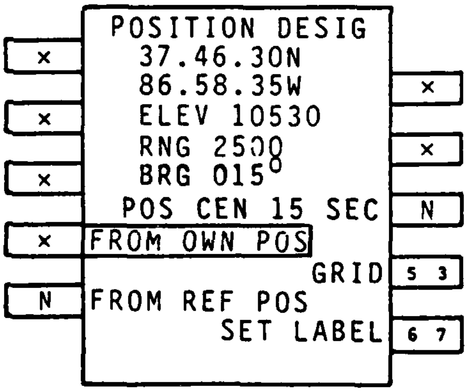
5-7



5-8

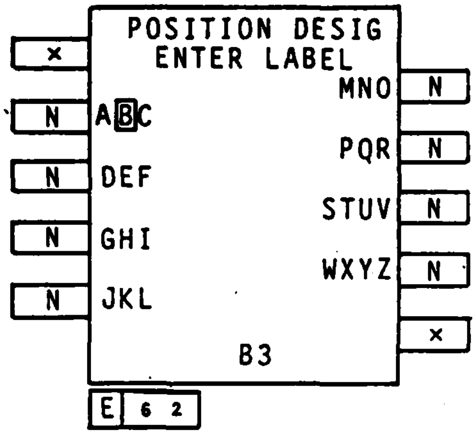


5-9

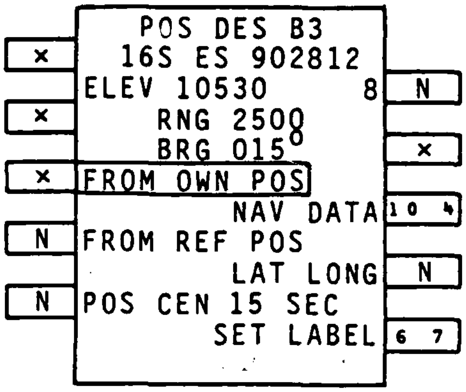


The fifth method of position designation is that of entry by label. Preselected geographic positions may be identified by an alpha-numeric code, such as "B3." Codes beginning with the letter A are used only with ACPs. Insertion of these coded positions will be discussed subsequently in this section of the report. When the LABEL line select key (on page 5-1) is pressed, the label entry page (6-1) is called. The alphabetic character is selected by pressing the line select key next to the desired letter. On the first press, the leftmost letter is highlighted by reverse video.

6-1



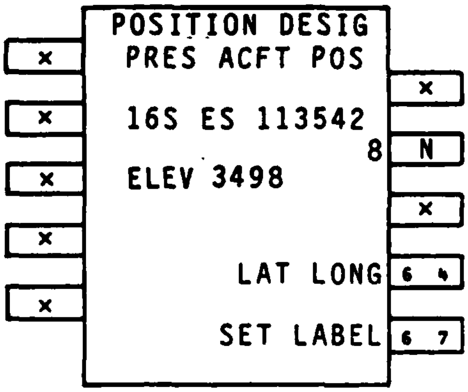
6-2



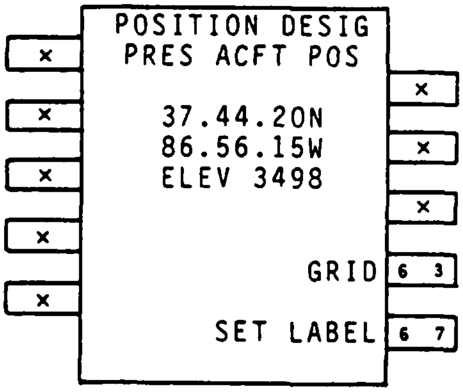
On each succeeding press, the next letter to the right is highlighted. The highlighted letter is also displayed in the scratch pad area. The associated number is entered via the keypad. When the ENTER button is pressed, the position data page appears just as in the other modes, except that the alphanumeric label is shown beside the page title (6-2).

The sixth method of position designation is that of present position entry. The only actuation required of the aviator is that of pressing the PRES POS key on page 5-1. The aircraft's present position coordinates and elevation are then displayed on page 6-3. The range and bearing data items are inapplicable and are eliminated from the position data page. Present position information may be interchanged between UTM coordinates at latitude-longitude data.

6-3

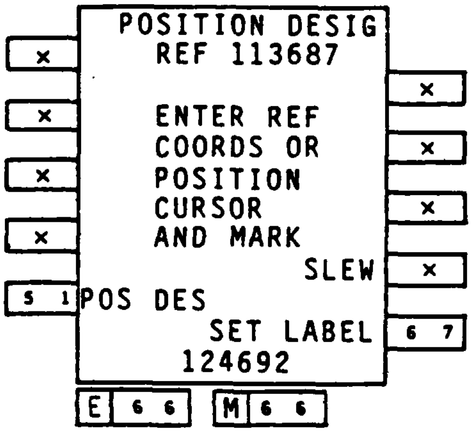


6-4

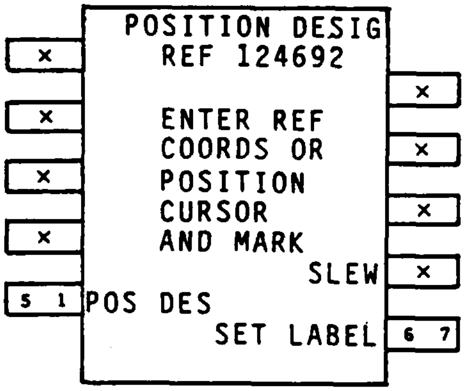


The position data page, in every case except present position mode, shows range and bearing data. This range and bearing may be either from the aircraft's present position or from some other reference position, at the aviator's option. Use of the reference position is particularly useful for target handoffs, where the reference position is the gunship's firing position. The reference position is also valuable for designating positions with reference to preselected checkpoints, objectives, or other features. Entry of the reference position is shown below.

6-5



6-6

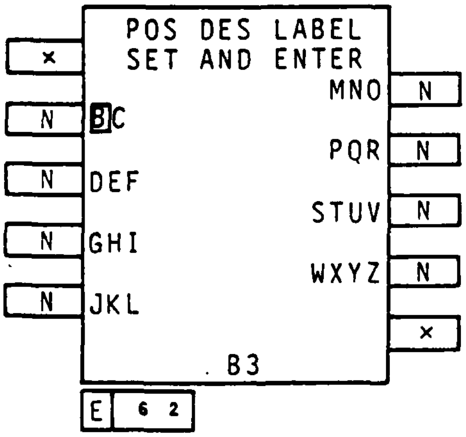


Pressing the line select key labeled SET REF POS on page 5-1 causes a prompting message to appear on page 6-5, indicating that the aviator may either enter the coordinates of the reference position, or use the AHC to position the cursor over the reference position and press the MARK button. The coordinates of the previously entered reference position are shown below the prompting message. If new coordinates are set on the keypad, they are shown in the scratch pad area until the ENTER button is pressed, when they replace the previously entered coordinates, and the scratch pad is cleared (page 6-6). Entries by cursor also result in display of new coordinates. The aviator is then provided with four options: he may enter another new reference position, press the key labeled POS DES to return to the position designation page, press the MENU button for access to any CDU function, or press the SET LABEL key to annotate the map.

Several of the CDU pages in the position designation (and other) parts of the IMPS dialogue include a SET LABEL function for map annotation. Map annotation is often, but not always, desired in the position designation mode. It would sometimes be convenient to have annotations automatically entered at each designated point, but records of every one of these points are not required and could lead to an undesirable level of map clutter, obscuring both terrain data and other more important symbols. On the other hand, some symbol must be introduced to show the location of designated points. In order to satisfy these conflicting demands, a temporary symbol (+) is used in the position designation mode. This symbol remains on the map display only until the MENU button is pressed.

If the aviator desires a "permanent" record of a position, he must enter a position label through use of the set label page (6-7). Alphanumeric codes are selected on this page in the same manner as described previously in the discussion of position designation by label entry. When the code is selected and the MARK button pressed, the + symbol defining the position previously designated changes to the selected code, such as "C1." This code is stored for later reference enroute. As described in the discussion of system components, the position log (POS LOG) button on the AHC provides an additional method of annotating the map display. The POS LOG button can be used in emergency situations to record the aircraft present with a single actuation.

6-7



At the end of the flight, these stored position labels and symbols are recorded on the tape cassette for later use in debriefing or subsequent flights.

If no further labels are required, the aviator presses the MENU button to prepare for other map functions. It is possible, however, that the aviator may wish to make a series of label entries while the system is in this mode. To meet this requirement, a + symbol appears at the center of the display after the first label entry. The AHC may be used to slew this symbol to any point on the display. The position label page may then be used, as described above, to enter alphanumeric codes replacing the + symbol. The CLR button, when pressed once, clears the numeric part of the code for a new entry, while leaving the alphabetic letter--thus speeding the entry of a series of codes of the same type (T1, T2, T3, etc.). An example of position labeling is shown in Figure 17. The FREEZE key may be used to stop map motion during this operation, if required.

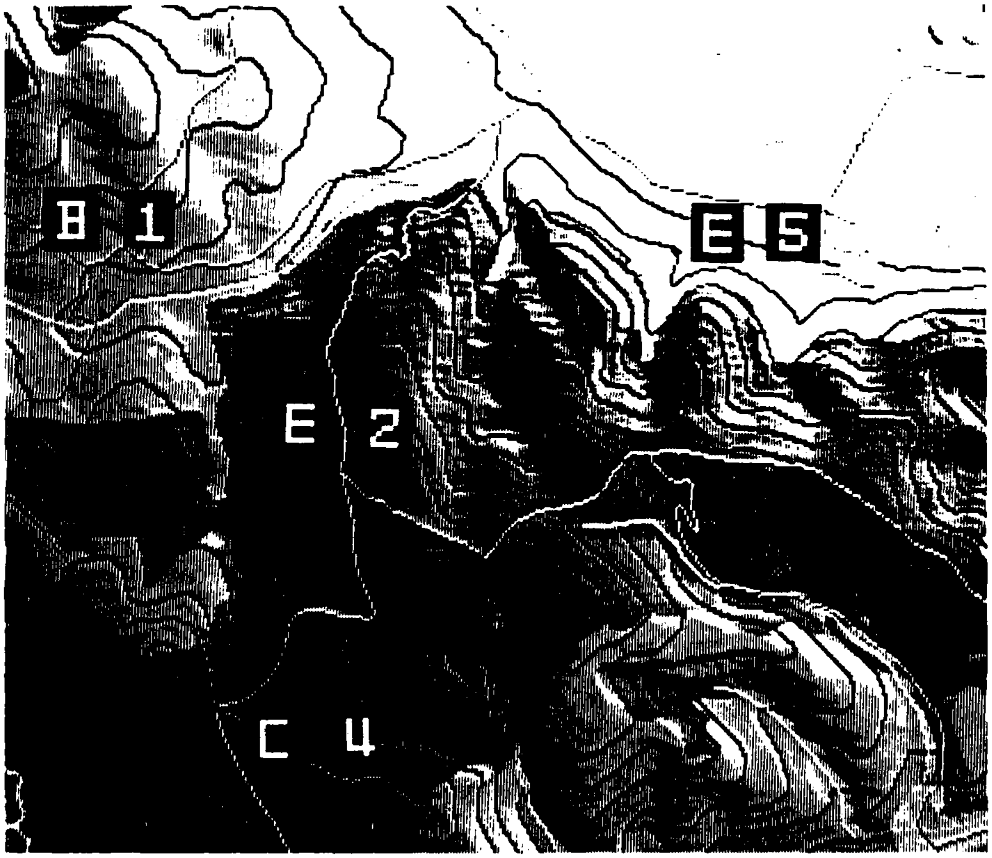


Figure 17. Example of position labeling.

MASKING AND INTERVISIBILITY

Requirements

The term "masking" refers collectively to cover from weapons fire and concealment from visual, optical, or electronic observation. Masking is the central objective of terrain flight, optical, or electronic observation. Masking is the central objective of terrain flight, whether of the NOE, contour, or low-level type. It is critical that the aviator be aware of the positions and altitudes at which masking is available. Helicopters exposed to the enemy for more than a few seconds are likely to be destroyed. However, NOE flight should be avoided when it is safe to do so because more sorties can be flown or greater distances covered using contour or low-level flight. In addition, higher altitudes provide a greater margin of safety in dealing with aircraft emergencies and hazard avoidance.

Masking considerations are crucial not only for the selection of flight altitudes and flight routes, but also for planning radio communications; determining enemy and friendly fields of fire; predicting checkpoint visibility; selecting LZs, rally points, pickup points, FARRPs, and other tactical sites; and determining one's own visibility to enemy forces.

Present Deficiencies

Although the importance of masking is clear, no practical methods of accurately determining the masked areas and altitudes from map study have been devised, except for the most obvious situations and solutions. For example, FM 1-1, Terrain Flying, offers only this advice on planning masked routes:

> To do this in mountainous or rolling terrain, plan the route on the friendly side and below the crest of a ridgeline. In very gently rolling terrain, plan the route across the low terrain such as stream beds where it does not serve as an avenue of approach to the enemy position. In arid or open areas, plan the route along stream beds or depressions where trees may exist.

Examination of standard topographic maps indicates that the masking determinations will often be considerably more complex. The procedure for manually plotting masked areas, based on a series of profiles, is described in FM 21-26, Map

Reading. This procedure entails an extremely time-consuming series of steps to plot the masked areas for even a relatively small geographical expanse. Such an approach is totally impractical for an aviator who needs to determine the masking available in broad and long flight corridors, with several known or suspected enemy positions in the area of operation.

IMPS Capabilities

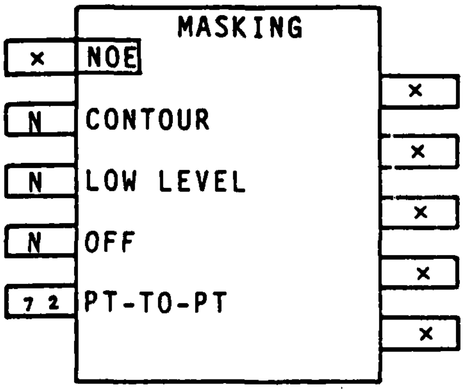
A computer-generated topographic display may perhaps make its greatest contribution in the computation of masked areas and altitudes for terrain flight. Such computations are relatively simple ones, but the requirement for hundreds or thousands of computations is the arena in which computers are most valuable and efficient. The IMPS system can quickly produce a plot of the areas visible and not visible to an observer or radar at the designated position.

A number of enemy positions could be designated, if desired, to depict the likelihood of being observed given the actual battlefield situation. It remains only for the aviator to choose the most direct path to this objective through the masked areas, and to select the shortest paths between masked areas when brief exposures are unavoidable. Similar computations may be performed to determine radio communication points, fields of fire, and the visibility of checkpoints or tactically important sites.

CDU Operation

When the MENU page is displayed, pressing the line select key labeled MASKING calls the masking page (7-1). The uppermost three keys on the masking page allow the aviator to select a display of masking available in the three

7-1



different flight modes: NOE, contour, or low-level. These modes are described in the introductory section of this report. The label of the line select key last pressed is shown in reverse video. This selection is also indicated next to the masking label on the MENU page as a reminder to the aviator.

Figure 18 shows a sample portion of a masking plot depicted on the map display. The horizontal bands show the area unmasked from enemy radar. The size of the unmasked areas varies with the altitude of the aircraft--the lower the altitude, the smaller the unmasked areas. Because it is not yet feasible to compute masked areas in real time, the computation of masked areas is done prior to the flight, at the mission-planning console, and is described subsequently in this section of the report.

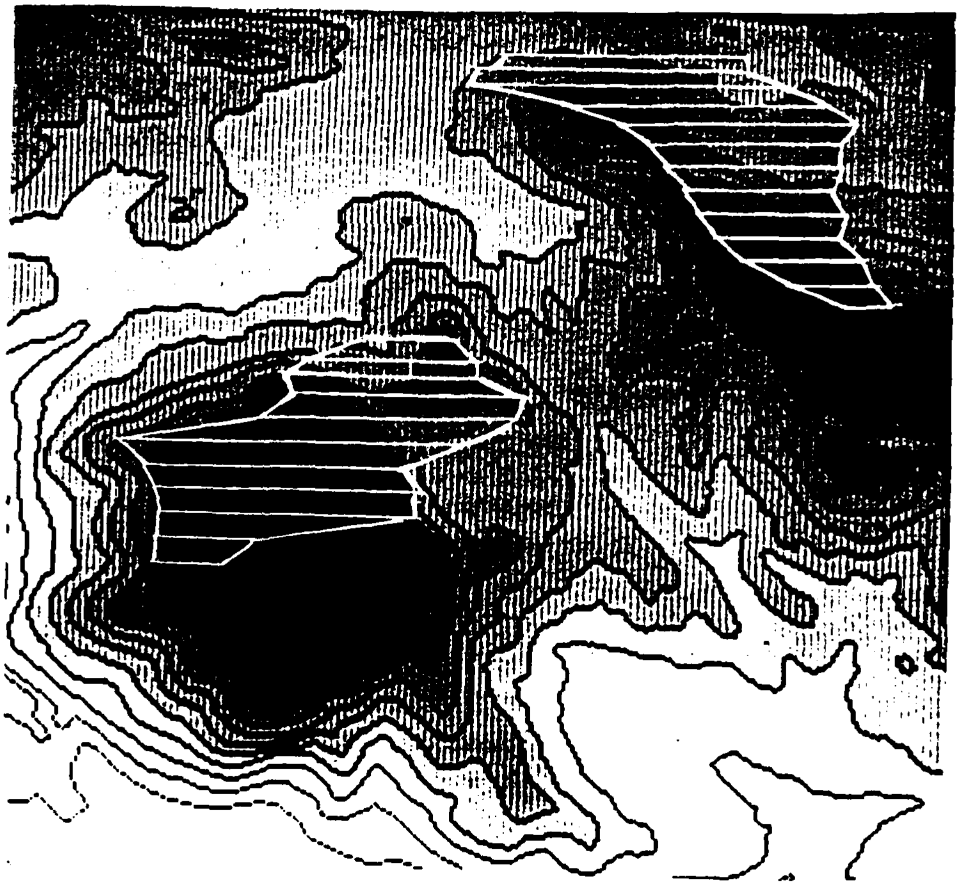
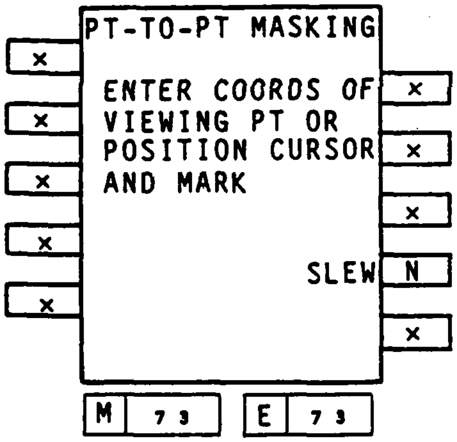


Figure 18. Examples of masking plots at NOE flight level.

Although the masked areas must be computed at the mission-planning console in the TOC, the aviator is able to compute intervisibility along a straight line while in flight. Selection of this option does not affect the display of masking plots. In order to exercise this capability, he presses the point-to-point (PT-TO-PT) button on page 7-1. The CDU first presents a prompting message (7-2) instructing the aviator to indicate the viewing point by entering coordinates or placing a cursor at the desired point on the map display. The AHC is used to move the cursor on the display, and the MARK button is pressed to place a + symbol on the indicated position. Map motion may be halted, if desired, by pressing the FREEZE button on the lower portion of the CDU. When the AHC is being used to drive the cursor, the map cannot be slewed. Pressing of the SLEW button permits map slewing via the AHC. The button may then be pressed again for additional cursor use. When in the slew mode, the SLEW button label is shown in reverse video.

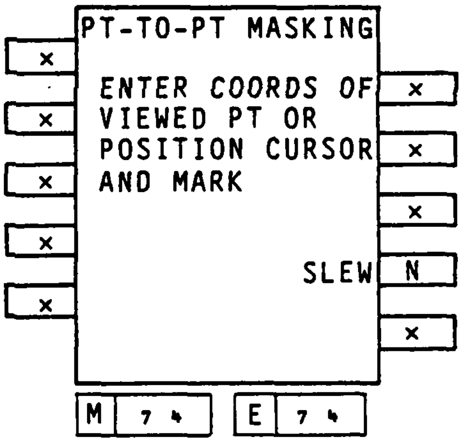
7-2



PT-TO-PT MASKING

ENTER COORDS OF
VIEWING PT OR
POSITION CURSOR
AND MARK

7-3

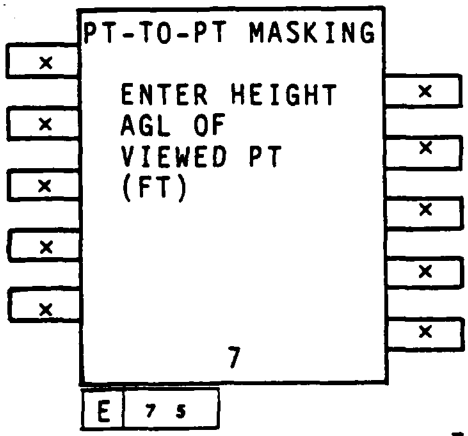


PT-TO-PT MASKING

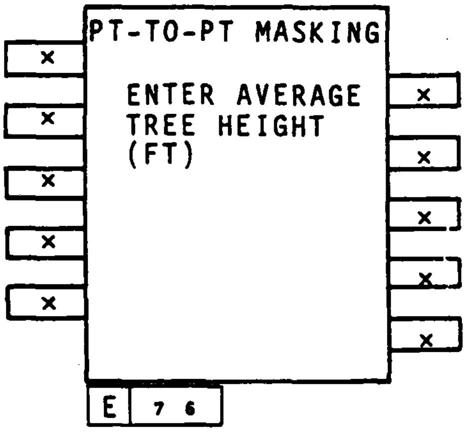
ENTER COORDS OF
VIEWED PT OR
POSITION CURSOR
AND MARK

After the viewing position is entered, page 7-3 instructs the aviator to enter the viewed point. After the second position has been marked, the aviator is instructed to enter the height (above ground level) of the viewed point and the average tree height (7-4 and 7-5). Following these entries, the masking data page (7-6) appears on the CDU.

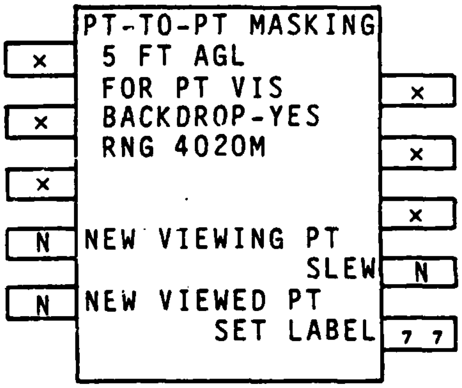
7-4



7-5



7-6



The masking data page indicates the required altitude above ground level (AGL) at the viewing point for visibility to the viewed point. In addition, this page shows whether or not the aircraft would have a terrain "backdrop" when hovering at the intervisibility altitude, and the range between the two positions. "Backdrop" is the case in which the line of sight from a viewed position is terminated by a landform (within the scene memory). The concept of the backdrop is illustrated in Figure 19. The line-of-sight from the tank to the aircraft in this figure is terminated by a landform. Thus, there is a terrain backdrop that greatly increases the difficulty of visually detecting the aircraft. If the aircraft rises to a greater altitude (as shown by the dashed aircraft outline), it would be silhouetted against the sky and would present a relatively easily detectable target to the enemy.

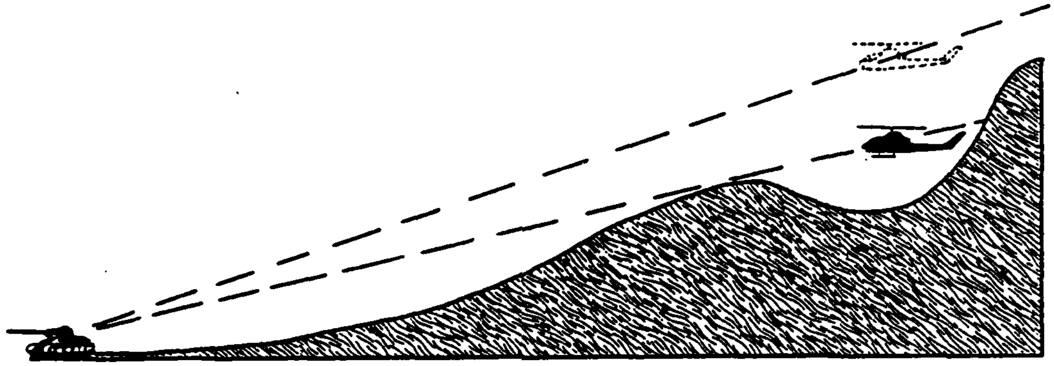
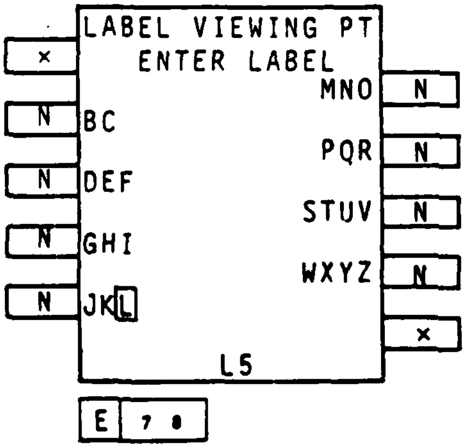


Figure 19. Examples of silhouetting and backdrop.

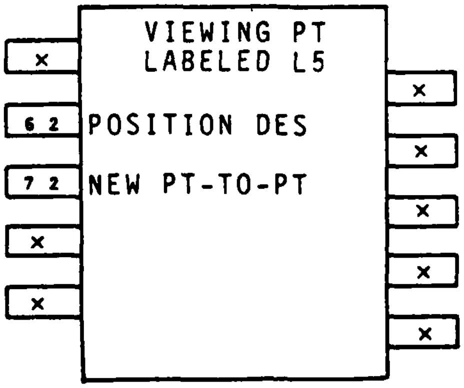
The NEW VIEWING PT and NEW VIEWED PT buttons permit the aviator to repeat the intervisibility computation with a change to only one of the two points. Following the depression of one of these buttons, a page identical to 7-2 or 7-3 appears in order to prompt the aviators. Subsequent to the entry, page 7-6 reappears.

The aviator may wish to annotate the map as a result of the point-to-point intervisibility computations. Annotations are entered in a manner similar to that employed in the position designation mode. When the ENTER button is depressed, the selected label will appear at the most recently designated viewer position. Additional labels may be entered by slewing the + symbol with the AHC and marking as described in the discussion of the position designation mode. If no additional labels are desired, the aviator may return to examination of intervisibility by pressing the PT-TO-PT button, or enter another mode by pressing the MENU button.

7-7



7-8



FEATURE SELECTION

Requirements

Because of the many different military activities supported by maps, it is very difficult to make generalizations about the types of features that should be shown on maps. Both the tactical situation and the geographic area determine the importance of various hydrographic, vegetation, and cultural features. If these features could become "key terrain" because of the tactical situation, or are by their nature good navigational checkpoints, they should be portrayed on the map. However, it is not possible to rank hydrographic, vegetation, and cultural features in order of their importance as key terrain or navigational checkpoints without very carefully defining the circumstances. Categories of features valuable in some situations are of little help in others. Although as many potentially useful features as possible should be portrayed, the density of features depicted on the map must not be so great as to create a "clutter" problem, with symbols crowded together, overlapping each other, and obscuring the basic landform contour information.

In order to correlate mission information with the topography in the area of operations, the Army aviator must heavily annotate his map, either directly or with a series of notes and overlays. Dozens of information items are absolutely required, and many more are extremely useful. Once again, it is important that the annotations and overlays do not obscure other important features on the map.

Present Deficiencies

Because of the high cost of producing paper maps, virtually all products of the Defense Mapping Agency are designed to serve the needs of several different classes of users. It would be impossible to produce maps with all information desired by all the potential users without cluttering the maps beyond the point of legibility. Consequently some compromises must be made in each map's information content, so that each class of user is likely to find the map deficient in some manner. Even a map designed specifically for Army aviators could not present all of the potentially useful topographic information because of the clutter problem, and the cartographer is forced to make judgments regarding the items of information best omitted. Paper maps must be oriented north-up to ensure legibility of alphanumerics and other symbols, although other orientations may be superior for navigation and planning purposes.

Aviators have found that direct annotations must be limited in number if the topographic information is not to be obscured, and that a limited amount of annotations are possible with overlays. Many annotations on a single overlay introduces unacceptable clutter, and attempting to use multiple overlays introduces the problems of positioning errors and lost time in overlay selection and alignment. In addition to the clutter problems, the aviators' attempts to copy tactical information from the situation map at the TOC (or from other aviators' maps) introduces two types of error--errors of inaccurate reproduction of the data, and errors of omission of critical items of information because their value is not immediately apparent.

IMPS Capabilities

The IMPS system permits the aviator to select any combination of topographic features and tactical information so that he may design an optimal map display for mission-planning and in-flight use, no matter what type of terrain or battlefield situation he encounters. Various overlays and annotations may be displayed at will or rapidly deleted to study the underlying topographic data. The point symbols created by the IMPS digital map generator are inset in the terrain data so that they are always upright, regardless of map rotation with aircraft heading. This technique provides optimal legibility of alphanumerics and other symbols with any map orientation. Because the aviator controls the feature selection rules, he is also in control of the density of displayed information and can prevent or eliminate disruptive clutter.

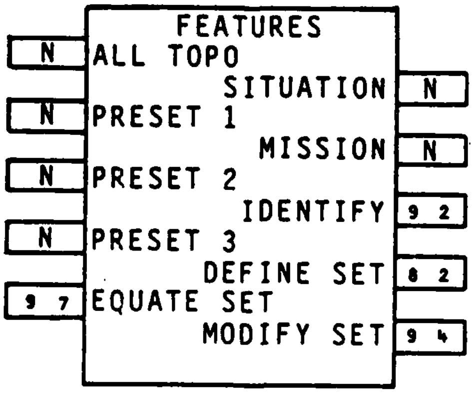
The battlefield situation data produced by the G2/S2 and G3/S3 is entered on the map cassette from a master tape at the TOC, so that the aviator is provided with the most recent data--and the time losses and errors accompanying manual reproducing of situation map data are eliminated. In addition, the problems of overlay selection, positioning, alignment, and smearing are avoided. Furthermore, the aviator may annotate the cassette with planned course lines, checkpoints, and other data, either at the mission-planning console or in the aircraft, and display this information at will. The IMPS system is also capable of providing the aviator with auxiliary descriptive data when needed, and otherwise limit alphanumeric information on the display. Just as grid coordinates and terrain elevations are available on demand, it is possible to query the system regarding other known characteristics of features, such as tree height and crown cover.

In summary, the IMPS system permits the aviator to tailor the feature selection rules to best suit his needs depending upon the type of terrain and the level of clutter acceptable on the display screen. This tailoring might take the form of selecting or eliminating an entire class of features. For example, all cultural features might be displayed in an area where their reliability is good, and no vegetation codes would be depicted where the vegetation patterns in the terrain are indiscriminable. More complex feature selection rules could be involved. The aviator can control the selection of specific features within a given class, such as displaying only the perennial drainage features and eliminating the intermittent streams. Like scale and contour interval selectability, feature selectability would permit the aviator to maximize the accuracy and utility of the terrain portrayal while minimizing the presence of irrelevant information and clutter on the display. The color plates following this page show examples of the addition of cultural, hydrographic, and vegetation features, as well as annotations with military point features.

CDU Operation

When the MENU page is displayed, pressing the line select key labeled FEATURES calls the feature selection page as shown below (8-1).

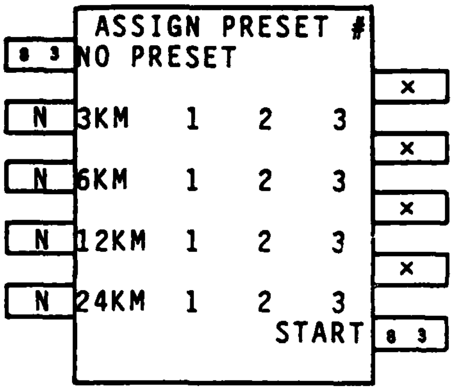
8-1



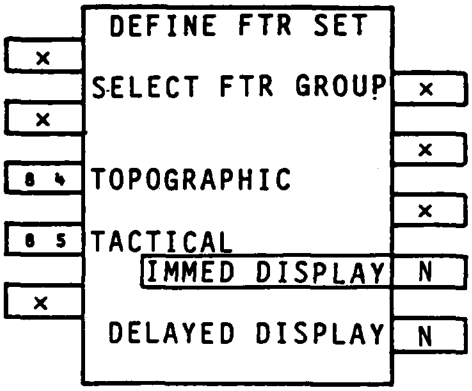
The ALL TOPO button permits display of all topographic features on the tape (Track 1 and 2). The SITUATION button permits display of all tactical data (Track 3), and the MISSION button permits display of all data entered by the individual aviator (Track 4). These three types of information may be selected or deselected in any combination. The PRESET buttons permit display of various combinations of topographic and tactical data, as desired by the aviator, or mandated by unit SOP. Use of a preset overrides the settings of the other buttons. The current setting is shown on page 1-1. If the aviator wishes to examine the features in a set, or to change them, the DEFINE SET button is pressed, and page 8-2 appears.

When the aviator plans to redefine the features in a preset, he may use page 8-2 to store the features in any (or all) of four map scales. If the aviator does not plan to store new features in a preset, but wishes to examine the feature lists or make temporary changes, the NO PRESET button is used. The sequence is initiated by stepping the reverse video across the page to the selected preset numbers and pressing START.

8-2



8-3



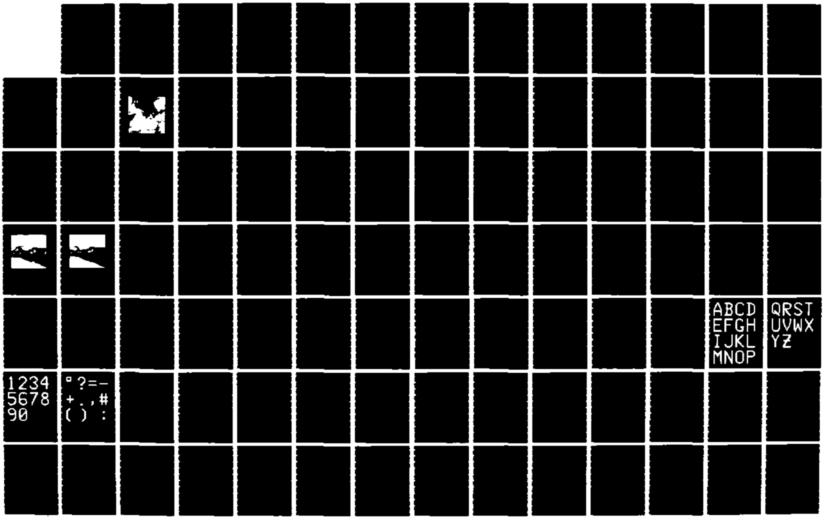
The aviator may wish to see features appear or disappear on the map as he makes the changes. If so, the IMMED DISPLAY option on page 8-3 is selected, and remains selected until manually changed to DELAYED DISPLAY. The disadvantage of the immediate display option is that several seconds may be required for each feature change. The delayed display mode makes all changes at once, at the end of the sequence (when the STORE button is pressed on page 8-4 or 8-5).

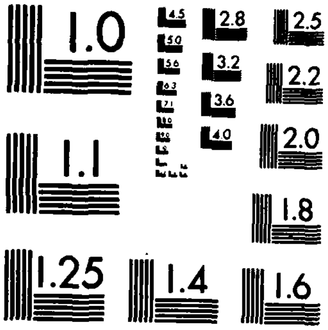
Slope-Shaded Terrain with Cultural Features

Slope-Shaded Terrain with Cultural and Point Features

AD-A136 909 THE INTEGRATED MISSION-PLANNING STATION: FUNCTIONAL 2/3
REQUIREMENTS AVIATOR-..(U) ANACAPA SCIENCES INC SANTA
BARBARA CA S P ROGERS AUG 83 475 DAAK80-81-C-0190

UNCLASSIFIED F/G 17/7 NL





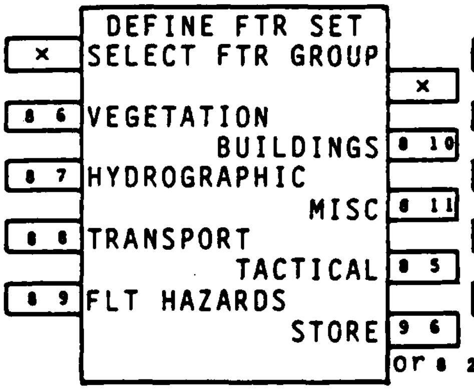
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Page 8-3 also provides the first choice in the hierarchical feature selection procedure--topographic or tactical data.

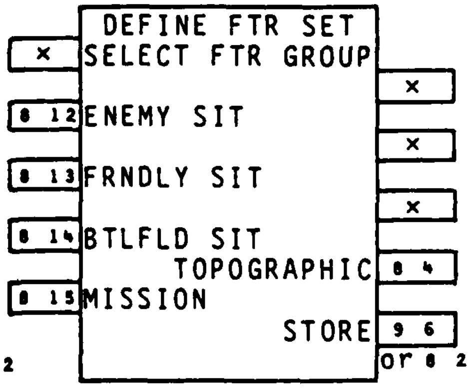
Pages 8-4 and 8-5 provide the second choice in the hierarchical procedure, as well as the ability to move from tactical to topographic categories. When a category is selected, such as TRANSPORT (page 8-8), the aviator may chose to have ALL, NONE, or PART of this data category. Previous selections for the current preset will be indicated by reverse video. Pressing the PART or LIST button calls the set of specific features (pages 8-20 and 8-21), and their present status is shown by means of reverse video. The LIST button is provided so that these specific features may be examined without changing the ALL or NONE settings, although use of the LIST button does not prevent changes from being made among the specific features displayed. In such a case, the system would present the resulting descriptor--ALL, NONE, or PART--in reverse video when the appropriate page was again displayed.

When the feature selection process is completed, the STORE button on page 8-4 or 8-5 may be used to end the sequence. If NO PRESET had been previously pressed but the aviator later decides to store the data, page 8-2 will appear for preset indication. In such a case, the START button is replaced by a STORE button. The entire set of CDU pages listing features is presented in Appendix 4.

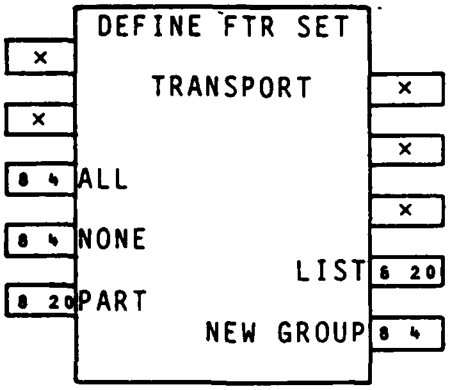
8-4



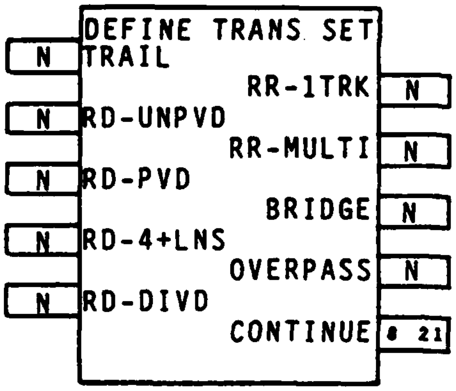
8-5



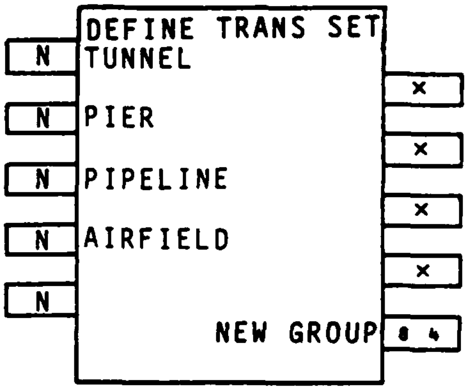
8-8



8-20

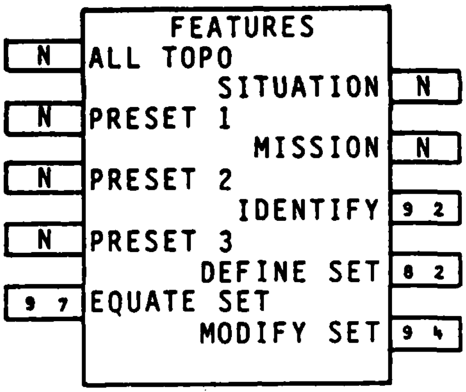


8-21

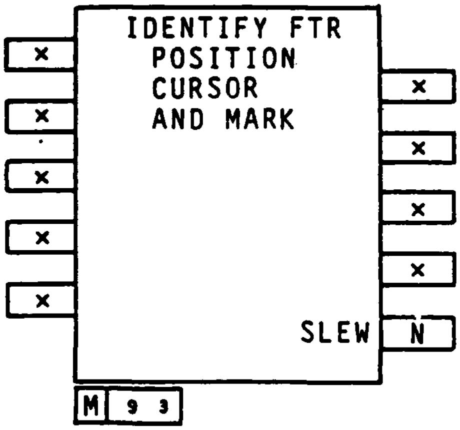


It is probable that digital terrain data bases will soon become extremely rich in content, so that more information will be available than can be simultaneously displayed. Such data bases are already in existence for limited geographic areas. When such rich data are available, the CDU can be used to interrogate the system regarding the characteristics of terrain features by pressing the IDENTIFY button shown on page 8-1. The CDU (page 9-2) instructs the aviator to position the cursor and press the MARK button to indicate the feature for which additional information is desired. In the example, the system has shown a vegetated area to be a stand of deciduous trees averaging 6 to 15 meters in height, with a 0 to 25 percent crown cover.

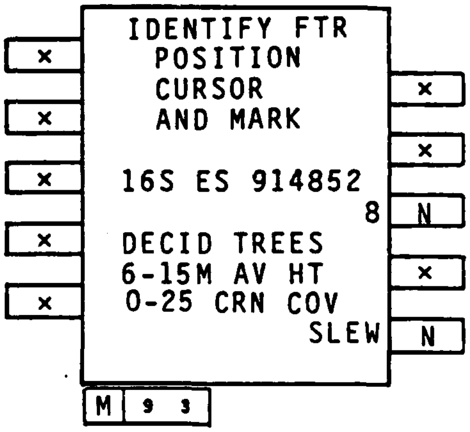
8-1



9-2

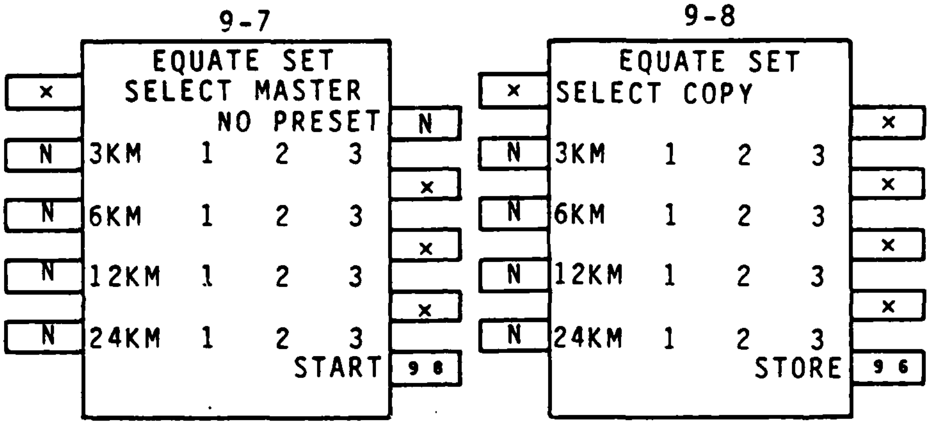


9-3



Employment of the MODIFY capability on page 8-1 requires that the aviator be provided with a card with a list of available features and a code number for each feature. As instructed by the CDU, the aviator enters the code number and then indicates whether the feature is to be added or deleted. The modified set may be stored if one of the presets has been previously selected. If a preset has not been selected, the STORE button is not present on page 9-5.

Once a feature set is defined, the aviator may subsequently decide to use the same features in another preset. The equate set feature, selected on page 8-1, is provided in order to permit such a transfer without completely reentering all of the features one by one. The master set is indicated on page 9-7 and the set to be equated to the master is selected on page 9-8.



The IMPS also provides a feature analogous to lifting up an overlay to study the underlying terrain data. This "declutter" (DCLT) option is selected by pressing a special-purpose pushbutton on the lower half of the CDU. This action deletes all track 3 and track 4 data from the map display. A second press of the DCLT button restores the deleted data.

FLIGHT PLAN

Requirements

After mission-planning tasks have been completed, the aviator must annotate his map with data to indicate the selected flight path to and from the objective and, in some cases, alternative routes to be used in the event of changes in the battlefield situation. The aviator normally annotates the map with air control points (ACPs) coincident with easily recognized terrain features. ACPs are often selected by unit commanders, and have the dual role of checkpoints and cues for some tasks, such as turning to a new general heading, communicating by radio, or changing from contour to NOE flight mode. Lines are usually drawn between the ACPs to define the legs of the flight, even though the actual flight path is a weaving one. The length of the legs is measured and the headings are determined by protractor (plotter). The length and heading data may be recorded on the map sheet or in some type of log or kneeboard.

When enroute, the ACPs and course line annotations are used to maintain the appropriate courses and airspeeds for successful performance of the mission. Frequent checks are made to determine the present position of the aircraft with reference to the ACPs, and to determine required changes in aircraft course and speed in order to arrive at ACPs or the objective on time. Timely arrival is particularly critical in crossing friendly lines at scheduled air passage points (to avoid friendly air defense artillery), in following a supporting artillery curtain along the flight route, and in massing for a surprise attack on enemy positions.

Present Deficiencies

Although paper maps are easily annotated, penciled-in lines tend to obscure topographic data, grease pencil annotations often smear, and acetate overlays may be difficult to keep in position. Measurement of the course line lengths and headings is somewhat clumsy, especially when contingency operations require that these tasks be performed at night. Determination of the appropriate headings and airspeeds for timely arrival at ACPs is inexact and inconvenient.

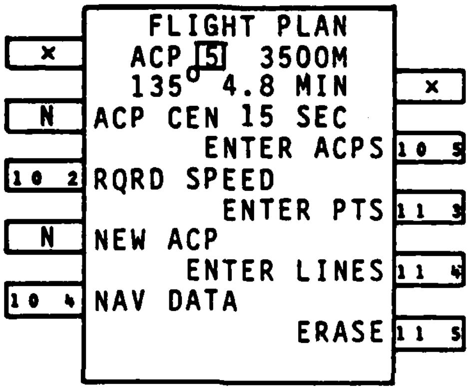
IMPS Capabilities

When it is possible for the aviator to report to the TOC for a pre-mission briefing, he will be able to use the special features of the IMPS ground-based system to perform mission-planning tasks. It is not unusual, however, for the aviator to receive fragmentary orders by radio. For this reason, the airborne IMPS system permits certain annotations to be made in the aircraft, including the entry of ACPs and the planned flight path. In flight, the IMPS system can provide the range and bearing of these ACPs on demand. In addition, the IMPS system can compute the time required to arrive at an ACP at current speed, or the speed required to arrive at a given time.

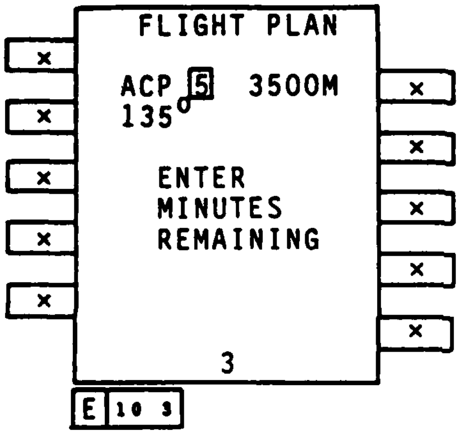
CDU Operation

When the MENU page is displayed, pressing the line select key labeled FLIGHT PLAN calls the flight plan page as shown below. The FLIGHT PLAN page shows the range, heading and time (at present speed) to the next ACP. The heading data accounts for wind drift angle, and the time assumes a direct flight path. Time is not shown if the aircraft is not moving. This range, heading, and time information is updated continuously.

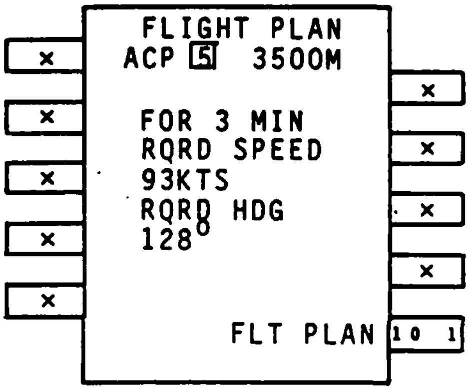
10-1



10-2



10-3

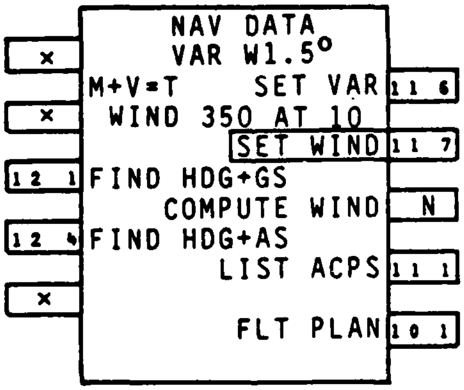


Because the aircraft will seldom fly in a straight line, the aviator will have to add some factor to the time advisory to account for the increment resulting from his flight mode and the terrain type. In some cases, however, meeting the arrival time requirements may be so critical as to necessitate flying in a path approximating a straight line. The required speed for this "dash" mode is displayed on the CDU when the aviator presses the RQRD SPEED key and enters the time remaining before arrival at the ACP, as shown on pages 10-2 and 10-3. Page 10-3 also displays the required heading, based on wind triangle computations. If no wind entry has been set or calculated on Page 10-4, zero wind is assumed. When the ACP is reached, the aviator selects a new ACP on page 10-1. The system could be programmed to simply step to the next ACP upon pressing this key, but an aviator entry permits the use of ACPs in any order--such as in reverse order for the return flight.

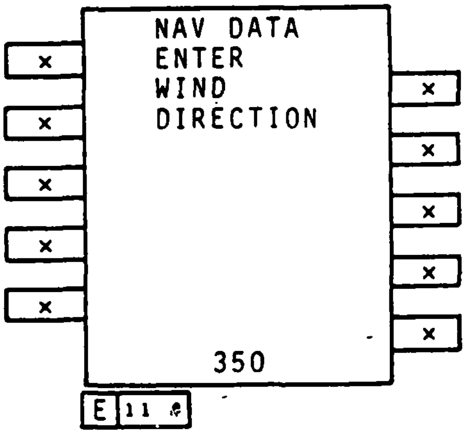
The ACP CEN key is used in a similar manner to the position center and destination center functions described in previous sections of this report. Pressing this key causes the designated ACP to appear at the center of the map display, and map motion is halted. The aircraft present position indicator moves toward an ACP symbol in accordance with the motion of the aircraft over the terrain. The map resumes its prior centered or decentered mode when the ACP CEN button is pressed again, or when other area selection buttons on page 2-6 are pressed. A time delay warning will be present on page 10-1 if use of the ACP CEN button would cause such a delay.

The NAV DATA page (10-4) shows magnetic variation, used for conversion from magnetic to true headings. The displayed variation is interpolated from ACP variations entered by the aviator, unless another variation is set through use of page 11-6. Ideally, variation data could be included on the cassette tape header. A reminder of the relationship of magnetic and true north shows M + V = T for west variation, and M - V = T for east variation. The wind direction and speed may be set by the aviator (pages 11-7 and 11-8) or automatically computed by the navigation system from differences in heading and airspeed vs. track and groundspeed. Reverse video shows which wind entry is in use.

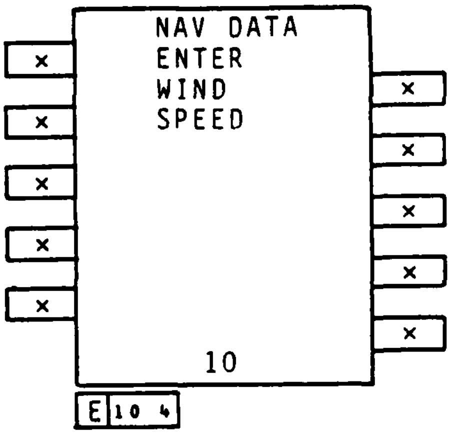
10-4



11-7

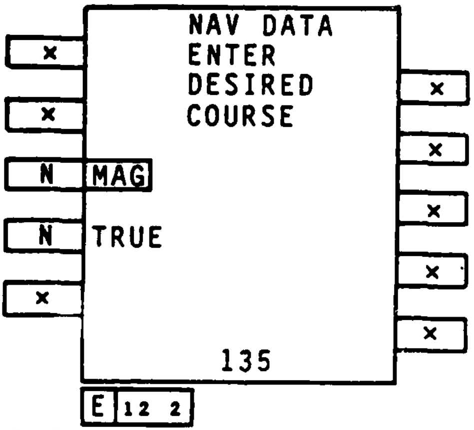


11-8

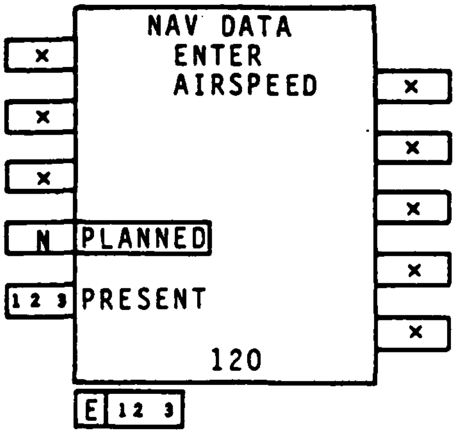


The NAV DATA page is also the initiation point for solving two of the most common wind triangle problems. The first problem is that of finding required heading and ground speed based on knowledge of desired course and planned or present air speed. Pages 12-1, 12-2, and 12-3 show the solution of this type of problem with the CDU.

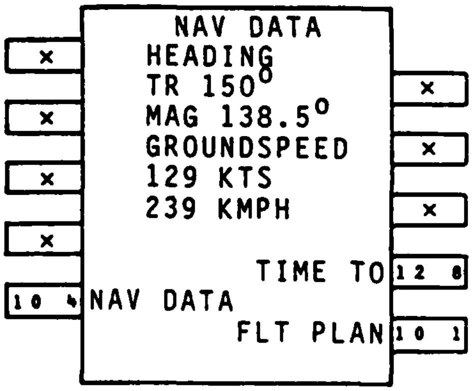
12-1



12-2

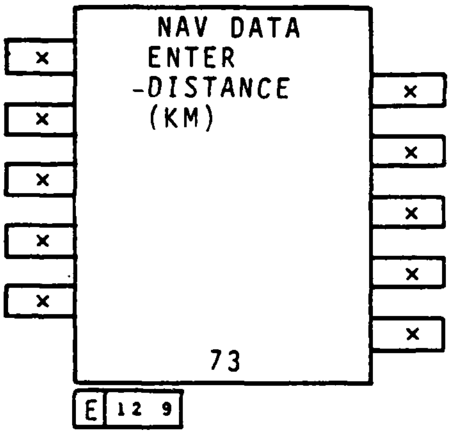


12-3

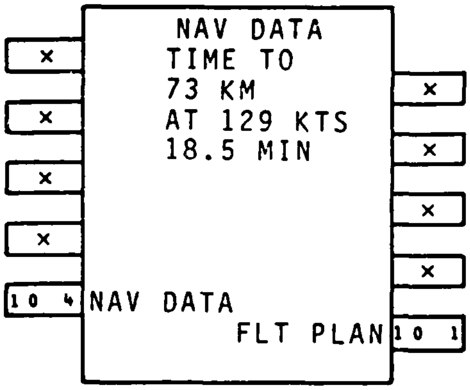


Aviators may enter magnetic or true desired course and use planned or present airspeed. The directional solution is given in both true and magnetic heading and the groundspeed solution is given both in nautical miles per hour and in kilometers per hour. The TIME TO button performs the time-distance calculation to points enroute (pages 12-8 and 12-9).

12-8

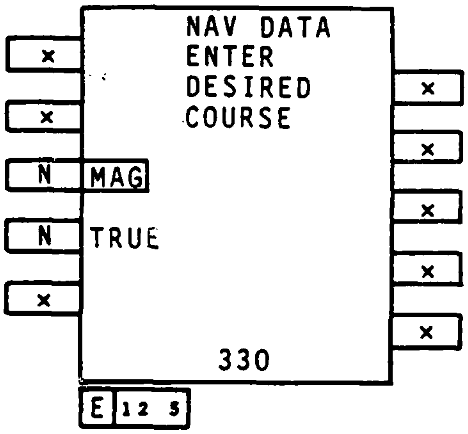


12-9

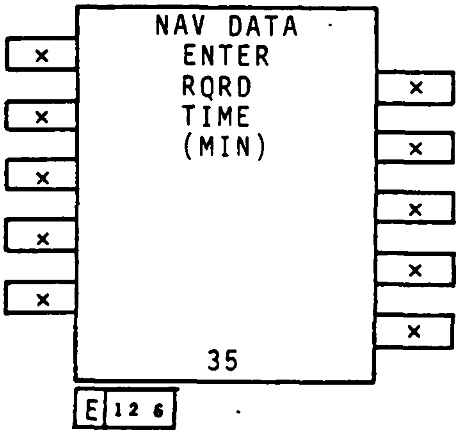


The second wind triangle problem is that of finding required heading and airspeed based on knowledge of desired course, time, and distance. Pages 12-4 through 12-7 show solution of this type of problem with the CDU.

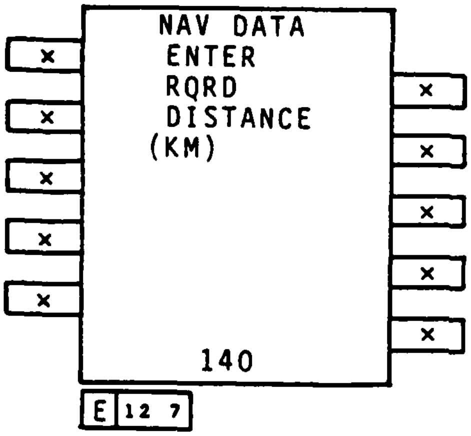
12-4



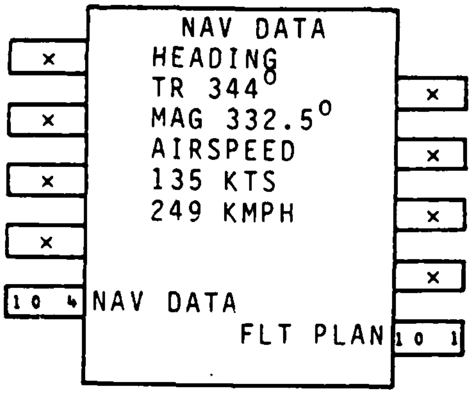
12-5



12-6

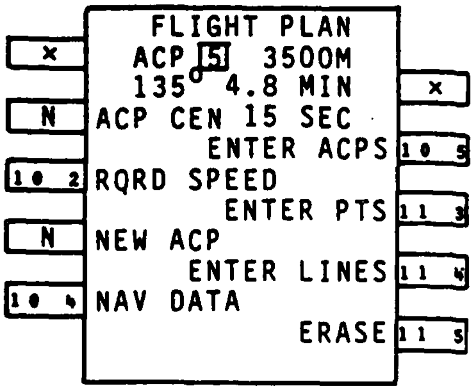


12-7

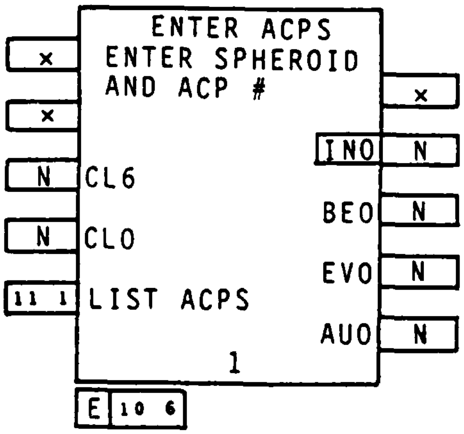


The flight plan page (10-1) is also used for activities preparatory to flight missions, specifically the entry of ACPs and the annotation of the map display with points and lines significant to the aviator. Entry of up to 20 ACPs is possible. Their entry automatically inserts labels at the designated positions. The labels shall be A0 through A19. The procedure for ACP entry is shown below.

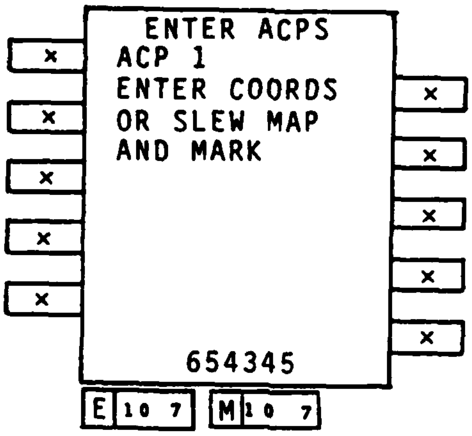
10-1



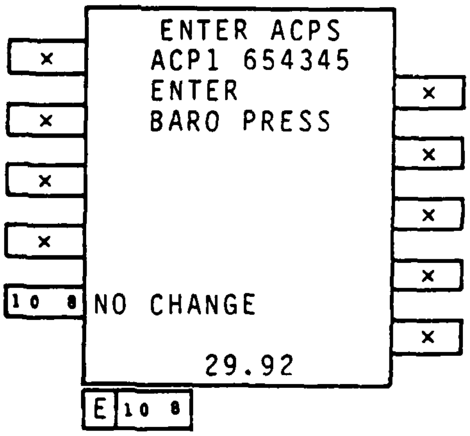
10-5



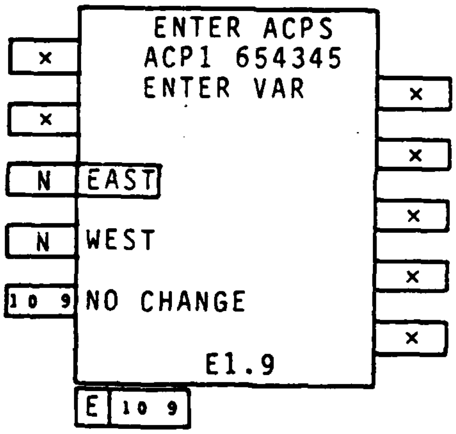
10-6



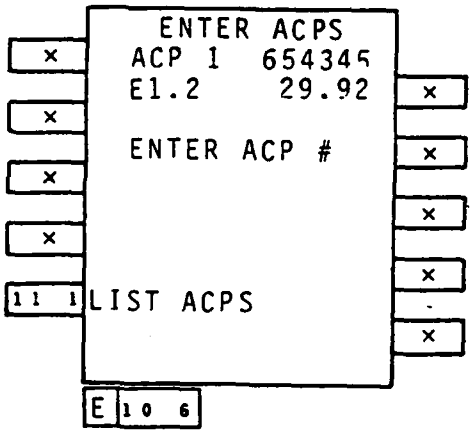
10-7



10-8



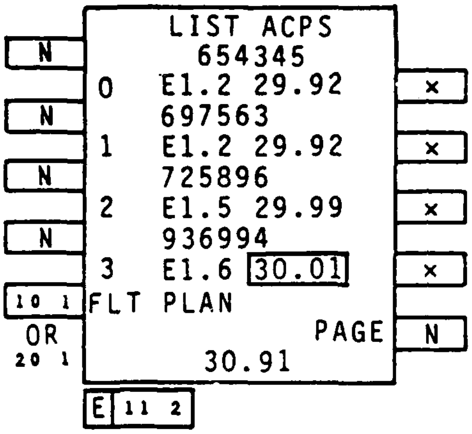
10-9



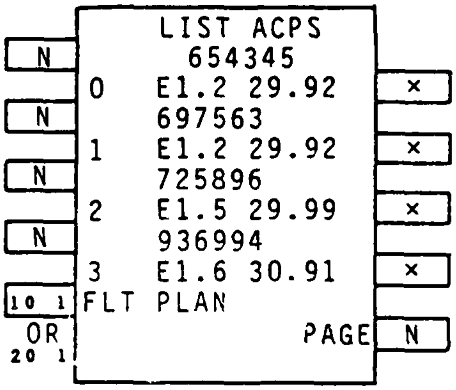
One page 10-6, spheroid entry for grid to latitude-longitude conversions remains as last set until change. ACP coordinates are entered automatically on page 10-6 if the ACP positions are designated by cursor and MARK button. If all of the ACPs share common barometric pressures and magnetic variations, the NO CHANGE button speeds entries.

A listing of all previously entered ACPs is available when the LIST ACPs button is pressed on page 10-4, 10-5, or 10-9. The LIST ACPs page, 11-1, is shown below.

11-1



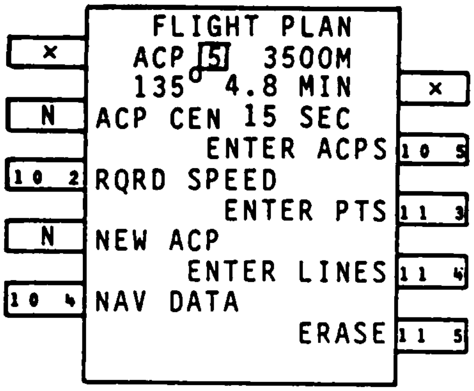
11-2



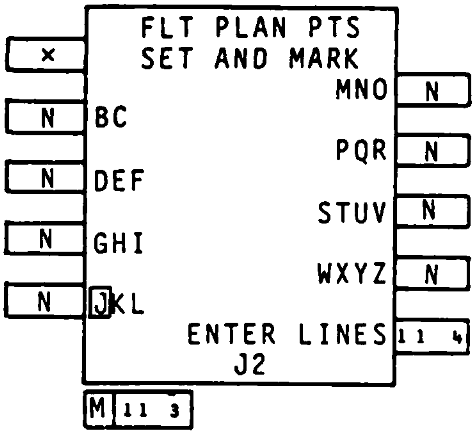
Listed ACPs may be modified by pressing buttons adjacent to their numbers, and stepping the reverse video across the coordinates, variation, and barometric pressure, and making changes with the keypad. If a new coordinate is entered, the related variation appears in reverse video, and if a new variation is entered, the related barometric pressure appears in reverse video. If either of these changes is undesired, the operator can use the line select keys to reverse video other data for change. If the ACP entry and list pages were reached from page 20-1, the lower left button on page 11-1 and 11-2 will read PILOT PLAN and their use will recall page 20-1.

The entry and erasure of flight plan points and lines is performed using the four pages shown on the following page.

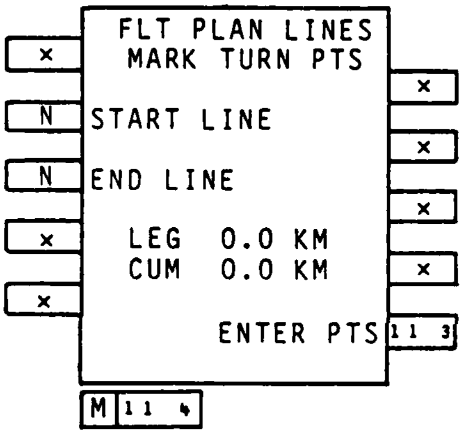
10-1



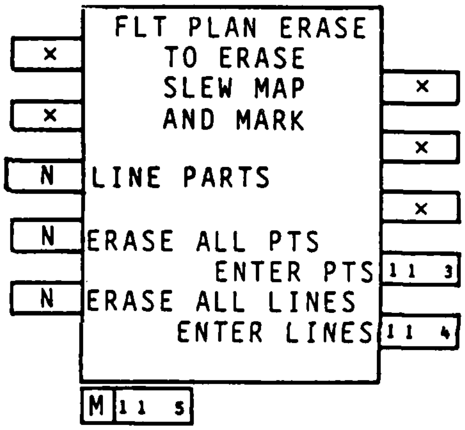
11-3



11-4



11-5



For point entry (page 11-3) the label selection is performed in the same manner as described in previous sections. The letter A is not shown because it is understood by the system to stand for ACP. During the marking of FLT PLAN PTS the use of the joystick causes the map to slew under the center marking position. Positions are designated for label entry by pressing the MARK button. Drawing lines between ACPs (or other types of lines) is initiated on page 10-1. The ENTER LINES key is pressed, pages 11-4 appears, the beginning point of a line is positioned under the centered cursor, and the START LINE button is pressed. The map is then slewed to bring the first turning point under the cursor, and the MARK button is pressed, causing a line to be drawn between the two points. The length of each line segment, or "leg", is shown during flight path entry. In addition, the cumulative flight path length is also displayed. The slew and mark operation is continued until the last point, where the aviator presses the key labeled END LINE. A virtue of this method is that it permits the aviator control over the complexity of the displayed route. He may use many turn points to approximate the actual flight path, or a few simply to connect the ACPs. Examples of point and line entries are shown in Figure 20.

Through the use of page 11-5, the aviator can erase points and lines entered on Track 4 by individually addressing them--slewing the map to center them and pressing the MARK button. This page automatically provides the RUB OUT erasure mode. RUB OUT is pixel-by-pixel erasure such as would be achieved with a pencil eraser. Touching any part of a point symbol, however, will eliminate the entire symbol. LINE PARTS is erasure of all interconnected parts of the same feature type. If only part of a line is to be eliminated, RUB OUT may be used to first indicate the bounds of the portion to be erased. All of the points or lines on Track 4 may be erased at once, if desired (although ACPs are not erased in this manner).

FLIGHT SIMULATION

Requirements

After performing the route-selection and map-annotation tasks, aviators will use any remaining map-study time to become familiar with the planned route. This familiarization often takes the form of a mission rehearsal and includes attempts to visualize the expected landforms, contemplate planned activities and contingency events enroute, and review the set of responses to these expected and unexpected events.

Present Deficiencies

Mission rehearsal with paper maps presents several problems. Many of these problems, such as the difficulties of contour interpretation, inability to select map scales or feature selection rules, and the near-impossibility of determining cover and concealment, have been discussed in other subsections of this report. Another deficiency in using paper maps is in the difficulty of determining the effects of wind speed and direction on aircraft flight, especially when the aviator must continuously change the heading of the aircraft during NOE flight.

Figure 20. An example of flight plan point and line entry.

IMPS Capabilities

The capabilities of the IMPS system to interact with the aviator and provide the desired map scales, features, contour visualization aids, and masking plots have been previously described. These capabilities are particularly valuable in the mission rehearsal activities because they assist in route familiarization without the presence of real-world terrain.

The IMPS flight simulation feature also enables the aviator to examine exactly what terrain depictions and areas will be shown on the color CRT during the mission, depending upon his control settings, by presenting a map display moving as if the aircraft were in flight. Movement of the map is based upon the route selected, the aircraft speed, and the wind speed and direction.

An additional benefit of the flight simulation feature is that it permits operation of all of the airborne controls and displays. Thus, part of the mission rehearsal activities may include practice with the IMPS control and display features both to review their characteristics, and to fine-tune their settings for the upcoming mission.

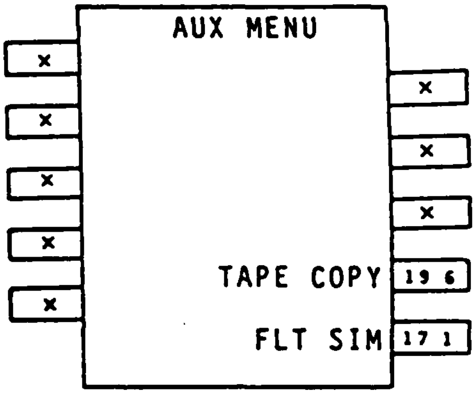
CDU Operation

The flight simulation feature is reached via the auxiliary (AUX) menu page. This page (13-1) provides the initiation point for eight different functions in the ground-based system, but only two, tape copy and flight simulation, are operational in the aircraft. Pressing the FLT SIM button calls pages 17-1 and 17-2, which request expected wind conditions. Subsequent pages request flight altitude (above ground level) and airspeed or groundspeed. Page 17-5 permits the aviator to select the type of simulated flight desired.

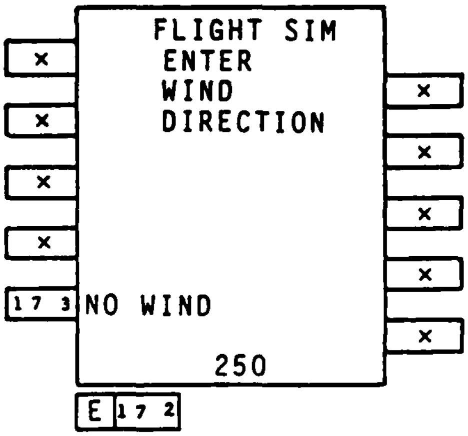
The aviator may choose to simulate direct flights between consecutive ACPs (ACP to ACP), to simulate the aircraft's flight along lines previously entered in the FLIGHT PLAN mode (FOLLOW PATH), or to use the AHC to manually direct the course of the aircraft during the simulation (MANUAL CONTR).

After the simulation mode is selected, the CDU prompts the aviator to designate the starting point on the map by cursor, coordinates, or ACP number (17-6). Following this designation, page 17-7 appears, permitting the aviator to

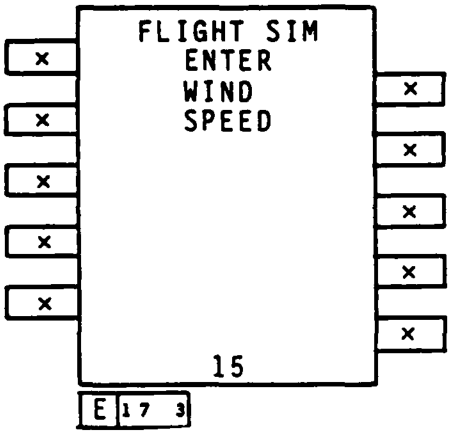
13-1



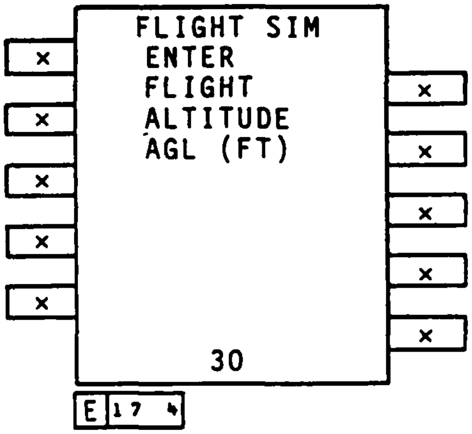
17-1



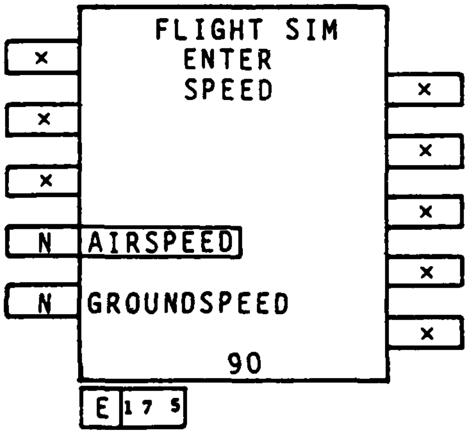
17-2



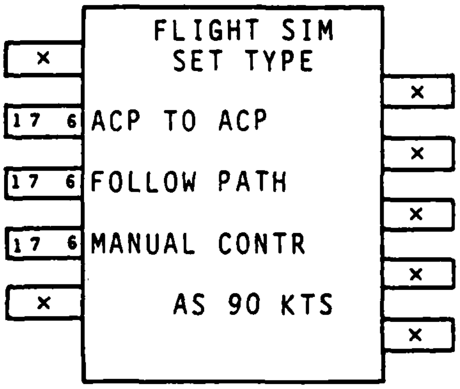
17-3



17-4



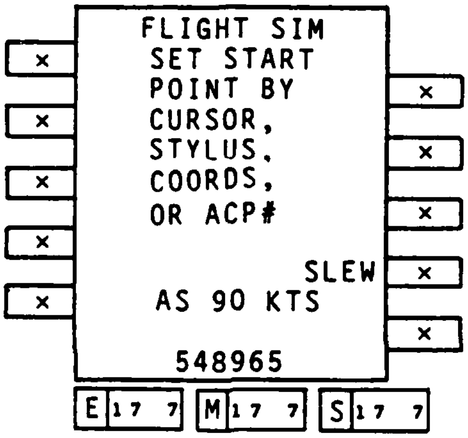
17-5



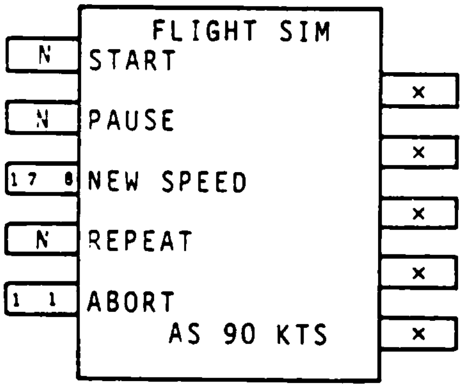
start the simulation, to pause at any time, to enter a revised flight speed, or to abort the simulation. Once a flight simulation has begun, the CDU system operates almost exactly as if the system were in flight. For example, the various orientation features may be selected, the flight plan page gives range and bearing to ACPs, and the map area selection becomes operational.

Selection of MANUAL CONTROL, however, does not permit the use of the primary menu because the AHC would be required to perform other tasks during conduct of the functions selectable on the primary menu.

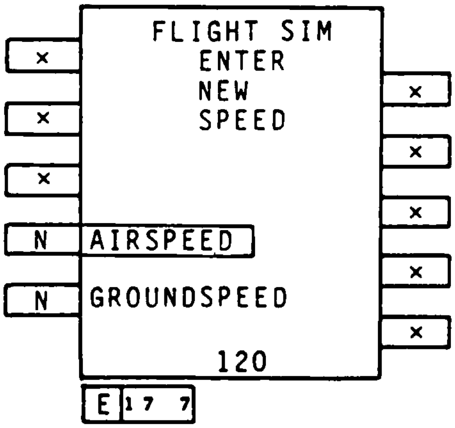
17-6



17-7



17-8



When a flight simulation is in progress, and the primary menu is in use, pressing the AUX button calls page 17-7. REPEAT causes the simulation to begin anew at the start point. NEW SPEED entries may be made without halting map motion.

TAPE COPYING

Requirements

Army aviators are expected to move rapidly over long distances in order to surprise the enemy and concentrate forces for decisive combat power. In order to perform their required missions, adequate maps are needed for flight to the new area of operations and additional maps and map overlays are needed to depict the battle area, the friendly and enemy situation, and other battlefield information.

Present Deficiencies

Obtaining the required large-scale paper maps for an area of operations has always been difficult for Army aviators, and the number of map sheets needed for a lengthy flight can cause significant map storage and handling problems in the cockpit. Obtaining and hand-copying suitable map overlays carries a penalty in lost time. Furthermore, the copied overlays are likely to be less accurate with each successive tracing, and critical information may be left out because its importance was not immediately obvious.

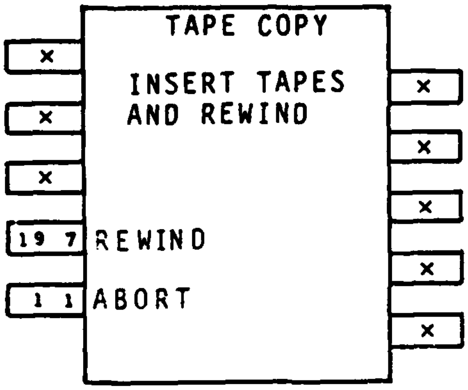
IMPS Capabilities

The IMPS system provides a tape-copying capability in each aircraft. The tape-copying feature permits extremely rapid transfer of error-free map and tactical overlay data from one cassette to another. Each cassette will contain map and overlay data for 100 x 100 kilometers--about 16 times the area shown on a standard 1:50,000 scale paper map. Prior to or upon arrival at a new area of operations, an aviator can borrow the required cassette and copy the data on a blank or previously used cassette. This method of dissemination can be used both for communication between superior and subordinate units and for ensuring that all aircraft in a unit have complete terrain and tactical data.

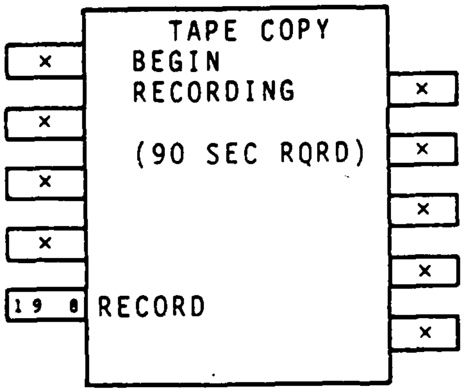
CDU Operation

The aviator is directed by page 19-6 to insert the master tape cassette and blank (or to-be-erased) tape cassette and rewind them. Recording is begun by pressing the RECORD button on page 19-7 and an "in-process" message is displayed until the recording is completed.

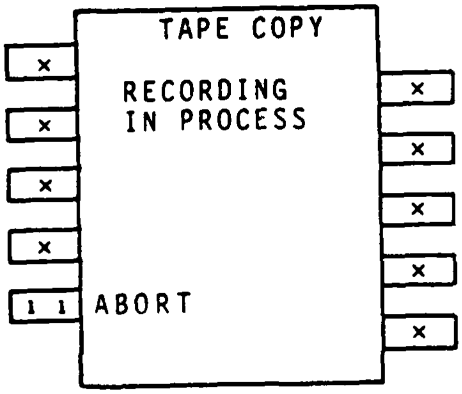
19-6



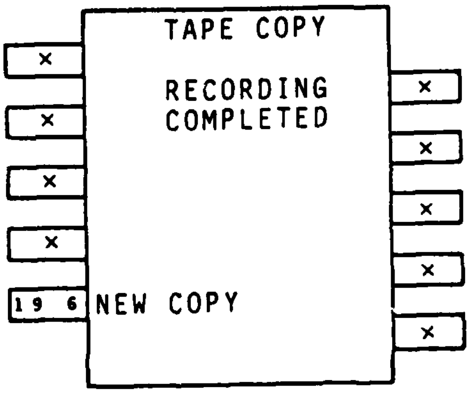
19-7



19-8



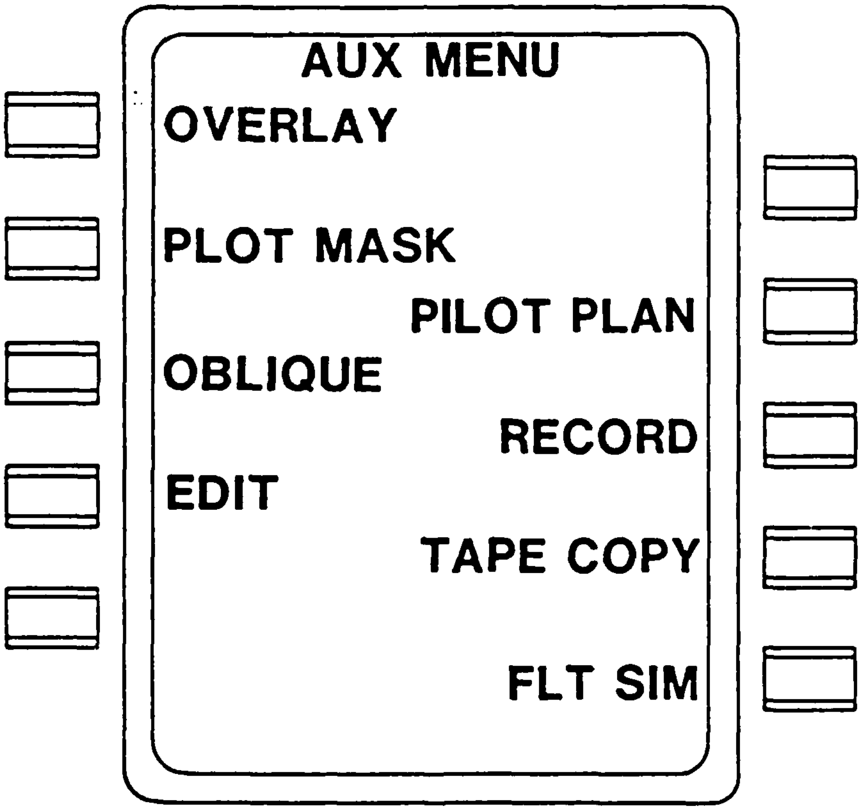
19-9



OPERATION OF THE GROUND-BASED SYSTEM

This section of the report describes the procedures employed in operation of the ground-based portion of the IMPS system. All of the functions performed by the airborne system are provided. In addition, the IMPS provides six sets of special functions important for mission planning. The requirements for each set of functions and the present deficiencies in providing these functions are briefly described, followed by short discussions of the capabilities of the IMPS system for meeting the requirements and overcoming the deficiencies. Once again, the specific procedures for operation of the system are presented by showing the progression of pages on the CDU.

The primary menu page is identical to that used in the aircraft, and the additional functions are initiated on the auxiliary menu page (13-1).



In the subsequent paragraphs, operational procedures are described for the following special IMPS functions:

Overlay Entry and Editing
Masking Plot Construction
Oblique View Construction
Pilot Plan Annotations

OVERLAY ENTRY AND EDITING

Requirements

One of the central activities at a tactical operations center (TOC) is the maintenance of well-edited situation boards and associated special overlays showing such data as enemy situation, friendly situation, fuel and armament locations, hazards and obstacles, battle positions, assembly areas, radar coverage charts, artillery target points, and the scheme of maneuver for operations. Some of these data are from combat information--raw data used for fire and maneuver as received, without interpretation or integration with other data. Another portion of these data are *intelligence--data that have been* analyzed, validated, or integrated with other data. Much of the information is operations data, either locally generated or received from superior or supported units.

Any of these types of information may be critical to successful military operations and must be supplied to aviators in accordance with their requirements for specific mission data.

Present Deficiencies

The primary deficiency in dealing with combat information, intelligence, and operations data is in conveying the critical information to those who need it most--aviators who must perform combat missions. The TOC typically has far more information than the aviator can use for a given mission and selecting just the important information items is a time-consuming task, whether it is performed by TOC personnel or the individual aviators. The situation board overlays are too large and often too cluttered for in-flight use. When portions of these data are copied for specific missions, however, two types of errors are introduced: errors of inaccurate data reproduction, and errors of omission of critical data. In addition, as previously discussed, overlay use presents problems in the aircraft, especially if multiple overlays are required for presentation of all of the useful information.

IMPS Capabilities

The IMPS system permits the storage and selective display of many types of digital overlays. These data bases may be updated rapidly by several types of entry devices. A keyboard, keypad, touch-sensitive screen, or joystick and cursor may be used to enter and erase features in the various data bases. A special tablet for map overlay digitization is also provided.

Any of the data base overlays generated by the IMPS can be selected or deleted in the cockpit by pressing line select keys. Thus, the problems of handling multiple acetate overlays and obscuration of topographic data during flight are eliminated. Furthermore, the IMPS editing capability significantly increases the likelihood that aviators will be provided with the most current, accurate, and complete information available.

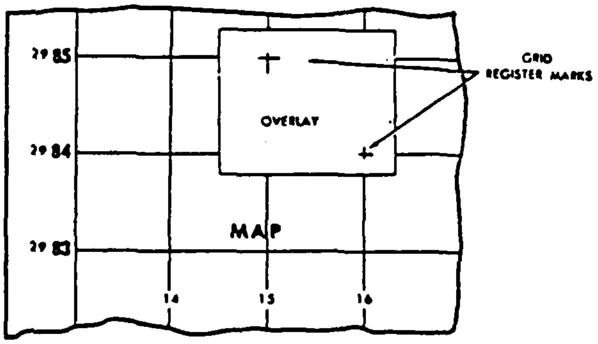
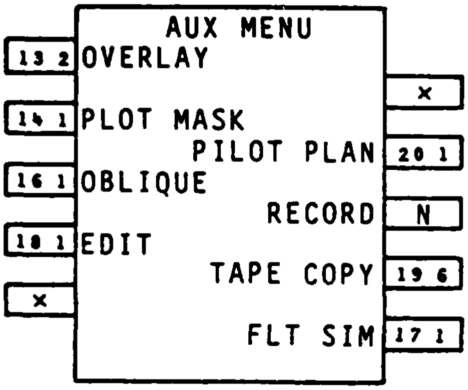


Figure 21. Overlay and grid register marks.

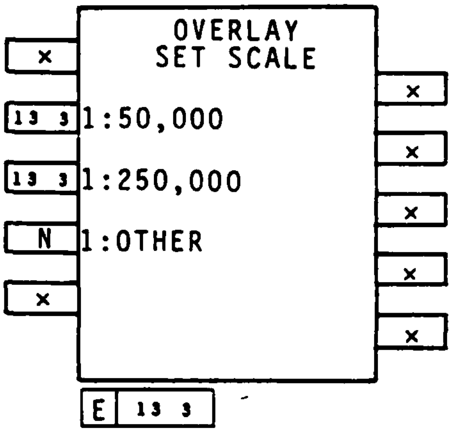
CDU Operation

Pressing the OVERLAY button on page 13-1 presents the aviator with a series of prompting messages as shown on pages 13-2 through 13-9. First, the aviator is directed to set the scale of the map or overlay, 1:50,000; 1:250,000; or 1:"OTHER". The "OTHER" setting permits the aviator to input unusual scales with the keypad. Next, the aviator is directed to place the map or overlay north-up on

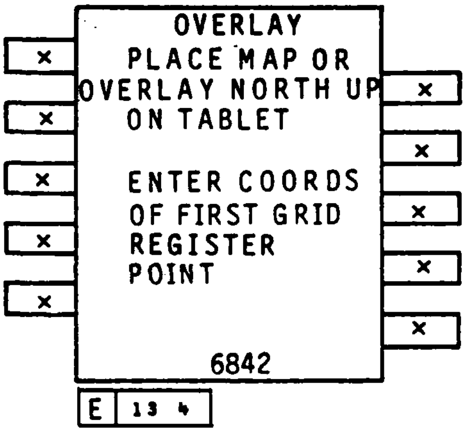
13-1



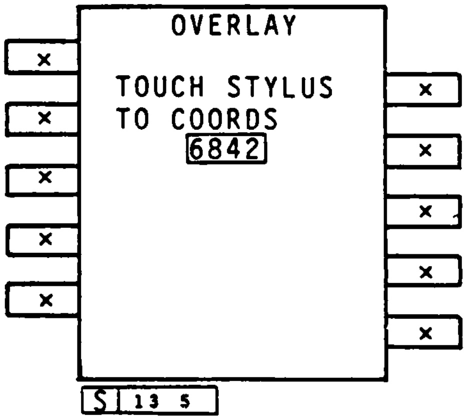
13-2



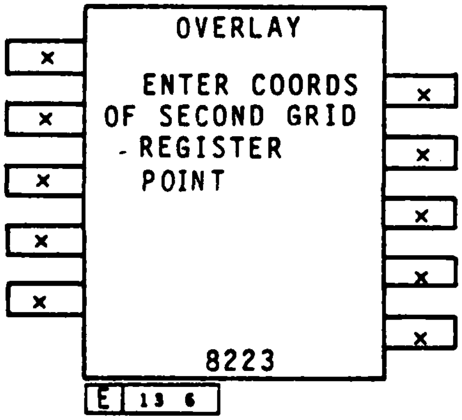
13-3



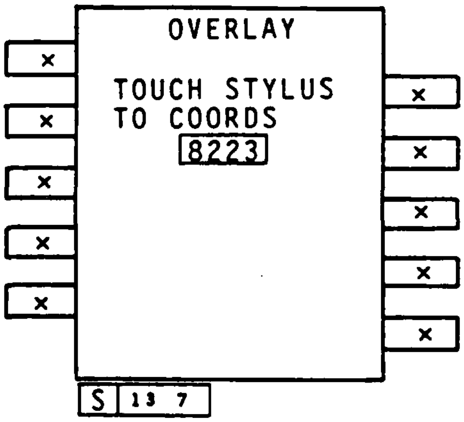
13-4



13-5



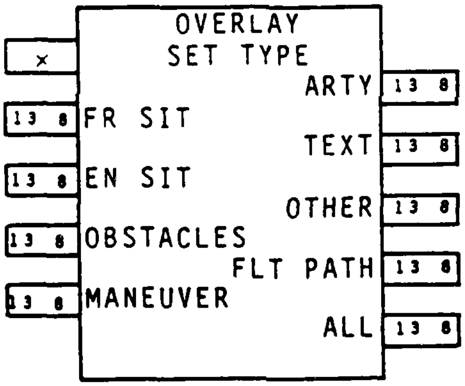
13-6



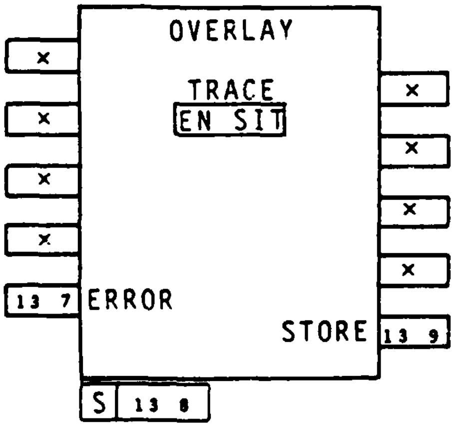
the digitizing tablet, enter the coordinates of the first grid register point on the keypad, and touch the digitizer stylus to the grid reference point on the map or overlay. Coordinate entry and digitizer stylus use are repeated to indicate the second grid register point.

Next (page 13-7), the CDU calls for a description of the type of overlay data to be entered such as friendly situation, enemy situation, obstacles, and so forth. This description serves two purposes. First, it permits the aviator to subsequently select these individual categories of information, either during mission planning or in flight. Second, this description automatically determines the overlay color. Should an overlay be received with all types of information intermingled, the operator may simply use the ALL key, or if desired he may selectively trace parts of the overlay to digitize different types of data separately. A sample overlay is shown in Figure 22.

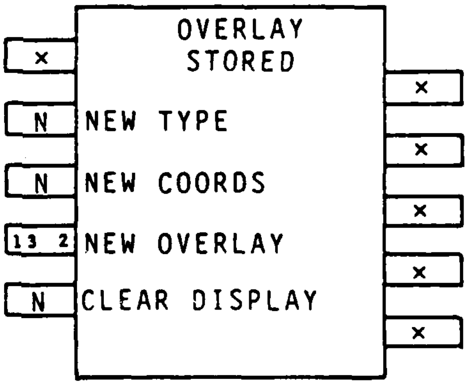
13-7



13-8



13-9



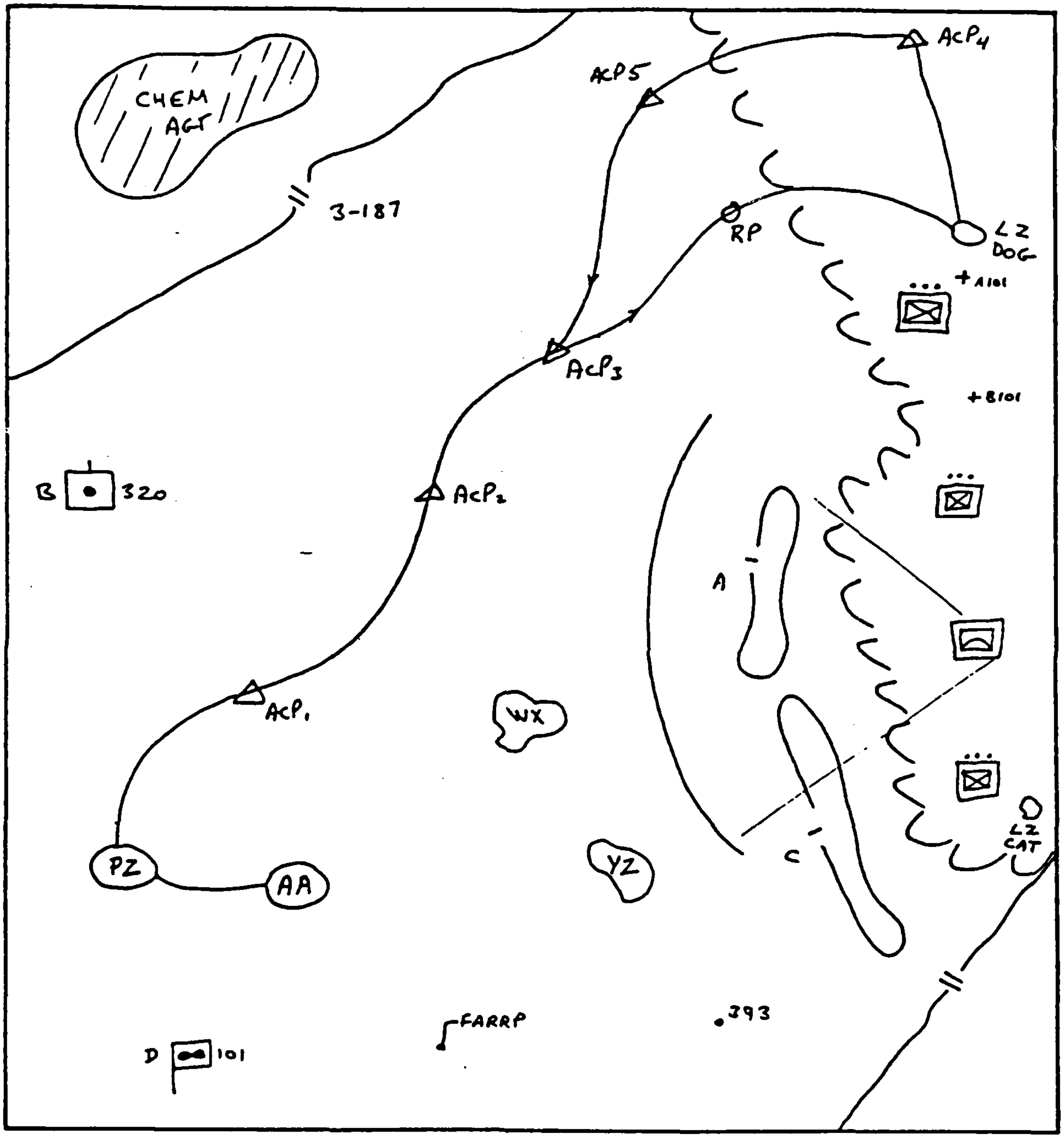
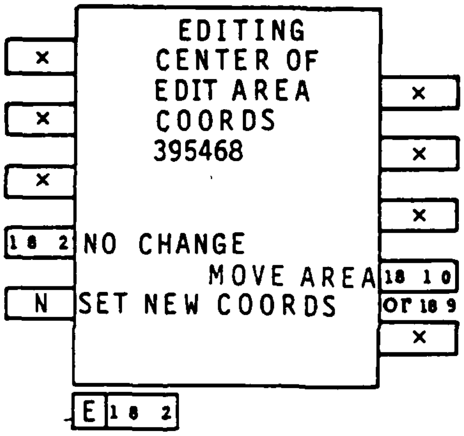


Figure 22. Examples of map annotations likely to be employed by the flight leader during an insertion mission conducted by an assault helicopter unit.

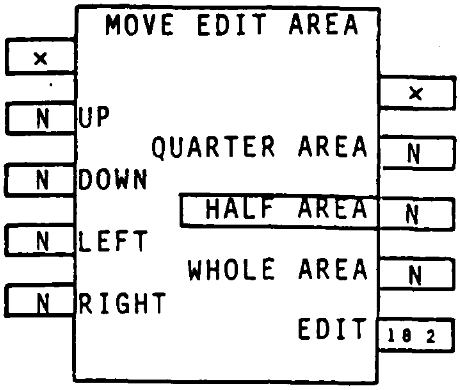
Page 13-8 provides a prompting message to remind the aviator to trace the selected type of data with the digitizing stylus. When the tracing is completed, the STORE button is pressed, and page 13-9 appears. The NEW TYPE button permits a return to page 13-7 without re-entering the grid register points. NEW COORDS permit selection of a new digitizing area on the map, while maintaining the same scale and overlay type. NEW OVERLAY is used when both type and area are to be changed, or when a scale change is required. CLEAR DISPLAY reduces the clutter by removing previous overlays from the map display.

When the EDIT button on the AUX MENU is pressed, page 18-1 appears. Initializing the map area for editing processes is performed by entering the coordinates of the center of the area. Subsequent shifts of the area can be achieved by entry of new coordinates or by pressing the MOVE AREA button.

18-1



18-10

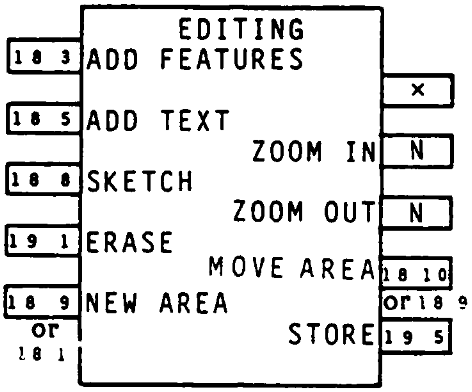


In the editing mode, the map display cannot be slewed with the joystick, but can be moved in steps using page 18-10. The size of the step remains as set until manually changed, and the direction of the step is controlled by the UP, DOWN, LEFT, and RIGHT buttons. Moving the edit area up is equivalent to moving the map image downward.

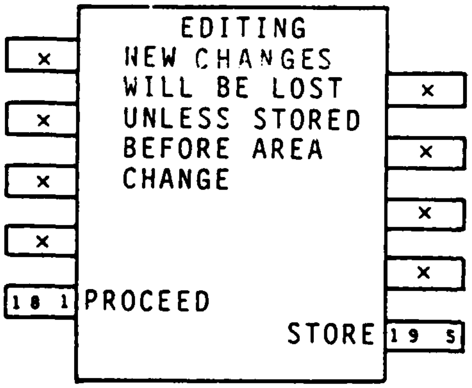
The editing "active area" is defined on the map display by a border line set just inside the perimeter of the display area. This slight inset permits the operator to determine whether displayed features continue into adjacent areas.

Once editing area is defined, the editing capabilities page (18-2) appears. This page is used to initiate procedures for entering point and line features of specific types, for adding short text messages, for "sketching" in various lines or notations, and for erasing previous entries. In addition, buttons on this page can be used to "zoom" the displayed area in or out, to move the area, to select an entirely new area, and to store the edited material in computer memory.

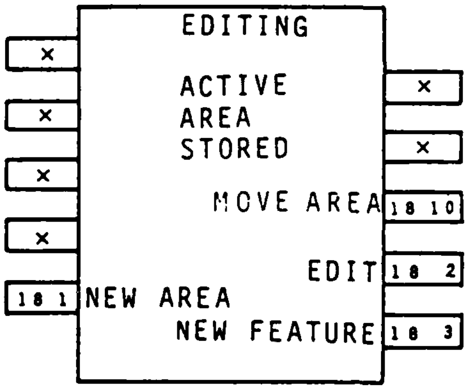
18-2



18-9



19-5



The use of the NEW AREA button calls page 18-9 if some feature has been added or erased since the last store command. If no such changes have been made, page 18-1 is called. The MOVE AREA button operates in a similar fashion, calling page 18-9 or 18-10. The STORE button on page 18-2 is not shown when this page immediately follows page 18-1.

When the ADD FEATURES button is pressed, the map is temporarily replaced by a list of all available point and line features on the color CRT, along with their numbers. A feature may be selected for insertion in the map by use of a stylus on the pressure sensitive screen, touching the name of the feature to be inserted. At this point, the map reappears and subsequent touches of the stylus to the screen introduce the point or line symbol selected. Samples of point symbols that might be entered in this fashion are shown in Figure 23. In case of pressure-sensitive screen failure, the feature may be selected by the number, via the keypad. As soon as a feature is selected and the map reappears on the color CRT, page 18-4 indicates the type of feature selected and the three methods of inserting the feature in the map data base: coordinates, cursor, or stylus. This page remains on the display until manually changed so that multiple entries of a single feature type are possible. A NEW FEATURE button equivalent for stylus use is incorporated below the active area of the map.

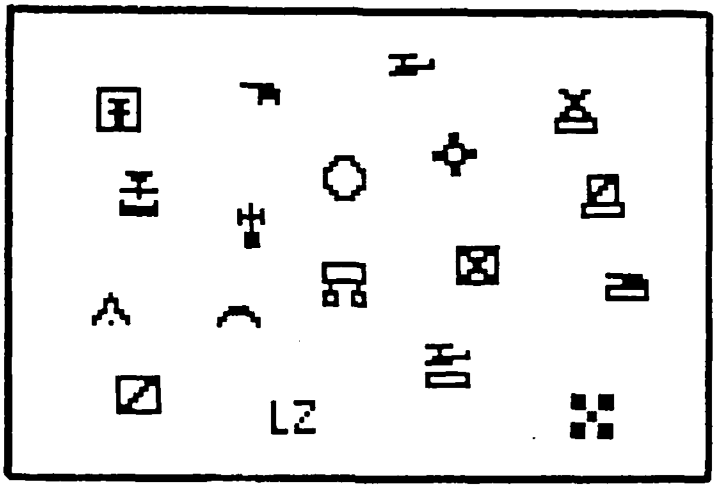
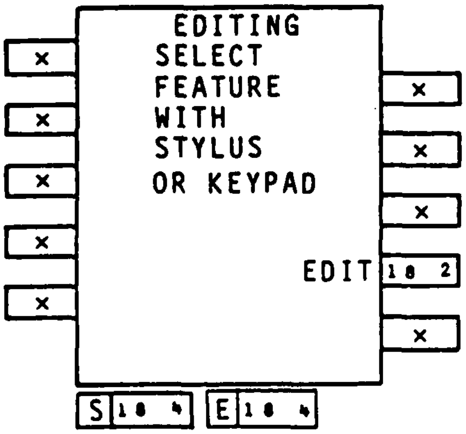
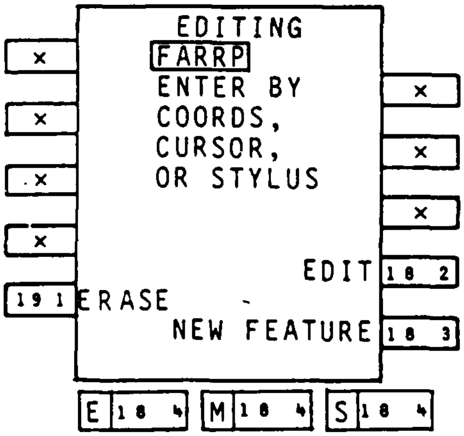


Figure 23. Samples of point symbols that can be input through *IMPS* editing procedures.

18-3

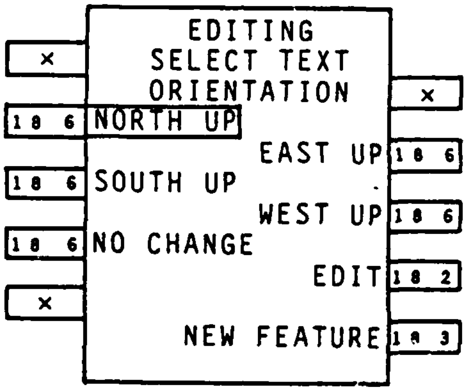

EDITING
SELECT
FEATURE
WITH
STYLUS
OR KEYPAD

18-4

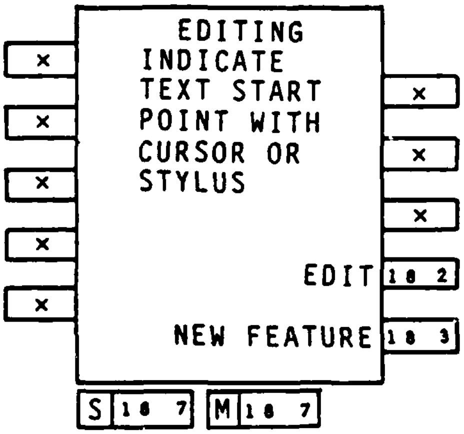

EDITING
FARRP
ENTER BY
COORDS,
CURSOR,
OR STYLUS

The ADD TEXT feature permits the aviator to incorporate brief verbal messages such as place names, terrain characteristics, or tactical notes in the map display. In order to ensure text legibility without the use of very large characters, the text must be entered so that CRT scan lines are parallel to horizontal character elements. This alignment is achieved by selecting any cardinal direction up for text entry, as shown on page 18-5.

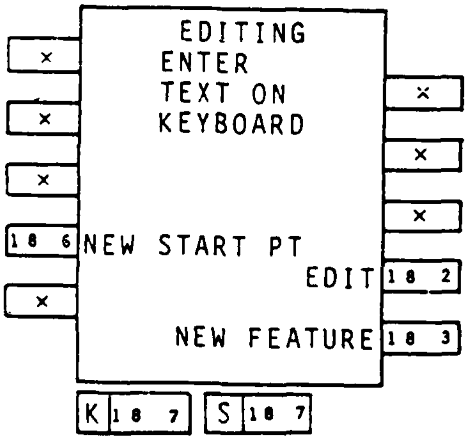
18-5



18-6



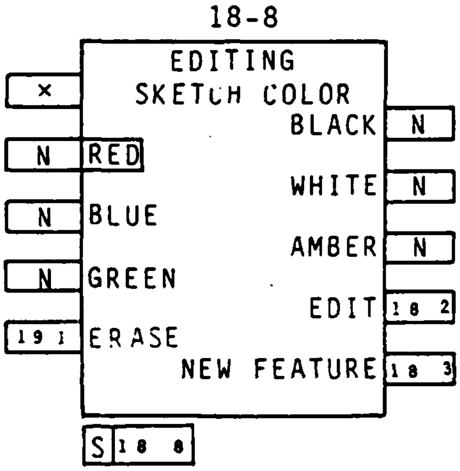
18-7



Next, the aviator indicates the text starting point with the stylus or cursor (page 18-6) and uses the keyboard to enter the desired message. The keyboard return key starts the next text line under the first letter of the previous line. The NEW START POINT button on page 18-7 can be disregarded by experienced operators; use of the stylus is sufficient. The clear button manipulates text in the same manner as numerics on the scratchpad.

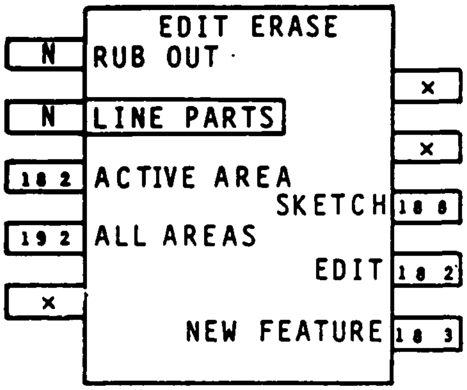
The SKETCH capability is provided as a back-up measure to permit the entry of linear features not explicitly defined in the ADD FEATURES mode of operation. Thus, special unforeseen display requirements may be met in the future.

Pressing the SKETCH key permits lines to be drawn in a freehand fashion using the stylus on the pressure-sensitive screen--an exceptionally direct and natural data-entry method. The sketch method can be exercised using either the joystick and cursor.

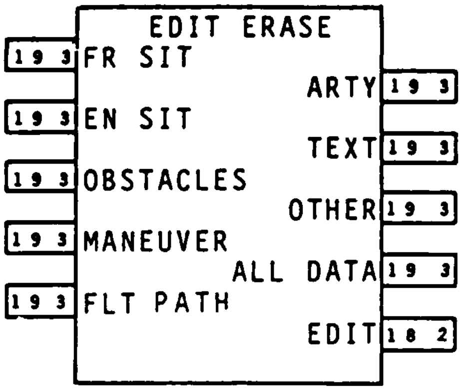


In order to delete incorrect or out-dated entries, the ERASE capability may be called (page 19-1). The RUB OUT and LINE PARTS erasure modes in the ground-based system may be performed with a stylus on the pressure sensitive screen as well as the cursor and MARK button. RUB OUT is pixel-by-pixel erasure such as would be achieved with a pencil eraser. Touching any part of a point symbol, however, will eliminate the entire symbol. LINE PARTS is erasure of all interconnected parts of the same feature type. If only part of a line is to be eliminated, RUB OUT may be used to first indicate the bounds of the portion to be erased.

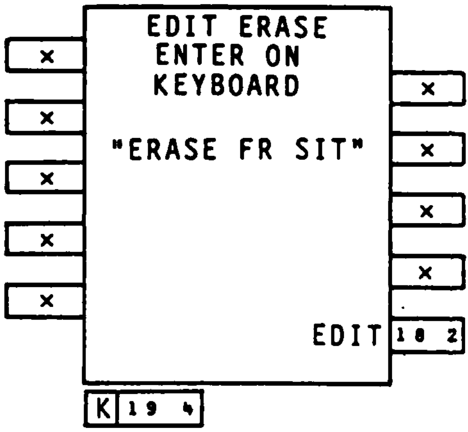
19-1



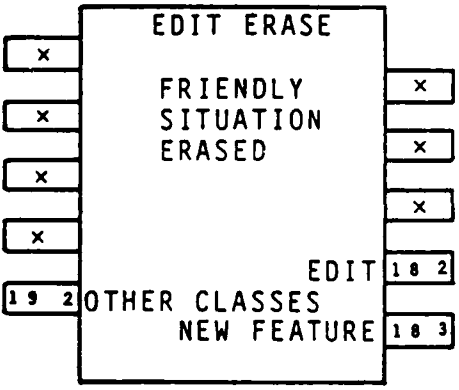
19-2



19-3



19-4



When the battlefield situation is changing rapidly, erasure of tactical features on an item-by-item basis may prove to be too time consuming. For this reason, the EDIT ERASE page provides two special methods for deletion of multiple features. Pressing the ACTIVE AREA on page 19-1 button deletes all tactical features in the active ara, and the CDU returns to the basic editing capabilities page (18-2). In order to erase features from the entire cassette tape area, the ALL AREAS button on page 19-1 is pressed. This action calls a list of erasure options (19-2). The operator may choose to delete broad, general categories of features or all tactical features. In the example on page 19-3, the operator has selected the friendly situation key. In order to prevent a major loss of data from a momentary lapse in judgment, the CDU instructs the operator to key in the erasure command on the keyboard before the system will perform the deletion. The same precautionary method is employed with the request for erasure of other broad categories of tactical data.

In order to speed the editing observations, the data additions and deletions are temporarily stored in the computer and are recorded on the cassette tape as infrequently as possible. In the aircraft, all recording takes place automatically, whenever the CDU is powered down. In the ground-based system, a RECORD button is provided for this purpose on page 13-1 and 20-1.

MASKING PLOT CONSTRUCTION

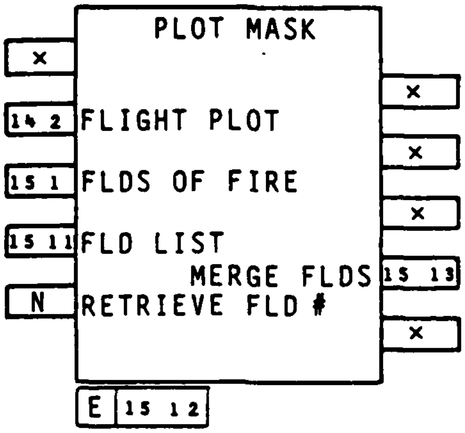
NOTE: The requirements, present deficiencies, and IMPS capabilities pertaining to masking plots have been described in the discussion of the airborne system. The following pages describe the procedures used in constructing the masking plots.

The masking computations may also be used to plot weapon fields of fire for use in TOC perimeter defense or other special purposes. These fields of fire plots can be stored for later study, if desired, but are not recorded on the cassette tape.

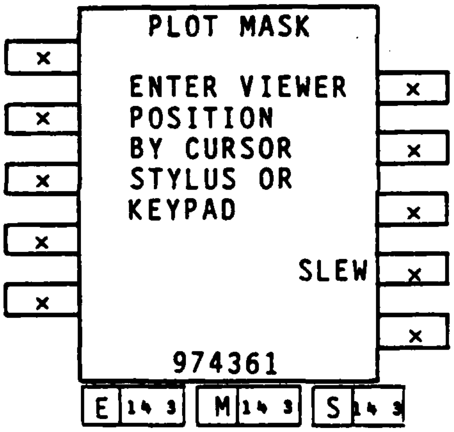
CDU Operation

The plot mask page (14-1) permits the operator to initiate the sequence of entries required for computing areas masked from enemy observation for aircraft use, or for computing fields of fire for ground commanders and local perimeter defense. Although the entries required for these two purposes are quite similar, they are treated separately in the dialogue to avoid potential confusions and ensure appropriate data storage. The plotting of masking diagrams for airborne use (FLIGHT PLOT) will be described first. The dialogue is primarily designed as a series of prompting messages to aid the aviator in performing the proper sequence of data inputs.

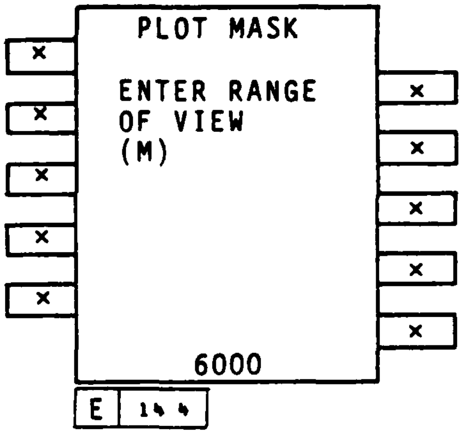
14-1



14-2



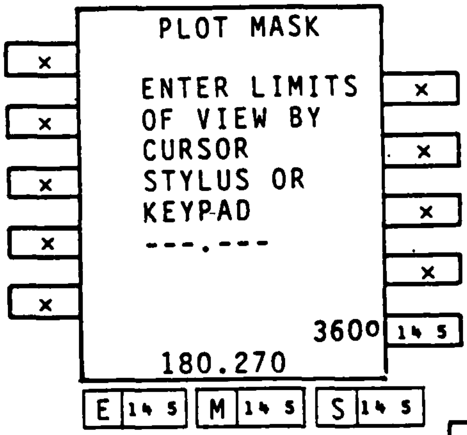
14-3



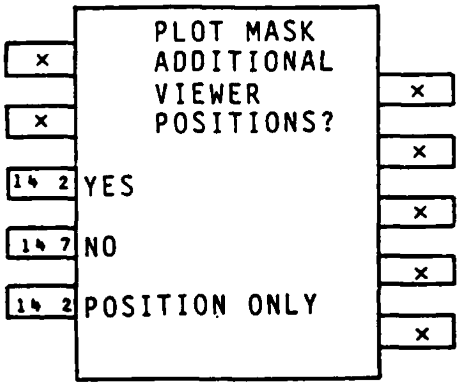
Page 14-2 instructs the aviator to enter known or suspected enemy radar, weapon, or observation positions by any of three methods. Next, he is directed to enter the range of the enemy radar or weapons system.

The limits of the field of view of concern to the aviator are entered by azimuths from the position (by keypad) or by marking the outer boundaries of the view with the stylus or cursor (page 14-4). Although a 360-degree field may sometimes be desired, reducing the field will speed the computations. The viewer height above ground level is entered on page 14-5.

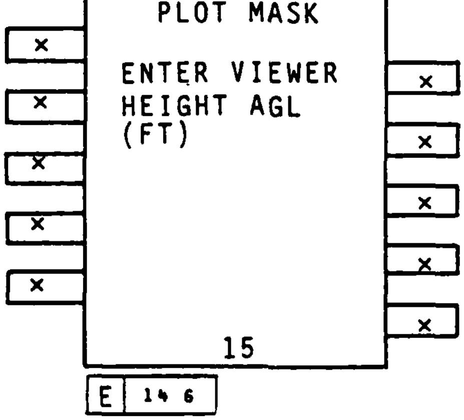
14-4



14-6

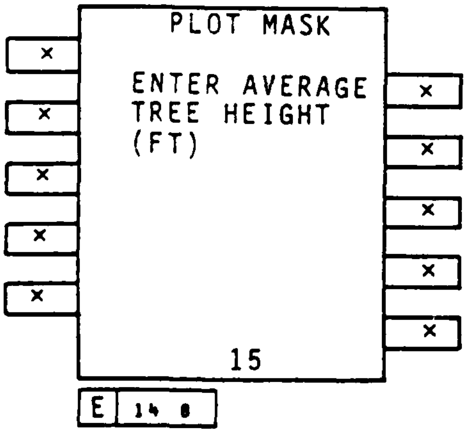


14-5

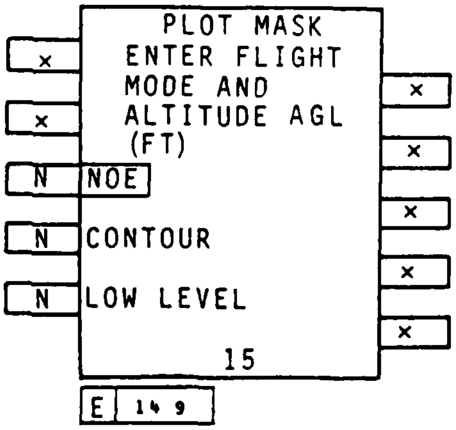


Page 14-6 queries the aviator regarding additional viewer positions of interest in the same general area. Pressing the YES button reinitiates the entry sequence. If the additional weapon ranges, view limits, and heights are identical, the POSITION ONLY button permits the operator to introduce other enemy positions through page 14-2 and then return directly to page 14-6, as many times as desired. When no further positions are required, page 14-7 instructs the aviator to enter the average tree heights in the area. In areas where vegetation coding is current and the trees provide effective masking, this entry will be extremely useful in identifying masked sites and routes. Otherwise, the operator may simply enter "0" to continue.

14-7

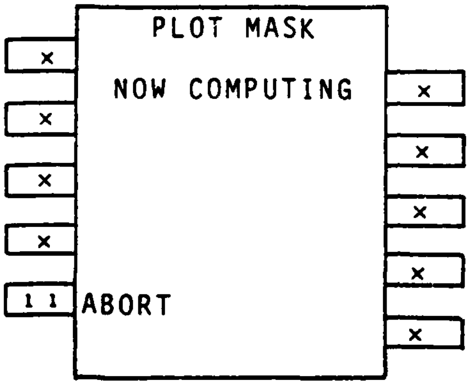


14-8

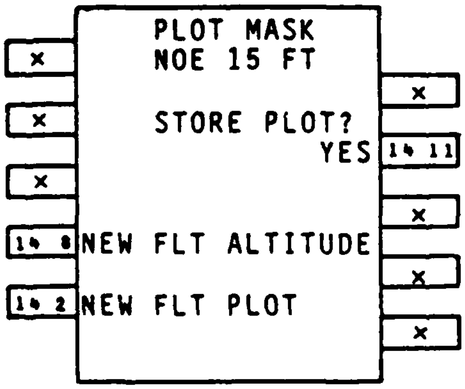


On page 14-8 the operator indicates the flight mode and altitude above ground level for which the masked areas are to be plotted. Depending upon the terrain type and unit SOP, different altitudes will be designated as corresponding to NOE, contour, and low-level flight. Page 14-9 indicates that the plot computations are in progress, and provides an ABORT key in case the CDU is urgently required for other purposes. When the computations have been completed, page 14-10 appears on the CDU, permitting the aviator to store the plot, if desired. Instead, he may elect to recompute the plot with a new flight altitude, or perform an entirely new plot. The NEW FLT ALTITUDE button permits the operator to return to page 14-8 so that the plots can be repeated for other flight altitudes without reentry of all other data. The NEW FLT PLOT is used when a plot in a different area is required. These options are also available after storage of a plot.

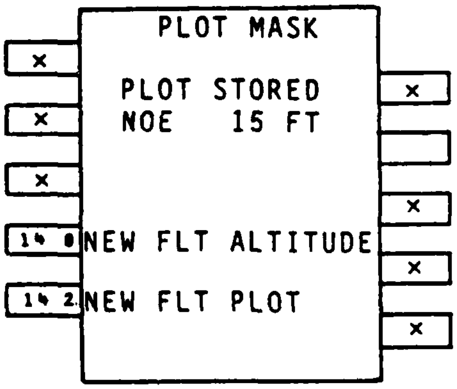
14-9



14-10



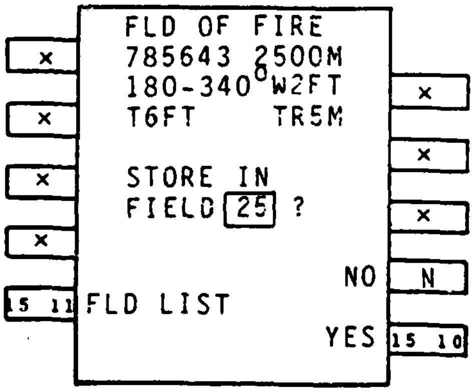
14-11



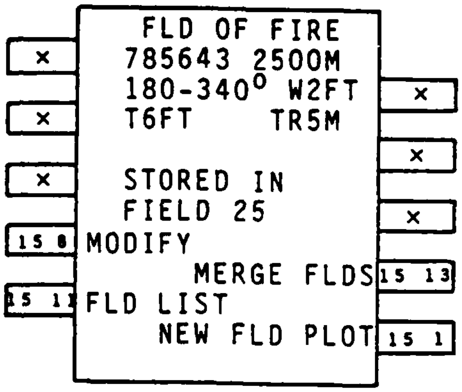
The fields of fire plots are directly analogous to the flight plots and are computed in identical fashion. The "viewer height" becomes "weapon height" and "flight altitude" becomes "target height." The complete sequence of CDU pages (15-1 through 15-8) is presented in Appendix 4.

Storage of the fields of fire plots, however, is executed differently from the flight plots because the fields of fire plots are not recorded on the cassettes for airborne use. Twenty-five storage bins, called "fields," are allocated for fields-of-fire plots. Page 15-9 is used to select a storage bin for a fields-of-fire plot. The page poses a question with a suggested field number (based on adding one to the last field used). The YES or NO responses permit storage or adding one to the suggested field number.

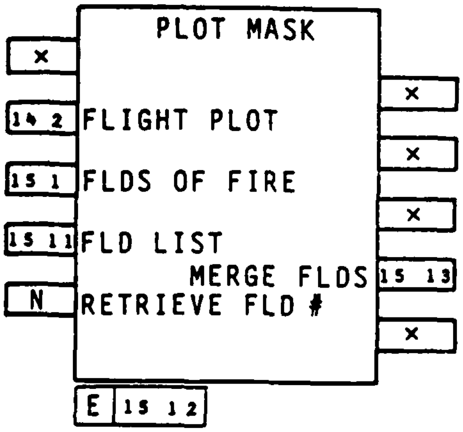
15-9



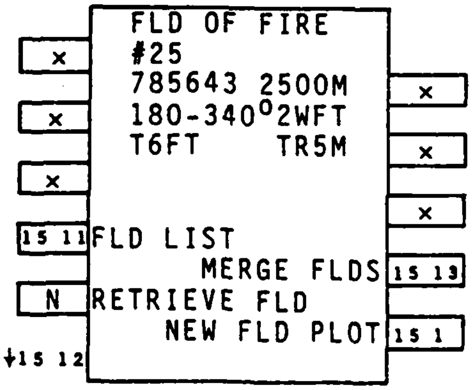
15-10



14-1



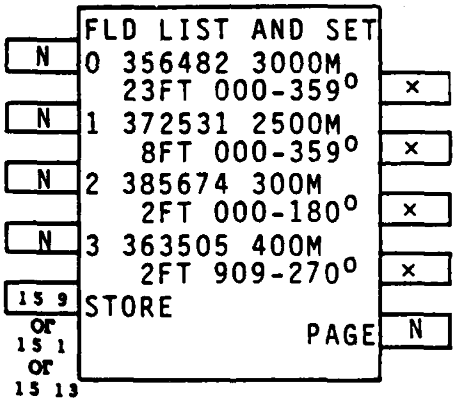
15-12



When fields of fire plots are stored in this manner, they may be recalled from page 14-1. When the RETRIEVE FLD # button on page 14-1 is pressed, a field plot number from 1 to 25 may be entered. Data pertaining to the plot are then shown on page 15-12.

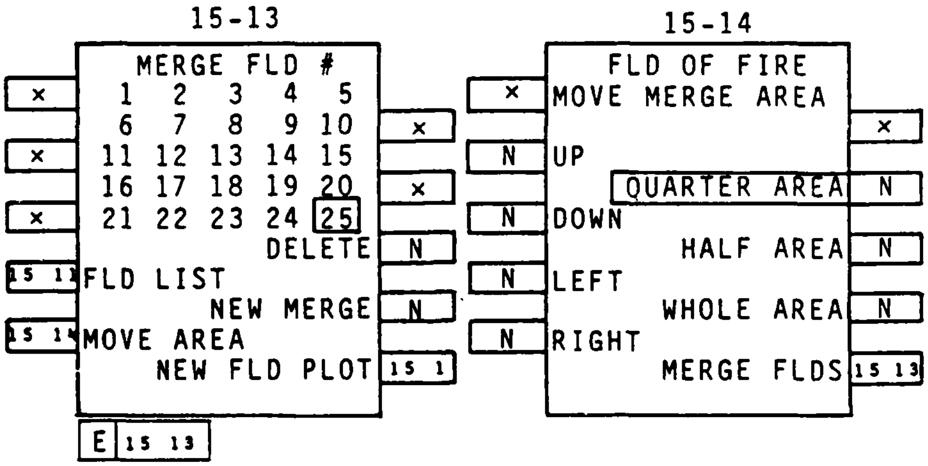
The list of stored fields of fire plots can be displayed by pressing the FLD LIST button on page 14-1 or other pages. The FLD LIST page (15-11) shows the field number, the coordinates of the weapon, the weapon range, the target height, and the sector of the weapon. Additional pages may be retrieved through use of the PAGE button. Pressing one of the numbered buttons causes the display of that plot. If the operator has arrived at page 15-11 from page 15-9, the STORE button will recall page 15-9. If he has arrived at 15-11 from 15-13, the STORE button is replaced by a MERGE FLDS button which calls page 15-13. If he has arrived at page 15-11 from a page other than 15-9 or 15-13, the STORE button is replaced by a NEW FLD button which calls page 15-1.

15-11



```
FLD LIST AND SET
0 356482 3000M
   23FT 000-359°
1 372531 2500M
    8FT 000-359°
2 385674 300M
    2FT 000-180°
3 363505 400M
    2FT 909-270°
STORE
                PAGE
```

Although the fields of fire plots are computed separately for each weapon position, tactical planners will often wish to evaluate the coverage of combined fields of fire of several weapons. The procedure for such a combination is to select the initial plot from the field list page (15-11) and then press the MERGE FLDS button on page 15-12. The MERGE FLDS page (15-13) presents an array of 25 fields, each of which can be added to the combined plot when entered by keypad. Selected field numbers are shown in reverse video. Use of the DELETE button permits elimination of specific fields in the same manner and returns their numbers to normal video. The NEW MERGE button clears the map display of all fields for a fresh start. The FLD LIST button can be used to examine the data on each field without loss of the merged fields. The MOVE AREA button calls page 15-14, the operation of which has been previously described. The MERGE FLDS button on page 15-14 permits a return to page 15-13, with changing the selection of field numbers.



OBLIQUE VIEW CONSTRUCTION

Requirements

An oblique view of the terrain is one which portrays the terrain as it might be seen from some angle between ground level and directly overhead. The virtue of oblique photographs is that they present terrain from a more familiar point of regard than that provided by the vertical (plan) view, and features are usually more recognizable. In particular, terrain relief becomes much more discernible in an oblique photograph than in a vertical photograph (except for special stereo photographs).

The preflight uses of the oblique view included its employment in route selection, tactical decision-making, and route rehearsal. The oblique view simplifies the specification of good checkpoints, barrier features, battle positions, landing zones, and many other such terrain-related mission-planning requirements. Examination of the features as portrayed by the oblique view offers the aviator an opportunity to develop an "area familiarity" without exposing him to the unacceptable risk of flight hundreds of feet above the actual terrain in a high-threat environment.

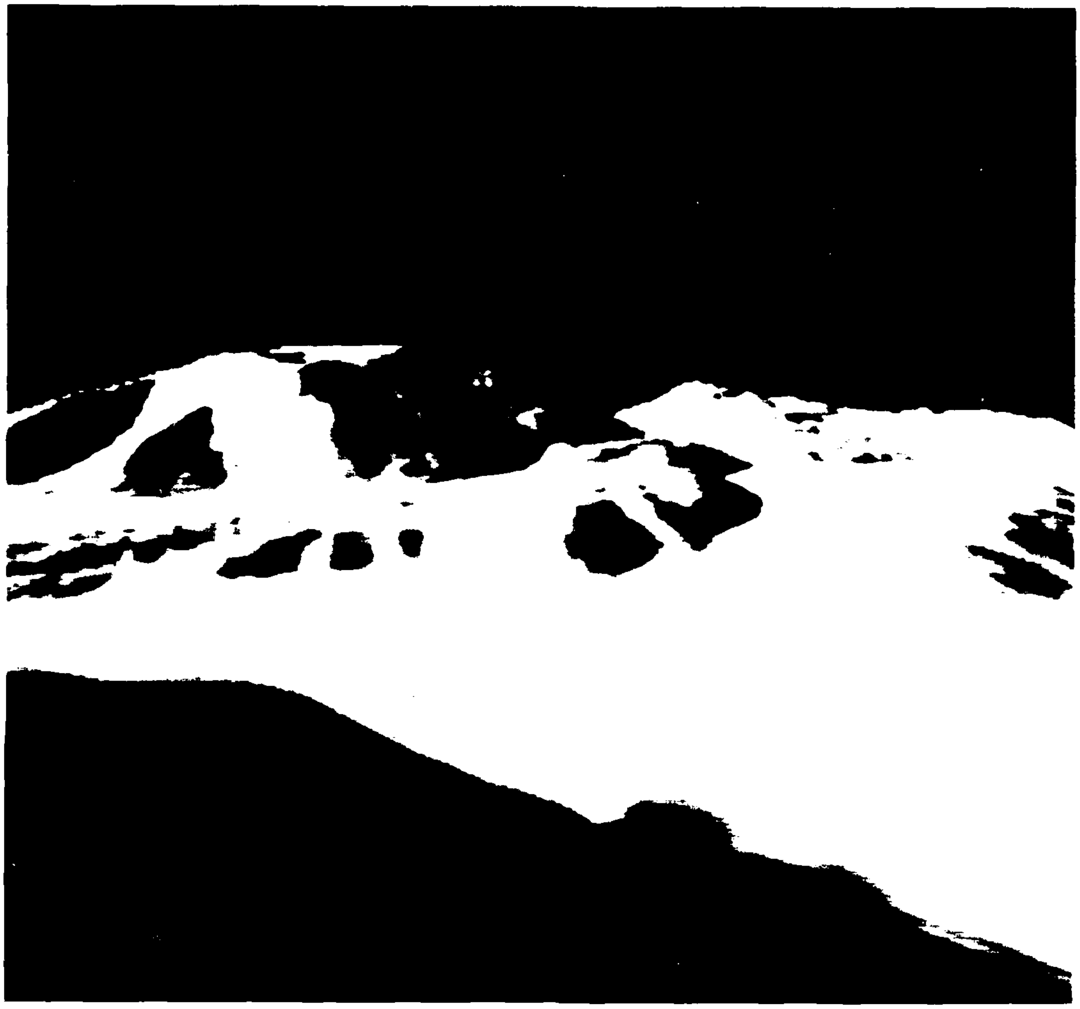
Present Deficiencies

Because of the risk and the time requirements involved in obtaining a sufficient number of oblique photographs to adequately cover an area of operations, they are very unlikely to be available to Army aviators. Another disadvantage of oblique photographs is that they cannot be used to determine distances between features. Since photographs present a perspective ("vanishing point") view of terrain, their scale is not constant.

IMPS Capabilities

A computer-generated topographic display system can, in many respects, substitute for oblique view photography. In some respects, computer-generated visualizations are actually superior to photographic imagery. With the IMPS system, the aviator need not search for or request specific aerial photographs, but can select exactly the views he needs to examine the terrain--either from well above ground level, or from NOE altitude. Such a system may be employed to construct a perspective view of the landforms as they might appear to the human eye, either at ground level or at any chosen elevation above the terrain. Although the current IMPS design does not include cultural, hydrographic, or vegetation features in the oblique views, this capability is being actively explored by AVRADA. Examples of computer-generated perspective views are shown in the color plates following this page.

Another kind of oblique view can be constructed by a computer-generated topographic display: the isometric projection. This kind of oblique view is unlike a photograph because it does not employ vanishing-point perspective. Instead, ground distances are kept proportional and constant, as in an engineering drawing used for shop measurements. In this manner, three-dimensional landforms may be portrayed, yet distances may be measured between points--a significant advantage in flight planning and tactical decision making.



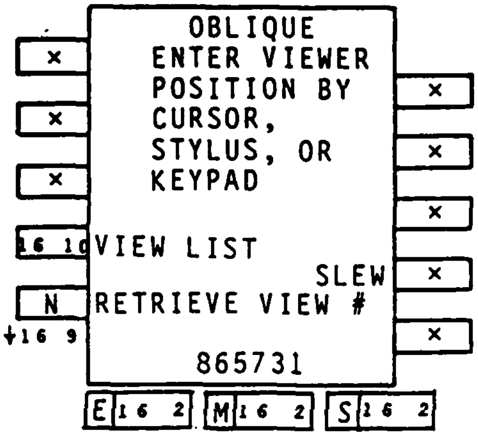
Slope-Shaded Terrain Perspective View

Slope-Shaded Terrain Perspective View with Cultural Features

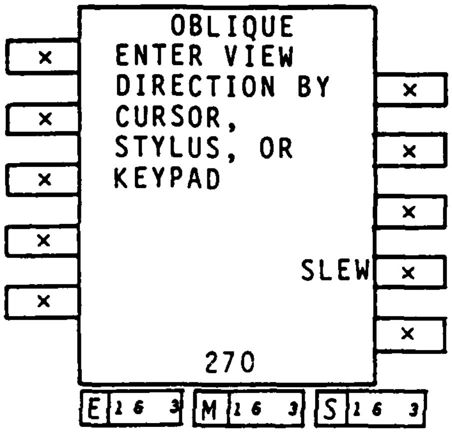
CDU Operation

When the AUX MENU page is displayed, pressing the line select key labeled OBLIQUE initiates the steps required for oblique view construction. The operator enters the position from which the view is desired, the direction of the view, and the altitude above ground level from which the view is to be computed. Next, the operator chooses between the perspective and isometric types and enters a vertical exaggeration factor appropriate to the terrain type.

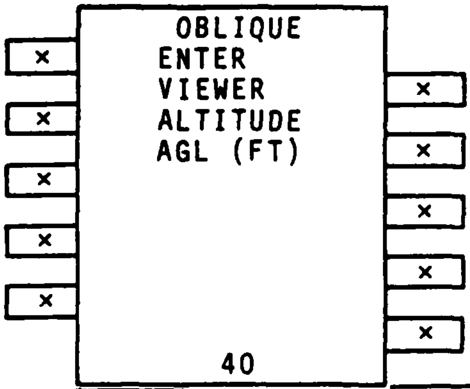
16-1



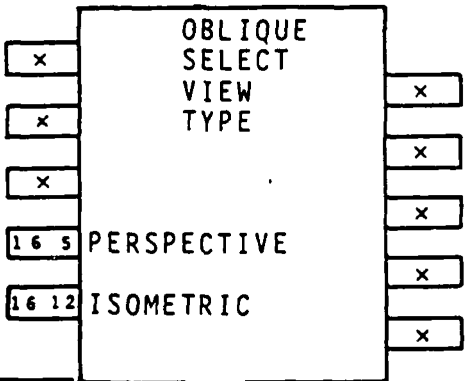
16-2



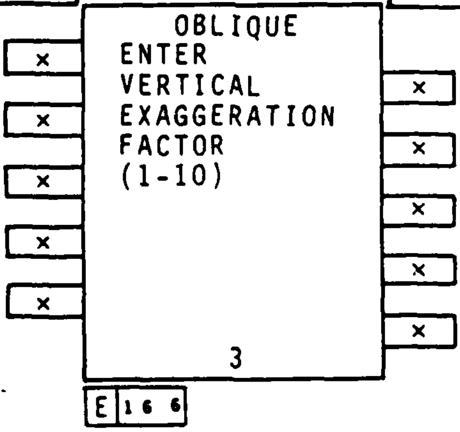
16-3



16-4

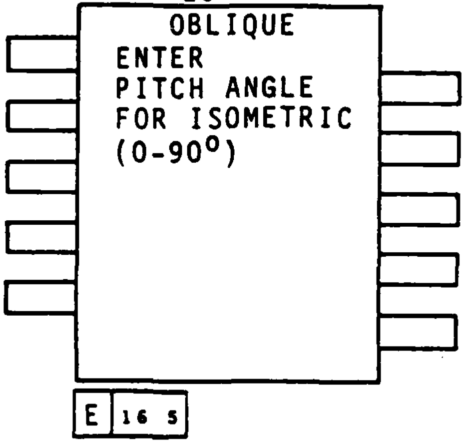


16-5

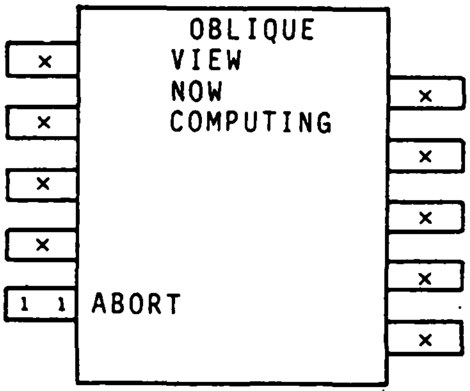


Use of the isometric oblique view requires entry of a "pitch angle" (the angle between horizontal and straight down) as shown on page 16-12. Page 16-6 advises that the view is being computed.

16-12

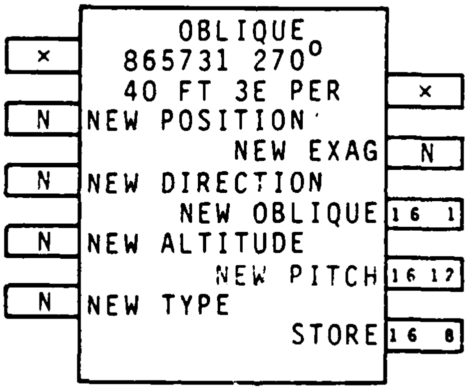


16-6

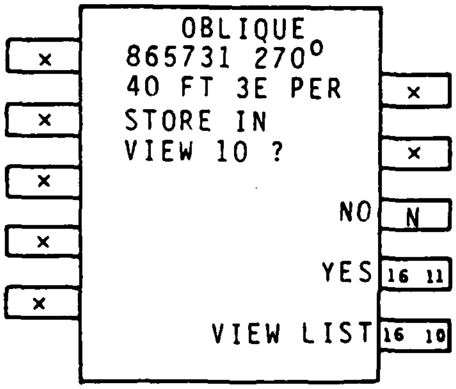


An ABORT key is provided on this page in case the IMPS system is urgently needed for other purposes. When the view is completed and displayed on the color monitor, the CDU displays the position, direction of view, altitude, and view type (16-7) and permits the aviator to alter any one of these variables for the construction of additional views. If more than one variable is to be changed, the NEW OBLIQUE key is pressed to return to page 16-1 in the sequence. When the desired views are achieved, the operator may elect to save them for later use by pressing the STORE key.

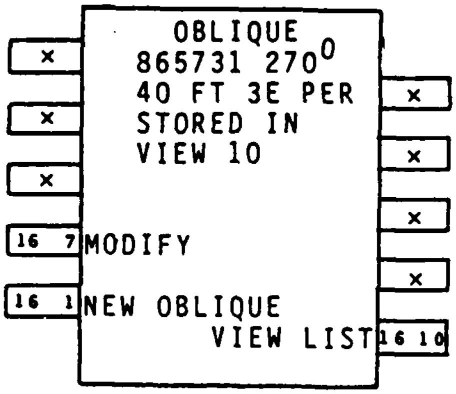
16-7



16-8



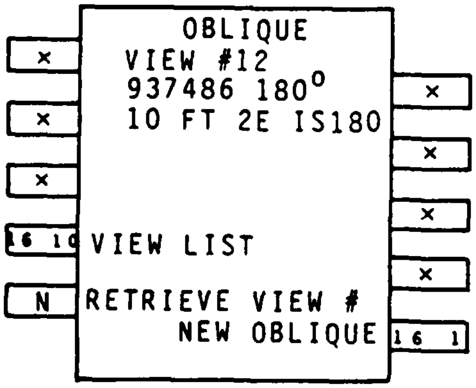
16-11



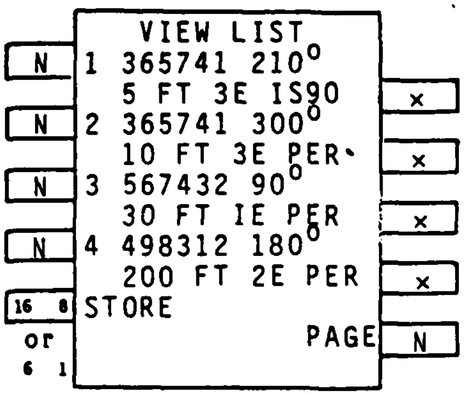
Page 16-8 is used to select a storage bin for oblique views, and operates in the same fashion as described for fields of fire (page 15-2). A YES response leads to page 16-11, which provides the option of modifying a stored view or initiating a new view. A VIEW LIST response leads to page 16-10.

To retrieve previously constructed oblique views, the operator presses the RETRIEVE VIEW # button on page 16-1 and enters the number of the desired view on the keypad. The view is then shown on the map, and associated data on the CDU (page 16-9). The view distance is equivalent to the current scale setting--3, 6, 12, or 24 kilometers.

16-9



16-10



The entire set of up to 25 stored views may be examined by pressing the VIEW LIST button on page 16-1 and other pages. The view list page (16-10) operates in the same fashion as page 15-4 (fields of fire). The view number is listed, along with the coordinates, direction of view, the viewer altitude, the vertical exaggeration factors, the view type, and the pitch angle of an isometric view. Pressing one of the numbered buttons recalls the associated view. The STORE button is present if the operator has arrived at page 16-10 from page 16-8. Otherwise, this button is labeled NEW OBLIQUE and calls page 16-1.

PILOT PLAN ANNOTATIONS

Requirements

Following the operations (G3/S3) and intelligence (G2/S2) briefing, the aviator selects and plots LZs, ambushes and/or firing positions, ACPs, flight routes, potentially hazardous points or areas, key terrain features, and other items of importance to the mission. The special considerations for route selection and annotations have been previously discussed.

The aviator must perform a map reconnaissance, studying the map (and aerial photos, if available) until he is able to visualize the entire route of flight. He must identify areas where detection must be expected because sufficient masking is not available, even at NOE flight levels, and plan for suppresive fires, smoke, chaff, or standoff jamming. The flexibility of mission conduct is in direct proportion to planning efforts, and extensive planning requires detailed map annotations. The ability to mark, draw, and write upon the map provides an unsurpassed aid in recalling the information noted during the planning process.

Present Deficiencies

As noted previously, paper maps are easily annotated, but pencil lines may obscure important topographic data, grease pencil annotations are easily smeared, and acetate overlays may be difficult to keep in position.

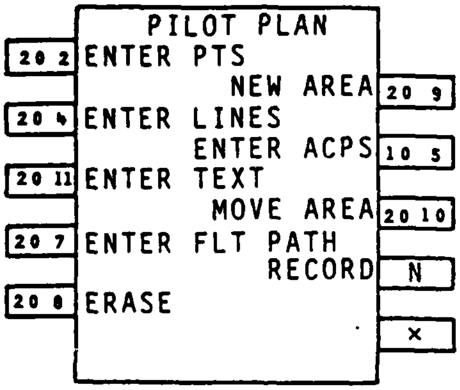
IMPS Capabilities

The ground-based IMPS can provide annotation capabilities similar to (and in some respects better than) those currently used on paper maps. The aviator can rapidly insert point symbols of his choosing, "draw" linear and area features of importance to the mission, and insert words when special notations are required. The pilot's annotations are similar, but simpler than those of the editing procedures previously described, and are recorded only on Track 4 of the cassette. In the aircraft, these annotations may be selected or deleted at the touch of a button, so that data obscuration or smearing is no longer a problem.

CDU Operation.

When the AUX MENU page is displayed, pressing the line select key labeled PILOT PLAN calls page 20-1. This page provides several important options to the aviator.

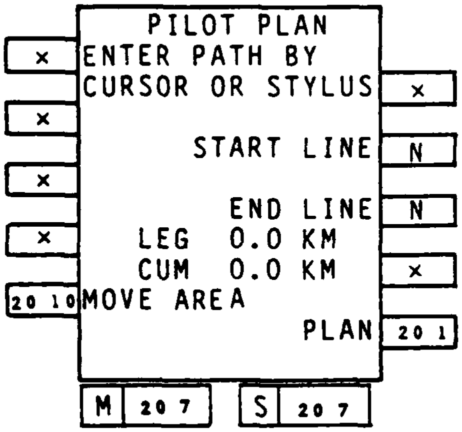
20-1



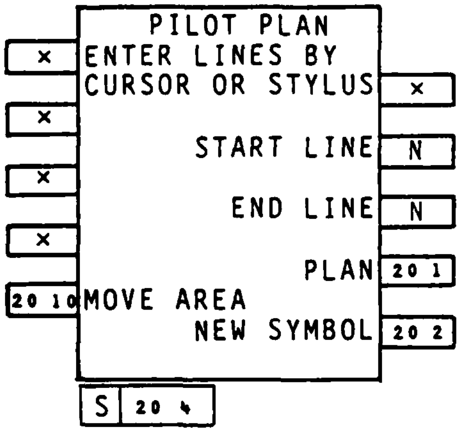
Many of these options are essentially identical to those discussed previously in the editing section and will not be described here. The specific pages for use of these options are shown in Appendix 4, and include ENTER POINTS, ENTER TEXT, ERASE, NEW AREA, and MOVE AREA. The ENTER ACPs function has been previously discussed in the flight planning section.

The ability to enter lines and flight paths through the PILOT PLAN mode is sufficiently different to warrant description.

20-7



20-4



In the PILOT PLAN mode, the aviator may enter smoothly curved lines (page 20-4) instead of the straight line segments possible in the aircraft, and they may be entered by the stylus directly onto the pressure-sensitive screen. The pilot does not, however, have the choice of several colors available in the SKETCH option of the EDIT MODE. The ENTER FLT PATH button on page 20-1 calls page 20-7 and permits a similar smooth line entry except that this line may be used with leg and cumulative distance indicators and as a method of preparing for a flight simulation operation.

Page 20-7 shows leg and cumulative flight path lengths in a manner similar to that of page 11-4. Although the path in this case is curved, "legs" may be defined by use of the MARK button, or by lifting the stylus from the screen. When subsequent flight segment is initiated, the "LEG" indicator zeros and begins a new real-time additive display of distance. Pressing END LINE followed by START LINE zeros both LEG and CUM counters.

When the pilot has completed his map annotations, entering the points, lines, ACPs, and text desired, he presses the RECORD button on page 20-1 or 13-1 to record all of his inputs on the tape cassette.

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APPENDIX 1

HARDWARE DESIGN CRITERIA FOR THE CONTROL-DISPLAY UNIT (CDU) OF THE INTEGRATED MISSION PLANNING STATION (IMPS)

IMPS CDU HARDWARE DESIGN CRITERIA

CONTROL SEPARATION

MIL-C-81774A, section 3.11.10, specifies that controls shall be separated by enough space to permit manipulation of controls without interference or delay. Controls shall be positioned so that the operation of one control shall not cause the operation of any other control. Where separation does not eliminate inadvertent actuation, guards shall be used. Minimum control separation requirements are given in Table V.

REQUIREMENTS FROM TABLE V

	TOGGLE SWITCHES	CONTINUOUS KNOBS	PUSH BUTTONS
TOGGLE SWITCHES	.75	1.0	.5
CONTINUOUS KNOBS	1.0	1.0	.5
PUSH BUTTONS	.5	.5	.5*

*Keypad push buttons .25" (from Sec. 3.8.8.3)

The size of the CDU panel is dictated by MIL-STD-25212. The area reserved for controls and displays is a maximum of 5 inches in width, and 8.875 inches in height. It is estimated that approximately half of the available area will be occupied by the CRT screen and associated line select keys, and half by the other control devices.

These size limitations do not permit the precise application of the control separation requirements presented above, in conjunction with the minimum control dimensions specified by MIL-C-81774A. The alternative solutions are to (1) increase the panel size, (2) decrease the control sizes, or (3) decrease the control separation distances. Alternative 1 would lead to incompatibility in cockpit mounting provisions. Alternative 2 could lead to difficulties in operating the controls, and difficulties in labeling the two-state push switches. Alternative 3 is recommended because of its low likelihood of impacting system performance or operability.

Separation of push buttons will be only ¼ inch instead of ½ inch. MIL-C-81774A already permits keypad button separation of ¼ inch, so the only push buttons not meeting the specification are the function select-deselect switches. It is noteworthy that MIL-STD-1472C permits ¼ inch push button separation for single finger sequential operation. Operation of the CDU push buttons could be considered to be sequential.

When the CDU power is turned off, the ON-OFF toggle will be about ½ inch from the CRT brightness knob, instead of 1 inch. Once the toggle is placed in the ON position, however, the separation is over 1 inch. Because the toggle may be gripped from the sides, interference with the CRT brightness knob is unlikely when moving to or from the OFF position.

The zero toggle is located at about ½ inch from the panel brightness knob, when the toggle is pressed downward, instead of 1 inch specified above. Because the zero toggle is recessed and covered, it offers no interference to use of other controls. Should use of the zero toggle ever be required, the inadvertent operation of the panel brightness control would be neither likely nor of any consequence.

CDU PANEL LABELING

The height of the control markings shall be at least .14 inches (MIL-C-81774A, Sec 3.7.1). Panel markings shall be white except when illuminated (MIL-C-81774A, Sec 3.5.7) and separated from controls by at least .08 inches (MIL-C-81774A, Table 3). Letter design is described in MIL-M-18012B and MS33558. Width shall be approximately 3/5 of height and stroke width shall be approximately 1/8 of letter height. Approximately one stroke width shall be the space between letters. Vertically arranged letters (PWR) shall be of equal width. Fonts for engraving include Gorton extended, normal, and condensed. Letter design specifications also apply to transilluminated control labels, for which the letter height shall be a minimum of .14 inch.

FUNCTION SELECT-DESELECT OPERATION

Four of the push buttons on the CDU show system status as well as providing input controls. These push buttons are used for selecting the terrain avoidance (TERA), declutter (DCLT), freeze (FREZ) and saved update (UPDT) features of the system. The buttons shall be horizontally split and the two portions shall be separately illuminated. The upper portion shall always be visible when the CDU is activated. The lower portion shall be illuminated only when the specific feature is selected by pressing the push button. A second press shall deselect the feature, and the illumination of the lower portion of the push button shall cease. In the case of the UPDT button, implementation of the saved update entry (through AHC use) shall also have the effect of deselecting the feature. The "spare" switches shown on the CDU panel drawing shall also operate in the fashion described above.

CDU COLORS AND LUMINANCE

The CDU panel face shall be black, and the brightness control knobs dark gray. The mounting plate and fasteners shall also be black. Toggle switches shall have a non-glaring metallic finish. Panel markings shall be white except when rear-illuminated, in which case they are green. Transilluminated push-button controls may be either white on a black background until illuminated or not legible until illuminated. All push buttons must be legible under high ambient illumination (10,000 fc) or in darkness. The two-state function select-deselect buttons shall be "sunlight readable" so that their state can be determined under any ambient illumination conditions. Transilluminated controls shall show green markings when illuminated. The green markings are anticipated to become standard in the future because night vision goggles will be "blind" to colors of wavelengths below about 520 nm.

Control panel luminance must be continuously dimmable throughout its range, from off to full on. Panel markings and transilluminated controls must all be of approximately equal perceived brightness throughout the range.

ABBREVIATIONS

Abbreviations used in the IMPS CDU dialogue and upon the CDU panel are selected, where available, from MIL-STD-783C (Legends for Use in Aircrew Stations) or AR 310-50 (Authorized Abbreviations and Brevity Codes).

In cases for which new abbreviations were required, the above documents were reviewed to avoid confusions with previously authorized abbreviations, and efforts were made to assure that meanings of abbreviations would be obvious to the intended readers.

In one case (terrain avoidance) the authorized abbreviation required shortening (from TER AVD to TERA) in order to fit in the available space. Abbreviations used in the dialogue are described elsewhere. Abbreviations to be used on the CDU panel are listed below:

BRT - Brightness (CRT or panel)
CLR - Clear (keypad entry)
CRT - Cathode ray tube
DCLT - Declutter (show topography only)
ENT - Enter (execute data entry)
FREZ - Freeze (halt map motion)
PNL - Panel
PWR - Power
SAVD - Saved (update)
TERA - Terrain avoidance
UPDT - Update (save feature)

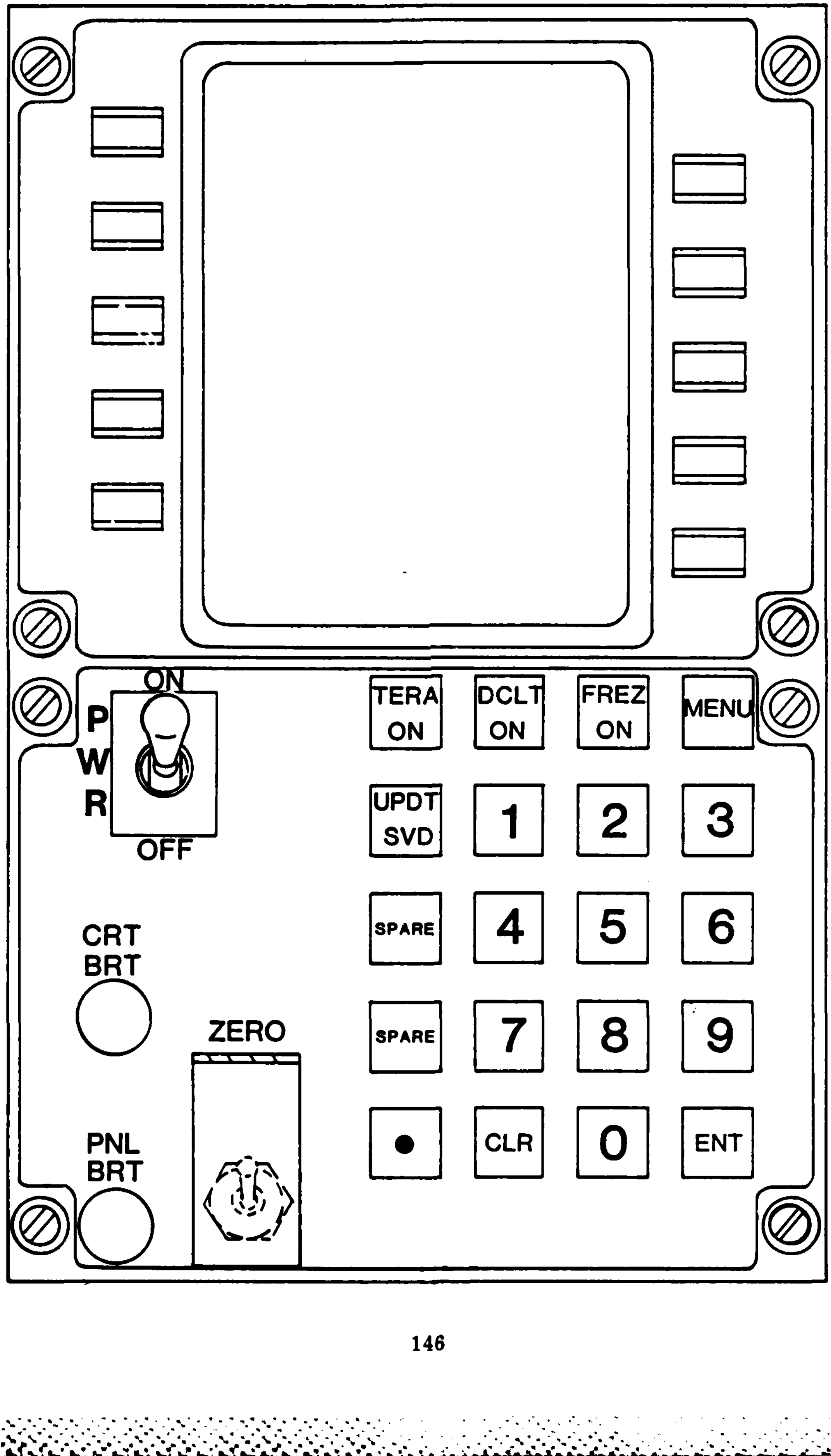
PANEL ARRANGEMENT

The layout of control and display components on the IMPS CDU panel shall be as portrayed on the attached drawing.

DESIGN REQUIREMENTS FROM MIL-C-81774A AND MIL-STD-1472C FOR CDU CONTROLS

FUNCTION	INPUT TYPE	CONTROL TYPE	DIMENSIONS	DISPLACEMENT	RESISTANCE
Power On-Off	Discrete, Two-Position	Lever-Lock Toggle	Height .95 Tip Diam .42 Mounting Plate Approx .75 x 1.0	33°	30 ± 10 oz
System Zero	Discrete, Two-Position	Cover-Guarded Toggle	Height .69 Tip Diam. 24 Cover Approx .75 x 1.5	33° (spring loaded)	30 ± 10 oz
CRT Brightness	Continuous Adjustment	Round Knob	Height .50 Diam .50 .02-.04 Above Panel	—	1-4.5 inch oz
Panel Brightness	Continuous Adjustment	Round Knob	Height .50 Diam .50 .02-.04 Above Panel	—	1-4.5 inch oz
Numeric Entry	Multiple Digit Selection	Keypad	.50 Square Tops Height .10-.25	.03 Min .19 Max	3.5 to 14 oz
Clear Error	Momentary Discrete	Push Button	.50 Square Tops Height .10-.25	.03 Min .19 Max	3.5 to 14 oz
Execute	Momentary Discrete	Push Button	.50 Square Tops Height .10-.25	.03 Min .19 Max	3.5 to 14 oz
Menu Call	Momentary Discrete	Push Button	.50 Square Tops Height .10-.25	.03 Min .19 Max	3.5 to 14 oz
Freeze Mode	Function Select-Deselect	2-State Push Switch	.50-.70 Square Tops Height .10-.25	.125 Min .50 Max	30 ± 10 oz
Declutter Mode	Function Select-Deselect	2-State Push Switch	.50-.70 Square Tops Height .10-.25	.125 Min .50 Max	30 ± 10 oz
Terrain Avoidance Mode	Function Select-Deselect	2-State Push Switch	.50-.70 Square Tops Height .10-.25	.125 Min .50 Max	30 ± 10 oz
Saved Update Mode	Function Select-Deselect	2-State Push Switch	.50-.70 Square Tops Height .10-.25	.125 Min .50 Max	30 ± 10 oz
CRT Line Selection	Momentary Discrete	Push Button	Height .10-.25 Width .25 Length .50 Approx	.03 Min .19 Max	3.5 to 14 oz

THE CONTROL-DISPLAY UNIT FOR THE INTEGRATED MISSION PLANNING STATION



APPENDIX 2

DESIGN OF A FONT FOR THE CONTROL-DISPLAY UNIT (CDU) OF THE INTEGRATED MISSION PLANNING STATION (IMPS)

DEVELOPMENT OF A FONT FOR THE IMPS CDU

BACKGROUND

The Integrated Mission Planning Station (IMPS) employs a multi-purpose control-display unit (CDU) which provides the operator with the primary means of exercising the extraordinary flexibility built into the IMPS system. The upper portion of the CDU is composed of a small monochrome CRT that displays 12 lines of data. The top line is reserved for advisory data, and the bottom line is used as a "scratch pad" to echo keypad entries. The central 10 lines may be used for data display, prompting messages, or labels for the adjacent line select keys. The labels change to indicate the current function of each line select key because the functions of any given line select key will differ depending upon the type of transaction in progress.

The purpose of this paper is to define the font of the letters, numerals, and symbols that will appear on the CDU CRT. For the purposes of this task, "font" is defined as the shape, size, and stroke width of these letters, numerals, and symbols. Definition of IMPS font requires the consideration of certain assumptions, including physical parameters of the display system, and human factors engineering practices. These assumptions are enumerated below.

ASSUMPTIONS

1. A 3" x 4" monochrome CRT screen will be used in the CDU design.
2. The active area of the screen will be 2.7" x 3.6" to minimize edge distortions.
3. This active area will be composed of 640 x 480 lines (long axis vertical).
4. Twelve lines of characters will be required.
5. Character cells must include proper spaces above, below, and to both sides of the character itself.
6. Character stroke widths composed of even numbers of raster lines are less subject to flicker effects.

7. Characters should have a vertical separation of ½ character or more (MIL-STD-1472C Sec. 5.5.5.13).

8. Letter and number widths should be 3/5 of letter height (MIL-STD-1472C Sec. 5.5.5.5. and 5.5.5.6).

9. Character stroke widths for white characters on black backgrounds should be 1/7 to 1/8 of character height (MIL-STD-1472C Sec. 5.5.59).

10. Spacing between characters should be a minimum of one stroke width (MIL-STD-1427C Sec. 5.5.5.11).

11. CRT signal sizes should not be less than 20 minutes of arc or 10 lines or resolution elements (MIL-STD-1472C Sec. 5.2.4.1).

12. Within the above constraints, character size should be as large as possible to maximize character legibility.

CHARACTER CELL DESIGN

The design assumptions stated above are best met by a character cell 52 elements in height by 30 elements wide, surrounding a character area 34 elements in height and 22 elements in width (see Figure 1). Thus, each character is surrounded by a blank area of 4 resolution elements on either side and 9 resolution elements at the top and bottom. Doubling these numbers by virtue by adjacent character cells provides the character clearances required by assumptions 7 and 10, while maximizing the character size. The character thus produced is 0.19125" tall, and subtends a visual angle of 23.48 minutes of arc at a 28" viewing distance. Each line contains 16 of these characters. A stroke width of 4/34 closely approximates the 1/8 recommended in Assumption 9. A character width of 22/34 closely approximates the 3/5 recommended in Assumption 8. Twelve lines of cells composed of 52 horizontal lines yields 624 lines. The remaining 16 lines of the 640 may be divided between the top-most and bottom-most portions of the screen. The 22 x 34 element character area may be dealt with as an 11 x 17 element area so that the characters are stroked during both phases of the raster interlace, reducing the likelihood of flicker.

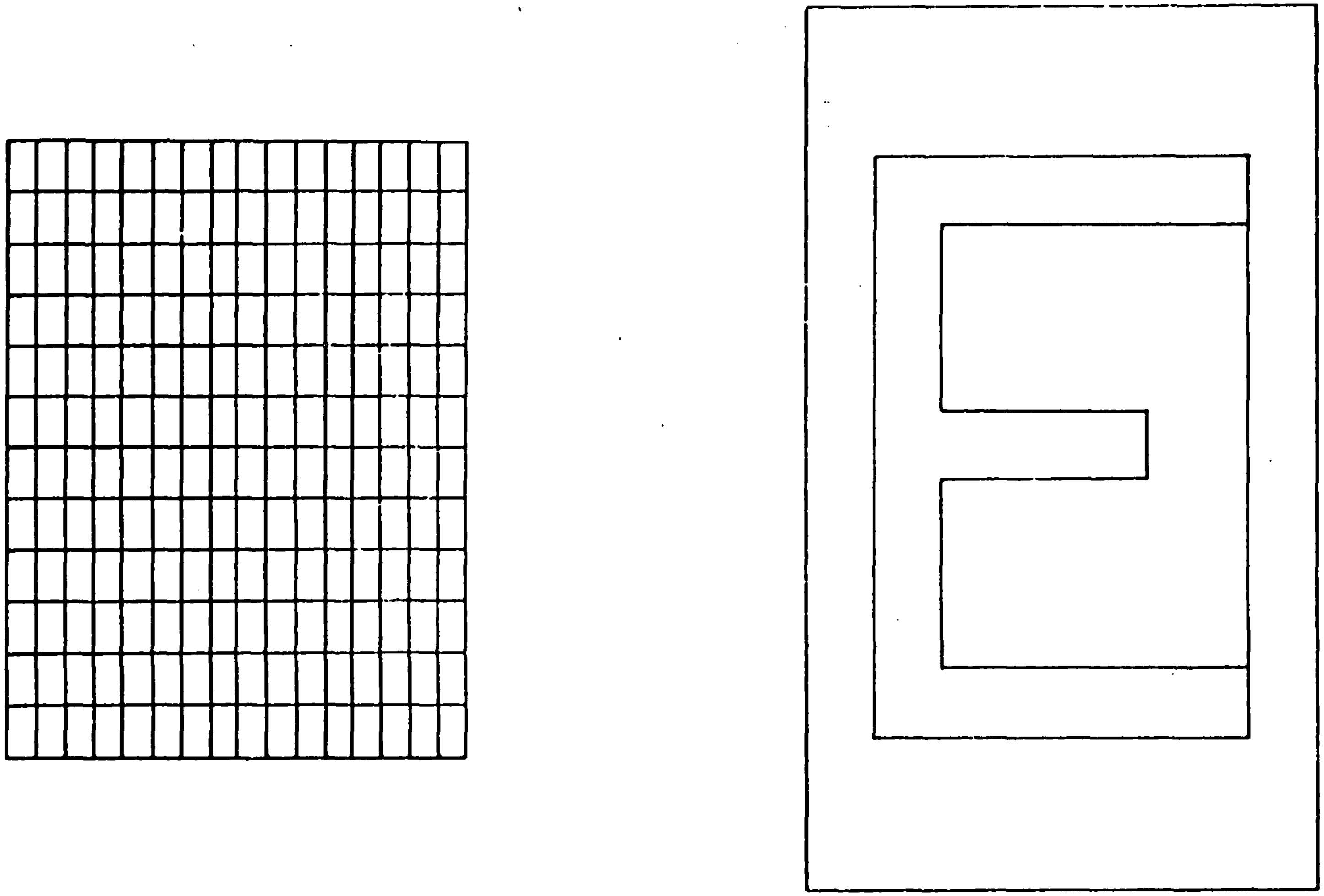
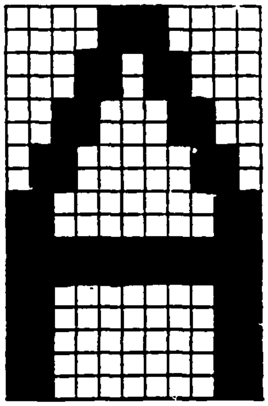
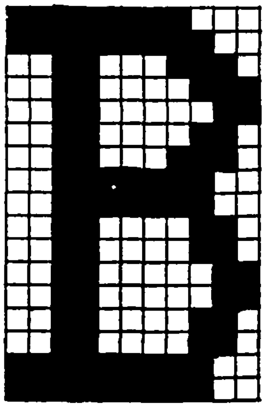


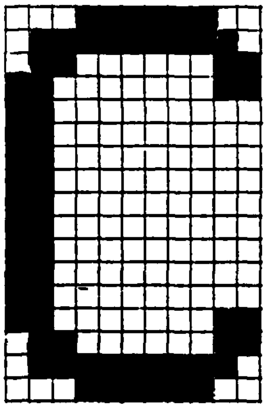
Figure 1. The array of 12 x 16 character cells on the CDU screen (actual size), and an enlargement of a 30 x 52 element character cell containing a 22 x 34 element character area.

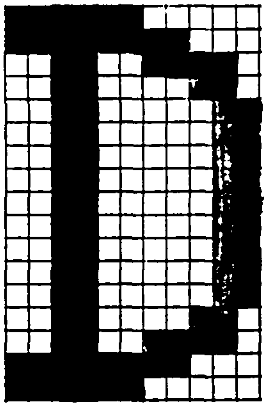
CHARACTER DESIGN

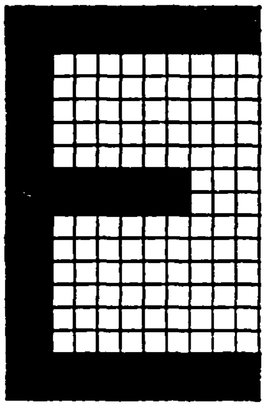
No previous uses of an 11 x 17 font have been identified. It was therefore necessary to design the character set in accordance with the findings of previous studies of letters and numerals and with known principles of form perception. Previously tested character matrices include the Lincoln/Mitre/Hazeltine, Vartebedian, Huddelston, Maximum Dot, Maximum Angle, and other special fonts. Fonts for use with the Near Term Scout Helicopter and the Agusta A-129 Attack Helicopter were also examined. The components and properties of the characters in these fonts judged most useful in augmenting legibility and discriminability were adapted for use in the IMPS 11 x 17 character set. The resulting character set is shown in the attached pages.

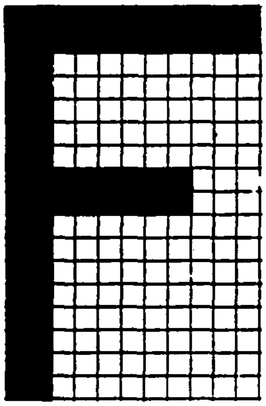


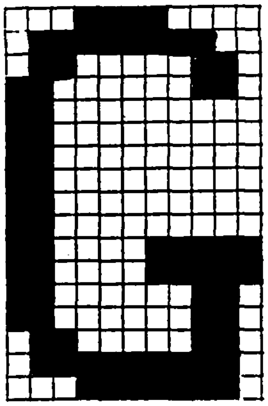


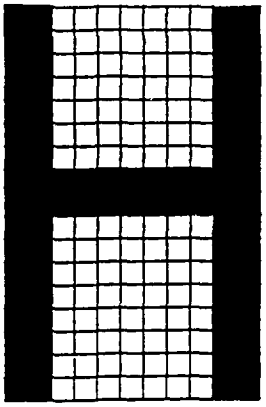


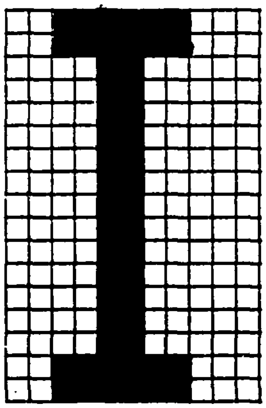


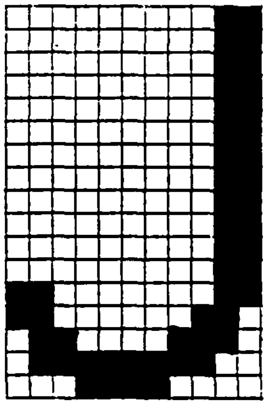


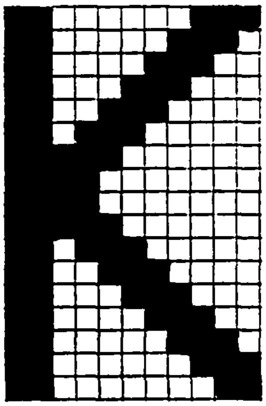


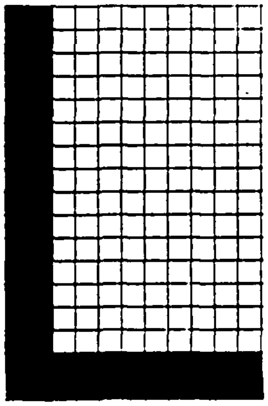


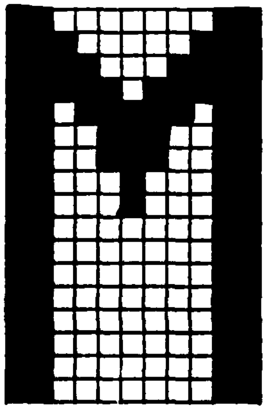


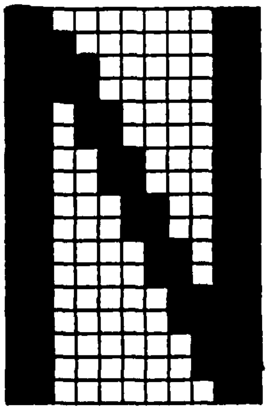


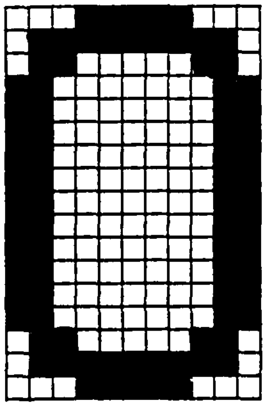


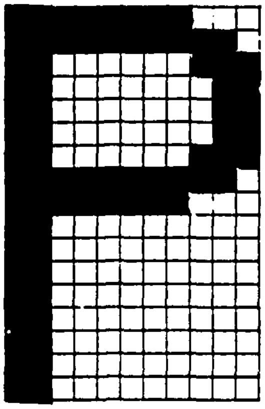


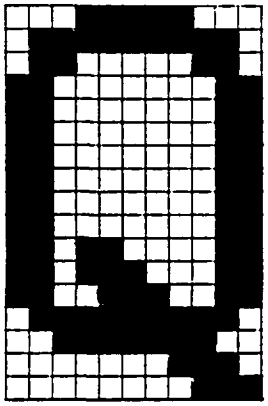
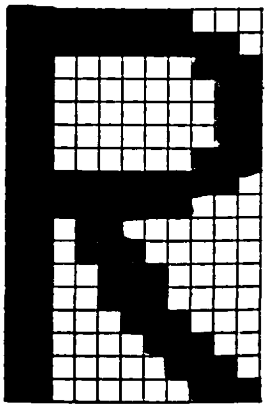
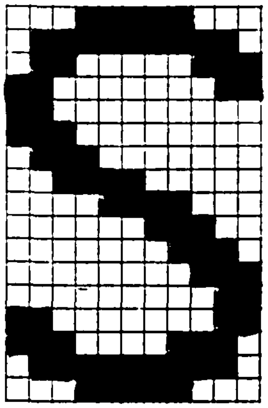
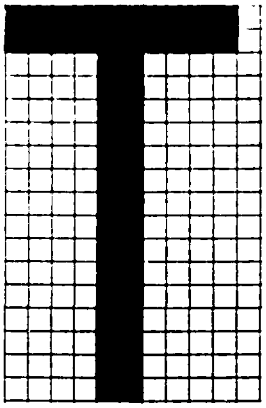
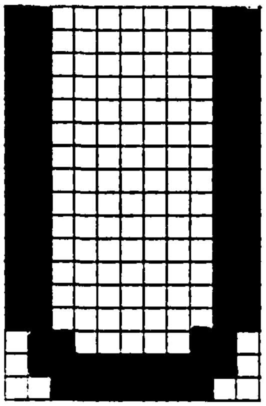
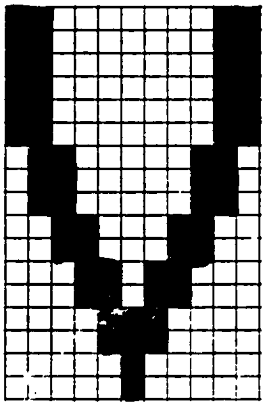
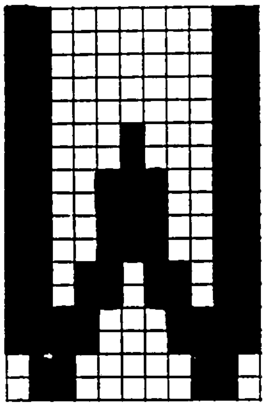
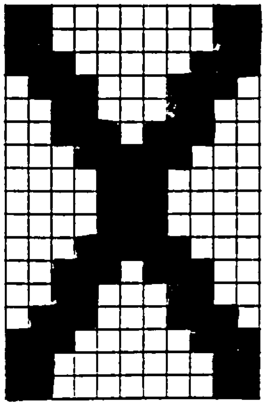
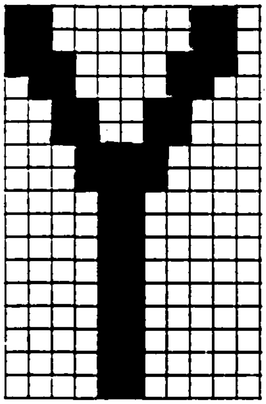
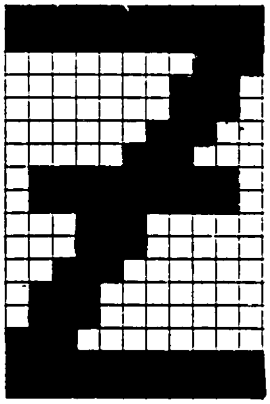


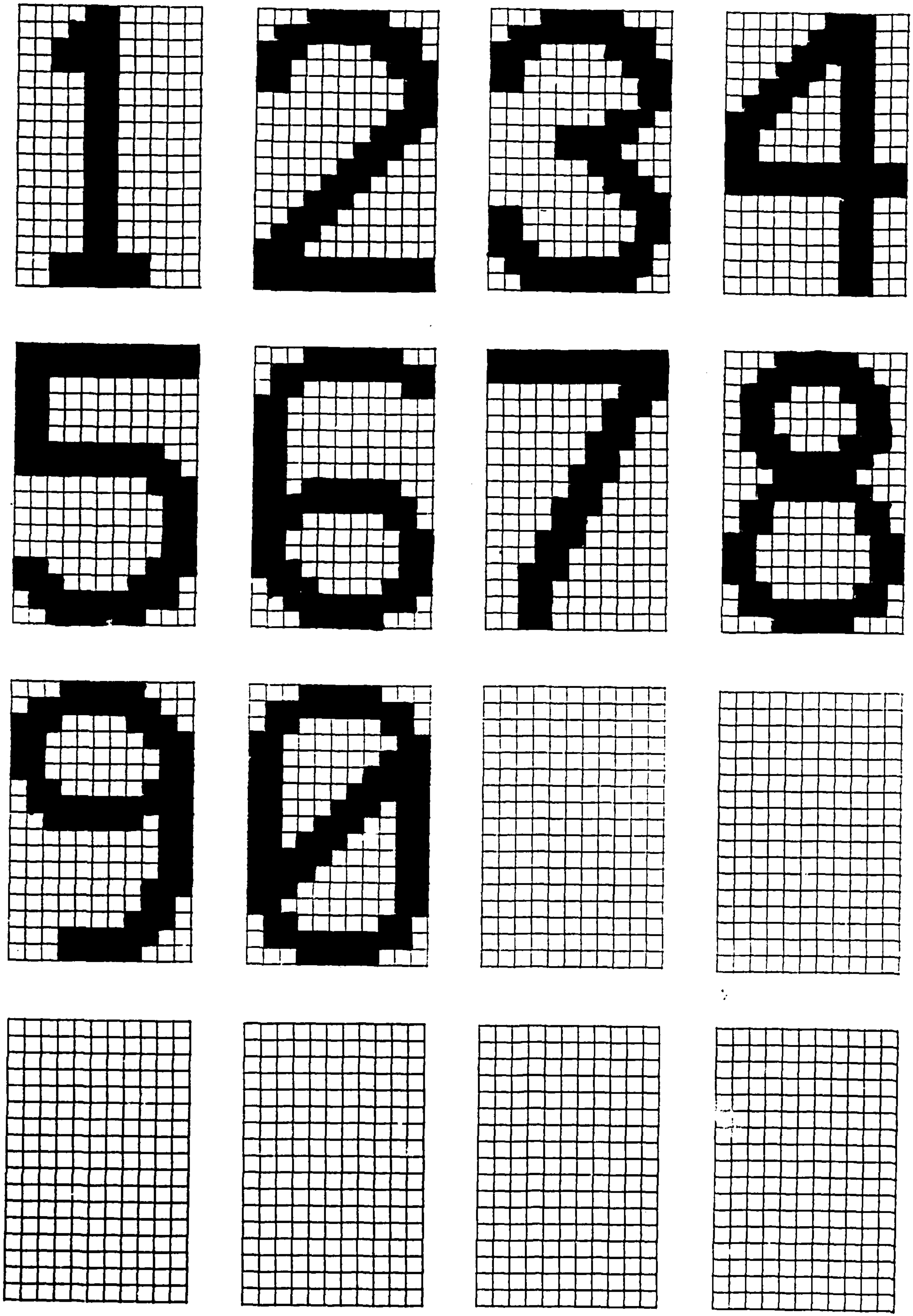


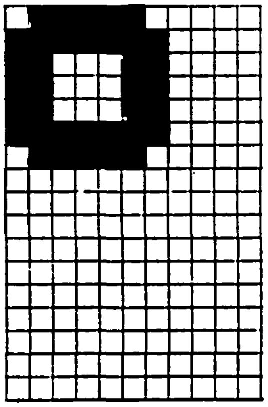


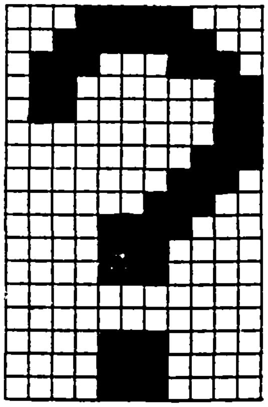


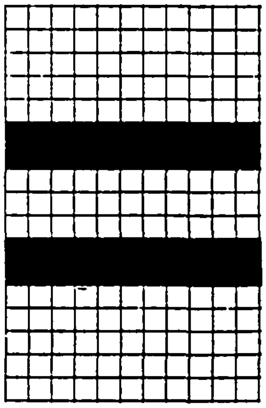


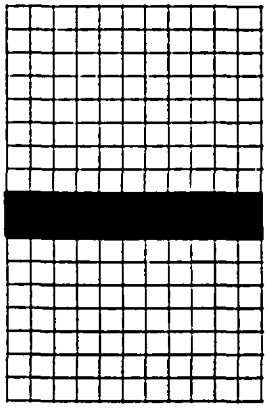











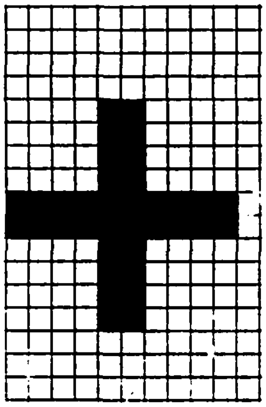


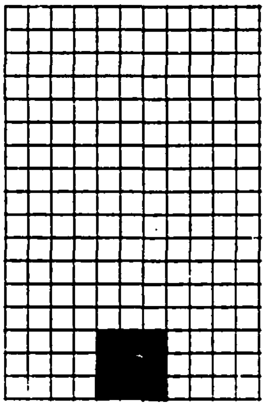


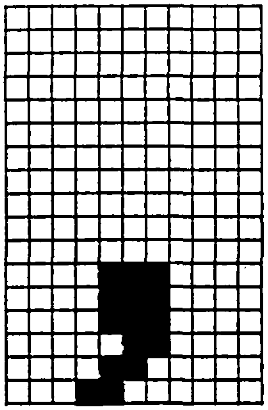


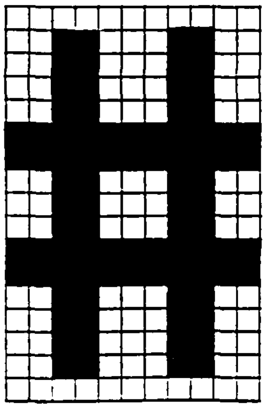


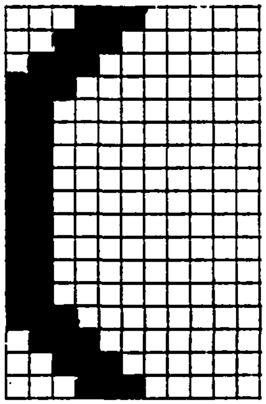


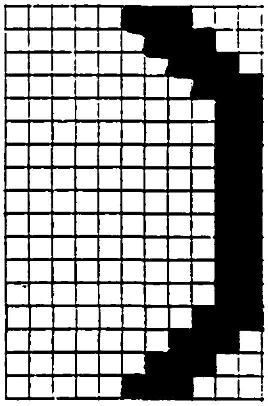












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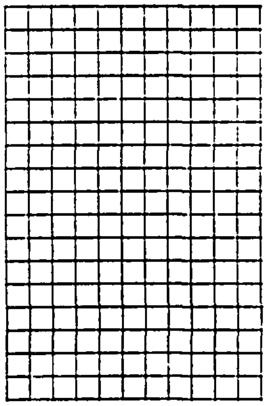
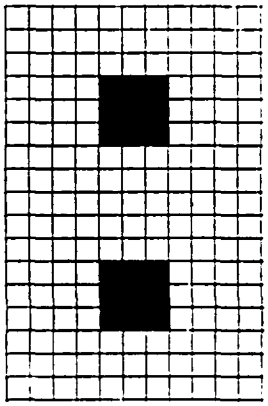
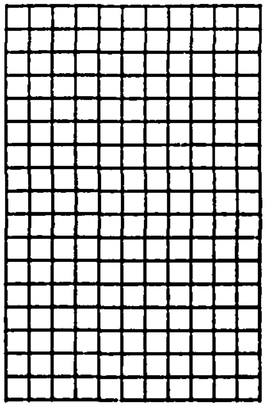
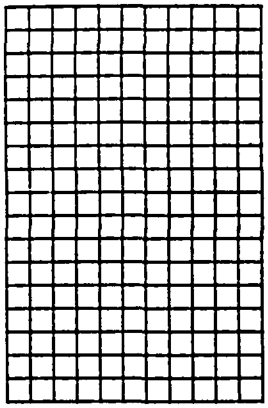
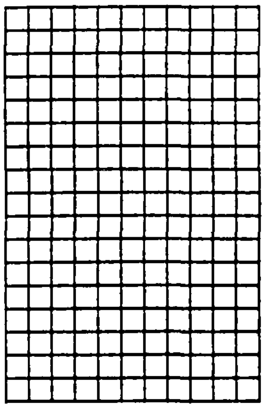
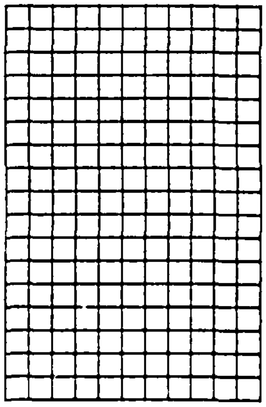












APPENDIX 3

HARDWARE DESIGN CRITERIA FOR THE AIRBORNE HAND CONTROLLER (AHC) OF THE INTEGRATED MISSION PLANNING STATION (IMPS)

IMPS AHC HARDWARE DESIGN CRITERIA

PURPOSE OF THE AIRBORNE HAND CONTROLLER

The Airborne Hand Controller (AHC) is used to support IMPS functional capabilities in several ways. The two most basic categories of requirements for the AHC are the following:

- To slew the map viewed by the aviator (the windowed portion of scene memory) for expanding the viewable area, for updating the navigation system, and for other special purposes.
- To slew a cursor across the map display in order to designate points in the terrain for obtaining range, bearing, coordinate, and elevation information, and for other position-indication tasks.

SELECTION OF AHC CONTROL TYPE

A joystick has been selected as the Airborne Hand Controller (AHC) after a human factors engineering analysis. This analysis consisted of several steps:

- Identification of tasks to be performed with the ACH.
- Determination of the types of inputs and the speed and accuracy requirements underlying performance of the tasks.
- Comparison of these requirements with known characteristics of general types of controls.

A summary of these analytical steps follows: The AHC was determined to be required for several different types of tasks including slewing the map, designating map positions for range and bearing information or coordinates, inserting symbology, updating the navigation system, and other activities.

Because all of these tasks involved positioning in two-dimensional space, discrete controls such as switches and pushbuttons were eliminated from consideration. "Mouse"-type controls are not suitable for the cockpit environment. Only the trackball and the joystick controls were compatible with task requirements. The speed and accuracy requirements underlying task requirements are unforgiving--both rapid slewing and fine positioning are mandatory. The control-display movement ratio cannot be optimized for both low travel time and low adjustment time with position (zero order) controls. The joystick, unlike the trackball, may be configured as a rate (first order) control, so that its fine positioning capability is excellent yet increased displacement (or pressure) yields increased display movement speed. Although a trackball can be spun to speed display movement, the high friction coefficient required for a vibration environment limits this capability. Finally, the isometric (pressure sensitive) joystick has additional advantages over the trackball in size, weight, and mechanical simplicity.

MIL-STD-1472C (5.4.3.2.3.1) offers the following suggestions regarding use of isometric joysticks:

> The isometric joystick may be used for control of various display functions such as data pickoff from a CRT. Isometric joysticks are particularly appropriate for applications: (1) which require return to center after each entry or readout; (2) in which operator feedback is primarily visual from some system response rather than kinesthetic from the stick itself; and (3) where there is minimal delay and tight coupling between control and input and system reaction. Isometric sticks should ordinarily not be used in any application where it would be necessary for the operator to maintain a constant force on the stick to generate a constant output over a sustained period of time.

These applications are in accordance with those expected with the IMPS tasks.

SELECTION OF AHC SPECIFIC CONTROL DEVICE

Because design and development of an isometric joystick was deemed beyond the scope of the IMPS effort, a commercially-available device was selected that most closely corresponded to the design criteria discussed in this document. The device, a Measurement Systems Model No. 869-20-10, is shown in Figure 1.

CONTROL SEPARATION REQUIREMENTS FROM MIL-C-81774A AND MIL-STD-1472C

> Controls shall be separated by enough space to permit manipulation of controls without interference or delay. Controls shall be positioned so that the operation of one control shall not cause the operation of any other control. Where separation does not eliminate inadvertent actuation, guards shall be used (MIL-C-81774A, Sec. 3.11.10).

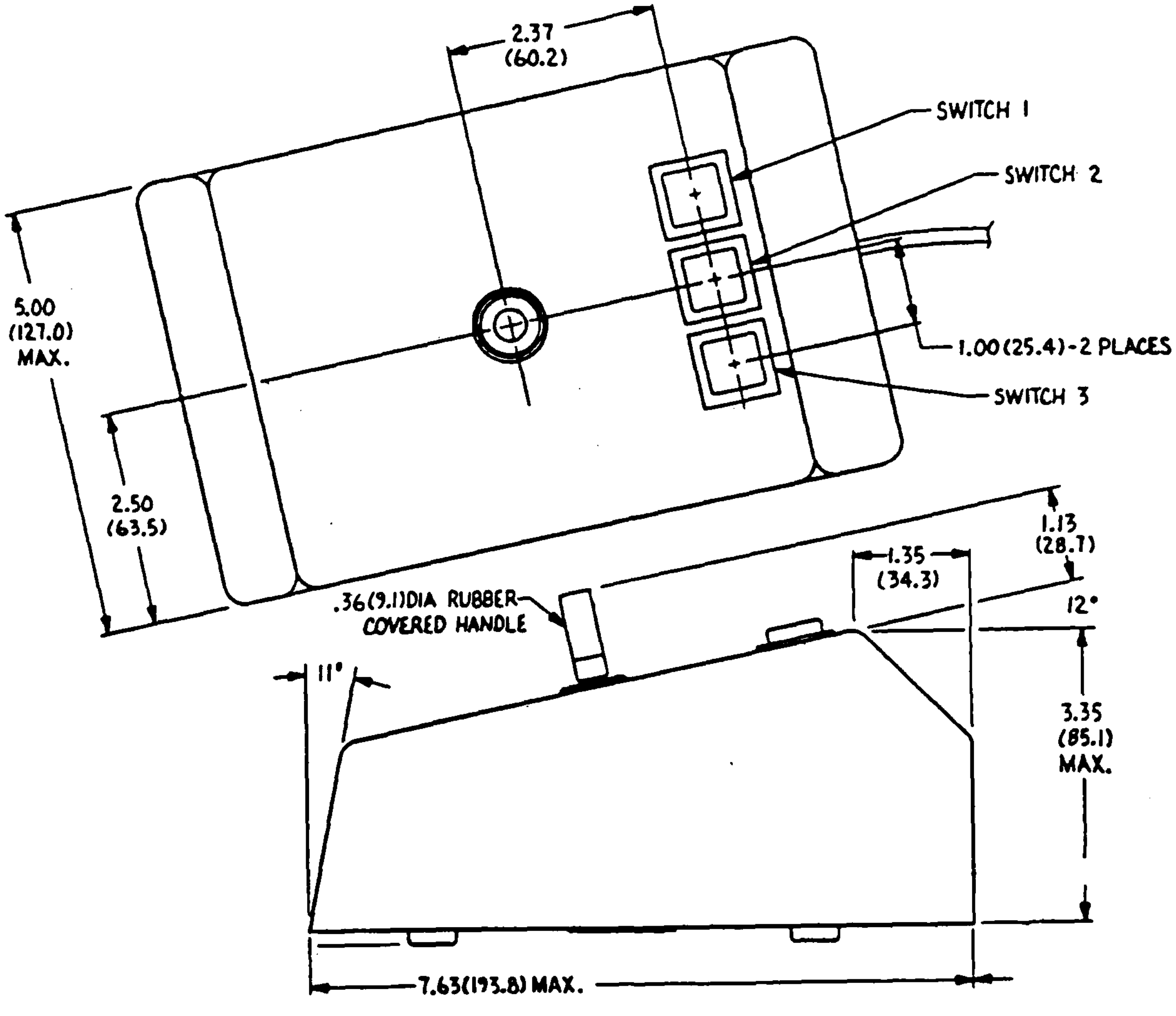


Figure 1. Device selected as the Airborne Hand Controller (Measurement Systems force-operated joystick Model No. 869-20-10).

Specifically, MIL-C-81774A calls for .5 inch between push buttons or .625 inch center to center. The edges of the AHC push buttons are somewhat less than .5 inch apart, but are 1.00 in center-to-center. Thus, inadvertent actuations are unlikely. No control separation requirements related to joysticks are presented in MIL-C-81774A. MIL-STD-1472C (5.4.3.2.3.3.2) suggests clearances of 4 inches to the side and 2 inches to the rear of isometric joysticks. The AHC joystick is approximately 2 inches from the three pushbuttons. As the location of the AHC within the aircraft has not been specified, sideward clearances cannot be determined.

AHC PUSHBUTTON LABELING

The height of the control markings shall be at least .14 inch (MIL-C-81774A, Sec 3.7.1). Letter design is described in MIL-M-18012B and MS33558. Width shall be approximately 3/5 of height and stroke width shall be approximately 1/8 of letter height. Approximately one stroke width shall be the space between letters. Fonts for engraving include Gorton extended, normal, and condensed.

AHC COLORS AND LUMINANCE

The AHC box shall be black. Transilluminated push-button controls may be either white on a black background until illuminated or not legible until illuminated. The push buttons must be legible under high ambient illumination (10,000 fc) or in darkness. Transilluminated controls shall show green markings when illuminated. The green markings are anticipated to become standard in the future because night vision goggles will be "blind" to colors of wavelengths below about 520 nm.

Control panel luminance must be continuously dimmable throughout its range, from off to full on. Transilluminated controls must all be of approximately equal perceived brightness throughout the range. The brightness may be controlled by the PNL BRT knob on the CDU, or provisions may be made for a suitable brightness control knob on the AHC itself.

AHC LEGENDS AND ABBREVIATIONS

The legends on the AHC push buttons are POS LOG (for position log), SLEW RET (for slew return) and MARK. The POS LOG push button is Switch 1 in Figure 1. The SLEW RET push button is Switch 2, and the MARK push button is Switch 3 in the same figure. Thus the only abbreviations are POS and RET. Abbreviations used on the AHC push buttons (and upon the CDU panel) are selected, where available, from MIL-STD-783C (Legends for Use in Aircrew Stations) or AR 310-50 (Authorized Abbreviations and Brevity Codes). In cases for which new abbreviations were required (such as RETURN) the above documents were reviewed to avoid confusions with previously authorized abbreviations, and efforts were made to assure that meanings of abbreviations would be obvious to the intended readers.

DIMENSION, DISPLACEMENT, AND RESISTANCE REQUIREMENTS FOR AHC CONTROLS MIL-C-81774A, MIL-HDBK-759A, AND MIL-STD-1472

Pushbuttons

Pushbuttons shall provide *momentary* discrete inputs. Their height shall be .10-.25 inch, their width shall be at least .5 inch, their displacement shall be .03-.19 inch, and their resistance shall be 30 ± 10 oz.

Isometric Joystick

Dimensions and resistances for joysticks are not specified in MIL-C-81774A. Recommendations from the other documents, and specifications of the Measurement Systems device are shown in Table 1.

It can be seen that the Measurement Systems device does not meet the minimum length and resistance characteristics of MIL-STD-1472C. This standard, however, does not discriminate between desirable characteristics for isotonic versus isometric joysticks. Furthermore, the 12 oz and 32 oz specifications date back at least to 1964 (when the document was identified as MIL-STD-803A) and the resistances were applied to lever (not joystick) controls. Thus the relatively small length and force characteristics of the Measurement Systems device should not necessarily be considered detrimental to peformance.

TABLE 1
ISOMETRIC JOYSTICK CHARACTERISTIC SPECIFICATIONS

Characteristic	MIL-STD 1472C	MIL-HDBK-759A	Measurement Systems Device
Minimum Diameter	.25 in	—	.36 in
Maximum Diameter	.625 in	.59 in	
Minimum Length	3.0 in	—	1.13 in
Maximum Length	6.0 in	4.72 in	
Minimum Resistance	12 oz	—	2.2 oz
Maximum Resistance	32 oz	158 oz	28.2 oz

JOYSTICK DYNAMICS

Because joystick dynamics can become extremely complex, military specifications tend to avoid the issues. MIL-STD 1472C (5.4.3.2.3.2) states only the following:

> The isometric stick shall deflect minimally in response to applied force, but may deflect perceptibly against a stop at full applied force. The x and y output should be proportional to the magnitude of the applied force as perceived by the operator.

Although firm requirements are not available, efforts should be made to reduce the potential for inadvertent cross-coupling between axes of motion and for cursor overshoot. Inadvertent cross-coupling can be avoided by introducing a "dead band." The dead band is the range of forces on the stick that produces no output change and thus allows the cursor to remain stationary on the screen. An optimum deadband permits, for example, the movement of the cursor to the side, without accidentally moving it upward or downward. The 2.2 oz deadband of the Measurement Systems joystick has been developed through empirical evaluations and appears to be suitable for the tasks envisioned with the IMPS system.

"Overshoot" is sometimes encountered with rate controls. It has been found that overshoot can be reduced by "aiding"--designing the device so that input to the control produces a corresponding postion change in addition to the resulting velocity. It is as yet unclear whether the AHC may require some level of aiding. The response curve of the Measurement Systems joystick is positively accelerated, so that equal force increments result in successively greater pulse rates as force is increased. This non-linear response typically reduces overshoot problems, so that aiding may be unnecessary for AHC requirements.

DIRECTION OF MOTION RELATIONSHIPS

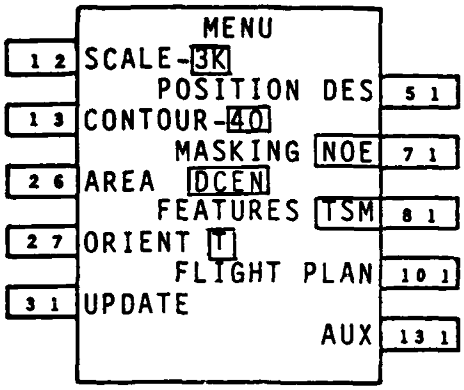
When the joystick controls a cursor moving across the display screen, movement of (or pressure on) the joystick should correspond with cursor movement. When the joystick controls the slewing of the map in the display window, movement of (or pressure on) the joystick should be opposite of the direction of map movement (as if the joystick were controlling the movement of the window).

APPENDIX 4

A DESCRIPTION OF THE DIALOGUE FOR CONDUCTING TRANSACTIONS WITH THE INTEGRATED MISSION PLANNING STATION (IMPS) THROUGH USE OF AN INTERACTIVE CONTROL-DISPLAY UNIT (CDU) AND ASSOCIATED SYSTEM COMPONENTS

PAGE 1. SELECT MAP SCALE; SELECT CONTOUR LINES; SELECT SHADED RELIEF; SELECT ELEVATION GUIDE

1-1



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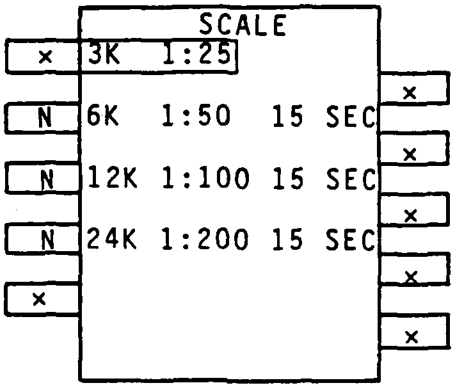

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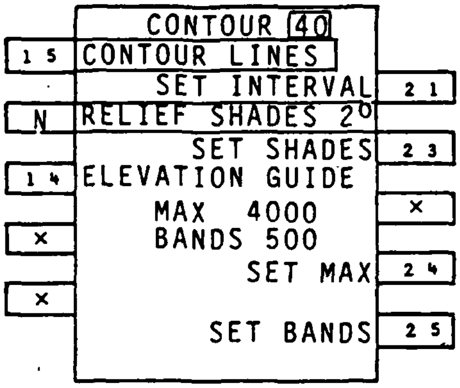

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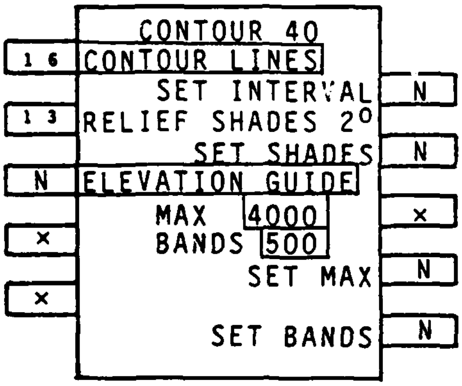

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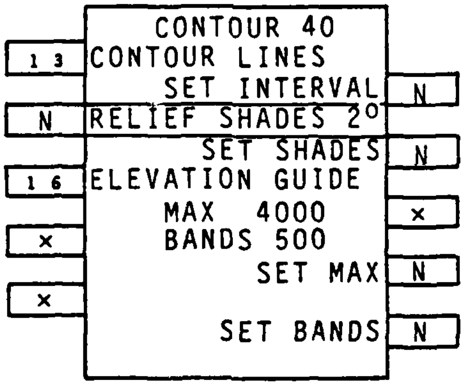

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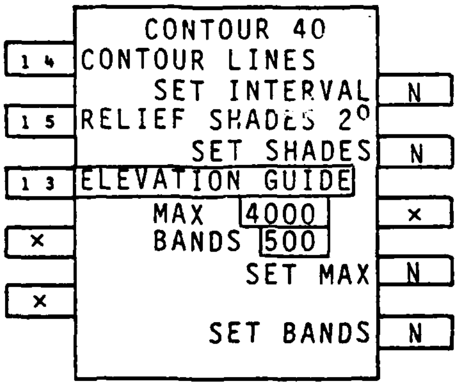

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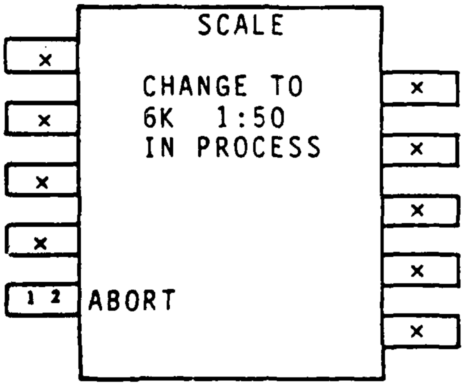
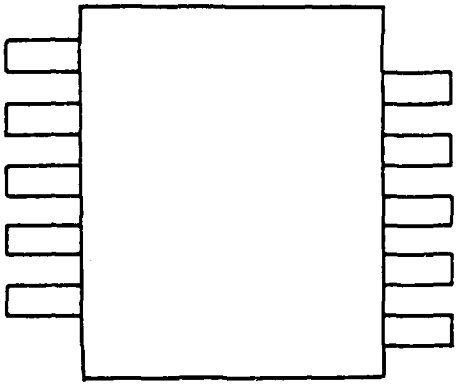
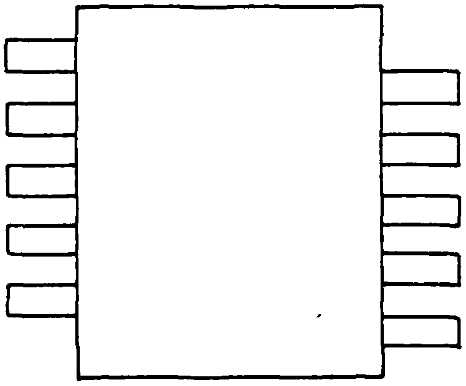
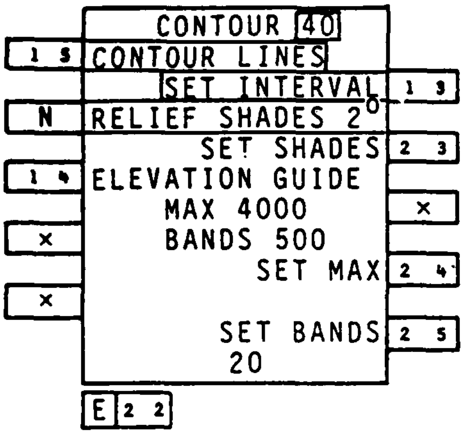






PAGE 2. SET CONTOUR INTERVAL; SET SHADED RELIEF; SET ELEVATION GUIDE; SET MAP WINDOW POSITION; SELECT MAP ORIENTATION

2-1



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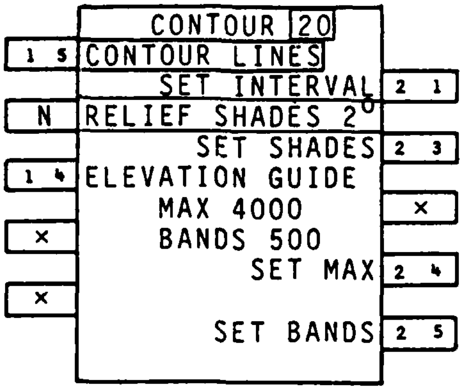

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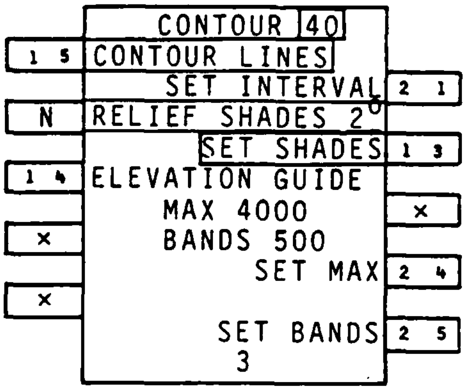

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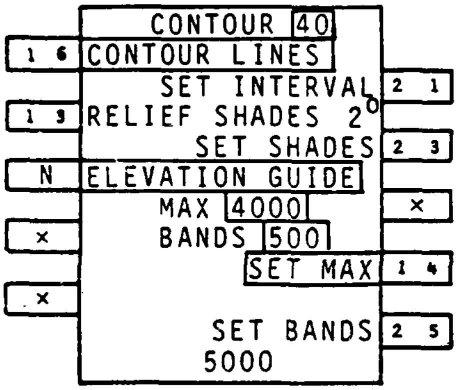

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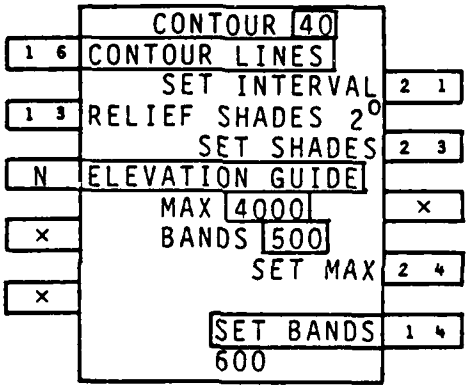

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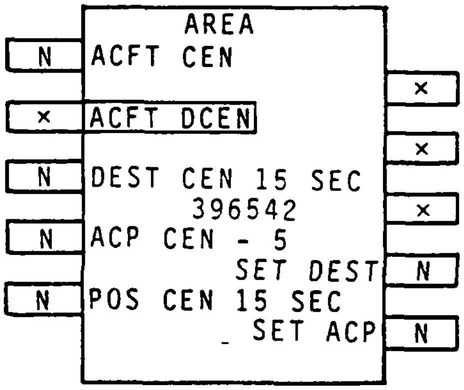

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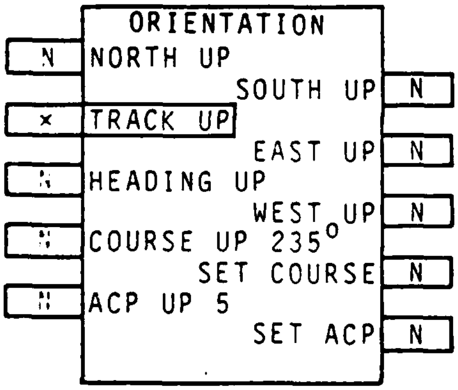

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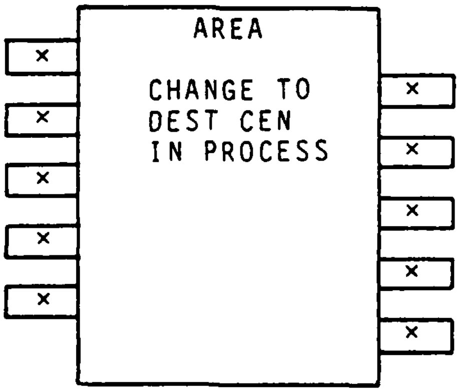
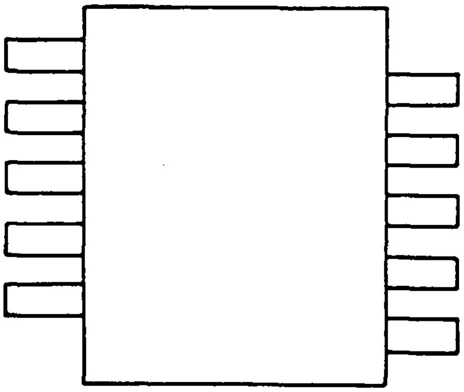
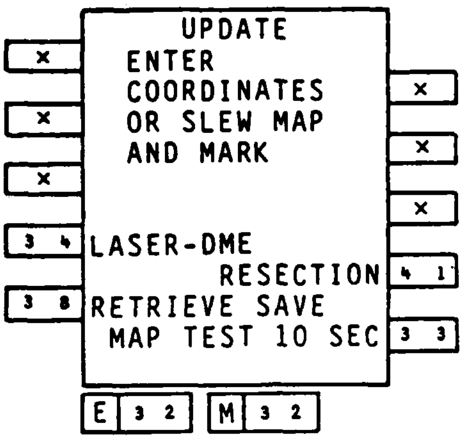




PAGE 3. PERFORM POSITION UPDATE; PERFORM LASER UPDATE; RETRIEVE SAVED UPDATE

3-1



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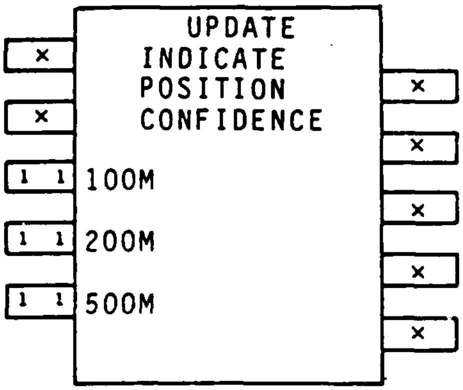

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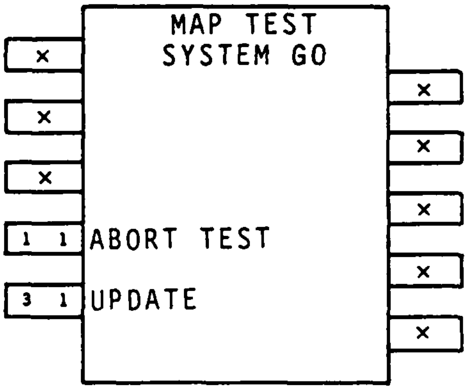
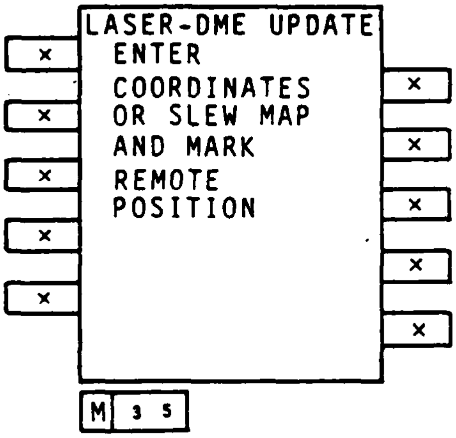


3-4



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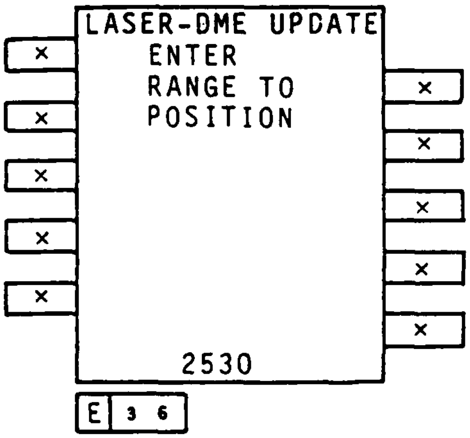

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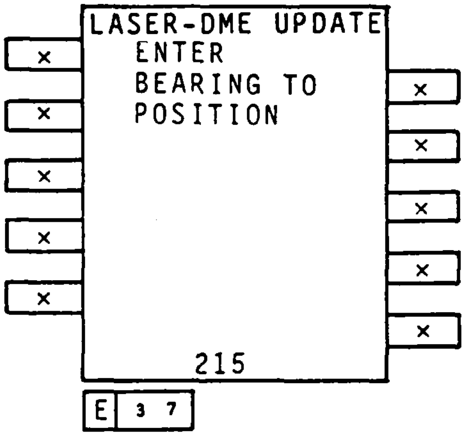

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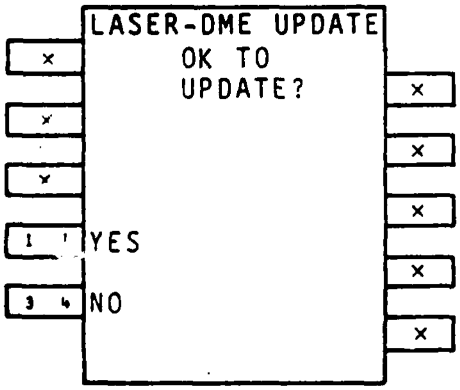

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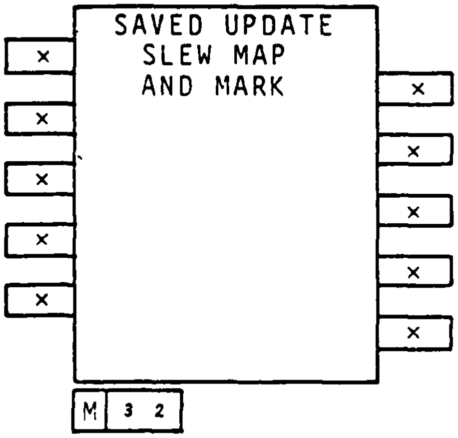
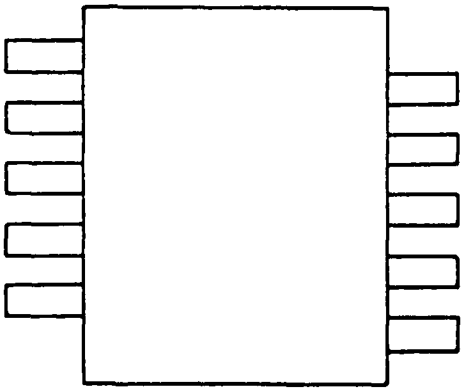
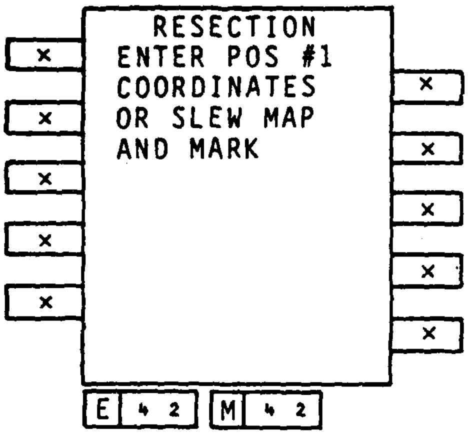




PAGE 4. PERFORM RESECTION UPDATE

4-1



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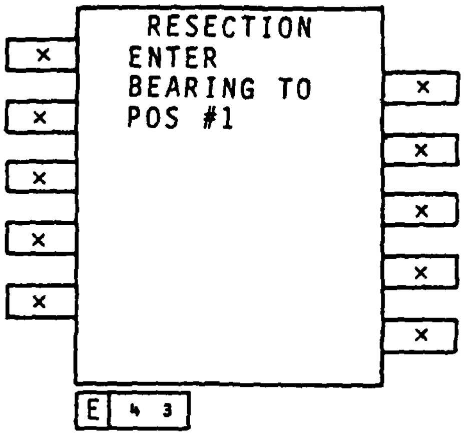

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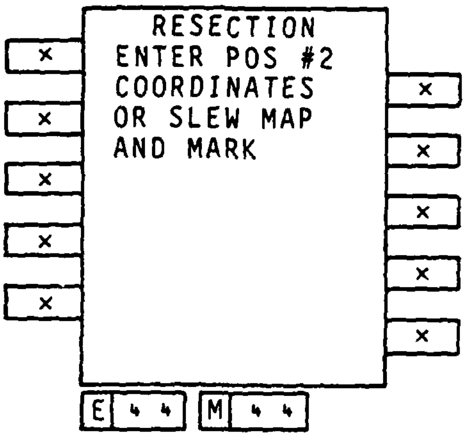

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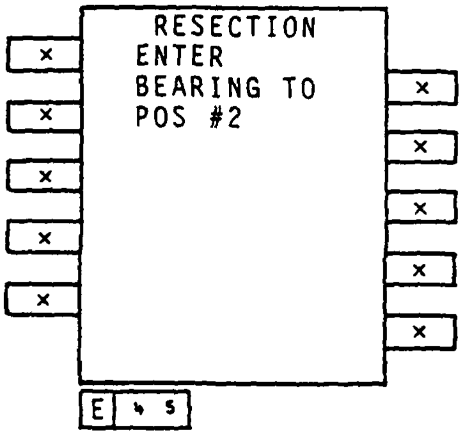

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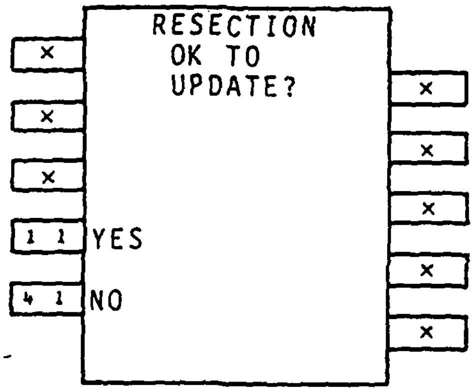
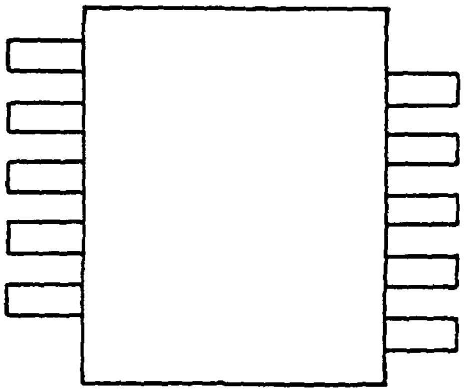
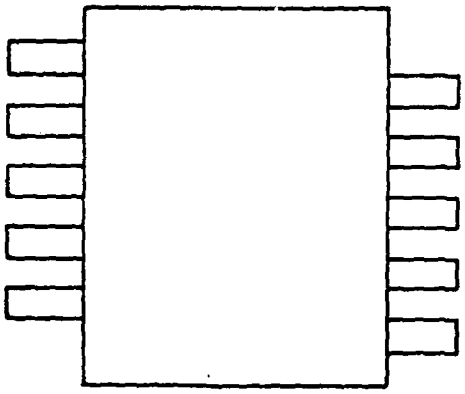
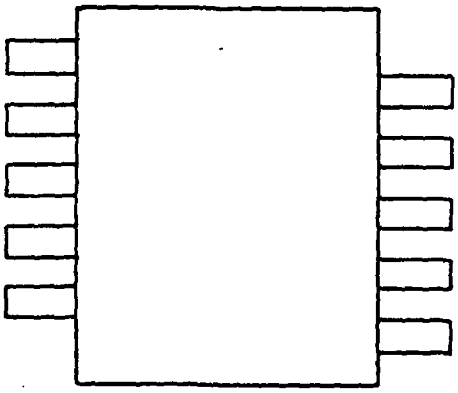
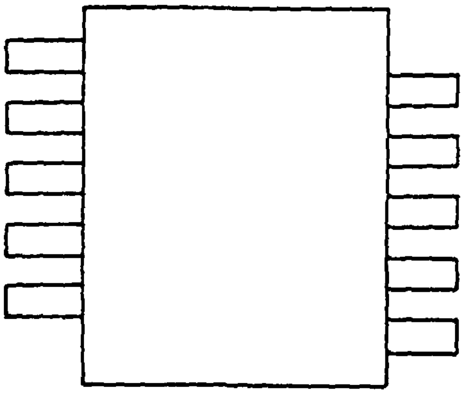




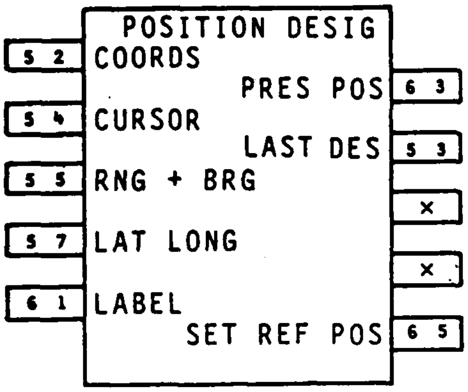






PAGE 5. DESIGNATE POSITIONS: BY COORDINATES; CURSOR; RANGE AND BEARING; LATITUDE-LONGITUDE

5-1



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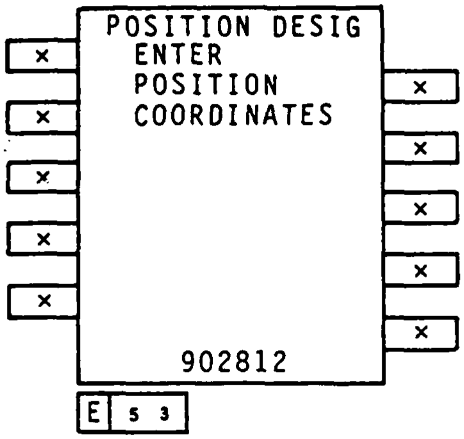

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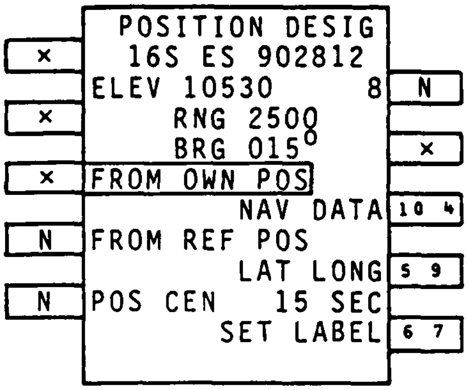

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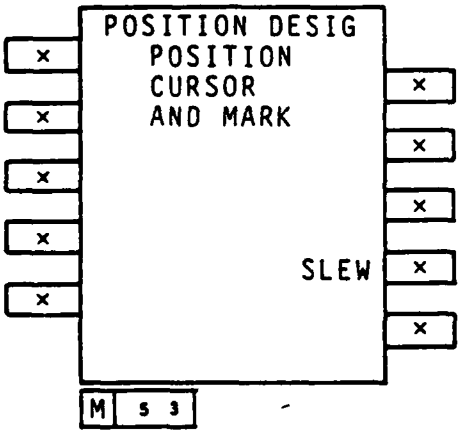

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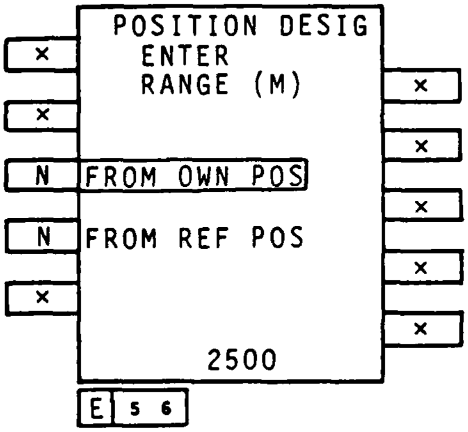

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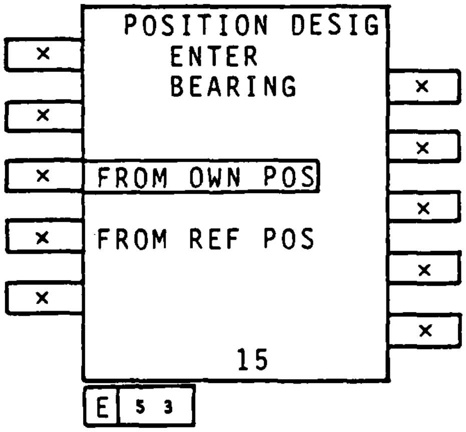

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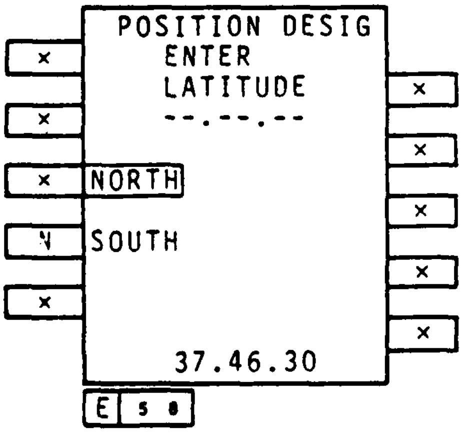

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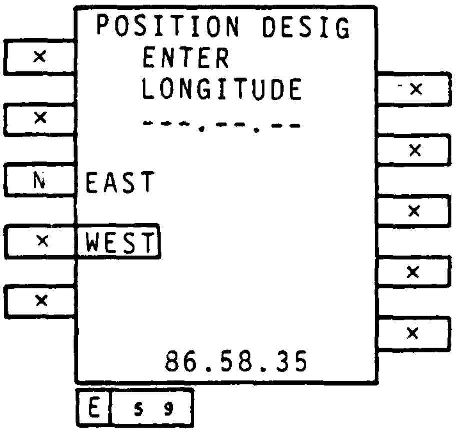

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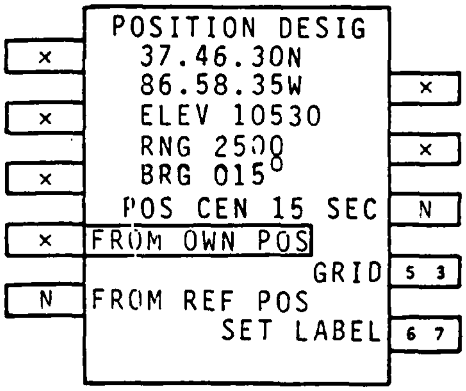
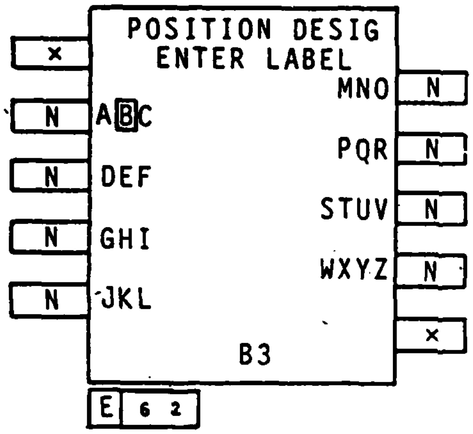


PAGE 6. DESIGNATE POSITIONS BY LABEL; DISPLAY PRESENT POSITION; SET REFERENCE POSITION; SET LABEL

6-1



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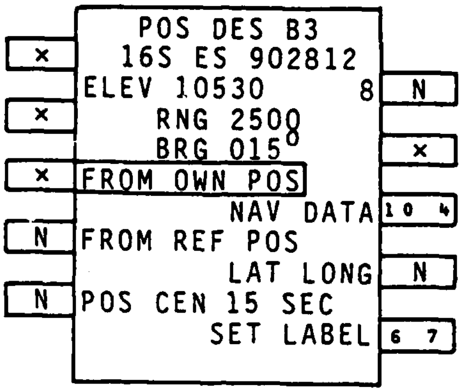

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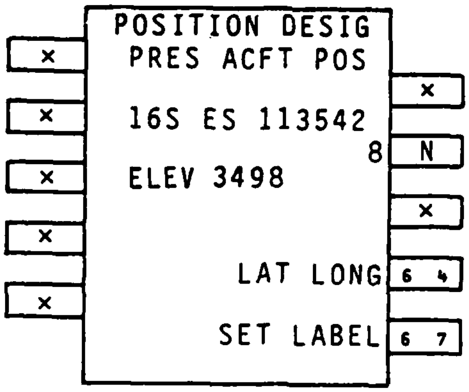

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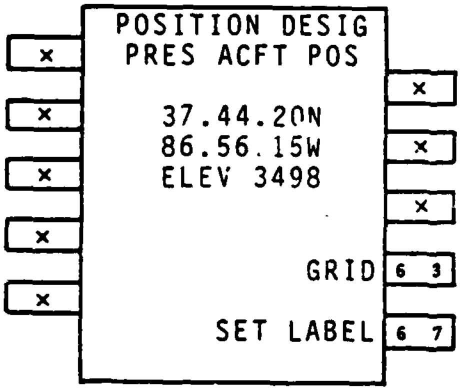

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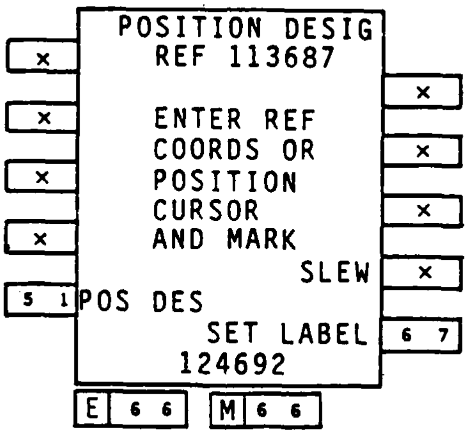
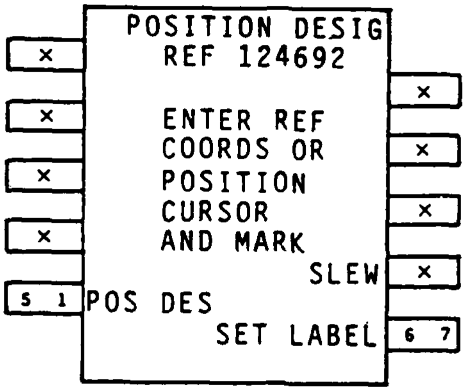


6-6



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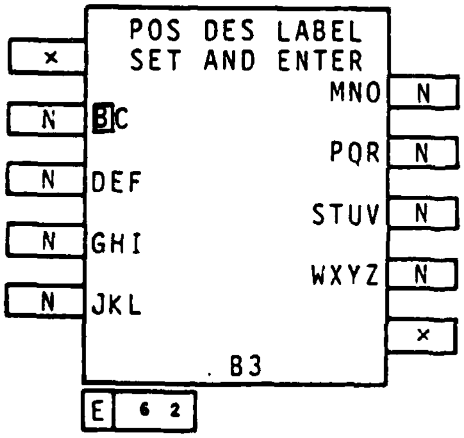

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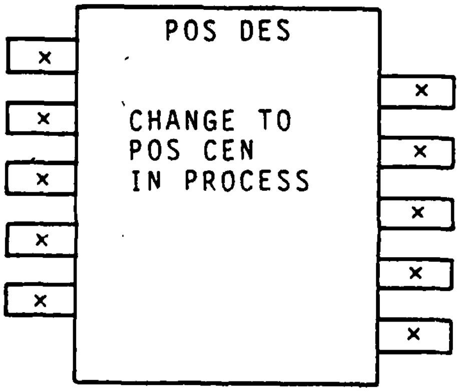
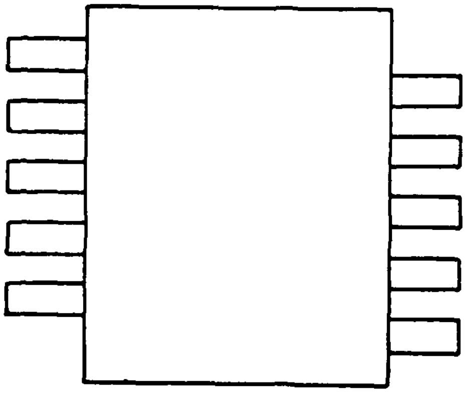
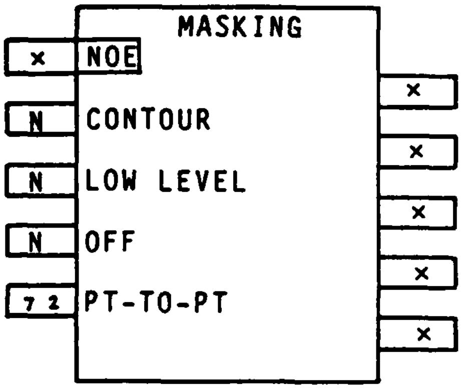


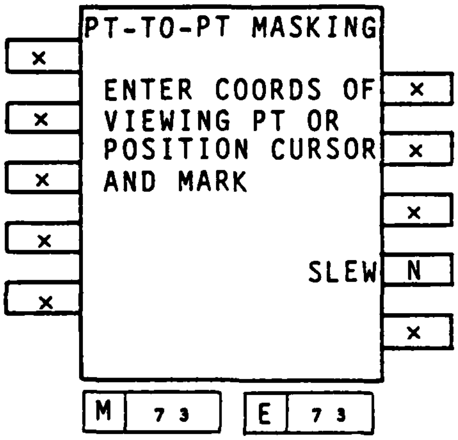


PAGE 7. SELECT MASKING TYPE; DETERMINE POINT-TO-POINT MASKING; SET LABEL

7-1



7-2



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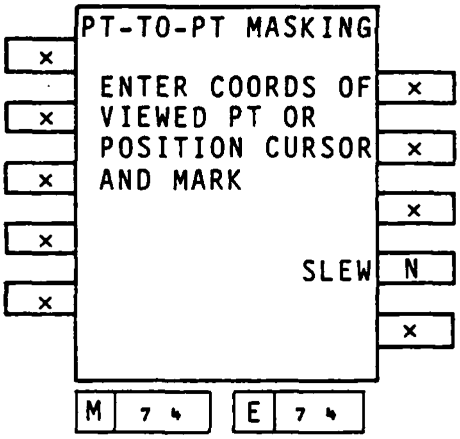

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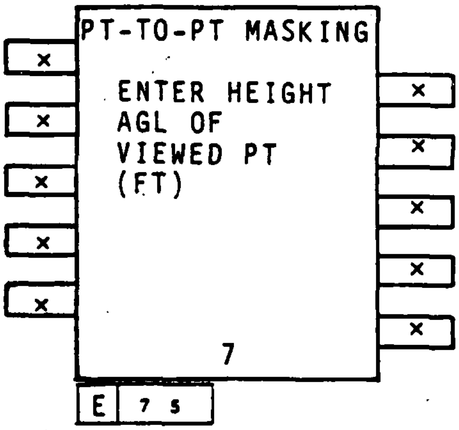

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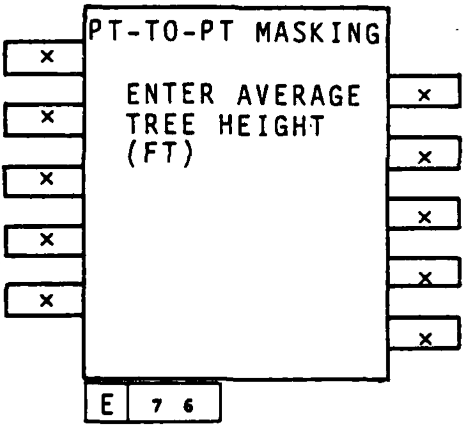

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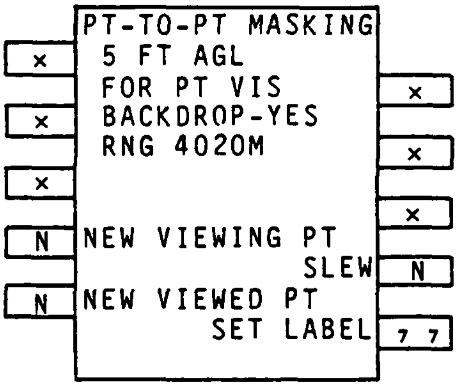
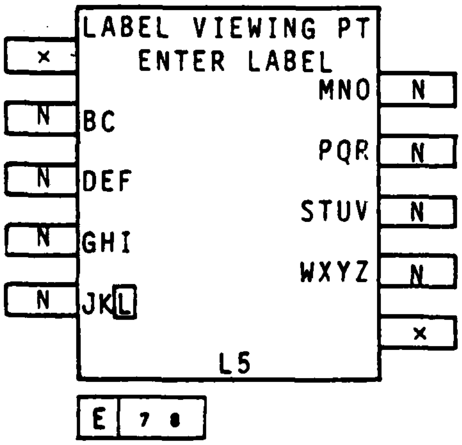
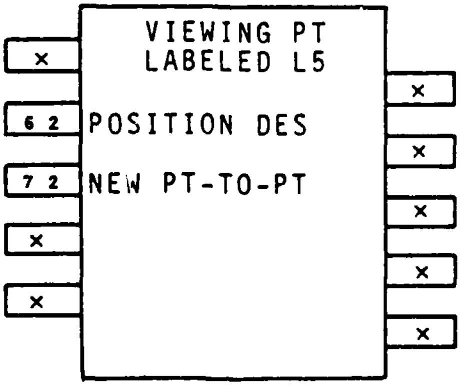
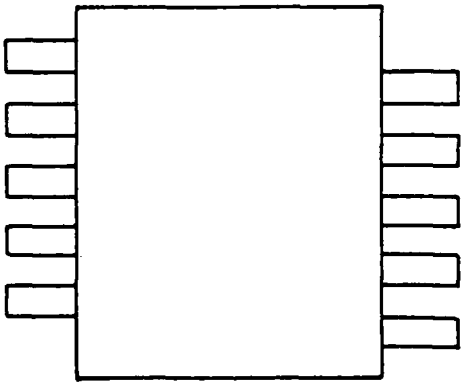


7-7

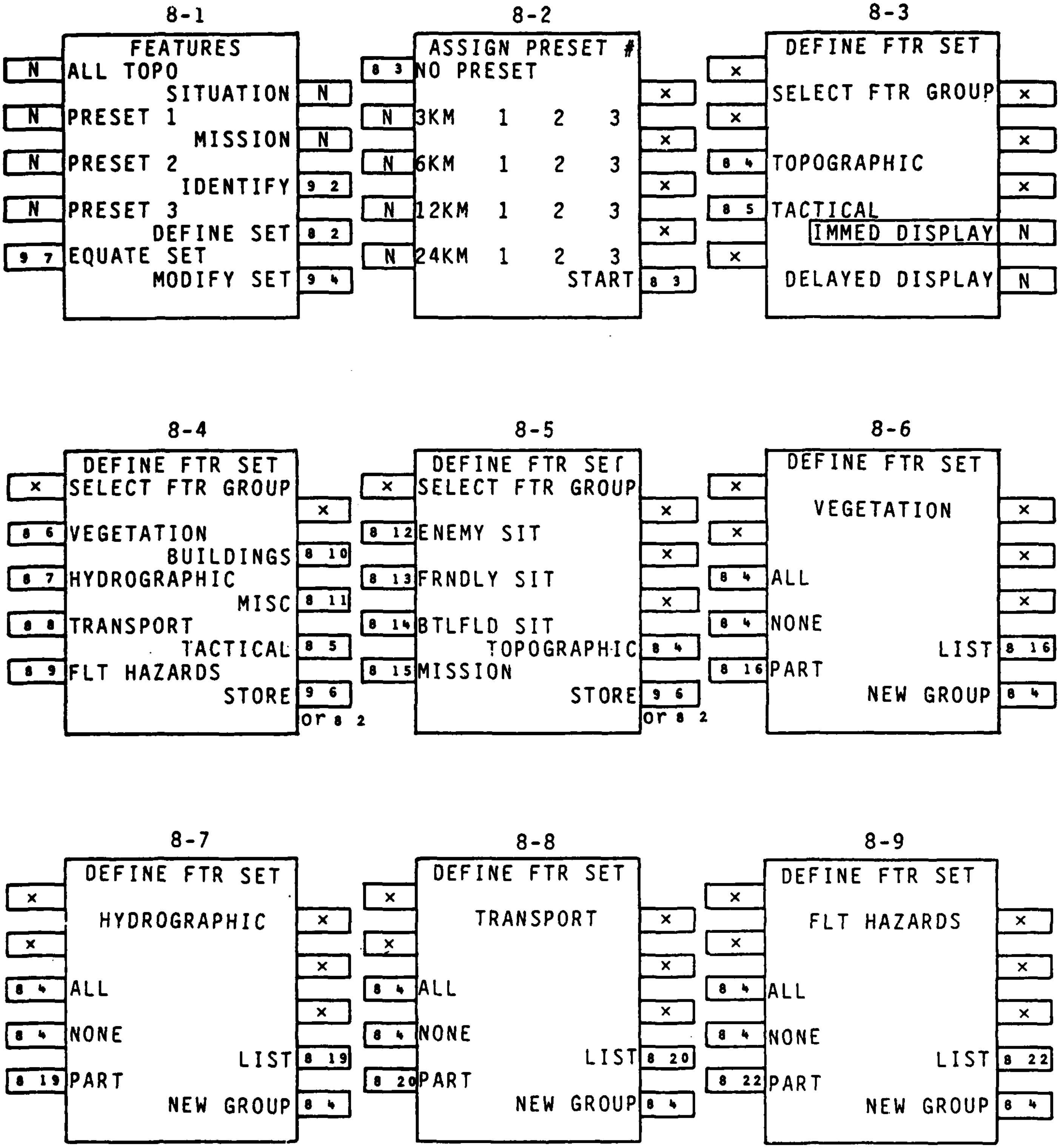


7-8



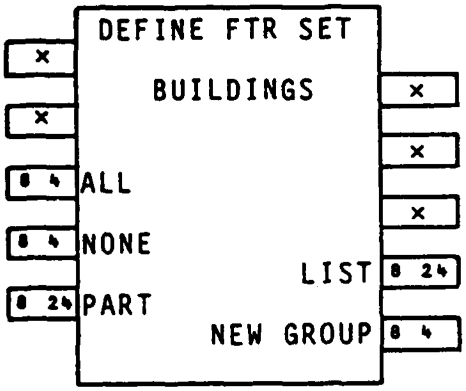


PAGE 8. SELECT FEATURES; DEFINE FEATURE SETS; STORE FEATURE SETS; LIST FEATURE SETS

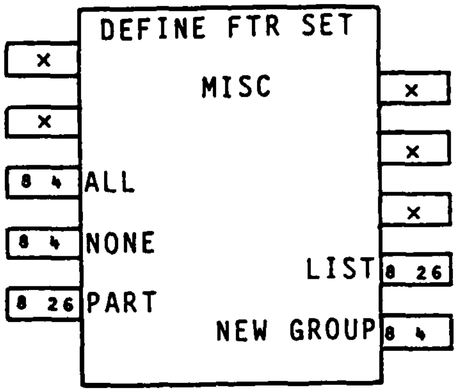


PAGE 8. (CONTINUED) SELECT FEATURES; DEFINE FEATURE SETS; STORE FEATURE SETS; LIST FEATURE SETS

8-10



8-11



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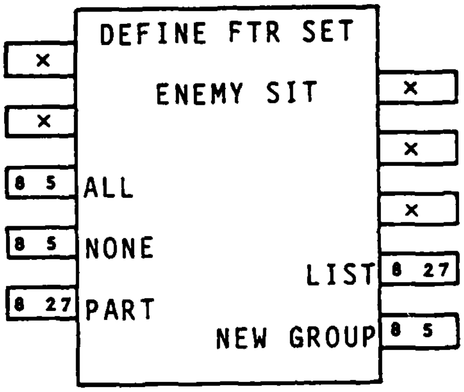

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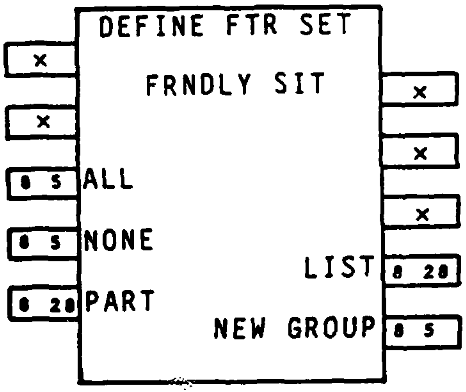

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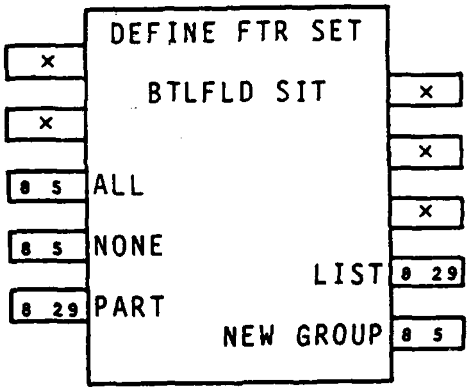

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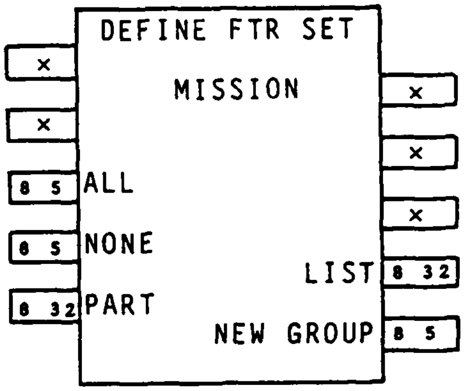

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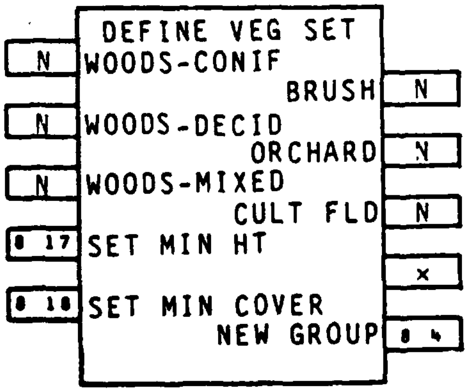

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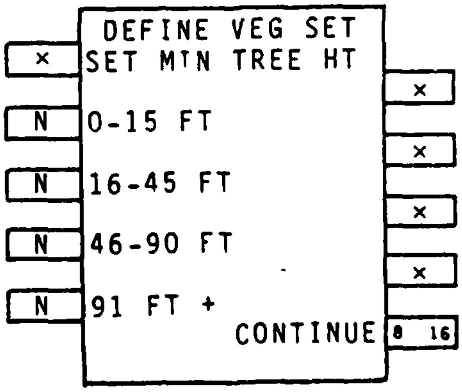

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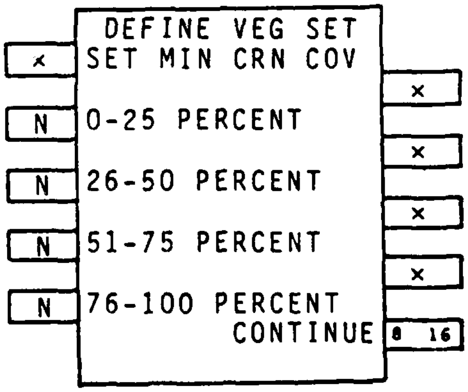
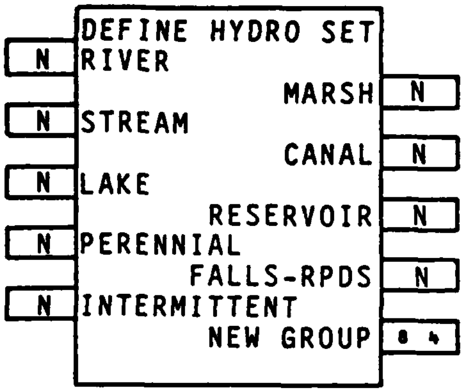


PAGE 8. (CONTINUED) SELECT FEATURES; DEFINE FEATURE SETS; STORE FEATURE SETS; LIST FEATURE SETS

8-19



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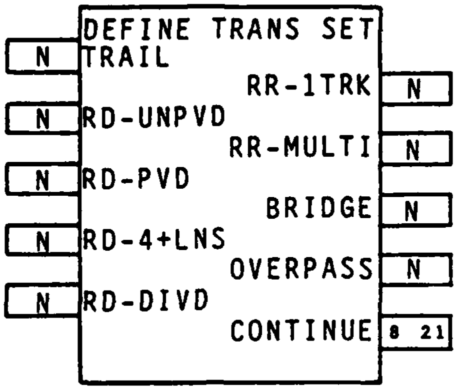

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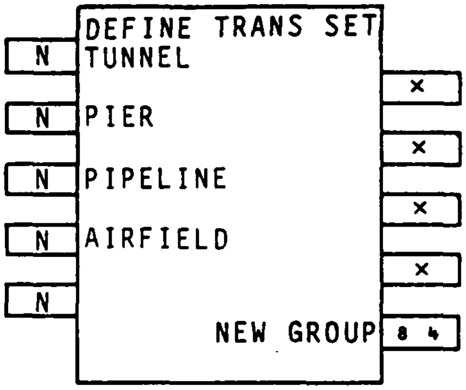

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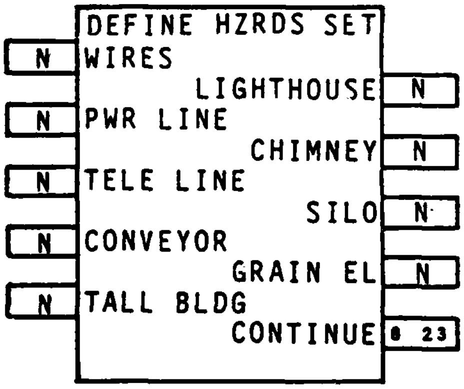

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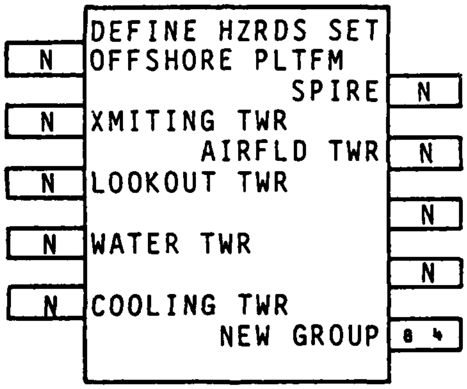

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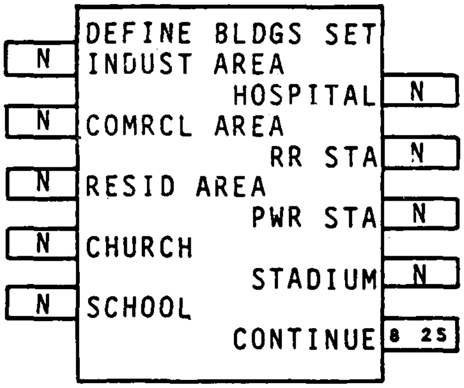

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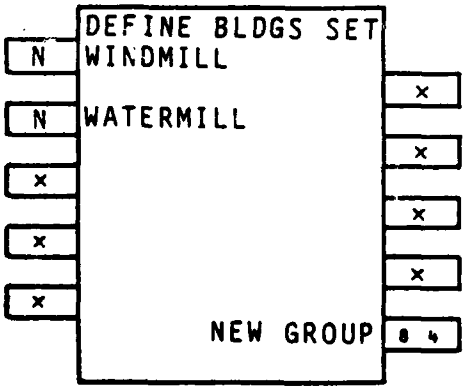

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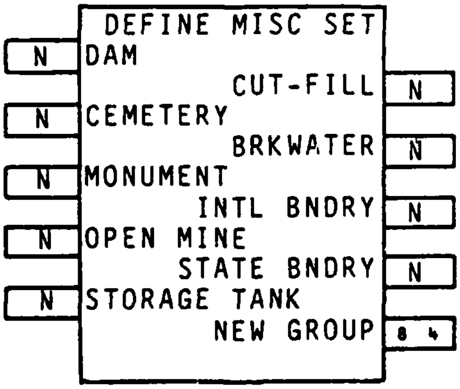

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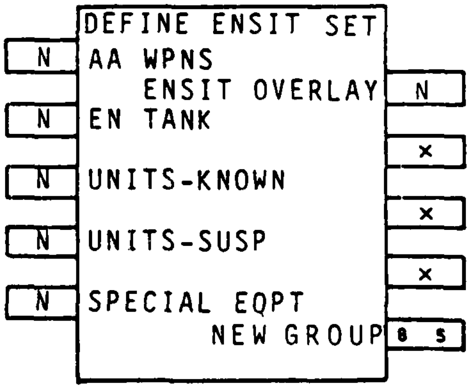
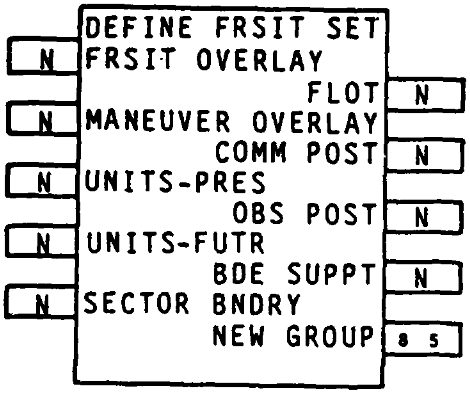


PAGE 8. (CONTINUED) SELECT FEATURES; DEFINE FEATURE SETS; STORE FEATURE SETS; LIST FEATURE SETS

8-28



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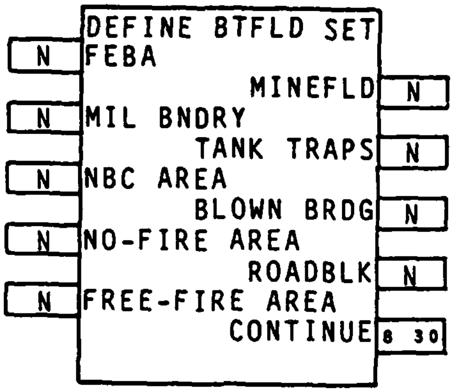

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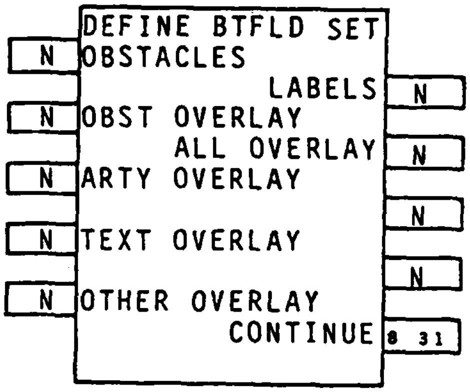

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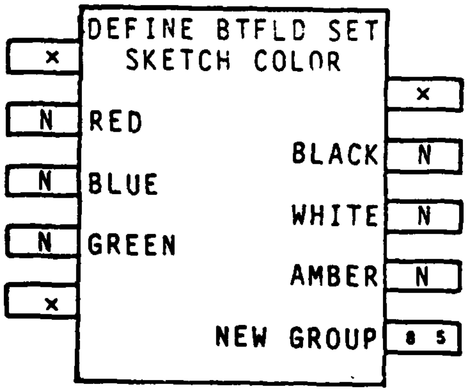

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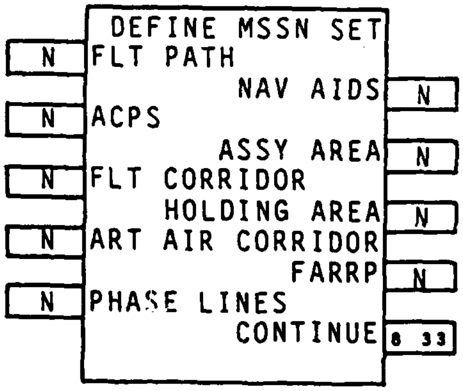

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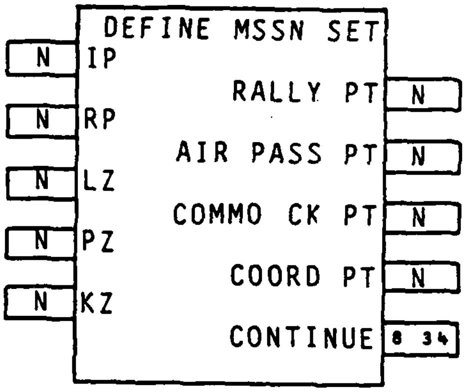

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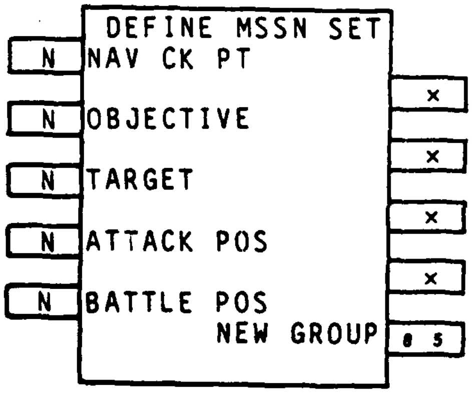
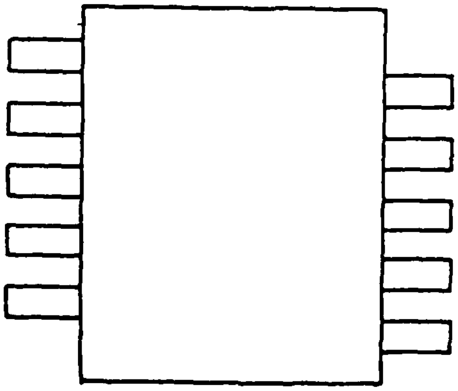
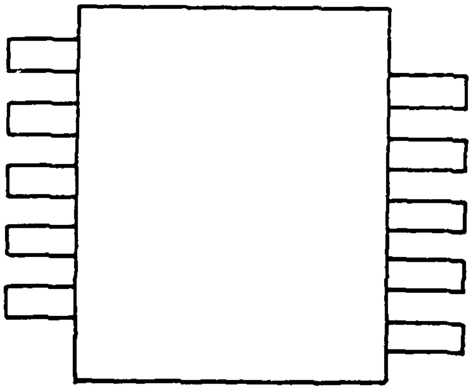
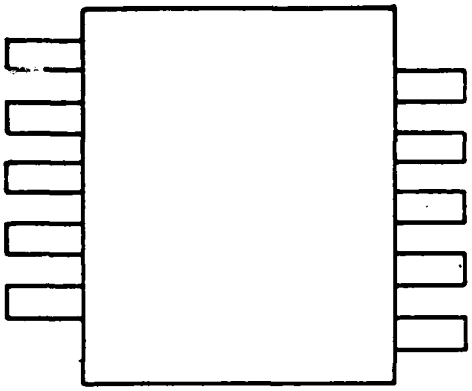




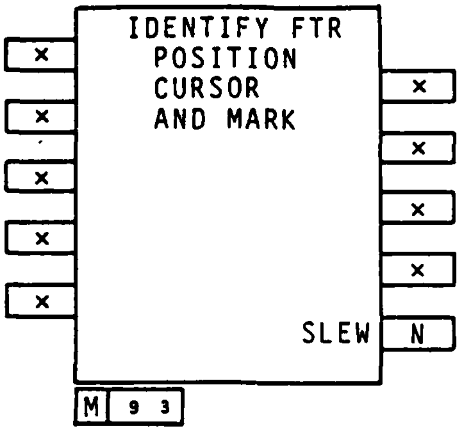


PAGE 9. IDENTIFY FEATURES; MODIFY FEATURE SET

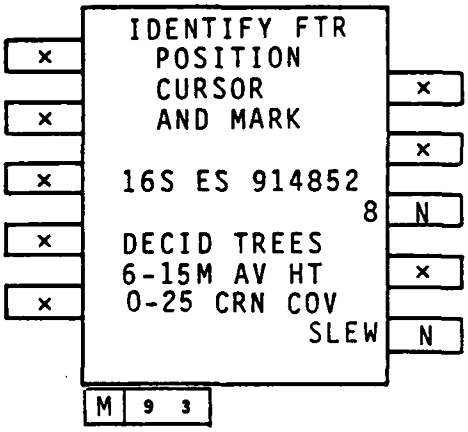
9-1



9-2



9-3



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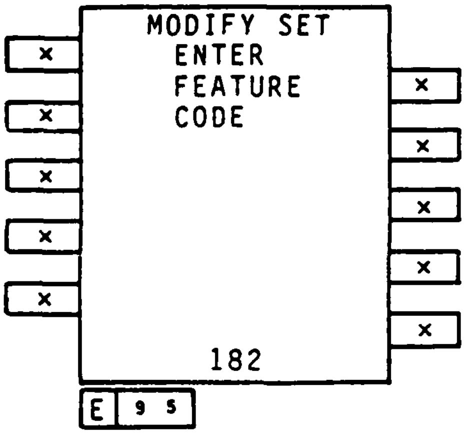

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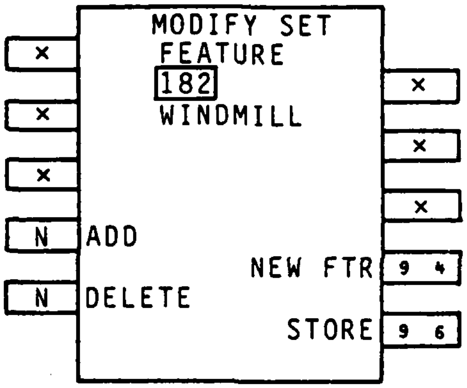

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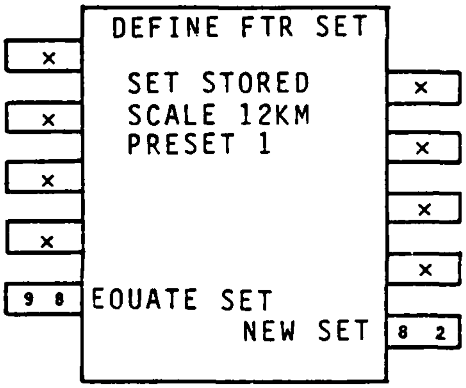
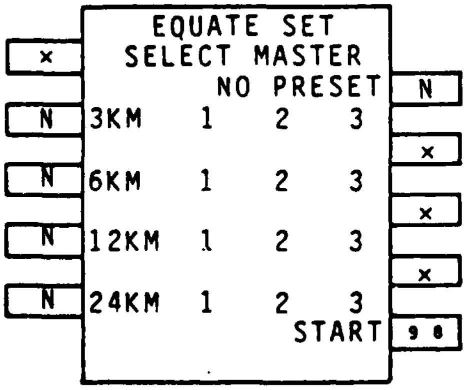
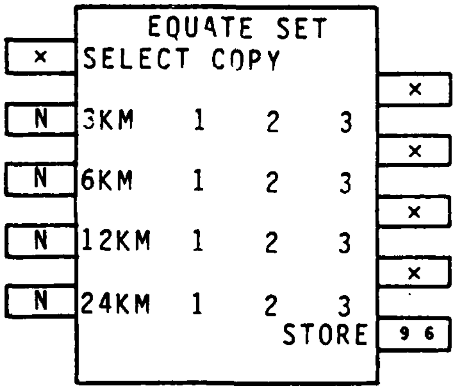
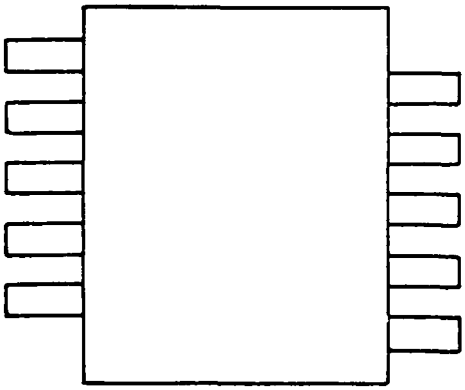


9-7



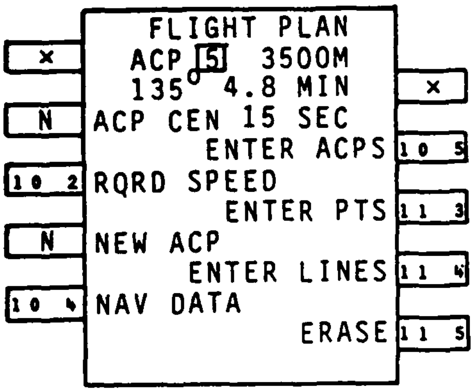
9-8



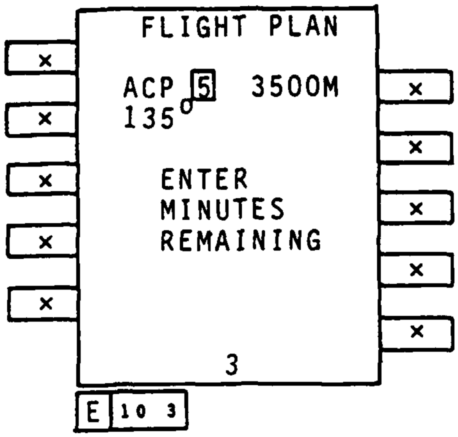


PAGE 10. DISPLAY FLIGHT PLAN DATA; DISPLAY NAVIGATION DATA; ENTER ACP DATA

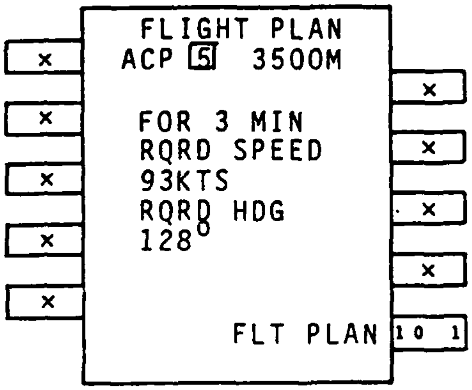
10-1



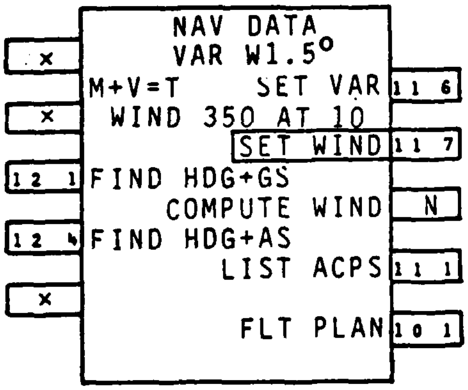
10-2



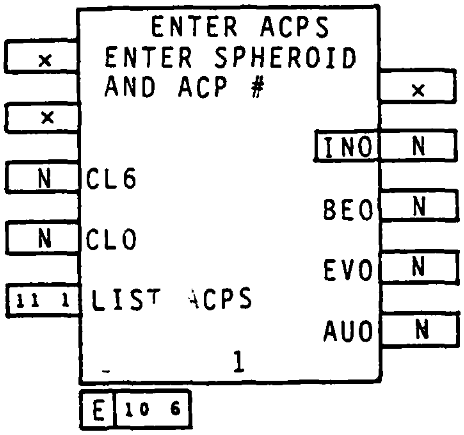
10-3



10-4



10-5



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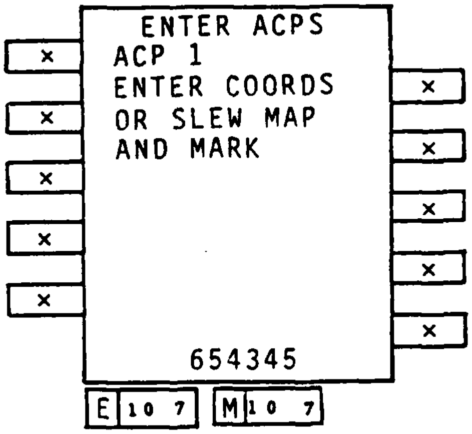

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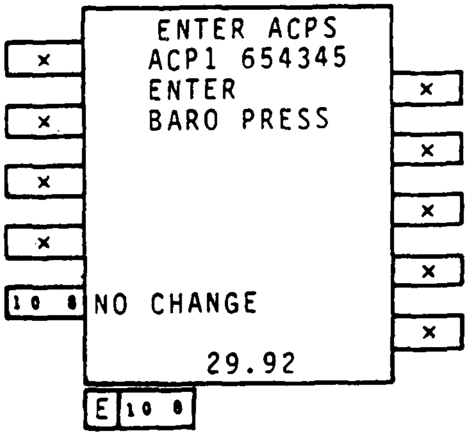
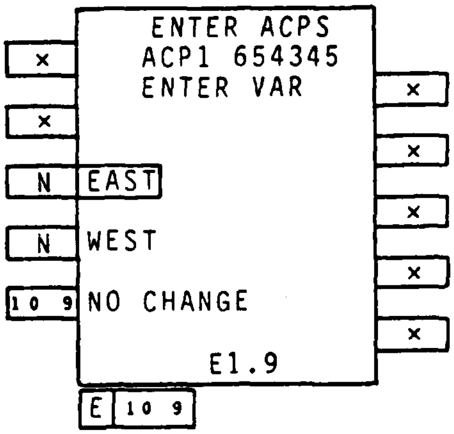
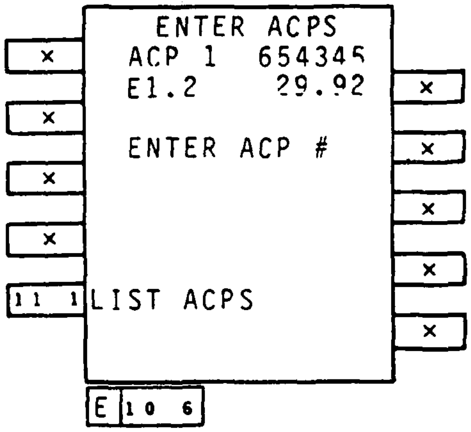


10-8

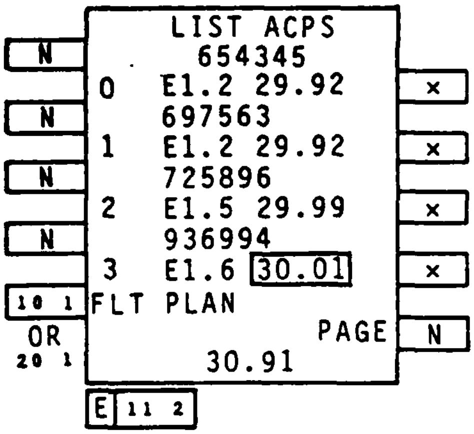


10-9

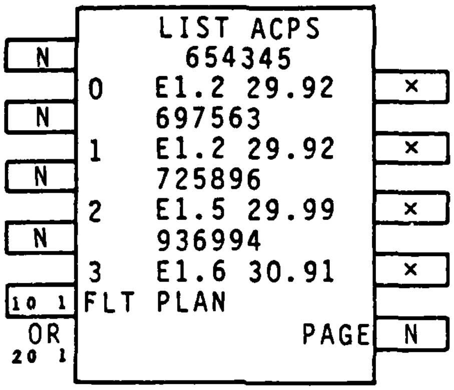


PAGE 11. LIST ACP DATA; SET POINTS; SET LINES; ERASE; SET WIND DATA

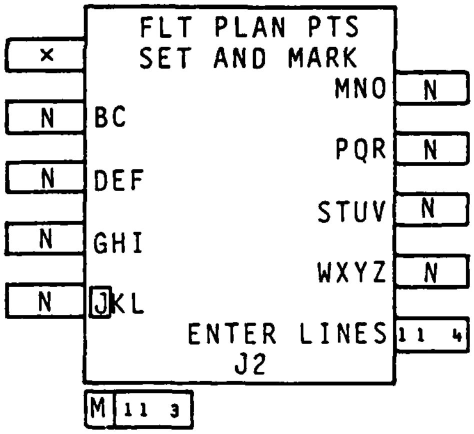
11-1



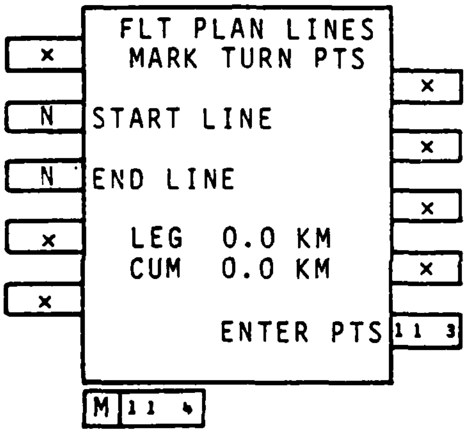
11-2



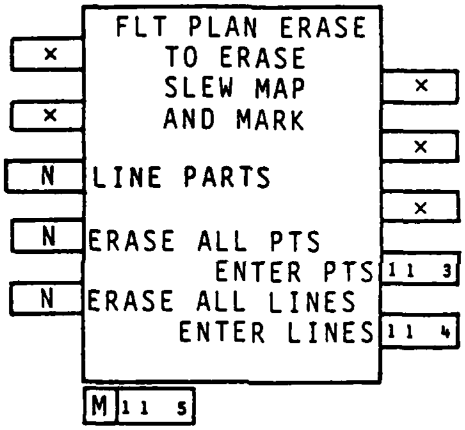
11-3



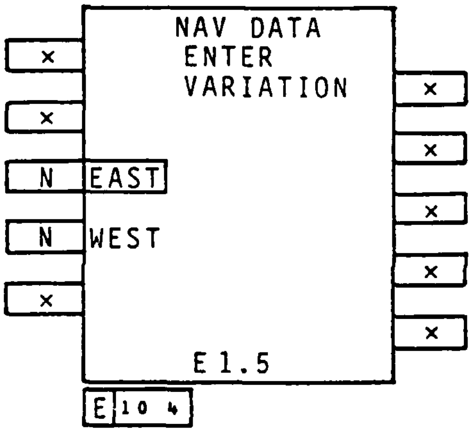
11-4



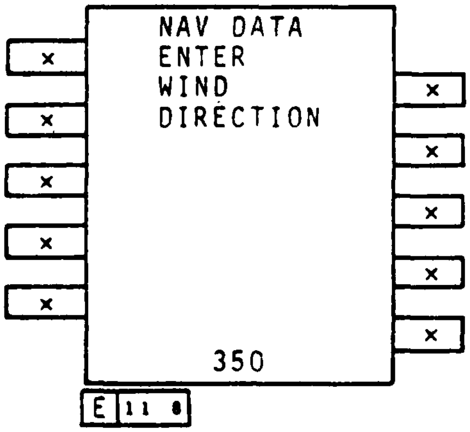
11-5



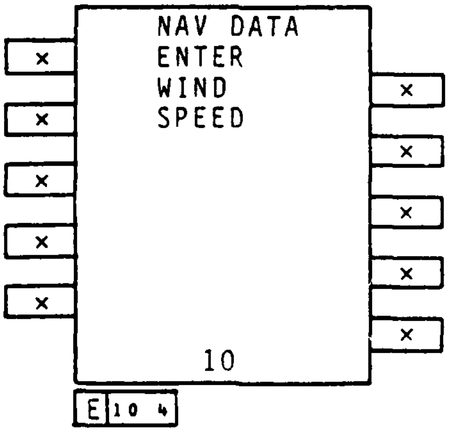
11-6

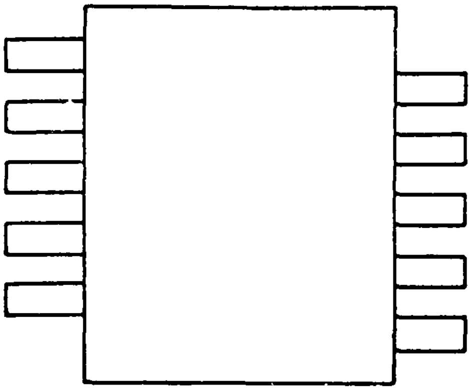


11-7



11-8





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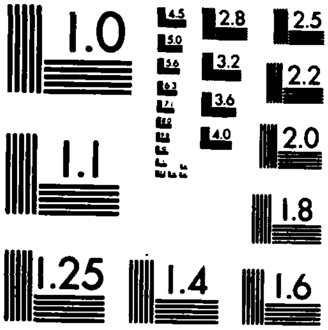
END



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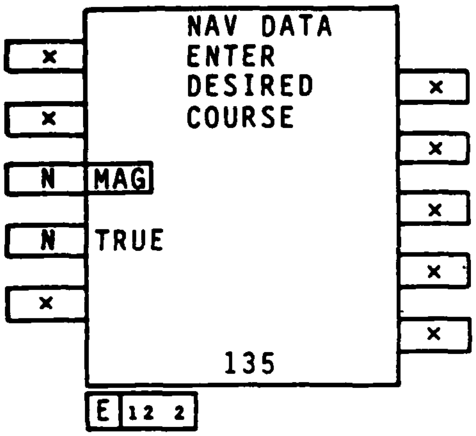
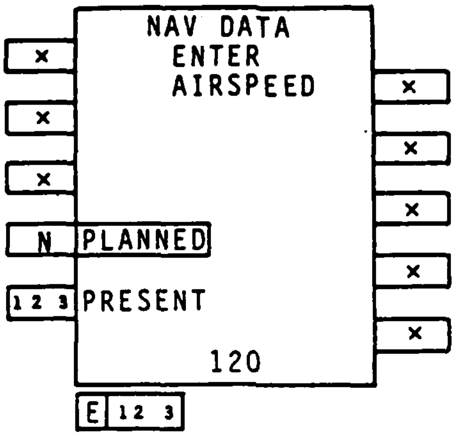
PAGE 12. PERFORM WIND TRIANGLE COMPUTATIONS

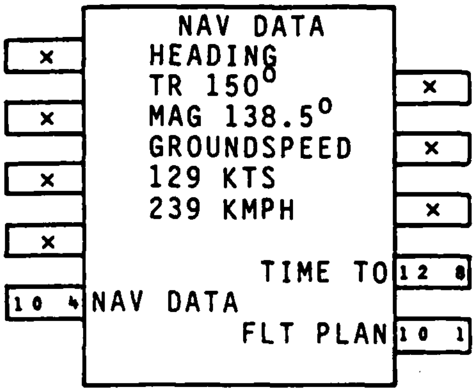
12-1



12-2



12-3



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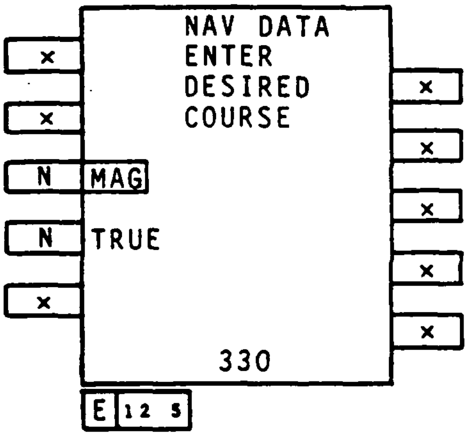

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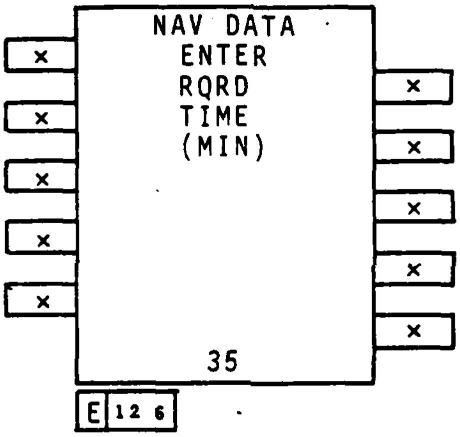

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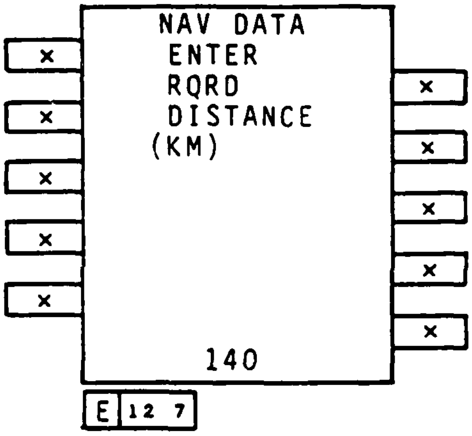

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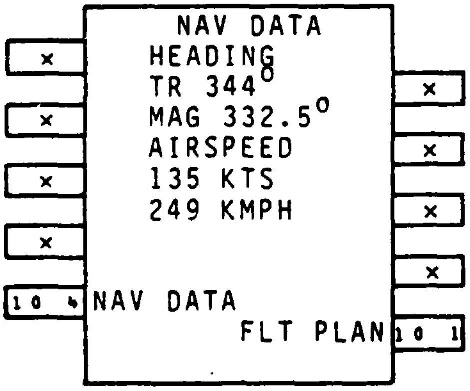

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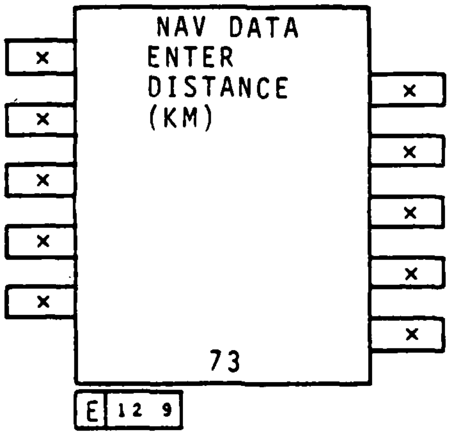

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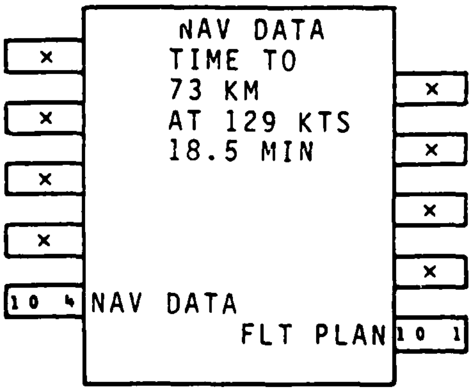
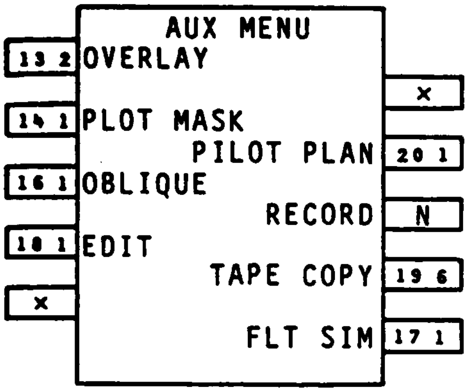
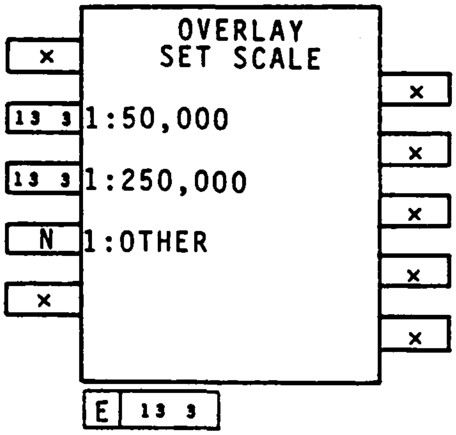


PAGE 13. CALL AUXILIARY (IMPS) MENU; ENTER OVERLAY

13-1



13-2



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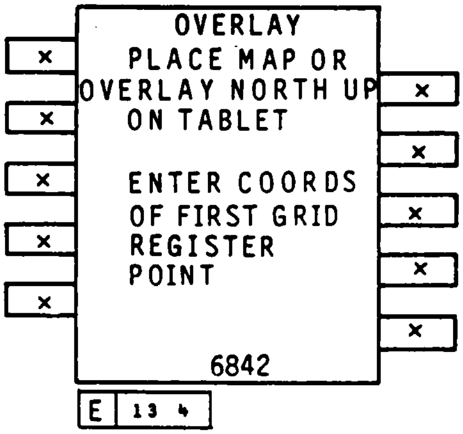

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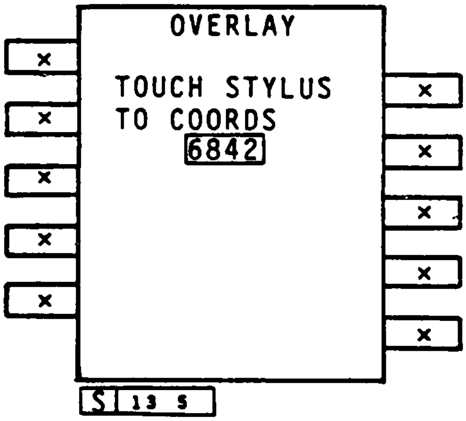

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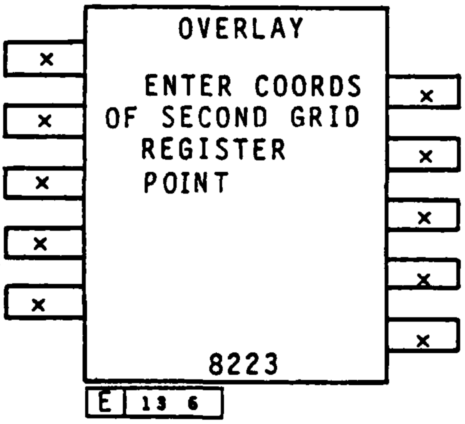

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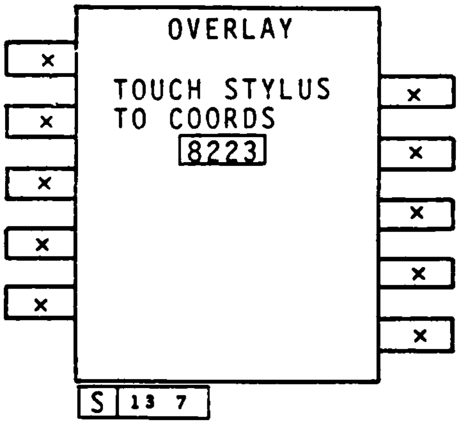

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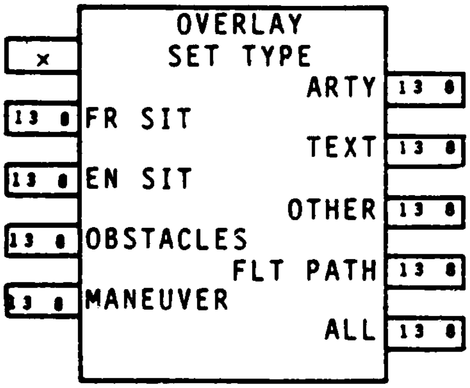

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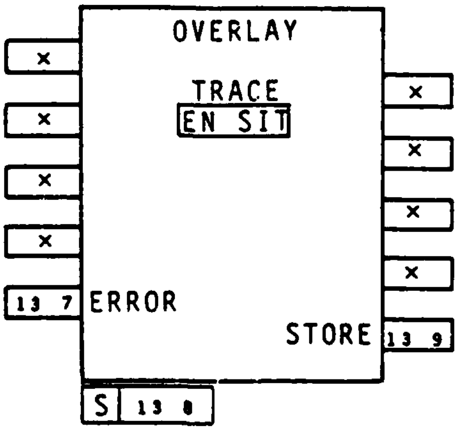

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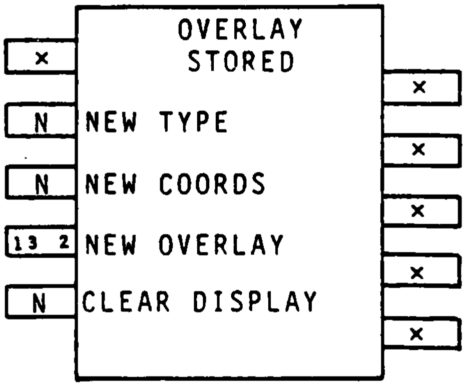
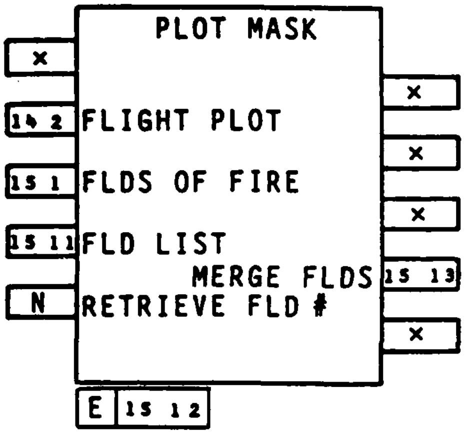
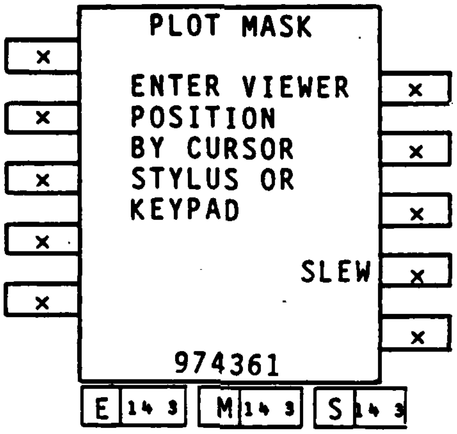


PAGE 14. PLOT MASKING DIAGRAMS

14-1



14-2



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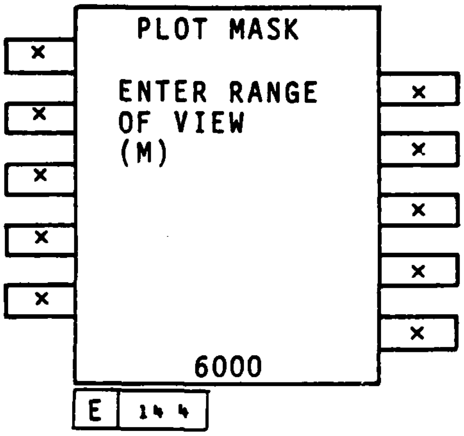

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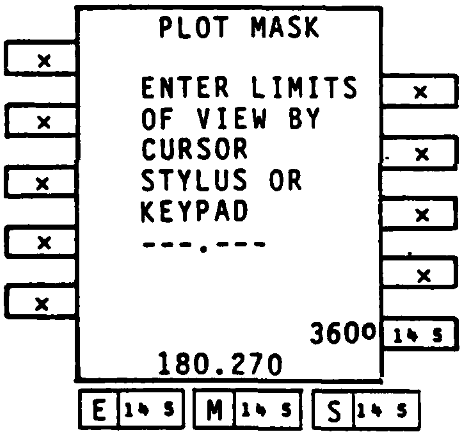

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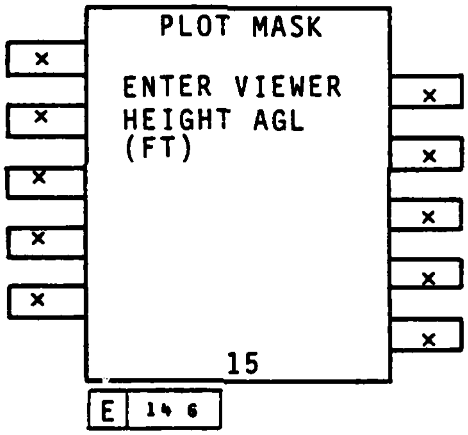

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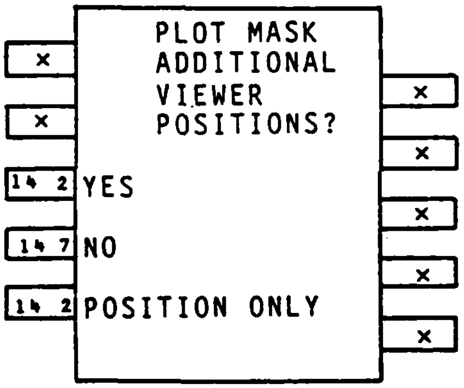

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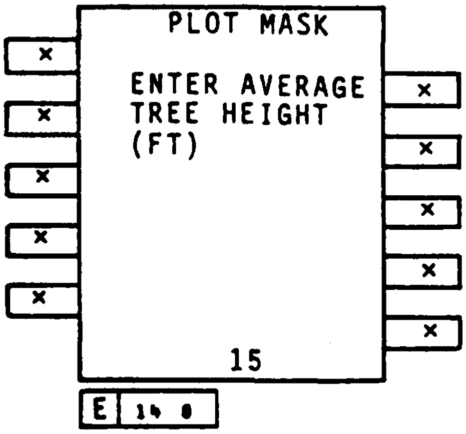

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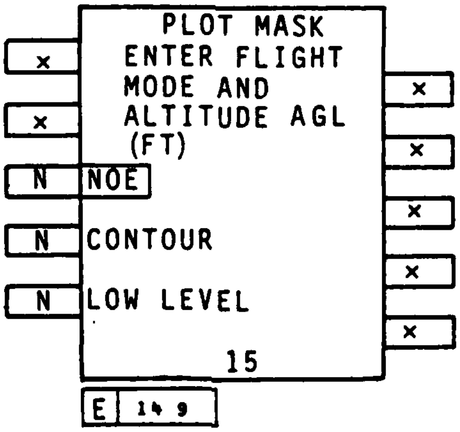

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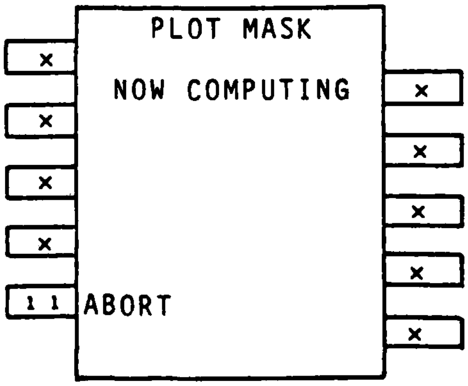
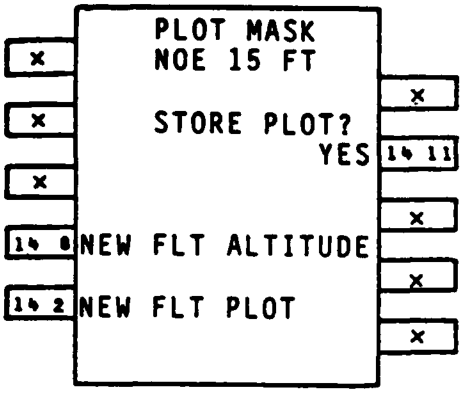
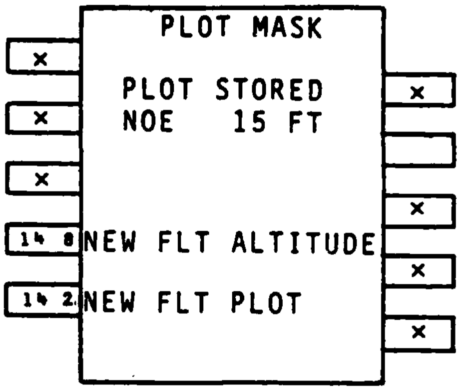


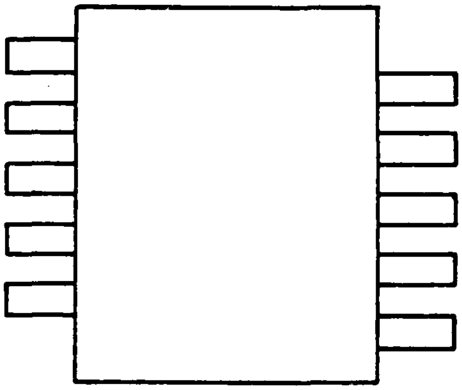
PAGE 14. (CONTINUED) PLOT MASKING DIAGRAMS

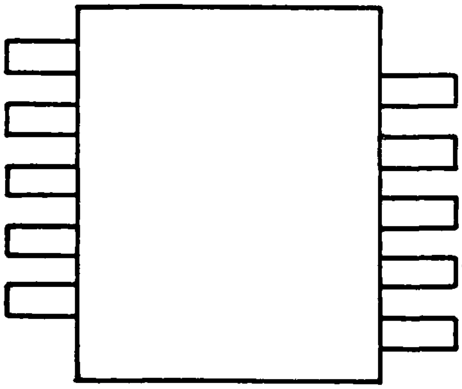
14-10

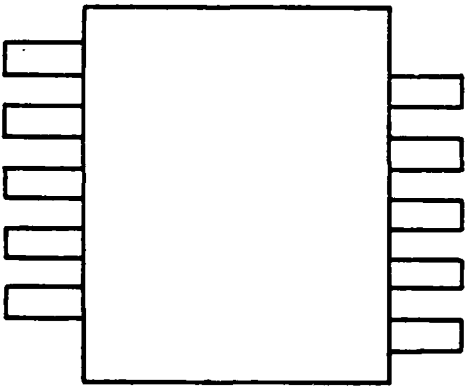


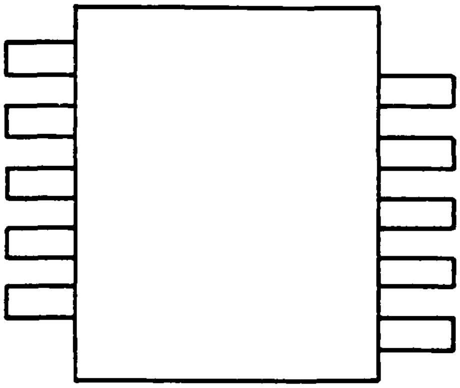
14-11

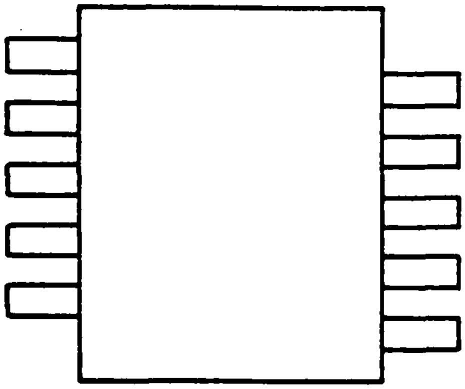


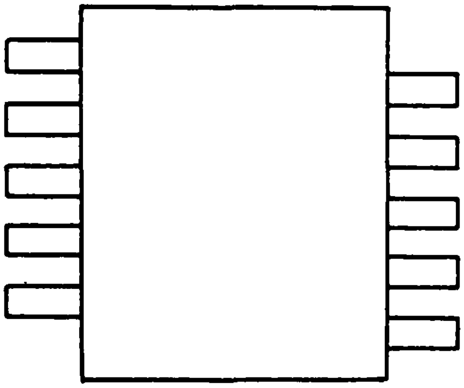


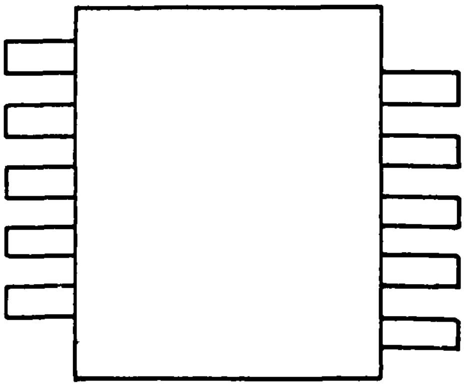






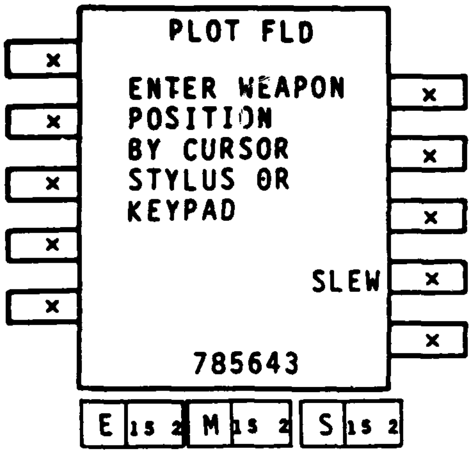






PAGE 15. PLOT MASKING DIAGRAMS

15-1



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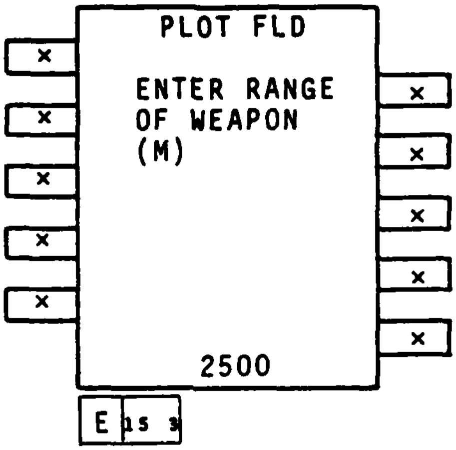

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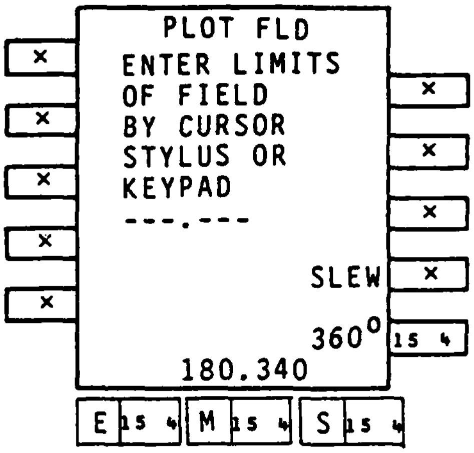

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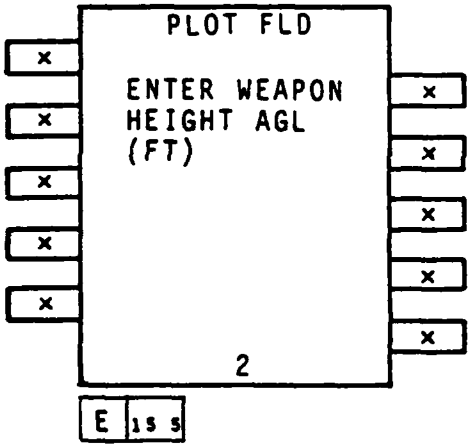

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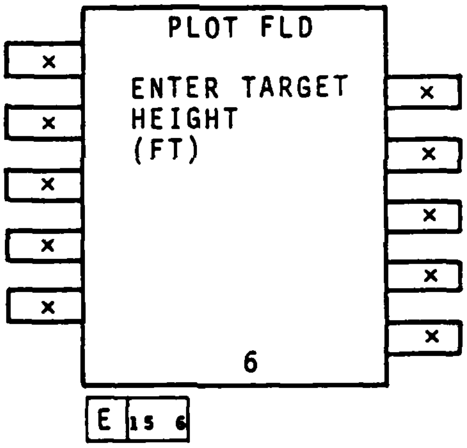
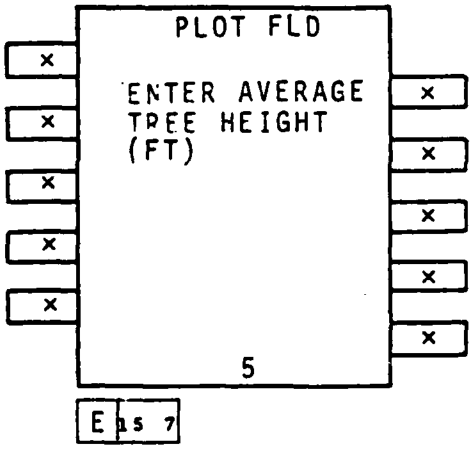


15-6



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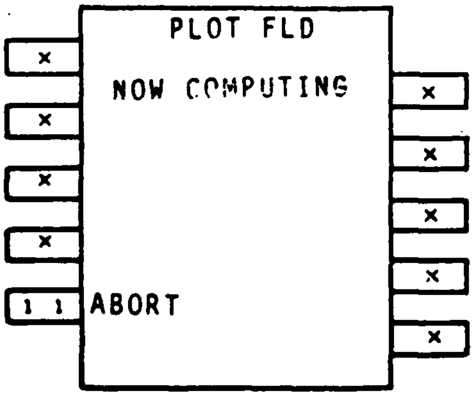

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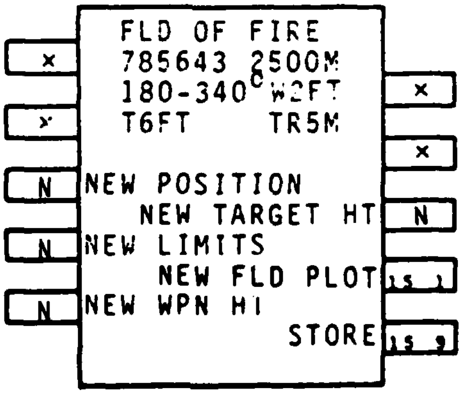

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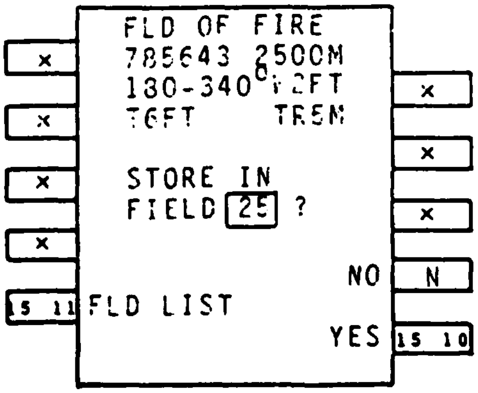
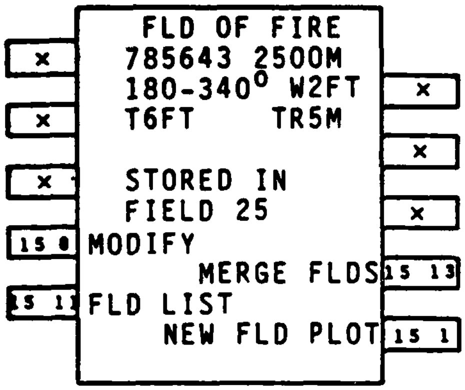


PAGE 15. (CONTINUED) PLOT MASKING DIAGRAMS

15-10



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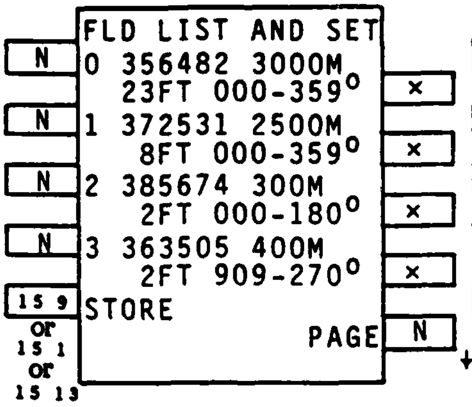
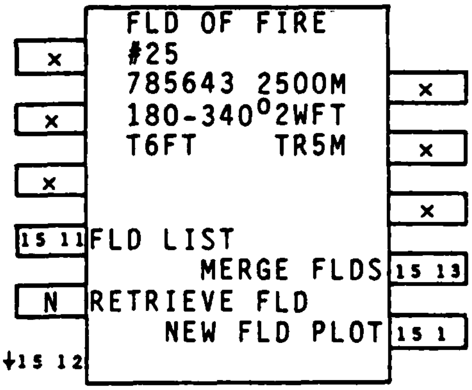
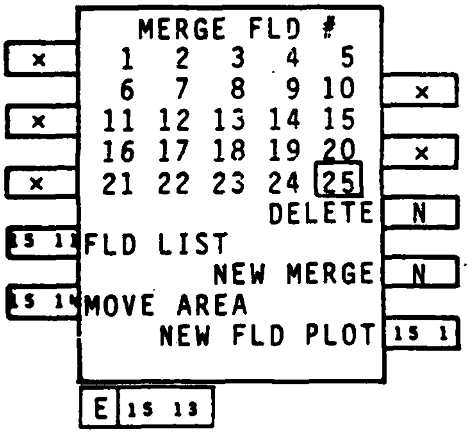


15-12



15-13



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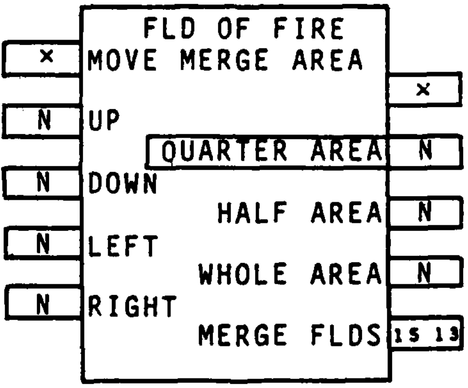
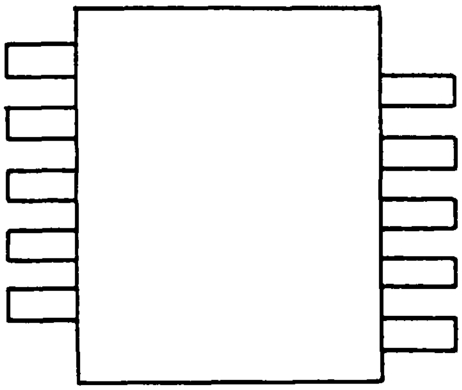
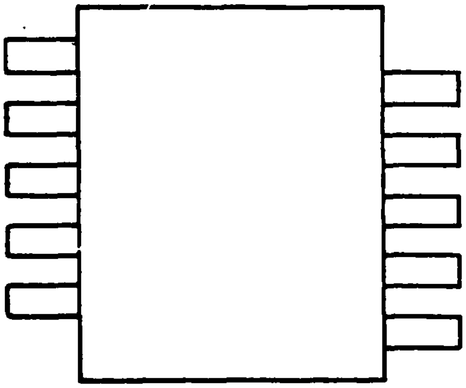
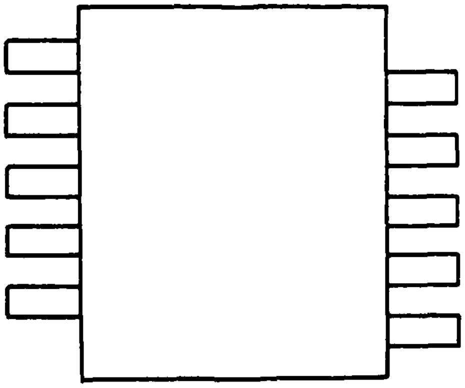
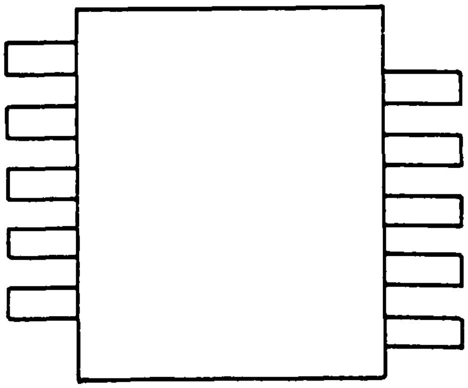




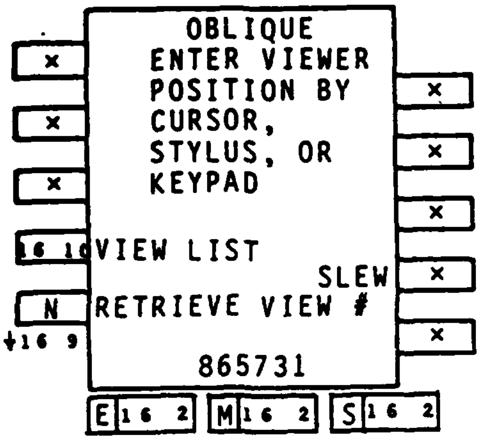




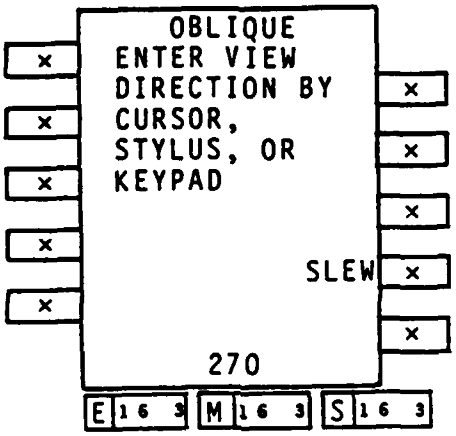


PAGE 16. CONSTRUCT OBLIQUE VIEW

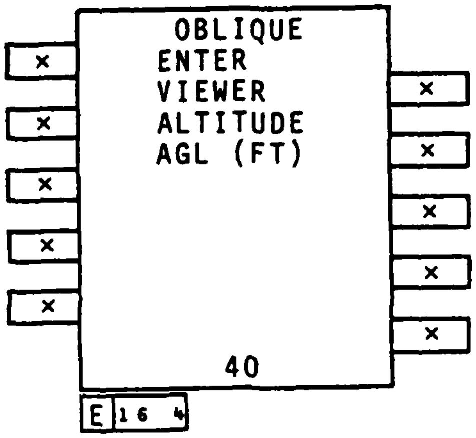
16-1



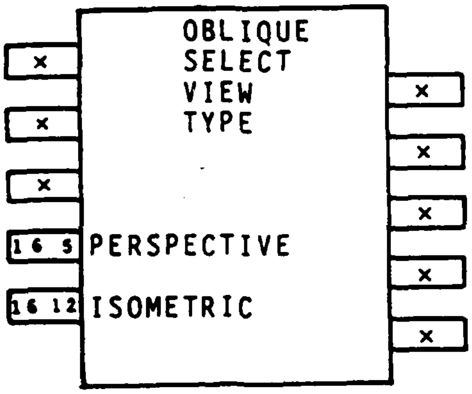
16-2



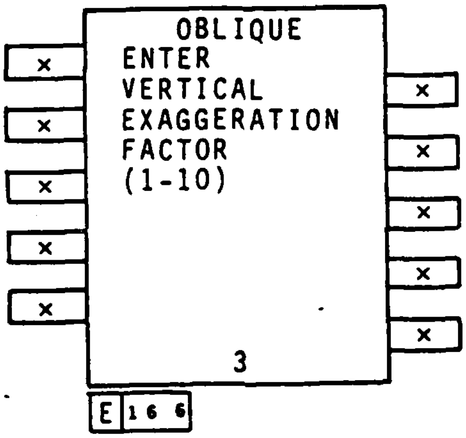
16-3



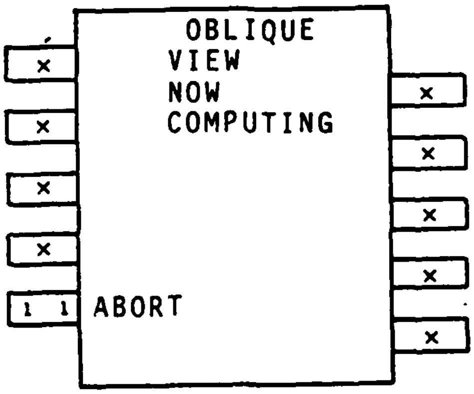
16-4



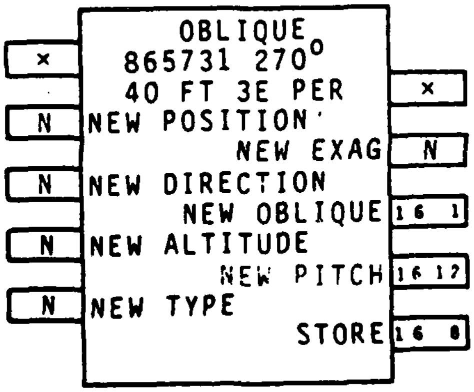
16-5



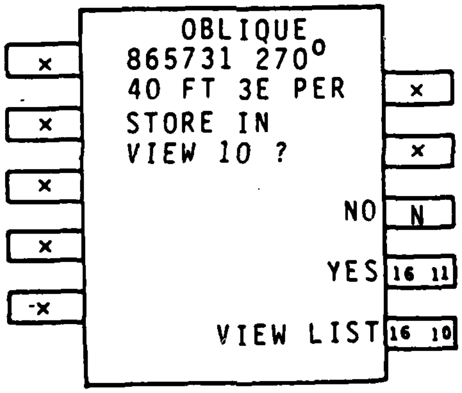
16-6



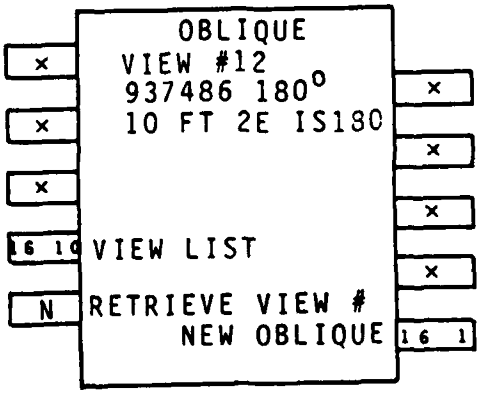
16-7



16-8

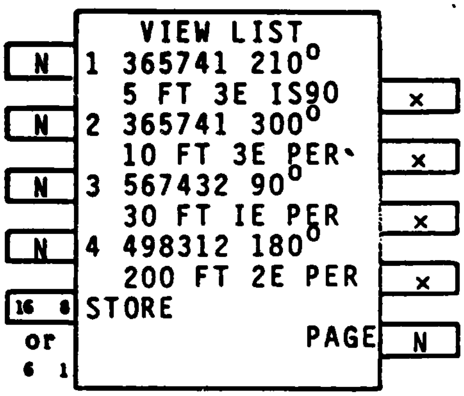


16-9

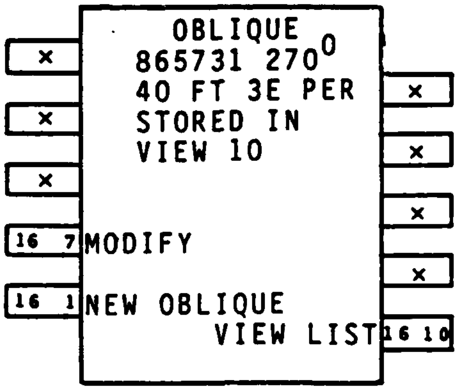


PAGE 16. (CONTINUED) CONSTRUCT OBLIQUE VIEW

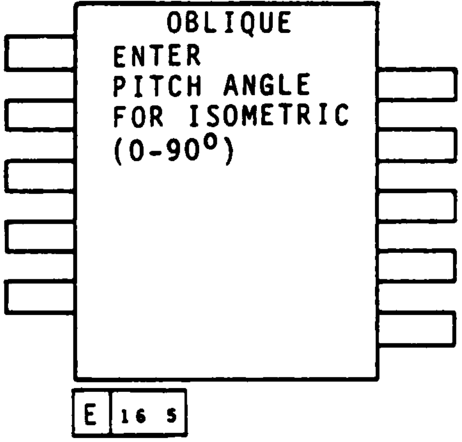
16-10


VIEW LIST
1 365741 210°
5 FT 3E IS90
2 365741 300°
10 FT 3E PER
3 567432 90°
30 FT IE PER
4 498312 180°
200 FT 2E PER
STORE
PAGE

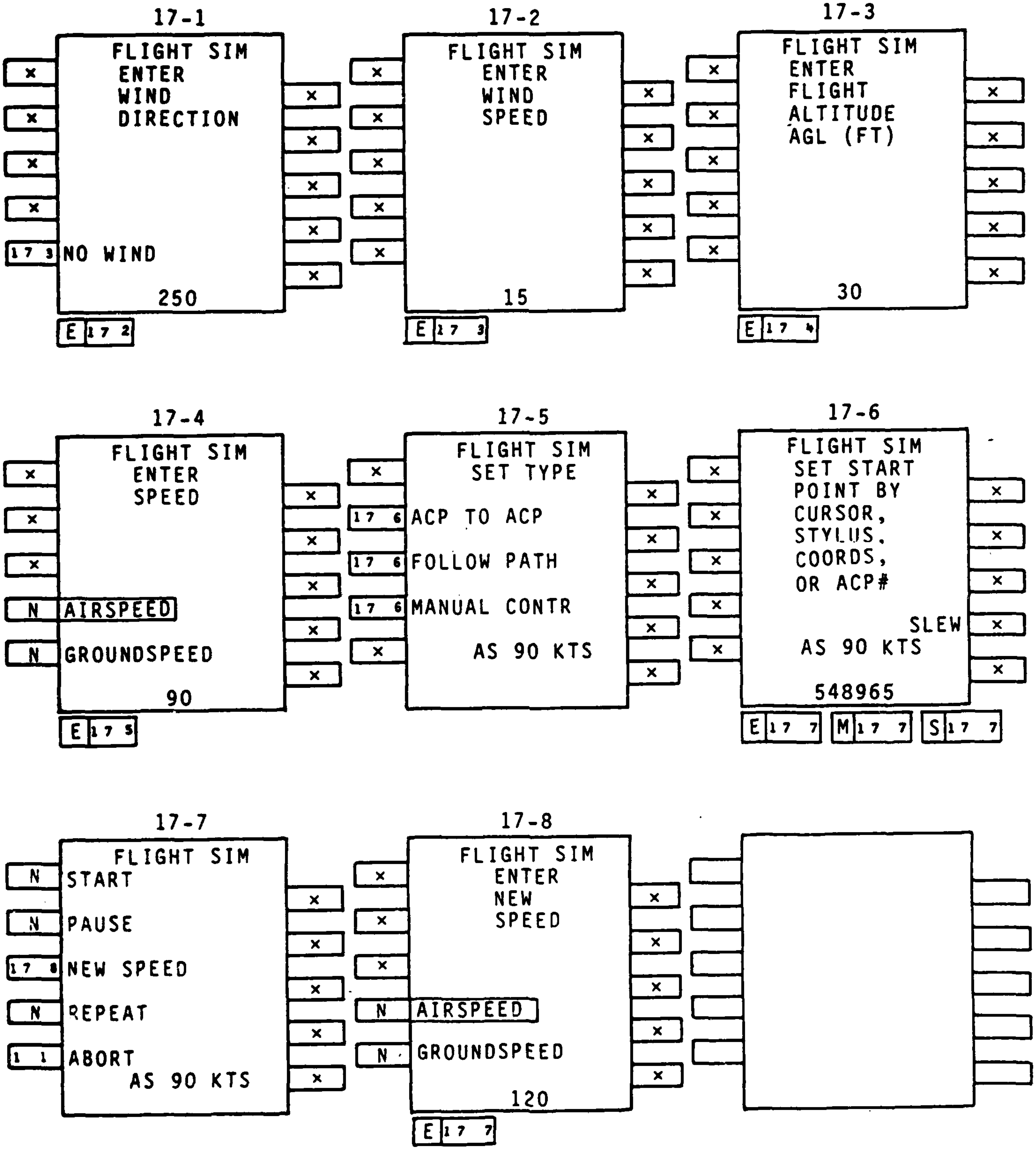
16-11


OBLIQUE
865731 270°
40 FT 3E PER
STORED IN
VIEW 10
MODIFY
NEW OBLIQUE
VIEW LIST

16-12

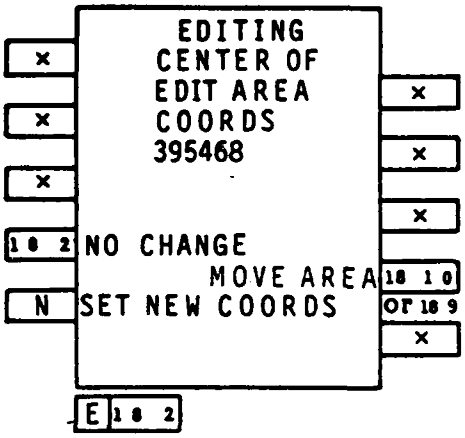

OBLIQUE
ENTER
PITCH ANGLE
FOR ISOMETRIC
(0-90°)

PAGE 17. PERFORM FLIGHT SIMULATION

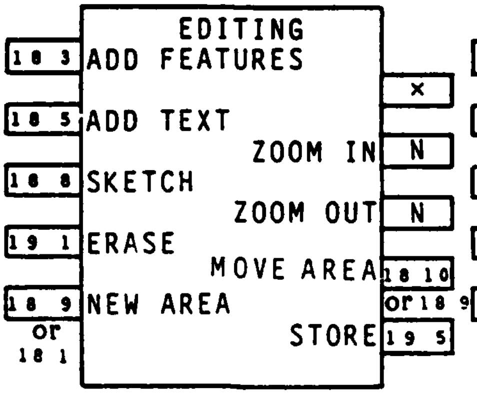


PAGE 18. PERFORM EDITING OPERATIONS; ADD FEATURES; ADD TEXT; SKETCH, SET NEW AREA

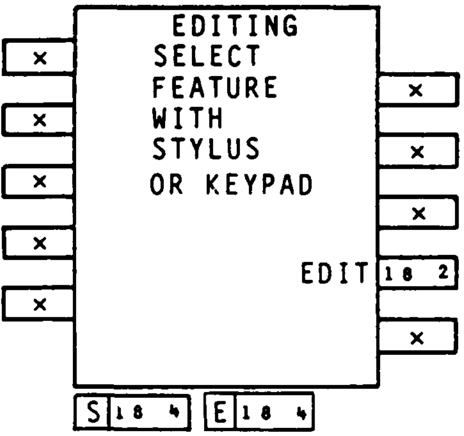
18-1



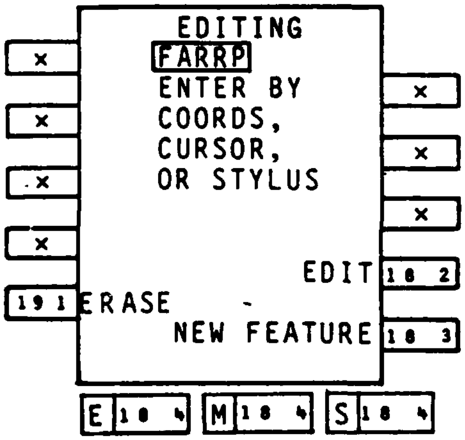
18-2



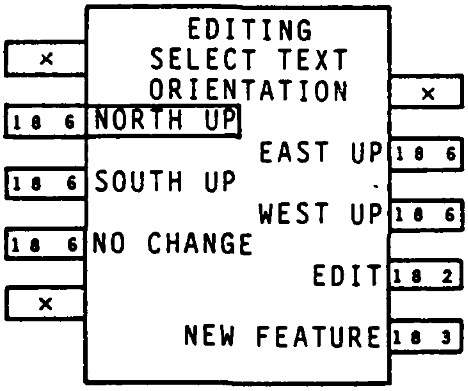
18-3



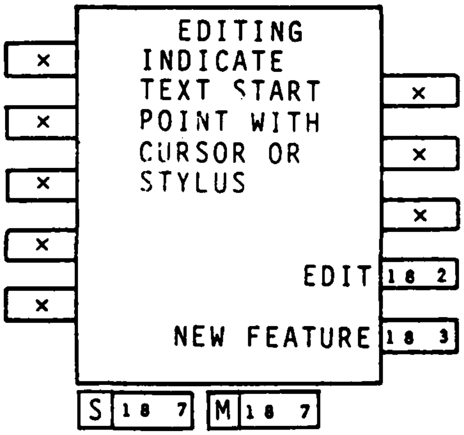
18-4



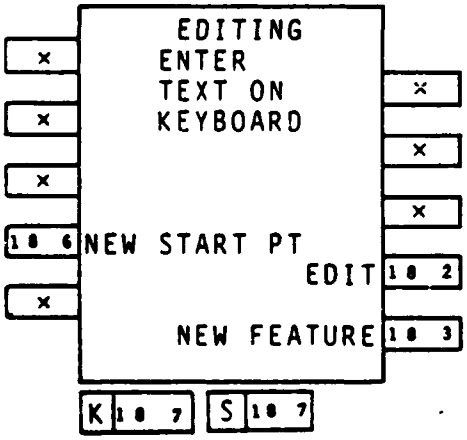
18-5



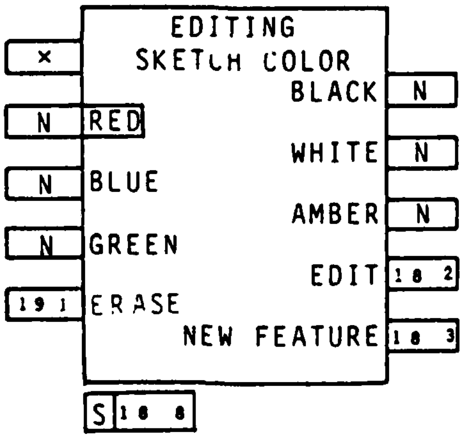
18-6



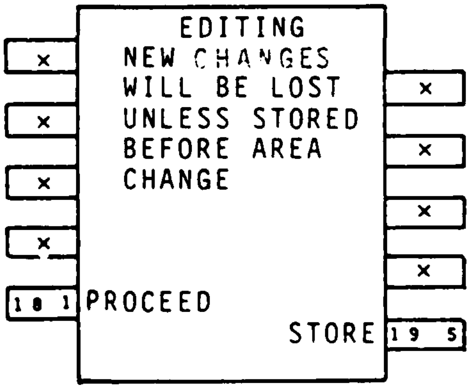
18-7



18-8

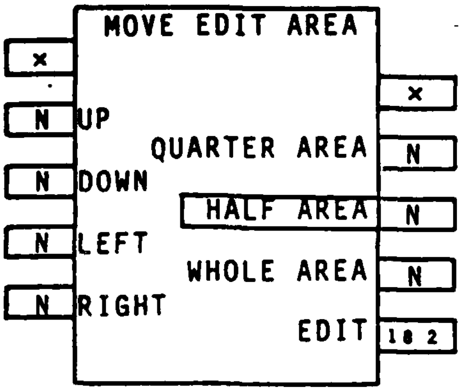


18-9

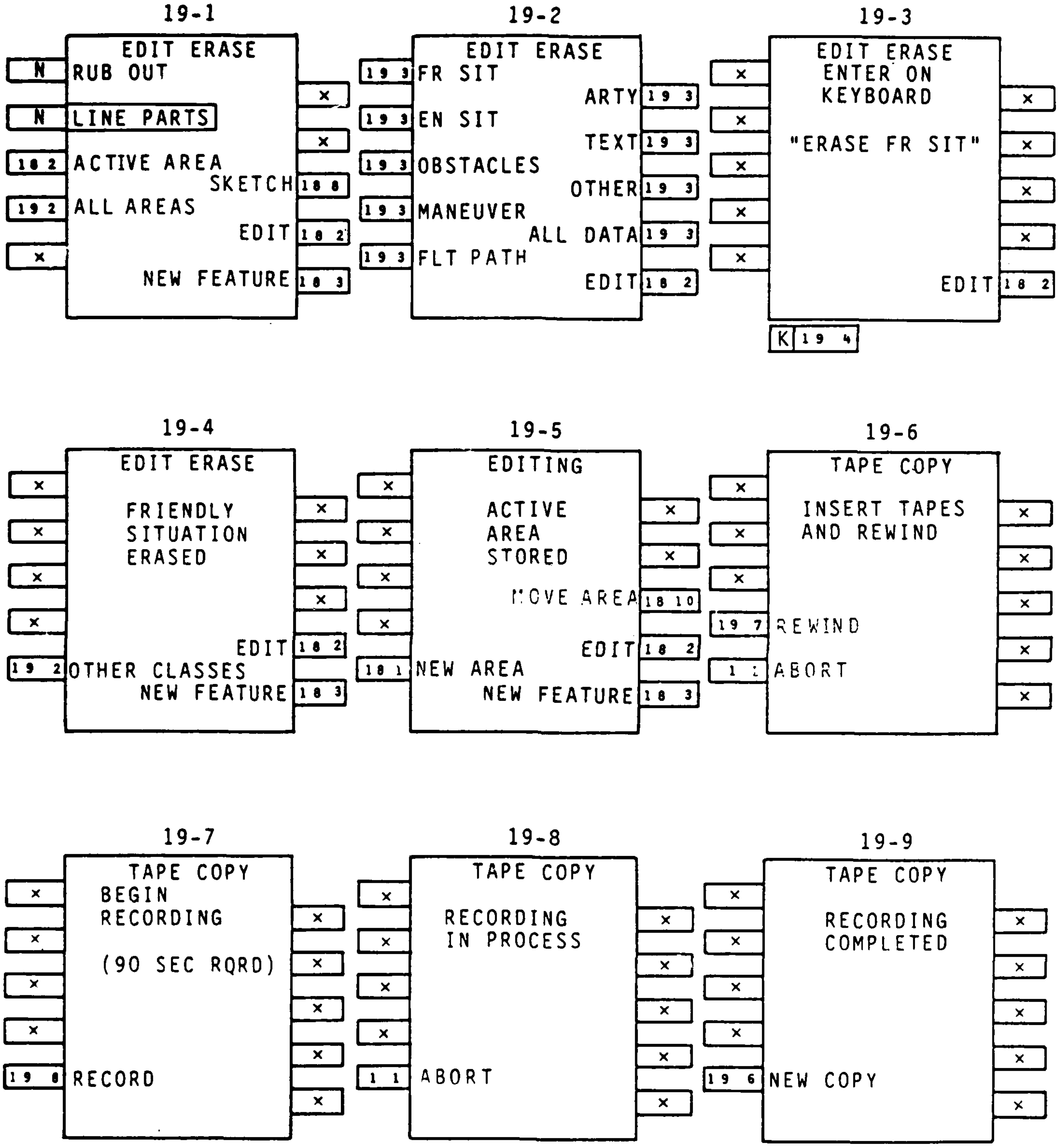


PAGE 18. (CONTINUED) PERFORM EDITING OPERATIONS; ADD FEATURES; ADD TEXT; SKETCH, SET NEW AREA

18-10

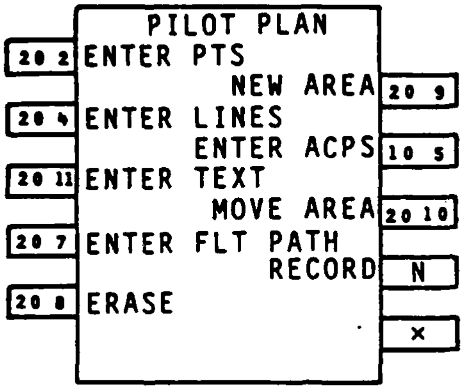


PAGE 19. PERFORM EDITING OPERATIONS: ERASE; STORE; COPY TAPES

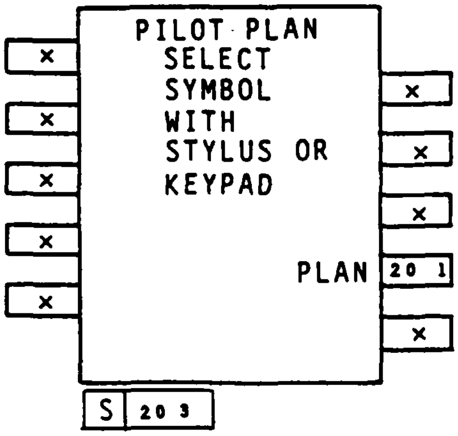


PAGE 20. ENTER PILOT PLAN: POINTS; LINES; TEXT; FLIGHT PATH; ERASE

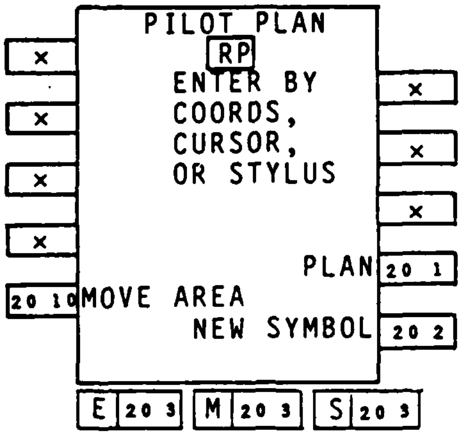
20-1



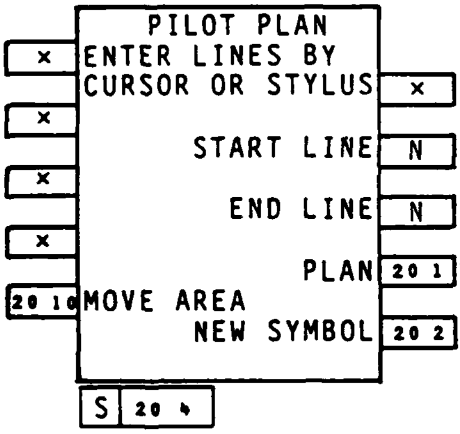
20-2



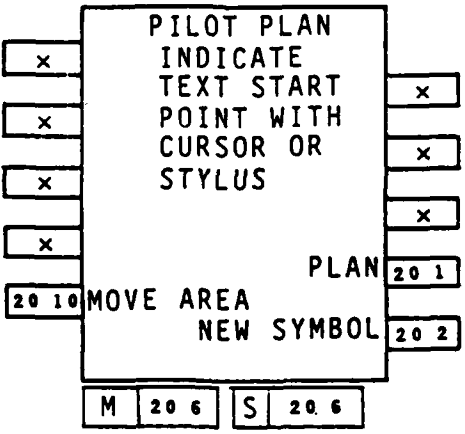
20-3



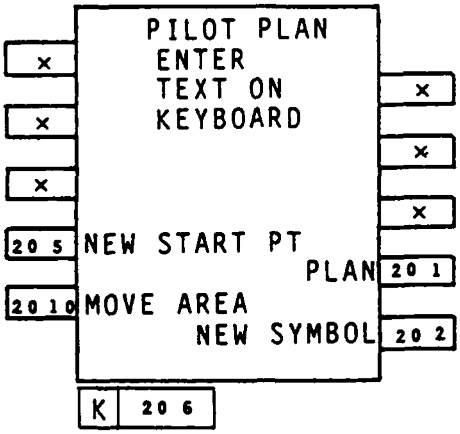
20-4



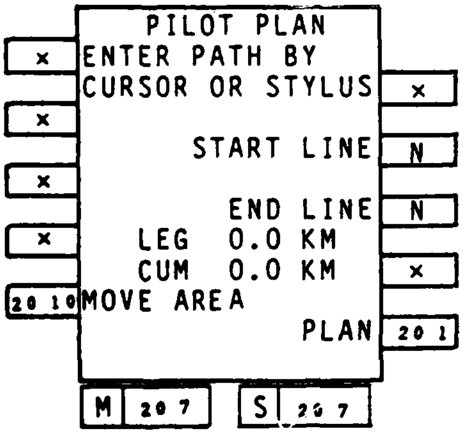
20-5



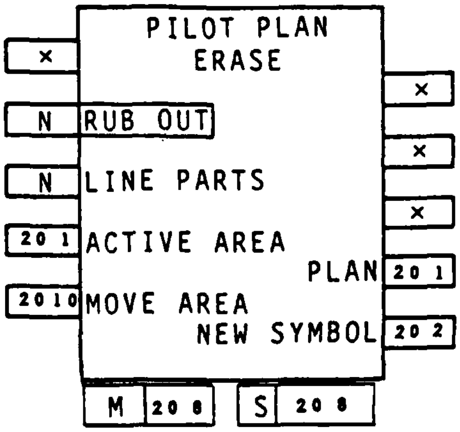
20-6



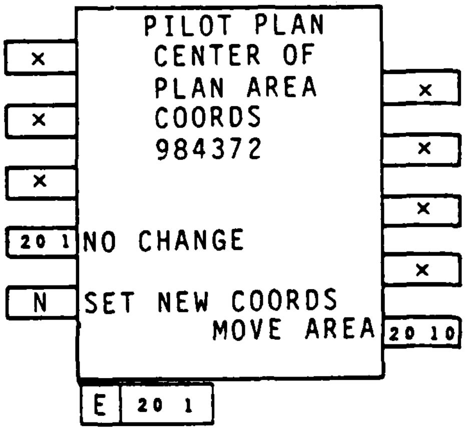
20-7



20-8

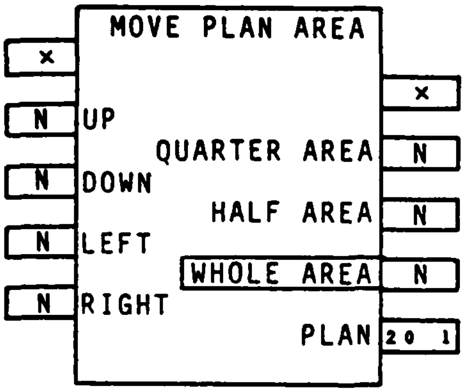


20-9

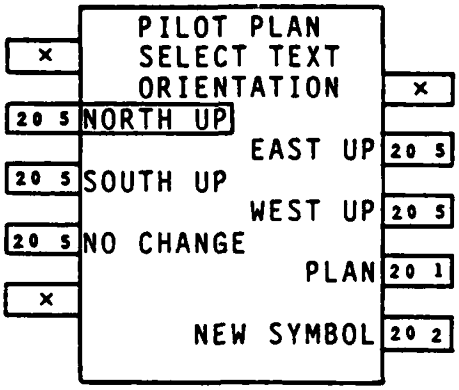


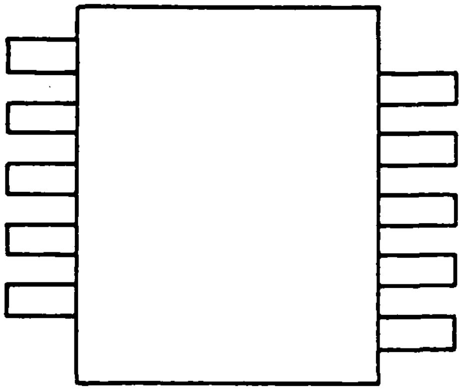
PAGE 20. (CONTINUED) ENTER PILOT PLAN: POINTS; LINES; TEXT; FLIGHT PATH; ERASE

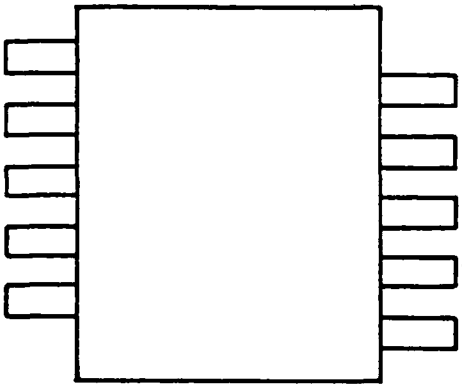
20-10

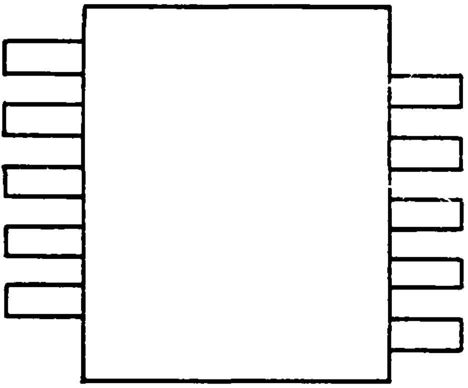


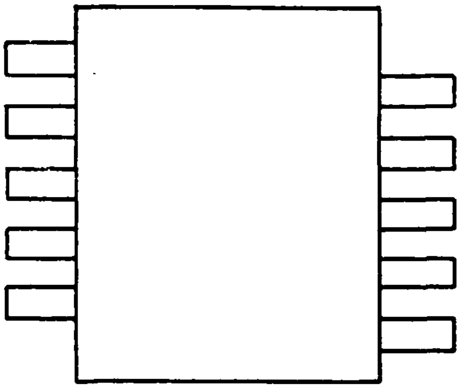
20-11

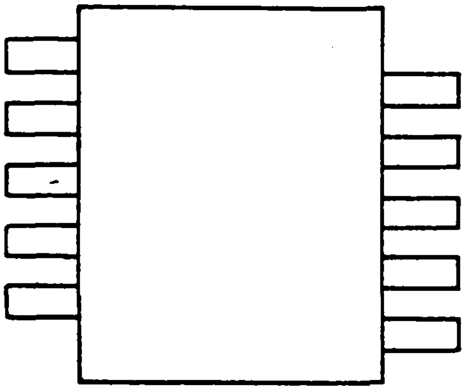


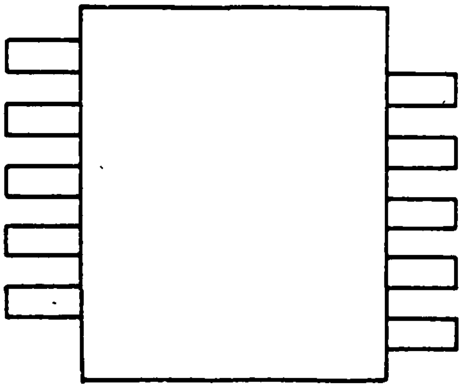


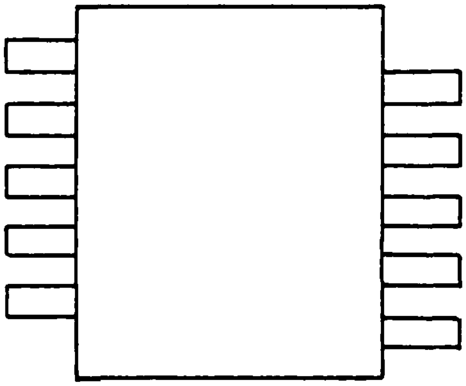












END

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2-84

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