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Report No. FAA-SS-73-19

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SST Technology
Follow-On Program—Phase II

ADEDS FUNCTIONAL/SOFTWARE REQUIREMENTS

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P.O. Box 3707
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DEPARTMENT OF TRANSPORTATION • UNITED STATES OF AMERICA

D6-60296
December 1973

FINAL REPORT

Task VI

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Prepared for

FEDERAL AVIATION ADMINISTRATION

Supersonic Transport Office
800 Independence Avenue, S.W
Washington, D.C. 20590

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(19)

TECHNICAL REPORT STANDARD TITLE PAGE

~~1. Report No~~
(10) FAA-SS-73-19

2 Government Accession No

3 Recipient's Catalog No

4 (6) SST Technology Follow-On Program-Phase II.
ADEDS FUNCTIONAL/SOFTWARE REQUIREMENTS.

~~5. Report Date~~
(11) December 1973

12 235p.

6 Performing Organization Code

~~7. Author(s)~~
(10) D. Cosley ~~and~~ A. J. Martin

~~8. Performing Organization Report No.~~
(14) D6-60296

~~9 Performing Organization Name and Address~~

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124

10 Work Unit No

~~11. Contract or Grant No.~~
(15) DOT-FA-72WA-2893

12 Sponsoring Agency Name and Address

Federal Aviation Administration
Supersonic Transport Office
800 Independence Ave. S.W.
Washington, D.C. 20590

13 Type of Report and Period Covered

(9) Final Report, Task VI

14 Sponsoring Agency Code

15 Supplementary Notes

16 Abstract

The advanced electronic display system (ADEDS) task of the SST Technology Follow-On Program includes the formal definition and documentation of the functional and software requirements for mechanization of the display and navigation systems. This report defines these functional and software requirements as they existed at the time of equipment delivery. Revisions to these requirements will be provided as part of the ADEDS flight test report (FAA-SS-73-22) to be released in mid-1974.

The report provides an ADEDS overview, followed by detailed definition of the multifunction display, bulk data storage, electronic attitude director indicator, four-dimensional guidance, navigation control and display unit, and navigation and subsidiary function requirements.

17 Key Words

Display system
Data buses
Interface
Guidance
Software requirements
Electronic attitude director indicator
Functional requirements
Multifunction display
Navigation computer unit
Navigation control display unit

18 Distribution Statement

Approval for U.S. Government only. Distribution of this report outside the U.S. Government must have prior approval of the Supersonic Transport Office.

19 Security Classif. (of this report)
Unclassified

20 Security Classif (of this page)
Unclassified

21 No of Pages
~~315~~

22 Price

Form DOT F 1700.7 (8-69)

PREFACE

This report is produced as part of the DOT/SST Technology Follow-On Program, phase II, task VI–Advanced Electronic Display System (ADEDS). The purpose of this report is to define the functional and software requirements for ADEDS as they existed at hardware delivery. Revisions resulting from simulation integration and flight test of the ADEDS equipment will be provided as an appendix to volume IV of the ADEDS flight test report (FAA-SS-73-22). This will permit release of the ADEDS baseline functional and software requirements several months earlier than would be possible if they were not released until after flight test.

Information presented reflects the technical work of many engineering personnel at Boeing during the SST prototype program and the ADEDS task, especially the following:

J. R. Gannett (SST project pilot)

D. A Patterson

J. E. Veitengruber

L. P. Giroir

K. L. McClellan

R. L. McPherson (ADEDS task pilot)

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CONTENTS--Continued

CONTENTS–Concluded

FIGURES

FIGURES–Concluded

TABLES

TABLES–Concluded

ABBREVIATIONS

ACCNORM	Normal acceleration
ADEDS	Advanced electronic display system
ADIZ	Air defense identification zone
ALT REF	Altitude reference
A/M	Auto/manual
ASCII	American Standard Code for Information Interchange
ATIS	Automatic Terminal Information Service
AU	Auxiliary unit
ac	Alternating current
BCD	Binary code decimal
C	Conic
CADIZ	Canadian air defense identification zone
CR	Carriage return
CRT	Cathode-ray tube
D	Direction of conic
DA	Drift angle
D_H	Hold direction
DM	Designation matrix
DME	Distance measuring equipment
DS	Display system
DSRTK	Desired track angle
E	East
EADI	Electronic attitude director indicator

E_nN_n	Position of the start of circular arc
EOD	End of data
EOT	End of transmission
EXEC	Execute
F	Failure
FIR	Flight information region
FPAC	Flightpath angle acceleration
GRP	Geographic reference point
GS	Glide slope, groundspeed
GUID	Guidance
HLDTK	Track hold
HSG	Hybrid symbol generator
HSI	Horizontal situation indicator
I&R	Increment and rotate
IAS	Indicated airspeed
IC	Increment coordinate
ICAO	International Civil Aviation Organization
ILS	Instrument landing system
INS	Inertial navigation system
I_S	Symbol intensity
I_T	Tag intensity
ITAN	Initial tangent angle
I_V	Vector intensity
L	On-screen limit
LANDA	Land arm

LED	Light-emitting diode
LF	Line feed
L_H	Hold label
LOC	Localizer
LSB	Least significant bit
lat	Latitude
lon	Longitude
MAP	Missed approach path
MCU	Manual control unit
MFD	Multifunction display
MOB, MOBS	Mountain or obstructions
MSB	Most significant bit
MSL	Mean sea level
magvar	Magnetic variation
N	North
NCDU	Navigation control display unit
NCU	Navigation computer unit
NDB	Nondirectional beacon
navaid	Navigation aid
OC	Offset center
OFS	Offset–tag
P	Parity
PCMD	Pitch command
PCU	Program control unit
PGS	Planned (programmed) groundspeed

PSTTKA	Preset track angle
PTA	Planned (programmed) time of arrival
R	Rotate
R/A	Radio altitude
RADBRG	Radial bearing
RADWPT	Radial waypoint
RC	Rotate coordinate
RCMD	Roll command
RS	Rotate symbol
RTE	Route
RWY	Runway
SCU	System control unit
SEL	Select
SID	Standard instrument departure
SOT	Start of transmission
SOW	Statement of work
SPBP	Split-phase bipolar
SS	Symbol size
ST	Tag size
STAR	Standard terminal arrival route
TA	Turn angle
TAS	True airspeed
TC	Table continued
TDZ	Touchdown zone
TK	Track angle

TKE	Track angle error
TKESEL	Selected track error
T-nav	Time navigation
VGS	Groundspeed velocity
V_H	Holding true airspeed
VHF	Very high frequency
V-nav	Vertical navigation
VOR	VHF omnidirectional range
VORTAC	VHF omnidirectional range/tactical air navigation—a collocated VOR and TACAN facility
VPC	Vertical path command
VTR	Video tape recorder
WF	Word follows
WPRTN	Radius of turn
WPT	Waypoint
XTK	Crosstrack distance

1.0 INTRODUCTION

1.1 GENERAL

This document defines the advanced electronic display system (ADEDS) functional/software requirements. The document is divided into the following sections:

Section 1–Introduction
2 MFD Requirements
3–Bulk Data Storage
4–EADI Requirements
5–Four-Dimensional Guidance Requirements
6–NCDU Requirements
7–Navigation and Subsidiary Function Requirements

Each section defines the functional requirements and assigns the software responsibility between the navigation computer unit (NCU) and the display system (DS), where applicable.

The General Electric Company is responsible for all DS software defined in this document. The NCU software responsibility is divided between Boeing and Litton as follows, in accordance with the ADEDS statement of work (SOW):

Boeing responsibility:	Sections 5 and 6
Litton responsibility:	Sections 2, 3, 4, and 7

The subsidiary function requirements in section 7 include all items identified in the Litton SOW. Litton will be responsible for integrating the NCU software subroutines defined in this document into the delivered ADEDS software package.

This document represents the ADEDS functional/software requirements at hardware delivery (September 30, 1973). The ADEDS software as developed at the completion of the laboratory and flight test programs will be documented in the form of an ADEDS system software specification, which will constitute a part of the ADEDS final report.

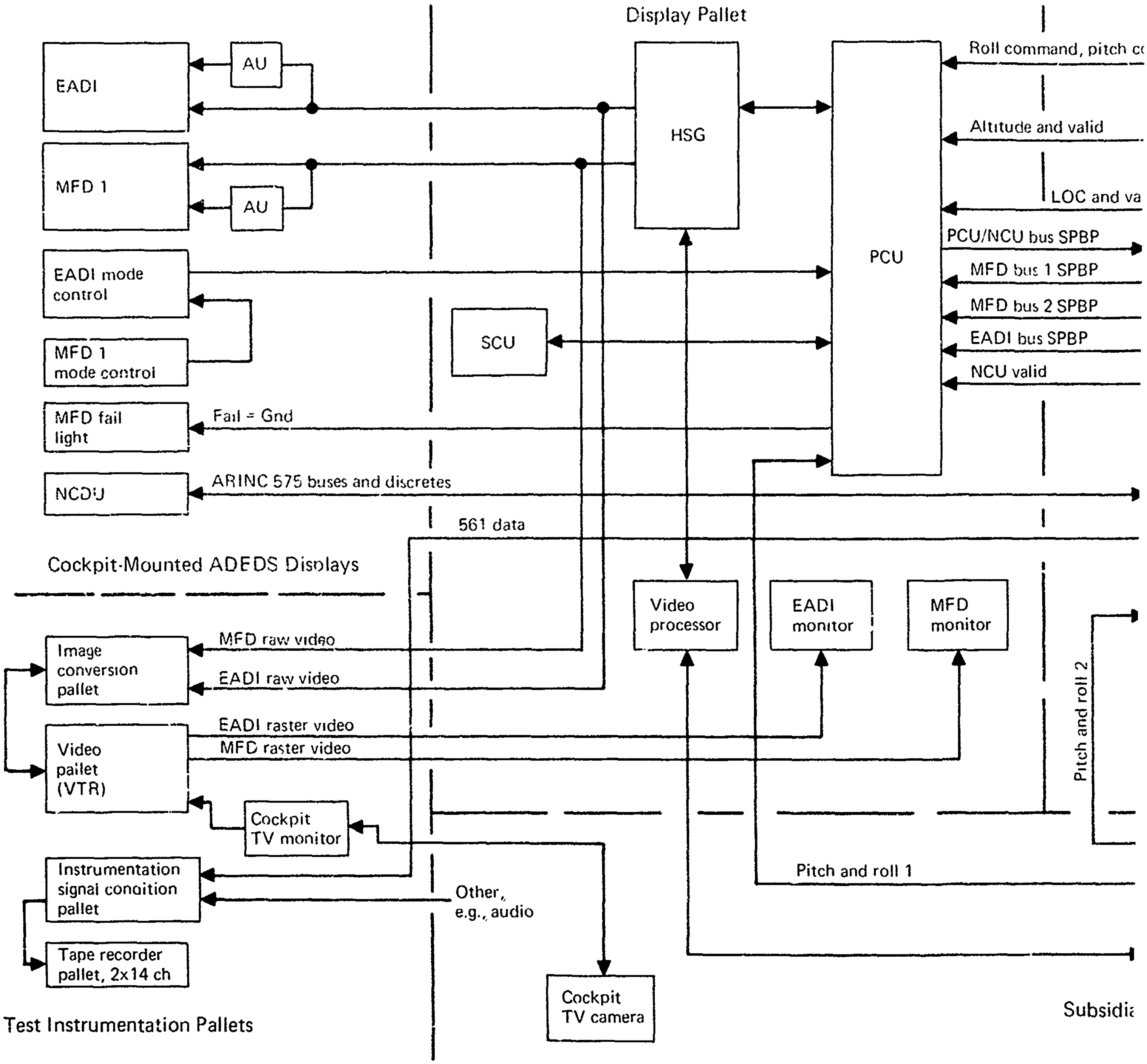
1.2 ADEDS SYSTEM CONFIGURATION

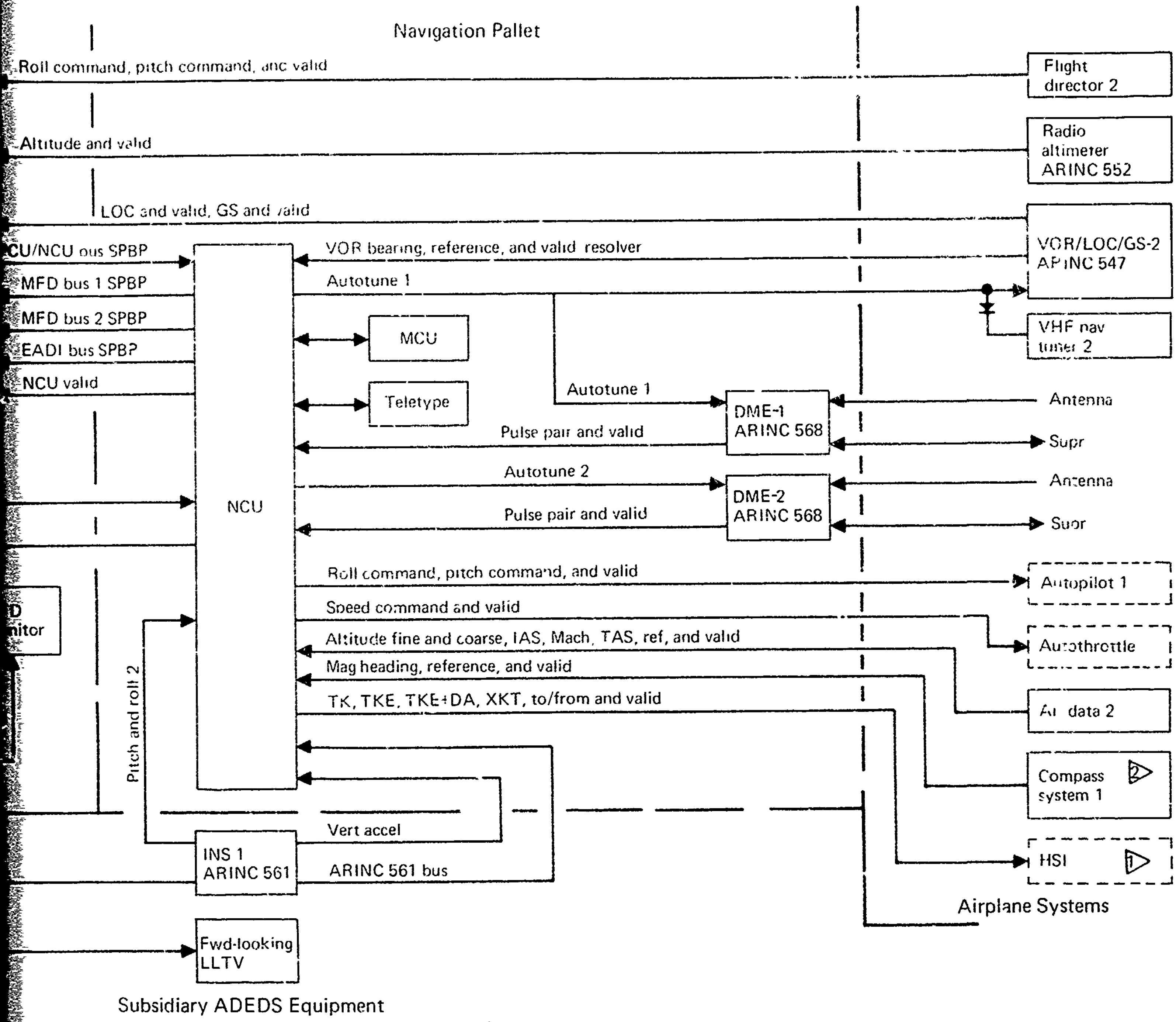
The ADEDS interface block diagram is depicted in figure 1-1. This diagram identifies the boxes and interfaces referred to in this document.

This document is concerned primarily with the Litton NCU software, the GE program control unit (PCU) software, and the interfaces used to transfer data between the two computers. These interfaces consist of the following four split-phase bipolar (SPBP) data buses utilizing a 100-kHz clock:

MFD bus 1: NCU to PCU
MFD bus 2. NCU to PCU
EADI bus: NCU to PCU
PCU/NCU bus: PCU to NCU

The data content, timing, and word formats for each of these buses are defined in this document.


Display Pallet
EADI
AU
MFD 1
AU
HSG
PCU
Roll command, pitch c
Altitude and valid
LOC and va
PCU/NCU bus SPBP
MFD bus 1 SPBP
MFD bus 2 SPBP
EADI bus SPBP
NCU valid
EADI mode control
MFD 1 mode control
SCU
MFD fail light
Fail = Gnd
NCDU
ARINC 575 buses and discretes
561 data
Cockpit-Mounted ADEDS Displays
Video processor
EADI monitor
MFD monitor
Image conversion pallet
MFD raw video
EADI raw video
Video pallet (VTR)
EADI raster video
MFD raster video
Pitch and roll 2
Cockpit TV monitor
Instrumentation signal condition pallet
Other, e.g., audio
Pitch and roll 1
Tape recorder pallet, 2x14 ch
Test Instrumentation Pallets
Cockpit TV camera
Subsidi



1 Provisions for three servo-type HSIs

2 Mag heading, reference, and valid available at F/O RMI connector (RMI deleted)

FIGURE 1-1.—ADEDS INTERFACE BLOCK DIAGRAM

2.0 MFD REQUIREMENTS

2.1 GENERAL

The multifunction display (MFD) is a cathode-ray tube (CRT) display designed to provide the pilot with sufficient information for him to perform all horizontal and time-controlled flight maneuvers and to monitor the automatic performance of these maneuvers. This display is configured as a primary flight instrument, replacing the electromechanical horizontal situation indicator (HSI). It depicts that portion of the horizontal navigation and guidance information that lends itself to graphic presentation and is of enough importance to warrant presentation in primary panel space.

The MFD has a viewable area 5.75 in. wide by 7.75 in. high. Data presented on the display are processed digitally in the navigation computer unit (NCU) and the display program control unit (PCU) and are scaled at 90 digital bits/in. to give a visual resolution of 0.011 in. on the display. The display is refreshed 50 times/sec and dynamic data are updated 20 times/sec to give a flicker-free data presentation.

The data presented on the MFD vary as a function of mode, scale, and symbology selected, and are generally subdivided into two groups–background data and dynamic data. Background data are processed by the NCU at a slow rate and transmitted to the PCU once every 1 or 2 sec, unless otherwise defined. Dynamic data, which typically include position increments, coordinate rotation angles, data words, and symbology, are computed and transmitted 20 times/sec.

2.2 NCU/PCU INTERFACE FOR THE MFD

2.2.1 Electrical Interface

The electrical interface between the NCU and the PCU consists of four split-phase bipolar (SPBP) 100-kHz clock data buses. Two are associated exclusively with the MFD, the third services the EADI only, and the fourth is used for both EADI and MFD mode control. The data content of these bus transmissions is shown in tables 2-1 through 2-4. Where label coding is applicable, the label assignments required for each function transmitted are shown, as well as the data content of each word. Full definition of the data content is provided in section 2.2.2. The SPBP characteristic is defined in reference 1.

In general, the functions of each bus are:

- MFD bus 1 transmits MFD display background data, including text messages, as a 512-word data block from the NCU to PCU.
- MFD bus 2 transmits a data block of 64 words, including special MFD functions, dynamic symbology, incremental position, and coordinate rotation angle, at a repetition rate of 20/sec from the NCU to PCU.

- The PCU/NCU bus transmits three mode words–one for MFD 1, one for EADI, and one for a second MFD.* These words are transmitted whenever there is a change of status. Following any mode change or parity failure detection, the word format on the PCU/NCU bus will be changed within 50 msec of the occurrence.

2.2.2 Interface Word Formats

The basic interface word format is adapted from that defined in reference 1, which defines the SPBP characteristic. The basic word format of 24-bit data and an eight-bit label has been retained, but the 24-bit data word has been optimized for the display interface application. The word formats are defined in sections 2.2.2.1 through 2.2.2.3.

Wherever possible in the MFD bus 2 and EADI bus word formats, the standard SPBP designation matrix (DM) has been used. The DM coding is shown below:

Bit no.		
31	30	Code
0	0	Test
0	1	Minus
1	0	Plus
1	1	Invalid

All binary angular data are coded in semicircular format, i.e., the sign bit 30 represents 180°, bit 29 represents 90°, etc., unless otherwise defined.

Note: In the following text, binary codes are always in the form shown in the example below:

0 0 1 0
MSB LSB

2.2.2.1 MFD Bus 1

The three basic groups of word formats used for MFD bus 1 are shown in figures 2-1, -2, and -3. These word formats are collectively called table data henceforth in this document. The function of each bit is defined, and a one- or two-letter code is assigned for

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*The display system has the capability for generating two MFD displays with the same format but with different map scales. The NCU/PCU interface has therefore been designed with provisions to exploit this growth capability at a later date in any follow-on to the ADEDS contract. These second MFD provisions are simply the allocation of a mode word for the second MFD on the PCU/NCU return bus, as well as word formats, so that the MFD bus 1 and bus 2 data blocks of 512 and 64 words, respectively, can be subdivided between two MFD displays.

each group of bits. These letter codes will be used when referring to the word formats of figures 2-1, -2, and -3. The organization of the 512-word data transmission is illustrated in table 2-1, with words numbered from 0 through 511.

2.2.2.2 MFD Bus 2

The label coding and the data transmission order for MFD bus 2 are shown in table 2-2 for the track-up map mode and table 2-3 for the north-up map mode.

The data formats on MFD bus 2 are divided into two different types—general functions and table data. The general functions are identified in the PCU by the eight-bit label code and are acted upon according to the stored PCU program. The MFD bus 2 table data are processed by the PCU in the same manner as MFD bus 1 table data. The word formats corresponding to table 2-2 general functions are shown in figure 2-4.

2.2.2.3 PCU/NCU Bus

The word formats for the MFD mode words generated in the PCU and transmitted to the NCU are shown in figure 2-5. These same word formats are transmitted back to the PCU on MFD bus 1, as shown in table 2-1 (word 509 for MFD 1), to signify compliance with the MFD mode control unit selection.

2.2.2.4 Summary of Coded Functions

The purpose of each bit or group of bits in the interface word formats defined in figures 2-1, -2, and -3 is summarized below.

P	Parity is set for odd bit sum in all NCU/PCU data transmissions.
WF	Word follows is controlled by the NCU and is set to 1 in the last word of a group of symbol or vector words. WF is 1 in all control words.
TC	Table continues is controlled by the NCU and is always 1 except in the EOD control word marking the end of data on MFD bus 1 and bus 2.

The following codes apply to the I&R control words that control the operations performed in the PCU on the table data following each I&R word.

OC bit 23	Offset adder control is set to 1 by the NCU in all I&R control words associated with the track-up and north-up map modes and is set to 0 when the NCU/PCU interface test is activated (see sec. 2.5.2). OC instructs the PCU to offset the 0,0 coordinate reference point by a prestored amount that is mode dependent.
RC bit 22	Rotate coordinates is set to 1 by the NCU in I&R control words when the PCU is required to resolve all coordinates received over MFD bus 1 through the angle received in the second word on MFD bus 2. When RC = 0, no coordinate rotation is required.

RS bit 21 When RS bit 21 is 1, the symbols defined in all following symbol word groups will be rotated through an angle as defined in the R logic of the symbol word group (see below).

IC bit 20, 19 IC bit 19 is set to 1 by the NCU in an I&R word when the PCU is required to increment the X or east coordinate received on MFD bus 1 by the increment contained in the first word received over MFD bus 2. IC bit 20 controls incrementing of the Y or north coordinate in the same manner.

The following codes apply to symbol word groups:

OFS Tag offset is prestored in the NCU bulk data to define one of four offset positions. The PCU positions any alphanumeric tag associated with the symbol at the starting position defined by the OFS code. OFS codes are:

Code	X (in.)	Y (in.)
0 0	+0.147	-0.300
0 1	+0.147	-0.147
1 0	-0.325	-0.374
1 1	+0.100	-0.200

OFS is ignored in all text instruction words.

R Rotate symbol, in conjunction with the control word RS bit 21, constitutes a two-bit code defining symbol rotation logic.

RS bit 21	R	Definition
0	0	Upright symbol
0	1	Symbol rotated by the angle defined in the symbol word type 3
1	0	Symbol rotated by the angle defined in MFD bus 2 word label 01000001
1	1	Symbol rotated by the difference of angles; symbol word type 3 and MFD bus 2 word label 01000010

The R bit is set by the NCU in each symbol word type 1.

SS Symbol size is set by the NCU to choose one of four sizes for each symbol defined in figure 2-2. Basic sizes are:

Code	Size (in.)	Percentage of size defined in table 2-6
0 0	0.15	37.5
0 1	0.233	58
1 0	0.316	79
1 1	0.40	100

I_S	Symbol intensity is set by the NCU: zero (00), dim (01), medium (10), or bright (11).
L	On-screen limit is set to 1 by the NCU when it is required that the PCU keep the symbol in view even though its position coordinates would place it outside the screen area. The PCU limiting is symmetrical in X and Y coordinates.
I_T	Tag intensity is set by the NCU to control the four possible intensity levels (see I_S) for the tag associated with any symbol.
ST	Tag size is set by the NCU to select one of two sizes for the alphanumeric tag. These are the two smaller sizes defined for SS: 0 = 0.15 in., 1 = 0.233 in.
I_V	Vector intensity is set by the NCU to select one of the four intensity levels (see I_S) for vector lines.
C	Conic is set to 1 by the NCU in the vector word type 2 when the following segment is a conic.
D	Direction of conic is set by the NCU to define in which direction from north (1 = clockwise, 0 = counterclockwise) the PCU must draw the conic.
Color	Three bits allow for eight color levels in future growth application.
7-bit code	(Defined in table 2-6)

2.2.3 Interface Failure Protection

Interface failure protection will rely primarily on odd parity detection on all four data buses.

The PCU will check for odd parity in each word received on the MFD bus 1, MFD bus 2, and EADI buses. The PCU will also check that an end of table (EOT) is contained in the 512th word (number 511) received on MFD bus 1.

The NCU will check for odd parity in each word received on the PCU/NCU bus.

In the event that one or more bad parities are detected in the MFD bus 1 transmission or the EOT control word is not detected in the 512th word received, the PCU will discard the complete 512-word transmission and continue to generate the MFD display using the last good data received over MFD bus 1. Immediately upon detecting MFD bus 1 bad parity or lack of EOT, the PCU will set bit number 30 (P_2) to 1 in the MFD 1 and MFD 2 mode words. (See fig. 2-5.) The sequence of events following detection of an error in the MFD bus 1 transmission is described in section 2.2.4.

The PCU will check parity of data received over MFD bus 2. If a parity error is detected in any of the first seven label coded words, the data in that word will not be used.

If a parity error is detected in the control word with label 01000111 or in any subsequent table data, the whole table will be discarded. If a parity error obscures the first label 01000000, the PCU will not accept any bus 2 data until a label 01000000 is detected. In all cases, the previous good data received will be used to generate symbology. After 20 successive MFD bus 2 data blocks with one or more bad parity checks, bit 29 (P_3) of the MFD mode word will be set to 1 and maintained at 1 until 20 successive MFD bus 2 data blocks have been received with no parity errors.

The NCU will respond to MFD bus 1 and bus 2 failure by annunciation of the NCDU, as defined in section 6.0.

When bad data are received by the PCU over MFD bus 1 and bus 2 during the same time interval, the DS will continue to generate symbology from the last valid data received over both buses. This mechanization is desirable initially for troubleshooting. Later in the program, it will be desirable to modify the display system software to cause the MFD display to go blank if no valid data are received over MFD bus 1 and/or bus 2 for a defined period of time.

The NCU will ignore MFD mode words on the PCU/NCU bus that have bad parity.

System self-test features for the MFD and the PCU/NCU interfaces are defined in section 2.5.

2.2.4 Interface Timing

Data are transmitted at an average rate of 750 μsec per word, as shown in figure 2-6. The timing relationship between MFD bus 1 and bus 2 transmissions is shown in figure 2-7.

The MFD bus 1, MFD bus 2, and EADI bus data transmissions will be initiated under NCU software control and, once initiated, will continue until the complete data block has been transmitted. The MFD bus 1 data block will conform to the mode selected on the MFD mode control unit and transmitted to the NCU over the NCU/PCU bus. When the NCU has responded to a mode change by editing and assembling the data corresponding to the mode selected, it transmits the data to the PCU with the MFD mode words corresponding to the data in word numbers 507 and 509, as shown in table 2-1.

The PCU changes its internal operations to perform the new mode selected on the MFD mode control unit only after it receives the mode word back from the NCU, as described above.

When the MFD bus 1 512-word transmission is completed, as signified by an EOT code in the last word transmitted, the following sequence of events will take place. Figure 2-[illegible] shows the transition from the n-1 to the nth data block for the track-up map mode.

- Prior to the nth data block EOT, the MFD display is being generated from the n-1 MFD bus 1 background data block previously received, and is incrementing and resolving the background data coordinates from increments and angle data pertaining to the n-1 data block received over MFD bus 2.

- The PCU will check each word of the nth data block for parity, check the 512th word for EOT (word number 511) and, if both checks are positive, accept the data. The PCU will transmit the MFD mode word with bit 30 set to 0 for acceptance, or 1 for bad data, within 50 msec of EOT receipt. Any change to 1 will be transmitted at least twice.

- If the bus 1 data are accepted, the PCU will take the delta word data from word number 510 (MFD 1) and word 508 (MFD 2) and use the data to override MFD bus 2 delta position data for the next 100 msec.

- If the bus 1 data are not accepted, the PCU will continue to use the n-1 data block and the delta position data from MFD bus 2.

- The NCU continues to transmit the delta data corresponding to the n-1 data block for the next two MFD bus 2 transmissions after it has transmitted the EOT for the nth data block on MFD bus 1, as shown in figure 2-7. Thereafter, the MFD bus 2 data will correspond to the nth MFD bus 1 data block, except when the nth data block was not accepted by the PCU.

- On receipt of the MFD mode word with bit 30 set to 1 (indicating that the nth MFD bus 1 data block was not accepted), the NCU will continue to put out delta position data for the n-1 data block.

2.2.5 PCU Data Buffers

The PCU has multiple-storage zones in its memory for the MFD 1 and MFD 2 data bus input data storage.

Two 512-word storage zones are required for MFD bus 1 data. While one is in use for display generation, the other is accumulating the incoming data. When 512 words have been received and parity and EOT checks are good, the PCU switches over to this memory zone at the end of the current 20-msec refresh cycle.

Three 64-word storage zones are required for MFD bus 2 data. During a particular display refresh cycle. one zone will be in use, another will complete the reception of a 64-word data block, and the third will start accumulating the next 64-word transmission.

2.3 MFD MODE/DATA CONTROL

MFD mode and map scale are selected with the MFD mode control unit (MCU) shown in figure 2-8 and as specified in table 2-5. Data displayed on the MFD are controlled through the navigation control display unit (NCDU), as summarized in section 2.6, and through the system control unit (SCU), as specified below. The SCU is a test tool only and is available to provide flexibility during testing.

The mode, scale, and symbology selections, defined in table 2-5, are encoded in the PCU and transmitted to the NCU via the PCU/NCU bus. This MFD 1 mode word is defined in figure 2-5.

The NCU will interpret the MFD mode word; process the data necessary for the particular mode, scale, and symbology options selected; and transmit the data to the PCU over MFD bus 1 and bus 2 as defined in section 2.2. This new transmission will include the MFD mode word in position 509 on MFD bus 1, as shown in table 2-1.

Background map data selected OFF on the MFD mode control unit will be deleted by the NCU from the background table data transmitted over MFD bus 1. Included in this category is the symbology controlled by the NAVAIDS, TERRAIN, GRP, and AIRPORTS symbology option buttons (see fig. 2-8).

The T-NAV symbology option button controls symbology transmitted as table data over MFD bus 2. When the button is selected OFF, these data will be deleted by the NCU from data transmission.

The display system does not react to the mode, scale, or symbology change until the MFD mode word is received back from the NCU. The exception to this rule is the test mode. The display system will respond directly to this mode selection independent of the NCU and will draw the predefined test pattern on the MFD display, overriding the data transmitted from the NCU (see fig. 2-14 for format). The normal delay between change of mode, scale, or symbology selection on the MFD mode panel and the appearance of the corresponding MFD display format shall not exceed 2 sec.

When the SCU is connected to the display system, the PCU will have the capability of controlling symbology defined by any general-function, label-coded data from MFD bus 2. This symbology will be controllable ON/OFF by the SCU selection switches; control is independent of the NCU.

The symbology under SCU control is limited to EADI direct inputs, EADI bus, and MFD bus 2 functions with label addresses. Display table data symbology is controlled via the MFD mode control unit and the NCDU. The MFD symbols under SCU control are defined in section 2.7.

2.4 MFD SYMBOLOGY

The symbology repertoire required for the MFD is defined in table 2-6. Note that the dimensions given in table 2-6 are maximum size. The seven-bit codes that are used to identify symbology are defined in table 2-7. Special-function symbology transmitted over MFD bus 2 does not have seven-bit codes assigned.

2.4.1 Track-Up Map Mode

A detailed description of the function, priority, and mechanization of each MFD symbol is presented below for the track-up map mode.

2.4.1.1 General

The track-up map mode shall display a track-up oriented map that moves about a fixed aircraft symbol. The format shall consist of an airplane symbol, a curved-trend vector, a straight-trend vector, a digital and analog indication of present track, two selected track indicators, major airfields, navaids, geographic reference points (GRPs), mountains, obstructions, ADIZ and FIR boundaries, waypoints, a route line, and digital navigation data. A representative track-up map display format is given in figure 2-9, and the location of reference points is shown in figure 2-10.

The NCU/DS shall be capable of providing six map scales: 1, 2, 4, 8, 16, and 32 nmi/in. These scales shall be selectable from the MFD mode control unit.

The NCU will extract the data required for each selected map scale from the bulk data memory, which is defined in section 3.0. From these bulk data and airplane present position, the NCU will edit and categorize the map background data for transmission to the PCU via MFD bus 1. Only the particular categories of data applicable to the map scale selected, and the symbology options selected on the MFD mode control unit or the NCDU, will be transmitted. The relationship between each symbol and the map scale selected is defined below for each symbol.

The NCU will generate the background MFD bus 1 data in true east and north position coordinates scaled according to the map scale selected. East and north position increments and sin and cos of true track angle (TK) will be computed to transmit 20 times/sec to the PCU over MFD bus 2, as shown in figure 2-4, to compensate for aircraft motion between MFD bus 1 data updates.

The PCU will transmit the MFD mode control word whenever status changes and will generate the display in accordance with the data and control instructions received from the NCU over the two data buses. The data received fall into three general categories:

1) Symbol, vector, and control word groups on MFD bus 1 (see figs. 2-1, -2, and -3), collectively called MFD bus 1 table data

2) Symbol, vector, and control word groups on MFD bus 2, collectively called MFD bus 2 table data

3) General-function data identified by label code on MFD 2 (see fig. 2-4)

The DS generates the symbology for category 1 and 2 table data directly in accordance with the instructions contained in the symbol and vector word formats and the preceding code words. The PCU processes category 3 general-function data, which are generally in the form of parameter values, and develops the appropriate symbology in accordance with the PCU stored program.

In the track-up map mode, the hybrid symbol generator (HSG) adds the east and north position increments, ΔE and ΔN, to the MFD bus 1 table data coordinates. It transforms these coordinates into screen coordinates X and Y by resolving the true east and north coordinates through true track angle in accordance with the I&R control words preceding the data (see table 2-1). It is therefore necessary for the DS internal processing to be able to handle the equivalent of

$$\sqrt{511^2 + 511^2} = 720 \text{ digital bits}$$

for positioning the beam on the CRT screen.

The PCU will also bias the transformed coordinates to position the (0,0) reference point as shown in figure 2-10, and will rotate the map about this point. Figure 2-11 is a typical representation of the background data editing and coordinate transformations required in the track-up mode.

The data rates required for computation and transmission of data from the NCU to the PCU are summarized in table 2-8. The data transmitted from the NCU to the PCU will correspond to those background points falling within the minimum edit area boundary shown in figure 2-11. The east and north position coordinates have a range of ±478 (±5.25 in.). The HSG can therefore accumulate 33 delta bits before the east and north position coordinates exceed ±511. When the incremented coordinates (east + ΔE, north + ΔN) of a symbol exceed ±511, the PCU will ensure that the symbol does not appear in the viewable area of the display unless the L bit for that symbol has been set to 1 in the symbol type 1 word. Similarly, when an incremented coordinate of a vector point exceeds ±511, the HSG will ensure that the vector line does not "wrap around" to an erroneous position in the viewable area. It will be acceptable if data points reappear in erroneous positions after the accumulated coordinates exceed ±1023.

2.4.1.2 Airplane Position

Airplane position shall be indicated by the apex of an elongated triangle, as specified in table 2-6. This airplane symbol shall be fixed to a location 1.30 in. below the center of the screen, as shown in figure 2-10. The map shall rotate about this point.

The airplane symbol and offset position will be generated within the DS as a function of the mode selected. No symbol or position words are required from the NCU, but the offset control (OC) bit (see table 2-1) will be set to 1 in all MFD bus 1 I&R control words to instruct the PCU to use the offset center.

The airplane symbol intensity (I_S) is 11.

2.4.1.3 Curved-Trend Vector

On 2-, 4-, 8-, 16-, and 32-nmi/in. scale maps, the curved-trend vector consists of three curved dashes, each dash being made up of five equal segments with the first segment blanked; on 1-nmi/in. scale maps, this trend vector shall be reduced to a single dash, i.e., five segments with the first segment blanked. The curved-trend vector shall be computed in the NCU as defined below and scaled according to the map scale selected. In the track-up map mode, the calculated coordinates $X_n Y_n$ are screen oriented.

$$X_{(n+1)} = X_n + K_2 (R-X_n) + K_1 (Y_n)$$

$$Y_{(n+1)} = Y_n + K_1 (R-X_n) - K_2 (Y_n)$$

where:

$K_1 = \frac{6 \text{ ACNORM}}{\text{VGS}}$

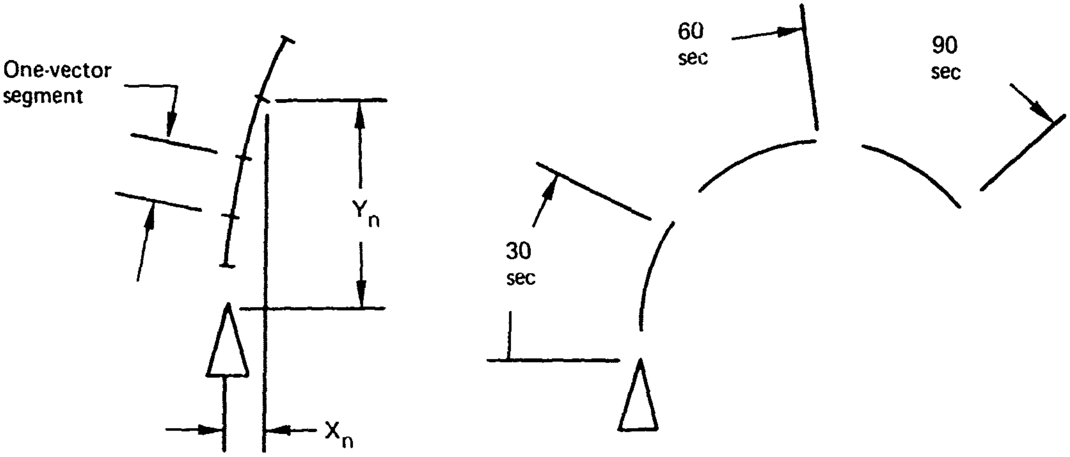
$K_2 = 18 \left(\frac{\text{ACNORM}}{\text{VGS}}\right)^2$

$R = \frac{\text{VGS}^2}{\text{ACNORM}}$

ACNORM = horizontal acceleration normal to the airplane velocity vector (ft/sec^2)

VGS = groundspeed (ft/sec)

n = 0 to 15



Data points X_1Y_1 through X_5Y_5 define the first trend vector segment, X_6Y_6 through $X_{10}Y_{10}$ define the second, and $X_{11}Y_{11}$ through $X_{15}Y_{15}$ define the third.

X_n, Y_n will be converted to screen coordinates according to the map scale selected. If either X_n or Y_n exceeds ±511, subsequent vector segments need not be calculated.

The curved-trend vector will be computed 20 times/sec in the NCU, with the data transmitted to the PCU via MFD bus 2 in the form of three vector word groups of four segments each. The position of these words in the MFD bus 2 64-word data block is shown in table 2-2. An I&R control word with IC = 00 and RC = 00 will precede the curved-trend vector data.

The vector code used is 1100000, as shown in table 2-7, and intensity I_V will be set to 11 by the NCU. The DS will generate the vectors in accordance with the control word.

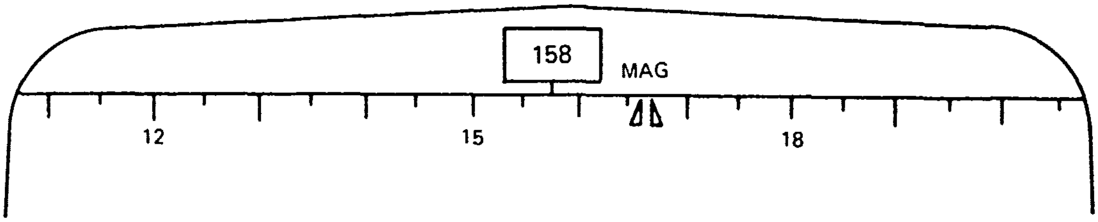
2.4.1.4 Straight-Trend Vector

The straight-trend vector will project straight ahead from a point 0.625 in. ahead of the apex of the airplane symbol to the lower edge of the track scale.

This symbol will be generated by the DS with an intensity I_V of 01. No data are required from the NCU.

2.4.1.5 Track (TK) Tape

Present track (magnetic) shall be indicated by a digital readout centered at the top of the screen, which shall indicate actual track to the nearest degree (three digits) and a track scale approximately 100° long. The track scale shall consist of 5° minor indices, 10° major indices, and labels spaced at 30° intervals. This segment of track scale, scaled at 16°/in., shall have a total travel of 360°; the index mark for this track scale shall be a vertical line extending from the digital readout to the top of the scale, as shown below and in table 2-6



The NCU will transmit magnetic track angle (TK_M) data in the form of a binary word defining degrees/180 and a BCD word defining degrees. The binary data word will be computed and transmitted 20 times/sec over MFD bus 2 with the label identification 01000010, and the BCD word will be computed once/sec and transmitted 20 times/sec with label 01000011, as shown in table 2-2.

The DS will generate the track tape and alphanumeric readout as shown above from the binary and BCD track data transmitted from the NCU whenever the DMs are valid.

2.4.1.6 Track Angle Error

Track angle error is defined in two forms depending on whether an autopilot track select mode has been activated. During normal flight plan guidance (GUID4D, GUID3D, or GUID2D), track angle error (TKE) is computed with respect to the flight plan path nominal track DSRTK as TKE = TK - DSRTK. When autopilot track select is activated (PSTTKA or TKSEL), the function TKESEL is computed, where TKESEL = HLDTK - TK. These two functions are used to drive the track angle error symbology as defined below.

2.4.1.6.1 Track Select Symbol—This symbol, illustrated in figure 2-9, is generated only when the autopilot mode PSTTKA or TKSEL has been activated.

The NCU will transmit the sin and cos of TKESEL to the PCU 20 times/sec over MFD bus 2 with the label 01000100 and the word format defined in figure 2-4. When TK HLD has been activated as described above, the designation matrix (DM) will be valid. Under all other conditions, DM will be set to invalid (11).

The DS will generate the line of dots symbol, as defined in table 2-6 and table 2-7 (code 0001011), with an intensity $I_S = 10$ whenever the DM is valid.

2.4.1.6.2 Track Angle Error Bug—This symbol, illustrated in figure 2-9, is displayed at all times when a flight plan has been entered into the system through the NCDU or an autopilot track select mode (PSTTKA or TKSEL) has been activated.

When the PSTTKA or TKSEL mode has been activated, the NCU will compute and transmit the quantity (±TKESEL x 90/16)° 20 times/sec over MFD bus 2 with label identification 01000101 and the word format shown in figure 2-4. When PSTTKA or TKSEL is not activated but a flight plan has been entered into the NCDU, the NCU will compute and transmit the quantity (±TKE x 90/16)° 20 times/sec over MFD bus 2 with label identification 01000101 and the word format shown in figure 2-4. The absolute value in both cases will be limited to 240.

When no flight plan has been entered into the NCU, and PSTTKA or TKSEL have not been activated, the designation matrix of word label 01000101 will be set to invalid (11).

When the DM is valid, the DS will generate the track angle error bug symbol (defined in table 2-6) with an intensity $I_S = 10$. The DS will position the symbol in the Y dimension so that the tips of the symbol will lie on the baseline of the track scale defined in section 2.4.1.5.

2.4.1.7 Map Background Data

The map background data are derived from the bulk data memory of the NCU, defined in section 3.0. These data include selected airfields, waypoints, navaids, geographic reference points, mountains and obstructions, FIR boundaries, and ADIZ/CADIZ boundaries. Other background data displayed include the flight plan data and selected functions entered into the system through the NCDU. Interaction of the NCDU with the MFD display is outlined in section 2.6. Note that if data have been selected for display in the NCDU look-up mode, these data will appear on the MFD display regardless of MFD mode control unit option selection.

The NCU shall edit these data in accordance with the mode, scale, and symbology options selected on the MFD mode control unit and encoded in the MFD mode word transmitted on the PCU/NCU bus as shown in figure 2-5. The edited data, called table data, are in the form of control words, symbol word groups including text, and vector word groups as defined in figures 2-1, -2, and -3, respectively. The table data are transmitted to the PCU via MFD bus 1 as specified in section 2.2.

The symbology position coordinates defined in the vector and symbol type 2 words are in the form of 10 bits of north and east position with respect to the airplane. A tangent plane projection method will be used to transform the locations of data points from the spherical earth coordinates (latitude and longitude) used for bulk data storage into the flat plane coordinates presented on the CRT display. The accuracy of this transformation shall be such that the position of data points relative to the airplane symbol on the display shall represent the bearing and great circle distance to the following accuracy:

Bearing: ±1°

East position: ±0.1 in. at remote display corners,
North position: ±0.01 in. at the reference point

2.4.1.7.1 Flight Plan—The flight plan is entered into the ADEDS system through the NCDU as defined in section 6.0. The flight plan consists of a series of waypoints at which a nominal time of arrival, nominal altitude, and nominal groundspeed can be assigned to make the flight plan four dimensional. A flight plan path is defined in the guidance algorithm consisting of great circle segments from waypoint to waypoint and circular arc transitions between segments. The data defining this path are generated in the 4D guidance software and stored in a flight plan buffer as defined in table 5-1.

The flight plan path and waypoints defining this path will be displayed at all times on the MFD map display whenever a flight plan has been entered through the NCDU. The NCDU has two levels of data entry, as outlined in section 2.6. After entry through the NCDU but prior to EXEC (execute), a flight plan is provisional and will be displayed as a dim dashed line showing the path defined in the provisional guidance buffer. After EXEC has been pressed, the entered flight plan is used to guide the airplane, and the flight plan path is displayed as a solid line complete with circular arc transitions and turn markers defined in section 2.4.1.7.12.

A provisional flight plan entry will be stored in the provisional guidance buffer as defined in section 6.0.

The MFD display requirements for the waypoint and flight plan path line are defined below.

2.4.1.7.1.1 Flight Plan Waypoints: The NCU will extract the latitude and longitude coordinates and designators of all waypoints in the flight plan buffers. In general, both provisional and accepted waypoint entries will be included. The NCU will generate a symbol word group defining the star symbol, its position, and alphanumeric designator. The type 1 word will include the symbol code 0011100, OFS = 00, R = 0, SS = 11, L = 0, I_S and I_T = 10, and ST = 0. The type 2 word defines E and N coordinates, and one or two type 4 words define the designator with WF = 0 in the last type 4 word.

There is one exception to this rule. The touchdown point on the runway, which will be included in the flight plan when a runway SID or STAR is selected, will be tagged in the flight plan buffer to signify that the star symbol 0011100 will not be used for this flight plan waypoint. This applies for both the takeoff and landing runway.

Note that when the MFD display options NAVAIDS, AIRPORTS, or GRP are selected on the MFD mode control unit, the respective symbology defined in sections 2.4.1.7.5, 2.4.1.7.3, and 2.4.1.7.4 will superimpose the star symbol, as shown in figure 2-9 for HQM.

The DS will generate the symbology as defined in table 2-6 and in accordance with the preceding I&R control words in the MFD bus 1 data transmission. Symbols and designators will remain upright as the map rotates

2.4.1.7.1.2 Flight Plan Path· The displayed path shall approximate the great circle line between waypoints, meeting the following accuracy requirement:

|displayed route - great circle route| < 0.01 in. in the vicinity of the airplane symbol

In general, the flight plan path will originate at the nominal liftoff point on the takeoff runway and terminate at the nominal touchdown point on the arrival runway.

The data defining the flight plan circular arcs, tangent points, turn initiation points, etc., generated by the guidance and control algorithms defined in section 5.0, will not include definition of all points necessary to define the vector line in latitude, longitude, or east and north coordinates. It will therefore be necessary for the MFD display's NCU software to generate a separate flight plan data buffer to store the data related to the flight plan required for transmittal to the PCU.

The NCU MFD software subroutine must also calculate the coordinates where the route line intersects the edit area boundary. This is a general requirement applicable to all vector lines crossing the edit area boundary.

The NCU will generate the vector word groups to define the flight plan. The vector will be defined by the vector 1100000 with $I_V = 01$ and will include conic vector words (see fig. 2-3) to define the circular arc transitions and circular arc flight legs. To satisfy the requirements of the DS for generating circular arcs, the NCU must provide:

- Radius of turn (WPRTN), defined in the 4D guidance (sec. 5.3.1.4)
- Arc length, available from the guidance software as defined in section 5.0 (WPA02 x 2)
- Position at the start of the circular arc ($E_n N_n$), dependent on the radius of turn defined above and the angular change in direction between the two flight legs (TA)
- Initial tangent angle (ITAN) with respect to true north, derived from the waypoint coordinates (E_i, N_i) and the previous waypoint coordinates (E_{i-1}, N_{i-1})

$$(\text{ITAN}) = \tan^{-1} \frac{(E_i - E_{i-1})}{(N_i - N_{i-1})}$$

To satisfy the accuracy requirements, it may also be necessary for the NCU to break down long great circle paths into shorter segments that can be represented by straight lines on the display.

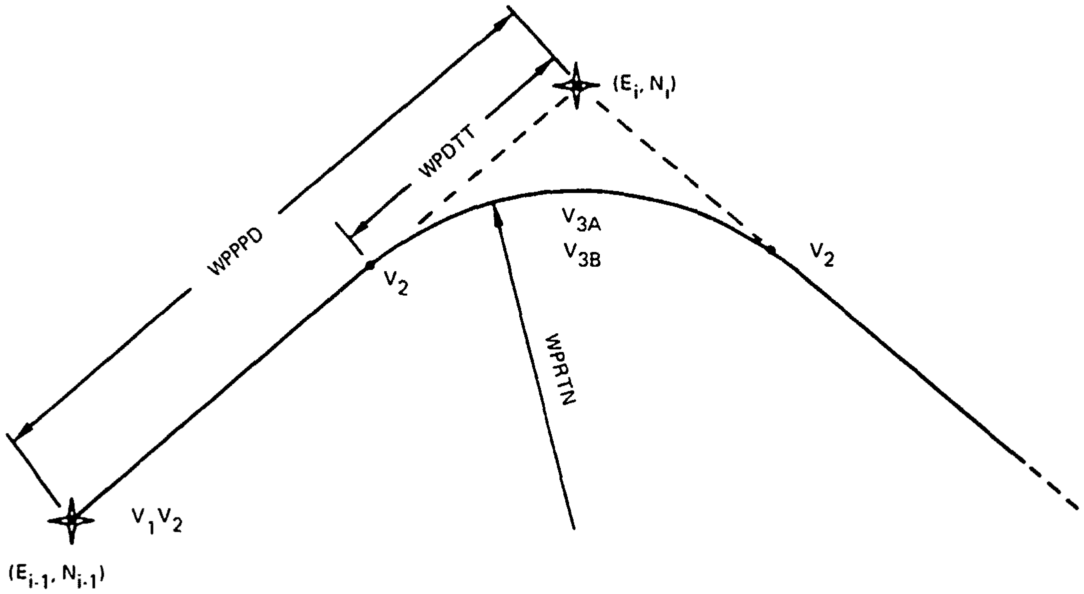
A simple flight plan segment is shown below with the type of vector words required to define it (see fig. 2-3) and the data available from the guidance software (table 5-1) to define the vector type 2 word coordinates by plane geometry. The data available from the flight plan buffer (table 5-1) are:

WPPPD = great circle distance from waypoint$_{i-1}$ to waypoint$_i$

WPDTT = distance from waypoint to tangent points

WPA02 = arc length of curved path divided by 2

WPRTN = radius of turn



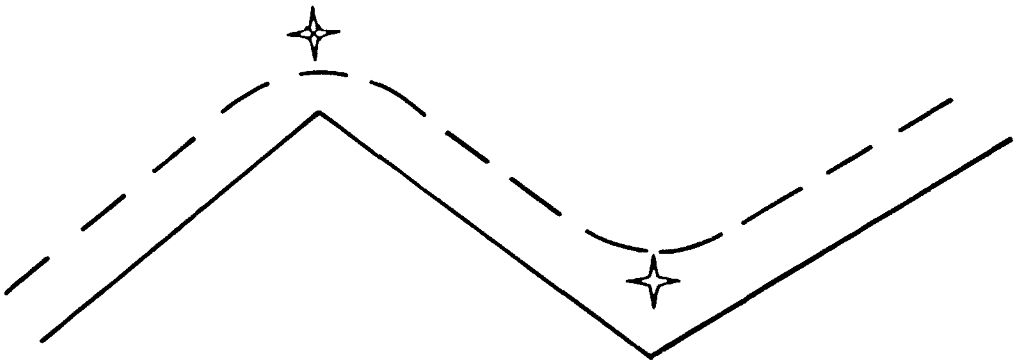
The transmission sequence will be V_1, V_2, V_2, V_{3A}, V_{3B}, V_2, V_2, where V_1 represents a vector type 1 word, etc. Each word will have the WF bit set to 0 until the end of the vector is reached. The second V_2 will have the C bit set to 1 in this example.

When a flight plan has been entered into the system through the NCDU but not accepted (prior to EXEC), the NCU will generate flight plan straight-line vectors from waypoint to waypoint with vector code 1100001 and $I_V = 01$.

The DS will generate the vector line symbology as defined in table 2-6 and in accordance with the preceding I&R control word in the MFD bus 1 data transmission.

2.4.1.7.1.3 Offset Flight Plan: A flight plan can be defined through the NCDU, as defined in section 6.0, such that a path parallel to the path defined by the flight plan waypoints is followed by the guidance system. This mode of operation is activated by SEL OFFSET mode selection on the NCDU. The offset is entered as miles left or right.

When OFFSET has been selected, the NCU will preserve the flight plan waypoint display as defined in section 2.4.1.7.1.1, and change the vector code to 1100001 with $I_V = 01$ for a dashed-line presentation of the original flight plan path. The NCU will generate an additional vector word group to represent the offset path, as shown below.



The end points of the offset vector line are positioned at the intercepts of the offset line parallel to the flight plan path and the angular bisector of the turn angle.

When the OFFSET mode has been canceled on the NCDU, as defined in section 6.0, the NCU will revert to the conditions defined in section 2.4.1.7.1.2. The NCDU routine will set the following functions:

OFSSEL = flag

OFBIAS = offset distance, positive right of track

The DS will generate the vector lines as defined in table 2-6 and in accordance with the preceding I&R control words in the MFD bus 1 data transmission.

2.4.1.7.2 SIDS and STARS–The SIDS and STARS for the primary flight test airfields shall be available for display when they have been individually selected into the flight plan through the NCDU as specified in section 6.0. They will be displayed as a sequence of waypoints, with the star symbology connected by a route line as described in section 2.4.1.7.1. The last waypoint on a STAR and the first waypoint of a SID will be the nominal touchdown point on the runway.

2.4.1.7.3 Airfields and Runways- The airfields, specified in the bulk data memory, shall be available for display purposes. These airfields are categorized as follows:

Category 1	All airfields required for flight test for which detailed terminal area data (runway parameters, SIDS, STARS, etc.) will be stored in the bulk data memory
Category 2	A select number of airfields for which only MFD symbol data will be stored

Category 2 airfields are recognized by RWY = 0 in the bulk data storage format defined in section 3.0. Symbology displayed on the MFD will be dependent on whether an airfield or an airfield and a runway have been entered into the flight plan through the NCDU. Flight plan airfields and runway data are included in the flight plan buffer memory defined in table 5-1. Symbology will also be dependent on map scale.

Generation of the symbology required for display is described below for the following categories: airfields, origin and destination airfields, runways, extended runway centerline, outer marker, missed approach waypoints, and missed approach route line (secs. 2.4.1.7.3.1 through 2.4.1.7.3.7). The data required to generate this symbology are stored in the airfield data block in the bulk storage of the NCU, as defined in section 3.0.

2.4.1.7.3.1 Airfields: All airfield symbology shall be selectable ON or OFF through the MFD mode control unit as specified in table 2-4. When selected OFF, the NCU will delete the airfield data from the MFD bus 1 transmission. When selected ON, the airfields will be represented by the symbol defined in table 2-6 with code 0001110. The symbol shall be displayed with the proper orientation, and the ICAO identifiers of the airfield shall be displayed as shown below; location of the four-letter ICAO identifier is defined by the OFS code.

The NCU will edit the airfield data stored in the bulk data memory according to the MFD map scale selected. The NCU will generate a symbol word group (fig. 2-2) including one type 1, one type 2, one type 3, and two type 4 words for each airport within the edit area. Word type 1 will include the symbol code 0001110, R = 1, OFS = 00, SS = 11, I_S = 10, L = 0, and I_T = 10. The type 2 word defines position coordinates derived from airport reference latitude and longitude coordinates stored in the bulk data memory. The type 3 word defines the orientation of the longest runway with respect to true north, and the two type 4 words define the four-letter-ICAO designator, WF = 1 in the last type 4 word.

The symbol word groups defining airfield symbology will be preceded in the MFD bus 1 data block by an I&R control word with WF = 0, TC = 1, OC = 1, RC = 1, RS = 1, and IC = 11.

The DS will generate the airfield symbol as defined in table 2-6, and rotate it through the angle defined in the symbol type 3 word, added to the angle defined in word label 01000010 on MFD bus 2. The ICAO designator will be maintained upright as the map and airfield symbol rotate.

2.4.1.7.3.2 Origin and Destination Airfields: An origin and destination airfield can be entered into the flight plan, as defined in section 6.0. When an airfield has been entered into the flight plan but no runway has been selected, the display symbology is identical to any other flight plan waypoint as defined in section 2.7.1.7.1.1 and as illustrated in figure 2-9 for KSEA. When a runway has been entered into the flight plan, the reference waypoints foı the runway are defined in the flight plan buffer, and additional symbology is as defined in section 2.4.1.7.3.3.

When the AIRPORTS option is selected on the MFD mode control unit, the airport symbol as defined in section 2.7.1.7.3.1 will be superimposed on the waypoint star symbol.

When a runway has also been entered into the flight plan and a map scale of 1, 2, or 4 nmi/in. has been selected on the MFD mode control unit, the airfield symbology is changed to include the runway symbology; extended runway centerline at the origin airport; runway symbology, runway centerline, and outer marker; missed approach waypoints; and missed approach path at the destination airport (secs. 2.7.1.7.3.3 through 2.7.1.7.3.7).

2.4.1.7.3.3 Runway: The NCU will use the runway threshold point coordinates to generate two vector end points to transmit to the PCU as a vector word group (fig. 2-3) over MFD bus 1 in the 1, 2, and 4 nmi/in. map scales only. The double-vector code 1101000, as defined in table 2-7, will be used with intensity I_V set to 10 by the NCU. The positions of the vector end points can be computed from the threshold reference points stored in bulk memory, with an offset of three bits to the left added to the coordinates so that the center of the double vector approximates the runway centerline.

The DS will draw the second line of a double-vector six bits (0.066 in.) to the right of the reference point.

The airport designator will be positioned as shown above and transmitted by the NCU as a symbol text word group (see fig. 2-2), with I_T set to 10 and ST to 0. The coordinates in the text word type 2 will be defined at the runway threshold point, with the four-character designator preceded by three spaces in the type 4 words to provide the desired position for the designator.

2.4.1.7.3.4 Extended Runway Centerline: This symbology will appear on the 1, 2, and 4 nmi/in. scales only, and will consist of a long dashed line scaled to represent 10 nmi.

The NCU will generate a vector word group using vector code 1100001 with I_V set to 01 in the vector word type 1. The first vector word type 2 coordinates (E_1N_1) will be defined by the runway threshold coordinates from bulk storage. The second vector word type 2 will have WF = 1 and will define the end point coordinates (E_2N_2) of the 10-nmi extension, computed as

$$E_2 = E_1 + K \times 10 \sin \psi$$

$$N_2 = N_1 + K \times 10 \cos \psi$$

where:

ψ = runway true heading

K = map scale factor

The DS will generate the vector symbology in its normal table mode.

2.4.1.7.3.5 Outer Marker: The NCU will generate a symbol word group (fig. 2-2) to represent the outer marker and designators on the 1, 2, and 4 nmi/in. scales only when the NAVAIDS option is selected on the MFD mode control unit. The symbol code will be 0010000 and OFS = 00, R = 1, SS = 11, L = 0, I_S and I_T = 10, and ST = 0. This symbol word group will include a type 3 word defining the symbol orientation with respect to true north, as well as three type 4 words with ST = 0 to define the designators for the marker and runway. This designator will include line feed and carriage return codes as shown in the following example:

LOM BF
21L

with the symbol type 4 words coded as follows

Word 1	L	O	M
Word 2	B	F	CR
Word 3	LF	2	1
Word 4	L	b	b

where:

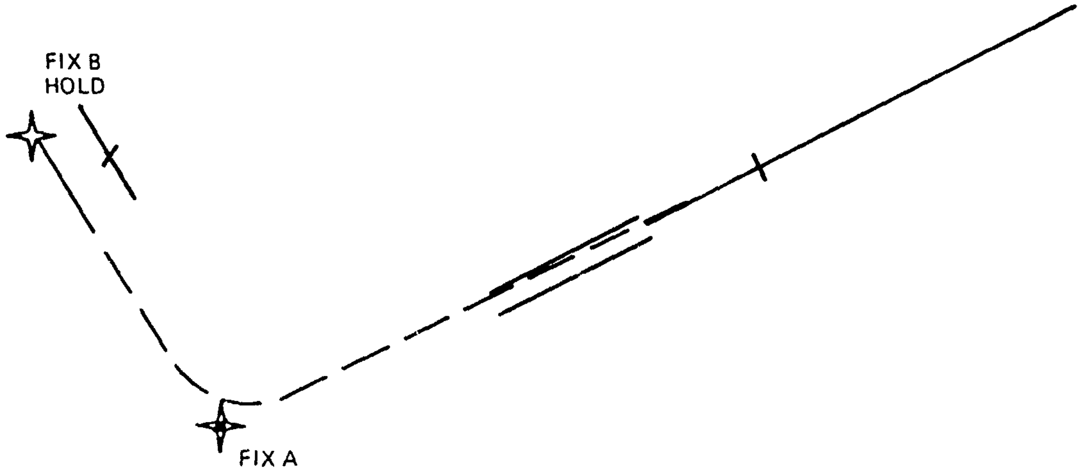
CR = carriage return code 0000011

LF = line feed code 0000010

b = blank

This symbol word group will be preceded in the MFD bus 1 data transmission by an I&R control word with WF = 0, TC = 1, OC = 1, RC = 1, RS = 1, and IC = 11. The DS will maintain the orientation of the outer marker symbol by adding track angle from the MFD bus 2 word label 01000010 to the type 3 word in accordance with the control word. The DS will also maintain the alphanumeric designator upright as the map rotates. The DS will interpret the CR code to return the beam to the symbol OFS reference point, X coordinate, and the LF will cause the beam to move down from that point by one to five times character height, defined by S_T.

2.4.1.7.3.6 Missed Approach Waypoints. Stored in the NCU bulk storage as part of the category 1 airfield data, these waypoints define a continuous path for the missed approach procedure for the selected runway. The first waypoint on the missed approach path will lie on the final approach path as shown below. This waypoint marks the missed approach decision point.



Missed approach procedures that direct the aircraft to a holding fix will be shown with the holding pattern displayed as defined in section 2.4.1.7.10.

The NCU will generate symbol word groups to define each missed approach waypoint as defined in section 2.4.1.7.1.1, except the missed approach decision point that uses the tick mark symbol defined in section 2.4.1.7.12.

The DS will generate the symbols in its normal table mode.

2.4.1.7.3.7 Missed Approach Route Line: Missed approach (MAP) data for primary runways at category II airfields will be stored in bulk data memory. These data will be extracted by the NCDU routine and transferred to the provisional guidance buffer memory when the waypoint prior to the runway touchdown point (TDZ) is passed. At this time it will be drawn as a provisional dashed line path on the MFD. When the EXEC key on the NCDU is pressed, the MAP data are transferred to the active guidance buffer and will then appear on the MFD as an accepted flight plan solid line path.

When the MAP path is stored in the provisional guidance buffer, the NCU will process the provisional guidance buffer data in the manner defined in section 2.4.1.7.1.2. The data will be transmitted in table format over MFD bus 1 using vector code 1100001. When the MAP path is stored in the active guidance buffer, the NCU will process the active guidance buffer data in the same manner; however, the data will be transmitted in table format over MFD bus 1 using vector code 1100000. In both cases, the MAP may include a holding pattern that will be processed by the NCU as defined in section 2.4.1.7.6.

The DS will generate the symbology for the MAP in its normal MFD bus 1 table mode.

2.4 1.7.4 Geographic Reference Points—These background data are defined as geographic points used for flight planning and route selection that are not radiating navaid facilities such as VOR and VORTAC.

Geographic reference points (GRPs) are divided into two categories: prestored data points defined in the bulk storage memory, and data points entered and defined through the NCDU keyboard. They are further divided into two types: high and low altitude. The symbol code is 0001001 (see table 2-7). GRPs are generally identified by a five-letter designator derived from the geographic name.

Impromptu GRPs entered as waypoints into the flight plan through the NCDU keyboard in the form of a latitude and longitude, or range and bearing from a navaid facility, will be identified by a sequence number designator such as WPT 07, which defines the seventh such waypoint entered into the flight plan. The symbol code for these flight plan waypoints is 0011100 (see table 2-7).

Geographic reference points selected for the flight plan through the NCDU will be displayed as defined in section 2.4.7.1.1. High-altitude GRPs will be selectable for display on all map scales. Low-altitude GRPs will be selectable for display on the 4, 2, and 1 nmi/in. map scales only. GRPs will be selectable ON and OFF by the GRP button on the MFD mode control unit. When selected ON, the GRP symbol will overwrite the waypoint star symbol.

The NCU will generate a symbol word group defining the GRP triangle symbol code, its position with respect to the MFD coordinate reference point, and the alphanumeric designator. OFS will be set to 00, R to 0, SS to 11, I_S and I_T to 10, L to 0, and ST to 0.

The DS will generate the symbology as defined in table 2-6 and will maintain the symbol and the alphanumeric designator upright as the map rotates in accordance with the preceding MFD bus 1 I&R control word.

2.4.1.7.5 Navaids—A select number of VORs, VORTACs, and nondirectional beacons, as specified in the bulk data memory, shall be available for display purposes. These navaids are categorized as follows:

Category 1	High-altitude VORs and VORTACs
Category 2	Low-altitude VORs and VORTACs
Category 3	Nondirectional beacons (NDBs)

Display of radio facilities shall be controlled by these categories as specified in table 2-9.

All navaids, except the two "tuned-in" navaids and the navaids entered as waypoints in the flight plan, shall be selectable ON or OFF as a group of data through the MFD mode control unit as specified in table 2-4. When selected OFF, the NCU will delete navaid data from the MFD bus 1 data transmission.

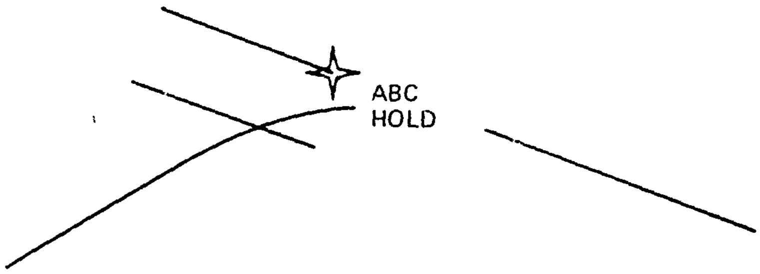
Standard VOR, VORTAC, and NDB symbols, as given in table 2-6, shall be used to indicate the location of each navaid. The VOR symbol code is 0010010, the VORTAC symbol is 0010011, and the NDB is 0011101.

The NCU will generate symbol word groups defining the symbol, position, and designator for each navaid. The navaids currently tuned in on the radio navigation receivers will have the symbol intensity I_S and designator intensity I_T set to 11. All other intensities will be set to 10. VORTAC, VOR, and NDB symbol words will have OFS = 00, R = 0, SS = 11, L = 0, and ST = 0.

The DS will generate the navaid symbols as defined in table 2-6 and will maintain the symbol and designator upright as the map rotates in accordance with the preceding MFD bus 1 I&R control word

2.4.1.7.6 Holding Pattern–Holding patterns are selected through the NCDU as defined in section 6.0. A standard right- or left-hand holding pattern can be selected, and the inbound course to the holding point can be specified.

When a holding pattern is selected at an upcoming flight plan waypoint and no inbound course is specified, the holding pattern will be positioned on the outbound flight plan track path extension from that waypoint, as shown below for a right-hand holding pattern. The tag HOLD is added to the waypoint designator. The holding pattern lines are oriented in the direction of the outbound desired track. If the inbound course is specified through the NCDU, the holding pattern is oriented accordingly.



When a holding pattern is initiated at present position, a waypoint star symbol will be positioned on the display at that point with a label HOLD and the two parallel lines defining the holding pattern. The holding pattern lines are oriented in the direction of the specified inbound course on the NCDU, or the TK HLD value selected on the NCDU, or the current nominal track angle of the flight plan, in this order of priority.

The NCDU routine will set the following functions to identify a holding pattern:

HLDSEL	Flag with positive for right, negative for left
HLDWPT	Pointer to waypoint address
HLDBRG	Inbound bearing

The holding pattern parameters L_H, D_H are tabulated in table 2-10 as a function of altitude. V_H is the holding true airspeed equivalent to the holding IAS specified in reference 2.

The NCU will generate two vector word groups to define the two lines of the holding pattern symbology using the parameters tabulated above and scaled according to map scale, oriented according to the desired track. These vector word groups will use vector code 1100000 and I_V = 01.

When holding at a flight plan waypoint, the tag HOLD will be added to the symbol word group for that waypoint (see sec. 2.4.1.7.1) in the form of type 4 words containing line feed (LF) and carriage return (CR) codes, and H, O, L, D character codes. For example, for

ABC
HOLD

the type 4 words required are:

Word 1	A	B	C
Word 2	CR	LF	H
Word 3	O	L	D

When holding at present position, the NCU will generate a symbol word group to define the star symbol and the HOLD tag positioned at the present position when the holding pattern was initiated through the NCDU. The symbol code will be 0011100, with OFS = 00, R = 0, SS = 11, I_S = 10, L = 0, I_T = 10, and ST = 0.

The DS will generate the symbology as defined in table 2-6 and will maintain the symbol and tag upright as the map rotates in accordance with the preceding MFD bus 1 I&R control word.

2.4.1.7.7 Latitude-Longitude Grid-Five-degree latitude and longitude lines with associated labels shall be displayed for overwater navigation as shown in figure 2-9. These latitude-longitude lines shall cover the region between the Pacific Coastal ADIZ and 135°W. Labels shall appear near the center of each 5° segment of latitude or longitude line, as shown in figure 2-9. These labels shall not be restricted from overwriting other symbology but shall be restricted to an upright orientation as the map rotates.

The NCU will generate vector word groups to define the grid using vector code 1100000 and intensity I_V = 01. The NCU will generate text word groups to define and position the latitude and longitude designators. These text words will have I_T = 10 and ST = 0.

The DS will generate the symbology as defined in table 2-6 and will maintain the designator upright as the map rotates.

2.4.1.7.8 Mountains—The mountain symbol defined in table 2-6 will be used to represent prominent terrain features defined in the bulk data storage. The altitude associated with the terrain feature will be as shown in table 2-6. These mountains will be selectable ON or OFF by the MFD mode control unit. When selected OFF, the NCU will delete these data from the MFD bus 1 transmission.

The NCU will generate a symbol word group representing the mountain symbol code 0011000, its position, and a numeric tag designating altitude in thousands of feet. OFS will be set to 10, R to 0, SS to 11, I_S to 10, L to 0, I_T to 10, and ST to 0.

The DS will generate the symbology as defined in table 2-6 and will generate the 000 symbol positioned after the NCU-transmitted altitude tag as shown for the mountain symbol code 0011000. The symbol and tag will be kept upright as the map rotates in accordance with the preceding I&R control word in the MFD bus 1 data transmission.

2.4.1.7.9 Obstructions—Obstructions, hazards, etc., in the takeoff and approach paths to the category 1 airfields will be stored in the bulk data memory. These points will be displayed on the 8, 4, 2, and 1 nmi/in. scales and will be selectable ON and OFF by the MFD mode control unit TERRAIN symbology select button (see table 2-5). The symbol is defined in table 2-6.

The NCU will generate a symbol word group defining the symbol code 0011011, its position, and a numeric designator showing the obstruction altitude in feet. Symbol I_S and designator I_T intensities will be set to 10, OFS to 11, R to 0, SS to 11, L to 0, and ST to 0. When selected OFF, the NCU will delete these data from the MFD bus 1 transmission.

The DS will generate the symbology as defined in table 2-6 and, in accordance with the preceding MFD bus 1 I&R control word, will maintain the symbol and designator upright as the map rotates.

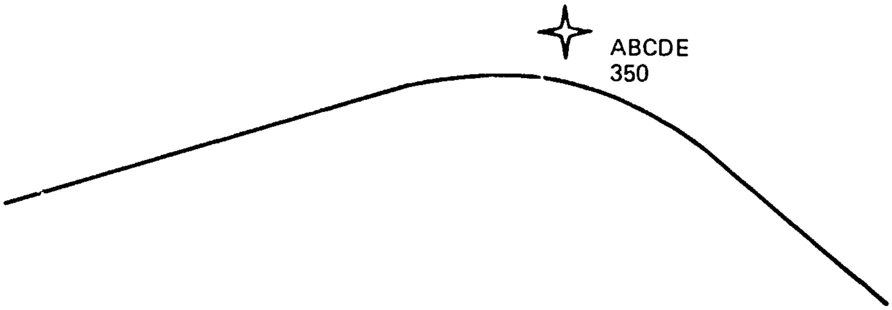
2.4.1.7.10 ADIZ and FIR Boundaries—The ADIZ and FIR boundaries, as specified in the bulk data memory, shall be displayed. A double line (table 2-6) shall be used to indicate an ADIZ boundary. The vector code is 1101000, as shown in table 2-7. A single line composed of short dashes (table 2-6) shall be used to indicate a FIR boundary. The vector code is 1100010, as shown in table 2-7.

The NCU will compute the screen coordinates of the ADIZ and FIR line end points from the geographic coordinates stored in the bulk data memory. These coordinates, together with the vector code specified in table 2-7, will be transmitted to the PCU over MFD bus 1 as a vector word group (fig. 2-3). An alpha label FIR, ADIZ, or CADIZ will be transmitted to the PCU as a text word group. The position of this text will be prestored in the bulk data memory as a geographic position and will be processed in the NCU identically to any other geographic reference point.

The NCU will set the line intensity I_V to 01 in the vector word group and I_T to 10, OFS to 11, and ST to 0 in the text word group.

The DS will generate the vector symbology as defined in table 2-6 and in accordance with the preceding I&R control word in the MFD bus 1 data transmission. The ADIZ and FIR labels shall not be restricted from overwriting other symbology, but the PCU will maintain them in an upright orientation as the map rotates.

2.4.1.7.11 Speed Change Point- When a four-dimensional flight plan has been entered into the system through the NCDU as defined in section 6.0, a planned groundspeed (PGS) is assigned to each waypoint. This PGS can be displayed on the MFD at each waypoint by adding the nominal groundspeed under the waypoint designator. For example:



The digital readout of nominal groundspeed is selected ON and OFF by the MFD mode control unit T-NAV symbol select button.

Whenever a four-dimensional flight plan has been entered into the NCDU and the symbology has been selected ON by the MFD mode control T-NAV button, the NCU will generate the symbol word type 4 formats to add the speed readout to the waypoint symbol group defined in section 2.4.1.7.1.1. For example:

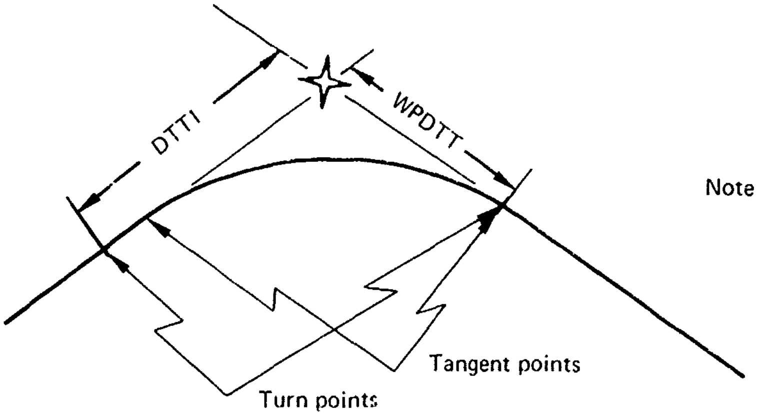
A B C D E
3 5 0

requires the following sequence of symbol type 4 words:

Word 1	A	B	C
Word 2	D	E	CR
Word 3	LF	3	5
Word 4	0	b	b

where b = blank.

2.4.1.7.12 Turn Points and Missed Approach Points–The tick mark symbol will be positioned on the flight plan route line at the turn points as shown in the figure below. The symbol is defined in table 2-6 and has the code 0001000 (table 2-7). The positions of the turn points are related to the tangent points of the circular arc transition between great circle legs. The distance from the waypoint to the tangent point (DTT) is computed by the guidance software and stored in the guidance buffer (see table 5-1).



Note: NOMBA is magnitude of the bank angle limit

The NCU will compute the position of the symbol on the flight plan line preceding a circular transition according to the algorithm:

$$DTTI = WPDTT + NOMBA \cdot \frac{VGS}{4}$$

where:

NOMBA = magnitude of the bank angle limit

VGS = velocity groundspeed

The turn point at the end of the circular transition will be positioned at the tangent point. The NCU will generate the symbol word group defining the symbol, position in E and N coordinates, symbol angle with respect to true north, and with R = 1, SS = 11, I_S = 10, and L = 0.

The DS will generate the symbol as defined in table 2-6 and will maintain the correct orientation as the map rotates in accordance with the preceding I&R control word.

This symbol is also used for missed approach points and is located by the guidance software from data stored in the flight plan buffer.

2.4.1.7.13 Waypoint Altitude—The nominal altitude for each waypoint on the flight plan can be entered through the NCDU as defined in section 6.0. The altitude or flight level is available for display on the MFD map display when selected ON through the MFD mode control unit WPT ALT option button.

When selected ON, the NCU will extract the altitude defined for each waypoint in the flight plan buffer (table 5-1) and add type 4 words to the symbol word group defined in section 2.4.1.7.1.1. For example:

A	B	C	D	E
1	5	0	0	0

The type 4 words required contain:

Word 1	A	B	C
Word 2	D	E	CR
Word 3	LF	1	5
Word 4	0	0	0

Note that if T-NAV has been selected on the MFD mode control unit (sec. 2.4.1.7.11), the designation for each waypoint will be:

A B C D E
3 5 0
1 5 0 0 0

The final type 4 word in each symbol group will always have WF = 1.

The DS will generate the symbology as defined in table 2-6 and in accordance with the preceding I&R control word in the MFD bus 1 data transmission. The designator will remain upright as the map rotates.

2.4.1.7.14 Radial Symbol—The radial symbol is a line of dots as defined in table 2-6. The symbol is referenced to a navaid or GRP through the NCDU SEL 1 mode specified in section 6.5.5.1. The NCDU will label the reference point as RADWPT and the bearing of the radial line in degrees magnetic as RADBRG.

The NCU will generate a symbol word group once per second and transmit the data over MFD bus 1. The data will be generated whenever the RADIAL mode has been selected on the NCDU SEL 1 mode and RADWPT and RADBRG have been entered. The symbol word group will include a word type 1 with the symbol code 0001011, and R = 1, SS = 11, I_S = 10, L = 0. The symbol has no offset or tag associated with it. Word type 2 will have the screen coordinates of the RADWPT, and word type 3 will be RADBRG + MAGVAR (MAGVAR positive = east magnetic variation).

In addition, if RADWPT is a navaid and the NAVAIDS option select on the MFD mode control unit is OFF, the NCU will transmit a symbol word group over MFD bus 1 to define the RADWPT symbol and designator. A similar procedure ensues if RADWPT is a GRP airfield or waypoint.

In all cases, additional type 4 words will be added to the RADWPT symbol word group to allow the seven-bit codes for RADBRG to be displayed underneath the waypoint designator, i.e., S,E,A,CR,LF,0,3,5,°,M., to provide the display format:

S E A
0 3 5 ° M .

The DS will generate the symbology using its normal MFD bus 1 table mode.

2.4.1.7.15 Look-Up Data—In the track-up map mode, the data selected through the NCDU look-up mode will be displayed on the map even if the appropriate symbology option button on the MFD mode control unit is selected OFF. The display data are defined by the look-up data buffer defined in table 6-5, which contains two labels: LOKWPT and LOKBUF. LOKWPT comprises two cells; cell 1 contains a pointer to an address in bulk data memory. Zero in this cell indicates that WPT look-up data have not been selected. Cell 2 contains a code to define the symbol. LOKBUF is 30 cells long and will contain pointers to bulk data addresses for look up of RTE, AWY, etc. Zero in cell 1 indicates that no RTE, AWY data have been selected.

The NCU will generate a symbol word group for each pointer defined in LOKWPT and LOKBUF. Each group will contain the symbol code and the alphanumeric designator. The symbol code for LOKWPT will correspond to the code defined in cell 2 of LOKWPT as follows:

0	Waypoint	0011100
1	Navaid	(see table 3-8)
2	GRP	0001001
3	Airport	0001110
4	Runway	(see below)

For a navaid, the type of symbol is defined by bits 1 to 4 of the second word in the navaid buffer (table 3-8). The symbol code for LOKBUF pointers will always be the waypoint star code 0011100, except for runway. Each waypoint symbol word group will have OFS = 00, R = 0, SS = 11, L = 0, and ST = 0.

The NCU will also generate a vector word group to link every waypoint defined in LOKBUF. The vector code will be 1100010, and I_V = 01.

When an airport and runway have been selected through the NCDU look-up mode, LOKWPT will point to the address of the airport in bulk data storage, and the first location in LOKBUF will point to the bulk data address of the runway data. This pointer will be set only if the look-up airport is a category 1 airport for which runway data are available in bulk storage. The data format for category 1 airports is shown in table 3-6. When LOKWPT is an airport and a runway pointer is set in LOKBUF, the runway, an extended centerline, and outer marker symbology will be computed by the NCU as defined in section 2.4.1.7.3.

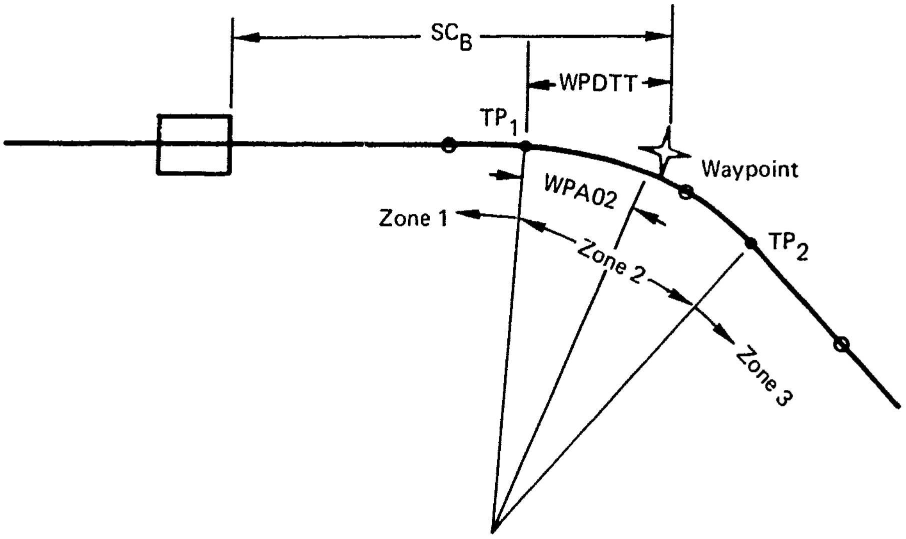
The DS will generate the symbol and vector symbology in its normal table mode.

2.4.1.8 Time Navigation

The desired location of the airplane along the route shall be indicated by a rectangular box and three small circles.

Scheduled aircraft position as determined by the guidance algorithm shall be indicated by the leading edge of the box. The box shall be oriented such that the long axis of the rectangle is always parallel to the route line.

The three small circles shall be located on the route line so as to indicate planned aircraft position 30, 60, and 90 sec ahead of the nominal. The small circles shall be intensity coded such that the 90-sec prediction circle is brighter (11) than the other two circles (10).



Zone Logic

To position the time box and each of the 30-, 60-, and 90-sec prediction dots on the display, it must be determined in which of the three zones, shown above, each of the points lies.

Zone 1	Calculate position along the inboard straight route line with respect to the inboard tangent point (TP_1) at waypoint B.
Zone 2	Calculate position along the curved transition path with respect to the outboard tangent point (TP_2) at waypoint B.
Zone 3	Calculate position along the outboard straight route line with respect to the outboard tangent point (TP_2) at waypoint B, using dummy variables P_i and Q_i.

SC_B - WPDTT	=	P_1	time box
SC_B - WPDTT - SDCC x 30	=	P_2	30-sec dot
SC_B - WPDTT - SDCC x 60	=	P_3	60-sec dot
SC_B - WPDTT - SDCC x 90	=	P_4	90-sec dot

If $P_i \geqslant 0$, point is in zone 1.

When $P_1 \geqslant 0$, box is on straight line. If $P_i < 0$, P_i is potentially in zone 2 ($i = 2, 3, 4$).

Calculate: $P_i + WPA02 \times 2 = Q_i$

If $Q_i \geqslant 0$, Q_i is in zone 2;

$Q_i < 0$, Q_i is in zone 3.

When $P_1 < 0$, box position on the curve (DMG) is computed by the guidance algorithm, where DMG is the angular distance made good traversing the curved-path segment.

Calculate:

$$2 \times WPA02 - DMG = R_1$$

$$2 \times WPA02 - DMG - SDCC \times 30 = R_2$$

$$2 \times WPA02 - DMG - SDCC \times 60 = R_3$$

$$2 \times WPA02 - DMG - SDCC \times 90 = R_4$$

If $R_i > 0$, point is in zone 2;

$R_i \leqslant 0$, point is in zone 3.

When DMG - WPA02 = 0, the guidance algorithm recomputes SC with respect to the next waypoint (C). Zone 3 then becomes zone 1 for waypoint C.

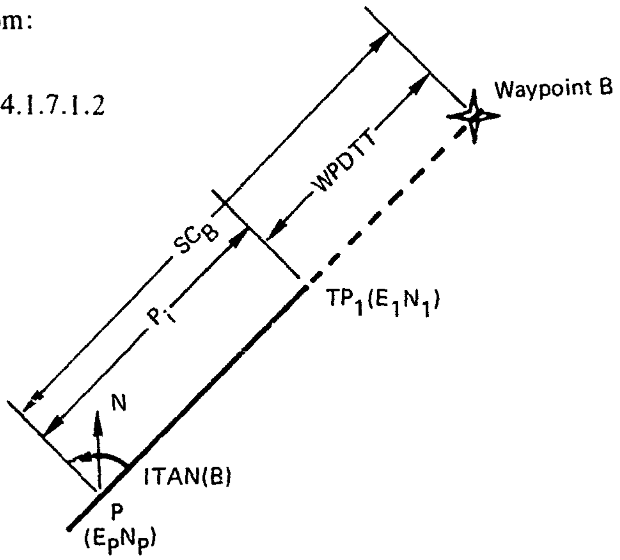
Symbol Position

Zone 1

Position of each point is computed from:

E_1N_1 of TP_1 } from section 2.4.1.7.1.2
ITAN (B)
P_i

Box symbol angle = ITAN (B)
$E_P = E_1 - P_i \cos ITAN (B)$
$N_P = N_1 - P_i \sin ITAN (B)$



Zone 2

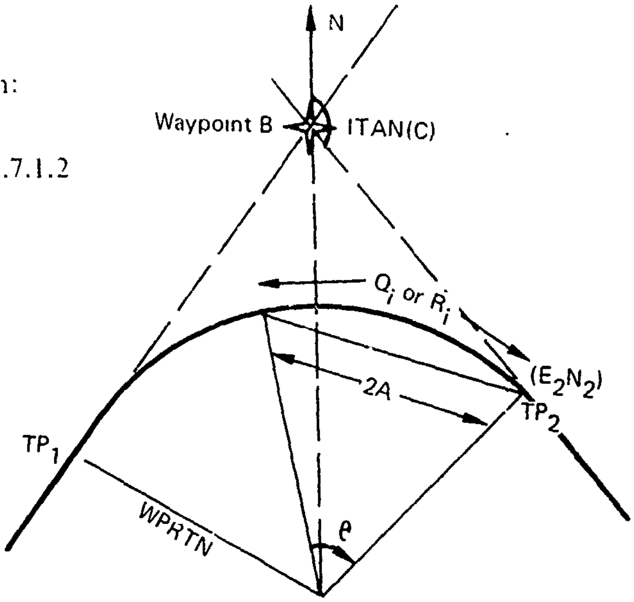
Position of each point is computed from:

E_2N_2 of TP_2 } from section 2.4.1.7.1.2
ITAN (C)
WPRTN

ATD02
DMG
Q_i or R_i

$$\theta = \frac{Q_i}{\text{WPRTN}} \text{ or } \frac{R_i}{\text{WPRTN}}$$

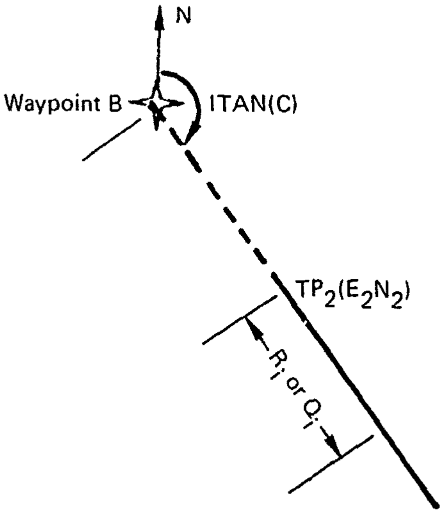
$$2A = 2 \times \text{WPRTN} \sin\frac{\theta}{2}$$



Zone 3

Position of each point is computed from:

E_2N_2 of TP_2 } from section 2.4.1.7.1.2
ITAN (C)
R_i



From the quantities defined above, the position of each point in true north and east coordinates, and the box symbol angle with respect to true north, will be calculated.

The NCU will compute these data whenever a 4D flight plan has been entered through the NCDU. The data will not be transmitted when the T-NAV symbol option button on the MFD mode control unit is selected OFF.

The DS will draw the symbology on the screen as defined in table 2-6 in accordance with the control word instructions. The position coordinates will not be incremented but will be rotated by the angle defined in the MFD bus 2 transmission word labeled 01000001. The symbols will be rotated through the sum of the angles defined in the symbol word type 3 and the word labeled 01000010 in the MFD bus 2 data transmission.

The NCU will compute four symbol word groups to define the symbology. The first group includes symbol code 0001101, position in E and N coordinates, and symbol angle with respect to true north to define the box symbol. R will be set to 1, SS to 11, I_S to 10, and L to 0. The other three symbol groups include the symbol code 0001111, position in E and N coordinates to define the 30-, 60-, and 90-sec prediction circles with intensity I_S as defined above, and R = 0, SS = 00, and L = 0. These calculations must be performed 20 times/sec, and the data will be transmitted at that rate over MFD bus 2. These data will be preceded in the MFD bus 2 transmission order by I&R control words defining no incrementation but coordinate rotation of the following data points. (See table 2-2.) The control word has TC = 1, OC = 1, RC = 1, RS = 1, IC = 00, and WF = 1 for the box symbol, and TC = 1, OC = 1, RC = 1, RS = 0, IC = 00 and WF = 1 for the circle symbols.

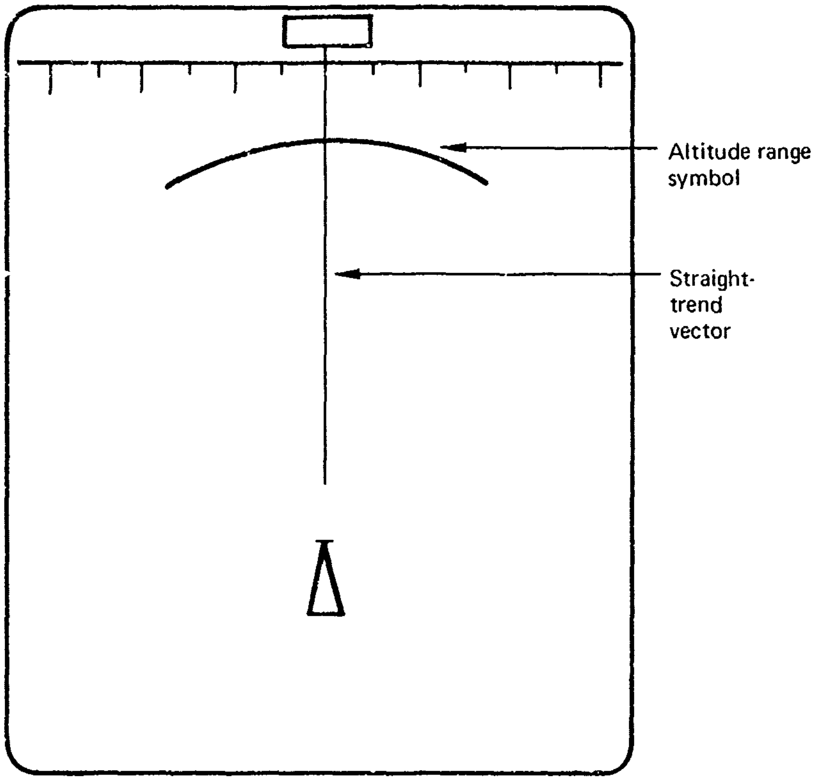
When the position of each bubble reaches the end of the path, the data for that bubble will be deleted from the data transmission.

2.4.1.9 Altitude/Range

When a 3D or 4D flight plan has been entered through the NCDU and accepted (EXEC), a vertical profile is defined in the guidance data buffer (fig. 5-1). Vertical navigation (VNAV) symbology on the EADI and readouts from the NCDU display pages define the vertical path, as well as progress and deviation from it. The MFD altitude/range symbology is intended to provide predictive information, relative to the aircraft vertical profile, via the MFD display for operational situations where only a 2D path is stored or when no path is stored. The altitude/range symbology is operative when: (1) ALT/REF has been entered via the NCDU SEL 3 page, (2) the MFD map is in track-up mode, and (3) the ALT/RANGE key is engaged on the MFD mode control unit.

The altitude/range symbology shown on the following page will consist of a vector arc segment transverse to the straight-trend vector at a distance (RALTY) from the airplane symbol that represents the spot where the airplane will reach the reference altitude (ALTREF) if the current flightpath angle (FPA) is maintained.

The symbol is stroke written by the DS and is an arc segment of a circle with an 8-in. radius extending on each side of the straight-trend vector. The position of the symbol shall be computed 20 times/sec by the NCU and transmitted to the PCU via MFD bus 2 in the form of two conic vector word groups.



The NCU will compute the position of the altitude/range symbology as defined below:

ALTC = instantaneous computed altitude of the aircraft (ft above MSL)

ALTREF = reference altitude entered via NCDU SEL 3 page (ft above MSL)

VGS = instantaneous groundspeed of aircraft (ft/sec)

HDOT = vertical speed of aircraft (ft/sec)

RALT = range to reach ALTREF

DELH = ALTC - ALTREF

where: $$\mathrm{RALT} = -\left(\frac{\mathrm{DELH}}{\mathrm{HDOT}} \cdot \mathrm{VGS} \cdot \frac{1}{6080}\right) \mathrm{nmi}$$

RALT will be converted to screen coordinates (RALTY) at 90 bits/in. according to the current map scale selected and limited so that

$$-220 < \text{RALTY} < 375$$

When RALTY exceeds these limits, the vector code will be changed from solid to dotted.

The NCU will assemble two vector word groups as follows whenever bit 23 is 1 in the MFD 1 mode word (fig. 2-5) and an ALTREF $\neq 0$ has been entered on the NCDU SEL 3 mode (sec. 6.5.5.3). Both groups are identical except for the word type 2 configuration.

Group 1

Word type 1	Vector code 1100000 unlimited or 1100011 limited and $I_V = 10$
Word type 2	Y = RALTY, X = 0, C = 1, D = 0
Word type 3	Arc length = 90 bits; rotation angle = +90°
Word type 4	Radius = 360 bits

Group 2

Same as group 1, except:

Word type 2 Y = RALTY, X = 0, C = 1, D = 1

These vector word groups will be preceded by an I&R control word with IC = 00, RC = 0, and RS = 0, and will be transmitted 20 times/sec over MFD bus 2.

The DS will generate the vector symbology in its normal bus 2 table mode.

2.4.1.10 Mode and Scaling Annunciation

The current map scale selected and the current guidance and/or hold mode activated will be displayed in the lower left-hand corner of the MFD map display. The display format will be, for example

Line 1	04NM/IN
Line 2	GUID2D or LINKUP
Line 3	HOLD/ALT/GS, etc.

The NCU will generate a text symbol word group to define this annunciation and will transmit it once per second over MFD bus 1. The text word group will be preceded by an I&R control word with TC = 1, OC = 1, RC = 0, RS = 0, and IC = 00. The text word type 1 will have I_T = 01, R = 0, and seven-bit code 0000001. Word type 2 will have C = 0 and coordinates X = -230, Y = -200. Word type 4 will have ST = 0 and the alphanumeric codes defined below:

Line 1:	XXNM/INCRLF	where XX is 01, 02, 04, 08, 16, or 32 corresponding to the map scale selected on the MFD NCU
Line 2:	XXXXXXCRLF	where XXXXXX corresponds to the current flag set by the guidance routine to indicate mode. This can be GUID4D, GUID3D, GUID2D, or LINKUP.
Line 3:	Will be used only when a select (SEL) mode or modes have been activated on the NCDU SEL 1 mode or external autopilot mode panel. The MFD will display the following annunciations corresponding to the mode flags set by the NCDU:	

HLDSEL	TKSEL	FPASEL
OFSSEL	ALTSEL	IASSEL

The line 3 character format will be:

SEL/XXX/XXX, etc.

where XXX is HLD, WPT, OFS, ALT, IAS, or FPA.

The DS will generate the symbology using its normal text mode in accordance with the I&R control word instructions so that the coordinates are not rotated or incremented.

2.4.2 North-Up Map Mode

A detailed description of the function, priority, and mechanization of each MFD symbol is presented below for the north-up map mode.

2.4.2.1 General

The north-up map mode shall display a fixed, true north-up oriented map on which the aircraft symbol moves. The displayed area shall be centered around the geographic point selected on the NCDU as specified in section 6.0. The format shall consist of an airplane symbol, a curved-trend vector, a straight-trend vector, a digital and analog indication of present track, a track error indicator, major airfields, navaids, mountains, obstructions, ADIZ and FIR boundaries, GRPs, and a route line. A representative north-up map display format is shown in figure 2-12.

The NCU/DS shall be capable of providing six map scales: 1, 2, 4, 8, 16, and 32 nmi/in. These scales shall be selectable from the MFD control panel.

The NCU will extract the data required for each selected map scale from the bulk data memory, which is defined in section 3.0. From these bulk data and the map center selected through the NCDU, the NCU will edit and categorize the map background data for transmission to the PCU via MFD bus 1. Only the particular categories of data applicable to the map scale selected, and the symbology options selected on the MFD mode control unit or the NCDU, will be transmitted. The relationship between each symbol and the map scale, MFD mode control unit symbol option switches, and NCDU symbology selection is defined below for each symbol. The NCDU relationship to the north-up map center is outlined in section 2.6.

The NCU will generate the background MFD bus 1 data in east and north position coordinates scaled according to the map scale selected. The edit area is governed by the screen dimensions about the offset coordinate reference point, as shown in figure 2-13. The NCU will compute intersection points where all vector lines on the display intersect the edit area boundary. The background data need only be generated once for a particular map center selection, and modified only to conform to map scale change or symbology option change initiated through the MFD mode control unit and NCDU. The NCU will transmit these background data as required over MFD bus 1. The NCU will compute the dynamic data required by this display, which include the airplane position, curved-trend vectors, track, track error, and time box symbology, and will transmit the data defining this symbology to the PCU 20 times/sec over MFD bus 2. The data rates required for computation and transmission of data from the NCU to PCU are summarized in table 2-11.

The NCU will transmit the appropriate control words with the MFD bus 1 and bus 2 data to instruct the PCU that no incrementation or coordinate rotation is required in the north-up map mode. The table data on MFD bus 1 and bus 2 will be preceded by a I&R control word with TC = 1. OC = 1. RC = 0, RS = 0, IC = 00 and WF = 0.

The PCU will transmit the MFD mode control word whenever status changes and will generate the display in accordance with the data and control instructions received from the NCU over the two data buses. The data received fall into three general categories:

1) Symbol, vector, and control word groups on MFD bus 1 (see figs. 2-1, -2, and -3)

2) Symbol, vector, and control word groups on MFD bus 2

3) Special-function data identified by label code on MFD bus 2 (see fig. 2-4)

The DS generates the symbology for category 1 and 2 directly in accordance with the instructions contained in the word formats. The PCU processes category 3 data, which are generally in the form of parameter value data, and develops the appropriate symbology in accordance with the PCU stored program.

2.4.2.2 Airplane Position

The airplane is represented by an elongated triangle symbol, as defined in table 2-6. This symbol moves over the background map, and the orientation of the triangle represents the instantaneous track angle at all times. Movement of the airplane symbol will be limited to within 0.4 in of the edge display. The fact that the airplane symbol has reached the limits will be distinguished by the absence of trend vectors, as defined below.

The NCU will compute the airplane position east and north from the map center reference point 20 times/sec and scale according to the map scale selected. No limiting is required in the NCU-computed values. The airplane position data will be transmitted to the PCU as a position word label 01000110 over MFD bus 2, as defined in table 2-3.

The DS will generate the airplane symbology through its special-function mode with no incrementation or coordinate rotation, but with the symbol rotated through the angle defined in the MFD bus 2 word label 01000010 (TK). The DS will maintain the symbol orientation when the symbol is limited.

2.4.2.3 Curved-Trend Vector

The curved-trend vector will be generated in a manner similar to that defined in section 2.4.1.3. The three-segment trend vector will emanate from the airplane symbol as shown in figure 2-12 When the airplane symbol is limited, the curved-trend vector will disappear and will not reappear until the airplane moves to within the display area limits.

The NCU will generate the curved-trend vector data 20 times/sec as follows:

- Compute the trend vector points in along- and across-track components using the algorithm defined in section 2.4.1.2.

- Transform through-track angle into north and east coordinates.

- Add to airplane symbol north and east coordinates.

These vector positions will be transmitted 20 times/sec as three vector word groups over MFD bus 2, using vector code 1100000 and intensity I_V = 11. When the airplane position coordinates (sec. 2.4.2.2) exceed any of the limits $+228 < E < -228$ or $+228 < N < -288$, the three trend vector words groups will be deleted from the MFD bus 2 data transmission.

Note that the vector end points will be defined up to ±511 north and east coordinates, and the vector line symbology may leave and reenter the display area. When any vector coordinate exceeds ±511 in east or north, succeeding points on the trend vector need not be computed.

The DS will generate the symbology using its normal MFD bus 2 table mode with no incrementation or coordinate rotation in accordance with the control word preceding the MFD bus 2 table data.

2.4.2.4 Straight-Trend Vector

The straight-trend vector shall project straight ahead from a point 0.625 in. ahead of the apex of the airplane symbol to the opposite edge of the screen. This trend vector shall be displayed only when the aircraft's position is not limited.

No data are required from the NCU.

The DS will generate this symbology in its general-function mode. The vector line will have an intensity I_V of 01 and will be referenced to the airplane position coordinates received from the NCU as defined in section 2.4.2.2 and oriented by the track angle defined in section 2.4.2.5.

2.4.2.5 Track (TK) Tape

The track tape symbology shown in figure 2-12 will be generated in the same manner as that defined in section 2.4.1.5. Track (TK) sin and cos for coordinate rotation, transmitted over MFD bus 2 in the track-up map mode, is not required for the north-up map mode. Magnetic track angle binary and magnetic track angle (BCD) are required for track tape generation.

The NCU will transmit valid magnetic track angle BCD data and binary TK over MFD bus 2 at a rate of 20 times/sec, as shown in table 2-3. Transmission of TK sin and cos in word label 01000001 is optional.

The DS will generate the track tape symbology defined in table 2-6 using its MFD general-function mode.

2.4.2.6 Track Angle Error

The track error bug symbol will be generated in a manner identical to that defined in section 2.4.1.6.2. The dotted line TK HLD symbology will not be used for the north-up map mode.

The NCU will compute the function (±TKE x 90/16)° or (±TKESEL x 90/16)°, as defined in section 2.4.1.6.2, and will transmit it in word number label 01000101 to the PCU over MFD bus 2 at a rate of 20 times/sec, as shown in table 2-3. The TKESEL sin and cos word label 01000100 will be set to invalid.

The DS will generate the track error bug symbology defined in table 2-6 in its general-function mode.

2.4.2.7 Map Background Data

Map background data will be generated as defined in section 2.4.1.7, except that data coordinates are referenced to the center reference point defined by the NCDU and need be computed only when the reference point, the map scale, or the symbology options are changed. The location of the map center reference point is labeled LATCEN, LONCEN by the NCDU. The symbol and designator associated with this point are defined by two cells labeled CENWPT. Cell 1 contains the address in bulk data memory, and cell 2 defines the associated symbol (see sec. 6.6). Zero in cell 1 indicates no symbol is required at map center. Cell 2 codes and associated symbols are:

0	Waypoint	0011100
1	Navaid	(see table 3-8)
2	GRP	0001001
3	Airport	0001110

For a navaid, the type of symbol is defined by bits 1 to 4 of the second word in the navaid buffer (table 3-8). The NCU will generate a symbol word group for CENWPT with OFS = 00, R = 0, SS = 11, L = 0, and ST = 0.

The DS will generate the map center symbol in its normal table mode.

The NCU will transmit the data to the PCU via MFD bus 1, as shown in table 2-1. The I&R control word in the second word with TC = 1, OC = 1, RC = 0, RS = 0, IC = 00, and WF = 1 instructs the PCU to generate the display referenced to the offset center defined in figure 2-13, with no incrementation or rotation of position coordinates.

The DS will generate the display as defined in table 2-6 in accordance with the I&R control word preceding the data.

2.4.2.8 Time Navigation

The NCU will compute time-navigation symbology in the manner defined in section 2.4.1.8, transmitting the data over MFD bus 2 as shown in figure 2-3. The preceding I&R control word has TC = 1, OC = 1, RC = 0, RS = 0, IC = 00, and WF = 1 because the time box symbol needs to be rotated through the angle defined in the symbol type 3 word. The PCU will generate the symbology and rotate the symbol through the angle defined in the symbol type 3 word.

2.4.2.9 Altitude/Range

There is no altitude/range symbology in the north-up map mode.

2.4.2.10 Mode and Scaling Annunciation

The map scale selected and the current guidance and/or hold mode activated will be displayed in the same manner as that defined in section 2.4.1.10. The X,Y coordinates in the text type 2 word will be X = -230 Y = -276.

2.5 MFD TEST FEATURES

This mode is initiated by pressing the TEST button on the MFD mode control unit (see fig. 2-8). Selection of this mode overrides all other MFD modes, and the MFD remains in the test mode until another mode is selected on the MFD mode control unit. The display test pattern seen on the MFD when this mode is selected is shown in figure 2-14.

2.5.1 MFD Self-Test

This mode is initiated by pressing the TEST button on the MFD mode control unit (see fig. 2-8). Selection of this mode overrides all of the MFD modes, and the MFD remains in the test mode until another mode is selected on the MFD mode control unit. The display test pattern seen on the MFD when this mode is selected is shown in figure 2-14.

2.5.2 NCU/PCU Interface Test

The NCU test mode is initiated by the test switch on the NCDU. Full details of the NCU self-test requirements are defined in section 7.0. Included in this test is the NCU/PCU interface test, which checks the MFD bus 1 and bus 2 transmissions to the PCU.

Activation of this test will generate the test patterns on the MFD defined in figure 2-15. These patterns are generated by transmitting the data listed in table 2-12 over MFD bus 1 and bus 2. If the test is successful, the following message will appear as shown in figure 2-15: MFD BUS #1 GOOD
MFD BUS #2 GOOD

If MFD bus 2 fails, the message will be (see fig. 2-14): MFD BUS #2 BAD. If MFD bus 1 and MFD 2 buses fail, neither message will appear.

The NCU will continue to transmit the data listed in table 2-12 as long as the NCDU test switch is in the TEST position.

The DS will operate in the normal manner during this test and will display all valid data it receives over MFD bus 1 and MFD bus 2.

2.6 NCDU/MFD INTERRELATIONSHIP

Actions on the NCDU keyboard influence the display on the MFD in several ways, as summarized below. The detailed keyboard procedures are defined in section 6.0.

2.6.1 Flight Plan Selection

Until a flight plan has been entered through the NCDU, there will be no route line or track error bug on the MFD map displays (see secs. 2.4.1.6.2 and 2.4.1.7.8). The waypoints that are selected for the flight plan, together with the navaids to which the VHF radio navigation receivers have been tuned, either by autotune or manually, become the first priority on the map display (see sec. 2.4.1.7.6).

Until planned times of arrival (PTAs) and planned groundspeeds (PGSs) have been assigned to the flight plan waypoints, no time-navigation symbology can be generated on the MFD (see sec. 2 4.1.8).

2.6.2 SEL (Select) Mode

The NCDU SEL mode is used to enter outer loop guidance control functions into the navigation and guidance system. Three selections impact the MFD map formats by activating the following symbology·

Holding pattern (see sec. 2.4.1.7.10)
Track hold (see secs. 2.4.1.6 and 2.4.2.6)
Offset path (see sec. 2.4.1.7.13)

2.6.3 Look-Up Mode

The mode button number 7-6 (line 7, row 6) on the NCDU will be designated LOOK-UP. This NCDU mode will enable display of data selected from bulk storage in the track-up and north-up map modes. The data for display are defined by LOKWPT and LOKBUF in the look-up data buffer (table 6-6).

In addition, the north-up map mode center can be selected by the look-up mode, and will be defined by the NCDU as LATCEN, LONCEN, and CENWPT (see sec. 2.4.2.7). Pressing the NCDU keys 2, R, N, O, ENT will, for example, center the MFD north-up map at RNO. The two cells labeled CENWPT contain the pointer to the bulk data address for RNO, as well as a code to define the symbol.

If no reference point has been entered through the look-up mode, the north-up map display will be referenced to the waypoint on line 4 of the FLT PLN display format. When this display is slewed UP or DOWN, the north-up map follows by changing its reference to the waypoint on line 4 after the slewing has stopped for 2 sec.

The data defined in LOKWPT and LOKBUF will become the first priority data for the MFD map displays and will be displayed even if the associated symbology option is selected OFF on the MFD mode control unit.

2.7 SCU INTERFACE

The symbol delete option switches on the SCU will have the capability of controlling only the general-function symbology on the MFD. This is symbology transmitted over MFD bus 2 with a label code. Three of the valid/erase switches will be mechanized for both the track-up and north-up map modes:

Switch 1 OFF	Track tape symbology deleted
Switch 2 OFF	Track digits deleted
Switch 3 OFF	Track select bug

TABLE 2-1.–MFD BUS 1 TRANSMISSION ORDER

		Track-Up Map	North-Up Map
	0	SOT control word	SOT control word
	1	I&R control word (TC = 1, OC = 1, RC = 1, IC = 11, WF = 1, RS = 0) Upright symbol word groups (R = 0) Text word groups Vector word groups I&R control word (TC = 1, OC = 1,RC = 1, IC = 11, WF = 1, RS = 1) Rotated symbol word groups (R = 1)	I&R control word (TC = 1, OC = 1, RC = 0, IC = 00, WF = 1, RS = 0) Symbol word groups Text word groups Vector word groups
(a)		EOD control word (TC = 1)	
(a)		I&R control word	
(a)		MFD 2 data	
		EOD control word (TC = 0)	
		Unused data words	
(a)	507	Mode MFD 2	
(a)	508	ΔMFD 2	
	509	Mode MFD 1	
	510	Δ MFD 1	
	511	EOT control word	

Note: There may be other I&R control words within an MFD 1 or MFD 2 data block.

[a] These data blocks and words are applicable only when two MFD displays are in use.

TABLE 2-2.–MFD BUS 2 LABEL CODES AND TRANSMISSION ORDER–TRACK-UP MAP[a]

Label	Function
MSB LSB	
8 7 6 5 4 3 2 1	
0 1 0 0 0 0 0 0	MFD 1 delta position E and N
0 1 0 0 0 0 0 1	MFD 1 coordinate rotation angle (TK sin and cos)
0 1 0 0 0 0 1 0	Track angle (TK)–binary
0 1 0 0 0 0 1 1	Track angle–BCD
0 1 0 0 0 1 0 0	Selected track error (TKESEL sin and cos)
0 1 0 0 0 1 0 1	Selected track error (TKESEL scaled binary)
0 1 0 0 0 1 1 0	Airplane position N and E (DM = 11)
0 1 0 0 0 1 1 1	MFD mode word
0 1 0 0 1 0 0 0	I&R control word with IC= 00, RC = 0, RS = 0[b]
0 1 0 0 1 0 0 1	Vector word type 1 Curved-trend vector
0 1 0 0 1 0 1 0	2
0 1 0 0 1 0 1 1	2
0 1 0 0 1 1 0 0	2 30-sec line
0 1 0 0 1 1 0 1	2
0 1 0 0 1 1 1 0	2
0 1 0 0 1 1 1 1	Vector word type 1
0 1 0 1 0 0 0 0	2
0 1 0 1 0 0 0 1	2
0 1 0 1 0 0 1 0	2 60-sec line
0 1 0 1 0 0 1 1	2
0 1 0 1 0 1 0 0	2
0 1 0 1 0 1 0 1	Vector word type 1
0 1 0 1 0 1 1 0	2
0 1 0 1 0 1 1 1	2
0 1 0 1 1 0 0 0	2 90-sec line
0 1 0 1 1 0 0 1	2
0 1 0 1 1 0 1 0	2
0 1 0 1 1 0 1 1	I&R control word with IC = 00, RC = 1, RS = 1, OC = 1
0 1 0 1 1 1 0 0	Symbol word type 1
0 1 0 1 1 1 0 1	(R = 1) 2 Time box
0 1 0 1 1 1 1 0	3
0 1 0 1 1 1 1 1	I&R control word with IC = 00, RC = 1, RS = 0, OC = 1
0 1 1 0 0 0 0 0	Symbol word type 1 30-sec dot
0 1 1 0 0 0 0 1	(R = 0) 2
0 1 1 0 0 0 1 0	1 60-sec dot
0 1 1 0 0 0 1 1	2
0 1 1 0 0 1 0 0	1 90-sec dot
0 1 1 0 0 1 0 1	2
0 1 1 0 0 1 1 0	EOD control word with TC = 0
0 1 1 0 0 1 1 1	Unassigned
0 1 1 1 1 1 1 1	

[a] Single MFD display configuration

[b] The data content following the I&R control word varies in content depending on the map scale and symbol options selected.

TABLE 2-3.—MFD BUS 2 LABEL CODES AND TRANSMISSION ORDER—NORTH-UP MAP

Label								Function	
MSB							LSB		
8	7	6	5	4	3	2	1		
0	1	0	0	0	0	0	0	Invalid	
0	1	0	0	0	0	0	1	TK sin and cos	
0	1	0	0	0	0	1	0	Track angle (TK)—binary	
0	1	0	0	0	0	1	1	Track angle—BCD	
0	1	0	0	0	1	0	0	Selected track error (TKESEL sin and cos)	
0	1	0	0	0	1	0	1	Selected track error (TKESEL scaled binary)	
0	1	0	0	0	1	1	0	Airplane position N and E	
0	1	0	0	0	1	1	1	MFD mode word	
0	1	0	0	1	0	0	0	I&R control word with IC = 00, RC = 0, RS = 0	
0	1	0	0	1	0	0	1	Vector word type 1	Curved-trend vector—first segment
0	1	0	0	1	0	1	0	2	
0	1	0	0	1	0	1	1	2	
0	1	0	0	1	1	0	0	2	
0	1	0	0	1	1	0	1	2	
0	1	0	0	1	1	1	0	2	
0	1	0	0	1	1	1	1	Vector word type 1	Curved-trend vector—second segment
0	1	0	1	0	0	0	0	2	
0	1	0	1	0	0	0	1	2	
0	1	0	1	0	0	1	0	2	
0	1	0	1	0	0	1	1	2	
0	1	0	1	0	1	0	0	2	
0	1	0	1	0	1	0	1	Vector word type 1	Curved-trend vector—third segment
0	1	0	1	0	1	1	0	2	
0	1	0	1	0	1	1	1	2	
0	1	0	1	1	0	0	0	2	
0	1	0	1	1	0	0	1	2	
0	1	0	1	1	0	1	0	2	
0	1	0	1	1	0	1	1	Symbol word type 1	Time box
0	1	0	1	1	1	0	0	2	
0	1	0	1	1	1	0	1	3	
0	1	0	1	1	1	1	0	Symbol word type 1	30-sec dot
0	1	0	1	1	1	1	1	2	
0	1	1	0	0	0	0	0	Symbol word type 1	60-sec dot
0	1	1	0	0	0	0	1	2	
0	1	1	0	0	0	1	0	Symbol word type 1	90-sec dot
0	1	1	0	0	0	1	1	2	
0	1	1	0	0	1	0	0	EOD control word with TC = 0	
0	1	1	0	0	1	0	1	Unassigned	
0	1	1	1	1	1	1	1		

Note: Data content is dependent on the symbology options selected.

TABLE 2-4.—PCU/NCU BUS LABEL CODES AND TRANSMISSION ORDER

Label								Function	
MSB							LSB		
8	7	6	5	4	3	2	1		
0	0	0	0	0	0	0	0	EADI mode word[a]	
1	0	0	0	0	0	0	0	MFD bus 1 mode word[a]	
0	1	0	0	0	0	0	0	MFD bus 2 mode word[a]	
1	1	0	0	0	0	0	0	Unassigned[b]	
0	0	1	0	0	0	0	0		
1	0	1	0	0	0	0	0		
1	1	1	1	1	1	1	0	Decision height	EADI mode control unit[c]
1	1	1	1	1	1	1	1	Pitch reference readout	

[a] Mode words are transmitted when there is a change of status.

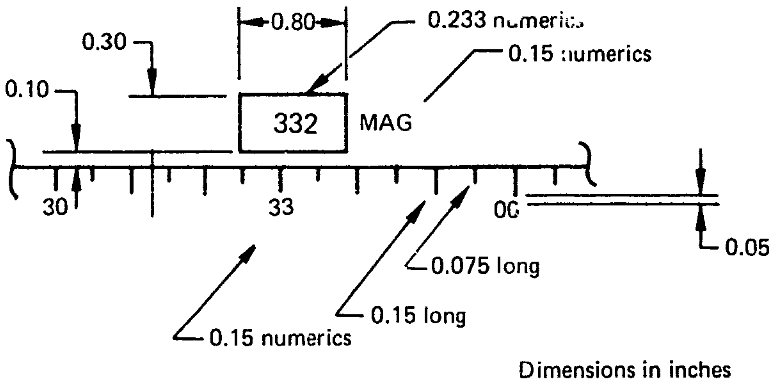
[b] Unassigned label words are not transmitted.

[c] These two words transmitted 5 times/sec

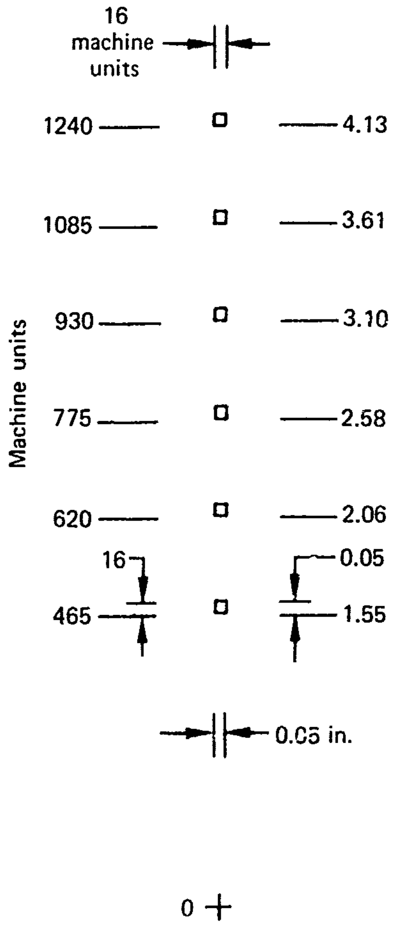
TABLE 2-5.—MFD MODE CONTROLLER OPERATION

Mode	
Rotary switch	Function
TRACK-UP MAP	Selects fixed aircraft/moving map track-up oriented format
NORTH-UP MAP	Selects fixed north-up oriented/moving aircraft map format
SPARE	
TEST	Causes a predefined test pattern to appear on the MFD (fig. 2-14)
Note:	At power ON, the mode corresponding to the current switch position will be generated.
Symbology options	
Button	Function
NAVAIDS	Switches non-flight-plan navaids ON/OFF
TERRAIN	Switches terrain data, mountains, obstructions ON/OFF
AIRPORTS	Switches airfields ON/OFF
T-NAV	Switches time-nav symbology ON/OFF (T-NAV symbology displayed if and only if a 4D flight plan has been entered through the NCDU); this switch also controls the acceleration command symbol on the EADI
GRP	Switches non-flight-plan geographic reference points ON/OFF
ALT/RANGE	Switches altitude/range symbology ON/OFF
WPT/ALT	Switches altitude readout at each flight plan waypoint ON/OFF
TREND VECTOR	Switches curved-trend vector ON/OFF
Notes:	These buttons operate only when TRACK-UP MAP or NORTH-UP MAP mode is selected. Symbology option—buttons light up green when pressed to signify ON. Second press changes color to white to signify OFF.
Rotary switch	Function
MAP SCALES	Selects 1, 2, 4, 8, 16, or 32 nmi/in. map scale for TRACK-UP MAP and NORTH-UP MAP modes.

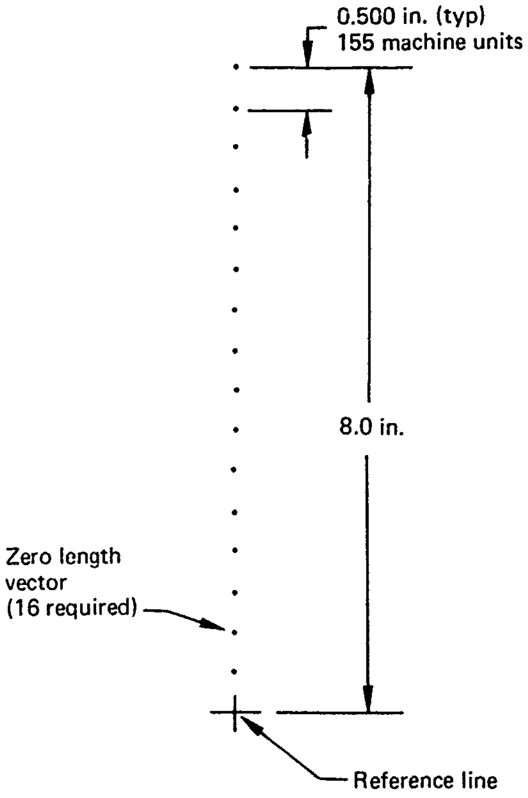
TABLE 2-6.—MFD SYMBOLOGY



MFD Track Tape and Digits

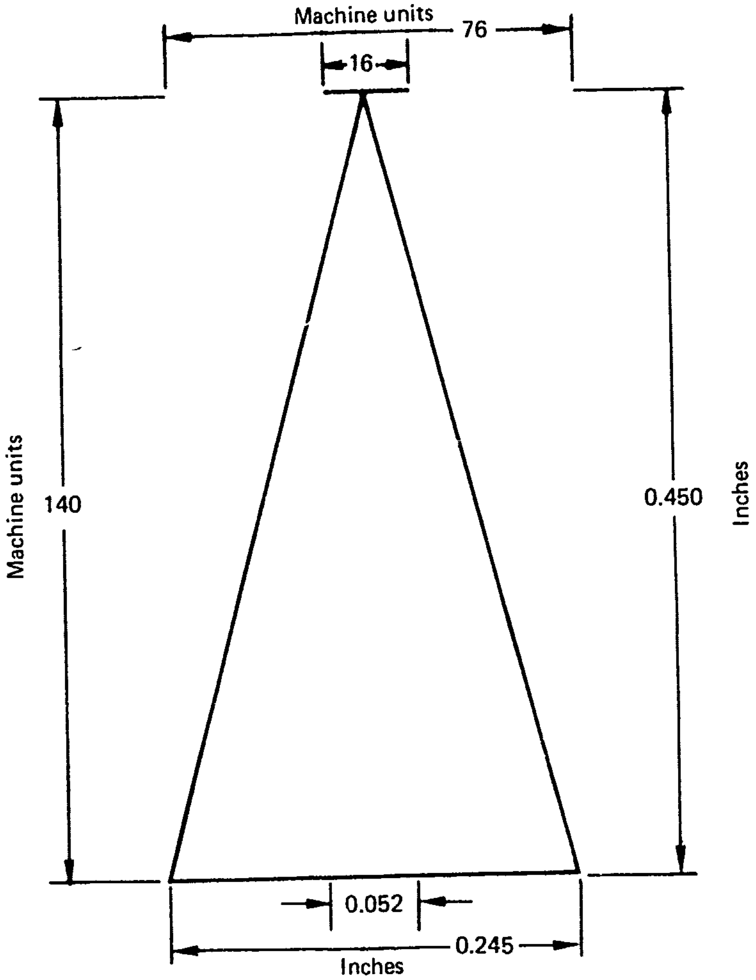


Track Select Symbol

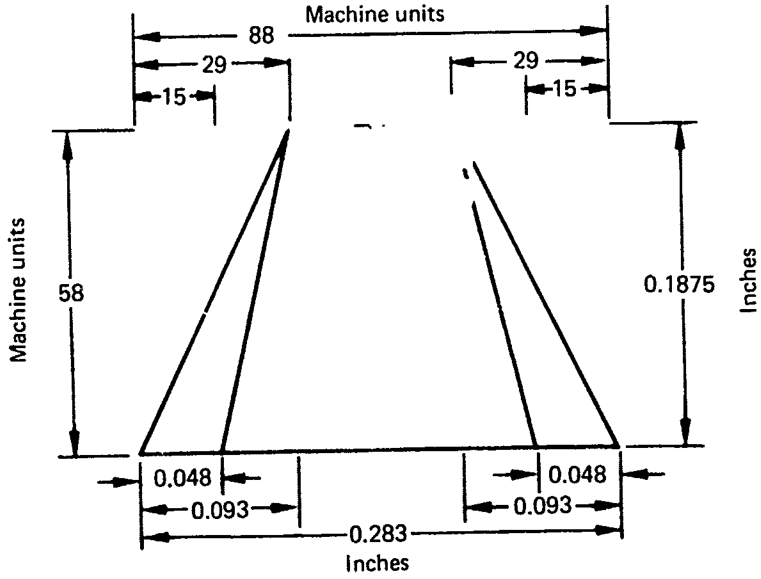


Radial Symbol

TABLE 2-6.–CONTINUED

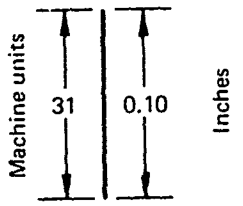


Aircraft Symbol

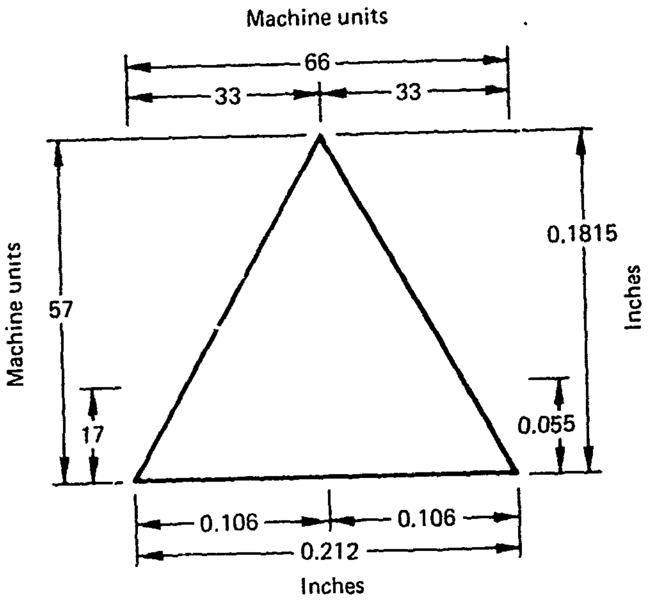


Desired Track Indicator (Track Bug)

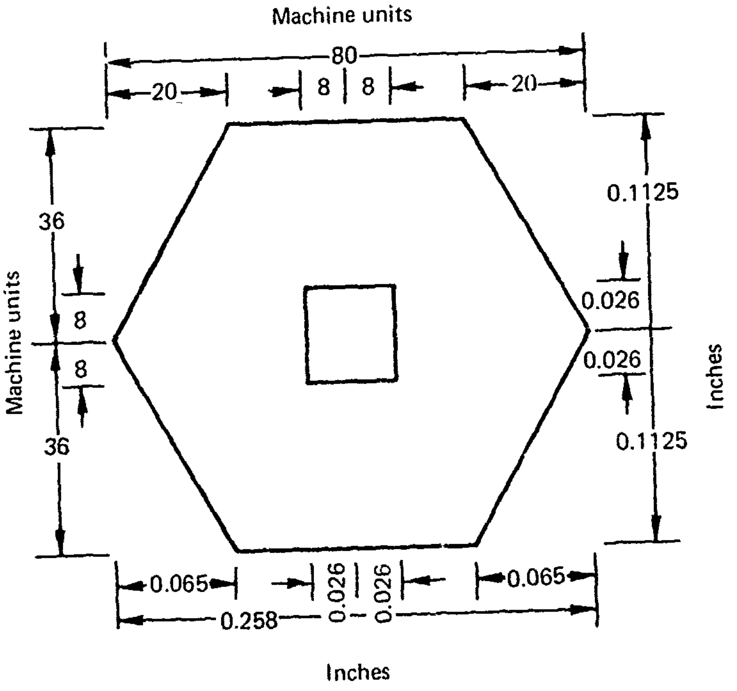
TABLE 2-6.–CONTINUED



Tick Mark Symbol

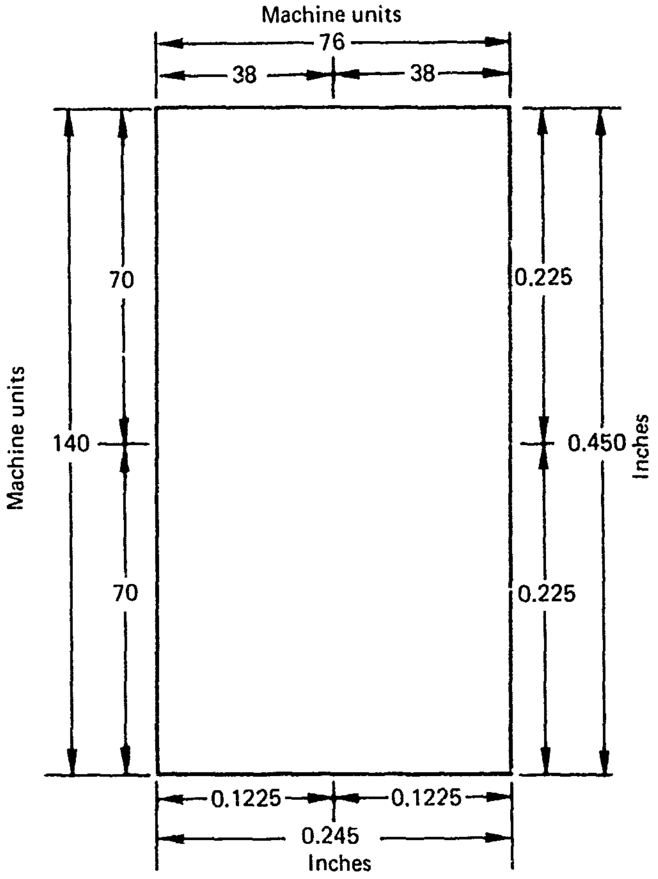


GRP Symbol

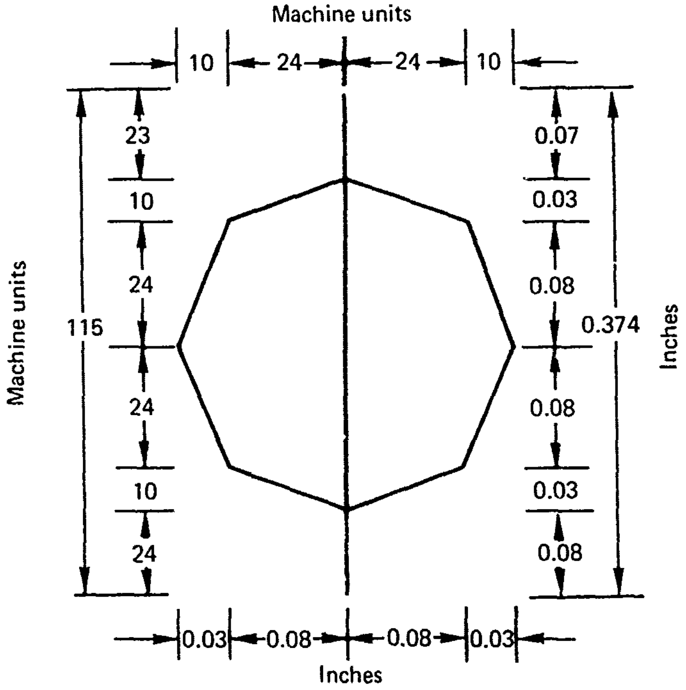


VOR Symbol (Reporting Point)

TABLE 2-6.—CONTINUED

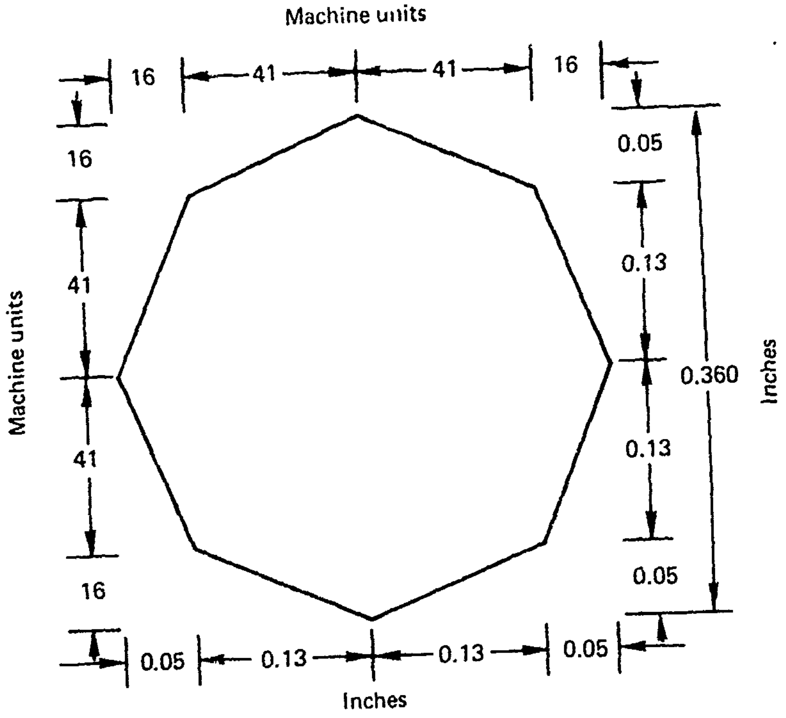


Time Box Symbol

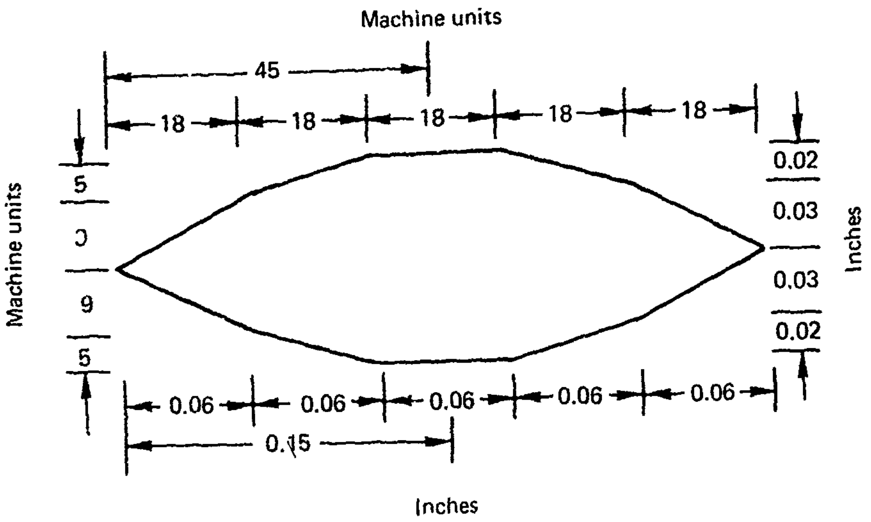


Airfield Symbol

TABLE 2-6.—CONTINUED

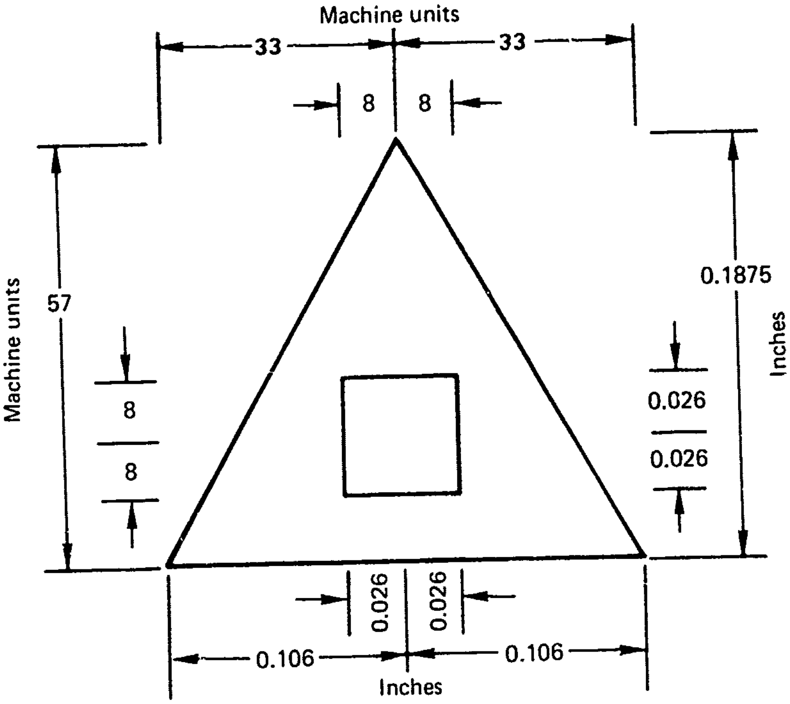


Standard Circle Symbol

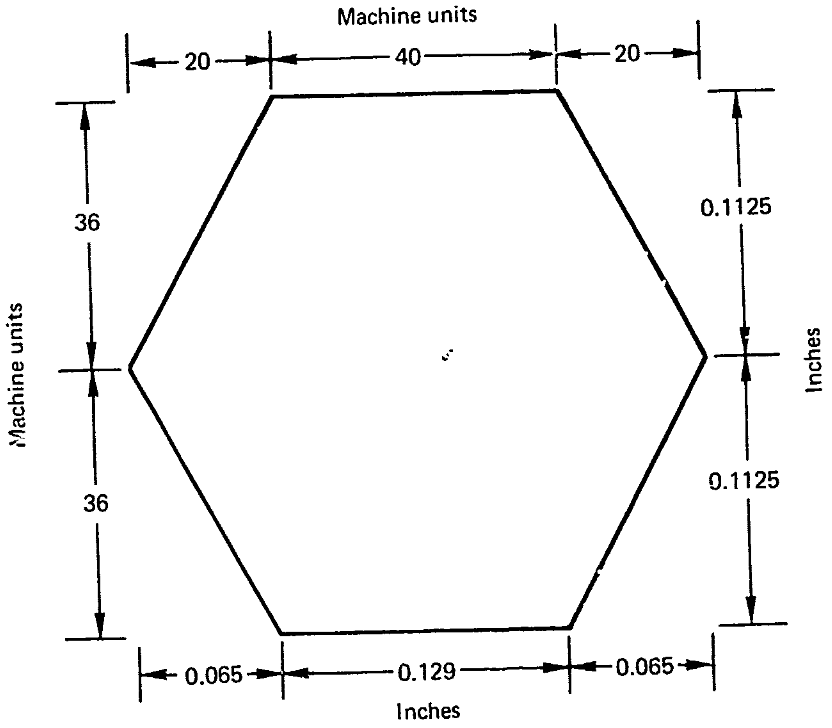


Fan Marker Symbol

TABLE 2-6.–CONTINUED

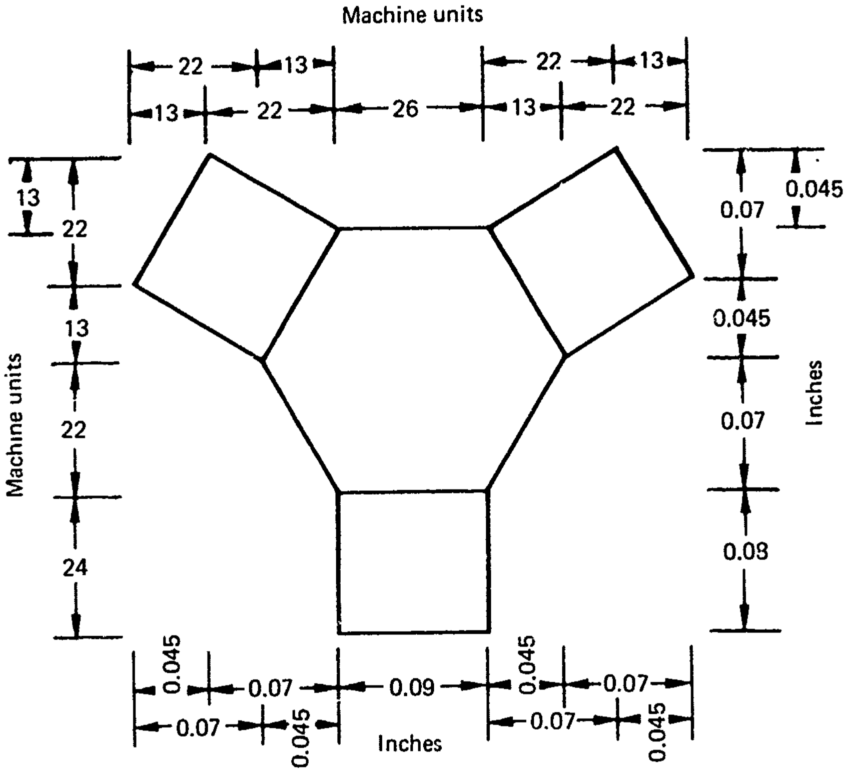


GRP Symbol (Reporting Point)

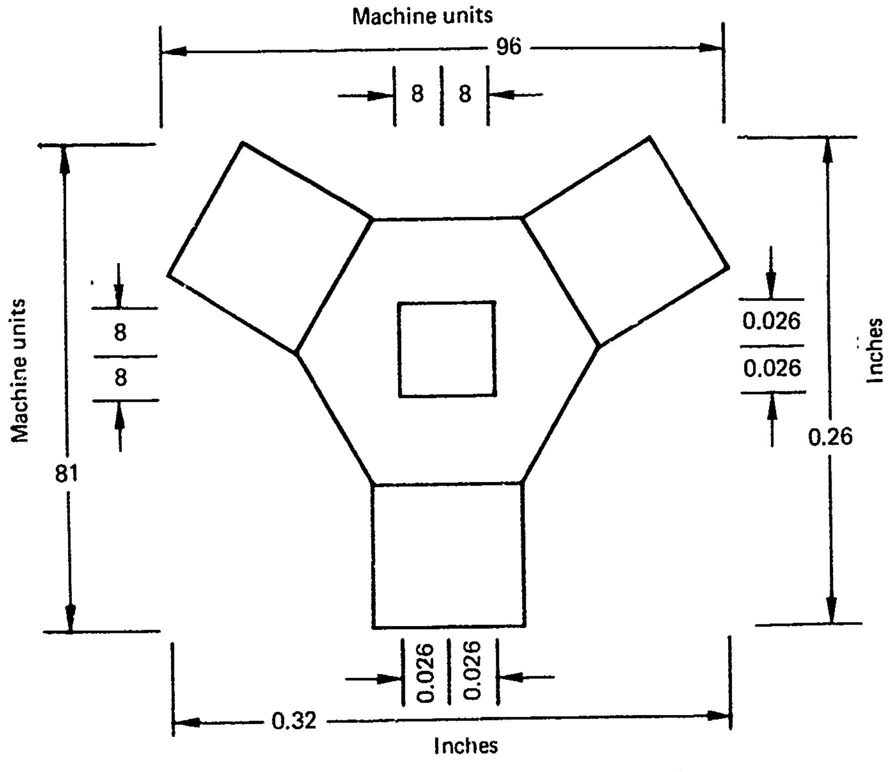


VOR Symbol

TABLE 2-6.—CONTINUED

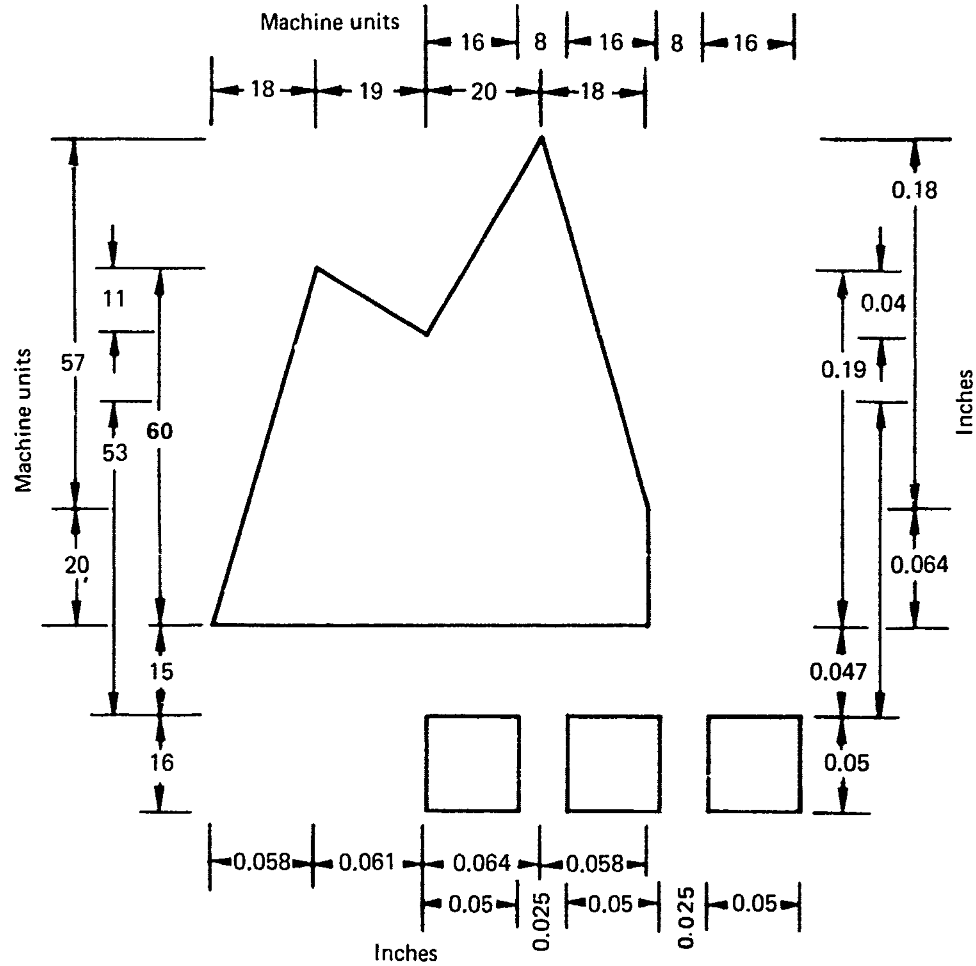


VORTAC Symbol

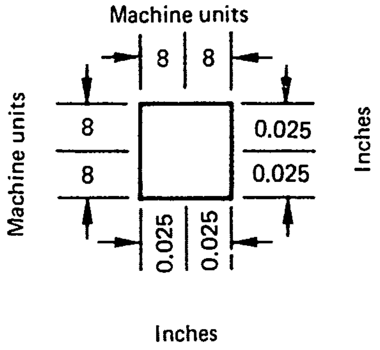


VORTAC Symbol (Reporting Point)

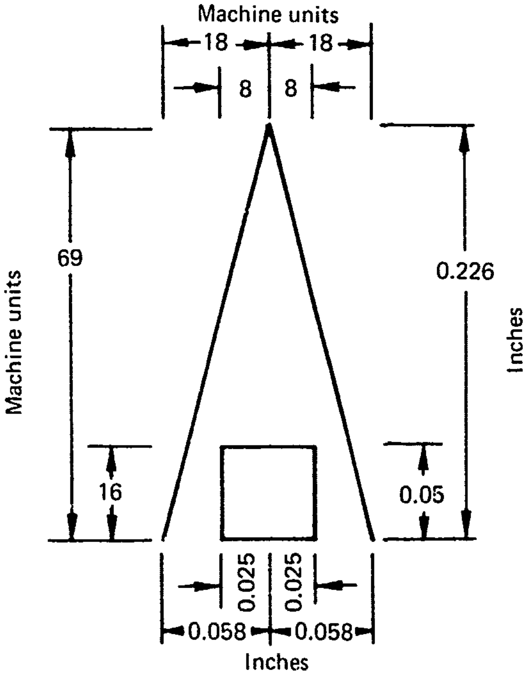
TABLE 2-6.—CONTINUED



Mountain Symbol

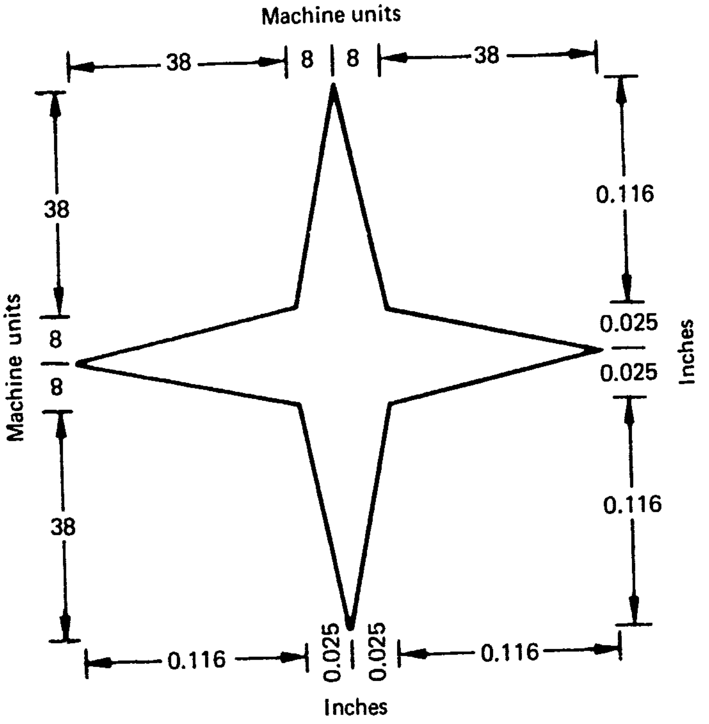


Standard Dot Symbol

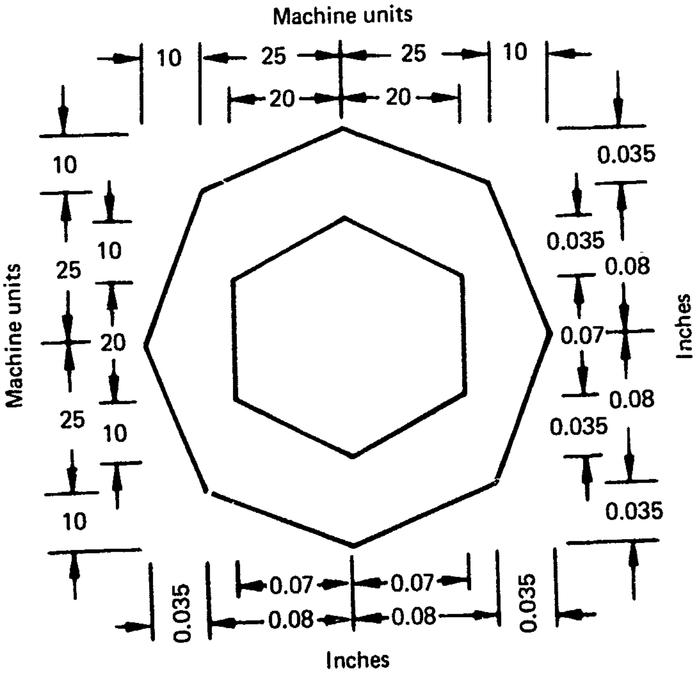


Obstruction Symbol

TABLE 2-6.–CONTINUED

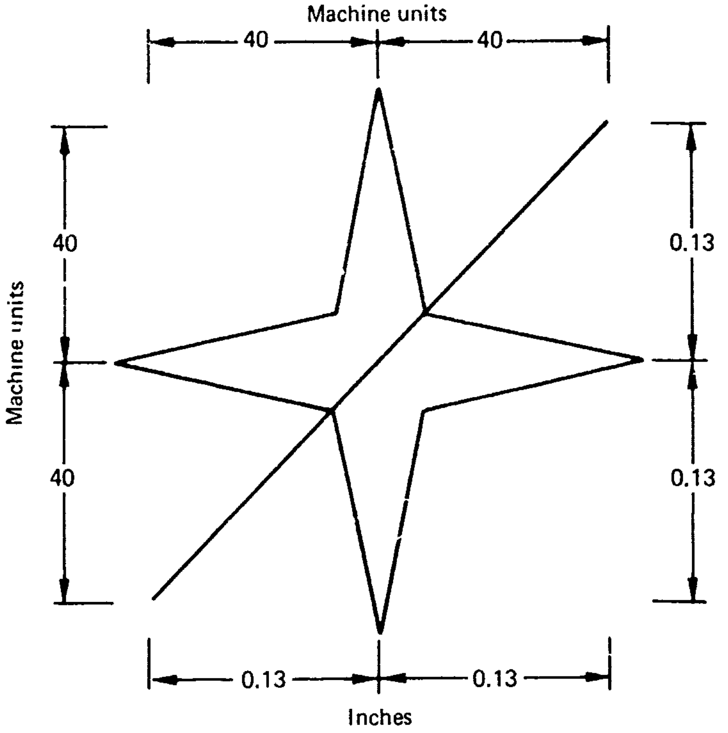


Waypoint Symbol

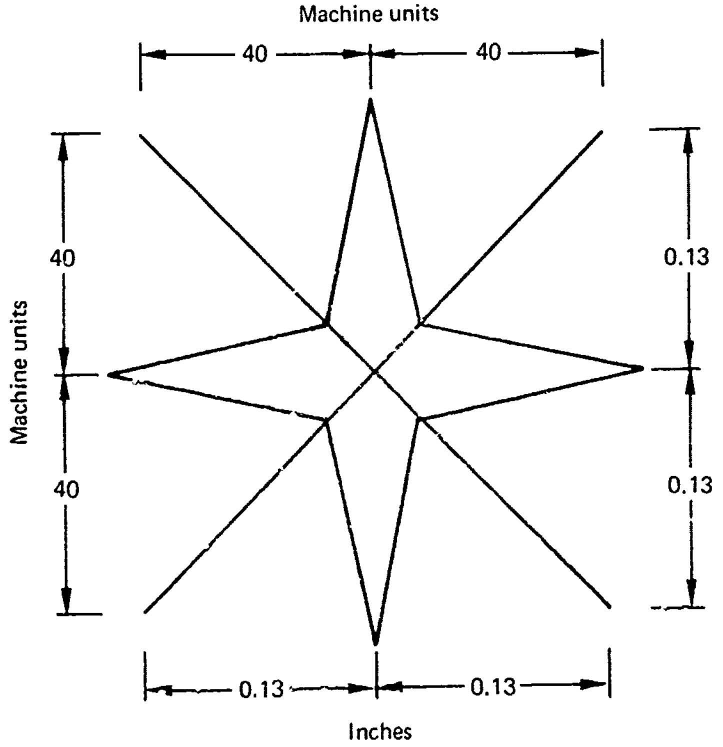


Nondirectional Beacon Symbol

TABLE 2-6.–CONTINUED

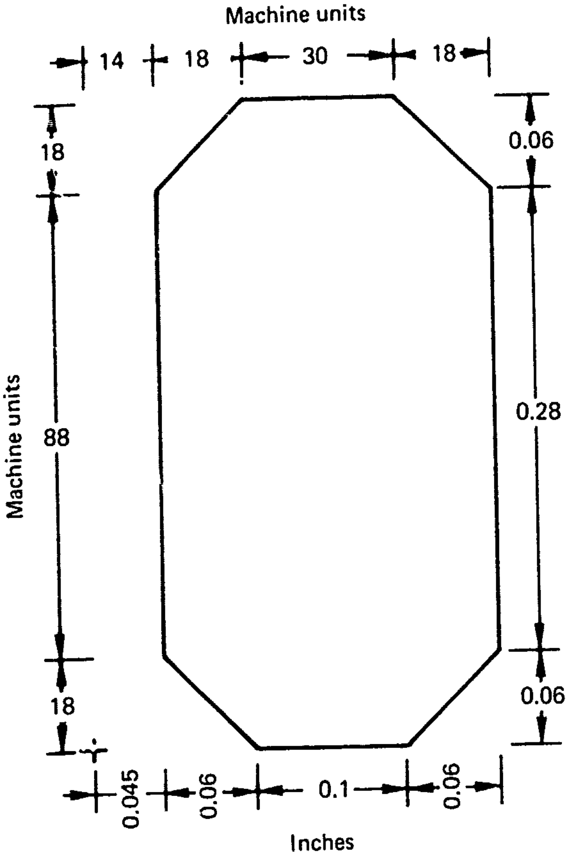


Waypoint and First Cue Symbol

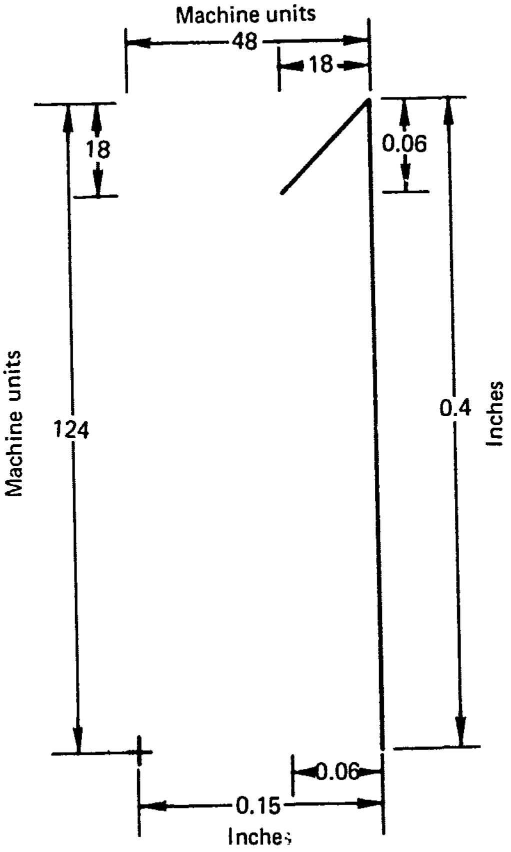


Waypoint and Second Cue Symbol

TABLE 2-6.–CONTINUED

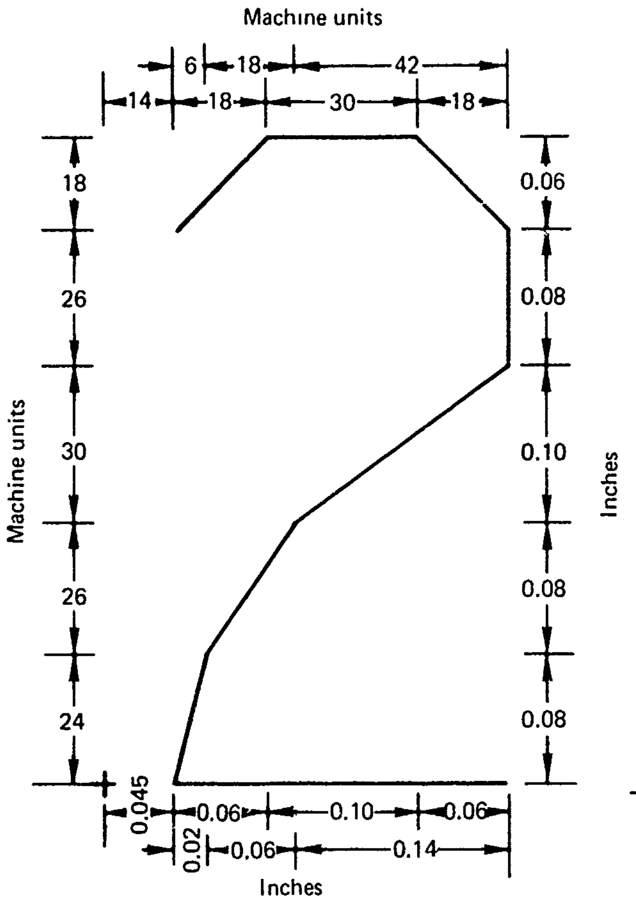


Alphanumeric 0

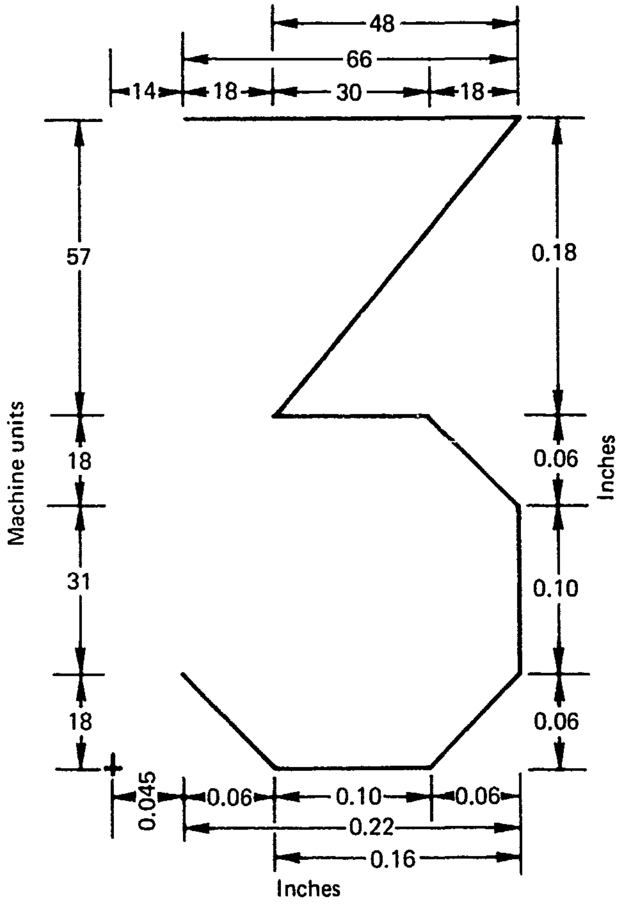


Alphanumeric 1

TABLE 2-6.—CONTINUED

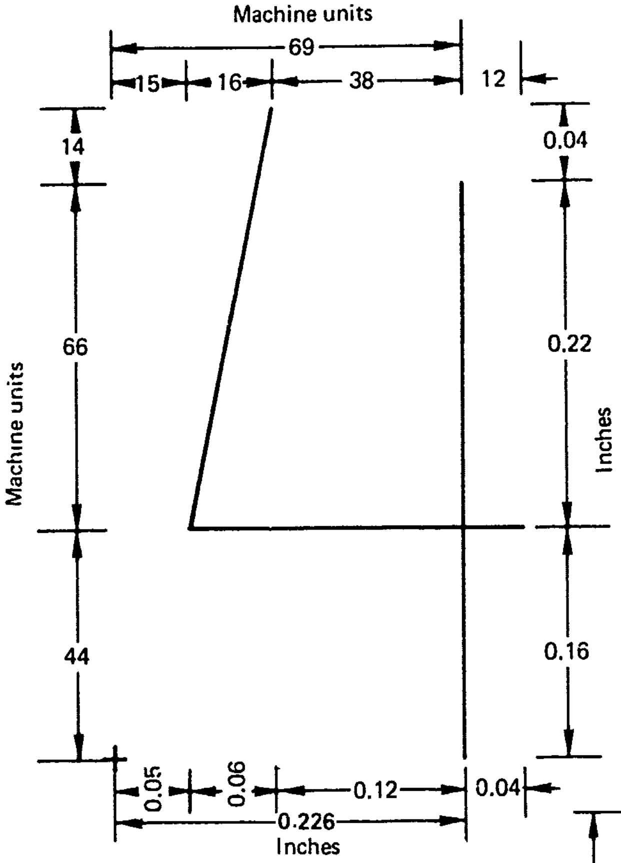


Alphanumeric 2

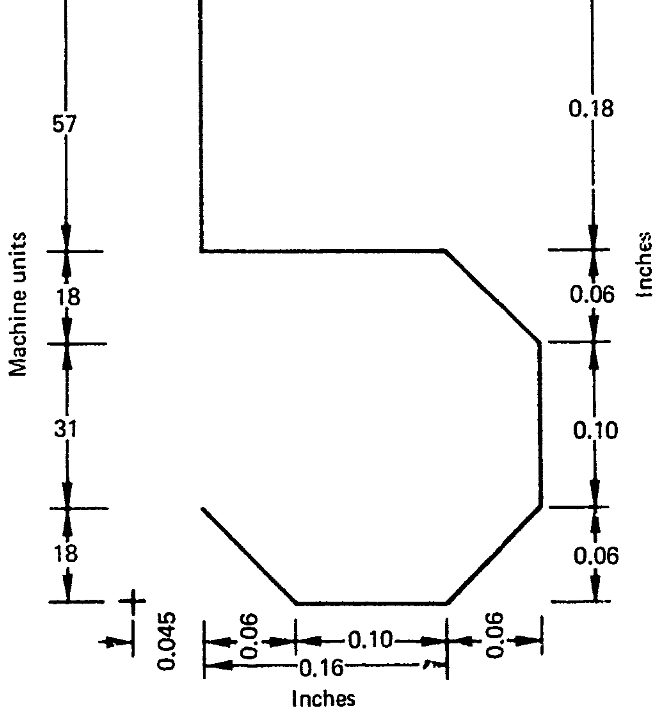


Alphanumeric 3

TABLE 2-6.—CONTINUED

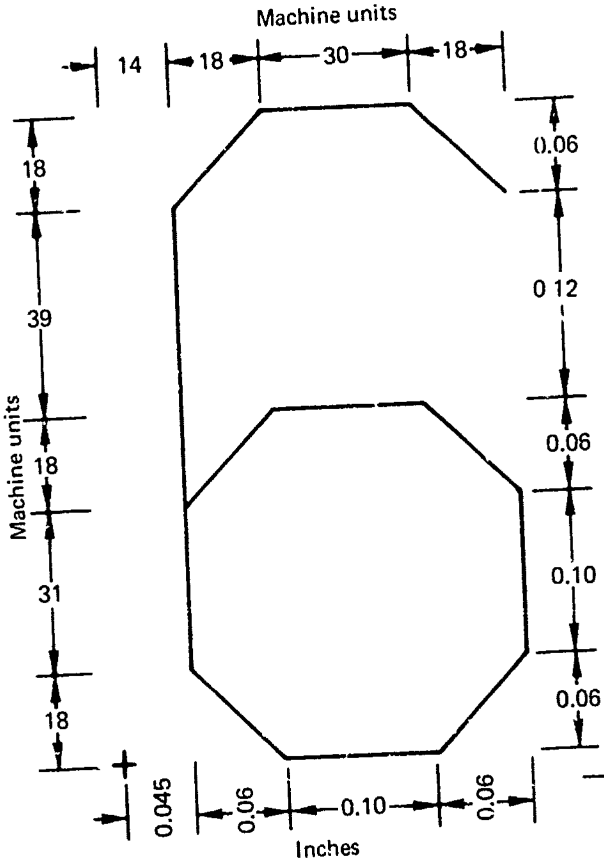


Alphanumeric 4

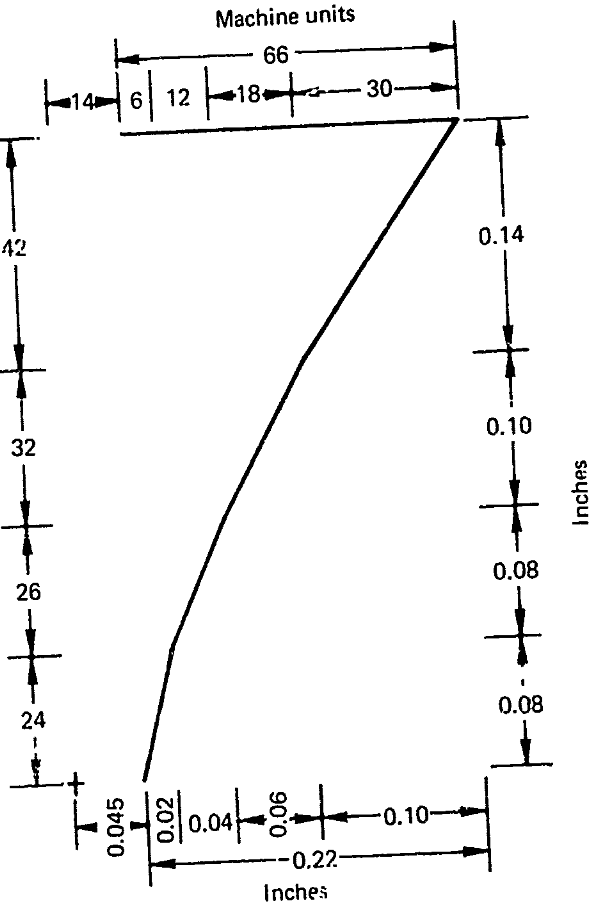


Alphanumeric 5

TABLE 2-6.—CONTINUED

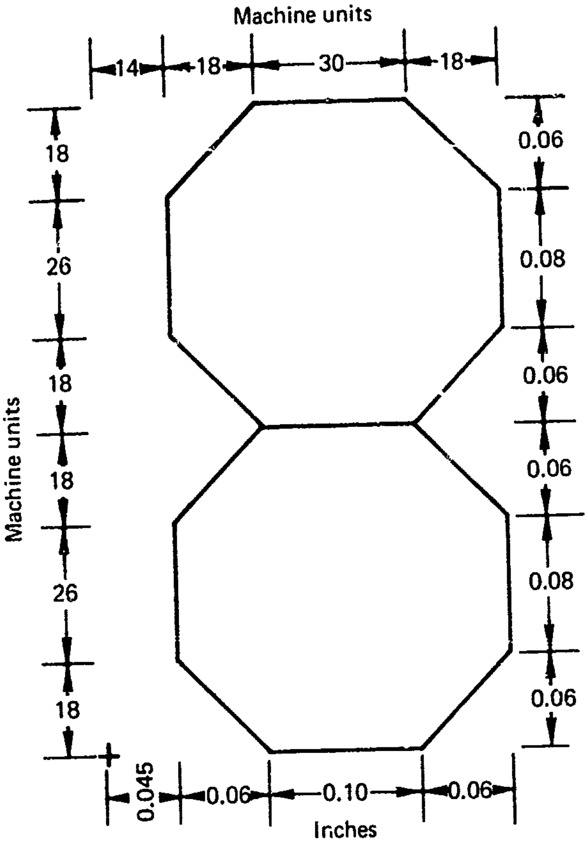


Alphanumeric 6

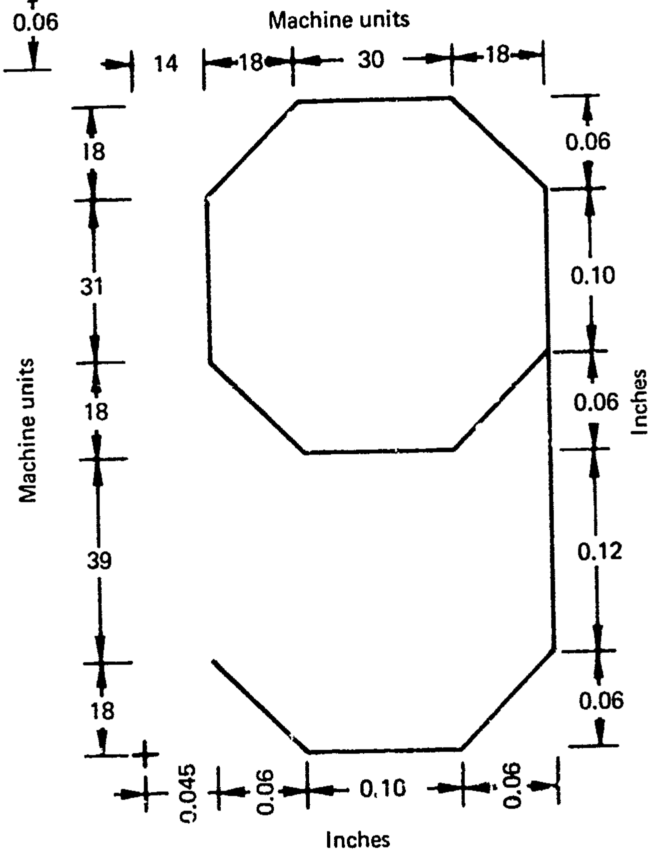


Alphanumeric 7

TABLE 2-6.—CONTINUED

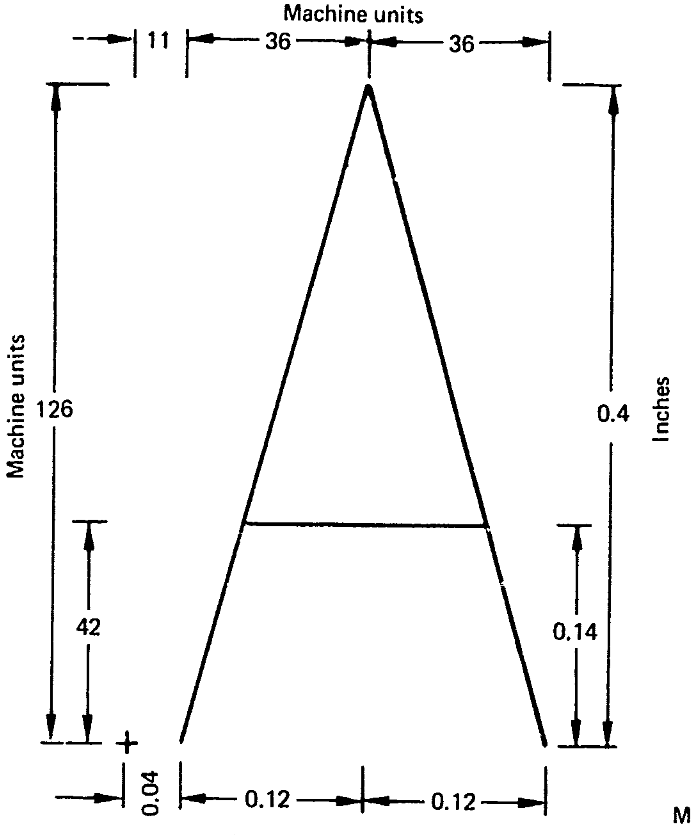


Alphanumeric 8

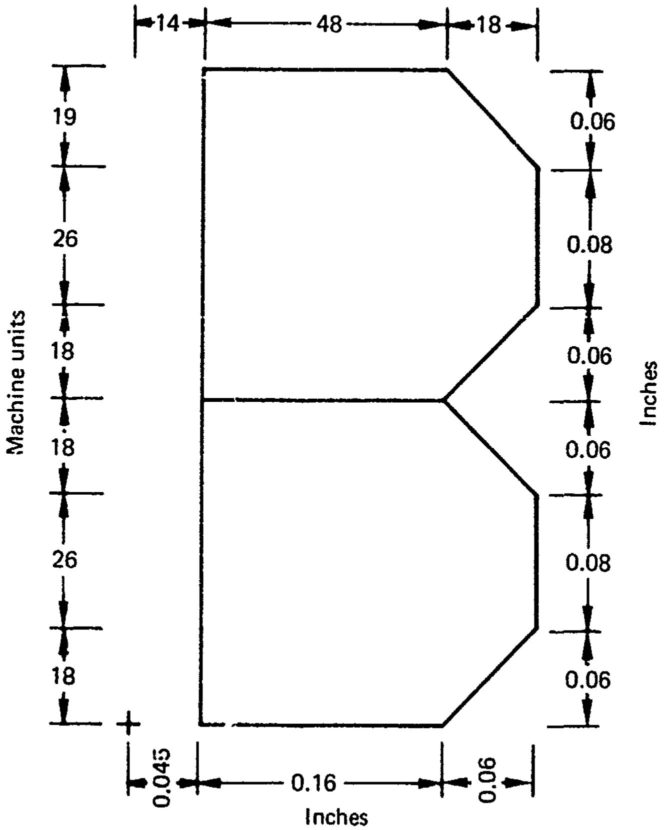


Alphanumeric 9

TABLE 2-6.—CONTINUED

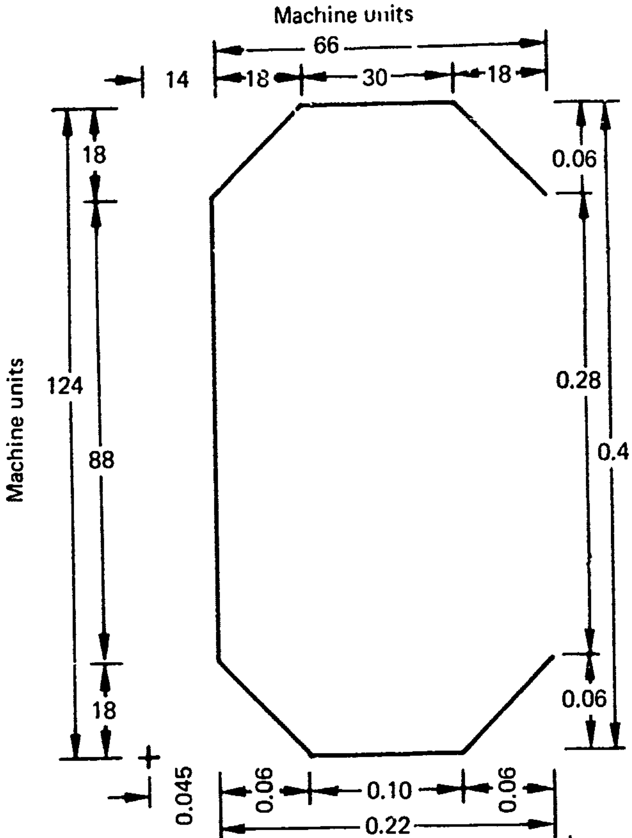


Alphanumeric A

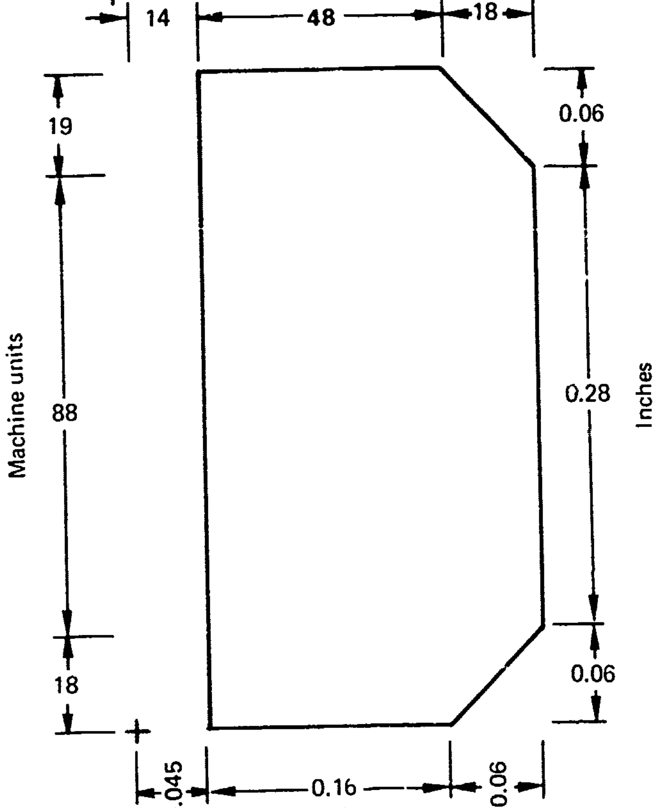


Alphanumeric B

TABLE 2-6.—CONTINUED

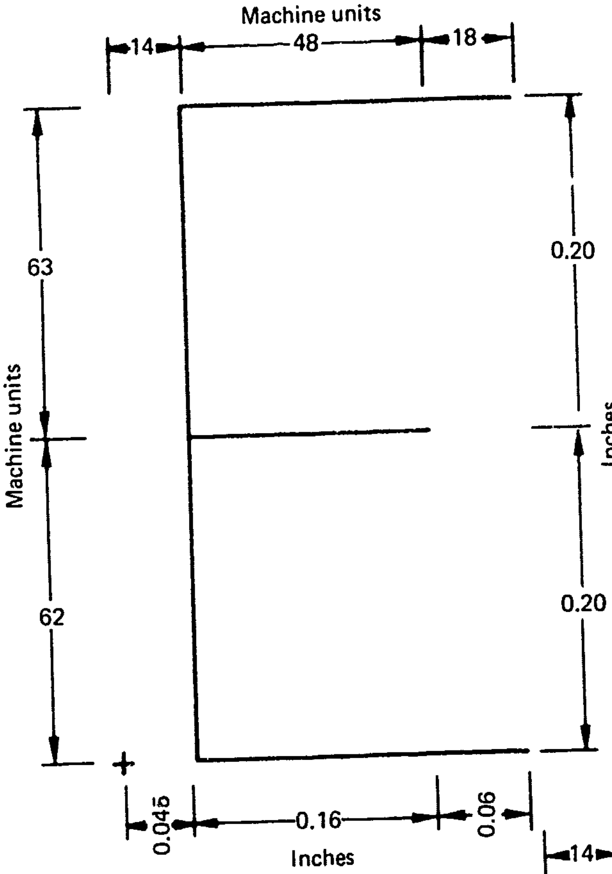


Alphanumeric C

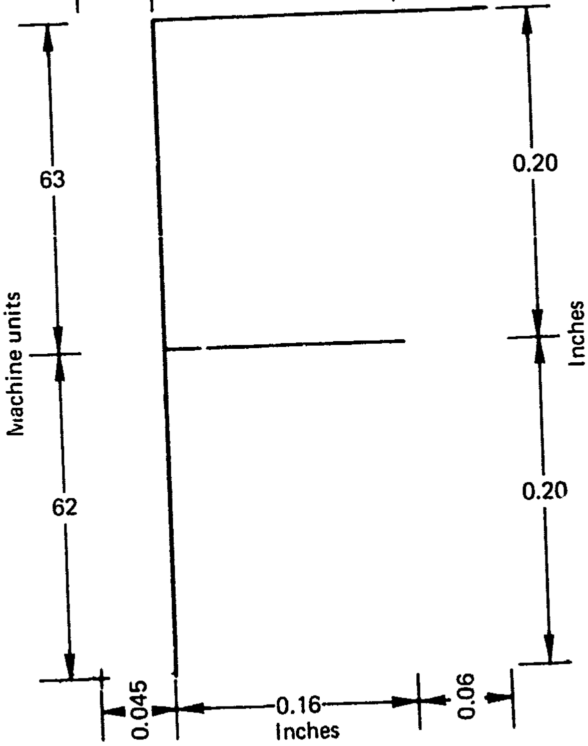


Alphanumeric D

TABLE 2-6.–CONTINUED

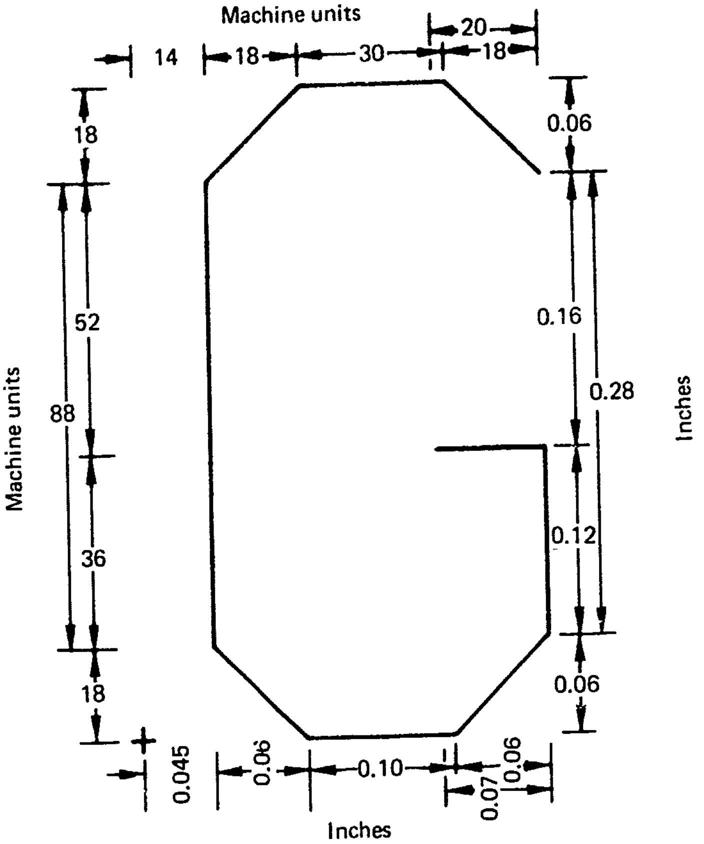


Alphanumeric E

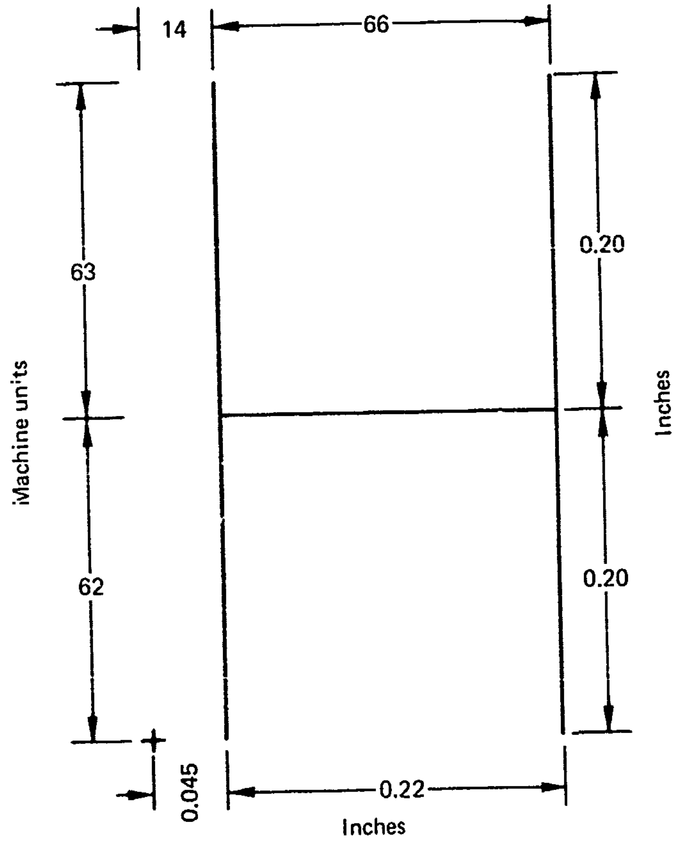


Alphanumeric F

TABLE 2-6.—CONTINUED

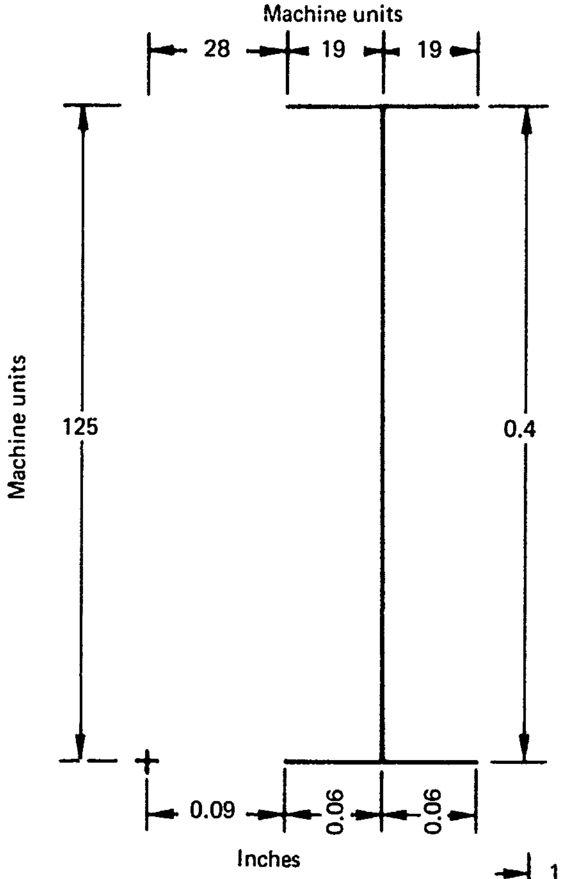


Alphanumeric G

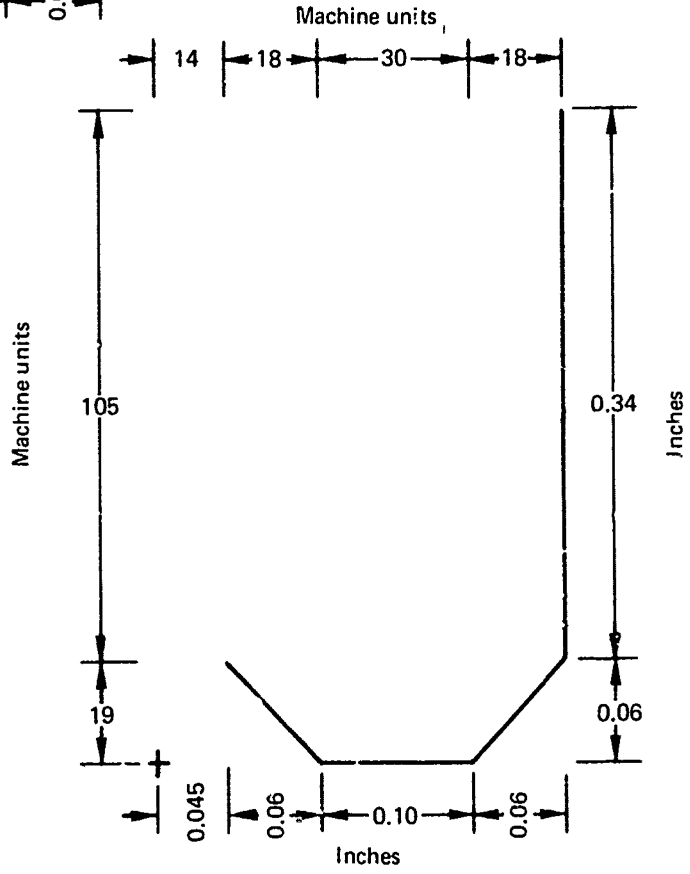


Alphanumeric H

TABLE 2-6.–CONTINUED

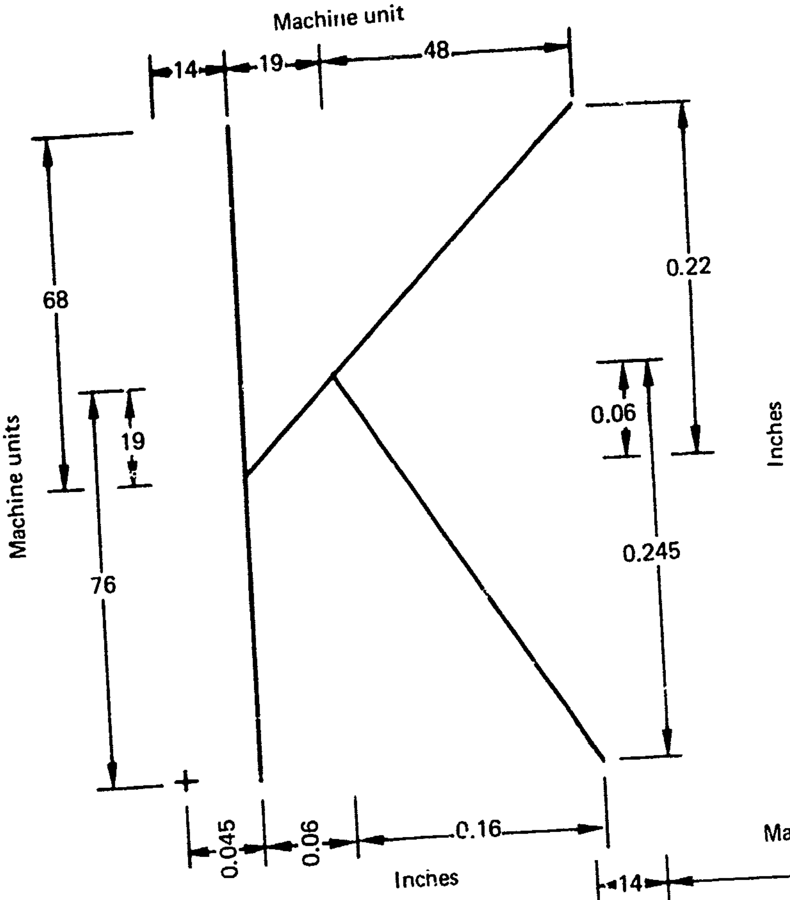


Alphanumeric I

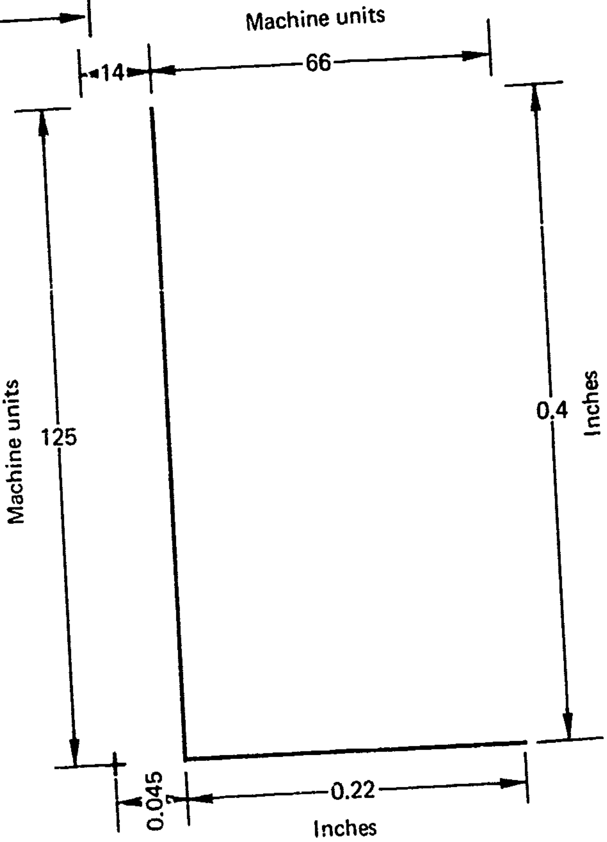


Alphanumeric J

TABLE 2-6.–CONTINUED

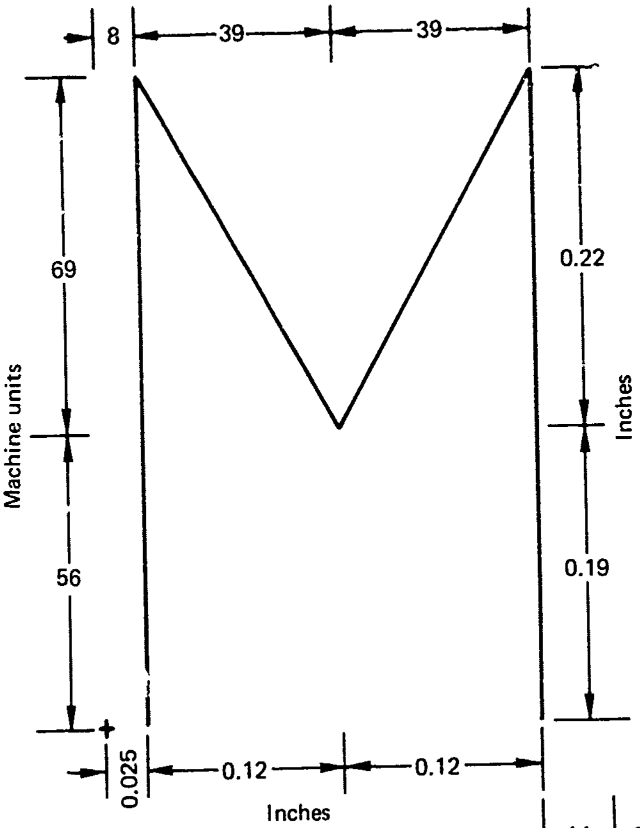


Alphanumeric K

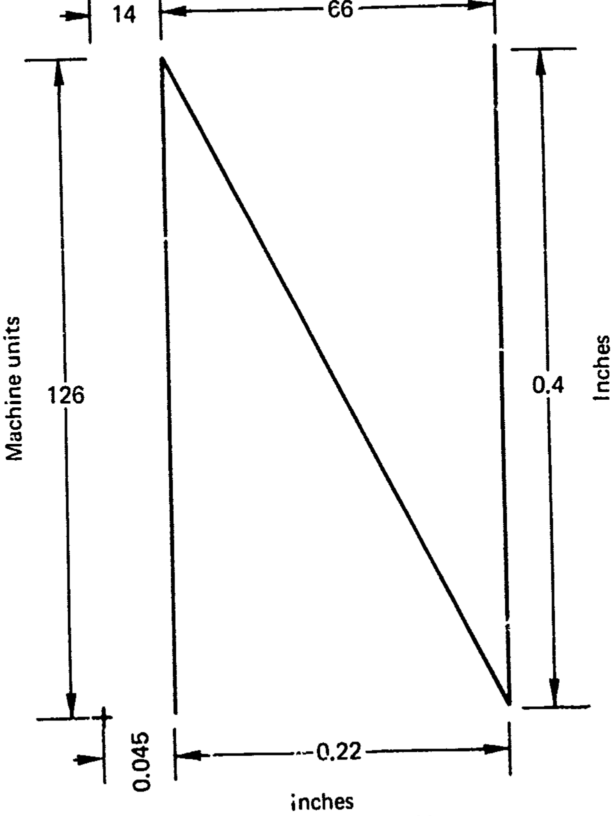


Alphanumeric L

TABLE 2-6.—CONTINUED

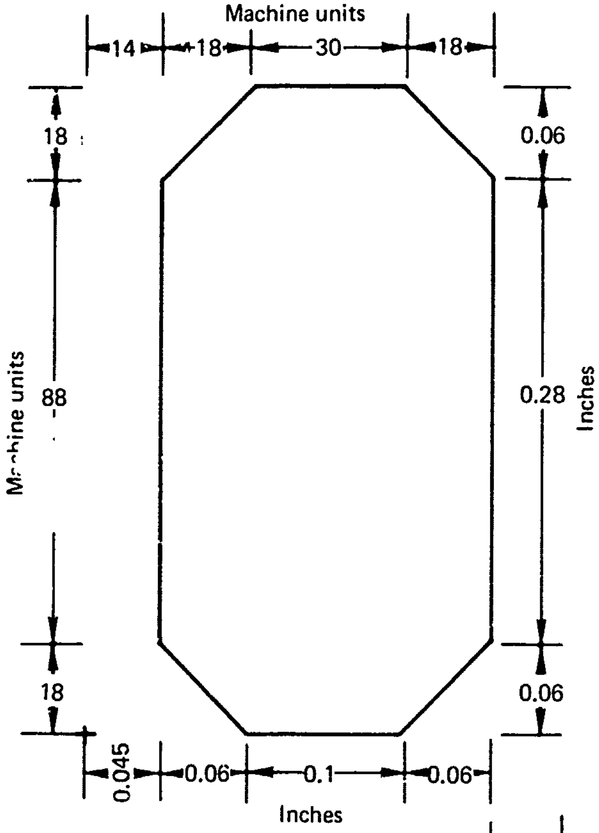


Alphanumeric M

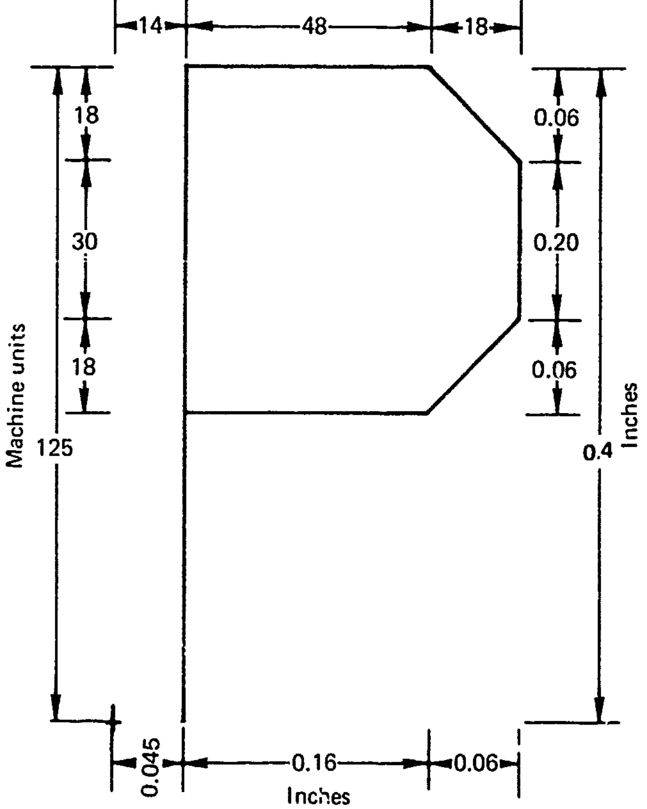


Alphanumeric N

TABLE 2-6.—CONTINUED

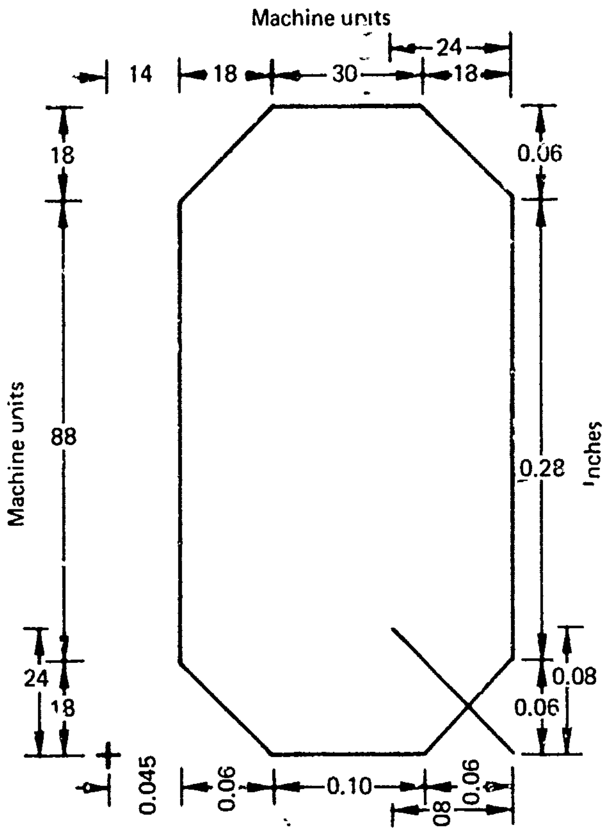


Alphanumeric O

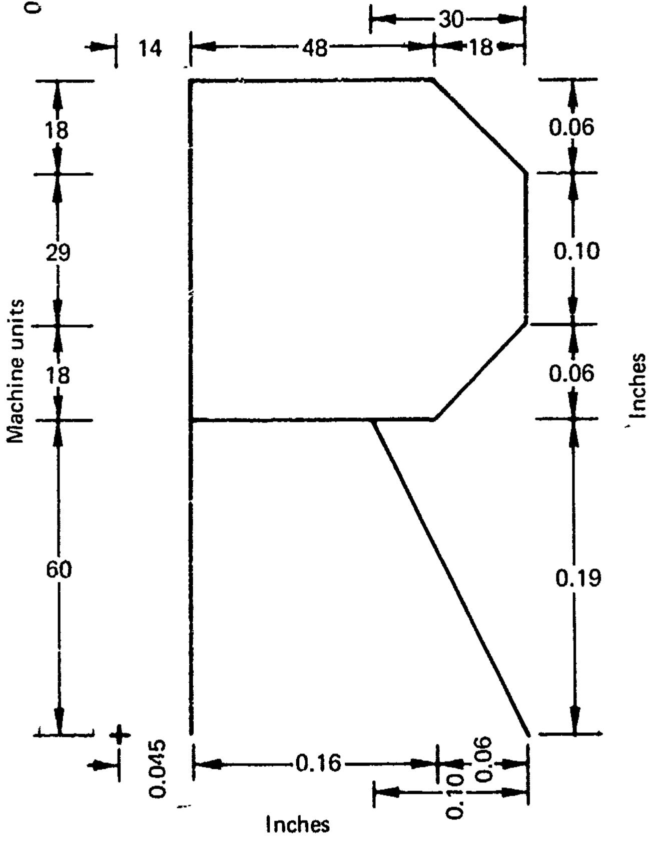


Alphanumeric P

TABLE 2-6.–CONTINUED

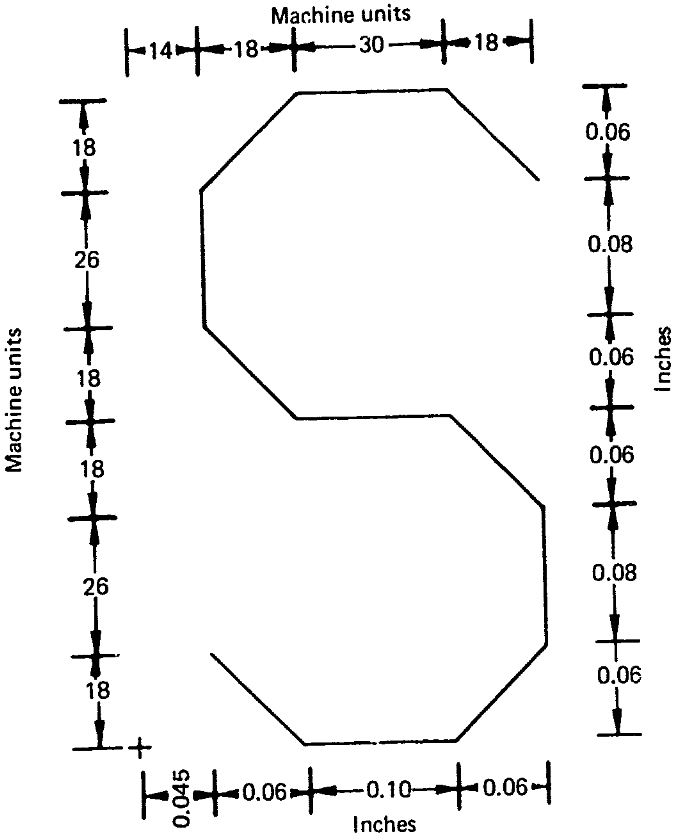


Alphanumeric Q

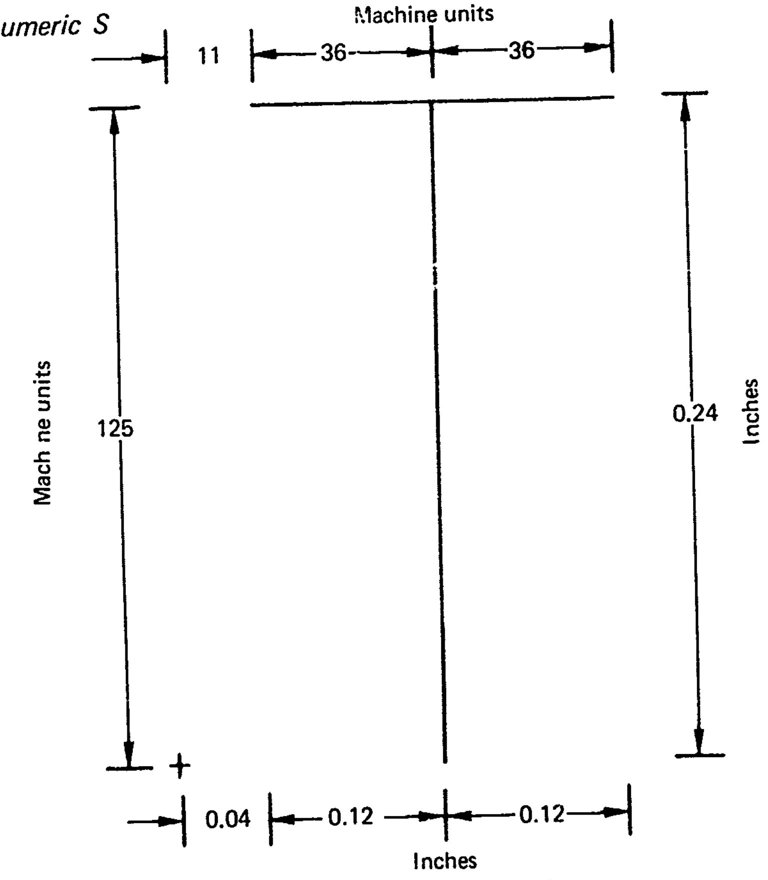


Alphanumeric R

TABLE 2-6.—CONTINUED

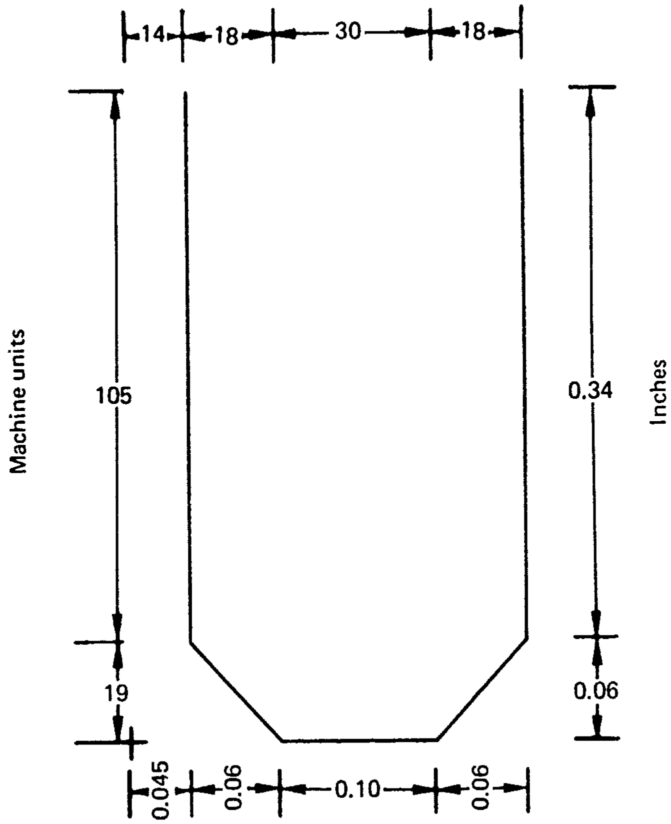


Alphanumeric S

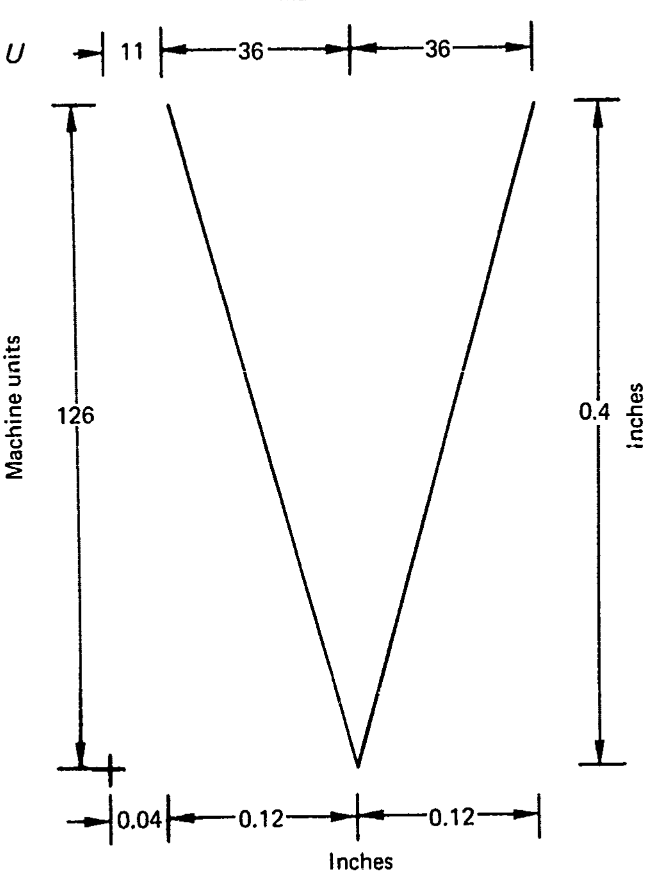


Alphanumeric T

TABLE 2-6.–CONTINUED

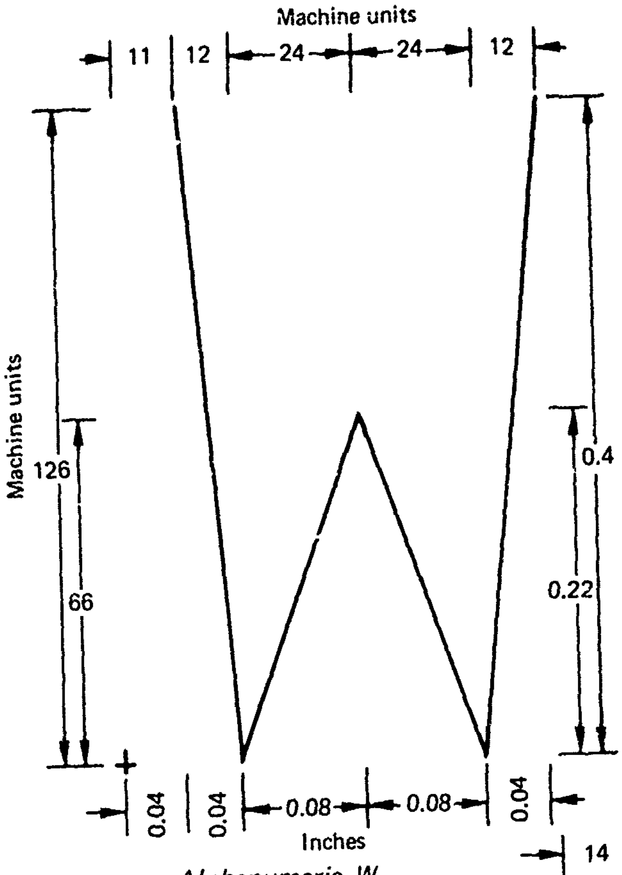


Alphanumeric U

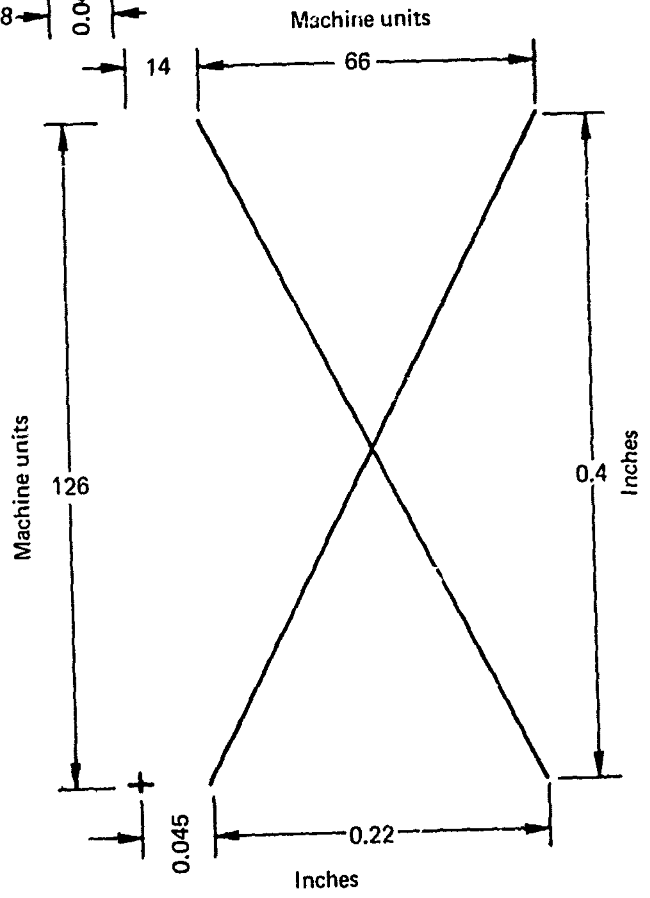


Alphanumeric V

TABLE 2-6.–CONTINUED

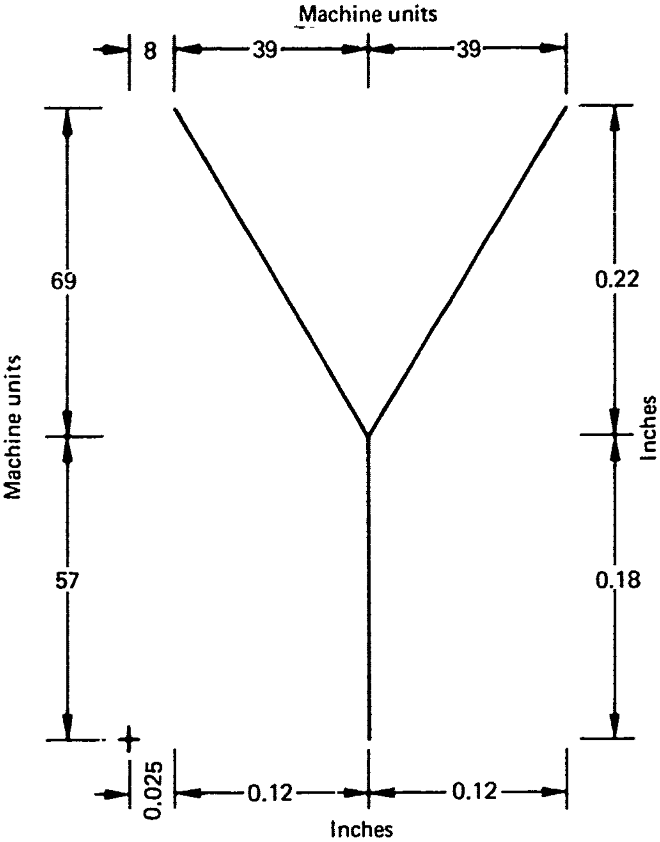


Alphanumeric W

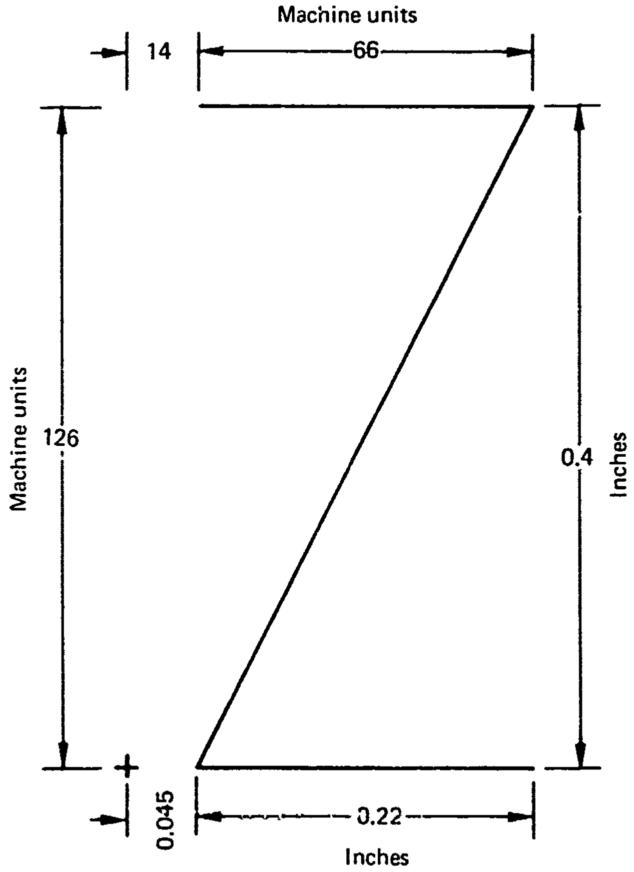


Alphanumeric X

TABLE 2-6.—CONTINUED



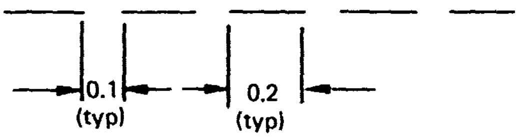
Alphanumeric Y



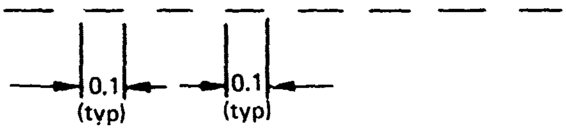
Alphanumeric Z

TABLE 2-6.—CONTINUED

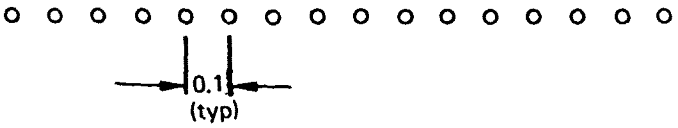
1100000



1100001



1100010

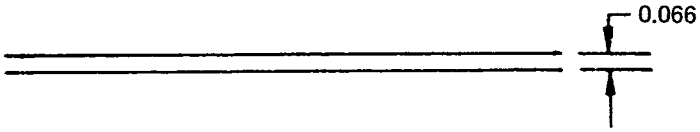


1100011

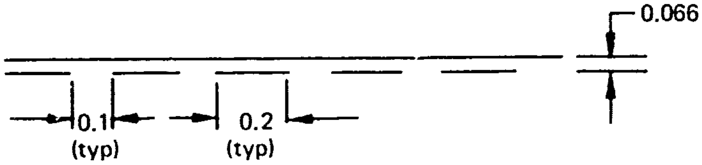
Dimensions in inches

Single-Vector Types

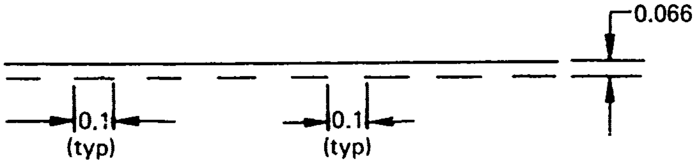
TABLE 2-6.—CONCLUDED



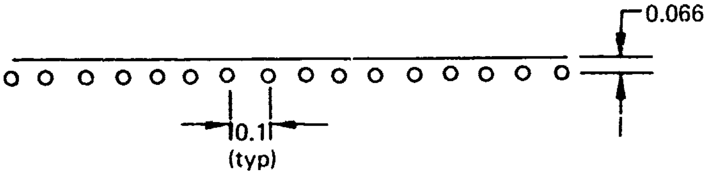
1101000



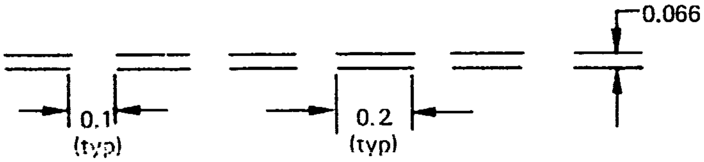
1101001



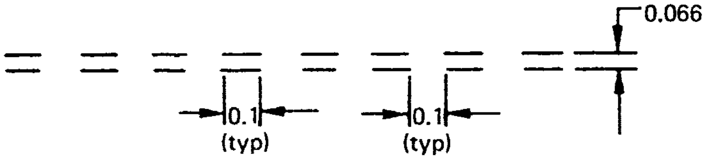
1101010



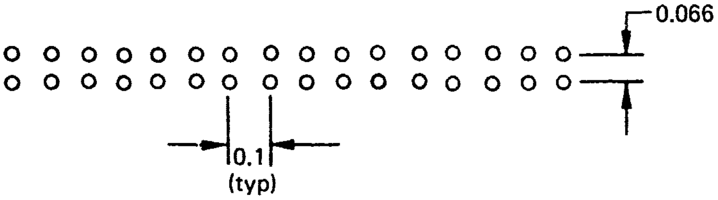
1101011



1101101



1101110



1101111

Dimensions in inches

Double-Vector Types

TABLE 2-7.–SEVEN-BIT CODES

Bit							Code	
7	6	5	4	3	2	1		
0	0	0	0	0	0	0		Do nothing
0	0	0	0	0	0	1		Text
0	0	0	0	0	1	0		Line feed (LF)
0	0	0	0	0	1	1		Carriage return (CR)
0	0	0	0	1	0	0		
0	0	0	0	1	0	1		
0	0	0	0	1	1	0		
0	0	0	0	1	1	1		
0	0	0	1	0	0	0	|	Tick mark
0	0	0	1	0	0	1	△	GRP
0	0	0	1	0	1	0	⬡	VOR and reporting point
0	0	0	1	0	1	1	ooooooo	Radial
0	0	0	1	1	0	0		Reserved
0	0	0	1	1	0	1	▯	Time box
0	0	0	1	1	1	0	Φ	Airfield and runway
0	0	0	1	1	1	1	○	Circle
0	0	1	0	0	0	0	⊙	Marker beacon
0	0	1	0	0	0	1	◬	GRP and reporting point
0	0	1	0	0	1	0	⬡	VOR
0	0	1	0	0	1	1	Y	VORTAC
0	0	1	0	1	0	0		Reserved
0	0	1	0	1	0	1	Y	VORTAC and reporting point
0	0	1	0	1	1	0		Reserved
0	0	1	0	1	1	1	□	Dot
0	0	1	1	0	0	0	⛰	Mountain
0	0	1	1	0	0	1		Reserved
0	0	1	1	0	1	0		Spare
0	0	1	1	0	1	1	Λ	Obstruction
0	0	1	1	1	0	0	✧	Waypoint
0	0	1	1	1	0	1	◎	Nondirectional radio beacon (NDB)
0	0	1	1	1	1	0	✧	Waypoint and cue
0	0	1	1	1	1	1	✳	Waypoint and cue

TABLE 2-7.–CONTINUED

Bit							Code
7	6	5	4	3	2	1	
0	1	0	0	0	0	0	Space
0	1	0	0	0	0	1	! (↑ NCDU)
0	1	0	0	0	1	0	" (↓ NDCU)
0	1	0	0	0	1	1	#
0	1	0	0	1	0	0	$
0	1	0	0	1	0	1	%
0	1	0	0	1	1	0	&
0	1	0	0	1	1	1	'
0	1	0	1	0	0	0	(
0	1	0	1	0	0	1	)
0	1	0	1	0	1	0	*
0	1	0	1	0	1	1	+
0	1	0	1	1	0	0	,
0	1	0	1	1	0	1	-
0	1	0	1	1	1	0	.
0	1	0	1	1	1	1	/
0	1	1	0	0	0	0	0
0	1	1	0	0	0	1	1
0	1	1	0	0	1	0	2
0	1	1	0	0	1	1	3
0	1	1	0	1	0	0	4
0	1	1	0	1	0	1	5
0	1	1	0	1	1	0	6
0	1	1	0	1	1	1	7
0	1	1	1	0		0	8
0	1	1	1	0	0	1	9
0	1	1	1	0	1	0	:
0	1	1	1	0	1	1	;
0	1	1	1	1	0	0	<
0	1	1	1	1	0	1	=
0	1	1	1	1	1	0	>
0	1	1	1	1	1	1	?

TABLE 2-7. –CONTINUED

Bit							Code
7	6	5	4	3	2	1	
1	0	0	0	0	0	0	@
1	0	0	0	0	0	1	A
1	0	0	0	0	1	0	B
1	0	0	0	0	1	1	C
1	0	0	0	1	0	0	D
1	0	0	0	1	0	1	E
1	0	0	0	1	1	0	F
1	0	0	0	1	1	1	G
1	0	0	1	0	0	0	H
1	0	0	1	0	0	1	I
1	0	0	1	0	1	0	J
1	0	0	1	0	1	1	K
1	0	0	1	1	0	0	L
1	0	0	1	1	0	1	M
1	0	0	1	1	1	0	N
1	0	0	1	1	1	1	O
1	0	1	0	0	0	0	P
1	0	1	0	0	0	1	Q
1	0	1	0	0	1	0	R
1	0	1	0	0	1	1	S
1	0	1	0	1	0	0	T
1	0	1	0	1	0	1	U
1	0	1	0	1	1	0	V
1	0	1	0	1	1	1	W
1	0	1	1	0	0	0	X
1	0	1	1	0	0	1	Y
1	0	1	1	0	1	0	Z
1	0	1	1	0	1	1	[
1	0	1	1	1	0	0	\ (→ NCDU)
1	0	1	1	1	0	1	] (✧ NCDU)
1	0	1	1	1	1	0	^ (° NCDU)
1	0	1	1	1	1	1	_

TABLE 2-7.–CONTINUED

Bit							Code
7	6	5	4	3	2	1	
1	1	0	0	0	0	0	────────
1	1	0	0	0	0	1	─── ─── ───
1	1	0	0	0	1	0	── ── ── ──
1	1	0	0	0	1	1	• • • • • • • •
1	1	0	0	1	0	0	
1	1	0	0	1	0	1	
1	1	0	0	1	1	0	
1	1	0	0	1	1	1	
1	1	0	1	0	0	0	════════
1	1	0	1	0	0	1	──────── ─── ─── ───
1	1	0	1	0	1	0	──────── ── ── ── ──
1	1	0	1	0	1	1	──────── • • • • • • • •
1	1	0	1	1	0	0	
1	1	0	1	1	0	1	═══ ═══ ═══
1	1	0	1	1	1	0	══ ══ ══ ══
1	1	0	1	1	1	1	: : : : : : : :
1	1	1	0	0	0	0	
1	1	1	0	0	0	1	
1	1	1	0	0	1	0	
1	1	1	0	0	1	1	
1	1	1	0	1	0	0	
1	1	1	0	1	0	1	
1	1	1	0	1	1	0	
1	1	1	0	1	1	1	
1	1	1	1	0	0	0	
1	1	1	1	0	0	1	
1	1	1	1	0	1	0	
1	1	1	1	0	1	1	
1	1	1	1	1	0	0	I&R
1	1	1	1	1	0	1	SOT
1	1	1	1	1	1	0	EOD
1	1	1	1	1	1	1	EOT

TABLE 2-7.–CONCLUDED

Bit							Code
7	6	5	4	3	2	1	
1	1	1	1	X	X	X	8 control codes
1	1	1	0	X	X	X	8 programmable symbols
1	1	0	0	X	X	X	8 single-vector codes
1	1	0	1	X	X	X	8 double vector codes
1	0	X	X	X	X	X	32 ASCII symbols
0	1	X	X	X	X	X	32 ASCII symbols
0	0	1	X	X	X	X	16 programmable symbols
0	0	0	1	X	X	X	8 programmable symbols
0	0	0	0	1	X	X	4 unassigned control codes
0	0	0	0	0	X	X	4 text control codes

TABLE 2-8.—TRACK-UP MAP DATA RATES

Symbology/function	Minimum computation rate (number/sec)	Data transmission	
		MFD bus 1	MFD bus 2
		1/sec	20/sec
Aircraft	—	—	—
Curved-trend vector	20		X
Straight-trend vector	—	—	—
Track angle (binary)	20		X
Track angle (BCD)	1		X
Track error bug	20		X
Track hold line	20		X
ADIZ line	1	X	
ADIZ label	1	X	
Airfield	1	X	
Airfield identifiers	1	X	
Runway identifiers	1	X	
Extended runway centerline	1	X	
Outer marker and label	1	X	
GRPs and identifiers	1	X	
Latitude-longitude grid	1	X	
Latitude-longitude labels	1	X	
Mountains and altitude labels	1	X	
Navaids and identifiers	1	X	
Route lines	1	X	
Waypoints and labels	1	X	
Track sin/cos	20		X
N/E coordinates	5		X
Holding pattern and label	1	X	
Obstructions and label	1	X	
Turn markers	1	X	
Speed change points	1	X	
Time box and dots	20		X
Altitude range	5		X

TABLE 2-9.—NAVAIDS DISPLAY

Map scale (nmi/in.)	Navaids	
	Selectable ON or OFF	Displayed full time
32	Category 1 navaids and NDBs	Navaids on flight plan; the two navaids presently "tuned in"
1, 2, 4, 8, and 16	Category 1 and 2 navaids and NDBs	Navaids on flight plan; the two navaids presently "tuned in"

TABLE 2-10.—HOLDING PATTERN PARAMETERS

Altitude (1000 ft)	V_H (kt)	L_H (nmi)	D_H (nmi)
0 - 5	205	2.72	2.63
5 - 10	215	2.64	2.39
10 - 14	235	2.41	3.45
14 - 20	280	3.98	4.90
20 - 25	305	3.58	5.81
25 - 30	330	3.06	6.81
30 - 35	365	5.17	8.33
35 - 40	405	4.15	10.25

TABLE 2-11.–NORTH-UP MAP DATA RATES

Symbology/function	Minimum computation rate (number/sec)	Data transmission	
		MFD bus 1	MFD bus 2
		1/sec	20/sec
Aircraft	20		X
Curved-trend vector	20		X
Straight-trend vector	20		X
Track digits/scale	20		X
Track select bug	20		X
ADIZ line		X	
ADIZ label	Computed once for each scale change; deleted when selected OFF	X	
Airfield		X	
Airfield identifiers		X	
Runway identifiers		X	
Extended runway centerline		X	
Outer marker		X	
Intersections and identifiers		X	
Latitude-longitude grid		X	
Latitude-longitude labels		X	
Mountains and altitude labels		X	
Navaids and identifiers		X	
Route lines		X	
Waypoints and labels		X	
Holding pattern and label		X	
Obstructions		X	
Turn markers		X	
Speed change points		X	
Time box and dots	20		X
Altitude/range	5		X

TABLE 2-12.—NCU/PCU INTERFACE TEST DATA TRANSMITTAL

Bus 1		
Word no.	Data	Data content
0	SOT	
1	I&R control word	IC=11, RC=1, RS-0, OC=0
2	Symbol word—text	I_T = 11
3	Symbol word—type 2	Position N 240, E -60
4	Symbol word—type 4	M F D
5	Symbol word—type 4	b B U
6	Symbol word—type 4	S b #
7	Symbol word—type 4	2 b b
8	Symbol word—type 4	B A D
9	Symbol word—text	I_T = 11
10	Symbol word—type 2	Position N -360, E -60
11	Symbol word—type 4	M F D
12	Symbol word—type 4	b B U
13	Symbol word—type 4	S b #
14	Symbol word—type 4	1 b G
15	Symbol word—type 4	O O D
16	Symbol word—type 4	b CR LF
17	Symbol word—type 4	M F D
18	Symbol word—type 4	b B U
19	Symbol word—type 4	S b #
20	Symbol word—type 4	2 b G
21	Symbol word—type 4	O O D
22	EOD control word	TC=0
509	Mode MFD 1	Track-up map
510	ΔMFD 1	ΔN = 0, ΔE = 0
511	EOT	

Notes: b = space
ST = 1 in all type 4 words

Bus 2		
Label	Data	Data content
0 1 0 0 0 0 0	ΔN, ΔE	+100, 0
0 1 0 0 0 0 1	Coordinate rotation angle	0°
0 1 0 0 0 1 0	TK binary	Current track (magnetic)
0 1 0 0 0 1 1	TK BCD	Current track (magnetic)
0 1 0 0 1 0 0	TKESEL sin/cos	Invalid
0 1 0 0 1 0 1	TKESEL binary	Invalid
0 1 0 0 1 1 0	Airplane position	Zero
0 1 0 0 1 1 1	EOD	
0 1 0 1 0 0 0 0 1 1 1 1 1 1	Unassigned	

Bit no.

32	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	1		-	-	-	-	-	-						1	1	1	1				-	-	-	-	-	-	-	-	-	-	-
P	WF	TC							OC	RC	RS	IC		7-bit code										Label							

– Insignificant bit

Bit			
30	TC	=	1: table continues
23	OC	=	1: offset adder control
22	RC	=	1: rotate coordinates
21	RS	=	1: rotate symbol
20	IC	=	1: increment Y coordinate
19	IC	=	1: increment X coordinate
31	WF	=	0: group continues
	WF	=	1: end of group

Control	
1 1 1 1 0 0 0	Spare
1 1 1 1 0 0 1	
1 1 1 1 0 1 0	
1 1 1 1 0 1 1	
1 1 1 1 1 0 0	I&R
1 1 1 1 1 0 1	SOT
1 1 1 1 1 1 0	EOD
1 1 1 1 1 1 1	EOT

Note: RC and IC are applicable only for the I&R control code.

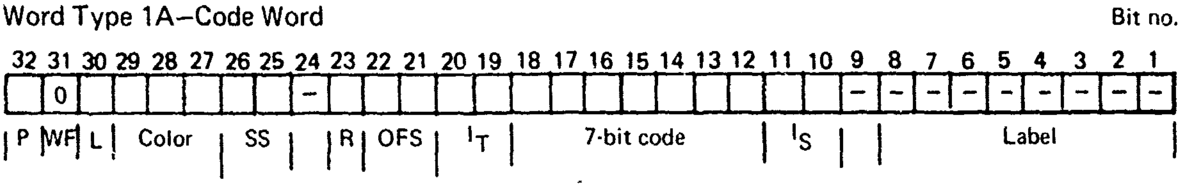
Control word requirements:

WF bit has to be 1
TC bit has to be 1 except for the last EOD
OC is 1 for track-up map mode Where: 0 = reference is screen center
  1 for north-up map mode 1 = reference is preset offset
  0 for NCDU test mode

Control word definitions:
I&R = coordinate increment and rotation control
SOT = start of transmission
EOD = end of data
EOT = end of transmission

FIGURE 2-1.–MFD BUS 1 CONTROL WORDS

Word Type 1A–Code Word



Tag offset (OFS) = 4 offsets
Rotate symbol (R) = 1: rotate
Symbol size (SS) = 4 sizes
Symbol intensity (I_S) = 4 intensities
On-screen limit (L) = 1: limit
Tag intensity (I_T) = 4 intensities

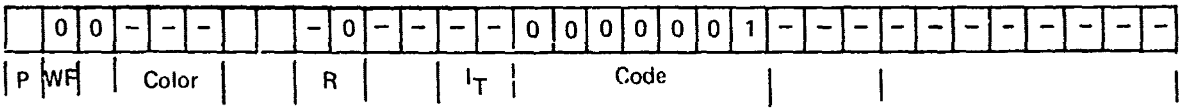
Symbol codes	
1 1 1 X X X X	8 special
1 0 X X X X X	32 ASCII
0 1 X X X X X	32 ASCII
0 0 1 X X X X	16 special
0 0 0 1 X X X	8 special

Intensity (I)	OFS	X (in.)	Y (in.)
00 = zero	00	+0.147	-0.300
01 = dim	01	+0.147	-0.147
10 = medium	10	-0.325	-0.374
11 = maximum	11	+0.100	-0.200

Symbol	Size (in.)	Percent of size defined in table 2-6
11	0.40	100 %
10	0.316	79 %
01	0.233	58 %
00	0.15	37.5%

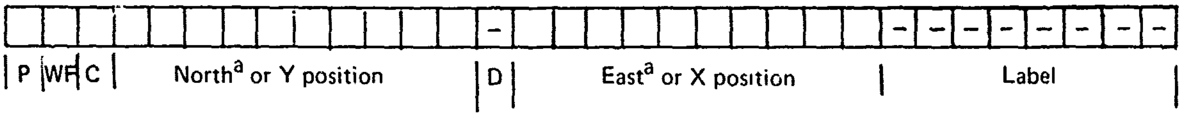
Text Instruction Word Type

Word Type 1B–Code Word



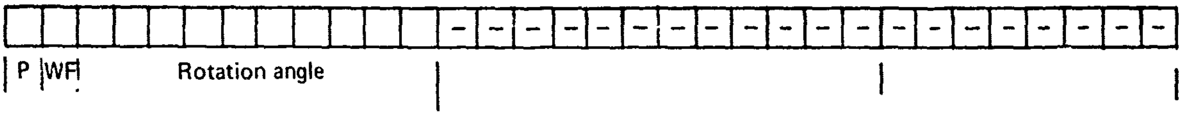
followed by symbol type 4 words

Word Type 2–Position Word

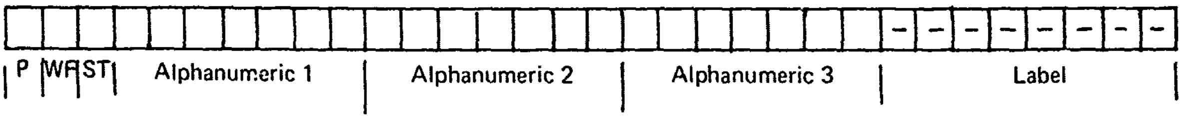


C (conic) has to = 0

Word Type 3–Symbol Rotation Word



Word Type 4–Tag Word



Tag size (ST) = 0: small

WF = 1 in last word of group; elsewhere, WF = 0

- Insignificant bit

[a] Track-up map mode

FIGURE 2-2.–MFD BUS 1 SYMBOL WORDS

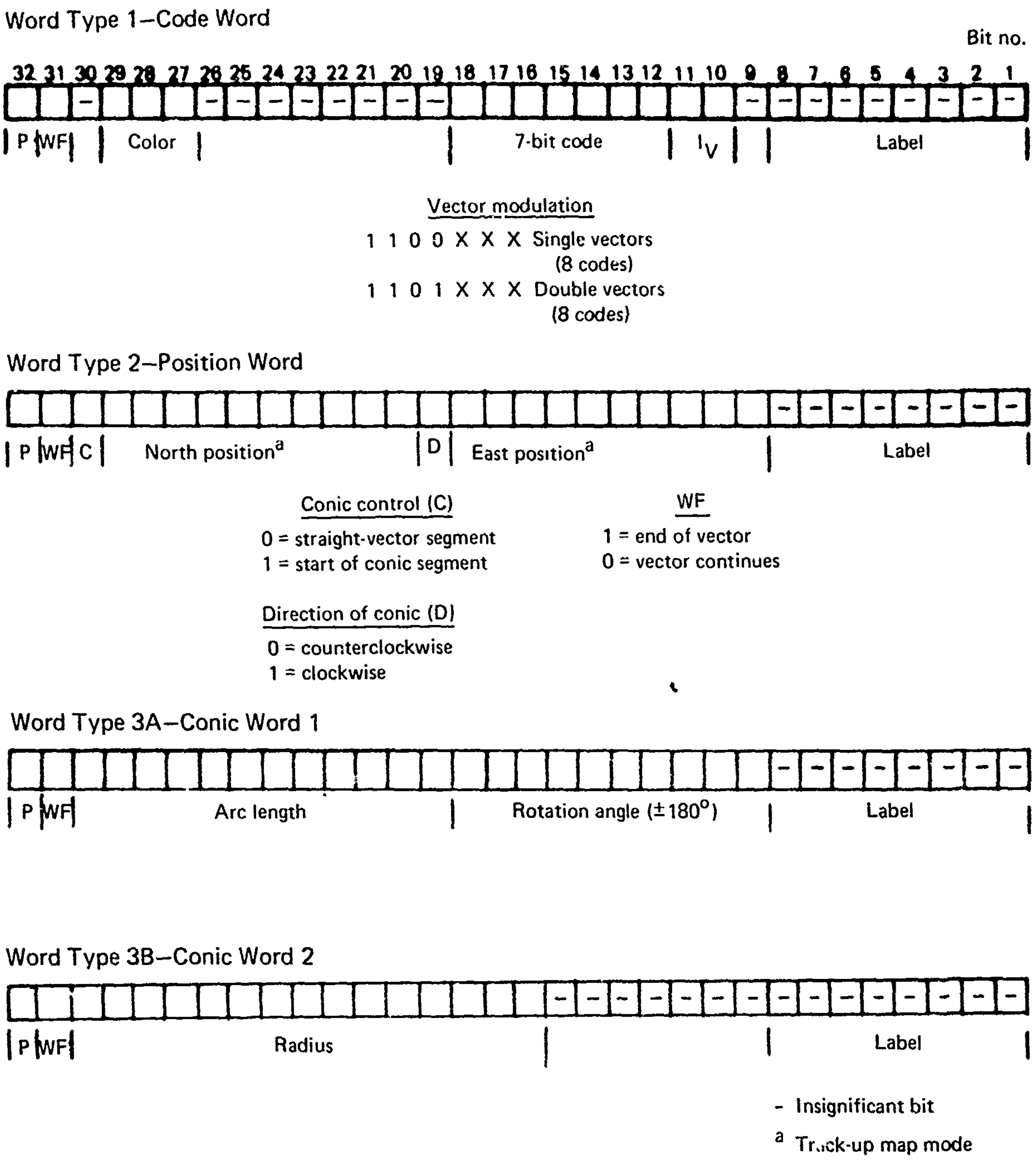
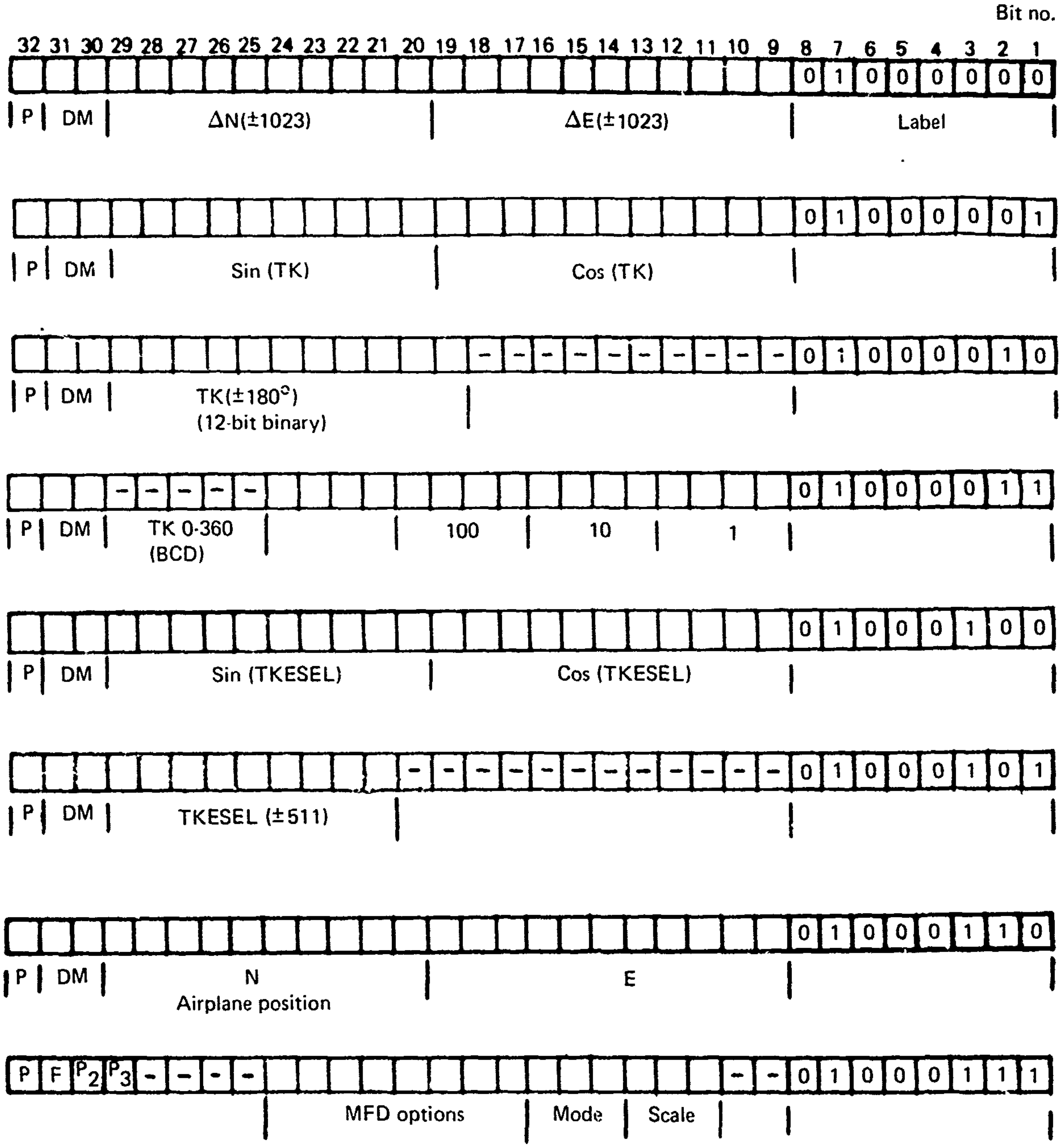


FIGURE 2-3.–MFD BUS 1 VECTOR WORDS

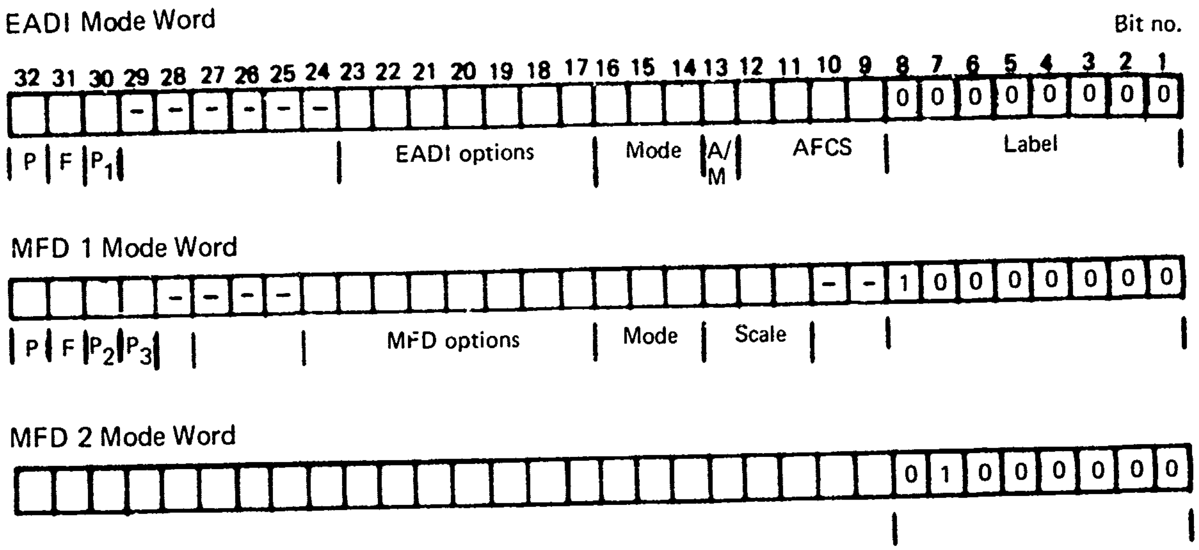


The following words (7 through 64) will contain control words, symbol words, and vector words formatted identically to MFD bus 1 data:

Bit no.		
31	30	
0	0	Test
0	1	Minus
1	0	Plus
1	1	Invalid

– Insignificant bit

FIGURE 2-4.—MFD BUS 2 WORD FORMATS



F = 1: Display failure

P_1 = 1: Bad parity on EADI bus

P_2 = 1: Bad parity on MFD bus 1

P_3 = 1: Bad parity on MFD bus 2

– Insignificant bit

MFD options:

Bit no.								
24	23	22	21	20	19	18	17	Symbol
0	0	0	0	0	0	0	1	NAVAIDS
0	0	0	0	0	0	1	0	TERRAIN
0	0	0	0	0	1	0	0	AIRPORTS
0	0	0	0	1	0	0	0	WPT/ALT
0	0	0	1	0	0	0	0	GRP
0	0	1	0	0	0	0	0	T-NAV
0	1	0	0	0	0	0	0	ALT/RANGE
1	0	0	0	0	0	0	0	TREND VECTOR

Mode:

Bit no.			
16	15	14	
0	0	0	TRACK-UP MAP
0	0	1	NORTH-UP MAP
0	1	0	TEST
0	1	1	Spare

Scale:

Bit no.			Scale
13	12	11	(nmi/in.)
1	0	1	1
1	0	0	2
0	1	1	4
0	1	0	8
0	0	1	16
0	0	0	32

FIGURE 2-5.–PCU/NCU WORD FORMATS AND TRANSMISSION ORDER

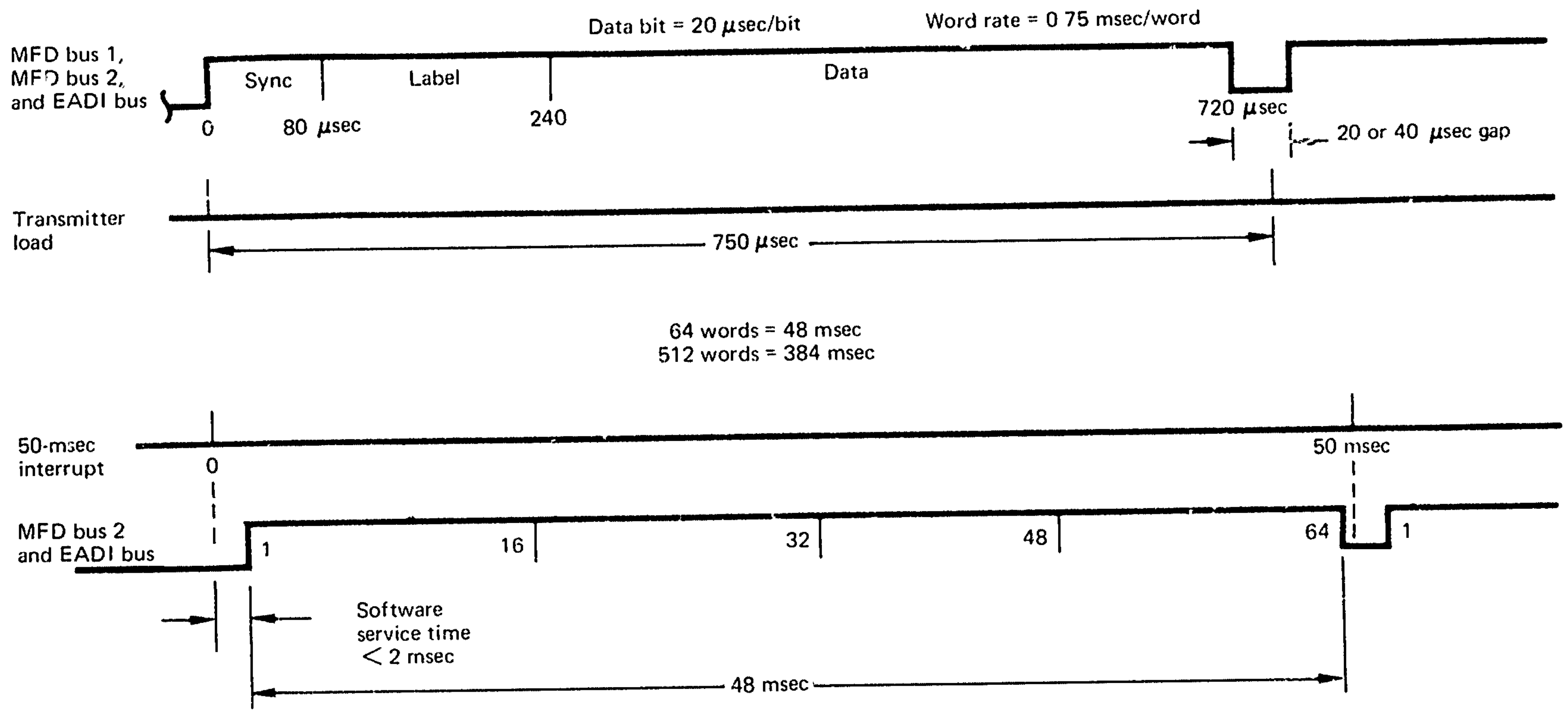


FIGURE 2-6.—SPBP TRANSMISSION TIMING

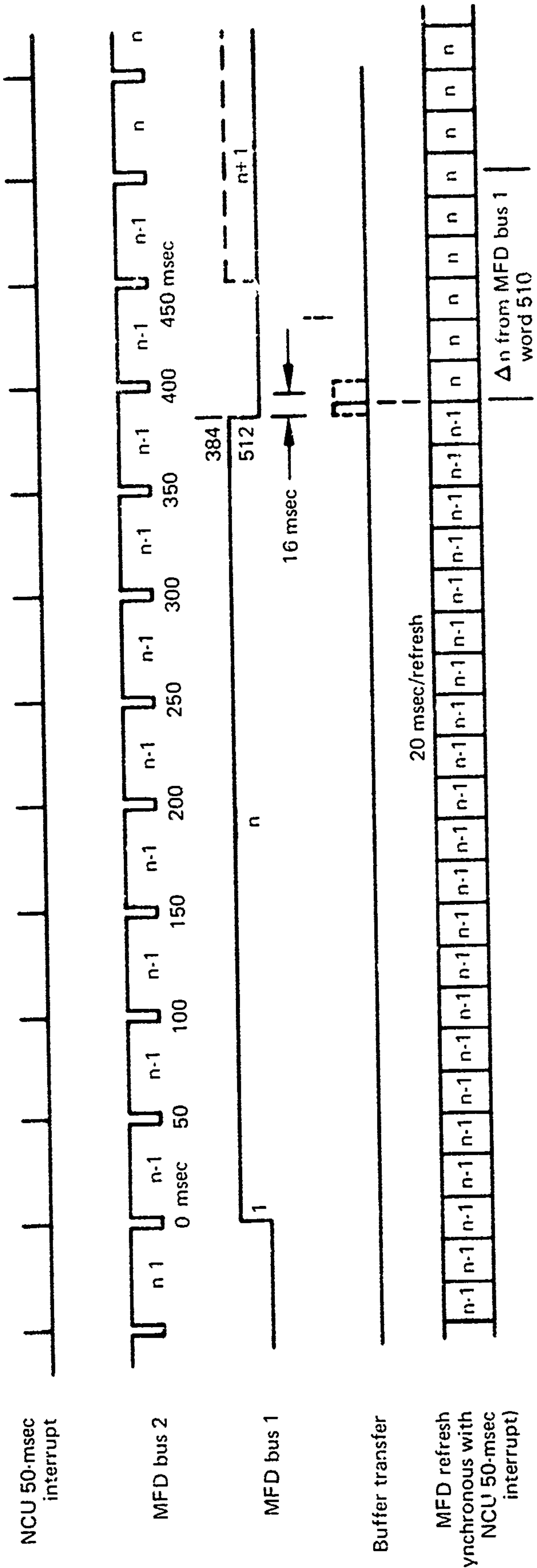


FIGURE 2-7.—MFD BUS 1, BUS 2, AND PCU TIMING RELATIONSHIP

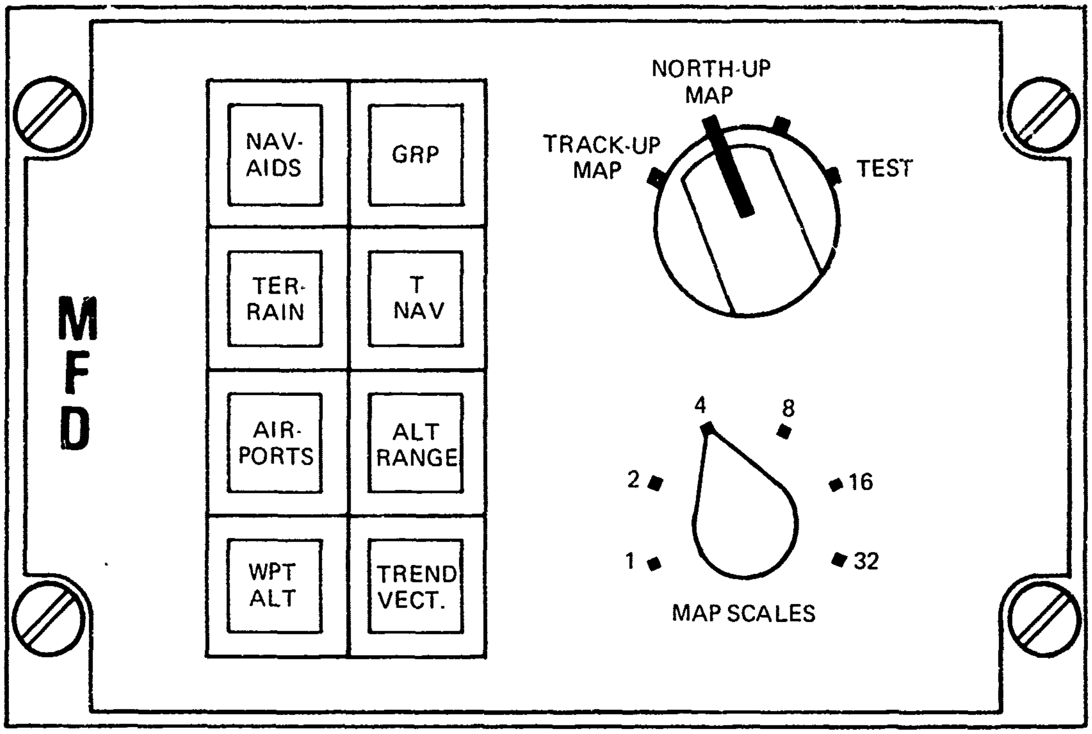


FIGURE 2-8.–MFD MODE CONTROL UNIT

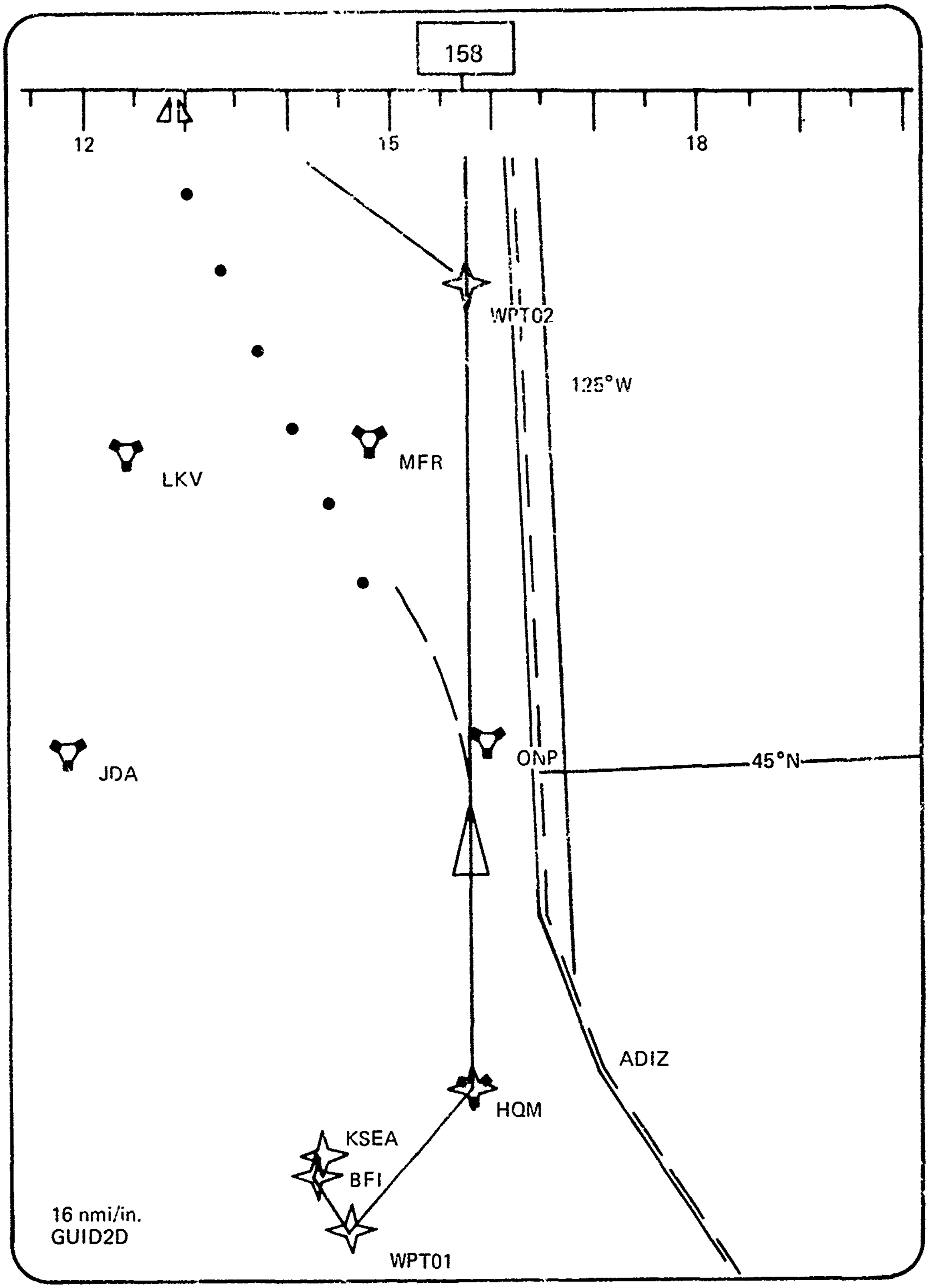


FIGURE 2-9.—TYPICAL TRACK-UP MAP FORMAT

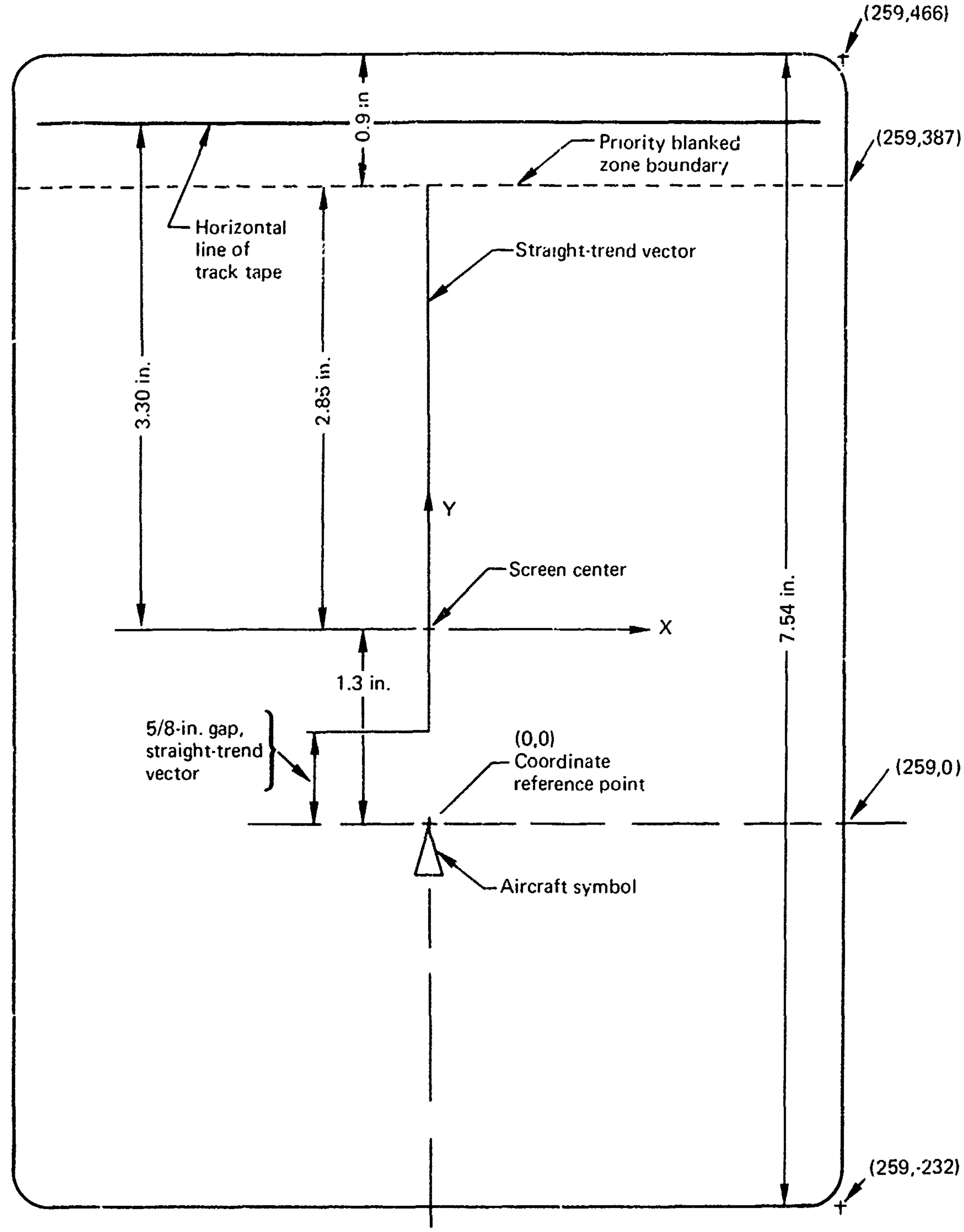


FIGURE 2-10.—LOCATION OF REFERENCE POINTS ON TRACK-UP MAP FORMAT

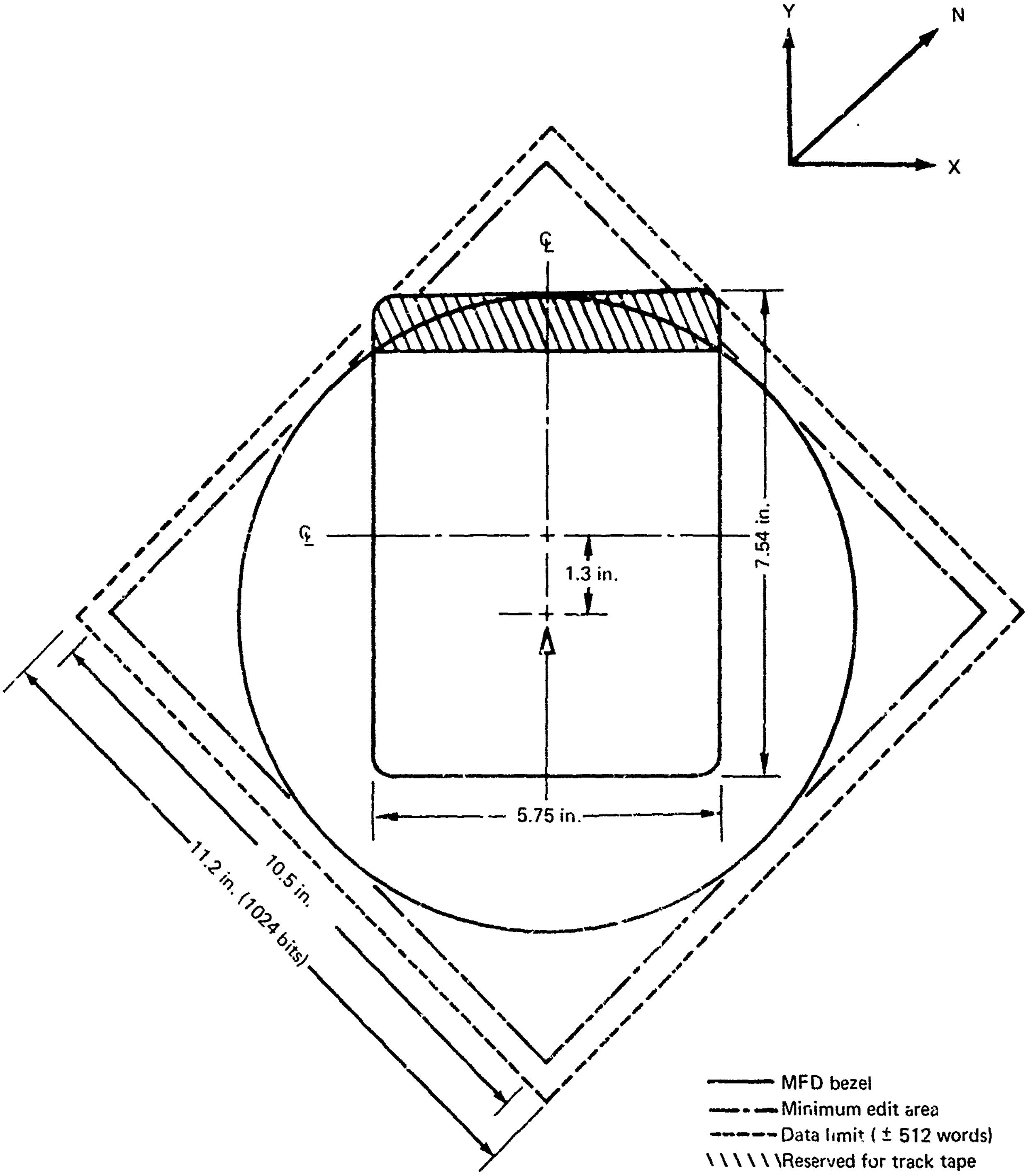
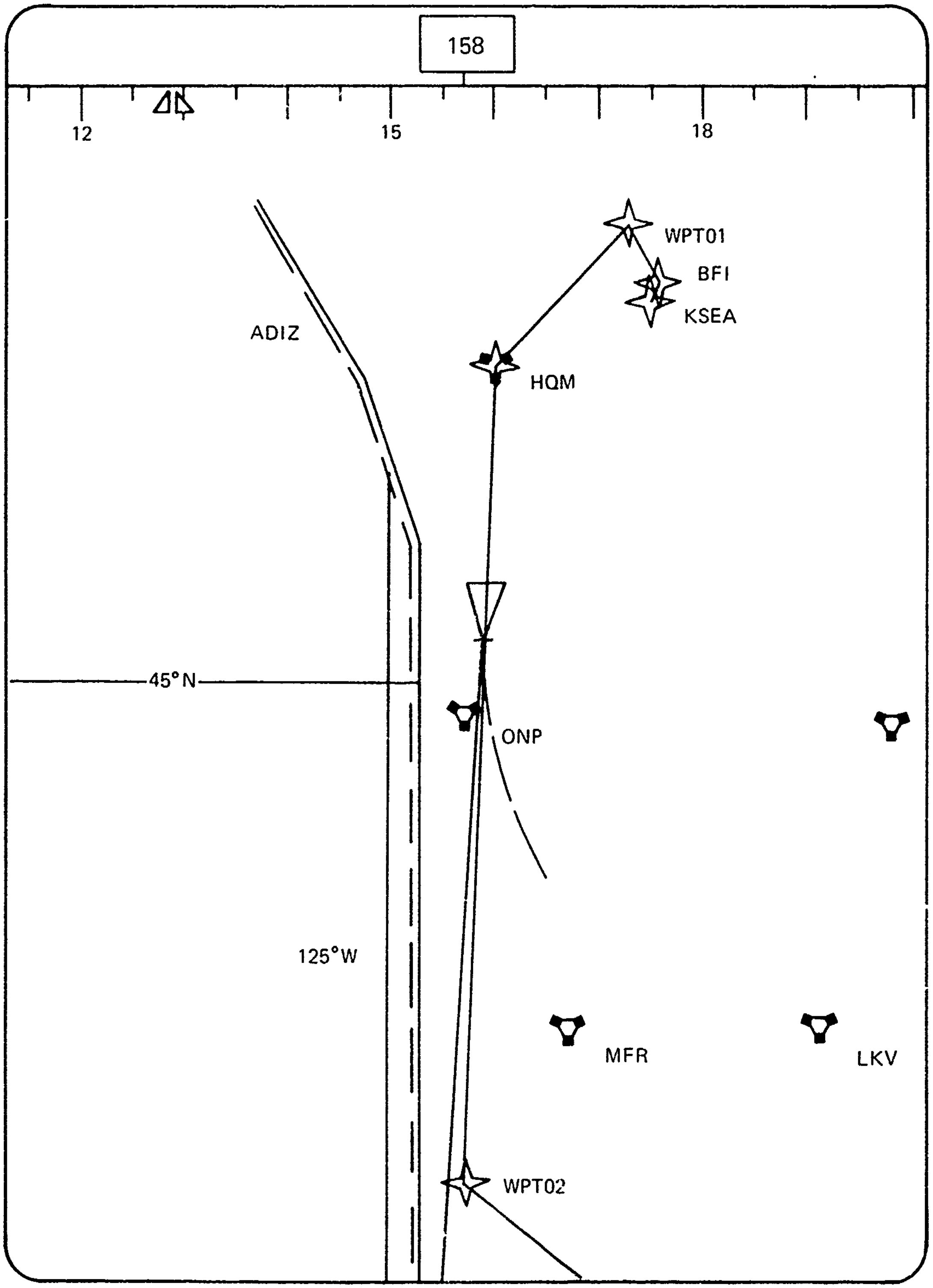


FIGURE 2-11.–MOVING-MAP DISPLAY AREAS



Note: ONP is map center

FIGURE 2-12.—TYPICAL NORTH-UP MAP FORMAT

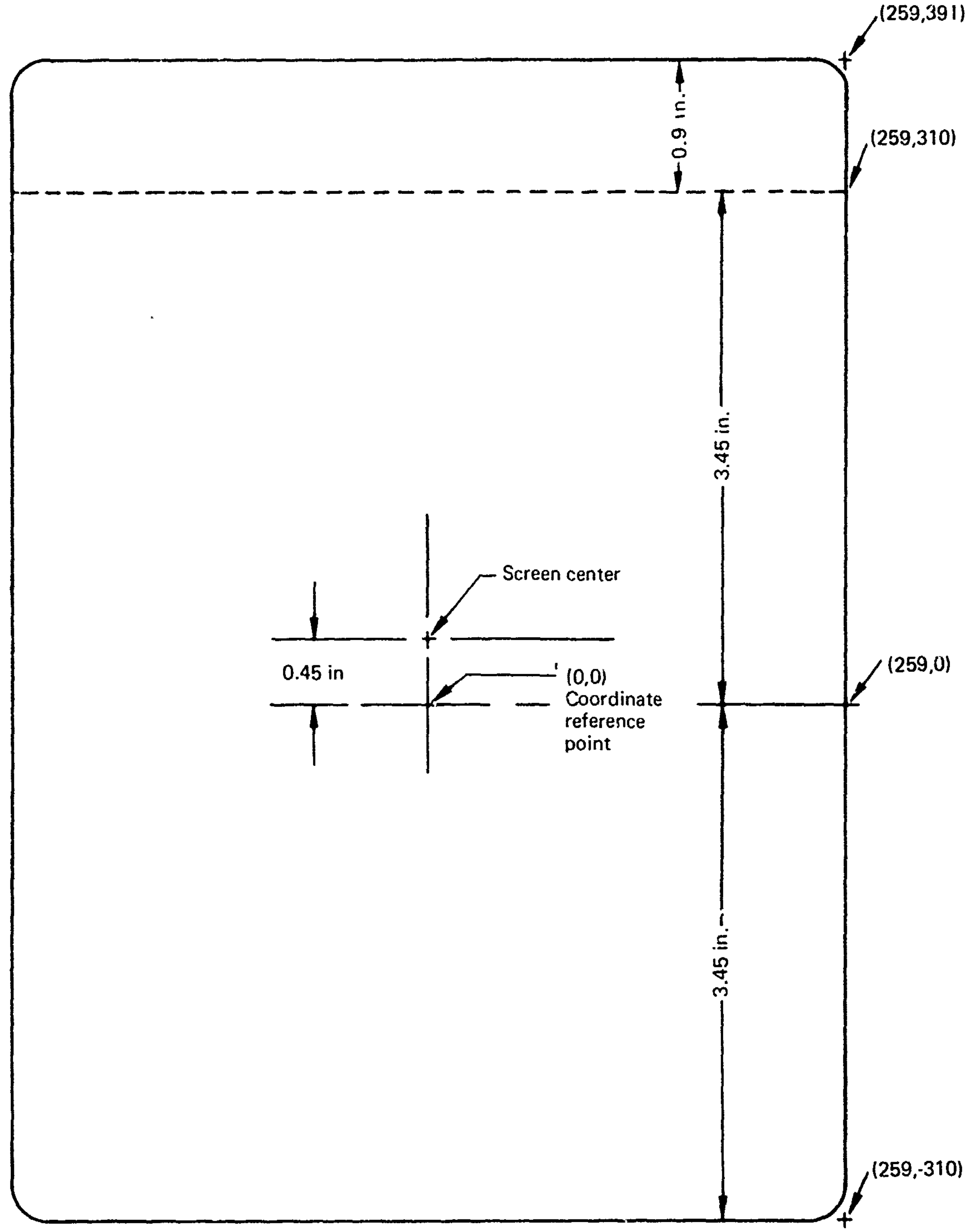


FIGURE 2-13.–LOCATION OF REFERENCE POINTS ON NORTH-UP MAP FORMAT

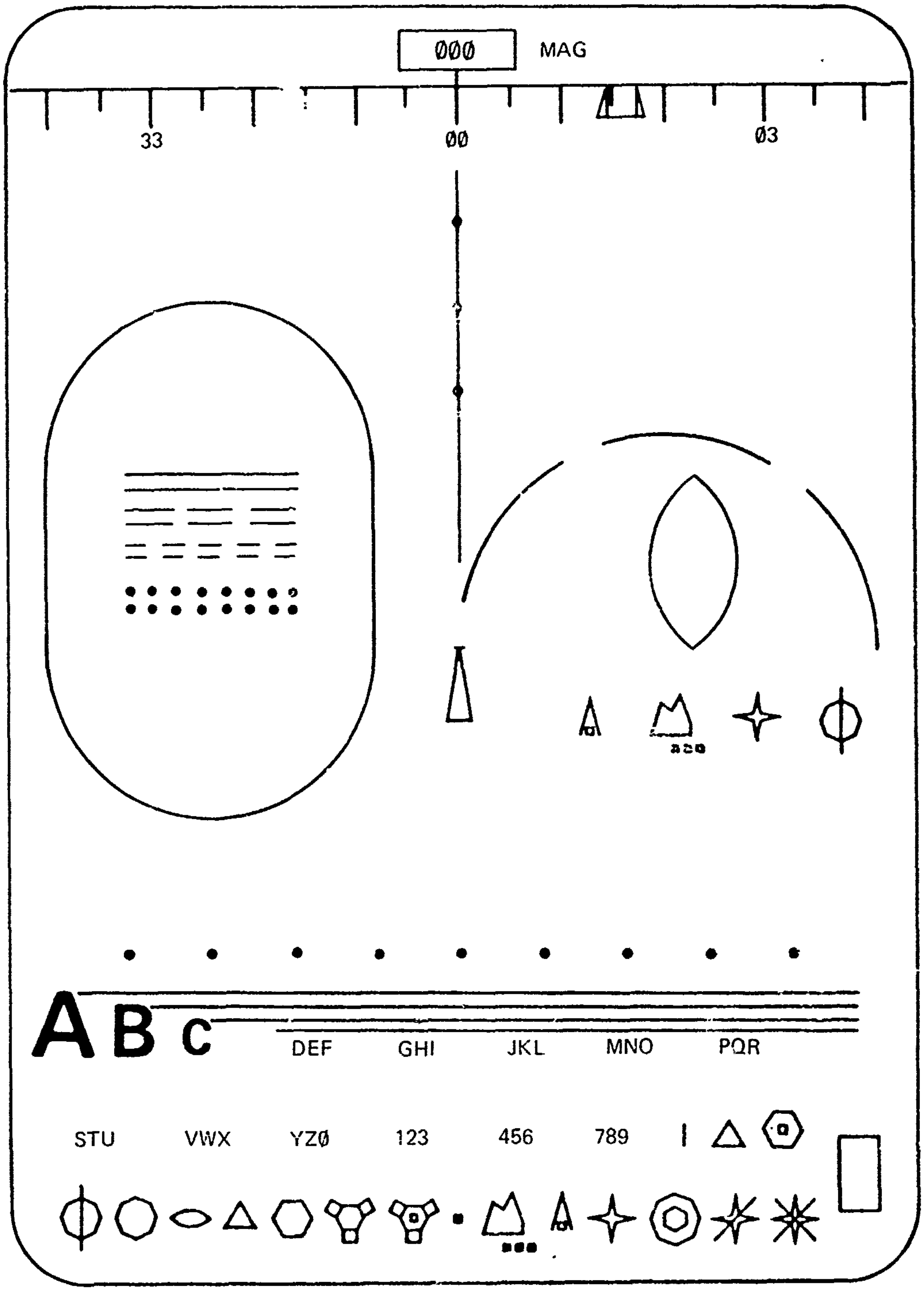
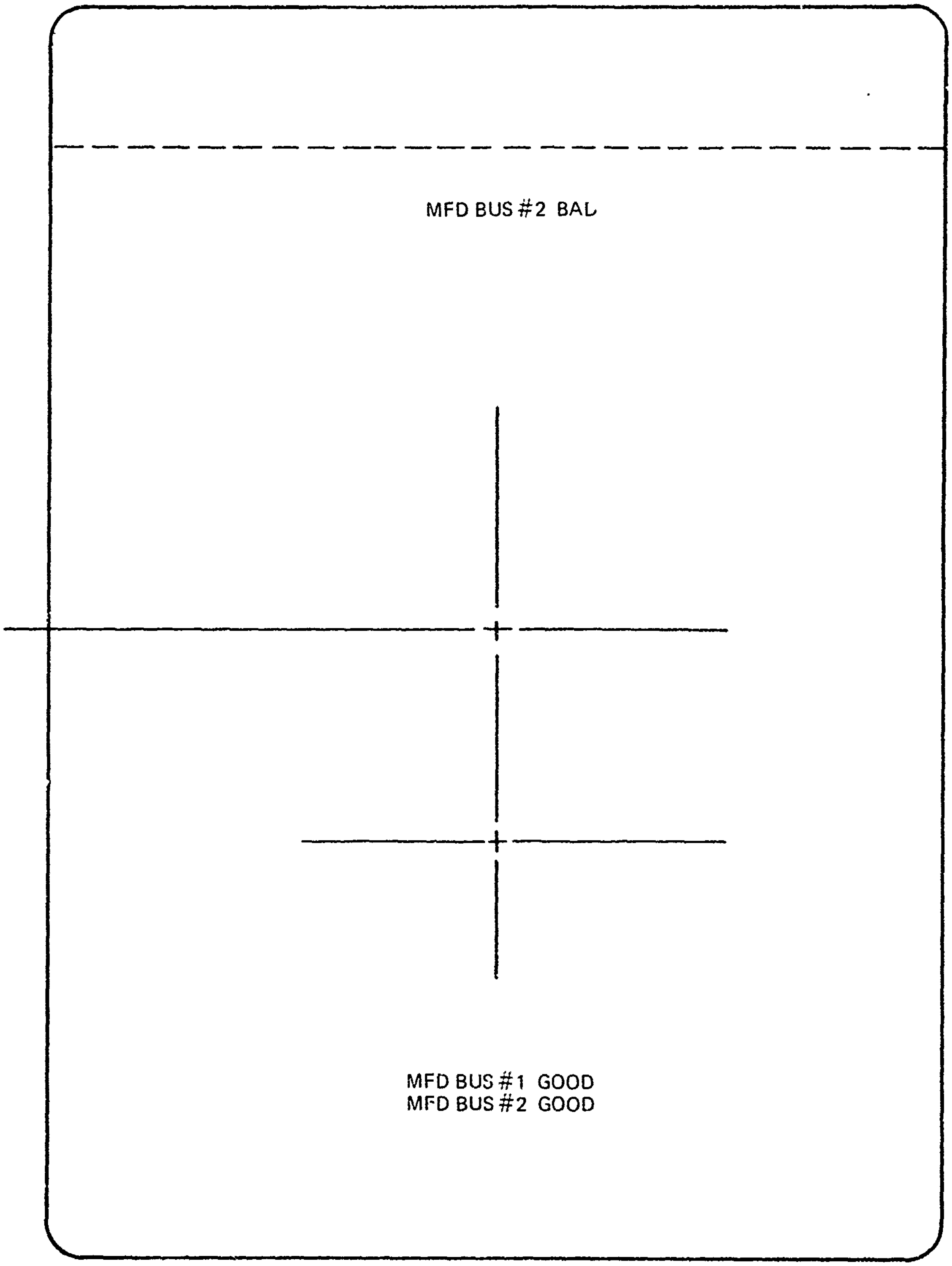


FIGURE 2-14.—MFD SELF-TEST DISPLAY FORMAT



MFD BUS #2 BAD

MFD BUS #1 GOOD
MFD BUS #2 GOOD

Note: Either the good or bad message will be displayed.

FIGURE 2-15.–NCU/PCU INTERFACE TEST MFD DISPLAY FORMATS

3.0 BULK DATA STORAGE

3.1 GENERAL

This section defines the organization for storage of navigation and geographic data, henceforth called bulk data, required for the guidance, MFD map display, and NCDU display functions of the ADEDS system. The data are separated into categories for convenience of access and are organized as defined in section 3.3. Section 3.5 describes the bulk data formatting method to be used for assembly of bulk data for the NCU. (The same method will be used for the ADEDS simulation on the EAI 8400.) The bulk data used for flight test are tabulated in the appropriate NCU program listing.

3.2 MEMORY

Twelve thousand 24-bit words of direct access memory are allocated for bulk data storage in the ADEDS configuration of the NCU. This allocation is somewhat arbitrary and can be amended if necessary because of program storage requirements or increased bulk data requirements.

3.3 DATA ORGANIZATION

The bulk data will be separated into primary categories: airways and routes, SIDs and STARs, airfields, geographic reference points (GRPs), navaids, terrain, terminal data, missed approach entry points, boundaries, and latitude-longitude oceanic grid (secs. 3.3.2 through 3.3.11). Data in each category will be tabulated and stored in a dedicated buffer memory zone. The format of each buffer is defined in tables 3-1 through 3-12.

The geographic area for which bulk data is stored is divided into strips bounded by lines of longitude. Separate buffers within each strip contain airfield, GRP, navaid, and terrain data. Access to these data is facilitated by an index block of memory defined in section 3.3.1.

3.3.1 Index Block

The index block shown in table 3-1 defines the locations in bulk data memory for each category of data in each longitude strip. These categories are:

- Airfields
- Geographic reference points
- Navaids
- Terrain

The printers in each strip contain the memory address of the first data word in the buffer associated with each category of data.

3.3.2 Airways and Routes

VOR/DME defined airways, area navigation airways, and special predefined routes representative of airline company routes will be defined in a buffer as shown in table 3-2. This buffer is organized to define each airway or route as a list of pointers (addresses) to data in other buffers such as navaids or GRPs.

The buffer will be subdivided into three areas dedicated to·

- Routes
- J airways, including high-altitude R-nav airways
- V airways

3.3.3 SIDs, STARs, and MAPs

SIDs and STARs are identified by an alphanumeric designator of up to six characters. They are stored in the form of four-dimensional paths in space. The buffer will have provisions to store latitude, longitude, altitude, and speed for each reference point on the path.

To facilitate access to the data, the buffer is preceded by SID and STAR index blocks organized as shown in table 3-3. The SID/STAR buffer organization is shown in table 3-4.

Missed approach paths (MAPs) are stored in the same buffer and use the same format as that for SIDs and STARs. The MAP buffer is accessed through the pointer in the runway data buffer (see table 3-6).

3.3.4 Airfields

The airfield data buffer will include airfield, runway, outer marker, and frequency data. Potential origin or departure airfields (category 1) are distinguished from airfields for map display only (category 2) by having no terminator = 0 following the ATIS frequency. The buffer is preceded by an index block (defined in table 3-1) for each longitude strip.

The category 2 airfield format is shown in table 3-5; the category 1 airfield format is shown in table 3-6.

3.3.5 Geographic Reference Points

All nonradiating geographic positions used for navigation and guidance purposes are collectively called GRPs in this document. Included in the GRP category are airway intersections, named waypoints in the VOR/DME route structure, and named waypoints in the area navigation route structure.

GRPs are usually identified by a five-letter code derived from their geographic name. The GRP buffer format is shown in table 3-7. The buffer is preceded by an index block as defined in table 3-1 for each longitude strip.

3.3.6 Navaids

The navaids buffer will store the pertinent data for all en route and terminal area radiating navigation aids except for ILS and runway marker beacons. The navaids buffer contains:

- VORTACs
- VORs
- Nondirectional radio beacons (NDBs)

The buffer format is defined in table 3-8. The buffer is preceded by an index block as defined in table 3-1 for each longitude strip.

3.3.7 Terrain

The terrain buffer is defined in table 3-9. The buffer includes two categories of data:

- Mountains
- Obstructions

The buffer is preceded by an index block as defined in table 3-1 for each longitude strip.

3.3.8 Terminal Data

The terminal data buffer format is defined in table 3-10. This buffer is used to store GRP and obstruction data associated with each category 1 airfield. These data will be called up for display on the MFD map displaying the origin and destination airport only. The data stored in this buffer are not repeated in the terrain buffer (see sec. 3.3.7).

3.3.9 Missed Approach Entry Points

The MAP buffer stores the latitude and longitude of the MAP locations for each runway defined in the category 1 airfield data (table 3-6). The MAP route is stored in the SID/STAR/MAP buffer (table 3-4), which points to a location in the MAP entry point buffer for the latitude and longitude of the entry waypoint for guidance and display on the MFD as defined in section 2.4.1.7.3.6. See table 3-11 for definition of MAP entry point buffer.

3.3.10 Boundaries

The boundary data buffer defines the CADIZ, ADIZ, and FIR boundaries as shown in table 3-12. The data are used for MFD map display only.

3.3.11 Latitude and Longitude Oceanic Grid

The latitude and longitude grid is required for the MFD map display over the oceans up to the ADIZ boundaries defined in section 2.4.1.7.7. No data buffer is required other than that contained in the ADIZ buffer (table 3-12).

3.4 ACCESS TO BULK DATA

Figure 3-1 illustrates the flow of data from bulk storage to the NCDU, guidance, and MFD display subroutines. All major data buffers are shown in figure 3-1 and are further defined in this document as follows:

NCDU	Provisional flight plan buffer (table 6-3)
NCDU	Look-up mode data buffer (table 6-6)
Guidance	Data buffers (table 5-1)
NCDU	Origin/destination data buffer (table 6-4)
NCDU	Pilot-created waypoint data buffer (table 6-5)

As shown in figure 3-1, both the NCDU and MFD subroutines have direct access to bulk data memory. The MFD direct access is to extract background data for the geographic area of the MFD map display. NCDU access is for generation of flight plans from keyboard entry (in the ATC CLR (ATC clearance) mode as defined in section 6.5.2) and for display of bulk data in the look-up mode as defined in section 6.5.6. The guidance subroutine obtains data from bulk storage via the NCDU subroutine.

3.4.1 Access Via Longitude Index

Figure 3-2 illustrates the method of access to the bulk data memory for MFD background data (airports, GRPs, navaids, and terrain features). Based on map center coordinates (LATCEN and LONCEN) and the map scale selected, the MFD subroutine checks the index block longitude limits to determine if data from that longitude strip are within the map edit area. Pointers locate the starting addresses within the longitude strip for each category, i.e., airports, GRPs, navaids, and terrain. Depending on the MFD display options selected (see sec. 2.3), the MFD subroutine extracts the data it requires from each longitude strip that overlaps the map edit area.

3.4.2 Access Via NCDU

Keys on the NCDU (see fig. 6-1) allow selection of waypoints (WPT), airways (AWY), routes (RTE), SIDs, STARs, and runways (RWY). Different coding allows selection of airports, navaids, or GRPs through the WPT key.

Figure 3-3 illustrates the method of access to the waypoints that comprise V airways, J airways, or routes. Each airway or route is stored as a series of pointers to navaid and GRP addresses within the memory that stores the longitude strip data.

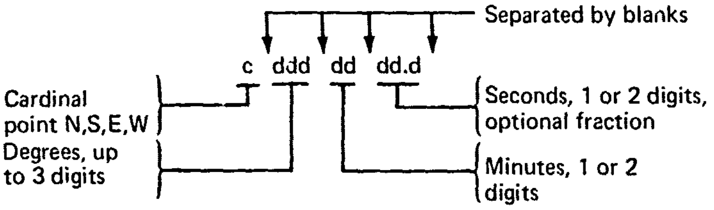
Figure 3-4 illustrates the access to airport-associated data including runways, SIDs, STARs, MAPs, and terminal area background data for the MFD map display. Once the origin and destination have been defined through the NCDU keyboard, the airport data for category I airports (see table 3-6) is extracted from the bulk data memory after a name search. The airport data block includes pointers to indices of SIDs, STARs, and MAPs associated with that airport, and a pointer to the terminal data block. Runway data are stored directly after the pointers.

After the runway has been selected on the NCDU, the runway data are found by name search within the airport data block. Associated with each runway is a pointer to the missed approach path (MAP) for that runway. When a SID or STAR is entered through the NCDU, a name search is made through the SID and STAR indexes associated with the airport previously selected.

3.5 BULK DATA FORMATTING

This section defines the methods and procedures to be used for the formatting of bulk data for assembly into the C-4000 and EAI 8400 computers. General rules are:

1. Each latitude and longitude has the format:



2. Each card is divided into fields separated by commas.

3. For compatibility between IBM 360 character codes (EBCDIC) and EAI 8400 codes (BCD), a restricted character set should be used:

Letters:	A through Z
Digits:	0 through 9
Others:	. (period)
	, (comma)
	- (minus sign)
	/ (slash)
	* (asterisk)
	$ (dollar sign)
	; (semicolon)

All other characters (in particular, + = ( ) < > [ ] : Δ \ ǂ ‡ ⧻) are incompatible and would have to be converted.

4. Five types of input cards are available to the formatter:

   - *ID cards* contain a label that is passed on to the assembler in the label field of the first data word generated. A fixed word on the ID card (e.g., INDEX, SID, NAVAID, etc.) informs the formatter what type of data are to follow.
   - *Data cards* generate DATA cards for the EAI 8400 or GEN cards for the C-4000 assemblers. The source information from the data cards will be placed in the comment field of the corresponding generated assembler cards.
   - *Terminator cards* contain a period in column 1 to inform the formatter of the end of a particular class of data. The formatter also generates the appropriate terminator card(s) for the data buffer being constructed at this point.
   - *In-line assembly cards* contain a slash (/) character in column 1; this character is removed by the formatter, and the remainder is passed unchanged to the output.
   - *Comment cards* contain * in column 1.

5. Braces { } define optional items.

6. The entire package of bulk data is terminated by a card with the form: END.

7. Names cannot contain embedded blanks, commas or periods.

8. OPTION $\left\{\begin{matrix}8400\\4000\end{matrix}\right\}, \left\{\begin{matrix}1\\2\end{matrix}\right\}, \left\{\begin{matrix}\ \\10\end{matrix}\right\}$

where:	8400	designates machine output
	or	
	4000	is generated for:
	1	phase 1 listing of source cards
	2	phase 2 listing of output cards
	10	Fortran unit number for output

3.5.1 Index Block

The index block is the directory to the bulk data and is preceded by an ID card of the form:

INDEX label

The label is passed to the assembler in the label field of the first data word generated. The bulk data are subdivided into strips, with each strip defined by a card of the form:

longitude 1, longitude 2, name 1, name 2, name 3, name 4

where:

longitude 1 = strip west boundary
longitude 2 = strip east boundary
name 1 = label of an AIRFIELD card
name 2 = label of a GRP card
name 3 = label of a NAVAID card
name 4 = label of a MOBS card

The index block is terminated by a card with a period in column 1.

3.5.2 Airways and Routes

Airway data are subdivided into three sections: J airways, V airways, and routes.

Jet airways are preceded by an ID card of the form:

JET label

followed by data cards of the form:

name 1, name 2, . . . , name n.

where:

name 1 = name of airway
name 2, . . . , name n = names of waypoints, including navaids or GRPs

The names may be spread over as many cards as necessary; the period follows the last name of the last card of a given airway. The JET subdivision is terminated by a terminator card (period in column 1).

Victor airways are similarly defined by:

VICTOR label
name 1, name 2, . . . , name n.

Airline company routes are similarly defined by:

ROUTE label
name 1, name 2, . . . , name n.

3.5.3 SIDs, STARs, and MAPs

The SID and STAR data for each airport have index tables. A SID index table is defined by:

SID label
name, name, . . . , name.

where the names are the names of SID data blocks.

A STAR index table is similarly defined by:

STAR label
name, name, . . . , name.

The SID, STAR, and MAP data are contained in a single buffer and each has the same form. Each begins with:

DATA label
name 1, name 2

where:

name 1 = name of SID, STAR, or MAP
name 2 = name of associated runway

Following the above header cards are waypoints, each defined by a card of the form:

$$\text{name, altitude, speed, radius} \left\{\begin{array}{l}\left\{\begin{array}{l}\text{DME bearing}\\ \text{Turn angle}\end{array}\right.\\ \text{IAS}\end{array}\right\}$$

where:

name = waypoint name
altitude = waypoint altitude (ft above MSL)
speed = groundspeed (kt)
radius = radius of turn at waypoint (ft)
bearing = a heading angle (deg)
turn angle = heading change to new path leg
IAS = change from groundspeed to IAS on approach

A SID/STAR/MAP block is terminated by a terminator card following the last waypoint in the block, and the entire buffer is terminated by a second terminator card.

3.5.4 Airfields

Each airfield begins with the ID card:

AIRFIELD label

Each airfield ID card is followed by three data cards:

name 1, lat, lon
length, azimuth, magvar, elevation, {name 2}
freq 1, freq 2, freq 3, freq 4

where:

name 1 = airfield name
lat, lon = airfield reference point location
length = length of principal runway (ft)
azimuth = heading of principal runway (deg)
magvar = magnetic variation (deg)
elevation = reference elevation (ft above MSL)
name 2 = name of terminal data block (optional—could be zero)
freq 1 = tower frequency (MHz)
freq 2 = clearance frequency (MHz)
freq 3 = ground control frequency (MHz)
freq 4 = ATIS frequency (MHz)

If runway data follow, an additional data card:

name 1, name 2

contains the names of SID and STAR index blocks, respectively. If the airfield data block is to contain no runway data, the above frequency card is followed by a terminator card. If runway data are to follow, an ID card is used for each runway:

RUNWAY label

with data for each runway as follows:

name 1, name 2
lat 1, lon 1, name 3, lat 2, lon 2
length, azimuth, elevation, glide slope, freq

where:

name 1 = runway identifier
name 2 = MAP name
lat 1, lon 2 = threshold location
name 3 = outer marker identifier
lat 2, lon 2 = outer marker location
length = runway effective length (ft)
azimuth = magnetic heading of runway (deg)
elevation = runway threshold elevation (ft above MSL)
glide slope = nominal glide slope angle (deg)
freq = ILS frequency (MHz)

Each runway data block and each airfield data block has a terminator. The airfield buffer also has a terminator.

3.5.5 Geographic Reference Points

The GRP table begins with the ID card:

GRP label

and each GRP is defined by a data card:

$$\text{name 1}, \left\{\begin{matrix} C \\ N \end{matrix}\right\}, \text{lat, lon, name 2}$$

where:

name 1 = GRP name
C = compulsory
N = noncompulsory
lat, lon = GRP location
name 2 = a navaid name

The buffer is terminated with a terminator card.

3.5.6 Navaids

The navaid table begins with the ID card:

NAVAID label

and each navaid is defined by a data card:

$$\text{name}, \left\{\begin{matrix} H & V & C \\ L & T & N \\ & O & \end{matrix}\right\}, \text{freq, lat, lon, magvar, elevation}$$

where:

name = navaid name
options:
  H = high
  L = low
  V = VOR
  T = VORTAC
  O = nondirectional beacon
  C = compulsory
  N = noncompulsory
freq = navaid frequency (MHz)
lat, lon = navaid location
magvar = magnetic variation (deg)
elevation = navaid elevation (ft above MSL)

The buffer is terminated with a terminator card.

3.5.7 Terrain

The terrain buffer, containing mountain and obstruction data, begins with the ID card:

MOBS label

and each terrain feature is defined by a data card.

name, $\begin{Bmatrix}M\\O\end{Bmatrix}$, latitude, longitude

where:

name = altitude of the mountain or obstruction (ft above MSL)
M = mountain
O = obstruction
lat, lon = location of mountain or obstruction

The buffer is terminated with a terminator card.

3.5.8 Terminal Data

To avoid MFD clutter due to symbol density, certain symbols are drawn in a geographic area only when the area is an origin or destination terminal area. These items are contained in a terminal data block.

A terminal data block begins with the ID card:

TERM label

and each item is defined by a data card:

name, $\begin{Bmatrix}GRP\\MOB\end{Bmatrix}$, latitude, longitude

where:

name = name of GRP or MOB
GRP = type of item
MOB = type of item
lat, lon = location of item

The terminal data block is terminated with a period in column 1.

3.5.9 Missed Approach Points

The MAP buffer begins with the ID card:

MAP label

and is followed by a data card for each point:

name, latitude, longitude

where:

name = a label for each point
lat, lon = location of each point

The buffer is terminated with a terminator card.

3.5.10 Boundaries

An index block for each category of data is begun with an ID card with one of three forms:

CADIZ label
ADIZ label
FIR label

Following an index block ID card are any number of box definition cards with the form:

lat 1, lat 2, lon 1, lon 2, name

where:

lat 1 = north boundary
lat 2 = south boundary
lon 1 = west boundary
lon 2 = east boundary
name = label of a POINT buffer

Each index block is terminated by a terminator card. Each box definition refers to a POINT buffer that is headed by an ID card with the form:

POINT label

The buffer contains points of the form

latitude, longitude

Each buffer is terminated by a terminator card.

3.6 BULK DATA FOR THE NORTHWEST U.S.

Data in the following categories will be stored in NCU memory bank 4 (locations 60,000 to 77,777 octal). In general, the data in each category are arranged in 2° longitude strips, tabulated in order of decreasing latitude.

Airways–low altitude
Airways–high altitude
Company routes
SIDs
STARs
MAPs
Airfields–category 2
Airfields–category 1
GRPs
Navaids
Mountains
Obstructions
ADIZ and FIR boundaries

The contents of the above memory block are tabulated in the NCU program listing.

TABLE 3-1.–INDEX BLOCK FOR LONGITUDE STRIPS

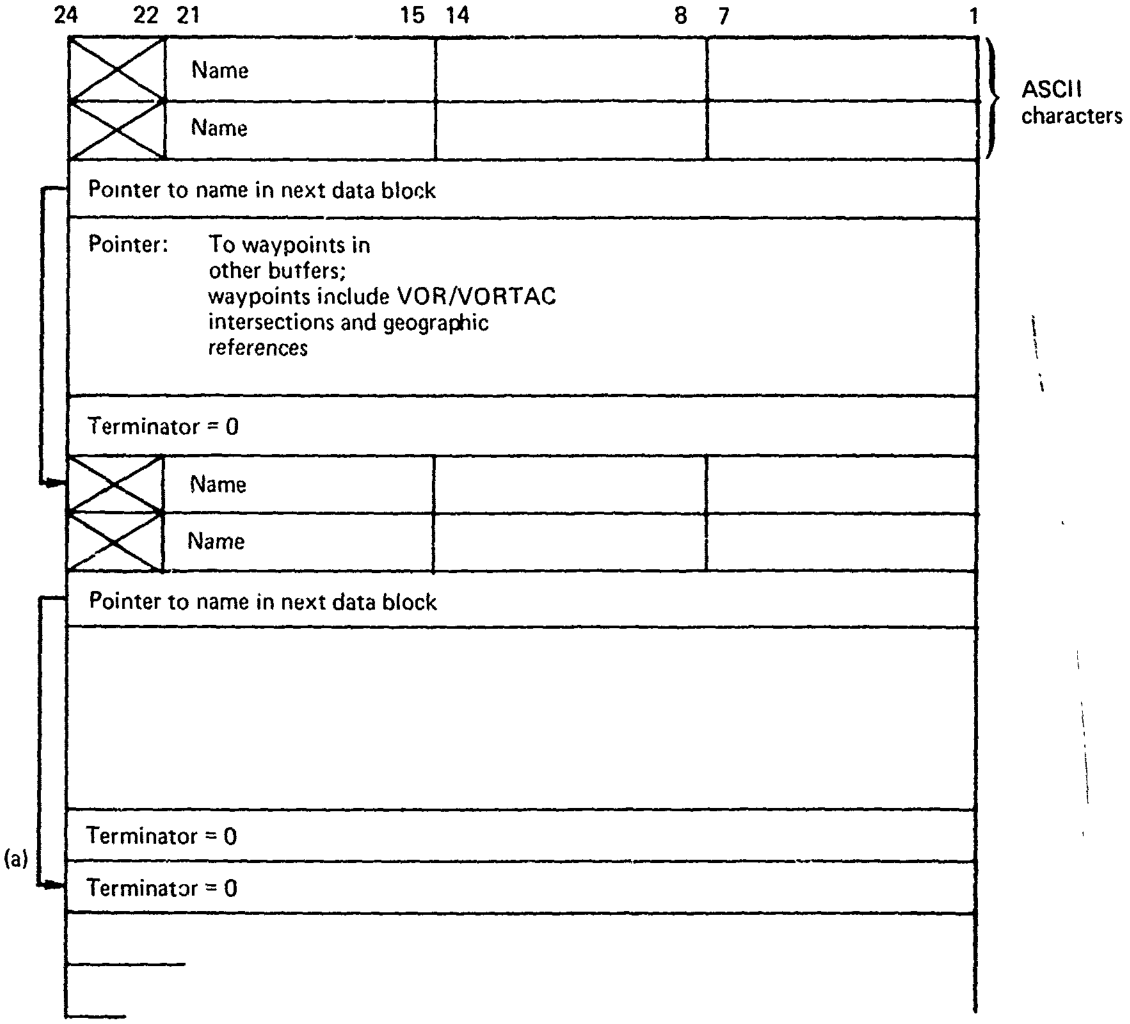
	West boundary longitude	°/180	B0	1st strip
	East boundary longitude	°/180	B0	
(a)	Pointer to airfields			
	Pointer to GRPs			
	Pointer to navaids			
	Pointer to terrain			
	West boundary longitude	°/180	B0	2nd strip
	East boundary longitude	°/180	B0	
(a)	Pointer to airfields			
	Pointer to GRPs			
	Pointer to navaids			
	Pointer to terrain			
	West boundary longitude	°/180	B0	Last strip
	East boundary longitude	°/180	B0	
(a)	Pointer to airfields			
	Pointer to GRPs			
	Pointer to navaids			
	Pointer to terrain			
(b)	Terminator (0)			Buffer terminator

Note: The first strip is geographically the westernmost strip.

[a] Pointer = 0 if no data in the strip

[b] There will be no zero longitude

TABLE 3-2.–AIRWAYS (AND ROUTES) INDEX BUFFER



[a] Two consecutive zero terminators indicates end of buffer.

TABLE 3-3.–SID AND STAR INDEX BLOCKS FOR EACH AIRPORT

SID Index Table

Pointer to SID name
Pointer to SID name
Pointer to SID name
Pointer to SID name
Pointer to SID name
Etc.
Terminator = 0

STAR Index Table

Pointer to STAR name
Pointer to STAR name
Pointer to STAR name
Etc.
Terminator = 0

TABLE 3-4.–SID/STAR/MAP DATA BUFFER

	24		1	
	Name			ASCII format
	Name			
	Pointer to name in next data block			
	Pointer to runway			
	Pointer to 1st waypoint this SID			
(a)	Altitude to 1st waypoint	ft	B23	
(b)	Speed to 1st waypoint	knots	B15	
	Radius of turn 1st waypoint	ft	B23	
	Bearing	°/360	B0	1st
	Pointer to 2nd waypoint	°/180	B0	SID or STAR
	Altitude			
	Speed	knots	B15	
	Radius of turn	ft	B23	
(c)	Bearing	c/360	B0	
	Pointer to 3rd waypoint			
	⋮			
	Terminator = 0			End of 1st SID
	Name			
	Name			
	Pointer to name in next data block			Last
	Pointer to runway			SID or STAR
	Pointer to 1st waypoint this SID/STAR			
	Terminator = 0			
(d)	Terminator = 0			End of last SID

[a] Negative altitude indicates this group defines the entry of an arc path segment.

[b] Negative speed indicates that IAS REF from NCDU should be used for display.

[c] Bearing of entry point from the reference point for an arc path segment; a second group defines the exit point

[d] Two consecutive zero terminators indicates end of buffer.

TABLE 3-5.–AIRFIELD BUFFER–CATEGORY 2 AIRFIELDS

	24			1	
		Name			ASCII character format: 7-bit characters
		Name			
	Latitude reference point		°/180	B0	
	Longitude reference point		°/180	B0	
	Pointer to name in next data block				
	Length of longest runway		ft	B23	
	Azimuth of longest runway (true)		°/180	B0	
	Magvar		°/180	B0	
	Elevation of reference point		ft	B23	
	Pointer to terminal data				
	Frequency–tower				2/5 code C-4000 format Bits 9-24
	Frequency–clearance				
	Frequency–ground control				
	Frequency–ATIS				
(a)	Terminator = 0				
	Terminator = 0				
(b)	Terminator = 0				

[a] There are no runways associated with the airfield symbol so the terminator = 0.

[b] Two consecutive zero terminators indicates end of buffer.

TABLE 3-6.–AIRFIELD BUFFER–CATEGORY 1 AIRFIELDS (WITH RUNWAY DATA)

	24		1	
	Name			ASCII character format
	Name			
	Latitude reference point	°/180	B0	
	Longitude reference point	°/180	B0	
	Pointer to name in next data block			
	Length of longest runway	ft	B23	
	Azimuth of longest runway (true)	°/180	B0	
	Magvar	°/180	B0	East positive
	Elevation of reference point	ft	B23	
	Pointer to terminal data			
	Frequency–tower			2/5 code C-4000 format Bits 9-24
	Frequency–clearance			
	Frequency–ground control			
(a)	Frequency–ATIS			
	SID index pointer			
	STAR index pointer			
	Name of runway			ASCII characters
	Pointer to missed approach			
	Latitude threshold	°/180	B0	
	Longitude threshold	°/180	B0	
	Name			Outer marker
	Name			
	Latitude outer marker	°/180	B0	1st runway
	Longitude outer marker	°/180	B0	
	Length	ft	B23	
	Azimuth	°/180	B0	
	Altitude	ft	B23	
	Glide slope angle	°/180	B0	
	Frequency–ILS			2/5 code, bits 9-24
	Etc.			2nd runway
(b)	Terminator = 0			
	Terminator = 0			

[a] Following frequency ATIS, test next word for terminator = 0. If no zero is detected, expect SID and STAR index and runway data to follow.

[b] Two consecutive zero terminators indicates end of buffer.

TABLE 3-7.—GEOGRAPHIC REFERENCE POINTS BUFFER

	24					1	
(a)	0		Name				1st data block
(b)	☒		Name		☒	0	
	Latitude				o/180	B0	
	Longitude				°/180	B0	
	Pointer to VORTAC/VOR for auto tuning						
	☒		Name				2nd data block
	☒		Name		☒		
	Latitude				°/180	B0	
	Longitude				°/180	B0	
	Pointer						
	Similar to above						Last data block this strip
	Terminator (end of data this strip) = 0						

[a]Bit 24:
0 = GRP
1 = navaid

[b]Bit 1:
1 = high-altitude GRP
0 = low-altitude GRP

TABLE 3-8.–NAVAIDS BUFFER

	24	4 3 2 1			
	1 ☒ Name			ASCII characters	1st data block
(a)	Frequency (2/5 code) 9				
	Latitude	°/180	B0		
	Longitude	°/180	B0		
	Magvar	°/180	B0	East positive	
	Elevation	ft	B23		
	Etc.				2nd data block
(b)	Terminator = 0				

[a] Bit 4:
1 = high
0 = low

Bits 2 and 3:
0 = VOR
1 = VORTAC
2 = NDB

[b] Terminator = 0 for end of buffer

TABLE 3-9.–TERRAIN BUFFER

<table>
<tr><td></td><td>24</td><td></td><td></td><td></td><td>1</td><td></td></tr>
<tr><td>(a)</td><td>0</td><td>☒</td><td>Altitude (10 thousands)</td><td>Altitude (thousands)</td><td>0</td><td rowspan="4">ASCII format</td></tr>
<tr><td></td><td colspan="3">0</td><td>0</td><td>☒</td></tr>
<tr><td></td><td colspan="5">Latitude</td></tr>
<tr><td></td><td colspan="5">Longitude</td></tr>
<tr><td>(a)</td><td>1</td><td>☒</td><td>Altitude (thousands)</td><td>Altitude (hundreds)</td><td>Altitude (tens)</td><td rowspan="4">ASCII format</td></tr>
<tr><td></td><td colspan="2">☒</td><td>Altitude (units)</td><td colspan="2">☒</td></tr>
<tr><td></td><td colspan="5">Latitude</td></tr>
<tr><td></td><td colspan="5">Longitude</td></tr>
<tr><td></td><td colspan="5"></td><td></td></tr>
<tr><td>(b)</td><td colspan="5">Terminator = 0</td><td></td></tr>
</table>

[a] Bit 24:
0 = mountains
1 = obstruction

[b] Terminator = 0 for end of buffer

TABLE 3-10.–TERMINAL DATA BUFFER

	24					
(a)	☒	Name	Name	Name	ASCII format	1st data block
	☒	Name				
	Latitude–GRP or obstruction or VORTAC °/180 B0					
	Longitude–GRP or obstruction or VORTAC °/180 B0					
(a)	☒				ASCII format	2nd data block
	☒					
	Latitude °/180 B0					
	Longitude °/180 B0					
(b)	Terminator = 0					Terminator

[a] Bit 24:
0 = GRP
1 = obstruction

[b] Terminator = 0 for end of buffer

TABLE 3-11.–MAP ENTRY POINT BUFFER

	0			Blank	Blank	Blank
				Blank	Blank	Blank
(a)	Latitude of MAP entry point 1				°/180	B0
	Longitude of MAP entry point 1				°/180	B0
	0			Blank	Blank	Blank
				Blank	Blank	Blank
	Latitude of MAP entry point 2				°/180	B0
	Longitude of MAP entry point 2				°/180	B0
(b)	Terminator = 0					

[a] Entry via pointer from table 3-4

[b] Terminator = 0 for end of buffer

TABLE 3-12.–ADIZ AND FIR BOUNDARIES

	CADIZ	ADIZ	FIR
Index	CAD	ADI	FIR
	IZ	Z	
	N lat °/180 B0	N lat °/180 B0	N lat °/180 B0
	S lat °/180 B0	S lat °/180 B0	S lat °/180 B0
	W lon °/180 B0	W lon °/180 B0	W lon °/180 B0
	E lon °/180 B0	E lon °/180 B0	E lon °/180 B0
	Pointer	Pointer	Pointer
Data	Lat °/180 B0	Lat °/180 B0	Lat °/180 B0
	Lon °/180 B0	Lon °/180 B0	Lon °/180 B0
	Lat °/180 B0	Lat °/180 B0	Lat °/180 B0
	Lon °/180 B0	Lon °/180 B0	Lon °/180 B0
	- - - -	- - - -	- - - -
	Lat °/180 B0	Lat °/180 B0	-
	Lon °/180 B0	Lon °/180 B0	-
	Terminator = 0	Terminator = 0	Lat °/180 B0
			Lon °/180 B0
			Terminator = 0

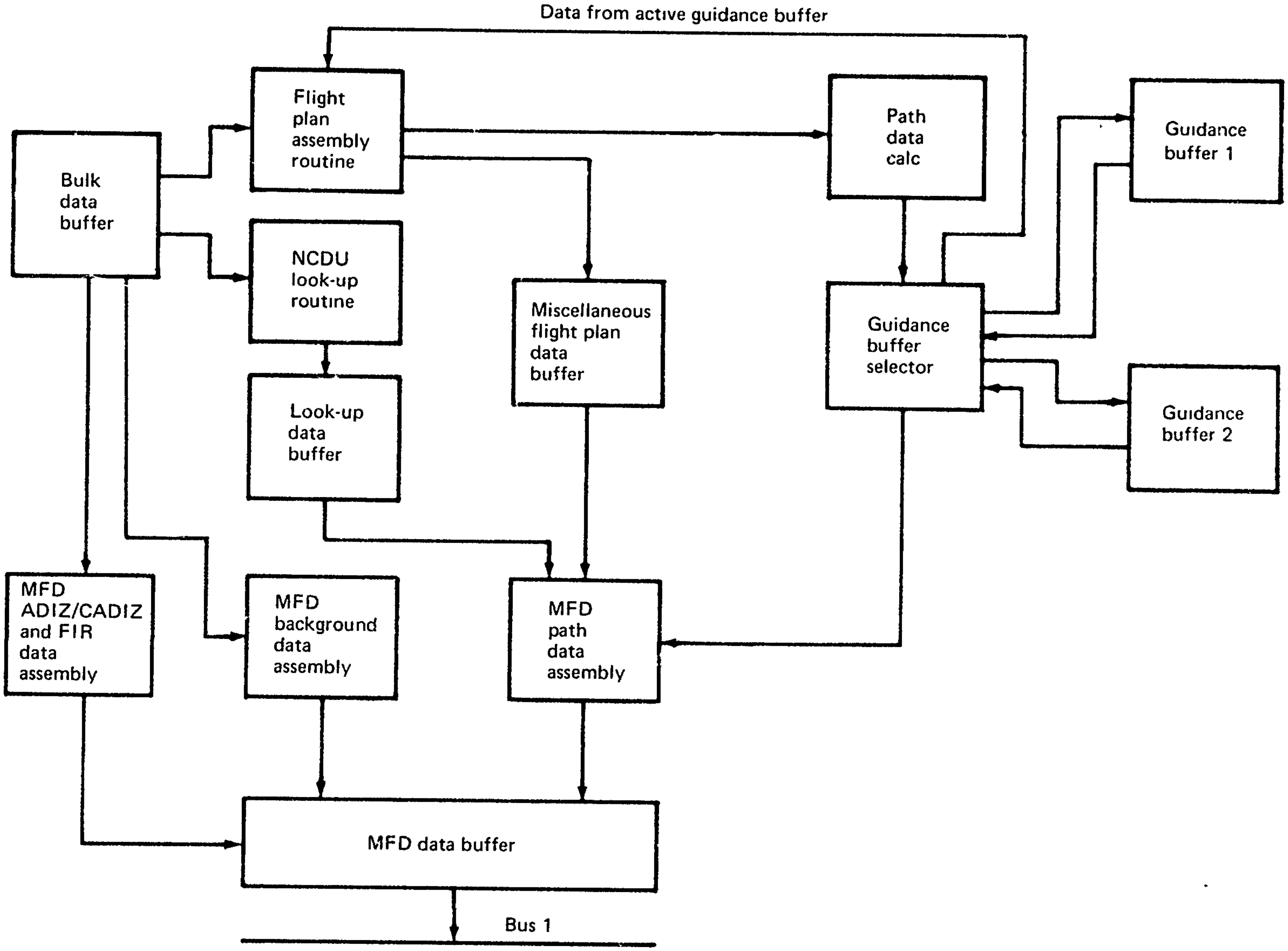


FIGURE 3-1.—BULK DATA FLOW

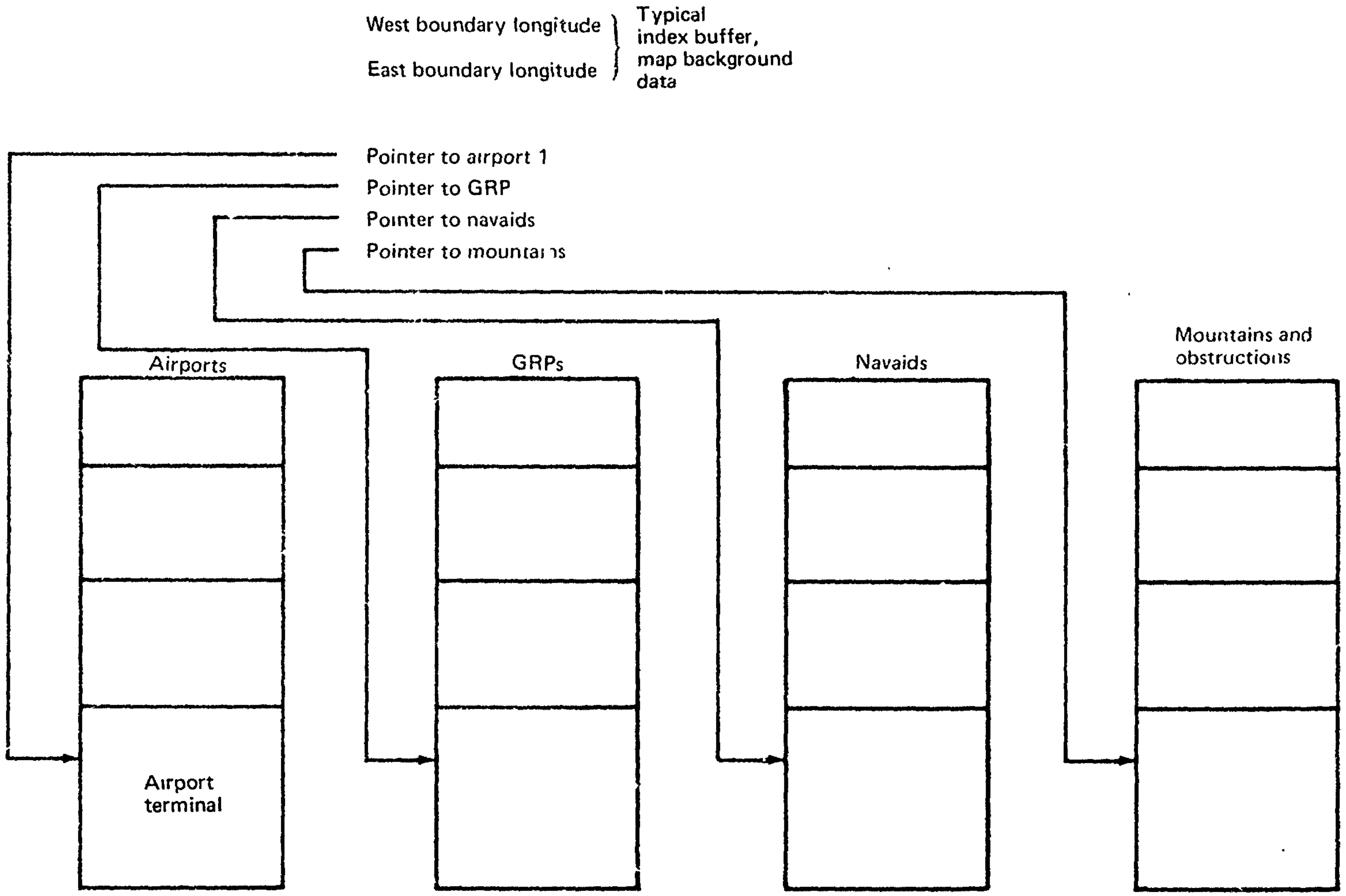


FIGURE 3-2.–BULK DATA ACCESS VIA LONGITUDE INDEX

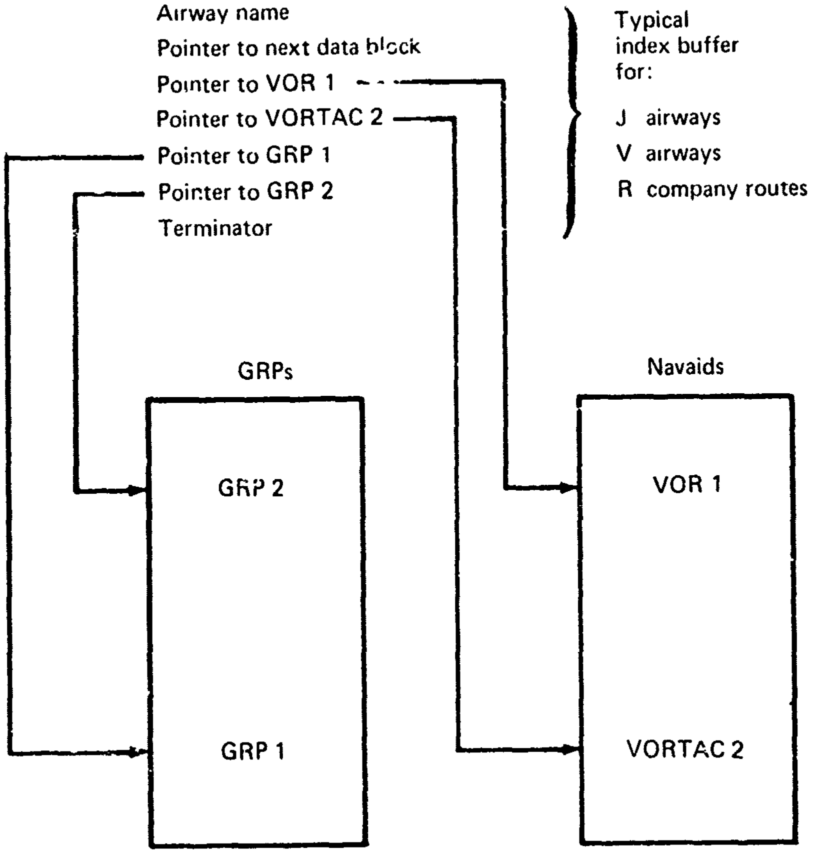


FIGURE 3-3.—BULK DATA ACCESS VIA AIRWAY

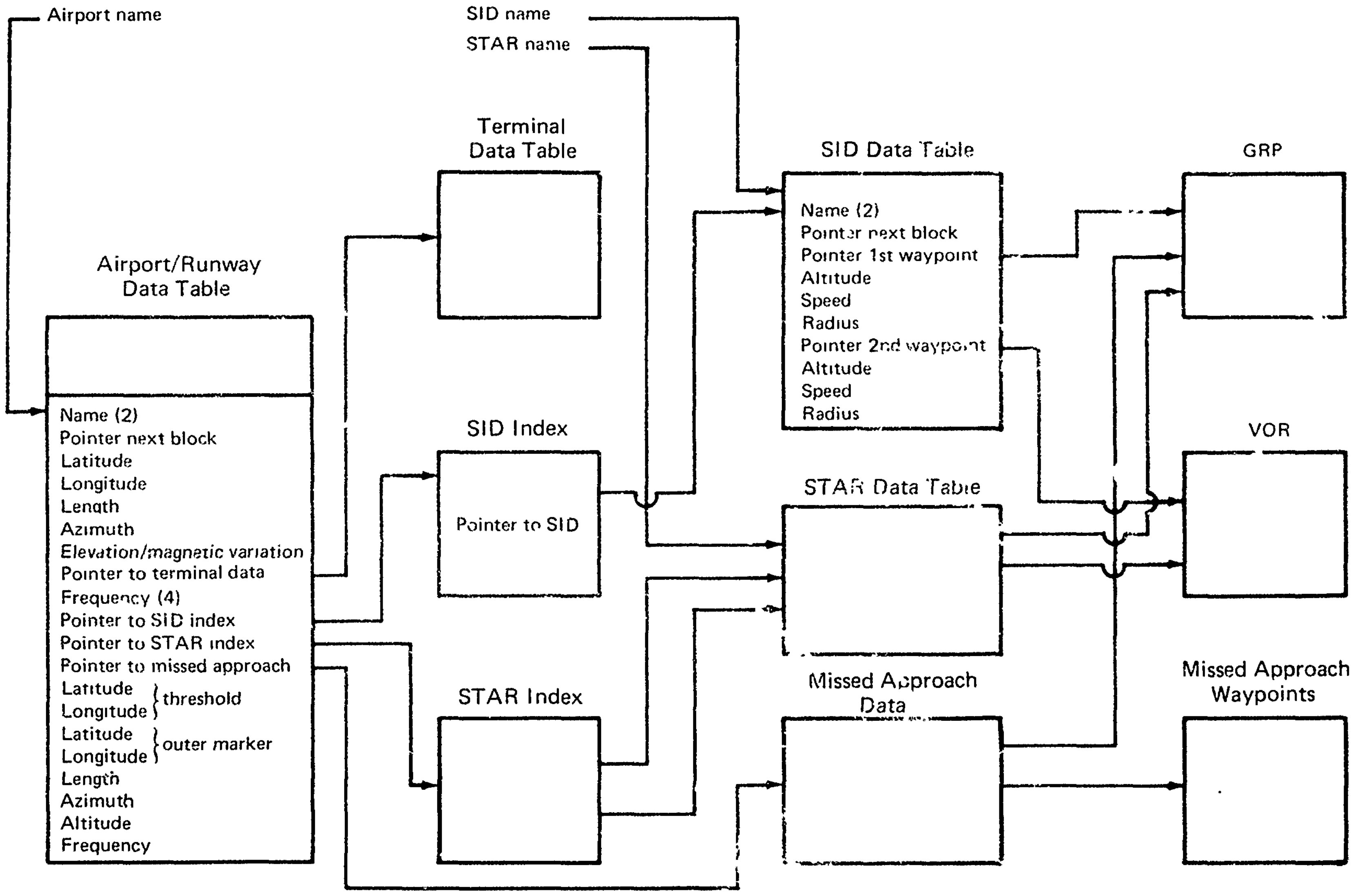


FIGURE 3-4.—BULK DATA ACCESS VIA AIRPORT

4.0 EADI REQUIREMENTS

4.1 GENERAL

The EADI is a replacement for the conventional ADI as the most primary display for the pilot. The EADI provides a head-down CRT type of display for vehicle attitude, vertical situation, flight director commands, energy management information, and navigation and control information based on signals received from navigation computer and sensor systems. The information displayed includes:

- Pitch attitude
- Roll angle
- Angle of attack
- TV imagery
- Velocity vector
    - Flightpath angle
    - Drift angle
- Pitch reference line
- Altitude
- Altitude reference
- Speed error
- Flightpath acceleration
- Flight director commands
- Vertical guidance
- Horizontal guidance
- Acceleration command

The EADI has a viewable area 6.68 in. wide and 4.88 in. high. Data presented on the display consists of two types: raster-generated symbology and stroke-generated symbology. Raster symbology is positioned on the screen scaled at 65 elements/in. horizontally and 87 elements/in. vertically. Stroke symbology is scaled at 146 bits/in. The display is refreshed 50 times/sec and dynamic data are updated 20 times/sec to give a flicker-free display presentation.

The EADI display formats are generated from data inputs from multiple sources, as shown in the ADEDS interface block diagram (fig. 1-1). Data inputs in the form of digital data from the NCU (navigation computer unit) and analog data from the airplane sensor system are processed in the PCU (program control unit) and transmitted to the HSG (hybrid symbol generator), which in turn drives the EADI display. The forward-looking TV is interfaced directly with the HSG. Details of the interface pertinent to the PCU and NCU software requirements are specified in section 4.2.

The data presented on the display vary as a function of mode and symbology option selected on the EADI mode control unit. Figure 4-1 shows the symbology available for display in the cruise mode, and figure 4-2 shows the symbology available for display in the land mode. Not all of this information is displayed simultaneously; some of it is pilot selectable ON or OFF as defined in section 4.3.

4.2 INTERFACE FOR THE EADI

4.2.1 Analog Inputs

The analog inputs defined in table 4-1 will be accepted by the PCU and converted into digital formats to position the symbology described in section 4.4.

4.2.2 NCU/PCU Interface for the EADI

4.2.2.1 Electrical Interface

One of the three split-phase bipolar (SPBP) 100-kHz clock data buses from the NCU to PCU is dedicated to EADI functions and henceforth in this document is referred to as the EADI bus. In addition, the SPBP 100-kHz PCU/NCU bus (see sec. 2.2.1) is used to transmit modes and symbology options selected on the EADI mode control unit.

The NCU will transmit 64 words of data 20 times/sec over the EADI bus as defined in table 4-2. The PCU will transmit three words of data to the NCU upon change of status and two words to the EADI mode control panel. Transmission will be at the rate of 5 times/sec over the PCU/NCU bus as defined in table 2-4.

4.2.2.2 EADI Bus Word Formats

The data transmitted over the EADI bus are shown in table 4-2. They consist of two types: general-function data, which are recognized by eight-bit label coding, and table data, which are preceded by an I&R control word. General-function word formats are defined in figure 4-3. Table data word formats are identical to those given in figure 2-1 (control words), figure 2-2 (symbol words), and figure 2-3 (vector words).

The NCU will assemble and transmit the EADI bus data in accordance with the EADI control word defined in section 4.2.2.3. Each label-coded general function will have the designation matrix (DM) set to invalid if that function is selected OFF or if the input data used to generate that function are detected as invalid by the NCU. When table symbology is selected OFF in the EADI mode word, the data defining that symbology are deleted from the table data transmitted. The EADI mode word received from the PCU is transmitted back to the PCU, with label 01001001 in the EADI bus transmission.

4.2.2.3 PCU/NCU–EADI Mode Word Format

The transmission order for the PCU/NCU bus is defined in table 2-4. As shown, the first word with label code 00000000 is the EADI mode control word. The definition of the EADI mode control word is shown in figure 4-4.

The NCU will adjust the data transmitted over the EADI bus in accordance with each EADI mode word received that has valid parity, except for the test mode, which will be ignored by the NCU. The NCU will continue to send data corresponding to the previous EADI mode word received.

4.2.2.4 Interface Failure Protection

Both the NCU and the PCU will transmit all words with odd parity and will check for odd parity in each word received.

The NCU will not act on any EADI mode word received that has bad parity.

The PCU will check parity of the data received over the EADI bus. If a parity error is detected in any of the first nine label-coded words, the data in that word will not be used. If a parity error is detected in the I&R control word with label 01001001 or any subsequent table data, the whole table will be discarded. If a parity error obscures the first label 01000000, the PCU will not accept any EADI data until a label 01000000 is detected. In all cases, the previous good data received will be used to generate symbology. After 20 successive EADI data blocks with one or more bad parity checks, bit 30 (P_1) of the EADI mode word will be set to 1 and maintained at 1 until 20 successive EADI data blocks have been received with no parity errors.

The NCU will respond to EADI bus parity failure by annunciation of the NCDU as defined in section 6.0. This mechanization is desirable initially for troubleshooting. Later in the program, it will be desirable to modify the display system software to cause the EADI display symbology generated from digital data to blank out if no parity error-free data are received over the EADI bus for a defined period of time.

The NCU will set the DM to invalid in general-function words whenever the EADI display option demands it, as defined in section 4.2.2.3, or whenever the input data to the NCU used to generate the display data are invalid. The NCU will determine validity by checking the sensor valid flag and checking the input data for reasonableness.

The PCU will check all digital data received on the EADI bus for valid DM and will monitor the valid flags of all direct analog inputs. Any data detected as invalid (DM = 11 or low valid discrete) by the PCU will blank the associated symbology *except* the roll and pitch input from the INS. When the INS flag is detected as invalid, roll and pitch data will continue to be used but a diagonal cross will be drawn across the display, as shown in figure 4-5.

4.2.2.5 Interface Timing

The timing of the EADI bus data transmission is identical to that defined in section 2.2.4 and shown in figure 2-6.

4.3 EADI MODE CONTROL

EADI mode and symbology shall be selected with the EADI mode control unit (MCU) shown in figure 4-6. Data displayed on the EADI will also be controlled through the navigation control display unit (NCDU) as specified in section 6.0, through the system control unit (SCU) as specified below, and through the MFD mode control unit as specified in table 2-5. The mode and symbology selections defined in table 4-3 are encoded in the PCU and transmitted to the NCU via the PCU/NCU bus. The mode word encoding is defined in figure 4-4.

The NCU will interpret the EADI mode word, process the data necessary for the particular mode and symbology options selected, and transmit the data to the PCU over the EADI bus as defined in section 4.2. The NCU shall ignore the TV code since that function is contained entirely within the display system.

The NCU will transmit an invalid code in the designation matrix of all symbology, except TV, which is selected OFF. TV will be deleted by an inhibit function within the display system.

The display system shall respond directly to the selection of the test mode and draw the predefined test pattern on the EADI display, overriding the data transmitted from the NCU. (The format for this EADI test pattern is shown in fig. 4-16.) The delay between change of mode or symbology selection on the EADI mode panel and the appearance of the corresponding EADI display format shall not exceed 2 sec.

When the SCU is connected to the display system, the PCU will have the additional capability to ON/OFF control any symbology defined as general-function label-coded data. This control is independent of the NCU. The symbology controlled by the SCU valid/erase switches is defined in section 4.7.

4.4 EADI SYMBOLOGY

4.4.1 General

The EADI will have two basic modes, cruise and land, as shown in figures 4-1 and 4-2. Within each of these modes, the pilot will have the option of selecting various symbology combinations, as described in section 4.3.

The PCU will transmit the EADI mode control word to the NCU upon change of status and will generate the display in accordance with the data and control instructions received from the NCU over the EADI data bus, as well as from direct analog data to the PCU. The data received from the NCU fall into two general categories: 1) table data, consisting of symbol, vector, and control word groups (see figs. 2-1, -2, and -3), and 2) general-function data identified by label (see fig. 4-3).

The display system (DS) generates the symbology for category 1 directly in accordance with the instructions contained in the word formats. The PCU processes category 2 data, which are generally in the form of parameter value data, and generates appropriate symbology in accordance with the PCU stored program. Analog inputs are converted to digital form in the PCU and processed as general-function data (category 2).

The computation rates required for data computed in the NCU and PCU are summarized in table 4-4. The NCU will monitor the symbology option, bits 17 through 23, in the EADI mode word (fig. 4-4) to determine what symbology data to compute and transmit to the PCU. The PCU will bias the data received from the NCU to the appropriate reference point (0,0) as shown in figure 4-7, and will pitch and roll the data about that point.

The EADI symbology repertoire shall consist of all symbols and vectors defined for the MFD plus the symbology given in table 4-5. The polarity of each EADI symbol is defined in figure 4-8. The nomenclature used to define the required computations is shown in table 4-6.

4.4.2 Reference Airplane

The reference airplane symbol is shown in table 2-5. As specified in figure 4-7, two preprogrammed locations for the reference airplane symbol shall be provided:

- Screen center
- 1.2 in. (104 elements) above screen center (upper position)

The reference airplane symbol itself shall maintain a fixed horizontal orientation–it shall not roll. However, the reference point of the airplane symbol shall be the center of rotation for all rolled symbology except the roll pointer. Symbology will be positioned relative to this reference point with or without an offset bias, $\Delta\theta$, added. Initially, $\Delta\theta$ will be zero ($\Delta\theta$ = PITCHB).

Aircraft pitch attitude shall be indicated by the location of the reference airplane symbol relative to the pitch attitude scale when no $\Delta\theta$ is added. If offset bias is added, the airplane pitch attitude θ will be displaced appropriately.

The airplane symbol position shall be generated within the DS as a function of the mode selected. The upper position will be used initially for both modes. The screen center position will be selectable through keyboard entries on the SCU to modify the PCU software.

No data are required from the NCU for generating or positioning this symbol.

The airplane symbol shall be raster generated as specified in table 4-5. The symbol shall be shaded white (11111) and have priority level 1.

The center square of the reference airplane symbol shall be mechanized to flash from white (11111) to black (00000) at approximately 1-sec intervals (0.5 sec white, 0.5 sec black) whenever the indicated radio altitude is below the radio altitude reference height set on the control panel. This function shall be totally mechanized within the display system.

4.4.3 Artificial Horizon

The artificial horizon symbol shall be in the form of sky/ground shading across the full width of the display, with a sharp boundary delineated by a double, solid stroke-written line. The horizon symbol shall pitch about the airplane symbol as a function of

$$(\theta + \Delta\theta)$$

where:

θ = pitch input

$\Delta\theta$ = offset bias defined in section 4.4.2

The horizon symbol will roll about the airplane symbol reference point in response to roll inputs.

The PCU shall add the bias ($\Delta\theta$), when applicable as defined above, to the pitch signal (θ) received from the INS, scale the pitch and roll data; and then position the artificial horizon accordingly. The PCU shall limit movement of the artificial horizon in pitch to within 0.60 in. of the edge of the display for all roll angles.

The sky shading shall be raster generated and shaded very light gray (101), with a priority level of 36. Ground shading shall also be raster generated; shading shall be gray (01) and the priority level will be 37.

A double, solid stroke-written line, vector code 1101000, with line intensity (I_V) set to 10 shall be used to delineate the horizon.

No data are required from the NCU for generating or positioning this symbology.

4.4.4 Pitch Attitude Scale

The pitch attitude scale shall be in the form of stroke-written lines across the entire width of the display at increments of 10° to ±90°, and intermediate lines 0.50 in. long at 2° increments between ±30°, as specified in table 4-5. The 2° increments shall be arranged in two columns symmetrically located about the vertical centerline of the display.

Solid stroke-written lines, vector code 1100000, with line intensity (I_V) set to 10 shall be used to generate the 10° pitch lines. Solid stroke-written lines shall also be used to generate the 2° pitch line; however, I_V shall be set to 01.

The 10° lines, except for the 0° pitch line, shall be annotated with two-digit numerics 0.233 in. high (SS = 01), with symbol intensity (I_S) set to 10. The 10° lines shall extend across the full width of the display, even when in a rolled orientation.

The tape generator routine mechanized within the display system shall be used to generate the pitch attitude scale. The pitch tape shall be scaled at 0.17 in./deg. Variable-pitch scale sensitivity from 0.04 to 0.32 in./deg shall be provided; provisions for dual-mode pitch sensitivity operation, i.e., pitch sensitivity programmed as a function of the EADI mode, shall also be made Although these provisions will not be mechanized initially, they will be possible through PCU software modification.

The PCU shall use pitch attitude ($\theta + \Delta\theta$) to translate the scale vertically and roll attitude (ϕ) to rotate the scale. Translation and rotation shall both occur about the reference airplane symbol's location.

No data are required from the NCU for generating or positioning this symbology.

4.4.5 Pitch Reference Line

The pitch reference symbol shall consist of a dashed line drawn across the entire width of the display except for a 0.5-in. gap that coincides laterally with the gap in the flightpath angle symbol specified in table 4-5. Note that this requires the gap to move laterally as a function of drift angle.

A long, dashed, double stroke-written line, modulated as vector code 1101100, with line intensity (I_V) set to 10 shall be used for this symbol. The symbol shall be drawn as follows:

- From screen center + drift angle + 0.25 in. to the right
- From screen center + drift angle - 0.25 in. to the left

The pitch reference line shall pitch and roll about the reference airplane symbol in response to the two attitude inputs in the same manner as the pitch scale.

The symbol shall be positioned relative to the horizon by either the NCU (automatic) or a pilot-selected control knob on the EADI mode control unit (manual). Whether the reference line is automatically or manually positioned shall be a function of a switch on the EADI mode control unit. The A/M bit (bit 13) in the EADI mode word shall be set to 0 for the manual mode and to 1 for the automatic mode.

4.4.5.1 Manual Mode (MAN)

In the manual mode, the position of the line shall be controlled entirely within the display system. The PCU shall scale the output of the pitch reference potentiometer on the EADI mode control unit, generate the symbol, position it accordingly, and backdrive the LED pitch reference readout.

The NCU shall set the DM in word label 01000011 to invalid (11) when the MAN code is detected in the EADI mode word (see fig. 4-4).

4.4.5.2 Automatic Mode (AUTO)

In the automatic mode, the NCU shall compute 20 times/sec and transmit to the PCU the unscaled position of the line on label 01000011, as specified in figure 4-3. When the flag PSTFPA or FPASEL is set, the NCU will use the function HLDFPA for transmission to the PCU with label 01000011. When PSTFPA and FPASEL are not set, the NCU will set the designation matrix to invalid.

The PCU shall scale the output, position the line relative to the horizon, and backdrive the LED pitch reference readout accordingly.

4.4.6 Roll Pointer and Scale

Airplane roll attitude shall be indicated by a pointer referenced to a series of 10° bank angle indices. The roll pointer shall be a stroke-written rectangular symbol, as shown in table 4-5, that rotates about the center of the screen, regardless of location of the reference airplane symbol, in response to roll inputs. The roll pointer symbol's intensity (I_S) shall be 11.

The bank angle graduations shall be raster generated, with indices of 0°, ±10°, ±20°, ±30°, and ±45° as specified in table 4-5. These indices shall be shaded black (00000) and have priority levels 00001 through 01001.

No data are required from the NCU for generating or positioning this symbol.

4.4.7 Flightpath Angle

Flightpath angle shall be displayed in the form of two stroke-written, wedge-shaped symbols located symmetrically about a vertical line through the center of the reference airplane symbol (see table 4-5). The flightpath angle symbol's intensity (I_S) shall be 11.

The flightpath angle symbol shall be mechanized to remain parallel to the artificial horizon during aircraft attitude changes. It shall be displaced at right angles to the horizon as a function of the airplane's flightpath angle and laterally parallel to the horizon line as a function of the airplane's drift angle, with the same angular scale factor as in pitch.

The NCU shall compute flightpath angle 20 times/sec and drift angle 5 times/sec as specified below:

$$\text{FPA} = f_1 \left(\frac{\text{HDOT}}{\text{VGS}}\right)\left(\frac{57.3}{180}\right) \quad \text{(deg)}$$

$$\text{DA} = \text{TK - HDG} \quad \text{(deg)}$$

where f_1 is a filter that will initially be set to unity.

The NCU shall then transmit the flightpath angle data to the PCU on label 01000000 and drift angle on label 01000010, as specified in figure 4-3, at a rate of 20 times/sec.

The DS shall scale the data received from the NCU, and generate and position the symbol relative to the horizon.

4.4.8 Flightpath Acceleration

Flightpath acceleration shall be displayed in the form of a stroke-written rectangle located immediately to the left of the flightpath angle symbol, as shown in table 4-5. The flightpath acceleration symbol will blink on and off 2 times/sec when the airplane IAS is less than the IAS reference speed set through the NCDU (IASREF) or greater than a stored value of maximum airspeed (IASMAX). The flightpath acceleration symbol's intensity (I_S) shall be 11. The symbol's orientation shall remain parallel to the artificial horizon during aircraft attitude changes.

The symbol shall be displaced with respect to the flightpath angle symbol by a signal proportional to the acceleration of the airplane along its flightpath, i.e.,

$$\mathrm{FPAC} = f_3\left(\frac{\mathrm{VGSDOT}}{g}\right)\left(\frac{57.3}{180}\right) \qquad \text{(deg)}$$

where f_3 is a filter that will initially be set to unity.

The NCU shall compute flightpath acceleration 20 times/sec as specified above, scale it at 57.3°/g (such that 1-g acceleration along the flightpath corresponds to 57.3° displacement from the flightpath angle symbol), sum this quantity with flightpath angle, and transmit the sum (FPA + FPAC) to the PCU on label 01000001, as specified in figure 4-3. When $\mathrm{IASMAX} \leqslant \mathrm{IAS} \leqslant \mathrm{IASREF}$, the NCU will set the DM to be repetitively invalid for 250 msec, valid for 250 msec.

The DS shall scale these data to display coordinates, and generate and position the symbology relative to the horizon.

4.4.9 Acceleration Command

Command acceleration for the four-dimensional guidance situation shall be displayed in the form of a dashed, rather than solid, stroke-written rectangle that is identical in shape and movement to the flightpath acceleration symbol. The symbol shall be constructed of dashes, as specified in table 4-5. The symbol's intensity (I_S) shall be 10.

The symbol shall be displaced with respect to the flightpath angle symbol by a signal, γ_{PC}, proportional to the acceleration required to capture and maintain an assigned time slot.

When a 4D flight plan has been entered (i.e., GUID4D flag is set in the guidance subroutine), *and* the airplane is not on an IASREF speed leg (see below), acceleration command γ_{PC} will be computed as follows:

$$\mathrm{GAMPC}\ (\gamma_{PC}) = \mathrm{FPAPC} + \mathrm{FPA}$$

where $\mathrm{FPAPC} = \left(\frac{\mathrm{SCMD}}{g}\right)\left(\frac{57.3}{180}\right)\text{(deg)}$

When bit 22 is set to 1 in the FROM waypoint data in the guidance buffer memory as defined in table 5-1, the airplane is on an IASREF speed leg, and γ_{PC} will be computed as follows:

$$\gamma_{PC} = \frac{0.23}{180}(\mathrm{IAS} - \mathrm{IASREF}) + \mathrm{FPA}$$

where IASREF is set by the NCDU subroutine to the value entered through the NCDU. If no value has been entered through the NCDU, IASREF is set to the speed defined in the guidance data buffer (table 5-1) for the FROM approach waypoint. Under any other conditions, IASREF will be set to zero by the NCDU subroutine. When GUID4D is not set, the airplane is not on an IASREF speed leg, γ_{PC} is not computed, and the DM is set to invalid by the NCU.

The NCU shall compute GAMPC γ_{PC} 20 times/sec as specified above, scaled at degrees/180 B0, and transmit it to the PCU on label 01001000.

The acceleration command shall be switched ON/OFF by the T-NAV switch on the MFD mode control unit, except when the aircraft is on final approach. When T-NAV is selected OFF, the NCU will set the DM to invalid (11). The NCU shall change the DM to valid (symbol switched ON) when the aircraft passes the final approach fix waypoint, which is identified by bit 22 in the guidance buffer (fig. 5-1). This indicates an IASREF leg, i.e., the acceleration command symbol is driven by the difference between indicated airspeed and the reference airspeed.

The PCU shall scale the data to display coordinates, as well as generate and position the symbology relative to the horizon.

4.4.10 Speed Error Bar

Speed error shall be displayed in the form of a bar whose length is proportional to the speed error input. The bar shall be 0.187 in. wide and shall vary in length from 0.125 in. (located symmetrically about the left wing of the reference airplane) to a maximum of 1.5 in. above (+20 kt) and 2.25 in. below (-30 kt) the reference airplane symbol. The vertical centerline of the bar shall be located 1.24 in. left of the display vertical centerline as specified in table 4-5.

The speed error bar shall be raster generated. The bar shall be shaded black (00000) with priority 01100.

The NCU shall compute DELV (ΔV) 20 times/sec as follows:

DELV	=	IAS - HLDIAS	when IASSEL flag is set
DELV	=	IAS - IASREF	when on an IASREF speed leg as defined in section 4.4.9 and IASSEL is not set
DELV	=	SPDE	when in 4D nav mode and not on an IASREF speed leg, and IASSEL is not set

and shall limit the result as follows:

$$+20 \geqslant \Delta V > -30 \text{ kt}$$

and

$$|\Delta V| > 1.54 \text{ kt}$$

The NCU will scale ΔV at 0.154 kt/bit and will generate a word as shown in figure 4-3, with label 01000100, to define a top and bottom Y coordinate for the speed error symbol. The coordinates will be defined as follows:

ΔV positive	Y top	=	ΔV
	Y bottom	=	-1.54 kt
ΔV negative	Y top	=	+1.54 kt
	Y bottom	=	ΔV

where Y coordinates are defined in raster elements. When GUID4D is not set and IASREF is zero, the DM will be set to invalid.

The PCU will generate the variable-size bar symbol as defined in table 4-5 whenever the DM is valid, using the Y coordinates received from the NCU to position the symbol relative to the reference airplane symbol.

4.4.11 ILS Gate

Localizer and glide slope deviation shall be indicated by the displacement of the ILS gate symbol, specified in table 4-5, from the boresight dot of the reference airplane symbol. The symbol shall be composed of four raster-generated rectangles as shown in table 4-5. The symbol shall be shaded white (11111) and have priority levels 01101 through 10000 assigned to it.

No data are required from the NCU to generate or position this symbol. The PCU shall use the localizer and glide slope signals, which are input directly to the PCU as dc analog signals (see table 4-1), to position this symbol.

The localizer deviation signal shall be mechanized to move the ILS gate left and right relative to the reference airplane symbol at 2.6 elements/μamp. The maximum lateral movement shall be limited to ±2 in. (±130 elements) from the zero position. Note that this corresponds to a 50-μamp (2/3 dot) localizer deviation. The maximum input signal will be ±150 μamp.

The glide slope deviation signal shall be mechanized to move the ILS gate up and down relative to the reference airplane symbol at 0.466 element/μamp. The maximum vertical movement shall be limited to ±0.875 in. (±77 elements) from the zero position, which corresponds to a 150-μamp (2 dot) glide slope deviation. The maximum input will be ±150 μamp.

Radio altitude shall be used to turn the ILS gate ON (when the mode and/or option switch selections are appropriate).

Starting at 200 ft radio altitude, the glide slope deviation signal shall be desensitized such that a fixed vertical displacement of the symbol shall be proportional to a constant vertical displacement of the airplane from the glide slope beam center:

$$\text{Glide slope displacement} = K\, f\,(\text{glide slope deviation})$$

where:

$$K = \begin{cases} 1 & \text{for } h_R > 200 \text{ ft} \\ \dfrac{h_R - 60}{140} & \text{for } 60 \leqslant h_R \leqslant 200 \text{ ft} \\ 0 & \text{for } h_R < 60 \text{ ft} \end{cases}$$

h_R = radio altitude

Descent through a radio altitude of 60 ft shall cause the ILS symbol to be zeroed in glide slope deviation. Thereafter, the absence of a glide slope valid signal shall not suppress the ILS gate.

4.4.12 Flight Director Command Bars

The pitch and roll flight director commands shall be displayed in the form of two raster-generated bars, as specified in table 4-4. The pitch command bar shall be oriented horizontally and move up and down relative to the reference airplane symbol. The roll command bar shall be oriented vertically and move horizontally left and right relative to the reference airplane symbol. All commands shall be interpreted as "fly-to" commands.

The dimensions of the bars shall be 0.75 by 0.075 in. The bars shall be shaded black (00000) and shall be assigned priority levels 01010 and 01011.

The NCU shall compute the flight director commands 20 times/sec as follows:

$$Y_P = K_P \text{ PCMD}$$

$$X_R = K_R \text{ RCMD}$$

where

Y_P, X_R = display raster mode elements

K_P = pitch command scale factor = 13.6

K_R = roll command scale factor = 2.4

PCMD and RCMD are calculated in the guidance routine as defined in section 5.0.

The NCU shall scale the pitch command at 13.6 bits/deg θ and the roll command at 2.4 bits/deg ϕ, and shall limit the respective movements of ±0.8 in. (±64 bits) vertically and ±1 in. (±64 bits) horizontally. The NCU shall then transmit these roll and pitch commands on labels 01000101 and 01000110 as an X and a Y coordinate, respectively.

The PCU shall generate the raster symbology defined in table 4-5, using the data received from the NCU to position the roll command symbol in the X dimension and the pitch command symbol in the Y dimension. The PCU shall interpret the data such that one bit equals one raster element, and shall position the symbology relative to the reference airplane whenever the data received from the NCU in word labels 01000101 and 01000110 have valid designation matrices and the flight director option has been selected on the EADI mode control unit.

4.4.13 Horizontal and Vertical

Four forms of guidance symbology shall be implemented. The pilot will choose one of the four by selecting the V-NAV option (star) on the EADI mode control unit and VNAV 1, 2, or 3 on the NCDU, as specified in section 6.5.5.2.

The four forms of guidance symbology to be implemented are:

- Star only (VNAVF = 0) and $STAR \neq 0$
- Star and circle–Situation (VNAVF = 1) and $STAR \neq 0$
- Star and dashed gamma wedges (VNAVF = 2) and $STAR \neq 0$
- Star and circle–Command (VNAVF = 3) and $STAR \neq 0$

Each is described in detail below.

If $VNAVF \neq 0$, and V-NAV is not selected on the EADI mode control unit (i.e., STAR = 0), the circle and dashed gamma wedges symbol will be generated alone. Similarly, if $STAR \neq 0$ and VNAVF = 0, the star only symbol will be generated, as discussed in section 4.4.13.1.

4.4.13.1 Star and Circle - Situation

The vertical navigation situation in this format shall be displayed as a circle whose displacement from the flightpath angle symbol represents the pilot's sighting angle to a point on the path 30 sec ahead of the airplane's abeam point. In addition, a star whose displacement from the flightpath angle symbol represents the pilot's sighting angle to the next waypoint will be displayed, together with cone edge lines connecting the edges of the circle with the center of the star. The cone is displayed only in conjunction with the star. The cone thus formed represents a perspective view of the "tube" that the airplane is supposed to fly within to the next waypoint. In addition, the next waypoint shall always be identified by an alphanumeric identifier display in the lower left corner of the EADI.

The circle and star symbols will move vertically to indicate flightpath angle to the path and next waypoint, as well as laterally to indicate the track angle to the path and next waypoint. The star symbol shall be mechanized to remain in an orientation fixed with respect to the horizon during aircraft roll attitude changes. The position of the star and circle symbols will be limited so that they remain in the field of view, correctly located in the vertical dimension relative to the horizon at all times.

The NCU shall compute the location of the star symbol 20 times/sec. Unrotated star symbol coordinates are defined by:

$$XS' = 24.8 \left[\text{ANGLE - DA - TKE} - \tan^{-1}\left(\frac{\text{XTK}}{\text{DTOGO + DIST}}\right)\right]$$

$$YS' = 24.8 \left[\tan^{-1}\left(\frac{\text{HERR}}{\text{DTOGO + DIST}}\right) + \text{PITCH} + \text{PITCHB}^{*}\right]$$

where HERR = altitude error with respect to the next waypoint. (See figures 4-9 and 4-10 for definition of terminology.)

After rotation through roll angle (ϕ), the star symbol screen coordinates are defined as:

$$XS = XS' \cos \phi - YS' \sin \phi$$

$$YS = XS' \sin \phi + YS' \cos \phi$$

The quantities ANGLE and DIST are added to the equations as defined in figure 4-11 to compensate for discontinuities and switchover points in the guidance subroutine calculations during a waypoint transition.

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*PITCHB included when reference airplane symbol is offset (see sec. 4.4.2).

Movement of the star symbol shall be limited to within 0.40 in. of the display edge. The NCU shall limit the position of the star symbol relative to the flightpath angle symbol, as shown in figure 4-10.

The NCU must calculate the position of the flightpath angle (FPA) symbol in screen coordinates as follows:

$$\mathrm{FPAX} = 24.8\,[(\mathrm{FPA} - \mathrm{PITCH} - \mathrm{PITCHB}^{*}) \sin\phi + \mathrm{DA} \cos\phi]$$

$$\mathrm{FPAY} = 24.8\,[(\mathrm{FPA} - \mathrm{PITCH} - \mathrm{PITCHB}^{*}) \cos\phi + \mathrm{DA} \sin\phi]$$

The slope of the line from the FPA symbol to the star symbol is:

$$\mathrm{SLOPE} = \frac{(\mathrm{YS} - \mathrm{FPAY})}{(\mathrm{XS} - \mathrm{FPAX})}$$

The NCU will calculate the limited star coordinates XSL, YSL as follows:

If:

$$-\mathrm{XSL} > \mathrm{XS} > +\mathrm{XSL}$$

XS = XSL, and YS = (XSL** - FPAX) SLOPE + FPAY.

If:

$$-\mathrm{YSL} > \mathrm{YS} > +\mathrm{YSL}$$

$$\mathrm{XS} = \frac{(\mathrm{YSL}^{\dagger} - \mathrm{FPAY})}{\mathrm{SLOPE}} + \mathrm{FPAX}, \text{ and } \mathrm{YS} = \mathrm{YSL}.$$

When the reference airplane symbol is positioned at screen center, the limit values XSL and YSL are:

$$\mathrm{XSL} = \pm 316 \text{ bits } (\pm 2.162 \text{ in.})$$

$$\mathrm{YSL} = \pm 438 \text{ bits } (\pm 3.0 \text{ in.})$$

For the upper airplane position, the YSL limits will be changed to:

$$\mathrm{YSL} = \begin{matrix} +140 \text{ bits } (0.962 \text{ in.}) \\ -491 \text{ bits } (3.362 \text{ in.}) \end{matrix}$$

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*PITCHB included when reference airplane symbol is offset (see sec. 4.4.2).
**Use the XSL value with the same sign as XS.
†Use the YSL value with the same sign as YS.

The NCU shall then generate a symbol word group defining the star symbol and its location whenever V-NAV is selected on the EADI MCU, except when the TO waypoint in the guidance buffer (table 5-1) is designated for IASREF. The type 1 word will include the symbol code 0011100, R = 1, SS = 11, L = 1, and I_S = 10. The type 2 word will define the coordinates XS and YS for positioning the symbol. The type 2 word will define the coordinates XS and YS for positioning the symbol. The type 3 word will define the rotation angle (ϕ) required for maintaining it in an orientation parallel to the horizon.

The DS shall generate the symbology as defined in tables 2-6 and 4-5, using its normal table mode. The PCU will generate the EADI mode word and transmit EADI mode data to the NCU. The DS will position the symbology relative to the reference airplane symbol.

The NCU shall compute the location of the circle symbol 20 times/sec as follows:

$$XC' = 24.8 \left[-DA - \tan^{-1} \left(\frac{XTK}{TAUL \cdot VGS} \right) - TKE \right]$$

$$YC' = 24.8 \left[\tan^{-1} \left(\frac{TAUL \cdot VGS \sin PFPA + HER}{TAUL \cdot VGS} \right) - (PITCH + PITCHB^*) \right]$$

where TAUL = 30 sec.

$$XC = XC' \cos \phi - YC' \sin$$

$$YC = XC' \sin \phi + YC' \cos$$

Movement of the circle symbol shall be limited to within 0.50 in. of the display edge. The NCU shall limit the position of the circle symbol in the same manner as that specified for the star symbol, except that the bit limit values XCL, YCL shall be:

Airplane at screen center: XCL = ±300, YCL = ±423

Airplane at offset position: $XCL = \pm 300, YCL = {}^{+125}_{-476}$

The NCU shall generate a symbol word group defining the circle symbol and its location whenever V-NAV is selected on the EADI MCU and VNAV option 1 is selected on the NCDU. The type 1 word will have the symbol code 0001111, R = 0, SS = 10, L = 1, and I_S = 10. The type 2 word will define the position coordinates XC and YC. No type 3 word is required since the circle symbol is totally symmetric.

The DS shall generate the symbology as defined in tables 2-6 and 4-5 using the table mode and shall position the symbology relative to the reference airplane symbol.

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*PITCHB added when the offset bias is selected (see sec. 4.4.2)

The cone shall be generated from two vectors connecting the top and bottom edges of the circle with the center of the star. The NCU shall compute the location of the vector end points as follows:

$X_1 = XC$

$Y_1 = YC + 26^*$

$X_2 = XS$

$Y_2 = YS$

$X_3 = XC$

$Y_3 = YC - 26^*$

The NCU will generate a vector word group using vector code 1100001 with I_V set to 01 in vector word type 1. The first two type 2 vector words will have WF = 0 and will define the coordinates (X_1Y_1) and (X_2Y_2). The third type 2 vector word will have WF = 1 and will define the end point coordinate (X_3Y_3). The DS will generate this vector using the table mode.

A three- to five-character alphanumeric label identifying the displayed waypoint and a two- to five-character guidance mode label shall be displayed in the lower left corner of the EADI, as shown in table 4-5. The NCU will transmit the identifier to the PCU as a text instruction word group. The type 1B word will have WF = 0 and I_T = 10. The first type 4 word will have WF = 0, ST = 1, and the codes for the first three alphanumerics.

Additional type 4 words will be transmitted to complete the waypoint designator if required, followed by CR and LF codes to start a second line of characters. These characters will define the current flight control mode of operation as follows, where the name in parentheses is the NCU flag name: LAND (RCAPT or PCAPT), 4D (GUID4D), 3D (GUID3D), 2D (GUID2D), LINK (LINKUP), SEL (HLDSEL, TKSEL, FPASEL, OFSSEL, ALTSEL, or IASSEL). Simultaneous modes will be separated by a slash, i.e., 2D/SEL. The location of this alphanumeric tag will be transmitted in the type 2 word as -420 bits in the X dimension and -290 bits in the Y dimension when the airplane symbol is located at screen center. For upper airplane symbol position, the Y value will be -465. The label will change when WPDTG < DTTI (see sec. 4.4.13).

4.4.13.2 Star and Dashed Gamma Wedges

The vertical navigation situation in this format shall be displayed as 1) a star whose displacement from the flightpath angle symbol represents the pilot's sighting angle to the

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*26 bits = 0.180 in., which is one-half the circle symbol diameter.

next waypoint and 2) a dashed flightpath angle symbol, as specified in table 4-5, whose displacement from the flightpath angle symbol represents the pilot's sighting angle, in the vertical dimension, to a point 30 sec ahead of the airplane's abeam point on the path.

The NCU shall compute the position of the star symbol, limit the position of the star symbol, and transmit the star symbol data to the PCU in the same manner as that specified for the star and circle in section 4.4.13.1.

The NCU shall compute the vertical position of the dashed flightpath angle symbol 20 times/sec as vertical path command (VPC):

$$VPC = \left[\tan^{-1}\left(\frac{TAUL \cdot VGS \sin PFPA + HER}{TAUL \cdot VGS}\right)\right]$$

where TAUL = 30 sec. The NCU shall transmit the data as an angular quantity to the PCU on label 01000111, as specified in figure 4-3. The DM will be set to valid when V-NAV is selected on the EADI mode control unit and VNAV option 2 is selected on the NCDU. When these conditions are not met, DM is set to invalid.

The DS shall scale these data at 0.17 in./deg and shall add pitch and pitch bias to vertically position the dashed flightpath angle symbol. The DS shall use the drift angle data transmitted on label 01000011, as specified in figure 4-3, to position this symbol laterally. Both lateral and vertical positions are relative to the reference airplane symbol.

The dashed flightpath angle symbol shall be constructed of dashes as shown in table 4-5. The symbol's intensity (I_S) shall be 10.

The NCU shall also provide the DS with data for generating the waypoint identifier in the same manner as that specified in section 4.4.13.1

4.4.13.3 Star and Circle–Command

The symbology for the VNAV 3 option is identical to that defined in section 4.4.13.1. The only difference is that the circle symbology is positioned by the flight director commands PCMD and RCMD.

The NCU will compute the position of the circle symbol 20 times/sec as follows:

$$XC' = KR' (RCMD)$$

$$YC' = KP' (PCMD - PITCH - PITCHB)$$

where:

KR′ = roll command scale factor = 10

KP′ = pitch command scale factor = 100

$$XC = XC' \cos \phi - YC' \sin \phi$$

$$YC = XC' \sin \phi + YC' \cos \phi$$

The circle coordinates will be limited in the manner defined in section 4.4.13.1.

The NCU will transmit the star and circle symbology as table data in two symbol word groups. Two vectors will define the cone, as detailed in section 4.4.13.1.

The DS will generate the symbology using the normal table mode of operation.

The NCU shall provide the PCU with data for generating the waypoint identifier in the same manner as that specified for the star and circle in section 4.4.13.1.

4.4.14 Radio Altitude

Radio altitude shall be displayed digitally in the upper right corner of the display using stroke-written characters on a dark rectangle, as shown in figure 4-2. The lower left corner of the rectangle shall be located 1.54 in. above and 1.75 in. to the right of the screen center. The rectangle shall be 0.50 in. high by 1.30 in. wide. The rectangle shall be shaded black (00000) and have priority level 1. The numerics shall be 0.315 in. high (SS = 10), with intensity (I_S) set to 11.

No data are required from the NCU for this symbology. The DS shall use the dc analog signal that it receives directly from the radio altimeter to display this symbology. The output characteristics of the dc analog signal are shown in figure 4-12.

Radio altitude shall be displayed below 2500 ft. Above 2500 ft, the PCU shall blank the radio altitude symbology. The display shall read in 2-ft increments from 0 to 100 ft and in 10-ft increments above 100 ft.

The DS shall update the displayed data 5 times/sec.

4.4.15 Runway

For approach/landing operations, a symbolic representation of the runway shall be displayed. The runway symbology shall consist of an oblique trapezoid with a dashed centerline and extended runway centerline. The runway perspective shall duplicate the real world runway image within the limits of navigation accuracy.

The NCU shall compute as follows the screen coordinates of the vectors constituting the runway symbol at a rate of 20 times/sec. See figures 4-13 and 4-14 for definition of parameters used in the equations.

$$\begin{aligned} X_{1,3} &= S_f\left\{\left[(\theta + \Delta\theta) + \tan^{-1}\frac{h}{R_{1,3}' \pm \Delta R_{1,3}}\right]\sin\phi \right. \\ &\quad \left. + \left[\psi_{RT_{1,3}} \mp \tan^{-1}\frac{W_R\cos\left(\psi_R - \psi_{RT_{1,3}}\right)}{2R_{1,3}} - \psi_H\right]\cos\phi\right\} \\ Y_{1,3} &= S_f\left\{-\left[(\theta + \Delta\theta) + \tan^{-1}\frac{h}{R_{1,3}' \pm \Delta R_{1,3}}\right]\cos\phi \right. \\ &\quad \left. + \left[\psi_{RT_{1,3}} \mp \tan^{-1}\frac{W_R\cos\left(\psi_R - \psi_{RT_{1,3}}\right)}{2R_{1,3}} - \psi_H\right]\sin\phi\right\} \end{aligned}$$

where $R_{1,3}' = R_{1,3}\cos(\psi_{RT_{1,3}} - \psi_H)$ and $R_{1,3}'$ is limited to $\geqslant 300$ ft.

$$\begin{aligned} X_{2,4} &= S_f\left\{\left[(\theta + \Delta\theta) + \tan^{-1}\frac{h}{R_{2,4}' \pm \Delta R_{2,4}}\right]\sin\phi \right. \\ &\quad \left. + \left[\psi_{RT_{2,4}} \mp \tan^{-1}\frac{W_R\cos\left(\psi_R - \psi_{RT_{2,4}}\right)}{2R_{2,4}} - \psi_H\right]\cos\phi\right\} \\ Y_{2,4} &= S_f\left\{-\left[(\theta + \Delta\theta) + \tan^{-1}\frac{h}{R_{2,4}' \pm \Delta R_{2,4}}\right]\cos\phi \right. \\ &\quad \left. + \left[\psi_{RT_{2,4}} \mp \tan^{-1}\frac{W_R\cos\left(\psi_R - \psi_{RT_{2,4}}\right)}{2R_{2,4}} - \psi_H\right]\sin\phi\right\} \end{aligned}$$

where $R_{2,4}' = R_{2,4}\cos(\psi_{RT_{2,4}} - \psi_H)$ When $R_{2,4}'$ is < 300 ft, the calculation of runway symbology will be discontinued.

The NCU will generate four vector word groups using vector code 1100000, with I_V set to 10 in vector word type 1 as shown in table 4-2. Each vector word group will define one side of the runway symbol and will consist of one type 1 and two type 2 words. The data will be transmitted over the EADI bus as shown in table 4-2 whenever the RUNWAY display option is selected on the EADI mode control unit and $R_{13} < 30$ nmi.

The NCU shall compute the location of the extended runway centerline using the following logic and equations:

Position 6 coordinates:

$$X_6 = 1/2\,(X_2 + X_4)$$

$$Y_6 = 1/2\,(Y_2 - Y_4)$$

Position 5 coordinates:

$$X_7 = 1/2\,(X_1 + X_3)$$

$$Y_7 = 1/2\,(Y_1 + Y_3)$$

$$R_5 = [(\text{-DSFGAM - ERW})^2 + (\text{DSRGAM})^2]^{1/2}$$

$$\text{SRT5} = \tan^{-1}\left(\frac{\text{-DSRGAM}}{\text{-DSFGAM - ERW}}\right) + \psi_R$$

where (-DSFGAM - ERW) ⩾ 300 ft and ERW = 30,000 ft.

$$Y_5 = -S_f\left\{\left[\tan^{-1}\left(\frac{h_R}{R_5 \cos(\text{SRT5} - \psi_H)}\right) \div \text{PITCH} + \text{PITCHB}\right]\cos\phi + (\text{SRT5} - \psi_H)\sin\phi\right\}$$

where $S_f = 24.8$

$$X_5 = \left(\frac{X_6 - X_7}{Y_6 - Y_7}\right)(Y_5 - Y_7) + X_7$$

See figures 4-13, -14, and -15 for definition of the parameters used in these equations.

The NCU will generate a vector word group using vector code 1100000, with I_V set to 01 in vector word type 1. The first vector word type 2 will have WF = 0 and will define the start point coordinate (X_5Y_5). The second vector word type 2 will have WF = 1 and will define the end point coordinate (X_6Y_6) of the centerline. The NCU will transmit these data over the EADI bus as shown in table 4-2 whenever the RUNWAY display option is selected on the EADI mode control unit and $R_{13} < 10$ nmi.

The basic data required to generate the runway-associated symbology will be extracted from the bulk data storage (sec. 3.0). The origin/destination buffer (table 6-3) identifies the origin and destination airport. The bulk data buffer (table 3-6) provides the following runway data:

Latitude of threshold

Longitude of threshold

Length of runway

Azimuth of runway

Altitude of threshold

Width of runway (150 ft assumed)

The DS will generate the runway and centerline symbology using the table mode and position the symbology with respect to the reference airplane symbol.

4.4.16 Belly Symbol

A truncated wedge-shaped symbol shall appear at the top of the EADI, as shown in table 4-5, whenever approach/landing TV imagery is displayed. The belly symbol shall be raster generated, shall have the same shade as the sky, and shall have priority level 34.

No data are required from the NCU for generating or positioning this symbology. The DS shall generate this symbol whenever the EADI TV option (0100000) is selected ON.

The belly symbol shall be mechanized such that, as the artificial horizon moves with pitch and roll into the area that it blanks, the symbol rolls back to allow the televisual scene to appear.

4.4.17 TV Scene

The approach/landing TV imagery received from the radome-mounted TV camera shall be displayed whenever the TV option is selected. The TV imagery shall be positioned such that the real world horizon (as seen through the TV camera) aligns with the artificial horizon, and scaled such that the real world picture pitches and rolls coincident with the pitch attitude scale.

TV imagery shall be scaled by the appropriate choice of TV camera lens, and shall have priority over the sky/ground shading, i.e., priority level 35.

No data are required from the NCU for generating or positioning this symbol.

4.5 EADI TEST FEATURES

4.5.1 EADI Self-Test

This mode is initiated by pressing the TEST button on the EADI mode control unit (see fig. 4-7). Selection of this mode overrides all other EADI modes. The EADI remains in the test mode until another mode is selected on the EADI mode control unit. The display test pattern seen on the EADI when this mode is selected is shown in figure 4-16.

4.5.2 NCU/PCU Interface Test

The NCU test mode is initiated by the test switch on the NCDU. Details of the NCU self-test requirements are defined in section 7.0. Included in this test is the NCU/PCU interface test, which checks the EADI bus transmissions to the PCU.

Activation of this test will superimpose the EADI test patterns defined in figure 4-17 on the normal EADI presentation. These patterns are generated by transmitting the data listed in table 4-7 over the EADI bus. If the test is successful, the message

EADI BUS GOOD

will appear as shown in figure 4-17. If the test fails, no message will appear.

The NCU will continue to transmit the data listed in table 4-7 as long as the NCDU test switch is in the TEST position.

4.6 NCDU/EADI INTERACTION

The waypoint star symbol, its alphanumeric designator, and the guidance symbology (V-NAV) will be dependent on the flight plan entered into the system through the NCDU. The star symbol represents the current TO waypoint identified in the guidance buffer (table 5-1).

The choice of guidance symbology option, VNAV 1, 2, or 3, is made through the NCDU SEL mode as defined in section 6.5.5.2 in conjunction with the V-NAV switch on the EADI mode control panel. The EADI guidance options are: VNAV 1, VNAV 2, and VNAV 3.

Pressing numeric key 1, 2, or 3 activates the appropriate symbology on the EADI display.

4.7 SCU INTERFACE

The symbol valid/erase switches on the SCU shall have the capability of controlling only the general-function symbology on the MFD. Eight switches shall be mechanized to delete symbology:

Switch 4	OFF	Roll template
Switch 5	OFF	Roll pointer
Switch 6	OFF	Flightpath angle wedges
Switch 7	OFF	Flightpath acceleration rectangle
Switch 8	OFF	Acceleration command

Switch 9	OFF	Dashed flightpath angle wedges
Switch 10	OFF	Pitch reference line
Switch 11	OFF	Reference airplane symbol position

TABLE 4-1.–ANALOG INPUTS FOR THE EADI

Input parameter	Signal type	Reference specification	Scale factor	Range
Pitch angle	Synchro	ARINC 407	1°/1°	±90°
Roll angle	Synchro	ARINC 407	1°/1°	±180°
Radio altitude	Dc	ARINC 552	See sec. 4.4.14 and fig. 4-12	0 to 2500 ft
LOC deviation	Dc	ARINC 547	± 75μamp/dot	± 150μamp
GS deviation	Dc	ARINC 547	± 75μamp/dot	± 150μamp

TABLE 4-2.–EADI BUS LABEL CODING AND TRANSMISSION ORDER

Label								Function		
MSB							LSB			
8	7	6	5	4	3	2	1			
0	1	0	0	0	0	0	0	Flightpath angle (FPA)		
0	1	0	0	0	0	0	1	Flightpath angle + flightpath acceleration (FPA + FPAC)		
0	1	0	0	0	0	1	0	Drift angle (DA)		
0	1	0	0	0	0	1	1	Planned flightpath angle (HLDFPA)		
0	1	0	0	0	1	0	0	Speed error (IASERR or SPDE)		
0	1	0	0	0	1	0	1	Flight director–roll command (RCMD)		
0	1	0	0	0	1	1	0	Flight director–pitch command (PCMD)		
0	1	0	0	0	1	1	1	Vertical path command (VPC)		
0	1	0	0	1	0	0	0	Flightpath angle + flightpath acceleration command (GAMPC)		
0	1	0	0	1	0	0	1	EADI mode word		
0	1	0	0	1	0	1	0	I&R control word with IC = 00, RC = 0, RS = 0, OC = 0, TC = 1		
0	1	0	0	1	0	1	1	Symbol word type	1 = (R = 1)	Star
0	1	0	0	1	1	0	0		2	Position
0	1	0	0	1	1	0	1		3	Rotation angle
0	1	0	0	1	1	1	0		1	Tickler symbol
0	1	0	0	1	1	1	1		2	Position
0	1	0	1	0	0	0	0	Text type	1	Text control
0	1	0	1	0	0	0	1		2	Position
0	1	0	1	0	0	1	0		4	Designator
0	1	0	1	0	0	1	1		4	Designator
0	1	0	1	0	1	0	0	Vector word type	1	Tickler lines
0	1	0	1	0	1	0	1		2	Position 1
0	1	0	1	0	1	1	0		2	Position 2
0	1	0	1	0	1	1	1		2	Position 3
0	1	0	1	1	0	0	0		1	Runway outline
0	1	0	1	1	0	0	1		2	Position 1
0	1	0	1	1	0	1	0		2	Position 2
0	1	0	1	1	0	1	1		1	
0	1	0	1	1	1	0	0		2	Position 2
0	1	0	1	1	1	0	1		2	Position 4
0	1	0	1	1	1	1	0		1	
0	1	0	1	1	1	1	1		2	Position 4
0	1	1	0	0	0	0	0		2	Position 3
0	1	1	0	0	0	0	1		1	
0	1	1	0	0	0	1	0		2	Position 3
0	1	1	0	0	0	1	1		2	Position 1
0	1	1	0	0	1	0	0		1	Runway centerline
0	1	1	0	0	1	0	1		2	Position 1
0	1	1	0	0	1	1	0		2	Position 2
0	1	1	0	0	1	1	1	EOD control word with TC = 0		
0	1	1	0	1	0	0	0	Unassigned		
0	1	1	1	1	1	1	1			

Note: The table data content following the I&R control word will vary in content depending upon display options selected.

TABLE 4.3—EADI MODE CONTROLLER OPERATION

Mode	Function
CRUISE	Selects CRUISE mode with the following basic symbology: Reference aircraft symbol Roll indication Sky/ground shading and horizon line Pitch scale Flightpath angle Flightpath acceleration Acceleration command (T-NAV) Vertical and horizontal guidance (V-NAV)
LAND	Selects LAND mode with the following basic symbology: Reference aircraft symbol Roll indication Sky/ground shading and horizon line Pitch scale Flightpath angle Flightpath acceleration Acceleration command (T-NAV) Vertical and horizontal guidance (V-NAV) Localizer/glide slope box (ILS) Speed error bar (SPD ERR) Artificial runway and extended centerline (RUNWAY) Television (TV) Belly symbol
TEST	Causes a predefined test pattern to appear on the EADI (fig. 4-16)
Note: Mode buttons are mutually exclusive. At power ON, the last mode selected will be reselected.	
Options	**Function**
FLT DIR	Switches the flight director symbology ON/OFF
ILS	Switches the ILS box ON/OFF
SPD ERR	Switches the speed error bar ON/OFF
V-NAV[a]	Switches the V-nav star symbology ON/OFF
RUNWAY	Switches the artificial runway symbology ON/OFF
TV	Switches the TV input ON/OFF
Note: Symbology option buttons light up green when pressed to signify ON. Second press changes the color to white to signify OFF. The appropriate option buttons light up when a mode is selected.	
PITCH REF	Potentiometer and digital readout used for setting or adjusting the pitch reference line
AUTO/MAN	Selects the mode of drive for setting the pitch reference line. In the MAN position, the reference line is set through the potentiometer. In the AUTO position, the reference line is set automatically by inputs from the navigation system computer.
D/H REF	Potentiometer and digital readout used for setting the decision height on the EADI
R/A TEST	Checks the radio altitude system by displaying a predetermined radio altitude number

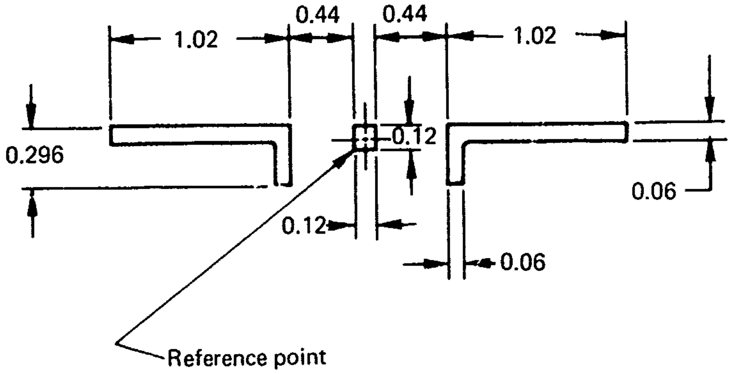
[a] Selection of one of three V-nav symbology options is made through the NCDU as defined in section 4.6.

TABLE 4-4.–EADI DATA COMPUTATION RATE REQUIREMENTS

Symbology/function	Minimum computation rate (number/sec)	Computed by	
		PCU	NCU
Reference airplane	Fixed symbol	X	
Artificial horizon	20	X	
Pitch altitude scale	20	X	
Pitch gamma reference line	20	X(MAN)	X(AUTO)
Roll pointer	20	X	
Roll scale	Fixed symbols	X	
Flightpath angle	20		X
Drift angle	5		X
Flightpath acceleration	20		X
Speed error bar	5		X
ILS gate			
Localizer	20	X	
Glide slope	20	X	
Flight director command	20		X
V-nav star and identifier			
Position of star	20		X
Identifier	1		X
Radio altitude	5	X	
Runway	20		X
Belly symbol	20	X	
Decision height	2	X	

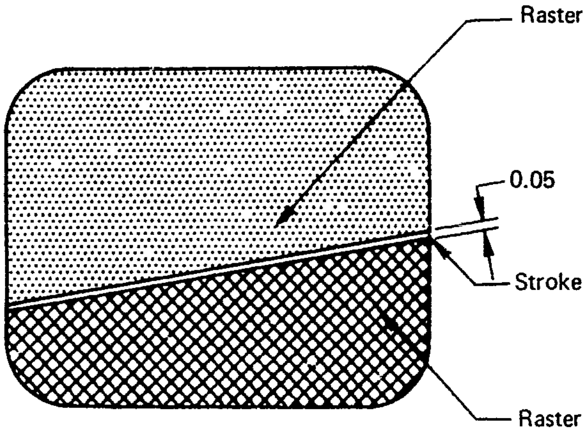
Note: All data computed in the NCU are transmitted to the PCU 20 times/sec.

TABLE 4-5.–EADI SYMBOLOGY



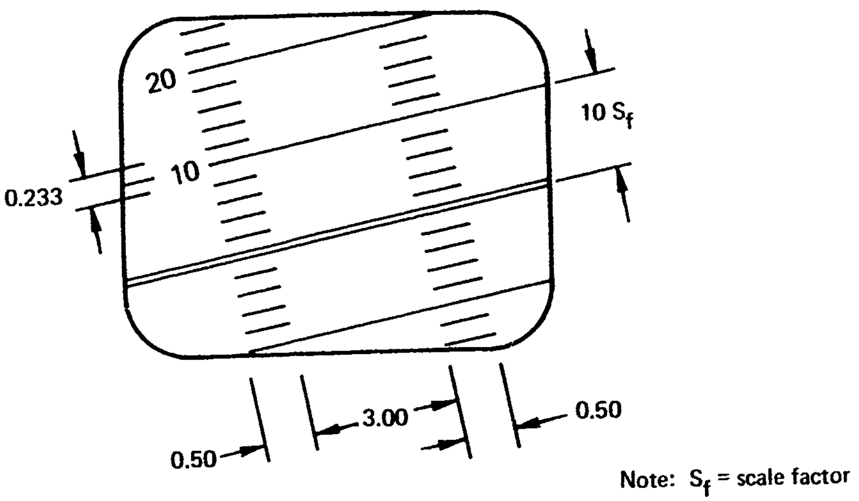
Reference Airplane (Raster)

Dimensions in inches



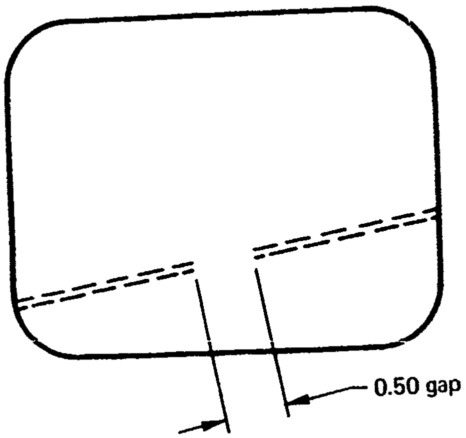
Artificial Horizon

TABLE 4-5.–CONTINUED



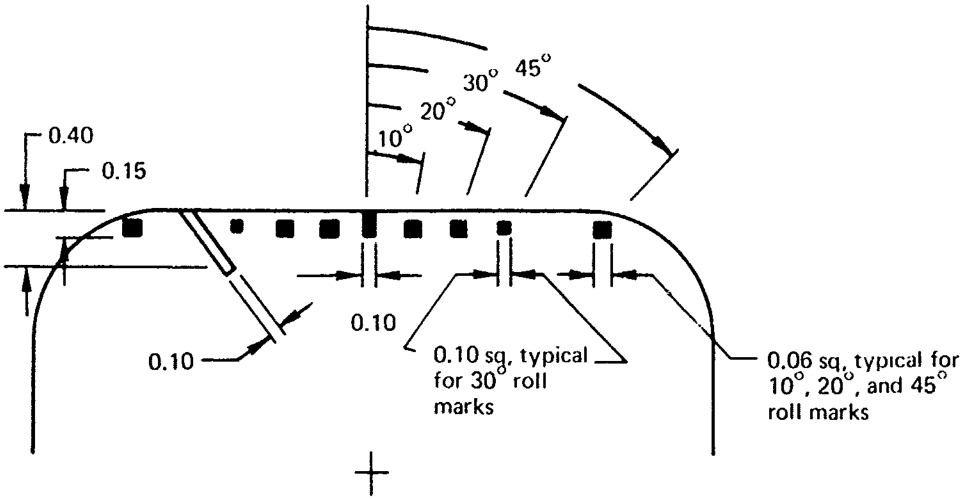
Pitch Attitude Scale

Dimensions in inches



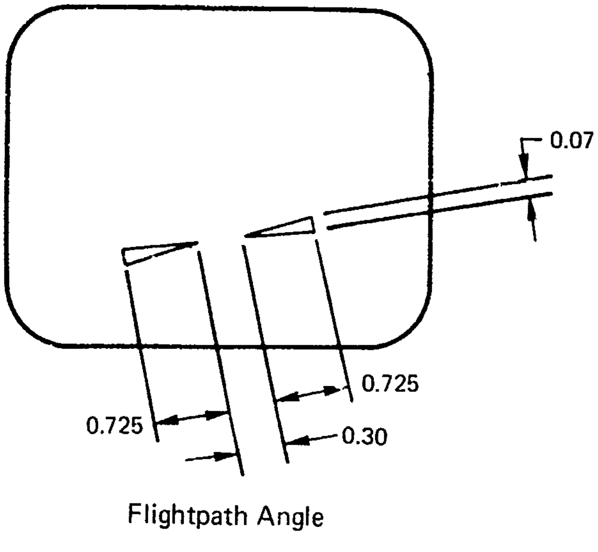
Pitch Reference Line

TABLE 4-5.—CONTINUED



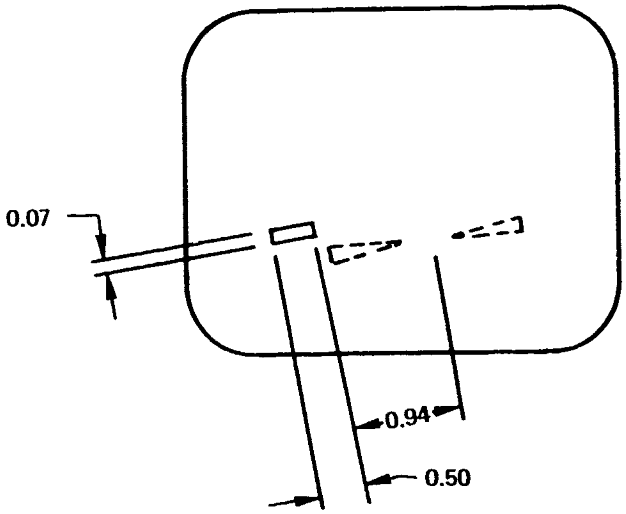
Roll Pointer and Scale

Dimensions in inches



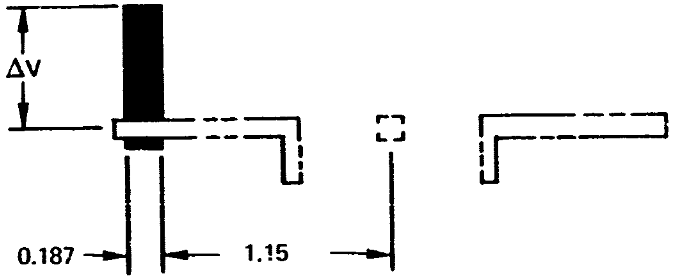
Flightpath Angle

TABLE 4-5.–CONTINUED



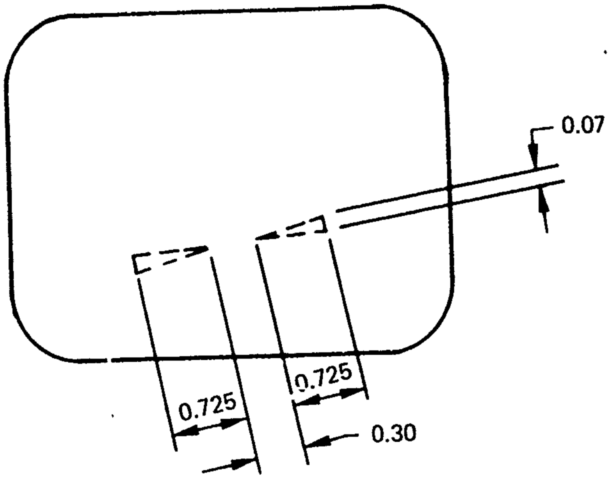
Flightpath Acceleration

Dimensions in inches



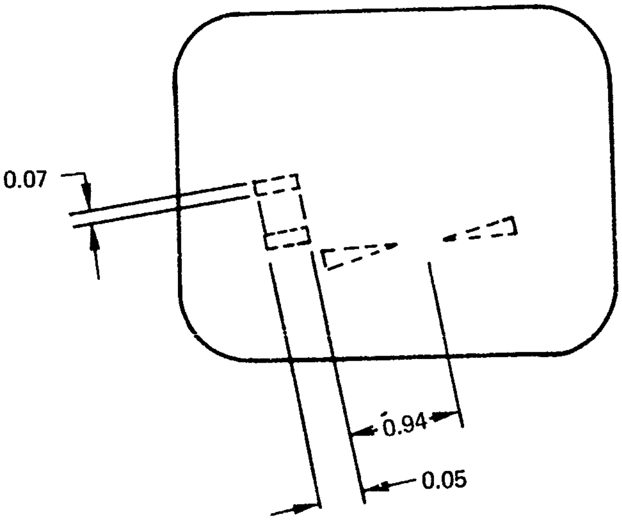
Speed Error Bar

TABLE 4-5.–CONTINUED



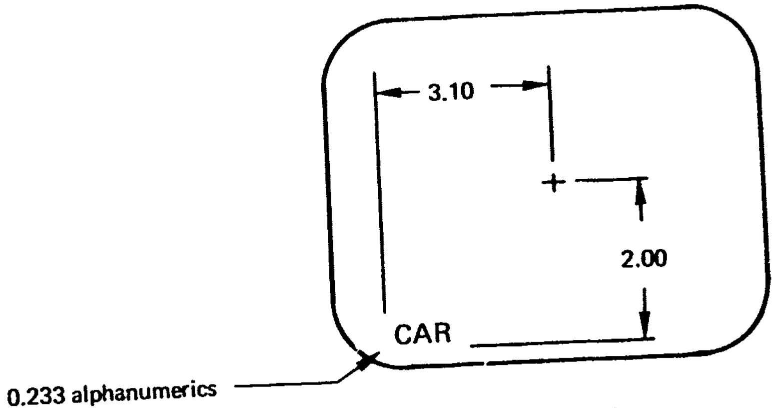
Dashed Gamma Wedges (V-Nav)

Dimensions in inches



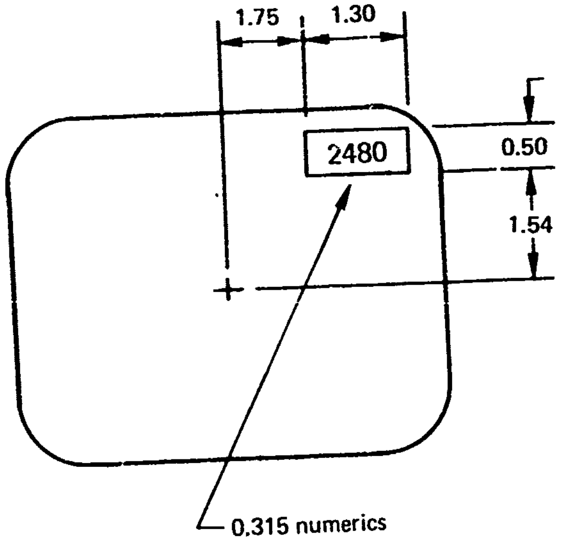
Acceleration Command

TABLE 4-5.–CONTINUED



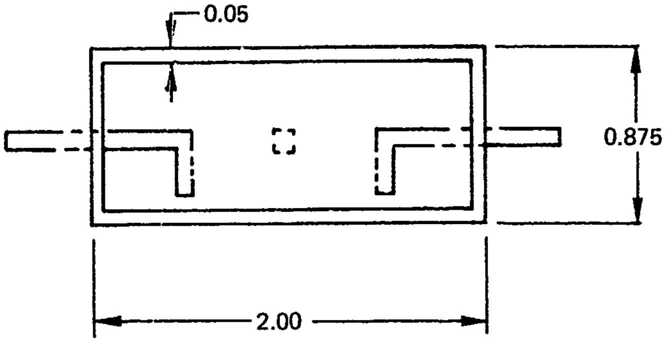
V-Nav Identifier

Dimensions in inches



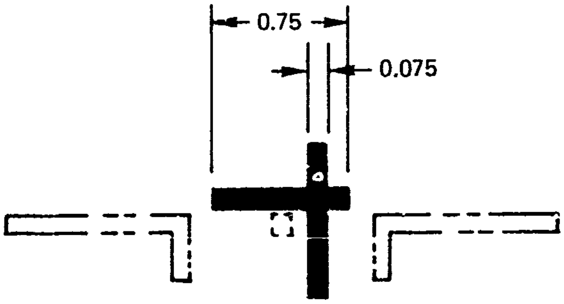
Radio Altitude

TABLE 4-5.–CONTINUED



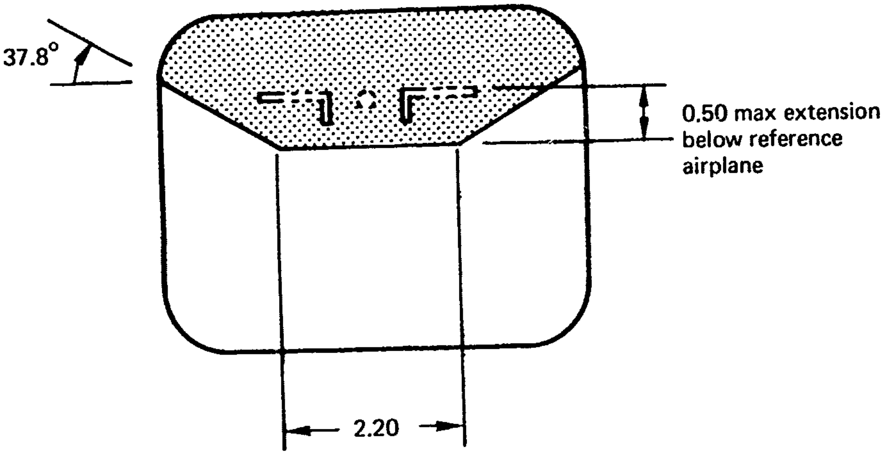
ILS Gate

Dimensions in inches



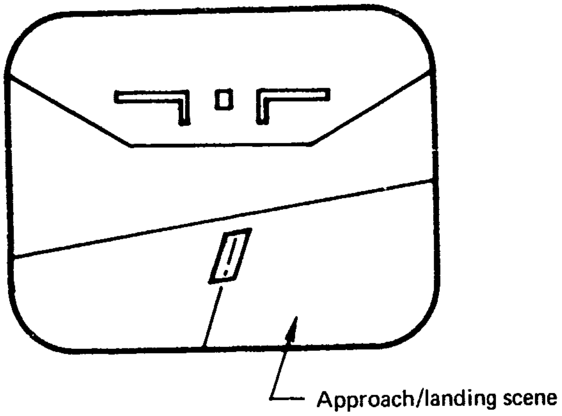
Flight Director Command Bars

TABLE 4-5.–CONTINUED



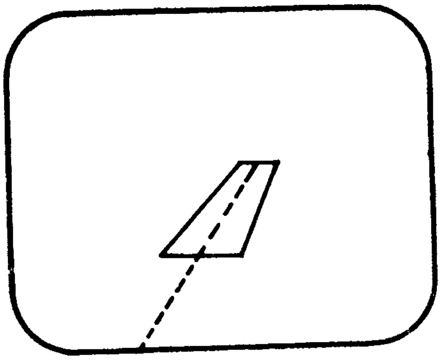
Belly Symbol

Dimensions in inches

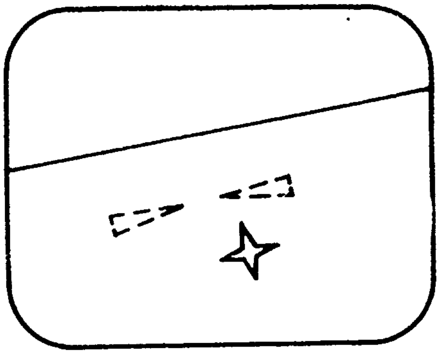


TV Scene

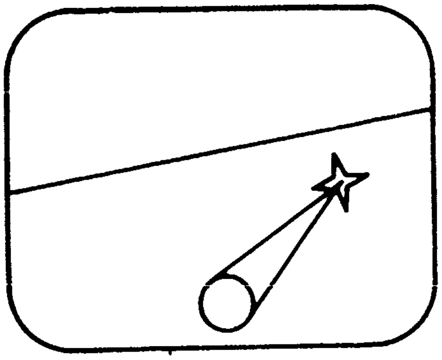
TABLE 4-5.—CONCLUDED



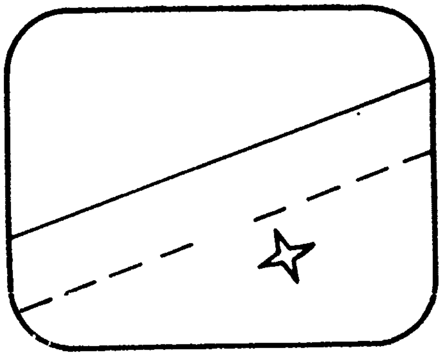
Runway



V-Nav
(star and dashed gamma wedges)



V-Nav
(star and circle command or situation)



V-Nav
(star and dashed reference line)

TABLE 4-6.–EADI NOMENCLATURE

Label	Mnemonic	Definition	Unit
	XS, YS	Coordinates of waypoint symbol on EADI screen relative to boresight in reference airplane symbol	bits
	XSL, YSL	Displacement limit on coordinates of waypoint symbol on EADI screen (X = horizontal axis, Y = vertical axis)	bits
	XS′, YS′	Coordinates of waypoint symbol on EADI screen prior to resolving through roll input	bits
	XC, YC	Coordinates of circle symbol on EADI screen relative to boresight in reference airplane symbol	bits
	XCL, YCL	Displacement limit on coordinates of circle symbol on EADI screen	bits
	XC′, YC′	Coordinates of circle symbol on EADI screen prior to resolving through roll input	bits
	$X_{1,3}, Y_{1,3}$	Coordinates of approach threshold corners of runway symbol on EADI screen	bits
	$X_{2,4}, Y_{2,4}$	Coordinates of takeoff threshold corners of runway symbol on EADI screen	bits
	X_5, Y_5	Coordinates of end of extended runway centerline on EADI screen	bits
	X_6, Y_6	Coordinates of takeoff end of runway centerline on EADI screen	bits
	X_7, Y_7	Coordinates of approach end of runway centerline on EADI screen	bits
	X_R	Coordinates of roll flight director bar on EADI screen	bits
	Y_P	Coordinates of pitch flight director bar on EADI screen	bits
FPAX, FPAY	X, Y	Coordinates of flightpath angle symbol on EADI screen	bits
PITCH	θ	Pitch attitude	deg/180
PITCHB	$\Delta\theta$	Pitch attitude bias—constant	deg/180
ROLL	ϕ	Roll attitude (bank angle)	deg/180
HDG	ψ	Heading	deg/180
TKE	$\delta\psi$	Track error	deg/180
TA	$\Delta\psi$	Track change required for a particular turn	deg/180
ANGLE		Dummy value used for V-nav star	deg/180
AMG		Track change completed through a turn at a waypoint	deg/180
	$\psi_{RT_{1,3}}$	Track to runway approach threshold	deg/180
	$\psi_{RT_{2,4}}$	Track to runway takeoff threshold	deg/180
	ψ_R	Runway heading	deg/180

TABLE 4-6.–CONTINUED

Label	Mnemonic	Definition	Unit
SRT5		Track to end of extended runway centerline	deg/180
FPA	γ	Flightpath angle	deg/180
FPAC	γ_P	Flightpath acceleration	deg/180
PFPA	γ_C	Command flightpath angle from guidance	deg/180
HLDFPA	γ_{REF}	Flightpath angle selected	deg/180
FPASEL	γ_{SEL}	Flag keyed to NCDU select mode for flightpath angle hold	
FPAPC		Acceleration command from guidance	deg/180
GAMPC	PC	Acceleration command symbol position	deg/180
SLOPE		Gradient of line from the FPA symbol to the star symbol	
DA		Drift angle	deg/180
ALTRWY	h	Altitude above runway threshold	ft
HDOT		Vertical velocity (baro/inertial filtered)	ft/sec
HER		Altitude below path	ft
HERR		Altitude above next waypoint	ft
IAS	V_{IAS}	Indicated airspeed	kt
IASMAX		Maximum indicated airspeed	kt
IASREF		Reference indicated airspeed	kt
VGS	V_G	Groundspeed	kt
VGSDOT	V_G	Rate of change of groundspeed	ft/sec^2
SPDE		Speed error	kt
DELV	ΔV	Y coordinates of speed error bar on EADI screen	bits
XTK		Crosstrack error	ft
DTOGO		Distance to go to next waypoint	ft
DIST		Dummy value used for V-nav star	
WPPCD		Distance between waypoints center of turn to center of turn	ft
DTTI		Distance from start of turn to waypoint	ft
	$R_{1,3}$	Distance to approach threshold of runway	ft
	$R_{2,4}$	Distance to takeoff threshold of runway	ft
	$R_{1,3'}$	Distance to approach threshold of runway projected along track of airplane	ft
	$R_{2,4'}$	Distance to takeoff threshold of runway projected along track of airplane	ft
	$\Delta R_{1,3}$	Component of skewed approach threshold projected along track of airplane	ft
	$\Delta R_{2,4}$	Component of skewed takeoff threshold projected along track of airplane	ft
	R_5	Distance to end of extended runway centerline	ft
	W_R	Runway width	ft

TABLE 4-6.—CONCLUDED

Label	Mnemonic	Definition	Unit
DSFGAM		Distance to threshold projected along runway centerline	ft
DSRGAM		Perpendicular displacement of airplane from extended runway centerline	ft
ERW		Length of extended runway centerline	ft
	S_f	Pitch scale factor	in./deg
	TAUL	Constant = 30	sec
	g	Gravity	ft/sec^2
	K_P	Pitch flight director command scale factor	bits/deg
	K_R	Roll flight director command scale factor	bits/deg
PCMD		Guidance output of flight director pitch command	deg/180
RCMD		Guidance output of flight director roll command	deg/180
VNAVF		Flag that determines form of V-nav to be used	

TABLE 4-7.—NCU/PCU INTERFACE TEST DATA TRANSMITTAL ON EADI BUS

EADI bus word no.	Word/type	Data content		
N + 1	Symbol word—text	I_T = 11, ST = 1		
N + 2	Symbol word—type 2	Position: X = -190 bits Y = -330 bits		
N + 3	Symbol word—type 4	E	A	D
N + 4	Symbol word—type 4	I	b	B
N + 5	Symbol word—type 4	U	S	b
N + 6	Symbol word—type 4	-	b	G
N + 7	Symbol word—type 4	O	O	D
N + 8	EOD control word	TC = 0		

N = last word of table data

b = space

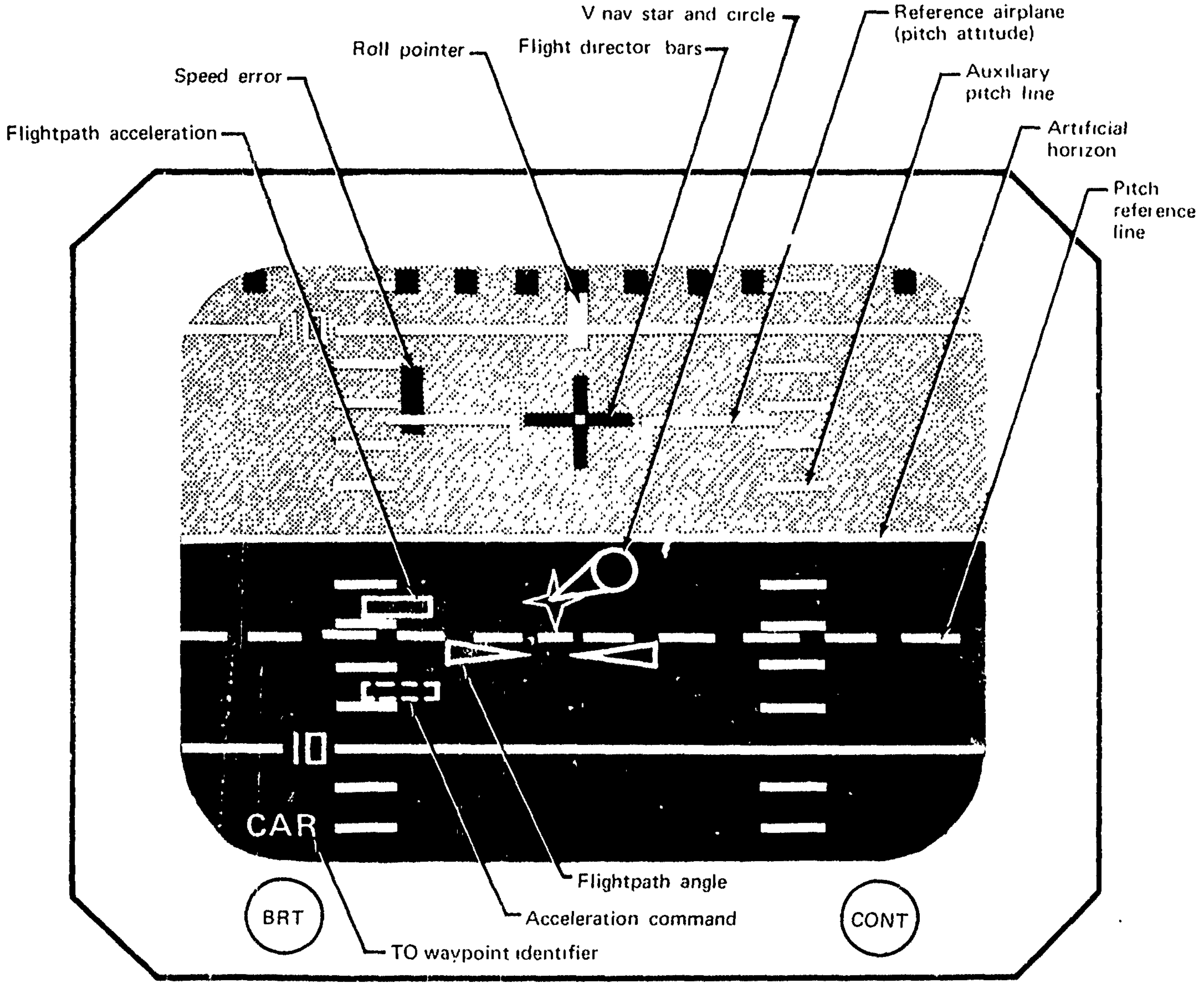


FIGURE 4-1.–ELECTRONIC ATTITUDE DIRECTOR INDICATOR (CRUISE MODE)

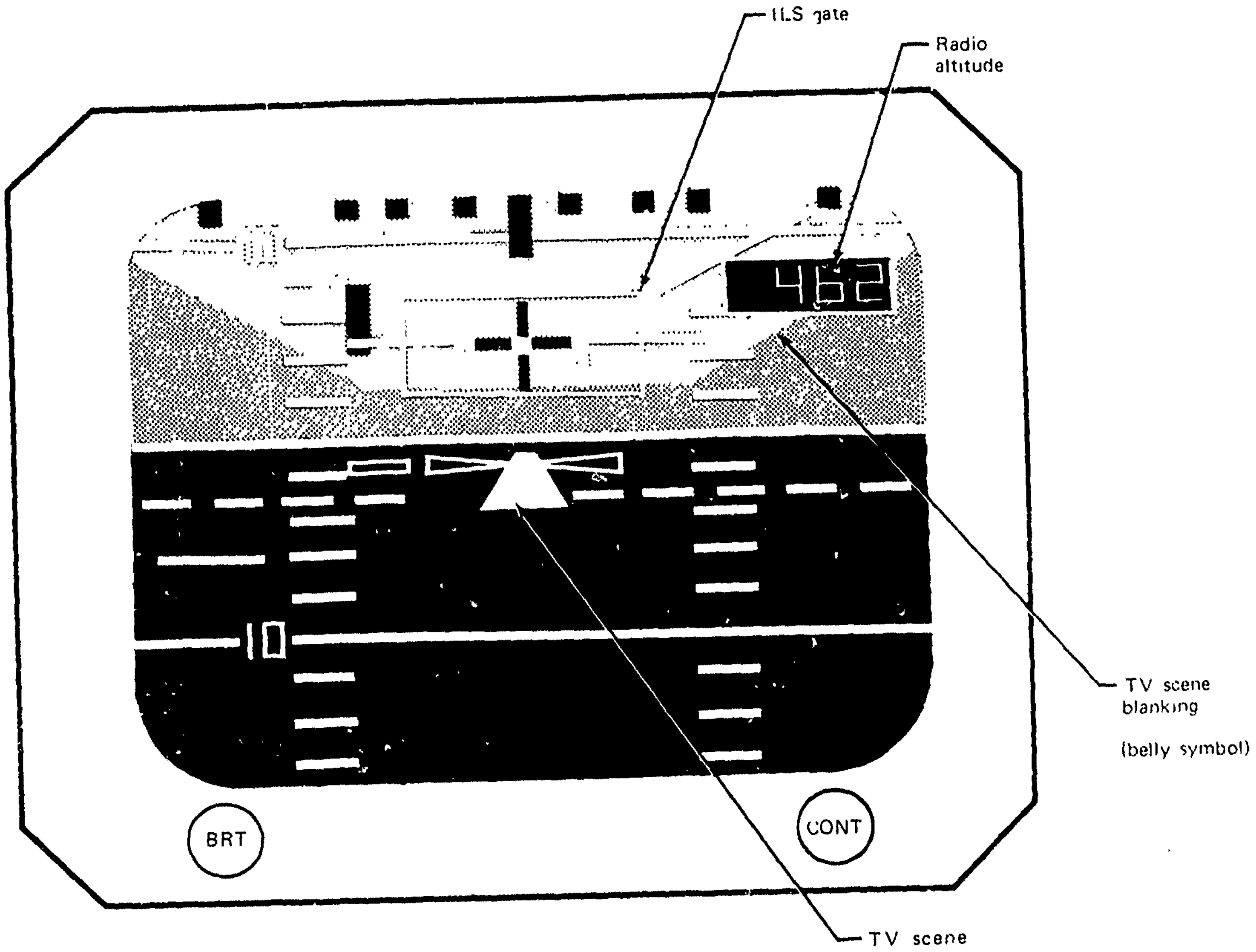


FIGURE 4-2.–ELECTRONIC ATTITUDE DIRECTOR INDICATOR (LAND MODE)

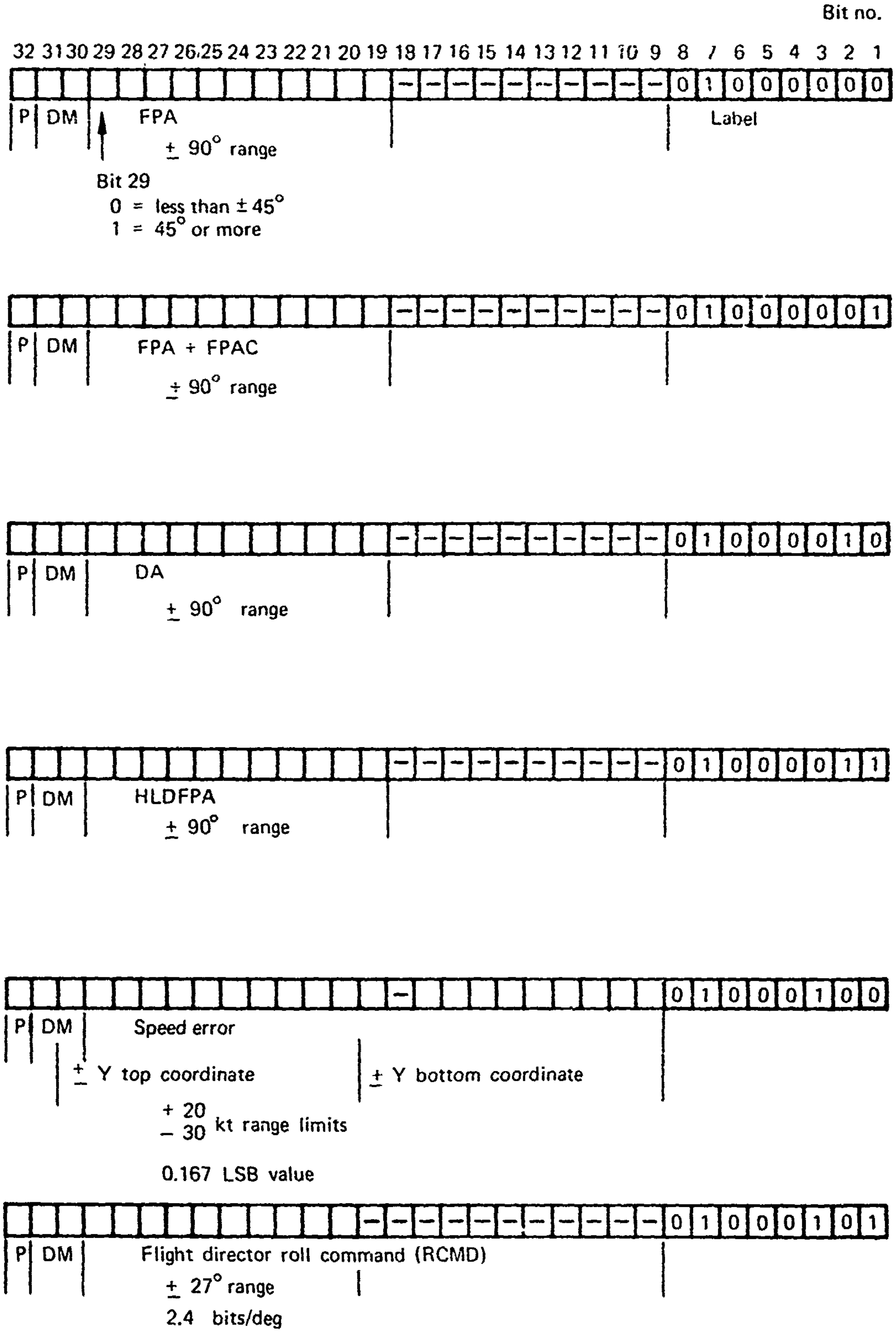


FIGURE 4-3.—EADI BUS WORD FORMATS

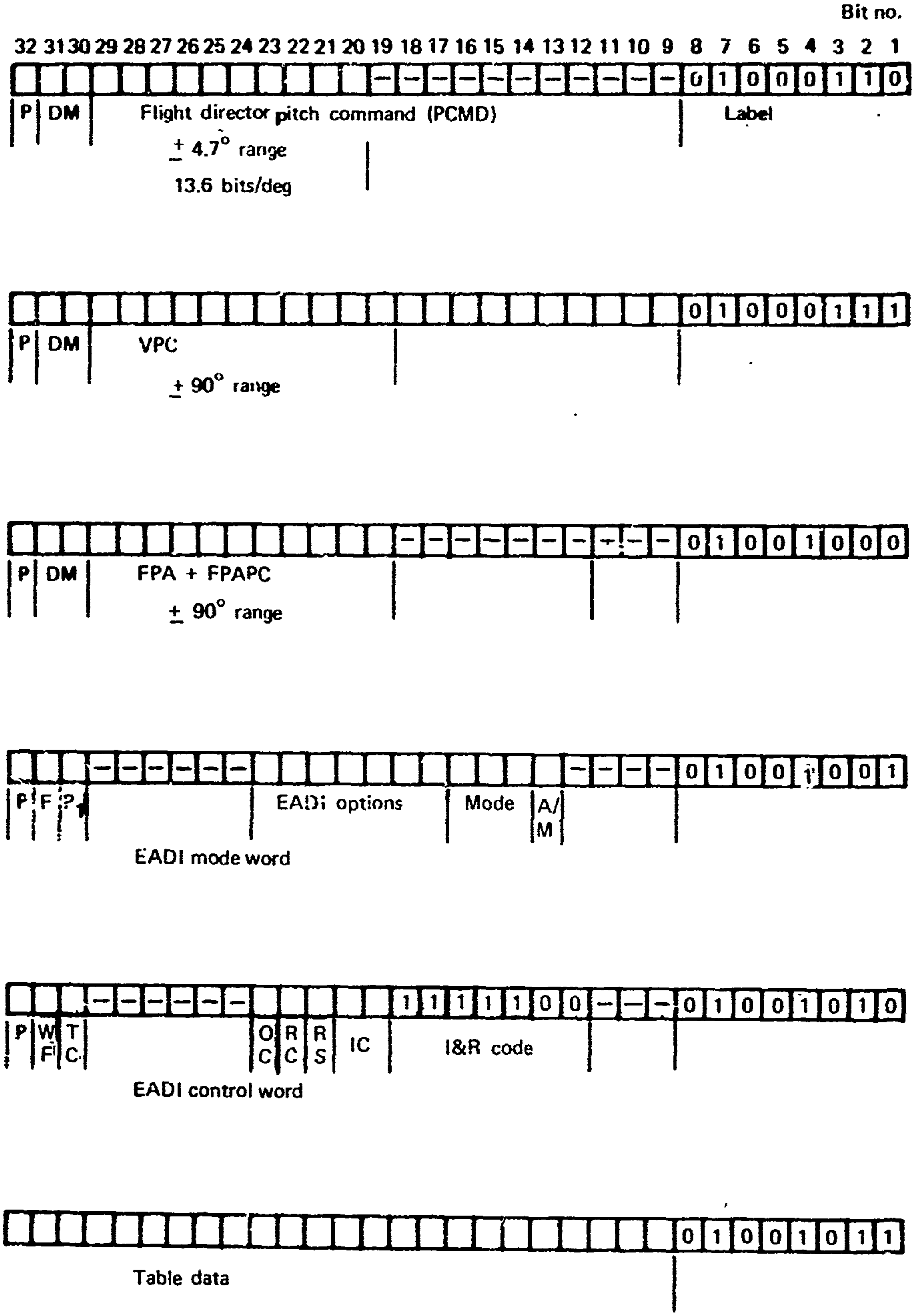
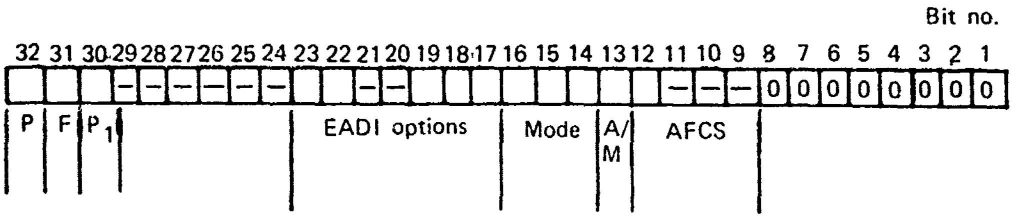


FIGURE 4-3.—CONCLUDED



Bit			
32	P =	word parity	
31	F =	display failure	
30	P_1=	EADI bus parity error detected	

EADI options: 1 = ON

23-17	23 17	
	0 0 0 0 0 0 1	V-NAV (vertical navigation)
	0 0 0 0 0 1 0	FLT DIR (flight director)
	0 0 0 0 1 0 0	SPD ERR (speed error)
	0 0 0 1 0 0 0	ILS
	0 0 1 0 0 0 0	RUNWAY
	0 1 0 0 0 0 0	TV
	1 0 0 0 0 0 0	Spare

EADI mode:

16-14	16 14	
	0 0 0	LAND
	0 0 1	CRUISE
	0 1 0	TEST

Pitch reference A/M:

13	0	MAN (manual)
	1	AUTO

AFCS select:

12-9	12 9		
	0 0 0 0	AUTO	Provisions for future AFCS integration
	0 0 1 0	AFCS 1	
	0 1 0 0	AFCS 2	
	1 0 0 0	AFCS 3	

FIGURE 4-4.– EADI MODE WORD FORMAT

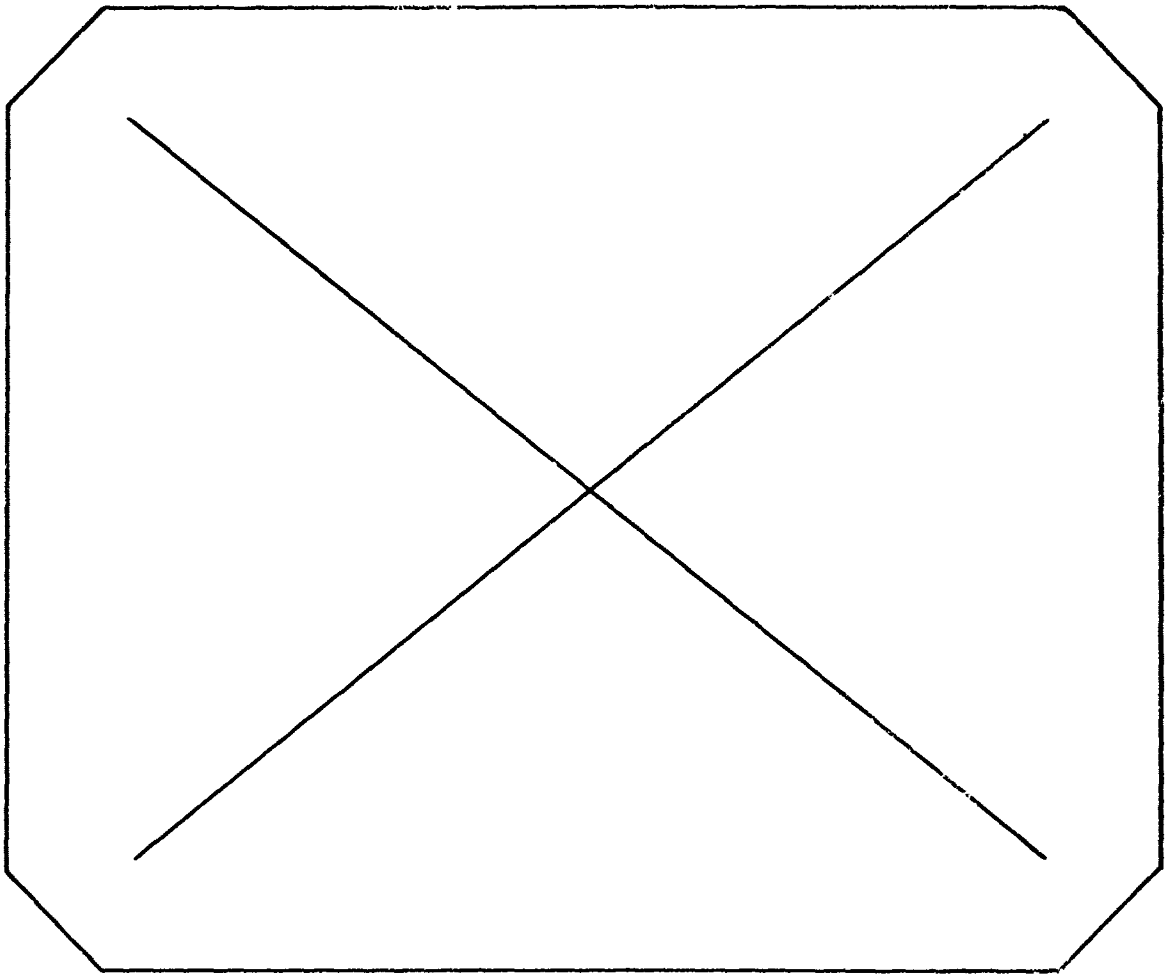


FIGURE 4-5.–EADI DISPLAY FORMAT WITH INVALID PITCH OR ROLL

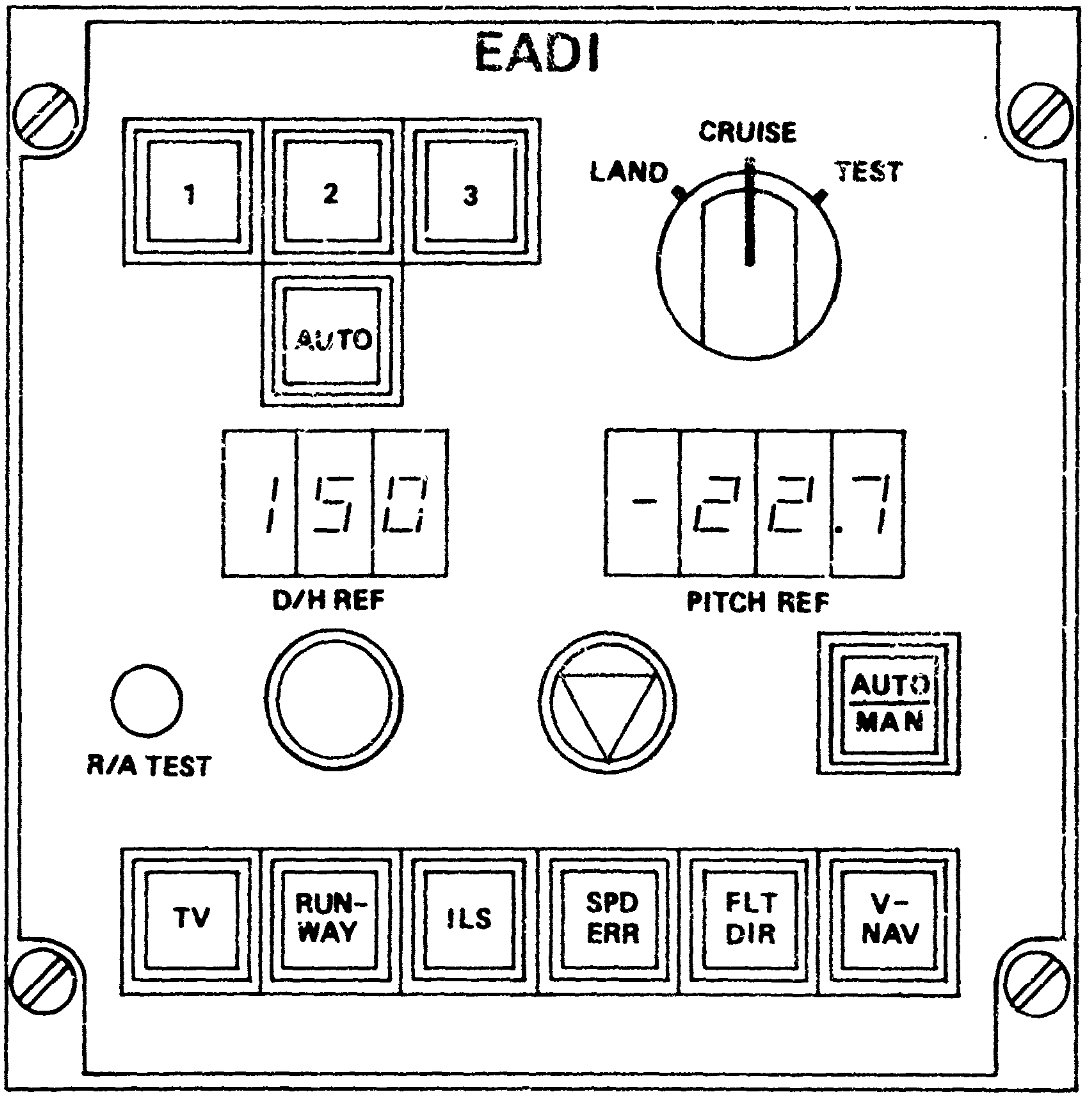


FIGURE 4-6.—EADI MODE CONTROL UNIT

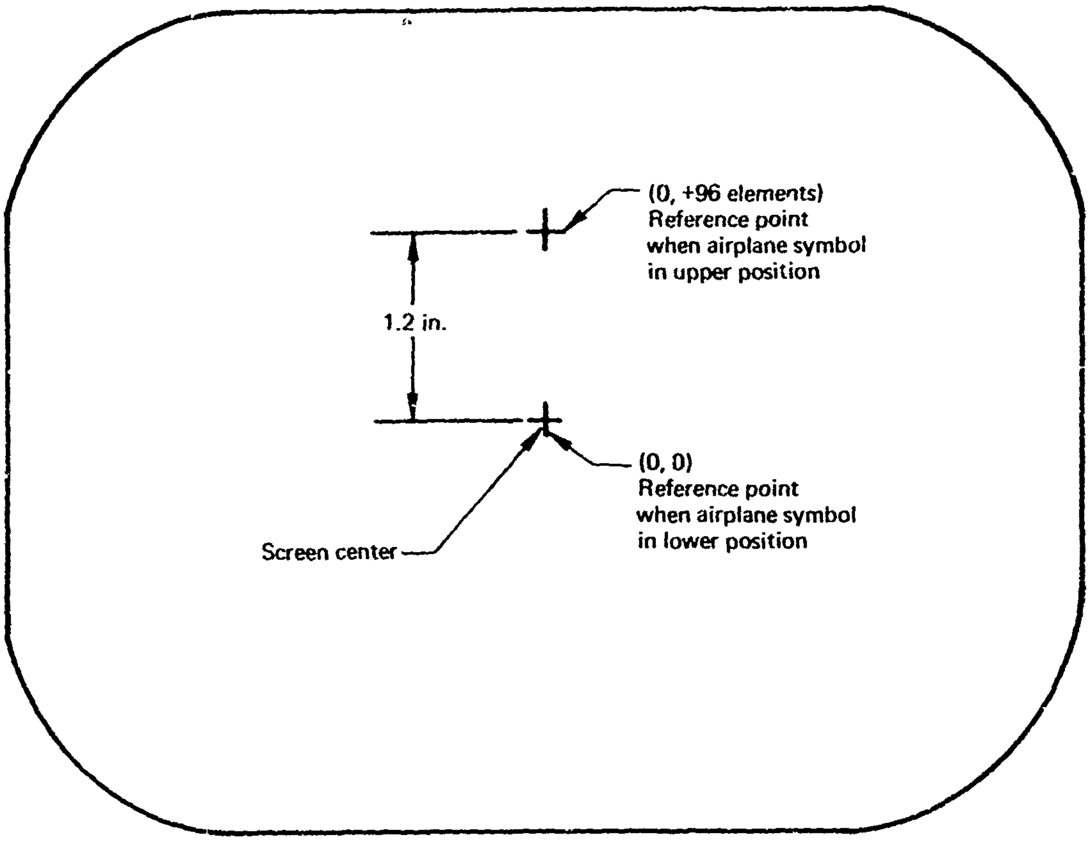
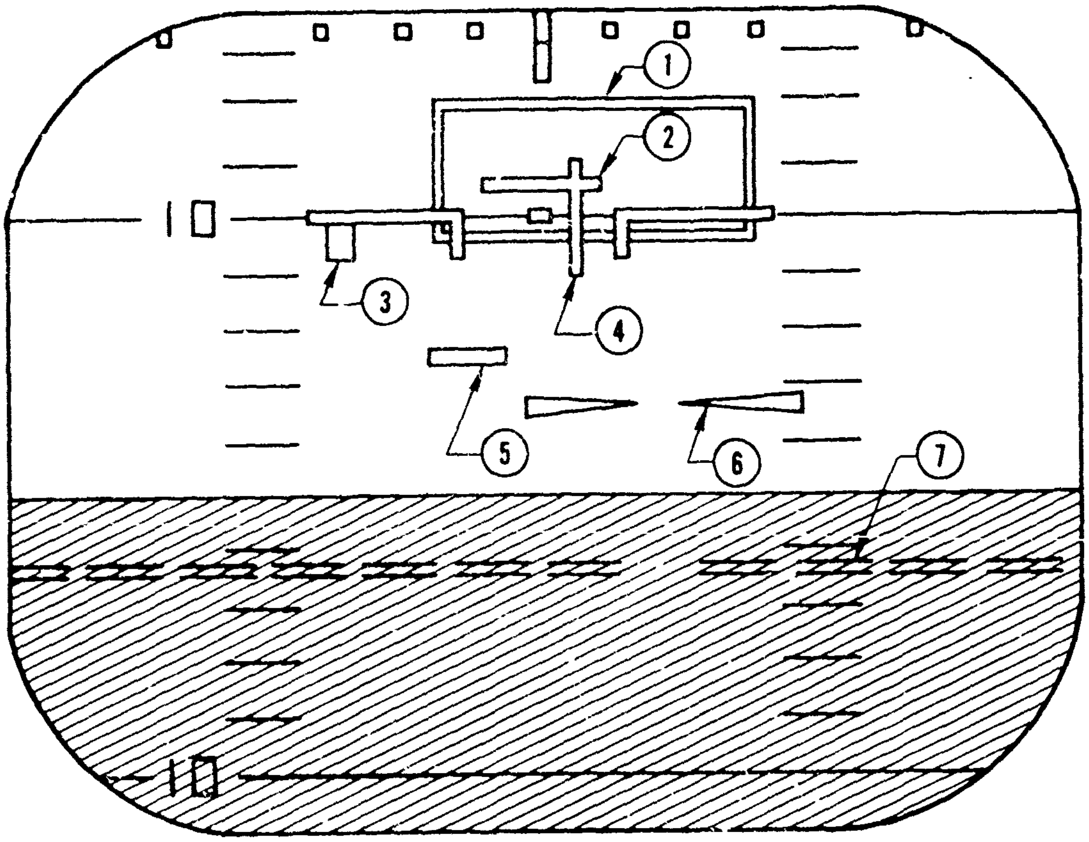


FIGURE 4-7.–LOCATION OF REFERENCE POINTS–EADI



① Center of beam above and to right of airplane

② Plus pitch command (calls for pitch up)

③ Plus speed error (calls for speed increase)

④ Plus roll command (calls for roll right)

⑤ Plus flightpath acceleration (forward acceleration)

⑥ Plus flightpath (above horizon) and plus drift angle (drift to right)

⑦ Minus pitch (or flightpath angle) reference

FIGURE 4-8.–POLARITY DEFINITION–EADI SYMBOLOGY

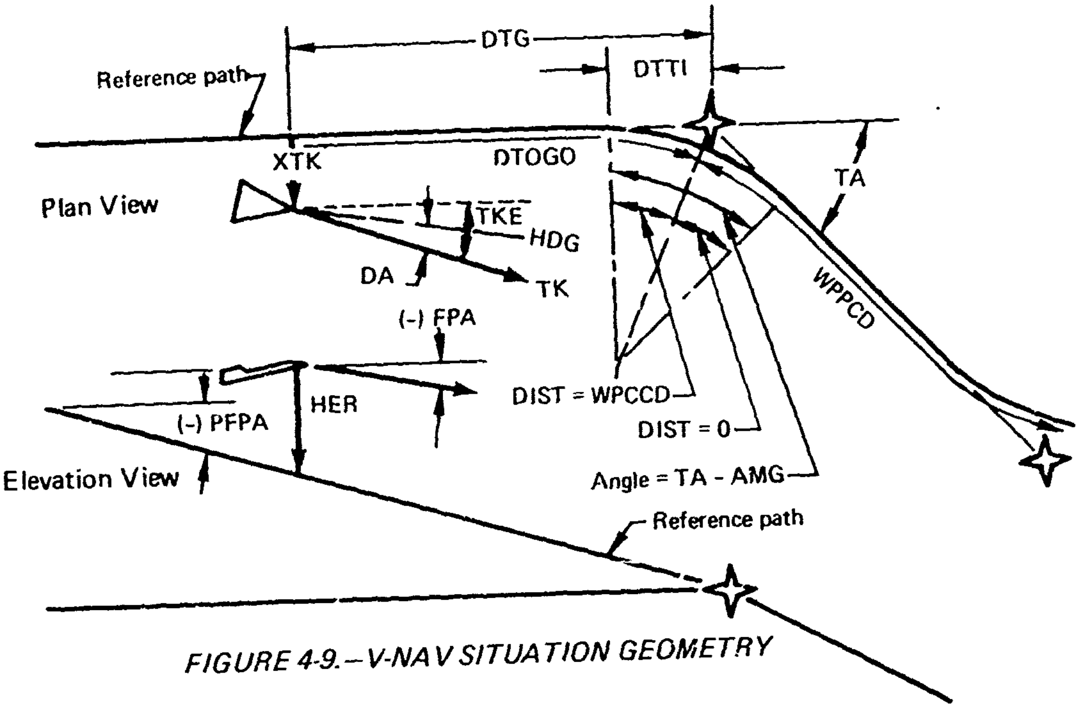


FIGURE 4-9.–V-NAV SITUATION GEOMETRY

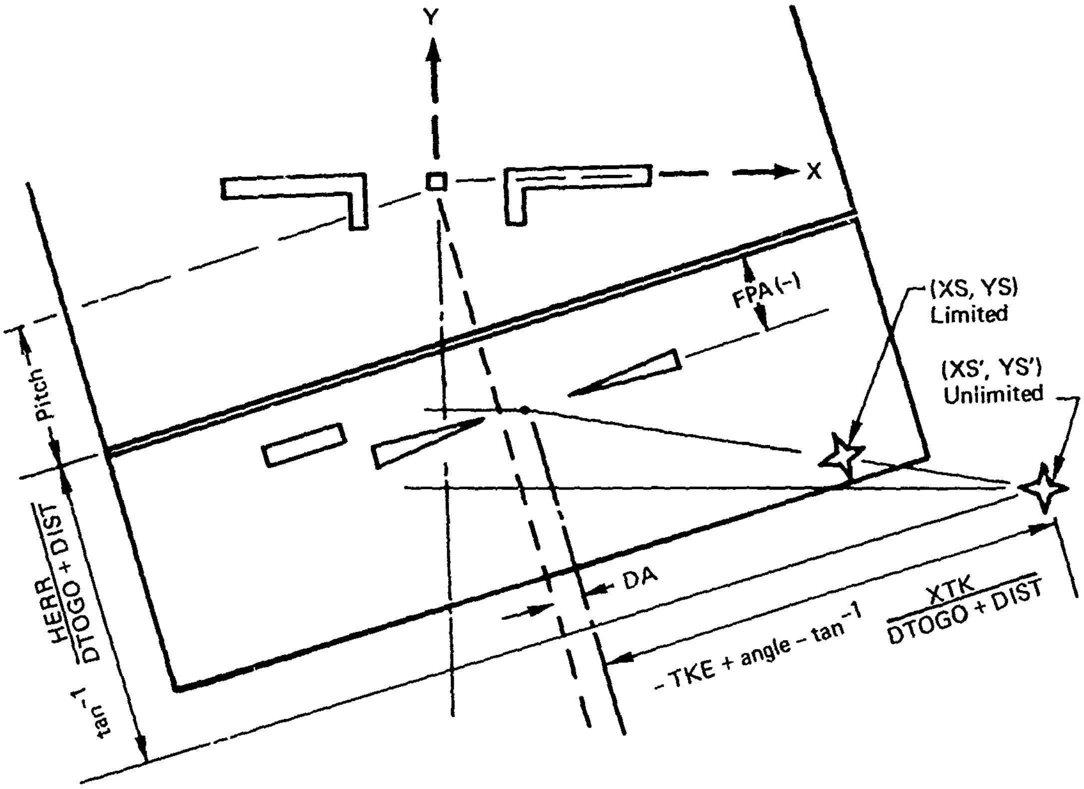


FIGURE 4-10.–EADI V-NAV STAR AND LIMITING

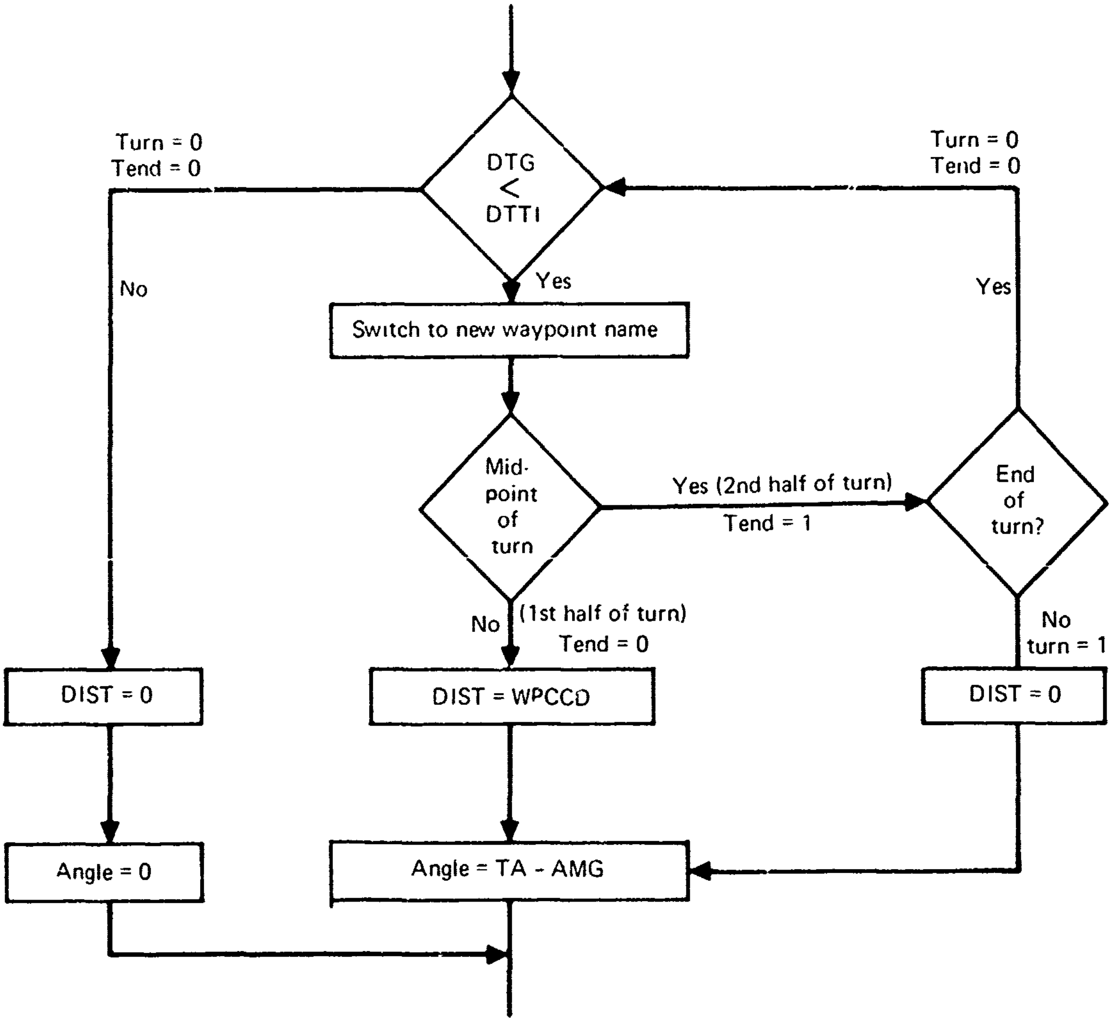
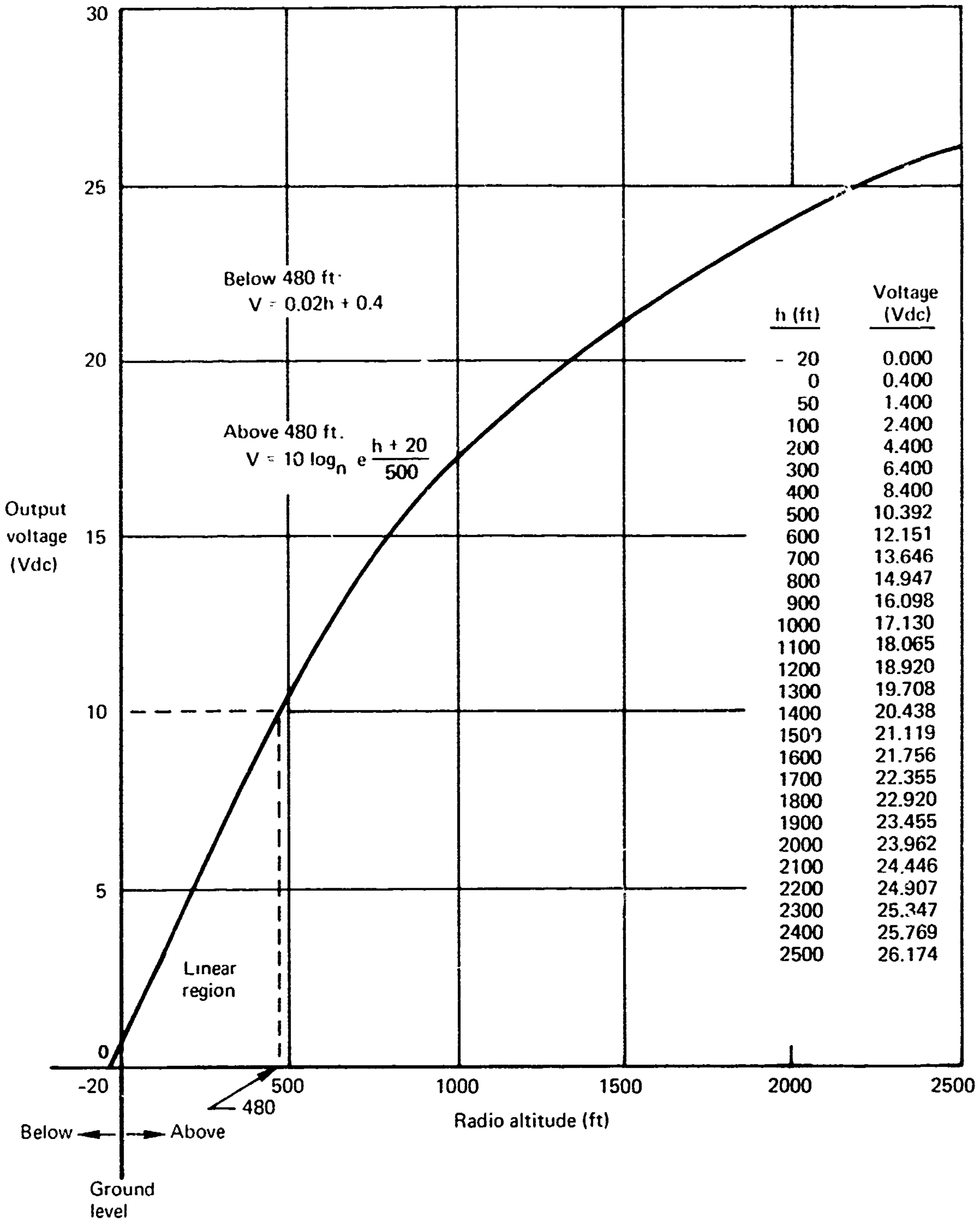
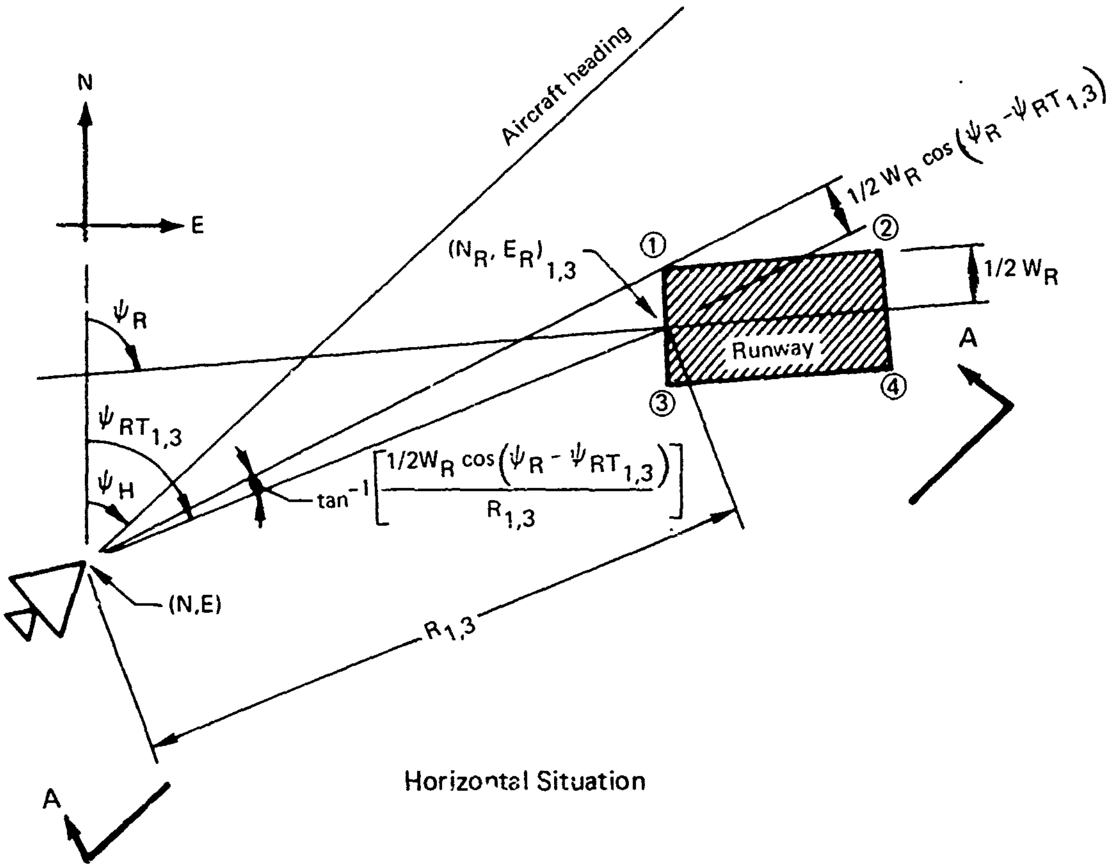


FIGURE 4-11.--GUIDANCE SUBROUTINE DETAIL

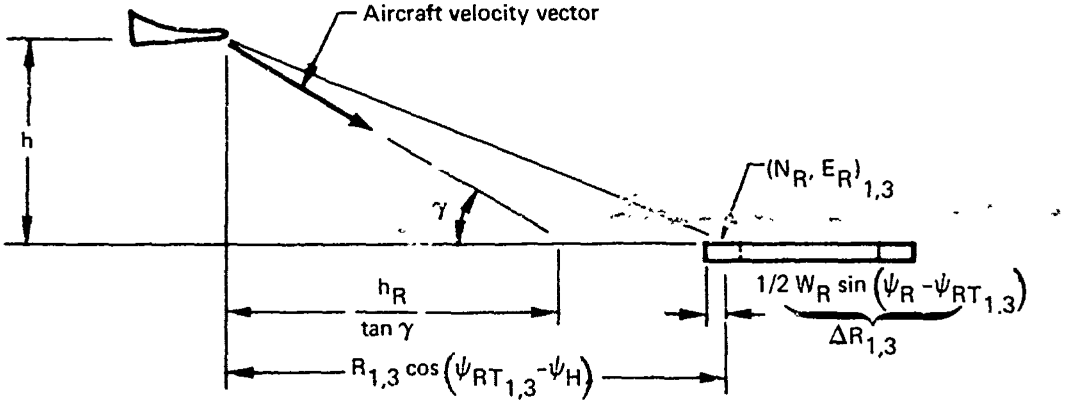


h (ft)	Voltage (Vdc)
- 20	0.000
0	0.400
50	1.400
100	2.400
200	4.400
300	6.400
400	8.400
500	10.392
600	12.151
700	13.646
800	14.947
900	16.098
1000	17.130
1100	18.065
1200	18.920
1300	19.708
1400	20.438
1500	21.119
1600	21.756
1700	22.355
1800	22.920
1900	23.455
2000	23.962
2100	24.446
2200	24.907
2300	25.347
2400	25.769
2500	26.174

FIGURE 4-12.–DC ALTITUDE OUTPUT (AUTOPILOT/INDICATOR DRIVE) VOLTAGE CHARACTERISTICS



Horizontal Situation



Vertical Situation
(Section A-A)

FIGURE 4-13.–APPROACH SITUATION GEOMETRY–RUNWAY THRESHOLD DETAIL

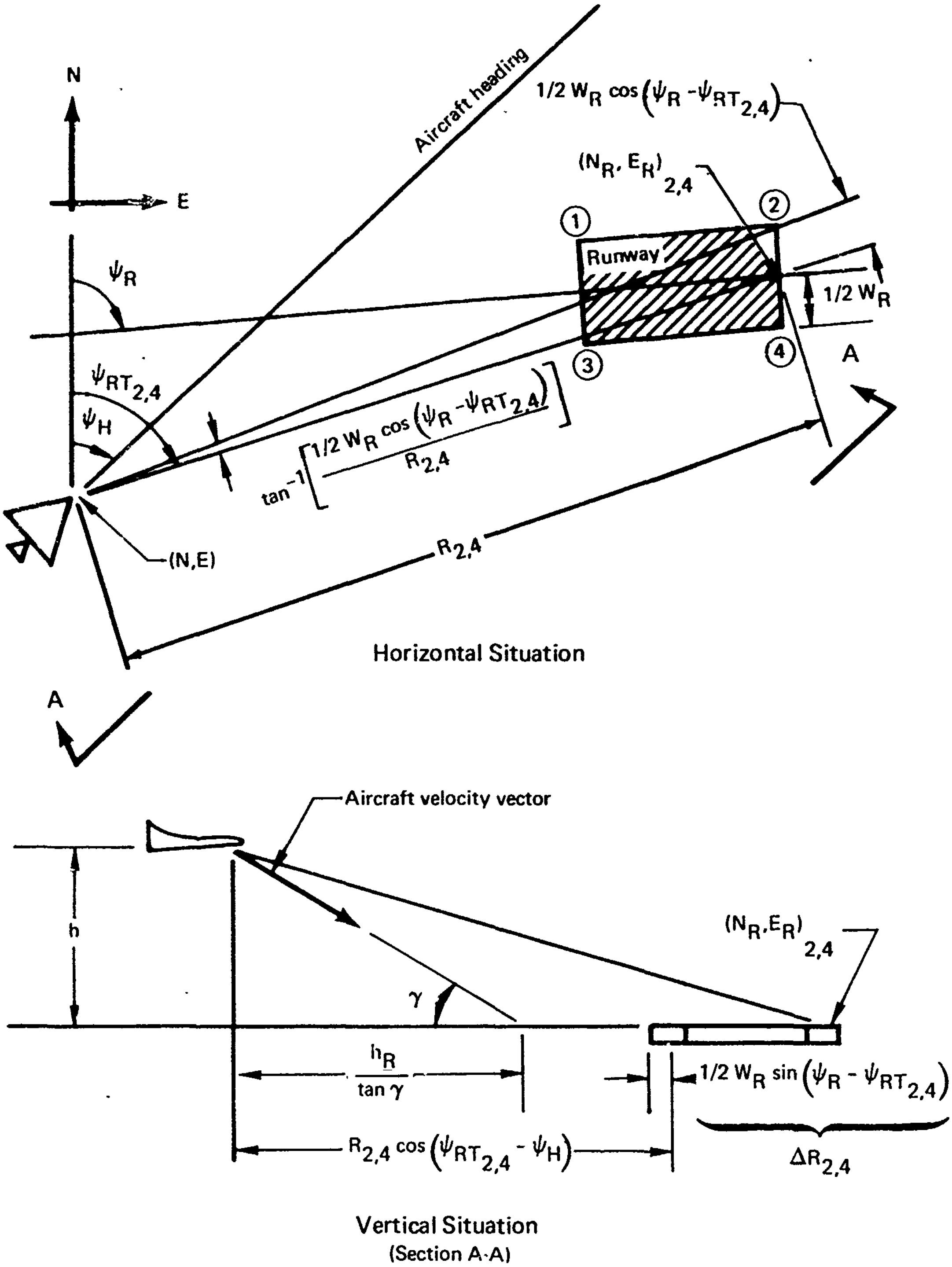


FIGURE 4-14.–APPROACH SITUATION GEOMETRY–RUNWAY ORIENTATION DETAIL

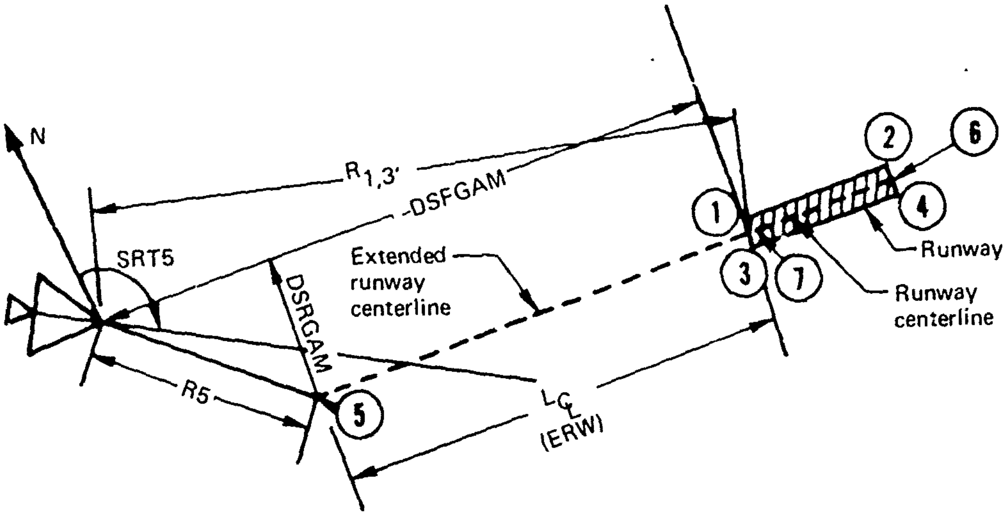


FIGURE 4-15.–APPROACH SITUATION GEOMETRY–RUNWAY CENTERLINE DETAIL

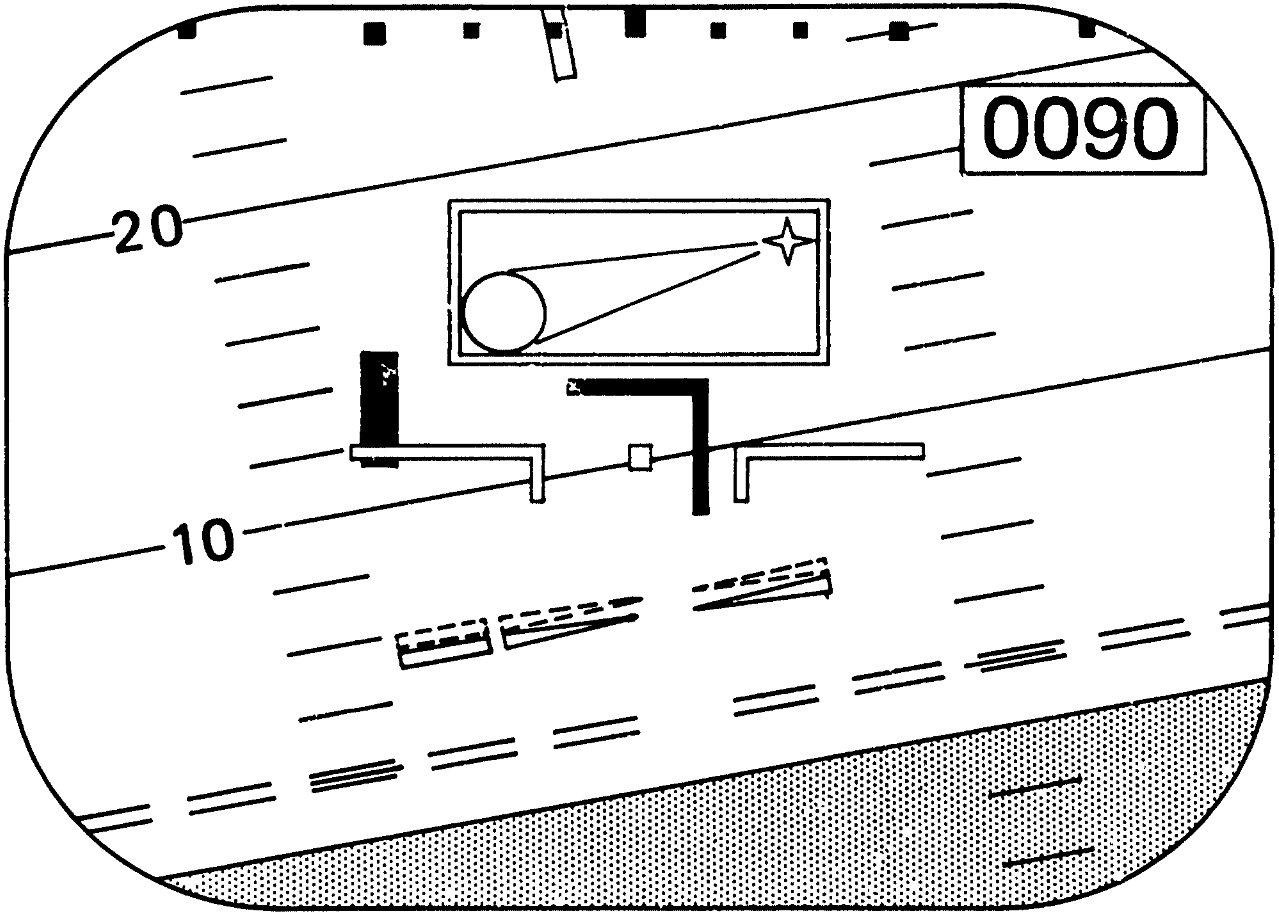


FIGURE 4-16.–EADI SELF-TEST DISPLAY FORMAT

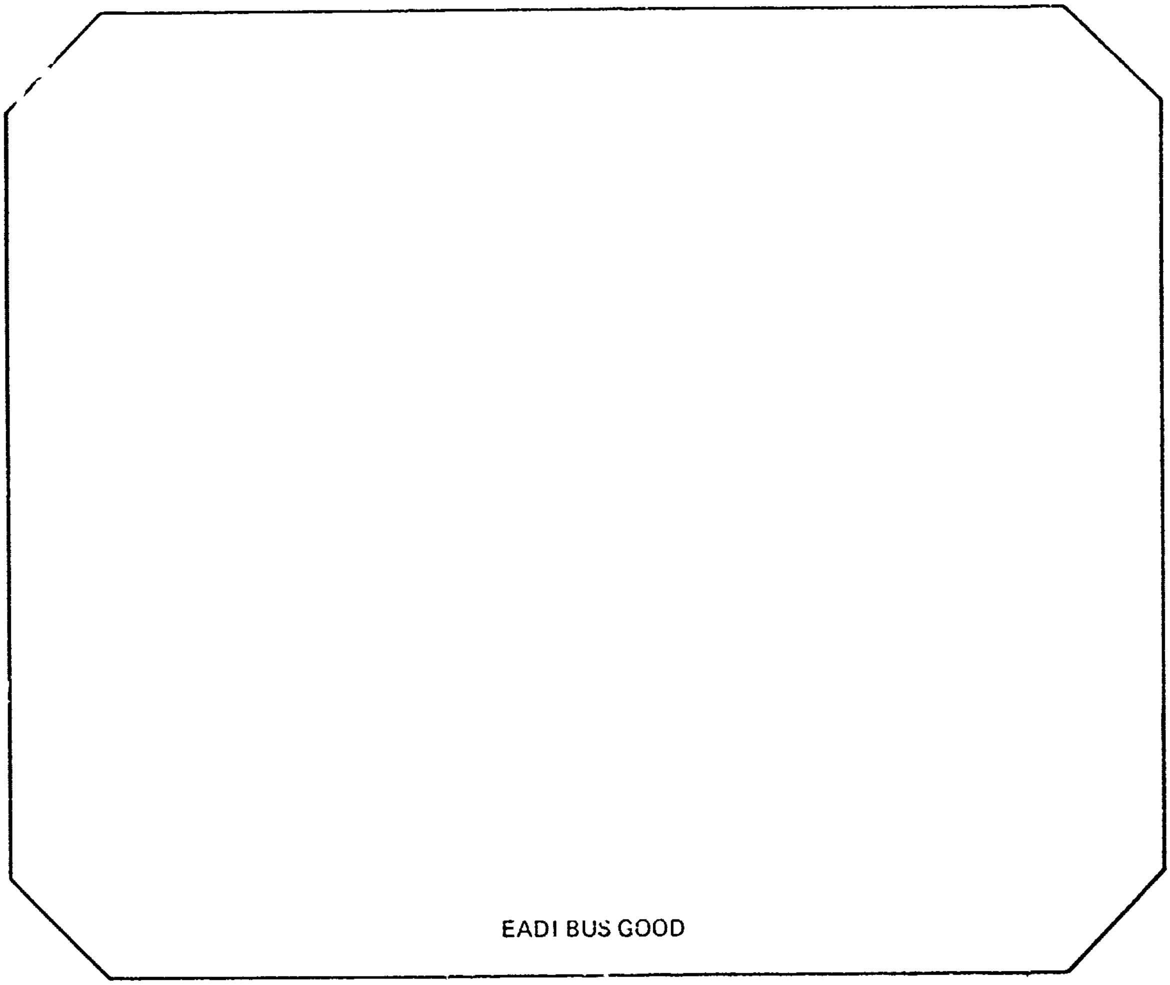


FIGURE 4-17.–NCU/PCU INTERFACE TEST–EADI DISPLAY FORMAT

5.0 FOUR-DIMENSIONAL GUIDANCE REQUIREMENTS

5.1 GENERAL

To fly a path in 4D with acceptable time errors, it is necessary to define the horizontal (2D) and vertical (3D) path in more detail than is currently required by the ARINC 561 navigation/guidance systems. In particular, the transition path from the inbound leg to a waypoint to the outbound leg must be defined in detail. The necessity for such detail stems from the fact that the 4D speed commands are derived in part using distances that are presumed to reflect the actual length of the path followed by the aircraft in flying from waypoint to waypoint. In the terminal area especially, the difference between the actual length of the path flown by the airplane and the sum of the distances between each successive pair of waypoints is large enough to have a significant degrading effect on 4D system performance if that difference is not taken into account.

The impact of these considerations on the guidance system has many aspects, which are covered in the following sections. One is that detailed definition of the path must be computed and stored for the duration of the flight. This benefits the display programs because quantities needed by the displays will have been calculated in the guidance routine. Another impact of 4D is that the basic data from which the path is defined must include altitude, velocity, and time information. Furthermore, en route modifications to the flight plan such as waypoint location changes or the addition of waypoints will necessitate a complete reexecution of the path-planning portion of the guidance routine. Special types of maneuvers such as 270° turns about a VORTAC facility will require special methods for entering the flight plan data so that the path definition part of the guidance program will "understand" how to format the information for the basic guidance package.

5.2 COORDINATE SYSTEM AND NOTATION

The coordinate system used by the guidance routine shall be an earth-centered, right-hand orthogonal coordinate system as shown in figure 5-1. The X-axis of the system shall be the polar axis, positive north. The Z-axis shall pierce the Greenwich Meridian at the equator. Latitudes shall be positive in the northern hemisphere and negative in the southern hemisphere. Longitudes shall be positive if measured east from the Greenwich Meridian.

When the airplane is flying along a guidance path, the waypoint immediately behind the airplane shall be termed P1; the upcoming or TO waypoint shall be termed P2; the one after that, P3,; and so forth, as illustrated in figure 5-2.

5.3 ORGANIZATION OF THE PROGRAM

The guidance software program will feature three main routines: 1) path definition, 2) horizontal/vertical guidance, and 3) time guidance.

5.3.1 Path Definition Program (PATHDF)

The path definition program shall calculate detailed path data from a provisional flight plan and enter these data, properly scaled, in a 4D guidance buffer. The format of the two guidance buffers is shown in table 5-1. If no flight plan has previously been entered in the system, the path definition program shall fill guidance buffer 1. If a flight plan has previously been entered and accepted, it shall constitute the active path, and execution of the PATHDF program shall fill the guidance buffer not containing the active path. In this way, detailed information about a provisional path may be calculated and examined prior to accepting it as the active path.

The quantities in both guidance buffers shall be accessible by the real-time guidance routines, HVGUID and TGUID, and by other programs in the computer. However, no changes shall be made in these buffers except via the path definition program.

The path definition program shall receive its input data from the NCDU, punched tape, and the bulk data stored in the computer.

Machine language labels for quantities appearing in the active guidance buffers shall begin with the prefix WP, and those in the provisional buffer shall begin with PW (see table 5-4). For example, the groundspeed assigned to a waypoint in the active buffer shall be named WPV, whereas the same quantity in the provisional buffer shall be named PWV.

5.3.1.1 Two-Dimensional Flight Plans

The minimum input data required by the path definition program to define a 2D path shall be a list of waypoint locations specified in terms of latitude and longitude. It shall be possible to input waypoint names or the names of geographic points instead of waypoint latitudes/longitudes, providing the latitudes/longitudes corresponding to these names are stored in the bulk data storage unit. It shall be possible to describe a waypoint by entering a reference waypoint and a range and bearing from that reference. Other possibilities for inputting 2D data may be programmed, but those mentioned above shall be considered a minimum requirement.

In all cases the path definition program shall compute or assign to the waypoint buffer the following quantities, which pertain directly to the 2D guidance:

WPLT	Waypoint latitude
WPLG	Waypoint longitude
WPRTN	Waypoint radius of turn
WPPPD	Waypoint point-to-point distance
WPCCD	Waypoint center-to-center distance
WPTA	Waypoint turn angle

WPAO2	Waypoint 1/2 arc length of turn
WPDTT	Waypoint distance to tangent point
WPMV	Waypoint magnetic variation

The above are illustrated in figures 5-2 and 5-3.

The other quantities in the waypoint buffer shall be assigned dummy values, such as zero, if 3D/4D data are not entered in the flight plan. A 2D flag shall be set if *and only if* the information input to the path definition program is adequate to define the 2D path and the path definition calculations have been executed.

5.3.1.2 Three-Dimensional Flight Plans

The minimum input data required by the path definition routine to define a 3D path shall include the minimum required to define a 2D path plus an altitude specified for each waypoint. It shall be possible to enter an altitude by specifying, via the NCDU or tape, the waypoint altitude in feet or the flight level number corresponding to that altitude. The quantities computed or entered by the PATHDF program for a 3D flight plan in the waypoint buffer include those computed for the 2D flight plan in addition to:

WPH	Waypoint altitude
WPGAM	Flightpath gradient inbound to waypoint

The other quantities in the waypoint buffer that do not result from the 2D/3D calculations shall be assigned a dummy value, such as zero, unless sufficient data to define a 4D path have been entered in the flight plan. A 3D flag shall be set if *and only if* the information input to the path definition program is adequate to define the 3D path and these calculations have been executed.

5.3.1.3 Four-Dimensional Flight Plans

The minimum input data required by the path definition program to define a 4D path shall include the minimum requirements for a 3D path definition. In addition, the data shall include a groundspeed assigned to each waypoint and a planned time of arrival at one waypoint. If two or more arrival times are specified as well as all waypoint velocities, the program will reject all arrival times except the last. Other techniques for entering time/velocity information may be implemented in the path definition program, however, in each case the program will compute the parameters specified for 3D in addition to:

WPV	Groundspeed assigned to waypoint
WPT	Time to fly inbound path segment
WPPTA	Waypoint planned time of arrival

A 4D flag shall be set if *and only if* the information input to the path definition program is adequate to define a 4D path and the 4D path definition calculations have been executed.

Each guidance buffer shall accommodate at least 30 waypoints.

5.3.1.4 Structure of the Horizontal Path

The horizontal path defined by the path definition routine shall consist of great circle paths between successive waypoints with circular arcs at each waypoint to define the transition from one leg of the path to the next. At waypoints where a track change is required, the circular arcs shall be characterized by a turn center location, a turn radius, and the magnitude of the track change required at the waypoint.

It shall be possible to enter the turn radius at a waypoint via the NCDU or punched tape. If no radius is assigned, but a groundspeed is designated for a waypoint, the path definition program shall assign a turn radius based on the formula:

$$R = V^2/(g \tan \phi)$$

where:

R = radius of turn

V = groundspeed assigned to waypoint

ϕ = nominal bank of 15°

g = gravitational acceleration (32.2 ft/sec^2)

If neither a groundspeed nor a turn radius is entered, the path definition program shall assign a turn radius as follows:

R = 15,000 ft when the waypoint altitude is below 15,000 ft; otherwise 50,000 ft

5.3.1.5 Structure of the Vertical Path

The vertical path shall be based on the altitude difference between successive waypoints and the center-of-turn to center-of-turn distances between successive waypoints as computed in the horizontal guidance calculations. The vertical guidance path shall consist of a constant gradient transition from one waypoint altitude to the next. A smooth transition from the inbound path gradient to the outbound path gradient shall be programmed.

5.3.1.6 Structure of the Speed/Time Profile

The speed profile shall be based on the center-of-turn to center-of-turn distances and the velocity assignments to each waypoint. The time to fly each leg of the path shall be computed assuming a constant acceleration from the speed at each waypoint to the speed at the next waypoint. The planned time of arrival at each waypoint shall be computed from the times to fly each leg and the PTA assigned to one waypoint via the NCDL or paper tape.

5.3.2 Horizontal and Vertical Guidance Program (HVGUID)

The HVGUID program will compute the position, velocity, and acceleration of the airplane relative to horizontal and vertical paths defined in the path definition program (PATHDF). Furthermore, HVGUID will generate vertical and horizontal steering commands with appropriate limiting and filtering for use by a flight control computer. These steering commands shall be appropriate to capture the specified guidance path and subsequently minimize the airplane's lateral and vertical deviations from the path.

The basic path guidance capability is augmented by the additional modes listed below:

- Path offsets (parallel offsets, right or left, from a primary guidance path at selectable offset distances)
- Track hold/select
- Altitude hold/select
- Flightpath angle hold/select
- Holding pattern

As a minimum requirement, the quantities outlined in table 5-2 shall be computed by the HVGUID software.

The following quantities shall be computed at least 20 times/sec:

XTK	Crosstrack distance (positive to right of path)
TAE	Track angle error (track minus desired track)
DSRTK	Desired track relative to true north
HER	Altitude error (command altitude minus actual altitude)
HDE	Altitude rate error (commanded rate minus actual rate)
HDDE	Vertical acceleration error (commanded acceleration minus actual acceleration)

5.3.3 Speed/Time Guidance Program (TGUID)

The function of the TGUID program shall be to compute the position, speed, and acceleration of a command spot as a function of time while the airplane is flying a 4D guidance path. The TGUID program shall also compute the speed associated with the point on the path abeam of the airplane, i.e., the speed of the command spot when its distance to go to the next waypoint in the airplane's path is equal to the airplane's distance to go. The TGUID program shall compute an autothrottle signal appropriate to control airplane speed in such a way as to minimize the along-track separation distance between the airplane and the command spot. As a minimum requirement, the quantities shown in table 5-3 shall be computed 20 times/sec.

5.3.4 Guidance System Alarm Flag

The guidance system shall set an alarm flag whenever one or both of the following conditions are satisfied:

$$|XTK| \geqslant 15{,}000 \text{ ft}$$

$$|DTG_i| > |DTG_{i-1}|$$

If neither condition is satisfied subsequent to setting the flag, it shall reset to its no-alarm state.

5.3.5 Machine Language Labels

The machine language labels defined in this section describe the parameters used by the EADI, MFD, and NCDU programs. Table 5-4 summarizes these quantities, their units, scale factors, rates, and use.

5.4 PROGRAM INTERFACES

5.4.1 Navigation/Guidance Interface

The guidance system requires the following quantities from the navigation computations at the data rates specified below:

		rate (updates/sec)
Airplane position	Latitude	20
	Longitude	20
	Altitude	20
Airplane velocity	Groundspeed	20
	Track angle	20

		rate (updates/sec)
Airplane accelerations	North	20
	East	20
	Vertical	20
Time	GMT	20

5.4.2 Guidance/EADI Interface

The guidance program will provide the EADI program with the following quantities:

Distance to go (DTOGO)

Altitude error (HER)

Crosstrack distance error (XTK)

Upcoming waypoint names (WPNAM1; WPNAM2)

Beginning of turn flag (TURN)

Halfway through turn flag (TEND)

Distance from waypoint at which turn begins (WPDTT)

Track angle error (TAE)

Flightpath angle command (PFPA)

Waypoint latitude (WPLT)

Waypoint longitude (WPLG)

Waypoint altitude (WPH)

Center-of-turn to center-of-turn distance (WPCCD)

Turn angle at waypoint (WPTA)

Longitudinal acceleration command (SDDC)

5.4.3 MFD/Guidance Interface

The guidance system will furnish the MFD program with the following quantities:

Airplane track angle error (TAE)

Airplane crosstrack distance (XTK)

Airplane acceleration–forward

Airplane acceleration–right

Waypoint latitudes (WPLT)

Waypoint longitudes (WPLG)

Inbound track angles

Arc lengths at waypoints

Waypoint speeds (WPV)

Waypoint scheduled time of arrival (WPPTA)

Turn tangent point latitude

Turn tangent point longitude

Arc length of turn

Anticipation point

Type-of-waypoint flag

VORTAC (in use) latitudes

VORTAC (in use) longitudes

Turn lead distance (DTTI)

TABLE 5-1.–GUIDANCE 1 AND GUIDANCE 2 DATA BUFFERS

	24							1		
(a)				Name	of	Waypoint				1st waypoint
(b)						☒			(c)	
	Latitude					°/180	B0			
	Longitude					°/180	B0			
	Altitude					ft	B23			
	Groundspeed					kt	B15			
	Radius of turn					ft	B23			
	Incremental time en route					sec	B15			
	Great circle distance					ft	B23		(WPPPD)	
	Waypoint center–center distance					ft	B23		(WPCCD)	
	Flightpath angle					°/180	B0			
	Turn angle at waypoint					°/360	B0			
	Arc distance of curve/2					ft	B23			
	Distance waypoint to tangent points					ft	B23			
	Planned time of arrival					sec	B23			
	Magnetic variation					°/180	B0			
	Pointer to navaid									
	Bearing from turn center					°/360	B0			
	DME arc reference latitude					°/180	B0			
	DME arc reference longitude					°/180	B0			
										nth waypoint
	Terminator = 0									

[a] Bit 24 = 1 Provisional path
23 = 1 Flight level waypoint
22 = 1 Use IASREF from NCDU for display

[b] Bit 24 = 1 For DME arc
23 = 1 For DME arc inhibit
Bit 22 = 1 Inhibit radius of turn calculation
3 = 1 Do not display waypoint star on MFD

[c] Bits 1 and 2:
0 = Airway/route
1 = SID
2 = STAR
3 = MAP

TABLE 5-2.–REAL-TIME COMPUTATIONS BY HVGUID

Name	Definition
ALCBA	Nominal bank angle during a turn
DMG	Total distance made good along the path by the airplane
DTG	Distance from the abeam point (fig. 5-2) to the upcoming waypoint measured on a great circle path
DTOGO	Distance from the abeam point to the center of the upcoming turn
XTK	Crosstrack error
TAE	Track angle error
AMG	Absolute value of turn angle made good
RALC	$(\phi ALC/\dot{\phi}_{Lim})$ VGS
DTTI	WPDTT + RALC; distance from waypoint at which to apply PHALC
ALCXA	Turn angle made good at which to remove PHALC
DSRTK	Track command
HER	Altitude error

TABLE 5-3.–REAL-TIME CALCULATIONS BY TGUID

Name	Definition
SDDC	Command spot acceleration
SDCC	Command spot speed
SC	Distance from the command spot to the next sheduled waypoint (see fig. 5-3).
SDC	Speed of the command spot when it is at the point where the airplane is now
DTOGO+1	Along-path distance to go of the command spot
SEPR	Distance measured along the path between the command spot and the airplane abeam point
SPDE	Difference between SDC and the airplane groundspeed
DMG	Sum of legs made good by airplane
DMG+1	Sum of legs made good by command spot
ADMG	Arc distance made good by box during a turn

TABLE 5-4.–GUIDANCE PROGRAM LABELS

Label	Unit	Scale	Rate (updates/ sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
WPNAM1	NA	NA		PATHDF		X	X	X	X		Waypoint name 1
WPNAM2	NA	NA		↑		↑	↑	X	X		Waypoint name 2
WPLT	deg	±180		↕		↕	↕	X	X		Waypoint latitude
WPLG	deg	±180		↕		↕	↕	X	X		Waypoint longitude
WPH	ft	2^{23}		↕		↕	↕	X	X		Waypoint altitude
WPV	kt	2^{15}		↕		↕	↓		X		Waypoint groundspeed
WPRTN	ft	2^{23}		↕		↕	X		X		Waypoint radius of turn
WPT	sec	2^{15}		↕		↕					Incremental time (on inbound leg)
WPGPD	ft	2^{23}		↕		↕	X				Great circle distance between waypoints (on inbound leg)
WPCCD	ft	2^{23}		↕		↕	X	X			Along-path distance between waypoints (on inbound leg)
WPGAM	deg	±180		↕		↕		X	X		Gradient of flightpath
WPTA	deg	±360		↕		↕	X				Track change at waypoint (+ for clockwise)
WPA02	ft	2^{23}		↕		↕	X				½ arc length of turn at waypoint
WPDTT	ft	2^{23}		↕		↕	X	X			Distance from tangent point to waypoint
WPPTA	sec	2^{23}		↓		↓			X		Planned time of arrival at waypoint
WPMV	deg	±180		PATHDF		X			X		Magvar at waypoint

NA = not applicable

TABLE 5-4.–CONTINUED

Label	Unit	Scale	Rate (updates/ sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
P1ADR	NA	NA	NA	HVGUID		X					2D address pointer for P1 vector
TC2ADR	↑	↑	↑	↑		↑					2D address pointer for TC2 vector
NM2A4A											4D address pointer for WPNAM2 (airplane)
CCDA4A											4D address pointer for WPCCD (airplane)
VADR4A											4D address pointer for WPV (airplane)
GAMA4A											4D address pointer for WPGAM (airplane) (+ for increasing altitude)
HADR4A											4D address pointer for WPH (airplane)
GUID2D								X	X		2D guidance switch
GUID3D	↓	↓	↓								3D guidance switch
GUID4D	NA	NA	NA				X				4D guidance switch
RALC	ft	2^{23}	20								Turn anticipation distance
ALCFLG	NA	NA	20								Advance lateral control flag
ALCXA	deg	0-360	NA								Advance lateral control exit angle
NOMBA	deg	0-180	20								Nominal bank angle
ALCBA	deg	±180	NA	↓		↓					Advance lateral control bank angle (+ for right wing down)
XTK	ft	2^{23}	20	HVGUID		X		X	X		Crosstrack position of airplane. (+ to right of path)

NA = not applicable

TABLE 5-4.–CONTINUED

Label	Unit	Scale	Rate (updates/sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
TKE	deg	±180	20	HVGUID		X		X	X		Track angle error (TK - DSRTK)
HER	ft	2^{23}	20	↕		↕		X	X		Vertical path position error (HC - ALT) (+ below path)
HC	ft	2^{23}	20	↕		↕					Vertical path commanded altitude
HDTC	ft/sec	2^{15}	20	↕		↕					Vertical path commanded velocity
HDDC	ft/sec^2	2^{15}	20	↕		↕					Vertical path commanded acceleration
PO	one	2°	20	↕		↕					Airplane present position unit vector
POP	↕	↕	20	↕		↕					Airplane abeam point unit vector
POPC	↕	↕	20	↕		↕					Abeam point unit vector during turn
U12C	one	2°	20	↕		↕					Normal path vector in turn
POADR	NA	NA	NA	↕		↕					PO address pointer
POPADR	↕	↕	↕	↕		↕					PO' address pointer
POPCAD	↕	↕	↕	↕		↕					PO'C address pointer
U12CAD	↕	NA	↕	↕		↕					U12C address pointer
(a) WPPTR	↕	2^{23}	↕	↕		↕			X		Initialize waypoint designation number
(b) PTR2D	NA	2^{23}	NA	HVGUID		X					2D reference pointer

[a] BSS2–Cell 1 refers to the airplane
Cell 2 refers to the time box

NA = not applicable

[b] BSS2–Cell 1 = 2D scalar pointer
Cell 2 = 2D vector pointer

TABLE 5-4.–CONTINUED

Label	Unit	Scale	Rate (updates/ sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
PTR3D	NA	2^{23}	NA	HVGUID		X					3D reference pointer
(a) PTR4D	↑	2^{23}	↑	TGUID		↑					4D reference pointer
(a) TURN	↓	NA	↓	HVGUID							Discrete (set during entire turn)
(a) TEND	NA	NA	NA	↑							Discrete (set during second half of turn)
(a) AMG	deg	0-360	20								Angle made good during a turn
(a) DMG	nmi	2^{12}	20								Cumulative distance made good
DTG	ft	2^{23}	20								Great circle distance from PO' to TO waypoint
(a) DTOGO	ft	2^{23}	20								Along-track distance from PO' to TO midturn
(a) MAGTA	deg	0-360	20								Magnitude of turn angle
MAXPA	deg	+360	NA	↓							Maximum positive angle (360°)
MAXTA	deg	+360	↑	HVGUID							Maximum turn angle (330°)
FTONM	nmi/ft	2^{-8}		CONST							Conversion (ft to nmi) .0001645791344B-8
NMTFT	ft/nmi	2^{13}	↓	CONST							Conversion (nmi to ft) 6076.1B13
RADFT	ft	2^{25}	NA	HVGUID		↓					Radius of earth (ft) 20926424B25
DELTAT	sec	2°	20	EXEC		X					Iteration time 50 msec, 20 times/sec

[a] BSS2–Cell 1 refers to the airplane
Cell 2 refers to the time box

NA = not applicable

TABLE 5-4.—CONTINUED

Label	Unit	Scale	Rate (updates/ sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
DTTAD4	NA	NA	NA	HVGUID		X					4D address pointer for WPDTT (time box)
A02AD4	↑	↑	↑	↑		↑					4D address pointer for WPA02 (time box)
CCDA4B											4D address pointer for WPCCD (time box)
NM2A4B											4D address pointer for WPNAM2 (time box)
VADR4B	↓	↓	↓	↓							4D address pointer for WPV (time box)
TAAD4B	NA	NA	NA	HVGUID							4D address pointer for WPTA (time box)
SEPR	ft	2^{23}	20	TGUID					X		Separation distance from box to airplane (+ for box ahead)
SPDE	ft/sec	2^{15}	20	↑					X		Speed error at progress point of airplane (+ for underspeed)
SC	ft	2^{23}	20								Distance from box to TO waypoint
SDCC	ft/sec	2^{15}	20	↓							Velocity of time box
SDDC	ft/sec	2^{15}	NA	TGUID							Average acceleration along path segment (time box segment) (+ for increasing velocity)
ADMG	ft	2^{23}	20	HVGUID							Arc distance made good in turn
KTOFPS	ft/sec/kt	2^{1}	NA	CONST							Conversion (kt to ft/sec) 1.688889B1
PCMD	deg	±180	20	HVGUID							Flight director pitch command bar (+ for pitch up)
RCMD	deg	±180	20	HVGUID		↓					Flight director roll command bar (+ for roll right)
SPEBAR	ft/sec	2^{15}	20	TGUID		X					Partial autothrottle command (+ for speed up)

NA = not applicable

TABLE 5-4.—CONCLUDED

Label	Unit	Scale	Rate (updates/ sec)	Routine	Used by						Definition
					NAV	GUID	MFD	EADI	NCDU	Other	
PFPA	deg	±180	20	HVGUID		X					Continuous flightpath angle (commanded) (+ for ascending path)
VGS	ft/sec	2^{15}	20	NAV		X					Groundspeed
VGSDOT	ft/sec^2	2^{15}	20	NAV		X					Groundspeed acceleration
PPDA4A	NA	NA	NA	HVGUID		X					4D address pointer for WPPPD (airplane)
PPDA4B	NA	NA	NA	HVGUID		X					4D address pointer for WPPPD (time box)
VERSTR	deg	±180	20	HVGUID		X					3D guidance pitch command
LATSTR	deg	±180	20	HVGUID		X					2D guidance roll command
ROLL	deg	±180	20	NAV	X			X			Airplane roll angle
PITCH	deg	±180	20	↑	X			X			Airplane pitch angle
MAGHDG	deg	±180	20	↓	X						Airplane heading (magnetic)
ALT	ft	2^{23}	20	NAV	X	X					Computed altitude (baro-inertial)

NA = not applicable

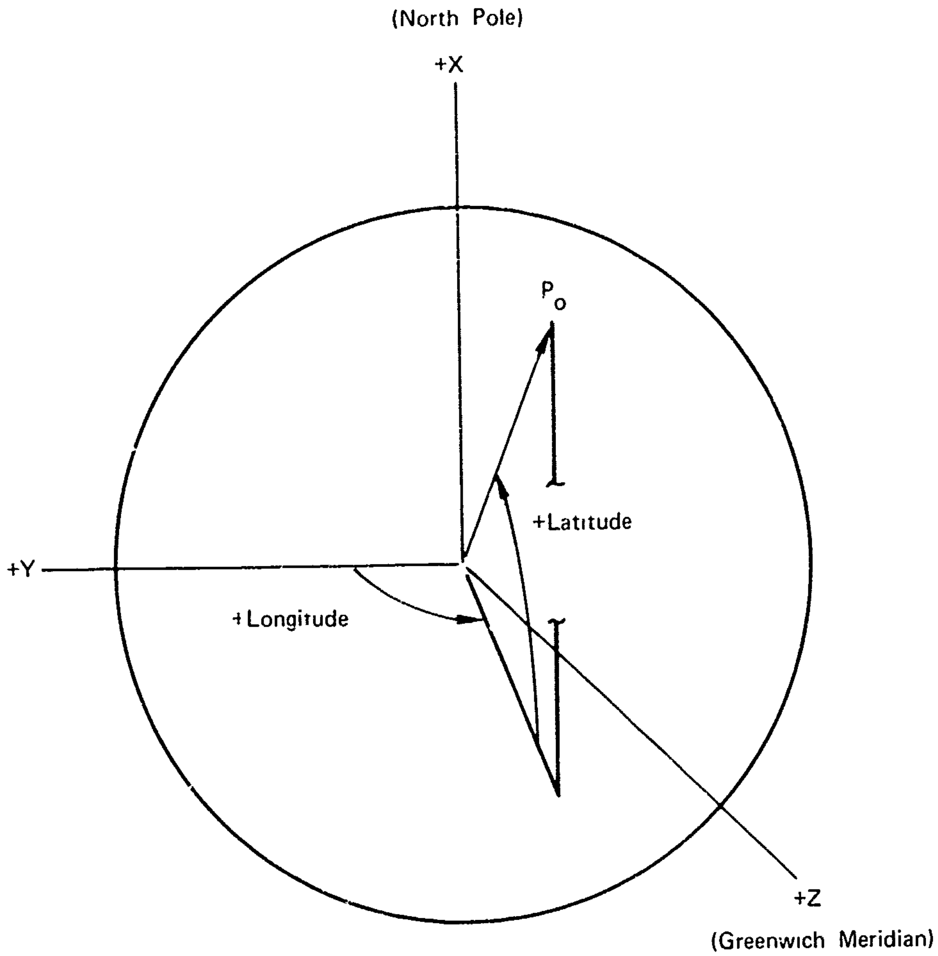


FIGURE 5-1.--COORDINATE SYSTEM

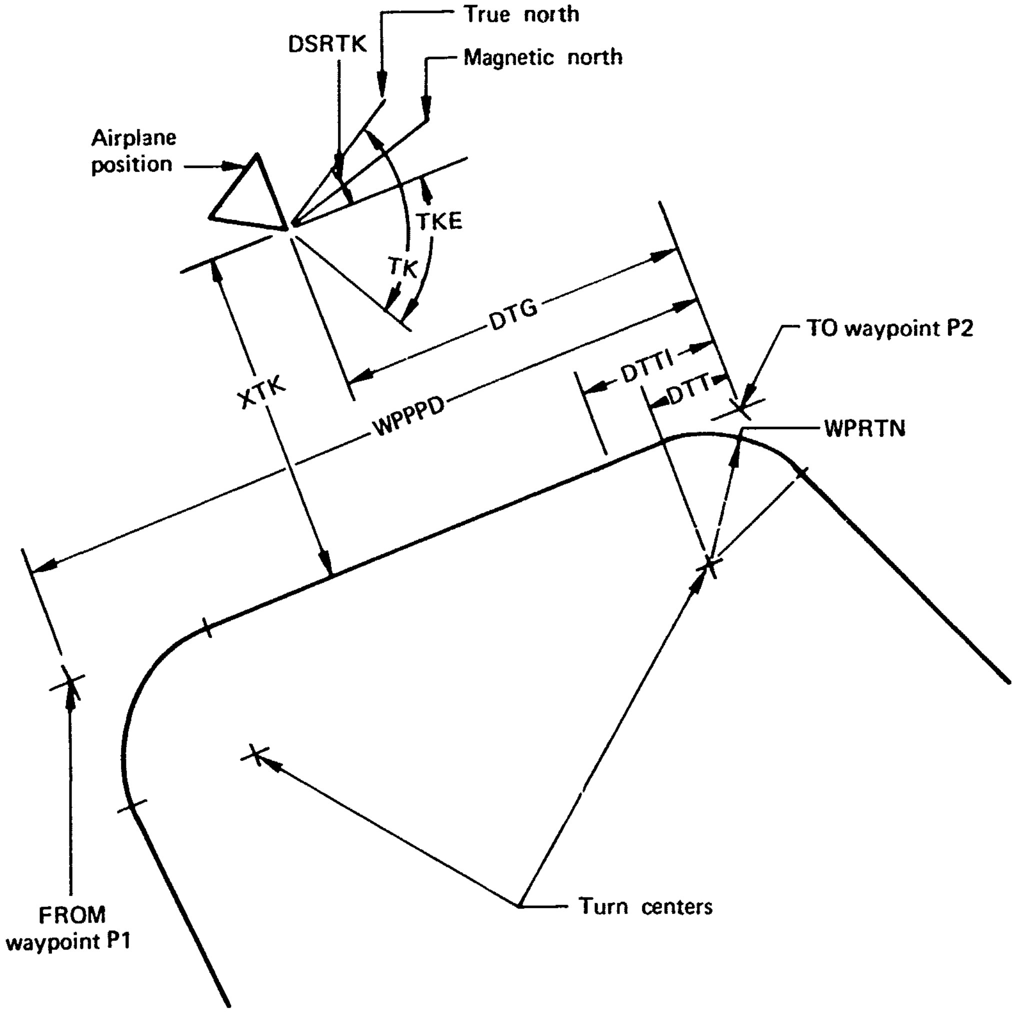


FIGURE 5-2.–PATH GUIDANCE NOTATION

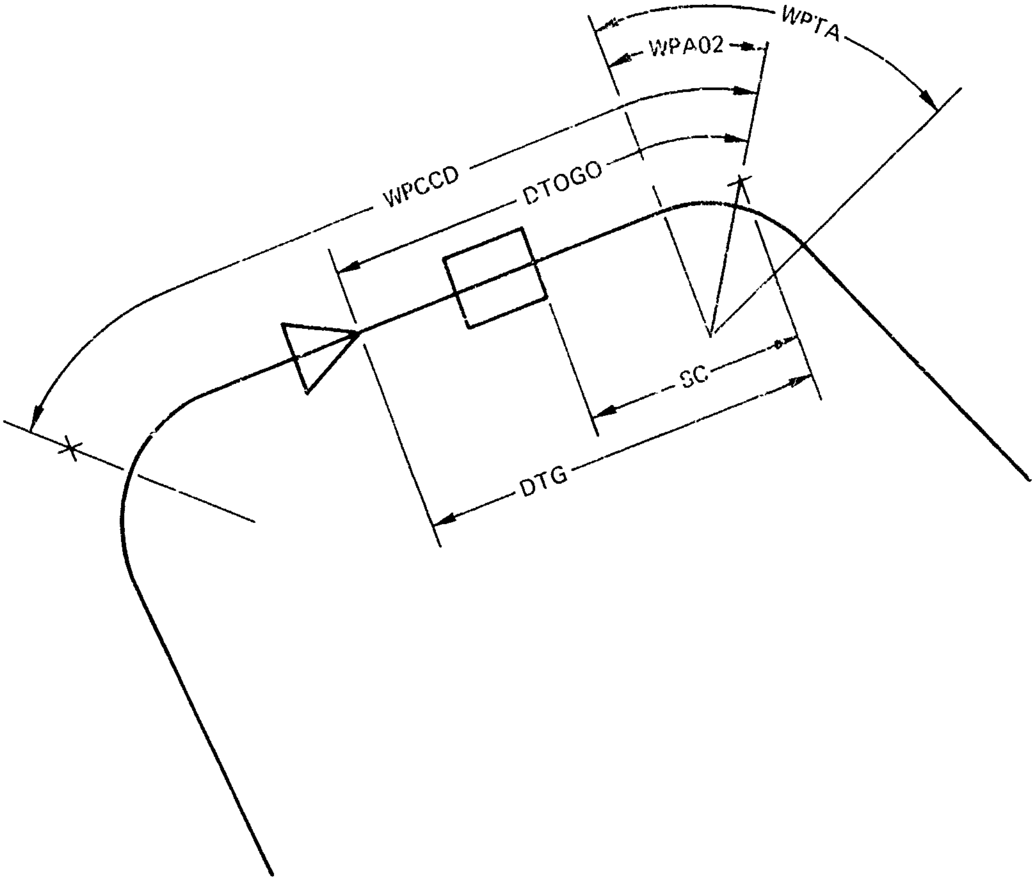


FIGURE 5-3.—4D GUIDANCE NOTATION

6.0 NCDU REQUIREMENTS

6.1 GENERAL

The navigation control and display unit (NCDU) is a keyboard and CRT readout that interfaces with the navigation computer unit (NCU). The NCDU keyboard provides the pilot with the means of communicating with the NCU to control the operation of the navigation and guidance system and to select or enable some display functions. The NCDU displays a variety of alphanumeric formats to present the pilot with detailed data required to monitor and control the navigation and guidance of the airplane in 2D, 3D, or 4D flight plans; and provides data supplementary to the primary EADI and MFD displays.

The NCDU is located in the cockpit on the central instrument aisle stand, immediately forward of the flap lever. Figure 6-1 shows the layout of the NCDU.

6.2 PHYSICAL CHARACTERISTICS

6.2.1 CRT Display

The CRT is a 5-in. diagonal display that is mechanized to provide eight lines of 24 characters, totaling 192 characters. The characters are displayed on a raster with a horizontal scan frequency of 8.1 kHz and a frame rate of 78 Hz. Each character is made up from a 5 by 7 dot matrix. The full characters set is shown in figure 6-2, together with the associated ASCII code.

The vertical space between character lines is three scans except between rows 1 and 2 and 7 and 8, where it is six scans. Line 1 is used primarily as a title line. Line 8 is the data entry line, coupled to the keyboard; line 8 also supplies significant cues to the pilot concerning requests for data insert, status, and malfunctions. Line 8 cues are listed in table 6-1. A solid white line is placed in the space between line 7 and 8 to highlight the special function of line 8.

6.2.2 Keyboard

The NCDU keyboard of 49 keys is a 7 by 7 matrix, and henceforth in this document the keys on the NCDU keyboard are identified by row number/column number, as shown in figure 6-3.

The keyboard is segmented into four categories:

- Mode
- Special purpose
- Dual function
- Single function

The following keys are mode keys:

Key location	Key label	Key function
7-1	INIT	Initialization data entry and display
7-2	ATC CLR	ATC clearance data entry and display
7-3	FLT PLN	Flight plan display and limited data entry
7-4	NAV DATA	Navigation data display only
7-5	SEL	Selection of outer loop control modes and associated data entry
7-6	LOOK UP	Look up of selected data from the computer memory

Note: The rotary switch positions labeled T (test), A (automatic), and M (manual) also act as mode keys.

Special-purpose keys are the following:

1-1 ENT	Transfers to the NCU, the eight words of data corresponding to line 8 of the NCDU, and puts the NCDU into an alphanumeric disabled mode so that the next alphanumeric key press will act as a dual-function key
1-7 UP	Moves (rolls) data up by one line on the NCDU display
2-7 DN	Moves (rolls) data down by one line on the NCDU display
6-1 EXEC	Causes provisionally entered data to be transferred to a buffer used by the guidance computation. EXEC is also used for SEL mode activation.
6-7 REJ	Cancels provisionally entered data and removes them from the respective buffer. REJ is also used to cancel SEL modes.
7-7 CLR	Deletes data on line 8 in positions 10 through 24 by hardware and, optionally, in positions 1 through 9 by software. After CLR has been pressed, the NCDU software will force the NCDU back into the alphanumeric disabled mode to await the pressing of another dual-function key.

Dual-function keys include:

Key location	Key label/function
3-1	A or WPT (waypoint)
3-2	B or AWY (airway)
3-6	F or F/L (flight level)
3-7	G or ALT (altitude)
4-1	H or RTE (company route)
4-2	I or RWY (runway)
4-6	M or GS (groundspeed)
5-1	O or SID (standard instrument departure)
5-2	P or STAR (standard arrival route)
5-6	T or PTA (planned time of arrival)

The NCDU software routine will respond to the first press of the above dual-function keys by transmitting in the next 64-word page transmission from the NCU:

- A bit to activate the alphanumeric keyboard, as defined in section 6.3
- A cue message on line 8 in positions 1 up to 9 corresponding to the key pressed, i.e., 3-1 WPT, 3-2 AWY, etc.

Additional dual-function keys are.

Key location	Key label	Function
1-2	1	Enters the indicated number on line 8 or automatically selects the listed option
1-3	2	
1-4	3	
1-5	4	

1-6	5	Enters the indicated number on line 8 or automatically selects the listed option
2-2	6	
2-3	7	
2-4	8	
2-5	9	
2-6	0	

Single-function keys are all other keys not included in the categories defined above.

The distinction between categories of keys involves both hardware and software. Mode keys and special-function keys are wired so that whenever they are pressed, the key code defined in table 6-2 is transmitted from the NCDU directly to the NCU. The NCU interprets the key code and takes the appropriate software action to respond to the key command; generally, a new display format is transmitted from the NCU to the NCDU.

Dual- and single-function keys, which together include all the numeric and alphabetic keys, behave in the same manner as defined above the first time they are pressed. The NCU software interprets the key code to determine if the key pressed represents a dual function in the particular mode currently selected on the NCDU. If the key does represent a dual function (i.e., key 3-1 = WPT), a code is transmitted to the NCDU to activate the alphanumeric data entry mode (see sec. 6.3.2). Subsequent presses of alphanumeric keys cause characters to be loaded into line 8 of the display through the NCDU hardware (i.e., key 3-1 = A).

If the key pressed first (i.e., key 3-4 = D) does not represent a dual function, the NCU software will not respond by activating the keyboard for alphanumeric data entry, and the key press is ignored. These single-function keys can, however, be used as dual-function keys by changing the NCU software. This mechanization ensures flexibility for growth and optimization.

When the keyboard is enabled for alphanumeric data entry, the character corresponding to the next key pressed will appear on line 8 in position 10, the next in position 11, and so on until 15 keys have been pressed. Subsequent presses of dual- and single-function keys are ignored until key ENT has been pressed. The result of pressing a mode key or special-purpose key other than ENT during a data entry sequence (i.e., prior to pressing the ENT key) will be identical to that of the CLR key.

Key 2-1 is unique in that although the key cap is decimal (.), when it is pressed for numeric data entry a slash (/) symbol will appear on line 8. After ENT, the NCU will change the coding so that data displayed on lines 1-7 will have . substituted for /.

6.2.3 Subsidiary NCDU Features

The NCDU contains two rotary switches and two annunciators (see fig. 6-1):

- Mode select switch

  The switch can be placed in T (test), A (automatic), or M (manual) modes at the pilot's discretion. The A and M positions are intended for multiple NCDU installations and will not be used for ADEDS. The T position will activate an NCDU and NCU/PCU interface test (see sec. 6.7).

- Brightness switch

  The brightness of the NCDU format can be adjusted for personal light levels.

- ALERT light

  An ALERT discrete is issued at 10 sec time to go (TTG) prior to reaching the turn point for the next waypoint, and will extinguish when the turn is initiated.

- FAIL light

  The NCU shall issue a FAIL discrete upon detection of a failure by its BITE system. This output is combined through a logic OR circuit with the NCDU monitor to drive the FAIL annunciator.

6.3 NCDU/NCU INTERFACE

6.3.1 Hardware

Data from the NCDU to NCU are transmitted by an ARINC 575 digital data bus. The format of the data transmission is either one word or eight words, as defined below. A discrete called end of transmission (ETD) is also transmitted.

An ARINC 575 digital data bus also transmits data from the NCU to NCDU. The transmission always consists of a 64-word page, each word containing three character codes for a total of 192 characters. The 64-word page is transmitted at a repetition rate of once per second.

In addition to the digital data buses, the NCU transmits discretes for new page (NPD), waypoint alert (ALERT), and NCU failure. Two discretes for parity checking, PAR1 and PAR0, are not used for ADEDS.

6.3.2 Interface

The NCDU display format is updated by a complete 64-word page transmission from the NCU once per second. This data transmission is preceded by the NPD. Bit 31 in the last word controls the mode of operation of the dual-function keys. A 1 in bit 31 activates the alphanumeric keys for entry and display on line 8 of the display, starting at character position number 10. Fifteen characters can be keyed in; additional characters are ignored.

Pressing the ENT (enter) key results in eight words being transmitted to the NCU followed by an ETD discrete. The next 64-word page transmission will have bit 31 set to zero in the last word. The NCDU dual-function keys are now set to their function mode, with alphanumeric data entry disabled.

Pressing CLR (clear) erases the data on line 8 from positions 10 through 24, and causes one word followed by the ETD discrete to be transmitted to the NCU. The NCU software sets bit 31 to zero in the last word of the next 64-word transmission and sets all of line 8 to blanks.

Pressing any other mode or special-function key causes one word followed by the ETD discrete to be transmitted to the NCU, which responds by formatting a new 64-word page with bit 31 in the last word set to zero. Any data keyed into line 8 are erased in a manner similar to the CLR operation.

When bit 31 in the last word has been set to zero, the dual-function keys behave exactly like the mode and special-function keys, and cause one word to be transmitted to the NCU when they are pressed.

6.3.3 Buffers

Several memory buffers in the NCU are associated with NCDU data processing:

- Provisional guidance buffer (table 6-3)
- Origin/destination buffer (table 6-4)
- Pilot-created waypoint data buffer (table 6-5)
- Look-up data buffer (table 6-6)

6.4 INTERFACE FAILURE PROTECTION

There is no interface parity detection logic mechanized for the NCU/NCDU digital interface. All words are transmitted with odd parity, and discretes PAR1 and PAR0 are provided for parity failure annunciation. However, the NCU/NCDU interface for the ADEDS system will not use these provisions. Data with bad parity will be accepted and used for display. Since the display is updated once per second, random parity errors are unimportant. Persistent parity errors will be detected by garbled display text.

Protection against NCU malfunction is provided by the NCU valid discrete, which drives the FAIL light on the NCDU. The internal NCDU monitors drive this FAIL light.

6.5 NCDU MODES

The NCDU modes are activated by mode keys 7-1 through 7-6, defined in section 6.2.2 and shown in figure 6-1. The display formats and operating procedures associated with these modes are described in this section.

The abbreviations used on the NCDU display are defined in table 6-7, together with the label used to identify each parameter in the NCU software. The cue messages used on line 8 of the display are listed in table 6-1.

6.5.1 INIT (Initialize) Mode

The initialize mode is controlled by a dedicated mode key with:

●	Legend	INIT
●	Position	7-1
●	Code	11100101

When power is applied to the NCU, the NCDU display will automatically display the INIT mode display format, and the data last entered during the previous power-on period will be displayed with the following cue message on line 8:

PRESS 1 FOR NEW ORIGIN

This situation is shown in figure 6-4a.

If the power off has been due to a power interruption, or if there is no requirement to reenter the origin airport, pressing CLR will cause the line 8 cue to be replaced by:

CHECK GMT/PRESS 3

GMT can be entered at the operator's discretion in the manner defined below, or the cue can be eliminated by pressing CLR. After either action, line 8 will read:

PRESS # FOR DATA ENTRY

If the power-on sequence is the start of a new flight, the data required to initialize the system will be entered as shown in the following example, with Boeing Field the origin airport and KBFI the ICAO designation:

- Press key 1 - The cue ORIGIN will appear on line 8.
- Press keys K, B, F, I, ENT.

KBFI will appear on line 2, and the data on lines 3 through 6 will go blank. A cue on line 8 will read:

PRESS 2

In addition, when the ENT key is pressed to enter the new origin airport, all data will be zeroed in the active and provisional guidance buffers, and the NCDU display formats for ATC CLR and FLT PLN modes will be blank except for lines 1 and 8. (See figs. 6-5a and 6-6a for ATC CLR and FLT PLN formats.) The buffers defined in tables 6-3 and 6-5 will also be zeroed out.

The destination airport (DESTIN), Greenwich Mean Time (GMT), and barometric altimeter setting (BAROSET) will be entered in sequence, in the manner defined above, after the origin airport (ORIGIN) has been entered. The display format during the keying in of BAROSET is depicted in figure 6-4b.

After each press of ENT, the cue messages on line 8 will be sequentially:

PRESS 2

PRESS 3

PRESS 4

PRESS # FOR DATA ENTRY

Line 1 always displays the identification number of the computer program, shown as a date in figure 6-4. New data, such as DESTIN, GMT, and BAROSET, can be entered at any time during flight if a change is required.

The ORIGIN and DESTIN airports are stored in the origin/destination buffer defined in table 6-4. The bulk data extraction routines will use this buffer to aid the data search, and the MFD and EADI routines use this buffer to process runway symbology on the two displays.

GMT entry will normally be made by keying in a time in hours and minutes in advance of the present time and by pressing ENT when time is synchronized. Thereafter, the GMT display on the INIT page will be dynamic. For example, press keys:

0, 9, 1, 5

and press ENT when clock time is 9:15 a.m.

6.5.2 ATC CLR (ATC Clearance) Mode

6.5.2.1 General

The ATC clearance mode is controlled by a dedicated mode key with·

- Legend ATC CLR
- Position 7-2
- Code 01101000

The flight clearance issued or approved by Air Traffic Control (ATC) is entered into the NCU through the NCDU ATC CLR mode. There are two exceptions to this rule:

- ORIGIN and DESTIN airports *must* be entered through the INIT mode as described in section 6.5.1. If an alternate airport is selected in flight, the DESTIN airport should be changed first. Note: This restriction is a compromise for handling ease of bulk data memory, especially magnetic tape memory.
- Altitude (ALT) or flight level (FL), groundspeed (GS), and time of arrival (PTA) schedules can also be entered in the FLT PLN (flight plan) mode, as defined in section 6.5.3. This provision adds flexibility and convenience.

The ATC CLR format after a clearance has been entered but before it is executed (accepted) is shown in figure 6-5a. Data entered are displayed with one WPT (waypoint), AWY (airway), RTE (company route), SID, or STAR per line. Simultaneously, the list of waypoints comprising the SID, AWY, etc., appear on the FLT PLN page as defined in section 6.5.3, as well as on the MFD map display as defined in section 2.0.

Two levels of data entry will be used: provisional (ENTered) and accepted (EXECuted). The data entered above are transferred by the NCDU routine to the provisional guidance buffer (see table 6-3) via the guidance path definition routine, which calculates the details of the flight plan path. The message on line 8:

EXEC OR REJ

gives the operator the cue to press the EXEC (execute) key if he approves the entered ATC clearance, after inspection, on the NCDU FLT PLN mode and/or the MFD map display. The entered ATC clearance will then become the active path for the guidance (GUID) routine. If the clearance is not satisfactory, pressing the REJ key will cause the last provisionally entered data line to be erased from the ATC CLR page on the first press. The second press will cause all provisionally entered data to be cleared from the ATC CLR buffer and the provisional guidance buffer, and deleted from the ATC CLR and FLT PLN pages.

ATC clearances can be divided into two categories: initial clearance and in-flight diversion or reclearance. For convenience, the requirements for the ATC CLR mode will be separated. Section 6.5.2.3 defines initial clearance data entry, and section 6.5.2.4 defines in-flight reclearance data entry.

6.5.2.2 Formatting Rules for ATC CLR Data Entry

Rules for the entry of waypoints using the WPT key are:

- Present position–Key in P, P, O, S, ENT or P, O, S, ENT.
- Airports–Key in standard four-letter ICAO designator, i.e., K, B, F, I, ENT.
- VORs, VORTACs, and nondirectional beacons–Key in standard FAA three-character code, i.e., S, E, A, ENT. For two-letter Canadian facilities, repeat the first character to change two-character codes into three characters.
- GRPs (intersections, named waypoints, etc.)–Key in a five-letter code derived from the geographic name as follows:
    - Less than five letters in name (i.e., RIO): Expand to five letters by repeating the last letter (i.e., R, I, O, O, O, ENT).
    - More than five letters in name (i.e., LOOKOUT): Use first four letters and last letter (i.e., L, O, O, K, T, ENT).
    - Multiple-word name (i.e., HALF MOON BAY): Use first three letters of the first word, and first and last letter of last word (i.e., H, A, L, B, Y, ENT).
- Range and bearing from a VORTAC or GRP (three- to five-letter designator): Key in

  A, B, C, 0, 3, 5, 1, 0, 5, ., 5, ENT

  where:

  ABC = FAA VORTAC designator

  035 = three-digit magnetic bearing

  105.5 = range, which may be one to five characters including the decimal point

  The data will be reformatted for display as:

  ABC/035°/105.5

- Latitude and longitude–Key in latitude and longitude together, i.e., N, 4, 7, 3, 2, ., 4, W, 1, 2, 2, 1, 8, ., 7. Minutes of latitude and longitude must be keyed in with a leading zero when less than 10, i.e., N, 4, 7, 0, 9, ., 6.

The data will be reformatted for display as:

N 47° 32.4/W 122° 18.7

A designator will be assigned to waypoints WPT01 through WPT10 corresponding to the sequence number of latitude/longitude or bearing/range waypoint entered, i.e., first entered is WPT01, next is WPT02. These waypoints will be stored in the pilot-created waypoint buffer defined in table 6-5. On the FLT PLN page, show WPTXX as the waypoint designator, but display as entered on ATC CLR. On the LOOK-UP page, show the latitude/longitude and/or bearing/range when WPTXX is selected, as defined in section 6.5.6.

Note: *All* angular data, except LAT and LON, will be entered and displayed with three digits, i.e., BRG 035 .

Rules for SID and STAR entry in ATC CLR are that if no exit and entry waypoints are specified, the NCDU will link the path from the end of the SID or STAR to the following or preceding waypoint, respectively. SIDs and STARs are entered by using the first three letters of the name, plus runway designator, i.e., WILSON CREEK 21 is WIL21. Entry of a SID and STAR is not mandatory. A sequence of waypoints started or terminated by a RWY (runway) can be entered to complete the path definition.

Rules of operation for AWY and RTE entry in ATC CLR are that the following sequence of entry must be followed:

WPT	B
AWY or RTE	AE
WPT	E

where:

B = entry waypoint on airway or route AE

E = exit waypoint

If the rule is violated, the AWY or RTE entry will be ignored and the cue message:

KEY WPT

will be displayed on line 8.

If a WPT, AWY, or RTE is entered and cannot be found in the bulk data memory, a cue message:

NOT IN MEMORY

will be displayed on line 8.

If a SID is entered and cannot be found, a cue message:

NOT IN MEMORY CHECK ORIG

will be displayed on line 8. If a STAR is entered and cannot be found, a cue message:

NOT IN MEMORY CHECK DEST

will be displayed on line 8.

6.5.2.3 Initial Clearance

The route data entry sequence for the example given in figure 6-5a is:

- Press SID key–Cue SID appears on line 8, positions 1-3.
- Press W, 0, 0, 3, I, L, ENT–W0031L appears on line 7, positions 1-6, and the cue EXEC or REJ appears on line 8, positions 1-11.
- Press WPT key–Cue WPT appears on line 8 in positions 1-3.
- Press S, C, E, N, C, ENT–SCENC appears on line 7, positions 1-5, and W0031L appears on line 6, positions 1-6. Cue EXEC or REJ appears on line 7, and previously entered data roll up one line. Data on line 1 disappear from view at each entry.

ALT, GS, and PTA data can be entered immediately after a WPT, AWY, or RTE entry in the ATC CLR mode, with one restriction. After AWY and RTE entry, ALT and GS can be entered, but PTA will be ignored. Note that no ALT, GS, or PTA data are accepted in ATC CLR after SID and STAR entry.

A sequence for additional data entry at a waypoint is shown in the example below for the waypoint Scenic:

Altitude	10,000 ft	Planned values
Groundspeed	250 kt	
Time of arrival	9.45' 15" GMT	

- Press WPT key.
- Press S, C, E, N, C, ENT–SCENC will appear on line 7.
- Press ALT key–Cue ALT appears on line 8, positions 1-3.
- Press 1, 0, 0, 0, 0, ENT–/10000 will appear on line 7 in positions 7-12.

  Note. If the waypoint entered is a range/bearing or a latitude/longitude waypoint, the ALT, GS, and PTA data will appear on the line below the waypoint.

- Press GS key–Cue GS appears on line 8, positions 1-2.
- Press 2, 5, 0, ENT–/250 will appear on line 7 in positions 13-16.
- Press PTA key–Cue PTA appears on line 8, positions 1-3.
- Press 0, 9, 4, 5, 1, 5, ENT–/0945:15 will appear on line 7 in positions 17-24.

The resulting display format is shown in figure 6-5b. When ALT (or FL) and GS are entered for a WPT, AWY, or RTE, the values will be cascaded down through all subsequent waypoints on the path up to the first waypoint of a STAR, and these ALTs and GSs will appear on the FLT PLN page. Note: SIDs and STARs will be prestored, four-dimensional paths in the ADEDS system. If no ALT, FL, or GS is entered, or cascaded down to a waypoint, the ALT, FL, and GS slots will be blank on the FLT PLN page. When one PTA value is entered for a waypoint, PTAs will be computed for all waypoints along the path until a waypoint is reached where no GS has been specified. These PTA values will appear on the FLT PLN page.

When the operator wishes to accept the flight plan data entered through the ATC CLR page, he will do so as follows:

- Ensure the NCDU is in the ATC CLR or FLT PLN mode
- Press EXEC

If the clearance entered does not terminate in a STAR or a runway (RWY) at the destination airport (DESTIN on INIT page), then the cue LINK UP will be added to the ATC CLR page format below the last entry. Figure 6-5c shows how the example clearance in figure 6-5a would be terminated if STAR WIL21 was not entered at the time the path was executed and if the path was subsequently terminated with a STAR (ROY21). This is an example of a reclearance discussed in the next section.

When EXEC is pressed, the NCDU will designate the active guidance buffer (AGBF), zero out all provisional bits (word 1, bit 24), and crossfill the other guidance buffer, which will be labeled provisional (PGBF).

6.5.2.4 Reclearance Data Entry

After the initial clearance has been entered (ENT) and accepted (EXEC), the route can be modified at any time through the ATC CLR mode. ALT or FL, GS, and PTA can be modified through the FLT PLN mode, defined in section 6.5.3.

Reclearances will be keyed into the ATC CLR mode in the same manner as that described in section 6.5.2.1 for the initial clearance. After each EXEC key press in the ATC CLR mode, one blank line will remain after the last readout of the accepted clearance. Figure 6-5c shows the situation after a reclearance:

WPT	LOOKT
WPT	ROYAL
STAR	ROY21

has been entered and EXEC has been pressed.

Twenty lines of ATC CLR data are available for display, using the UP and DN keys. Successive entries in excess of 20 will result in the earliest data being discarded and lost for display purposes.

A reclearance can be initiated in three ways:

- Reenter the ORIGIN airport on the INIT page. This will zero out all buffers and allow entry of an initial clearance as defined in section 6.5.2.3.
- Enter a waypoint defining a point of departure from the existing accepted clearance.
- Enter a waypoint PPOS (present position) as follows: Press keys WPT, P, P, O, S, ENT or WPT, P, O, S, ENT. The NCDU will designate a WPTXX in the pilot-created waypoint buffer using the latitude/longitude of the present position when the ENT key was pressed.

A reclearance can be terminated by any of the following:

- Entry of a waypoint on the previously accepted clearance
- Entry of a new DESTIN (destination) on the INIT page and entry of a STAR or RWY for that airport

  If neither of these conditions is satisfied, the cue LINK UP will appear at the end of the reclearance after EXEC is pressed.

Additional rules for data entry of reclearances, over and above those defined in section 6.5.3, are as follows:

- If the reclearance "shortcuts" the accepted path by bypassing waypoints on the previously accepted flight plan path, and if no new waypoints are involved, a new PTA schedule will be computed working backward from the end of the defined path. ALT and GS will remain unchanged unless new data are entered.

- Any new waypoints for which no ALT, FL, GS, or PTA are entered will remain blank on the FLT PLN page, and GUID4D, GUID3D, etc., will be set to zero when such waypoints become the TO waypoint. The PTA schedule downstream from such waypoints will also be blanked out on the FLT PLAN page and the guidance buffer. The entry of ALT (or FL) and GS values for the new waypoints will correct this situation, and PTAs for all waypoints on the new path will be recomputed by holding the final waypoint PTA equal to its original value.

- If the path guidance has been overruled by pilot action, either by manual control or by engaging overriding autopilot modes, the GUID routine will set a flag LINKUP when it detects abnormal conditions in the path guidance calculations. The linkup flag will be set whenever DTG to the TO waypoint is increasing or when YER is greater than 15,000 ft. The linkup flag will be inhibited when WPT HOLD mode is activated on the NCDU SEL 1 page.

  When the LINKUP flag is detected, the NCDU will set the cue message:

  LINK UP PPOS TO WPT

  on line 8 of the NCDU, whatever the mode selected. This message will be removed from all pages by pressing CLR or initiating a reclearance entry in the ATC CLR mode.

  Note: The message LINK UP will also appear on the EADI and MFD displays.

- When a new clearance is being entered (ENT) and then accepted (EXEC), the NCDU will reorganize the active and provisional guidance buffers as follows:

  - During provisional entry, the provisional guidance buffer will build up a waypoint sequence and computed path parameters starting from the current FROM waypoint or PPOS, i.e., PPOS will be the FROM waypoint in this type of reclearance. Each waypoint will have the provisional bit (word 1, bit 24) set to 1. The active guidance buffer is unchanged.

  - When EXEC is pressed, the provisional guidance buffer is relabeled active (AGBF) and vice versa. All the provisional bits are set to zero. The contents of the new active buffer are then crossfilled into the new provisional buffer so that both buffers contain the same data until a new data entry sequence is begun.

6.5.2.5 Missed Approach Path (MAP)

When a STAR or runway for the destination airport has been accepted (EXEC) through the ATC CLR mode, the missed approach path for the runway will be stored automatically in the provisional guidance buffer when the aircraft passes either the defined final approach fix, where speed control reverts to airspeed reference (see table 3-4), or the last waypoint on the path prior to the runway. The cue EXEC or REJ will appear on line 8.

This provisional path can be accepted, rejected, or modified in the manner defined in section 6.5.2.4.

6.5.3 FLT PLN (Flight Plan) Mode

6.5.3.1 General

The flight plan mode is controlled by a dedicated mode key with:

- Legend FLT PLN
- Position 7-3
- Code 11100110

This mode is used to display the waypoint sequence and data entered in the ATC CLR mode (shorthand entry). Both accepted and provisional route data are displayed. The 3D and 4D portions of a flight plan (FL, ALT, GS, PTA) can be entered in the FLT PLN or ATC CLR mode. Data entered in the FLT PLN mode are accepted directly into the active guidance buffer and used for guidance.

The FLT PLN display format after completion of ATC CLR entry (defined in sec. 6.5.2) is shown in figure 6-6a for the first press of the FLT PLN key; figure 6-7 shows the format when the FLT PLN key is pressed for the second time. On the next press, page 1 (FLT PLN 1) will reappear. The FLT PLN 1 format centered on the TO waypoint is referred to as the home page.

Both FLT PLN display formats can be moved up or down using the UP and DN keys. Each press causes a movement of two lines up or down. Pages 1 and 2 move together, so pressing the FLT PLN key results in the same waypoints being on lines 2, 4, and 6.

Whenever a new mode is selected and then the FLT PLN mode reselected, the FLT PLN will reappear in the home page position, which has the TO waypoint marked by a ✧ symbol on line 4. The exception to this will occur during route entry through the ATC CLR mode. Selecting FLT PLN during the ATC CLR entry sequence (prior to EXEC or REJ being pressed) will cause the last waypoint entered, or last waypoint of a SID or STAR entered, to appear on line 4 of the FLT PLN display. Waypoints from a RTE or AWY entry in ATC CLR will not appear on the FLT PLN page until the exit waypoint is specified.

The waypoints on the page will move up two lines automatically to change the FROM, TO, and NEXT waypoints when the turn is initiated to start the circular arc transition or DME arc. The new TO waypoint will now be on line 4.

If the FLT PLN page has to be slewed UP or DN, only the symbol signifying the TO waypoint will change at the start of the transition.

Provisional route entries through ATC CLR will be identified by a ? in position 1 preceding the waypoint name (see fig. 6-6b). When a provisional waypoint is in the NEXT waypoint position, the cue EXEC or REF will flash (1 sec on, 1 sec off) on line 8 of ATC CLR and FLT PLN pages at 2 min TTG to the waypoint. If no action is taken, the waypoint will be ignored and guidance will continue to be based on the accepted clearance.

If the ATC clearance entered does not terminate in a STAR or RWY, or if a reclearance does not rejoin the previously accepted clearance, the cue LINKUP will appear instead of a waypoint name on line 2, 4, or 6 at the end of the waypoint list. See figure 6-6b.

When a SID is entered in ATC CLR for the origin airport, the first waypoint on the path displayed in FLT PLN will be the brake release point (BR31L or BRP24). This will initially appear on line 2 of the display, i.e., the FROM waypoint position.

When a STAR is entered in ATC CLR for the destination airport, the last waypoint on the path displayed in FLT PLN will be the touchdown point (TDXXX or TDZXX).

Latitude and longitude, bearing and range, and PPOS waypoints entered through the ATC CLR mode will be displayed as WPTXX on the FLT PLN page, where XX is the sequence number automatically assigned by the guidance routine.

When a reclearance is accepted (EXEC), the waypoint sequence displayed on the FLT PLN page will start from the FROM waypoint at the time of entry. Preceding waypoints will have been discarded from the guidance buffers and will not be available for display.

When a reclearance from PPOS has been accepted (EXEC), the first waypoint in the FROM position will be WPTXX, where WPTXX is the waypoint number assigned to the present position in the pilot-created waypoint buffer (table 6-5).

When a circular arc path segment is included in the provisional or accepted clearance, it will be annunciated on the flight plan pages on the line between the waypoints defining the end points of the curve. The annunciation will be

TURN L or TURN R

in positions 1-6.

When a SEL mode data entry has been accepted by pressing EXEC, the interaction of the SEL modes (sec. 6.5.6) with the FLT PLN displays will be:

- HOLD at PPOS

  A waypoint name, i.e., WPT09, will be inserted into the FLT PLN (see fig. 6-6c) in the TO waypoint position, and HOLD will be displayed on the line below in positions 1-4. WPT09 will be assigned in the pilot-created waypoint buffer (table 6-5) in the same manner as latitude/longitude and bearing/range waypoints.

- HOLD at WPT

  Similarly, HOLD will be displayed under the waypoint named on the SEL page in positions 1-4 if the holding waypoint is on the flight plan.

- OFFSET, TK SEL,* ALT ENG,* FPA ENG,* IAS ENG*

  All these modes will be annunciated on line 8 of the FLT PLN page starting from position 1 as follows:

  SEL/OFS or

  SEL/OFS/ALT/IAS

6.5.3.2 FLT PLN 1 Mode (Home Page)

The FLT PLN page 1 format includes the following features:

- Line 1, positions 1-9, shows the ORIGIN-DESTIN airport entered in the INIT page.
- Line 2 contains the FROM waypoint, line 4 shows the TO waypoint, and the NEXT waypoint is shown on line 6. The ✦symbol denotes the TO waypoint.
- Lines 2, 4, and 6, positions 9-13, show the planned altitude (PALT) for each waypoint.
- Lines 2, 4, and 6, positions 15-24, give the planned time of arrival (PTA) at each waypoint, as calculated by the guidance routine.
- Lines 3, 5, and 7, positions 9-14. show the flightpath angle (PFPA) required between the two waypoints to connect the PALT entered on the line above and the line below (↑ means UP).

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*These modes can be selected externally to the NCDU on an autopilot mode control panel.

- Lines 3, 5, and 7, positions 18-24, show the planned groundspeed (PGS) in knots for the flight leg between the waypoints on the line above and the line below.

Rules for entry of ALT or FL, GS, and PTA in the FLT PLN 1 mode are as follows.

- Each entry is associated with the waypoint on line 6.

- ALT (or FL) and GS entered for the en route waypoint will cascade down through all subsequent en route waypoints up to but excluding the first waypoint of a STAR.

- ALT (or FL) and GS entered for a SID or STAR waypoint will apply to that waypoint only.

- Entry of one PTA will initiate recomputation of all PTAs forward and backward along the path until a waypoint is reached for which no GS has been entered.

- If a GS is changed at any waypoint after the PTA schedule has been calculated, the PTA schedule will be recalculated backward from the end of the defined path. The PTA for the end waypoint is unchanged.

- If the keys PTA, REJ are pressed, the PTA schedule for the whole path will be eliminated and guidance will change from 4D to 3D.

6.5.3.3 FLT PLN 2 Mode

The FLT PLN page 2 format (fig. 6-7) includes the following additional features:

- Lines 2, 4, and 6, positions 8-15, show the remaining distance (REMD) in nautical miles from the waypoint to the end of the defined path entered through the ATC CLR mode.

- Lines 2, 4, and 6, positions 17-24, show the remaining time (REMT) in minutes from the waypoint to the end of the defined path.

- Lines 3, 5, and 7, positions 8-15, give the leg distance (LEGD) in nautical miles between waypoints.

- Lines 3, 5, and 7, positions 17-24, show the time for the leg (LEGT) in minutes.

There will be no data entry capability in the FLT PLN 2 mode.

Note: Key 3-3 will be mechanized as a dual-function key for use in the FLT PLN mode so that the radius of the curved transition at a waypoint can be changed for test and checkout. The method of data entry will be, for example:

Press key 3-3

Press 2, 0, 0, 0, 0, ENT

A radius of 20,000 ft will be used at the waypoint currently on line 6 of the display format.

6.5.4 NAV DATA (Navigation Data) Mode

6.5.4.1 General

The NAV DATA mode is controlled by a dedicated mode key with:

- Legend NAV DATA
- Position 7-4
- Mode 11101100

Each press of the NAV DATA key brings up in sequence the display formats NAV DATA 1 (fig. 6-8), NAV DATA 2 (fig. 6-9), and NAV DATA 3 (fig. 6-10). NAV DATA display parameters are defined in table 6-7.

6.5.4.2 NAV DATA 1 and 2

The NAV DATA 1 page displays selected data for monitoring 4D, 3D, and 2D flight plans, as well as current navigation status. The NAV DATA 2 page displays subsidiary navigation parameters and current navigation status. Neither NAV DATA 1 nor NAV DATA 2 enables the keyboard, and data cannot be entered.

The NAV DATA 1 and NAV DATA 2 pages will have blank data slots under the following conditions:

If flag GUID4D is not set	TE blank TE/MIN blank GSE blank
In addition, if flag GUID3D is not set	AE blank FPAE blank
In addition, if GUID2D is not set	ETA blank TKE blank XTK blank TTG blank DTG blank

If no valid true airspeed (TAS) data are received by the NCU	WD blank WS blank
If no valid baro altitude (ALTB) data are received by the NCU	ALT blank

Note: Whenever a SEL mode is activated, the corresponding error readout on the NAV DATA 1 page will relate to the SEL value, i.e., TKE for TK SEL, AE for ALT ENG, FPAE for FPA SEL. ALT ENG and FPA SEL are mutually exclusive, so only AE or FPAE will be displayed.

Line 8 on NAV DATA 1 and NAV DATA 2 shows:

- Current FROM-TO waypoint in positions 1-11, or HOLD WPT09, or FROM-TO waypoint followed by OFS if the WPT HOLD or OFS modes are activated through the SEL 1 mode (sec. 6.5.5). If the TK SEL mode, i.e., 320°, is engaged through the AGCS mode panel, TK SEL 320° will be displayed.
- Navigation status code (see table 6-7) in positions 13-18.

6.5.4.3 NAV DATA 3

The NAV DATA 3 page shows present computed position and navaid tuning data and gives tuning selection capability as defined below.

NAV DATA 3 will have the capability of entering data; NAV DATA 1 and 2 will not. In normal operation, all data displayed on NAV DATA 3 will be computed and displayed automatically. POS is the best estimate of aircraft position computed by the NAV subroutine, and NAVAID 1, NEXT 1, and NAVAID 2 will be defined by the NAV autotune routine from the FROM, TO, and NEXT waypoints on the FLT PLN. The data entry capability gives the operator a means of overriding the autotune station selections.

Initial present position (PPOS) can also be entered. This entry is for checkout purposes and will be disabled when groundspeed (GS) is greater than 5 kt.

Data entry in the NAV DATA 3 mode will be mechanized as follows.

- The cue PRESS # is displayed in line 8, as shown in figure 6-10.
- Press keys 1 through 5. This selects the type of data entry required and enables the keyboard for data entry. Display line 8 now shows the name of the data entry selected:

1	PPOS	(LAT)
2		(LON)

3	NAVAID	#1
4	NEXT	#1
5	NAVAID	#2

- The required data can now be keyed in by using the appropriate letter or number key. Data entered on lines 1 and 2 will override any initial latitude and longitude from the INS when groundspeed is less than 5 kt. Data can be entered on lines 3 and 5, which will override the autotune station selection. Reversion to the autotune of navaid 1 will occur when keys 3, REJ are pressed in the NAV DATA 3 mode. Similarly, keys 5, REJ cause reversion to the autotune of navaid 2.

  For example, to tune NAVAID 1 to Hoquiam VORTAC (HQM):

  - Press key 3. Cue KEY VOR will appear on line 3, positions 1-7.
  - Press H, Q, M, ENT. HQM 115.4 will appear on line 4 in positions 12-20.

- Whenever the autotune system (see sec. 7.1.2.3) is unable to receive acceptable DME pulse pair data for navaid 1, which is specified by the flight plan, a flag RETUN1 is set and the cue RETUNE NAVAID #1 will appear on line 8 of the NCDU in all modes. This cue disappears when CLR is pressed and will not reappear until the next waypoint is pressed and the same condition of no acceptable data occurs.

6.5.5 SEL (Select) Mode

The SEL mode is controlled by a dedicated mode key with:

Legend	SEL
Position	7-5
Code	01100111

There are two SEL modes: hold modes and EADI options. Each display format is activated by successive presses of the SEL key.

6.5.5.1 SEL 1–Hold Modes

The first and third press of the SEL key will bring up the display format SEL 1 (see fig. 6-11), and the cue message on line 8:

PRESS # FOR MODE SELECT

The selectable modes are:

WPT HOLD	Holding pattern at a waypoint
OFFSET	Flight plan path parallel to the path defined in ATC CLR and FLT PLN
IAS REF	Reference airspeed for EADI display
ALT REF	Reference altitude for the MFD display
RADIAL	Radial symbol selection for the MFD display

The SEL 1 modes WPT HOLD and OFFSET, when activated, override the corresponding path guidance output to the flight controls, autothrottle, and EADI display, and cause additional symbology to appear on the MFD.

- WPT HOLD
    - GUID–Lateral path guidance output suspended. Acceleration command will revert automatically to control IAS (see table 6-8 for IAS/ALT values).
    - MFD–Holding pattern symbology (see sec. 2.4.1.7.6).
    - EADI–VNAV symbology deleted. HOLD displayed below the waypoint designator.
- OFFSET
    - GUID–Lateral path guidance for the offset path. Time navigation continues on original path.
    - MFD–Offset path displayed, original path shows as provisional. Time box stays on original path.
    - EADI–VNAV 1 and flight director options driven by offset guidance, and OFFSET added below waypoint designator.

The additional autopilot select modes, controlled by an external autopilot mode select panel, also impact the guidance and displays as follows:

- TK SEL
    - GUID–Lateral path guidance to hold magnetic TK angle.
    - MFD–Track select symbology displayed. SEL/TK displayed.

    - EADI–VNAV and flight director continue to reference the flight plan path, and LINKUP displayed below waypoint designator when the linkup flag is set.

- ALT ENG
    - GUID–Vertical path guidance to hold altitude.
    - MFD–SEL/ALT displayed.
    - EADI–VNAV and flight director continue to reference the flight plan path. SEL/ALT displayed below the waypoint designator.
- IAS ENG
    - GUID–Autothrottle output to hold IAS computed.
    - MFD–Time box continues to be driven by 4D path guidance. SEL/IAS displayed.
    - EADI–Acceleration command and speed error respond to IAS hold, and SEL/IAS displayed below the waypoint designator.
- FPA SEL
    - GUID–Vertical path guidance to hold FPA.
    - MFD–SEL/FPA displayed.
    - EADI–VNAV and flight director continue to reference the flight plan path. If the EADI mode panel pitch reference line switch is in AUTO, the pitch reference line will drive to HLDFPA. SEL/FPA will be displayed below the waypoint designator.

Note: Simulataneous modes will be annunciated SEL/ALT/IAS.

SEL 1 modes are activated as follows:

- WPT HOLD

    To hold at a waypoint on the flight plan path (see FLT PLN mode, sec. 6.5.3):

    - Press key 1. The cue KEY WPT will be displayed on line 8.
    - Key in waypoint designator, i.e., R. A, N, G, R, ENT. RANGR will appear on line 2, positions 12-17, and cue L-R/BRG will appear on line 8.

- Press CLR key if a standard right-hand holding pattern, oriented on the outbound course for that waypoint as defined by the GUID routine, is required. No more data are required. Line 8 will display EXEC OR REJ.

- Press keys L, 0, 7, 0, ENT if a left-hand holding pattern with an inbound course of 070° magnetic is required. Line 8 will display the cue EXEC OR REJ. ?RANGR/L/070° will appear on line 2, positions 12-23.

- Press the EXEC key The ? symbol will disappear from line 2 and HOLD will appear below RANGR on the FLT PLN page. The NCDU routine will set the pointer HLDWPT to the address of the hold waypoint. A zero in HLDSEL indicates that the mode is not engaged. Also, the cell HLDBRG will be set to the inbound course in degrees/360 (true), with bit 24 set to 0 for a right-hand pattern and 1 for a left-hand pattern.

- When the holding pattern is initiated, the annunciation on line 8 of the NAV DATA 1 and NAV DATA 2 pages will become HOLD RANGR.

To enter a holding pattern at present position:

- Press key 1. The cue KEY WPT will be displayed on line 8.

- Press keys P, P, O, S, ENT. ?PPOS will appear on line 2, positions 12-16, and the cue L-R/BRG will appear on line 8.

- Press CLR if a standard right-hand holding pattern oriented on the current TK angle (DSRTK) is desired. The line 8 cue will become EXEC OR REJ.

- Press keys L, 0, 7, 0, ENT if a left-hand holding pattern with an inbound course of 070° magnetic is required. The display on line 2 will become ?PPOS/L/070°, and a cue EXEC OR REJ will be displayed on line 8.

- Press the EXEC key. The ? symbol will disappear from line 2, and the NCDU will designate a waypoint, i.. WPT09, in the next sequential position available in the pilot-created waypoint buffer (table 6-5) with the latitude and longitude of the present position at the instant EXEC was pressed. WPT09 will be inserted into the FLT PLN page TO waypoint position, with the designation HOLD on the line below. Also, the annunciation on line 8 of the NAV DATA 1 and NAV DATA 2 pages will become HOLD WPT 09. The pointer HLDWPT will be set to the relevant address in the pilot-created waypoint buffer, the cell HLDBRG will contain the inbound course and pattern direction, and the flag HLDSEL will be set to nonzero.

- OFFSET

  - Press key 2. The cue message L-R/OFS will appear on line 8.

  - Press keys R, 1, 0, ENT for 10 nmi offset to the right.

  - ?R.10 will appear in positions 12-15 on line 3, and the cue EXEC OR REJ will appear on line 8.
  - Press EXEC and the ? symbol will disappear; the message SEL/OFS will appear on line 8 on the FLT PLN, as defined in section 6.5.3. The cell OFBIAS (in nautical miles) will contain the offset value and sign (R = +), and the flag OFSSEL will be set to nonzero.

    Note: If ALT HOLD is also activated, the FLT PLN line 8 message will become SEL/OFS/ALT.

- ALT REF
  - Press key 1. A cue KEY ALT will appear on line 8.
  - Key in altitude, i.e., 1, 2, 0, 0, 0, ENT. The numbers 12000 will appear on line 2 in positions 13-17, and the ALT REF symbology will appear on the MFD as defined in section 2.4.1.9.
- RADIAL
  - Press key 2. A cue WPT/BRG will appear on line 8.
  - Key in waypoint designator and the radial bearing required, i.e., SEA 035. SEA /035° will appear on line 3, positions 13-19, and the radial symbol from SEA will appear on the MFD map display, as defined in section 2.4.1.7.14. The waypoint can be from two to five characters and will be labeled RADWPT. Bearing will be labeled RADBRG.

ALL SEL 1 modes will be canceled as follows:

- Press the appropriate number key.
- Press the REJ key. The mode is now canceled and the data in positions 13-24 will go blank, HOLD annunciation on the FLT PLN and NAV DATA pages will disappear, and the GUID routine will revert to normal path guidance. The appropriate flags WPTSEL, OFSSEL, IASREF, ALTREF, and RADIAL will be set to zero.

6.5.5.2 SEL 2–EADI Options

The second press of the SEL key will bring up the SEL 2 format shown in figure 6-12.

SEL 2 EADI display options will be activated as follows:

- Press the number key. SELECTED will appear on the line corresponding to the number key and the flag VNAVF=1, VNAVF=2, VNAVF=3 set. Any option previously selected will be canceled.
- If the ENT or EXEC key are pressed, they will be ignored.

SEL 2 EADI options can also be canceled as follows:

- Press the number key.
- Press the REJ key.

6.5.6 Look-Up Mode

6.5.6.1 General

The look-up mode is controlled by a dedicated mode key with·

Legend	LOOK UP
Position	7-6
Code	01101110

There are three primary look-up modes: status, route data and airport data. Each display format is activated by successive presses of the LOOK-UP key. The look-up mode interface with the MFD display is controlled by the look-up data buffer (table 6-6).

6.5.6.2 Status (LOOK-UP 1 Mode)

The first and fourth press of the LOOK-UP key will bring up the status page (see fig. 6-13). This page shows the current status of all systems interfacing with the NCU.

The EADI bus, MFD 1 bus, and MFD 2 bus status reflects the parity detected by the PCU, as indicated by the mode word (see fig. 2-5).

The remaining readouts show the status of the valid discretes received by the NCU. Any invalid message detected will cause BAD to be displayed on the status page for a minimum of 10 sec, and the cue LOOK UP–STATUS will appear on line 8, whatever the current mode selected on the NCDU. If data entry is in process, the cue LOOK UP–STATUS will not appear until ENT has been pressed. Pressing the CLR key will clear this message.

6.5.6.3 Route Data (LOOK-UP 2 Mode)

The second press of the LOOK-UP key will bring up the route data page (see fig. 6-14a). This page allows any waypoint, airway, route, or SID for the origin airport, and STAR for the destination airport, to be examined. The mode is activated by using the appropriate function key. The data selected will also appear on the MFD display.

Function key data selections will include:

- WPT
  - Press WPT key, and key in designator, i.e., R, A, N, G, R, ENT. The display format shown in figure 6-14b will appear. The ?---? will be used in all look-up modes to indicate that this waypoint is the potential center of the north-up MFD map display as defined in section 2.4.2. To make the waypoint the map center, press EXEC. The ?---? will change to <--->. The NCDU will use the latitude and longitude of this waypoint to set LATCEN and LONCEN. The last waypoint executed (EXEC) will remain the map center unless the REJ key is pressed when the waypoint is being displayed in the LOOK-UP page, or when another waypoint is EXECuted on another LOOK-UP page.
  - When WPT01, etc., is entered as the waypoint designator, the full details of the waypoint will be displayed, including latitude, longitude, range, bearing, and reference navaid in the case of a range/bearing waypoint (see fig. 6-14c). Lines 6 and 7 will display REF , followed by data that show how the data were formatted during entry through the ATC CLR page.
- AWY
  - Press AWY key, and key in designator, i.e., V, 2, N, ENT. The display format shown in figure 6-14d will appear. The ?---? indicates the center waypoint on the MFD north-up map display.
  - If EXEC is pressed, the ?---? will change to <--->, as defined above. In this case, pressing the UP and DN keys will change the map center as <---> stays on line 3 and the waypoints move up and down. The cue KEY UP PAGE CONTINUES will appear on line 8 if the AWY has more than five waypoints. Pressing UP four times will bring the last waypoint MLP onto line 7, EPH to line 3, and the cue on line 8 will disappear.
- RTE–Identical to AWY.
- SID and STAR–Similar to AWY but will have waypoint altitude (PALT) in positions 10-14 and PGSXXX in positions 16-21.

Pressing the REJ key will cause the look-up data buffer (table 6-6) to be zeroed out and the NCDU display format to revert to figure 6-14a. LATCEN and LONCEN will revert to the FLT PLN reference waypoint.

6.5.6.4 Airport Data (LOOK-UP 3 Mode)

The third press of the LOOK-UP key will bring up the airport data format shown in figure 6-15a. The cue on line 8 will say PRESS 1.

- Press key 1. Cue will change to KEY ICAO.
- Press keys K, S, E, A, ENT. ?KSEA? will appear on line 2, positions 13-16, and the cue PRESS # FOR DATA SELECT will appear on line 8.

  Note: ?---? indicates potential center of north-up map display and will become the map center if EXEC is pressed, in which case ?---? will change to <--->. (See fig. 6-15b.)

Pressing any number 2 through 6 will call up lists of runways, SIDs, STARs, missed approach paths (MAPs), and communication frequencies stored for the airport specified on line 2, as shown in figure 6-15c for runways; figure 6-15d for SIDs, STARs, and MAPs; and figure 6-15e for communications frequencies. The cue KEY UP PAGE CONTINUES indicates that the list continues. Lines 1 and 2 remain unchanged, but pressing UP will cause data to cycle up through lines 3-7 at one line per press.

Reselecting 1 and keying in an airport ICAO designator will cause the display format to revert to that shown in figure 6-15b. Changing mode and reselecting LOOK-UP 3 will also bring up the display format shown in figure 6-15b; i.e., once entered, the airport designator is not cleared except by inserting a new origin in the INIT mode (at which time all buffers will be cleared) or by pressing REJ when the format of figure 6-15b is displayed.

Further branching from the display formats defined in figures 6-15c and 6-15d allows detailed data for each runway, SID, STAR, or MAP to be displayed. For example, the selection is as follows:

- For runway 34R data from figure 6-15c format–Press key 5. Display changes to that shown in figure 6-15f.
- For STAR GOR 34R data from figure 6-15d format–Press key 6. Display changes to that illustrated in figure 6-15g.

The format in figure 6-15g applies to SIDs and missed approach paths also.

Pressing REJ at any time in the LOOK-UP 3 mode will cause the display format to revert to the next lower branch page, i.e., figure 6-15f to figure 6-15c, etc.

6.6 MFD AND NCDU INTERRELATIONSHIPS

6.6.1 North-Up Map Center

This section summarizes the relationships between the NCDU and the MFD north-up map as specified in sections 6.5.3 (FLT PLN) and 6.5.6 (LOOK UP).

The map center coordinates will be defined by the NCDU and LATCEN and LONCEN. LATCEN and LONCEN will be set by the NCDU in one of three ways, defined below in ascending order of priority.

- At initial power on, or when ORIGIN is entered, LATCEN and LONCEN will be updated once with the current value of present position, latitude, and longitude.

- When ATC clearance entry is started, LATCEN and LONCEN will be updated to the latitude and longitude of the waypoint displayed on line 4 of the FLT PLN page. LATCEN and LONCEN will henceforth correspond to the waypoint on line 4 of the FLT PLN page throughout all manipulations due to the ATC CLR data entry or FLT PLN UP and DN slewing. However, a map center chosen through the LOOK-UP page will override the FLT PLN map center.

- LATCEN and LONCEN will be set to the latitude and longitude of a waypoint specified on any of the several LOOK-UP page formats defined in section 6.5.6. This is mechanized by pressing the key EXEC when the symbology ?---? brackets the desired map center reference waypoint. The ?---? will then change to <--->, which symbolizes map center. The look-up map center point can be changed by pressing EXEC when a different LOOK-UP page is selected or can be rejected by pressing REJ when the LOOK-UP page with <--> is displayed. In this case, LATCEN and LONCEN will revert to correspond to line 4 of the FLT PLN page.

Two cells labeled CENWPT will be associated with LATCEN, LONCEN when set by the look-up mode. Cell 1 will contain a pointer to the address of the map center point in the bulk data memory or pilot-created waypoint buffer. Cell 2 will contain a code to identify the symbol required on the MFD display.

0 = waypoint star

1 = navaid

2 = GRP

3 = airport

6.6.2 Look-Up Data

Data selected on the LOOK-UP 2 and LOOK-UP 3 pages will be displayed on both the north-up and track-up MFD map modes. The data to be displayed are defined by the look-up data buffer (table 6-6), which includes labels LOKWPT and LOKBUF. LOKWPT is two cells similar to CENWPT defined above. LOKBUF is comprised of 15 cells containing pointers. Zeros in cell 1 of LOKWPT indicate that no waypoint or airport has been selected. Zero in cell 1 of LOKBUF indicates that no airway, route, SID, STAR, or missed approach path has been selected.

6.6.3 SEL Mode

WPT HOLD, OFFSET, and TK HOLD directly impact the MFD map display as defined in sections 2.4.1.7.6, 2.4.1.7.1.3, and 2.4.1.6.1, respectively. The flags WPTSEL, OFSSEL, and TKSEL equal to nonzero indicate that a SEL mode has been executed.

6.7 NCDU TEST MODE

The NCDU test mode is initiated by setting the M/A/T rotary switch (fig. 6-1) to the T position. A code 11010110 will then be transmitted to the NCU. On receipt of this code, the NCU will initiate the test mode defined below. When the switch is returned to the A or M position, causing codes 10010111 or 01010111 to be transmitted, the NCDU will revert to the display format selected before the test mode was activated.

6.7.1 NCDU Test Mode

The test format defined in figure 6-16 will be displayed on the NCDU. The pattern will shift left one position every second, and circulate line 1, position 1, to line 8, position 24, i.e., the third cycle will have:

Line 1 BCDEF---------

Line 8 ------------- = ? Ab (b = blank)

This pattern will be generated by starting with a seven-bit designator 0000000 and adding 1 for each successive character to generate a 192-character page. The second cycle will be generated by starting with a seven-bit code 0000001, and so on.

6.7.2 NCU Interface Test Mode

When the test switch is selected on the NCDU, the NCU will generate the outputs defined below for the various interfaces:

Dc analog	Half scale
Ac analog–synchro	Equivalent to 45°
Ac analog–2-wire	Half scale
Discretes	28 V
MFD SPBP buses	As defined in section 2.5.2
EADI SPBP bus	As defined in section 4.5.2
561 and 575 buses	Data content alternative 1 and 0 with designation matrix set to TEST

6.8 NCDU SOFTWARE LABELS

The machine language labels for the variables defined in section 5.6 are summarized in table 6-9. These labels are used by the NAV, GUID, MFD, and EADI programs.

TABLE 6-1.—CUE MESSAGES ON LINE 8

EXEC OR REJ
LOOK UP - STATUS
KEY UP PAGE CONTINUES
FORMAT ERROR
FORMAT ERROR PRESS #
INVALID FUNCTION
INVALID FUNCTION PRESS #
BUSY
RETUNE NAVAID # 1
PRESS 1 FOR NEW ORIGIN
PRESS 2
PRESS 3
PRESS 4
ORIGIN
DESTIN
GMT
BAROSET
PRESS # FOR DATA ENTRY
CHECK GMT/PRESS 3
SID
WPT
AWY
RAD
RTE
RWY
STAR

GS
ALT
F/L
PTA
LINK UP
NOT IN MEMORY
NOT IN MEMORY CHECK ORIG
NOT IN MEMORY CHECK DEST
LINK UP PPOS TO WPT
KEY WPT
KEY ALT
WAYPOINT BUFFER FULL
KEY WPT ON AWY/RTE
KEY WPT ON PATH
INVALID THIS WPT
KEY RWY ON PATH
KEY LAT
KEY LON
KEY VOR
PRESS # FOR MODE SELECT
L-R/OFS
WPT/BRG
L-R/BRG
PRESS # FOR DATA SELECT
KEY ICAO
PRESS FUNCTION KEY

TABLE 6-2.–KEY CODES

Key	Primary	Dual function	Code	Key	Primary	Dual function	Code
			MSB LSB				MSB LSB
1-1	Enter	X	None	5-1	O	SID	01001111
1-2	1	Option 1	11110001	5-2	P	STAR	11010000
1-3	2	Option 2	11110010	5-3	Q		01010001
1-4	3	Option 3	01110011	5-4	R		01010010
1-5	4	Option 4	11110100	5-5	S		11010011
1-6	5	Option 5	01110101	5-6	T	PTA	01010100
1-7	Up	X	01100010	5-7	U		11010101
2-1	.	/	11101111	6-1	EXEC	X	01100001
2-2	6	Option 6	01110110	6-2	V		11010110
2-3	7	Option 7	11110111	6-3	W		01010111
2-4	8	Option 8	11111000	6-4	X		01011000
2-5	9	Option 9	01111001	6-5	Y		11011001
2-6	0	Option 10	01110000	6-6	Z		11011010
2-7	Down	X	11100011	[illegible]	REJ	X	01101101
3-1	A	WPT	11000001	7-1	INIT	X	11100101
3-2	B	AWY	11000010	7-2	ATC CLR	X	01101000
3-3	C		01000011	7-3	FLT PLN	X	11100110
3-4	D		11000100	7-4	NAV DATA	X	11101100
3-5	E		01000101	7-5	SEL	X	01100111
3-6	F	F/L	01000110	7-6	LOOK UP	X	01101110
3-7	G	ALT	11000111	7-7	CLEAR	X	01100100
4-1	H	RTE	11001000	Switch	A	X	11101001
4-2	I	RWY	01001001		M	X	11101010
4-3	J		01001010		T	X	01101011
4-4	K		11001011				
4-5	L		01001100				
4-6	M	GS	11001101				
4-7	N		11001110				

X = dedicated mode key or special-purpose key

Note: Codes shown above are for the first press of the key when bit 7 is set to 1

TABLE 6-3.–PROVISIONAL GUIDANCE BUFFER

	24			1		
(a)	Name of Waypoint					
(b)		☒			(c)	
	Latitude	°/180	B0			1st waypoint
	Longitude	°/180	B0			
	Altitude	ft	B23			
	Groundspeed	kt	B15			
	Radius of turn	ft	B23			
	Incremental time en route	sec	B15			
	Great circle distance	ft	B23			(WPPPD)
	Waypoint center–center distance	ft	B23			(WPCCD)
	Flightpath angle	°/180	B0			
	Turn angle at waypoint	°/360	B0			
	Arc distance of curve/2	ft	B23			
	Distance waypoint to tangent points	ft	B23			
	Planned time of arrival	sec	B23			
	Magnetic variation	°/180	B0			
	Pointer to navaid					
	Bearing from turn center	°/360	B0			
	DME arc reference latitude	°/180	B0			
	DME arc reference longitude	°/180	B0			
						nth waypoint
	Terminator = 0					

[a] Bit 24 = 1 Provisional path
23 = 1 Flight level waypoint
22 = 1 Use IASREF from NCDU for display

[b] Bit 24 = 1 For DME arc
23 = 1 For DME arc inhibit

Bit 22 = 1 Inhibit radius of turn calculation
3 = 1 Do not display waypoint star on MFD

[c] Bits 1 and 2.
0 = Airway/route
1 = SID
2 = STAR
3 = MAP

Note: The format is the same as that shown in table 5-1.

TABLE 6-4.–ORIGIN/DESTINATION BUFFER

<table>
<tr><td>☒</td><td>Name</td><td></td><td></td></tr>
<tr><td>☒</td><td></td><td>☒</td><td>☒</td></tr>
<tr><td colspan="4">Origin airport address</td></tr>
<tr><td colspan="4">Origin runway address</td></tr>
<tr><td>☒</td><td></td><td></td><td></td></tr>
<tr><td>☒</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Destination airport address</td></tr>
<tr><td colspan="4">Destination runway address</td></tr>
</table>

TABLE 6-5.–PILOT-CREATED WAYPOINT DATA BUFFER

	☒	W	P	T	
(a)	☒	X	X	☒	
	Latitude		°/180	B0	
	Longitude		°/180	`0	
	Navaid address				1st waypoint
					6 ASCII words
	☒			☒	
	☒			☒	
	Latitude		°/180	B0	
	Longitude		°/180	B0	
	Navaid address				2nd waypoint
	Terminator = 0				End

[a] Sequence numbers 01, 02, . . . 10

TABLE 6-6.–LOOK-UP DATA BUFFER

Name	Cell number	Remarks
LOKWPT (2 cells)	1	Pointer to address in bulk data memory. A zero in this location indicates no LOOK-UP option has been selected.
	2	Code word for symbol required on MFD: value 0 = WPT 1 = NAVAID 2 = GRP 3 = AIRPORT
LOKBUF (30 cells)	1 2 3 . . . . 28 29 30	Pointer to addresses in bulk data memory. Used when RTE, AWY, SID, STAR, or MAP are selected. A waypoint symbol (star) will be displayed on the MFD display for each pointer. A zero in this location indicates no look-up AWY, RTE, SID, STAR, or MAP option has been selected.

TABLE 6-7.–NCDU DISPLAYED PARAMETER DEFINITIONS

Displayed name	Mode (page) used	Parameter	Units
ORIGIN	INIT	Origin airport	–
DESTIN	INIT	Destination airport	–
GMT	INIT and NAV DATA 1	Greenwich Mean Time	hr, min, sec
BAROSET	INIT	Altimeter setting	in. of Hg, 1/10, 1/100, 1/1000
ETA	NAV DATA 1	Estimated time of arrival	hr, min, sec
TE		Time error	min, sec
TE/MIN		Time error rate	sec/min
TK–M		Track angle (magnetic)	deg
TKE		Track angle error	deg
XTKE		*Crosstrack distance error*	nmi, 1/10 and 1/100
ALT		Computed altitude	ft (MSL)
AE		Altitude error	ft
FPAE		Flightpath angle error	deg, 1/10
GS		Groundspeed	kt
GSE		*Groundspeed error*	kt
HDG–M	NAV DATA 2	Heading (magnetic)	deg
HDG–T		Heading (true)	deg
DA		Drift angle	deg
FPA		Flightpath angle	deg, 1/10
GRAD		Gradient	ft/nmi
WD		Wind direction (magnetic)	deg

TABLE 6-7.—CONCLUDED

Displayed name	Mode (page) used	Parameter	Units
WS	NAV DATA 2	Windspeed	kt
TTG	↓	Time to go	min, sec
DTG	↓	Distance to go	nmi
POS	NAV DATA 3	Present position — Lat and lon	deg, min, 1/10
NAVIDD	NAV DATA 1 and 2	Navigation mode — INS/DME/DME	—
NAVIDV	↓	— INS/VOR/DME	—
NAVIDX	↓	— INS/DME	—
NAVADD	↓	— Air data/DME/DME	—
PI	↓	Performance index	nmi, 1/10
PTA	FLT PLN 1	Planned time of arrival	hr, min, sec
PGS	FLT PLN 1	Planned groundspeed	kt
REMD	FLT PLN 2	Distance to destination	nmi
LEGD	↓	Distance between waypoints	nmi
REMT	↓	Time to destination	min
LEGT	↓	Time between waypoints	min
OFFSET	SEL #1	Offset distance from flight plan	nmi
IASREF		Indicated airspeed reference	kt
ALTREF		Reference altitude	ft (MSL)
RADIAL		Radial bearing from reference point (magnetic)	deg

TABLE 6-8.—HOLDING PATTERN ALTITUDE/AIRSPEED VALUES

Altitude (1000 ft)	TAS (kt)	IAS (kt)
0 - 5	205	190
5 - 10	215	190
10 - 14	235	190
14 - 20	280	210
20 - 25	305	210
25 - 30	330	210
30 - 35	365	210
35 - 40	405	210

TABLE 6-9.—NCDU SOFTWARE LABELS

Label	Unit	Scale	Rate (updates/ sec)	Used by						Definition
				NAV	GUID	MFD	EADI	NCDU	Other	
ORIGIN	ASC	–	–			X				Origin/destination buffer
DESTIN	ASC	—	—			X				Origin/destination buffer
BINTME	sec	B23	1		X					GMT (sec)
BARSET	in.	B6	—	X						Barometer setting (in. Hg)
LATCEN	°/180	B0				X				
LONCEN	°/180	B0				X				
LATBN	°/180	B0		X						Initial position input when INS not operating
LONGBN	°/180	B0		X						Initial position input when INS not operating
LOKWPT	—	—	—			X				Look-up code word to define MFD symbol
LOKBUF	—	—	—			X				15 max pointers to bulk data addresses
RADWPT	—	—	—			X				Pointer to address in bulk data (0 indicates mode not selected)
RADBRG	°/180	B0	—			X				
VNAVF	—	—	—				X			0, 1, 2, or 3 EADI options
IASREF	kt	B15	—		X		X			
CENWPT	—	—	—				X			Code word to define MFD symbol

TABLE 6-9.–CONCLUDED

Label	Unit	Scale	Rate (updates/ sec	Used by						Definition
				NAV	GUID	MFD	EADI	NCDU	Other	
HLDSEL			—							Flag (0 indicates mode not selected)
HLDBRG	°/360	B0	—		X	X				Inbound bearing in degrees true Bit 24: 0 = right 1 = left
HLDWPT	—	—	—		X	X				Pointer to waypoint address
OFSSEL	—	—	—							Flag (0 indicates mode not selected)
OFBIAS	nmi	B10	—		X	X				
TKSEL	—	—	—		X	X				Flag (0 indicates mode not selected)
HLDTK	°/180	B0	—		X	X				Stored as degrees true
ALTSEL	—	—	—							Flag (0 indicates mode not selected)
HLDALT	ft	B23			X					
GSSEL	—	—	—							Flag (0 indicates mode not selected)
HLDGS	kt	B15	—		X					
IASSEL	—	—	—							Flag (0 indicates mode not selected)
HLDIAS	kt	B15	—		X					
FPASEL	—	—	—		X					Flag (0 indicates mode not selected)
HLDFPA	°/180	B0	—		X					
ALTREF	ft	B23	—			X				*(0 indicates mode not selected)*

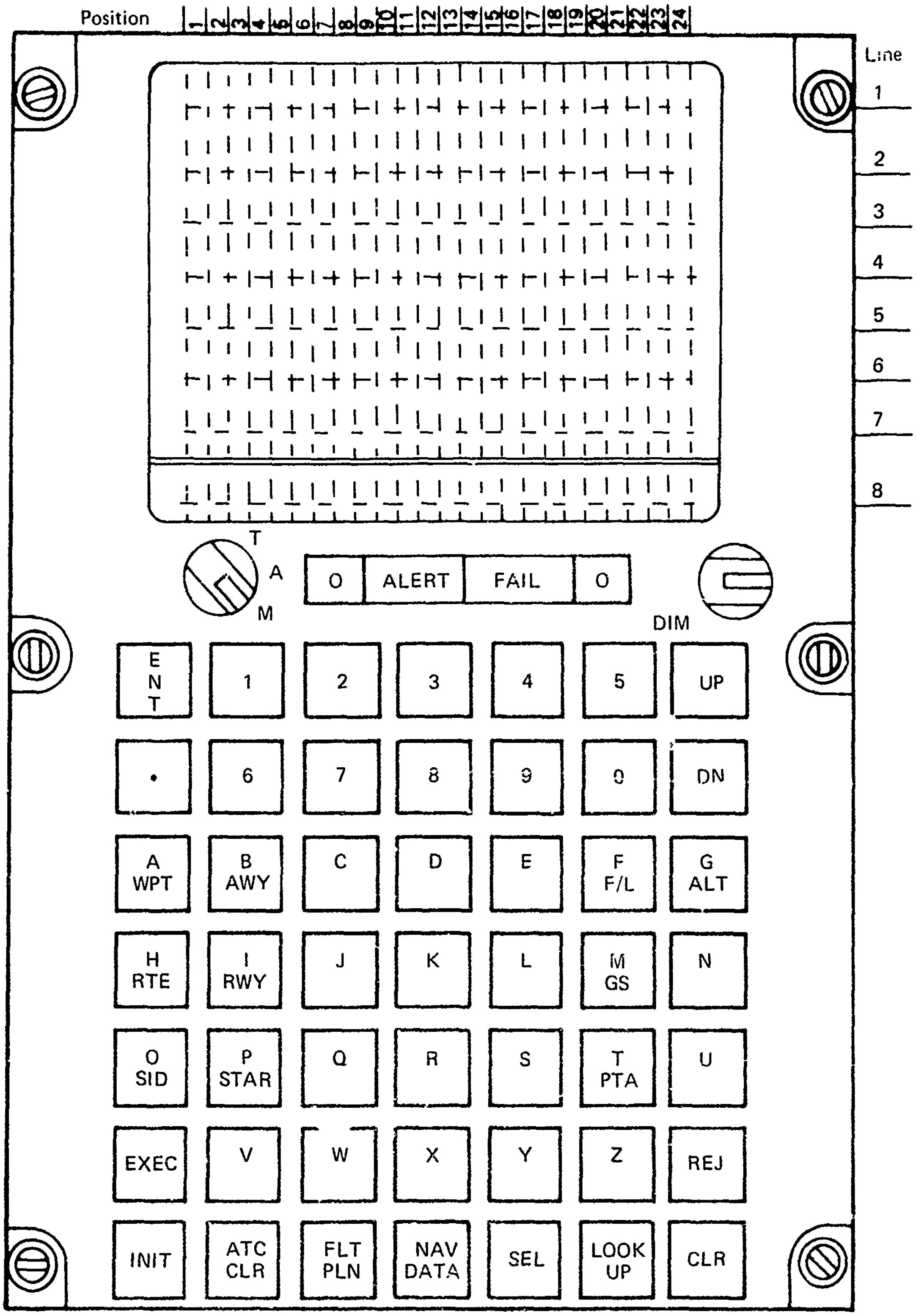
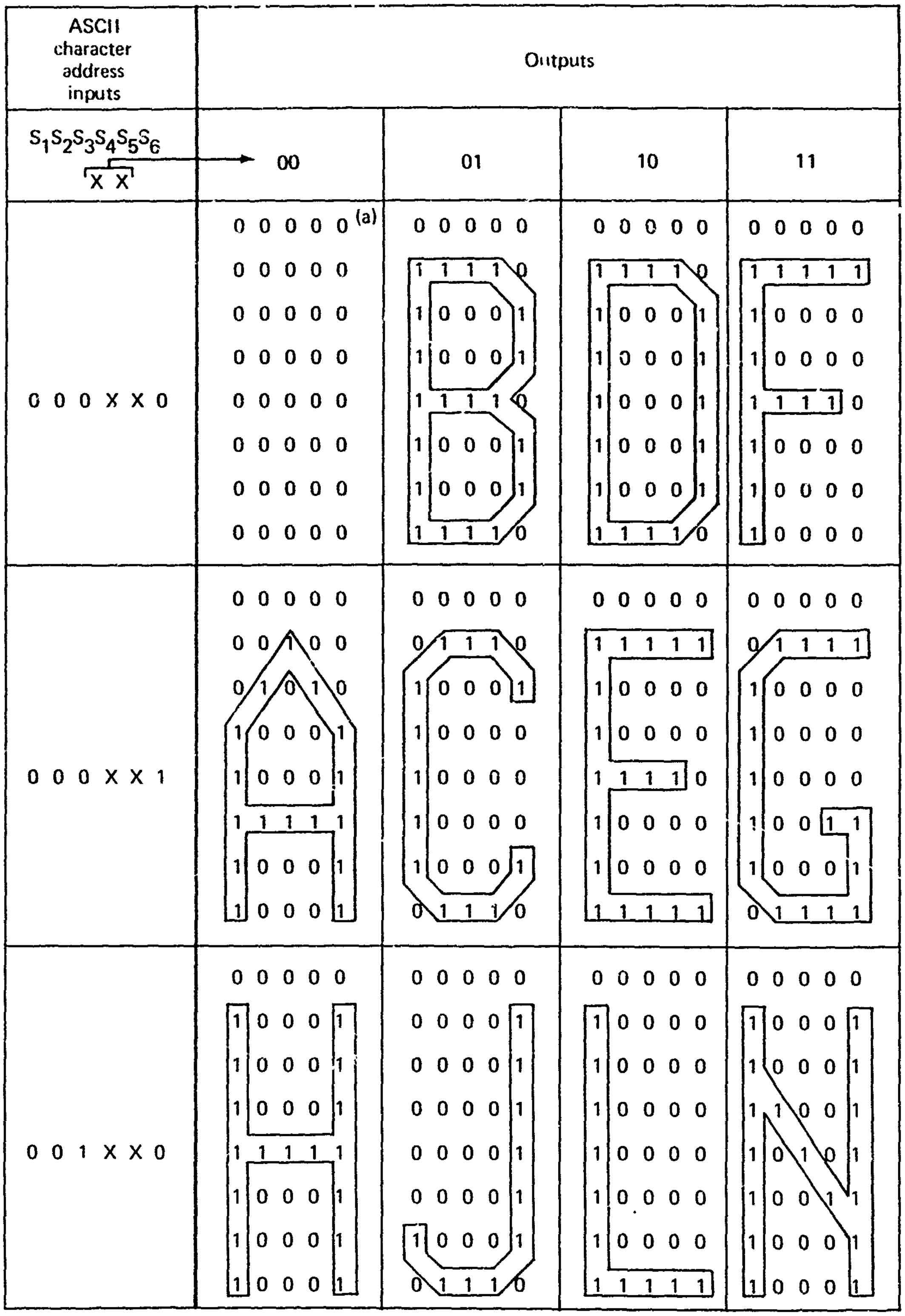


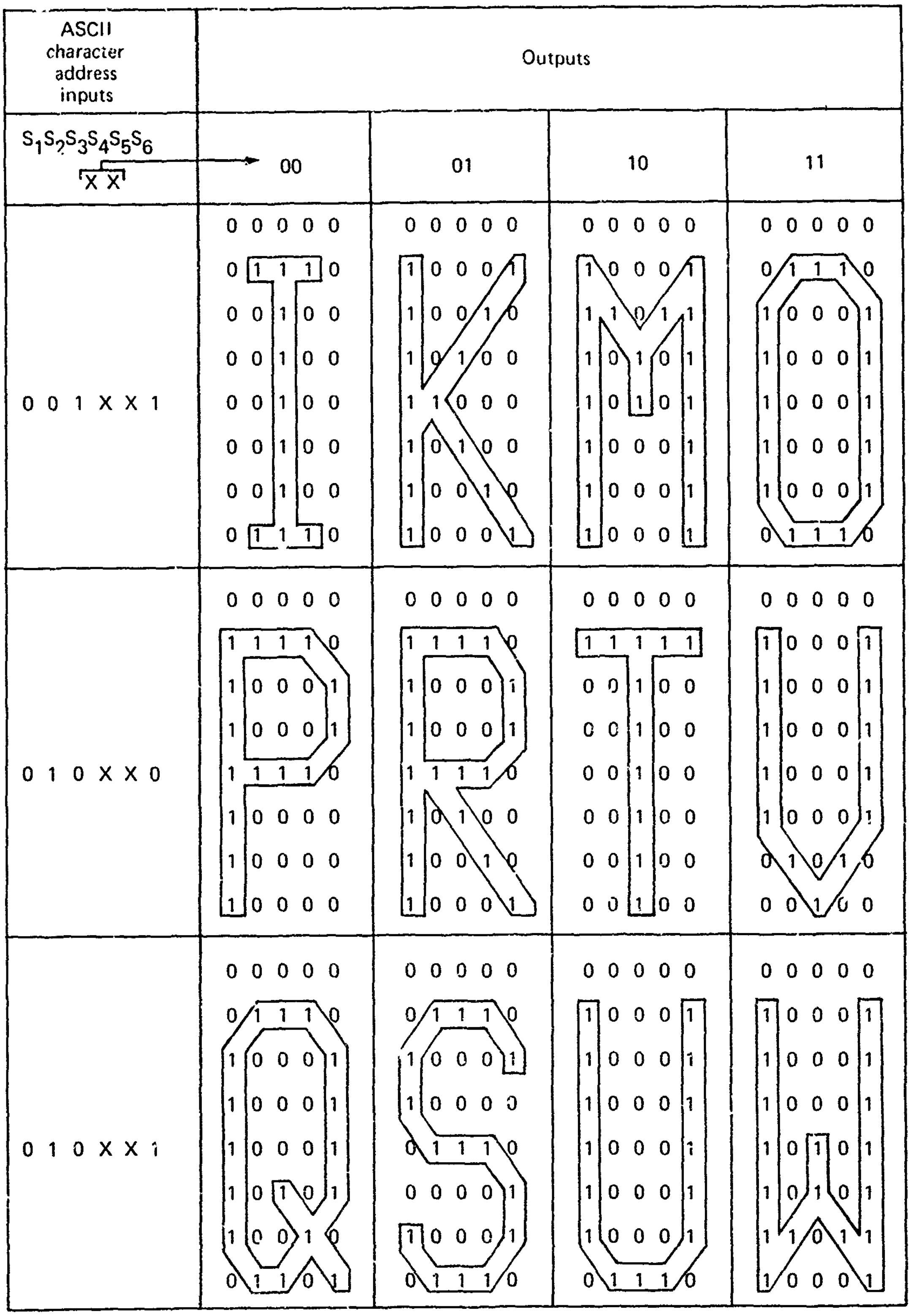
FIGURE 6-1.—NCDU



ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X →	00	01	10	11
0 0 0 X X 0	0 0 0 0 0 (a) 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 1 1 1 0	0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 1 1 1 0	0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 1 0 0 0 0 1 1 1 1 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0
0 0 0 X X 1	0 0 0 0 0 0 0 1 0 0 0 1 0 1 0 1 0 0 0 1 1 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 1 0 0 0 0 1 1 1 1 0 1 0 0 0 0 1 0 0 0 0 1 1 1 1 1	0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 1 1 1 0 0 0 1 0 1 1 1 1
0 0 1 X X 0	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1	0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 1 1 1 1	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 1 1 0 0 1 1 0 1 0 1 1 0 0 1 1 1 0 0 0 1 1 0 0 0 1

[a] Modification to ASCII code

FIGURE 6-2.—BIT PATTERN



ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X	00	01	10	11
0 0 1 X X 1	0 0 0 0 0 0 1 1 1 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 1 1 0	0 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1 0 1 0 0 1 1 0 0 0 1 0 1 0 0 1 0 0 1 0 1 0 0 0 1	0 0 0 0 0 1 0 0 0 1 1 1 0 1 1 1 0 1 0 1 1 0 1 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 0 1 1 1 0
0 1 0 X X 0	0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 1 1 1 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0	0 0 0 0 0 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 1 1 1 0 1 0 1 0 0 1 0 0 1 0 1 0 0 0 1	0 0 0 0 0 1 1 1 1 1 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 0 1 0 1 0 0 0 1 0 0
0 1 0 X X 1	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 1 0 1 1 0 0 1 0 0 1 1 0 1	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 0 0 0 1 1 1 0 0 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 1 0 1 1 0 1 0 1 1 1 0 1 1 1 0 0 0 1

FIGURE 6-2—CONTINUED

ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X	00	01	10	11
0 1 1 X X 0	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 0 1 0 1 0 0 0 1 0 0 0 1 0 1 0 1 0 0 0 1 1 0 0 0 1	0 0 0 0 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 1 1 1 1 1	0 0 0 0 0 (a) 0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 1 1 1 1 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0	0 0 0 0 0 (a) 0 1 1 0 0 1 0 0 1 0 1 0 0 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 1 X X 1	0 0 0 0 0 1 0 0 0 1 1 0 0 0 1 0 1 0 1 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 1 1 1 1	0 0 0 0 0 (a) 0 0 1 0 0 0 0 1 0 0 0 1 1 1 0 1 1 0 1 1 0 1 1 1 0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1
1 0 0 X X 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 (a) 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 1 0 1 0 1 0 1 1 1 0 0 0 1 0 0	0 0 0 0 0 0 0 1 0 0 0 1 1 1 1 1 0 1 0 0 0 1 1 1 0 0 0 1 0 1 1 1 1 1 0 0 0 1 0 0	0 0 0 0 0 0 1 0 0 0 1 0 1 0 0 1 0 1 0 0 0 1 0 0 0 1 0 1 0 1 1 0 0 1 0 0 1 1 0 1

FIGURE 6-2.– CONTINUED

[a] Modification to ASCII code

ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X	00	01	10	11
1 0 0 X X 1	0 0 0 0 0 (a) 0 0 1 0 0 0 1 1 1 0 1 0 1 0 1 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0	0 0 0 0 0 0 1 0 1 0 0 1 0 1 0 1 1 1 1 1 0 1 0 1 0 1 1 1 1 1 0 1 0 1 0 0 1 0 1 0	0 0 0 0 0 1 1 0 0 0 1 1 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 1 0 0 0 1 1	0 0 0 0 0 (a) 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 0 1 X X 0	0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0	0 0 0 0 0 0 0 1 0 0 1 0 1 0 1 0 1 1 1 0 0 0 1 0 0 0 1 1 1 0 1 0 1 0 1 0 0 1 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0
1 0 1 X X 1	0 0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0	0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 1 1 1 1 1 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0

FIGURE 6-2.–CONTINUED

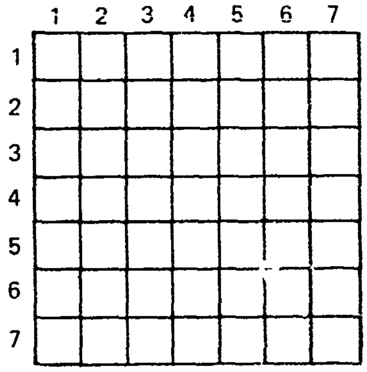
[a] Modification to ASCII code

ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X	00	01	10	11
1 1 0 X X 0	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 1 1 1 0 1 0 1 1 1 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 0 0 0 0 1 0 0 1 1 0 0 1 0 0 0 1 0 0 0 0 1 1 1 1 1	0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 1 0 1 0 1 0 0 1 0 1 1 1 1 1 0 0 0 1 0 0 0 0 1 0	0 0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 0 0 0 0 1 1 1 1 0 1 0 0 0 1 1 0 0 0 1 0 1 1 1 0
1 1 0 X X 1	0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 1 1 1 0	0 0 0 0 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 0 0 0 1 1 0 0 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 1 1 1 1 1 0 0 0 0 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 1 1 1 1 1 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 1 0 0 0 0 1 0 0 0
1 1 1 X X 0	0 0 0 0 0 0 1 1 1 0 1 0 0 0 1 1 0 0 0 1 0 1 1 1 0 1 0 0 0 1 1 0 0 0 1 0 1 1 1 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0	0 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 0

FIGURE 6-2.–CONTINUED

ASCII character address inputs	Outputs			
$S_1S_2S_3S_4S_5S_6$ X X	00	01	10	11
1 1 1 X X 1	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0
	0 1 1 1 0	0 0 0 0 0	0 0 0 0 0	0 1 1 1 0
	1 0 0 0 1	0 0 0 0 0	0 0 0 0 0	1 0 0 0 1
	1 0 0 0 1	0 0 1 0 0	1 1 1 1 1	0 0 0 1 0
	0 1 1 1 1	0 0 0 0 0	0 0 0 0 0	0 0 1 0 0
	0 0 0 0 1	0 0 1 0 0	1 1 1 1 1	0 0 1 0 0
	0 0 0 1 0	0 0 1 0 0	0 0 0 0 0	0 0 0 0 0
	1 1 1 0 0	0 1 0 0 0	0 0 0 0 0	0 0 1 0 0

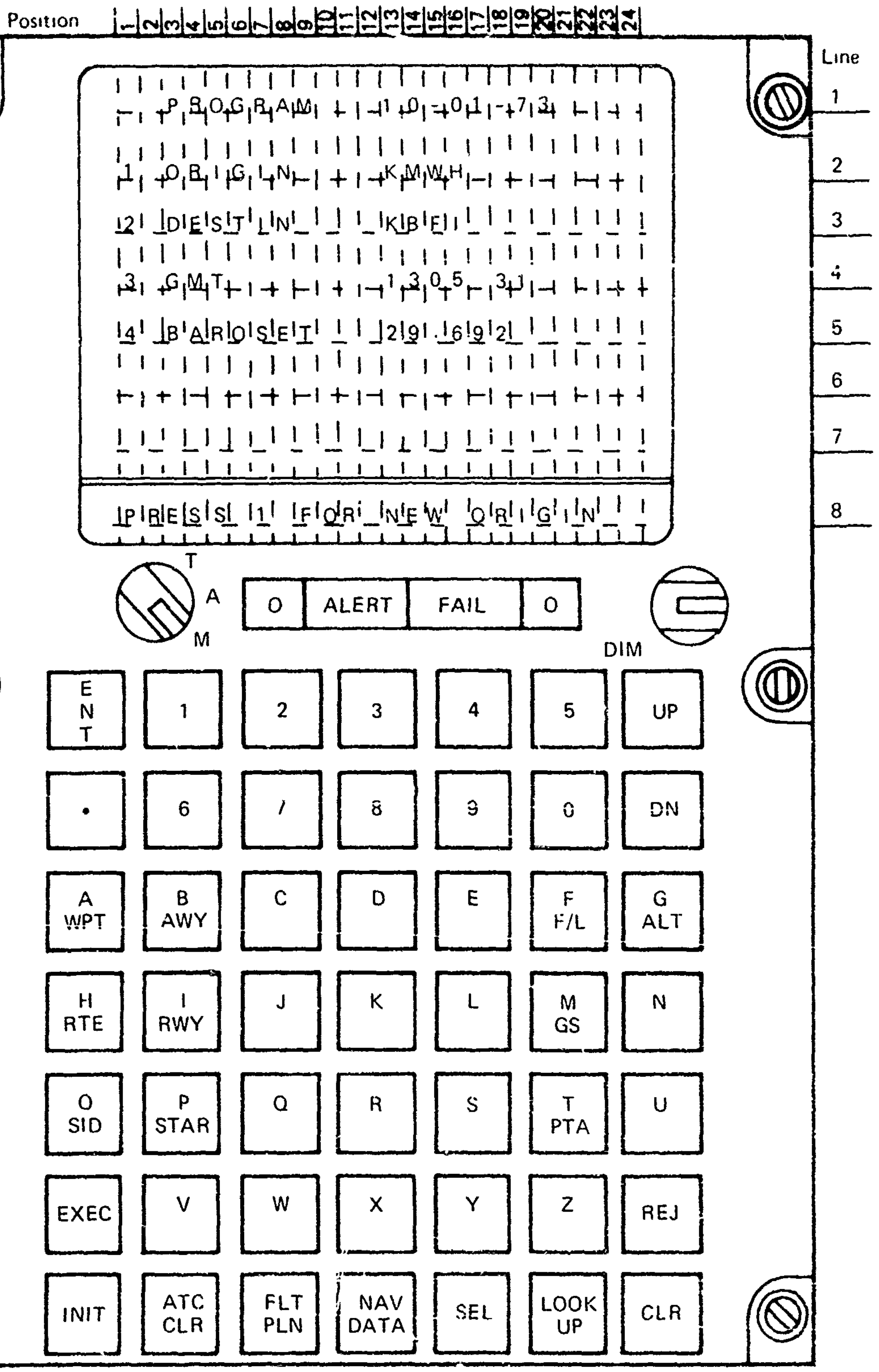
FIGURE 6-2.- CONCLUDED



Example:

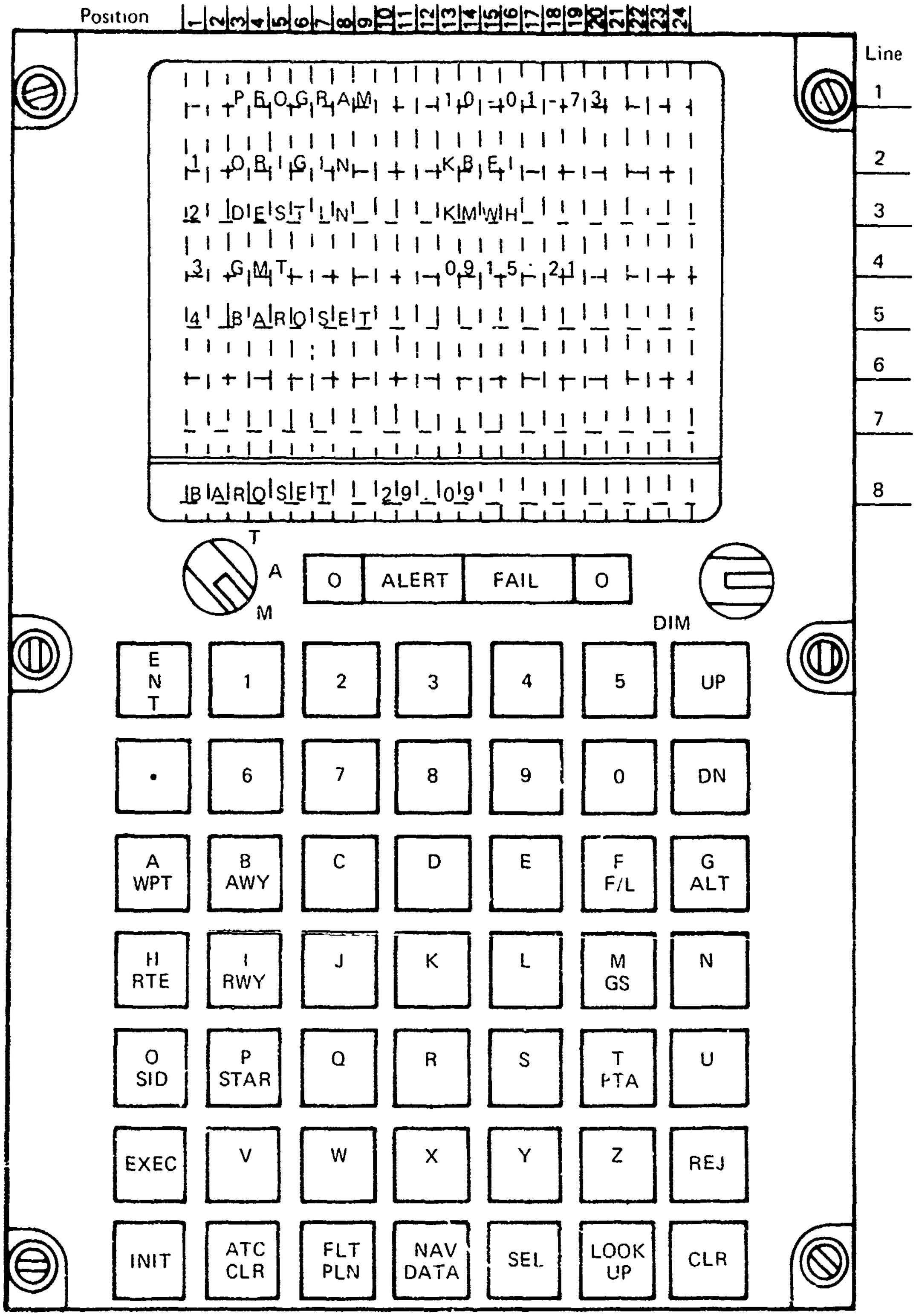
Key 3/6 is F:F/L dual function

FIGURE 6-3.–NCDU KEY IDENTIFICATION



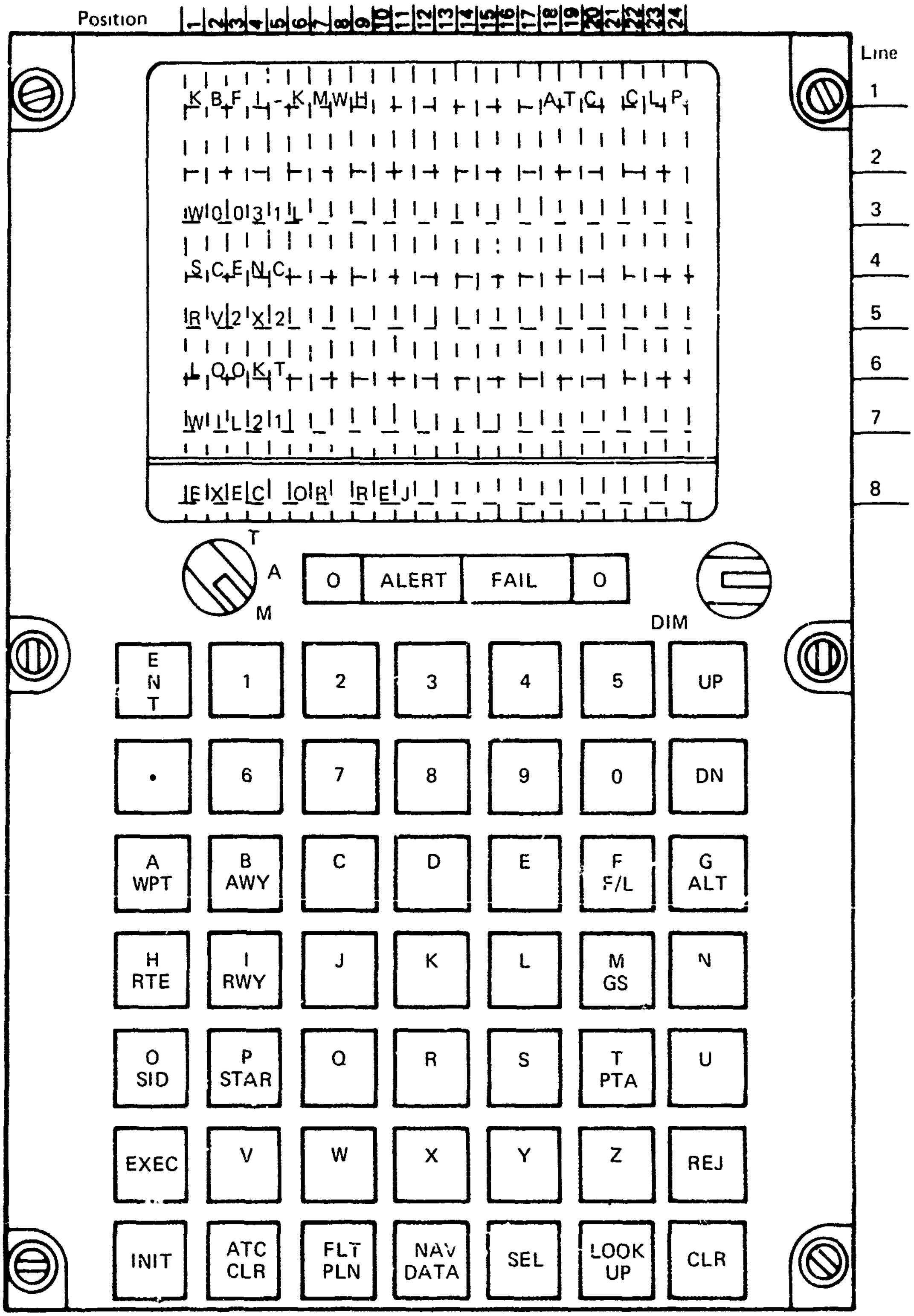
a. After Power On—Old Data

FIGURE 6-4.—INIT (INITIALIZE) MODE



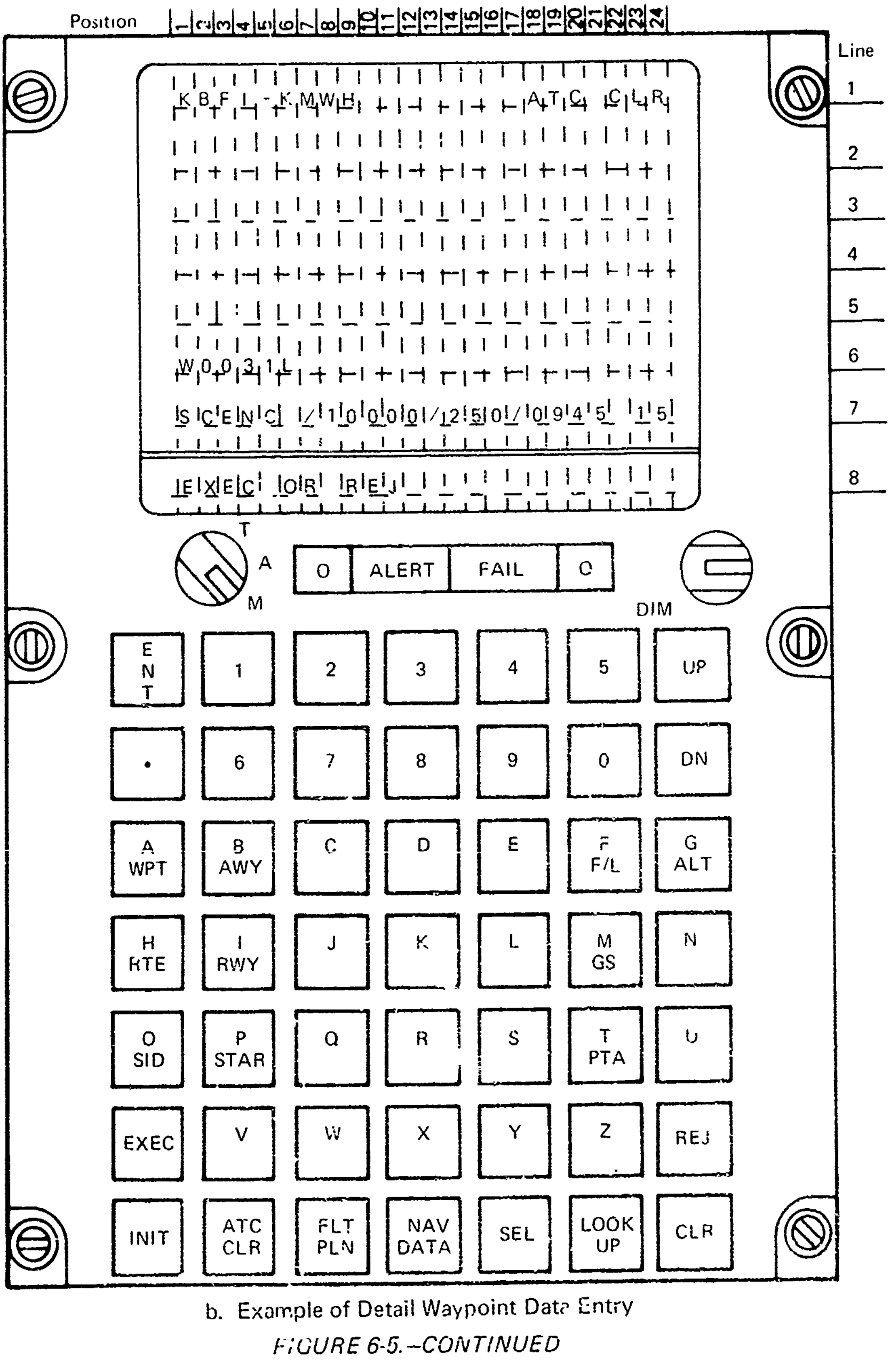
b. New Data Before Entry of Baroset

FIGURE 6-4.–CONCLUDED



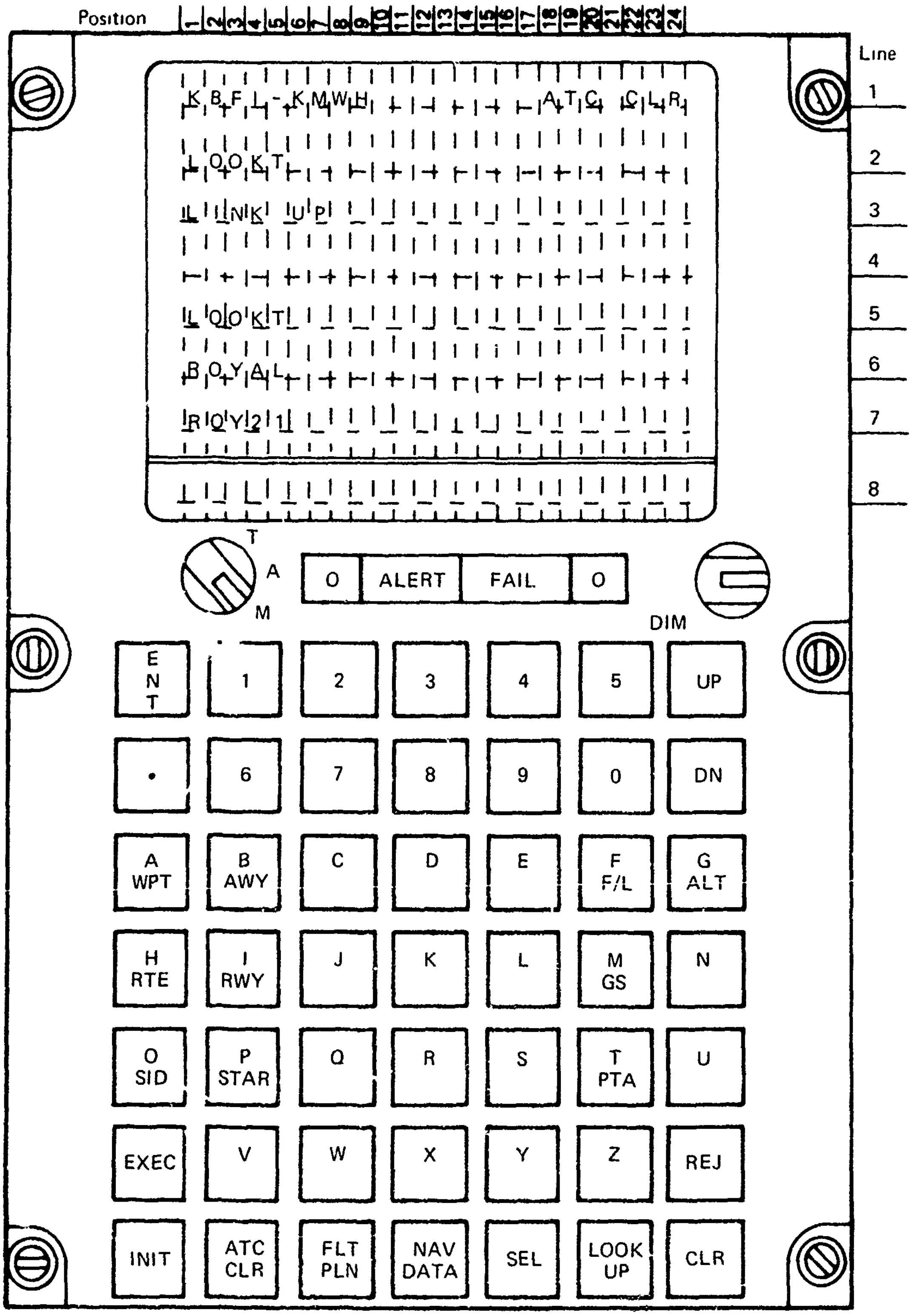
a. Clearance Prior to Acceptance

FIGURE 6-5.—ATC CLR (ATC CLEARANCE) MODE



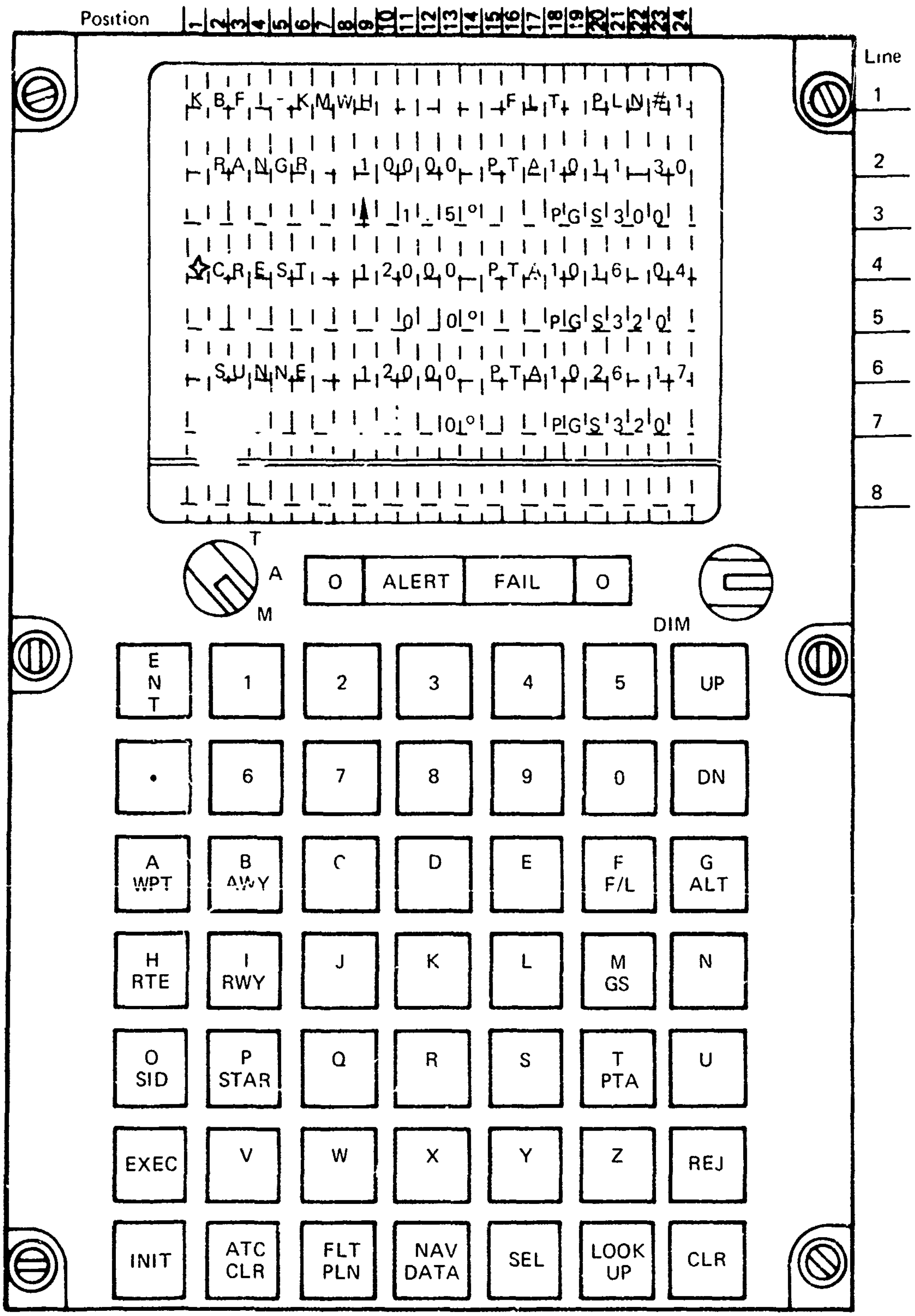
b. Example of Detail Waypoint Data Entry

FIGURE 6-5.–CONTINUED



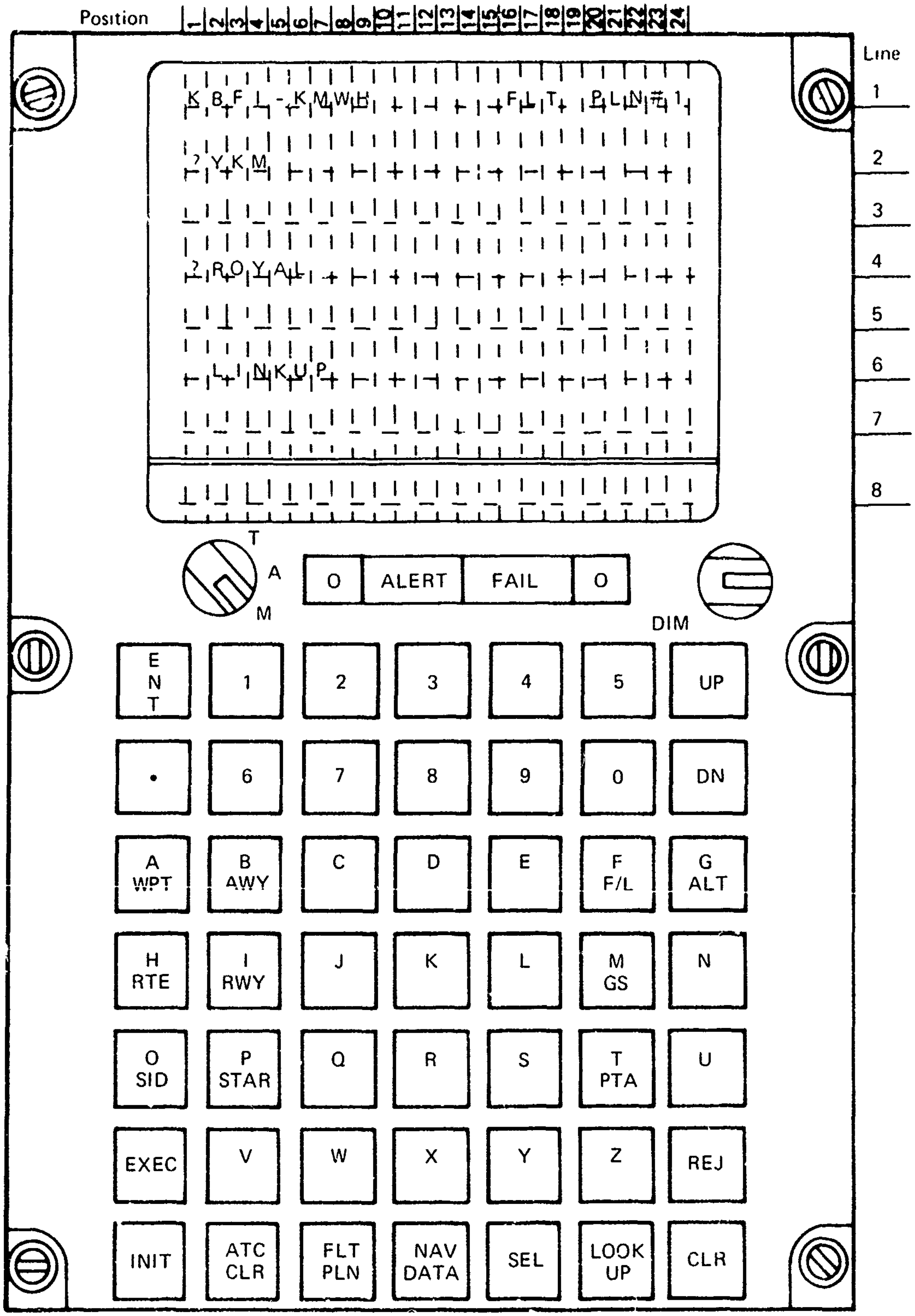
c. Example of Clearance Amendment

FIGURE 6-5.—CONCLUDED



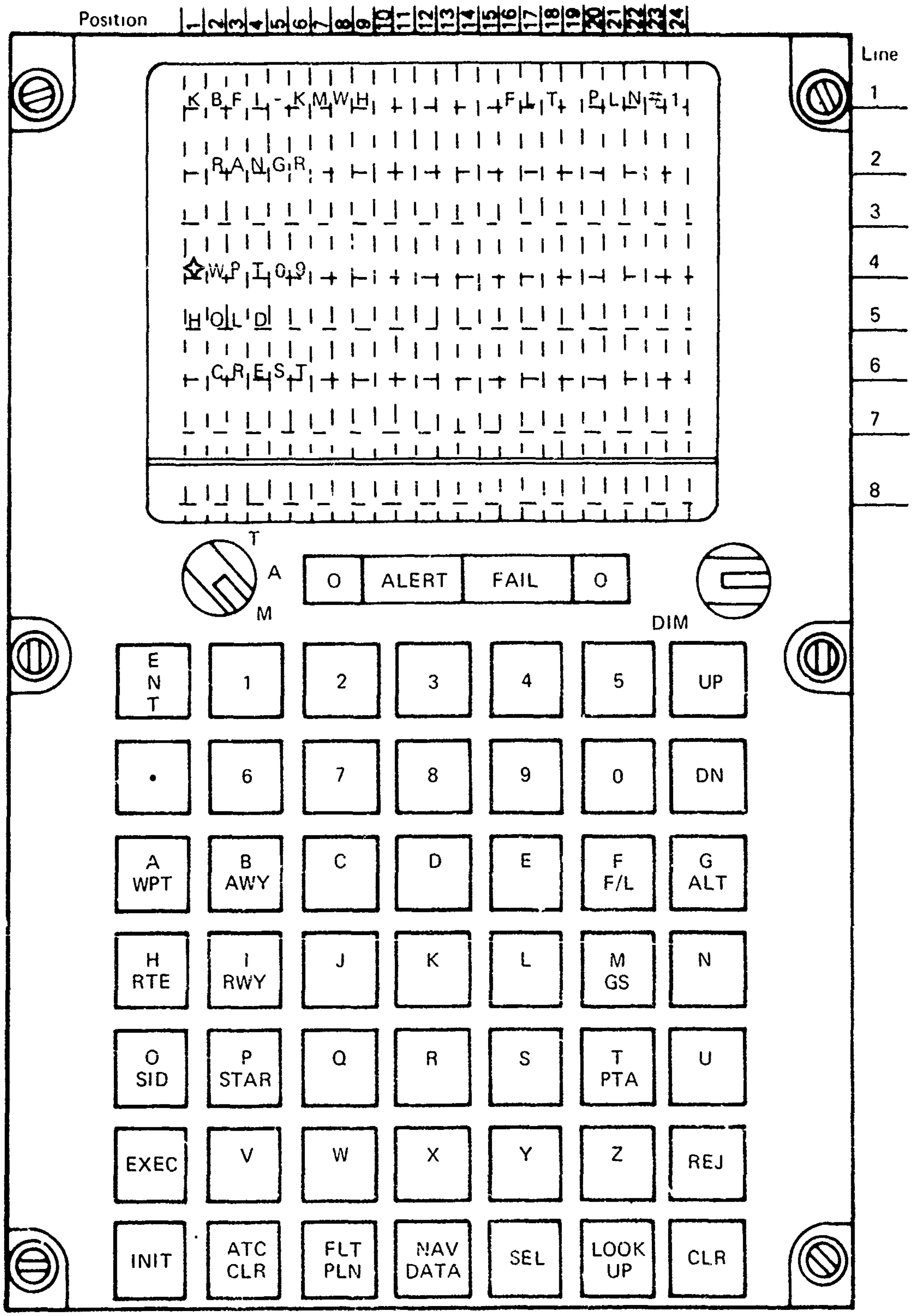
a. Portion of Active (Accepted) Clearance in Waypoint by Waypoint Format

FIGURE 6-6.—FLT PLN 1 (FLIGHT PLAN 1) MODE



b. Format During Provisional Path Entry

FIGURE 6-6.–CONTINUED



c. Format Resulting From a Holding Pattern Entry

FIGURE 6-6.—CONCLUDED

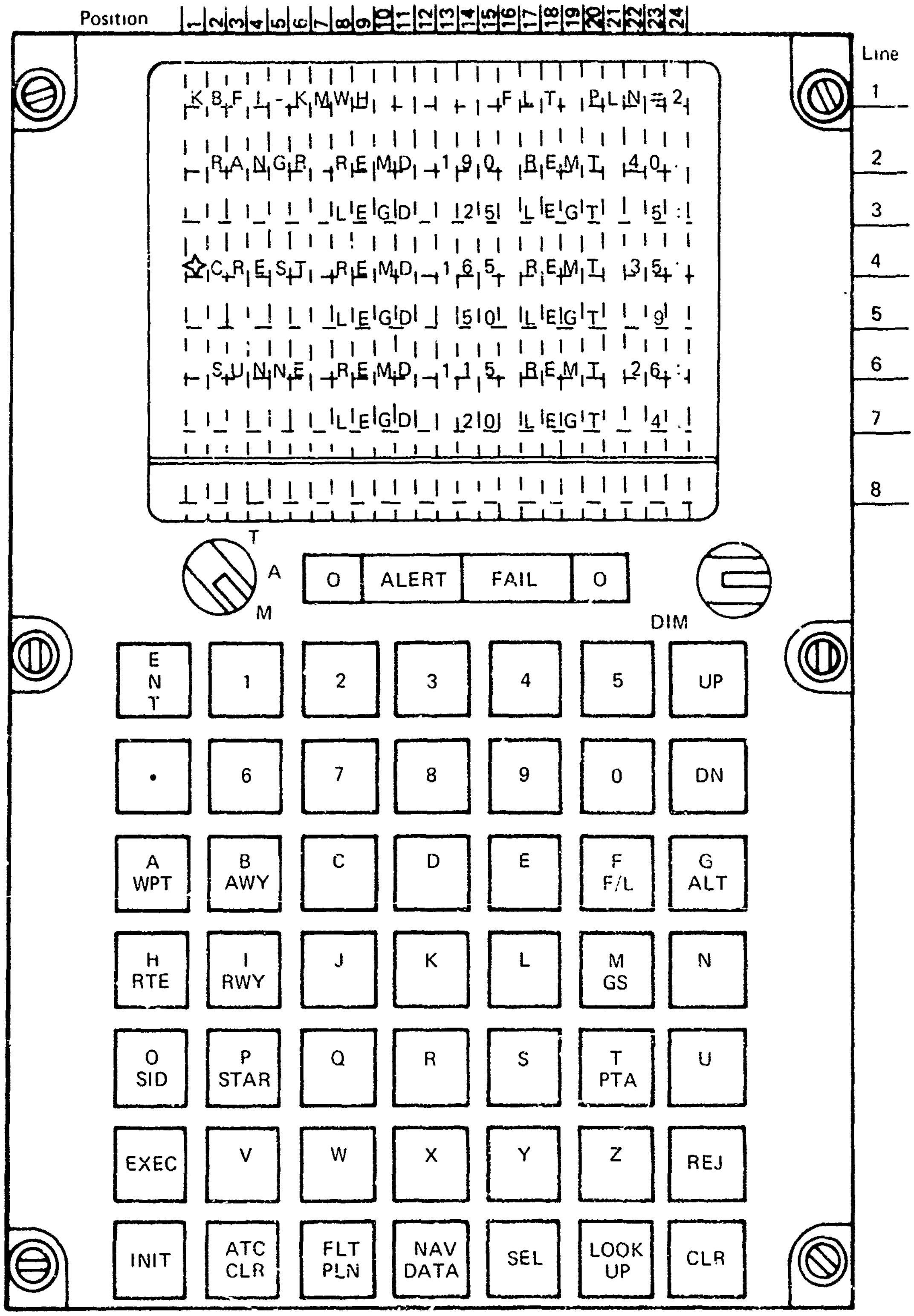


FIGURE 6-7.–FLT PLN 2 (FLIGHT PLAN 2) MODE

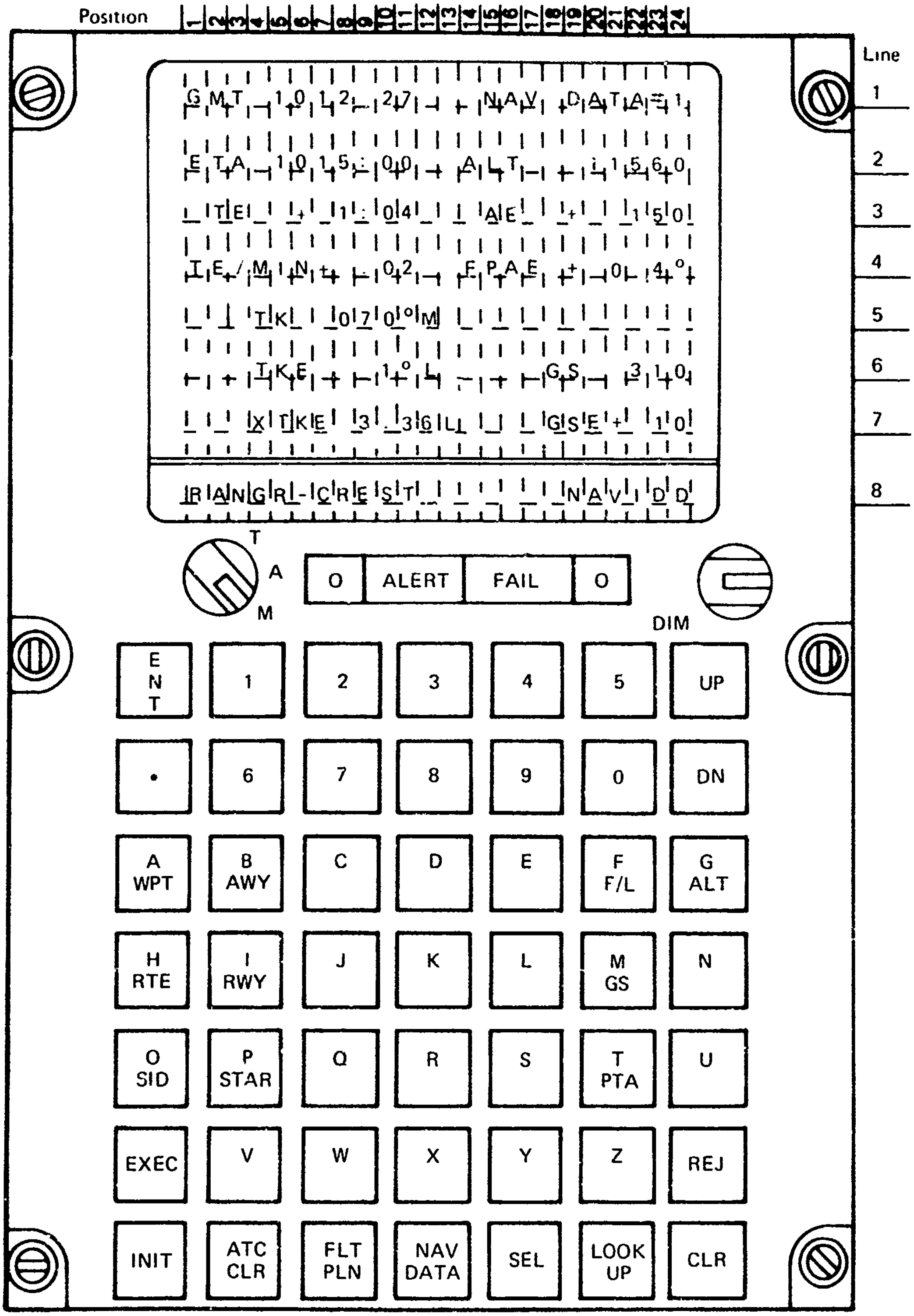


FIGURE 6-8.–NAV DATA 1 (NAVIGATION DATA 1) MODE

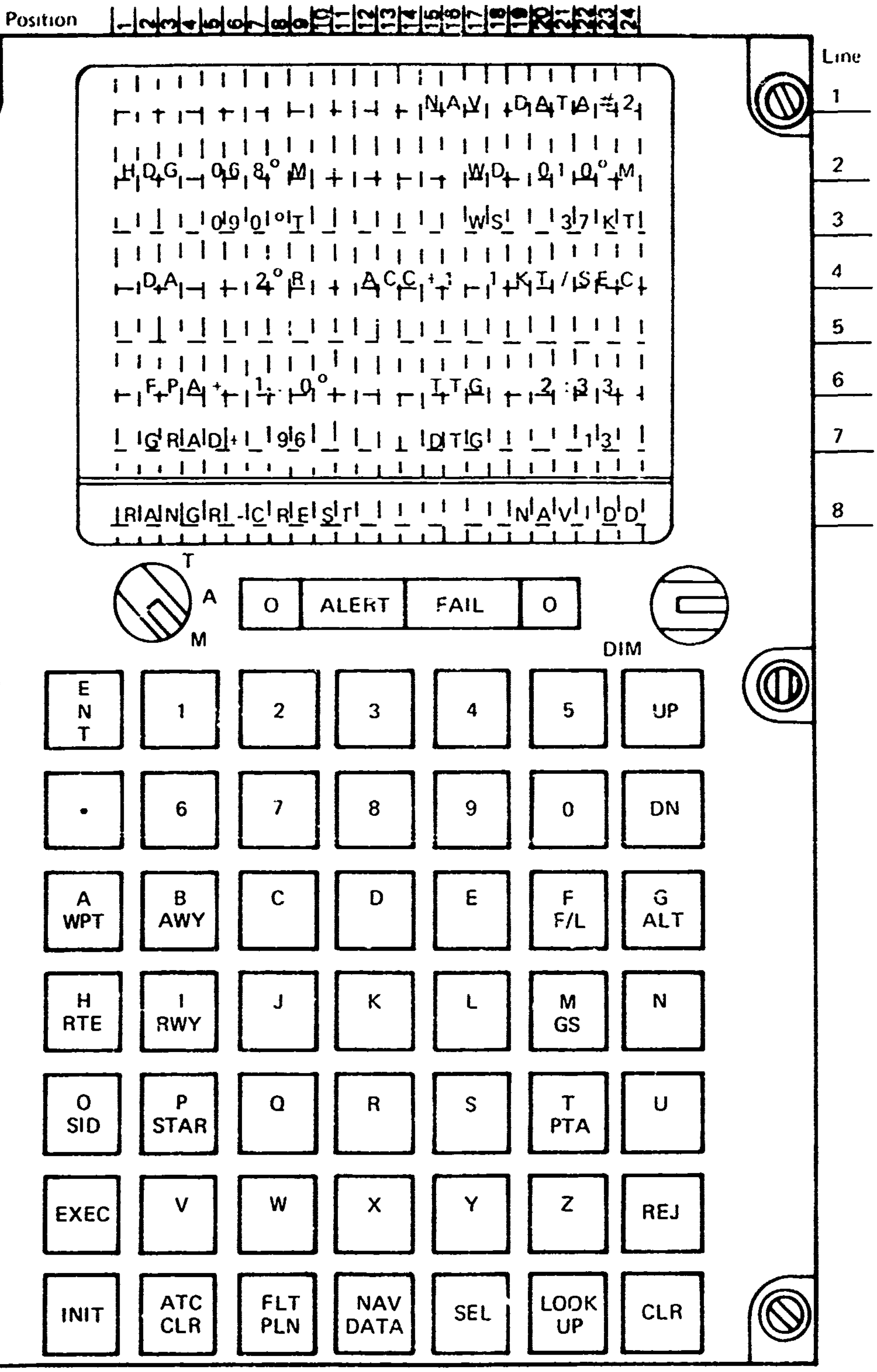


FIGURE 6-9.–NAV DATA 2 (NAVIGATION DATA 2) MODE

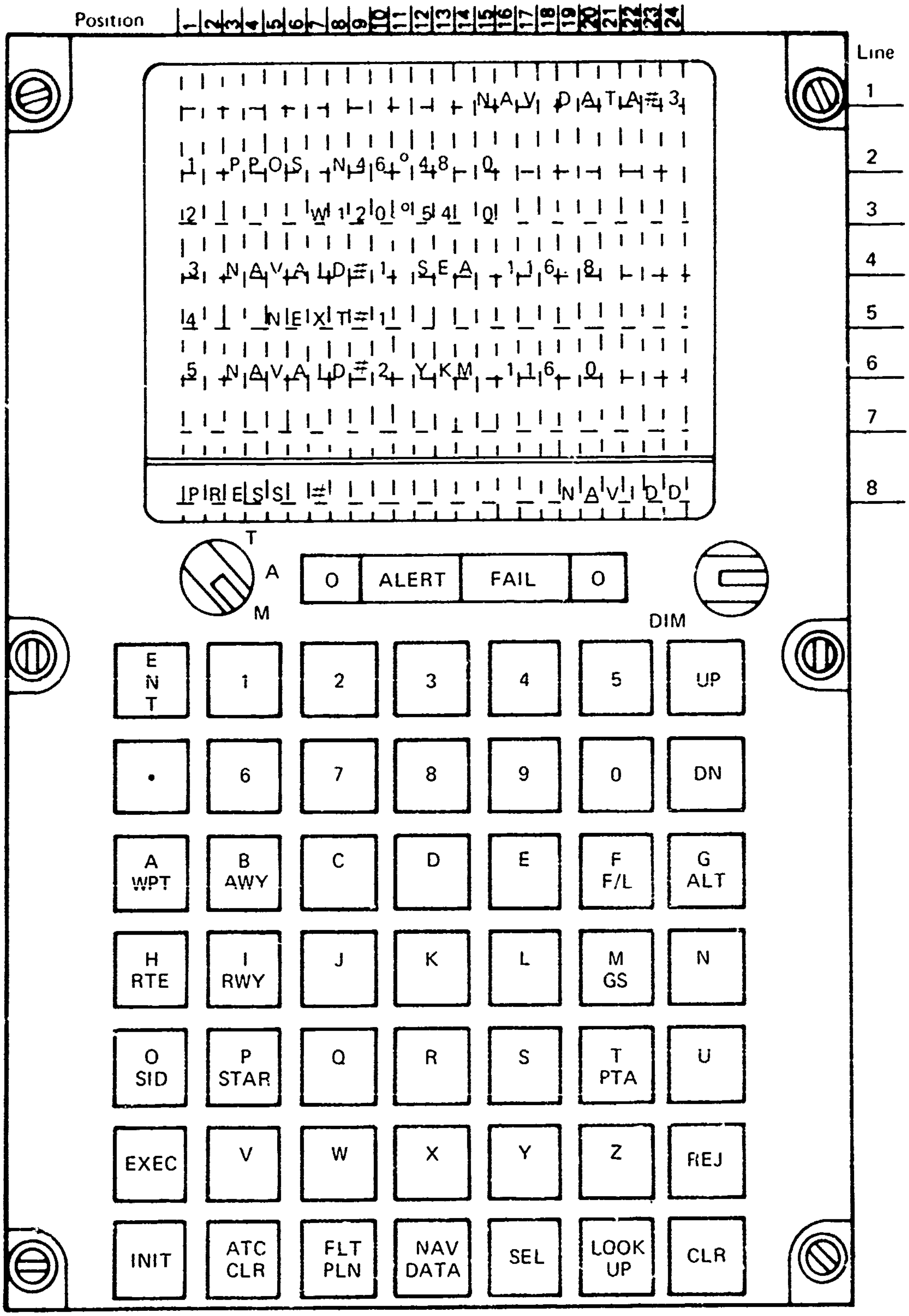


FIGURE 6-10.–NAV DATA 3 (NAVIGATION DATA 3) MODE

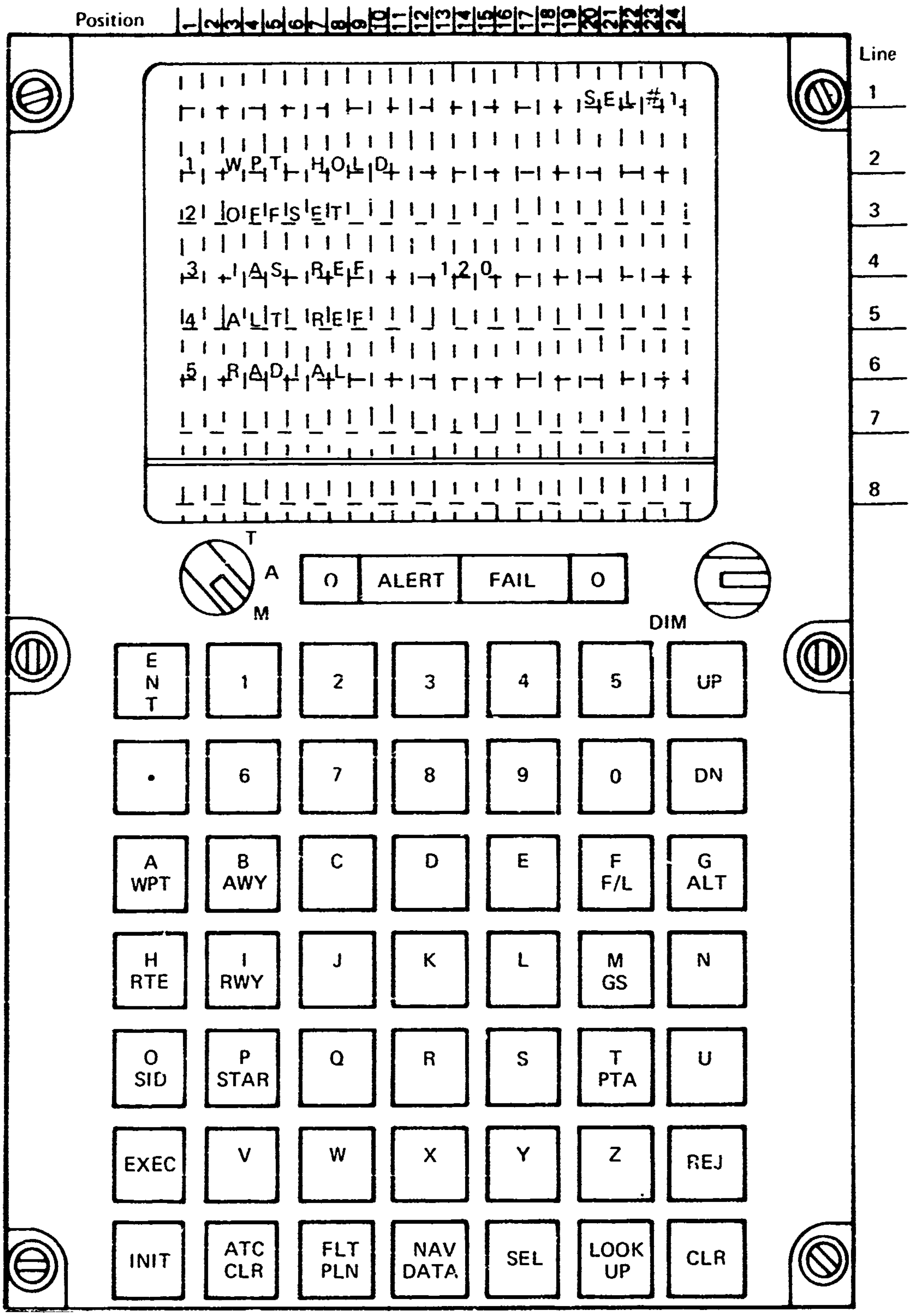


FIGURE 6-11.—SEL 1 (SELECT 1) MODE

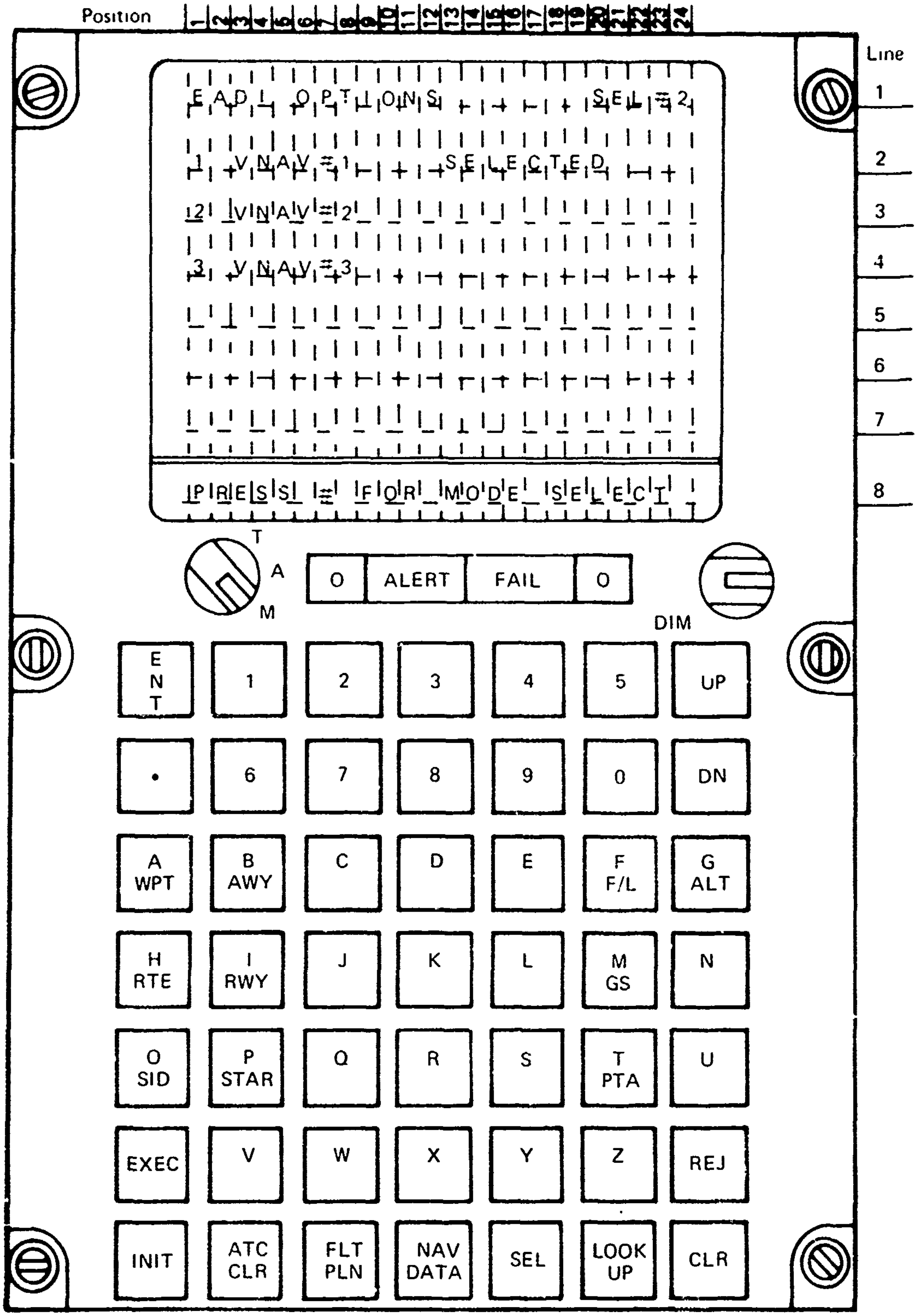


FIGURE 6-12.–SEL 2 (SELECT 2) MODE

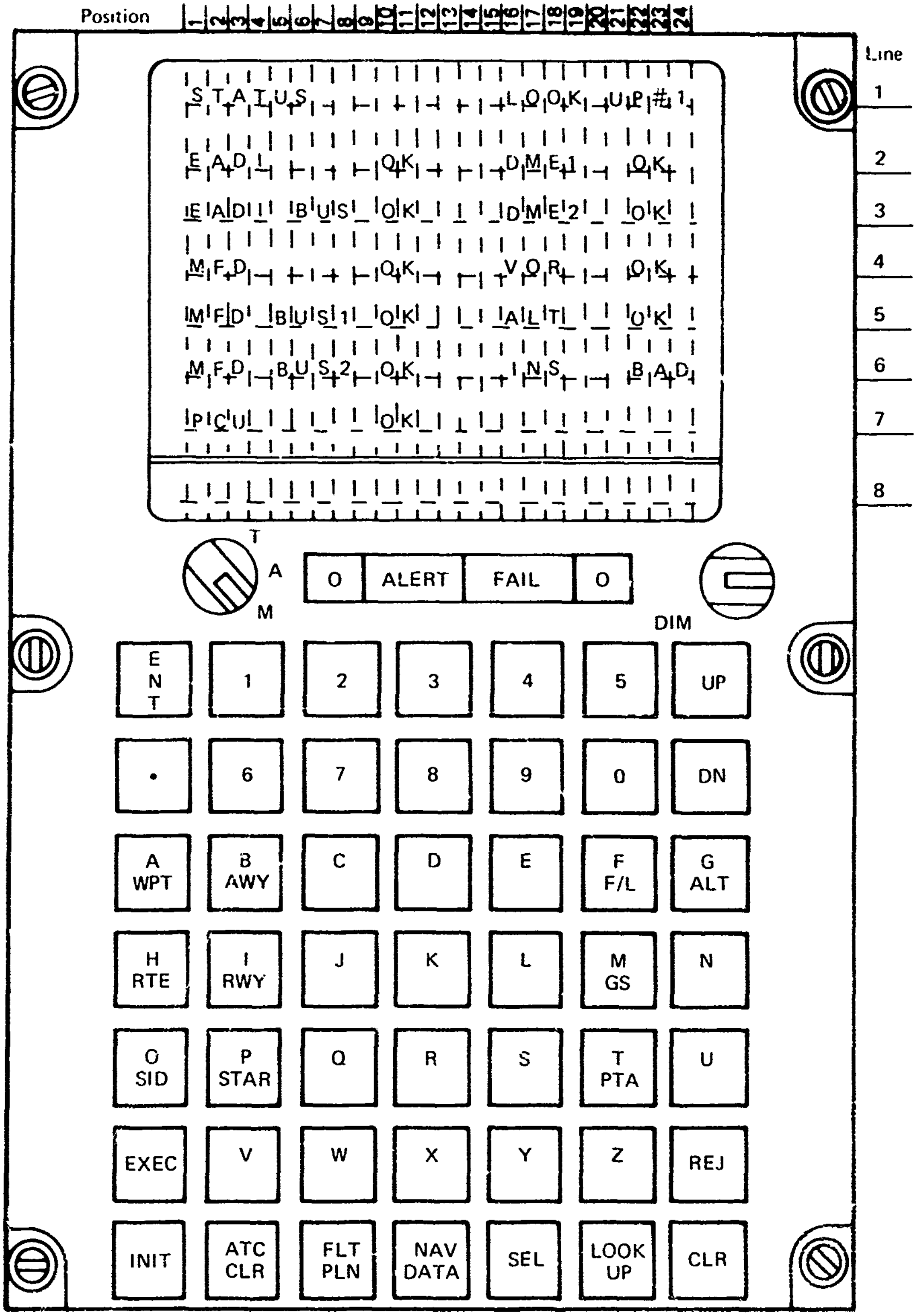
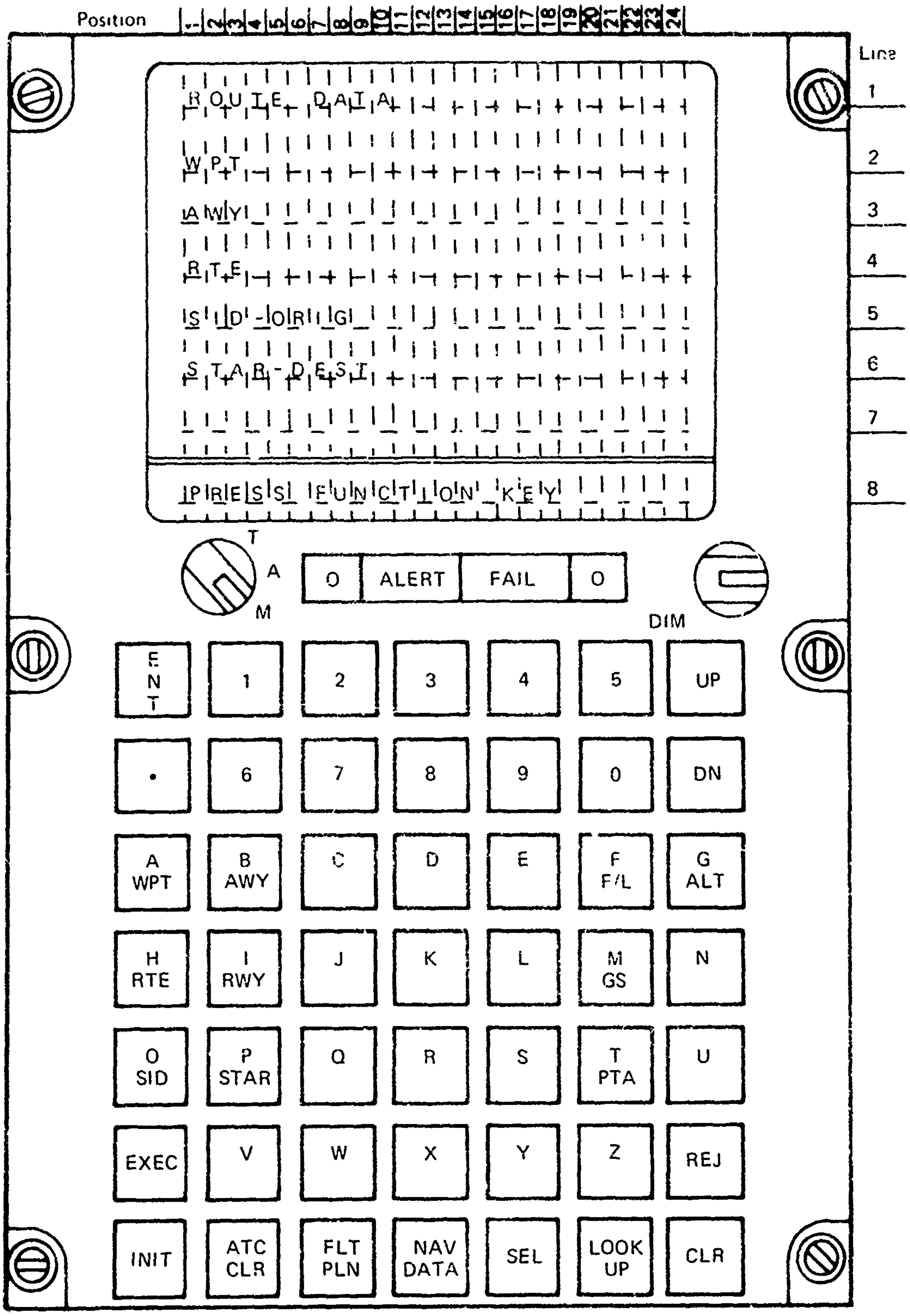
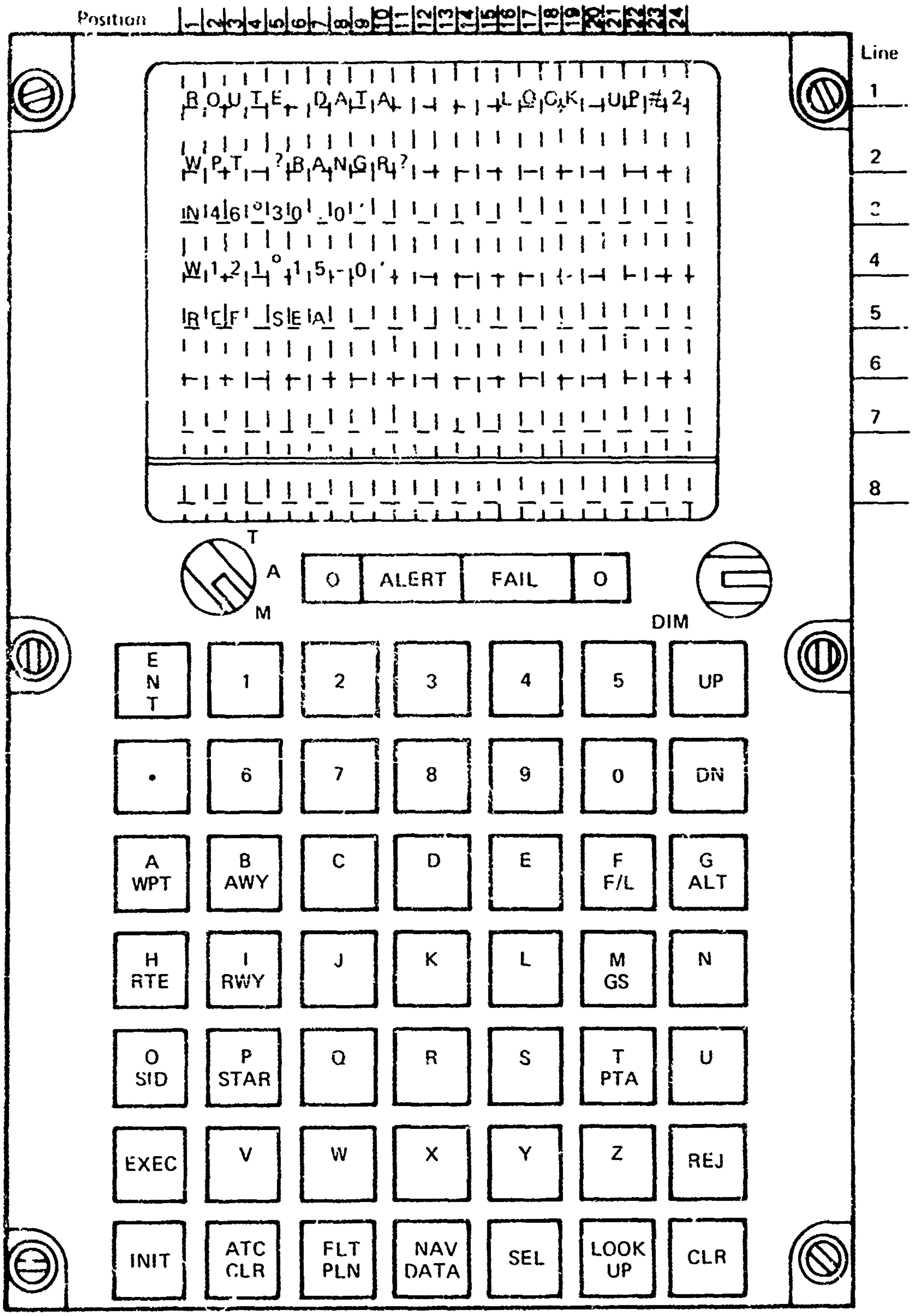


FIGURE 6-13.–LOOK-UP 1–STATUS



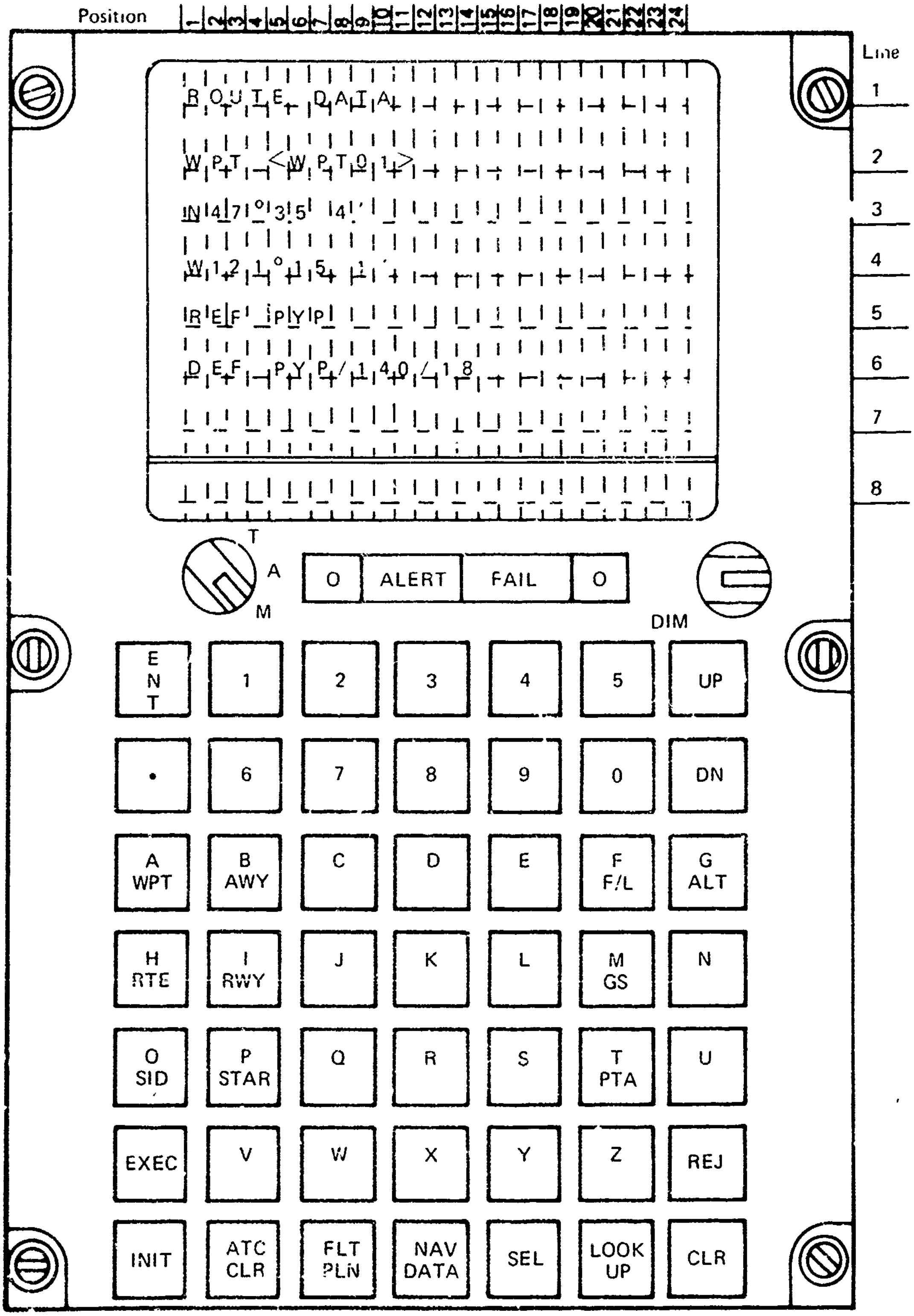
a. Reminder or Category Format

FIGURE 6-14.–LOOK UP 2–ROUTE DATA



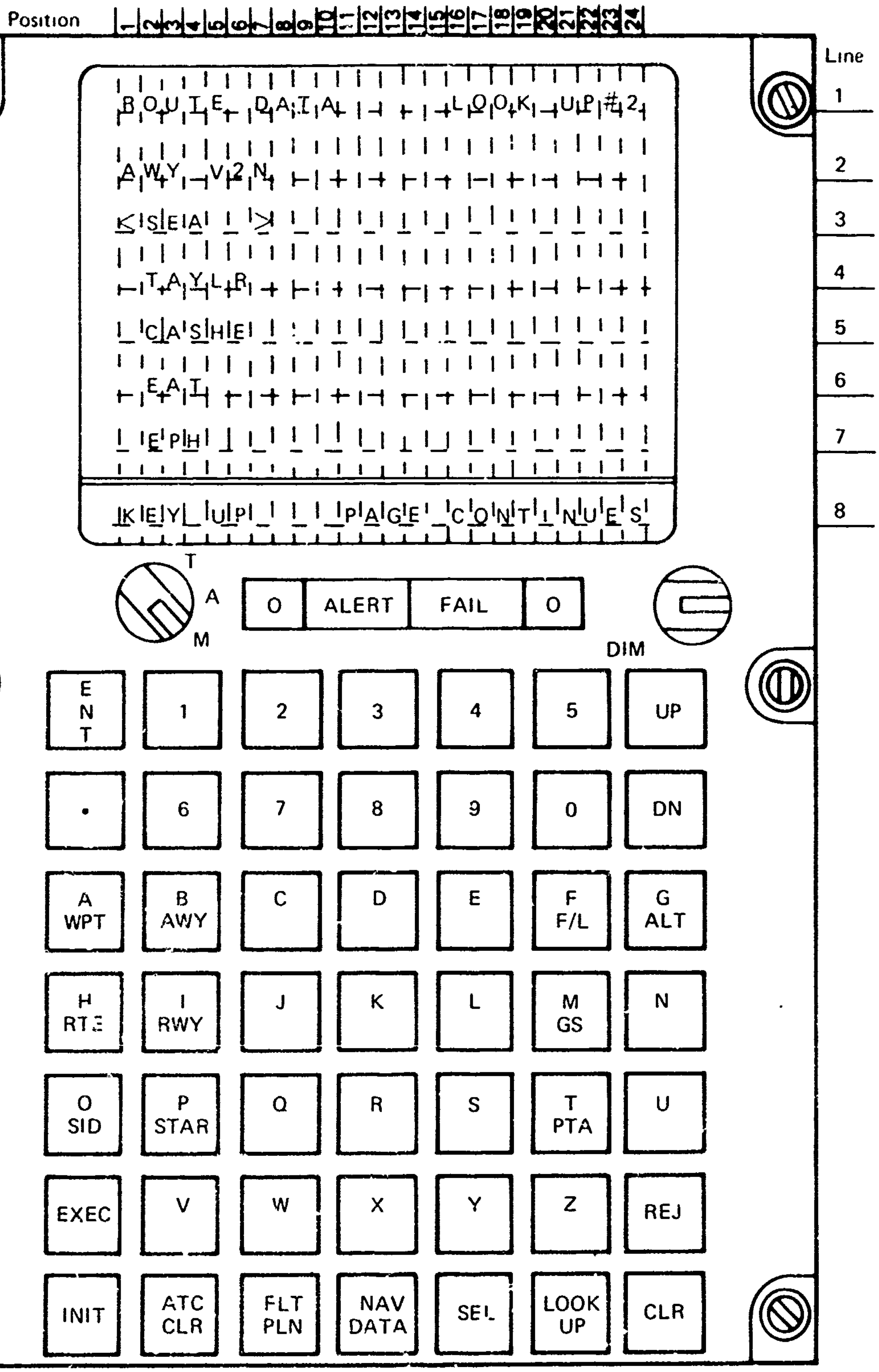
b, Waypoint Data

FIGURE 6-14.–CONTINUED



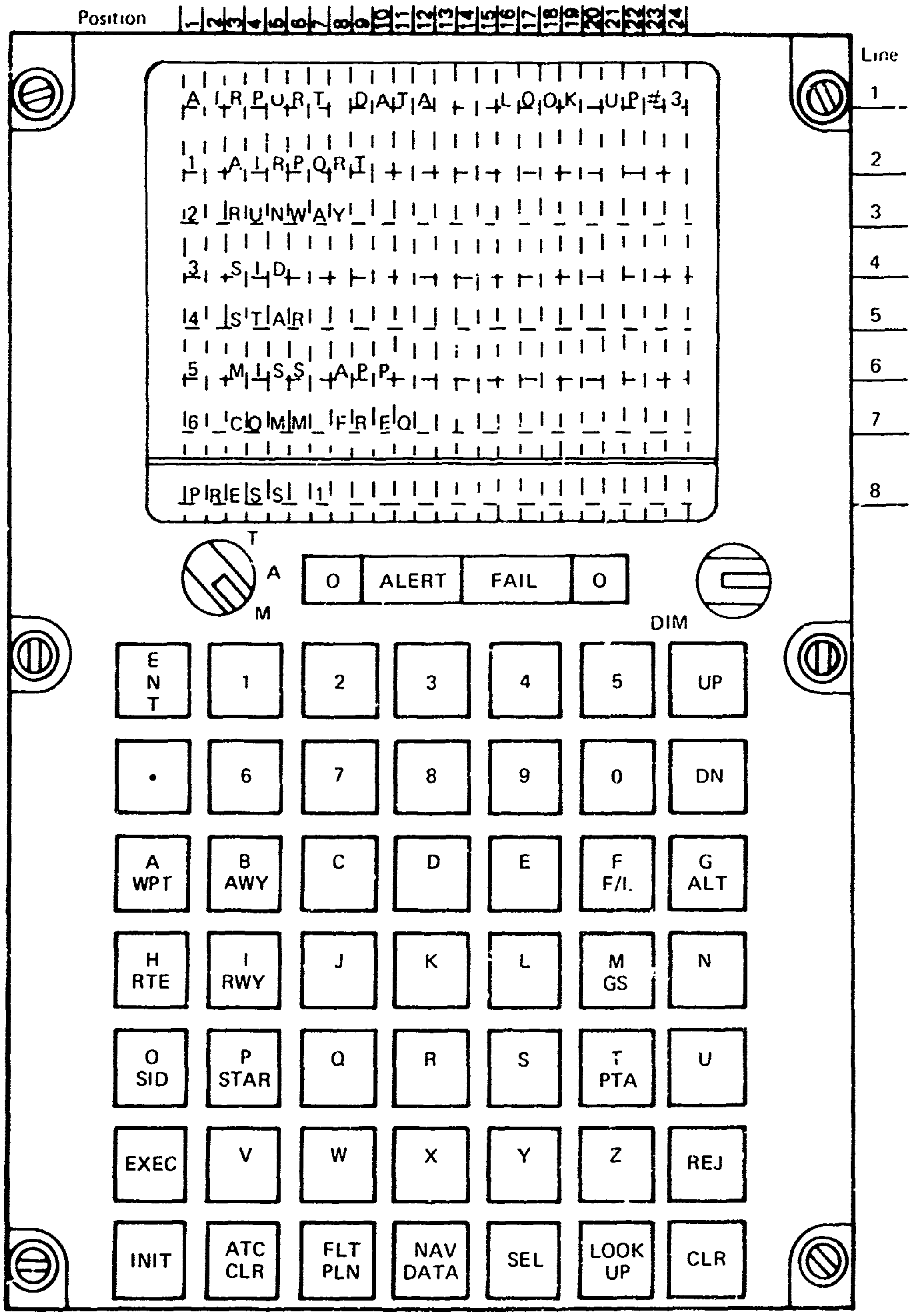
c. Waypoint Detail Data for Waypoint Defined by Bearing-Range Procedure; Also, Waypoint Selected as North-Up Map Center

FIGURE 6-14.–CONTINUED



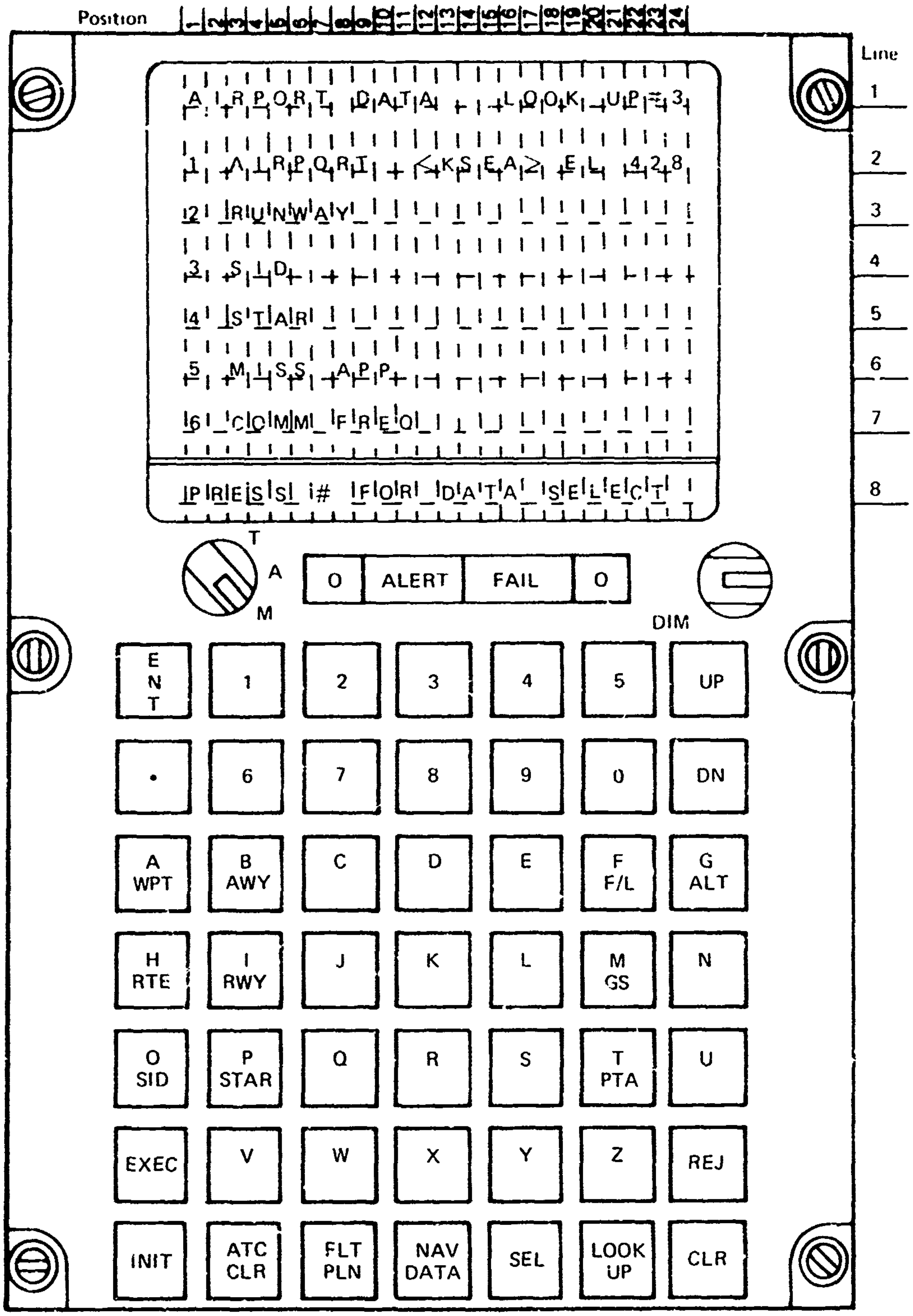
d. Airway (Or Route) Display Format

FIGURE 6-14.—CONCLUDED



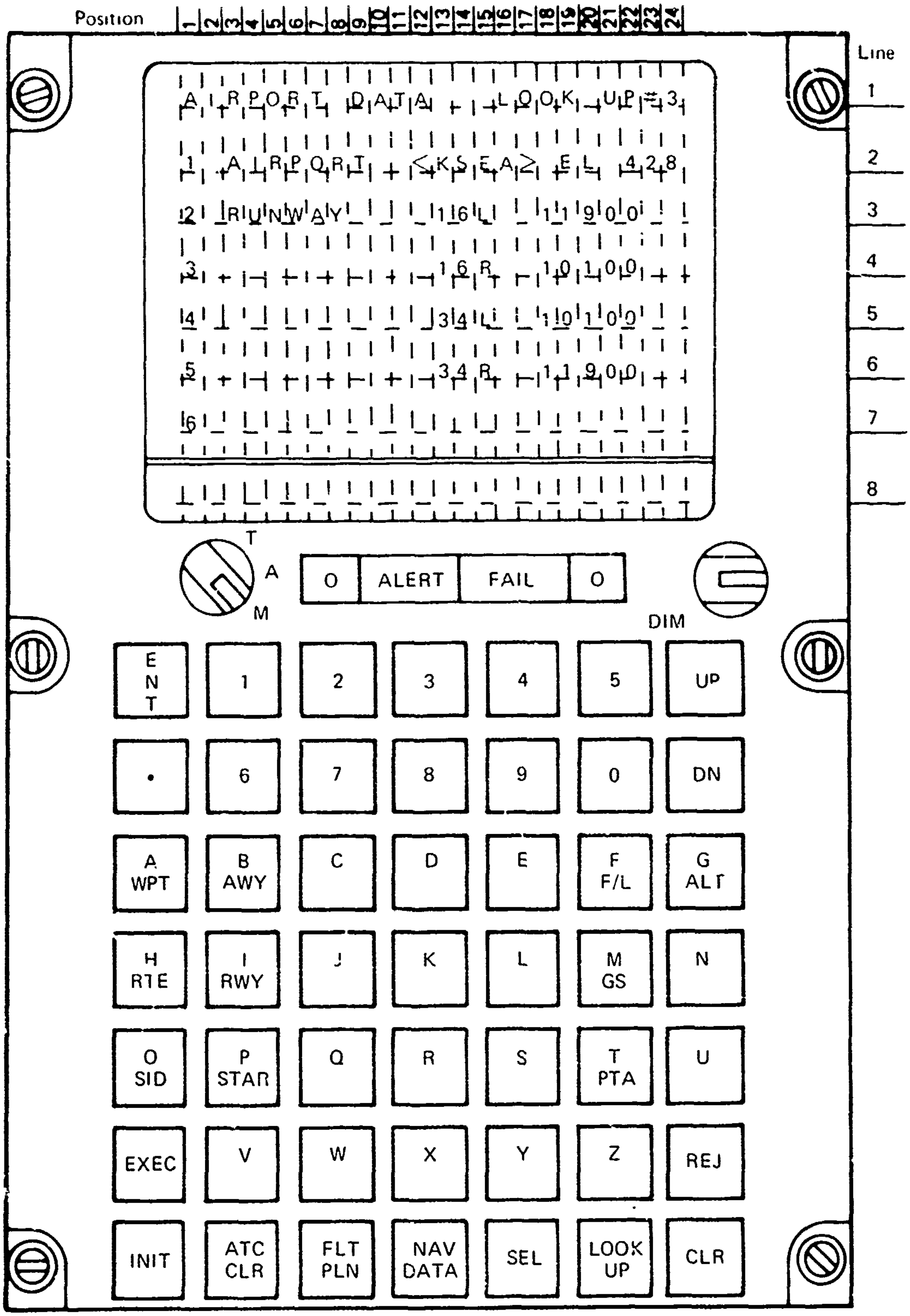
a. Page Ready for Airport Name Entry

FIGURE 6-15.--LOOK-UP 3--AIRPORT DATA



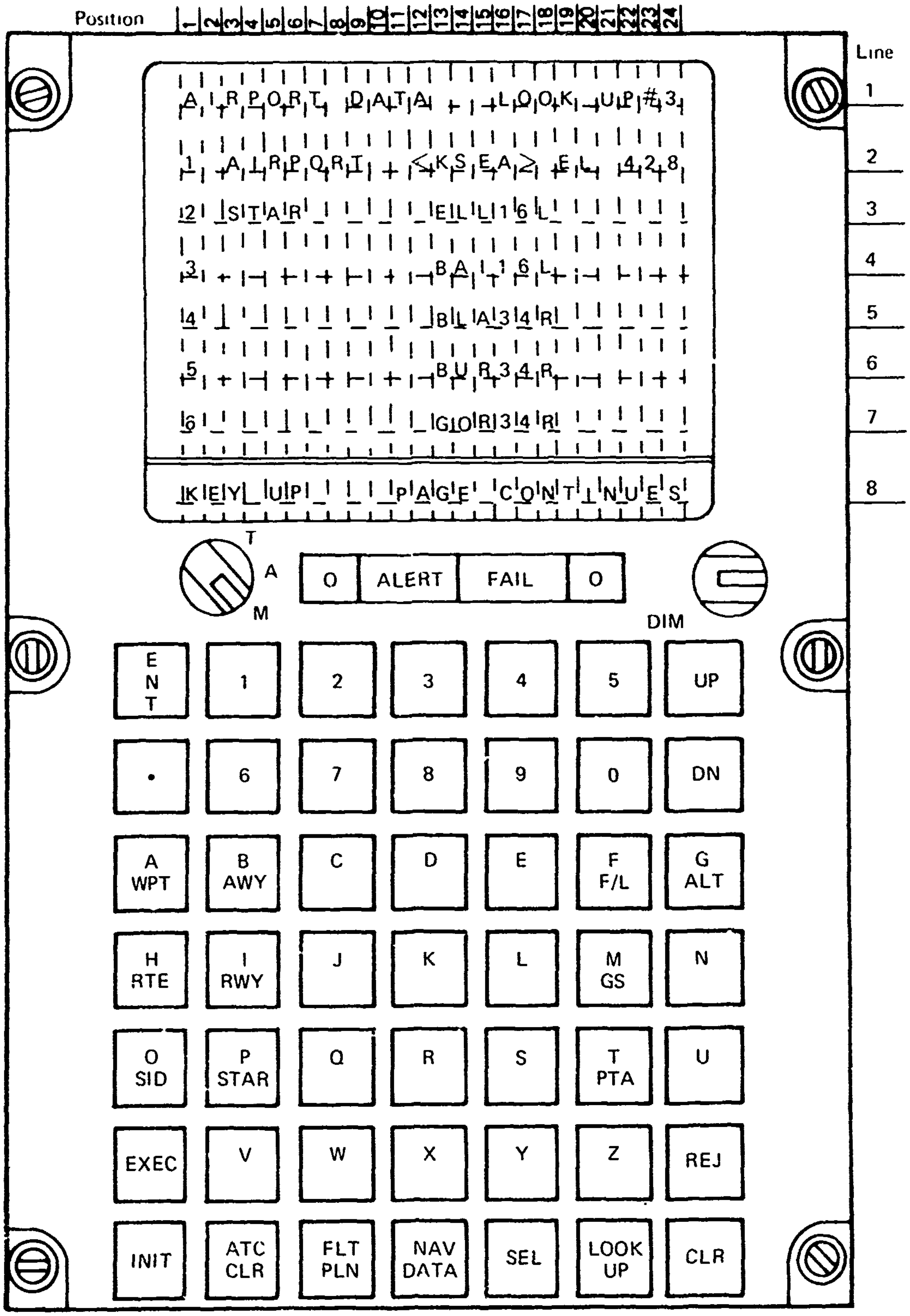
b. Airport Identified and Selected for North-Up Map Center

FIGURE 6-15.—CONTINUED



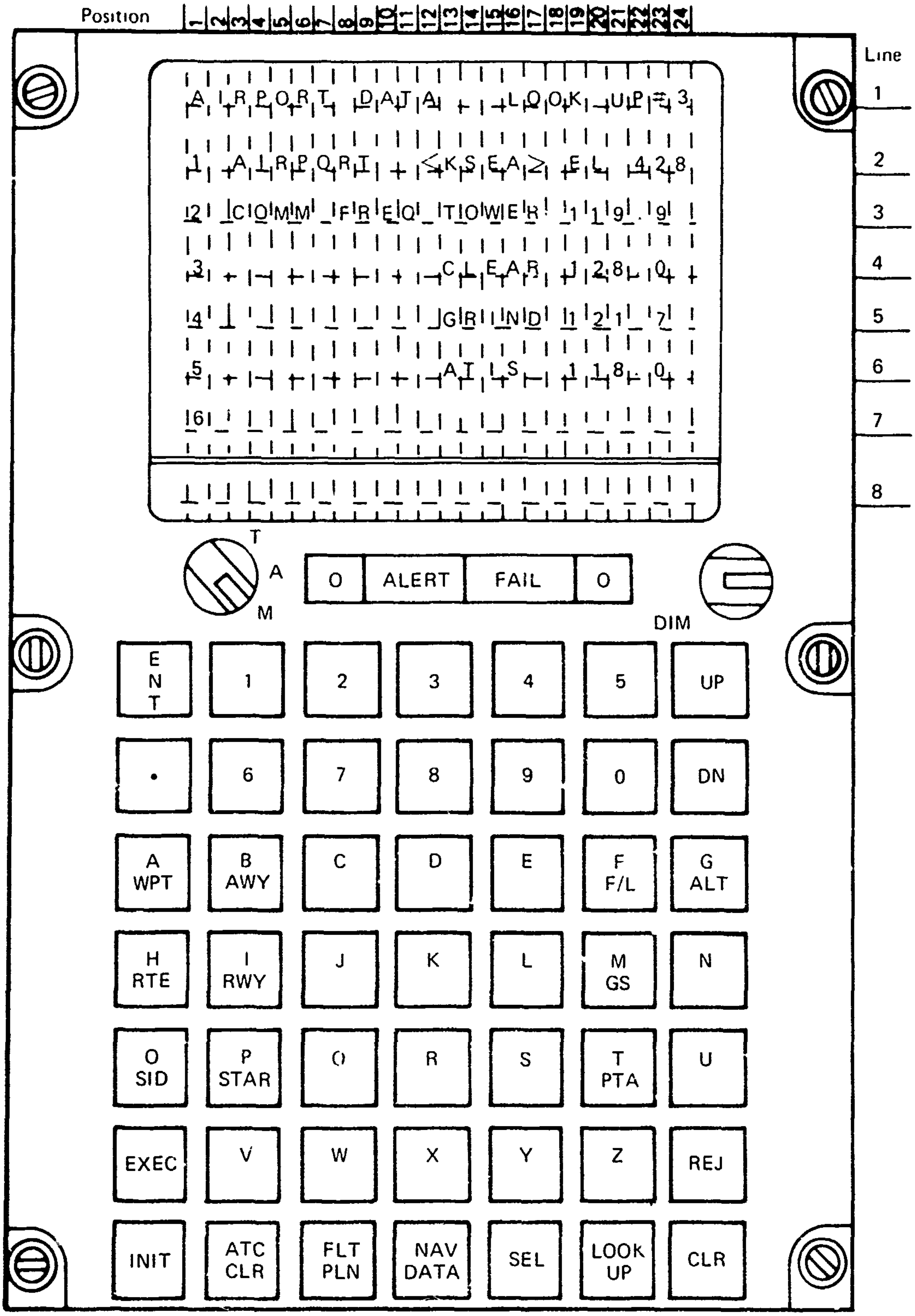
c. Runway List

FIGURE 6-15.–CONTINUED



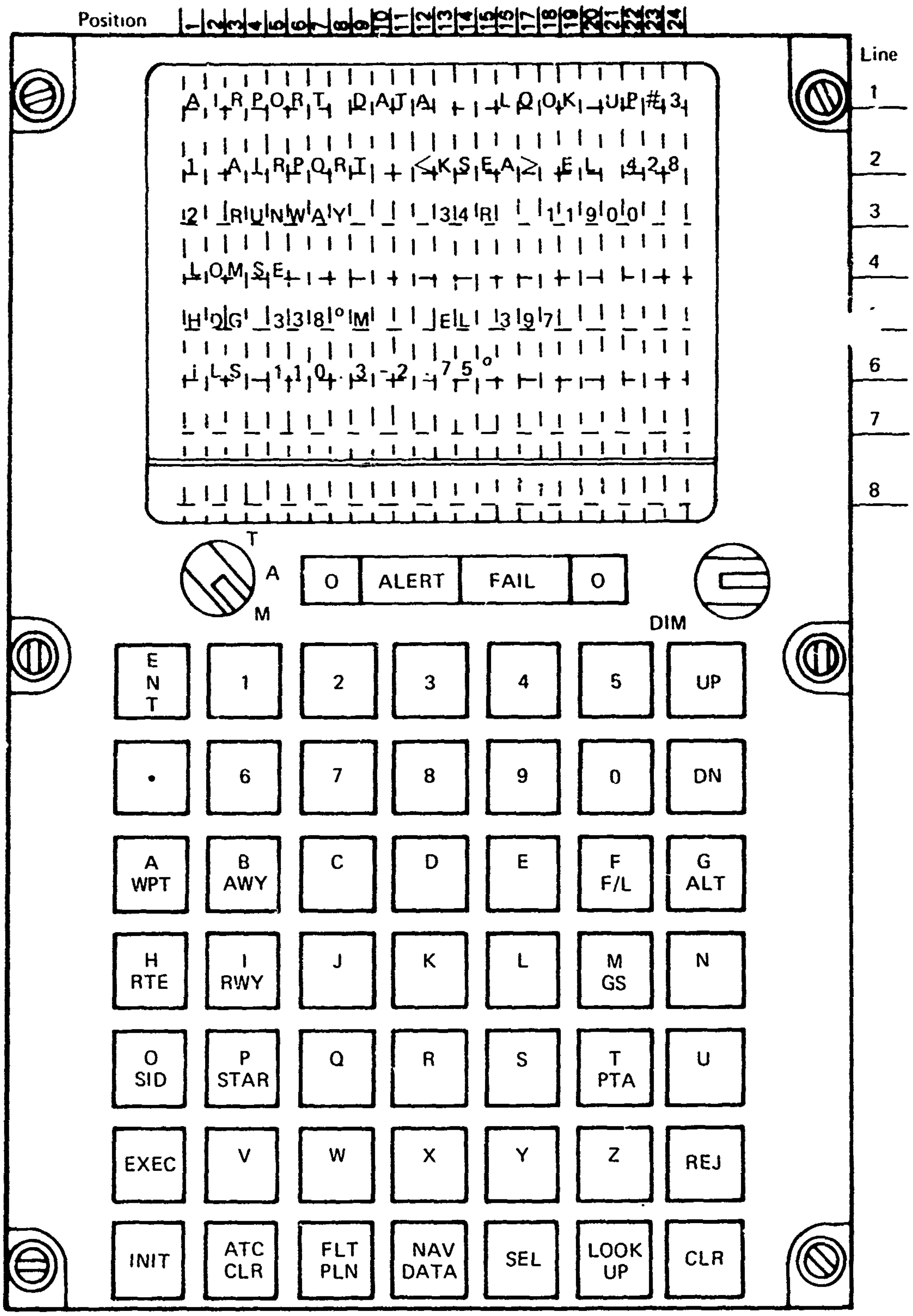
d. STAR List (Same Format for SIDs and MAPs)

FIGURE 6-15.–CONTINUED



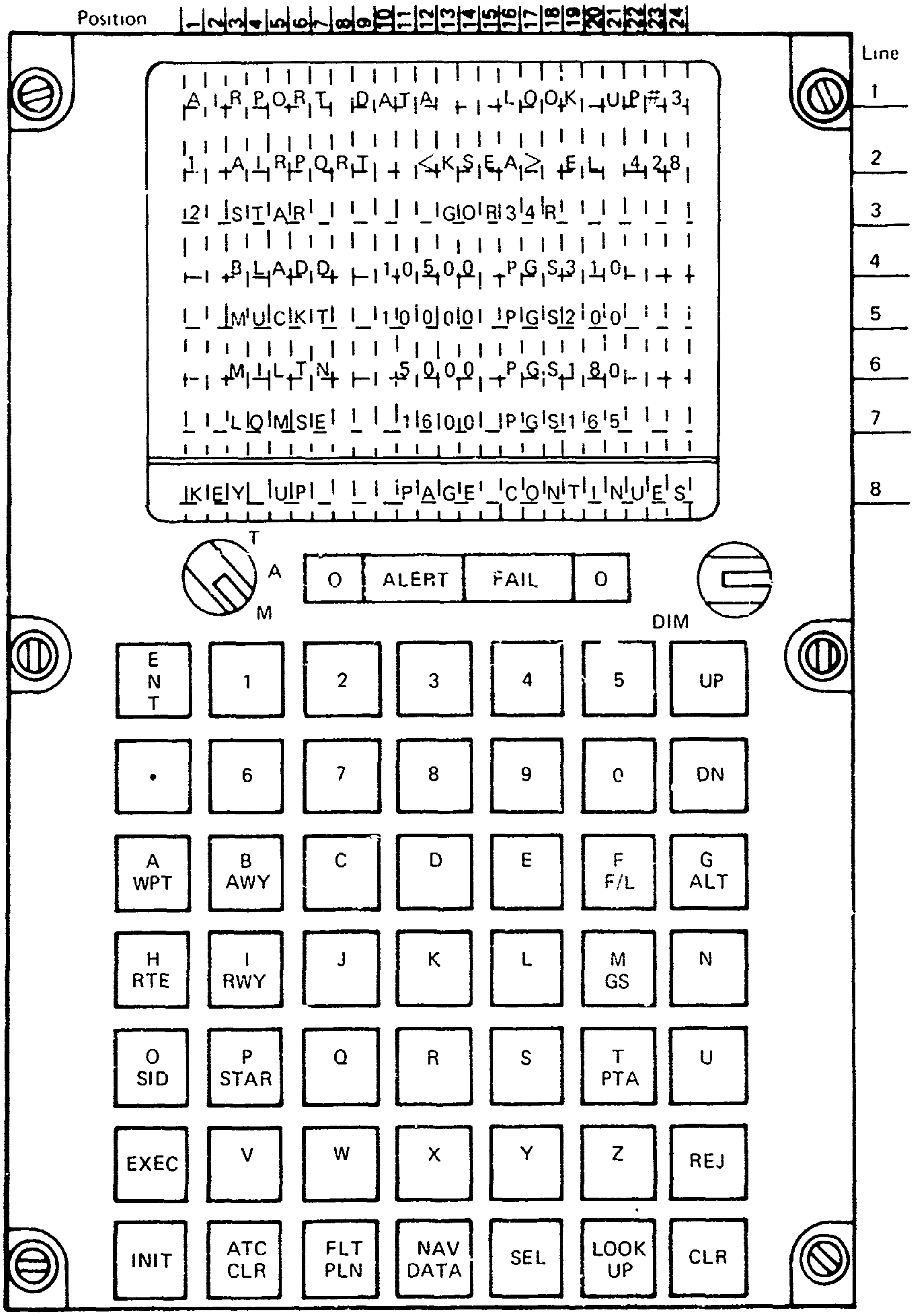
e. Frequency List

FIGURE 6-15.–CONTINUED



f. Runway Detail Data

FIGURE 6-15.–CONTINUED



```
AIRPORT DATA  LOOK UP#3
1 AIRPORT <KSEA> EL 428
2 STAR     GOR34R
 BLADD  10500 PGS310
 MUCKT  10000 PGS200
 MLLTN  5000 PGS180
  LOMSE  1600 PGS165
KEY UP   PAGE CONTINUES
```

g. Detail STAR Data

FIGURE 6-15.–CONCLUDED

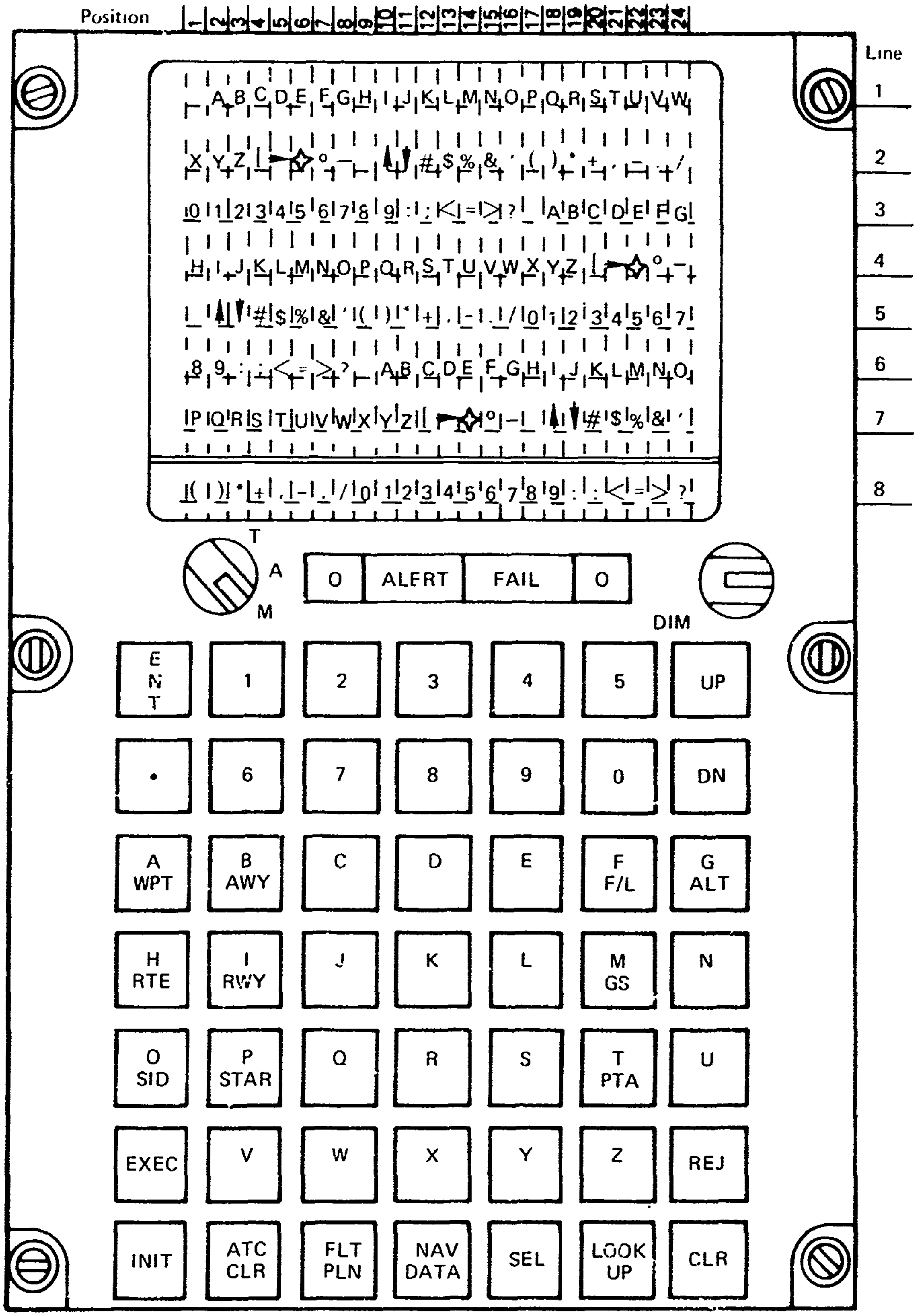


FIGURE 6-16.–NCDU TEST FORMAT

7.0 NAVIGATION AND SUBSIDIARY FUNCTIONS

7.1 NAVIGATION--GENERAL

This section outlines the various computations required to compute a best estimate of aircraft position and velocity based on combining data received from a single Litton LTN-51 inertial navigation system (INS), two DMEs, and a single VOR. Air data and magnetic inputs are also used in the event INS fails.

This section also contains the various modes and update methods used. The major computations are outlined, together with the assignment to the fast and slow computation loops. The fast loop is accomplished 20 times/sec, while the slow loop is accomplished 1 time/sec.

7.1.1 Navigation Modes

The basic modes of horizontal navigation are as follows:

INS updated by two DMEs (IDD)

INS updated by one DME and one VOR (IDV)

INS updated by one DME (IDX)

INS alone (IXX)

Air data and magnetic heading updated by two DMEs (ADD)

Air data and magnetic heading updated by one DME and one VOR (ADV)

Air data and magnetic heading updated by one DME (ADX)

Air data and magnetic heading alone (AXX)

Radio navigation alone (XDD, XDV, XDX)

The navigation mode designation (IDD, etc.) is displayed on the NCDU as defined in section 6.5.4 of this document.

The navigation modes above are listed in order of preference. Automatic mode switching is dependent on successful checks for data validity. The flow chart for INS mode selection is shown in figure 7-1. A similar selection sequence applies for air data/magnetic heading modes in the event of INS failure, and pure radio navigation modes in the event of both INS and air data or magnetic heading failure. This mode switching is controlled by a system of flags, as shown in table 7-1.

7.1.2 Radio Navigation Updates

7.1.2.1 Radio Mode Flags

The various modes of radio updates -DME/DME, DME/VOR, and DME–are controlled by the three flags–F0, F1, and F2. These flags are defined in table 7-2.

7.1.2.2 Radio Navigation Station Tuning

The frequencies to which the two DME receivers are tuned can be controlled in three ways:

1) Manually through the radio navigation tuner in the cockpit

2) Manually through the NCDU as defined in section 6.5.4.3

3) Automatically (autotune) in response to the flight plan stored in the navigation computer

Cases 2 and 3 are tuned by the navigation computer autotune A (DME 2) and autotune B (DME 1) outputs when the AUTO/MAN switch in the cockpit is in the AUTO position. VOR 1 tuning is always under manual control.

7.1.2.3 Autotune

Bulk data memory (see sec. 3.0) stores a block of data for each navaid, containing geographic location, station ICAO identification code, elevation, type of facility (VOR, VORTAC, NDB), and frequency. All geographic reference points (GRPs) and SID and STAR waypoints stored in bulk data also contain a pointer to a reference VORTAC facility. The autotune system tunes navaid 1 to the VORTACs defined in the guidance buffer (table 5-1). Changeover to the next VORTAC occurs at the midpoint of each flight plan leg, at which time the NCU will output the tuning code for the reference VORTAC for the upcoming waypoint. If the upcoming waypoint in the flight plan is a latitude/longitude waypoint entered through the NCDU keyboard, it will not have a reference VORTAC. The autotune output for navaid 1 will remain tuned to the VORTAC it is currently tuned to until the pulse pair input is lost or the range limitation is exceeded, at which time the autotune output for navaid 1 will change to the next referenced VORTAC in the flight plan. If at any time no acceptable pulse pair range input is received for navaid 1 corresponding to either the referenced VORTAC for the upcoming or next waypoint, a flag (RETUN1) will be set. The alert message TUNE NAVAID #1 will be displayed on line 8 on the NCDU. This is a cue for the pilot to manually tune navaid 1.

The navaid 2 autotuning selects the best VORTAC station available for triangulation with navaid 1 data. When airplane altitude is below 18,000 ft, a search is made of all VORTAC stations within a range of 40 nmi and a station bearing estimation is made. The first station whose bearing relative to the navaid 1 satisfies the expression defined below will be autotuned as navaid 2.

$$135° > (\text{bearing navaid 1 - bearing navaid 2}) > 45°$$

If acceptable DME pulse pair data are not received from this navaid, the NCU will continue the search until acceptable data are received. If airplane altitude is > 18,000 ft, only VORTACs labeled high altitude in bulk data memory will be considered.

If no acceptable navaids are found within the 40-nmi-range zone, the search is expanded to 80, 120, and finally 160 nmi, and continues until acceptable pulse pair DME data are received.

Whenever the autotune has been overridden by the manual tuning of either navaid 1 or navaid 2 or both using the NAV DATA 3 page on the NCDU, the autotuning of the navaid or navaids that have been manually tuned is discontinued until such time as the reject (REJ) procedure has been used, as defined in section 6.5.4.3.

7.1.3 Velocity Processing

7.1.3.1 Inertial Velocity

The NCU receives along-track and across-track acceleration from the INS 20 times/sec over an ARINC 561 digital bus (see table 7-3). These accelerations are integrated and resolved into north and east velocity components 20 times/sec.

V_N = INS north velocity

V_E = INS east velocity

7.1.3.2 Air Data Velocity

The NCU receives true airspeed (TAS) and magnetic heading (MAG HDG) as synchro inputs. TAS is resolved 20 times/sec as follows:

$$V_N = V_{TAS} \cos(\psi)$$

$$V_E = V_{TAS} \sin(\psi)$$

$$\psi = \psi_m + \Delta\psi_m$$

where:

V_{TAS} = input true airspeed

ψ_m = magnetic heading (MAG HDG)

$\Delta\psi_m$ = magnetic variation (MAGVAR)

MAGVAR is calculated in the INS and transmitted to the NCU as shown in table 7-3. However, since the air data/magnetic heading mode is a reversionary mode in the event of INS failure, a second source of MAGVAR is required for this mode. Therefore, $\Delta\psi_m$ in the above equation is made equal to the value of MAGVAR stored in bulk data memory for the current TO waypoint in the flight plan. If this happens to be a manually entered latitude/longitude waypoint, the next waypoint along the flight plan for which a MAGVAR is stored is used.

7.1.4 Slow-Loop Computations

The following computations are performed once per second in the slow loop.

7.1.4.1 Computation of Radio Updates

Let:

$$Z_m = [R_{m1}, B_{m1}, R_{m2}, B_{m2}]^T$$

$$Z_c = [R_{c1}, B_{c1}, R_{c2}, B_{c2}]^T$$

where:

R_{m1}/R_{m2} = measured range to DME 1/measured range to DME 2

B_{m1}/B_{m2} = measured bearing to VOR 1/measured range to VOR 2

R_{c1}/R_{c2} = computed range to DME 1/computed range to DME 2

B_{c1}/B_{c2} = computed bearing to VOR 1/computed bearing to VOR 2

Then:

$$\Delta Z = Z_m - Z_c$$

$$\Delta Z = [\Delta R_1, \Delta B_1, \Delta R_2, \Delta B_2]^T$$

Let:

H be the weighted observation matrix of the form:

$$H = \begin{vmatrix} h_1w_1 & h_2w_2 & h_3w_3 & h_4w_4 \\ h_5w_5 & h_6w_6 & h_7w_7 & h_8w_8 \end{vmatrix}$$

$h_1 = \cos(B_{c1})$ $\quad h_5 = \sin(B_{c1})$

$h_2 = R_{c1}\sin(B_{c1})$ $\quad h_6 = R_{c1}\cos(B_{c1})$

$h_3 = \cos(B_{c2})$ $\quad h_7 = \sin(B_{c2})$

$h_4 = R_{c2}\sin(B_{c2})$ $\quad h_8 = R_{c2}\cos(B_{c2})$

Then

$$P = H\,\Delta Z$$

$$P = [\Delta P_N, \Delta P_E]^T$$

where:

ΔP_N = north position correction

ΔP_E = east position correction

7.1.4.2 Computation of Bearing and Range

Let:

X, Y, Z be coordinates with respect to station n

Then:

$$X = (\phi - \phi_n)R'_M$$

$$Y = (\lambda - \lambda_n)R'_N$$

$$Z = (h_{A/C} - h_n)$$

$$R_g = X^2 + Y^2)^{1/2}$$

$$R_c = (X^2 + Y^2 + Z^2)^{1/2}$$

$$B_c = \tan^{-1}(X/Y)$$

$$\sin(B_c) = X/R_g$$

$$\cos(B_c) = Y/R_g$$

7.1.4.3 Selection of Weights w_1 Through w_8

For the DME/DME mode:

$$w_1 = w_3 = w_5 = w_7 = 0.5$$

$$w_2 = w_4 = w_6 = w_8 = 0.0$$

For the VOR/DME 1 mode:

$$w_1 = w_5 = 0.5$$

$$w_3 = w_7 = w_4 = w_8 = 0$$

$$w_2 = w_6 = (0.5)\left(\frac{R_{max} - R_{M1}}{R_{max}}\right) \text{for } R_{M1} < R_{max}$$

$$w_2 = w_6 = 0 \text{ for } R_{M1} \geqslant R_{max}$$

$$R_{max} = 200 \text{ nmi}$$

For the VOR/DME 2 mode:

$$w_3 = w_7 = 0.5$$

$$w_1 = w_5 = w_2 = w_6 = 0$$

$$w_4 = w_8 = (0.5)\left(\frac{R_{max} - R_{M2}}{R_{max}}\right) \text{for } R_{M2} < R_{max}$$

$$w_4 = w_8 = 0 \text{ for } R_{M2} \geqslant R_{max}$$

7.1.4.4 Computation of Filter First and Second Order Feedback Terms

$$K_1 = 2w\,dt = 2/Tdt$$

$$K_2 = w^2dt = 1/T^2dt$$

$$T = 20 \text{ sec air data mode}$$

$$T = 50 \text{ sec INS mode}$$

$$\begin{pmatrix} N_{F1} \\ E_{F1} \end{pmatrix} = K_1 \begin{pmatrix} \Delta P_N \\ \Delta P_E \end{pmatrix}$$

$$\begin{pmatrix} N_{F2} \\ E_{F2} \end{pmatrix} = K_2 \begin{pmatrix} \Delta P_N \\ \Delta P_E \end{pmatrix}$$

7.1.4.5 Computation of Meridional Radius of Curvature and Radius of Curvature Normal to Meridian

Normal radius of curvature:

$$R'_N = h_{A/C} + a\ (1 + f \sin^2 \phi) \cos \phi$$

Meridional radius of curvature:

$$R'_M = h_{A/C} + A\ (1\text{-}2f + 3f \sin^2 \phi)$$

7.1.5 Fast-Loop Computations

The following computations are performed 20 times/sec in the fast loop.

7.1.5.1 First and Second Order Gains

$$K'_1 = 1/K_1 dt$$

$$K'_2 = 360\ K_2 dt$$

7.1.5.2 Velocity Updates

Error velocity:

$$\Delta V_N = \Delta V_N + K'_2 \Delta P_N$$

$$\Delta V_E = \Delta V_E + K'_2 \Delta P_E$$

System velocity:

$$V_N = \hat{V}_N + \Delta V_N$$

$$V_E = \hat{V}_E + \Delta V_E$$

7.1.5.3 Latitude/Longitude Updates

Update:

$$\Delta\phi_R = \Delta\ \phi_R + (V_N dt + K'_1 \Delta P_N)/R'_M$$

$$\Delta\lambda_R = \Delta\lambda_R + (V_E dt + K'_1 \Delta P_E)/R'_N$$

System latitude/longitude:

$$\phi = \phi + \Delta\phi_R$$

$$\lambda = \lambda + \Delta\lambda_R$$

7.1.5.4 Inertial Latitude/Longitude Updates

This calculation of uncorrected inertial position is required for instrumentation purposes.

$$\phi_I = \phi_I + \frac{V_N dt}{R'_M}$$

$$\lambda_I = \lambda_I + \frac{V_E dt}{R'_N}$$

7.1.6 Symbols

Symbol definitions are listed in table 7-4.

7.2 INPUT/OUTPUT DATA

Defined in table 7-5 are the signals, channel selects, and associated memory locations in the NCU system.

7.3 INS

ADEDS requires an ARINC 561 type INS to provide data to the NCU. A modified Litton LTN-51 is used to satisfy the ADEDS system requirements.

7.3.1 Hardware Modifications

The LTN-51 is modified to provide an acceleration pulse weight of 1/256 ft/sec^2 in the navigate mode instead of the standard 1/8 ft/sec^2 per pulse. The resolution provided by this change is compatible with the EADI display functions of flightpath angle and flightpath acceleration. In addition, an accelerometer identical to the horizontal accelerometers is installed in the vertical position.

7.3.2 Input/Output Modifications

The following changes are required to the INS inputs for the ADEDS configuration:

- The ARINC 561 integration A input bus is connected to the NCU ARINC 561 test data output bus to receive runway heading data on label 301.

- The air data system 28-V valid input is connected to the NCU to receive a discrete whenever runway heading is changed

- Program pins 9 and 11 are connected to the flight control computer to receive ground discretes that indicate the following autopilot modes:

  No. 9 ground = track synchronized mode

  No. 11 ground = land mode

The INS outputs are not changed except that the HSI and BCD outputs are disabled and the data transmitted over the ARINC 561 binary output bus are modified as defined in table 7-6.

7.3.3 Delta Track Mechanization

The delta track output will be computed according to the following logic:

Case 1: LANDA (land arm mode)

ΔTK = current TK (magnetic) - RWYHDG

where RWYHDG (runway heading) has been transmitted by the NCU on the ARINC 561 test data output bus. The INS reads the RWYHDG data in word label 301 when the 28-V discrete is received on the ADS warning input.

Case 2: $\overline{\text{LANDA}}$ $\overline{\text{TKSYN}}$ (not land arm mode and not track synchronized)

ΔTK = current TK - TK at the time $\overline{\text{TKSYN}}$ (open) was detected by the INS

Case 3: $\overline{\text{LANDA}}$ TKSYN (not land arm and track synchronized)

ΔTK = 0

where LANDA transitions to $\overline{\text{LANDA}}$ with TKSYN already in the NOT state ($\overline{\text{TKSYN}}$). Figure 7-2 shows how ΔTK selection is mechanized.

As shown in table 7-6, the value of delta track is transmitted on the ARINC 561 binary output bus on two separate labels—007 and 017. This mechanization is to facilitate input data processing in the flight control computer.

TABLE 7-1.–FLAG SYSTEM FOR MODE SWITCHING

Mode	Flag state			Remarks
	Air data[a]	Radio mode[b]	Update[c]	
Inertial	Off	Off	Off	Computes velocity, position from inertial data
Air data	On	Off	Off	Computes velocity, position from TAS, magnetic heading
Radio inertial	Off	Off	On	Computes velocity, position from INS with radio updates
Radio air data	On	Off	On	Computes velocity, position from TAS, magnetic heading with radio update
Radio	Off	On	On	Computes velocity, position from radio data
DR	Off	On	Off	System dead reckoning on last available velocities

[a] Air data flag is set upon failure of inertial system.

[b] Radio mode flag is set upon failure of INS and ADS or MAG HDG system.

[c] Update flag is set if radio data are available and position update is less than 5 nmi.

TABLE 7-2.–NAVIGATION MODE FLAG STATES

Mode	Flag state		
	F0 (DME 1)[a]	F1 (VOR 1)[b]	F2 (DME 2)[c]
DME/DME	Off	—	Off
VOR 1/DME 1	Off	Off	On
VOR 1/DME 2	On	Off	On
DME 1	Off	On	On
DME 2	On	On	Off

[a] F0 is set ON if:
- DME 1 is invalid or not received
- DME 1 range $>$ 200 nmi
- Measured-estimated range $>$ 5 nmi

[b] F1 is set ON if:
- VOR 1 is invalid or not received
- F0 and F2 are ON
- Range $<$ 2 nmi
- Measured-estimated bearing $> 1^\circ$

[c] F2 is set ON if:
- DME 2 is invalid or not received
- DME 2 range $>$ 200 nmi
- Measured-estimated range $>$ 5 nmi
- $135^\circ >$ (bearing navaid 1 - bearing navaid 2) $> 45^\circ$

TABLE 7-3.–DISCRETE WORD FORMATS

Bit position	Input location 46	Output location 60
1	VOR/LOC valid	Tune 1 invalid
2	PCU valid	Tune 2 invalid
3	MFD 1 valid	WPT alert
4	INS valid	NCU valid
5	DME 1 valid	Digital data valid
6	DME 2 valid	NCDU NPD
7	Altitude valid	To/from flag (low level)
8	EADI valid	Not used
9	Spare	Vertical low level flag valid
10	True heading/magnetic heading	XTK low level flag valid
11		
12		
13		
14		
15		Not used
16		Not used
17		Not used
18		Not used
19	Not used	Not used
20	Not used	Not used
21	Not used	Not used
22	Not used	Not used
23	Not used	Not used
24	Not used	Not used

TABLE 7-4.–NAVIGATION SYMBOL DEFINITIONS

Symbol	Definition
V_N	System north velocity
V_E	System east velocity
$\hat{V}_N$	(INS north velocity/V_{TAS}) cos (ψ_m)
$\hat{V}_E$	(INS east velocity/V_{TAS}) sin (ψ_m)
ΔV_N	North velocity error
ΔV_E	East velocity error
V_{TAS}	True airspeed
ψ_m	Magnetic heading
ϕ	Best estimate of latitude
ϕ_I	Inertial latitude
$\Delta\phi$	Latitude update
$\Delta\phi_R$	Latitude update remainder
λ	Best estimate of longitude
λ_I	Inertial longitude
$\Delta\lambda$	Longitude update
$\Delta\lambda_R$	Longitude update remainder
R'_N	Normal radius of curvature
R'_M	Meridional radius of curvature
A/C	Aircraft altitude
a	Earth radius
N_{F1}	First order north filter term
N_{F2}	Second order north filter term
E_{F1}	First order east filter term
E_{F2}	Second order east filter term
K_1	First order position feedback gain
K_2	Second order velocity feedback gain
$K_{1'}$	Scaled first order position gain
$K_{2'}$	Scaled first order velocity gain

TABLE 7-4.–CONCLUDED

Symbol	Definition
ΔP_N	North position correction
ΔP_E	East position correction
d^t	0.05 sec

TABLE 7-5.–NCU INPUT/OUTPUT DEFINITIONS

Source/destination	ARINC	No. of words	Memory location	Channel select
ARINC 561/575 Receiver Inputs:				
NCDU	571	8	160-167	FC-14
INS 1	561	10	See table 7-6	FC-10
Spare	575	8	200-207	FC-3
SPBP Receiver Inputs:				
Display system		8	300-307	FC-1
Spare		8	310-317	SFC-1
ARINC 561/575 Transmitter Outputs:				
Simulator and mode panel	575	32	640-677	FC-5
NCDU	575	64	500-577	FC-2
INS and test data	561	32	600-637	FC-4
SPBP Transmitter Outputs:				
MFD display, bus 1		512	2000-2777	SPBP 1
MFD display, bus 2		64	1700-1777, 1500-1577	SPBP 2
Output bus (EADI)		64	1600-1677, 1400-1477	SPBP 3
Spare		16	400-417	SPBP 4
Radio Navigation Receiver Inputs:				
Pulse pair 1	568	1	40	SCS 1
Pulse pair 2	568	1	41	SCS 2
2 x 5 receiver 1		1	42	SCS 3
2 x 5 receiver 2		1	43	SCS 4
Nav tune 1		1	64	SCS 5
Nav tune 2		1	65	SCS 6
Discretes:				
Input		1	46 } See table 7-3	SCS 7
Output		1	60	SCS 1

TABLE 7-5.–CONCLUDED

Source/destination	ARINC	No. of words	Memory location	Channel select
Digital/Analog Outputs:				
XTRK (low level)		1	120	SCS 1
VTRK (low level)		1	121	SCS 2
Vertical steering		1	123	SCS 4
Speed command		1	125	SCS 6
Analog/Digital Inputs:				
Localizer dc		1	143	
Glide slope dc		1	144	
Vertical acceleration dc		1	145	
Altitude fine		1	146	
Roll		1	147	
Pitch		1	150	
True airspeed		1	151	
Mach		1	152	
Magnetic heading		1	153	
Altitude coarse		1	154	
Calibrated airspeed		1	155	
VOR		1	156	
Teletype Interface:				
Input		1	47	SCS 8
Output		1	61	SCS 2
Digital/Synchro Outputs:				
Drift angle sin		1	100	SCS 1
cos		1	101	SCS 2
HDG/TK sin		1	102	SCS 3
cos		1	103	SCS 4
(DA+TKE)/TKE sin		1	104	SCS 5
cos		1	105	SCS 6
Lateral steering		1	106	SCS 7

TABLE 7-6.–INPUT SIGNALS FROM INS

Octal label	Signal name	Rate (updates/sec)	NCU memory location
007	ΔTrack 1	5	220
017	ΔTrack 2	5	(a)
010	Latitude	1	221
011	Longitude	1	222
014	True heading	1	223
024	Magnetic variation	1	224
025	X acceleration	20	225
026	Y acceleration	20	226
066	Velocity–north	5	227
067	Velocity–east	5	230
100	Groundspeed	5	231

[a] Used by flight control computer only

Note: All of the navigation modes illustrated assume that the INS is the primary navigation mode with radio nav update.

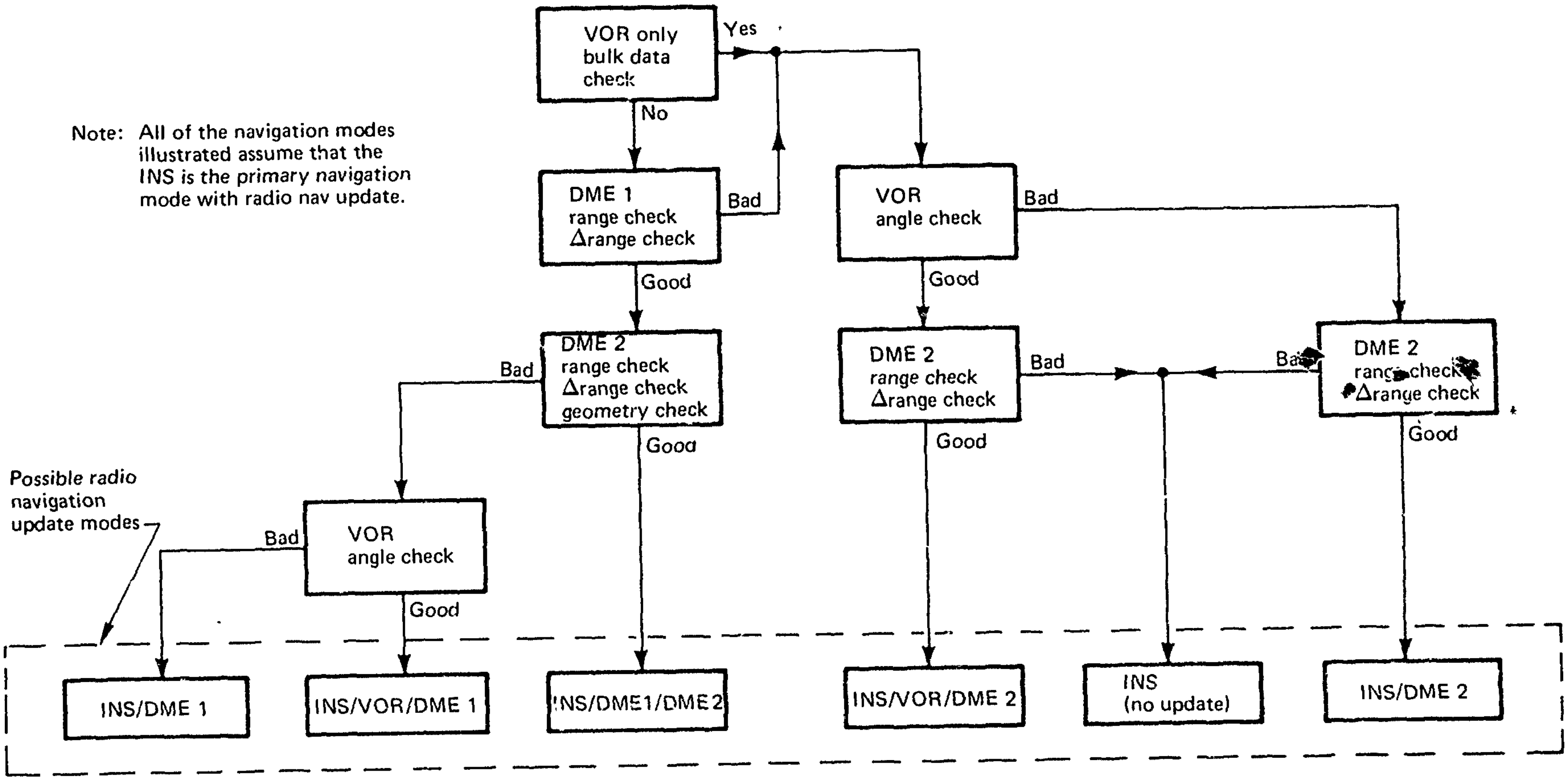


FIGURE 7-1.–INS/RADIO NAVIGATION MODE HIERARCHY

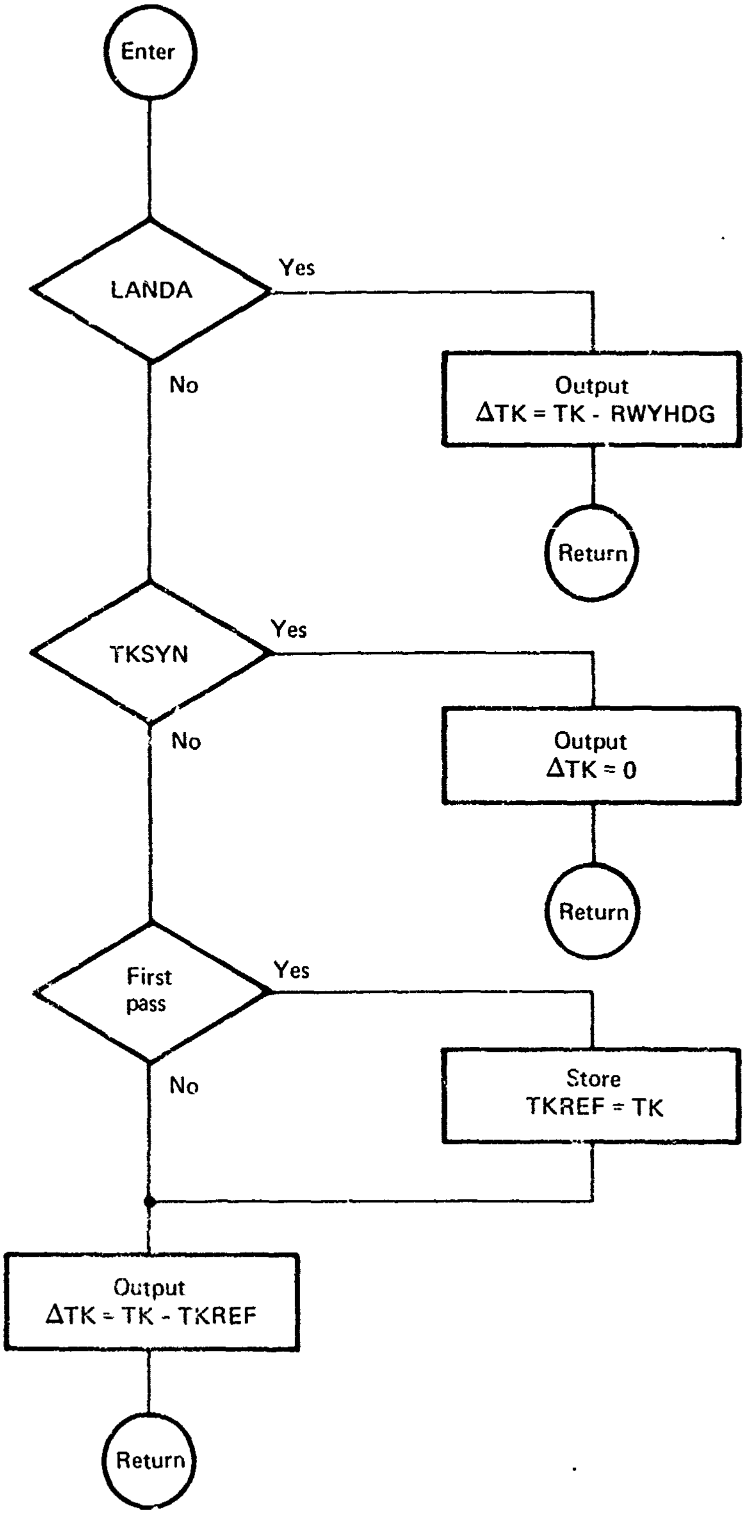


FIGURE 7-2.—LTN-51 ΔTK FLOW CHART

REFERENCES

1. R. E. Spradlin, *Digital Data Transmission Signal Criteria,* D6A11741-1, The Boeing Company, December 10, 1969.

2. *Boeing 737 Operations Manual,* D6-27370-130, The Boeing Company, March 30, 1968.