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MAY 78 W E BRANDT, K A ALDRICH F33615-75-C-5152

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PROGRAM DOCUMENTATION FOR THE TERRAIN AND FLIGHT DYNAMICS PROGRAM

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MAY 1978

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AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICES

TECHNICAL REVIEW AND APPROVAL

AMRL-TR-78-35

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Chief
Human Engineering Division
Aerospace Medical Research Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Terrain and Flight Dynamics (TFD) Program is a real-time, interactive graphics system developed to support the Helmet-Mounted-Display Processor (HMDP) activities. The primary task of the TFD Program is to simulate airframe movement and to supply the resultant dynamic values of aircraft state to the HMDP. Other tasks include the production of an instrument display and a dynamic perspective terrain display. Both displays are on the IBM 2250 and can be remoted

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20. Abstract (Continued)

by T.V. to the F-16 cockpit if desired. A cockpit selector switch was installed to allow the aircraft to be controlled by either of two sets of cockpit controls - one set in the F-16 cockpit and one set at the 2250 display unit.

The program was written for an IBM System/370, Model 155 computer operating under the standard MVT version of the Operating System. Both assembler language and Fortran were used in coding the subroutines and the IBM 2250 Graphics Programming Services were utilized for the graphic software support.

PREFACE

This program was developed for the Human Engineering Division, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433. The work was performed by International Business Machines Corporation, Owego, New York 13827, under Contract Number F33615-75-C-5152. Dean F. Kocian of the Visual Display Systems Branch was the contract monitor for the Aerospace Medical Research Laboratory. The work was performed in support of Project 7184, "Man-Machine Integration Technology," Task 718414, "Operator Workload Assessment."

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SECTION I

INTRODUCTION

The Terrain and Flight Dynamics (TFD) Program was developed to support the Helmet-Mounted-Display Processor (HMDP) activities. This program operates on the system 370-155 and provides the HMDP with dynamic inputs that are similar to the inputs that the HMDP would receive in an actual flying situation. In an actual airborne situation, the HMDP would receive aircraft state from the Central Air Data Computer (CADC), the Attitude Heading and Reference Unit (AHRU), and the Bombing-Navigation Computer. In the absence of these real inputs in the ground based simulation, TFD must provide them. In addition, developing these values requires that the TFD Program emulate the activities of some of this airborne electronic equipment. Further, the flight of the aircraft itself must be simulated so that cockpit control movement results in a realistic change in aircraft state. Therefore, the basic requirement for TFD was driven by the need to supply the digital simulation of the airframe movement and the resultant values required for HMDP inputs.

In addition to the above simulation activities, it was necessary to produce instrument displays on the IBM 2250 so that the aircraft could be flown in those instances when the HMDP was unavailable. As an adjunct, these instrument displays can be remoted to the F-16 cockpit via TV so that they serve the purpose of panel-mounted instruments. (Figure 2)

The inclusion of dual control facilities was thought to be desirable so that the aircraft could be controlled by two sets of cockpit controls -- one set in the F-16 cockpit and one set at the 2250 display unit. A cockpit selector switch is used to command TFD to use one, or the other, set for all commands. (Figure 1)

Another distinct task that TFD executes is the generation of a dynamic perspective terrain view that is responsive to aircraft state and helmet pointing angle. The simulated terrain view is a perspective view of a checkerboard oriented on cardinal heading angles. Also included are simulated towers that add a vivid perspective quality at low altitudes. This terrain display can be used in its native form on the IBM 2250 display, or it can be remoted via TV to appear on the helmet-mounted display as a TV image (Figure 1). This latter employment is useful because it serves as a replacement for the dynamic terrain view that occurs naturally in flight.

Section II of this document contains a list of the hardware components used by this program. The program description is contained in Section III and the input formats and 1827 DCU interface assignments are contained in Section IV. Section V contains listings of the program card decks, and Section VI contains the program flowcharts. Operator instructions for the computer operator are presented in the Appendix.

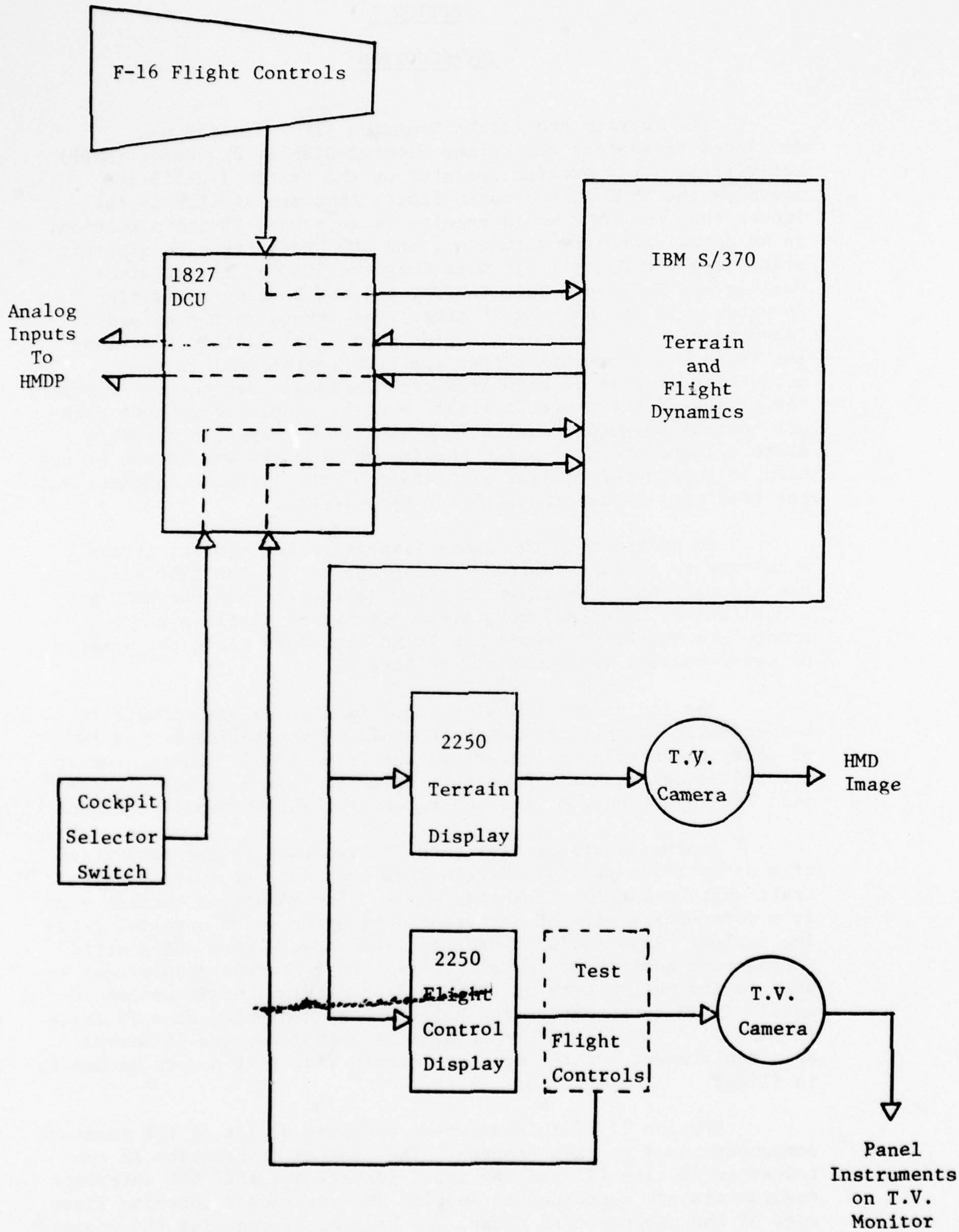

Figure 1. Support Hardware For The TFD Program

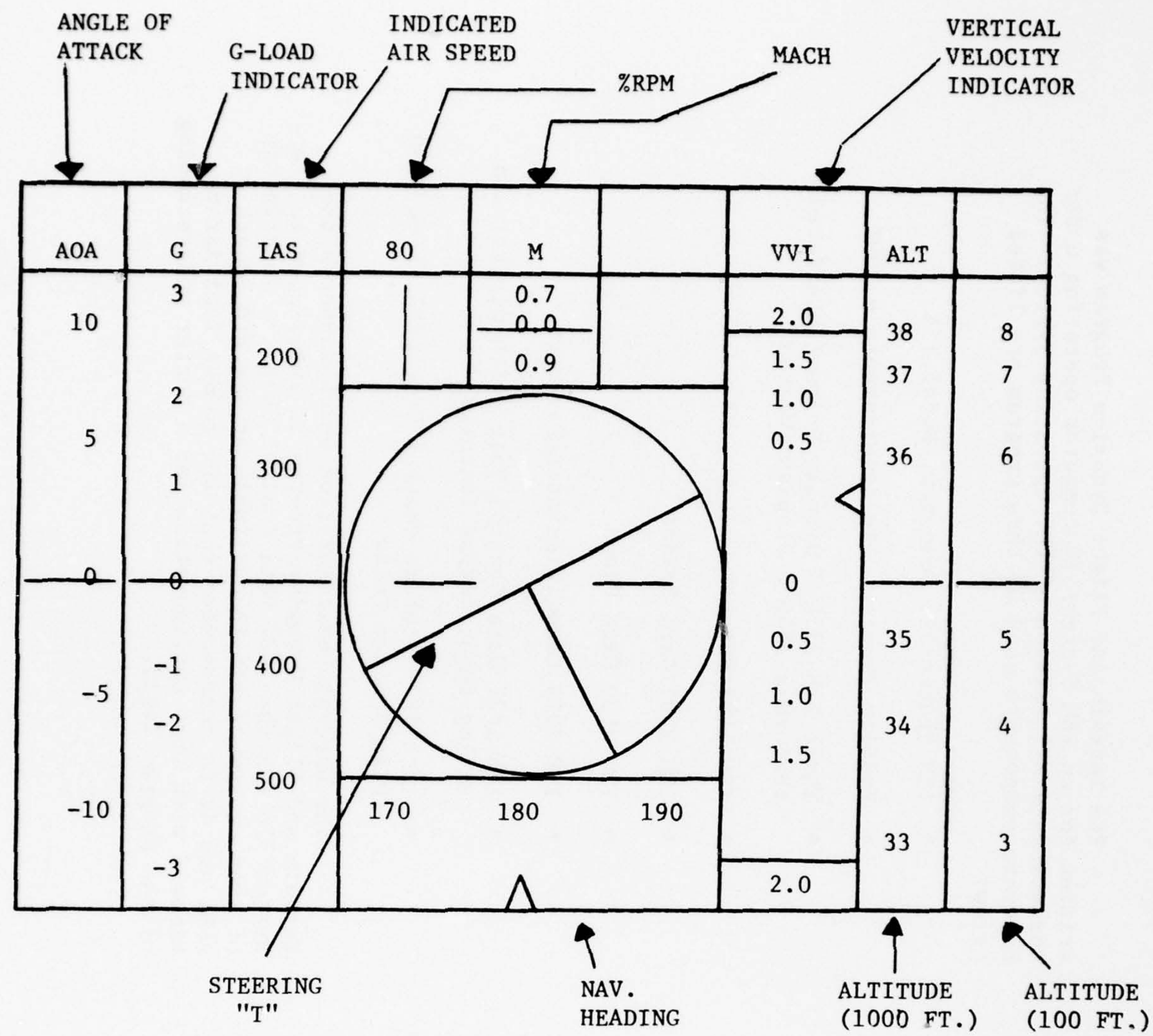

Figure 2. - FLIGHT CONTROL DISPLAY

SECTION II

MACHINE DEFINITION

The Terrain and Flight Dynamics Program was written for an IBM System/370 computer operating under the standard MVT version of the Operating System. The hardware components used by this program are listed below:

* IBM System/370 Computer, Model 155
* Problem Program Core Requirements - 200K
* Three IBM 2250-3 Display Units (interfaced through a 2840-2 Display Control)
* IBM 1403 Printer
* IBM 2501 Card Reader
* IBM 2520 Card Punch
* IBM 3215 Console Printer-Keyboard
* IBM 1827 Data Control Unit (with digital and analog input/output features)
* ITEL 7830 Storage Control Unit with three 7330 Disk Storage Units

The hardware configuration which supports the Terrain and Flight Dynamics Program is interfaced to the System/370 via the 1827 Data Control Unit. A description of that equipment set is available at the HEB Branch of AMRL and it is recommended that the reader familiarize himself with that configuration for a better understanding of the program logic.

SECTION III

PROGRAM DESCRIPTION

The Terrain and Flight Dynamics Program was written for an IBM System/370, Model 155 Computer running under the standard MVT version of the Operating System. It includes fourteen assembler language subroutines and six Fortran subroutines. In addition, the macro and graphics subroutines of the IBM 2250 Graphics Programming Services (GPS) were used for 2250 software support (reference manual, "IBM System/360 Operating System, Graphic Programming Services for IBM 2250 Display Unit," File No. S360-30, Form GC27-6909).

After reading the input data sets and performing all the general initialization procedures, the program enters a "WAIT" state and remains in a wait until the "GO" PFK key is pressed (Figure 3). The program then cycles through a timer-controlled loop, the duration of which is parametric, until the program is terminated. Termination is accomplished by hitting the 'CANCEL' key on the 2250 keyboard.

The logic flow control is all contained in the main subroutine, DLOGIC. As the various processing functions are required, DLOGIC branches to the appropriate subroutines. The logic within each of the subroutines is directed toward a specific function and can easily be followed in the program flowcharts in Section VI.

Intercommunication among the subroutines is done through a large COMMON CSECT. This CSECT is stored on a disk data set and invoked with a "COPY" statement at assembly time.

Table 1 contains a list of all user-written subroutines contained in the TFD Program. Along with each name is a brief description of the subroutine function(s) and a list of calling subroutine(s). In order to facilitate any changes in the terrain display, an additional more detailed description of the subroutine TRMATH will be presented in the remainder of this section.

The primary function of TRMATH is to compute the vector coordinates for the terrain display. This display consists of a horizon line and numerous longitude-latitude lines forming a uniform grid pattern. Three-legged towers which are evenly spaced throughout the grid are added to the display if the aircraft altitude is below 2048 feet.

After some initial housekeeping which includes the computation of the horizon angle and the distance between consecutive grid lines, the latest voltages from the helmet are taken from a common area used to communicate between subroutines. These voltage valves are converted to corresponding head azimuth and elevation

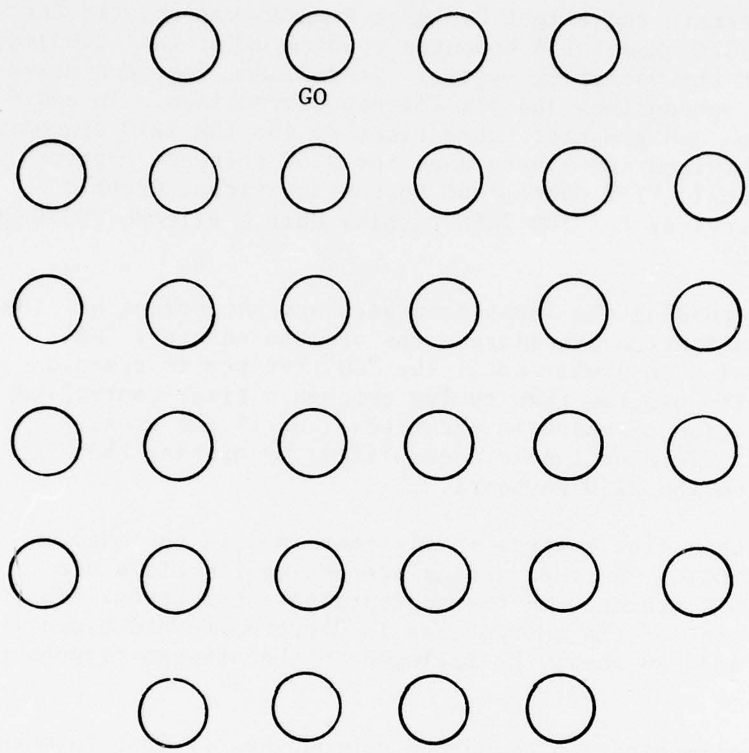

Figure 3. Flight Control Console PFK Overlay Card

Subroutine Name	Function(s)	Called by:
DLOGIC	Controls overall logic flow of the entire program. Contains timer control routine.	Operating System
DCBS	Storage area for all program control blocks. This routine contains no executable code.	None
DDATA	Reads input data files. Constructs storage tables and initializes variables.	DLOGIC
DGINIT	Opens all data sets. Initializes graphics control blocks. Sets up initial displays.	DLOGIC
DWRITE	Writes the flight control display to the 2840 buffer.	DLOGIC
DREADD	Reads digital input groups.	DLOGIC
DREADA	Reads analog input channels.	DLOGIC
DCOMP	Updates all the aerodynamic flight control parameters of the simulated aircraft. Computes display coordinates for the flight control display.	DLOGIC
TRRAIN	Generates Terrain Display.	DLOGIC
TRMATH	Computes Terrain Coordinates for Display.	DLOGIC
TRANSF	Transforms earth coordinates to screen coordinates.	TRMATH, LINE1
LINE1	Computes line vector coordinates for Terrain Display.	TRMATH
TOWER	Computes tower vector coordinates for Terrain Display.	TRMATH

Table 1. Subroutine Functions

Subroutine Name	Function(s)	Called by:
DFLDSPY	Generates the flight control display.	DLOGIC
DCLOSE	Closes all data sets at program termination time.	DLOGIC
DATN1	Attention handler for scope 1. Used only for testing hardware interface without digin.	Attention Handler
DATN2	Attention handler for scope 1. Used only for test hardware interface without digin.	Attention Handler
DATN3	Attention handler for scope 3. Used for processing inputs from experimenter's control console.	Attention Handler
DUMINIT	Initializes the COMM and IFF System Status Displays.	DGINIT
DWRITDO	Writes digital output groups.	

Table 1. Subroutine Functions (continued)

angles (90-97). These angles along with the current aircraft heading, pitch, and roll angles are then used to compute the transformation matrix V (98-121). This matrix is used to transform points from earth coordinates to head coordinates.

Two angles, ROT1 and ROT2, are then computed using the V matrix (122-138). These angles represent heading and pitch, respectively, of the pilot's line of sight. They are used later in the program to determine certain points within the pilot's FOV.

After more housekeeping (139-149), two points on the horizon are computed and transformed to screen coordinates and the slope of the horizon on the screen is determined (150-159). The two points at which the horizon intersects the sides of the screen are computed, converted to raster units for the 2250, and stored in array XYTBL3 (160-196).

After the vector coordinates for the horizon have been determined, the corner coordinates for the section of terrain to be displayed are computed (197-215). This will determine which longitude and latitude lines are to be displayed. Statements 225 thru 375 set up screen limits which are used in a subroutine called LINE1. LINE1 takes each line which is to appear on the display and determines its vector coordinates by intersecting the line with the sides of the screen and with the horizon. After the screen limits are set and further initialization is done, control is given to LINE1, first to compute and scale latitude vector coordinates and then to compute and scale longitude vector coordinates (376-396). These vector coordinates are then taken and stored with the horizon vector coordinates in XYTBL3 (397-405).

Vector coordinates for the tower legs are now computed if the aircraft is below 2048 feet. Coordinates for all towers which appear in the pilot's FOV are computed and transformed to screen coordinates (406-431). Next a check is made to determine if a tower leg intersects a side of the display screen. If it does, control is given to a subroutine called TOWER which will compute the point of intersection. After tower vector coordinates are computed, they are converted to raster units, and stored along with horizon and line vector coordinates (432-480).

Another function of TRMATH is to determine azimuth and elevation angles from the center line of the aircraft to the CCIP. This is done by computing the CCIP in earth coordinates, transforming them to screen coordinates, and scaling them in relation to the FOV. These angles are converted to voltages and put in common for later use (528-539). If desired, TRMATH is capable of displaying the CCIP along with the terrain display on the 2250 (488-521). This option was originally included as a test routine for the CCIP. It is branched around in the latest version of TRMATH, but it can be exercised by removing statement 487.

Finally, in order to calibrate the television picture of the terrain display and the current field-of-view, four calibration marks are created and displayed four degrees from the middle of each side to the center of the screen. These marks are continuously displayed until the aircraft climbs above 5000 feet (544-579).

Statements 580 and 581 blank any unused positions in array XYTBL3 so that XYTBL3 contains only those vector coordinates which are to be displayed.

By the end of each pass through TRMATH all vector coordinates for the horizon, grid lines, and towers have been computed, converted to raster units for display on the 2250 and stored in XYTBL3. These values are then passed through a common area to a subroutine called TRRAIN. TRRAIN then uses the values in XYTBL3 to generate the terrain display.

The subroutine DCOMP performs the flight dynamics simulation mathematics. DCOMP was configured specifically to meet the requirements for a flight simulation that assumed that a yaw damper and turn coordinator were constantly engaged, thereby obviating the need for rudder pedals in the F-16 mockup. The control inputs are:

- o Angle-of-attack inputs from a joystick.
- o Roll rate inputs from a joystick.
- o Engine thrust from a throttle.
- o Afterburner from an A/B switch.

At any given point in the simulation, the aircraft is accelerated in accordance with the resultant of the combined vector forces acting upon it. That is, no matter what the attitude of the aircraft is, each vector force is calculated, all forces are vectorially summed and then the acceleration due to this resultant is calculated. Integration of this acceleration provides delta velocities in each axis, which are then integrated to provide delta positions.

The following discussion is keyed to the FORTRAN statement numbers in DCOMP so that the reader can follow the development of these flight variables during one execution of DCOMP.

At statement 82, DCOMP computes the angle-of-attack (AOA). The new AOA is derived from the old AOA and the current joystick position by applying scaling to the joystick voltage in accordance with the ALFARX calibrate value, proportioning for the MAXG capabilities of the aircraft, and then applying corrections for inverted flight.

The roll rate command is then scaled and integrated to produce BETA with special conditions applied for small control inputs and for inverted flight. The balance of the code down to statement 99 is used to compute the artificial horizon display using RHO developed from the flight path angle (GAMMA), which is a resultant of the preceding pass through the program.

At statement 99, the heading computations are performed, but are preceded by a development of the current environment of the airframe. The roll angle PHI and pitch angle THETA are set to provisional values prior to entering the integration and correction sequence. Then the local atmosphere is computed to develop temperature (TEMP), pressure (PRES), and density (DENS) and the speed of sound (SOUND) at the present altitude.

At 1020 the computation of aerodynamic forces begins with dynamic pressure (Q) and continues with calculation of the coefficients of lift (CL) and drag (CD). The CL is then limit checked to provide a CL of 1.0 at an AOA of 0.4 radians, a CL of 0.0 at excess lift commands, an AOA of 0.6 radians as an upper limit, and an AOA of 0.0 at velocities less than 100 feet per second.

The throttle command is then converted to thrust as a function of altitude and mach number, FALT and FMACH. This is performed by first computing the maximum thrust (TMAX) at altitude and then proportioning for throttle setting. If afterburner is commanded, the TMAX is expanded by a factor of four. After the lift magnitude is developed from Q, CL, and AREA, the component normal to the airframe is found. Then the thrust is further modified by the AOA to account for engine inlet angle.

At the comment DYNAMICS the integrations for velocity (VEL), heading (PSI), and flight-path angle (GAMMA) are performed. If GAMMA has gone through 90 degrees, special adjustments are made for heading reversal and roll angle definition.

After all adjustments are made, the program continues at statement 1040 by integrating position along the GAMMA vector referenced to the ground, X, Y, and Z coordinates. Rates along these axes and special scaling for the aircraft instruments are then performed. This includes the computation of eight display coordinates for the compass tape.

The computations for TRGHD account for the differences between the counter-clockwise increasing angles in trigonometric convention versus the aircraft heading convention, which is clockwise increasing.

At statement 176, the aircraft position is scaled to miles for convenient usage by other subroutines. This is followed by display scaling for the RPM indicator. At 850 the MACH display is scaled. At 900 the airspeed display is scaled and at 910 the vertical velocity display is scaled. At 950, some integer values for the floating point variables are created and then the scaling of the fine and coarse grain altimeter display is performed. The accelerometer display is scaled at 1250, followed by scaling for the angle-of-attack display at 1351.

The preparation for transmitting aircraft state via the 1827 DCU analog outputs begins at statement 1451. There are two classes of preparation, one for scalar values and the other for the biphase rotating vector values. For the scalar values, the preparation consists of scaling to the desired physical units to be denoted by the voltage values. The biphase values for modular heading, position and altitude are created by using the remainder that results from a divide by the modulo value. The remainder is formed by subtracting the whole number part of the quotient from the floating point quotient. The result is a fraction of a modulo circle that is then used as an argument for developing the sine and cosine values of the rotating vector. These trigonometric values are then scaled up to voltage values that will result in employing nearly the full voltage range of the digital-to-analog converters for component transmission.

SECTION IV

INPUT FORMATS/1827 DCU INTERFACE ASSIGNMENTS

This section describes the input file formats as well as the 1827 DCU interface assignments for the Terrain and Flight Dynamics Program.

Figure 4 illustrates the format for input file 1. Note that the Fortran format used for reading each variable is listed. The user is cautioned to adhere to the specified format, left-justifying A-format data and right-justifying I-format data. The fields marked "Unused" were inserted just to maintain uniformity in specific field positions and also for full word alignment where necessary.

Tables 2,3, and 4 define the address assignments for analog input, digital input, and analog output respectively.

Record Number(s)	Record Position(s)	Contents	Fortran Format	Units
1	1-2	"ID" = type identifier	A2	-
	3-14	Subject's name	3A4	-
	15-26	Experimenter's name	3A4	-
	27-78	Miscellaneous information	13A4	-
	The next record defines control parameters for the experiment.			
2	1-2	"CT" = type identifier	A2	-
	3-9	Unused	-	-
	10-14	Program cycle time	F5.3	Seconds
	15-18	Unused	-	-
	19-22	Starting velocity of aircraft	I4	Knots
	23-26	Unused	-	-
	27	Test procedure indicator ('F' = off, 'T' = on)	L1	-
	28	Unused	-	-
	29-32	Field-of-view	F4.0	Degrees

Figure 4. Format for Input File 1.

Record Number(s)	Record Position(s)	Contents	Fortran Format	Units
The next record defines the scaling parameters for the joy-stick and throttle control arm located at the 2250 Display Unit.				
3	1-2	"HC" = type identifier	A2	-
	3-8	Angle of Attack Center	F6.1	-
	10-15	Angle of Attack Multiplier	"	-
	17-22	Throttle Center	"	-
	24-29	Throttle Multiplier	"	-
	31-36	Roll Rate Center	"	-
	38-43	Roll Rate Multiplier	"	-
The next record defines the scaling parameters for the joy-stick and throttle control arm located inside the F-16 cockpit.				
4	1-2	"DC" = type identifier	A2	-
	3-8	Angle of Attack Center	F6.1	-
	10-15	Angle of Attack Multiplier	"	-

Figure 4. Format for Input File 1. (continued)

Record Number(s)	Record Position(s)	Contents	Fortran Format	Units
4 (Cont.)	17-22	Throttle Center	F6.1	-
	24-29	Throttle Multiplier	"	-
	31-36	Roll Rate Center	"	-
	38-43	Roll Rate Multiplier	"	-
The next record defines the scaling parameters for azimuth and elevation.				
5	1-2	"AC" = Type identifier	A2	-
	3-8	Azimuth Center	F6.1	-
	10-15	Azimuth Multiplier	F6.1	-
	17-22	Elevation Center	F6.1	-
	24-29	Elevation Multiplier	F6.1	-

Figure 4. Format for Input File 1. (continued)

5

CHANEL NUMBER	USE
9	Bank angle for DAIS cockpit
10	Throttle control for DAIS cockpit
12	Angle-of-attack for DAIS cockpit
14	Bank angle for F-16 cockpit
15	Throttle control for F-16 cockpit
16	Angle-of-attack for F-16 cockpit
17	Helmet azimuth
18	Helmet elevation

NOTE: Voltage scaling values have been omitted because all analog input voltages are scaled as desired after they have been read. A center and multiplier for each voltage are located on the HC, DC, and AC cards of the execution card deck (Figure 6).

Table 2. Analog Input Assignments

Decimal Address	1827 Bit Number	Use Or Meaning
68	0	Afterburner switch on test throttle (1 = on)
68	1	Afterburner switch on simulator throttle (1 = on)
68	2	Freeze for DAIS cockpit (1=off)
68	3	Freeze for F-16 cockpit (1=off)
68	4	Select cockpit desired (1=DAIS)

Table 3. Digital Input Bit Assignments

CHANEL NUMBER	CHANEL NAME	VOLTAGE SCALING
01	Helmet Azimuth	0.1 volt per degree (nominal), plus volts for right azimuth.
02	Helmet Elevation	0.1 volt per degree (nominal), plus volts for up elevation.
03	Heading Sine	Sine component times 9.8 volts, one revolution for 20° heading change.
04	Heading Cosine	Cosine component times 9.8 volts, one revolution for 20° heading change.
05	Roll	-9.8 volts for 180° left roll, +9.8 volts for 180° right roll. Linear
06	Pitch	-9.8 volts for 90° down pitch, +9.8 volts for 90° up pitch. Linear.
07	Speed	-9.8 volts for zero speed, +9.8 volts for 1500 knots. Linear.
08	Angle-of-attack	Same as pitch.
09	Latitude Sine	Sine component times 4.8 volts plus 5 volts, one rev. for 20 sec. lat. change
10	Latitude Cosine	Cosine component times 4.8 volts plus 5 volts, one rev. for 20 sec. long. change
11	Longitude Sine	Same as latitude sine.
12	Longitude Cosine	Same as latitude cosine.
13	Altitude Sine	Sine component times 4.8 volts plus 5 volts, one rev. for 2,000 ft. alt. change
14	Altitude Cosine	Cosine component times 4.8 volts plus 5 volts, one rev. for 2,000 ft. alt. change

Table 4. Analog Output Assignments

SECTION V

PROGRAM CARD DECKS

Source program card decks and program object decks for the DAIS Triple Task Experiment Program are available at the Systems Research Branch, Human Engineering Division of AMRL. A set of printed listings of the source code is also available, both in card image format and in assembled format. These data are stored on magnetic tape, AMRL serial number 000409. File 26 contains the program object decks, with JCL for link-editing the subroutines. File 27 contains the source code, with JCL, for assembling and compiling the entire set of subroutines. Both files are in card image format, fixed-length, 80-byte records, 3200 bytes per block.

Figure 5 lists the control cards for link-editing the DAIS Triple Task Experiment Program. For ease of handling, the SYSPUNCH output from the assembler and compiler was all stored in a partitioned data set called IBM.DUMBO. At link-edit time, the various subroutines are then retrieved using INCLUDE statements as shown in Figure 5. Figure 6 lists the program execution deck.

```
//LINKTED    JOB  WARTLUFT,MSGLEVEL=1
//  EXEC  LINK
//LKED.SYSLMOD DD DSN=IBM.EXEC(DUMCAIS),DISP=(OLD,KEEP),VOL=SER=SYSTEM
//LKED.MY DD DSN=IBM.DUMBO,DISP=SHR
//LKED.SYSIN DD *
 INCLUDE MY(DLOGIC)
 INCLUDE MY(DCBS)
 INCLUDE MY(DDATA)
 INCLUDE MY(DGINIT)
 INCLUDE MY(DWRITE)
 INCLUDE MY(DREADD)
 INCLUDE MY(DREADA)
 INCLUDE MY(DCOMP)
 INCLUDE MY(TRRAIN)
 INCLUDE MY(TRMATH)
 INCLUDE MY(DFLDSPY)
 INCLUDE MY(DCLOSE)
 INCLUDE MY(DATN1)
 INCLUDE MY(DATN2)
 INCLUDE MY(DATN3)
 INCLUDE MY(DUMINIT)
 INCLUDE MY(DWRITDD)
 INCLUDE MY(DRECORD)
/*
```

Figure 5. Link-Edit Card Deck

```
//EXECTFD    JOB   BRANDT,MSGLEVEL=1
//STEP1   EXEC   PGM=DUMDAIS,REGION=200K,DPRTY=(15,15)
//STEPLIB   DD   DSN=IBM.EXEC,DISP=(OLD,KEEP),VOL=SER=SYSTEM,UNIT=SYSDA
//OUT          DD   DUMMY
//DDG1 DD UNIT=2E2
//DDG2 DD UNIT=2E0
//DDG3 DD UNIT=2E3
//DDAN DD UNIT=002
//DDIN DD UNIT=004
//DDOUT DD UNIT=005
//SYSUT1   DD   SPACE=(TRK,(30)),UNIT=SYSDA
//SYSUDUMP DD SYSOUT=A
//FT06F001 DD SYSOUT=A
//FT07F001 DD SYSOUT=B
//SYSPLOT   DD   UNIT=GOULD
//FT05F001 DD *
ID
CT T F F  .100 01  500 28 F  26.
HC -0.02   0.25    0.0   -0.4  0.195    .5
DC  .028     .2    .03   -.34   .013  -0.33
AC   0.0 -0.225    0.0  -0.25
/*
```

Figure 6. Execution Card Deck

SECTION VI

PROGRAM FLOWCHARTS

The program flowcharts are presented in Figure 7. Although the flowcharts were done by hand, the conventions used are the same as those described in "AUTODOC-V an Automatic Documentation and Symbolic Flow Charting Program," 360D-001.1.014, available at the Systems Research Branch, Human Engineering Division of AMRL.

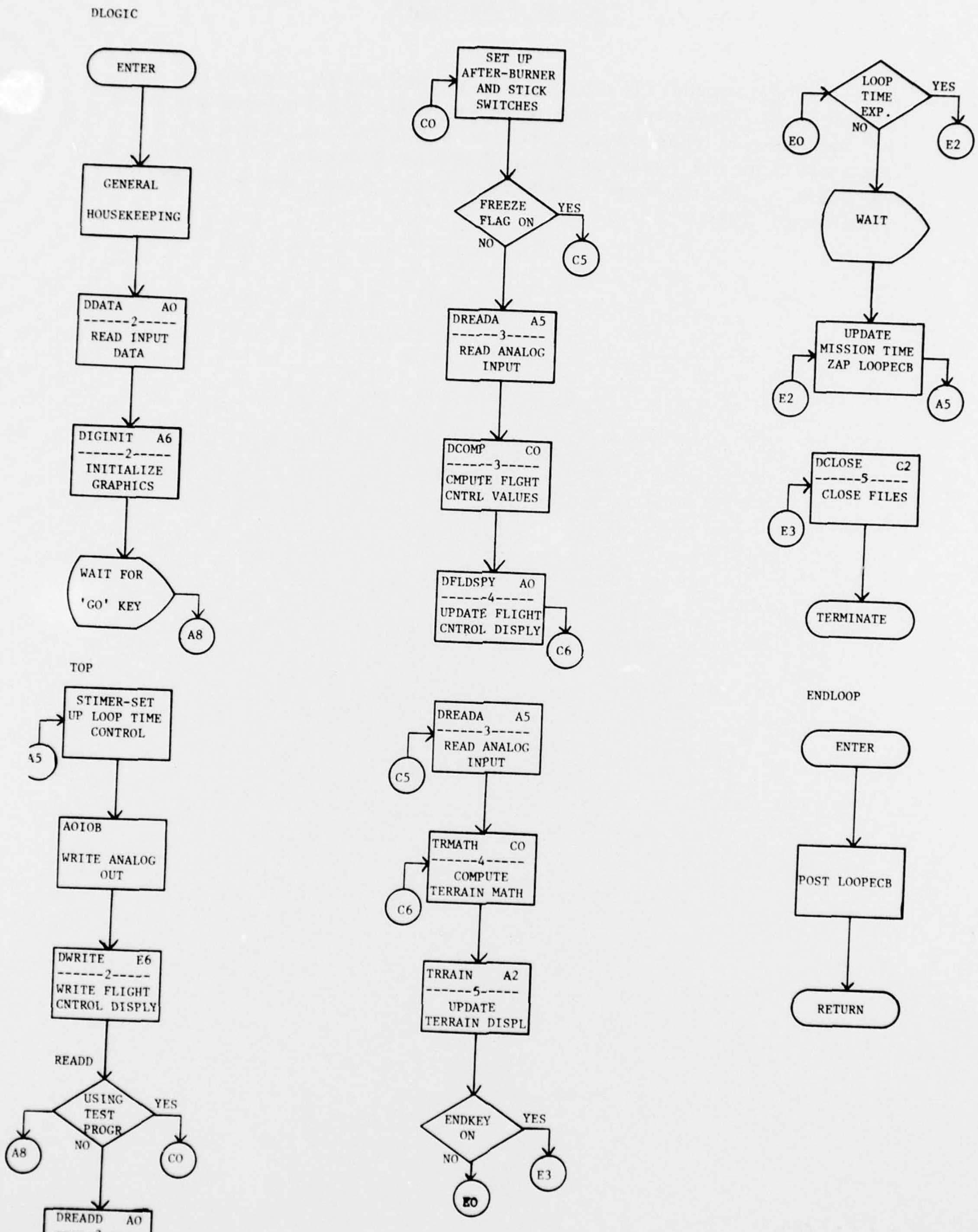

Figure 7. Program Flowcharts

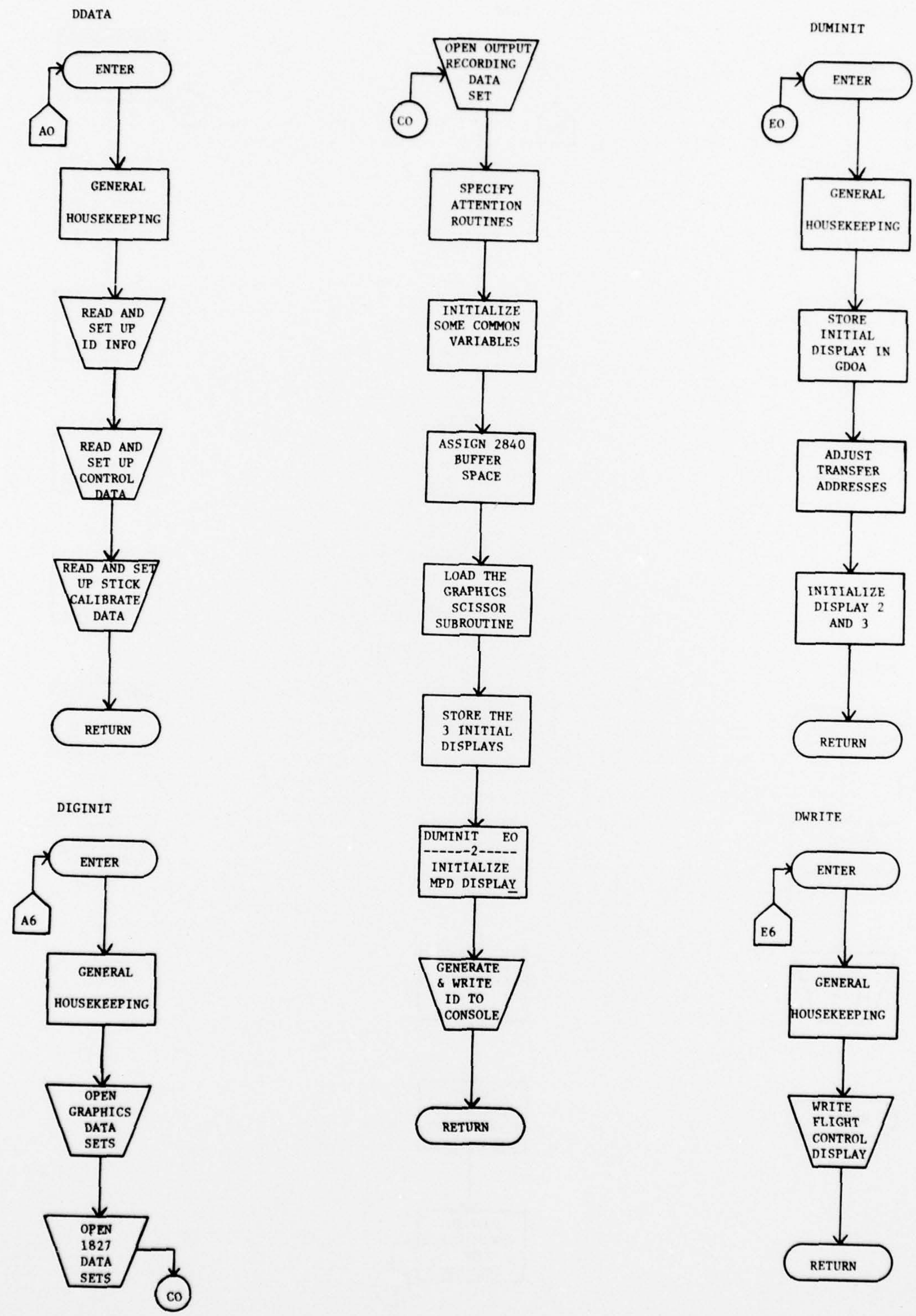

Figure 7. Program Flowcharts (Continued)

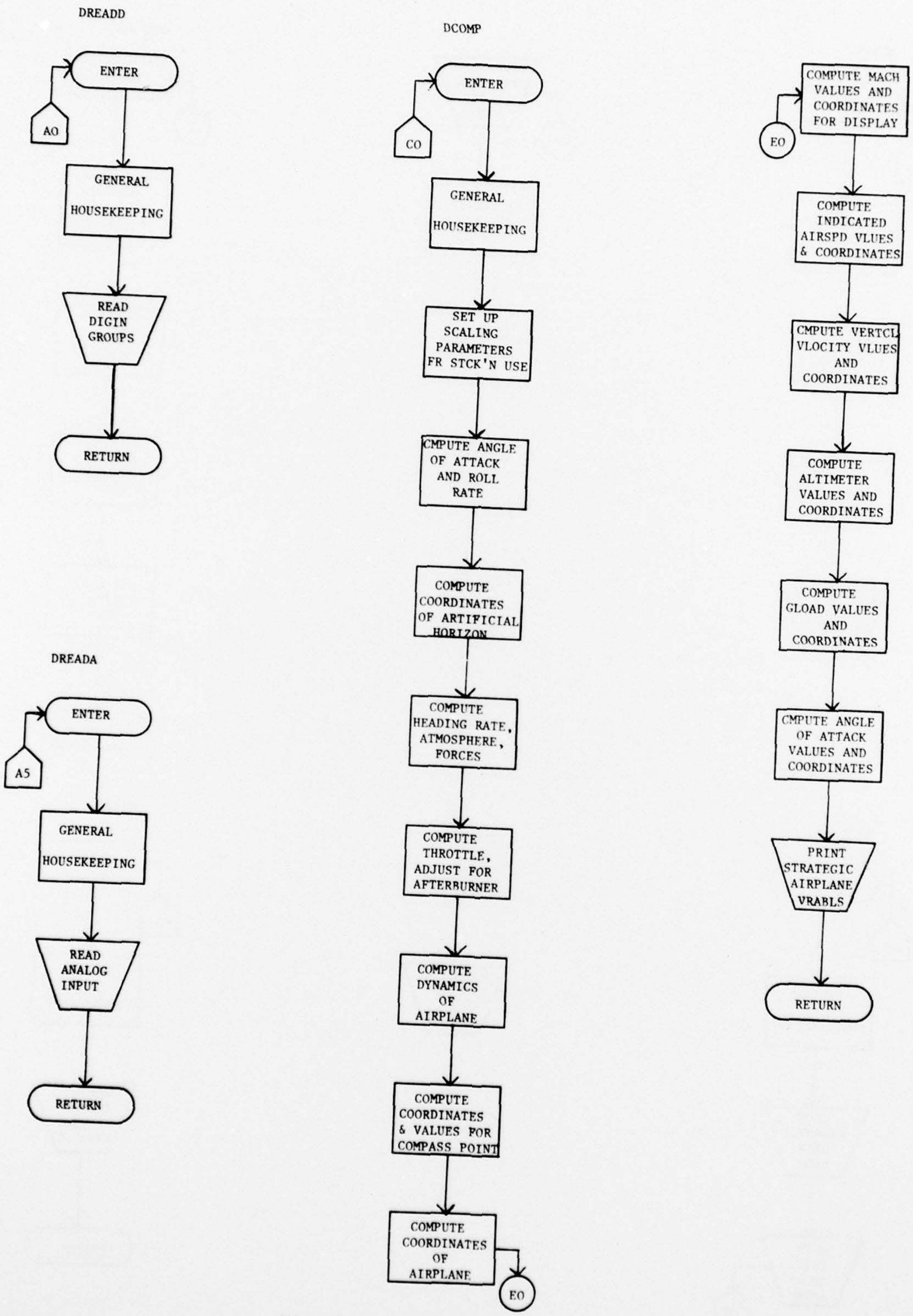

Figure 7. Program Flowcharts (Continued)

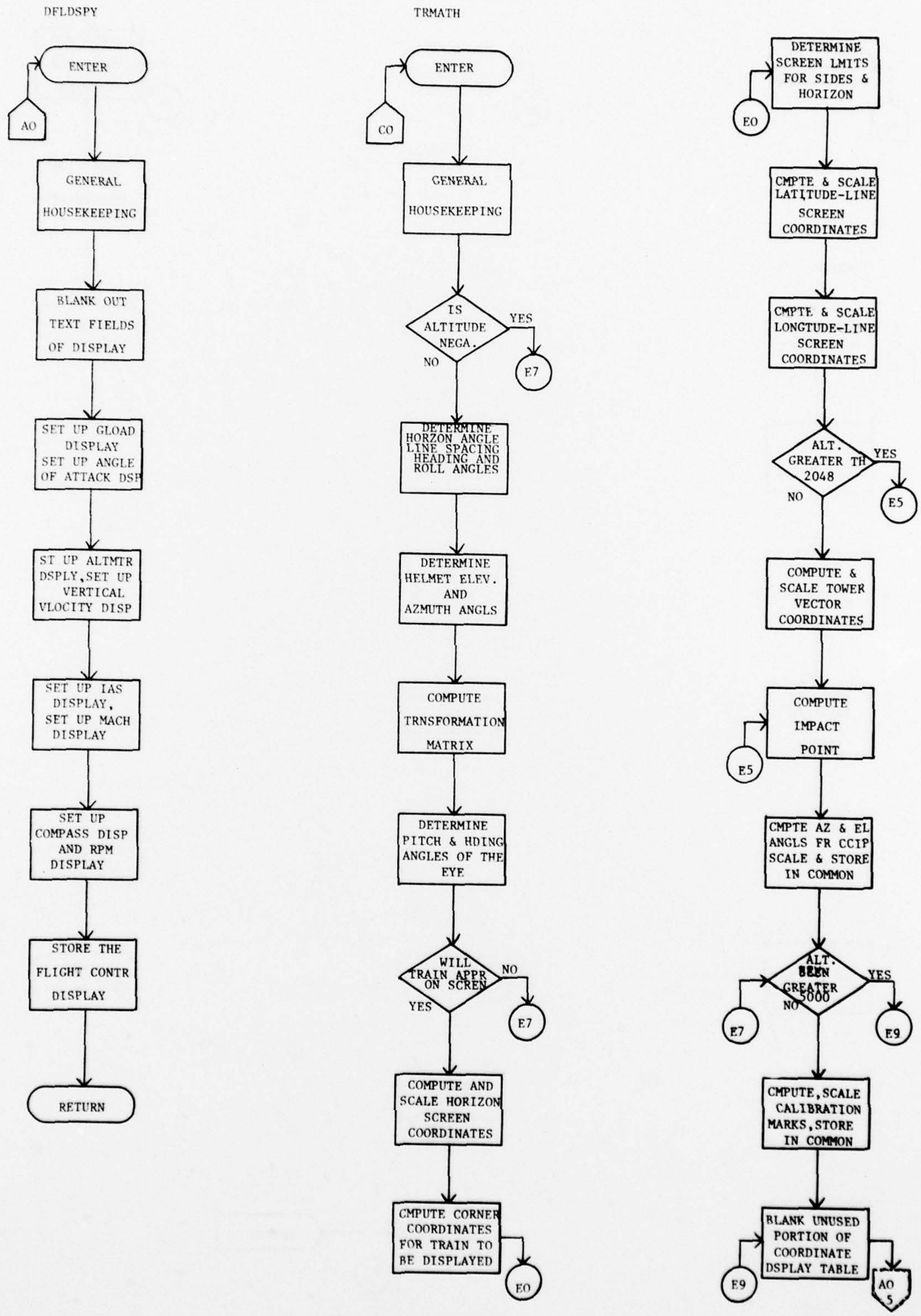

Figure 7. Program Flowcharts (Continued)

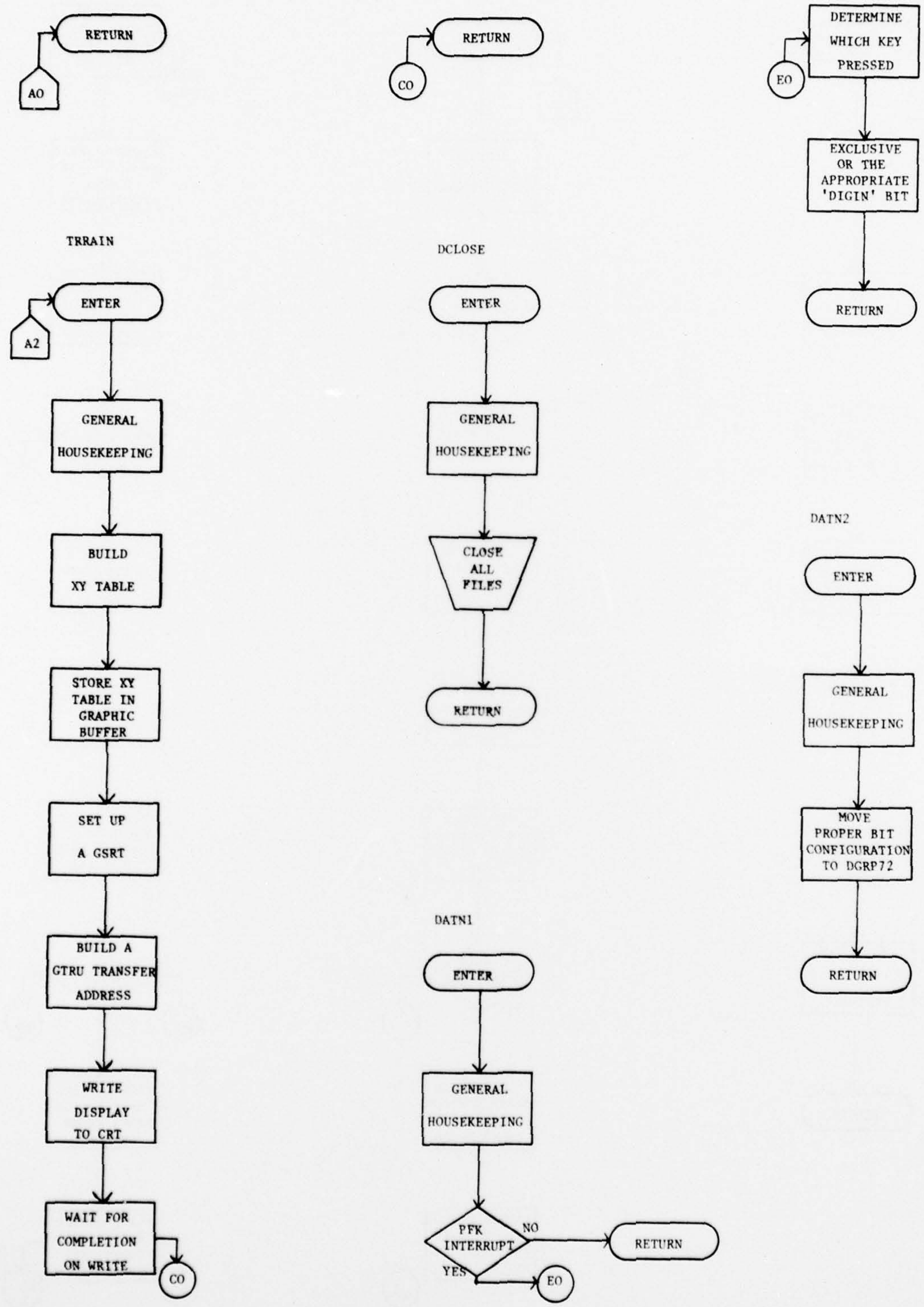

Figure 7. Program Flowcharts (Continued)

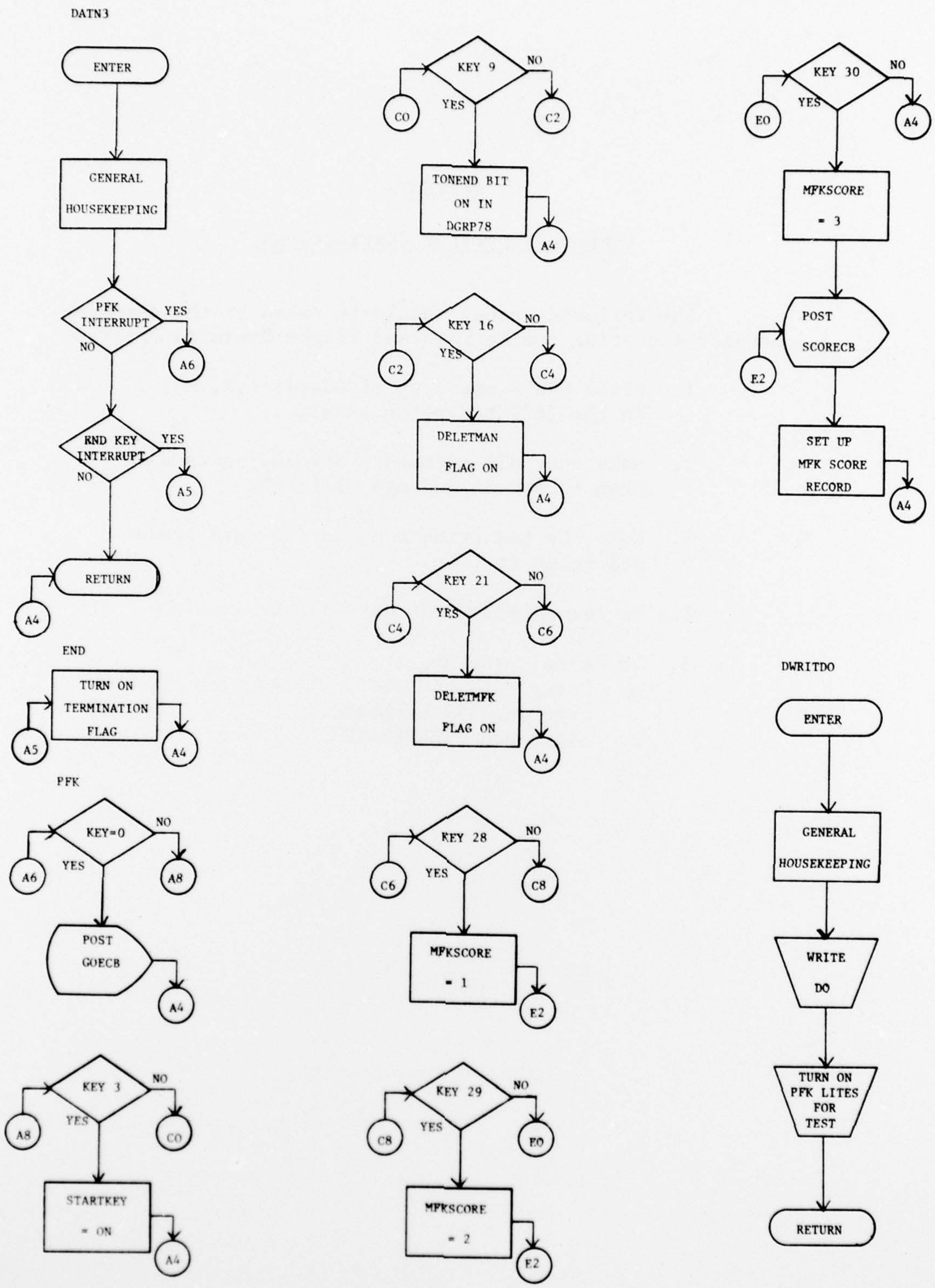

Figure 7. Program Flowcharts (Continued)

APPENDIX

Computer Operator Instructions

The following steps should be taken by the computer operator executing the Terrain and Flight Dynamics Program.

1. Place VCASS patch panel boards 1,2, and 3 in the 1827 DCU patch panel.

2. Make sure all necessary display units have been turned on and are on-line.

3. Load the execution deck in the card reader and ready it.

4. If requested, mount disk packs.

5. To cancel program.
   a. Press "ALTN CODING", "LOCK", and "CANCEL" keys on 2250 keyboard.
   b. Light pen "TERMINATE".

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