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ADVANCED TRANSPORT OPERATING SYSTEM SOFTWARE UPGRADE

FLIGHT MANAGEMENT / FLIGHT CONTROLS SOFTWARE DESCRIPTION

Computer Sciences Corporation
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INTRODUCTION

This document describes the Flight Management/Flight Controls (FM/FC) software for the Norden #2 (PDP-11/70M) computer installed on the NASA 737 airplane. The software computes the navigation position estimates, guidance commands, and those commands to be issued to the control surfaces to direct the airplane in flight based on the modes selected on the Advanced Guidance Control System (AGCS) mode panel, and the flight path selected via the Navigation Control/Display Unit (NCDU).

Real-time data recording and data display for inflight analysis is also provided for. These functions are provided by several "stand-alone" utility tasks that are executed on an as required basis.

In addition to the FM/FC functions performed, a compool of data (DISNAV Compool) which contains the active and provisional guidance buffers as well as other variables needed to generate displays is shipped to the Norden #1 computer via a DR11-B interprocessor link.

The software described in this document is delivery 4.1 (D4.1) of the baseline FM/FC system which was released in July 1987.

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ALPHABETICAL LIST OF FM/FC MODULES

2.0 EXECUTIVE

SYSTEM OVERVIEW

The Flight Management/Flight Controls (FM/FC) software resides in a PDP-11/70M computer herein referred to as Norden #2. As the name FM/FC implies, this computer contains software that performs the flight management functions, guidance, navigation, and flight controls functions which generate commands that are issued to the control surfaces to direct the airplane in flight.

These functions are performed by three tasks which execute under the RSX-11S operating system. The version used at the time of this document is RSX-11S version 4.2 revision A. The tasks which perform the flight functions are FLTHDL, FAST, and SLOW. Since each of these tasks is described in detail later in this document, only a synopsis of each will be given here.

TASK	PRIORITY	DESCRIPTION
FLTHDL	175	FM/FC system executive task. Performs all I/O functions with the exception of terminal advisory messages.
FAST	160	Application software task. Performs all time critical operations. Invokes SLOW task on first pass and aborts SLOW task if FAST task is terminated.
SLOW	40	Application software task. Performs all operations that are not time critical.
TERMX	55	Utility task. Allows up to three terminals to "log on" to data monitor program.
TERMAK	50	Utility task. Allows inspection and modification of resident common data areas.
DSTAR	50	Utility task. Allows operator interaction via a VT-100 compatible terminal with the Data Acquisition System (DAS) recording variables list.

Only one task may have control of the computer's CPU at any given time. The operating system has the responsibility of granting individual tasks control. The following definitions will be used to describe the five states that a task may be in. Note that the last three are actually sub-states of the second.

Dormant No instructions will be executed until the console operator or another task issues a "RUN" command.

Active Not dormant.

Waiting An active task that has relinquished control of the CPU pending the initiation or completion of some system event.

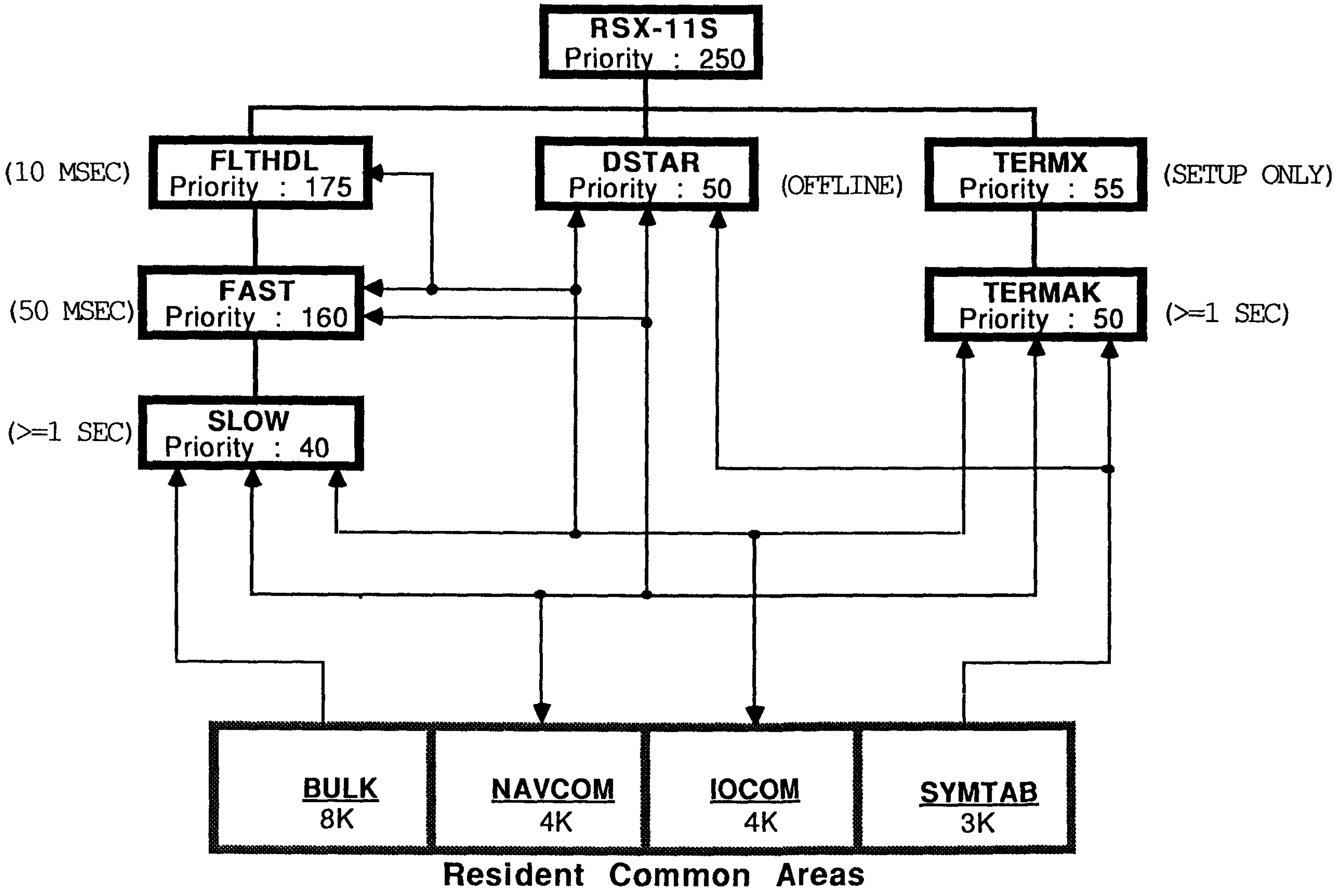
Competing An active task wanting control of the CPU.

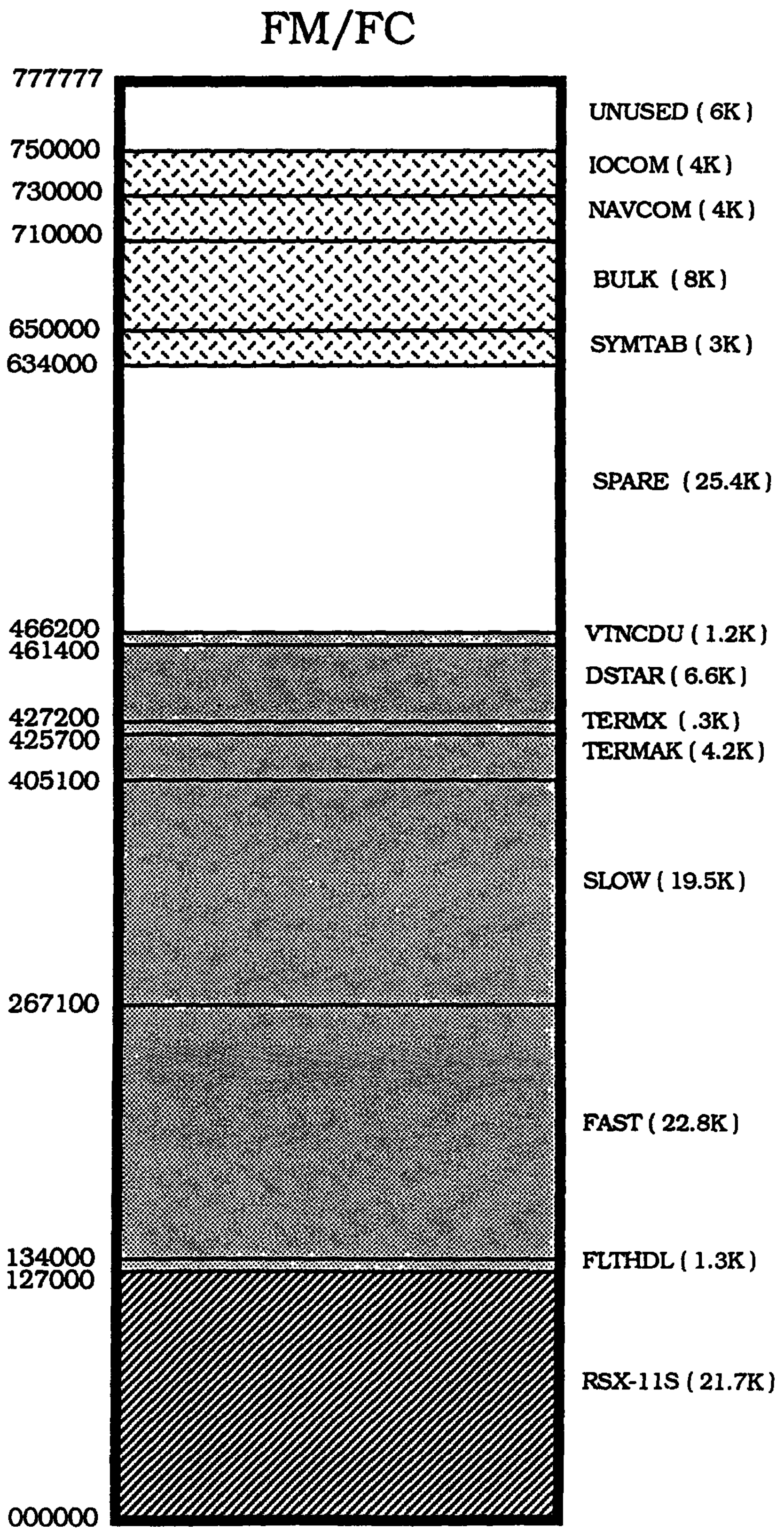
Executing An active task currently using the CPU.

The operating system grants control of the CPU to the highest priority competing task.

In addition to these program tasks, there are resident common data areas through which data are shared among tasks. These areas are called BULK, NAVCOM, and IOCOM. BULK contains the geographic and navigation data required for guidance and for the generation of the Navigation Display (ND), Primary Flight Display (PFD) and NCDU display functions. NAVCOM Rescom contains primarily compools that contain data with initial values. These compools are BCKCOM, FCPOOL, NAVCOM, IOPOOL, and RECOM. IOCOM Rescom contains those compools that do not have initial data values other than zero. These compools are DISNAV and FMBFCM. The IOCOM Rescom is the only Rescom accessed by FLTHDL.

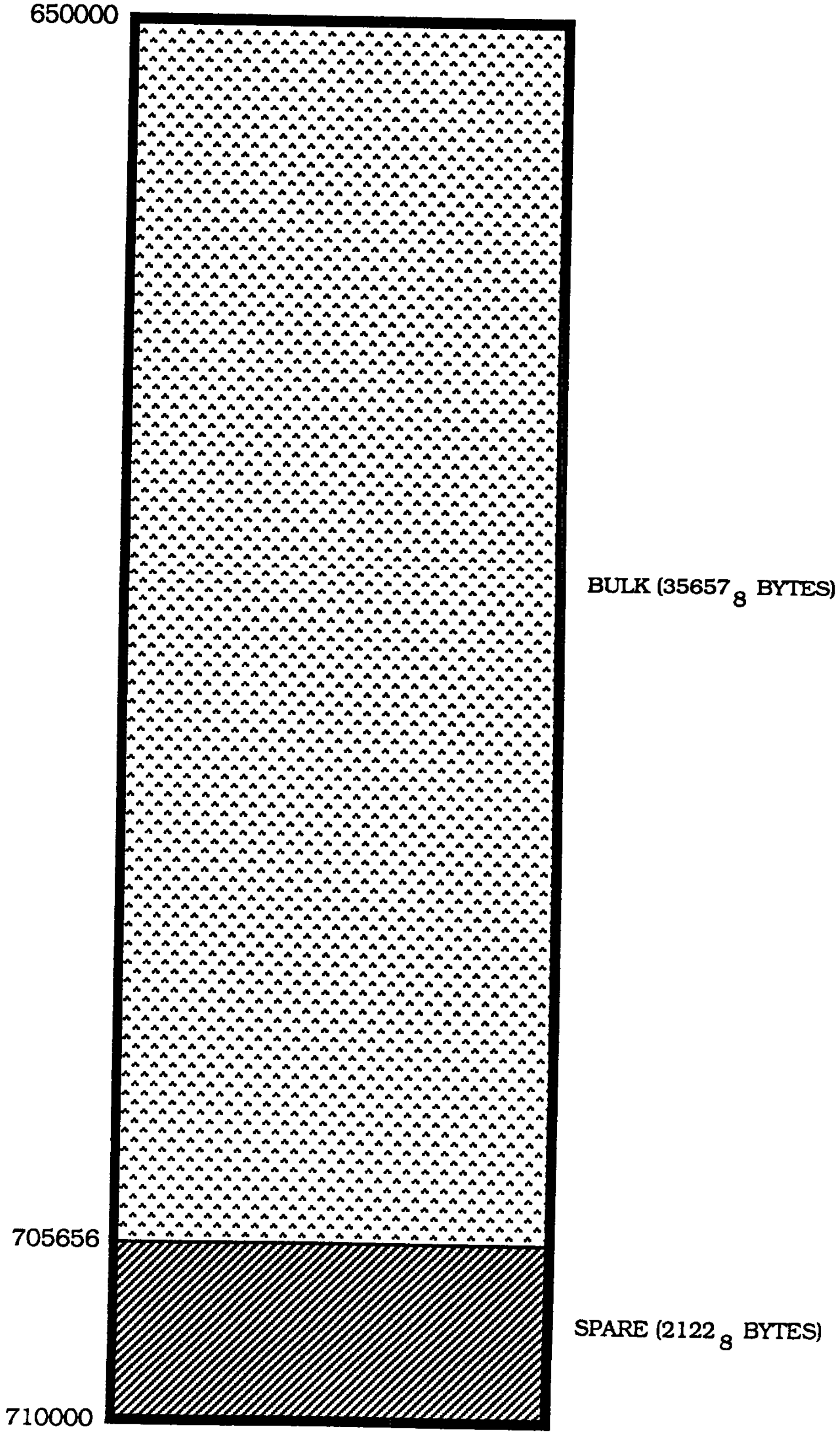
FLIGHT MANAGEMENT/FLIGHT CONTROLS SOFTWARE FOR ATOPS





PHYSICAL MEMORY LAYOUT

BULK (FM/FC)



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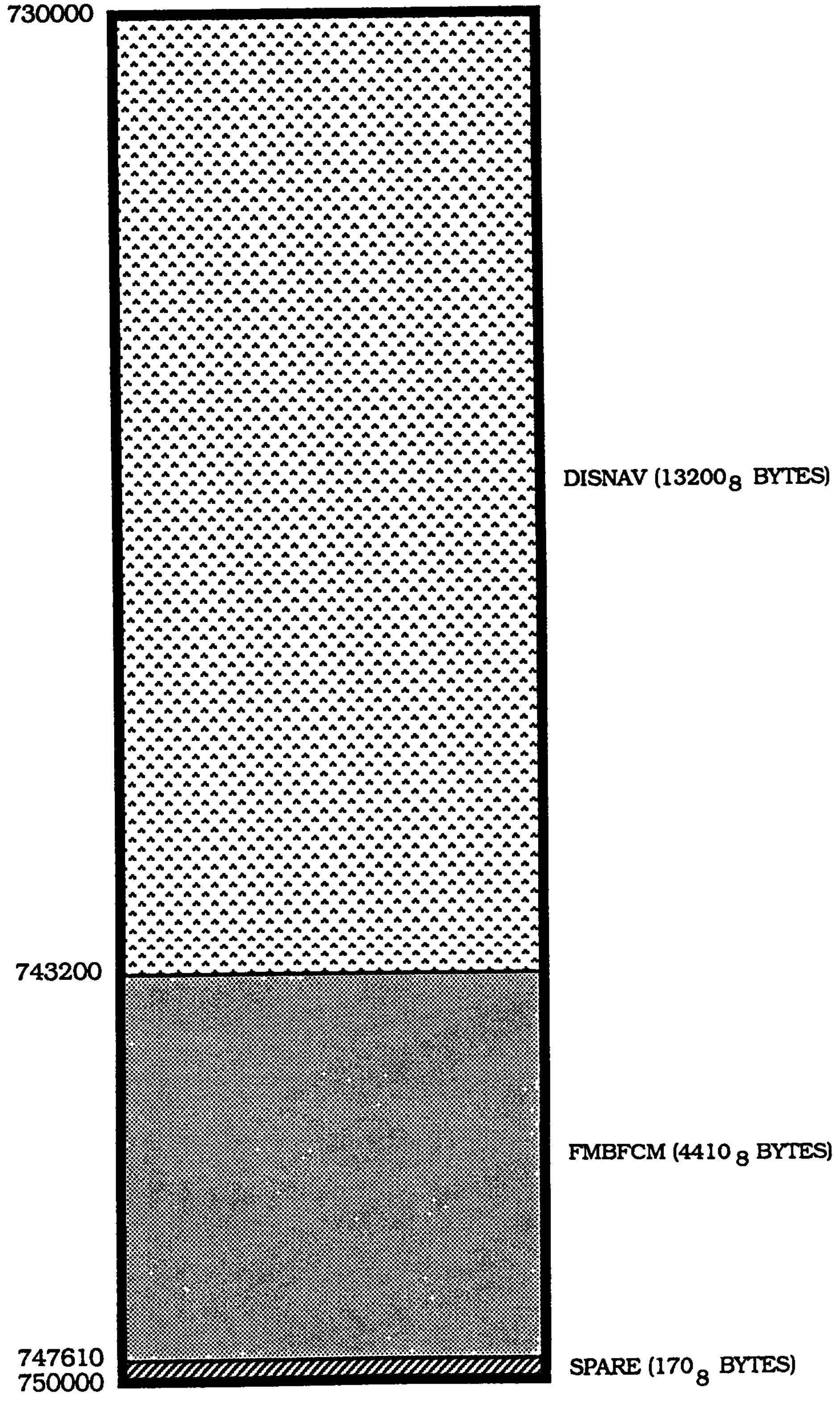
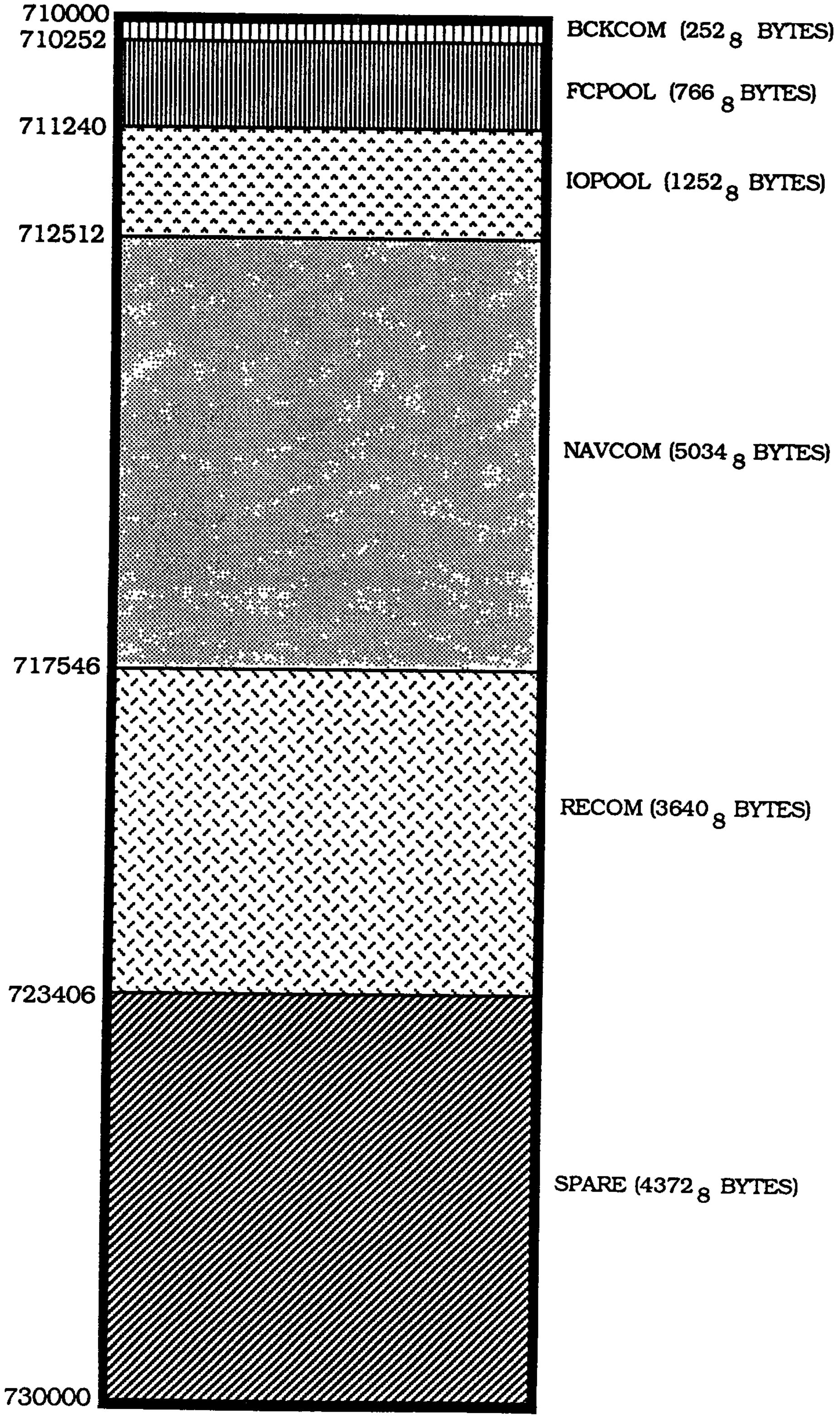

730000
DISNAV (13200$_8$ BYTES)
743200
FMBFCM (4410$_8$ BYTES)
747610
750000
SPARE (170$_8$ BYTES)

NAVCOM (FM/FC)


710000
710252
711240
712512
717546
723406
730000
BCKCOM (252_8 BYTES)
FCPOOL (766_8 BYTES)
IOPOOL (1252_8 BYTES)
NAVCOM (5034_8 BYTES)
RECOM (3640_8 BYTES)
SPARE (4372_8 BYTES)

TASK NAME: FLTHDL

PURPOSE: Executive for Norden #2

TASK SIZE: 1280 words

TASK PRIORITY: 175

INVOKED BY: RSX-11S (RUN FLTHDL)

TASKS INVOKED: None

RESCOMS USED: IOCOM

DESCRIPTION:

This task serves as the overall ATOPS controller, operating in conjunction with the RSX-11S operating system. The entire system is driven by the occurrence of a 10 msec interrupt received via the KW11-P interrupt handler. This interrupt is generated by a 10 msec pulse received from the Digital Autonomous Terminal Access Communication (DATAC) system. The receipt of this interrupt indicates that 10 msec input data can be read and that the 10 msec output data should be written. This is accomplished in FLTHDL by calls to IN10M and OUT10M respectively.

FLTHDL is organized such that it recognizes five distinct 10 msec interrupts. These 10 msec intervals are referred to as minor frames 0-4. In each 10 msec minor frame, the high speed data is output to the EIU/SIU followed immediately by the high speed data input. The high speed data output consists of the following signals:

RUDCMD - rudder command
AILCMD - aileron command
DECMD - delta elevator command

The high speed input data consists of the following signals:

Q - pitch rate
P - roll rate
R - yaw rate
HDD - vertical acceleration
BMACC - body mounted accelerometers.

Five of these 10 msec minor frames are combined to form one 50 msec major frame. During minor frame 0, which coincides with the 50 msec attention bit from the DR11-B DMA interface, denoting the start of a major frame, the large data input is done in addition to the high speed data input. This data block input consists of 362 words being read from the DATAC Shared Interface Ram (SIR) memory using the DR11-B DMA interface. The output of the Data Acquisition System (DAS) recording variables is also done in minor frame 0. A maximum of 150 words can be output to the DATAC SIR memory for subsequent data recording. The limit as far as data recording is concerned is 200 words but a decision has been made to allocate 150 to the FM/FC computer and 50 to the Displays/Data Formatting computer. This decision is not inflexible in that the I/O handler in both machines can be modified to accommodate any combination as long as the total does not exceed the 200 word limit, however this would require concommitant changes in the DATAC system.

In minor frames 1 - 3 only the 10 msec output and 10 msec input is activated. Minor frame 4 begins by activating the 10 msec I/O. Following the 10 msec I/O a test is made to determine whether or not the interprocessor communication, initiated during the previous minor frame 4, has completed. If not, the missed interprocessor communication counter (MSINTP) is incremented for system monitoring purposes. Next, the interprocessor link communication is enabled. This consists of transferring a portion of the resident NAVCOM common area (DISNAV compool in particular) to the Displays/Data Formatting computer. The size of this interprocessor link communication link varies from 219 words to a maximum of 2919 words, depending on the size and status of the guidance buffers. If the guidance buffers are modified, event flag 34 is set by the flight software to initiate the guidance buffer transfer in addition to the basic data during the next major frame. In addition, to guard against software/hardware anomoly, the guidance buffers are transferred once every 4 seconds to ensure that the Display/Data Formatting computer always has the most recent copy of the guidance buffer. This 4 second update rate is also triggered in the flight software by setting event flag 34.

The I/O handler then executes in a continuous loop until it is terminated via an 'ABO FLTHDL' directive. The actual loop performed begins at the label 'LOOP' and continues through frame 4, 'FRM04'.

When the I/O handler is initiated a status check is performed on the external devices needed by the FM/FC computer, namely the EIU/SIU DATAC. Processing will not begin until the connect bit is clear. If a disconnect is sensed, the following message will be displayed on the terminal from which the I/O handler was activated - 'EIU SIU DATAC DISCONNECTED'. Also, processing cannot begin until a 10 msec interrupt is received from the KW11-P real-time clock. The clock interrupt routine is located in the I/O handler and uses the RSX-11S connect to interrupt vector (CINT$) directive to process the interrupt directly. When an interrupt is received from the real-time clock, the interrupt processor sets event flag 4 to signal the handler to begin processing.

One other error condition, the power fail interrupt is addressed by the I/O handler. When this occurs the 10 msec interrupt is re-enabled, the external device status registers cleared (the EIU/SIU DR11-B) the cold start (COLDST) flag is set and processing begins from a restart location (RESTRT).

The two ATOPS computers are designed to operate, to the extent possible, independently of each other. This means that the FM/FC computer can operate even though the Display/Data Formatting computer is not operational or vice versa. While operating in this mode, the interprocessor link is inoperative and, if the flight software is executing, the following message will be displayed on the task initiating terminal - 'tt:tt nn.n% INTERPROCESSOR LINK MISSES, where tt:tt is the time of the message and nn.n is the percentage of interprocessor link misses for the previous 60 seconds. Because the message is actually being printed by the background task (SLOW) and the exact time frame in which it operates varies, the percentage could have a +/- 5% error.

MODULES CONTAINED: IN1OM, OUT1OM

VIRTUAL MEMORY MAP: FLTHDL: 120000 - 124773
IOCOM: 140000 - 157777

TASK NAME: FAST

PURPOSE: Controlling task for the FM/FC Norden.

TASK SIZE: 23328 words

TASK PRIORITY: 160

INVOKED BY: RSX-11S (RUN FAST)

TASKS INVOKED:	RQST$C SLOW	(initially)
	RQST$C DSTAR	(initially)

RESCOMS USED: NAVCOM, IOCOM

DESCRIPTION:

FAST serves as the controlling task for the entire FM/FC ATOPS. It invokes SLOW and calls several procedures that perform system I/O, data recording, mode select panel processing and NCDU functions.

To initiate FAST the user must enter the command "RUN FAST" via the RSX-11S system utility MCR. FAST waits for the occurrence of a 50 millisecond interrupt before processing can begin. A fifty msec interrupt is communicated by task FLTHDL (the I/O handler) when an attention bit is received from the DMA/DATAC interface. It sets event flag 33 for which FAST has been waiting, signaling that external data is available to be read and fast loop processing can begin. The event flag is cleared by FAST, the frame counter updated, and fast loop procedures called.

The main loop processing checks to see if LABFLG is set and MLSVAL is false. If so, an approximation of XYZ position is computed from raw MLS range, azimuth and ALTCOR. This is used to drive the X-Y plotter in the lab. FAST calls each of its modules in the order required to insure that all time critical signals are computed in the same cycle as they are used. In the few cases where best ordering of the modules did not accomplish this, signal computations were moved from one module to another. A brief decription of each module follows, in order as they appear in the calling sequence.

MODULES CONTAINED:

DISFD: DISFD detects momentary discrepancies and failed sensor or serial bus errors for the packed discretes. These discretes are input from triplicated sensors and "debounced" to ensure that any bit change was not a fluke.

IOFLL: This module serves as the link between the Sensor Interface Unit (SIU) and the Input area of the IOPOOL compool. It converts raw sensor data to engineering units for use in the flight software.

MSPLGC: MSPLGC processes inputs from the Control Mode Panel (CMP) to perform the logic associated with the various configurations of the automatic flight mode.

MLSEX: This module is called only when Flight Controls is in RUN mode. Its primary outputs are MLSVAL and the vectors POSHAT. VELHAT. and ACCHAT from the third order complementary filter. The navigation and flight controls variables formerly computed in subrutines NAVOT and FCCOT are now computed in the using modules (HNAVFS, MLOG, LATRL. ELEVP). The subroutine which had computed the MLS derived glideslope and localizer errors (DSPOT), has also been removed from MLSEX and is now a module called from FAST.

MLOG: MLOG controls the operational mode of the Automatic Flight Controls System. Its primary outputs are the operate mode discretes (ICM, RUNM, HOLDM), the flight mode indices (MODEX. MODE2), and the FLAGS array, which contains discretes corresponding to each possible value of MODEX, plus additional discretes for transitional states. In addition, control law variables which are also required by MLOG (DLPSI, HTDZ), or are used or modified by Navigation routines (HDCF, GPGSDV, GPLOCD), are computed here. MLS mode discretes and selected constants (MSW1, MSW6, XFLARE, XGPIP, TANGSA, HGPIP) are set on the first pass that MLSMOD is true.

If no other mode is selected. the operate mode defaults to IC. In this mode, the flight control laws are called, but critical filters are locked in the IC state. The operational flight mode is RUN, selected by pressing the RUN button on the Flight Controls pallet. HOLD is selected by pressing the HOLD button, or is forced when PRE-FLIGHT is selected on the Systm Test Panel (MSWIT = 1) and AEE is true. In HOLD mode, the control law modules (LATRL and ELEVP). the MLS module and the recording modules (DASOT, SNAP, SNPOUT) are bypassed, and MLOG checks only for input of the IC or RUN switches. Note that the AFD/FFD paddles will not remain engaged when in HOLD unless preflight is active. Also. logic in FAILCP prevents the STP mode switch from latching in the preflight position unless SQUAT is true and WSPIN is false.

For a description of the flight modes, see the MLOG documentation.

ACCPRC: This module manipulates the INS Along Track Acceleration (ATKACC) and Cross Track Acceleration (XTKACC) inputs in one of several different ways depending on the bits set in the MLS configuration word (MCONF).

NAVIG: This module operates the simulated airplane. When SIMFLG is set appropriately, it initializes the navigation position and velocity estimates to a given point in space, with a given flight path angle and track angle, then 'flys' the airplane by monitoring the commands output by HVGUID and TGUID, updating its internal variables and over-writing certain input sensor values. The Flight Controls modules are not involved in this process, and should be left in IC or HOLD mode. When operating under ACD simulation, NAVIG is used to initialize the NAV position estimate at the ACD IC position. When Flight Controls is moded from IC to RUN, SIMFLG is cleared, providing a smooth transition to active flight conditions. Note that logic exists in various modules throughout the system to resolve conflicts that might occur between signals generated in NAVIG and signals generated in other modules.

HNAVFS: This module computes the aircraft heading, position, velocities, and accelerations based on any of several sources. Position is output as LAT and LON in degrees and ALTCOR in feet; velocity is output as VN and VE in knots and HDCF in feet/sec; acceleration outputs are VGSDOT, XTACC, and HDDOT, all in ft/sec/sec. Additionally, TK, TKMAG, GS, and GSFPS are derived from VN and VE, GAMMA is derived from HDCF and GSFPS, and DFTANG is derived from TK and HDGTRU. HNAVFS also computes the output booleans, NAVFLG, NAV64K, and LLINIT (based on ground speed), MLSVAL and MLSMOD (based on MLSVLD and MLSSLI), and computes the sine and cosine of LAT, LON, TK and HDGTRU.

If MLSMOD is true, all output variables (except true heading) are derived directly from the MLS vectors POSHAT, VELHAT, and ACCHAT, and the latitude, longitude and elevation of the MLS azimuth site from the RWYDEF array in FSTCOM. If MLSMOD is false, the outputs are assigned from an analogous set of IDD___ variables computed from an initial position and the best available velocity source, corrected by the slow loop radio navigation computations. If the simulated airplane is engaged, initial position, velocities and accelerations are set by NAVIG. Otherwise, INS inputs are used if INAVV is true. Lower quality solutions based on true air speed, magnetic heading and MAGVAR are also available. The vertical vector is derived from INS HDD and HBARO in either event.

HVGUID: HVGUID compares the aircraft position calculated by HNAVFS to the desired path (if any) in the guidance buffers, and generates path and track error signals (XTK, TKE, HER, DFPA3D) and steering signals (LATSTR, VERSTR) depending on the state of the GUID2D, GUID3D and NAV64K discretes and the WPPTR indices. It also computes the indices PTR2D and PTR4D (based on WPPTR) and the booleans, BCFLAG, TURN, TEND, ALTARM, MDWARN, PATHND, and PTH4DN. The following variables are also output from HVGUID for use in other modules: AMG, DTG, DTOGO, RALC, NOMBA, DSRTK, DTOTL, SDC.

TGUID: TGUID calculates the speed command when time guidance or speed mode is selected; i.e, ground speeds are specified for each leg of the path, an arrival time is specified, (if TIME PATH is to be selected), CAS is engaged, and TIME PATH or speed is selected on the Mode Control Panel. TGUID then 'flys' the time box along the path at the speed specified for each leg in the guidance buffers. The distance between the time box and the aircraft position (SEPR) is then calculated, and from this the acceleration command (SCMD) required to bring the airplane position into coincidence with the time box. If the airplane is ahead of the time box and the required speed to capture would be below safe limits, the TOSLOW flag is set and PSTIAS is cleared. This, with additional logic in NCFM and MSPLGC, causes speed control to revert to CAS HOLD at the present speed. If the speed has been increased beyond the CAS or MACH limit, SCMD is forced to -.25 until the speed is again within limits. TGUID clears GUID4D and sets PTH4DN at the end of the path. SEPR, SDCC, and PTH4DN are referenced by NVDMOD for display on the NCDU.

NCFM: This module outputs the steering commands used by flight controls depending on flight mode, and conditionally updates IASSUM, TKASUM, FPASUM, and ALTSUM. BACMD is computed from TK and TKASUM if TKSEL is true, and set to HORPTH otherwise. VACMD is computed from GAMMA and FPASUM if FPASEL is true, from ALTCOR and ALTSUM if ALTSEL is true, and set to VERPTH otherwise. ATCMD is computed from CAS and IASSUM unless TIMPTH is true, in which case it is set to SCMD. NCFM also computes TASFPS, ALFSYN and KALFA.

LATRL: LATRL computes the aileron and rudder commands, based on control inputs selected according to flight mode:

PRENG: AILCMD and RUDCMD are set to ALVDT and DRPOS, respectively.

FFDE: Control input is FWHL and output is AILCMD. RUDCMD is not computed. In this and all higher modes, roll angle and roll rate are feedback terms.

MANEL: Control inputs are DWHL, PEDAL, and ATRIM. In this and all other AFD modes, the sum of ALVDT and ATRIM at AFD engagement is "remembered" as SYNCL, which is subsequently subtracted from the basic aileron command.

ACWSE: Control inputs are as above. Submodes are ATTitude SYNC and ATTitude HOLD. In ATT_SYNC, roll attitude is tracked by PHICMD, which then becomes the reference attitude for ATT_HOLD. If FLAP > 20 deg, PHICMD is washed out and summed with RUDCMD for turn coordination.

VCWSE: This mode has three submodes. Operation in ATT_SYNC and ATT_HOLD is identical to ACWSE. TRACK_HOLD is entered when roll and roll rate are both near zero. In this mode, cross track acceleration is integrated to provide terms used in maintaining a constant ground track.

AUTOE: Control input is BACMD from NCFM unless LAND is selected. Then, once LOCE becomes true, the controlling term is GPLOCD, if in ILS mode, or DELTY (derived from XHAT and YHAT) if in MLS mode.

ELEVP: ELEVP computes the elevator command, stabilizer trim discretes and the throttle position command. DECMD is set to DEPOS if in PRENG, derived from FCOL if in FFDE, or from DCOL if in ACWS OR VCWS. In AUTO mode, the controlling input is VACMD until GSENG, when GPGSDV (in ILS mode) or DELTH (derived from XHAT and ZHAT in MLS mode) becomes the controlling input. At FLARE, one of two flare laws is used to reduce the sink rate to 2 to 3 ft/sec at touchdown. Finally at RLOUT, DECMD is ramped back to zero to lower the nose wheel. Primary feedback terms are PITCH and pitch rate (Q), except in VCWS, where GAMMA is substituted for PITCH. Vertical acceleration is used for additional damping in VCWS, AUTO and LAND, and filtered HDOT (HDCF) is used during LAND. Radio altitude is also used during FLARE.

The stabilizer trim discretes are generated as required to maintain the stab trim (ASTP) signal near zero in all modes except PRENG and MANEL, unless the aircraft is on the ground (GRD = true).

Throttle control is performed wholly within the subroutine ATHCL. The autothrottle engaged discrete (ATE) is set when GRD is false and either IASSEL or TIMPTH is true (TIMPTH is set true for both 4D (TIME) and ground speed modes). If ATE is false, APCDG is synchronized to throttle handle position via the ATFDBK discrete. Otherwise, it is controlled by ATCMD from NCFM and limited by MXEPR from procedure EPRLMT in the slow loop. Feedback terms are TASFPS, ATKACC, EPR1, EPR2, and ROLL. When FLARE becomes true, APCDG is ramped back to zero at 2.8 deg/sec.

DSPOT: DSPOT computes the localizer deviation (ETAH), glide slope deviation (BETAH), lateral beam sensed (DLBS) and vertical beam sensed (DVBS) for transmission to the Display/Data Formatting computer.

FDSTR: This procedure monitors sensor and data path failure indicators, and stores the data for the associated error message in one of two buffers, depending on whether the mode switch on the System Test Panel (STP) is in the FLIGHT or PRE-FLIGHT position. Failures monitored are:

- sensor first and second failures detected by SSFD.
- valid sensor selection index (lower byte of sensor status word < 3).
- sensor validity discretes (e.g, INAVV).
- SSFD interface operational (indicated by toggling of BF+1522).
- watch dog timer wraparound.
- analog (A/D - D/A) wraparound.
- SEIU status (BF+1054).

When a failure is logged, the 'failure read' lamp on the STP is lit, and a flag is set to inhibit logging that same message again. The 'failure logged' flags are cleared only on disengaging/re-engaging the system or pressing the 'ERSET' button on the Flight Controls pallet. Parameters for 16 messages may be logged in each buffer. When the buffer is full, any further errors are ignored. Message buffers are cleared by pressing the 'message clear' button on the STP, and read out by pressing the 'failure read' button.

PRFLT: Subroutine PRFLT contains the control logic for the automated preflight tests. There are seven routines associated with pre-flight, all of which are called from FSTTSK when MSWIT (set in FDSTR) = 1. Note that when pre-flight is active the calls to MLSEX, LATRL, ELEVP, DINUSE and SINUSE are bypassed, and MLOG processing is minimal. The other routines and their functions are as follows.

CTLCK - checks the AFD wheel column, rudder pedal and trim inputs.
CLBIS - sets values in AILCMD, RUDCMD and DECMD.
RDALT - tests the radar altimeters.
ILSRC - tests the ILS localizer and glideslope receivers.
RGYRO - tests the rate gyros (yaw, pitch, roll).
SRVCK - tests the aileron, spoiler panel, rudder, elevator and stabilizer position inputs.

Procedure FDSTR is active during pre-flight and logs errors resulting from sensor disagreement. Errors of magnitude are logged by the preflight routines directly.

DINUSE: DINUSE sets the 'discrete-in-use' flags based on flight mode (MODEX) and the LOCE, GSENG, ATE, and MLSMOD discretes. These flags enable error checking of the associated discrete. DINUSE is not called in preflight.

SINUSE: SINUSE sets the in-use flags for variable input signals. These flags, plus the CRSET discrete and the INSST flag, are packed into four words (SINUSO, -1, -2, -3) and shipped to the DS/DF computer for use by the SSFD module. SINUSE is not called in pre-flight, as pre-flight sets its own in-use flags.

F2CMP: This module checks the signal second fail flags (set by SSFD/DISFD) for each signal in use in the engaged mode (indicated by MODEX), and sets the mode second fail flag if any required signal is failed. MODEX is limited to 7 (LANDE) for these checks. Entry 8 of the FAIL2 table is used to record autothrottle failure (if ATE), and entry 9 is used to record MLS mode failure. If CRSET is true the FAIL2 table is cleared, and if ERSET is true the 'failure logged' tables are cleared and the FAILURE READ lamp turned off. If preflight is engaged, only CRSET and ERSET checks are performed.

PANEL: PANEL is the System Test Panel service routine. It builds the SWITCH and LIGHTS words, formats and displays stored messages, and clears the message table on request.

MSPRO: This module contains the logic required to compute the outputs needed to light the appropriate mode lights and airspeed, altitude, flight path angle, and track angle digital displays.

DASOT: This module processes the recording tables set up by DSTAR and loads the DAS recording buffer accordingly. It also sets the variables for MLS valids (MLSOV, DMFLC), the packed discrete word (DISOUT) and the recording selection words (SELWD1, SELWD2, SELWD3). It computes the difference between IDD latitude and MLS latitude (LATDIF) and the difference between IDD longitude and MLS longitude (LONDIF).

NCDKEY: NCDKEY interprets the NCDU inputs, posts alert messages, and synchronizes the navigation display updates with the guidance buffer changes. This module is the foreground executive which controls the NCDU background.

OUTIO: This module serves as the link between the Effector Interface Unit (EIU) and the output area of the IOPOOL compool. It converts output data from engineering units to fixed point data for output to the effectors.

SNAP: SNAP records single-event values, called snapshots, for selected variables and stores them in a data table for output to the line printer. This routine is called only if the run switch has been pressed on the flight controls mode panel (this sets the "RUNM" boolean true). If this is the first pass of the FAST task since the cold start flag, "COLDST", has been set, the system diagnostic variables are cleared. These include the following:

MSWIT	-	Flight Controls Mode Switch
OVER	-	Timer Overflow counter for 60 seconds
SUMOVR	-	Timer overflows, cumulative since last cold start
MAXF	-	Maximum Frame Time
FIFTY	-	The 50 Msec Interrupt Counter

FRAMES - The 10 Msec Frame Counter
COLDST - Cold Start Flag

A comparison is then made of the current frame time to the maximum frame time and the greater of the two stored in "MAXF". A filtered frame time is then computed and stored in FSTCNT to show the approximate time in milliseconds the fast loop is consuming. A test is made to see if the next 50 msec interrupt has occurred, and if so the overflow variable, "OVER", is incremented and event flag 33 cleared to force a wait until the next 50 msec interrupt.

The SLOW task, which was invoked by FAST at priority 40, runs continually in the background mode. Therefore any time remaining in the 50 msec interval not used by the FAST task will allow the SLOW task to resume execution until the next 50 msec interrupt occurs, which reactivates the FAST task. FAST then goes back to the process of calling its embedded procedures.

To terminate the ATOPS software, the user enters the command "ABO FAST" via the RSX-11S MCR utility. When FAST recognizes that an abort command has been entered, it aborts the other active task (SLOW) and exits back to the RSX-11S operating system.

MODULES CONTAINED: ACCPRC, CLBIS, CTLCK, DASOT, DINUSE, DISFD, DSPOT, ELEVP, FDSTR, F2CMP, HNAVFS, HVGUID, ILSRC, IOFLL, LATRL, MLOG, MLSEX, MSPLGC, MSPRO, NAVIG, NCDKEY, NCFM, OUTIO, PANEL, PRFLT, RDALT, RGYRO, SINUSE, SNAP, SRVCK, TGUID,

VIRTUAL MEMORY MAP:

FAST:	000000 - 127226
NAVCOM:	160000 - 177777
IOCOM:	140000 - 157777

MODULE NAME: FAST

PURPOSE: Initiate tasks and procedures in NORDEN #2 computer.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: None (main program)

CALLING SEQUENCE: N/A

CALLS TO:

ABORT	(C)	ACCPRC	(A)	CLBIS	(C)	CTLCK	(C)
DASOT	(C)	DINUSE	(C)	DISFD	(A)	DSPOT	(B)
ELEVP	(C)	FDSTR	(B)	F2CMP	(A)	HNAVFS	(A)
HVGUID	(A)	ILSRC	(C)	IOFLL	(A)	LATRL	(C)
MLOG	(A)	MLSEX	(A)	MSPLGC	(A)	MSPRO	(B)
NAVIG	(A)	NCDKEY	(A)	NCFM	(A)	OUTIO	(A)
PANEL	(A)	PRFLT	(C)	RDALT	(C)	RGYRO	(C)
SINUSE	(C)	SNAP	(C)	SNPSET	(C)	SRVCK	(C)
TGUID	(A)						

(A) Called every frame (50 milliseconds)
(B) Called on alternate frames (100 milliseconds)
(C) Called conditionally

DESCRIPTION:

FAST is the fast loop task's (FAST.TSK) driver program. The console command "RUN FAST" causes both tasks FAST and SLOW to start. See TASK documentation for information on the interaction between the tasks. FAST also calls fast loop procedures to perform necessary 50 and 100 millisecond functions.

The first thing done in FAST is to set up ASTs (Asynchronous System Traps) to provide for fielding attempted aborts of the task and floating point errors. The console command "ABO FAST" will cause both the FAST and SLOW Task to terminate. Floating point processor errors which occur in FAST (overflow conversion to integer, and divide by zero) will be displayed on the console by a floating point exception AST. See "RSX-11M EXECUTIVE REFERENCE MANUAL" for information on ASTs.

The main body of FAST is the 50 millisecond loop (major frame). All previously mentioned activities are performed once before entering into a continuous loop. The start of a new major frame is synchronized with the handler (see TASK documentation on FLTHDL) via system event flag 33. The setting of event flag 33 causes FAST to immediately enter into a major frame. Within this major frame, time computations are made and procedures are called. One set of conditional inline code computes an approximation of POSHAT (the X,Y,Z position vector) when LABFLG is true and CFRUN is zero (indicating that MLSEX is not computing POSHAT) from raw MLS azimuth and range inputs. This is used to drive the X-Y plotter in the lab

Some procedures are called on alternate frames to give a 100 millisecond loop. The time computations involved are the running time count (BINTME), the maximum frame time (MAXF), and the filtered frame time (FSTCNT). The units of BINTME is seconds, therefore an increment is performed every 20 frames. Each major frame is divided into five 10 millisecond minor frames. The current minor frame (0 - 4) is available in the compool variable MFRAME. At the finish of the major frame, MFRAME is used to determine how many minor frames have elapsed since the start of the major frame. The result is filtered to give an approximate average time elapsed in performing all 50 millisecond computations. Also the maximum MFRAME detected at the finish is stored as MAXF. The major frame is concluded by testing whether the processing time exceeded the allowed 50 milliseconds by testing event flag 33 to see if another major frame should have already begun. If so, the overflow count (OVER) is incremented and event flag 33 is cleared, which causes FAST to wait for the next major frame before starting again.

GLOBAL INPUTS: ALTCOR, COLDST, CFRUN, FSTSNA, LABFLG, HOLDM, RUNM,
MFRAME, MLSRAW, MSWIT, POSHAT, ZOMLS

GLOBAL OUTPUTS: BF (selected areas), BINTME, COLDST, FIFTY, FRAMES,
FSTCNT, MAXF, KHD, MSWIT, OVER, SPBPSW, SUMOVR, TAT,
TOG100

TASK NAME: SLOW

PURPOSE: To provide the background software functions which include navigation, NCDU functions, and error monitoring.

TAS SIZE: 19968 words

TASK PRIORITY: 40

INVOKED BY: FAST (RQST$C SLOW - issued by module FAST)

TASKS INVOKED: None

RESCOMS USED: IOCOM, NAVCOM, BULK

This task contains all the background functions for the ATOPS flight software. Included in these functions are the NCDU functions, navigation, earth radius computations, wind speed/direction computations, EPR limit computations, failure message processing and error monitoring.

SLOW is invoked by FAST at the lowest priority in the system (priority 40) so that it runs in the background, i.e.; only when no other tasks are active. Since SLOW is the lowest priority task in the computer, it runs constantly until interrupted by a higher priority task or until stopped by aborting task FAST which, as part of the shutdown process, also aborts SLOW.

While running, SLOW counts the number of 10 millisecond frames required for the background functions to execute. This time is stored in a global variable, SLWCNT, so that it can be monitored at execution time to analyze system performance. SLOW then maps to the appropriate memory resident overlay if SIMFLG is on (Simulated Airplane active), to initialize the simulated airplane (procedure SMINIT). The background functions are then called in the following order:

NCDUEX	-	NCDU Executive
HNAVSL	-	Navigation Slow Loop
ERAD	-	Earth Radius Computations
BLOW	-	Wind Speed/Direction Computations
EPRLMT	-	Engine Pressure Ratio Limits Computations

Since SLOW exceeds 32K words of memory it has been organized into memory resident overlays. Memory resident means that the entire task is physically resident in memory but due to limits of the PDP-11/70 architecture, only 32K words of the task can be active at any given time (refer to the RSX-11M Task Builder Manual for a complete discussion of memory resident overlays). Each overlay portion of the task is referred to as a segment. Two procedures, SLOW and NCDUEX, determine which segment will be "mapped" at any given time during execution of SLOW. Procedure MAP handles the manual segment switching.

The NCDU executive (NCDUEX) determines from the NCDU mode switch or the selected NCDU function key which overlay segment to "map".

Following is a list of segment numbers and the procedures contained in each segment:

segment #	procedures contained
1	ATCMOD,FLTMOD,INIMOD,ACTOPV,LABEL
2	LOKMOD,NVDMOD
3	TSTMOD,DEBUG,DECODE,SELMOD,SMINIT,SNPOUT GMSG
4	PATHDF,SRPTA,NCDGUD,BUFSWT
5	FLTEM
0 (ROOT)	SLOW,NCDUEX,INSELH,WPINVT,HNAVSL,TUNCK, TUNXTK,ERAD,BLOW,EPRLMT

Once a given segment has been "mapped", it remains active until a function is selected via the NCDU which requires that another segment be mapped. (See NCDU documentation for more details.)

The mainline functions of SLOW are contained in the root segment. These are the navigation functions, EPR computations, the wind speed/direction computations, and the earth radius computations, which are called during each iteration of SLOW. During each iteration, a test is also made to determine whether any "snapshot" data needs to be printed. This is determined by comparing the "store" pointer to the "read" pointer. If they are not equal then "snapshot" data needs to be printed. This is accomplished by "mapping" to segment 3 and calling the SNPOUT procedure.

Following completion of the mainline routines, a 60 second timer AST-set flag is tested to see if 1 minute has elapsed and if it has, segment 5 is "mapped" and the error monitor (FLTEM) is called to display any error conditions that have occurred during the previous minute. These errors include missed 10 millisecond interrupts, missed 50 millisecond interrupts, 50 millisecond timer overflows, and missed interprocessor links.

Finally a test is made to determine if a message needs to be displayed on the system test panel. If so, this requires the "mapping" of segment 3 and calling the GMSG procedure.

If at any time during the execution of the SLOW task a floating point exception should occur, the floating point exception procedure (FPEXCP) is invoked which displays a message on the system console device. This message gives the location of the program counter and register contents and the type of exception as a debugging aid.

MODULES CONTAINED: ACTOPV, ATCMOD, BLOW, BUFSWT, DEBUG, DECODE, EPRLMT, ERAD, FLTEM, FLTMOD, GMSG, HNAVSL, INIMOD, INSELH, LABEL, LOKMOD, NCDGUD, NVDMOD, NCDUEX, PATHDF, SELMOD, SLOW, SMINIT, SNPOUT, SRPTA, TSTMOD, TUNCK, TUNXTK, WPINVT

VIRTUAL MEMORY MAP:

NAVCOM:	160000 - 177777
IOPOOL:	140000 - 157777
BULK:	100000 - 137777
SLOW:	000000 - 057777

BULK:	100000 - 137777
SLOW:	000000 - 057777

MODULE NAME: SLOW

PURPOSE: Calls background procedures.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: None (main program)

CALLING SEQUENCE: None

CALLS TO:

SMINIT	(B)
HNAVSL	(A)
ERAD	(A)
BLOW	(A)
EPRLMT	(A)
FLTEM	(C)
SNPOUT	(B)
GMSG	(B)
FPEXCP	(B)
MAP	(B)
NCDUEX	(A)
SNPSET	(B)

(A) Called each time.
(B) Called conditinally.
(C) Called every minute.

DESCRIPTION:

SLOW is a background task's (SLOW.TSK) driver program. The module acts mainly as a caller, but also performs a background elapsed time calculation and handles floating point processor exception traps, and controls the breakpoint/SNAP function for the task.

GLOBAL INPUTS: BINTIME, FRAMES, LABFLG, SIMFLG, IOACT, RPTR, SLWSEG, SLWSNA, SPTR, WRDCNT

GLOBAL OUTPUTS: SEG, IOACT, SLWCNT

MODULE NAME: FLTEM

PURPOSE: Display I/O handler related error messages at system console.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: SLOW

CALLING SEQUENCE: CALL FLTEM

CALLS TO: BCDTIM

DESCRIPTION:

FLTEM is called once each minute, from the background task SLOW, to display I/O handler error messages. Error counts for the previous minute are checked and if none exceed a threshold value a return is made after reseting all the error counters to zero. The threshold value for all but the timer overflow counter is 2 percent of the maximum errors that could occur in the 1 minute time span. If any timer overflow errors occur during the preceeding minute that error message will be displayed. See FLTHDL documentation for the description of the error counters. Also see description of module FAST for the description of the timer overflow counter.

The following is a sample console print out when all six counters have errors beyond the toleration threshold.

```
08:47:25    10.0% 10 MSEC MISS
08:47:25     2.8% 50 MSEC MISS
08:47:25     6.4% I/P LINK MISS
08:47:25     5.0% EIU/SIU ERR
08:47:25    12.1% I/P LINK ERR
08:47:25     8.3% OVERFLOWS
```

GLOBAL INPUTS: EIUERR, INTERR, MS10ML, MS50ML, MSINTP, OVER, SUMOVR

GLOBAL OUTPUTS: None

MODULE NAME: MAP

PURPOSE: Change mapping registers for various overlay segments.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX, SLOW

CALLING SEQUENCE: SEG = N (N - number of desired overlay segment)
CALL MAP

CALLS TO: $LOAD

DESCRIPTION:

Before a call to a subroutine that resides in a memory resident overlay segment is made, a call to MAP is made to assure the virtual address mapping registers are set to the desired overlay segment. A number corresponding to the desired segment is stored in the global SEG before the call to MAP. The subroutine MAP has the currently mapped segment number in its local variable CSEG. If SEG and CSEG are the same an immediate return results. Otherwise the desired segment is mapped by calling the system subroutine $LOAD with the name of the segment that corresponds to the number in SEG. See RSX-11M Task Builder manual for information about $LOAD and overlays. Also see task documentation for SLOW for the description of the task overlay setup.

GLOBAL INPUTS: SEG

GLOBAL OUTPUTS: None

2.8 COMPOOLS

BCKCOM COMPOOL

BCKCOM is included in the NAVCOM resident common. BCKCOM contains variables that are referenced only from the background navigation software.

BCKCOM COMPOOL VARIABLES

ACMODE	INTEGER	ATC CLEAR MODE
ACTPOS	INTEGER	ACTIVE STR. POSITION
ALRMES	INTEGER	ALERT MESSAGE CODE
ATCMWP	BOOLEAN	THREE WAYPOINT FLAG
ATC2	ARRAY(12) INTEGER	"EXEC OR REJ" MSG
AUMODE	BOOLEAN	NCDU AUTO MODE
BARALR	BOOLEAN	BAROSET ALERT FLAG
BAZFLG	BOOLEAN	BACK AZIMUTH ILD GAINS
BRGLS	SCALAR	BRG FROM LOCALIZER SHACK
DATNUM	INTEGER	FUNCTION DATA READY
DECNUM	INTEGER	DECODED KEY CODE
		1=WPT 7=RWY 13=EXEC
		2=AWY 8=GS 14=UP
		3=RAD 9=SID 15=DN
		4=F/L 10=STAR 16=CLR
		5=ALT 11=PTA 17=RJCT
		6=RTZ 12=ARPT
DUALNM	INTEGER	DUAL NUMBER FUNCTION
FLSTA2	BIT(16)	STATION 2 FAIL FLAGS
FLSTA3	BIT(16)	STATION 3 FAIL FLAGS
FPMODE	INTEGER	FLIGHT PLAN MODE
FUNUMB	BOOLEAN	NUMERIC FUNCTION FLAG
F0G	INTEGER	DME 3 FAIL FLAGS
F2G	INTEGER	DME 2 FAIL FLAGS
F3G	INTEGER	VOR 2 FAIL FLAGS
GDTIME	SCALAR	BUFFER SEND TIMER
INMODE	INTEGER	INITIALIZE MODE
KEYUNL	BOOLEAN	KEYBOARD ENABLED
LOKCEN	BOOLEAN	MAP CENTER REF. FLAG
LUMODE	INTEGER	NCDU LOOK-UP MODE
MAMODE	BOOLEAN	NCDU MANUAL MODE
MNAVTY	BIT(16)	NAVIGATION MODE
MODPAG	INTEGER	PAGE MODE
MODUPD	BOOLEAN	MODE UPDATE
NCDERR	INTEGER	NCDU ERROR CODE
NCDSPC	INTEGER	NUMBER FUNCTION RECEIVE
NCDUFN	INTEGER	FUNCTION INPUT
NCMESG	ARRAY(11) INTEGER	NCDU INPUT LINE
NDMODE	INTEGER	NAV DATA MODE
NUPAGE	INTEGER	NEW PAGE REQUEST
PAGSEN	BOOLEAN	PAGE SEND FLAG
PROV	BOOLEAN	PROVISIONAL MODE
PRVMP	BOOLEAN	PROV MAP
PTAFLG	BOOLEAN	PTA'S CALC FLAG
PTAPOS	INTEGER	PTA WAYPOINT POSITION
PTATIM	SCALAR	PTA AT THE WAYPOINT PTAPOS
PWEND	INTEGER	WAYPOINT TERMINATION POINTER
RINPFL	BOOLEAN	STATION SEARCH IN PROGRESS
RNGLS	SCALAR	RANGE TO LOCALIZER SHACK
RSTCTR	INTEGER	STATION CYCLE INDEX
RTNPRV	ARRAY(5) INTEGER	TUNDM2 SCRATCH
RTNSCR	INTEGER	SCRATCH VARIABLE
RWYCNT	INTEGER	RWY HEADING TO INS CTR.

BCKCOM COMPOOL VARIABLES (cont)

RZNCTR	INTEGER	ZONE COUNTER (CYCLIC)
RZNPTR	INTEGER	ZONE POINTER
SEMODE	INTEGER	NCDU SELECT MODE
SLLAT	SCALAR	LOCAL IDDLAT
SLLON	SCALAR	LOCAL IDDLON
STATUS	BOOLEAN	NAV SOURCE SIGNAL FAILURE
ZONELM	INTEGER	ZONE LIMIT

BULK DATA STORAGE

Bulk Data is the organization for storage of navigation and geographic data required for guidance, ND map display, and NCDU display functions of the ATOPS system. 8192 words (2 APRs) of memory are allocated for storage in both the Display and FM/FC Nordens.

Bulk Data is separated into primary categories: longitudinal strips, airways and routes, Standard Instrument Departures (SID) and Standard Terminal Arrival Routes (STAR), airfields, geographic reference points, navaids, terrain objects, and boundaries. Data in each category is tabulated and stored in a dedicated format.

The first 14 words of Bulk Data consists of the pointer table (see Table 2-1). Each location in this table is a pointer to a dedicated buffer zone.

-- Longitudinal Strip Data Zone (Index Block)
-- Airways and Routes Data Zone
-- Boundary Data Zone

INDEX BLOCK POINTER

The index block pointer (IBPTR) points to a category of data in each longitudinal strip. These categories are:

-- West Boundary Longitude
-- East Boundary Longitude
-- Airfields
-- Geographic Reference Points
-- Navigational Aids
-- Terrain Objects

The pointers in each strip contain the memory address of the first data word in the buffer associated with each category of data (see Table 2-2).

AIRWAYS AND ROUTES POINTERS

The Airways and Routes pointers (JETPTR, VICPTR, RTEPTR) point to VOR/DME defined airways, area navigation airways and special predefined routes representative of airline company routes. This buffer is organized to define each airway or route as a list of pointers (addresses) to data in other buffers.

The buffer is subdivided into three areas dedicated to:

-- Routes
-- Jet Airways
-- Victor Airways

BOUNDARY ZONE POINTER

Restricted area (RESPTR), Air Defense Identification Zone (ADZPTR) and Coastal Air Defense Identification Zone (CDZPTR) pointers point to the boundary data zone.

INDEX BLOCK FOR LONGITUDE STRIPS BUFFER

The first four words of data consists of the East and West boundaries for the longitudinal strip. The first strip is geographically the western-most strip. The next four words are pointers to specific data buffers. If a pointer is zero, there is no data in the buffer for that strip. There can be no zero longitude, so two consecutive zero terminators will indicate an end of the longitude strip buffer. (See Table 2-2.)

AIRWAYS AND ROUTES DATA BUFFER

The airway and route buffers contain the name of the JET or VICTOR airway in ASCII characters, a pointer to the name in the next data block, and a pointer to each waypoint in the airway or route; waypoints include VOR/VORTAC intersections and geographic references. (See Table 2-3.)

SID/STAR INDEX BLOCK AND DATA BUFFER

SIDs and STARs are identifed by an alphanumeric designator of up to six characters. To facilitate access to the data, the buffer is preceded by SID and STAR index blocks organized as shown in Table 2-4. The SID index table includes pointers to SID data buffers. The STAR index table follows the same format. The SID/STAR buffer organization is shown in Table 2-5. This buffer contains the following:

-- SID/STAR name, in ASCII format (3 words)
-- pointer to the next SID/STAR in the data block
-- pointer to the associated runway

For each waypoint in the SID/STAR the buffer contains
-- pointer to the waypoint referenced by this SID/STAR
-- altitude of the waypoint (negative altitude denotes the entry of a DME Arc path segment)
-- speed at the waypoint (negative speed indicates that airspeed references from the NCDU should be used for display)
-- radius of turn
-- zero unless a DME turn, in which case it contains bearing from the turn center to the inbound waypoint (turn angle is stored in this position of the outbound waypoint of a DME turn. A negative turn angle denotes a left turn.)

Two consecutive zero terminators indicate the end of the buffer.

AIRFIELD AND RUNWAY BUFFER

The airfield data buffer will include airfield name, latitude and longitude of the reference point, a pointer to the next airfield in the block, the length of the longest runway, azimuth of longest runway, magnetic variation, elevation of reference point, pointer to terminal data (not used), and 4 words of 2x5 frequency data. Potential origin or departure airfields are distinguished from airfields for ND display only by having no terminator (equal to zero) following the last 2x5 frequency (ATIS). Instead, SID and STAR index, name of runway, latitude and longitude threshold, outer marker, and runway data follow. (See Table 2-6.)

NAVAIDS BUFFER

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

-- VORTAC's
-- VOR's
-- Non-directional Radio Beacons (NDB)

The buffer format is defined in Table 2-8. The format has the navaid name in ASCII characters, frequency in 2x5 code, a formatted word giving the navaid type, where:

-- bit 4	0 = low altitude, 1 = high altitude
-- bit 2,3	00 = VOR, 01 = VORTAC, 10 = NDB

also the latitude and longitude, magnetic variation, and the elevation in feet.

TERRAIN BUFFER

The buffer contains two categories of data:

-- Mountains
-- Obstructions

This buffer includes altitude (ASCII characters) in thousands, a zero in bit position 15 for mountains and a one for obstructions, and latitude and longitude of the terrain object. (See Table 2-9.)

BOUNDARY DATA BUFFER

This data is used for ND map display only. The boundary data buffer defines restricted areas, coastal air defense indentification zones (CADIZ), and air defense identification zones (ADIZ) boundaries. The first three words in the block define the zone name in ASCII characters, followed by the boundaries in latitude and longitude pairs. Two consecutive zero terminators indicate the end of the buffer. The boundary data buffer is the last information in Bulk Data. It is followed by a global label, B4CKZ2, which contains two ASCII characters for the version I.D. (See Table 2-10.)

```
KWAL:    .WORD    "KW               ;KWAL
         .WORD    "AL               ;
         .FLT2    37.9427777        ;N 37 56 34
         .FLT2    -75.466666        ;W 75 28 00
         .WORD    G28               ;GENERATED BLOCK POINTER
         .FLT2    8748.             ;RUNWAY LENGTH
         .FLT2    32.1899999        ;HEADING
         .FLT2    -9.0              ;AZIMUTH
         .FLT2    41.               ;ELEVATION
         .WORD    0                 ;
         .WORD    005060            ;126.5       Tower frequency
         .WORD    024510            ;0           Clearance frequency
         .WORD    024510            ;0           Ground control frequency
         .WORD    024510            ;0           ATIS frequency
         .WORD    SIDWAL            ;SID/STAR
         .WORD    STRWAL            ;SID/STAR
WAL04X:  .WORD    "04               ;04
         .WORD    0                 ;MISSED APPROACH PATH
         .FLT2    37.9270277        ;N 37 55 37.3
         .FLT2    -75.470944        ;W 75 28 15.4
         .WORD    0                 ;OUTER MARKER NAME - NOT USED
         .WORD    0                 ;OUTER MARKER NAME - NOT USED
         .FLT2    37.9502777        ;N 37 57 01.0
         .FLT2    -75.452472        ;W 75 27 08.9
         .FLT2    8748.             ;RUNWAY LENGTH
         .FLT2    32.1899999        ;AZIMUTH
         .FLT2    40.               ;ELEVATION
         .FLT2    3.0               ;GLIDE SLOPE
         .WORD    024510            ;0
         .WORD    0                 ;BLOCK TERMINATOR
```

TABLE 2-6.- AIRFIELD/RUNWAY BUFFER

```
 GRW74:                              ;GRW74
GAPAN:   .WORD    "GA
         .WORD    "PA
         .WORD    116
         .FLT2    37.89458333
         .FLT2    -75.49711111
         .WORD    SWL
LEE01:   .WORD    "LE
         .WORD    "E0
         .WORD    61
         .FLT2    37.8635
         .FLT2    -75.52180556
         .WORD    SWL
LEE02:   .WORD    "LE
         .WORD    "E0
         .WORD    62
         .FLT2    37.83325
         .FLT2    -75.46116667
         .WORD    SWL
```

TABLE 2-7.- GEOGRAPHIC REFERENCE POINT BUFFER

CONCOM COMPOOL

CONCOM is included in the SLOW and FAST tasks of both the Flight Management and Displays systems. CONCOM contains standard vales for constants that are used throughout the system.

CONCOM COMPOOL VARIABLES

BSETO	INITIAL (29.92) SCALAR	SEA LEVEL PRESSURE (IN)
C360	INITIAL (360.) SCALAR	360 DEGREES
DEG15	CONSTANT (15.) SCALAR	15 DEGREES
DEG25	CONSTANT (25.) SCALAR	25 DEGREES
DELTAT	INITIAL (0.05) SCALAR	DELTA TIME FRAME (SEC)
DLT100	INITIAL (0.1) SCALAR	DELTA TIME FOR 100 MSEC LOOP
DTOR	INITIAL (.0174532925) SCALAR	CONV DEG TO RADIANS
ELLIP	INITIAL (.0033901) SCALAR	ELLIPTICITY FACTOR
FTONM	INITIAL (1.6457883E-4) SCALAR	FEET TO NM CONV
GRAVO	INITIAL (32.1739) SCALAR	NOMINAL ACC OF GRAVITY (FPS2)
ITIME	CONSTANT (0.5) SCALAR	ITERATION TIME CONSTANT
KTOFPS	INITIAL (1.687809858) SCALAR	CONV FROM KNOTS TO FPS
NMTFT	INITIAL (6076.11549) SCALAR	CONV FROM NM TO FT
ONE80	CONSTANT (180.) SCALAR	180 DEGREES
PI	INITIAL (3.1415927) SCALAR	PI
RADIUS	INITIAL (3443.93618) SCALAR	NOMINAL EARTH RADIUS (NM)
RTOD	INITIAL (57.29578) SCALAR	CONV RADIANS TO DEG
WPSIZ	INITIAL (90) INTEGER	WAYPT BUFFER SIZE (BYTES)
ZERO	CONSTANT (0.) SCALAR	ZERO

DISNAV COMPOOL

DISNAV is included in the IOCOM resident common of both Flight Management and Displays systems. DISNAV contains navigation and display variables that are set by the FM/FC Norden #2 and transmitted to Norden #1 over the interprocessor link. In addition to containing many discretes, integer flags and scalar signals, DISNAV contains the active and provisional guidance buffers.

DISNAV COMPOOL VARIABLES

ACTERM	INTEGER INITIAL	0 WORD TERMINATOR TO ACTIVE
ACTIVE	STRUCTURE	THE ACTIVE GUIDANCE BUFFER
ACTIVE.PWA02	SCALAR	ARC LENGTH OF CURVE 0 2 (FT).
ACTIVE.PWASS	INTEGER	0=AWY 1=SID 2=STR 3=MAP 4=NOMAP
ACTIVE.PWBRG	SCALAR	BEARING
ACTIVE.PWCCD	SCALAR	CENTER TO CENTER DIST (FT).
ACTIVE.PWDMA	BOOLEAN	DME ARC?
ACTIVE.PWDMI	BOOLEAN	DME ARC STOP CALC
ACTIVE.PWDTT	SCALAR	TANGENT PT TO WPT DIST (FT).
ACTIVE.PWFLL	BOOLEAN	FLIGHT LEVEL?
ACTIVE.PWGAM	SCALAR	PATH GRADIENT (DEG).
ACTIVE.PWH	SCALAR	ALTITUDE (FT).
ACTIVE.PWIRL	BOOLEAN	IAS REFERENCE?
ACTIVE.PWLAT	SCALAR	LATITUDE (DEG).
ACTIVE.PWLGRF	SCALAR	DME ARC REFERENCE LON (DEG).
ACTIVE.PWLON	SCALAR	LONGITUDE (DEG).
ACTIVE.PWLTRF	SCALAR	DME ARC REFERENCE LAT (DEG).
ACTIVE.PWMV	SCALAR	MAGNETIC VARIATION (DEG).
ACTIVE.PWNAM	ARRAY(3) INTEGER	WPT NAME
ACTIVE.PWPPD	SCALAR	CIRCLE PT TO PT DIST (FT).
ACTIVE.PWPTA	SCALAR	PLANNED TIME OF ARRIVAL (SEC).
ACTIVE.PWRAD	BOOLEAN	RADIUS INHIBIT?
ACTIVE.PWRTN	SCALAR	RADIUS OF TURN (FT).
ACTIVE.PWTA	SCALAR	TURN ANGLE AT WPT (DEG).
ACTIVE.PWT	SCALAR	DELTA TIME EN ROUTE (SEC).
ACTIVE.PWVPTR	INTEGER	ADDR OF VOR
ACTIVE.PWV	SCALAR	GROUND SPEED (KNOTS)
ACTIVE.PWWAY	BOOLEAN	PROVISIONAL?
ALT	INITIAL (0.) SCALAR	INERTIALLY SMOOTHED ALTITUDE (FT).
ALTARM	INITIAL (OFF) BOOLEAN	ALTITUDE MODE ARMED
ALTATT	INITIAL (ON) BOOLEAN	ALTATT ATTAINED FLAG
ALTCOR	INITIAL (0.) SCALAR	BARO CORRECTED ALTITUDE (FT).
ALTSEL	INITIAL (OFF) BOOLEAN	ALT HOLD MODE DISCRETE
ALTSUM	INITIAL (0.) SCALAR	ALTITUDE SUMMER VALUE (FT).
BARSET	INITIAL (29.92) SCALAR	BAROMETRIC REFERENCE SETTING (IN)
BETAH	SCALAR	MLS OR ILS BETA HAT (DEG).
BINTIME	INITIAL (0.) SCALAR	REAL TIME CLOCK (SEC).
COSRH	INITIAL (0.) SCALAR	COS (RWY HEADING)
CRAD	INITIAL (0.) SCALAR	RADIUS OF CIRCLE (MILES/TENTHS)
DECTY	INITIAL (0.) INTEGER	TYPE OF CIRCLE WPT
DESTIN	INIT. (0) ARRAY (4) INTEG.	DESTINATION AIRFIELD AND RUNWAY
DFTANG	INITIAL (0.) SCALAR	DRIFT ANGLE (DEG).
DLATFT	INITIAL (364567.) SCALAR	LENGTH OF 1 DEGREE OF LATITUDE (FT).
DLONFT	INITIAL (288693.) SCALAR	LENGTH OF 1 DEGREE OF LONGITUDE (FT).
DSRTK	INITIAL (0.) SCALAR	DESIRED TRACK (DEG).
DTOGO	INITIAL (0.) SCALAR	DIST TO MID-TURN (FT).
ETAH	SCALAR	MLS OR ILS ETA HAT (DEG).

DISNAV COMPOOL VARIABLES (cont.)

FCFLGS	INITIAL (HEX 'O')BIT (16)	FLIGHT CONTROLS FLAGS TO DISPLAYS
FPASEL	INITIAL (OFF) BOOLEAN	FPA HOLD MODE DISCRETE
FPASUM	INITIAL (0.) SCALAR	FPA SUMMER VALUE (DEG).
GAMC	INITIAL (0.) SCALAR	COMMANDED GAMMA VALUE (DEG).
GAMMA	INITIAL (0.) SCALAR	FLIGHT PATH ANGLE (DEG).
GS	INITIAL (0.) SCALAR	GROUND SPEED (KNOTS).
GSA	INITIAL (0.) SCALAR	GLIDE SLOPE ANGLE (DEG).
GSFPS	INITIAL (0.) SCALAR	GROUND SPEED (FPS).
GUID2D	INITIAL (OFF) BOOLEAN	GUID 2D POSSIBLE
GUID3D	INITIAL (OFF) BOOLEAN	GUID 3D POSSIBLE
GUID4D	INITIAL (OFF) BOOLEAN	GUID 4D POSSIBLE
HDCF	INITIAL (0.) SCALAR	HDOT COMP FILTER (FPS).
HDDOT	INITIAL (0.) SCALAR	VERTICAL ACCEL (FPS2).
HDGTRU	INITIAL (0.) SCALAR	TRUE HEADING (DEG).
HER	INITIAL (0.) SCALAR	ALTITUDE ERROR (FT).
HLDBRG	INITIAL (0.) SCALAR	BRG OF HOLD WPT (DEG).
HLDSEL	INITIAL (OFF) BOOLEAN	HOLD WPT SELECTED?
HLDWPT	INITIAL (0) INTEGER	HOLD WPT
HORPTH	INITIAL (OFF) BOOLEAN	HORIZONTAL PATH MODE
IASSEL	INITIAL (OFF) BOOLEAN	IAS HOLD MODE DISCRETE
IASSUM	INITIAL (0.) SCALAR	MSP IAS SUMMER (KNOTS)
ILSZON	INITIAL (OFF) BOOLEAN	AP WITHIN ILS ZONE
LABFLG	INITIAL (OFF) BOOLEAN	ON=OPERATING IN HOT BENCH
LAT	INITIAL (0.) SCALAR	UPDATED LATITUDE (DEG).
LATCEN	INITIAL (0.) SCALAR	NORTH UP MAP CENTER-LAT (DEG).
LBS	INITIAL (OFF) BOOLEAN	LATERAL BEAM SENSED DISC
LOKBUF	ARRAY (31) INTEGER	LOOK-UP WPT/RTE BUFFER
LOKWPT	ARRAY(2)INTEGER INITIAL(0)	LOOKUP WPT
LON	INITIAL (0.) SCALAR	UPDATED LONGITUDE (DEG).
LONCEN	INITIAL (0.) SCALAR	NORTH UP MAP CENTER-LON (DEG).
MAGVAR	INITIAL (0.) SCALAR	MAGNETIC VARIATION (DEG).
MFDREQ	INITIAL (OFF) BOOLEAN	MFD UPDATE REQUEST
MXEPR	INITIAL (2.23) SCALAR	SELECTED EPR LIMIT
NAVTYP	ARRAY(2)INTEGER INITIAL(0)	NAVIGATION MODE TYPE
NAV64K	INITIAL (OFF) BOOLEAN	GS > 64 KNOTS
NVAD2A	INTEGER	PTR TO NAV2 AUTO
NVAD3A	INTEGER	PTR TO NAV3 AUTO
OFBIAS	INITIAL (0.) SCALAR	OFFSET BIAS (NM).
OFSSEL	INITIAL (OFF) BOOLEAN	OFFSET MODE DISCRETE
ORIGIN	ARRAY(4)INTEGER INITIAL(0)	ORIGIN AIRFIELD AND RUNWAY
PFPA	INITIAL (0.) SCALAR	PLANNED FLIGHT PATH ANGLE (DEG).
PGBUF	STRUCTURE	THE PROVISIONAL GUIDANCE BUFFER
PGBUF.PWA02	SCALAR	ARC LENGTH OF CURVE/2 (FT).
PGBUF.PWASS	INTEGER	0=AWY1=SID2=STAR3=MAP4=N
PGBUF.PWBRG	SCALAR	BEARING (DEG).
PTBUF.PWCCD	SCALAR	CENTER TO CENTER DIST (FT).
PGBUF.PWDMA	BOOLEAN	DME ARC?
PGBUF.PWDMI	BOOLEAN	DME ARC STOP CALC
PGBUF.PWDTT	SCALAR	TANGENT PT TO WPT DIST (FT).
PGBUF.PWFLL	BOOLEAN	FLIGHT LEVEL?
PGBUF.PWGAM	SCALAR	PATH GRADIENT (DEG).

DISNAV COMPOOL VARIABLES

PGBUF.PWH	SCALAR	ALTITUDE (FT).
PGBUF.PWIRL	BOOLEAN	IAS REFERENCE?
PGBUF.PWLAT	SCALAR	LATITUDE (DEG).
PGBUF.PWLGRF	SCALAR	DME ARC REFERENCE LON (DEG).
GBUF.PWLON	SCALAR	LONGITUDE (DEG).
PGBUF.PWLTRF	SCALAR	DME ARC REFERENCE LAT (DEG).
PGBUF.PWMV	SCALAR	MAGNETIC VARIATION (DEG).
PGBUF.PWNAM	ARRAY (3) INTEGER	WPT NAME
PGBUF.PWPPD	SCALAR	CIRCLE PT TO PT DIST (FT).
PGBUF.PWPTA	SCALAR	PLANNED TIME OF ARRIVAL SET
PGBUF.PWRAD	BOOLEAN	RADIUS INHIBIT?
PGBUF.PWRTN	SCALAR	RADIUS OF TURN (FT).
PGBUF.PWTA	SCALAR	TURN ANGLE AT WPT (DEG).
PGBUF.PWT	SCALAR	DELTA TIME EN ROUTE (SEC).
PGBUF.PWVPTR	INTEGER	ADDR OF VOR
PGBUF.PWV	SCALAR	GROUND SPEED (KNOTS)
PGBUF.PWWAY	BOOLEAN	PROVISIONAL?
PGTERM	INTEGER INITIAL (0)	0 WORD TERMINATOR TO PGBUF
PSTALT	INITIAL (OFF) BOOLEAN	PRE-SELECTED ALTITUDE DISCRETE
PSTFPA	INITIAL (OFF) BOOLEAN	FPA PRESELECT
PSTIAS	INITIAL (OFF) BOOLEAN	PRE-SELECTED IAS ENGAGE DISCRETE
PSTTKA	INITIAL (OFF) BOOLEAN	TRACK ANGLE PRESELECT
PTR2DN	INITIAL (0) INTEGER	2D PTR UPDATED AT BEGIN OF TURN
PWNUM	INITIAL (0) INTEGER	# OF WPTS IN PBUFF
RADBRG	INITIAL (0) SCALAR	BRG OF RADIAL WPT (DEG)
RADWPT	ARRAY(2) INTEGER INITIAL(0)	RADIAL WPT
RWPTAD	INITIAL (0) INTEGER	ADDR OF CIRCLE WPT
RWYHDG	INITIAL (0.) SCALAR	TRUE RUNWAY HEADING (DEG).
RWYLAT	INITIAL (0.) SCALAR	LAT OF RUNWAY THRESHOLD (DEG).
RWYLEN	INITIAL (0.) SCALAR	LENGTH OF RUNWAY (FT).
RWYLON	INITIAL (0.) SCALAR	LON OF RUNWAY THRESHOLD (DEG).
RYELEV	INITIAL (0.) SCALAR	RUNWAY ELEVATION (FT).
SINRH	INITIAL (0.) SCALAR	SIN (RWY HEADING)
SINUS0	INITIAL (HEX '0')BIT(16)	PACK SENSOR IN USE WORD 0
SINUS1	INITIAL (HEX '0')BIT(16)	PACK SENSOR IN USE WORD 1
SINUS2	INITIAL (HEX '0')BIT(16)	PACK SENSOR IN USE WORD 2
SINUS3	INITIAL (HEX '0')BIT(16)	PACK SENSOR IN USE WORD 3
TIMPTH	INITIAL (OFF) BOOLEAN	TIME PATH MODE SELECT
TK	INITIAL (0.) SCALAR	AIRPLANE TRUE TRACK (DEG).
TKASUM	INITIAL (0.) SCALAR	TRACK ANGLE SUMMER VALUE (FT).
TKSEL	INITIAL (OFF) BOOLEAN	TRACK HOLD MODE DISCRETE
VBS	INITIAL (OFF) BOOLEAN	VERTICAL BEAN SENSED FLAG
VERPTH	INITIAL (OFF) BOOLEAN	VERT PATH MODE DISCRETE
VGSDOT	INITIAL (0.) SCALAR	ALONG TRACK ACCEL (FPS2)
WD	INITIAL (0.) SCALAR	VERTICAL NAVIGATION FLAG
WPNUM	INITIAL (0.) INTEGER	# OF WPTS OF ABUFF
WS	INITIAL (0.) SCALAR	WIND SPEED (KNOTS)
XTACC	INITIAL (0.) SCALAR	CROSS TRACK ACCEL (FPS2)
XTK	INITIAL (0.) SCALAR	CROSS TRACK ERROR (FT).

FCPOOL COMPOOL

FCPOOL is included in the NAVCOM resident common. FCPOOL contains variables that are referenced from the Flight Controls software.

FCPOOL COMPOOL VARIABLES

ACCHAT	VECTOR	ACCEL'N ESTIMATE VECTOR (FPS2)
	REPLACE XDDH BY "ACCHAT$(1)"	X ACCELERATION
	REPLACE YDDH BY "ACCHAT$(2)"	Y ACCELERATION
	REPLACE ZDDH BY "ACCHAT$(3)"	Z ACCELERATION
ACC	VECTOR	MLS ACCELERATIONS - XDD, YDD, ZDD
AFTLIM	SCALAR	ATHCL APC LOWER LIMIT (DEG).
ANTSEL	INTEGER	ANTENNA SELECT INDEX
		0 - TAIL
		1 - ROOF
		2 - CHIN
APCPRM	SCALAR	ATHCL APC RATE COMMAND (DPS).
ATT_SYNC	BOOLEAN	ACWS/VCWS ROLL COMMANDED
AUTOTC	BOOLEAN	TURN COORDINATOR SWITCH
		FALSE-ACWS/VCWS ONLY
		TRUE-ADD AUTOE
BMAFLG	BOOLEAN	BODY MTD ACCEL FLAG
CFRUN	INTEGER	MLS CFILT RUN COUNTER
CFXCC	ARRAY(3) INTEGER	MLS OUTLIER ERROR CNTRS
CROLL	SCALAR	COSINE OF ROLL
CTHET	SCALAR	COSINE OF PITCH
CXRSW	BOOLEAN	XTVEL SOURCE SWITCH
		FALSE - INS XRWY VEL
		TRUE - CXRVEL
CXRVEL	SCALAR	COMPUTED XRWY VEL (FPS)
DCOLF	SCALAR	GAINED & FILTRD DCOL (IN)
DELTH	SCALAR	MLS ALT. DEVIATION (FT)
DELTY	SCALAR	MLS DELTA Y (FT).
DLPSI	SCALAR	YAW RELATIVE TO RUNWAY (DEG)
DSPLF	ARRAY(9) BOOLEAN	FAIL DISPLAYED FLAGS
		1 - AFCS
		2 - FFD
		3 - MANEL
		4 - ACWS
		5 - VCWS
		6 - AUTO
		7 - LAND
		8 - AUTO THROTTLE
		9 - MLS
DSTAT	ARRAY(14) INTEGER	DISCRETE STATUS TABLE
DZNE	SCALAR	VARIABLE COLUMN DEAD ZONE (IN)
EL2F	BOOLEAN	EL2 IN USE SWITCH
ETAFT	SCALAR	GAIN PROGRMD LOCDEV (FT)
EX	VECTOR	CFILT ERROR TERMS - EX,EY,EZ (FT).
FAIL2	ARRAY(9) BOOLEAN	SECOND FAILURE STATUS
		1 - AFCS
		2 - FFD
		3 - MANEL
		4 - ACWS
		5 - VCWS
		6 - AUTO

		7 - LAND 8 - AUTO THROTTLE 9 - MLS
FIDENT	ARRAY(7) INTEGER	FAILURE ID TABLE
FLRSEL	BOOLEAN	FLARE CONTROL LAW SWITCH FALSE - VAR TAU TRUE - H(X)
FSIDX	INTEGER	FAIL STATUS INDEX POINTER
GAMD	SCALAR	GAMMA DOT (DPS)
GAMER	SCALAR	GAMC - (THETA OR GAMMA) (DEG).
GRD	BOOLEAN	ON-GROUND DISCRETE
HDCFSW	BOOLEAN	HDCF SOURCE SWITCH FALSE - HDCF = FM HDOT TRUE - HDCF = FC HDCF
HDILS	SCALAR	HDOT = F(H,HDD) FOR FLARE (FPS)
HTDZ	SCALAR	MLS ALTITUDE (WHEEL HT) (FT)
INSST	INTEGER	INS SINGLE THREAD FLAG 0 - NORMAL 1 - SELECT INS 'A' 2 - SELECT INS 'B' 3 - SELECT INS 'C'
KV	SCALAR	AIRSPEED GAIN
LIGHTS	INTEGER	STP LAMP CONTROL WORD
LOCVL	SCALAR	ETA/DELTY VARIABLE LIMIT
MCONF	BIT(16)	MLS CONFIGURATION WORD BIT 15 - MLS COMPUTE BIT 14 - REAL MLS BIT 13 - EL2 FLAG BIT 12 - BMACC FLAG BIT 11 - RADAR TRACK FLAG BIT 10 - VGS FLAG BIT 9 - 6 UNUSED BIT 5 - MLS SWITCH 6 BIT 4 - 1 UNUSED BIT 0 - MLS SWITCH 1
MLSC	BOOLEAN	MLS COMPUTE SWITCH
MLSFC	INTEGER	MLS PACKED SIGNAL STATUS BIT 15 - 13 UNUSED BIT 12 - RNGE OUTLIER VLD BIT 11 - AZ VALID BIT 10 - EL1 OUTLIER VALID BIT 9 - EL2 OUTLIER VALID BIT 8 - EX COUNT VALID BIT 7 - EY COUNT VALID BIT 6 - EZ COUNT VALID BIT 5 - 4 UNUSED BIT 3 - RANGE COUNT VALID BIT 2 - AZMTH COUNT VLD BIT 1 - EL1 COUNT VALID BIT 0 - EL2 COUNT VALID
MLSM	BOOLEAN	MLSMOD SECONDARY

FCPOOL COMPOOL VARIABLES (cont.)

MLSSVC	ARRAY(4) INTEGER	MLS SIGNAL VALID COUNTERS
MODEX	INTEGER	CURRENT MODE INDEX
MSBUF	ARRAY(19) INTEGER	NEXT STP MESSAGE W/CTRL CHARS
MSGST	INTEGER	ADDRESS OF NEXT MSG TO STP
MSWIT	INTEGER	MSP MODE: 0-FLT, 1-PREFLT
MSW1	BOOLEAN	MLS SWITCH 1
MSW2	BOOLEAN	MLS SWITCH 2
MSW3	BOOLEAN	MLS SWITCH 3
MSW4	BOOLEAN	MLS SWITCH 4
MSW5	BOOLEAN	MLS SWITCH 5
MSW6	BOOLEAN	MLS SWITCH 6
NCI02	SCALAR	ATHCL WINDSHEAR FILTER (FPS2)
NCI03	SCALAR	ATHCL APC INTEGRATOR (DEG).
NCL1	SCALAR	ATHCL ACCEL DAMPING TERM (FPS2)
OTLERR	ARRAY(4) SCALAR	MLS SIGNAL OUTLIER ERRORS
PDTCMD	SCALAR	ROLL COMMAND RATE (DPS)
PHICMD	SCALAR	COMMANDED ROLL ANGLE (DEG)
PHIERR	SCALAR	PHICMD-ROLL (DEG)
PMSWIT	INTEGER	PREVIOUS VALUE OF MSWIT
POSHAT	VECTOR	POSITION ESTIMATE VECTOR (FT)
	REPLACE XHAT BY "POSHAT$(1)"	X POSITION
	REPLACE YHAT BY "POSHAT$(2)"	Y POSITION
	REPLACE ZHAT BY "POSHAT$(3)"	Z POSITION
QFB1	SCALAR	WASHED OUT Q FOR CTL LAWS (DPS)
RADTKF	BOOLEAN	RADAR TRACK FLAG
RECWD1	INTEGER	NORMAL RECORDING SELECT
RECWD2	INTEGER	ALTERNATE RECORD SELECT
		BITS SELECT GROUP
		0-2 0 (VAR1)
		3-5 1 (VAR2)
		6-7 2 (DISC)
RLMLS	BOOLEAN	REAL MLS FLAG
RSWADR	INTEGER	ADRS OF RECORD SELECT DISCRETE
RWYSEL	INTEGER	RUNWAY SELECT INDEX
		1 - WALLOPS
		2 - NAFEC
		3 - SPARE
SROLL	SCALAR	SINE OF ROLL
STFAIL	ARRAY(26) INTEGER	FAILURE STORED FLAGS
STHET	SCALAR	SINE OF PITCH
SWITCH	INTEGER	STP SWITCH STATUS WORD
SYNCL	SCALAR	LATRL TRIM VALUE (DEG).
TANGSA	SCALAR	TANGENT OF GLIDE SLOPE ANG
TRACK_HOLD	BOOLEAN	VCWS TRACK HOLD ENABLED
VELHAT	VECTOR	VELOCITY ESTIMATE VECTOR (FPS)
	REPLACE XDH BY "VELHAT$(1)"	X VELOCITY
	REPLACE YDH BY "VELHAT$(2)"	Y VELOCITY
	REPLACE ZDH BY "VELHAT$(3)"	Z VELOCITY
VGAIN	ARRAY(6) SCALAR	DYNAMICALLY VARIABLE GAINS
WRDCNT	INTEGER	# OF WORDS TO OUTPUT TO STP
XTK1	SCALAR	FIRST INT. OF XTACC (FPS)

XTK2	SCALAR	SECOND INT. OF XTACC (FT).
XYZER	VECTOR	MLS SOLUTION ERROR (FT).

FMBFCM COMPOOL

FMBFCM is included in the IOCOM resident common. FMBFCM contains a block of 1156 words through which data is passed to and from the SIR memory. This input/output is done by FLTHDL. FLTHDL also stores in the 1156 word block the selection indices received from the Norden #1 SSFD (Signal Select/Failure Detect) software, for use by IOFLL in formatting the input SIU/RFDIU data.

FMBFCM also contains global variables used in FM/FC Software. There are 5 error counters set in FLTHDL that FLTEM checks to flag hardware/software errors. There is a display status word (at label DISPST) that is passed from the Norden #1, followed by A/C gross weight (WEIGHT) also computed in NORDEN #1. At DSPST2 + 2 is the SSFD toggle word, used to validate the selection indices received from Norden #1.

FMBFCM also contains space for the data recording buffer, DASBF, filled in by DASOT, the high rate data variables processed by IN10M and OUT10M, and assorted other variables that did not conveniently fit elsewhere.

FMBFCM COMPOOL VARIABLES

AILCMD	SCALAR INTEGER	AILERON COMMAND (DEG).
BF	INTEGER	0000H - 0483H OF SIR MEMORY.
BMACC	VECTOR	BODY MOUNTED ACCELEROMETERS. (FPS2)
CBFADD	INTEGER	HANDLER DATA FOR DEBUG.
CDATBF	INTEGER	HANDLER DATA FOR DEBUG.
COLDST	BOOLEAN	COLD START FLAG.
CWDCNT	INTEGER	HANDLER DATA FOR DEBUG.
DASBF	ARRAY (150) INTEGER	BOTTOM OF DAS RECORDING BUFFER.
DATADR	BIT (16)	OPTIONAL DUMP ADDRESS.
DATIN	ARRAY (352) INTEGER	50 MS MAJOR FRAME INPUT DATA.
DATOUT	ARRAY (106) INTEGER	START OF OUTPUT BUFFER.
DATSAV	ARRAY (30) INTEGER	DUMP DATA. (FROM DATADR)
DECMD	SCALAR	ELEVATOR COMMAND (DEG).
DECMQ	SCALAR	ELEVATOR COMMAND-PITCH RATE. (DEG).
DISPST	INTEGER	DISPLAY STATUS BITS.
DIUERR	INTEGER	NOT USED.
DSPST2	ARRAY (2) INTEGER	LAST 2 WORDS OF DISPLAYS STATUS.
EIUERR	INTEGER	EIU/SIU DMA ERROR.
EXPIN	ARRAY (98) INTEGER	INPUT DATA FOR EXPERIMENTS.
EXPOUT	ARRAY (4) INTEGER	OUTPUT DATA FOR EXPERIMENTS
FDATIN	ARRAY (23) INTEGER	10 MS DATA INPUTS
FRAMES	SCALAR	RUNNING 10 MILL FRAME COUNT.
FRGSAV	ARRAY (6) SCALAR	AC0-AC5 SAVED
FR4NZ	INTEGER	HANDLER DATA FOR DEBUG
FSTCNT	SCALAR	FAST LOOP 10 MILL FRAMES.
FSTIN	ARRAY (4) INTEGER	10 MS STATUS INPUTS.
FSTSNA	BIT (16)	SNAP ADDRESS FOR FAST.
F4NRDY	INTEGER	HANDLER DATA FOR DEBUG.
HDD	SCALAR	VERTICAL ACCELERATION (FPS2).
INSSAV	BIT (16)	FIRST WORD OF SAVED INSTRUCTION.
INSSV2	BIT (16)	SECOND WORD OF SAVED INSTRUCTION.
INTERR	INTEGER	INTERPROCESSOR DMA ERROR.
INX2	ARRAY (40) INTEGER	BLOCK INDEX (0200H).
IPERR	INTEGER	HANDLER DATA FOR DEBUG.
KQ	SCALAR	GAIN FOR Q FEEDBACK.
MAXF	INTEGER	HIGHEST FRAME FOR FAST LOOP FINISH.
MFRAME	INTEGER	CURRENT FRAME (0 - 4).
MSINTP	INTEGER	INTERPROCCESOR MISSES.
MS10ML	INTEGER	10 MILL INTERRUPT MISSES.
MS50ML	INTEGER	50 MILL INTERRUPT MISSES.
NCDOUT	ARRAY (128) INTEGER	NCDU OUTPUT BUFFER.
NDAS	INTEGER	NUMBER OF ENTRIES IN DAS LIST.
OVER	INTEGER	CURRENT OVERFLOW COUNT.
P	SCALAR	ROLL RATE (DPS)
Q	SCALAR	PITCH RATE (DPS)
QX	SCALAR	Q WASHOUT BIAS (DPS)
R	SCALAR	YAW RATE (DPS)
REGSAV	ARRAY (9) INTEGER	R0 - R7 AND FP STAT SAVED.
RFDIN	ARRAY (90) INTEGER	RFDIU INPUTS
RUDCMD	SCALAR	RUDDER COMMAND (DEG).
SAVCSR	INTEGER	HANDLER DATA FOR DEBUG

FMBFCM COMPOOL VARIABLES (continued)

SLWCNT	SCALAR	SLOW LOOP 10 MILL FRAMES.
SLWSEG	BIT (16)	SEGMENT NUM FOR SLOW SNAP
SLWSNA	BIT (16)	SNAP ADDRESS FOR SLOW
SNPFLG	BIT (16)	TRIGGER TO 'SNAP'
SPBPSW	INTEGER	SPBP CONTROL WORD (0292H)
STATIN	ARRAY (44) INTEGER	SIGNAL STATUS INPUTS FROM SSFD
SUMOVR	INTEGER	CUMULATIVE OVERFLOW COUNT.
VDISC	INTEGER	VOTED DISCRETE WORD.
WEIGHT	SCALAR	AIRCRAFT TOTAL WEIGHT (LBS).

FSTCOM COMPOOL

FSTCOM is included in the FAST task. FSTCOM contains variables that are referenced only by routines in the FAST task.

FSTCOM COMPOOL VARIABLES

AZ_BRG	SCALAR	AZIMUTH ANTENNA BEARING (DEG).
DELAY	INTEGER	MODE ENGAGE DELAY COUNTER
ERINT	SCALAR	INT(K GAMD + K GAMER) (DEG).
ETAVL	SCALAR	LIMITED ETA (LOCDEV) (DEG).
HGPIP	SCALAR	MLS ELEV OF TD POINT (FT).
KALFA	SCALAR	F(ALPHA): ANTI-STALL GAIN
LAT_MLS	SCALAR	AZIMUTH ANTENNA LATITUDE (DEG).
LON_MLS	SCALAR	AZIMUTH ANTENNA LONGITUDE (DEG).
MLSVAL	BOOLEAN	MLS VALID FLAG
MODE2	INTEGER	LAST MODE INDEX
NCI01	SCALAR	ATHCL WINDSHEAR FILTER (FPS)
RWYDEF	ARRAY(3,8)SCALAR	RUNWAY CONSTANTS FOR ANY OF THREE POSSIBLE RUNWAYS. CONSTANTS INCLUDE VALUES FOR XFLARE, X_GPIP, YPROF, H_GPIP, ZO_MLS, AZ_BRG, LAT_MLS, LON MLS
XFLARE	SCALAR	MLS FLARE @ XGPIP + 884 (FT).
XGPIP	SCALAR	X DIST OF TD POINT (FT).
YPROF	SCALAR	MLS X-RWY CENTER LINE (FT).
ZDIF	SCALAR	ZO + EARTH CURVATURE (FT).
ZOMLS	SCALAR	AZIMUTH ANTENNA MSL ELEVATION (FT).

IOPOOL COMPOOL

IOPOOL is included in the NAVCOM resident common. IOPOOL contains the input and output variables for the FM/FC computer. IOPOOL is organized with all the input variables first, followed by all the output variables. The input variables are filled in by IOFLL, using the selection indices and scaled data from the FMRFCM compool. The output variables are sent to the FMBFCM compool by OUTIO. High rate data handled by IN10M and OUT10M are stored in FMBFCM.

IOPOOL COMPOOL VARIABLES

```
ACWSS   BOOLEAN                 ACWS SELECT
AEE     BOOLEAN                 AFCS ENGAGED       (26F:0)
AFCSS   BOOLEAN                 AFCS ENGAGE SELECT
AFCSV   BOOLEAN                 AFCS VALID
AFDTH   SCALAR                  AFD THROTL HDL POS (DEG).
AGCSS   BOOLEAN                 AGCS SELECT
ALFAV   SCALAR                  ANG OF ATTACK [ALPHA] (DEG)
ALTOMP  ARRAY(2) INTEGER        ALTITUDE TO CMP
ALVDT   SCALAR                  AILERON POS           (DEG)
APCDG   SCALAR                  AUTO THROTL POS CMD   (DEG)
ASTOMP  ARRAY(2) INTEGER        AIR SPEED TO CMP
ASTP    SCALAR                  AUTO STAB TRIM POT    (DEG)
ATDC    BOOLEAN                 AUTOTHROTTLE DISENG
ATE     BOOLEAN                 AUTO THROTTLE ENGAGED
ATFDBK  BOOLEAN                 AUTOTHROTTLE FEEDBACK
ATKACC  SCALAR                  ALONG TRK ACCEL       (FPS2)
ATRIM   SCALAR                  AFD AILERON TRIM POT  (DEG)
ATUNE2  INTEGER                 DME #2 TUNE FREQUENCE (2X5)
ATUNE3  INTEGER                 DME #3 FREQ TUNE      (2X5)
AUTOS   BOOLEAN                 AUTO SELECT
BETAV   SCALAR                  SIDESLIP ANGLE [BETA] (DEG)
BSLECT  BOOLEAN                 'B' SYSTEM SELECTED
CALTV   BOOLEAN                 CADC ALTITUDE VALID
CAS     SCALAR                  CALIBRATED AIRSPEED   (KTS)
CASV    BOOLEAN                 CADC AIRSPEED VALID
CDTISE  BOOLEAN                 CDTI SELECTED
CRSET   BOOLEAN                 COMP RESET SELECT
DCOL    SCALAR                  AFD COLUMN POSITION   (IN)
DEPOS   SCALAR                  ELEVATOR POS          (DEG)
DME2A   BOOLEAN                 DME #2 AUTOTUNE
DME2FQ  INTEGER                 DME #2 FREQ SELECTED  (2X5)
DME2VD  BOOLEAN                 DME#2 VALID
DME3FQ  INTEGER                 DME #3 FREQ SELECTED  (2X5)
DME3VD  BOOLEAN                 DME#3 VALID
DRPOS   SCALAR                  RUDDER SERVO POS      (DEG)
DSBV    BOOLEAN                 DIU SERIAL BUS VALID
DSTOMP  ARRAY(2) INTEGER        DISCRETES TO CMP
DWHL    SCALAR                  AFD WHEEL POSITION    (DEG)
EPR1    SCALAR                  #1 ENGINE PRESS RATIO
EPR2    SCALAR                  #2 ENGINE PRESS RATIO
ERSET   BOOLEAN                 ERROR RESET ON MODE CHANGE
FALST   INTEGER                 SYSTEM TEST PANEL SWITCH
FCOL    SCALAR                  FFD COLUMN FORCE      (LBS)
FFDS    BOOLEAN                 FWD FLIGHT DECK SELECT
FFLER   INTEGER                 PARITY ERROR COUNTER
FLAGS   ARRAY(18) BOOLEAN
     REPLACE PRENG BY "FLAGS$(1:)"      NOT O/P
     REPLACE FFDE  BY "FLAGS$(2:)"      NOT O/P
     REPLACE MANEL BY "FLAGS$(3:)"      NOT O/P
     REPLACE ACWSE BY "FLAGS$(4:)"      0425:0+
     REPLACE VCWSE BY "FLAGS$(5:)"      0425:1+
          REPLACE AUTOE BY "FLAGS$(6:)"      0425:2+
          REPLACE LANDE BY "FLAGS$(7:)"      0425:3+
          REPLACE DECRB BY "FLAGS$(8:)"      0425:4
          REPLACE FLARE BY "FLAGS$(9:)"      0425:5
          REPLACE RLOUT BY "FLAGS$(10:)"     0425:6
          REPLACE LANDA BY "FLAGS$(11:)"     0425:7+
          REPLACE LOCA  BY "FLAGS$(12:)"     0425:8
          REPLACE LOCE  BY "FLAGS$(13:)"     0425:9
          REPLACE GSARM BY "FLAGS$(14:)"     0425:10
          REPLACE GSENG BY "FLAGS$(15:)"     0425:11
          REPLACE LANDR BY "FLAGS$(16:)"     NOT O/P
          REPLACE GSTRK BY "FLAGS$(17:)"     NOT O/P
          REPLACE ONCRS BY "FLAGS$(18:)"     NOT O/P
     FLAP     SCALAR                 FFD FLAP HANDLE POS    (DEG)
     FLPPOS   SCALAR                 FLAP POSITION          (DEG)
     FPTOMP   ARRAY(2) INTEGER       FLIGHT PATH ANGLE TO CMP
     FSBV     BOOLEAN                RFDIU (FUEL FLOW) S.B.VLD
     FWHL     SCALAR                 FFD WHEEL FORCE        (LBS)
     GAE      BOOLEAN                GO AROUND ENGAGED  (0425:12)
     GAS      BOOLEAN                GO AROUND SELECT NOT
     GEAR     BOOLEAN                NOSE GEAR DOWN
     GSDEV    SCALAR                 GLIDESLOPE DEVIATION  (DEG)
     GSINS    SCALAR                 GROUND SPEED          (KTS)
     GSVLD    BOOLEAN                ILS G/S RCVR VALID
     HBARO    SCALAR                 BARO ALTITUDE          (FT)
     HDOTB    SCALAR                 CADC ALTITUDE RATE    (FPS)
     HOLD     BOOLEAN                HOLD MODE SELECT
     HOLDM    BOOLEAN                SYSTEM HOLD MODE   (0426:15)
     HRAD     SCALAR                 RADIO ALTITUDE         (FT)
     HRSS     INTEGER                DAYS/HOURS            (BCD)
     HRV      BOOLEAN                RADIO ALTITUDE VALID
     IATTV    BOOLEAN                INS ATTITUDE VALID
     IC       BOOLEAN                IC MODE SELECT
     ICM      BOOLEAN                SYSTEM IC MODE     (0426:13)
     INAVV    BOOLEAN                INS NAVIGATION VALID
     INSAER   INTEGER                PARITY ERROR COUNTER
     INSBER   INTEGER                PARITY ERROR COUNTER
     INSCER   INTEGER                PARITY ERROR COUNTER
     ISBV     BOOLEAN                INS SERIAL BUS VALID
     LAMP     BOOLEAN                LAMP TEST SELECT
     LANDS    BOOLEAN                LAND SELECT
     LATINS   SCALAR                 INS LATITUDE          (DEG)
     LOCDEV   SCALAR                 LOCALIZER  DEVIATION  (DEG)
     LOCFS    BOOLEAN                LOCALIZER FREQ SLCTD
     LOCVLD   BOOLEAN                ILS LOC RCVR VALID
     LONINS   SCALAR                 INS LONGITUDE         (DEG)
     MACH     SCALAR                 MACH NUMBER
     MACHV    BOOLEAN                MACH VALID (NEW TRPLX DISC)
     MAGHDG   SCALAR                 MAGNETIC HEADING      (DEG)
     MDME2    SCALAR                 DME #2 DISTANCE        (NM)
     MDME3    SCALAR                 DME #3 DISTANCE        (NM)
```

IOPOOL COMPOOL VARIABLES (cont.)

MDWARN	BOOLEAN	MODE REVERSION WARNING
MINS	INTEGER	MINS/SECS (BCD)
MLSER	INTEGER	PARITY ERROR COUNTER
MLSMOD	BOOLEAN	MLS VALID AND SELECTED
MLSRAW	ARRAY(4) SCALAR	MLS SIGNALS: R,AZ,L1,L2
MLSSLI	BOOLEAN	MLS SELECT
MLSSV	ARRAY(4) BOOLEAN	MLS SIGNAL VALIDS
MLSVLD	BOOLEAN	GATED MLS VALID
MSPER	INTEGER	PARITY ERROR COUNTER
MVINS	SCALAR	INS MAG VARIATION (DEG)
MVOR2	SCALAR	VOR #2 BEARING (DEG)
NCDUER	INTEGER	PARITY ERROR COUNTER
NCDUL8	ARRAY(12) INTEGER	NCDU#1 INPUTS (CHAR)
NCDUNP	BOOLEAN	NCDU #1 NEW PAGE DISC
NCUVAL	BOOLEAN	NCU VALID
NPAGE	ARRAY(96) INTEGER	NCDU #1 OUTPUTS (CHAR)
PEDAL	SCALAR	AFD RUD PED + TRIM (DEG)
PITCH	SCALAR	INS PITCH [THETA] (DEG)
RASELT	BOOLEAN	RANGE ALTITUDE SELECT [N/U]
RATOMP	ARRAY(2) INTEGER	RANGE/ALT TO CMP
ROLL	SCALAR	INS BANK ANGLE [PHI] (DEG)
RSTOMP	ARRAY(2) INTEGER	RANGE/SPEED TO CMP
RTRIM	SCALAR	AFD RUDDER TRIM POT (DEG)
RUN	BOOLEAN	RUN MODE SELECT
RUNM	BOOLEAN	SYSTEM RUN MODE (0426:14)
RWYOUT	BOOLEAN	RUNWAY HEADING SET
SPFINH	BOOLEAN	SPLER FDBCK INHIBIT(0426:4)
SPIS1	SCALAR	DELTA PSI RWY [N/U] (DEG)
SPIS2	SCALAR	RUDDER SURF POS [N/U] (DEG)
SPL2	SCALAR	SPOILER PAN #2 POS (DEG)
SPOB1	BOOLEAN	NCDU #2 NEW PAGE DISC (NEWD)
SPOB2	BOOLEAN	SPARE BOOLEAN (OLD YAWD1)
SPR7	SCALAR	SPOILER PAN #7 POS (DEG)
SQUAT	BOOLEAN	OLEO SQUAT SWITCH
STABP	SCALAR	STABILIZER POS [N/U] (DEG)
STRUA	INTEGER	SERVO OUTPUT
STRUB	INTEGER	SERVO OUTPUT
STRUC	INTEGER	SERVO OUTPUT
TAS	SCALAR	TRUE AIR SPEED (KTS)
TASV	BOOLEAN	MACH/TAS VALID
TAT	SCALAR	TOTAL AIR TEMP (DEG-CENT)
TDSER	INTEGER	PARITY ERROR COUNTER
THDG	SCALAR	INS TRUE HEADING (DEG)
THROT	SCALAR	FFD THROTL HDL POS (DEG)
TKTOMP	ARRAY(2) INTEGER	TRACK ANGLE TO CMP
TOGGLE	INTEGER	NCDU/CMP INPUTS VALID IND
TRIMD	BOOLEAN	STAB TRIM DOWN (0426:1)
TRIMT	BOOLEAN	STAB TRIM RUN (0426:2)
TSBV	BOOLEAN	TDS SERIAL BUS VALID
VATRD	BOOLEAN	TRIM DOWN SELECT
VATRL	BOOLEAN	TRIM LEFT SELECT

IOPOOL COMPOOL VARIABLES (cont.)

VATRM	BOOLEAN	TRIM UP SELECT	
VATRR	BOOLEAN	TRIM RIGHT SELECT	
VCWSS	BOOLEAN	VCWS SELECT	
VEINS	SCALAR	INS EAST VELOCITY	(KTS)
VNINS	SCALAR	INS NORTH VELOCITY	(KTS)
VORVLD	BOOLEAN	LOC RCVR 'B' VALID	
WPTALR	BOOLEAN	WAYPOINT ALERT	
WSPIN	BOOLEAN	WHEEL SPIN UP	
XTKACC	SCALAR	INS CROSS TRACK ACCEL	(FPS2)
XTVEL	SCALAR	INS CROSS RWY VELOCITY	(FPS)
XYZ	VECTOR	RADAR TRACKING DATA	(FT)

NAVCOM COMPOOL

NAVCOM is included in the NAVCOM resident common. NAVCOM contains variables and initialized constants that are referenced from all the FM/FC tasks.

NAVCOM COMPOOL VARIABLES

ADMG	SCALAR	ARC DISTANCE MADE GOOD IN TURN (FT)
ALFSYN	SCALAR	SYNTH. ALFA [GAMMA - THETA] (DEG)
ALTGSF	BOOLEAN	ALT/GS =0. FLAG 2D/3D
AMG	SCALAR	ANGLE MADE GOOD (DEG)
AMG1	SCALAR	GOOD ANGLE IN TURN-TB (FT)
ANTLAT	SCALAR	LATITUDE OF ANTENNA (DEG)
ANTLON	SCALAR	LONGITUDE OF ANTENNA (DEG)
ATCMD	SCALAR	LONGITUDINAL ACC COMM (FPS2)
ATNAV2	BOOLEAN	AUTO TUNE NAV2
ATNAV3	BOOLEAN	AUTO TUNE NAV3
AVECTS.PWP1	VECTOR(3)	WAYPOINT UNIT VECTOR
AVECTS.PWU12	VECTOR(3)	NORMAL UNIT VECTOR
AVECTS.PWTC2	VECTOR(3)	CENTER OF TURN UNIT VECTOR
BACMD	SCALAR	BANK ANGLE COMMAND (DEG)
BADRAD	ARRAY(3) INTEGER	BAD RADIUS WPT NAME
BCFLAG	BOOLEAN	BE CAREFUL GUID ALERT FG
CDME2	SCALAR	COMPUTED DME2 (NM)
CDME3	SCALAR	COMPUTED DME3 (NM)
CENWPT	ARRAY(2) INTEGER	MAP CENTER WAYPOINT
CLAT	SCALAR	COS(LATITUDE)
CLON	SCALAR	COS(LONGITUDE)
COSTH	SCALAR	COS(AP HEAD)
COSTKA	SCALAR	COSINE OF TRACK ANGLE
CVOR2	SCALAR	COMPUTED VOR2 (DEG)
DELALT	SCALAR	ALTITUDE SELECT ERROR (FT)
DELCAS	SCALAR	AUTOTHROTTLE CAS ERROR (KTS)
DELTKA	SCALAR	TRACK ANGLE ERROR SELECT (DEG)
DFPA3D	SCALAR	3D GUIDANCE PATH ERROR (DEG)
DLAT2	SCALAR	DOUBLE PREC. EXTN. OF IDDLAT
DLON2	SCALAR	DOUBLE PREC. EXTN. OF IDDLON
DMG	SCALAR	SEPARATION REFERENCE DISTANCE (FT)
DPE	SCALAR	EAST POS ERROR (NM)
DPN	SCALAR	NORTH POS ERROR (NM)
DTG	SCALAR	ABEAM PT DIST TO 'TO' WPT (FT)
DTOTL	SCALAR	PROGRESS DISTANCE OF AP WPT (FT)
DVE	SCALAR	EAST VEL ERROR (KTS)
DVN	SCALAR	NORTH VEL ERROR (KTS)
FIFTY	SCALAR	FIFTY MILL. COUNTER CLOCK
FLADM	BOOLEAN	AIR DATA MODE
FLRM	BOOLEAN	RADIO MODE ONLY
FLYFLG	BOOLEAN	0= REAL A/P
GPGSDV	SCALAR	G.P. GLIDE SLOPE DEVIATION
GPLOCD	SCALAR	G.P. LOC DEVIATION
HDOT	SCALAR	RATE OF CHANGE OF ALT (FPS)
IASREF	SCALAR	IAS INIT REF (KTS)
IDDALT	SCALAR	INERTIALLY SMOOTHED BARO ALT (FT)
IDDATK	SCALAR	ALONG TK ACC VIA INS DATA (FPS2)
IDDGS	SCALAR	GS FROM INS DATA (KTS)
IDDLAT	SCALAR	LAT BASED ON INS DATA (DEG)
IDDLON	SCALAR	LON BASED ON INS DATA (DEG)
IDDXTK	SCALAR	CROSS TK ACC INS (FPS2)

NAVCOM COMPOOL VARIABLES (cont.)

KHD	SCALAR	VERTICAL PATH VEL. ERROR GAIN
K1P	SCALAR	POSITION GAIN
K2P	SCALAR	VELOCITY GAIN
LATCN	SCALAR	TRACK UP MAP CENTER-LAT (DEG)
LATDIF	SCALAR	IDDLAT - MLSLAT (DEG)
LATSTR	SCALAR	LATERAL STEERING SIGNAL (DEG)
LLINIT	BOOLEAN	LAT/LON INIT ON NCDU
LONCN	SCALAR	TRACK UP MAP CENTER-LON (DEG)
LONDIF	SCALAR	IDDLON - MLSLON (DEG)
MCLEPR	SCALAR	EPR LMT. FOR MAX CLIMB THRUST
MCREPR	SCALAR	EPR LMT. FOR MAX CRUISE THRUST
MCTEPR	SCALAR	EPR LMT. FOR MAX CONT. THRUST
NAVFLG	BOOLEAN	GS > 4 KNOTS FLAG
NOMBA	SCALAR	NOMINAL BANK ANGLE (DEG)
NVAD2B	INTEGER	PTR TO NEXT NAV2 AUTO
PATHND	BOOLEAN	PATH END FLAG
PDG3D	INTEGER	3D GUIDANCE FLAG
PDG4D	INTEGER	4D GUIDANCE FLAG
PHISYM	SCALAR	SIMULATION ROLL COMMAND (DEG)
PTAREJ	BOOLEAN	REJECT PTA
PTAXFG	BOOLEAN	SET PTAPOS/PTATIME APPLY
PTH4DN	BOOLEAN	TIMEBOX HAS REACHED PATH END
PTR2D	INTEGER	2D REFERENCE POINTER
PTR3D	INTEGER	3D REFERENCE POINTER
PTR4D	INTEGER	AP 4D REFERENCE POINTER
PTR4D1	INTEGER	TIMEBOX 4D REFERENCE POINTER
PVECTS.PWP1	VECTOR (3)	WAYPOINT UNIT VECTOR
PVECTS.PWTC2	VECTOR (3)	CENTER OF TURN UNIT VECTOR
PVECTS.PWU12	VECTOR (3)	NORMAL UNIT VECTOR
RADFT	SCALAR	LOCAL EARTH RADIUS (FT)
RALC	SCALAR	DISTANCE BEFORE TURN TO APPLY ALCBA (FT)
RASUM	SCALAR	RSP RANGE/ALT SUMMER (N/U)
RETUN2	INTEGER	RETUNE NAV 2 IF SET
RMP	SCALAR	LOCAL NORTH RAD OF CURV+ALT (NM)
RNP	SCALAR	RNH PROJECTED ON LAT PLANE (NM)
RWPTNM	ARRAY(3) INTEGER	WPT NAME CIRCLE
SC	SCALAR	DISTANCE FROM BOX TO WPT (FT)
SCMD	SCALAR	FLIGHT DIR SPEED CMD (FPS2)
SDC	SCALAR	PROGRESS PT VEL COMM (FPS)
SDCC	SCALAR	TIMEBOX VELOCITY (FPS)
SDD	SCALAR	PROGRESS PT ACC COMM (FPS2)
SEPR	SCALAR	DIST BETWEEN BOX AND AP (FT)
SIMALT	SCALAR	ALTITUDE OF SIM. A/P (FT)
SIMCAS	SCALAR	AIR SPEED SIM. AIRPLANE (KTS)
SIMFLG	BIT(16)	SIMULATED AP ENGAGED BIT 1 == IC AIRPLANE 2 == FLY AP (200KTS) 3 == FLY CAS OR TIME 4 5 == HOLD AIRPLANE 6 ==

NAVCOM COMPOOL VARIABLES (cont.)

		7 == GOOD DME3
		8 == GOOD DME2
		9 == GOOD VOR2
SIMHDG	SCALAR	HEADING OF SIM A/P (DEG)
SIMLAT	SCALAR	LATITUDE SIM. AIRPLANE (DEG)
SIMLON	SCALAR	LONGITUDE SIM. AIRPLANE (DEG)
SINTH	SCALAR	SIN(AP HEAD)
SINTKA	SCALAR	SINE OF TRACK ANGLE
SLAT	SCALAR	SIN(LATITUDE)
SLON	SCALAR	SIN(LONGITUDE)
SMMAGV	SCALAR	SIM. AIRPLANE MAGVAR (DEG)
SMUHDG	SCALAR	INIT HEADING FOR SIM A/P (DEG)
TASFPS	SCALAR	TRUE AIR SPEED (FPS)
TASGS	SCALAR	GS FROM TAS (KTS)
TEND	BOOLEAN	2D 2ND HALF TURN FLAG
TEND1	BOOLEAN	4D 2ND HALF TURN FLAG
TKE	SCALAR	TRACK ANGLE ERROR (DEG)
TKMAG	SCALAR	MAGNETIC TRACK (DEG)
TMEFLG	BOOLEAN	TIME FLAG
TOG100	BOOLEAN	100 M. SEC. TOGGLE FLAG
TOSLOW	BOOLEAN	4D SPEED COMMAND < 1ASREF
TOTIME	SCALAR	CLOCK TIME OF THE WPT (SEC)
TSMODE	INTEGER	NCDU TEST MODE
TURN	BOOLEAN	2D IN TURN FLAG
TURN1	BOOLEAN	4D IN TURN FLAG
VACMD	SCALAR	VERT ACC COMMAND (FPS2)
VE	SCALAR	VELOCITY EAST (KTS)
VERSTR	SCALAR	VERTICAL STEERING SIGNAL (FPS2)
VN	SCALAR	VELOCITY NORTH (KTS)
VNAVF	INTEGER	VERTICAL NAVIGATION FLAG
VSTRA	SCALAR	VERT. PATH HDOT COMMAND (FPS)
VSTRB	SCALAR	VERPTH HDOT ACTUAL (FPS)
WPEND	INTEGER	ACTIVE GUIDANCE BUFFER END
WPPTR	ARRAY(2) INTEGER	PATH WP POINTER
XTKLIM	SCALAR	HORPTH CAPTURE LIMIT (FT)

RECOM COMPOOL

RECOM is included in the NAVCOM resident common. RECOM contains variables for data recording; snap variables and DAS lists. These include a 450 word block, DASPAR, that is filled in by DSTAR. A maximum of 150 different variables may be selected for data recording and their addresses and scale or shift factor (total of 3 words) are kept in RECOM. DASOT takes these addresses and scales and puts the variables at location DASBF, in the FMBFCM compool. RECOM also contains a 288 word block, ALTPAR, that is also filled by DSTAR, and contains space for twelve, 8-item alternate strip chart recorder tables.

RECOM COMPOOL VARIABLES

ALTPAR	ARRAY(12,8,3) INTEGER	ALTERNATE STRIP CHART TABLES 8 ENTRIES PER TABLE 3 WDS PER ENTRY 12 TABLES (SEE DSTAR LIST FOR DETAILS)
DASPAR	ARRAY(150,3) INTEGER	PARAMETERS FOR 150 DASLST ITEMS FORMAT: WORD1: ADDRESS OF VARIABLE (ODD IF NOT F.P. VAR) WORD 2/3: F.P. SCALE FACTOR - OR - WORD2: INTEGER SCALE FACTOR WORD3: INTEGER SHIFT FACTOR
DISOUT	BIT(16)	PACKED DISCRETES FOR OUTPUT
DMLFC	BIT(16)	MLS PF VALIDS AND EX VALIDS FROM MLSFC
MLSOV	BIT(16)	MLS OUTLIER VALIDS FROM MLSFC
RECWD	BIT(16)	RECORD OF DASLST ALT CHART CONFIG SET BY DSTAR OR DASOT
RPTR	INTEGER	SNAP READ POINTER
SCRIT1	ARRAY(20) INTEGER	SVARA: ADRS OF KEY VARIABLE STYPE: FLAGS: BIT 15 SET - SNAP DONE BIT 9 SET - KEY > THRESHOLD BIT 8 SET - KEY < THRESHOLD NEITHER - KEY = THRESHOLD BIT 1 SET - KEY IS F.P VAR BIT 0 SET - KEY IS INTEGER NEITHER - KEY IS BOOLEAN SVART: THRESHOLD VALUE (B,F/P,OR I) SVARS: COMPARISON RANGE (IF F/P OR INT VAR AND COMPARE =) SADRT: SNAP INDEX TO TITLE SADR: ADR TBL OF SNAP DATA
SCRIT2	ARRAY(20) INTEGER	SNAP 2 CRITERIA BLOCK
SCRIT3	ARRAY(20) INTEGER	SNAP 3 CRITERIA BLOCK
SCRIT4	ARRAY(20) INTEGER	SNAP 4 CRITERIA BLOCK
SCRIT5	ARRAY(20) INTEGER	SNAP 5 CRITERIA BLOCK
SPTR	INTEGER	SNAP STORE POINTER
SRST	INTEGER	SNAP RESET FLAG
SDATA	ARRAY(4.16) SCALAR	SNAP OUTPUT BUFFERS SELECTION WD PACKED AT 2 BITS PER VOTED SIGNAL: 0=A, 1=B, 2=C
SELWD1	BIT(16)	GSDEV, HDOTB, FWHL, HRAD, HDD, R, P, Q
SELWD2	BIT(16)	SPLR2, FLAP, CAS, DWHL, DCOL, FCOL, RTRIM. LOCDEV
SELWD3	BIT(16)	HBC, MACH, DRPOS, PHI, THETA, ATRIM, PEDAL, SPLR7

SLWCOM COMPOOL

SLWCOM is included in the SLOW task. SLWCOM contains variables that are referenced only from the NCDU software.

SLWCOM COMPOOL VARIABLES

ABSTAT	BOOLEAN	AIRBLEED STATUS
AM1	INTEGER	CONSTANT -1
A0	INTEGER	CONSTANT 0
A1	INTEGER	CONSTANT 1
A2	INTEGER	CONSTANT 2
A3	INTEGER	CONSTANT 3
A4	INTEGER	CONSTANT 4
A5	INTEGER	CONSTANT 5
A6	INTEGER	CONSTANT 6
ATCBOT	ARRAY(12) INTEGER	BOTTOM LINE OF ATC PAGE
ATCBUF	ARRAY(228) INTEGER	20 LINES OF ATC PAGE
ATCLN8	INTEGER	HOLDS ADDR. OF MESSAGE TO BE DISPLAYED ON LINE 8
ATCLUP	BOOLEAN	CLEARANCE NOT TERMINATED
BLANKS	INTEGER	8-BIT-ASCII BLANKS
CASKAL	SCALAR	"CASCADED" ALTITUDES (FT)
CASKFL	SCALAR	CASCADED FLIGHT LEVEL (FT/100)
CASKGS	SCALAR	CASCADED GROUND SPEED (KTS)
CINPFL	BOOLEAN	STATION SEARCH IN PROGRESS
COP	SCALAR	1/2 DIST. BETWEEN WAYPOINTS (FT)
COSCB	SCALAR	COS (COMPUTED BRG)
COSDA	SCALAR	COS (DEPRESSION ANGLE)
DECADR	INTEGER	DECODED WPT ADDRESS
DECBNG	SCALAR	DECODED WPT BEARING (DEG)
DECLAT	SCALAR	DECODED WPT LATITUDE (DEG)
DECLON	SCALAR	DECODED WPT LONGITUDE (DEG)
DECMV	SCALAR	DECODED WPT MAGNETIC VAR (DEG)
DECNAM	ARRAY(3) INTEGER	DECODED WPT NAME
DECNAV	INTEGER	DECODED WPT NAV. ADDR
DECRNG	SCALAR	DECODED WPT RANGE (FT)
DECTYP	INTEGER	DECODED WPT TYPE 1 = NAVAID 2 = AIRPORT 3 = GRP 4 = WPT/BRG/RNG 5 = LAT/LON WPT 6 = PPOS 7 = PPT(N) 8 = RTE,AWY 9 = SID,STAR
DECVAL	SCALAR	DECODED WPT VALUE
DELBR	SCALAR	VOR DELTA BRG (DEG)
DELGN	SCALAR	NAV ERROR GAIN
DLAM1	SCALAR	DME DELTA LONGITUDE (DEG)
DMEER	INTEGER	DME ERRORS LOGGED
DPHI1	SCALAR	DME DELTA LATITUDE (DEG)
DVECT	VECTOR	DIFFERENCE VECTOR
EPRFLG	INTEGER	0=MCTEPR,1=MCLEPR,-1=MCREPR
FPPWP	INTEGER	MIDDLE WPT PTR IN GBUFF
FRMBUF	INTEGER	FORMATTED BUFFER
FRMNUM	INTEGER	NUMBER OF CHARACTERS FORMATTED

SLWCOM COMPOOL VARIABLES (cont.)

FRMVAL	SCALAR	FORMAT VALUE
F0	INTEGER	DME3 FAIL FLAGS
F1LIM	BOOLEAN	A/P WITHIN DME3 H/R CONE
F2	INTEGER	DME2 FAIL FLAGS
F2LIM	BOOLEAN	A/P WITHIN DME2 H/R CONE
F3	INTEGER	VOR2 FAIL FLAGS
F4	BOOLEAN	ILS NAV UPDATING
HOLDIN	INTEGER	HOLD WPT. ENTERED
GRMAG	SCALAR	GROUND RANGE TO DME (NM)
HIALTF	BOOLEAN	HI ALTITUDE FLAG
ICLAT	SCALAR	COS (IDDLAT)
ICLON	SCALAR	COS (IDDLON)
ISLAT	SCALAR	SIN (IDDLAT)
ISLON	SCALAR	SIN (IDDLON)
LOKPGN	INTEGER	ACTIVE PAGE MODE
LUADDR	INTEGER	LOOK UP ADDR
NCDMSC	INTEGER	SCRATCH NCDU
NEWDES	INTEGER	NEW DESTINATION CHANGE
NEWPTA	INTEGER	NUMBER OF PTA WPT
NGIDON	BOOLEAN	GUIDANCE DONE
PRVDEF	INTEGER	EXEC PATH DEF
PRVEXC	INTEGER	MAKE PROV PATH ACTIVE
PSRTFG	INTEGER	CALL POSERT FLAG
PSFAIL	BOOLEAN	TSTPS STATUS RETURN
PSTMR	SCALAR	PATH DEF TIMER
PSVECT	VECTOR	A/P VECTOR
PTHSTA	BOOLEAN	PATH DEF. STATION FLAG
PTRPS	INTEGER	STATION POINTER
PTRSTA	INTEGER	PTR TO WPT BUFFER
PTVECT	VECTOR	STATION VECTOR
SEG	INTEGER	REQUESTED OVERLAY SEGMENT
SET4D	INTEGER	CALC AND STORE PTA'S
SINCB	SCALAR	SIN (COMPUTED BRG)
SMER61	INTEGER	SEL PAGE1=1 HOLD WPT
SMER62	INTEGER	SEL PAGE1=2 OFFSET
SMER63	INTEGER	SEL PAGE1=3 CIRCLE
SMER64	INTEGER	SEL PAGE1=3 BLANK
SMER65	INTEGER	SEL PAGE1=5 RADIAL
SMER66	INTEGER	SEL PAGE1=6 'TO' WPT
SMF61	INTEGER	SELECT PG.1 MOD. LINE6
STRACT	INTEGER	STARTING POS IN ABUFF
STRPRV	INTEGER	STARTING POS IN PBUFF
TIMS1	SCALAR	STATION 1 TIMER
TIMS2	SCALAR	STATION 2 TIMER
TRANSV	VECTOR	TRANSPOSE VECTOR
TUNPRV	ARRAY (5) INTEGER	SCRATCH
TUNSCR	INTEGER	SCRATCH
UPDTMR	SCALAR	UPDATE TIME LIMIT
VORER	INTEGER	VOR ERRORS LOGGED
WAYNEW	INTEGER	LAST WPT NUMBER
WAYPNT.PPLAT	SCALAR	PRESENT POSITION LATITUDE (DEG)

SLWCOM COMPOOL VARIABLES (cont.)

WAYPNT.PPLON	SCALAR	PRESENT POSITION LONGITUDE (DEG)
WAYPNT.PPMSG	ARRAY(10) INTEGER	NCDU COMMAND LINE FOR PPOS
WAYPNT.PPNAME	ARRAY(2) INTEGER	NAME OF 'POS' WAYPOINT
WAYPNT.PPNAV	INTEGER	ADRS OF ASSOC. WAYPOINT
WTERM	INTEGER	0 WORD TERMINATOR TO WAYPOINT
XSTCTR	INTEGER	STATION CYCLE INDEX
XSTMR	SCALAR	CROSS STA. TIMER (4 SEC)
ZONLIM	INTEGER	ZONE LIMIT
ZONCTR	INTEGER	ZONE COUNTER (CYCLIC)
ZONPTR	INTEGER	ZONE POINTER

I/O OVERVIEW

The I/O routines covered by this section handle the following:

Information coming into the NORDEN #2 computer from hardware sensors and switch/button settings. The interface to the hardware in this case is the SIU (Sensor Interface Unit).

Data to be output from the NORDEN #2 computer to control aircraft surfaces and panel lighting. The EIU (Effector Interface Unit) is the hardware device that interfaces to the NORDEN.

The EIU/SIU interface software uses the compool data block FMBFCM for block transfer of raw information. The actual I/O transfers to/from these units is accomplished by the system executive task (FLTHDL).

The input routines in this section (IOFLL,IN10M) take raw data from FMBFCM and format it to be directly usable by the NORDEN #2 software. Fixed point numeric values are made into floating point values in engineering units and packed discrete words are unpacked to form boolean variables. IOFLL handles data at the 50 millisecond rate, while IN10M takes care of the 10 millisecond cycle.

OUTIO and OUT10M are the counterparts to IOFLL and IN10M. Values in formats usable by the NORDEN software are scaled/packed, and placed in the FMBFCM compool for transmission to the EIU.

See Table 3-1 for a list of the input signals. This includes signal name, units, source, scaling, SIR address, the number of sensors and other pertinent information.

Table 3-2 contains an analogous list of output signals.

MODULE NAME: IOFLL

PURPOSE: Format and fill IOPOOL with inputs from sensors.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL IOFLL

CALLS TO: None

DESCRIPTION:

IOFLL is the link between the SIU (Sensor Interface Unit) and the input area of the IOPOOL compool. IOFLL formats raw sensor data obtained from the SIU via the DATAC. Several classes of raw input are handled:

A) Triplex data to be formatted to floating point.
B) Simplex data to be formatted to floating point.
C) Simplex data to be formatted to boolean.
D) Simplex data, stored across two consecutive memory cells, to be formatted to floating point.
E) Triplex data, stored across two consecutive memory cells, to be formatted to floating point and their respective valids stored as booleans.
F) Miscellaneous data: radar altitude, barometric altitude, flap position, and NCDU line #8 inputs.

Note that each triplex data item has its own selection index to specify which sensor will be used. The selection index is stored in FMBFCM compool each 50 millisecond frame. See documentation on SSFD module for more information on signal selection.

Because of the repetitive nature of the data formatting, IOFLL defines several MACROS to be used on the raw inputs. Each MACRO handles one class (A - E above) of data. The MACROS have parameters such as scaling and biases to define particular aspects of the data item to be formatted.

The miscellaneous items are unique data inputs. Flap handle position (FLAP) is found with a table look up on the raw data word. The raw data for radar altitude (HRAD) is duplex and is used to perform a table look up with interpolation followed by compensation for pitch angle to rotate the raw measurement to wheel height reference. Barometric altitude (HBARO) is computed in a local subroutine (HBSUB). A fine and coarse signal are combined, along with boundary error adjustments, to obtain the value. The NCDU input (NCDUL8) must be massaged to delete the label and reorder the characters to PDP memory positions. This is done also in a local subroutine (NCDIN). IOFLL also limits the minimum value of GSINS to 1 knot and computes TAS from CAS and HBARO whenever the raw value of TAS is less than 150 knots.

All the formatting done by IOFLL is repeated at a 50 millisecond rate. A small portion of the data inputs must be done at a 10 millisecond rate as described in the documentation for the module IN10M.

GLOBAL INPUTS: FMBFCM compool (raw data from SIU).

GLOBAL OUTPUTS: The input section of IOPOOL compool (see IOPOOL documentation)

MODULE NAME: IN1OM

PURPOSE: Format sensor inputs to fill IOPOOL

TASK: FLTHDL

LANGUAGE: MACRO-11

CALLED BY: FLTHDL

CALLING SEQUENCE: CALL IN1OM

CALLS TO: None

DESCRIPTION:

Seven sensor inputs from the SIU (Sensor Interface Unit) need to be formatted at the 10 millisecond rate. These are handled by IN1OM instead of IOFLL (see module documentation on IOFLL). Pitch, roll, and yaw rates, and INS vertical acceleration are all triplex fixed point binary data inputs that need to be scaled and converted to floating point. The X, Y, and Z components of the body mounted accelerometers additionally are filtered in their conversion to floating point.

A selection index, for each triplex data item, is stored in FMBFCM compool. This index is used by IN1OM to determine which memory cell to use in the conversion. See module documentation for SSFD (in the DISPLAYS Computer Software Description document) for more information on selection indices.

GLOBAL INPUTS: FMBFCM raw data areas

GLOBAL OUTPUTS: P, Q, R, BMACC, HDD

INPUT SIGNALS - 10 MSEC ANALOG (IN10M)

SIGNAL	UNITS	SOURCE	SCALING	BIAS	SENSE	SENSOR A	#
			MU/UNIT	MU	(+ INPUT)	SIR ADRS	SENSORS
Q	DPS	RATE GYRO	104.5	-	NU	0001	3
P	DPS	RATE GYRO	104.5	-	RWD	0002	3
R	DPS	RATE GYRO	104.5	-	RT	0003	3
HDD	FPS2	INS ACC	102.4	-	UP	0004	3
BMACC	-	BODY MOUNTED ACCELEROMETERS					
-AX	FPS2	BMACC	64.23	17	FWD	0005	1
-AY	FPS2	BMACC	64.08	-39	RT	000D	1
-AN	FPS2	BMACC	101.23	-3005	DN	0015	1

INPUT SIGNALS - 50 MSEC ANALOG (IOFLL)

SIGNAL	UNITS	SOURCE	SCALING	BIAS	SENSE	SENSOR A	#
			MU/UNIT	MU	(+ INPUT)	SIR ADRS	SENSORS
HRAD	FT	RADAR ALTIMETER	4.1 (BELOW 475')	-1946.	>475'	002A	2
FWHL	LBS	FFD WHL	61.44	-	RWD	002B	3
HDOT	FPS	CADC	12.8	-	UP	002C	3
GSDEV	DEG	NAV RADIO	2048.	-	FLY DN	002D	3
LOCDEV	DEG	NAV RADIO	409.6	-	FLY RT	002E	3
RTRIM	UNITS	AFD TRIM	85.6	-	RT	002F	3 (N/U)*
FCOL	LBS	FFD COL	61.44	-	UP	0030	3
DCOL	IN.	AFD COL	204.8	-	UP	0031	3
DWHL	DEG.	AFD WHL	40.96	-	RWD	0032	3
CAS	KNOTS	CADC	6.86	-412.	>60 KTS	0033	3
FLAP	DEG	FFD FLP HDL	NON-LINEAR	-850.	>10 DEG	0034	3
SPL2	DEG	SPOILER	51.2	-	LWD	0035	3 (N/U)*
SPR7	DEG	SERVO	-51.2	-	RWD	0036	3 (N/U)*
PEDAL	IN	AFD RUN PEDAL + TRIM	409.6	-	RT	0037	3
ATRIM	UNIT	AFD TRIM	204.8	-	RWD	0038	3
PITCH	DEG	INS	182.04	-	NU	0039	3
ROLL	DEG	INS	182.04	-	RWD	003A	3
MACH	-	CADC	65536.±	-13107	>.2	003C	3
HBARO							
-HBC	FT	CADC	.48545±	-	ABOVE MSL	003D	3
-HBF	FT	CADC	13.107±	-	MODULO 5000	003E	3
TAS	KTS	CADC	65.536±	-13107	>200	003F	3
XTKACC	FPS2	INS	128	-	RT	0041	3

TABLE 3-1. - INPUT SIGNALS

INPUT SIGNALS - 50 MSEC ANALOG (CONT.)

SIGNAL	UNITS	SOURCE	SCALING	BIAS	SENSE	SENSOR A	#
	INTERNAL		MU/UNIT	MU	(+ INPUT)	SIR ADRS	SENSORS
GSINS	KTS	INS	5	-	ALWAYS	0043	3
XTVEL	FPS	INS	10.28	-	RT OF RWY	0047	3
ATKACC	FPS2	INS	128	-	FWD	0049	3
VNINS	KTS	INS	10	-	NORTH	004B	3
VEINS	KTS	INS	10	-	EAST	004D	3
THDG	DEG	INS	182.04	-	EAST	004F	3
LATINS	DEG	INS	182.04	-	N. OR EQ.	0051	3
LONINS	DEG	INS	182.04	-	E. OF GRWCH	0053	3
MVINS	DEG	INS	182.04	-	THDG RT.	0055	3
MLSRAW		MLS RAW SIGNAL INPUT VECTOR					
-RANGE	FT	MLS RCVR	.16458	-	ALWAYS	00EC	1
-AZIMUTH	DEG	MLS RCVR	200.	-	LFT OF CTR	00F0	1
-EL1	DEG	MLS RCVR	200.	-	ABOVE RWY	00F4	1
-EL2	DEG	MLS RCVR	443.41	-	ABOVE RWY	00F8	0
STABP	DEG	STABILIZER	96.67	372	>7.25(ND)	0089	1 (N/U)*
TAT	DEG-C	TEMP PROBE	20.06	-	POS TEMP	0109	1
BETAV	DEG	BETA VANE	35.31	-	NOSE RT.	008B	1 (N/U)
ALFAV							(2) (N/U)
-ALV1	DEG	L. ALPHA VANE	34.13	529.	<-15.5	010A	1
-ALV2	DEG	R. ALPHA VANE	34.13	34	<1.0	010B	1
DEPOS	DEG	ELEVATOR PCU	102.4	-	ND	008C	1
ALVDT	DEG	AILERON PCU	102.4	-	RWD	010C	1
THROT							(2) (N/U)
-	DEG	FFD LF THROT	19.25	140	<7.29	010F	1
-	DEG	FFD RT THROT	19.66	40	<2.02	0110	1
MDME2	NM	NAV RCVR	100	-	ALWAYS	0095	1
MDME3	NM	NAV RCVR	100	-	ALWAYS	0115	1
ASTP	DEG	STAB TRIMPOT	20.48	-	TRIMUP	0118	1
FLPPOS	DEG	FLAP SERVO	NON-LIN	-1687.	NEVER	016B	1 (N/U)
AFDTH	DEG	AFD THROT	20.48	-	ALWAYS	016C	1 (N/U)
MAGHDG	DEG	SHIP COMPASS	182.04±	-	EAST	0198	1
MVOR2	DEG	NAV RCVR	182.04±	-21845	>60	019A	0
EPR1	-	LFT ENG.	2171.8	3594.	<1.65	01DC	1
EPR2	-	RT ENG.	2149.0	-3557.	>1.65	01DD	1

NOTES:

* NOT USED BY FLIGHT SOFTWARE, BUT IS CHECKED BY SSFD AND/OR PREFLIGHT SOFTWARE

± 14 BIT SYNCHRO - DIGITAL INPUT: ACTUAL RESOLUTION IS 1/4 THAT SHOWN AS 2 LSB's ARE ZERO.

TABLE 3-1. - (CONTINUED)

INPUT SIGNALS - 50 MSEC BINARY (IOFLL)

SIGNAL	TYPE	SOURCE	INPUT BIT(S)	SENSOR A SIR ADRS	# SENSORS	NOTES
TOGGLE	BIT STRING	SIU	0-15	0021	-	Based on NCDU/MSP inputs
HRV	BOOLEAN	RADAR ALTIMETER	0	0022	2	
DME2VD	BOOLEAN	NAV RCVR	1	00A2	1	
DME3VD	BOOLEAN	NAV RCVR	1	0122	1	
LANDS	BOOLEAN	MSP	2	0022	3	
AUTOS	BOOLEAN	MSP	3	0022	3	
VCWSS	BOOLEAN	MSP	4	0022	3	
ACWSS	BOOLEAN	MSP	5	0022	3	
GSVLD	BOOLEAN	NAV RCVR	6	0022	3	
LOCVLD	BOOLEAN	NAV RCVR	7	0022	3	AND'ED W/LOCFS
VORVLD	BOOLEAN	NAV RCVR	7	00A2	1	ALWAYS FALSE
LAMP	BOOLEAN	MSP	8	0022	3	
IATTV	BOOLEAN	INS	9	0022	3	
CASV	BOOLEAN	CADC	10	0022	3	
CALTV	BOOLEAN	CADC	11	0022	3	
LOCFS	BOOLEAN	NAV RCVR	12	0022	3	
INAVV	BOOLEAN	INS	13	0022	3	
MACHV	BOOLEAN	CADC	14	0022	3	
TASV	BOOLEAN	CADC	15	0022	3	
IC	BOOLEAN	FC PALLET	0	0023	1	
RUN	BOOLEAN	FC PALLET	1	0023	1	
HOLD	BOOLEAN	FC PALLET	2	0023	1	
CRSET	BOOLEAN	FC PALLET	3	0023	1	ALSO SET BY MLOG
ERSET	BOOLEAN	FC PALLET	4	0023	1	ALSO SET BY MLOG
MINS	BCD	SYSTEM CLOCK	0-15	0024	1	MINS/SECS (4 DIGITS)
HRSS	BCD	SYSTEM CLOCK	0-15	00A4	1	(2 DIGITS)
DME2A	BOOLEAN	NAV SELSW	0	0124	1	
ATDC	BOOLEAN	AFD THROT	1	0124	1	
GEAR	BOOLEAN	NOSE GEAR	2	0124	1	
MLSSLI	BOOLEAN	NAV PALLET	3	0124	1	
RASELT	BOOLEAN	-	5	0124	0	NOT USED
ATFDBK	BOOLEAN	AFD THROT	6	0124	1	
CDTI	BOOLEAN	-	7	0124	0	NOT USED
FALST	BIT STR	STP	8-15	0124	1	
DME2FQ	2X5 CODE	NAV RCVR	0-15	0026	1	
DME3FQ	2X5 CODE	NAV RCVR	0-15	00A6	1	

TABLE 3-1. - (CONTINUED)

INPUT SIGNALS - 50 MSEC BINARY (IOFLL)

SIGNAL	TYPE	SOURCE	INPUT BIT(S)	SENSOR A SIR ADRS	# SENSORS	NOTES
AGCSS	BOOLEAN	FC PALLET	0	0126	1	
GAS	BOOLEAN	AFD THROT	1	0126	1	
WSPIN	BOOLEAN	MAIN GEAR	2	0126	1	
BSLECT	BOOLEAN	FFD CCP	3	0126	1	NOT USED
VATRD	BOOLEAN	AFD BROLLY	4	0126	1	
AFCSV	BOOLEAN	28VDC	5	0126	0	ALWAYS TRUE
AFCSS	BOOLEAN	FFD CCP	6	0126	1	
FFDS	BOOLEAN	FFD CCP	7	0126	1	
SQUAT	BOOLEAN	OLEO STRUTS	8	0126	1	
VATRM	BOOLEAN	AFD BROLLEY	10	0126	1	
VATRR	BOOLEAN	AFD BROLLEY	11	0126	1	NOT USED
VATRL	BOOLEAN	AFD BROLLEY	12	0126	1	NOT USED
ISBV	BOOLEAN	SIU	0-2	0117	3	BITS VOTED BY DISFD
DSBV	BOOLEAN	SIU	3	0117	1	*
TSBV	BOOLEAN	SIU	4	0117	1	*
FSBV	BOOLEAN	SIU			1	*

NOTE*: FAILURE OCCURRENCES COUNTED IN MLSER. TDSER, FFLER, RESPECTIVELY BY IOFLL, BUT OTHERWISE UNUSED.

TABLE 3-1. - (CONTINUED)

MODULE NAME: OUTIO

PURPOSE: Formal IOPOOL outputs for DATAC transmission to EIU.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL OUTIO

CALLS TO: None

DESCRIPTION:

OUTIO is the link between the output area of IOPOOL compool and the EIU (Effector Interface Unit). PDP machine formatted data is reformatted to fixed point binary and packed discrete words to be sent via DATAC to the EIU. Most of the formatting is done with MACROS defined in OUTIO. Each has a set of parameters to specify certain characteristics of the particular data item being formatted.

The NCDU page output is accomplished with a local subroutine (NCDOUT). The ASCII data stored at NPAGE is rearranged around label bytes and stored in the output area to be sent to the EIU.

Several software tests of the EIU/SIU hardware are initiated in OUTIO. A discrete and analog set of values is output to the EIU to be wrapped back through the SIU (Sensor Interface Unit) and tested in FAILCP for hardware transmission errors.

All the formatting done by OUTIO is repeated at a 50 millisecond rate. Several outputs must be repeated every 10 milliseconds. See documentation for the module OUTIO for information about these data items.

GLOBAL INPUTS: Output area of IOPOOL compool (see IOPOOL
Description)

GLOBAL INPUTS: FMBFCM compool (raw data to SIU)

MODULE NAME: OUT10M

PURPOSE: Format IOPOOL outputs for transmission to EIU

TASK: FLTHDL

LANGUAGE: MACRO-11

CALLED BY: FLTHDL

CALLING SEQUENCE: CALL OUT10M

CALLS TO: None

DESCRIPTION:

Three data items must be formatted and output to the EIU (Effector Interface Unit) at a 10 millisecond rate. These items are done by OUT10M instead of OUTIO (the 50 millisecond output formatter). Rudder, aileron, and elevator commands are formatted to fixed point integer using a MACRO defined to accept parameters for individual items.

Elevator Command (DECMD) output requires special handling as the pitch rate (Q) feedback is applied to the basic elevator command (DECMQ) in this routine. The equation implemented is:

$$DECMD = DECMQ + (Q-QX)*KQ$$

where QX is a 16 second lag on Q (computed in ELEVP) used to wash out possible bias on the pitch rate signal, and KQ is the mode dependent pitch rate gain also computed in ELEVP. The Digital Systems Diagram for this operation is shown in the DSD for ELEVP.

GLOBAL INPUTS: RUDCMD, AILCMD, DECMQ, Q, QX, KQ

GLOBAL OUTPUTS: FMBFCM raw data areas, DECMD

OUTPUT SIGNALS - 10 MSEC ANALOG (OUT10M)

SIGNAL	UNITS	DESTIN.	SCALING MU/UNIT	BIAS MU	SENSE (+ OUTPUT)	'A' OUTPUT SIR ADRS	'B' OUTPUT SIR ADDS
RUDCMD	DEG	RUDDER	81.92	-	YAW RT	0401	0409
AILCMD	DEG	AILERON	102.4	-	LWD	0402	040A
DECMD	DEG	ELEVATOR	102.4	-	ND	0403	040B

OUTPUT SIGNALS - 50 MSEC ANALOG (OUTIO)

SIGNAL	UNITS	DESTIN.	SCALING MU/UNIT	BIAS MU	SENSE (+ INPUT)	OUTPUT SIR ADRS
APCDG	DEG	THROTTLE	20.48	-	ALWAYS NEG.	040C
REF	VOLTS	SIU/EIU	204.8	*SAWTOOTH FOR	TEST	042F
RWYHDG	DEG	INS	182.04	-	EAST	0462/0463

OUTPUT SIGNALS - 50 MSEC BINARY (OUTIO)

SIGNAL	TYPE	DESTIN.	OUTPUT BIT(S)	SIR ADDRS
STRUA	BIT STR	NOTE 1	0-15	0413
STRUB	BIT STR	NOTE 1	0-15	0414
STRUC	BIT STR	NOTE 1	0-15	0415
ATUNE2	2X5 CODE	NAV RCVR	0-15	0417
WPTALR^2	BOOLEAN	NCDU	0	041B
RWYOUT	BOOLEAN	INS	1	041B
NCOUNP	BOOLEAN	NCDU	2	041B
MDWARN	BOOLEAN	AVON LADY	4	041B
MLSVLD^2	BOOLEAN	NAV PALLET	5	041B
ATE	BOOLEAN	THROTTLE	6	041B
MLSMOD^2	BOOLEAN	NAV PALLET	7	041B
NCUVAL	BOOLEAN	NCDU	8	041B
SPBPSW	BIT STRING	SIU	0-9	041D

NOTES

1. SELF TEST BITS FOR RATE GYROS (A,B,C), ILS RCVRS (A,B,C). RADIO ALTIMETER (A,B) YAW DAMPER AND MACH TRIM. SET BY PREFLT ROUTINES. ELSE ZEROED BY OUTIO.
2. THESE BITS ARE ALSO SET IN FCFLAGS FOR TRANSMISSION TO DISPLAYS NORDEN

TABLE 3-2. - OUTPUT SIGNALS

OUTPUT SIGNALS - 50 MSEC BINARY (CONT.)

SIGNAL	TYPE	DESTIN.	OUTPUT BIT(S)	SIR ADRS	NOTES
ACWSE[2]	BOOLEAN	VARIOUS PALLET LIGHTS	0	0425	2. THESE BITS ARE ALSO SET IN FCFLAGS FOR TRANSMISSION TO DISPLAYS NORDEN
VCWSE[2]	BOOLEAN		1	0425	
AUTOE[2]	BOOLEAN		2	0425	
LANDE[2]	BOOLEAN		3	0425	
DECRB	BOOLEAN		4	0425	
FLARE	BOOLEAN		5	0425	
RLOUT	BOOLEAN		6	0425	
LANDA	BOOLEAN		7	0425	
LOCA	BOOLEAN		8	0425	
LOCE	BOOLEAN		9	0425	
GSARM	BOOLEAN		10	0425	
GSENG	BOOLEAN		11	0425	
GAE	BOOLEAN		12	0426	
AEE[2]	BOOLEAN	FFD CCP	0	0426/0427	
TRIMD	BOOLEAN	STAB TRIM	1	0426/0427	
TRIMT	BOOLEAN	STAB TRIM	2	0426/0427	
SPFINH	BOOLEAN	SPOILER FDBK	4	0426/0427	
ICM	BOOLEAN	FC PALLET	13	0426	
RUNM	BOOLEAN	FC PALLET	14	0426	
HOLDM	BOOLEAN	FC PALLET	15	0426	
(WDTV)	BIT STRING	SIU	0-15	042C/042D	ALTERNATE 1's & 0's
(EOT-001)	BIT STRING	SIU	0-15	042E	WALKING BIT
ALTOMP	BIT STRING	MSP	0-15	0432	32 BIT OUTPUTS
FPTOMP	BIT STRING	MSP	0-15	0434	
TKTOMP	BIT STRING	MSP	0-15	0436	
ASTOMP	BIT STRING	MSP	0-15	0438	
DSTOMP	BIT STRING	MSP	0-15	043A	
RSTOMP	BIT STRING	N/U	0-15	043C	
RATOMP	BIT STRING	N/U	0-15	043E	

TABLE 3-2. - (CONTINUED)

4.0 FLIGHT CONTROLS

FLIGHT CONTROLS OVERVIEW

This section describes the software that receives sensor inputs from the Sensor/Effector Interface Unit (SEIU), calculates according to mode control logic and control laws, and issues commands to direct the aircraft in flight.

The primary commands issued to the control surfaces include aileron command (AILCMD), elevator command (DECMD), rudder command (RUDCMD), autothrottle position command (APCDG), and stabilizer trim discretes (TRIMR, TRIMD). The computation of these commands, as well as the accompanying mode logic and error reporting are covered in detail in the following pages.

MODULE NAME: DINUSE

PURPOSE: To tell DISFD which discrete sensors it is required to check at any given time.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: If not in preflight CALL DINUSE.

CALLS TO: None

DESCRIPTION:

Based on the current flight mode and condition of the aircraft, DINUSE sets the sensor in use bit (#2000 octal) of the appropriate sensor status word. Each discrete signal is allocated one status word. This is then detected by DISFD which votes the signal if the bit is set.

GLOBAL INPUTS: MODEX, FLAGS, MLSMOD, LOCFS, LOCVLD, GSVLD, VBS, LBS

GLOBAL OUTPUTS: DSTAT

NAME: DISFD (Discrete Select and Failure Detect)

PURPOSE: To detect momentary discrepancies and failed sensor or serial bus errors for the packed discretes.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL DISFD

CALLS TO: None

DESCRIPTION:

Raw discretes arrive from the triplicate sensors, packed in one word per sensor, via the DATAC bus. The three words are "debounced" over a period of 5 input cycles to insure that any bit change was not a fluke. The output is a single packed word with each bit set with slightly different logic depending on whether it is a select, a valid, or the duplex HRV. The output is stored in the compool BF at VDISC (BF + 60) for subsequent unpacking by the routine IOFLL.

For selects, the individual debounced bits are compared with the majority logic vote from the debounce routine. If any select bit differs from the majority three times within 512 cycles, then a fail flag for that channel is set in the status word. A second channel failure causes the second-fail flag to be set.

For the valids, if any bit is invalid 3 times within the 512 pass cycle, then the fail bit is set in the status word for that channel. A second fail results in the second-fail bit being set in the status word.

If the INS Single Thread flag has been set, then IATTV, INAVV and ISBV in all 3 raw discrete words are set to agree with the selected channel as determined by bits 0-1 (INSST) in the global word SINUS3.

PACKED DISCRETES WORD FORMAT

BIT	SIGNIFICANCE	
0	HRV	(Duplex)
1	ISBV	
2	LANDS	
3	AUTOS	
4	VCWSS	
5	ACWSS	
6	GSVLD	
7	LOCVLD	
8	LAMPS	
9	IATTV	
10	CASV	

11	CALTV
12	LOCFS
13	INAVV
14	MACHV
15	TASV

DEBOUNCE ALGORITHM

```
A3 = A2
A2 = A1
A1 = A  .XOR.  MLO
A2 = A2 .AND. A1
AF = AF .AND.  .NOT. A3 .OR.  A .AND. A3

     (REPEAT FOR CHANNELS B & C)

MLV = AF  .AND.  BF  .OR.
      AF  .AND.  CF  .OR.
      BF  .AND.  CF

MLO = MLO  .AND.  PMLV  .OR.
      MLV  .AND.  PMLV

    WHERE:  A    = NEW INPUT
            A1   = FIRST BOUNCE, ETC.
            AF   = DEBOUNCED VALUE
            MLO  = MAJORITY LOGIC OUTPUT
            MLV  = MAJORITY LOGIC VOTE
            PMLV = MLV FROM LAST PASS
```

GLOBAL INPUTS: BF, CRSET, DSTAT, SINUS3.

GLOBAL OUTPUTS: DSTAT, VDISC.

MODULE NAME: DSTOR

PURPOSE: Stores data for error messages into failure data table.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FDSTR, ILSRC, SRVCK

CALLING SEQUENCE: In FIDENT load address of failure message.
In FIDENT+10. load failed data value.
In FIDENT+12. load voted data value.
CALL DSTOR

CALLS TO: None

DESCRIPTION:
DSTOR packs eight words of information needed to create an error message into a data area for retrieval later by FMTMG. The arrangement of these eight words is as follows.

Word 1	Failure ID (address of failure message in MESG)
Word 2	Sensor channel failed/MODEX mode at failure time
Word 3	Hour of failure
Word 4	Minute of failure
Word 5	Second of failure
Word 6	Failed data value
Word 7	Voted data value
Word 8	Null word (set boolean true by FDSTOR if system reset)

This routine shares common local data with FDSTR, PANEL, FMTMG, and F2CMP.

GLOBAL INPUTS: FIDENT, MODE2, HRSS, MINS

GLOBAL OUTPUTS: FLTBL or PFLTBL, FIDENT

NAME: ELEVP -- ELEVator control laws (Pitch)

PURPOSE: To calculate the elevator command and to calculate the stabilizer trim and autothrottle commands.

LANGUAGE: HAL/S

TASK: FAST

CALLING SEQUENCE: CALL ELEVP

CALLED BY: FAST

CALLS TO: ATHCL, HXFCL, LIMINT, PAFD, PAL, PFFD, PVPC, SCOSD, STABT, VTFCL, $$EXP.

DESCRIPTION:

Only two modes are available from the forward flight deck for elevator commands: pre-engage (PRENG) and forward flight deck attitude control wheel steering (FFDE). During the PRENG mode, the autopilot is disengaged. The computational requirements for the elevator command for the FFD mode are described in PFFD. All inputs shown are voted from the "outside world" except for KV and PHIVS, which are computed in the ELEVP executive routine.

There are five distinct modes that can be flown from the aft flight deck: MANEL, ACWSE, VCWSE, AUTOE and LANDE. The overall DSD showing the computational requirements for the elevator command for these AFD modes is given in the DSD section in the back of this document. The overall static gains are included in these figures.

Procedure ELEVP is the driver for all the sub-procedures which comprise the longitudinal axis control law. It consists of initialization routines, the glide slope engage (GSENG) and track (GSTRK) logic, and procedure calls.

ELEVP begins with a check for a change in flight mode since the last iteration. If there was such a change, the easy-on/off switch is initialized (INIT = TRUE) to gradually phase in the elevator comand for the new mode. Also, the high rate Q feedback gain (KQ) is set to zero. This gain is reset to the appropriate value for those modes which use it by mode dependent logic. If the current mode is PRENG or if the ICM flag is set, the filters and command outputs are initialized. Then, for all modes, pitch rate (Q) is filtered and stored in QFB1 and QX. Versine (PHI) is approximated and stored in PHIVS. The ILS vertical velocity, HDILS, is initialized as required; the "flare set on last pass" flag, FLARE_1, is updated, and filtered vertical acceleration (HDDF) is computed. GSENG logic is executed; airspeed gain (KV) is calculated, and the ten second countdown from GSENG to GSTRK is begun (if GSENG is TRUE). Subsequently, through a case statement, ELEVP processes the active mode as indicated by the value of MODEX.

For each of the modes described below, the intermediate output is DECGL, which is passed through the 1/2 second easy-on/off switch initialized at ICM or mode change. Except for LANDE, DECRB, and FLARE, the final elevator command is phased in as DECMQ. Then, the switch in control law source (and setting of INIT) occurs at GSENG. The next switch occurs at FLARE, but the control law itself takes care of the easy-on.

For PRENG mode, the elevator servo position (DEPOS) is simply passed to DECGL, without modification.

For MANEL mode, the column force input, DCOL, is processed through a deadzone, and, if out-of-detent, it is multiplied by -6.96.

For FFDE mode, the sub-procedure PFFD is called.

For ACWSE and VCWSE modes, sub-procedure PAFD is called.

For AUTOE mode, if GSENG is set for the first time, then the easy-on switch is initialized and sub-procedure PAL is called. Otherwise, sub-procedure PVPC is called to generate the elevator command. The present setting of GSENG is saved in GSENG_1 for the next iteration.

For LANDE mode, the pitch autoland control law sub-procedure, PAL, is called and the easy-on/off switch is disabled. This permits the intermediate elevator command DECGL to pass directly through to the output DECMQ.

For DECRB and FLARE modes, if the flare control law flag, FLRFLG, is TRUE, then the H(x) control law, sub-procedure HXFCL, is used. If FLRSEL is FALSE, then the variable-tau law, sub-procedure VTFCL, is called.

For DECRB mode, if the FLARE flag is FALSE, sub-procedure PAL is also called. In this mode also, the easy-on/off switch is disabled.

For RLOUT mode, the elevator is driven to zero by a 1 second lag filter for nose wheel letdown. For all high speed modes (FFD, ACWS, VCWS, AUTO), the summation of pitch rate feedback is done externally at the 10 Msec rate, using the ELEVP outputs KQ, QX, DECMQ, and the 10 Msec pitch rate (Q) input.

To conclude ELEVP processing, the stabilizer trim sub-procedure, STABT, and the authrottle control logic sub-procedure, ATHCL, are both called unconditionally.

SUB-PROCEDURES:

PFFD (Pitch, Forward Flight Deck)

This routine computes the delta elevator command in the forward flight deck CWS mode. The column force (FCOL) is processed through a +/- 5 lb. deadzone to yield FCOM, then filtered to give FFD1. If the elevator authority limit flag (DEAL) is FALSE, FCOM is multiplied by .1935 and integrated to give PINT1, with a limit of +/- 40 degrees pitch command. The error signal (PFFDE) is calculated by subtracting PINT1 from PITCH. This error is integrated only if FCOL is less than 5 lbs, and if the roll angle command (PHICMD) is less than 5 deg. The result of this integration, PINT2, is multiplied by .05, added to PFFDE, reduced by .1904 FFD1, and the result multiplied by 4.32 to give FCWSE. This signal is reduced by PHIVS to produce FDED. It is then used to set the elevator authority limit flag (DEAL) if the effective elevator command is greater than 15 degrees. Finally, it is attenuated as a function of KV and output as DECGL.

PAFD PROCEDURE (Pitch, Aft Flight Deck)

This procedure computes the delta elevator command (DECGL) in the velocity and attitude CWS modes and gamma commanded (GAMC) in the velocity CWS mode. It provides the DECGL command by direct pilot control over the commanded fight path angle (GAMMA) for VCWSE, or the pitch attitude (PITCH) for ACWSE. When the column is released, the commanded GAMMA (or PITCH) holds constant. The control law takes column input in a proportional and in an integral path. The proportional path gives the initial elevator command to initiate the maneuver to change the path angle or pitch angle.

The AFD column deflection (DCOL) is passed through a 0.1 inch deadzone and programmed with ground speed such that the commanded normal acceleration per inch of column input remains constant over the speed range. If GAE (go-around engaged) is set then a 2 degree bias is integrated into GAMC (gamma commanded) calculation until the 2 degree fly-up is achieved. At this point GAE is reset. The appropriate term for column deflection is filtered, integrated, and stored in GAMC. The GAMC integrator is modified if the VATRM (manual stab trim) flag is set; a 0.5 degree/sec bias is added. If VATRD (manual auto stab trim down) is set, a 0.5 degree/sec bias is subtracted.

The commanded gamma is subtracted from either GAMMA or PITCH to produce the error signal, GAMER. This is used in both the proportional and integral paths to develop the elevator command. Feedback of filtered pitch rate (QFB1) and the rate of change of error signal GAMD provide damping terms for the control law. DECGL is returned to ELEVP.

PAL (Pitch Auto Land control law)

This procedure computes the delta elevator command, DECGL, in auto-engage with glide slope engage, land engage or decrab modes.

If in MLS mode, the beam error is derived from DELTH (the MLS altitude error) gained as follows:

GSPF = 1.06(.0666 DELTH)

For ILS mode, it is derived from GPGSDV with modifications depending on the state of GSTRK. If GSTRK (which is set 10 secs. after GSENG) the difference between the altitude rate of a path parallel to the glideslope (GSFPS * tan(GSA)) and the filtered rate of altitude change (HDCF), is integrated with the beam error, and the output is filtered over 15 seconds to produce GSPF. If NOT GSTRK, the slope deviation is calculated as 1.06 GSGPA (gain programmed glideslope deviation) and filtered over 1.5 seconds to produce GSPF.

Subsequent processing is common to both MLS and non-MLS modes. ALC is generated by summing 4.0 (GSPF + .39 HDCF) with the filtered vertical acceleration (HDDF). A portion of the original gain programmed deviation signal (.28 GSGPA) is integrated and limited to give GSI. (GSI was initialized as DECMD - ALC.) This serves as an easy-on during glideslope capture and compensates for inaccuracies in the slope of the glideslope beam.

The final output, DECGL, is calculated as follows:

DECGL = KV(ALC + GSI + 2.16 QFB1 - PHIVS)

Where:

QFB1 is the filtered pitch rate feedback.

DECGL is returned to ELEVP.

PVPC (Pitch Vertical Path Command)

This routine computes the elevator command DECGL for AUTOE mode when the glide slope has not been engaged. (PAL is called when GSENG IS TRUE.)

A vertical path command (EVPC) is derived as the difference between the vertical acceleration signal, HDDF, and the vertical acceleration command, VACMD. This difference is integrated whenever TRIMT is false (indicating stabilizer trim is not active) or when the sign of EVPC differs from the sign of the integrator output (INT2). The integrator output is limited to +/- 20 degrees, gained by .25, and summed with PHIVS and the original estimated path command, EVPC, to produce EVPCS. This is gained by KV and output as DECGL.

HXFCL (H(x) FLARE CONTROL LAW)

HXFCL is the newer of the two flare control laws. It is called if the flag FLRSEL (IC = FALSE) is TRUE. The H(x) routine initializes itself, and sets the FLARE flag, at descent through 42 feet of altitude (in ILS mode), or when XHAT is less than XFLARE (MLS mode). It commands altitude as a function of distance (XFF) from FLARE to touchdown and thereby provides better control over the touchdown point than does the variable tau law. For MLSM, XFF is computed as the difference between

XFLARE and XHAT, where the former is a predefined (RWYDEF) distance from the MLS azimuth transmitter to a TD point at a nominal distance past XGPIP. For ILS, XFF is computed indirectly as the integral of INS ground speed. Subsequent processing is identical for both ILS and MLS modes.

The altitude command computations generate the commanded altitude (HC), rate (HDC), and acceleration (HDDC) as follows:

```
HC = (K1/K2**2) (EXPO -.25 EXPOSQ) + K3 XFF + K4,

HDC = VGF ((K1/K2) (.5(EXPOSQ - EXPO) + K3),

HDDC = (VGF**2) K1 (EXPO - EXPOSQ)

     Where:
          EXPO   = e**(-K2 XFF)
          EXPOSQ = EXPO**2
          K1     = .0001816455
          K2     = .002047959
          K3     = -.0079918
          K4     = 9.51766
          VGF    = Ground speed in ft/sec:
                      For MSW1 . EL2F. VGF = -XDH,
                      ELSE, VGF = GSINS  KTOFPS.
          XFF    = Runway dist. in feet from flare pt.
```

The difference between the altitude and commanded altitude (KHXH - HC) is computed and stored in HEPS. HDERX and DEFL1F are then calculated as:

```
HDERX  = HDILS - HDC

DEFL1F = 4.0 HDERX + 2 HEPS - 2.5 HDDC
```

The quantity (KHXDD + 5.46 QFB1 - HDDQF) is integrated and the result added to .72 HEPS (HEK) and filtered QFB1 (KDTW). This is stored in HDDQF.
The output of the HXBIAS filter, which is zero at initialization and decreases to -5 degrees, is added to DEFL1F to produce DEFL2F. This is added to HDDQF and multiplied by KV to give the elevator command DECGL.

VTFCL (Variable Tau Flare Control Law)

VTFCL is the default flare control law, called when FLRSEL is FALSE (the initial state). This routine initializes itself, and sets the FLARE flag, at descent through 42 feet of altitude (HTDZ for MLSM, HRAD for ILS). The variable tau law functions to drive the rate of descent exponentially to 2 fps at touchdown.

On the first pass, the filters and integrators are initialized. The height is biased up 10 feet, multiplied by the ground speed, added to the vertical velocity, HDILS, and the result stored in DEFL1. Errors in the sink rate are then corrected by use of a complementary filter using HDD for ILS OR ZDDH for MLS, and filtered pitch rate, QFB1. The result is stored in HDDQ. The output of the FTAUF3 filter, which is initially set to zero and decreases to -4 degrees to set the elevator command bias, is added to DEFL1 and HDDQ.

This, multiplied by KV, yields the output DECGL.

STABT (STABilizer Trim)

This routine determines the stabilizer trim command, ASTP, and the on-ground discrete, GRD. GRD is set when SQUAT becomes TRUE, and remains set as long as the radar altitude remains less than 10 feet.

The discrete, TRIMT, is cleared if GRD, MANEL, or PRENG are set. If the magnitude of the auto stabilizer trim position, ASTP, is less than one degree, then TRIMT is cleared; if the magnitude is greater than one degree and less than 1.33 degrees, TRIMT is not changed. If ABS(ASTP) remains greater than 1.33 for 24 cycles, then TRIMT is set TRUE. If ASTP is negative and TRIMT is set, the trim down discrete, TRIMD, is set, otherwise, TRIMD is cleared.

ATHCL (AutoTHrottle Control Law)

ATHCL is called unconditionally on each cycle of ELEVP. There are three operating modes which depend on authrottle engagement (ATE) and on the state of the FLARE flag. The routine first evaluates the indicators for authrottle engagement and sets the ATE flag accordingly. Then the throttle position aft limit, AFTLIM, is set to zero during flare or whenever the airspeed is greater than 250 knots. Otherwise, it is increased as a function of airspeed in order
to reduce "spool-up" time of the engines.

$$\begin{aligned} \text{AFTLIM} &= 10 \text{ degrees}, && \text{for CAS} < 200 \text{ knots.} \\ &= .2\ (250. - \text{CAS}), && \text{for } 200 <= \text{CAS} <= 250 \text{ knots.} \\ &= 0, && \text{for CAS} > 250 \text{ knots.} \end{aligned}$$

The complementary filtered longitudinal acceleration signal, NCI01, is derived by washing out the inertial longitudinal acceleration, VGSDOT, with the true airspeed signal, TASFPS.

$$\text{TEMP} = 5.\ (\text{TASFPS} - \text{NCI01})$$

$$\text{NCI01} = \text{NCI01} + \text{DELTAT}\ (\text{TEMP} + \text{VGSDOT})$$

This signal is then passed through a turbulence filter to limit high frequency components:

$$\text{TEMP} = \text{TEMP} - \text{NCI02}, \quad \text{limit} = +/- 1.$$

NCIO2 = NCIO2 + (.2 DELTAT) TEMP

NCL1, the longitudinal acceleration damping signal, is computed as the sum of VGSDOT and NCIO2, and limited to +/- 16.0 ft per sec per sec (fps2).

If the autothrottle is engaged (ATE) and the FLARE flag is set, then the raw commanded autothrottle position rate, APCPRM, is set to -2.8. This will cause the position command integrator, NCIO3, to be ramped back to zero at a 2.8 degrees per second rate.

If NOT ATE, APCPRM is set to 10.0 if the autothrottle feedback flag, ATFDBK, is set, otherwise, it is set to -10.0. This causes the autothrottle command to be synchronized to the throttle handle position.

If (ATE . $\overline{\text{FLARE}}$), then a series of actions occur. The raw throttle position rate command, APCPRM, is calculated as

APCPRM = 3.0 (VSPHI - LAG16S + ATCMD -NCL1)
Where:
VSPHI = 5 -(5 cos(ROLL))

LAG16S = last cycle filter output

VSPHI is then passed through a 16 second washout filter to generate a new roll compensation signal:

LAG16S = e**(-.05/16.0) (LAG16S - VSPHI) + VSPHI.

The engine pressure ratio (EPR) limit calculation then controls the throttle position command so as not to exceed the limits for the engine with the highest current EPR. If the throttle command is positive, the gain (SEPR) is calculated as the difference between the maximum EPR and EPR, gained by 3.3333, and limited to 1.0. APCPRM is then gained by SEPR. This attenuates the rate command as the engine approaches maximum output. However, if one EPR already exceeds MXEPR, (SEPR less than zero), then the raw throttle command is immediately set to 10 times SEPR.

For all modes, APCPRM is integrated to form NCIO3, then limited to a value between 60 degrees and AFTLIM. Finally, the intermediate command is conditionally summed with the damping term to produce the final autothrottle position command, APCDG.

APCDG = 2.4 NCL1 - NCIO3

If FLARE is set,

APCDG = -NCIO3.

GLOBAL INPUTS: ACCHAT, ASTP, ATCMD, ATE, ATFDBK, CAS, CROLL, DCOL, DECMD, DEPOS, EL2F, EPR1, EPR2, FAIL2, FCOL, FLAGS, FLRSEL, GAE, GPGSDV, GS, GSDEV, GSFPS, GSVLD, HDCF, HDD, HGPIP, HRAD, HTDZ, IASSEL, ICM, MLSC, MLSM,

MODE2, MODEX, MSW1, MSW6, MXEPR, PHICMD, PITCH,
POSHAT, Q, ROLL, SQUAT, TANGSA, TASFPS, TIMPTH, VACMD,
VATRD, VATRM, VELHAT, VGSDOT, XFLARE, XGPIP.

GLOBAL OUTPUTS: APCDG, ATE, DECMQ, DSPLF, FLAGS, GAE, GAMC, GAMMA,
GRD, KQ, KV, MODEX, QX, TRIMD, TRIMT, VBS.

NAME: EPRLMT (Engine Pressure Ratio LiMiT)

PURPOSE: To calculate the maximum engine pressure ratio (EPR) for the Boeing-737 aircraft jet engine.

LANGUAGE: HAL/S

TASK: SLOW

CALLED BY: SLOW

CALLING SEQUENCE: CALL EPRLMT

CALLS TO: None

DESCRIPTION:

EPRLMT produces maximum EPR limits for climb (MCLEPR), cruise (MCREPR), and continuous thrust (MCTEPR). Depending upon the setting of EPRFLG, one of these is selected as the maximum EPR (MXEPR) for display.

The program is organized in two logical sections, for engine bleed-air on, and for engine bleed-air off. The calculations consider the effect of static air pressure (STAT_PRES), true air temperature (TAT), and altitude (ALT). A first order approximation is used to calculate the maximum EPR for each possible case. Constants for the approximations were supplied by Boeing for the JT8D-7 engine and are documented in the flow chart.

GLOBAL INPUTS: ABSTAT, ALT, BARSETO, EPRFLG, TAT.

GLOBAL OUTPUTS: MCLEPR, MCREPR, MCTEPR, MXEPR.

MODULE NAME: FDSTR

PURPOSE: Examines status of redundant sensors to detect failure flags and record failure information in a table of failure data.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL FDSTR

CALLS TO: DSTOR

DESCRIPTION:

This routine has five major parts. The first four incorporate checking the sensor status as reported by the SSFD. These four parts are segregated mainly by the allocation of the sensors they each process. The first section involves testing of the 10 ms sensors. The second and third test the 50 ms analog and 50 ms digital INS sensors, respectively. The fourth tests the discrete signals. Lastly five separate tests are run on the Sensor-Effector Interface Unit (SEIU), Research Flight Deck Interface Unit (RFDIU) System and a test on the DATAC link between the two NORDEN computers.

All sensors are checked for their failure status using a similar procedure. Each sensor is scanned initially for second failures and then for first fails. For a description of the meaning of first and second failures see the description of SSFD. If a failure is indicated and has not already been recorded, the needed failure data is formatted into eight words and stored in a failure data table by the routine DSTOR for later retrieval by FMTMG when a failure display is requested.

A series of tests is performed on the SEIU/RFDIU system. The first test checks communication between the Norden #2 and the SEIU. Second is a check for power failure on the SEIU. Thirdly, a test is run on the six SEIU and two RFDIU analog to digital converters. Fourth is a test of Norden #2 to RFDIU communication. Fifth, a test for RFDIU power fail is made. Last, a test of the DATAC link from Norden #1 to Norden #2 is made.

This routine shares common local data with DSTOR, PANEL, FMTMG, and F2CMP.

GLOBAL INPUTS: SQUAT, WSPIN, FALST, MSWIT, STFAIL, BF, DSTAT, HRV, ANDS,
AUTOS, VCWSS, ACWSS, GSVLD, LOCVLD, IATTV, CASV, CALTV,
LOCFS, INAVV, ISBV, DSTAT, TASV, FLAGS, CRSET

GLOBAL OUTPUTS: PMSWIT, MSWIT, STFAIL, FIDENT, LIGHTS

MODULE NAME: FMTMG

PURPOSE: Formats failure messages from the form stored in the failure data tables into an ASCII form which can be output to the system test panel by GMSG.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: PANEL, PRFLT, CTLCK, ILSRC, DETNT (MLOG)

CALLING SEQUENCE: In R1 load address of message to be formatted. It is used to determine if the message is of the demand type. In R2 load address of first word of eight stored in the failure data table (R2 is required only if the message is of the type stored in the failure data tables). CALL FMTMG

CALLS TO: None

DESCRIPTION:

Four different types of messages are formatted by FMTMG. The first byte of the message to be formatted contains a control character that denotes its type. The four control characters and their meanings are:

<space> - Demand message. Format only the message text. This type of failure is not stored in the failure data tables. Contains up to 32 characters of text.

< 1 > - Analog sensor failure. Format time of failure. Nine characters of message text, channel failed, flight mode when failure occurred, analog failed value, and analog voted value.

< 2 > - Discrete sensor failure. Format time of failure. Seventeen characters of message text, channel failed, flight mode when failure occurred, discrete failed value, and discrete voted value.

< 3 > - General purpose failure. Format time of failure. Seventeen characters of message text, failed channel, flight mode when failure occurred.

This routine uses a local subroutine called ICO to convert octal values into decimal ASCII.

This routine shares common local data with FDSTR, DSTOR, PANEL, and F2CMP.

GLOBAL INPUTS: MSWIT, LIGHTS, MESG (pool of error messages)

GLOBAL OUTPUTS: MSBUF, MSGST, WRDCNT

MODULE NAME: F2CMP

PURPOSE: Checks individual sensor second fails to determine if a mode failure is required.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: (If in flight mode) CALL F2CMP

CALLS TO: FMTMG

DESCRIPTION:

Given the existing flight mode this routine determines which sensors are critical for that mode and checks them for second failures. If a second failure is found, a failure of that mode is flagged and the appropriate mode failure message is displayed on the system test panel. This routine also clears all mode failure flags upon CRSET and clears the error message table upon ERSET.

This routine shares common local data with FDSTR, DSTOR, PANEL, and FMTMG.

GLOBAL INPUTS: BF, MODEX, MLSVAL, BMAFLG, AFCSV, CASV, IATTV, DSTAT, INAVV, CALTV, MLSMOD, GSVLD, LOCVLD, ATE, TAS, TASV, FAIL2, DSPLF, FSIDX, MESG (pool of error messages), CRSET, ERSET

GLOBAL OUTPUTS: FAIL2, DSPLF, LIGHTS, STFAIL

MODULE NAME: GMSG

PURPOSE: To output data to the system test panel and printer.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: SLOW

CALLING SEQUENCE: MSGST contains address of message start. WRDCNT contains
the number of bytes to be output.
If WRDCNT <> 0 CALL GMSG

CALLS TO: None

DESCRIPTION:

GMSG drives the system test panel display and lights with data stored in a message buffer. This buffer's location is dynamic and it's address must be stored in the word MSGST. The length of the buffer is also dynamic and must be stored in WRDCNT (number of bytes). A special case calling this procedure is when the test pattern is required on the system test panel. This is accomplished by clearing MSGST before calling GMSG.

GMSG also outputs to a line printer all messages (except panel test pattern).

GLOBAL INPUTS: WRDCNT, MSGST

GLOBAL OUTPUTS: WRDCNT, IOACT

MODULE NAME: LATRL (Lateral axis control law)

PURPOSE: To calculate aileron and rudder commands for the flight control system.

LANGUAGE: HAL/S

TASK: FSTTSK

CALLING SEQUENCE: CALL LATRL

CALLED BY: Fast loop executive (FAST)

CALLS TO: FRCWS, RCOM, RBASC, CMPF, DCRAB, LIMINT, SRLMT

DESCRIPTION:

LATRL is the scheduler which calls the other procedures which make up the lateral axis control laws. It is composed primarily of logic checks, initialization routines, and procedure calls.
The sub-procedures are:

FRCWS	Forward flight deck control wheel steering
RCOM	Roll command computer
RBASC	Basic roll computer
CMPF	Complementary filter
DCRAB	Decrab flight mode calculations

LATRL first assigns or calculates the parameters for the MLS or ILS modes, especially determining whether the localizer is engaged (LOCE) and the aircraft on-course (ONCRS). For both MLS and ILS, if LOCE is TRUE the localizer deviation logic is executed and the complementary filter procedure CMPF is called.

Next, the lower flight modes are checked and processed as appropriate. ICM and PRENG are done first. Then, if FFDE mode is active, procedure FRCWS is called. If the mode is MANEL, that logic is performed in-line and LATRL terminates.

For the higher flight modes, procedure RCOM is called unconditionally, followed by DCRAB if DECRB flight mode is active and by RBASC. The aileron servo command (AILCMD) and rudder servo command (RUDCMD) are determined, the initialization flags are reset, and LATRL terminates.

Various combinations and levels of automatic fight control assistance are available to the AFD and FFD pilots. The lateral control laws for each mode are depicted in the DSD's found in the back of this manual. Each mode is listed below, with the source of inputs and the control law used. Note that the AFD cab does not have an aileron trim mechanism, therefore the aileron trim knob command is brought into the FCC separately and is summed with the aileron command.

MODE PROCESSING:

PRENG:

The aileron trim command is initialized to zero at auto-pilot engagement regardless of aileron trim knob position. This is done by summing the aileron trim command with the aileron position signal. This is not done outside the pre-engage mode but the pre-engage value of the aileron position and trim command is available in SYNCL. The aileron synchronization routine is:

1. SYNCL = 1.52 ATRIM (Limited to +/- 5.0)

   SYNCL = ALVDT + SYNCL

2. AILCMD = ALVDT

3. RUDCMD = DRPOS

FORWARD FLIGHT DECK CWS (FFD):

The lateral axis control signals for the forward flight deck CWS mode is programmed entirely in one procedure. The FFD CWS has two submodes, attitude hold and attitude synchronization. In the ATT_SYNC submode, roll attitude is controlled by the pilot's wheel inputs. Roll command (FPHCMD) is forced to track roll attitude (PHI) by feeding the difference between the two signals as an error signal to the FPHCMD integrator. ATT_SYNC submode is entered when the pilot applies a control wheel force sufficient to exceed the wheel input deadzone. When the wheel force is released, the control wheel centers, roll rate is reduced, and the difference between PHI and FPHCMD becomes increasingly small. When the difference (FPHIER) is sufficiently small, the altitude hold submode (unlabeled) is entered by default. In this submode, the roll command (FPHCMD) is held constant by removing the input to the roll command integrator. This submode is transparent in that the FRCWS procedure normally generates a "hold" roll command and changes it only if ATT_SYNC is TRUE.

AFT FLIGHT DECK MODES:

MANEL:

In the manual-electric mode, pilot inputs (DWHL) and aileron trim knob input (ATRIM) are processed in the roll basic (RBASC) procedure and are summed to form aileron command.

WHLINP = 0, IF DWHL < 1.0

= -.448 * (DWHL - SIGN(DWHL)) otherwise.

AILTRM = ATRIM * 1.52

RUDCMD = PEDAL * 6.55

AILCMD = -(WHLINP + AILTRM - SYNCL)

ACWS:

The Attitude Control Wheel Steering mode uses sensor feedback to stabilize the airplane. Roll rate feedback is computed in mainline code. The difference between roll command and roll angle is PHIERR and is computed in procedure RCOM. The main stabilizing term is roll rate (PHDOT) which is filtered, then summed with PHIERR to form the aileron command (AILCD1). The roll rate signal would tend to cancel the pilot's input, so roll rate feedback is removed when RCWOD becomes TRUE. In order to maintain the same performance at all speeds, aileron command is gain programmed as a function of airspeed.

In ATTCWS, the roll computer, procedure RCOM, has two submodes. These are attitude-synchronization (ATT_SYNC) and attitude-hold, which is the normal mode. When the pilot moves the panel mounted controller (PMC) far enough to exceed the DWHL deadzone, the RCWOD logic is satisfied and the ATT_SYNC submode is entered. In ATT_SYNC, the difference between PHI and PHICMD is used to drive PHIERR to zero, i.e, to make PHICMD track PHI. In this submode, the roll computer has a loop gain of 15. This value was chosen empirically for best pilot response. The limit (ROL_LIM) on the PHICMD integrator is 50. degrees.

When the airplane is at the desired roll attitude, the pilot centers the PMC, RCWOD is no longer TRUE, and roll rate decreases. When PHIERR is sufficiently small, ATT_SYNC changes to the attitude hold submode. In this mode, the input (PDTCMD) to the PHICMD integrator is zero.

The roll basic (RBASC) procedure processes the pilot's ATRIM and PEDAL inputs and also contains the turn coordinator. Turn coordination is used in the control wheel steering modes when the flaps are down to improve lateral handling. Since roll command anticipates a turn, it is used to command some corresponding yaw through the rudder. The rudder input is only required for turn initiation, however, so roll command is passed through a washout circuit. The output of the turn coordinator is summed with the pilot's pedal input to form the rudder command.

VCWS:

Velocity control wheel steering has three submodes. The first two, ATT SYNC and attitude-hold, are the same as in ACWSE, where attitude-hold is the unlabelled default mode. The third submode is called TRACK_HOLD. In procedure RCOM, upon leaving ATT_SYNC submode, either attitude-hold or TRACK_HOLD is entered. If roll attitude is greater than 5 degrees, attitude-hold is entered; if less, TRACK_HOLD is entered. The purpose of TRACK_HOLD is to maintain a constant ground track. This is achieved by keeping average cross track acceleration (XTACC) zero. XTACC is calculated in HNAVFS and is based on INS or MLS sources, depending on the active mode. XTACC is integrated once (XTK1) and used as an input to the roll computer to command a roll angle (PHICMD).

If the airplane were mistrimmed in the lateral axis, some XTK1 signal could be required to command sufficient aileron to return the airplane to trim. This would result in some cross track drift. To remove this error source, XTK1 is integrated to form XTK2 which is summed in the mainline code with aileron command. When the pilot makes a wheel input to turn to a new heading, the XTK1 integrator is reset to zero. Since the mistrim will change minimally with heading, the XTK2 integrator is "washed out" with a 5 second time constant whenever the wheel is out of detent and it is reset to zero only when switching out of the VCWSE mode.

AUTO:

In the AUTO mode the horizontal path command is processed in procedure RCOM. It is derived from LOCCMD if the localizer is engaged (LOCE) or from BACMD otherwise. It is then limited to a maximum angle of 5 degrees if in FLARE mode, 10 degrees if ONCRS is TRUE, or 25 degrees otherwise. Maximum roll angle and roll rate limits are determined and the roll angle command (PHICMD) is produced with respect to those limits.

AUTOLAND:

The computation of the localizer command signal (LOCCMD) is different for ILS and MLS operation. Hence, these processes will be discussed separately. Subsequent lateral axis computations are essentially the same for ILS and MLS and will be discussed in combination.

ILS PROCESSING:

Localizer capture is initiated at localizer-engage (LOCE). The gain programmed and limited localizer deviation is calculated in the mode logic procedure (MLOG) and input as ETAFT.

ONCRS logic is used to change from localizer capture to localizer track submode. It is computed as:

ONCRS = (ABS(RF4) < .0271) . (ABS(LOCDEV) < LOCVL)

. (ABS(ROLL) < 3.0)

Where:

RF4 is the estimate of localizer beam rate.

At localizer capture (LOCE), ETAFT is used to generate a guidance signal to capture the beam center. It is input to the complementary filter procedure (CMPF) where it is passed through a noise filter composed of a first order filter with a 2 second time constant. A cross track damping term (XTKDMP) is added to the filtered localizer beam error to form the localizer command signal, LOCCMD.

When ONCRS logic is satisfied, the localizer-track submode is entered. Localizer beam error limit changes from 2 degrees to less than 0.8 degrees. The gain programmed beam error is complementary filtered with the selected cross track velocity signal, SEL_XTV. The complementary filtering takes place in a first order filter with a 20 second time constant. The output of the 20 second lag (LOCCF2) is initialized to be the same as the 2 second lag (LOCCF1), so that no transients will occur at ONCRS. The gain on XTKDMP is increased at ONCRS and XTKDMP is added to the complementary filtered beam error. At ONCRS a localizer beam integral path is added to the control law. Localizer beam error is integrated and the output of the integrator (LOCINT) is added to complementary filter beam error and XTKDMP to form LOCCMD.

MLS PROCESSING:

Localizer capture is initiated at localizer engage (LOCE) as in ILS operation. However, for MLS operations, on course (ONCRS) occurs simultaneously with LOCE. The LOCE/ONCRS logic is the first code block in LATRL and equates to:

ONCRS/LOCE = MLSM . LOCA . (ABS(DELTY) < (LOCVL - 2.67))

. (ABS(ROLL) < 3.0)) . (ABS(YDH) < (.000473 * XHAT))

When ONCRS/LOCE logic is satisfied, the MLS derived lateral position error (DELTY) is brought directly into procedure CMPF and becomes equivalent to the ETAFT signal from ILS operations. Complementary filter processing is not performed on the lateral position error. DELTY is integrated to form LOCINT which is summed with DELTY and a cross track damping term (XTKDMP) to form the localizer command (LOCCMD) signal. The MLS derived YDH (Est. Xtrack Vel.) is used to develop XTKDMP.

MLS/ILS COMPUTATIONS:

The bank angle limiter in procedure RCOM limits LOCCMD to 25 degrees of roll command at LOCE and 10 degrees of roll command at ONCRS. Since LOCE and ONCRS occur simultaneously for MLS, the lower limit will be used starting at localizer capture. The limit is reduced to 5 degrees at FLARE. In procedure RCOM the roll computer rate limit is raised from 4 degrees/sec to 7 degrees/sec at ONCRS. The effect of these changes is to allow the airplane to track localizer beam center more closely, and at the same time reduce the possibility of a violent maneuver by limiting command authority.

At 150 feet of altitude the DECRB mode is selected by mode logic and the DCRAB procedure by LATRL. The purpose of the decrab maneuver is to align the centerline of the airplane with the centerline of the runway. This is done by bringing the difference between airplane heading and runway heading (DLPSI) into the DCRAB routine where it is passed through a 5 degree limiter. The output of the limiter is called PSILIM. To avoid transients, PSILIM is passed through a 6 second "easy-on". The output of the easy-on (YTEMP) is passed through parallel integral paths, then incorporated with YTEMP to form YAWCMD. This is fed to the rudder to decrab the airplane. In a crosswind situation, unless sideslip compensation is used, lateral deviation will occur as soon as rudder is applied to decrab the airplane. Therefore, YAWCMD is multiplied by 1.4 and used as an aileron crossfeed (AILXFD) signal to command the appropriate roll angle. Note that localizer beam error is still used, outside this procedure, for lateral guidance in DCRAB submode.

The DLPSI limiter referred to earlier limits the amount of decrab to 5 degrees from the airplane heading existing at the time DECRB occurred (150 ft.). If, due to a cross wind, the airplane heading was 7 degrees from the runway centerline heading when DECRB occurred, then after the decrab maneuver the airplane heading would be 7 - 5 or 2 degrees. The limit is necessary to retain sufficient control authority for lateral guidance.

The roll-out (RLOUT) submode is the natural sequel to the decrab routine and occurs when weight on the landing gear causes the SQUAT switch to activate and when wheel spin (WSPIN) is sensed. In procedure RCOM, PHIERR now commands wings level. Lateral guidance on the ground is achieved by summing lateral beam error, suitably scaled, with YAWCMD to drive the rudder. A damping term is needed for lateral stability, so DLPSI is differentiated in YF1 to form PSIDMP. PSIDMP is summed with PHICMD to form YAWDMP. The original decrab command (PSILIM) was passed through a proportional and a parallel integral path. At roll-out, the input to the integral path is removed. Thus, rudder commands stored on the integrator output will be held constant during the roll out.

SUB-PROCEDURES:

LOCAL PROCEDURE: FRCWS (FoRward flight deck Control Wheel Steering)

If the first pass flag is set, the roll rate filter and the roll command integrator are initialized. If the pilot's control wheel is out of detent the wheel force (FWHL) is integrated, limited and stored as FCOM. Next, roll rate (P) is filtered and stored in FRF1.

There are two submodes within FRCWS: attitude-hold and attitude-synchronization (ATT_SYNC). The difference is that ATT_SYNC tracks the roll angle commanded when the control wheel is out of detent, whereas the attitude-hold mode maintains whatever roll attitude is established when the wheel is returned to detent. In the ATT_SYNC submode the ROLL input is filtered, limited and output as FPHCMD. FPHIER is calculated as FPHCMD - ROLL. If the wheel is out of detent, FPHIER is doubled, otherwise, it is doubled and reduced by 1.5 * FRF1. This value, AIL1, is input to the final aileron command calculation:

AILCMD = - (KV * AIL1 + FCOM).

The result is negated because of aircraft wiring polarity requirements.

In the attitude-hold sub mode, the wheel is in detent and the minimized value of AIL1 is used. FRCWS will remain latched in this mode until the pilot moves the wheel out of detent.

LOCAL PROCEDURE: CMPF (CoMPlementary Filter)

This routine provides a noise filter and first order lag filter for the ETAFT (720. * GPLOCD) signal upon localizer engage and integrates that signal (in MLS the DELTY signal), and adds the cross track damping term.

On first pass, LOCINT is initialized to zero, LOCCF to .0171 ETAFT, and XTKDMP to SEL_XTV. Subsequent CMPF processing is dependent on the state of MLSM, as follows:

ILS MODE:
Prior to localizer on course (ONCRS), gain programmed localizer error, ETAFT, is filtered into LOCCF using a first order lag with a 2 second time constant. The cross track damping term, XTKDMP, is derived from cross track velocity (XTVEL). XTKDMP is added to LOCCF to form localizer command (LOCCMD). Subsequent to ONCRS, complementary filtered localizer beam error is obtained by summing localizer beam error (ETAFT) and XTVEL and filtering them into

LOCCF using a 20 second time constant. ETAFT is integrated and stored in LOCINT. LOCINT, LOCCF, and XTKDMP are summed to form the output LOCCMD.

MLS MODE:
Lateral position error (DELTY) is stored in LOCCF and integrated to form LOCINT. XTKDMP is derived from MLS cross track velocity (YDH). When RLOUT is detected and XHAT is less than 10743 feet, DELTY is scaled up by 10743/XHAT. LOCINT, LOCCF and XTKDMP are summed to form the output LOCCMD.

In both modes, LOCCMD is passed to procedure RCOM as an input to the roll command signal PHICMD.

LOCAL PROCEDURE: RCOM (Roll COMputer)

The routine first checks the first pass flag and initializes the filters and mode discretes if true. It then checks whether in AUTO or one of the control wheel steering (CWS) modes, attitude CWS (ACWS), or velocity CWS (VCWS). If in CWS, further checks are made to determine the appropriate submode: attitude synchronization (ATT_SYNC), attitude hold, and track hold (TRACK_HOLD). Note that attitude hold does not have an explicit boolean, but is inferred when AUTOE, ATT_SYNC and TRACK_HOLD are all false.

Engage criteria for the CWS submodes are as follows:

ATT_SYNC = RCWOD = (ABS(DWHL) > 1.0)

ATT_HOLD = $\overline{\text{RCWOD}}$. (ABS(PDTCMD) < 0.75)

TRACK_HOLD = VCWSE . $\overline{\text{ATT\_SYNC}}$. (ABS(PHICMD) < 5.0)

Attitude sync is exited by obtaining the conditions required for attitude hold; track hold (not available in ACWS) is exited when RCWOD becomes true, and attitude hold is exited by obtaining the conditions required for either ATT_SYNC or TRACK_HOLD.

Input to the PHICMD integrator (PDTCMD) is computed based on the selected submode. For ATT_SYNC, PDTCMD = -15. PHIERR. In effect, then, PHICMD is a .067 second lag on roll attitude. In attitude hold, PDTCMD is set to zero, forcing PHICMD to hold the last commanded roll angle. In TRACK_HOLD, PDTCMD is set to the gained and limited difference of PHICMD and the first integral of cross track acceleration (XTACC). PHICMD is thus a 0.36 second lag on cross track velocity with a 4 degree/second rate limit. Note that XTACC is selected from MLS or INS cross track acceleration in the Navigation fast loop (HNAVFS). The second integral of XTACC (XTK2) is also computed when in TRACK HOLD. This is summed with AILCD1 in mainline to compensate for any lateral mistrim. This integrator is washed out with a 5 second time constant when in ATT_SYNC, and cleared when not in VCWS.

If in AUTO mode, another set of submodes is available. If LOCE is false, the limited roll command (RCLIM) is derived from BACMD. This signal is generated in NFCM from track angle command or horizontal path command (depending on the TKSEL discrete) and limited to 25 degrees. If LOCE is true, RCLIM is derived from the LOCCMD output of the complementary filter procedure

(CMPF), limited to 25 degrees until ONCRS, then limited to 10 degrees until FLARE, then limited to 5 degrees. In any case, PDTCMD is then set as the gained and limited difference of RCLIM and PHICMD. PHICMD then becomes a 0.2 second lag on RCLIM with a rate limit of 7 degrees/second if ONCRS is true, and 4 degrees/second otherwise.

Finally, PHICMD is computed as the integral of PDTCMD, and PHIERR is computed as the difference between PHICMD and ROLL. Exception processing sets PHIERR to -ROLL to command wings level at RLOUT.

PHIERR is the principal output of the RCOM routine, although PHICMD is used during decrab and XTK2 is used in velocity CWS mode.

LOCAL PROCEDURE: RBASC (Roll BASiC)

This routine processes the aileron trim knob and rudder pedal plus rudder trim. It also computes the turn coordinator.

On first pass, the turn coordinator filter is zeroed. Next, aileron trim input (ATRIM) is muiltiplied by 1.52 and stored in AILTRM. The turn coordinator (DELRF) is calculated in a washout filter as follows:

DELRF = PHICMD - RF2

RF2 = PHICMD - EXP(-0.3 ITIME) DELRF

DELRF = .235 DELRF

The PEDAL input is multiplied by 6.55 and stored in RUDCMD.

If a CWS mode is engaged, or if AUTOTC and AUTOE are true while ONCRS is false, and the flaps are extended at least 20 degrees, and PHICMD is less than 2 degrees, then the turn coordinator is engaged. Turn coordination remains latched until one of the conditions above is not satisfied. If DECRB mode is active, then RUDCMD is decreased by the DECRB value. (Note that AUTOTC exists for experimental purposes and may be set through TERMX to enable AUTO mode turn coordination.)

LOCAL PROCEDURE: DCRAB (DeCRAB)

This routine generates decrab and aileron crossfeed signals to align the aircraft and runway centerline headings just prior to touchdown.

The first-pass flag is checked and if set, the yaw filter FLTR_1 (the lag portion of the washout filter YF1) and the yaw integrator YINT1 are initialized to zero, and the runway heading error, DLPSI, is passed through a 5 degree deadzone and placed in PSIDZ. Before RLOUT, PSILIM = DLPSI. Otherwise, PSIDZ is subtracted from DLPSI and the difference is stored in PSILIM. PSILIM is passed through a 6 second easy-on to produce YTEMP. DLPSI is differentiated and stored as YF1. Prior to RLOUT the yaw damping term YAWDMP is zero and the output of the 6 second easy-on, YTEMP, is integrated, limited, and stored in YINT1. Subsequent to RLOUT, YINT1 is held constant and the output of the 5 degree deadzone is ignored. YAWDMP is derived from YF1 and PHICMD. Finally, for both values of RLOUT, the aileron cross-feed and DECRAB output are generated as follows:

YAWCMD = YTEMP + .756 YINT1

DECRAB = YAWCMD + YAWDMP

AILXFD = 1.4 YAWCMD

GLOBAL INPUTS: ALVDT, ATRIM, BACMD, DELTY, DLPSI, DRPOS, DWHL, FLAGS, FLAP, FWHL, GPLOCD, ICM, KV, LOCDEV, LOCFS, LOCVLD, MLSM, MODEX, P, PEDAL, POSHAT, ROLL, VELHAT, XTACC, XTVEL, YPROF.

GLOBAL OUTPUTS: AILCMD, LBS, PHICMD, RUDCMD, SPFINH, TRACK_HOLD, ATT_SYNC, SYNCL, XTK1, XTK2, PDTCMD, PHIERR, PHICMD.

MODULE NAME: MESG

PURPOSE: ASCII data area for error messages.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: None

CALLING SEQUENCE: None.

CALLS TO: None

DESCRIPTION: MESG contains a pool of ASCII error messages to be displayed by the system test panel.

GLOBAL INPUTS: None

GLOBAL OUTPUTS: None

NAME: MLOG (Mode Logic)

PURPOSE: To determine and control the flight mode for operation of the Flight Controls programs.

TASK: FSTTSK

LANGUAGE: HAL/S

CALLED BY: FSTTSK

CALLING SEQUENCE: CALL MLOG

CALLS TO: ANGL, DETNT, TAND, UNPK

DESCRIPTION:

Mode Logic (MLOG) determines and selects a flight control mode under the Advanced Guidance Control System (AGCS). It first checks the system run status and terminates if it is in HOLD Mode, otherwise, processing continues.

Preliminary matters include the assignment of alternate sources for some variables depending on whether or not an airport has been selected, MLS has been selected, MLS operation is real or simulated, and whether in IC or Run mode. This processing is done here, rather than by LATRL/ELEVP as was done previously, since they are also used by some navigation functions which run after MLOG and before the flight controls procedures.

For MLSMOD, the MLS runway parameters are initialized and MLSM is set TRUE. For non-MLS mode, the ILS parameters are processed. Prior to localizer ONCRS, localizer deviation is limited to 2 degrees of beam error. At ONCRS, localizer deviation has a variable limit applied to it which is a function of altitude. The limiter is used to reduce localizer deviation due to external disturbances.The localizer variable limit function is:

LOCVL = .2 degrees, for H < 500 feet.

= .0006 * H - .1 degree, for H => 500 feet.

Since the localizer beam converges as the transmitter is approached, the localizer error signal needs to be attenuated as distance from the localizer transmitter decreases in order to maintain constant beam error per foot of deviation from beam center. Since this distance is not known directly, altitude is used as an analog of distance. The gain does not decrease below .20 because localizer beam error is used for rollout guidance. After gain programming, localizer deviation (GPLOCD) is "per foot", rather than "per degree".

If the DELAY variable is non-zero, it indicates that there was a mode logic "dropout" and that mode determination is being delayed for four iterations (200 Msec) to allow time for the engage paddle to drop.

For AGCS, either the forward or aft flight deck paddle must be raised on the FFD Control & Command panel. Successful engagement of the FFD panel occurs when several conditions are satisfied and the AGCS Engage Enable flag (AEE) becomes TRUE. To allow time for this logic the pilot must hold the paddle up for at least .15 seconds. If AEE is FALSE, the paddle will spring down to the OFF position. AEE TRUE is a precondition for all flight modes except PRENG. The logic for initial AEE determination is:

AFCSS = FFDS + AFDS (performed in hardware)

AEE = AFCSS . AFCSV . DETNT(1.5,4.5) . $\overline{\text{FAIL2(AFCS)}}$
Where:
AFCSV = Auto Flight Control System Valid

DETNT is a function which returns TRUE if both DCOL & DWHL, respectively, are within parameter limits.

And to remain valid:

AEE = AFCSS . AFCSV . $\overline{\text{FAIL2(AFCS)}}$

MODE OVERVIEW:

There are ten flight modes available. Pre-engage (PRENG) is the default when no other mode can be sustained. Forward Flight Deck Engage (FFDE) permits control wheel steering (CWS) from the forward flight deck (FFD). All other modes pertain only to the aft flight deck. Manual-Electric mode (MANEL) permits manual control with minimum computer aid. The AFD CWS modes permit automatic flight control with reference to attitude (ACWS) or to the velocity vector (VCWS). The Autoland modes provide automatic flight control for the 3D guidance and the landing phase, through decrab (DECRB), FLARE, and rollout (RLOUT).

FFDE (Forward Flight Deck Engage Mode):

FFDE is the only computer aided flight mode available to the FFD. If AEE is TRUE or becomes TRUE according to the logic above, then, if FFD is selected (FFDS) and the 2nd fail flag is clear, the FFDE mode is selected and further mode determination is bypassed. The pilot then has CWS in the forward cockpit. The logic for FFDE is:

FFDE = AEE . FFDS . $\overline{\text{FAIL2(FFD)}}$

AFT FLIGHT DECK MODES:

ACWSE (Attitude CWS Engaged Mode):

Attitude control wheel steering maintains whatever pitch and roll attitude exists when the pilot returns the column and wheel to detent. It is the default mode for the AFD when no other mode is selected. ACWS will engage when:

$$\mathrm{ACWSE} = \mathrm{AEE} \;.\; \overline{\mathrm{FFDS}} \;.\; (\mathrm{ACWSS} + \mathrm{ACWSE} + \mathrm{MODEX} = 0)$$

$$.\overline{(\mathrm{ACWSE} \;.\; \mathrm{ACWSS})} \;.\; \mathrm{AGCSS} \;.\; \overline{\mathrm{FAIL2(ACWS)}}$$

Where:
The flag AGCSS corresponds with the position of the guarded MANEL/AGCSS toggle switch on the flight controls pallet. If all conditions except AGCSS are met, control goes to MANEL.

VCWSE (Velocity CWS Engaged Mode):

This mode provides aided CWS with respect to the velocity vector of the aircraft. The bank, track and flight path angles are the autopilot hold references. VCWSE mode may be selected by depressing the VEL CWS button on the MCP. It is also the primary default mode when AUTOE is lost, Autoland modes are lost or Go-Around (GAS) is selected. The VCWSE mode is engaged when:

1) VEL CWS is selected when VCWSE is FALSE and AEE is TRUE.

2) GAS is selected with AEE TRUE.

3) AUTOE becomes FALSE when AUTO is TRUE.

4) AUTO is selected while in AUTOE Mode.

5) LANDE goes from TRUE to FALSE.

Disengagement occurs when:

1) AEE is lost, causing reversion to PRENG.

2) ATT CWS, VEL CWS or AUTO is selected while in VCWSE Mode.

3) VCWS second fail occurs, causing reversion to ACWSE

AUTOE (AUTO Engage Mode):

The AUTOE mode is a precondition for the higher modes: LAND, DECRB, FLARE and RLOUT. It can be set TRUE only by pressing the AUTO button on the Mode Control Panel (MCP). The initial criteria are:

$$\mathrm{AUTOE} = \mathrm{AUTOS} \;.\; \overline{\mathrm{AUTOE}} \;.\; \mathrm{AEE} \;.\; \overline{\mathrm{FFDS}} \;.\; \overline{\mathrm{ACWSS}} \;.\; \overline{\mathrm{GAS}}$$

$$.\; \mathrm{DETNT(DZNE,1.0)} \;.\; \overline{\mathrm{FAIL2(AUTO)}}$$

Where:
DZNE = selected column dead zone.
AUTOE selection is completed when AUTO mode
remains set until read into the FLAGS
array at the end of MLOG.

Subsequently, AUTOE mode will be disengaged if:

1) Another mode is selected.

2) GAE becomes TRUE, causing reversion to VCWSE.

3) AEE becomes FALSE, causing reversion to PRENG.

4) DETNT (0.78, 8.0) becomes FALSE, causing reversion to VCWSE.

5) AUTO is selected on the MCP when in AUTOE mode, causing reversion to VCWSE.

6) FAIL2(AUTO) becomes TRUE, causing reversion to VCWSE.

7) LANDE becomes FALSE, having been TRUE, causing reversion to VCWSE.

LANDE (Land Engage Mode):

When AUTOE mode is established MLOG evaluates the criteria for the Autoland mode. There are several submodes or conditions required for Autoland control. These are outlined below:

1) LANDR (LAND READY):

$$\mathrm{LANDR} = \mathrm{AUTOE} \;.\; \overline{\mathrm{(LANDE\ .\ LANDS)}} \;.\; \mathrm{(LANDS + LANDR)}$$

$$.\; \mathrm{DETNT(.78,8.0)} \;.\; \overline{\mathrm{FAIL2(AUTO)}} \;.\; \overline{\mathrm{FAIL2(LAND)}}$$

2) LOCA (Localizer Armed):

$$\mathrm{LOCA} = \mathrm{LANDR} \;.\; \mathrm{(ABS(DLPSI) < 90.)}$$

$$.\; \mathrm{(MLSMOD + LOCVLD)} \;.\; \overline{\mathrm{LOCE}}$$

3) GSARM (Glide Slope Armed):

$$GSARM = LANDR \cdot (ABS(DLPSI) < 90.) \cdot (MLSMOD + GSVLD) \cdot \overline{GSENG}$$

4) LANDE (Land Engage Mode):

$$LANDE = LANDR \cdot LOCE \cdot ONCRS \cdot GSENG \cdot GSTRK$$

Where:
GSENG and, 10 seconds later, GSTRK are set by ELEVP. (See Sec 5.0, ELEVP.)

LOCE and ONCRS are set by LATRL. (See Sec 6.0, LATRL.)

Furthermore, IF LANDE was TRUE on the last pass, but FALSE on the current pass, then control reverts to VCWSE.

THE AUTOLAND MODES:

When LANDE mode is established, the autoland modes are entered, in sequence, as their associated logic is satisfied. At 150 feet altitude, DECRB mode should be activated to align the aircraft with the runway heading. Next, FLARE mode raises the nose of the aircraft and establishes a landing attitude. Finally, the Rollout (RLOUT) mode maintains a course down the runway centerline as the aircraft rolls to a stop. If Go-Around (GAS) is selected, the autoland progression terminates and control reverts to VCWSE with a 2 degree fly-up bias. The logic for each mode follows:

1) DECRB (Decrab Mode):

$$DECRB = LANDE \cdot ((H < 150.) + DECRB)$$

2) FLARE (Flare Mode):

FLARE criteria are evaluated in ELEVP once DECRB is TRUE. If MLSM and H(x) flare law is selected (FLRSEL = TRUE), then FLARE is set when XHAT becomes less than XFLARE. Otherwise, it is set when the selected altitude reference (HRAD or HTDZ) becomes less than 42 feet.

3) RLOUT (Rollout Mode):

$$RLOUT = DECRB \cdot ((WSPIN \cdot SQUAT) + RLOUT)$$

DEFAULT OR SPECIAL MODES:

MANEL (Manual-Electric Mode):

This is not a normal flight mode. Rather, it is a "utility" mode used for development and checkout. MANEL permits the AFD pilot to hand-fly the aircraft with computer assistance limited to "translation" of the wheel/column inputs. It is entered by raising the MANEL toggle switch on the flight controls pallet. It will then engage only if the AFD paddle is raised on the FFD Control & Command panel and no other mode is selected. The toggle switch enables MANEL in lieu of ACWS. If another mode is selected while in MANEL mode, MANEL will terminate. It will also terminate if the toggle is lowered when no other mode is selected. Control then defaults to ACWS.

The MANEL enabling logic is:

$$\mathrm{MANEL} = \mathrm{AEE} \; . \; \overline{\mathrm{FFDS}} \; . \; \overline{(\mathrm{ACWSS} \cdot \mathrm{ACWSE})}$$

$$. \; (\mathrm{MODEX} = 0) \; . \; \overline{\mathrm{AGCSS}} \; . \; \overline{\mathrm{FAIL2(MANEL)}}$$

PRENG (Pre-Engage Mode):

This is the ultimate default when all else fails. It is entered whenever conditions for "higher" modes are not satisfied or when the engage paddles will not remain in the raised position.

In mode logic final processing, if no mode has been set the variable DELAY is set to four to allow the 200 Msec intermission for the engage paddle to drop, and PRENG Mode is set. If the VCWS Mode was not selected, the Go-Around flag (GAE) is set FALSE. Last, the FLAGS array is updated to reflect the selected mode and to clear any flags not appropriate to that mode.

BIT/ARRAY/INDEX ALIGNMENTS:

VALUE /INDEX	MODEX	FAIL2/DSPLF	FLAGS
0	UNDEF	---	---
1	PRENG	AFCS	PRENG
2	FFDE	FFD	FFDE
3	MANEL	MANEL	MANEL
4	ACWS	ACWS	ACWSE
5	VCWS	VCWS	VCWSE
6	AUTO	AUTO	AUTOE
7	LAND	LAND	LANDE
8	DECRB	AUTOTHROTTLE*	DECRB
9	FLARE	MLS*	FLARE
10	RLOUT	---	RLOUT
11	---	---	LANDA
12	---	---	LOCA
13	---	---	LOCE
14	---	---	GSARM
15	---	---	GSENG
16	---	---	LANDR
17	---	---	GSTRK
18	---	---	ONCRS

* Entries 8 & 9 of FAIL2/DSPLF are used to record autothrottle & MLS failures, but this has no relationship to MODEX or the flight modes.

GLOBAL INPUTS:
ACWSS, AFCSS, AFCSV, AGCSS, AUTOS, COSRH, CXRSW, DESTIN, DZNE, FAIL2, FCOL, FFDS, FLAGS, FLYFLG, FWHL, GAS, GSA, GSDEV, GSVLD, HDD, HDGTRU, HDOTB, HOLD, IC, INAVV, LABFLG, LANDS, LOCDEV, LOCVL, LOCVLD, MCONF, MLSMOD, MLSRAW, MSWIT, POSHAT, RLMLS, RUN, RWYDEF, RWYHDG, RWYSEL, SINRH, SQUAT, VE, VN, WSPIN.

GLOBAL OUTPUTS:
AEE, CRSET, CXRVEL, DELAY, DLPSI, DSPLF, ERSET, ETAVL, FLAGS, GAE, GPGSDV, GPLOCD, HDCF, HGPIP, HOLDM, HTDZ, ICM, LBS, LOCVL, MLSC, MLSM, MLSVAL, MODE2, MODEX, MSW1, MSW6, RUNM, SIMFLG, VBS, VCWSS, XFLARE, XGPIP, XTVEL, YPROF.

MODULE NAME: PANEL

PURPOSE: Services the system test panel requests.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL PANEL

CALLS TO: FMTMG

DESCRIPTION:
The following system test panel buttons are checked, and if they have been pushed the appropriate operation is performed :

1.) PANEL RESET - Results in a hardware reset of the system test panel. If this button is depressed, PANEL is exited with no further button checks.

2.) MODE FAIL - Turns off the mode fail lamp.

3.) PANEL TEST - Produces a momentary illumination of all lights and display segments for test purposes.

4.) DATA CLEAR - Clears failure data table and blanks display.

5.) STATUS ALERT - Displays status alert (mode-failure) messages on the system test panel.

6.) FAILURE READ - Displays recorded sensor failure messages on the system test panel.

This routine shares common local data with FDSTR, DSTOR, FMTMG, and F2CMP.

GLOBAL INPUTS: FALST, MSWIT, SWITCH, WRDCNT, FSIDX

GLOBAL OUTPUTS: SWITCH, LIGHTS, MSGST, WRDCNT, MSBUF

MODULE NAME: SINUSE

PURPOSE: To tell the SSFD which analog sensors it is required to check at any given time.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: (If not in preflight) CALL SINUSE

CALLS TO: None

DESCRIPTION:

SINUSE outputs four packed discrete words called SINUS0, SINUS1, SINUS2, and SINUS3 which contain information on which redundant sensors the SSFD should vote. The selection of which sensors to vote is made by virtue of the flight mode and condition of the aircraft at any given time. These four words are sent to NORDEN #1 for use by the SSFD. The last of the four words contains no sensor information but does contain the computer reset, hardware SSFD enabled, displays inoperative, and INS single thread flags. These four words are packed as follows.

BIT	SINUS0	SINUS1	SINUS2	SINUS3
15	Q	SPR7	VEINS	CRSET
14	P	PEDAL	THDG	
13	R	ATRIM	LATINS	
12	HDD	PITCH	LONINS	
11	HRAD	ROLL	INSMV	
10	FWHL	DRPOS		
9	HDOTB	MACH		HRDW-SSFD
8	GSDEV	HBARO-C		DISP-INOP
7	LOCDEV	HBARO-F		
6	RTRIM	TAS		
5	FCOL	XTKACC		
4	DCOL	GSINS		
3	DWHL	DLPSI		
2	CAS	XTVEL		
1	FLAP	ATKACC		INSST
0	SPL2	VNINS		INSST

GLOBAL INPUTS: FLAGS, MLSMOD, VBS, LBS, INSST, CRSET

GLOBAL OUTPUTS: SINUS0, SINUS1, SINUS2, SINUS3

5.0 PRE-FLIGHT

PREFLIGHT OVERVIEW

The Preflight software performs an automatic operational test of various flight control systems. Upon initiating this procedure several tests are made on the system in parallel. These include stimulating and checking sensors and servos, checking sensor valids, and testing pilot control inputs. After concluding, preflight will list all failures found on the system test panel.

MODULE NAME: CLBIS

PURPOSE: This preflight procedure sets the airplane control surfaces for testing by SRVCK.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in preflight and SQUAT and not WSPIN) CALL CLBIS

CALLS TO: None

DESCRIPTION:

CLBIS is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If its INHIBT bit is set this program is exited. If not, CLBIS will either reset the control surfaces (aileron, rudder, and elevator) or set them to test values. This is determined by the flag RST (local variable to the preflight routines) which is controlled by the SRVCK test. The test values which the control surfaces are set to are the following:

AILERON	: 5 DEG left wing down
RUDDER	: 10 DEG LEFT
ELEVATOR	: 13.84 DEG FLY UP

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: None

GLOBAL OUTPUTS: AILCMD, RUDCMD, DECMD

MODULE NAME: CTLCK

PURPOSE: This preflight test checks the various controls for proper displacement by the operator.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in preflight and SQUAT and not WSPIN) CALL CTLCK

CALLS TO: FMTMG

DESCRIPTION:

CTLCK is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If this test's inhibit bit is cleared the following prompts will be issued one at a time on the system test panel, waiting each time for the requested stimulus.

TURN RUDR TRM RT-LT	(Turn rudder trim knob right and left > 7.4 DEG)
PUSH RUDR PEDALS RT-LT	(Push rudder pedals right and left > 2.64 DEG)
TURN AILRN TRM RT-LT	(Turn aileron trim knob right and left > 5.05 DEG)
ROLL PMC RWD-LWD	(Turn wheel panel mounted controller RT-LT > 27.7 DEG)
PUSH-PULL PMC ND-NU	(Push-pull column panel mounted controller > 1.7 IN)
RE-CTR AILRN TRM	(Re-center aileron trim < 1.01 DEG)
RE-CTR RUDR TRM	(Re-center rudder trim < 0.83 DEG)

This program contains two local subroutines called DISP and NULL. DISP performs the first five displacement tests above. NULL performs the remaining two re-centering tests.

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: WRDCNT, RTRIM, ATRIM, PEDAL, DWHL, DCOL, MESG (pool of messages)

GLOBAL OUTPUTS: FLAGS

MODULE NAME: ILSRC

PURPOSE: To test the ILS receivers during preflight testing.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in preflight
and SQUAT and not WSPIN) CALL ILSRC

CALLS TO: FMTMG, DSTOR

DESCRIPTION:

ILSRC is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If this test's INHIBT bit is clear, this module first checks for the presence of LOCalizer Frequency Selected (LOCFS). If not present a message is displayed to alert the operator and the test is aborted, otherwise the signal valids for the localizer and glide-slope are checked. Provided these are found to be true, the localizer and glide-slope receivers are both tested for the proper response (LOC between 0.8911 and 1.074 deg. and GS between 0.3274 and 0.4126 deg.) to the stimulus provided by PRFLT immediately after pushing the start-test button. If the response is not within expected limits an error is flagged.

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: LOCFS, LOCVLD, LOCDEV, GSVLD, GSDEV, MESG (pool of messages)

GLOBAL OUTPUTS: FIDENT, STRUA, STRUB, STRUC, FLAGS

MODULE NAME: PRFLT

PURPOSE: To initiate and control the system preflight tests.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in pre-flight and SQUAT and not WSPIN) CALL PRFLT

CALLS TO: FMTMG

DESCRIPTION:

The preflight system is composed of seven modules that are called serially from FAST (if in preflight mode) in the following order:

```
        CALL    PRFLT           ; Preflight control procedure.
        CALL    CTLCK           ; Control check test.
        CALL    CLBIS           ; Control bias procedure.
        CALL    RDALT           ; Radio altimeter test.
        CALL    ILSRC           ; ILS self test.
        CALL    RGYRO           ; Rate gyro test.
        CALL    SRVCK           ; Servo dispacement test.
```

Each of the test modules performs a certain system check by stimulating individual sensors and then checking for the proper response. The tests and procedures are controlled by a packed test inhibit word called INHIBT. Each routine has its own bit which, if set, suspends that test from running. There is also a master inhibit bit which, if set, inhibits all preflight tests from running.

The bits in the INHIBT word are packed as follows:

BIT	0	PRFLT
	1	CLBIS
	2	RDALT
	3	ILSRC
	4	RGYRO
	5	CTLCK
	6	SRVCK
	7-14	N/U
	15	MASTER INHIBIT

The module PRFLT is the first called once the system test panel mode switch is moved from flight to preflight and the routine FDSTR has acknowledged that the preflight mode is possible (by checking for the presence of SQUAT and not WSPIN). The module PRFLT on its first pass performs initialization on preflight variables and flags including setting the master inhibit bit to prevent the remainder of the modules from running. PRFLT itself is immune to the master inhibit bit. PRFLT then checks whether the Aft Flight Deck (AFD) is engaged. If not, a message is displayed to prompt the operator to engage the AFD paddle. Once engaged, a message is displayed to prompt the user to push the start test button. PRFLT then waits for this response and once detected clears the INHIBT word so that all tests begin running. After all the tests are completed (each test sets its own INHIBT bit when finished) PRFLT tests if any failures were detected. If so a message is displayed to alert the operator.

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: PMSWIT, MSWIT, AEE, AFCSV, WRDCNT, FAIL2, SWITCH, LIGHTS, MESG (pool of messages)

GLOBAL OUTPUTS: MODEX, MODE2, FLAGS, MSGST, WRDCNT, LIGHTS, STRUA, STRUB, STRUC, AEE, SWITCH, MSBUF

MODULE NAME: RDALT

PURPOSE: To test the radio altimeters during preflight.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in
pre flight and SQUAT and not WSPIN) CALL RDALT

CALLS TO: None

DESCRIPTION:

RDALT is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If this test's INHIBT bit is not set this test checks both radio altimeters for proper response to an artificial 100 ft. stimulus (failing if not between 95 and 105 feet) and ground level (failing if greater than 2 feet).

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: BF

GLOBAL OUTPUTS: BF, STRUA, STRUB, DSTAT

MODULE NAME: RGYRO

PURPOSE: To test the pitch, roll, and yaw rate gyros during preflight testing.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in preflight and SQUAT and not WSPIN) CALL RGYRO

CALLS TO: None

DESCRIPTION:

RGYRO is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If this test's INHIBT bit is set, the program is exited. If not, each of the three rate gyros are checked against values that are expected (between 0.85 and 1.43 deg/sec) as a result of stimuli supplied by PRFLT immediately after pushing the start-test button. This is done by the local subroutine RGTST. After stimulation, the gyros are checked for null values (below 0.7 deg/sec). This is performed by the local subroutine NORM. Any errors are recorded for display by the system test panel.

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: Q, P, R

GLOBAL OUTPUTS: STRUA, STRUB, STRUC, BF

MODULE NAME: SRVCK

PURPOSE: Tests the aileron, elevator, and rudder servos during preflight testing.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: IF MSWIT = 1 (System Test Panel mode switch in preflight and SQUAT and not WSPIN) CALL SRVCK

CALLS TO: DSTOR

DESCRIPTION:
SRVCK is one of seven preflight modules that are all associated. For an overview of the whole preflight system see the description of PRFLT. If this test's INHIBT bit is not set, one of three possible paths is chosen. After being called if it has been less than three seconds since the start-test button was pushed the test is exited. At exactly three seconds the boolean RST is cleared and the INHIBT bit for CLBIS is toggled so that it may clear AILCMD, RUDCMD, and DECMD which had previously been set to static test values at start-test time. After three seconds from start-test four local subroutines are called serially to test the servos. These four tests are listed below.

1.) LATAX - Tests aileron position and rate of change of spoiler position. Commands 5 deg. aileron and fails if response after three seconds is not between 4.0 and 5.5 deg. or if spoiler change is not between 3.0 and 12.0 deg.

2.) ELEVT - Tests elevator position. Commands 5 deg. elevator and fails if response after three seconds is not between 4.5 and 5.5 deg.

3.) HZSTB - Tests the stabilizer trim. Sets trim true and checks change in stabilizer after twenty seconds. Failure is indicated if change is not between 0.5 and 0.7 deg. for flaps < 2 deg., or 2.9 and 4.3 deg. for flaps >= 2 deg.

4.) AFRUD - Tests rudder position. Commands 5 deg. rudder and fails if response is not between 4.0 and 6.0 deg. after three seconds.

If any discrepancies are noticed between actual and expected values an error is recorded for later display on the system test panel.

This routine shares common local data with all other preflight modules.

GLOBAL INPUTS: SPR7, ALVDT, DEPOS, DRPOS, STABP, FLAP, MESG (pool of messages)

GLOBAL OUTPUTS: AILCMD, RUDCMD, DECMD, FIDENT, LIGHTS, TRIMT, TRIMD

6.0 FLIGHT MANAGEMENT

FLIGHT MANAGEMENT OVERVIEW

The Flight Management routines provide the ability to create and interact with the aircraft flight plan. The ability to inspect and enter information that affects the flight plan is provided through software that controls the NCDU (Navigation Control and Display Unit) and MSP (Mode Select Panel). The look-up and usage of the system data base (Bulk Data) is done via the NCDU.

The NCDU can be used to create a flight path that the aircraft will follow when some of the various automatic modes of flight are chosen.

The MSP controls the selection of the various modes of automatic guidance and depending on the selected mode, can control the position of the aircraft directly using the MSP knobs for airspeed. altitude, flight path angle and track.

MODULE NAME: ALTGSX

PURPOSE: Set or clear guidance possible and path incomplete flags.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: PATHDF, ATCMOD

CALLING SEQUENCE: CALL ALTGSX

CALLS TO: None

DESCRIPTION:

When path changes have been made, this routine determines if guidance modes 3D and 4D are possible for the current provisional path. Guidance 3D is possible if there are 3 or more waypoints on the path and each has a non-zero altitude entry. In this routine 4D is possible (PDG4D is ON) when 3D is valid (PDG3D is ON) and each waypoint has a nonzero ground speed entry. Prior to making the provisional path the active path, procedure SRPTA is called from procedure NCDGUD which will clear PDG4D if no planned time of arrival has been entered. When the provisional path is made the active path, the provisional guidance possible flags (PDG3D, PDG4D) are copied into the active guidance possible flags (GUID3D, GUID4D). To engage guidance modes in actual flight, the horizontal and vertical path buttons on the mode control panel must be manually selected.

If either of the provisional guidance possible flags is cleared (mode not allowed), the altitude/groundspeed failure flag (ALTGSF) is set to cause the "PATH INCOMPLETE" message to be displayed on the NCDU.

GLOBAL INPUTS: PWNUM, PWEND, PGBUF, WPSIZ

GLOBAL OUTPUTS: PDG3D, PDG4D, ALTGSF

MODULE NAME: BTOBCD

PURPOSE: To convert floating point values into three digit BCD for MSPRO.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: MSPRO

CALLING SEQUENCE: CALL BTOBCD

CALLS TO: None

DESCRIPTION:
DTOBCD converts a PDP-11 floating point number into a three digit binary coded decimal representation for use by the mode control panel display windows. The result replaces the input.

GLOBAL INPUTS: None

GLOBAL OUTPUTS: None

MODUEL NAME: BUFSWT

PURPOSE: Move the provisional guidance and vector buffers to their active counterparts.

TASK: SLOW

LANGUAGE: MACRO-11

CALLING SEQUENCE: CALL BUFSWT

CALLS TO: None

DESCRIPTION:
BUFSWT is called when a provisional path is being made active. The provisional path will have all its static features computed (PATHDF) and all automatic guidance modes turned off before BUFSWT is called. Exact copies of the provisional waypoint and guidance vector buffers (PGBUF,PVECTS) are moved to their active counterparts, ACTIVE and AVECTS. The modes of guidance that will be allowed are determined from PATHDF flags (PDG3D,PDG4D), and the guidance possible flags (GUID2D,GUID3D,GUID4D) are set appropriately.

GLOBAL INPUTS: BADRAD, PDG3D, PDG4D, PGBUF, PTRSTA, PVECTS, PWEND, PWNUM

GLOBAL OUTPUTS: ACTIVE, AVECTS, GUID2D, GUID3D, GUID4D, WPEND, WPNUM

MODULE NAME: MSPLGC

PURPOSE: To process inputs from the Control Mode Panel (CMP) and to perform the logic associated with the various configurations of the AUTO flight mode.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL MSPLGC

CALLS TO: None

DESCRIPTION:

MSPLGC consists of two fundamental parts. The first part handles inputs from the CMP knobs (using the local subroutine KNOBER) and buttons (less the bottom-left four which are handled by MLOG). The second section contains the logic used to calculate which AUTO flight modes are required. These modes are then output to the CMP and the rest of the system via the set of booleans outlined in the description of MSPRO. This logic is outlined below.

```
PSTTKA = NOT(TKSEL) AND (RTKNOB OR (NOT(D2D) AND PSTTKA))
         where RTKNOB is a boolean set by turning the track knob, and D2D
         is a momentary boolean set when the horizontal button is pushed.

HORARM = GUID2D AND AUTOE AND NOT(LOCENG) AND ((NOT(HORARM) AND D2D) OR
         (NOT(DTKSEL) AND NOT(D2D) AND HORARM))
         where DTKSEL is a momentary boolean set when the track button is
         pushed.

HORPTH = HORARM AND NOT(BCFLAG)

TKSEL  = AUTOE AND NOT(LOCENG) AND NOT(HORPTH)

PSTALT = NOT(ALTARM) AND (RAKNOB OR NOT(D3D OR DFPSEL))
         where RAKNOB is a boolean set when the altitude knob is turned, D3D
         is a momentary set when the vertical button is pushed, and DFPSEL is
         a momentary set when the FPA button is pushed.

PSTFPA = NOT(FPASEL) AND (RFKNOB OR NOT(D3D OR DALSEL))
         where RFKNOB is set when the FPA knob is turned
         and DALSEL is a momentary set when the altitude button is pushed.

VERARM = GUID3D AND AUTOE AND NOT(GSENG) AND (HORPTH OR LOCENG) AND
         ((D3D AND NOT(VERARM)) OR (VERARM AND NOT(D3D OR DALSEL OR DFPSEL)))

VERPTH = VERARM AND (VERPTH OR
         ((ABS(HER) < 152') OR ((HER > 0) AND (VSTRA < VSTRB)) OR
         ((HER < 0) AND (VSTRA > VSTRB)))
         where HER is vertical path error, VSTRA is vertical velocity
         commanded, and VSTRB is gained vertical velocity.
```

```
ALTARM = AUTOE AND NOT(GSENG) AND ((NOT(ALTARM) AND DALSEL) OR
         (ALTARM AND NOT(DALSEL OR D3D OR DFPSEL)))

ALTSEL = ALTARM AND
         (((ABS(DELALT) < 1200') AND ALTSEL) OR ((ABS(DELALT) <152')) OR
          ((DELALT >= 0) AND (DELALT < 20*HDCF)) OR
          ((DELALT < 0) AND (DELALT > 20*HDCF)))
         where DELALT is altitude select/hold error and HDCF is
         filtered vertical velocity.

FPASEL = AUTOE AND NOT(GSENG) AND NOT(VERPTH OR ALTSEL)

PSTIAS = NOT(IASSEL) AND (RCKNOB OR (NOT(D4D) AND PSTIAS))
         where RCKNOB is set when the CAS knob is turned and
         D4D is a momentary set when the time path button is pushed.

TIMARM = AUTOE AND GUID4D AND VERARM AND NOT(TOSLOW OR ATDC) AND
         ((NOT(TIMARM) AND D4D) OR (TIMARM AND NOT(D4D OR DIASEL)))
         where DIASEL is a momentary set when the CAS button is pushed.

TIMPTH = TIMARM AND VERPTH AND (NOT TIMPTH OR (TIMPTH AND ATE))
         where ATE is autothrottle engaged.

IASSEL = NOT(ATDC) AND ((IASSEL AND NOT(DIASEL OR TIMPTH)) OR
         (NOT(IASSEL) AND DIASEL) OR (NOT(TIMPTH) AND PTIMPT AND
         NOT(IASSEL) AND NOT(DIASEL)))
         where ATDC is autothrottle disconnect flag and PTIMPT is TIMPTH from
         the previous frame.
```

These equations must be executed in the order they appear here.

This routine shares common local data with MSPRO.

GLOBAL INPUTS: BF, COLDST, TOGGLE, ALTSUM, FPASUM, TKASUM, IASSUM, FLAGS, TKSEL, IASREF, GUID2D, GUID3D, GUID4D, BCFLAG, TOSLOW, ALTARM, FPASEL, HORPTH, VERPTH, TIMPTH, ALTCOR, VSTRA, VSTRB, HER, ALTSEL, DELALT, HDCF, IASSEL, ATDC, MSPER, ATE.

GLOBAL OUTPUTS: BF, ALTSUM, FPASUM, TKASUM, IASSUM, ALTATT, PSTTKA, HORPTH, VERPTH, TIMPTH, TKSEL, PSTALT, PSTFPA, ALTARM, ALTSEL, FPASEL, PSTIAS, IASSEL, MDWARN, MSPER

MODULE NAME: MSPRO

PURPOSE: Commands the Control Mode Panel (CMP) to light the appropriate mode lights and to display air speed, altitude, flight path angle, and track angle.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL MSPRO

CALLS TO: BTOBCD

DESCRIPTION:

In the first half of MSPRO the following booleans are checked and if true the corresponding light is lit. These booleans are packed into two words (DSTOMP, DSTOMP+2) for output. A low bit turns the light on and a high bit turns it off (active low).

DSTOMP BIT	BOOLEAN	MEANING	LAMP COLOR
8	PSTTKA	PRESELECT TRACK ANGLE MODE	BLUE
10	TKASEL	TRACK ANGLE MODE ENGAGED	GREEN
11	PSTFPA	PRESELECT FLIGHT PATH ANGLE	BLUE
13	FPASEL	FLIGHT PATH ANGLE MODE ENGAGED	GREEN
14	PSTALT	PRESELECT ALTITUDE HOLD	BLUE
15	ALTARM	ALTITUDE HOLD MODE ARMED	AMBER

DSTOMP+2 BIT			
0	ALTSEL	ALTITUDE HOLD MODE ENGAGED	GREEN
1	PSTCAS	PRESELECT CALIBRATED AIR SPEED	BLUE
3	IASSEL	CALIBRATED AIR SPEED ENGAGED	GREEN
4	TIMARM	TIME PATH MODE (4-D) ARMED	AMBER
5	TIMPTH	TIME PATH MODE (4-D) ENGAGED	GREEN
6	VERARM	VERTICAL PATH MODE (3-D) ARMED	AMBER
7	VERPTH	VERTICAL PATH MODE (3-D) ENGAGED	GREEN
8	HORARM	HORIZONTAL PATH MODE (2-D) ARMED	AMBER
9	HORPTH	HORIZONTAL PATH MODE (2-D) ENGAGED	GREEN

The second half of MSPRO calculates the correct values to be output to the four display windows on the CMP. These windows display one of three possible values for CAS, ALTITUDE, FPA, and TKA. The value displayed is either the preselected value (if in preselect mode), the selected value (if mode is engaged), or the actual value (if no mode is preselected or engaged).

This routine shares common local data with MSPLGC.

GLOBAL INPUTS: PSTTKA, TKSEL, PSTFPA, FPASEL, PSTALT, ALTSEL, ALTARM, PSTIAS, ATE, IASSEL, TIMPTH, VERPTH, HER, HORPTH, ALTSUM, FPASUM, TKASUM, MAGVAR, IASSUM, ALTCOR, IASREF, ALTOMP. FPTOMP, TKTOMP, ASTOMP
GLOBAL OUTPUTS: DSTOMP, ALTOMP, FPTOMP, TKTOMP, ASTOMP

MODULE NAME: PATHDF

PURPOSE: To process flight plan parameters entered via the NCDU, or extracted from Bulk Data, and perform preliminary calculations required for path guidance.

LANGUAGE: HAL/S

CALLED BY: NCDGUD

CALLING SEQUENCE: Call PATHDF

CALLS TO: SRPTA

DESCRIPTION:

The Path Definition routine uses, as input, a provisional guidance buffer (PGBUF) that has been partially built via the Air Traffic Clearance (ATC) Page of the Navigation Control Display Unit (NCDU) and computes the following parameters:

1. The waypoint turn radius (PWRTN).
2. The change in track angle required at each waypoint (PWTA).
3. The length of the circular arcs to be flown at each waypoint (PWAO2).
4. The distance between the tangent point inbound at the next waypoint and the next waypoint on the path (PWDTT).
5. The great circle distance between each pair of successive waypoints (PWPPD).
6. The flight path gradient between each pair of successive waypoints (PWGAM).
7. The center of turn to the center of turn distance for each pair of successive waypoints (PWCCD).
8. The incremental time to fly from center of turn to the center of turn at each successive pair of waypoints on the path (PWT).
9. The waypoint unit vector from the center of the earth pointing toward each waypoint (PWP1).
10. The path normal unit vector which is normal to the plane formed by the waypoint it is associated with, the previous waypoint, and the center of the earth (PWU12).
11. The waypoint center of turn unit vector from the earth center to the center of turn at each waypoint (PWTC2).

This routine is activated by NCDGUD as a result of the provisional execution flag (PRVDEF) being set when a function has been entered on the ATC page or Flight Plan page. It is also called when a request has been made to make the provisional guidance buffer the active guidance buffer by depressing the execute button on the ATC or Flight Plan pages. During the path activation process the following flags are set to determine the possible guidance modes:

(GUID2D) set indicates 2D guidance possible,
(GUID3D) set indicates 3D guidance possible,
(GUID4D) set indicates 4D guidance possible.

Each higher mode requires all lower mode information plus additional data. A 2D path needs altitude information to become a 3D path and the addition of a planned time of arrival makes a 3D path a 4D path.

When defining a path via the ATC page, either one waypoint or a group of waypoints may be added to the path with each line of data entered by the pilot. A group of waypoints is entered by selecting the type of group (SID, STAR, etc.) followed by the name. Procedures are then called by the ATC subroutines to search Bulk Data and add the waypoint descriptor information to the provisional guidance buffer.

The guidance system utilizes scalar and vector waypoint descriptor blocks. The scalar waypoint descriptor block contains 26 descriptors per waypoint. These descriptors consist of integer, boolean, and floating point variables occupying a total of 45 words of storage for each waypoint. The vector waypoint descriptor block contains 3 unit vector descriptors of 3 scalars each, or 18 words (2 words per scalar entry) per waypoint descriptor. Each buffer handles a maximum of 30 waypoints, therefore the scalar buffer requires (45*30 = 1350) words and the vector buffer requires (18*30 = 540) words. These buffers are defined via HAL/S structures GD_BUFFER for the scalar buffer and VECTOR_BUFFER for the vector buffer (see Table 6-1).

On the first pass of PATHDF, the initialization code path is taken. This is determined by the next waypoint pointer (NXWP) being less than or equal to one in the PD2 procedure. Thereafter processing continues by calling PD3A, PD4, and PD5A which are all imbedded in the PATHDF procedure. The path definition process is terminated by the last pass flag (LASTPASS) being set in the PDEND procedure as a result of a zero name being detected in the guidance buffer or an active waypoint detected in the provisional buffer. An active waypoint will have the boolean (PWWAY) provisional waypoint flag off. Each pass through path definition (controlled by PDLOOP) will complete the calculations for one waypoint. Except at the path endpoints, the computations require vector and scalar information on the two waypoints adjacent to the waypoint being processed. For the first and last waypoints on the path those parameters requiring a preceding and following waypoint respectively are not computed since such waypoints do not exist.

After the first call to the PD2 procedure, a test is made for a DME arc type waypoint as indicated by a boolean flag (PWDMA). Special computations are required for DME arc turns which are discussed later. The normal code path is then followed through Path Definition. If after an entire path has been entered and any waypoint does not have an altitude or groundspeed, PATHDF causes a "PATH INCOMPLETE" message to appear on the NCDU via the Boolean variable ALTGSF.

Following the computation of the great circle distance between waypoints, a test is made to determine if the ARC radii are acceptable. The test is made by comparing the point to point distance between two waypoints to the combined tangent distances for the waypoints. If the point to point distance is less than the combined tangent distances then a bad radius message will be displayed on the NCDU for the current waypoint. The problem may be resolved by using a smaller radius at WPT(i) and/or WPT(i-1).

This and the following pages describe the computations required for building the guidance buffer and vector guidance buffer using the following symbology:

TABLE 6-1

```
STRUCTURE GD_BUFFER:               /*  GUIDANCE BUFFER                 */
   1 PWNAM ARRAY(3) INTEGER,            /*  WPT NAME                    */
   1 PWWAY BOOLEAN,                     /*  PROVISIONAL?                */
   1 PWFLL BOOLEAN,                     /*  FLIGHT LEVEL?               */
   1 PWIRL BOOLEAN,                     /*  IAS REFERENCE?              */
   1 PWDMA BOOLEAN,                     /*  DME ARC?                    */
   1 PWDMI BOOLEAN,                     /*  DME ARC STOP CALC           */
   1 PWRAD BOOLEAN,                     /*  RADIUS INHIBIT?             */
   1 PWASS INTEGER,                     /* 0=AWY1=SID2=STAR3=MAP4=N     */
   1 PWLAT SCALAR,                      /*  LATITUDE   DEG.             */
   1 PWLON SCALAR,                      /*  LONGITUDE  DEG.             */
   1 PWH SCALAR,                        /*  ALTITUDE   FT.              */
   1 PWV SCALAR,                        /*  GROUND SPEED KNOTS          */
   1 PWRTN SCALAR,                      /*  RADIUS OF TURN FT.          */
   1 PWT SCALAR,                        /*  DELTA TIME EN ROUTE SEC.    */
   1 PWPPD SCALAR,                      /*  CIRCLE PT TO PT DIST FT.    */
   1 PWCCD SCALAR,                      /*  CENTER TO CENTER DIST FT.   */
   1 PWGAM SCALAR,                      /*  PATH GRADIENT DEG.          */
   1 PWTA  SCALAR,                      /*  TURN ANGLE AT WPT DEG.      */
   1 PWA02 SCALAR,                      /*  ARC LENGTH OF CURVE 0 2 FT. */
   1 PWDTT SCALAR,                      /*  TANGENT PT TO WPT DIST FT.  */
   1 PWPTA SCALAR,                      /*  PLANNED TIME OF ARRIVAL SEC. */
   1 PWMV SCALAR,                       /*  MAGNETIC VARIATION DEG.     */
   1 PWVPTR INTEGER,                    /*  ADDR OF VOR                 */
   1 PWBRG SCALAR,                      /*  BEARING       DEG.          */
   1 PWLTRF SCALAR,                     /*  DME ARC REFERENCE LAT DEG.  */
   1 PWLGRF SCALAR,                     /*  DME ARC REFERENCE LON DEG. */
```

SCALAR GUIDANCE BUFFER

```
STRUCTURE VECTOR_BUFFER:
     1 PWP1 VECTOR(3),            /* WAYPOINT UNIT VECTOR */
     1 PWU12 VECTOR (3),          /* NORMAL UNIT VECTOR */
     1 PWTC2 VECTOR(3);           /* CENTER OF TURN UNIT VECTOR */
```

VECTOR GUIDANCE BUFFER

$\wedge$ implies a unit vector

- implies a vector

x denotes cross product

. denotes dot product

The waypoint unit vector is defined by:

$$\hat{WP} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \sin LAT \\ -\cos LAT \sin LON \\ \cos LAT \cos LON \end{bmatrix}$$

The X, Y, Z components for WP are stored at the base address identified by PWP1.

The vector to the waypoint is described in terms of the unit vector WP as follows:

$$WP = Re\ \hat{WP}\text{, where Re is the earth's radius.}$$

The relationship of these vectors to the guidance software coordinate system is shown in figure 6-1. The positive X-axis pierces the North Pole and positive longitudes are measured eastward from the Greenwich Meridian.

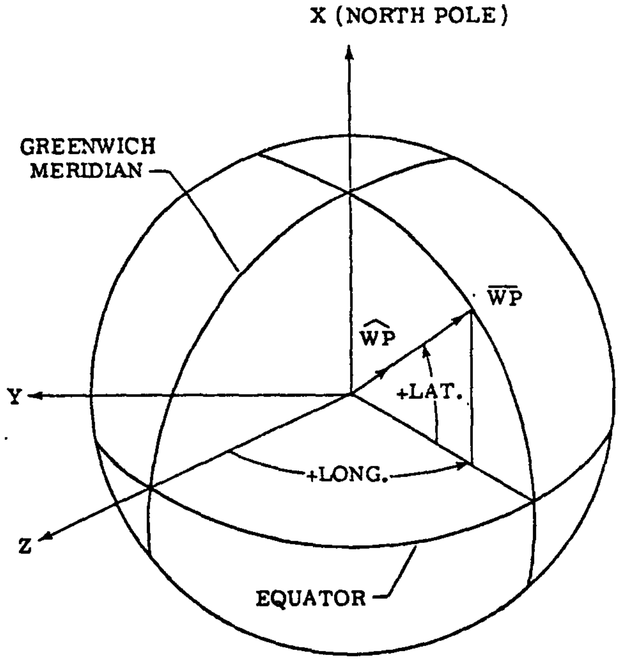


FIGURE 6-1. GUIDANCE SOFTWARE COORDINATE SYSTEM

Normal Unit Vector

The normal unit vector is computed as follows:

$$U12(i+1) = \frac{WP(i) \times WP(i+1)}{|WP(i) \times WP(i+1)|}$$

where i denotes the current waypoint (CWP) and (i+1) denotes the next waypoint (NXWP).

The components of the cross product WP(i) x WP(i+1) are stored at the base address identified by the label PWU12 (see TABLE 1)

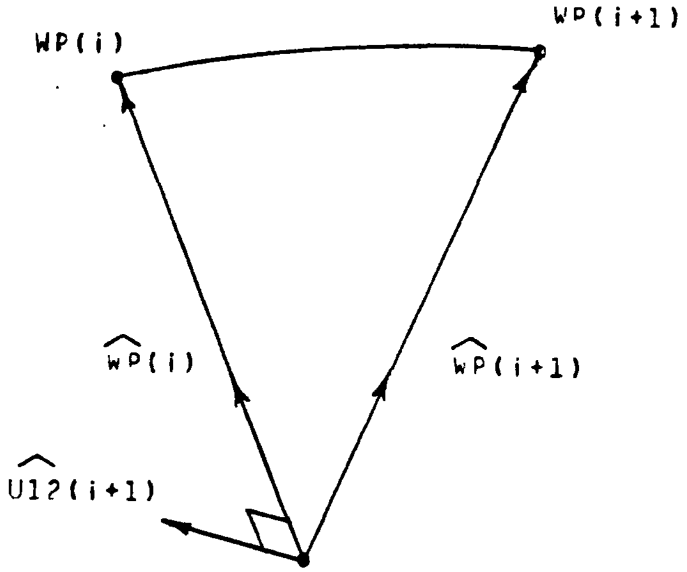


FIGURE 6-2. NORMAL UNIT VECTOR

Track Angle Change at Each Waypoint

The normal unit vector and the waypoint unit vectors are used to compute the track angle change (i) at each waypoint using the following equations:

$$\sin\Delta\psi(i) = -\widehat{U12}(i) \times \widehat{U12}(i+1) \cdot \widehat{WP}(i)$$

$$\cos\Delta\psi(i) = \widehat{U12}(i) \cdot \widehat{U12}(i+1)$$

where (·) is the dot product and (x) is the cross product between vectors. The track angle change is given by:

$$\Delta\psi(i) = \arctan2(\sin\Delta\psi(i),\cos\Delta\psi(i))$$

This value is stored at provisional base address identified by the label PWTA (see TABLE 6-1).

The relationship between the waypoint vectors. the normal unit vectors which define the plane of the path and the track angle change is shown in FIGURE 6-2. These computations are performed for all but the first and last waypoints on the path.

The Length of the Circular Arcs to be flown at each Waypoint

The ARC length of the curve over 2 is computed using the following equation:

```
AO2(i) = RTN*(PWTA(i)/360)*PI
```

where RTN is the radius of turn computed in local routine SRRTN. This value is stored at the provisional base address identified by the label PWAO2.

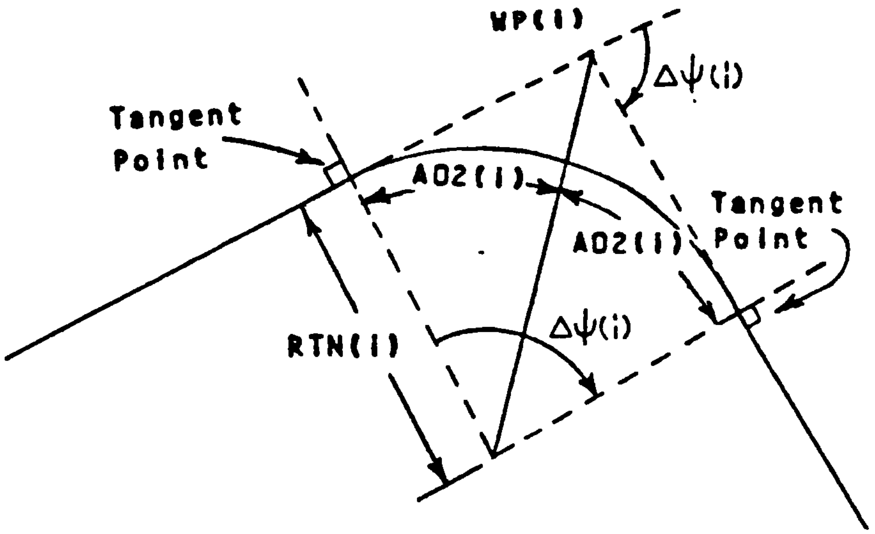


Figure 6-3. Arc Distance of Curve/2

The Tangent Point to Waypoint Distance

The tangent point to waypoint distance is computed from the track angle change and the radius of the turn:

$$DTT(i) = RTN*[\sin(\Delta\psi i)/(1+\cos(\Delta\psi i))]$$

This value is stored at the provisional base address identified by the label PWDTT (see TABLE 6-1).

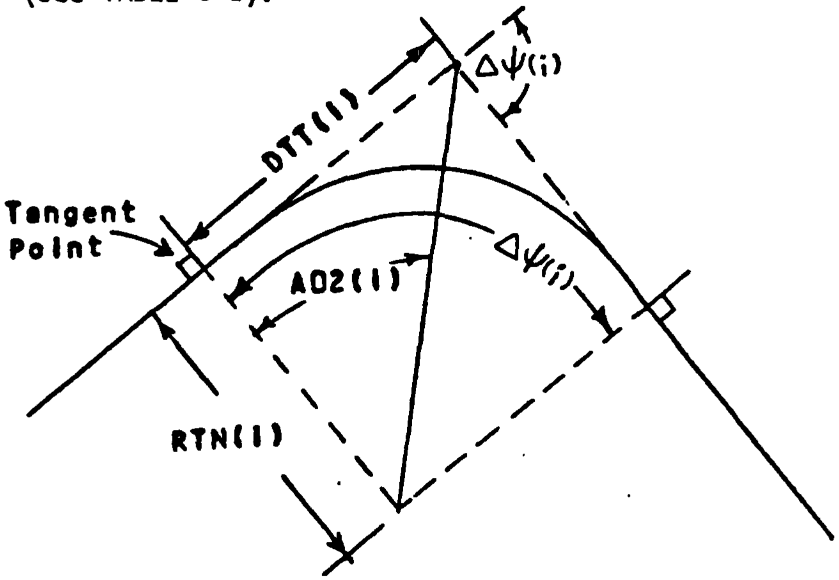


Figure 6-4. Tangent Point to Waypoint

The Turn Center Vectors

The waypoint to tangent point vector is computed from the tangent point to waypoint distance, the waypoint unit vectors and the normal unit vector by:

$$TP= Re\overline{WP}(i)+DTT(i)[\overline{WP}(i)x\widehat{U12}(i)]$$

where Re is the earth's radius and x is the cross product between the two vectors. This vector is then used to compute the center of turn unit vector in the following manner:

$$\widehat{C(i)} = \frac{\overline{TP}(i)+RTN*\widehat{U12}(i)}{\overline{TP}(i)\pm RTN*\widehat{U12}(i)}$$

where the + sign applies if $\Delta\psi(i)$ is negative and the - sign applies if $\Delta\psi(i)$ is positive. The relationship between the waypoint vectors, the waypoint to tangent point vector and the center of turn vector where:

$$\overline{C(i)} = TP(i)\pm RTN*\widehat{U12}(i)$$

is shown in FIGURE 6-5. This value is stored at the provisional base address identified by the label PTTC2 (see TABLE 6-1).

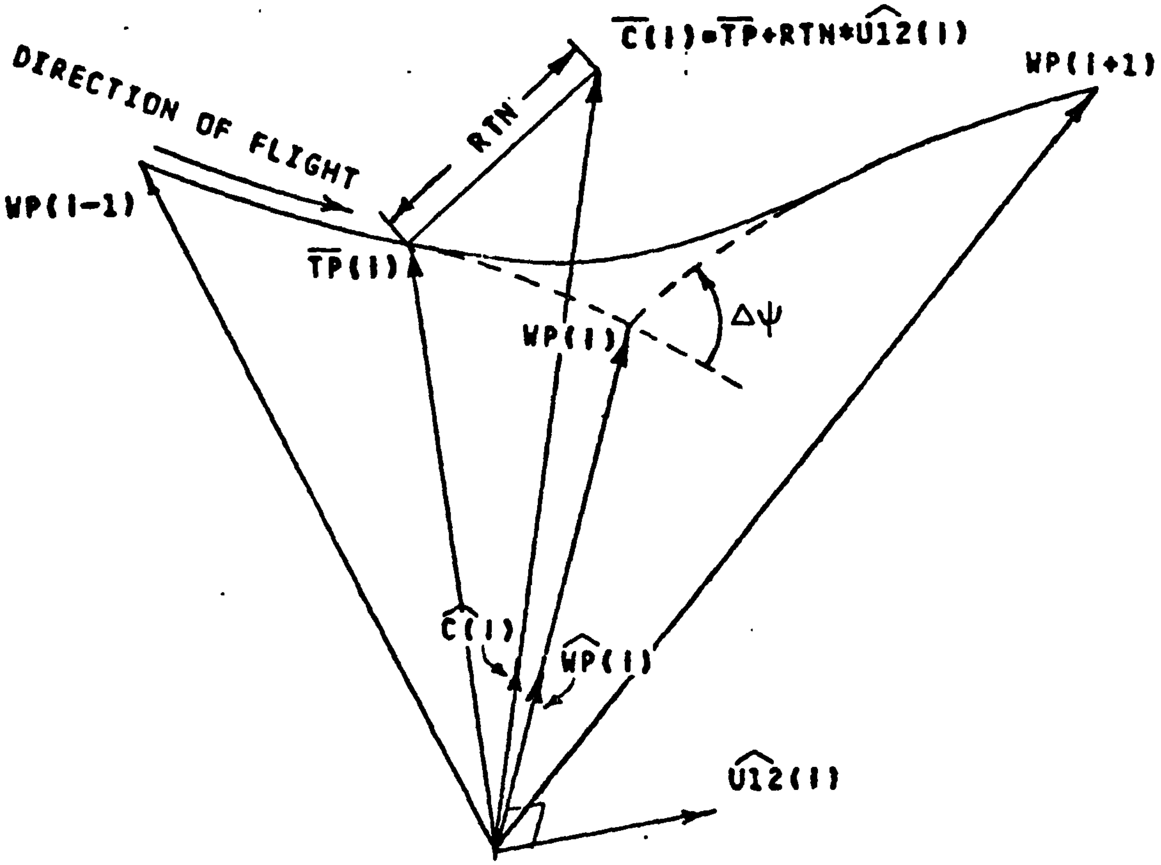


FIGURE 6-5 WAYPOINT CENTER OF TURN VECTOR

The Great Circle Distance Between Waypoints

The great circle distance between two successive waypoints is found by computing the angle between the unit vectors WP(i-1) and WP(i) and multiplying the result by the earth's radius. For maximum accuracy the sine and cosine of the angles are found, and these results are used in a double argument arctangent routine:

$$\sin(r) = \widehat{WP}(i-1) \times \widehat{WP}(i)$$

$$\cos(r) = \widehat{WP}(i-1) \cdot \widehat{WP}(i)$$

The great circle distance is then given by:

$$PPD(i) = Re \ \arctan2(\sin(\theta),\cos(\theta))$$

which is stored at the base address in the provisional guidance buffer identified by the label PWPPD (see TABLE 6-1).

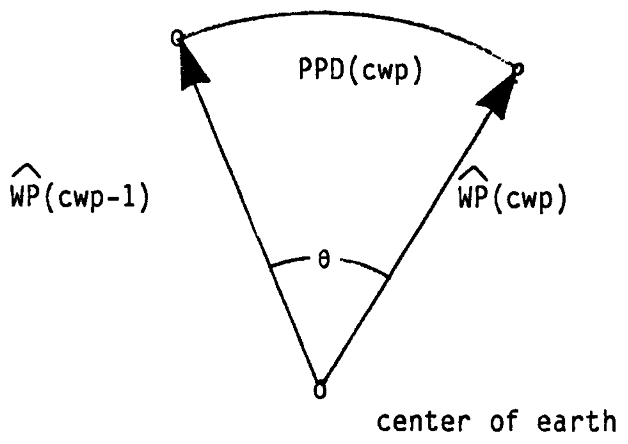
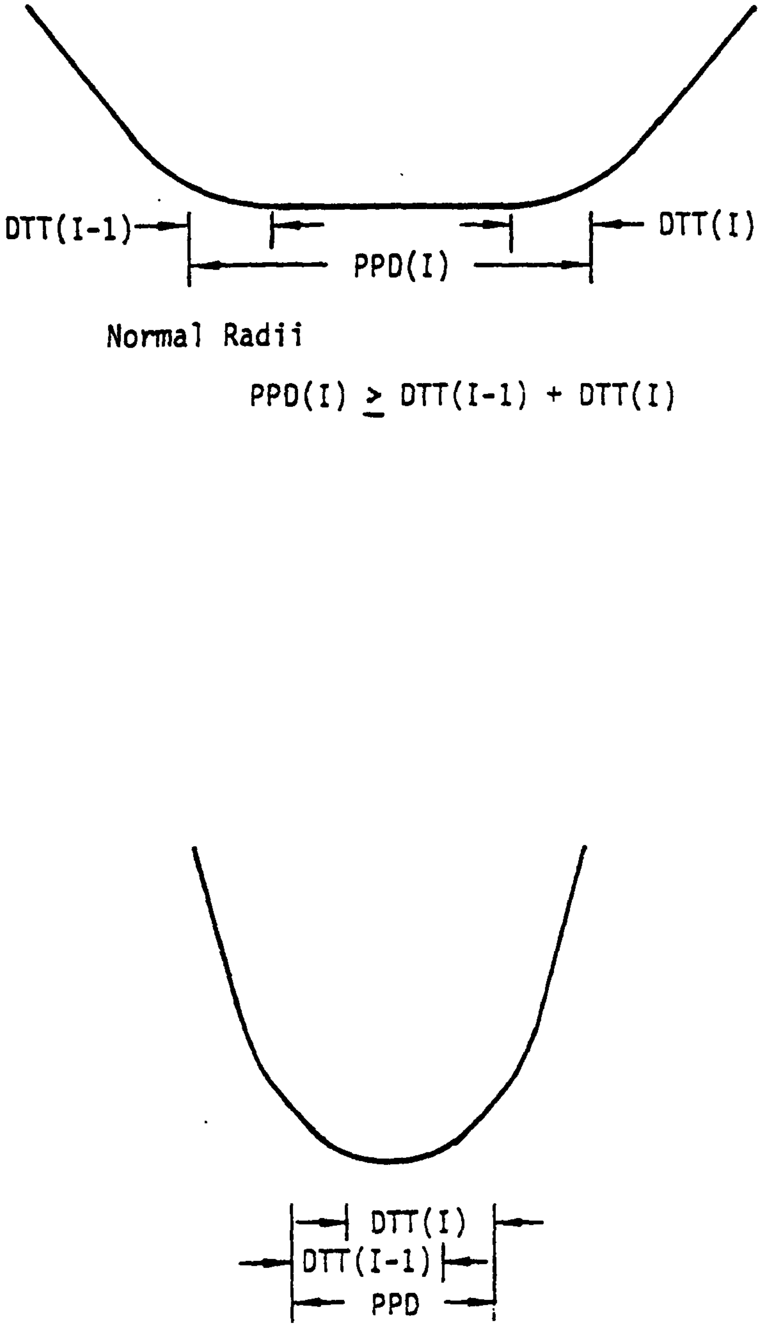


Figure 6-6 Great Circle Distance

After the great circle distance is computed a test is made to determine if the ARC radii are acceptable. The test is made on the tangent distances and failure implies that the tangents overlap as shown in FIGURE 6-7.
If there is an overlap, the message "BAD RADIUS (WPT NAME)" is displayed on the NCDU.



Normal Radii

$PPD(I) \geq DTT(I-1) + DTT(I)$

Bad Radii

$PPD(I) < DTT(I-1) + DTT(I)$

FIGURE 6-7 TANGENT OVERLAP

Center-of-Turn to Center-of-Turn Distance

The center-to-center of turn distance is computed by adding to the great circle distance one-half the arcs at each end of the path leg and subtracting the straight segments from the tangent points to the waypoints. One-half the length of each arc is found by multiplying the track angle change by one-half the turn radius. Since these computations have been performed previously to build the waypoint descriptors (see TABLE 1), the provisional waypoint buffer is accessed to compute the center to center distance as follows:

$$\begin{aligned} PWCCD(i) = {} & PWPPD(i)-PWDTT(i)+PWAO2(i)- \\ & PWDTT(i-1)+PWAO2(i-1) \end{aligned}$$

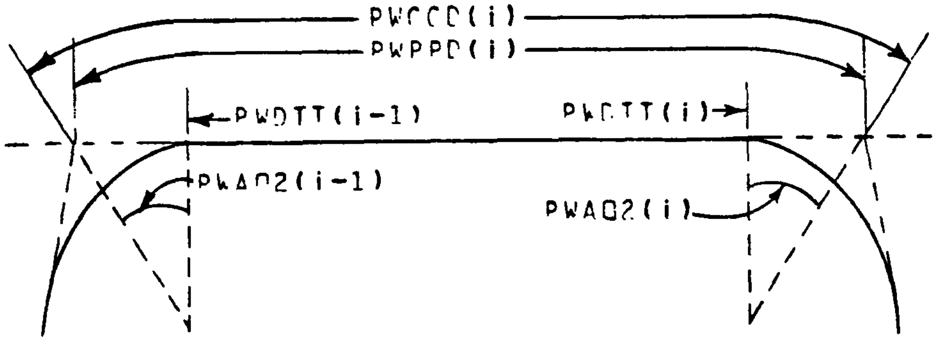


Figure 6-8 Center-to-Center Distance

The Flight Path Gradient Between Waypoints

The flight path gradient required between two successive waypoints is computed from the required altitude change and the center-of-turn to center-of-turn distance:

$$PWGAM(i) = \frac{PWH(i)-PWH(i-1)}{PWCCD(i)*(Pi/180)}$$

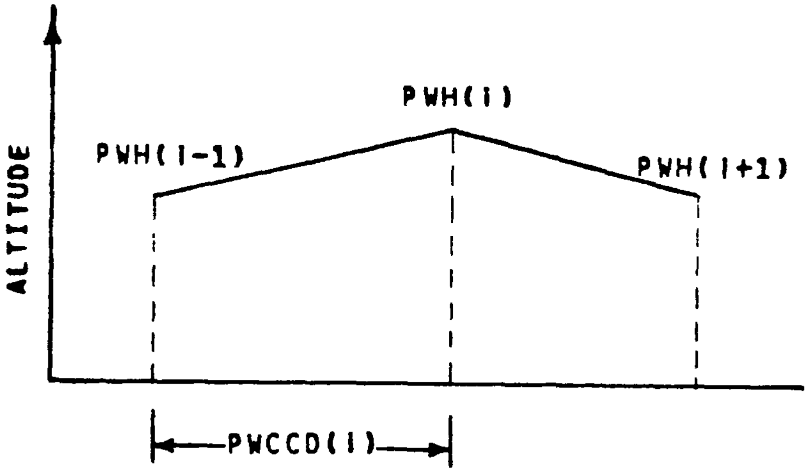


Figure 6-9 Flight Path Gradient

The Incremental Time

The incremental time associated with the ith waypoint is a time computed from the groundspeeds assigned to the (i-1)th and ith waypoints and the center-of-turn to center-of-turn distance between them. The computation assumes a linear speed transition with distance as given by the equation:

$$PWT(i) = \frac{PWCCD(i)}{((PWV(i-1)+PWV(i))\ KTOFPS)/2}$$

where KTOFPS=1.687809858

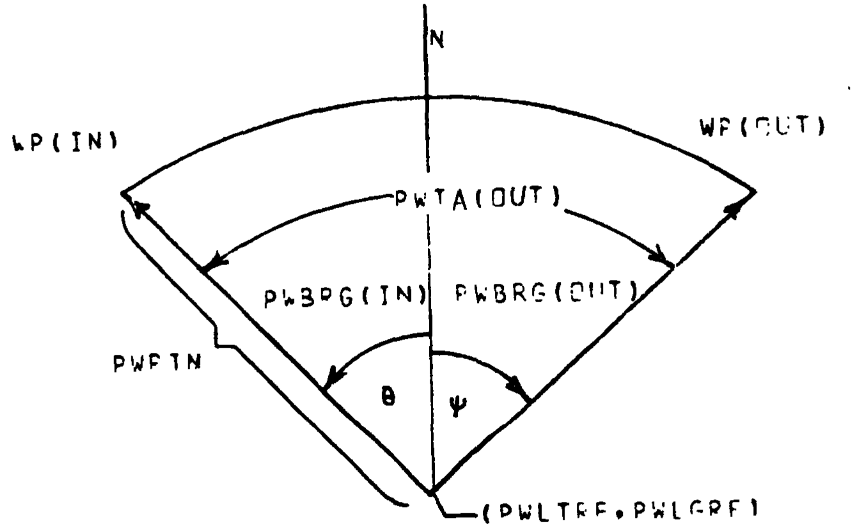
If a planned time of arrival at one waypoint is entered from the NCDU before Path Definition is executed, the Path Definition software assigns that time to the appropriate waypoint and by using the PWT(i)'s proceeds to assign arrival times to the remaining waypoints.

The DMEARC Label

In the beginning of the PATHDF routine the second waypoint word (PWNAM2) in the provisional waypoint buffer (see TABLE 6-1) is fetched and checked for the DME ARC bit; if it is set a transfer is made to the DMEARC label. This module has two basic tasks:

1. To compute certain DME ARC descriptive parameters
2. To set flags to modify the Path Definition logic to fulfill DME ARC requirements

A typical DME ARC is shown below:



where:

PWTA(OUT) is the angle turned from WPT(IN) to WPT(OUT), θ is the bearing center to WPT(IN), ψ is the bearing center to WPT(OUT), PWRTN is the turn radius and (PWLTRF, PWLGRF) is the center of turn latitude and longitude.

Since the radius of turn of the DME ARC is provided in feet, this distance must be converted to degrees of latitude and longitude for several different calculations as given by:

$$T1 = \frac{PWRTN}{DLATFT}$$

$$T2 = \frac{PWRTN}{\cos(PWLTRF)*DLATFT}$$

where DLATFT is the length of 1 degree of latitude in feet.

After the conversion, the latitude and the longitude of the inbound and outbound waypoints are computed as follows:

PWLT(IN)=PWLTRF(IN)+T1*COS(PWBRG(IN))

PWLG(IN)=PWLGRF(IN)+T2*SIN(PWBRG(IN))

PWLT(OUT)=PWLTRF(OUT)+T1*COS(PWBRG(OUT))

PWLG(OUT)=PWLGRF(OUT)+T2*SIN(PWBRG(OUT))

The DME ARC length and DME ARC Half Arc length are then computed as follows:

PWCCD(OUT) = PWTA(IN)*DTOR*PWRTN(IN)

PWAO2(IN) = PWCCD(OUT)/2

The DME ARC flag (ARCSKIP) is then loaded and tested; if = 0, set it to 3; else set to -1.

SRRTN - Compute Radius of Turn

There are three ways in which a turn radius may be assigned to a waypoint:

1. It may be assigned to the waypoint directly via the NCDU or a stored path such as a SID or a STAR. If a radius has been assigned, the boolean PWRAD in the provisional waypoint buffer is set inhibiting the radius of turn computation in this routine.

2. If no radius is assigned, but a groundspeed is designated, the turn radius is calculated from the following formulas:

   R = (V**2)/(g*tan(15 deg))

   where:

   R = radius of turn in feet
   V = groundspeed in ft/sec
   g = gravitational acceleration (32.174 ft/sec^2)

3. If neither a groundspeed nor turn radius is entered, the radius is assigned as follows:

   if the waypoint altitude is below 15,000 feet, R=15,000 feet

   if the waypoint altitude is 15,000 feet or higher, R = 50,000.

MODULE NAME: SRPTA

PURPOSE: To Compute the planned time of arrival (PTA) for each waypoint on the path, or if none has been entered, set the PTA to zero for each waypoint.

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: NCDGUD

CALLING SEQUENCE: CALL SRPTA

CALLS TO: None

DESCRIPTION:

This routine starts with a PTA at a given waypoint as defined on the ATC page or Flight Plan page and cascades times forward and/or backward from that point. Therefore, this routine is called each time a new PTA is entered via the NCDU and thus provides the capability to change the time guidance profile while remaining in the 3D guidance mode.

The delta time enroute (PWT) from the provisional guidance buffer is used to adjust the time at each waypoint based on the starting time (PTATIM) and the starting waypoint position (PTAPOS) as set by the ATC or Flight Plan page.

If a time greater than or equal to the current time (BINTME) is not found in the guidance buffer, then the pointer for the time box position is left at the first waypoint and 'TOTIME' set to zero to indicate that the time path is invalid. If 'PTAPOS', the position of the entered PTA on the path is zero upon entry to this routine, then the entire path has its PTA at each waypoint set to zero. In addition, the 4D guidance possible flag, PDG4D, is also cleared when PTAPOS is zero. When a valid time is entered, the PDG4D flag is set to permit the time guidance mode.

GLOBAL INPUTS: Provisional Guidance Buffer(PGBUF), PTAPOS, PWNUM, PTATIM, BINTME,PTAXFG,PTAFLG

GLOBAL OUTPUTS: PGBUF, WPPTR(2), PDG4D, TOTIME, PTAXFG, PTAPOS, PTATIM, PTAFLG

6.1 NCDU

MODULE NAME: ACTOPV

PURPOSE: Copy active waypoints to provisional guidance buffer.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: ATCMOD

CALLING SEQUENCE: CALL ACTOPV

CALLS TO: None

DESCRIPTION:

ACTOPV copies the active path, starting with the waypoint designated by the offset in STRACT, to the position in the provisional guidance buffer marked by STRPRV. The provisional guidance buffer end markers are updated to the new buffer-end position.

The following is a pictorial example of ACTOPV execution. Initially, the active guidance buffer contains waypoints 1 - 8 while the provisional buffer has a - f.

```
           ACTIVE              PROVISIONAL

      *****************      *************
      *1*2*3*4*5*6*7*8*      *a*b*c*d*e*f*    (Before)
      *****************      *************

              STRACT -> 4,  STRPRV -> c
_____________________________________________________________

           ACTIVE              PROVISIONAL

      *****************      ***************
      *1*2*3*4*5*6*7*8*      *a*b*4*5*6*7*8*    (After)
      *****************      ***************
```

GLOBAL INPUTS: ACTIVE, STRACT, STRPRV, WPEND

GLOBAL OUTPUTS: PGBUF, PWEND, PWNUM

MODULE NAME: ATCMOD

PURPOSE: Allows the entry of a flight plan via the NCDU.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL ATCMOD

CALLS TO: ACTOPV, C7TO8, FRMTIM, INSELH, LUGUID, LURWY, WPINVT

DESCRIPTION:

When the "ATC" button on the NCDU has been pressed the ATC page display appears and the subroutine ATCMOD interprets user function and data entries for the creation of an aircraft flight plan. There are 15 legal function keys that may be used while on the ATC page. These functions can be divided into the following two classes.

Class #1 - Functions that require user text entry immediately following selection: WPT, AWY, FL, ALT, RTE. RWY, GS, SID, STAR, PTA

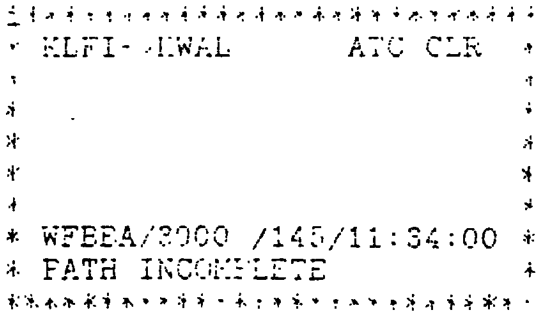
Class #2 - Functions having immediate effect upon selection: EXEC, UP, DOWN, CLR, REJ

As a prerequisite to reading on, the module document for DECODE should be read for a description of class #1 functions. Class #1 functions are used to select waypoints or their characteristics in defining the flight plan. The WPT, AWY, RTE, RWY, SID and STAR function keys are those used to define the path (waypoints) while FL, ALT, GS and PTA describe or override certain waypoint characteristics.

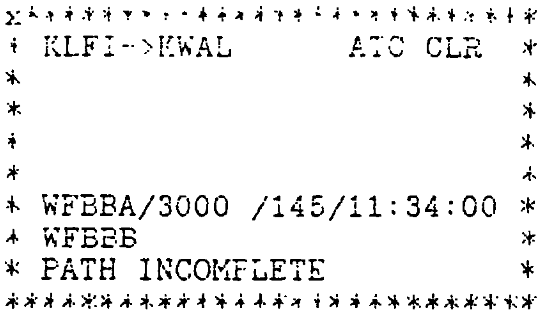
The following is an example ATC page display. The key strokes used to obtain this display are: (function keys noted by <>, <ENT> means pressing the data entry complete key)

<WPT>WFBBA<ENT><ALT>3000<ENT><GS>145<ENT><PTA>11.34<ENT><WPT>WFBBB<ENT>
<WPT>WFBBC<ENT>

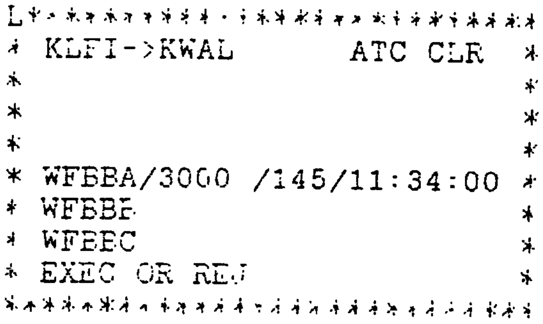
As can be seen the ATC page display scrolls upward for each new waypoint entry.



```
 KLFI-KWAL        ATC CLR






 WFBBA/3000 /145/11:34:00
 PATH INCOMPLETE
```



```
**************************
* KLFI->KWAL      ATC CLR *
*                         *
*                         *
*                         *
*                         *
* WFBBA/3000 /145/11:34:00 *
* WFBBB                   *
* PATH INCOMPLETE         *
**************************
```



```
L*************************
* KLFI->KWAL      ATC CLR *
*                         *
*                         *
*                         *
* WFBBA/3000 /145/11:34:00 *
* WFBBB                   *
* WFBBC                   *
* EXEC OR REJ             *
**************************
```

ATC page #1

Class #2 functions are used to perform desired functions once a flight plan has been started by the use of class #1 functions. The UP/DOWN keys are used to scroll the display when the number of entries made exceed the 6 allocated lines on the display. The CLR key is used to cancel a class #1 function entry before its completion.

As waypoint entries are being made via class #1 functions, the generated flight plan is considered provisional. If a flight plan was previously entered and accepted, it will still be considered the active flight plan during the entries of the provisional path. If no path was previously activated before the provisional entries, the NAV software does not recognize any flight plan as valid for flight. When enough information has been entered on the provisional flight plan, the bottom line message "EXEC OR REJ" appears. At this point the pilot may enter more waypoint information, press "EXEC" to activate the provisional path, or press "REJ" to clear out the last provisional entry. Two consecutive REJects will clear all provisional entries made. A provisional path is considered having adequate information to form an active flight plan when the path contains three or more waypoints and each waypoint has a non-zero altitude and ground speed entry. Note that altitude and ground speed data may be associated with a waypoint in the following three ways:

1) Direct user entry.
2) Default values obtained from waypoint group entries such as a STAR.
3) Cascaded values obtained from direct entries on previous waypoints.

When there is no active path entered in the system, provisional entries made on the ATC page are called "Original Clearance". Otherwise the entries made are called "Reclearance" operations. There are three methods of initiating the reclearance mode. One allows alterations to be made to the active path, another uses the current position of the aircraft to start a totally new path, and the last one allows the pilot to enter a Standard Instrument Departure (SID) from a runway following the successful touch down from the last path. In the first two cases the WPT function is pressed to start the reclearance operation. The last starts with pressing "SID".

An active path is modified by entering the name of a waypoint that exists on the active path somewhere ahead of the current aircraft position. This designates the position that the new path will break away from the old one. More waypoint information may then be entered through any of the class #1 functions. If the last waypoint inserted lies on the active path, the rest of the active waypoints after that point are automatically included in the new path. The pilot may execute or reject the provisional path once enough information has been entered.

To create a totally new path by reclearance, the WPT function is selected and the entry "POS" is made in response to the prompt. This creates a new waypoint at the current position of the aircraft. Then waypoint information is entered via class #1 functions as in standard original clearance. Note that there is no mechanism for rejoining the current active path.

The "SID" reclearance mode is identical in effect to the "POS" method. The only difference is that a group of waypoints forming a departure route becomes the new start of the provisional flight plan.

GLOBAL INPUTS: ACMODE, ACTIVE, ALTCOR, BADRAD, BINTME, CASKAL, CASKFL, CASKGS, DECADR, DECLAT, DECLON, DECMV, DECNAM, DECNAV, DECNUM, DECTYP, DECVAL, DESTIN, GS, GUID2D, GUID3D, GUID4D, LAT, LON, LUADDR, NCMESG, NEWDES, NEWPTA, NGIDON, ORIGIN, PGBUF, PTAPOS, PTAREJ, PTR2DN, PWEND, PWNUM, WAYADA, WAYNEW, WAYPNT, WPEND, WPNUM

GLOBAL OUTPUTS: ACTIVE, ACTPOS, ALRMES, ALTGSF, ANTLAT, ANTLON, ATCLN8, ATCLUP, ATCMWP, CASKAL, CASKFL, CASKGS, FPPWP, GDTIME, GSA, LATCN, LATEAD, LONCN, LONEAD, NCDERR, NEWPTA, NPAGE, NUPAGE, PATHND, PDG3D, PDG4D, PGBUF, PROV, PRVDEF, PRVEXC, PRVMP, PTAPOS, PTATIM, RWYCNT, RWYHDG, RYELEV, SET4D, SMER61, SMER66, STRACT, STRPRV, WPPTR

MODULE NAME: DEBUG

PURPOSE: Allows the display and modification of compool data via the NCDU

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL DEBUG

CALLS TO: None

DESCRIPTION:

When the NCDU is to be used for monitoring compool data, the T-M-A knob (Test-Manual-Automatic) on the NCDU must be turned to the manual mode setting. While in manual mode the DEBUG display, consisting of 7 lines for compool entries and a message line, will always be displayed on the NCDU. To show the contents of a memory word, the number corresponding to a line on the display must be pressed. The prompt "C/OFF" then appears on the bottom line of the NCDU to queue the user for the compool and offset numbers for the desired memory cell. Note that the offsets for all compool variables are listed in a table contained on the file COMMON.DAT which is automatically created when the system is built. The compool numbers are assigned as follows:

1	IOPOOL
2	NAVCOM
3	SLWCOM
4	FCPOOL
5	BCKCOM
6	FMBFCM
7	DISNAV

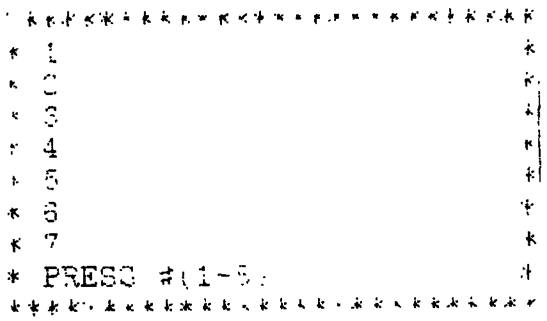
When the compool and offset has been entered, the chosen line on the display will have the line number, compool number, offset and contents of the memory location. Note that all numbers entered and displayed on the DEBUG page are octal values.

To change the contents of a memory location the item must first be displayed on one of the 7 lines. The user then presses the the "8" key to select change mode which causes the prompt "L/VAL" to be issued on the bottom line. At this point the line number of the data item and the new octal value are entered.

The entire page may be reset by pressing the reject key, and the clear key will cancel an error message given from an illegal entry.

The following is an example of displaying the memory contents at 326 bytes into DISNAV compool.

USER ENTRY	LINE 8 MESSAGE
	PRESS #(1-8)
1<ENT>	C/OFF
7/326<ENT>	PRESS #(1-8)



```
*************************
* 1                     *
* 2                     *
* 3                     *
* 4                     *
* 5                     *
* 6                     *
* 7                     *
* PRESS #(1-5:          *
*************************
```

(Manual Mode Example)

GLOBAL INPUTS: DECNUM, KEYUNL, MAMODE, NCDSPC, NCMESG, PAGSEN

GLOBAL OUTPUTS: FUNUMB, NPAGE, NUPAGE

MODULE NAME: DECODE

PURPOSE: Parse NCDU data entries and set values for page routines to use.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL DECODE

CALLS TO: ANGL, ASCBIN, FORMAT, FORMLL, LLBIN, LUARP, LUGRP, LUJET, LUNAVA
LURTE, LUVIK, LUWAY, SCOSD, TIMBIN, WPINVT

DESCRIPTION:

DECODE parses a text string input that was entered in response to one of 12 NCDU line #8 prompts. When the variable DATNUM contains a non-zero value, a call to DECODE is made by the NCDU executive (NCDUEX) prior to calling the currently active NCDU page subroutine. DATNUM will contain a number designating the item type of the entry made, with values ranging from 1 to 12. The input ASCII text corresponding to the code in DATNUM is contained in the array NCMESG. The following is a list of the DATNUM values, prompt text, response examples and definitions of the entry.

#	PROMPT	RESPONSE	DEFINITION
1	WPT	WFBBA07510.5	waypoint specification
2	AWY	V38	airway name
3	RAD	4000	radius value (feet)
4	F/L	50	flight level value (hundreds of feet)
5	ALT	5000	altitude value (feet)
6	RTE	FAAR1	route name
7	RWY	22	runway number
8	GS	150	ground speed value (knots)
9	SID	ISL25	standard instrument departure route
10	STAR	WFB13	standard terminal arrival route
11	PTA	14.32.55	planned time of arrival
12	ARPT	KWAL	airport name

The DECODE processing of each of these items is described in the following sections. DATNUM is stored into the output variable DECNUM once DECODE has finished so the active NCDU page routine, looking for a non-zero DECNUM, will perform its function on the other DECODE outputs.

*** WPT ***

The waypoint entry is the most diverse of all the various entry types, having the following four different classes of acceptable inputs:

Class #1	specific waypoint name
Class #2	present position
Class #3	waypoint, bearing and range
Class #4	designated latitude and longitude

DECODE creates the following outputs for all four classes.

DECADR	Address in memory of the item.
DECNAV	Address of the navaid associated with the item.
DECMV	Value of the magnetic variation at the item's position
DECTYP	Type code (NAVAID,ARPT,GRP,PPT)
DECLAT	Latitude of the item
DECLON	Longitude of the item
DECNAM	Name of the item (from NCMESG)

Valid entries for class #1 are the names of existing navaids, airports, geographic reference points and pilot defined waypoints from the system database.

The user entry text for class #2 has two equivalent forms, POS or PPOS. Each causes a new waypoint, called a PPT for pilot defined waypoint, to be created in the system data base with the aircraft's current position, speed and altitude.

The waypoint/bearing/range entry of class #3 allows the creation of a new waypoint positioned relative to an existing waypoint (navaid,GRP,airport). For example, if a waypoint is desired 5 1/2 nautical miles from the navaid CCV at a bearing of 15 degrees, the entry "CCV0155.5" is made. Note the bearing must be a three digit number.

A pilot defined waypoint may also be created by entering the desired latitude and longitude of its position (class #4). For example the entry "N3745.9W07514.4" causes a waypoint to be created at north latitude 37 degrees 45.9 minutes and west longitude 75 degrees 14.4 minutes. Since longitude values can range up to 180 degrees, a three digit value must always be supplied.

*** AWY ***

The only entry format for the airway is the name of an existing airway defined in the system data base. Airway names may be from two to six characters long, starting with the letters J or V. The J and V designate jet (above 18,000 feet) and victor (below 18,000 feet) airways. Airways define sets of waypoints connecting VOR radio beacons and are FAA recognized routes that are shown on navigational charts. The entry and exit waypoints on the airway must be supplied immediately before and after the airway entry. On exit, DECODE stores the number 8 in DECTYP and the address of the airway in DECADR.

*** RAD ***

A radius entry is made when the pilot wishes to override the default radius of a turn between two waypoints. The number of feet, up to six digits, is entered and the ASCII alpha-numeric string is converted into a machine format floating point number stored in the output variable DECVAL.

*** F/L ***

A flight level is an altitude entry in hundreds of feet. DECODE processes the three digit flight level by converting it to a floating point value, multiplying by 100 and storing the result in the output variable DECVAL.

*** ALT ***

An alpha-numeric string up to five digits in length must be in NCMESG for a valid ALT input. DECODE converts the string to a floating point value and stores the result in DECVAL.

*** RTE ***

Routes are groupings of airways defined by individual organizations to define paths connecting ones origin and destination. Refer to AWY segment for more information about the RTE entry.

*** RWY ***

When a runway entry has been received, only the name and DATNUM value are saved in DECNAM and DECNUM respectively. The page routines (ATC,LK-UP) perform the data base search for themselves in this instance.

*** GS ***

Ground speed is an alpha-numeric entry that is converted and stored in DECVAL for use by either ATCMOD or FLTMOD.

*** SID ***

A valid SID entry is the name of a data base defined group of waypoints forming a departure route from an airport. The search for a SID in the database is confined to one airport. If the SID request was made from the ATC page the origin airport is used, while the destination airport is used when on the Look-up page. The origin and destination airports are those defined by pilot entry on the INIT page of the NCDU. DECODE outputs are DECTYP set to 9 and DECADR containing the SID address.

*** STAR ***

A STAR consists of a set of waypoints converging on a particular airport and a runway number designating the runway at that airport to be used for a landing. The STAR name in NCMESG is found in the data base for the destination airport chosen on the INIT page of the NCDU. The outputs associated with this entry are DECTYP set to 9 and the address of the STAR in DECADR.

*** PTA ***

The PTA entry is an ASCII string containing a time to be formatted into the floating point number of seconds it represents. The general form is "HH.MM.SS" for hours minutes and seconds, however since blanks are considered zeroes, short hand entries may be made. The entry "09" would be considered exactly nine o'clock and the number 32,400 would be stored in DECVAL.

*** ARPT ***

The ARPT entry is made when the pilot wishes to look-up all STAR names associated with a particular airport. This is done by pressing the PTA button while the NCDU is on the look-up page #2. The same outputs are created for this entry as are when an airport is used for a waypoint (see WPT segment).

GLOBAL INPUTS: BLANKS, DATNUM, DESTIN, DLATFT, FRMVAL, LAT, LON, LUADDR,
LUMODE, MAGVAR, NCMESG, NVAD2A, ORIGIN, SEMODE, SMER65

GLOBAL OUTPUTS: DECADR, DECBNG, DECLAT, DECLON, DECMV, DECNAM, DECNAV,
DECNUM, DECRNG, DECTYP, DECVAL, NCDERR, SMF61

MODULE NAME: FLTMOD

PURPOSE: Format the display for the flight plan on the NCDU

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

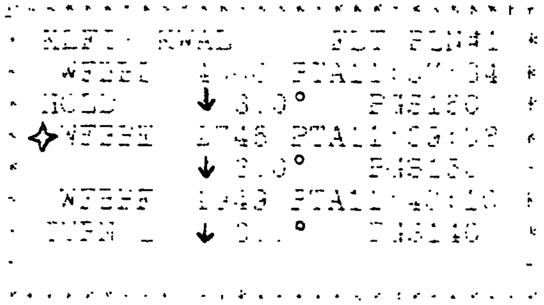
CALLING SEQUENCE: CALL FLTMOD

CALLS TO: ATCXQ, C7TO8, FORMAT, FRMTIM

DESCRIPTION:

FLTMOD formats the Flight Plan page display buffer to show up to three waypoints of the current provisional or active flight plan contained in the guidance buffer (PGBUF). The information shown for each waypoint depends on which of two flight plan pages is being displayed. Flight Plan page #1 is displayed when the "FLT" button of the NCDU keyboard is pressed and the NCDU is not currently on FLT page #1. If the NCDU is on FLT page #1, a "FLT" key stroke sends the NCDU display to FLT page #2. Both pages have a banner line at the top of the display. Text to identify the page number is on the right hand side of the banner line while the origin and destination airport names, if selected, are shown on the left.

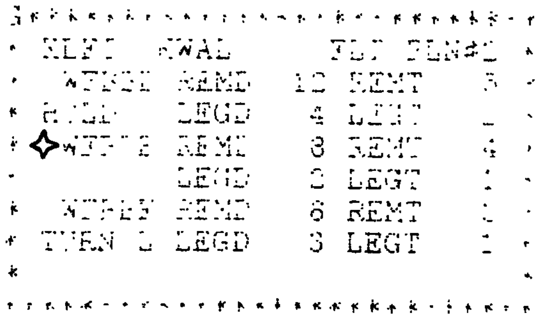
Flight Plan page #1 displays six items, contained on two lines, for each waypoint on the display. The first of the two lines contains the waypoint name, altitude and planned time of arrival while the second line contains a message, flight path angle and ground speed. A field of blanks may be present if one of the five parameters associated with the waypoint name is null.



```
KLFI KWAL          FLT PLN#1
  WPEEE  [illegible] PTA11:[illegible]34
HOLD      ↓ 3.0°      GS160
✧WPEEE   1748 PTA11:[illegible]
          ↓ [illegible]°      GS13[illegible]
  WPEEF  1443 PTA11:[illegible]
TURN      ↓ [illegible]°      GS140
```

(Flight Plan page #1)

Flight Plan page #2 also contains six items on two lines for each waypoint. The waypoint name, remaining distance to final waypoint (nautical miles), and the estimated elapsed time to the final waypoint are on the first of the two lines. The next line has the message, distance to the next waypoint, and the estimated elapsed time to the next waypoint.



```
 NLFT  ?WAL      FLT PLN#2
   WTPT1 REMD  12 REMT    5
 HOLD    LEGD   4 LEGT    _
✧WTPT2 REMD   8 REMT    4
         LEGD   2 LEGT    1
   WTPT3 REMD   6 REMT    1
 TURN L LEGD   3 LEGT    1
```

(Flight Plan page #2)

Either page may have one of the following three messages in the message field directly under the waypoint name.

TURN L	Left DMA turn starts at this waypoint
TURN R	Right DMA turn starts at this waypoint
HOLD	Engage holding pattern at this waypoint

The waypoint names may have a one character prefix inserted by the Flight Plan page. A question mark means the waypoint is considered provisional while a star means the waypoint is the current destination waypoint on the active path.

When the Flight Plan page is initially activated, the center waypoint on the display will be the "to" waypoint, marked by the star, if all the waypoints on the path are active. Otherwise the center waypoint will be the most recent provisional waypoint entered. As a path is flown and the "to" waypoint updates to each succesive waypoint, the Flight Plan Page display will automatically update to show the new "to" waypoint in the center position. If the pilot wishes to review more of the flight plan than the 3 waypoints shown on the display, he may press the "UP" or "DOWN" keys on the NCDU keyboard to scroll the display to other waypoints. Once either the up or down key has been used to alter the default display, "to" waypoint changes will not affect the display any more. An exit and re-entry of the Flight Plan page must be performed to enable the automatic scrolling again.

There are seven NCDU functions that may be used to affect the flight plan while on either of the Flight Plan pages. All but the execute and reject functions can be used on a provisional or active path. See NCDU function table in the module documentation for DECODE for the description of the RAD, F/L, ALT, GS, and PTA. See ATCMOD documentation for a description of the EXEC and REJ functions. Note that when an alteration is made to an active path, appropriate guidance modes are dropped and must be re-selected, after the path definition stage is complete, to engage automatic navigation of the path.

GLOBAL INPUTS: ACTPOS, ARPLIN, ATCLN8, ATCLUP, ATCREJ, BADRAD, DECNUM, DECVAL, FPMODE, HLDSEL, HLDWPT, MODPAG, NGIDON, PROV, PTR2DN, PWEND, WPPTR

GLOBAL OUTPUTS: CASKAL, CASKFL, CASKGS, FPPWP, KEYUNL, GDTIME, LATCN, LONCN, NCDERR, NEWPTA, NPAGE, NUPAGE, PRVDEF, PRVEXC, PTAPOS, PTATIM, SET4D

MODULE NAME: INIMOD

PURPOSE: To process INIT page data entered via the NCDU and format the
INIT page for the NCDU.

LANGUAGE: Macro-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL INIMOD

CALLS TO: ASCBIN,BCDTIM,C7TO8,FRMTIM,LUARP,PROVOG,INSELH,TIMBIN

DESCRIPTION:

INIMOD processes INIT page data entered via the NCDU and displays appropriate cue messages on line 8 of the NCDU. Five parameters may be entered on the INIT page corresponding to the five numeric lines dislayed as follows:

1 ORIGIN
2 DESTIN
3 GMT
4 BAROSET
5 IASLIM.

When INIMOD is entered for the first time version and title information are retrieved from a data block that is generated by the system build process. This information is displayed at the top of the INIT page and the message "CHECK GMT PRESS 3" is displayed on line eight of the NCDU. The GMT entry functions as an interlock to ensure that the real-time clock in the flight management software is started. No other page can be selected until after a GMT entry has been made. Once the GMT has been entered, the message "PRESS # FOR DATA ENTRY" is displayed on line eight. The actual entry of Greenwich Mean Time (GMT) can be by default, i.e.; pressing 3 then the ENT key which causes the system time, supplied by the Data Acquisition System (DAS), to be displayed on the NCDU. To override the default system time, the time may be entered in hours, minutes and seconds in the following format - HH.MM.SS.

As each parameter is entered its validity is checked and an appropriate error message displayed for invalid entries. The following error messages may appear for the respective parameter:

1 - "NOT IN MEMORY PRESS #" - this message indicates that the selected origin airport could not be found in bulk data. To reenter the origin press 1.

2 - "NOT IN MEMORY PRESS #" - this message indicates that the selected destination airport could not be found in bulk data. To reenter the destination press 2.

3 - "FORMAT ERROR PRESS #" - the entered time was incorrectly formatted. The correct format is HH.MM.SS. To reenter the time press 3.

4 - "FORMAT ERROR PRESS #" - the entered barometric pressure setting was incorrectly formatted and/or differed from the default setting of 29.92 by more than |1.5|. To reenter the Baroset press 4.

5 - "FORMAT ERROR PRESS #" - the entered speed was incorrectly formatted or the entered value was less than 105 knots. To reenter IASLIM press 5.

In addition to the error messages and INIT page cue messages previously entered, other informative messages may appear on NCDU line eight announcing system status and/or directives.

GLOBAL INPUTS: BINTME, BSETO, B4CKZ2, DECNUM, DESTIN, FRMVAL, INMODE, KEYUNL, LABEL, LATINS, LONINS, NAVFLG, NCDSPC, NCMESG, NPAGE, ORIGIN, TMEFLG

GLOBAL OUTPUTS: ATNAV2, ATNAV3, BARALR, BARSET, BINTME, CENWPT, DECNUM, DESTIN, FUNUMB, IASREF, IDDLAT, IDDLON, INMODE, KEYUNL, LLINIT, LOKBUF, LOKCEN, LOKPGN, LOKWPT, MODUPD, NCDERR, NCDSPC, NEWDES, NVAD2A, NVAD2B, NVAD3A, NUPAGE, ORIGIN, PATHND, SMER61, SMER62, SMER63, SMER65, SMER66, TMEFLG

MODULE NAME: INSELH

PURPOSE: Initialization of select page #1 options.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: SELMOD, ATCMOD, INIMOD

CALLING SEQUENCE: CALL INSELH

CALLS TO: None

DESCRIPTION:

INSELH selectively resets memory areas pertaining to Select page #1 options. Each of the five options numbered 1 through 6 (option #4 is undefined) has text data on the page and variables that need to be reset at certain instances. The flags SMER61 - SMER66 are tested for non-zero values to initiate the reset of the corresponding option.

The three areas of memory (SE11, SE21, SE31) used to store the text data used for the Select page display are contained within this module.

GLOBAL INPUTS: SMER61, SMER62, SMER63, SMER65, SMER66

GLOBAL OUTPUTS: CRAD, HLDBRG, HLDSEL, HLDWPT, HOLDIN, OFBIAS, OFSSEL,
RADBRG, RADWPT, RWPTAD, SE11, SMF61

MODULE NAME: LOKMOD

PURPOSE: Display status and allow pilot look-up of data base items.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

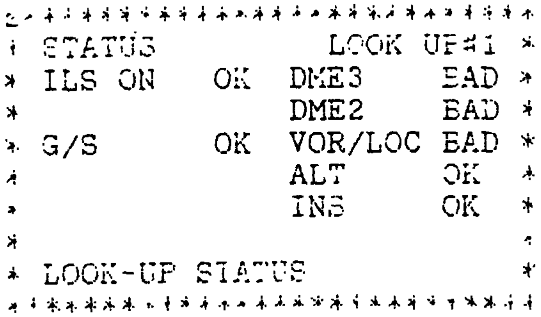
CALLING SEQUENCE: CALL LOKMOD

CALLS TO: C7TO8, FORMAT, FORMLL, FRMFRQ, LURWY

DESCRIPTION:

The look-up pages of the NCDU have two distinct functions that are performed depending on which of the two pages is being displayed. Consecutive presses of the "LOOK" button on the NCDU keyboard toggle the display between pages #1 and #2.

Look-up page #1 allows the examination of a system status report. Two columns of entries are displayed along with either "OK" or "BAD" following each entry. An example display is shown below followed by a description of each entry.



```
******************************
* STATUS          LOOK UP#1  *
* ILS ON    OK  DME3     BAD *
*               DME2     BAD *
* G/S       OK  VOR/LOC  BAD *
*               ALT      OK  *
*               INS      OK  *
*                            *
* LOOK-UP STATUS             *
******************************
```

LOOK-UP PAGE #1

ILS ON — The tuning heads have been set so that the Instrument Landing System (ILS) frequency will be tuned instead of a VHF Omni-range beacon (VOR).

G/S — Glide slope landing signal valid.

DME3 — Distance measuring navaid beacon #3 (cross station) valid.

DME2 — DME path station valid.

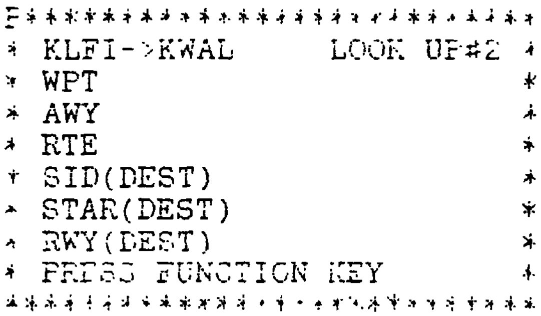
VOR/LOC — VOR signal valid ORed with localizer signal valid.
(VOR hardware not presently implemented on aircraft).

INS — Inertial Navigation System operative.

ALT Central Air Data Computer (CADC) barometric altitude valid.

Whenever the status of any of the items is "BAD", the message "LOOK UP STATUS" is displayed on line #8 of the NCDU no matter which NCDU display is active. This alert may be canceled by pressing clear while the message is shown.

Look-up page #2 is used to examine information stored in the system database (rescom BULK.TSK). There are seven types of data base items that can be looked-up, six of which are shown below in the example look-up page #2 menu.



```
**************************
* KLFI->KWAL    LOOK UP#2 *
* WPT                     *
* AWY                     *
* RTE                     *
* SID(DEST)               *
* STAR(DEST)              *
* RWY(DEST)               *
* PRESS FUNCTION KEY      *
**************************
```

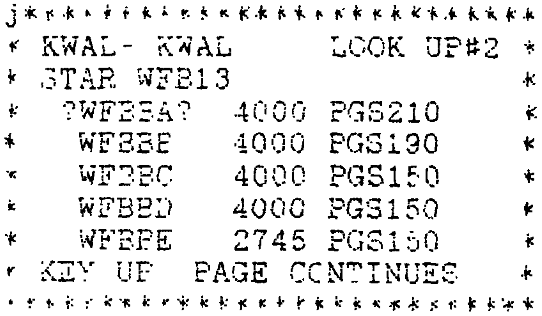
LOOK-UP PAGE #2 (menu)

The page #2 menu is the default page #2 display which will be shown until one of the seven items is looked-up. The seventh item, not shown on the menu, is the airport function which displays all STAR names at a particular airport. Unlike the other six functions, which have a designated NCDU key, the ARPT look-up is initiated by the PTA button. The module description of DECODE may be consulted for definition of the seven items.

All seven look-ups are performed in the same manner. The function button on the NCDU keyboard is selected, the appropriate prompt is issued on line #8, a name in response to the prompt is entered, and information is displayed instead of the menu. Pressing the reject key causes the menu to re-appear. All of the seven item types except WPT and RWY cause the display of a list of the waypoints associated with the name. If more information is desired the WPT look-up must be performed on each particular waypoint in the list. In many cases the list of waypoints will be too long for the display. The line #8 message "KEY UP PAGE CONTINUES" will appear and the UP/DOWN keys will be enabled for display scrolling.

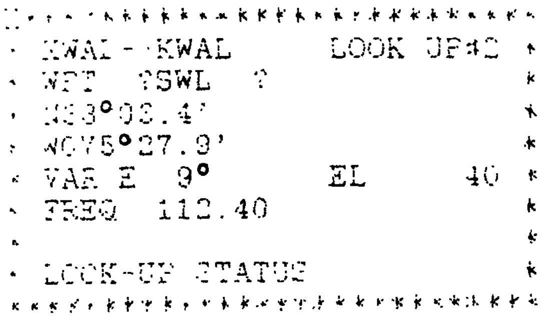
If the Navigation display unit (ND) is in the "plan" mode, then when a look-up has been completed, the ND will have a pictorial layout of all waypoints that fall in its current screen boundaries. The ND display may be centered at one of these waypoints by scrolling the NCDU display until the desired waypoint is moved within the question mark field and pressing the EXEC button on the NCDU keyboard. The question marks will change to angle brackets and the Nav display center will update.

The following are example NCDU displays of STAR and WPT look-ups:



```
***************************
* KWAL- KWAL      LOOK UP#2 *
* STAR WFB13                *
*   ?WFBBA?  4000 PGS210    *
*     WFBBB  4000 PGS190    *
*     WFBBC  4000 PGS150    *
*     WFBBD  4000 PGS150    *
*     WFBBE  2745 PGS150    *
* KEY UP  PAGE CONTINUES    *
***************************
```

STAR LOOK-UP



```
***************************
* KWAL - KWAL     LOOK UP#2 *
* WPT  ?SWL  ?              *
* N33°03.4'                 *
* W075°27.9'                *
* VAR E  9°      EL      40 *
* FREQ  112.40              *
*                           *
* LOOK-UP STATUS            *
***************************
```

WPT LOOK-UP

GLOBAL INPUTS: BLNTB, DECADR, DECLAT, DECLON, DECNAM, DECNAV, DECNUM, DECTYP, DESTIN, LOKPGN, LUADDR, LUMODE, MODPAG, ORIGIN

GLOBAL OUTPUTS: CENWPT, GDTIME, LATCEN, LOKBUF, LOKCEN, LOKWPT, LONCEN, LOKWPT, LONCEN, NCDERR, NPAGE, NUPAGE

ORIGINAL PAGE IS
OF POOR QUALITY

MODULE NAME: NCDGUD

PURPOSE: Interface the NCDU and the various path definition functions

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL NCDGUD

CALLS TO: PATHDF, PRVSIZ, SRPTA, BUFSWT

DESCRIPTION:

NCDGUD calls path definition routines to perform functions requested by NCDU modules ATCMOD and FLTMOD when changes have been made to the flight path in the Active or Provisional guidance buffers. One of the following three variables will be set to a non-zero value to initiate a call to NCDGUD.

PRVDEF Define static path features for waypoints in the provisional guidance buffer only.

PRVEXC Same as PRVDEF plus activating the provisional path.

SET4D Cascade planned times of arrival for each waypoint in the active guidance buffer when a PTA has been entered on ATC or Flight Plan page.

The guidance possible flags (GUID2D,GUID3D,GUID4D) are cleared for a minimum of 50 milliseconds to cause the appropriate loss of guidance mode when PRVEXC is used. Only GUID4D is cleared in response to the setting of SET4D. This causes the pilot to reselect guidance modes after a change was made that invalidated previously selected modes.

After any of the three operations have completed, the navigation interface done flag (NGIDON) is set to cause NCDU page software to continue from the NCDU busy mode entered upon initiating action from NCDGUD.

GLOBAL INPUTS: PRVDEF, PRVEXC, FIFTY, SET4D, PDG4D, PGBUF, PWNUM

GLOBAL OUTPUTS: NGIDON, GUID2D, GUID3D, GUID4D, PTAXFG, STRACT, STRPRV, ACTIVE, PTAFLG

MODULE NAME: NCDKEY

PURPOSE: Perform NCDU fast loop functions such as the interpretation of NCDU inputs, posting alert messages, and synchronizing the NAV display updates with guidance buffer changes.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL NCDKEY

CALLS TO: CLREF, C7TO8, NCDUIO, PAGRST, RESETM, RESET2, SETEF

DESCRIPTION:

NCDKEY is called every 50 milliseconds to perform miscellaneous NCDU functions. The following discussion handles NCDKEY in the sequential order found on the program listing.

First a test is made to determine if a change has been made to the guidance buffers, a new symbol for the navigation display has been requested by NCDU software, or 4 seconds have elapsed since the last guidance buffer transfer (see FLTHDL task description for information on the DMA transfer between the two NORDEN computers). The 4 second update is accomplished by comparing the difference between the current time of day (BINTME) and the time of the last update (GDTIME) to 4 seconds. The other two forms of update requests are achieved when a NCDU routine sets the variable GDTIME to zero. This causes the appearance of 4 seconds expiring and an update sequence is started. The boolean MFDREQ and RSX-11S event flag 34 are set to inform the NORDEN #1 display computer and the I/O handler of the update. MFDREQ is "ON" for two 50 millisecond frames, while event flag 34 is on for one frame.

When NCDU routines have detected an error on user entry, a non-zero index value will be stored in NCDERR. A call to the local subroutine KEYERR is made to post the appropriate error message on the bottom line of the NCDU when the non-zero NCDERR is found.

NCDU variables that need to be computed every 50 milliseconds are done at this point with a call to NCDK3. The following is a summary of the values computed by NCDK3.

PTR2DN The byte offset into the guidance buffer of the "to" waypoint.

WPTALR Alert boolean that is set for the final 10 seconds of a waypoint approach. The boolean causes the ALERT light on the NCDU to be lit.

ALRMES The index value corresponding to an alert message that will be posted on NCDU display line #8. Various logic is performed for the six possible alert messages, including the check of message inhibit bits.

LATCEN/
LONCEN The position values for NAV Display center. These values are set corresponding to what functions have been performed on the NCDU.

NVAD2B The address of the next navaid to be used as VOR #2.

RWYOUT Flag set to cause the Inertial Navigation System (INS) to read runway heading.

NCDU I/O interfacing is done by a call to NCDUIO (see module documentation). When a function entry has been made on the NCDU, the variable NCDUFN is set to a non-zero function code by NCDUIO. The cold start flag is checked and NCDU variables are reset if the condition is true. The NCDU is forced to the INIT page until a new time has been entered since the computer time will be incorrect after recovering from power off. NCDKEY tests NCDUFN and returns when no function entry was made. When a non-numeric function entry was made and a valid time entry was made on the INIT page, the subroutine FUNCTION_CODE is called to process the entry. On numeric function entry (NCDU buttons 1 - 9) a test is made to see if numeric options are enabled on the current page. If enabled, the input function is saved in NCDSPC for use by the active page and in DUALNM to wait for completion of a NCDU data entry. When not enabled the INVALID FUNCTION message is displayed. The following is a list of the different classes of function entries.

CLASS #1 - Functions causing a NCDU bottom line prompt.

Function Keys: WPT, AWY, RTE, RWY, SID, STAR, RAD, FL, GS, ALT, PTA

NCDKEY checks if the active NCDU page allows the function key. If so, the prompt is issued and a unique function code is placed in DUALNM to be saved until the user entry is complete. The function code is stored in DATNUM to enable the input parsing routine DECODE after the input is finished.

CLASS #2 - Page Selection Functions.

Function Keys: INIT, FLT, SEL, ATC, NAV, LOOK

NCDU variables are reset and the page corresponding to the function becomes active. Subsequent presses of the same function cause the various sub-pages of the active page to be displayed.

CLASS #3 - Numeric Functions.

Function Keys: 0 - 9

Numeric functions have specific page dependent meanings. The function number is stored in DUALNM like CLASS #1 functions and also in NCDSPC to notify the active page of the function entry. The page routine has the responsibility of issuing the NCDU prompt.

CLASS #4 - Miscellaneous Functions.

Function Keys: EXEC, UP, DOWN, CLR, REJ

These functions cause no user prompts and are passed along to NCDU background routines through the variable DECNUM. Each cause the cancelation of NCDU key entry mode. The clear function also is used to inhibit the display of alert messages.

CLASS #5 - NCDU mode dial.

Mode Positions: Automatic, Manual, Test

Determines the mode of the NCDU display.
Automatic: standard NCDU page.
Manual: Debug mode. (When in Debug mode, 0 key can be used as Debug page Select key.)
Test: NCDU test pattern display.

GLOBAL INPUTS: ACTIVE, ACTPOS, ALTCOR, ALTGSF, ATCMWP, ATNAV2, BADRAD, BCFLAG, BINTME, COLDST, DESTIN, DTG, DTOGO, FUNUMB, GDTIME, GS, GSFPS, NAV64K, NCDERR, GUID2D, NCDUFN, LAT, LOKCEN, LON, PGBUF, PROV, PTR2D, PTR4D, RETUN2, RWYCNT, STATUS, TMEFLG, TURN, WPSIZ

GLOBAL OUTPUTS: ACMODE, ALRMES, ATCMWP, AUMODE, BARALR, DECNUM, DUALNM, MAMODE, FPMODE, MFDREQ, MODPAG, INMODE, NCDSPC, KEYUNL, LATCEN, NDMODE, LATCN, NPAGE, NUPAGE, NVAD2B, LONCEN, LONCN, LUMODE, PRVMP, PTAREJ, PTR2DN, RETUN2, RWYOUT, TSMODE, SEMODE, WPTALR

MODULE NAME: NCDUEX

PURPOSE: Executive for NCDU routines.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: SLOW

CALLING SEQUENCE: CALL NCDUEX

CALLS TO: MAP, TSTMOD, DEBUG, NCDGUD, DECODE, ATCMOD, FLTMOD, INIMOD, LOKMOD, PRVMAP, NVDMOD, POSERT, SELMOD

DESCRIPTION:

NCDUEX calls the various page formatting and path definition interface routines. Also the valids associated with Look-up page #1 are computed and reflected in the variable STATUS.

The first thing done in NCDUEX is to compute the boolean variable VORLOC, which is the logical OR of localizer and VOR valids. The logical NOT of this and six other valids (LOCFS,DME3VD,DME2VD,GSVLD,CALTV,INAVV) are ORed to form a failure alert boolean (STATUS) which is used by module NCDKEY to post the message "LOOK-UP STATUS" on line #8 of the NCDU. When this message appears the NCDU should be changed to Look-up page #1 to note which signals are invalid.

Next, conditions are checked to determine which NCDU subroutines need to be called. The T/M/A knob (Test/Manual/Automatic) at the upper left of the NCDU keyboard controls the NCDU mode. In test mode a moving pattern of the NCDU character set is displayed and nothing can be entered from the keyboard. Manual mode provides the capability of displaying and altering compool memory cells (see documentation for module DEBUG). Almost all NCDU activity is done while in automatic mode. One of the six NCDU pages will always be displayed, depending on the page buttons located on the bottom row of the keyboard, while in automatic mode. The various pages are called Air Traffic Clearance, Flight Plan, Initialization, Look-up, Navigation Data and Select. Information on these can be found in the documentation for modules ATCMOD, FLTMOD, INIMOD, LOKMOD, NVDMOD and SELMOD respectively. Two other subroutines involved with guidance interfacing are called if conditions are met. NCDGUD is called when changes to waypoints in one of the guidance buffers have been made and PRVMAP is called when a missed approach path (MAP) is to be added at the end of the path.

All subroutines called from NCDUEX are preceeded by a call to MAP to determine if the correct overlay segment is mapped. Task documentation for SLOW and the RSX-11S Executive Reference Manual can be consulted for information on overlays.

GLOBAL INPUTS: VORVLD, LOCFS, LOCVLD, TSMODE, MAMODE, PRVDEF, PRVEXC, SET4D, DATNUM, ACMODE, FPMODE, INMODE, LUMODE, NDMODE, PSRTFG, GUID2D, ACTIVE, PTR2DN, PRVMP, AUMODE, BINTME, CALTV, DME2VD, DME3VD, GSVLD, INAVV

GLOBAL OUTPUTS: BLNTB, VORLOC, STATUS, SEG, NPAGE, NUPAGE, KEYUNL, GDTIME

MODULE NAME: NCDUIO

PURPOSE: Prepares NCDU I/O memory buffers for transmission.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: NCDKEY

CALLING SEQUENCE: CALL NCDUIO

CALLS TO: None

DESCRIPTION:

NCDUIO manipulates NCDU input and output data areas and controls the timing sequence of I/O operations.

A non-zero first element of the 12 element array NCDUL8 means a function or data entry has been made. Function entries are single key strokes of the keyboard that request a particular action by the NCDU. Data entries are character strings submitted in response to a previous function entry. Bit 6 of NCDUL8 element 1 is set by the hardware when the input is a function. Upon receiving an entry, the function code is moved from NCDUL8 into NCDUFN or the text data is moved to NCMESG. When a function that requires data entry is used, its code is stored in DUALNM. Upon completing a data entry, NCDUIO moves the code stored in DUALNM into either DATNUM or DECNUM depending on its value. This causes the function and its corresponding text string to be used as a pair in the currently active NCDU page routine. DECNUM is used for numeric functions (option 1, 2, ...) and DATNUM for all others.

The next section handles NCDU outputs. An output is initiated when the flag NUPAGE is set and the previous output cycle has completed (PAGSEN = 0). NUPAGE is set by the currently active NCDU page routine when a change to the display is needed, however NCDUIO can also set NUPAGE if the one second update mode is not active (MODUPD = 0), no NCDU I/O has occurred for 2 seconds, and the NCDU is not currently waiting for a text data entry in response to a function prompt. When in the one second update mode, NUPAGE is set automatically every second by the currently active page routine. The flag KEYUNL is tested next to determine if the NCDU needs to be placed in data entry mode. This is done by setting bit 14 of the next to last element of the array NPAGE, when KEYUNL is non-zero. Upon receiving the transmission with bit 14 set, the NCDU hardware interprets key strokes as ASCII text until the "ENTER" key is pressed. If the NCDU is not to be placed in input mode, NCDUIO determines if an alert message needs to be put out on line #8 of the NCDU display. A non-zero value in ALRMSG, set by NCDKEY, causes one of the following seven messages to be displayed depending on the value of ALRMSG.

"LINK UP PPOS TO WPT"
"LOOK-UP STATUS"
"RETUNE NAVAID #2"
"EXEC OR REJ"
"PATH INCOMPLETE"
"CHECK BAROSET"
"SIMULATED A/P ENGAGED"

The last message is displayed once every four output cycles if the boolean SIMFLG is true. Finally the NCDU output cycle is started by setting the boolean variables PAGSEN and NCDUNP. NCDUNP is an IOPOOL variable that is packed into a discrete word by OUTIO and sent to the Effecter Interface Unit (EIU). The cycling of the discrete (ON,OFF) causes the hardware to transmit the SIR memory buffer area designated for the NCDU. PAGSEN is used to hold any new attempts to initiate an output before the current output cycle is done. The output cycle consists of ten 50 millisecond frames. NCDUNP will be on for the first two frames and set off for the remaining eight. PAGSEN is on for all ten frames to keep another cycle from starting. After the tenth frame PAGSEN is cleared so the next output request will be accepted.

GLOBAL INPUTS: ALRMES, ATC2, DUALNM, KEYUNL, MODUPD, NCDUL8, NUPAGE, SIMFLG

GLOBAL OUTPUTS: DATNUM, DECNUM, NCDUFN, NCDUNP, NCMESG, NPAGE, PAGSEN, PTAREJ

MODULE NAME: NVDMOD

PURPOSE: Display dynamic navigation information pertaining to the current flight plan

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL NVDMOD

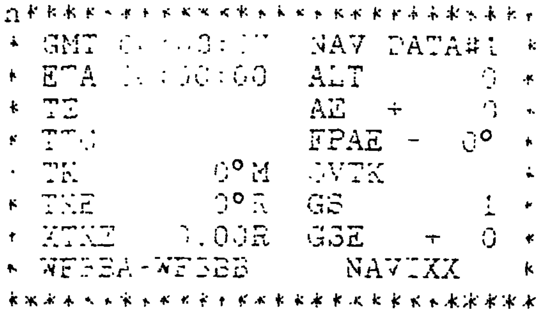
CALLS TO: C7T08, FORMAT, FORMLL, FRMFRQ, FRMTIM, LLBIN, LUNAVA, SCOSD

DESCRIPTION:

Each of three Navigation Data pages are displayed in order by consecutive key strokes of the "NAV" button on the bottom row of the NCDU. The first two pages are for information display only, allowing no user entries. Page #3 however displays information subject to user modification.

Nav Data page #1 displays 13 values along with header and message text. The header is shown on the top line, right justified. The bottom line of the display contains one of several possible messages. It may be a general NCDU alert message or a special Nav Data message (see documentation for the module NCDUIO for alert messages). The Nav Data message contains three fields which are used to display the name of the last waypoint reached, the next waypoint to be reached and the three letter code for the current navigation mode (see HNAVSL documentation for information about navigation modes). The word "HOLD" may replace either the "from" or "to" waypoint name if a holding pattern has been selected at that waypoint. The following are the 13 items displayed:

GMT	Current time of day.
ETA	Estimated time of arrival at the next waypoint.
TE	Time error when flying time guidance.
TTC	Time to capture. (How long to capture time path position).
TK	Track angle in degrees (magnetic north).
TKE	Track angle error in degrees left or right of the path.
XTKE	Cross track error. Displacement off the path (nautical miles).
ALT	Altitude in feet.
AE	Altitude error in feet when flying 3D path.
FPAE	Flight path angle error in degrees.
OVTK	Over take speed in capturing the time path position.
GS	Ground speed in knots.
GSE	Ground speed error (knots) from the time path ground speed.

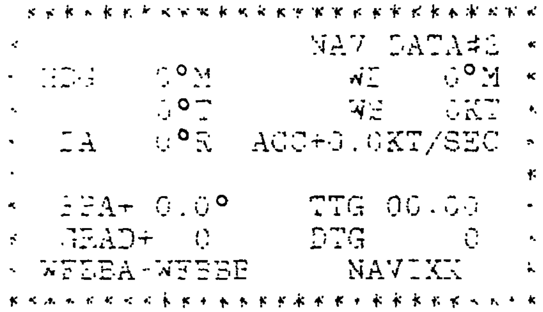


```
******************************
* GMT 00:00:00   NAV DATA#1  *
* ETA 00:00:00   ALT       0 *
* TE             AE  +     0 *
* TTG            FPAE -   0° *
* TK        0°M  DVTK        *
* TKE       0°R  GS        1 *
* XTKE    0.00R  GSE   +   0 *
* WFEBA-WFEBB     NAVIXX     *
******************************
```

(Nav Data page #1)

Nav Data page #2 has a banner and message line like page #1. It displays the value of the following 10 variables.

HDG True and magnetic heading.
DA Drift angle in degrees left or right.
FPA Flight path angle in degrees above or below horizontal.
GRAD Gradient. Altitude change (feet) in 1 nautical mile at the present FPA.
WD Wind direction (magnetic).
WS Wind speed in knots.
ACC Acceleration. Change in speed (knots/sec).
TTG Time to go to the next waypoint.
DTG Distance to go to the next waypoint (nautical miles).



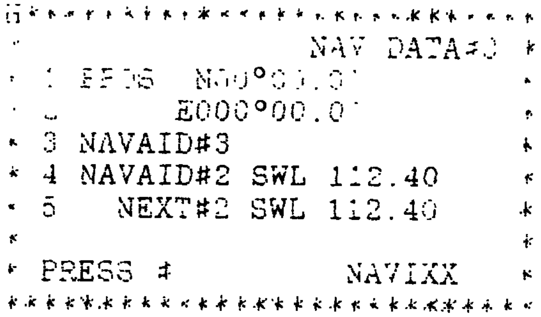
```
******************************
*                NAV DATA#2  *
*  HDG    0°M       WD   0°M *
*         0°T       WS   0KT *
*   DA    0°R  ACC+0.0KT/SEC *
*                            *
*   FPA+ 0.0°     TTG 00.00  *
*   GRAD+  0      DTG      0 *
*  WFEBA-WFEBB     NAVIXX    *
******************************
```

(Nav Data page #2)

Nav Data page #3 shows the banner line and navigation mode like pages one and two. The left of the bottom line, if not containing an alert message. will contain one of the following user prompts:

PRESS #
KEY LAT
KEY LON
KEY VOR

The first prompt notifies the user that the buttons 1 - 5 on the NCDU may be pressed to select new values for the items displayed on the lines. Once a numeric key has been pressed, one of the other prompts is given to note that the NCDU is ready for input. The aircraft position may be initialized manually by using keys 1 and 2 to alter the latitude and longitude. Since the degree symbol, appearing in the displayed LAT/LON, does not have a corresponding key on the NCDU keyboard, entered LAT/LON values have no delimiter between the degrees and minutes. Otherwise position entries appear just as displayed on the screen. The system automatically attempts to tune navigation radio aids (see HNAVSL documentation), however manual overrides can be made on Nav Data page #3. NCDU key 3, 4 and 5 are used to initiate manual tuning of navaids. Once the "KEY VOR" prompt has been displayed, the name of a data base defined navaid waypoint is entered. Following a manual tune, the letter "M" will appear on the line of the manually tuned navaid. Whether manually or automatically tuned, the lines containing navaids will also have displayed the frequency of that navaid.



```
******************************
*                NAV DATA#3  *
* 1 EFIS  N00°00.0'          *
* 2       E000°00.0'         *
* 3 NAVAID#3                 *
* 4 NAVAID#2 SWL 112.40      *
* 5   NEXT#2 SWL 112.40      *
*                            *
* PRESS #          NAVIXX    *
******************************
```

(Nav Data Page #3)

GLOBAL INPUTS: ALTCOR, ATNAV2, ATNAV3, BINTME, DECNUM, DFPA3D, DFTANG, DTOGO, FRMVAL, GAMMA, GS, GSFPS, GUID2D, GUID3D, GUID4D, HDGTRU, HLDSEL, HLDWPT, KEYUNL, LAT, LON, MAGVAR, MODPAG, NAVFLG, NAVTYP, NAV64K, NCDSPC, NCMESG, NDMODE, NPAGE, NVAD2A, NVAD2B, NVAD3A, OFFSEL, PATHND, PTH4DN, PTR2DN, PTR4D, SDC, SDCC, SEPR, TK, TKE, VGSDOT, WD, WS, XTK, ACTIVE, A0, A1, A2, A3, A4, A5, A6, BLANKS, FTONM, HER, IDDLAT, IDDLON, KTOFPS, WPSIZ

GLOBAL OUTPUTS: ATNAV2, ATNAV3, FUNUMB, IDDLAT, IDDLON, LLINIT, MODUPD, NCDERR, NUPAGE, NVAD2A, NVAD2B, NVAD3A

MODULE NAME: PAGRST/RESETM/RESET2

PURPOSE: Initialize NCDU variables after some NCDU function entries.

TASK: FAST

LANGUAGE: MACRO-11

CALLED BY: NCDKEY

CALLING SEQUENCE: CALL PAGRST
CALL RESETM
CALL RESET2

CALLS TO: none

DESCRIPTION:

These routines are separate entry points into one subroutine that exists on the file RESET.MAC. They are all used to initialize some NCDU variables when the NCDU software has been in some transitional state. RESET2 is performed no matter which of the three entry points is used.

PAGRST is used when the NCDU mode is changed from either TEST or MANUAL to AUTOMATIC (the standard NCDU page display). It finds whichever page was last active and sets the first pass bit for that page to enable specialized initialization. RESETM resets NCDU variables after a display page change and RESET2 resets other variables when a mode change from AUTOMATIC to either TEST or MANUAL is made.

GLOBAL INPUTS: ACMODE, FPMODE, INMODE, LUMODE, NDMODE, SEMODE

GLOBAL OUTPUTS: ACMODE. FPMODE, INMODE, LUMODE, NDMODE, SEMODE, DATNUM.
DECNUM, NCDSPC, FUNUMB, KEYUNL, MODUPD, PTAREJ

MODULE NAME: PRVSIZ

PURPOSE: Set provisional guidance buffer end pointers and optionally set/clear provisional bit for each waypoint.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: NCDGUD

CALLING SEQUENCE: CALL PRVSIZ(DO_BIT,POLARITY);

```
C... DO_BIT     Boolean for enabling the changing of the
C...            provisional bit.
C... POLARITY   The boolean value that the provisional bit
C...            will be set to.
```

CALLS TO: none

DESCRIPTION:

PRVSIZ is called, after changes have been made to the provisional guidance buffer, to set the global variables PWNUM and PWEND. PWNUM is the number of waypoints in the buffer and PWEND is the byte offset from the start of the buffer to the location of the first empty waypoint.

If the first of the two input parameters has the value 'ON', then the provisional bit for each waypoint is set to the boolean value contained in the second input parameter.

GLOBAL INPUTS: PGBUF, WPSIZ

GLOBAL OUTPUTS: PWNUM, PWEND

MODULE NAME: SELMOD

PURPOSE: Perform NCDU 'Select Page' I/O

TASK: SLOW

LANGUAGE: MACRO 11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL SELMOD

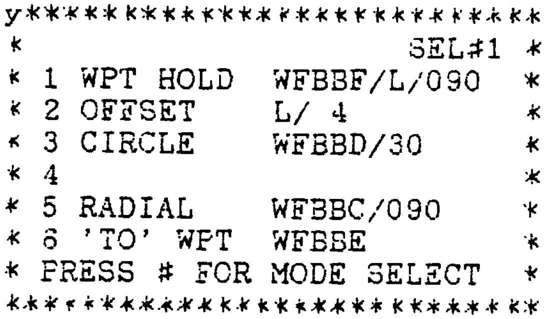
CALLS TO: INSELH, LUGUID, ATN2D, ASCBIN, FORMAT, LUGRP, LUNAVA

DESCRIPTION:

The select pages of the NCDU allow the AFD pilot to select desired horizontal navigation, vertical guidance and power setting options. There are three separate pages that can be displayed by consecutive presses of the SEL button on the NCDU.

****** PAGE #1 ******

The first select page has six pilot options, however option #4 is currently undefined. An option is chosen by pressing the numeric button on the NCDU corresponding to the number displayed preceeding each option. Any option in effect can be cancelled by pressing its function number followed by a REJECT.



```
y**************************
*                   SEL#1 *
* 1 WPT HOLD  WFBBF/L/090 *
* 2 OFFSET    L/ 4        *
* 3 CIRCLE    WFBBD/30    *
* 4                       *
* 5 RADIAL    WFBBC/090   *
* 6 'TO' WPT  WFBBE       *
* PRESS # FOR MODE SELECT *
***************************
```

(NCDU SELECT PAGE #1)

Option #1 causes a holding pattern to be displayed on the navigation display unit. The pattern consists of two parallel lines appropriately oriented with respect to the designated waypoint on the active flight path. One line is joined to the waypoint while the other is optionally to the left or right. The lines are oriented on a magnetic bearing chosen by the pilot. To enable a holding pattern function #1 is pressed and the prompt "KEY WPT" is displayed on NCDU line eight. After entering a waypoint name or POS, for present position, "L-R&BRG" is displayed on line eight. Upon entering position and bearing the option to "EXEC OR REJ" is given.

Option #2 causes an offset flight path to be drawn on the navigation display unit. The original flight path is drawn dashed as if it were provisional and the offset path is drawn as a series of solid lines and arcs at a fixed distance from the flight path.

To choose an offset flight path, press button #2 on the NCDU. Enter L or R (for left or right) and offset in nautical miles in response to the prompt "L-R&OFS". The prompt "EXEC OR REJ" is issued to allow a final choice of displaying the offset path.

Option #3 causes a circle to be drawn about any waypoint stored in the NAV resident common data base (BULK.TSK). Press button #3 and enter a waypoint name and circle radius, in nautical miles, in response to the prompt "WPT&RAD". The waypoint and circle will immediately be displayed if it lies within the screen boundaries of the display.

Option #5 is used to select the display of a radial symbol through any waypoint in the data base. A series of small circles passes through the chosen waypoint in a line oriented to a chosen magnetic bearing.

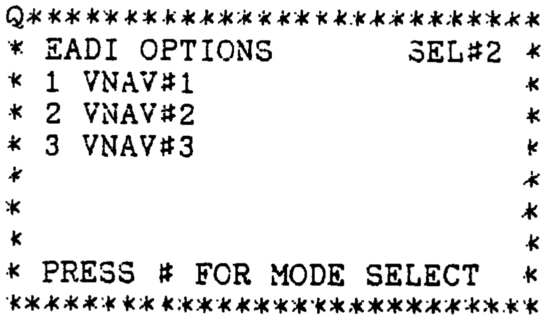
Select the radial option by pressing button #5 on the NCDU. Enter waypoint name and bearing in response to the "WPT&BRG" prompt. The waypoint and symbol will appear immediately on the navigation display if its position lies within the screen boundaries.

Option #6 allows the selection of the waypoint on the path that the airplane will fly to. By default the 'TO' waypoint is initially the second on the path. The altering of the 'TO' waypoint can be done only when the A/P is not moving, therefore this option is only useful when flying EASILY lab simulations or departing from an airport.

Press button #6 to get the prompt "KEY WPT" and enter the name of a waypoint on the path. "EXEC OR REJ" is displayed next for finalizing the decision.

****** PAGE #2 ******

The second select page has three vertical guidance options which are presently unused. These were used in previous versions of the displays software but at the present time these options have no effect on the primary flight display.

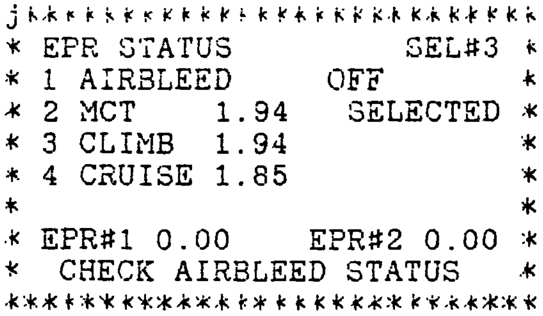


```
Q***************************
* EADI OPTIONS      SEL#2  *
* 1 VNAV#1                 *
* 2 VNAV#2                 *
* 3 VNAV#3                 *
*                          *
*                          *
*                          *
* PRESS # FOR MODE SELECT  *
****************************
```

(NCDU SELECT PAGE #2)

****** PAGE #3 ******

The third select page allows the selection of power settings. The current state of AIRBLEED, engine pressure limits and pressure ratios of both engines are displayed on this page. The status of AIRBLEED can be changed and a desired EPR limit chosen by pressing the numeric NCDU button corresponding to the numbers displayed preceeding the options. See module documentation of EPRLMT for the description of maximum continuous thrust, climb and cruise engine pressure ratio limits.



```
j**************************
* EPR STATUS        SEL#3 *
* 1 AIRBLEED     OFF      *
* 2 MCT    1.94   SELECTED *
* 3 CLIMB  1.94           *
* 4 CRUISE 1.85           *
*                         *
* EPR#1 0.00    EPR#2 0.00 *
*  CHECK AIRBLEED STATUS  *
***************************
```

(NCDU SELECT PAGE #3)

GLOBAL INPUTS: ACTIVE, ATC2, BINTME, CLAT, DATNUM, DECADR, DECBNG, DECMV, DECNAM, DECNUM, DECTYP, DSRTK, DUALNM, EPR1, EPR2, FRMVAL, FUNUMB, GUID2D, GUID3D, LUADDR, MCLEPR, MCREPR, MCTEPR, MODPAG, MODUPD, NCDSPC, NCMESG, NGIDON, SEMODE, SE11, SE21, SE31, WPEND, WPSIZ

GLOBAL OUTPUTS: ABSTAT, CRAD, DECTY, EPRFLG, GDTIME, HLDBRG, HLDSEL, HLDWPT, HOLDIN, KEYUNL, NCDERR, NPAGE, NUPAGE, OFBIAS, OFSSEL, PSRTFG, RADBRG, RADWPT, RWPTAD, RWPTNM, SMER61, SMER62, SMER63, SMER65, SMER66, SMF61, VNAVF, WPPTR

MODULE NAME: TSTMOD

PURPOSE: Display test pattern on the NCDU

TASK: SLOW

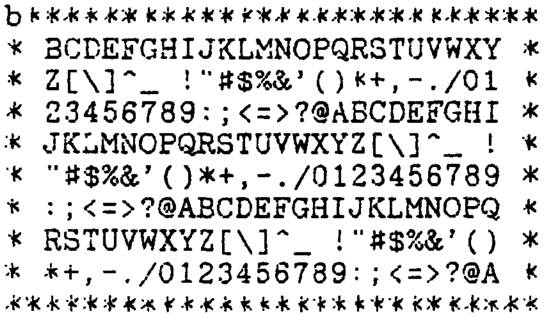
LANGUAGE: MACRO-11

CALLED BY: NCDUEX

CALLING SEQUENCE: CALL TSTMOD

CALLS TO: None

DESCRIPTION:
The test pattern on the NCDU is displayed when the T-M-A (Test-Manual-Automatic) knob on the the NCDU is turned to "T". A repeated pattern of all 64 NCDU characters is then displayed on the screen. Every second the display is shifted 1 character to the left giving the appearance of a moving string of characters that wrap around at the right and left screen boundaries.



```
b*************************
* BCDEFGHIJKLMNOPQRSTUVWXY *
* Z[\]^_ !"#$%&'()*+,-./01 *
* 23456789:;<=>?@ABCDEFGHI *
* JKLMNOPQRSTUVWXYZ[\]^_ ! *
* "#$%&'()*+,-./0123456789 *
* :;<=>?@ABCDEFGHIJKLMNOPQ *
* RSTUVWXYZ[\]^_ !"#$%&'() *
* *+,-./0123456789:;<=>?@A *
**************************
```

(Test Pattern)

GLOBAL INPUTS: BINTME, MODUPD, TSMODE

GLOBAL OUTPUTS: DECNUM, NCDSPC, NPAGE, NUPAGE

MODULE NAME: WPINVT

PURPOSE: Create a new waypoint.

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: ATCMOD, DECODE

```
CALLING SEQUENCE:  MOV   #N,RO          (N - number)
                   CALL  WPINVT
```

CALLS TO: None

DESCRIPTION:

When the pilot has entered commands to the NCDU that call for the creation of a new waypoint, WPINVT defines a waypoint with the name "PPTn" where "n" is a number from 1 to 9. The latitude, longitude and address of a navaid to be associated with the waypoint are set up prior to calling WPINVT in the variables DECLAT, DECLON and DECNAV. A code number, passed in through register #0, used to differentiate between various types of pilot defined waypoints is stored in the variable DECTYP. The following items for each created waypoint are stored in the pilot defined waypoint buffer (WAYPNT) which can contain up to nine waypoints before wrapping back around to the start.

NAME — The name of the waypoint (created by WPINVT)
LATITUDE — The latitude of the waypoint (from DECLAT)
LONGITUDE — The longitude of the waypoint (from DECLON)
NAVAID — The address of the navaid to be used for guidance (from DECNAV)
MESSAGE — The text entered causing the creation (from NCMESG)

GLOBAL INPUTS: DECLAT, DECLON, DECNAV

GLOBAL OUTPUTS: DECADR, DECNAM, DECTYP

7.0 NAVIGATION

NAVIGATION OVERVIEW

The navigation routines find aircraft position, altitude and velocities via various position measuring techniques. Factors external to the aircraft are computed such as wind speed/direction and local earth radius of curvature.

The tuning of ranging stations such as DME (Distance Measuring Equipment) and VOR (VHF Omni-range), is done by HNAVSL to find position estimates relative to known transmitter locations. These values are combined with sensor data such as INS (Inertial Navigation System) or MLS/ILS ground telemetry data by HNAVFS every 50 ms to produce the aircraft position, altitude and velocities.

MODULE NAME: ACCPRC

PURPOSE: To compute alternate values of the along track and crosstrack acceleration terms.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: JSR PC,ACCPRC

CALLS TO: ACCSTP, IAND, SCOSD, SQRT

DESCRIPTION:

This module manipulates the INS ATKACC and XTKACC inputs in one of several different ways depending upon the bits set in the MLS configuration word (MCONF). If MCONF$9 is set, these inputs are modified to simulate those inputs that might be expected from a standard LTN-51 INS, using an algorithm supplied by Bill Lynn. If MCONF$10 is set, the inputs are modified according to Harry Fuller. If MCONF$11 is set, these inputs are simply replaced by analogous signals derived from the body mounted accelerometers. If none of the above bits are set, the routine simply exits.

GLOBAL INPUTS: ATKACC, BMACC, CTHET, CROLL, DFTANG, MCONF, MLSC, PITCH, ROLL, STHET, SROLL, XTKACC

GLOBAL OUTPUTS: ATKACC, XTKACC

MODULE NAME: BLOW

PURPOSE: Calculate wind speed and direction.

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: Slow Loop Executive (SLOW)

CALLING SEQUENCE: JSR PC,BLOW

CALLS TO: None

DESCRIPTION:

If the radio altitude HRAD is less than five feet then wind direction remains unchanged and wind speed is set to zero.

If HRAD is greater than or equal to five feet then wind speed and direction are computed as:

```
        WD = ATN2D (X,Y)
        WS = SQRT (X**2 + Y**2)

WHERE:  X = SINTH TASGS - VE
        Y = COSTH TASGS - VN
        VE = velocity east in knots
        VN = velocity north in knots
        SINTH = sin of true heading
        COSTH = cos of true heading
        TASGS = true airspeed corrected for gamma
```

GLOBAL INPUTS: COSTH, HRAD, SINTH, TASGS, VE, VN

GLOBAL OUTPUTS: WD, WS

MODULE NAME: ERAD

PURPOSE: Compute the radii of curvature in the east-west and north-south planes.

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: Slow loop executive (SLOW)

CALLING SEQUENCE: JSR PC,ERAD

CALLS TO: GETDAT

DESCRIPTION:

If the simulated airplane is engaged, then magnetic variation (MAGVAR) has been set from the simulator data tables (SMMAGV). If not, then MAGVAR is set by ERAD as follows:

If INS navigation is valid (INAVV true) then MAGVAR = MVINS; else if a path has been entered (GUID2D true) then MAGVAR is set from the guidance buffers (PWMV$(PTR2D)); else if a valid DME is tuned (FLSTA2 or FLSTA3 = 0) then MAGVAR is set from the bulk data address pointed to by NVAD2A or NVAD3A, respectively, via a call to GETDAT. If none of the above conditions prevail, then MAGVAR is not set.

The local north and east radius of curvature and several related variables used by the nagivation and guidance procedures are then set by evaluating the following equations:

```
RN = RADIUS (1. + ELLIP*SLAT**2)
RM = RADIUS (1. - 2.ELLIP + 3.ELLIP*SLAT**2)
RNP = (ALTCOR FTONM + RN) CLAT
RMP = ALTCOR FTONM + RM
```

where: RADIUS is the nominal earth radius in NM.
(taken as 3443.9362 NM)
ELLIP is the eccentricity (3.3901E-3).
SLAT is the sine of the present latitude.
CLAT is the cosine of the present latitude

```
RADFT = RMP NMTFT
DLATFT = RADFT DTOR
DLONFT = RNP NMTFT
```

where: RADFT is the local earth radius in feet,
DLATFT is the number of feet per degree of latitude,
DLONFT is the number of feet per degree of longitude.

GLOBAL INPUTS: ALTCOR, CLAT, ELLIP, FLSTA2, FLSTA3, FLYFLG, FTONM, GUID2D, INAVV, MVINS, NVAD2A, NVAD3A, SLAT

GLOBAL OUTPUTS: MAGVAR, RMP, RNP, RADFT, DLATFT, DLONFT

NAME: HNAVFS (Horizontal/vertical NAVigation, FaSt)

PURPOSE: To provide fast loop signal selection and integrations for navigation.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL HNAVFS

CALLS TO: ANGL, ATN2D, DPINTG, SCOSD.

DESCRIPTION:

The Horizontal/Vertical Navigation routine (HNAVFS) is the only fast loop navigation routine. All integrations in the navigation filter take place here. The radio corrections to the INS positions and velocities are received from HNAVSL, and the east-west and north-south local radii of curvature are received from ERAD. These are combined and integrated to form the corrections to the velocities (knots) and position (degrees). A simplified overview is depicted in figure 7-4.

HNAVFS first initializes (OFF) FLRM and INSVAL and, if COLDST is TRUE, it also initializes NAVFLG, LLINIT and PASS1. The value for TASGS (ground speed based on true airspeed) is computed as the square root of TASFPS**2 minus HDOT**2, converted to knots. Subsequent initializations occur as required after the determination of flight mode.

Air Data or Radio Mode must be engaged if neither FLYFLG nor INAVV is TRUE. The acceleration inputs, normally input from the INS, are derived from the body mounted accelerometers by external code and assigned to ATKACC and XTKACC if bit 13 of MCONF is set. If so, these accelerations will be assigned to IDDATK and IDDXTK. Otherwise, no acceleration input is available; IDDATK and IDDXTK are zeroed and NCUVAL is set FALSE. In either case, true heading is taken as mag heading corrected for local variation, and external procedure SCOSD is called to form the sine and cosine of true heading (SINTH,COSTH).

Air Data Mode will be selected if the true airspeed input is valid (TASV = TRUE) and the directional velocities are then calculated as:

EWVAVE = TASGS SINTH
NSVAVE = TASGS COSTH.

Furthermore, on the first pass for Air Data Mode, DVN and DVE are initialized as the difference between the directional velocities and the estimated INS velocities:

DVN = IDDVN - NSVAVE
DVE = IDDVE - EWVAVE.

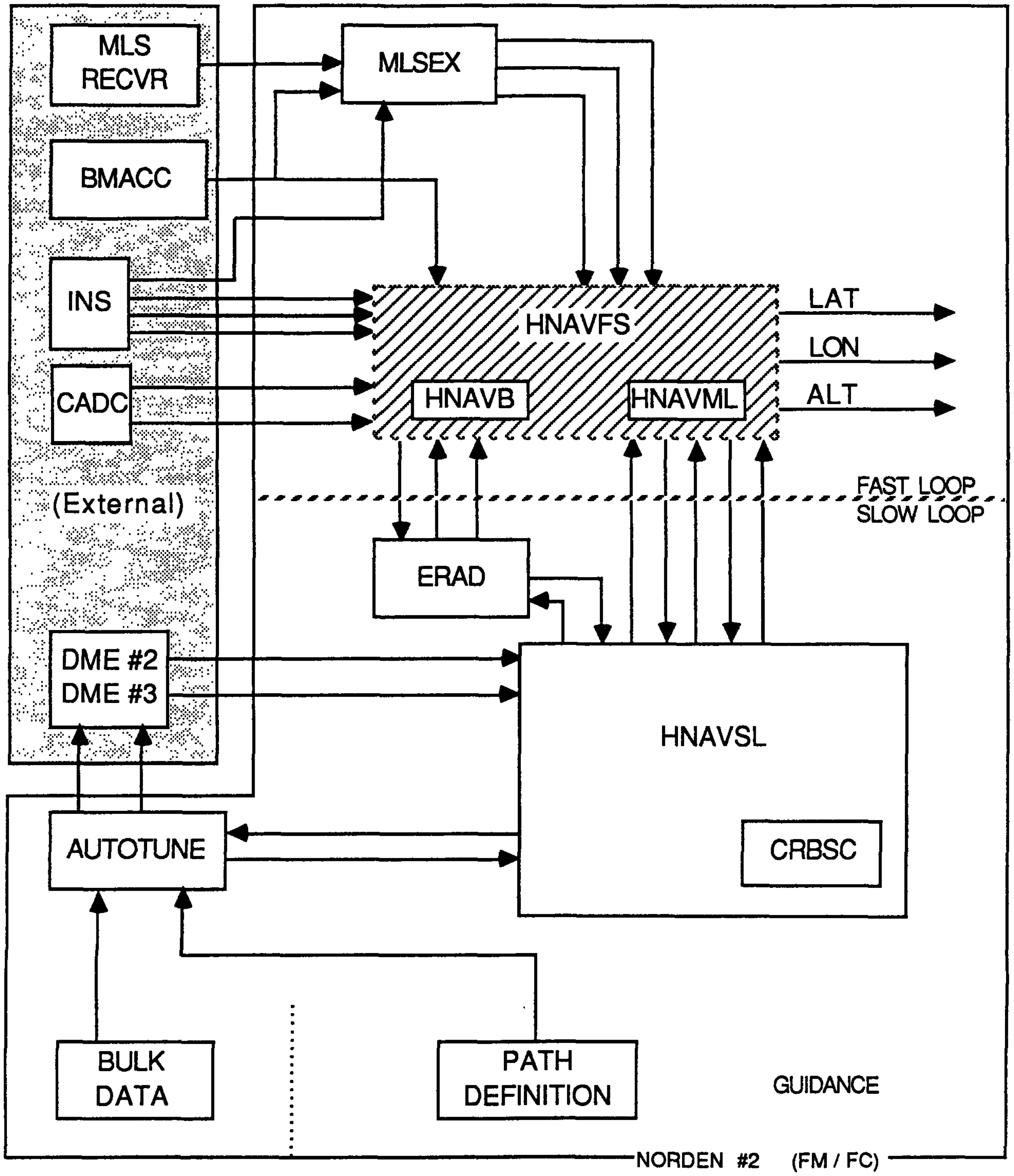


FIGURE 7-4: RELATIONSHIP BETWEEN HNAVFS AND THE REST OF THE NAVIGATION SOFTWARE AND HARDWARE.

Radio Mode is selected by default if there is no valid true airspeed input. No initializations are performed except for the mode flags FLRM (ON) and FLADM (OFF).

The Simulated Airplane is engaged if FLYFLG is TRUE. Otherwise, INAVV must be TRUE and Inertial Mode engaged.

The Simulator provides its own true heading (SMUHDG), calibrated airspeed (CAS), and cross track velocity (IDDXTK). Inertial Mode, naturally, uses INS derived values. Initializations, for one mode or the other, occur as depicted below:

VARIABLE	SIMULATOR (FLYFLG)	INERTIAL (INAVV)
HDGTRU	SMUHDG	THDG
SINTH	SCOSD(HDGTRU)	SCOSD(HDGTRU)
COSTH	SCOSD(HDGTRU)	SCOSD(HDGTRU)
NSVAVE	CAS COSTH	VNINS
EWVAVE	CAS SINTH	VEINS
IDDATK	ZERO	ATKACC
IDDXTK	IDDXTK	XTKACC

Additionally, for both modes, INSVAL is set ON and FLADM is set OFF. This concludes the initialization and mode selection for Air Data, Radio, and Simulator modes.

Next, the conditions for the Microwave Landing System (MLS) mode are evaluated. The MLS data valid flag, MLSVLD, is initialized as MLSVAL AND RUNM. If the simulator is engaged or if MLS has not been selected, the mode flag (MLSMOD) is set OFF. Otherwise, MLSMOD is set ON if MLS data is valid and enabled, and destination runway data is available. If the MLS data flag is not valid or MLS is not selected, then MLSMOD is turned OFF. MLS mode may be selected via the toggle switch on the NAV pallet (MLSSLI becomes true) or by depressing the MLS bezel button on the ND display unit. Code in the DS/DF Norden sets the sign bit of the DISPST word for one iteration when the bezel button is depressed. This word is transmitted from the DS/DF to the FM/FC Norden via the DATAC and is used to set the MLS_ENABL Boolean if MLSVLD is true and MLSMOD is false, or clear it if MLSMOD is true. If the MLS data flag is not valid or MLS is not selected, then MLSMOD is turned OFF.

If MLSMOD is TRUE then sub-procedure HNAVML is called to calculate the navigation variables. HNAVML sets the MLS first-pass flag, PASS1.

Sub-procedure HNAVB is called unconditionally to calculate the navigation variables based on INS and radio nav data. Then, if MLS is deselected, this set of variables is used.

Once all the required data have been selected, the sines and cosines of latitude and longitude are derived through calls to SCOSD. Then, if the groundspeed equals or exceeds 64 knots, or if both MLSMOD and NAVFLG (GS > 4) are set, the track angle is calculated from the north and east velocities. The east and north velocities are divided by groundspeed to produce the sine and cosine of the track angle, respectively. Otherwise, the track angle, and the sine and cosine of the track angle, are based on the true heading as it was set during initial mode determination and initialization. The flight path angle, GAMMA, is calculated as the quotient of the filtered rate of altitude change (HDCF), divided by groundspeed and converted to degrees.

Unconditionally, the drift angle and magnetic track angle are calculated through calls to external procedure ANGL. If the groundspeed is below 4 knots, both the navigation mode flag, NAVFLG, and the 64 knot flag, NAV64K, are turned OFF and the ground speed references (GS & GSFPS) are limited, respectively, to a minimum 1 knot and the corresponding value in feet per second. The limit protects against subsequent division by zero. If the groundspeed exceeds 4 knots, NAVFLG is turned ON, but NAV64K is kept OFF until 64 knots is reached. At that point, the Lat/Lon initialization flag, LLINIT, is also turned ON to indicate that the latitude and longitude variables have been initialized either from the INS or Nav data page 3.

PROCEDURE HNAVML:

This routine calculates velocities, accelerations, and positions based on MLS data inputs. It is called only when MLS mode has been selected. It consists of only eleven equations, mostly trigonometric, to calculate GSFPS, VGSDOT, XTACC, VN, VE, GS, LAT, LON, HDCF, and ALTCOR.

PROCEDURE HNAVB:

This routine calculates the velocity, acceleration, and position values based on the selected source velocities and radio updates. If MLSMOD and PASS1 are both TRUE, the radio nav gains and error terms are replaced by terms calculated from the MLS position estimates. If MLSMOD is FALSE, PASS1 is cleared. The output depends on several conditions.

Depending on the state of the navigation mode flag, NAVFLG, the north/east velocities, IDDVN and IDDVE, and the position coordinates IDDLAT and IDDLON are computed. If NAVFLG is true, DVN and DVE are integrated from DPN and DPE to correct for position errors determined in the slow loop. They are then summed with the velocities NSVAVE or EWVAVE, computed in mainline code during initial mode determination, to produce the north and east velocity estimates, IDDVN and IDDVE. Then, these velocities are converted to earth coordinates and, through calls to external procedure DPINTG, integrated to form the inertially derived latitude, IDDLAT, and longitude, IDDLON. However, if NAVFLG is OFF, the velocity estimates are taken directly from NSVAVE and EWVAVE. Then, if the INS signals are valid but the position coordinates not yet initialized (GS < 4 KTS), the raw INS latitude and longitude are used for IDDLAT and IDDLON.

The inertial ground speed estimate, IDDGS, is figured with the aid of Pythagoras. IDDVN and IDDVE are squared and summed, and the SQRT function outputs IDDGS.

If the simulated airplane is engaged, then HDOT is taken from the complementary filtered vertical velocity, HDCF (set by NAVIG). Otherwise, the vertical acceleration, velocity, and altitude are computed through a series of integrations. The vertical acceleration bias, DVH, is formed by integrating DELH, the difference between HBARO and ALT. This is gained by XKA and summed with HDD (vertical acceleration) to form HDDOT, the vertical acceleration estimate in ft/sec/sec. Then, HDOT, the vertical velocity, is formed by integrating the sum of HDDOT and XKV times DELH. Finally, the altitude, ALT, is computed by integrating the sum of HDOT and KD times DELH.

The final calculations produce IDDALT, the inertially smoothed altitude estimate, by applying a filtered, rate limited, barometric correction (FBARC) to ALT. FBARC is derived by converting the deviation from the standard barometric pressure to feet, taking the difference between that delta and the current value of FBARC, limiting that to a 10 foot maximum, and integrating.

GLOBAL INPUTS:

ACCHAT, ALT, ATKACC, AZ_BRG, BARSET, BSETO, CAS,
COLDST, DESTIN, DLATFT, DLONFT, DPE, DPN, FLYFLG, HBARO,
HDCFSW, HDD, HDOTB, INAVV, K1P, K2P, LATINS, LLINIT, LONINS,
MAGHDG, MAGVAR, MCONF, MLSSLI, MLSVAL, POSHAT, RADFT, RLMLS, RWYDEF,
RWYSEL, SMUHDG, TASFPS, TASV, THDG, VEINS, VELHAT, VNINS,
XTKACC.

GLOBAL OUTPUTS: ALT, ALTCOR, CLAT, CLON, COSTH, COSTKA, DFTANG, DLAT2,
DLON2, DPE, DPN, DVE, DVN, FLADM, FLRM, GAMMA, GS, GSFPS,
HDCF, HDDOT, HDGTRU, HDOT, IDDALT, IDDATK, IDDGS, IDDLAT,
IDDLON, IDDXTK, LAT, LAT_MLS, LLINIT, LON, LON_MLS,
MLSMOD, MLSVLD, NAV64K, NAVFLG, NCUVAL, SINTH, SINTKA, SLAT,
SLON, TASGS, TK, TKMAG, VE, VGSDOT, VN, XTACC, ZOMLS, ZDIF

MODULE NAME: HNAVSL

PURPOSE: The radio update navigation routine is the navigation update executive. It calls the routines that manually or automatically tune and monitor the path defined and cross track stations. Information from these stations such as range and bearing are used to update aircraft position and velocity estimations. In addition, HNAVSL performs the ILS update computations.

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: SLOW

CALLING SEQUENCE: CALL HNAVSL

CALLS TO: TUNXTK, TUNDM2

DESCRIPTION:
HNAVSL is logically partitioned into the following modules:

Initialization Code:
Boolean error flags F0, F2, F3. DMERR, and VORER to be used in the current HNAVSL pass are cleared. Local variables are assigned the most recent position estimate from fast loop navigation.

TUNPTH:
TUNPTH is an internal procedure which either manually tunes station #2 or automatically tunes a path defined station.

* Manual Mode *
If manual tune conditions are met, a check is made to see if certain station #2 error conditions exist. Under these conditions, the procedure RETMSG is called and the retune-station-2 flag for the NCDU is set if the ground speed is greater than 140 knots. The station #2 frequency is fetched and assigned to the output frequency variable ATUNE2. Proper tuning of the station is then confirmed by substantiating equality between ATUNE2 and the input frequency variable DME2FQ. If ATUNE2 does not equal DME2FQ, HAL bit 3 of fail flag FLSTA2 is set and a timer which allows four seconds for proper tuning is initiated.

* Auto Mode / NAV64K not set *
If automatic tune conditions are met and aircraft speed is less than or equal to 64 knots. 2-D guidance validity is examined. If 2-D guidance is possible (GUID2D ≠ 0), the pointer to the station defined by the next waypoint in the path is retrieved. The station #2 frequency is then fetched. assigned. and checked for proper tuning. If 2-D guidance is not possible (GUID2D = 0). the station pointer is set to zero and the station-not-tuned bit of fail flag F2 is set. The less-than-64 knots bit of FLSTA2 is set in any case.

* Auto Mode / NAV64K set *

If automatic tune conditions are met and aircraft speed is greater than 64 knots, the less-than-64 knots bit of FLSTA2 is cleared. If the timer that allows four seconds for proper tuning is zero and FLSTA2 registers an error, the boolean PSFAIL is set to true; otherwise, it is set to false.

Next, the waypoint indicator PTRSTA is compared to the current PTR2D to check for a waypoint change.

If PTRSTA is greater than PTR2D, PSFAIL is tested and if true, the auto-tune routine, TUNDM2, is called to find a new station. If PSFAIL is false, the current station is maintained.

If PTRSTA is less than PTR2D, PTRSTA is updated to equal PTR2D and the station defined by the next waypoint is retrieved. If PTRSTA equals PTR2D, the station is not updated. If the aircraft has not surpassed half the total distance to the upcoming waypoint and PSFAIL is false (indicating no station #2 failures), the current station is maintained. If the aircraft has passed the halfway point to the next waypoint or PSFAIL is true, a check is made to see if the station defined by the next waypoint is already tuned. If this station is not already tuned and 2-D guidance is possible (GUID2D ≠ 0), the station is tuned. If this station is already tuned or GUID2D = 0, PSFAIL is examined. If no failures were detected, (PSFAIL is false) this station is maintained; however, if a failure exists, PTRSTA is incremented and the next path defined station is retrieved. At this point, if 2-D guidance is valid, this new path defined station is tuned; otherwise, TUNDM2 is called to find a new station.

TUNDM2:

TUNDM2 is an external procedure which automatically tunes a station #2. It is called by HNAVSL under certain conditions as described in the TUNPTH section above. See TUNDM2 documentation for more information.

TUNXTK:

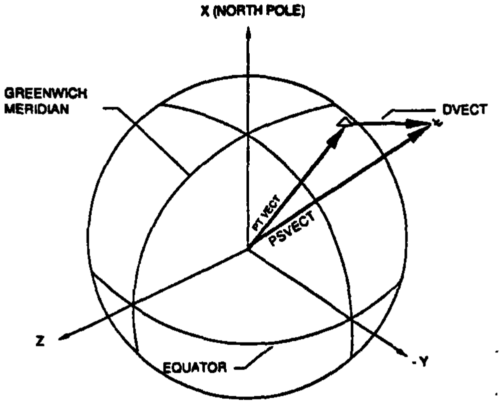
TUNXTK is an external procedure which manually or automatically tunes the cross-track station. See TUNXTK documentation for more information.

CRBSC:

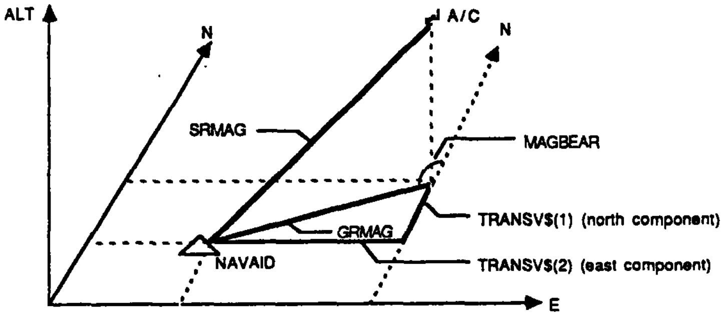
CRBSC is an internal routine that calculates range and bearing parameters of a navaid relative to the aircraft.

If the boolean PTHSTA is set, the delta latitude (DPHI1) and delta longitude (DLAM1) between the aircraft and the navaid are computed. PTHSTA is cleared.

The sines and cosines of the navaid latitude and longitude are computed. They are used in calculating the components of a vector (PTVECT) whose origin is the center of the earth and whose endpoint is the navaid. DVECT is computed by subtracting PTVECT from PSVECT, where PSVECT is the vector from the earth's center to the aircraft. The magnitude, or slant range of DVECT is assigned to SRMAG.



Using DVECT, the north and east components from the aircraft to the navaid are derived and assigned to the array TRANSV. Taking the square root of the sum of the squared components yields the ground range magnitude (GRMAG). Also, the components are used to calculate the magnetic bearing (MAGBEAR) of the navaid.



Radcal Processing Code:

The extended radius of the geoid to the aircraft is calculated. The vector PSVECT contains the components of the extended radius. PSVECT is derived in the same manner as PTVECT of the CRBSC routine.

Station #3 Processing:

If HAL bit 7 of SIMFLG is set, the local copy of MDME3 (DME3) is set equal to the canned value of CDME3. The appropriate bits of error flag DMEER are set if:

* Error flag FLSTA3 is not zero
* Boolean DME3VD is invalid
* DME3 > 200 nm
* DME3 <= 0

If the navaid address pointer NVAD3A is zero, CMDE3 is set to zero; otherwise, the internal routine CRBSC is called to calculate the slant range magnitude and assign it to CDME3. If CDME3 is greater than 327.67 nm or equal to zero, bits in DMEER are set to indicate an out-of-range error.

If CDME3 has a valid value, the delta range (DRANGE) between CDME3 and MDME3 is computed. If the delta range is greater than or equal to 5 nm, a bit in DMEER is set. If DRANGE is less than 5 nm, two elements of the position error component array (H) are computed as follows:

H$(1) = DRANGE * COSCB * DELGN
H$(5) = DRANGE * SINCB * DELGN

where COSCB and SINCB are the cosine and sine of the navaid bearing and DELGN is a delta gain. If FLADM or FLRM is set, DELGN = 0.5; otherwise DELGN = 0.25. The array H is used for position and velocity updating in a later section. At this point, if aircraft altitude is greater than the ground range magnitude (GRMAG) calculated in CRBSC, HAL bit 8 of FO is set.

FO is updated to reflect all station #3 errors registered during the current pass. If errors are registered in DMEER, a fifteen second timer is initiated. If the errors persist after the timer has elapsed, the appropriate bit of FLSTA3 is set so that a new station #3 will be tuned (by TUNXTK).

Station #2 Processing:

If HAL bit 8 of SIMFLG is set, the local copy of MDME2 (DME2) is set equal to the canned value of CDME2. Likewise, if HAL bit 9 of SIMFLG is set, the local copy of MVOR2 (VOR2) is set equal to the canned value of CVOR2. The boolean PTHSTA is set and DMEER is cleared of all previously detected errors so that it may be reused for station #2 error logging. The appropriate bits of DMEER are now set if:

* Error flag FLSTA2 is not zero
* Boolean DME2VD is invalid
* DME2 > 200 nm
* DME2 <= 0

The appropriate bits of fail flag VORER are set if the boolean VORVLD is false. If the navaid address pointer NVAD2A is zero, CDME2 and CVOR2 are set to zero; otherwise, the internal routine CRBSC is called. CRBSC returns the slant range (SRMAG) from the aircraft to the navaid and assigns it to CDME2. CVOR2 is assigned the magnetic bearing to the navaid.

If CDME2 is greater than 327.67 nm or equal to zero, bits in DMEER and VORER are set to reflect an out-of-range error. Also, an additional fail bit in VORER is set if CDME2 is greater than or equal to 150 nm. If CDME2 has a valid value, the delta range (DRANGE) between CDME2 and MDME2 is computed. If the delta range is greater than or equal to 5 nm, bits in VORER and DMEER are set. If DRANGE is less than 5 nm, two more elements of the position error component array (H) are computed as follows:

H$(3) = DRANGE * COSCB * DELGN
H$(7) = DRANGE * SINCB * DELGN

where COSCB and SINCB are the cosine and sine of the navaid bearing and DELGN is a delta gain. DELGN is the same for station #2 as it was for station #3. At this point, if aircraft altitude is greater than the ground range magnitude (GRMAG) calculated in CRBSC, HAL bit 8 of F0 is set.

If VORVLD is valid and the delta bearing between MVOR2 and CVOR2 (DELBR) is less than 30 degrees, the weighted difference used for position and velocity updating is calculated as:

VOR_WEIGHT = .125 * ABS(DME - DMEMAX) * DELBR * DELGN / DMEMAX

Two more error components of H are calculated as:

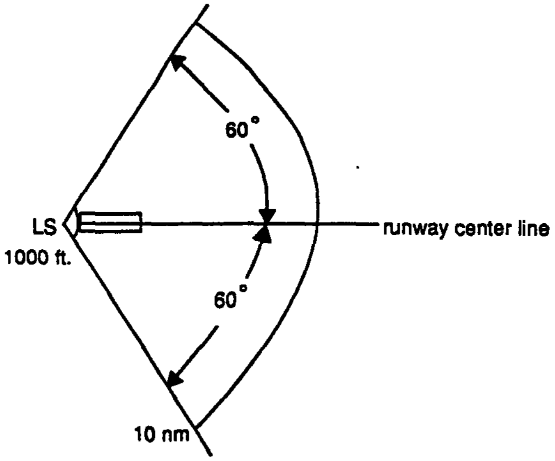
H$(4) = VOR_WEIGHT * TRANSV$(1)
H$(8) = VOR_WEIGHT * TRANSV$(2)

where TRANSV contains the north and east components from the aircraft to the station.

F2 is updated to reflect the errors registered in DMEER and F3 is updated to reflect the errors registered in VORER during the current pass. If errors are registered in DMEER, a fifteen second timer is initiated. If errors persist after the timer has elapsed, the appropriate bit of FLSTA2 is set so that a new station will be tuned.

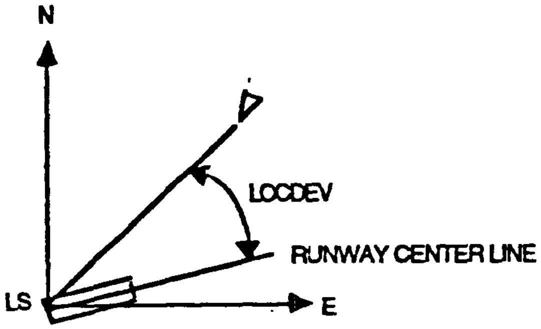
ILS Update Computations:

The boolean F5 is cleared. If the aircraft is not within an ILS zone (ILSZON is false), it must be ensured that the delta latitude and delta longitude between the aircraft and the localizer shack are both less than 1.40625 degrees before further processing. If this holds true, F5 is set and the tangent of the glide slope angle (TANGSA) is assigned.



ILS processing stops at this point if ILSZON and F5 are cleared. If either is set the parameters (CRBLT, CRBLG, CRBMV, CRBEL) used in the internal routine CRBSC are assigned localizer data. Thus, when CRBSC is called, the slant range (RNGLS) and bearing (BRGLS) to the localizer shack will be computed. If RNGLS is assigned a value that is less than or equal to 1000 feet, or greater than 10 nm, or the absolute value of BRGLS is greater than or equal to 60 degrees, ILS processing is discontinued.

If ILS processing conditions are valid thus far, boolean ILSTMP is set to true, F5 is cleared, and the localizer deviation angle (SLOCDV) is compared to 1.9 degrees. Processing continues if SLOCDV is less than 1.9 degrees, and LOCFS and LOCVLD are both true. F4 is set. Using SLOCDV and the north and east components from the aircraft to the localizer shack (computed by CRBSC and stored in TRANSV), estimates are made for the aircraft's north (DLNPP) and east (DLEPP) position components. A second corrected estimate of the components using glide slope data is performed if VBS is true, F2 indicates station #2 errors, and the current 2-D waypoint (PTR2D) equals the number of waypoints on the path (WPNUM).



If the ILS receiver is not tuned or the aircraft is not receiving valid data, the aircraft position estimates are not computed and F4 is cleared.

Regardless of the occurence of ILS update computations, ILSZON is set to ILSTMP, and if false, F4 and F5 are cleared. If F4 is cleared and roll is greater than 15 degrees, or NAV64K is false, the appropriate bits of F0 and F2 are set and F4 is cleared.

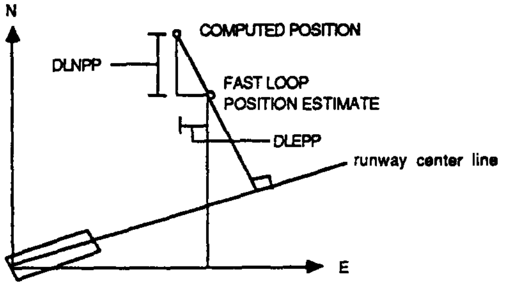


Figure 5 Error Vector Perpendicular to Runway Resolved Into Its North and East Components

Error Component Setting:

The navigation mode determines the values of the error component variables used for aircraft position and velocity updating in the fast loop navigation computations.

If F0, F2, and F4 all register failures, the position error components DPN and DPE are set to zero indicating no updates. The velocity error components DVN and DVE are zeroed if these failures persist for five minutes, and FLADM or FLRM are not set.

If F0, F2, or F4 do not register failures, the position error components will be set according to navigation mode. These modes and settings are:

ILS: DPN = DLNPP
DPE = DLEPP

ILS / DME #2:

DPN = DLNPP + H\$(3)
DPE = DLEPP + H\$(7)

DME #2 / DME #3:

DPN = H\$(1) + H\$(3)
DPE = H\$(5) + H\$(7)

DME #3 / VOR:

DPN = H\$(1) + H\$(4)
DPE = H\$(5) + H\$(8)

DME #2 / VOR:

DPN = H\$(3) + H\$(4)
DPE = H\$(7) + H\$(8)

DME #3 only:

DPN = H\$(1)
DPE = H\$(5)

NOTE: If CDME3 < 2 nm, DPN and DPE are zeroed
and HAL bit 14 is set in F0.

DME #2 only:

DPN = H\$(3)
DPE = H\$(7)

NOTE: If CDME2 < 2 nm, DPN and DPE are zeroed
and HAL bit 14 is set in F2.

Position and Velocity Gain Settings:

K1P and K2P are velocity and position gains that are set equal to locally declared constants and used in the fast loop navigation computations. Their values are dependent upon the system mode of operation.

NCDU Message:

Two variables NAVTYP and MNAVTY are used to pass navigation mode information to the NCDU. (See DISNAV documentation for details). The NCDU code is a three letter acronym. The first letter represents the system mode. The second and third letters represent station validity. The table below depicts the various combinations.

LETTER POSITION

FIRST	SECOND	THIRD	MEANING
I			Inertial Navigation Mode
A			Air Data Computer Mode or MLS
X			Radio Receiver Mode
	D		Valid Station #3
		D	Valid Station #2
	V		Valid VOR #3
		V	Valid VOR #2
	L		Cross runway position estimated from Localizer
	X		Station #3 Not Tuned
		X	Station #2 Not Tuned
	M	X	MLS Mode
		G	Along runway position estimated from Glideslope

TUNE STATION FAIL FLAG TABLE

HAL BIT	FO	F2	F3	MEANING
2	*	*		Station not tuned.
3	*	*	*	Receiver not valid.
4	*	*		MDME <= 0.
			*	CDME >= 150 nm.
5	*	*	*	MDME > 200 nm.
6	*	*	*	CDME out of range.
7	*	*	*	CDME - MDME >= 5 nm.
8	*	*	*	Altitude >= Calclated ground range
9	*	*	*	CDME = 0.
10	*	*		(GS < 64 kt) or (Roll > 15 deg and ILS invalid).
			*	Invalid ILS and Stations
11	*	*		CDME < Single DME minimum range.

HAL BIT	FLSTA3	FLSTA2	MEANING
2	*	*	Invalid data for 15 seconds.
3	*	*	Tune output not equal input.
4	*	*	GS < 64 knots.
5	*	*	Bad station geometry.

GLOBAL INPUTS: ACTIVE, ALTCOR, ANTLAT, ANTLON, ATNAV2, BAZFLG, BINTME,
BRGLS, CDME2, CDME3, COSCB, COSDA, COSRH, DESTIN,
DME2VD, DME3VD, DTG, DTOGO, DTOR, ELLIP, FLADM, FLRM,
FTONM, FO, F2, F3, GS, GSA, GSDEV, GUID2D, IDDALT,
IDDLAT, IDDLON, LOCDEV, LOCFS, LOCVLD, MDME2, MDME3,
MLSMOD, MVOR2, NAV64K, NVAD2A, NVAD3A, PSTMR, PTRPS,
PTR2D, RADIUS, ROLL, RWYHDG, RYELEV, SIMFLG, SINCB,
SINRH, TIMS1, TIMS2, TRANSV, UPDTMR, VBS, VORVLD, WPNUM

GLOBAL OUTPUTS: ATUNE2, CDME2, CDME3, COP, COSCB, COSDA, CVOR2, DELBR,
DELGN, DLAM1, DMEER, DME2FQ, DPE, DPHI1, DPN, DVE,
DVECT, DVN, FLSTA2, FLSTA3, FO, FOG, F2, F2G, F3, F3G,
F4, GRMAG, ICLAT, ICLON, ILSZON, ISLAT, ISLON, K1P,
K2P, MNAVTY, NAVTYP, NVAD2A, PSFAIL, PSVECT, PTHSTA,
PTRPS, PTVECT, PTRSTA, RETUN2, RNGLS, SLLAT, SLLON
TANGSA, TIMS1, TIMS2, TRANSV, UPDTMR, VORER

MODULE NAME: MLSEX (Microwave Landing System (MLS) Executive

PURPOSE: To calculate the aircraft position and velocities in the MLS coordinate system.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL MLSEX

CALLS TO: ATND, ATN2D, DISMF, SCOSD, TAND, UNPK

MLS SUMMARY:

The conventional MLS ground equipment transmits three cone-shaped time-reference scanning radio beams from the runway area (Figure 7-3). One beam scans 60 degrees from side to side of the runway center at a rate of 13 1/2 times per second to provide azimuth (AZ) referencing. The second beam scans up 20 degrees and down to some minimum angle above the runway (which varies from airport to airport) at a rate of 40 times per second to provide basic glideslope guidance (EL1). The third beam (if available) scans up 7 1/2 degrees and down to the reference plane for flare guidance (EL2). A fourth non-scanning beam transmitted from a distance measuring equipment (DME) site provides ranging information. This DME beam transmits on interrogation and has an angular coverage of 120 degrees in azimuth and 20 degrees in elevation. Time reference means that the receiving equipment on the aircraft will measure the time difference between successive 'to' and 'fro' sweeps of the scanning beams to determine aircraft position relative to the runway centerline and to a preselected glide path.

The following discussion is based on the Wallops Island MLS facility but applies equally well to any MLS installation, except for specific antenna locations, etc., which would vary from airport to airport.

The MLS coordinate system (Figure 7-1) has as its origin a point 1283 feet from the stop end of runway 22 at the Wallops facility. It is located on runway centerline at a height of 41 feet above MSL. The DME is located 6 feet behind and 62 feet to the right of the azimuth antenna at the MLS origin. The EL1 site is offset from the runway centerline by -400 feet (YEL1 = -400 ft) in the MLS coordinate frame, with an X coordinate of 9218 feet.

Using the computation of the aircraft center of gravity (X, Y, Z) in the MLS coordinate system, the MLS / Flight Controls software will track the defined glideslope shown in Figure 7-2.

Figure 7-3 illustrates the MLS coordinate system with its origin established at the azimuth transmitter site. The positive X-axis is defined by the line of zero azimuth. It is assumed that the azimuth

ITEM	LAT	LON	h_{MSL}
Az	37.923962°	-75.473675°	41.1 ft.
DME	37.924066°	-75.473845°	49.7 ft.
EL	37.944799°	-75.455473°	34.7 ft.
T.P.6	37.926944°	-75.471304°	34.19 ft.
T.P.12	37.929268°	-75.469457°	34.75 ft.
T.P.74	37.946930°	-75.455418°	32.6 ft.
T.P.75	37.947274°	-75.455145°	32.18 ft.

True Heading Runway 22 = 212.193°

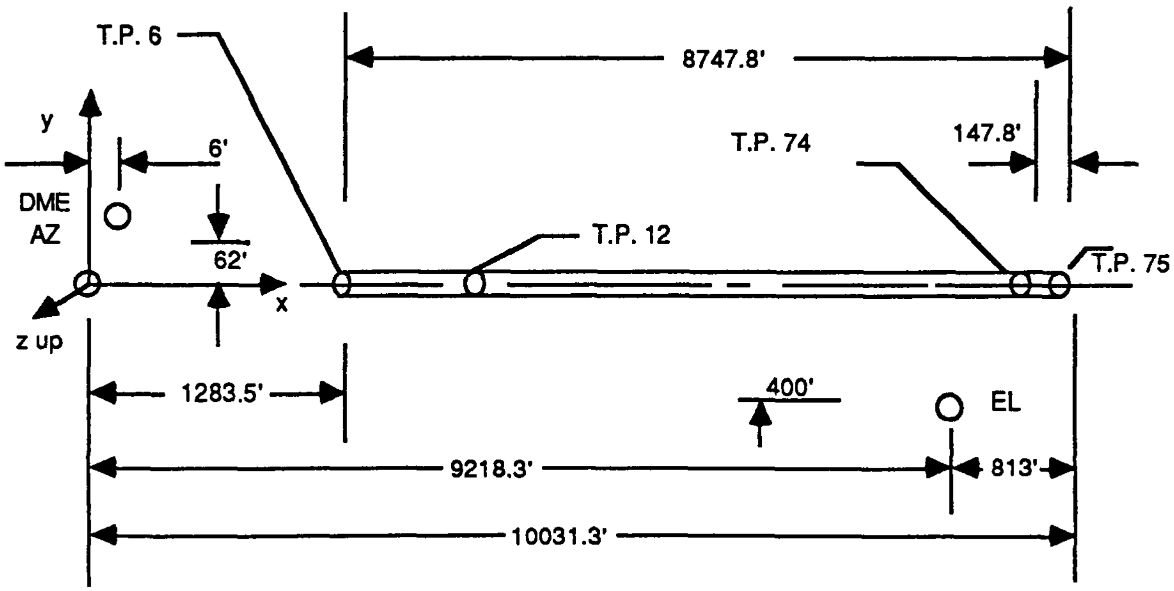


FIGURE 1. WALLOPS FLIGHT CENTER MLS Antenna and Test Point Locations on Runway 22

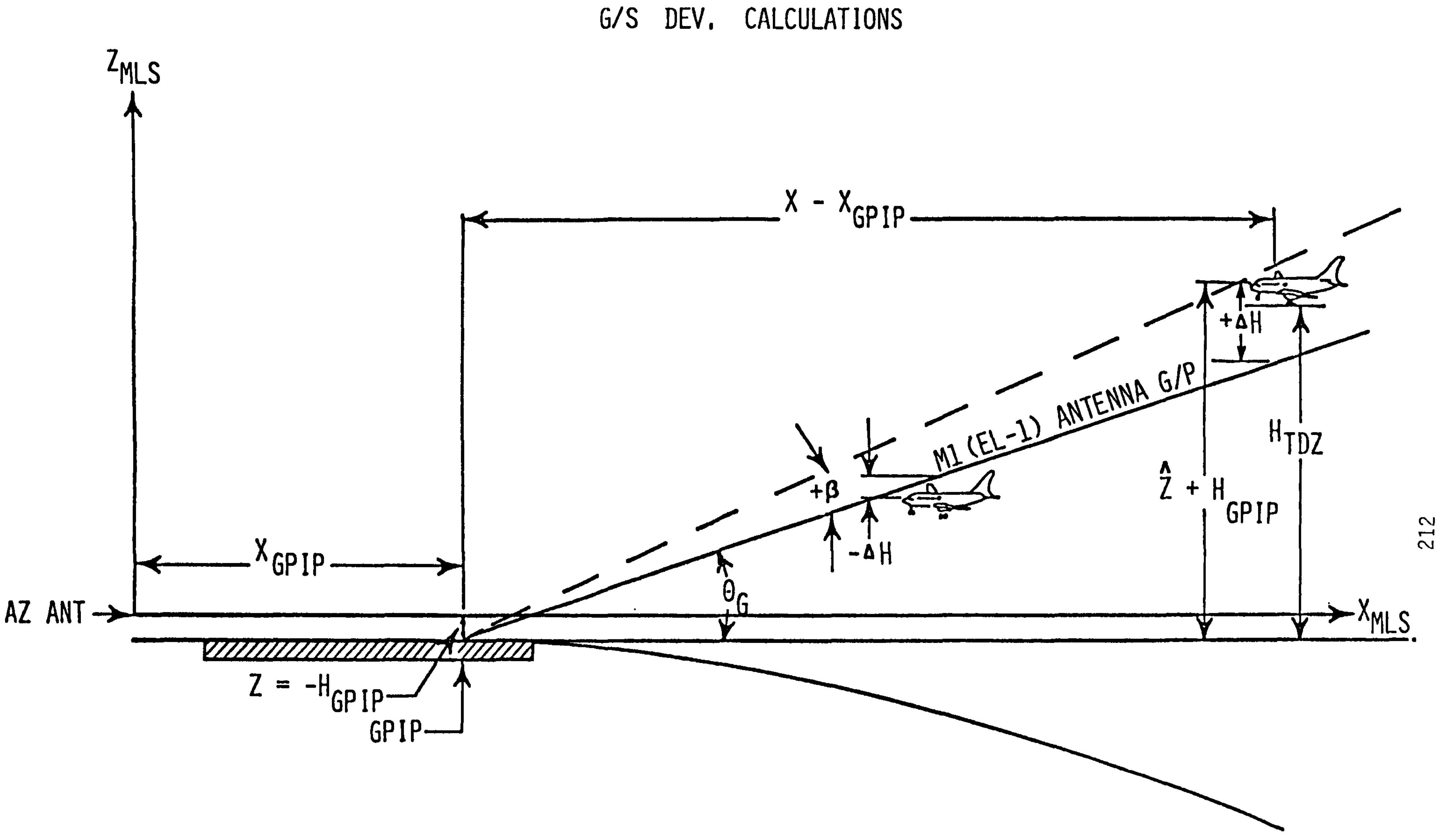


Figure 7-2 MLS COORDINATE SYSTEM

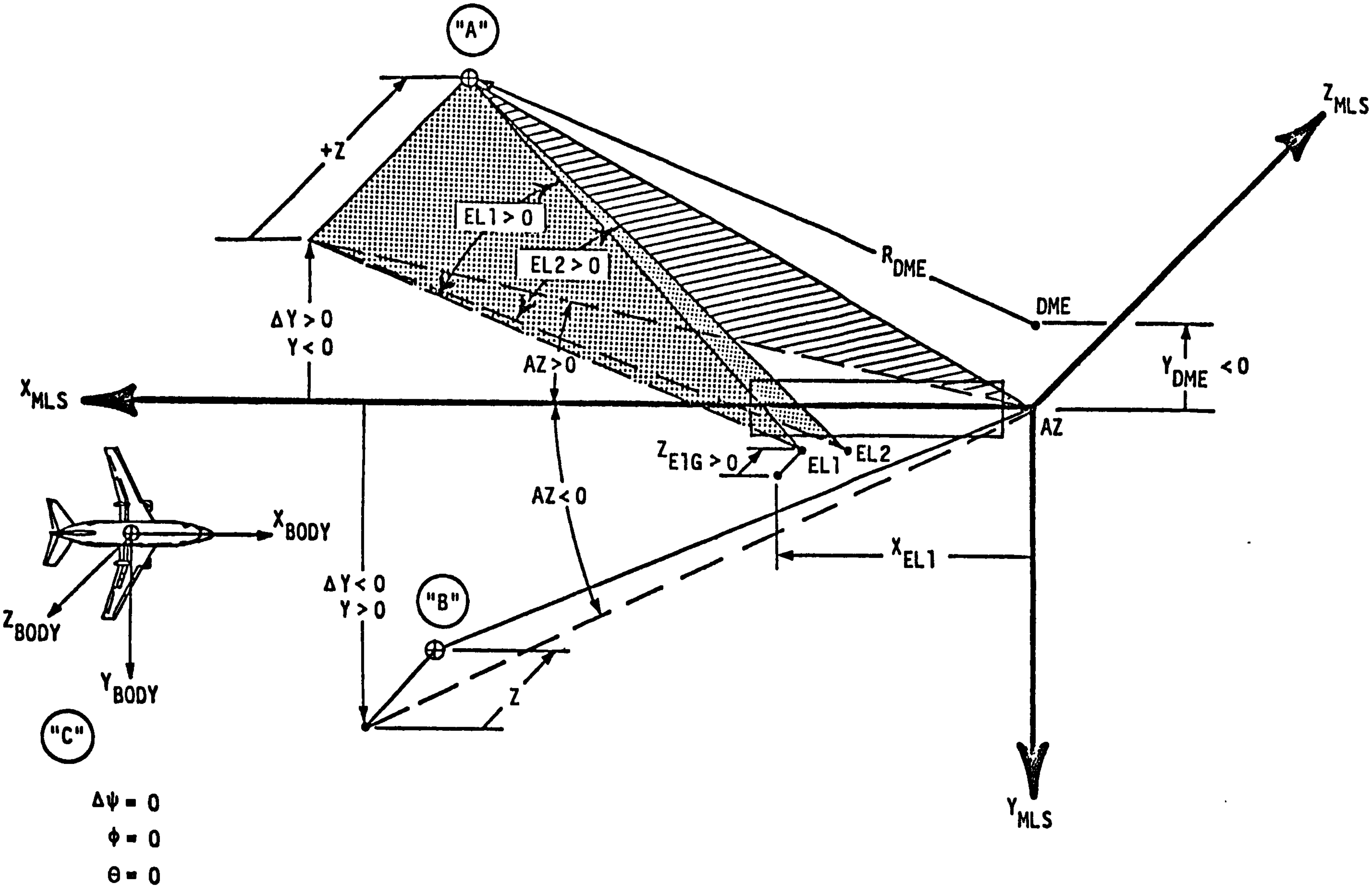

"A"
+Z
EL1 > 0
EL2 > 0
R_DME
DME
Z_MLS
Y_DME < 0
ΔY > 0
Y < 0
AZ > 0
X_MLS
AZ
Z_E1G > 0
EL1
EL2
AZ < 0
X_BODY
X_EL1
ΔY < 0
Y > 0
"B"
Z_BODY
Z
Y_BODY
"C"
Y_MLS
Δψ = 0
φ = 0
θ = 0

FIGURE 7-3

antenna system has been aligned with the physical runway centerline, i.e, bore sighted, although provision has been made to operate with an MLS system which has the AZ beam parallel to the runway but displaced to one side of the center-line. The positive Z direction is defined vertically up and the positive Y direction is defined as shown to complete the right-hand Cartesian coordinate system. Figure 7-3 has represented the aircraft at three hypothetical positions, A, B and C.

At position 'A' the aircraft is to the left of runway centerline, where the viewer is assumed to be facing in the direction of magnetic runway heading. The aircraft is at some altitude (Z) above the MLS X-Y plane. The sense of various quantities are as follows:

- positive EL1 and EL2
- positive X, range, and Z displacement
- positive azimuth and 'delta Y'
- negative Y displacement

Note that the 'delta Y' (DELTY) signal derived from the MLS processing is equivalent to the gain programmed localizer deviation signal ETAFT, which is derived from the ILS localizer deviation angle (LOCDEV). As the sense of ETAFT is 'positive to cause a fly-right command', it is also required that DELTY be defined with positive sense for fly-right command, i.e, when the aircraft is to the left of runway centerline.

At position 'B', the aircraft is assumed to be to the right of runway centerline, therefore DELTY is negative to cause a fly left command from the lateral control law. Note also that azimuth is negative at position 'B', while Y(mls) is positive.

Although not obvious from Figure 7-3, Z may be either positive or negative. Likewise, X may be either positive or negative, although flight testing to date has been confined to regions where X is positive.

The planform view of the aircraft, with aircraft heading equal to runway heading, is shown at position 'C'. This illustration is presented to clarify velocities and accelerations developed relative to aircraft body axes, versus velocities and accelerations expressed in MLS coordinates. Two factors are responsible for some confusion over these items:

1) In the normal landing attitude the X-body axis is in a direction approximately 180 degrees to the X-axis of the inertial MLS reference frame.

2) In the normal landing attitude the Z-body axis is in a direction approximately 180 degrees to the Z-axis of the MLS reference frame.

These factors result in the following:

$$X(mls) = -X(body)$$
$$Y(mls) = Y(body)$$
$$Z(mls) = -Z(body) = h$$

The parameters XDME, YDME and ZE1G are simply defined with respect to the MLS coordinate system: if the DME transmitter is located to the left/right of the azimuth transmitter, the YDME parameter will have negative/positive sense; if the EL1 antenna is located above/below the MLS X-Y plane, the ZE1G parameter will have positive/negative sense.

Table 7-1 lists several of the frequently used parameters in the MLS software and their respective polarities.

MLS MODULE DESCRIPTION:

Module MLSEX contains the computational routines which provide the MLS derived inputs to the Navigation, Display and Flight Control systems. It consists of a short executive portion and a series of subroutines called conditionally from the executive. All processing is under the control of the MLS Configuration word (MCONF), which is normally set via the TERMX utility. Among other things, this word determines whether MLS calculations are to be made and, if so, whether the real or simulated input data is to be used. The configuration control parameters are identified and described in Table 7-1.

MLSEX first checks the MLS Compute discrete (MLSC). If false, the MLS valid discrete (MLSVAL) is cleared and the first pass flag (FPF) is set to force re-initialization when computations are next begun. The MSB of the configuration word (MCONF$1) is then checked. If clear, MLSC is cleared and processing ends. Otherwise, processing continues by checking the FPF flag.

If FPF is true, MACRO procedure UNPK is called to unpack the upper five bits of the configuration word into the respective booleans. (The lower bits of MCONF affect only the usage of MLS parameters by other modules, and are unpacked in procedure MLOG when MLS mode is selected.) Subroutine RSCON is then called to set up the airport and receiving antenna parameters according to the selection words RWYSEL and ANTSEL.

In either event, MLSEX next calls each of the remaining subroutines in the order as described below, and returns to the executive.

SUBROUTINE RSCON:

RSCON is called only on the first pass after MLSC becomes true. It loads an entry of the AIRPORTS array into the RWYDEF vector according to the RLMLS flag and the RWYSEL index, and loads an entry of the ANT_OFF array into the ANT_POS vector according to the ANTSEL index. The ANT POS vector describes the position of the selected aircraft receiving antenna relative to the aircraft center of gravity (C.G.), and the RWYDEF vector describes the location of the Range, EL1 and EL2 transmitter antennas relative to the MLS Azimuth antenna (MLS origin). It also sets the loop index (K) to control the number of signals processed, depending on whether EL2 processing was specified in the configuration word (EL2F set).

Note that another table of runway specific constants - also bearing the name RWYDEF - exists in compool FSTCOM. This latter is used by Flight Controls and navigation processing, and is referenced by procedures MLOG and HNAVSL on the first pass after MLS mode is selected.

SUBROUTINE CNTRM:

This module maintains a 128-cycle history of the valid flags associated with the MLS data ([MLSSV] = [RV, AZV, EL1V, EL2V]), and the complementary filter position limit exceedants ([CFXCV]), and sets the IC_PF, PF_IC, and PF_CVAL Boolean arrays. Each history consists of a 128 bit- bit string (8 words). The associated counter (CFX_CC) is updated only when the state of the validity bit differs from the state of the history bit for that cycle.

If the FPF or ICMLS flag is set, all flags, counters and histories are reset to their initial values and the ICMLS flag is cleared. (FPF is used again in subroutine CTLBK). Otherwise, processing continues. Processing of the signal valids is in a loop 'DO FOR I = 1 TO K;', where K is set by RSCON to 4 if EL2F is true, otherwise to 3. Initially, the local signal valid (MLSLSV) is set equal to the raw signal valid. Then, once the complementary filter has run at least 120 cycles (CFRUN > 120), outlier errors are computed as (MLSRAW - MLSS_PRED). OTLIR V is set true if the corresponding OUTLIR_ERR is less than OUTLIR_LIM, and MLSLSV is set to the 'AND' of MLSSV and OUTLIR_V.

Next the validity histories (MLSS_HIST) and valid counters (MLSS_VC) are updated. The counter value is then checked to set the operate discretes. If MLSLSV is true, the following is performed:

- if the validity count is equal to 1 or 58, the corresponding IC_PF flag is set, indicating that some prefilter initialization must be performed. If equal to 58, the PF_IC flag is also set, indicating that the prefilter for this signal has been fully initialized.

- if the validity count is >= 115, the PF_CVAL flag is set to indicate that the corresponding signal is usable for position computation.

If MLSLSV is false the following is performed:

CFRUN > 120:

- if the validity count is < 18, the PF_IC and PF_CVAL flags are cleared.

CFRUN <= 120:

- if the validity count is < 115, the PF_CVAL flag is cleared.
- if the validity count is < 58, the PF_IC flag is cleared.
- if the validity count = 0, the IC_PF flag is set.

If MLS is valid (MLSVAL set by CTLBK when CFRUN reaches 200), the complementary filter exceedance counters and histories are updated next. If CF_LIM_XC is true (a limit has been exceeded), the appropriate history is updated. If CF_XC_C then exceeds 70, CFXCV is set false, which will subsequently cause MLSVAL to be lost. If CF_LIM_XC is false, the counter and history are updated. No further action is necessary, as CFXCV is set true during initialization, and can only be set false when MLSVAL is true and CF_LIM_XC is also true.

Finally, the history pointers are updated and DISMF is called to pack the OTLIR_V, CFXCF and PF_CVAL boolean arrays into the packed discrete word MLSFC for recording.

SUBROUTINE CTLBK:

This module controls selection of the altitude ('Z') reference, initialization of the MLS complementary filter, operation of the CF run counter, and setting of the MLS valid discrete, MLSVAL.

Initially, the first pass flag is checked. If set, it is cleared, the IC_MLS flag is set, the MLS second fail flag (FAIL2$9: set by F2CMP if any signal required by MLS is invalid) is cleared, and the procedure is exited. If clear, processing continues by setting the CF Count Valid discrete initially equal to the 'AND' of the three exceedance count valid flags, the PF count valid flags for Range and Azimuth, and the 'NOT' of FAIL2$9. If CF_CVAL is true, the altitude reference is selected as follows:

EL2 Processing Selected (EL2F true):
If altitude is above ZUPPER, EL1 is primary and EL2 secondary;
If ZLOW < altitude < ZUPPER, EL2 is primary and EL1 secondary;
If 0 < altitude < ZLOW, EL2 is primary and HRAD secondary;
If GRD = true, HRAD is primary and only.

EL2 Not Selected (EL2F false):
If the MLS 'X' position is greater than X_HRSW, EL1 is primary and only;
Else HRAD is primary and only.

If EL2 is primary and not valid, the EL2F flag is cleared. If neither the primary nor secondary (if one exists) altitude reference is valid, CF_CVAL is cleared. Otherwise, the switch ALTREF is set to the selected reference. A check is then made of the INS validity flags. If the INS Attitude Valid is false, or either INS NAV Valid or INS serial bus Valid is false when BMAFLG is not true, a counter is incremented. If this counter reaches 5, CF_CVAL is cleared.

If, after all checks, CF_CVAL is true, the CFRUN counter is checked:

If CFRUN = 0, ICCF is set true (initializing the complementary filter); If CFRUN = 200, MLSVAL is set true; else CFRUN = CFRUN + 1. If, however, CF_CVAL is false, MLSVAL is set false and CFRUN is cleared to 0. If CFRUN was previously non-zero, ICMLS is set true, causing complete reinitialization of the MLS logic.

TABLE 7-1 MLS PARAMETER INFORMATION

VECTOR:

Vector name	Computed by	Contents
MLSRAW	IOFLL	R, AZ, EL1, EL2
MLSS_P	PFILT	Phat, ... , EL2hat
MLSS_PRED	PRINV	Rp, ... , EL2p
OTLERR	CNTRM	[MLS_P] - [MLSS_PRED]
XYZ	IOFLL	X, Y, Z (Radar Tk)
POS_CG	XYZIN	X, Y, Z (Compt'd)
POSHAT	CFILT	Xhat, Yhat, Zhat
XYZER	XFORM	[POSHAT] - [XYZ]
VELHAT	CFILT	XDH, YDH ZDH
BMACC	IOFLL	Ax, Ay, Fn
ACC	CFILT	XDD, YDD, ZDD
ACCHAT	CFILT	XDDH, YDDH, ZDDH

POLARITY INFORMATION:

Parameter	Polarity
R, Rhat, Rp	always positive
Az, Azhat, Azp	+ left of Rwy C.L.
El1, El1hat, El1hat	+ above phase center
El2, El2hat, El2hat	+ above phase center
X, Xhat, HGPIP	+ from Az antenna to threshold
Y, Yhat, YPROF	+ right of Rwy centerline
Z, Zhat	+ above MLS X-Y Plane
XDH, YDH, ZDH	+ on increasing X, Y, Z
XDDH, YDDH, ZDDH	+ on increasing XDH, YDH, ZDH
HGPIP	+ GPIP below MLS X-Y plane
ETAH	+ above glideslope
BETAH	+ left of Rwy centerline

MCONF BIT CONFIGURATION:

HAL BIT	BOOLEAN SET	USE
1	MLSC	Enable MLS computations
2	RLMLS	Use real vs. simulated MLS data
3	EL2F	Enable EL2 computations
4	BMAFLG	Use body MTD vs. INS accelerations in CFILT
5	RADTKF	Enable radar tracking computations
6	VGS_FLG	Use VN and VE vs. prefilter velocities to initialize CFILT X and Y velocities
7-9	--	unused
10	MSW6	Use MLS ZDDH vs. HDDF in VCWS, Auto, and glidescope tracking

11	MSW5	unused
12	MSW4	unused
13	MSW3	unused
14	MSW2	unused
15	MSW1	Use MLS derived values in flare control law

SUBROUTINE PFILT:

The Prefilter module uses alpha-beta filters to prefilter the MLS input parameters (Range, Azimuth, EL1 and EL2 (if in use)). The IC_PF flags are OR'ed with the ICMLS flag to determine initialization processing. If the result is one, the respective prefilter is IC'd by setting both the filtered output value (S_HAT) and the next predicted value (MLSS_P) equal to the measured value (MLSRAW). Note that IC_PF will be true on the first and 58th cycles of initialization. If both IC PF and ICMLS are true, the filter velocity (MLSS_DHAT) is also zeroed.

If no initialization is to be performed, processing continues as follows:

If MLSVAL is false, filter input (TEMP) is the difference between the measured and predicted values when the input signal valid is true, and zero otherwise. If MLSVAL is true, filter input is the difference between the measured and predicted (MLSS_P) values when the input signal valid is true, and the difference between MLSS_P and the prediction from PRINV (MLSS_PRED) otherwise. If PF_IC is false, (indicating that the particular filter has operated less than 58 cycles since initialization), the value of TEMP is doubled, effectively cutting the filter time constant in half. This is to cause the filter to converge more rapidly during the initialization phase.

The following equations are then evaluated:

```
S_HAT     = MLSS_P + ALPHA TEMP;
MLSS_DHAT = MLSS_DHAT + BETA TEMP;
MLSS_P    = S_HAT + MLSS_DHAT DELTAT;
```

Finally, if MLSVAL is true and MLSLSV is also true, the filter output for that signal is set equal to the measured value. This prevents the prefilter lags from affecting the complementary filter once that filter is initialized and stable, but retains the availability of stable prefiltered values for CF initialization and for those periods when the input signal may be erratic.

SUBROUTINE XFORM:

This module computes the 3 X 3 transformation matrix necessary to expand an aircraft body axis vector on the MLS coordinate frame. It also computes the vector ANT_VEC used by XYZIN and PRINV, which translates the X, Y, Z position from the aircraft antenna position to the aircraft center of gravity. If the Radar Tracking Flag is set, the TDS input position vector (XYZ) is also translated from the tail antenna position to the aircraft C.G. and corrected for transport lag. The error vector, XYZER, is then computed as the difference between XYZ and the MLS position estimate, POSHAT. The following equations are evaluated:

$$\text{LMB} = \begin{bmatrix} C\theta\ Ca & S\phi\ S\theta\ Ca - C\phi\ Ca & C\phi\ S\theta\ Ca + S\phi\ Sa \\ -C\theta\ Sa & -S\phi\ S\theta\ Sa - C\phi\ Ca & -C\phi\ S\theta\ Sa + S\phi\ Ca \\ S\theta & -S\phi\ C\theta & -C\phi\ C\theta \end{bmatrix}$$

where: $C\theta$ = cosin θ , $s\theta$ = sin θ , etc.
a = DLPSI + 180

$$\left\{ \text{ANT\_VEC} \right\} = [\text{LMB}] \left\{ \text{ANT\_POS} \right\}$$

where: {ANT_POS} is the X,Y,Z position of the MLS receiving antenna relative to the aircraft C.G.

(if RADTKF)

$$\left\{ \text{XYZ} \right\} = \left\{ \text{XYZ} \right\} + [\text{LMB}] \left\{ \text{TAIL V} \right\} + \text{VGAIN\$4} \left\{ \text{VELHAT} \right\}$$

$$\left\{ \text{XYZER} \right\} = \left\{ \text{POSHAT} \right\} - \left\{ \text{XYZ} \right\}$$

where: TAIL_V is the position vector of the radar reflector on the TCV aircraft;
VELHAT is the MLS velocity vector;
VGAIN$4 is an estimate of the TDS data transport lag in seconds.

SUBROUTINE XYZIN:

This module calculates the position of the aircraft center of gravity in the MLS coordinate system. It derives position information from one of the following set of sources depending on the switch ALTREF.

```
         0) range, azimuth and radio altitude data
ALTREF = 1) range, azimuth and elevation 1 data
         2) range, azimuth and elevation 2 data
```

XYZIN begins calculations when both range and azimuth prefilters have run at least 58 iterations (PF_IC), even though the solution is not used until 115 iterations (PF_CVAL). This permits the use of a semi-iterative method. Position is first calculated at the receiving antenna, then translated to the aircraft C.G. The following equations are evaluated.

$$\text{Raz} = \text{R} + \text{Xdme} \cos(\text{Az}) - \text{Ydme} \sin(\text{Az})$$

$$\text{Ya} = -\text{Raz} \sin(\text{Az})$$

$$\text{Xa} = \text{sqrt}(\text{Raz}^2 - \text{Ya}^2 - \text{Za}^2)$$

ALTREF = 0:

$$Za = Hrad - Htdc - ANT\_VEC\$3$$

ALTREF = 1:

$$Za = \tan(EL1)\ \mathrm{sqrt}((Xa - Xel1)^2 + (Ya - Yel1)^2) + Zel1$$

ALTREF = 2:

$$Za = \tan(EL2)\ \mathrm{sqrt}((Xa - Xel2)^2 + (Ya - Yel2)^2) + Zel2$$

(all cases)

$$\{POS\_CG\} = \{ANT\_VEC\} + \begin{Bmatrix} Xa \\ Ya \\ Za \end{Bmatrix}$$

SUBROUTINE CFILT:

The CFILT subroutine initializes and operates the MLS third order complementary filter, with operator selectable options as specified below. The MLS CF integrates accelerations into velocities and positions, with a complementary correction term (EX) derived from the position output of XYZIN (POS_CG).

Filter initialization occurs when ICCF is set true by CTLBK. During initialization, position output is set to POS_CG, acceleration biases are zeroed, and vertical velocity (ZDH = VELHAT$3) is set to HDOT. XDH and YDH may be initialized from MLS prefilter velocity terms or from INS VN and VE, depending on the setting of VGS_FLG.

The filter is operated whenever CFRUN is non-zero. Input accelerations in the MLS coordinate frame may be derived from the INS or from the Body Mounted Accelerometers, depending on BMAFLG. BMA accelerations are rotated into the MLS frame using the Lambda (LMB) matrix developed by module XFORM. INS cross track and along track accelerations are rotated into the MLS frame using the sine and cosine of delta track. (Vertical acceleration from the INS (HDD) is already in the proper coordinate frame).

The residual term (EX) is limited, and a flag (CF_LIM_XC) set for each element which exceeds the limit. Module CNTRM keeps a record of exceedances and causes loss of MLSVAL if any counter reaches 70 out of the previous 128 iterations.

SUBROUTINE PRINV:

PRINV computes predicted values for the next set of MLS measurements based on the present position estimate (POSHAT) and the antenna configuration of the selected runway. These predictions are used in outlier computations, and to selectively edit the signal inputs to PFILT whenever the measured signals are determined to be invalid.

First POSHAT is transformed to the receiving antenna location using the ANT_VEC output of module XFORM. Slant range to the DME antenna is next computed using the Pythagorean theorem.

$$Rp = \mathrm{sqrt}(\ (Xa - Xdme)^2 + (Ya - Ydme)^2 + Za^2\ )$$

Note that the difference in elevation between the DME and Azimuth antennas is assumed to be insignificant.

The angle transmitters (Az, EL1, EL2) define a conical angle. Thus Azimuth is computed as follows, using the four quadrant arctan.

$$Azp = \mathrm{atan2}(\ -YAH\ ,\ \mathrm{sqrt}(Xa^2 + Ya^2)\ )$$

EL1 (and EL2, if EL2F is true) is computed using the small angle arctan:

$$EL1p = \mathrm{atan}\ \frac{Za - Zel1}{\mathrm{sqrt}(\ (Xa - Xel1)^2 + (Ya - Yel1)^2)}$$

$$EL2p = \mathrm{atan}\ \frac{Za - Zel2}{\mathrm{sqrt}(\ (Xa - Xel2)^2 + (Ya - Yel2)^2)}$$

GLOBAL INPUTS: ANTSEL, ATKACC, BMACC, COSRH, DLPSI, FAIL2, FLAGS, GRAVO, GRD, GSINS, HDD, HDOT, HRAD, HRV, IATTV, IDDALT, INAVV, ISBV, MCONF, MLSRAW, MLSSV, PITCH, ROLL, RWYSEL, SINRH, VE, VEINS, VN, VNINS, XTKACC, XYZ.

GLOBAL OUTPUTS: ACCHAT, BMAFLG, CFRUN, CFXCC, CROLL, CTHET, EL2F, EX, FAIL2, MLSC, MLSFC, MLSSVC, MLSVAL, OTLERR, POSHAT, RADTKF, RLMLS, SROLL, STHET, VELHAT, XYZER.

MODULE NAME: NAVIG

PURPOSE: To permit ground checkout of several dynamic functions of the Flight Management/Flight controls computer.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL NAVIG

CALLS TO: ANGL, TAND, IAND

DESCRIPTION:

The simulated airplane NAVIG is controlled via the Debug Page of the NCDU, or the utility program TERMX, by setting certain bits of the simulation control word SIMFLG. The actions initiated by setting different bits in SIMFLG are emunerated below:

- Bit 0 - Initialize airplane
- Bit 1 - Fly airplane 200 knots
- Bit 2 - Fly calibrated air speed or 4D path
- Bit 3 - Not used
- Bit 4 - Hold airplane

NOTE: The setting of bits in SIMFLG follows the PDP 11/70 word structure, which has bit 0 as the rightmost bit and bit 15 as the leftmost or most significant. It should be further noted that the HAL/S language follows a bit pattern that has bit 1 starting as the leftmost position of the word and bit 16 as the rightmost or least significant.

Example: SIMFLG = 21 (octal) places airplane in hold and also initializes airplane.

Upon entry a check is made to determine if the flight controls RUN mode is selected. If so, the simulation control word SIMFLG is zeroed, FLYFLG is turned off which signifies that the real airplane is in operation, and control returns to FAST.

If bit 0 of SIMFLG is set, which signifies initialization of the airplane, the following takes place:

A branch is made to routine FLYIC which sets the following:
Latitude (IDDLAT) is set to the value stored in SIMLAT.
Longitude (IDDLON) is set to the value stored in SIMLON.
Altitude (ALT) is set to the value stored in SIMALT.

Airplane Heading (SMUHDG) is set to the value stored in SIMHDG.
Magnetic Variation (MAGVAR) is set to the value stored in SMMAGV.
The NCDU latitude/longitude initialization flag LLINIT is turned on, 2D guidance, 3D guidance and 4D guidance flags are turned off. The simulation roll command (PHISYM) and HDOT complimentary filter (HDCF) are set to zero. Auto engage (AUTOE), path and (PATHND), localizer engage (LOCE), and glide slope engage (GSENG) flags are turned off. The

calibrated air speed (CAS) is set to 2 knots. NAVFLG, which specifies ground speed greater than 2 knots is turned off. Procedure ENGAGE_CAS is called. The IC bit of SIMFLG (bit 0) is turned off.

If any one of the bits (other than bit 0), that drive the simulated airplane is turned on the following occurs:

FLYFLG and AUTOE are turned on signifying that the simulated airplane is now in operation.

If the hold bit is on calibrated air speed (CAS) is set to 2 knots and NAVFLG (GS greater than 4 knots flag) is turned off. If the hold bit is off a check is made to determine if the CAS bit is selected. If so, the calibrated air speed is computed from the longitudinal acceleration command (ATCMD) and ground speed feet per second variable (GSFPS). If not, the calibrated airspeed is set to a constant 200 knots, or the value stored in SIMCAS.

Procedure ENGAGE_CAS is called.

Following this control returns to program FAST.

LOCAL ENGAGE_CAS PROCEDURE:

If the hold or initialize bits have not been selected via SIMFLG the following variables are computed:

The simulated roll command (PHISYM)
The bank angle (ROLL)
The heading for the simulated airplane (SMUHDG)
The cross track acceleration (IDDXTK)
The vertical acceleration (HDDOT)
The HDOT complimentary filter (HDCF)
The intertial altitude (ALT)

Following the computation of the above variables control returns to the main routine NAVIG.

GLOBAL INPUTS: ALT, ATCMD, BACMD, CAS, DELTAT, GRAVO, GSFPS, HDCF, HDGIC, IDDXTK, KTOFPS, PHISYM, PDG3D, RUN, RUNM, SIMALT, SIMCAS, SIMFLG, SIMHDG, SIMLAT, SIMLON, SMMAGV, VACMD

GLOBAL OUTPUTS: ALT, CAS, FLAGS, FLYFLG, GUID2D, GUID3D, GUID4D, HDCF, HDDOT, IDDLAT, IDDLON, IDDXTK, LLINIT, MAGVAR, NAVFLG, PATHND, PHISYM, ROLL, SIMFLG, SMUHDG

MODULE NAME: SMINIT

PURPOSE: Initialize simulated airplane (NAVIG).

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: SLOW

CALLING SEQUENCE: CALL SMINIT

CALLS TO: None

DESCRIPTON:

SMINIT is used to initialize the variables used by the navigation simulated airplane (NAVIG). The variable SIMFLG must be manually modified, via TERMX or the DEBUG page, to 1 of 4 octal values to choose a corresponding test case. This test case is used to uniquely identify initial conditions corresponding to those used by NAVIG as well as those used by the airplane simulator which executes on a remote computer.

OCTAL VALUE	CASE	SPEED	HDG	ALT	LAT	LON
100000	E	130	-117	1440	N38.02	W75.37
120000	I	150	106	2745	N38.04	W75.48
140000	B	130	-17	2745	N37.95	W75.36
160000	J	130	-147	2775	N38.09	W75.44

GLOBAL INPUTS: SIMFLG

GLOBAL OUTPUTS: SIMCAS, SIMALT, SIMHDG, SIMLAT, SIMLON, SIMFLG

MODULE NAME: TUNCK

PURPOSE: To check for favorable geometry between a path defined station and a cross track station.

TASK: SLOW

LANGUAGE: HAL/S

CALLED BY: TUNXTK

CALLING SEQUENCE: CALL TUNCK (stalat, stalon, max range) ASSIGN
(test boolean)
where STALAT = station latitude
STALON = station longitude

CALLS TO: None

DESCRIPTION:

The position of a cross track station with respect to the path defined station is checked to determine if the separation angle (relative to the aircraft) is within limits.

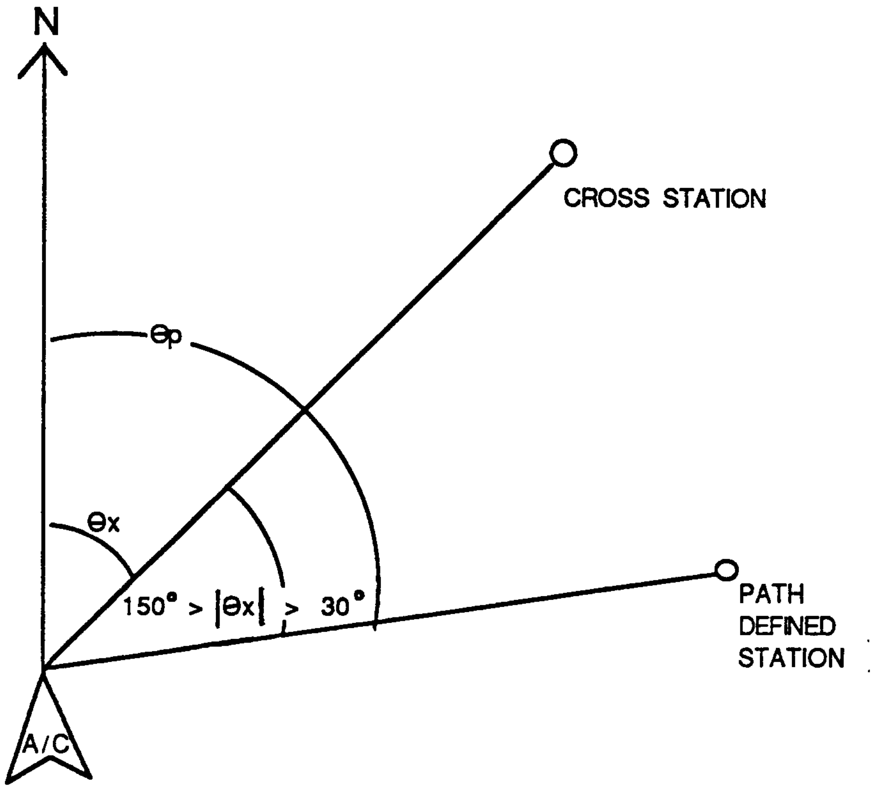


Figure 7-13. Minimum Separation Angle For Cross Path Tuning

The separation angle THETA is calculated as:

$$THETA = THETAp - THETAx$$

Where: THETAp is the bearing of the path defined station.
THETAx is the bearing of the cross track station.

The geometry will be favorable if THETA is greater than the minimum separation wedge angle (WEDGAN = 30 degrees) and less than 150 degrees. Following is the test for these conditions:

If ABS (cos(THETA)) * tan(WEDGAN) - ABS(sin(THETA)) > 0 then
THETA <= WEDGAN or THETA >= 150 degrees and the test fails.

If ABS (cos(THETA)) * tan (WEDGAN) - ABS (sin(THETA)) < 0 then
150 degrees > THETA > WEDGAN and is the favorable condition.

Use of the absolute values of the sine and cosine of THETA are necessary so that the calculation will be correct regardless of whether the separation angle is to the left, right, or behind the aircraft.

The sine and cosine of the separation angle are calculated as follows:

sin (THETA) = sin (THETAp - THETAx)
= sin (THETAp) * cos (THETAx) - cos (THETAp) * sin (THETAx)

cos (THETA) = cos (THETAp - THETAx)
cos (THETAp) * cos (THETAx) + sin (THETAp) * sin (THETAx)

In this routine the sines and the cosines of the path defined station and cross tract station are computed as:

cos (THETAp) = path defined station latitude - A/C latitude
= DPHI1

sin (THETAP) = (path defined station longitude - A/C longitude)
* cos(A/C latitude)
= DLAM1 * ICLAT

cos (THETAx) = cross track station latitude - A/C latitude
= STALAT - SLLAT
= DTLAT

sin (THETAx) = (cross track station longitude - A/C longitude)
* cos(A/C latitude)
= (STALON - SLLON) * ICLAT
= DTLON

NOTE: While latitudes are equidistant, longitudes are not. The difference in longitude must be multiplied by the cosine of the latitude to determine the correct distance.

The test now becomes a simple matter of substitution. If the test fails, a test failure boolean is set to true and control is returned to the calling routine. The geometry is not favorable because the separation angle is invalid.

If the separation angle is valid, the distance between the aircraft and the cross track station is tested to see if it exceeds the maximum range. If the cross track station is greater than 200 miles away, the test failure boolean is set true and control is returned to the calling routine.

GLOBAL INPUTS: DLAM1, DPHI1, SLLAT, SLLON, ICLAT

GLOBAL OUTPUTS: NONE

MODULE NAME: TUNDM2

PURPOSE: To automatically select and tune the path station (station #2).

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: HNAVSL

CALLING SEQUENCE: CALL TUNDM2

CALLS TO: SQRT

DESCRIPTION:
HNAVSL calls TUNDM2 when it becomes necessary to auto-tune a new station #2.

Search In Progress:
If there is a search in progress (RINPFL is set), the high altitude flag (HIALTF) is cleared. If the aircraft altitude is greater than or equal to 18.000 feet, HIALTF is set. A transfer of control to label TUN8 is executed to obtain the next navaid in Bulk Data to be tested and tuned.

Search Not In Progress:
If RINPFL is not set (signifying the beginning of a search), the maximum allowed distance between the aircraft and a new station (ZONELM) is initialized to 40 miles. The zone counter (RZNCTR) is cleared.

Navaids in bulk data are organized by longitudinal strips which are two degrees wide. IBPTR points to the first strip index in Bulk Data. A search is initiated to find the strip containing the aircraft. This is done by comparing the IDD longitude of the aircraft to the longitudinal boundaries of the index. If it is not found, the index block pointer is incremented to point to the next strip index and set of longitudinal boundaries until the correct strip is found or the end of the longitudinal strips is reached.

Once the correct strip is found, the pointer to those navaids lying within that strip is stored in RZNPTR and the address of the first navaid within that strip is stored in RTNSCR. RINPFL is then set and the station counter (RSTCTR) is initialized to one. Testing and tuning of the new navaid can now be done.

Navaid Testing and Tuning:
Once a new navaid has been found, it must pass a number of tests before it can be tuned. If the navaid is not a high altitude type, and the aircraft is flying at the high altitude range (above 18,000 feet), a different navaid must be found. Also, it this navaid is the same as the one currently being used, the search must continue. If the navaid passes these tests, its address is stored in RTNSCR.

The distance between the navaid and aircraft position is computed next. A new navaid must be sought if the distance is greater than the current ZONELM. If the range is valid, the RTNPRV array which contains the four most recently tuned path sations is scanned to see if the navaid in question has been recently tuned. If it is found in the table, a new navaid must be found; otherwise, it is ready to be tuned. NVAD2A is set to the address of the navaid in Bulk Data, the station counter (XSTCTR) is incremented (unless it is equal to four in which case it is reset to one). Control then returns to the navigation slow loop.

Strip and Zone Limit Modifications:

In the case that a condition for tuning is not fulfilled, a transfer is made to TUN8 to find a different station. In the event that a suitable navaid is not found within the original strip, the two adjacent longitudinal strips to the east (if present) are cycled through next. Once searching progresses past these strips, the two strips adjacent to the west (if present) of the original are cycled through. At most, two strips to the east and two strips to the west of the strip containing the aircraft can be searched. Once the search reaches the end of the last allowable strip, the zone limit (ZONELM) is increased by forty miles and the process repeats.

If the range reaches 200 miles, RINPFL is cleared and RZNCTR is reset to 1. Clearing RZNCTR will cause an update to the address pointer of the first strip to be searched (RZNPTR) if the aircraft has moved into a different longitudinal strip. Thus, a new set of longitudinal strips will be searched.

GLOBAL INPUTS: IBPTR. ICLAT, IDDALT, RINPFL, RTNPRV, RTNSCR, RZNPTR,
SLLAT, SLLON

GLOBAL OUTPUTS: HIALTF, NVAD2A, RINPFL, RSTCTR, RTNPRV, RTNSCR, RZNCTR,
RZNPTR, ZONELM

MODULE NAME: TUNXTK

PURPOSE: To select and tune the cross track station (station #3), either manually (VOR) or automatically (DME).

TASK: SLOW

LANGUAGE: MACRO-11

CALLED BY: HNAVSL

CALLING SEQUENCE: CALL TUNXTK

CALLS TO: TUNCHK

DESCRIPTION:

If the groundspeed is less than 64 knots, the local tune cross station routine (TUNEXS) is called. The groundspeed fail bit of flag FLSTA3 is set, and control is returned to the navigation slow loop.

If the groundspeed is greater than or equal to 64 knots, a test is made to determine if manual or auto tuning is desired. Auto tuning is performed if ATNAV3 is not equal to zero, or if NVAD3A equals zero. Manual tuning is performed if ATNAV3 equals zero and NVAD3A does not equal zero. A VOR may only be tuned manually.

Manual Mode:

If manual tuning, a transfer is made to label TUN12. The variable F2 is tested and if non-zero (indicating an invalid path defined station), the geometry test becomes unnecessary and a jump to label T2STA is executed to maintain the current cross station. If F2 equals zero (indicating a valid path defined station), the Bulk Data navaid NVAD3A is used to obtain the selected navaid latitude and longitude. These arguments, along with the maximum tuning range (200 miles), are sent to the TUNCHK routine where they are used to check for favorable geometry between the navaid and the current path defined station.

TUNCHK returns a boolean value which indicates geometry and range validity. If the boolean is set, the bad geometry bit of FLSTA3 is set and control is returned to the navigation slow loop. If the geometry is valid, a transfer is made to label T2STA to tune to the station.

Station Tuning:

Under T2STA, TUNEXS is called to get the cross station frequency. A comparison is made to verify that the tuned output frequency (ATUNE3) equals the tuned input frequency (DME3FQ). If they are equal, the error timer which allows four seconds for proper station tuning is cleared and control is returned to the navigation slow loop. If ATUNE3 does not equal DME3FQ, the appropriate bit of FLSTA3 is set. If the error timer is zero, it is reset to BINTME; otherwise, it remains unchanged. In the manual tuning mode, the error timer has not effect. In the auto tuning mode, the expiration of the error time causes the algorithm to search for a new station.

TUNEXS loads in a frequency for a navaid from bulk data via the navaid address pointer NVAD3A and stores it in ATUNE3. The fail flag FLSTA3 is cleared and control passes back to TUNXTK.

Auto Mode:

The auto tune logic begins with label T2AUTO. If a failure has not been detected, a test is performed to determine if the aircraft is within the height (H) > range (R) cone for the path defined station. If it is within this "zone of confusion", the current cross station is maintained through a transfer to T2STA.

If a failure has been detected or the aircraft is not in the H > R cone, the station search in progress flag (CINPFL) is tested. If the search is in progress, the address of the most recently tested navaid is fetched and the search is allowed to proceed. If a search is not in progress and there are no failures, a station has been found and its geometry is checked by branching to TUN12. Tuning proceeds at T2STA if the station geometry is good.

If there is a station search in progress and a station failure has been detected, it must be determined whether the tuning-output-not-equal-input failure is the only failure. If this is the sole failure and the error timer has not surpassed its limit of four seconds, the station geometry is checked at TUN12. Tuning proceeds at T2STA if the station is good. If the error time has expired or there was an additional failure, a new station will be sought.

The search for another cross station starts at label T2A1. First, the error timer is cleared. Bulk Data will be cycled through to obtain a navaid that is within a certain range of the aircraft and has good geometry.

The station cycle index (XSTCTR) varies between zero and four. If it is zero (search is just starting), the high altitude flag (HIALTF) is cleared. If aircraft altitude is greater than or equal to 18,000 feet, HIALTF is set. The first searching range, 40 miles, is stored in ZONLIM and the zone counter (ZONCTR) is cleared.

Navaids in bulk Data are organized by longitudinal strips which are two degrees wide. IBPTR points to the first strip index in Bulk Data. A search is initiated to find the strip containing the aircraft This is done by comparing the IDD longitude of the aircraft to the longitudinal boundaries of the index. The index block pointer is incremented to point to the next strip index and set of longitudinal boundaries until the correct strip is found.

Once the correct strip is found, the pointer to those navaids lying within that strip is stored in ZONPTR. The search in progress flag (CINPFL) is set and the station cycle index (XSTCTR) is set to 1.

The frequency word of the navaid is obtained and tested to determine if the navaid is a VORTAC. The next station in Bulk Data will be examined if the navaid in question is not a VORTAC, or if it is a low altitude range (above 18,000 feet). If it is a high altitude VORTAC, the geometry is checked by TUNCK with the range ZONLIM.

If the geometry of the VORTAC with the path defined station is acceptable and it is not the same as the path defined station or present cross station, it is necessary to see if it was one of the past stations tuned in the cycle.

The array TUNPRV contains a maximum of four previously tuned stations. The TUNPRV array is scanned to see if the VORTAC has been used before. If the VORTAC is found in TUNPRV, a new station must be found. If the station has not previously appeared in the cycle, it is ready to be tuned. The pointer to the navaid is stored in NVAD3A. The station counter is incremented unless it equals four, in which case it is reset to one. A transfer is made to T2STA to complete the tuning process.

> CAUTIONARY NOTE: The code described in the paragraph above that tests for previous tuning of a navaid is not currently implemented.

In the case that a condition for tuning is not fulfilled, a transfer is made to TUN8 to find a different station. In the event that a suitable navaid is not found within the original strip, the two adjacent longitudinal strips to the east (if present) of the original are cycled through. At most, two strips to the east and two strips to the west of the strip containing the aircraft can be searched. Once the search reaches the endn of the last allowable strip, the zone limit (ZONLIM) is increased by forty miles and the process repeats.

If the range reaches 200 miles, CINPFL is cleared and XSTCTR is reset is 1.

GLOBAL INPUTS: ATNAV3, ATUNE3, BINTME, CINPFL, DME3FQ, F2, FLSTA3, IBPTR, IDDALT, NAV64K, NVAD2A, NVAD3A, SLLON, TUNPRV, TUNSCR, XSTCTR, XSTMR

GLOBAL OUTPUTS: ATUNE3, CINPFL, FLSTA3, HIALTF, NVAD3A, TUNSCR, XSTCTR, XSTMR, XSTCTR, ZONCTR, ZONLIM, ZONPTR

GUIDANCE OVERVIEW

The guidance routines use the position, altitude and velocity from navigation to find errors associated with desired position. The desired position, depending on which automatic mode is in effect, is defined from either a previously defined flight path or the knob settings on the Mode Control Panel. Horizontal/vertical steering commands along with the auto-throttle position command will be used to correct for the position errors. 2D and 3D guidance (horizontal and vertical) are calculated by HVGUID while 4D (time) is done by TGUID. NCFM is the interface between the flight control software and the 2D, 3D and 4D commands from HVGUID and TGUID.

MODULE NAME: DSPOT

PURPOSE: To compute analogs of the glideslope and localizer deviation variables to be used by the Displays task.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL DSPOT

CALLS TO: SRLMT

DESCRIPTION:

Prior to glideslope engage, the vertical path deviation (BETAH) is set to the negative of RNAV altitude error (HER). Prior to localizer engage the cross-track error (ETAH) is set to the negative of XTK.

Once within .7 degree of the glideslope, BETAH is defined as:

For MLS mode:

$$\hat{\beta} = 81850. \left(\frac{\text{ZHAT + HGPIP}}{\text{XHAT - XGPIP}} - \text{TANGSA} \right)$$

For ILS mode:

$$\hat{\beta} = 1428.5 \text{ GSDEV}$$

until proximity to the antenna makes calculation impossible. Then, BETAH = 0.

Once within 2.5 degrees of the runway centerline, ETAH is defined as :

For MLS mode:

$$\hat{\eta} = \frac{28645.}{1.25} \; \frac{\text{YPROF - YHAT}}{\text{XHAT}}$$

For ILS mode:

$$\hat{\eta} = \frac{500.}{1.25} \text{ LOCDEV}$$

In any case, both BETAH and ETAH are limited to +/- 1000.

GLOBAL INPUTS: GSA, GSDEV, GSVLD, HGPIP, LOCDEV, LOCVLD, MLSMOD, MLSRAW(AZ, EL), POSHAT(XHAT, YHAT, ZHAT), TANGSA, XGPIP, YPROF.

GLOBAL OUTPUTS: BETAH, ETAH, FCFLGS(DLBS,DVBS)

MODULE NAME: HVGUID

PURPOSE: To provide the horizontal/vertical path commands
for automatic aircraft guidance in 2D/3D/4D modes.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL HVGUID

CALLS TO: None

DESCRIPTION:

The HVGUID software receives information about the present position of the airplane from the navigation software (HNAVFS, HNAVSL) via compool data. Planned flight path information is obtained from the guidance buffer which is prepared by the path definition (PATHDF) software. These two sets of data are used in the computation of the two major outputs of this module - Lateral Steering Signal (LATSTR) and Vertical Steering Signal (VERSTR).

LATSTR is the solution to a linear second order differential equation. It is an acceleration command that returns the airplane to the horizontal path near the abeam point.

VERSTR represents the solution of a linear second order differential equation. This solution is a command that takes the airplane back to the planned flight path in the vertical plane.

Since HVGUID has two major outputs and the logic involved in computing the two major outputs is clearly divided and defined, the horizontal and vertical axes will be addressed separately.

Horizontal Guidance

Processing begins in the HVGUID procedure and any of four different paths can be taken from there - Initialization, Straight Segment processing, Turn processing, or Path Termination. Once the horizontal path calculations have been completed, control passes to the Vertical Guidance equations or to the executive if path end has been reached.

I. Initialization

The initialization path is taken if the flags PATHND, GUID2D, and NAV64K are not set. PATHND is set when the final waypoint on the path has been reached. GUID2D is set when there are at least three waypoints in the guidance buffer and NAV64K is set when the groundspeed is greater than 64 knots.

During initialization, the "to" waypoint pointer (WPPTR) is limited to two or more (2 indicating the second waypoint on the path) with the assumption that the airplane is initially in the area of the first waypoint. The pilot may select any waypoint on the path (except the first) as the "to" waypoint via the NCDU select page.

Once the proper "to" waypoint has been determined, the 2D pointers and the 4D pointers for the airplane are set and the HVGP1 and PTH4DN flags are cleared. The HVGP1 flag is used to indicate that one pass has been made through the HVGUID routine and the PTH4DN flag indicates whether or not the time box has reached the end of path. After the HVGP1 and PTH4DN flags are cleared the program drops into Path Termination loop, clears certain variables and transfers to the Vertical Guidance Off procedure.

II. Straight Segment Calculations

At the beginning of the Straight Segment the following flags are turned off and variables are zeroed in the LEGSW procedure:

TURN - Airplane in the Turn Flag

TEND - Airplane halfway through Turn Flag

ALCFLG - Advanced Lateral Control Flag

ALCBA - Advanced Lateral Commanded Bank Angle

AMG - Angle Made Good

In addition DTOGO (Abeam Point to Next Waypoint Distance) is initialized to the initial value of DTG (Distance to Go), HVGP1 is then set and DTOGO is calculated from then on by the regular guidance equations.

The following quantities are computed in the Straight Segment portion of the routine:

1. The Airplane Position Unit Vector ($\widehat{PO}$)
2. The Abeam Point Unit Vector ($\widehat{POP}$)

3. The Abeam Point to Next Waypoint Distance (DTG)

4. The Abeam Point to Middle of Arc at the Next Waypoint Distance (DTOGO)

5. The Crosstrack Distance to the Planned Flight Path (XTK)

6. The Desired Track along a Great Circle Path (DSRTK)

7. The Track Angle Error (TKE)

8. The Be Careful Flag (BCFLAG)

Airplane Position Unit Vector $(\widehat{PO})$

The airplane position vector is one of the primary references in the Guidance Equations. The Airplane Position Unit Vector $(\widehat{PO})$ is calculated from the airplane latitude (LAT) and longitude (LON) supplied by the navigation algorithms. This value is computed at label HVG1 in procedure HVGUID as follows:

$$\widehat{PO} = \begin{bmatrix} SIN(LAT) \\ -COS(LAT)\ SIN(LON) \\ COS(LAT)\ COS(LON) \end{bmatrix} = \begin{bmatrix} SLAT \\ -CLAT * SLON \\ CLAT * CLON \end{bmatrix}$$

The values CLAT, SLAT, CLON and SLON are the cosine and sine of latitude and longitude as computed by the Navigation equations. The following figure describes PO in relationship to the position of the airplane.

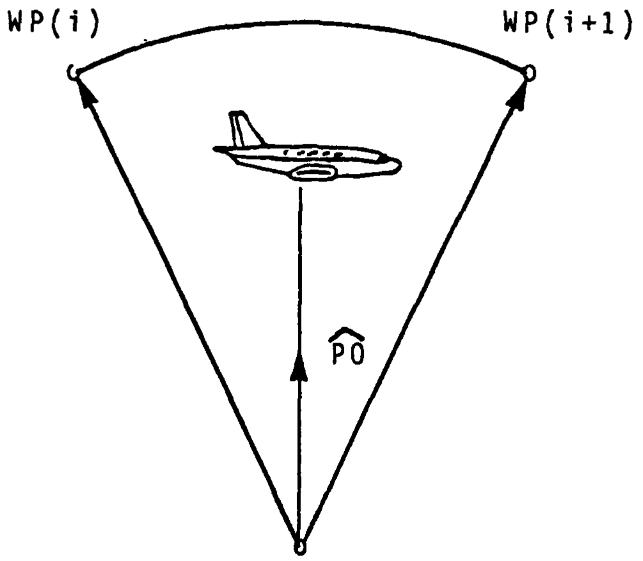


Figure 8-1. Position Unit Vector

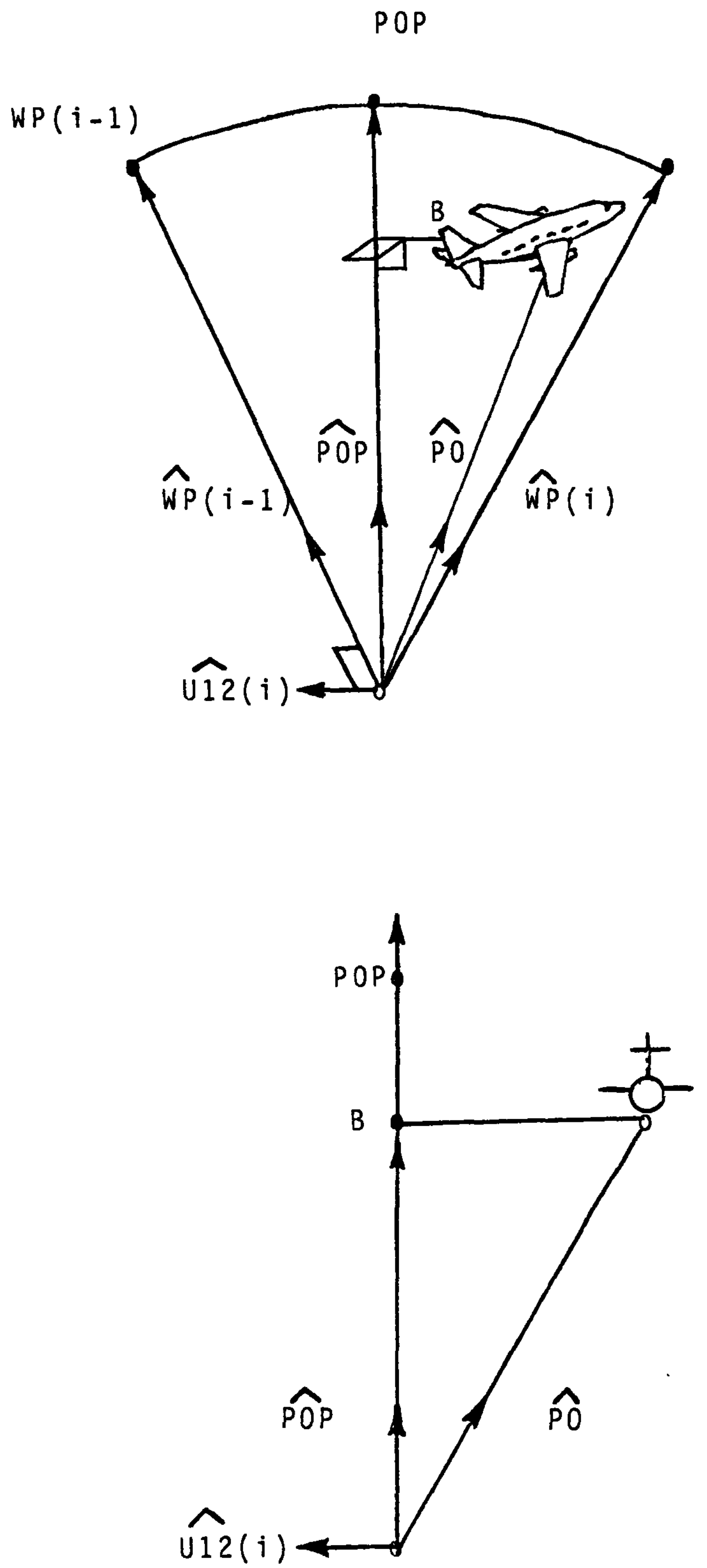
Abeam Point Unit Vector ($\widehat{POP}$)

The Abeam Point Unit Vector plays an important role in the horizontal guidance computations. The Abeam Point Unit Vector ($\widehat{POP}$) points to the point on the great circle path to which the airplane has progressed at any time. A line from the airplane perpendicular to the plane of the great circle intersects the plane at point B. and the extension of a straight line from the earth's center through B intersects the great circle at the abeam point POP. The components of the corresponding unit vector $\widehat{POP}$ are found by subtracting the component of $\widehat{PO}$ which is perpendicular to the plane of the great circle (i.e., parallel to $\widehat{U12}$) from the vector $\widehat{PO}$ as follows:

$$\widehat{POP} = \widehat{PO} - (\widehat{PO} \cdot \widehat{U12}(i))*\widehat{U12}(i)$$

where: $\widehat{U12}(i)$ is the Flight Path Normal Unit Vector calculated in the Path Definition routine.

POP locates the point on the great circle path to which the airplane has progressed at any particular time; therefore, the point POP is sometimes referred to as the airplane's "progress point" as illustrated in FIGURE 8-2.



PERSPECTIVE VIEW

PARALLEL TO THE GREAT CIRCLE PLANE VIEW

Figure 8-2. GEOMETRY OF THE ABEAM VECTOR

Abeam Point to Next Waypoint Distance (DTG)

The great zero circle distance from POP to WP(i) is found by computing the angle subtended at the earth center by the unit vectors $\widehat{POP}$ and $\widehat{WP}(i)$, and multiplying this angle in radians by the earth radius. The length of this cross product could be found by squaring each component of the product, adding and taking the square root. However, this lengthy computation can be avoided by dotting the cross product into the normal unit vector $\widehat{U12}(i)$. Since $\widehat{POP}$ and $\widehat{WP}(i)$ both lie in the plane of the great circle, their cross is perpendicular to that plane and therefore parallel to $\widehat{U12}(i)$ as given by:

$$\sin(\beta) = (\widehat{POP} \text{ X } \widehat{WP}(i)) \cdot \widehat{U12}(i)$$

In addition to reducing computational time the general technique of using the cross and dot products together makes it possible to maintain the sense (positive or negative) of the computed quantities. The cosine of the angle is found from dot product as follows:

$$\cos(\beta) = \widehat{POP} \cdot \widehat{WP}(i)$$

The angle is found from a double argument arctangent subroutine, hence the distance is given by:

$$DTG = Re*\text{arctangent }(\sin(\beta)/\cos(\beta))$$

where Re is the local radius of the earth

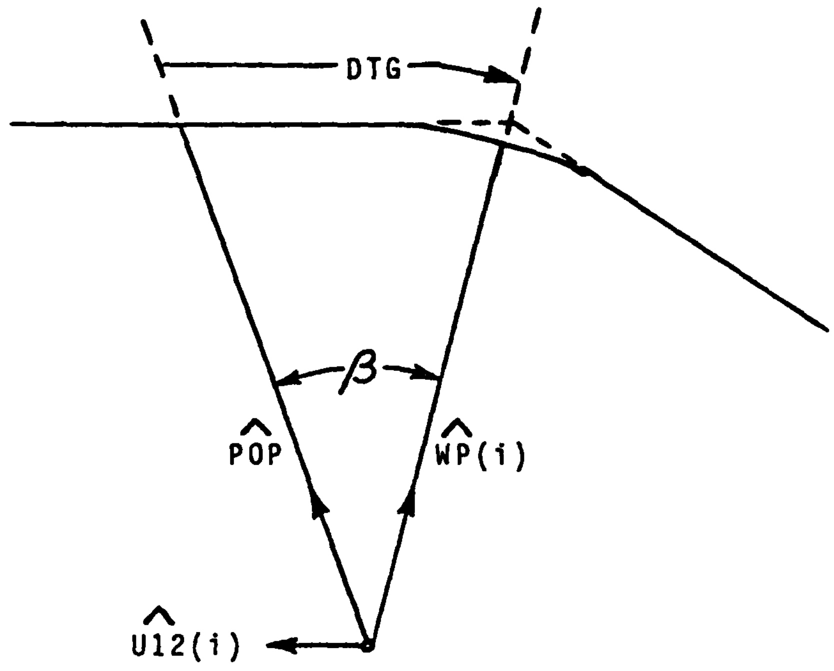


Figure 8-3. Abeam Point to Waypoint Distance

Abeam Point to Middle of Arc at the Next Waypoint Distance (DTOGO)

The purpose of the Abeam Point to the Middle of the Arc Distance (DTOGO) is to aid in determining the time to the next waypoint. The DTOGO value is determined by subtracting the Tangent Point to Waypoint Distance DTT(i) from the Abeam Point to Waypoint distance (DTG), and then adding the half Arc Distance AO2(i) as given:

$$DTOGO=DTG-DTT(i)+AO2(i)$$

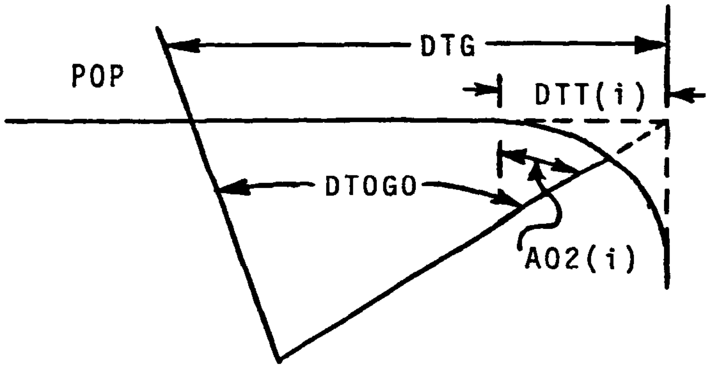


Figure 8-4. Abeam Point to Middle of Arc

If the upcoming waypoint is the inbound waypoint of a DME-Arc then the equation for the Abeam Point to the Middle of the Next Waypoint is simply the Abeam Point to Waypoint Distance (DTG) as given:

$$DTOGO = DTG$$

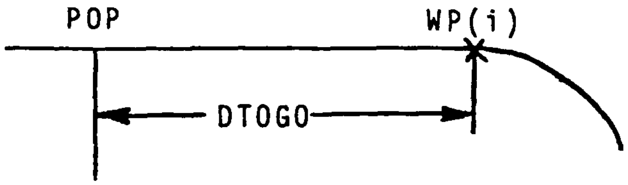


Figure 8-5. DME-Arc Distance

Crosstrack Distance to the Planned Flight Path (XTK)

The Crosstrack Distance to the Planned Flight Path (XTK) is used to compute the Lateral Steering Command, LATSTR, as well as determining the status of the Be Careful Flag, BCFLAG. The Crosstrack Distance XTK is the distance from the airplane to the abeam point. It is positive when the airplane is to the right of the path. The distance is computed by multiplying the angle between the Airplane Position Unit Vector ($\widehat{PO}$) and the Abeam Point Unit Vector ($\widehat{POP}$), in radians, by the radius of the earth as given:

Re = local radius of the earth

$\sin(\alpha) = \widehat{PO} \cdot \widehat{U12}(i)$

$\cos(\alpha) = \widehat{PO} \cdot \widehat{POP}$

then:

XTK = Re*arctangent $(\sin(\alpha)/\cos(\alpha))$

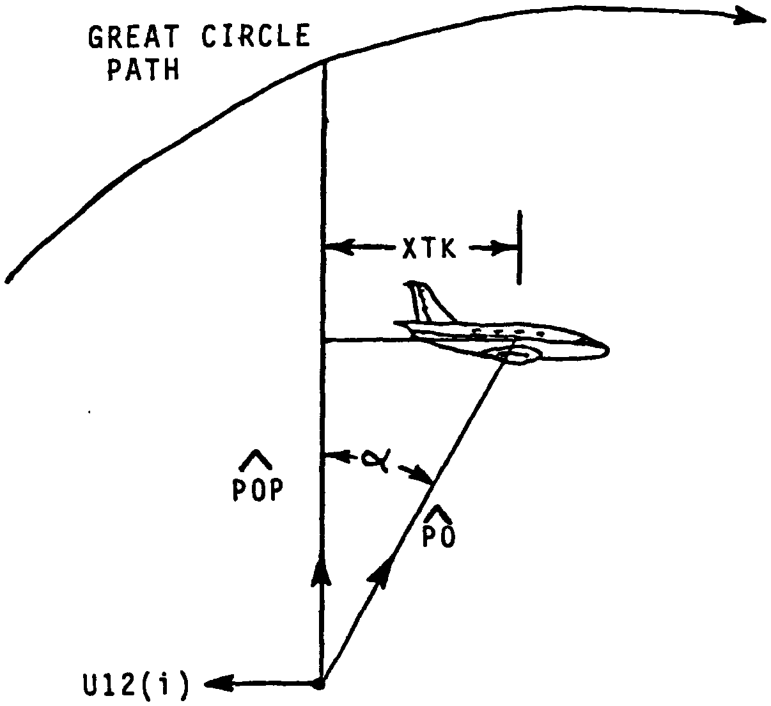


Figure 8-6. Crosstrack Distance

Desired Track Along a Great Circle Path (DSRTK)

By definition, the desired track is the track angle relative to True North of a vector tangent to the great circle path at the abeam point $\widehat{POP}$, pointing in the forward direction along the path. The computation of the desired track involves the unit normal vector $\widehat{U12}(i)$ and a unit vector $\hat{M}$ which points westward at $\widehat{PO}$. A westward pointing vector was chosen because, unlike a north pointing vector, one component is always zero and the other two components depend only on longitude, thus simplifying the calculations. The vector $\hat{M}$ is given by the equations:

$$\hat{M} = \begin{matrix} 0 \\ \cos(LON) \\ \sin(LON) \end{matrix}$$

where LON is the longitude at the abeam point $\widehat{POP}$. The orientation of $\hat{M}$, $\widehat{U12}(i)$ and the path are shown below.

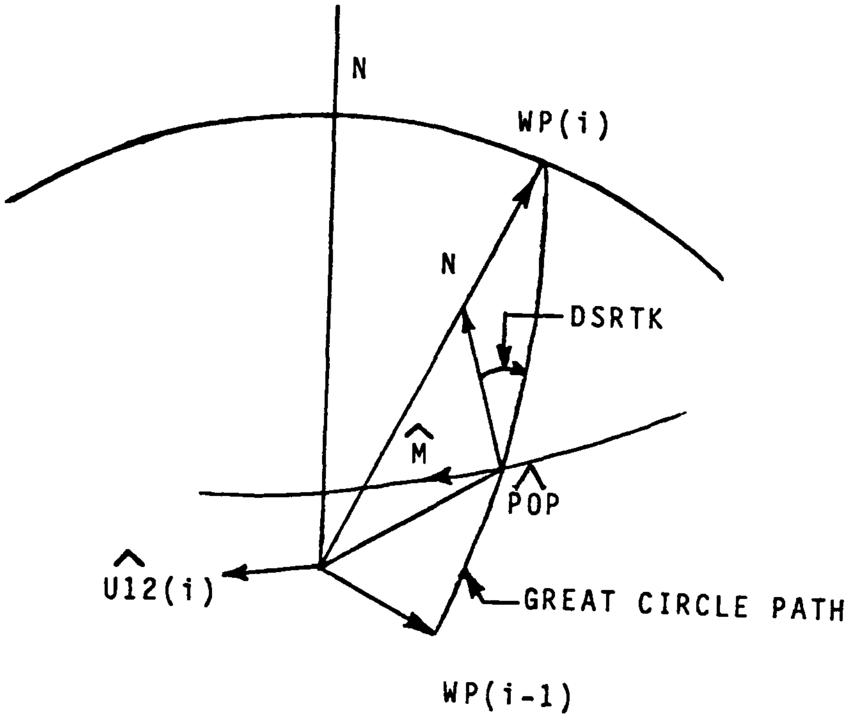


Figure 8-7. Desired Track

The desired track DSRTK is found from the equation:

$$DSRTRK = \text{arctangent } (\sin A/\cos A)$$

where

$$\sin A = (\widehat{U12}(i) \times \hat{M}) \cdot \widehat{POP}$$
$$\cos A = \widehat{U12}(i) \cdot \hat{M}$$

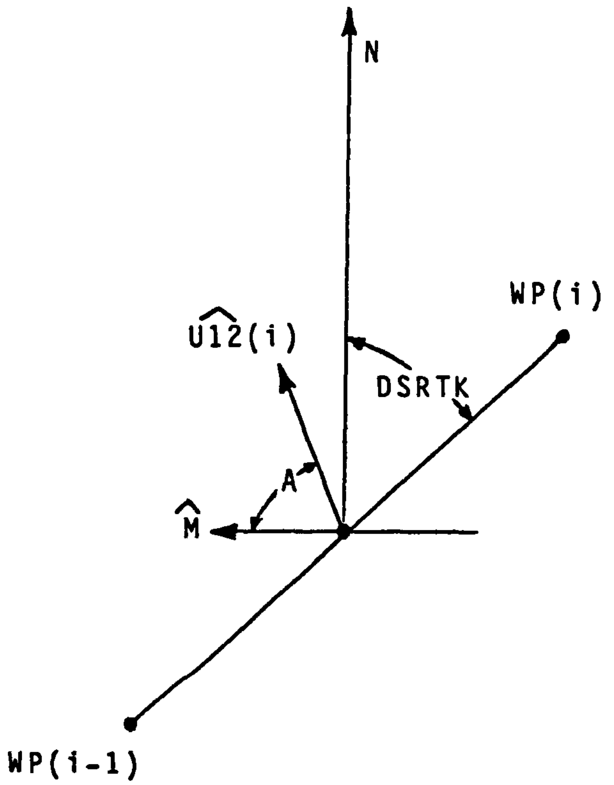


Figure 8-8. End View of POP

The computation of sin A utilizes a dot product with $\widehat{POP}$ to convert the vector $\hat{M} \times \widehat{U12}(i)$ to a scalar quantity. This is legitimate because $\widehat{POP}$ is a unit vector parallel to $\hat{M} \times \widehat{U12}(i)$.

Track Angle Error (TKE)

The Track Angle Error is used as one of the parameters in the Lateral Steering Command LATSTR calculations; it is also used to compute the Overtake Rate (OVTK) and the Star and Circle parameters. This value is computed from the airplane's track (TK) and the Desired Track Angle (DSRTK).

$$TKE = TK - DSRTK$$

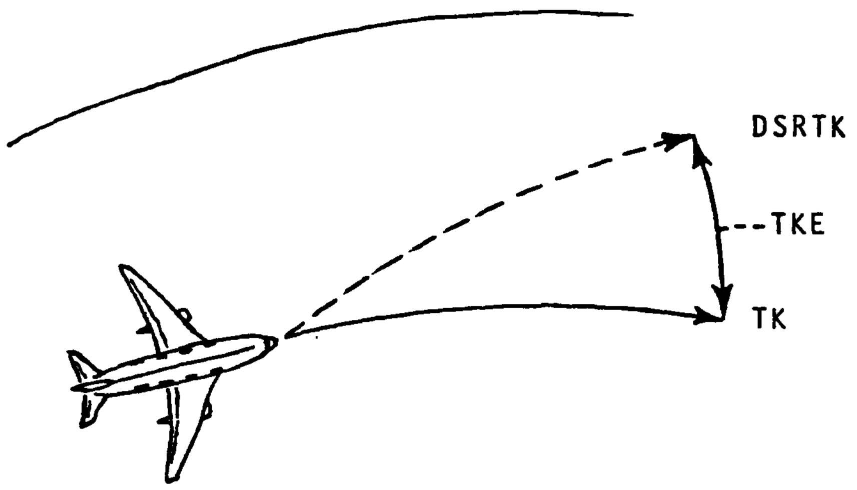


Figure 8-9. Track Angle Error

Be Careful Flag (BCFLAG)

The Be Careful Flag inhibits Horizontal Path engage by the AGCS mode equations. This flag is set when the Crosstrack Distance (XTK) is greater than 15,000 feet or the Track Angle Error (TKE) is greater than 90 degrees.

$$\text{If } |TKE| > 90 \text{ degrees or}$$

$$(|XTK| > XTKLIM \text{ and}$$

$$|XTK| > (GSFPS^2/.268\ GRAVO)(1.-CTKE))$$

Then: BCFLAG = ON
Else: BCFLAG = OFF

where XTKLIM is initialized to 15000'
CTKE is the COS(TKE)

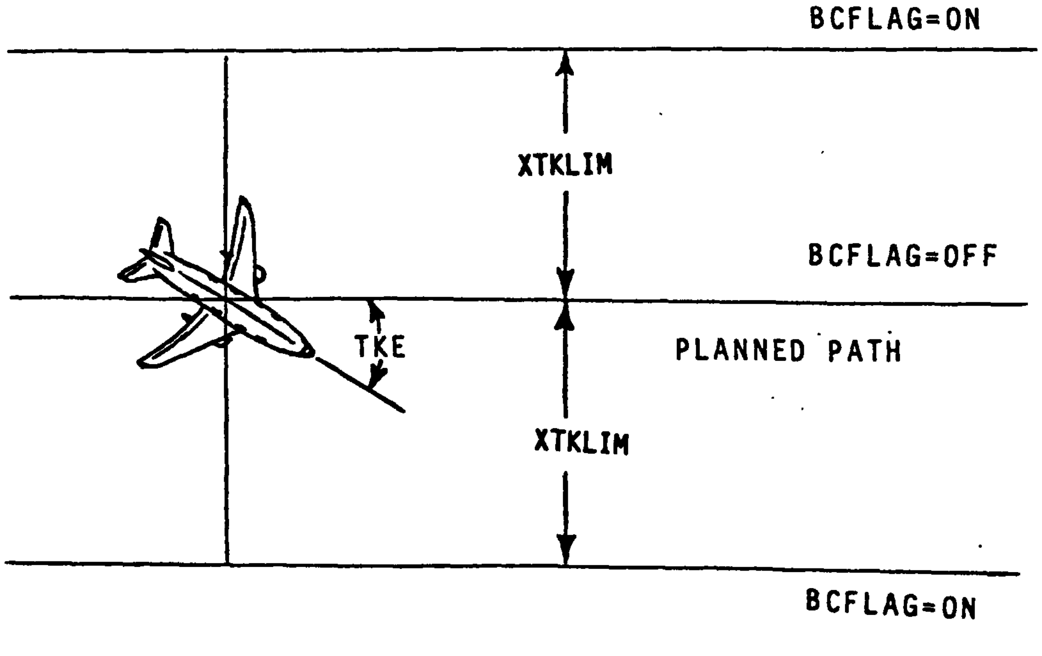


Figure 8-10. Be Careful Flag

III. Turn Computations

The turn calculations start when the Abeam Point of the airplane gets to the Tangent Point of the turn as shown below.

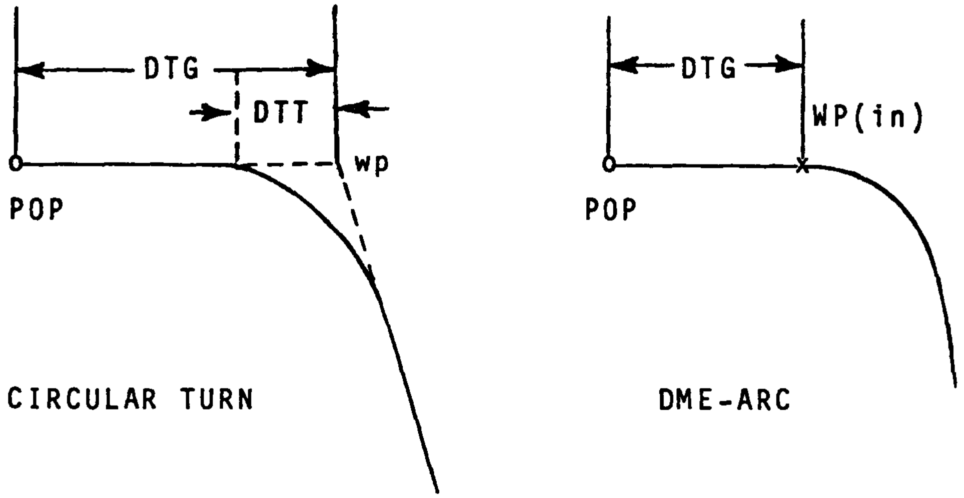


Figure 8-11. Distances to the Turn

There are three criteria for determining that the guidance routine should be making turn calculations:

1. $TURN \neq 0$

2. $VGS * DELTAT \geq DTG$

3. $DTG < WPDDT$

The first check is for the turn discrete (TURN). If the guidance equations have previously decided that the airplane is in the turn, TURN is set. The second test determines if the distance the airplane traveled since the last time through the loop (VGS * DELTAT) is greater than or equal to the Abeam Point to Next Waypoint Distance (DTG). This test is used in the DME-Arc case where the inbound waypoint WP(IN) is at the Tangent Point. So when the airplane passes the waypoint, the guidance routine should switch to the turn calculations. The third test is for the circular turns.

The following quantities are computed in the Turn portion of the routine:

1. The Nominal Bank Angle (NOMBA)

2. The Magnitude of the Track Angle Change (MAGTA)

3. The Turn Normal Unit Vector ($\widehat{U12C}$)

4. The Crosstrack Distance to Planned Flight Path During Turns (XTK)

5. The Desired Track During Turns (DSRTK)

6. The Turn Angle Made Good (AMG)

7. The Airplane Distance Made Good (DMG)

8. The Progress Distance of the Airplane (DTOTL)

9. The Abeam Point to Middle of Arc to Next Waypoint Distance (DTOGO)

10. The Distance Before the Turn to Apply Advanced Lateral Control (RALC)

11. The Advanced Lateral Control Exit Angle (ALCXA)

12. The Advanced Lateral Control Bank Angle (ALCBA)

13. The Lateral Steering Signal (LATSTR)

Nominal Bank Angle (NOMBA)

The Nominal Bank Angle (NOMBA) is the bank angle necessary for the airplane to turn at the specified turn radius. It is used for the Advanced Lateral Control equations and as an element of the Lateral Steering Command. It is based on the turn radius and speed of the airplane, as given:

NOMBA = arctangent (GSFPS**2/(GRAVO*WPRTN(i)))

where GRAVO = Nominal acceleration of gravity (32.1739).

Magnitude of the Track Angle Change (MAGTA)

The Magnitude of the Track Angle Change (MAGTA) is used to determine the mid-point and end of a turn. It is calculated by taking the absolute value of the Track Angle Change WPTA(i) (see TABLE 4.9-1) defined for the next waypoint, as follows:

$$MAGTA = |WPTA(i)|$$

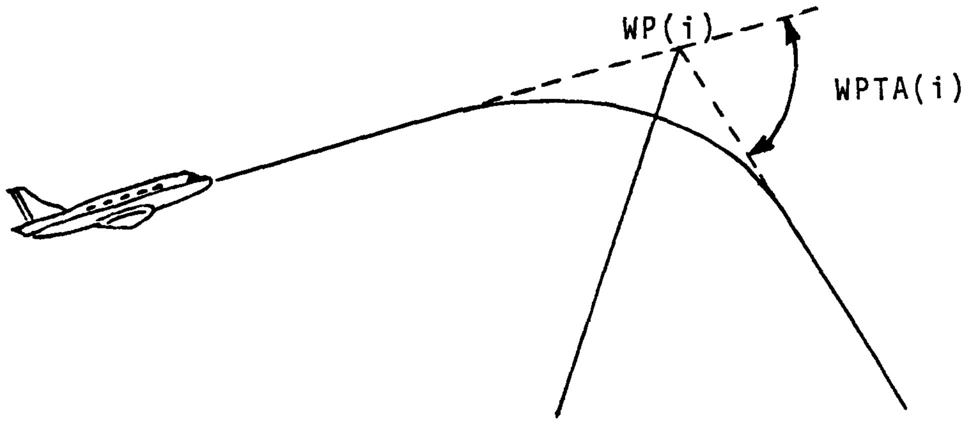


Figure 8-12

Turn Normal Unit Vector ($\widehat{U12C}$)

The Turn Normal Unit Vector is used to calculate airplane position for Horizontal Guidance during turns. It is derived by subtracting from the difference between the Airplane Position Vector $\widehat{PO}$ and the Turn Center Unit Vector $\widehat{WPTC2}$, the component of that vector in the Turn Center Unit Vector direction $(((\widehat{PO} - \widehat{WPTC2}) . \widehat{WPTC2}) \times \widehat{WPTC2})$ as given:

$$\widehat{U12C} = ((\widehat{PO} - \widehat{WPTC2}(i)) -$$

$$(((\widehat{PO} - \widehat{WPTC2}\ (i)) \cdot \widehat{WPTC2}(i)) \times WPTC2(i))))SIGN(TA)$$

where TA positive for right turn, negative for left turns

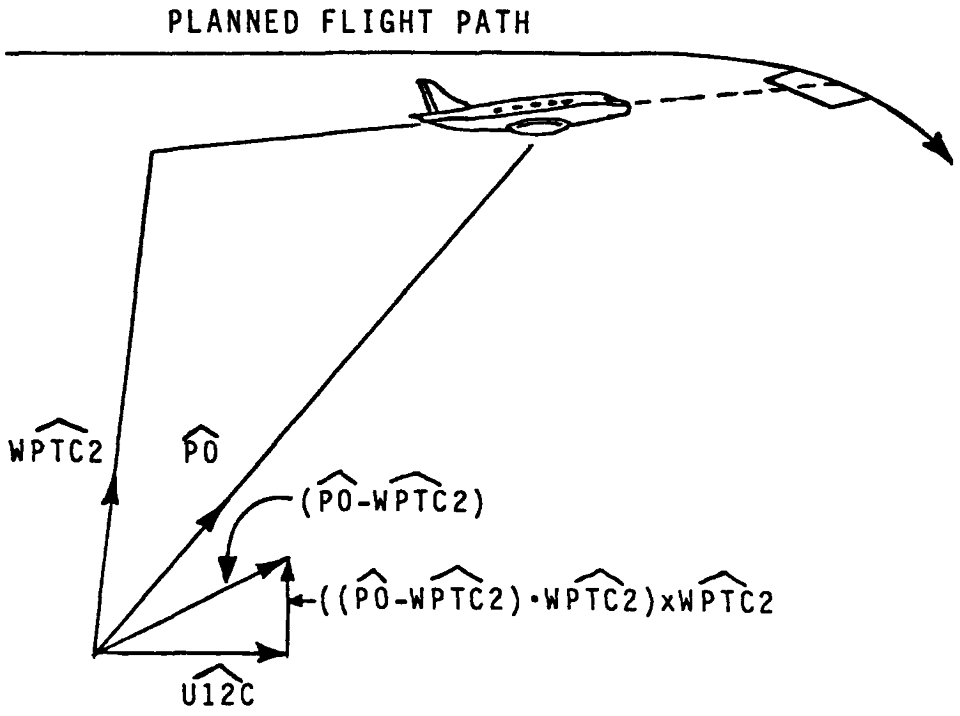

PLANNED FLIGHT PATH
$\widehat{WPTC2}$
$\widehat{PO}$
$(\widehat{PO}-\widehat{WPTC2})$
$((\widehat{PO}-\widehat{WPTC2})\cdot\widehat{WPTC2})x\widehat{WPTC2}$
$\widehat{U12C}$

Figure 8-13. Turn Normal Unit Vector

Crosstrack Distance to Planned Flight Path during Turns (XTK)

The purpose of Crosstrack Distance (XTK) is to compute the Lateral Steering signal LATSTR and to determine the status of the Be Careful Flag, BCFLAG. The Crosstrack distance is adjusted during the turn to reflect the distance from the airplane PO to the Abeam Point POP, as given:

$$XTK = Re{*}arctangent\ (-(\widehat{PO} \cdot \widehat{U12C})/(\widehat{PO} \cdot \widehat{POP}))$$

where Re is the local radius of the earth.

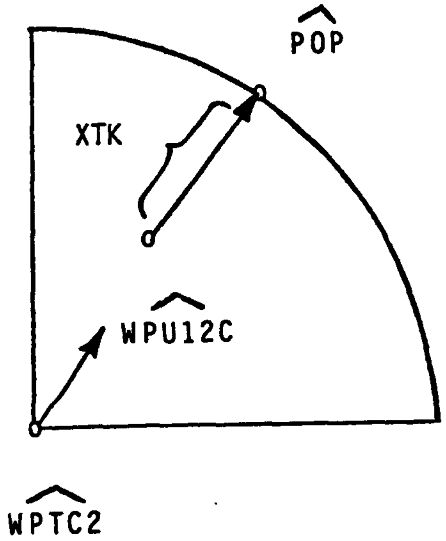


Figure 8-14. Crosstrack Distance to POP

Desired Track Angle During Turns (DSRTK)

The Desired Track Along the Great Circle Path is used to compute the Track Angle Error (TKE), an important element of the Lateral Steering Signal (LATSTR). The Desired Track calculation is modified during turns by replacing WPU12 with WPU12C and PO with WPTC2 (refer to DSRTK for straight segments), as follows:

$$DSRTK = \text{arctangent}(((\widehat{WPU12C}\times\widehat{M})\cdot\widehat{WPTC2})/(\widehat{WPU12C}\cdot\widehat{M}))$$

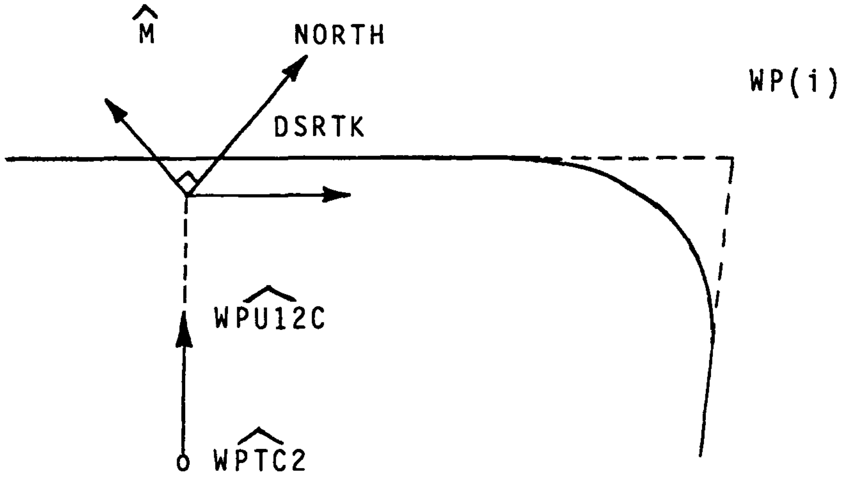


Figure 8-15. Desired Track during Turns

Turn Angle Made Good (AMG)

The purpose of computing the Turn Angle Made Good (AMG) is to continually determine the progress of the airplane around the turn. The Angle Made Good is the angle between the Path Normal Unit Vector ($\widehat{U12}$) and the Turn Normal Unit Vector ($\widehat{U12C}$), as given:

$$\sin(AMG) = (\widehat{WPU12C}(i) \times \widehat{WPU12}(i)) \cdot \widehat{WPTC2}(i)$$
$$\cos(AMG) = \widehat{WPU12C}(i) \cdot \widehat{WPU12}(i)$$

$$AMG = \text{arctangent}\ (\sin(AMG)/\cos(AMG))$$

If the track angle is negative, (WPTA(i) < 0), then:

$$AMG = 360 - AMG$$

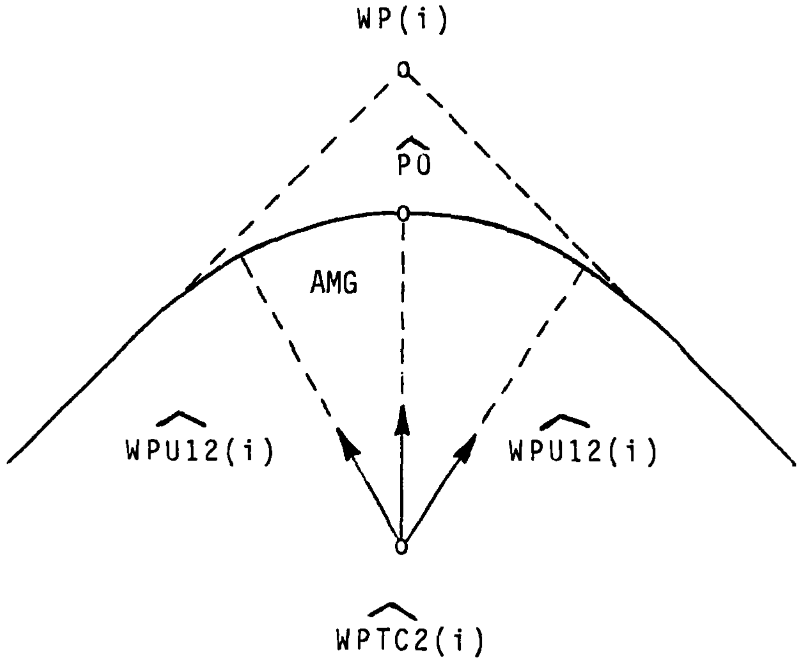


Figure 8-16 Turn Angle Made Good

Airplane Distance Made Good (DMG)

The Airplane Distance Made Good (DMG) is the length of the path segments between the reference waypoint and the airplane. The reference waypoint is the waypoint closest to but behind the airplane and the time box. When the airplane reaches the end of a path segment, the length of that segment (WPCCD) is added to DMG. In the TGUID routine the DMG is compared to the Distance Made Good of the time box (DMG + 1) and they are used to update each other, as given:

when: $2 * AMG \geq MAGTA$

then: $DMG = DMG + WPCCD$

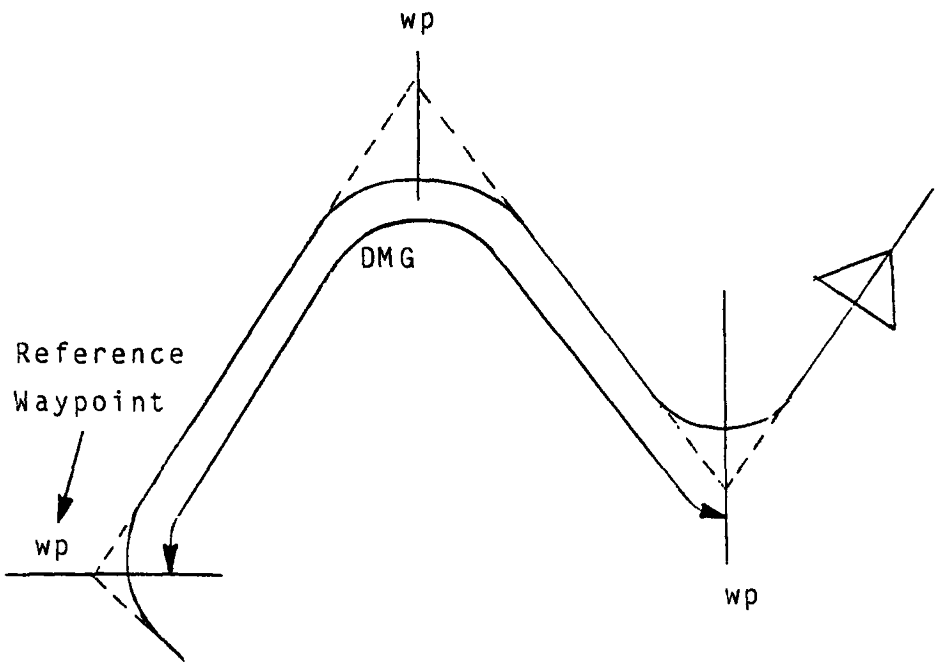


Figure 8-17 Distance Made Good

Progress Distance of the Airplane (DTOTL)

The Progress Distance (DTOTL) is used in the calculation of Separation Distance (SEPR) in the Time Path routine. The Progress Distance is calculated from the Distance Made Good (DMG) plus the Turn Center to Turn Center Distance (WPCCD) of the "to" Waypoint Distance, minus the Abeam Point to the Next Waypoint Center of Turn Distance (DTOGO), as given:

$$DTOTL = DMG+WPCCD(i)-DTOGO$$

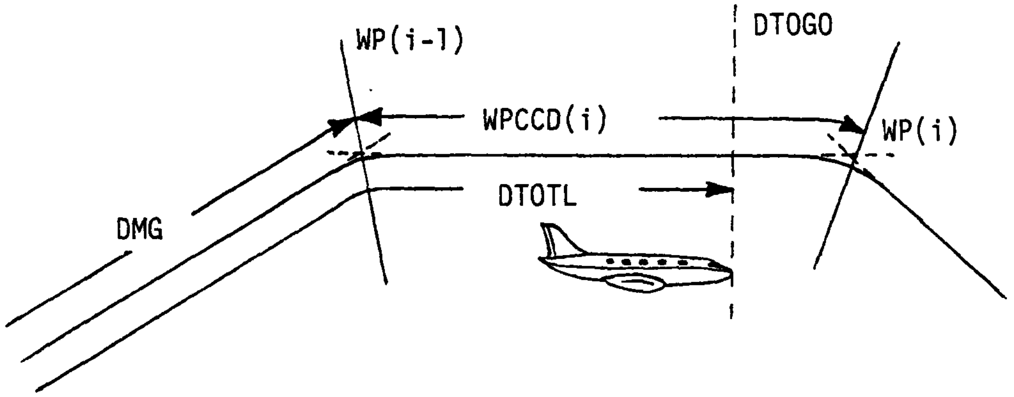


Figure 8-18 Progress Distance

Distance to Apply Advanced Lateral Control (RALC)

The roll command must be given prior to the point of tangency (tp) so that the airplane has enough time to be at the proper bank angle when it begins the turn. The time necessary for the roll is approximately equal to the nominal bank angle divided by the roll rate limit of the control system:

t = NOMBA/ROLL RATE LIMIT

Then the distance before the tangent point is:

RALC = NOMBA*CP25*GSFPS

where CP25 is the constant .25.

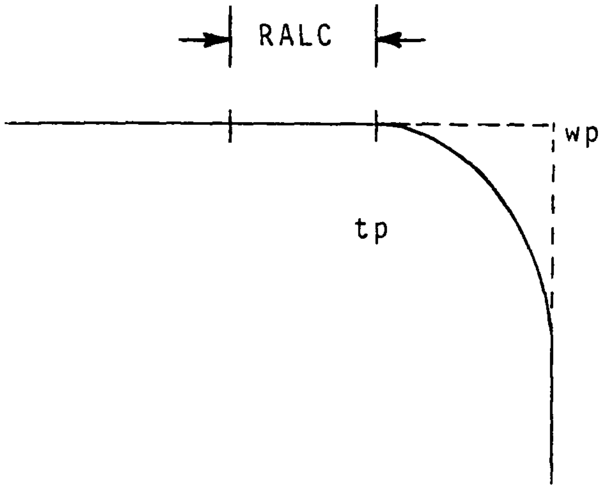


Figure 8-19

Distance to Remove Bank Angle Command (ALCXA)

In order to smoothly meet the next leg of a flight path, it is necessary to begin the roll out after a turn before the end of the turn. The roll out to wings level is begun when the arc length remaining is equal to the time necesary for roll out times the angular speed of the airplane (GSFPS/WPRTN), as given:

$$\text{ALCXA} = \frac{\text{NOMBA*180}}{\text{Roll Rate Limit}} * \frac{\text{GSFPS}}{\text{WPRTN(i-1)}} = \frac{\text{RTOD*RALC}}{\text{WPRTN(i-1)}}$$

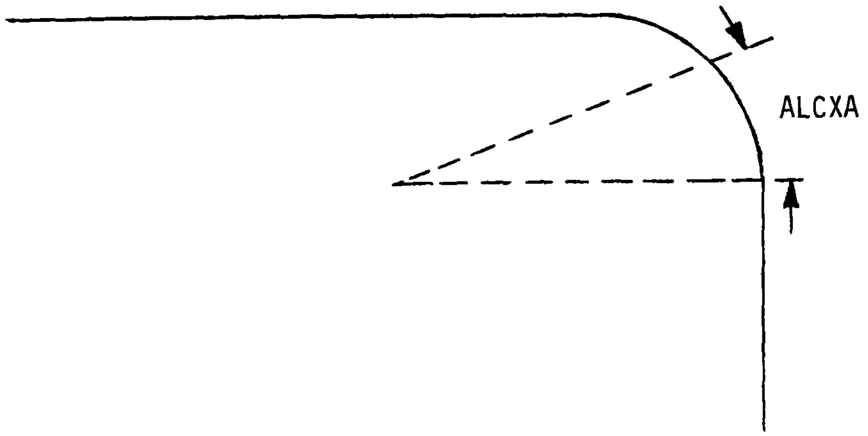
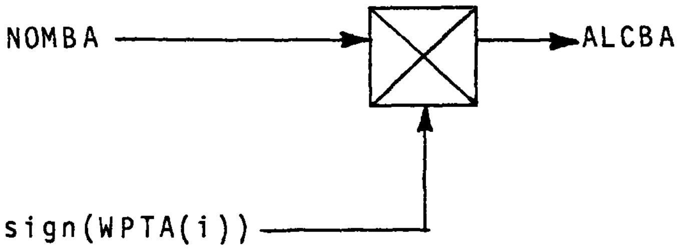


Figure 8-20

Advanced Lateral Control Bank Angle (ALCBA)

The Advanced Lateral Control Bank Angle (ALCBA) is the element of the Lateral Steering Signal (LATSTR) that represents the lateral acceleration necessary to stay on the curved path during turns. ALCBA is only used when the airplane is beyond the Distance Before the Turn to Apply Advanced Lateral Control (RALC) and has not yet reached the Distance Before the end of Turn to Remove the Advanced Lateral Control (ALCXA). The bank angle is calculated from the Nominal Bank Angle (NOMBA) and the sign of the Waypoint Turn Angle (WPTA) as shown in the following Digital System Diagram (DSD):



The Bank Angle is computed under the following conditions:

1. when $DTOGO \geq RALC + WPA02$

   then: the airplane has not reached the roll-up point (RALC) and ALCBA = 0

2. when $DTOGO < RALC + WPA02$

   then: in the first half of turn and ALCBA = Sign (WPTA(i)) * NOMBA

3. when $MAGTA - AMG \geq ALCXA$

   then: in the turn, not to roll out point and ALCBA = Sign (WPTA(i)) * NOMBA

4. when $MAGTA - AMG < ALCXA$

   then: beyond the roll out point and ALCBA = 0

Lateral Steering Signal (LATSTR)

The Lateral Steering Signal (LATSTR) represents the solution of a linear second order differential equation, as given:

$$LATSTR = \Delta y * KY + \Delta\dot{y} * KYD + \ddot{y}$$

The equation is made up of crosstrack (lateral distance) error, crosstrack rate (lateral velocity) error and bank angle (lateral acceleration) components, as given:

LATSTR = XTK * KY + TKE * DTOR * GSFPS * KYD + ALCBA + FWDPTH

(FWDPTH is defined on page 262)

IV Horizontal Guidance:

The following computations are done in horizontal guidance for both straight segments and turns. The following quantities are computed:

1. The Lateral Steering Signal Intercept Angle (PSIi)

2. The Lateral Steering Course Cut Limit (limit)

3. The Lateral Crosstrack Error Signal (Δy)

4. The Forward Path Integrator (FWDPTH)

5. The Lateral Steering Crosstrack Rate Error Signal ($\dot{\Delta y}$)

6. The Lateral Steering Signal (LATSTR)

Lateral Steering Signal Intercept Angle (PSIi)

The intercept angle is the component of the Lateral Steering Signal which determines the direction that the airplane approaches the planned flight path. The angle is determined by the Cross Track Error (XTK) and the Ground Speed (GSFPS) and is limited from 30 to 90 degrees as described below.

```
if X < 30          then PSIi = 30
if 30 ≤ X ≤ 90     then PSIi =  X
if X > 90          then PSIi = 90

where:   X = ((470*|XTK|)/GSFPS**2))-30
```

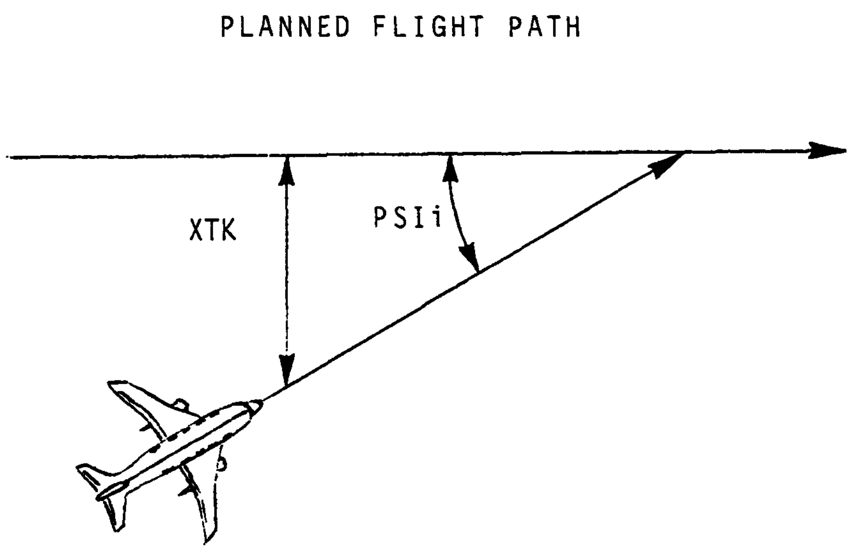


Figure 8-21. Intercept Angle

Lateral Steering Course Cut Limit (limit)

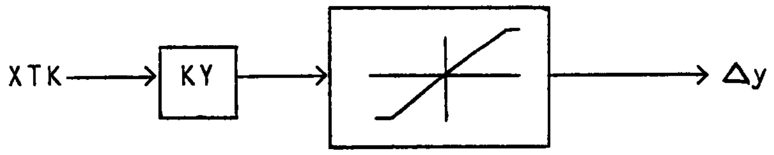
The purpose of the Course Cut Limit is to limit the crosstrack error signal preventing it from predominating the crosstrack rate signal. The limit is varied with groundspeed (VGS) and intercept angle (PSIi), as given:

$$\text{limit} = \text{GSFPS} * \text{DTOR} * \text{PSIi} * \text{KYD}$$

where DTOR is the degrees to radians conversion factor.

Lateral Steering Crosstrack Error Signal (Δy)

The Crosstrack Error Signal is one of the three inputs that make up the Lateral Steering signal (LATSTR). The Crosstrack Error Signal is made up of the scaled crosstrack error (XTK * KY), limited by the Course Cut Limiter (limit) as shown in the DSD below.



The Error Signal is computed under the following conditions:

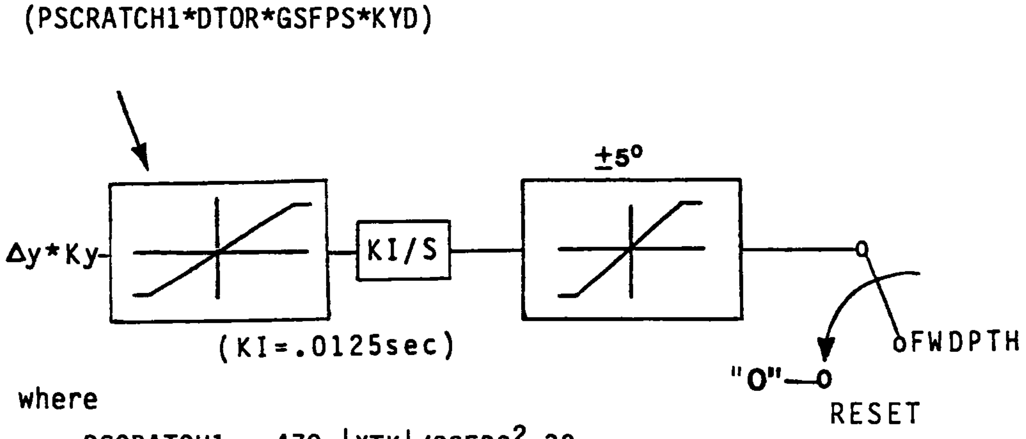
Δy = -limit for -limit $\leq$ XTK * KY

Δy = XTK * KY for -limit < XTK * KY<limit

Δy = limit for XTK * KY$\geq$limit

Forward Path Integrator (FWDPTH)

Guidance errors caused from mistrim and biases in the autopilot that result in differences between the actual bank angle and the commanded bank angle are referred to as stand-off error. The purpose of the Forward Path Integrator (FWDPTH) is to improve the tracking accuracy of Horizontal Path by nulling the cross path stand-off error. The FWDPTH is the summation of the Crosstrack Error Signal $\Delta y*Ky$ with respect to time, as given:



where

$$\text{PSCRATCH1} = 470.|\text{XTK}|/\text{GSFPS}^2-30$$

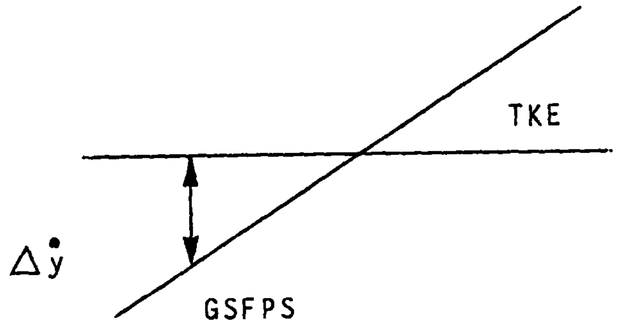
$$\text{RESET} = \overline{\text{AUTO}} + \text{TKSEL} + |\text{XTK}| > 1000\text{FT} + |\text{TKE}| > 5 \text{ deg}$$

The bank angle command increment generated by the FWDPTH is limited to ±5 degrees, regardless of the actual integrator output.

Crosstrack Rate Error Signal ($\Delta\dot{y}$)

The Crosstrack Rate Signal is one of the three main inputs to the Lateral Steering Signal (LATSTR). The Signal $\Delta\dot{y}$ is computed from the Ground Speed of the Airplane (GSFPS) and the Track Angle Error (TKE) as given:

$$\Delta\dot{y} = GSFPS * TKE * DTOR$$



Lateral Steering Signal (LATSTR)

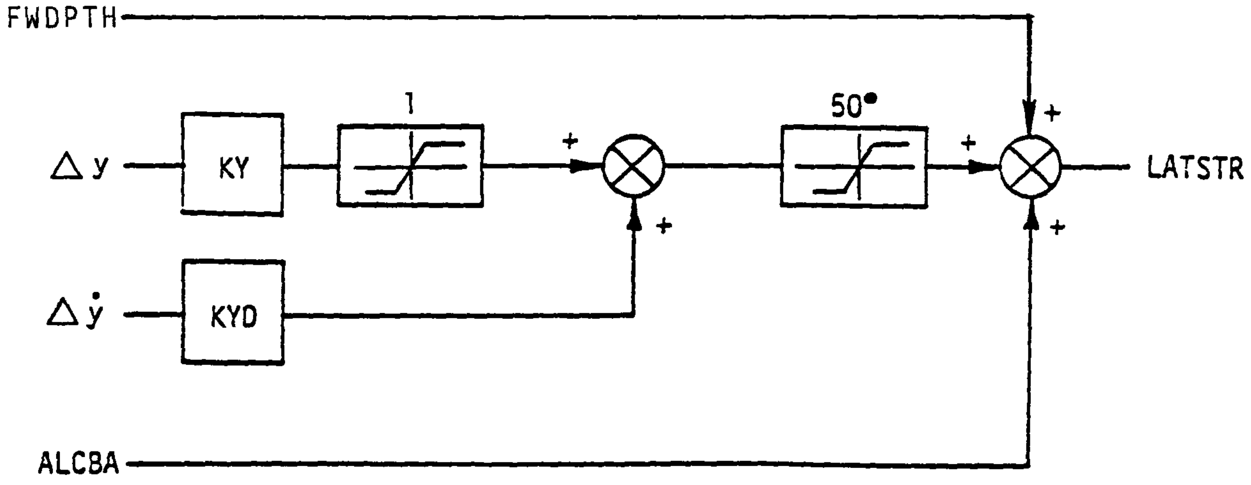
The Lateral Steering Signal is the primary output of the Horizontal Guidance equations. It is used to calculate the Bank Angle Command (BACMD) for the simulated Airplane, and to the Flight Controls equations; LATSTR is made up of the crosstrack error signal (Δy) limited by the course cut limit (1), the crosstrack rate error signal ($\Delta \dot{y}$) and the Advanced Lateral Control Bank Angle (ALCBA), as follows:

$$\text{LATSTR} = (\Delta y * \text{KY} + \Delta \dot{y} * \text{KYD}) + \text{ALCBA} + \text{FWDPTH}$$

where: KY and KYD are the TKE and XTK gains respectively.

LATSTR = SRLMT(-(TKE*DTOR*KYD*GSFPS + PSCRATCH),50.)
+ FWDPTH + ALCBA

where: PSCRATCH = SRLMT ((XTK*KY), (470.|XTK|/GSFPS^2 - 30)
*DTOR*GSFPS*KYD))



Abeam Point Commanded Altitude (HC)

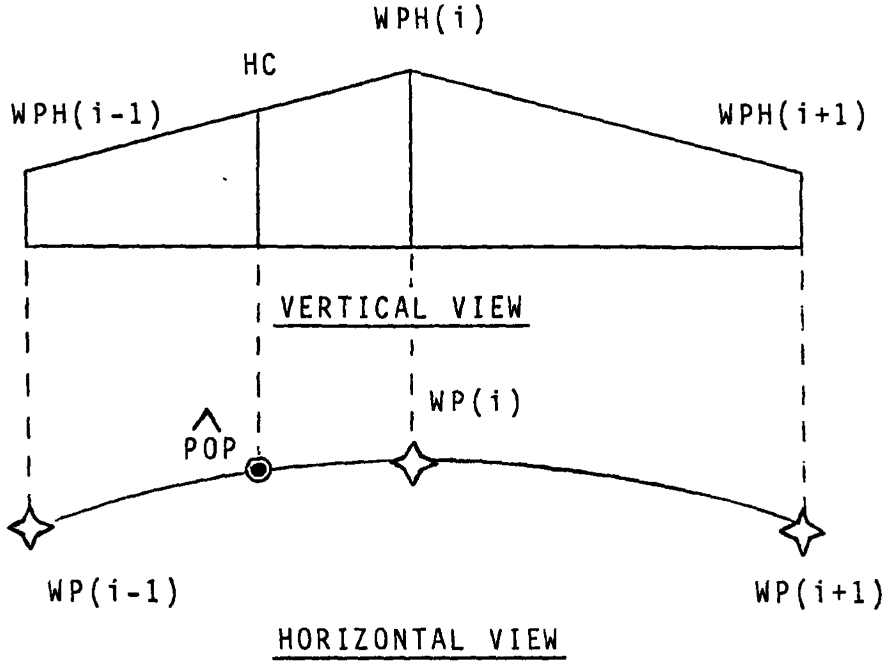
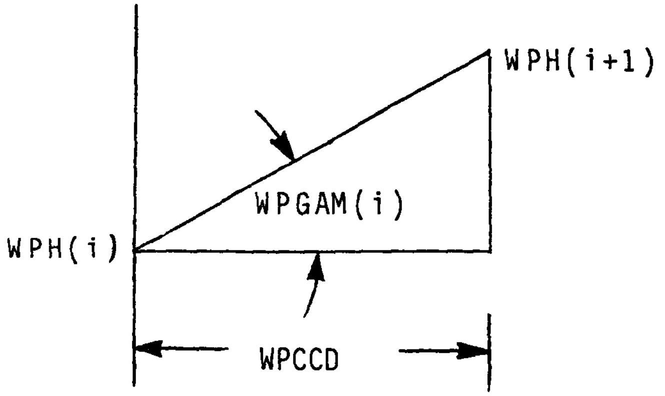


Figure 8-22 Commanded Altitude

The change from WPH(i-1) and WPH(i) is a linear transition with distance beginning at the midturn of WP(i-1) and ending at the midturn of WP(i). The Waypoint to Waypoint Gradient (WPGAM) describes this transition. To determine the abeam point planned altitude it is only necessary to subtract from the waypoint height the product of the Waypoint to Waypoint Path Gradient and the distance to the midpoint (DTOGO), as given:

HC = WPH(i) - WPGAM(i) * DTOGO * DTOR

where: the Gradient WPGAM is illustrated in the following figure.



Because the DME-Arc parameters are defined and computed differently, the computation of HC during the first half of the DME-Arc becomes:

HC = WPH(i+1) - WPGAM(i+1) * DTOGO * DTOR

Vertical Guidance Switch Point Distance (HDIS)

The 3D pointers to the Waypoint to Waypoint Path Gradient (WPGAM) are switched (or updated) before the midpoint of the turn to anticipate vertical maneuvers. There are three different ways that the switch point is determined; first, if the waypoint half arc distance of the 'to' waypoint WPA02 is greater than 1000 feet, the switch point will be set to the half arc distance and the descriptor pointer will switch at the tangent point; secondly, if WPA02 is less than 1000 feet, the switch distance is forced to 1000 feet along the path from the midturn point; finally, if the waypoint to tangent point distance WPDTT is zero, the switch point is also forced to the minimum 1000 feet distance.

$$\mathrm{HDIS} = 1000 \quad \text{if:} \quad \begin{array}{c} \mathrm{WPDTT}(i) = 0 \\ \text{or} \\ \mathrm{WPA02}(i) < 1000 \end{array}$$

$$\mathrm{HDIS} = \mathrm{WPA02}(i) \text{ otherwise}$$

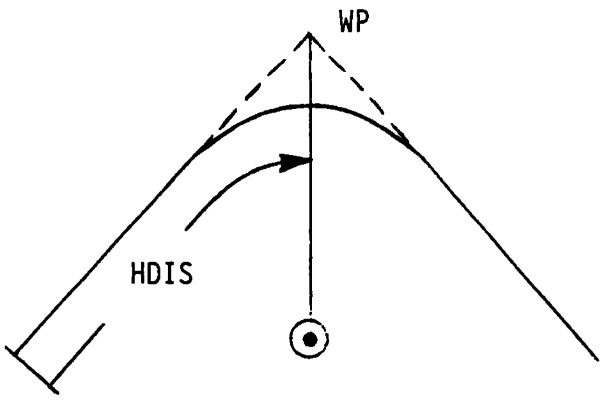
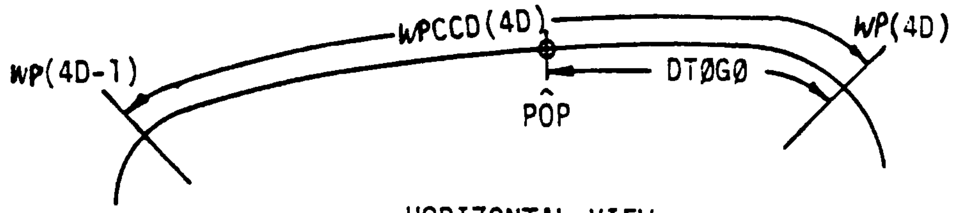
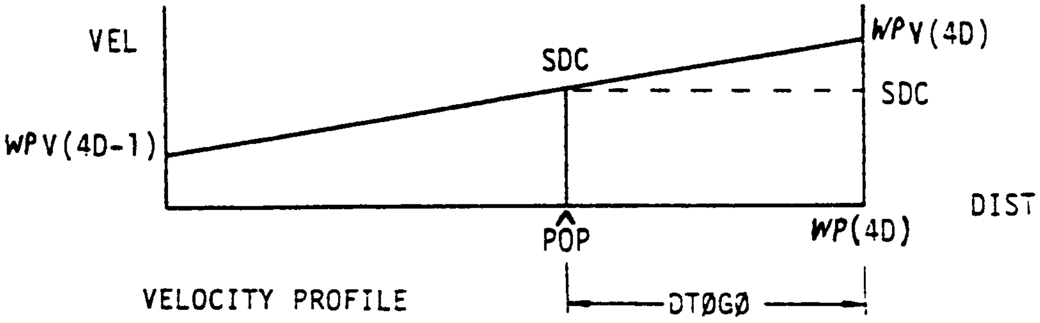


Figure 8-23. Switch Point Distance

Abeam Point Commanded Ground Speed (SDC)



HORIZONTAL VIEW



VELOCITY PROFILE

The Abeam Point Commanded Ground Speed is calculated from the defined waypoint groundspeeds (ACTIVE.PWV), the waypoint center to center distance (ACTIVE.PWCCD), and the abeam point to middle of arc at the next waypoint distance (DTOGO).

$$SDC = \left(\left(-\frac{WPV(4D) - WPV(4D-1)}{WPCCD(4D)} * DTOGO\right) + WPV(4D)\right) * KTOFPS$$

During the first half of a DME-arc turn, the abeam point commanded groundspeed equation is as follows:

$$SDC = \left(\left(-\frac{WPV(4D+1) - WPV(4D)}{WPCCD(4D+1)} * DTOGO\right) + WPV(4D+1)\right) * KTOFPS$$

NOTE: It is necessary to modify the equation when in the first half of a DME turn because PTR4D is not updated until the middle of the turn is reached.

Vertical Guidance Computations

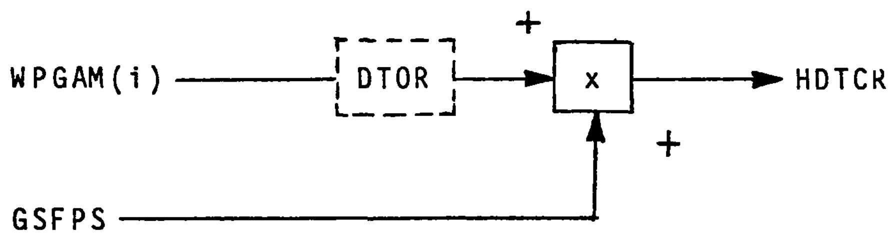
The following quantities are computed in the Vertical Guidance portion of the routine:

1. The Abeam Point Commanded Altitude (HC)
2. The Vertical Guidance Switch Point Distance (HDIS)
3. The Raw Vertical Speed Command (HDTCR)
4. The Vertical Acceleration Command (HDDC)
5. The Vertical Path Error (HER)
6. The Vertical Speed Command (HDTC)
7. The Planned Flight Path Angle (PFPA)
8. The Flight Path Angle Error (DFPA3D)
9. The Altitude Rate Command (VSTRA)
10. The Altitude Rate Response (VSTRB)
11. The Vertical Steering Command (VERSTR)

Raw Vertical Speed Command (HDTCR)

The purpose of the Vertical Speed Command (HDTCR) is to derive a desired vertical speed command for comparison with the actual vertical Guidance Speed Command (HDTC). The HDTCR is derived from the Waypoint to Waypoint Path Gradient (WPGAM(i)) and the current ground speed of the airplane (GSFPS), as given:

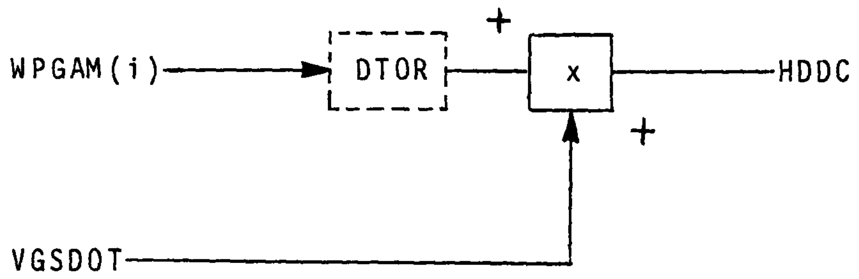
$$HDTCR = GSFPS * WPGAM(i) * DTOR$$



Vertical Acceleration Command (HDDC)

The purpose of the Vertical Acceleration Command is to compute the vertical acceleration portion of the Vertical Steering Command (VSTRA). The Vertical Acceleration Command is derived from the ground acceleration (VGSDOT) and the Waypoint to Waypoint Path Gradient (WPGAM), as given:

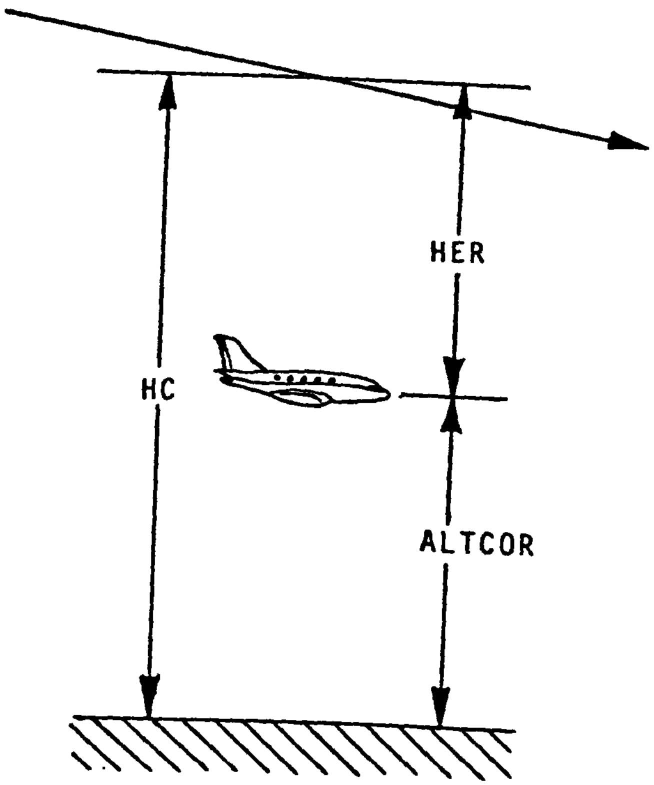
$$HDDC = VGSDOT * WPGAM(i) * DTOR$$



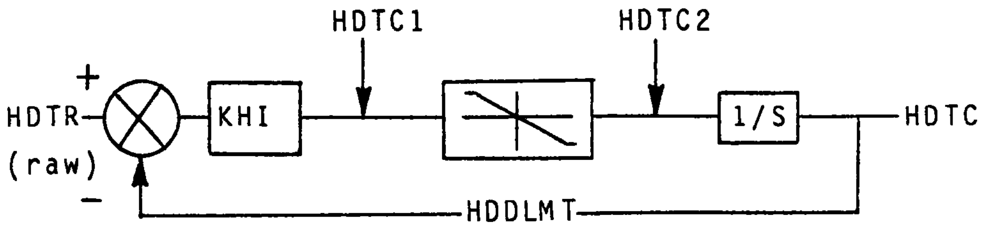
Vertical Path Error (HER)

The Vertical Path Error is one of the major elements used in the calculation of the Altitude Rate Command (VSTRA). The HER is the difference between the Abeam Point Commanded Altitude (HC) and the actual altitude (ALTCOR), as given:

$$HER = HC - ALTCOR$$



Vertical Speed Command (HDTC)



The Vertical Speed Command is one of the three major elements which make up the Altitude Rate Command (VSTRA). HDTC is developed by scaling, limiting and integrating the Raw Vertical Speed Command (HDTR). The following steps are taken to develop HDTC.

scaled by KHI:

$$HDTC_1(i) = (HDTCR(i) - HDTC(i-1)) * KHI$$
where $KHI = .16$

limited by HDDLMT:

if $HDTC_1(i) \leq -|HDDLMT|$

then $HDTC_2(i) = -|HDDLMT|$

if $-|HDDLMT| < HDTC_1(i) < |HDDLMT|$
then $HDTC_2(i) = HDTC_1(i)$

```
if $HDTC_1(i) > |HDDLMT|$
    then $HDTC_2(i) = HDDLMT$
    where $HDDLMT = 2$
```

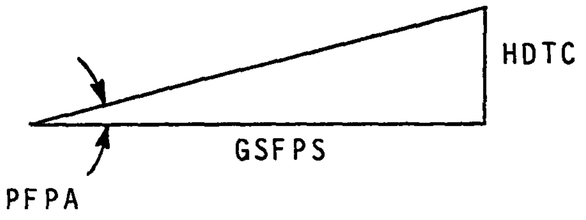
and integrated:

$$HDTC(i) = HDTC(i-1) + HDTC_2(i) * DELTAT$$

Planned Flight Path Angle (PFPA)

The Planned Flight Path Angle is used in the calculation of the Flight Path Angle Error (DFPA3D) and to generate the gamma bars for the EADI. The PFPA is determined by dividing the Vertical Speed Command (HDTC) by the present Ground Speed of the Airplane (GSFPS).

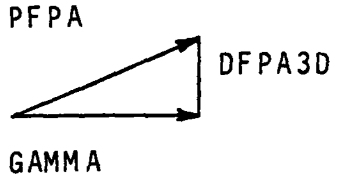
PFPA = (HDTC/(GSFPS) RTOD



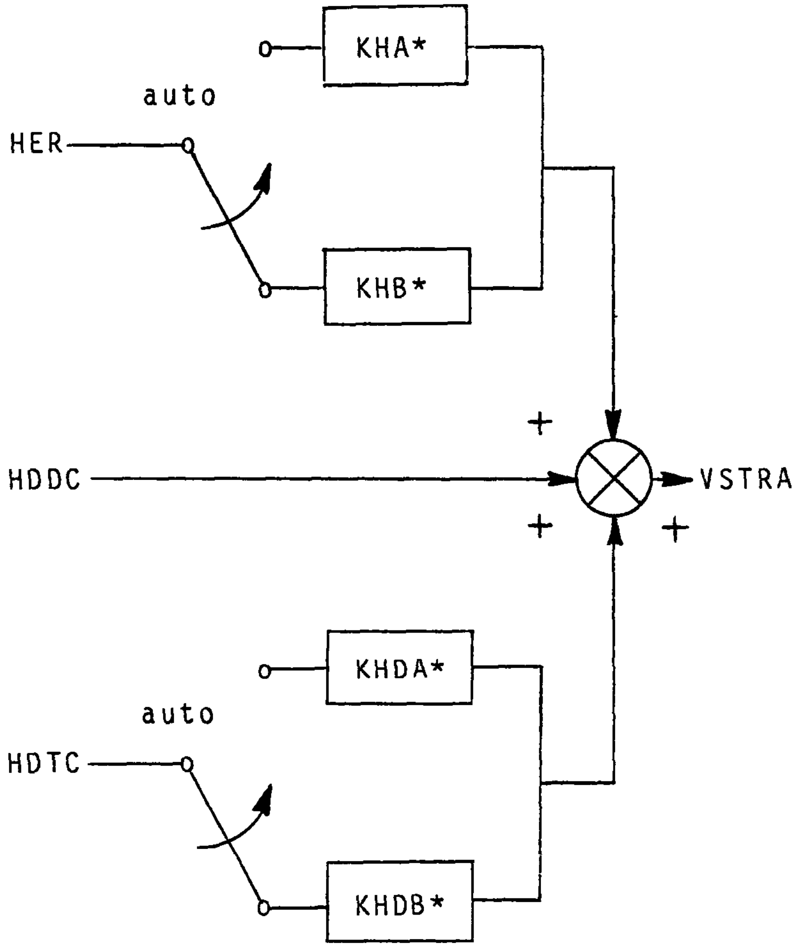
Flight Path Angle Error (DFPA3D)

The purpose of the Flight Path Angle Error is to be available for display on the NCDU navigation data pages. The Flight Path Angle Error is computed from the difference between the Planned Flight Path Angle (PFPA) and the actual Flight Path Angle (GAMMA).

DFPA3D = PFPA - GAMMA



Altitude Rate Command (VSTRA)

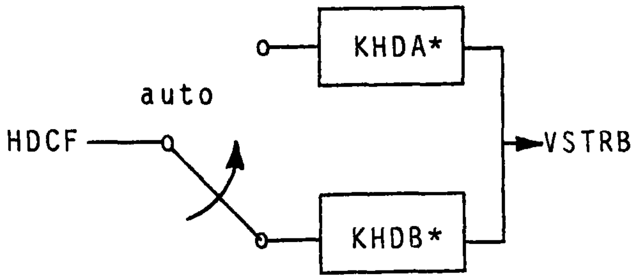


The Altitude Rate Command is one of the major elements that makes up the Vertical Steering Signal (VERSTR). The Altitude Rate Command (VSTRA) is the sum of the scaled Altitude Error (HER), the Vertical Speed Command (HDTC) and the Vertical Acceleration Command (HDDC), as given:

VSTRA = HER * KH + HDTC * KHD + HDDC

* where KHA is the vertical path position error gain when AUTO is on; KHB is the vertical path position error gain when AUTO is off; KHDA is the vertical path velocity error gain when AUTO is on; KHDB is the vertical path velocity error gain when AUTO is off.

Altitude Rate Response (VSTRB)

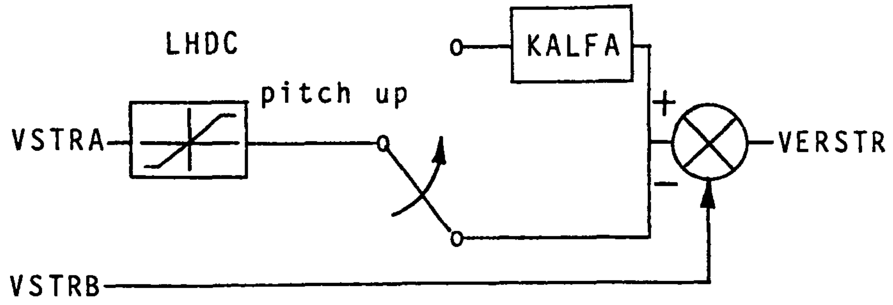


The Altitude Rate Response is the feedback signal for the Vertical Steering Signal (VERSTR). The Altitude Rate Response is Baro-Inertial Altitude Rate, complementary Filtered (HDCF) and scaled to correspond to the Altitude Rate Command (VSTRA) input to the Vertical Steering Signal, as given:

$$\text{VSTRB} = \text{HDCF} * \begin{bmatrix} \text{KHDA -AND- AUTO} \\ \text{-OR-} \\ \text{KHDB -AND- AUTO} \end{bmatrix}$$

*where KHDA is the vertical path velocity error gain when AUTO is on; KHDB is the vertical path velocity error gain when AUTO is off.

Vertical Steering Signal (VERSTR)



where KALFA is an anti-stall gain processed only for a pitch up command and LHDC is the vertical path velocity command limit.

The Vertical Steering Signal (VERSTR) is the difference between the Altitude Rate Command (VSTRA) and the Altitude Rate Response (VSTRB) after the command has been limited and degained if the command was pitch up.

$$VERSTR = VSTRA - VSTRB$$

The Vertical Steering Signal is the main output of the Vertical Guidance equations. It is one of the possible inputs to the Flight Controls ELEVP procedure.

```
GLOBAL INPUTS:  ACTIVE,ALTCOR,AMG,CLAT,CLON,COLDST,DELTAT,DMG,
                DSRTK,DTG,DTVGO,DTOTL,FLAGS,GAMMA,GSFPS,GUID2D,
                GUID3D, HDCF, HER,KALFA,KHD,NAVG4K,NOMBA,PATHND,
                PFPA,PTRZD,PTR3D,PTR4D,RALC,SLAT,SLON,TEND,TK,TRE,
                TKSEL,TURN,VERPTH,VGSDOT,VSTRA,VSTRB,WPPTR,XTK

GLOBAL OUTPUT:  ALTARM,AMG,AVECTS,BCFLAG,DFPA3D,DMG,DSRTK,DTG,
                DTOGO,DTOTL,GUID2D,GUID3D,GUID4D,HER,KHD,LATSTR,
                MDWARN,NCUVAL,NOMBA, PATHND,PFPA,PTH4DN,PTR2D,PTR3D,
                PTR4D,RALC,SDC,TEND,TKE,TURN,VERSTR,VSTRA,VSTRB,
                WPPTR,XTK
```

MODULE NAME: Non Critical Flight Modes (NCFM)

PURPOSE: To calculate guidance commands to the flight controls modules according to the selected mode.

LANGUAGE: HAL/S

TASK: FAST

CALLING SEQUENCE: CALL NCFM

CALLED BY: FAST

CALLS TO: ANGL, SRLMT

DESCRIPTION:

NCFM provides intermediate calculations of the flight path and acceleration command inputs to the flight controls modules based on the current flight situation and on the mode control panel inputs. The primary outputs are:

BACMD	Bank Angle Command,
VACMD	Vertical Acceleration Command, and
ATCMD	Autothrottle Command.

Preliminary calculations determine the angle of attack (ALFSYN) and the anti-stall gain (KALFA). Below 64 knots, ALFSYN equates to PITCH. Above that speed, it is calculated as GAMMA - PITCH, where GAMMA is approximated as HDCF/TASFPS. The anti-stall gain is based on the existing angle of attack. Up to 7 degrees, the gain is one. Above 7 degrees, it is decreased from one to 0.0 at 10 degrees. It remains zero for all angles above 10 degrees.

The logic is generally similar for all three command outputs. The user input comes from the values set by the rotary knobs on the mode control panel. These inputs are stored in the "summers" TKASUM, ALTSUM, FPASUM, and IASSUM, which are incremented or decremented as the knobs are rotated. If a mode is active or preselected, then the relevant command is based on the delta between the summer and the current value. Then, a gain, a limit, or both may be applied. When the mode is not active or preselected, the "summer" is preset to the present value of CAS, FPA, etc.

For BACMD, the calculations are essentially as indicated above. If Track Hold mode is active, DELTKA (TKASUM - TKA) is Gained for groundspeed (.00475 GSFPS). Otherwise, BACMD is taken directly from the lateral steering signal (LATSTR). In either case, BACMD is limited to +/- 25 degrees.

The VACMD calculations are more complex. For altitude hold, the delta value (DELALT) is gained by KHALT. If the command is to pitch up (DELALT > 0) then the anti-stall gain (KALFA) is applied. This intermediate value (ASC) is the altitude select signal. If Flight Path Angle Hold is selected or active, the delta FPA (DFPAHM) is taken from FPASUM and GAMMA, gained by a function of groundspeed. If the FPA Hold mode is active, this delta FPA becomes the VACMD. Otherwise, if the Altitude Hold mode is active, the altitude select signal (ASC) is used. Finally, if neither mode is active, the vertical steering signal (VERSTR) is used. In any case, VACMD is limited to 5 ft/sec**2.

The Airspeed Select/Hold calculations are straightforward. The delta is figured normally, and if Time Path mode is not active, ATCMD is the delta (DELCAS) in FT/SEC, times the gain (.1). Otherwise, the Time Guidance speed command (SCMD) is used. Limiting is performed by the autothrottle logic.

GLOBAL INPUTS: ALTARM, ALTCOR, ALTSEL, ALTSUM, CAS, FPASEL, FPASUM, GAMMA, GSFPS, HDCF, IASSEL, IASSUM, LATSTR, NAV64K, PITCH, PSTALT, PSTFPA, PSTIAS, PSTTKA, SCMD, TAS, TIMPTH, TK, TKASUM, TKSEL, VERSTR

GLOBAL OUTPUTS: ALFSYN, ALTSUM, ATCMD, BACMD, DELCAS, DELALT, FPASUM, IASSUM, KALFA, TASFPS, TKASUM, VACMD

MODULE NAME: TGUID

PURPOSE: Process time box calculations and compute flight director speed command.

TASK: FAST

LANGUAGE: HAL/S

CALLED BY: FAST

CALLING SEQUENCE: CALL TGUID

CALLS TO: SRLMT

DESCRIPTION:

Upon entry there are three possible branches:

1. time guidance off
2. time guidance first pass
3. time guidance integration loops

Each of these is explained below.

TIME GUIDANCE OFF:

If GUID4D is off the logic takes this path. The following is performed: the time box waypoint pointer (PTR4D1) is set to two if it is not already greater than or equal to two. PTR4D1 is computed to determine the address of the data for the "to" waypoint. The speed command, separation distance of the box and airplane, and first pass flag are all initialized.

TIME GUIDANCE FIRST PASS:

The first pas loop is only executed the first time TGUID is called after the 4D guidance flag is set. The 4D flags for a half and full turn (TEND1 and TURN1) are reset. The distance made good for the box and airplane (DMG1,DMG) are computed according to whether the airplane is ahead or the time box is ahead.

Following this the time guidance first pass flag (TGP1) is set. The initial values of the time box velocity (SDDC) and the time box position (SC) are computed.

The algorithm determines whether or not the box is in a turn or on a straight segment, or if the "to" waypoint is a dme-arc inbound waypoint.

If the "from" waypoint is a dme-arc inbound waypoint, the bos is in the second half of a turn. TEND1, a flag which signifies the second half of the turn, is set. The time box magnitude of change value (MAGTA1) and the time box arc distance made good (ADMG) are initialized before branching to the turn loop (AAT).

If the box is in aturn or in a dme-are, the are distance made good is set (ADMG), and a branch to the turn loop (AAT) is made.

If the box is on a straight segment, a branch is made to the speed command loop (CDG).

If the "to" waypoint is a dme-arc incound waypoint, or if the "from" waypoint is anot a dme-arc inbound waypoint, the time box is either on a straight segment, in a turn, or in the first half of a dme-arc. In these cases the time box magnitude of the track change (MAGTA1) is set prior to branching to the turn or straight segment processing.

TIME GUIDANCE INTEGRATION:

Procedure IAVS:

The time box velocity, and the distance from the box to the "to" waypoint is are updated (SDCC,SC). If the box is already in a turn, loop is called (AAT). If not, a check is made to determine if the box is entering a turn. If it is not, control transfers to the flight director speed command loop (CDG). There are two conditions that signify if the box is entering a turn: the distance form the box to the next waypoint is less than the distance from the waypoint to the tangent point, or the distance from the next waypoint is negative.

When the time box reaches the end of the planned flight path, the 4D guidance flag (GUID4D) is turned off and the end of the path flag (PATHDN) is set. Control then passes to the calling routine.

PROCEDURE ITN:

Start of turn calculations are performed here. The time box average acceleration along each path segment, the time box velocity, and the distance from the box to the next waypoint are computed.

PROCEDURE AAT:

Turn calculations in AAT are performed when the time integration procedure IAVS is called and the TURN1 flag is on.

When the mid-turn flag is set (TEND1) and the box is at the end of a turn (AMG1 >= MAGTA1), the turn flags are cleared and the flight director speed command procedure (CDG) is called.

When the box is halfway through the turn, the second half turn flag (TEND1) is set. The distance made good, which is the legnth of the path between the path segment just completed by the time box and the reference waypoint, is updated. The 4D reference pointer is updated to point to the next waypoint. If the turn is not dme-arc a new box acceleration (SDCC), time box box velocity (SDCC), and time box to next waypoint distance (SC) are computed. The flight director speed command procedure (CDG) is called.

PROCEDURE CDG: (FLIGHT DIRECTOR SPEED COMMAND)

The flight director speed command is an auto throttle command. It is the acceleration required to minimize the along track distance, velocity, and acceleration between the airplane and the time box. The separation distance from the box to the airplane (SEPR) is used to compute the speed command (SCMD). To prevent the airplane from closing in on the box faster than the dynamics of the airplane allow, the closure rate limit is one-tenth the ground speed associated with the abeam point. The rate is multiplied by the time path velocity error gain in orfer to size it properly to limit the closure rate.

A condition that might cause a stall is identified by the flight director speed command "too slow" tests. The conditions that might cause the airplane to stall are:

1. The synthesized angle of attack (ALFSYN) is greater than 10 degrees.
2. The airplane is flying too slow to maintain enough lift to fly.

If either of these conditions are met the TOSLOW flag is set and the airplane will not use the speed command in the computaitons of the auto throttle command.

GLOBAL INPUTS: ACTIVE, ALFSYN, BINTIME, CAS, GSFPS, GUID4D, IASREF, KTOFPS, PTR4D, PTR4D1, SDC, TITIME, TURN1, WPPTR

GLOBAL OUTPUTS: ADMG, AMG1, DMG, DMG1, GUID4D, PSTIAS, PTH4DN, PTR4DN, PTR4D1, SC, SCMD, SDCC, SEPR, TEND1, TOSLOW, WPPT

9.0 DATA RECORDING/AQUISITION

DATA RECORDING OVERVIEW

There are five data recording programs which provide the capability to record selected data on tape, paper, and strip charts. DSTDAT, task built with DSTAR, contains a list of data to be recorded on tape through the Data Acquisition System (DAS). It also contains a group of alternate tables which contain data lists to be plotted on the strip charts. DSTAR is the only interactive data recording program. It permits the experimenter to modify the data and parameter lists from DSTDAT and also to set up "snap" tables to print certain groups of data on the onboard line-printer. Finally, it processes the lists and tables and stores addresses and scale factors for DAS.

The SNAP program works with tables generated through DSTAR. When a user specified condition is encountered. SNAP records the associated set of data. Subsequently, in near real-time, SNPOUT formats the data and prints it out on the line-printer.

DASOT takes the data specified by the DAS lists from DSTAR, formats it, and stores it for the DAS, which has a set of 150 words reserved in SIR memory for this purpose. The strip chart data are also included in this data set and are routed to the strip charts by the DAS.

Output from SNAP and the strip charts is, of course, available in flight. Data stored on the DAS tape are available for a "quick look" a day or so following the flight. They are also available over the long term for more thorough data reduction and analysis.

MODULE NAME: DASOT (Data Acquisition System Output)

PURPOSE: To collect and format for output specified aircraft sensor and performance data.

LANGUAGE: MACRO-11

TASK: FAST

CALLING SEQUENCE: CALL DASOT

CALLED BY: FAST

CALLS TO: None

DESCRIPTION:

DASOT first checks the globals RECWD, RECWD1, RECWD2, and RSWADR to determine which set of alternate tables should be stored in the global DASPAR parameter list for strip chart recordings. If RSWADR is clear or if there is a boolean FALSE at the address contained in RSWADR, then the "normal" table set specified in RECWD1 is used, otherwise, RECWD2 is used. RECWD contains the current configuration. If it does not match the selected pattern, then a new set of alternate tables is loaded into DASPAR. This will happen when the alternate tables have been changed through DSTAR and RECWRD is set to -1. The values in RECWD1, RECWD2, and RSWADR are user specified through task TERMAK as follow:

RSWADR: USAGE

CLEAR = The primary set of alternate tables will be written to the DASLST strip chart blocks. (RECWD1)

ADDRESS= The address of some discrete, such as MLSVAL, which will, when TRUE, cause the secondary set of alternate tables to be used. (RECWD2)

RECWD1/RECWD2: BIT MAP

```
BITS 2,1,0:  Value 0-7,  Use Alt Tables 0 - 7 for Strip Blk 1.
BITS 5,4,3:    "    "     "   "    "     "  "  "    "    "  2.
BITS 7,6  :    "   0-3,   "   "    "    8 - 11 "    "    "  3.
   E.G.: For a normal configuration of tables 0, 1 and 8,
         RECWD1 would be set to 000010 octal. For a secondary
         configuration of tables 4, 5, and 9, RECWD2 would
         be set to 000154 octal.
```

Data output is performed starting at label CONT. Because of timing limitations, this code is skipped for any cycle in which the strip chart output configuration is changed. In this case, only the code beginning at label DOIT is executed. The initial logic determines which block of code to use.

At label CONT, the status return bits are packed as follow:

SELWD1: GSDEV, HDOTB, FWHL, HRAD, HDD, R, P, Q

SELWD2: SPLR2, FLAP, CAS, DWHL, DCOL, FCOL, RTRIM,
LOCDEV
SELWD3: TAS, HBF, MACH, DRPOS, THETA, ATRIM, PEDAL,
SPLR7

Each entry rates 2 bits in the select word. The values may be 0, 1, or 2 which signify channel A, B, or C, respectively.

Next, the boolean discretes from the global MLSFC are divided and stored in the global words DMLFC and MLSOV . The discretes addressed by the local table DISLST are shifted into the global word DISOUT. The MLS/IDD position error is calculated and output in the global words LATDIF and LONDIF. Finally, the entire DASPAR list is processed with each entry being fetched, scaled and stored in the global buffer DASBF. The length of the buffer is reported in NDAS and DASOT terminates.

GLOBAL INPUTS: ALTPAR, BCFLAG, FLADM, FLRM, IDDLAT, IDDLON, LAT, LON, MLSFC,
NAVFLG, NAV64K, PATHND, RECWD, RECWD1, RECWD2, RSWADR, TOSLOW

GLOBAL OUTPUTS: DASBF, DASPAR, DISOUT, DMLFC, LATDIF, LONDIF, MLSOV, NDAS,
RECWD

TASK NAME: DSTAR (DAS/SNAP Table Access Routine)

PURPOSE: A utility to interactively build or modify parameter lists
for use by SNAP and DASOT.

LANGUAGE: MACRO-11

INVOKED BY: A. FAST (On cold start and fresh boot)
B. User (Manually)

CALLING SEQUENCE: A. FAST: CALL DSTAR
B. Manually: Put system in Hold mode.
RUN DSTAR

TASK SIZE: 6720 Words.

TASK PRIORITY: A. AUTO mode: 180
B. Manual mode: 50

TASKS INVOKED: None

RESCOMS USED: IOCOM, NAVCOM, SYMTAB

DESCRIPTION:

DSTAR fills or modifies the SNAP and DASLST tables which are used to select, format and print a prescribed set of SNAP data and to select, scale, and output a prescribed set of data to the Data Acquisition System (DAS) for recording and/or for display on the strip charts. (See SNAP and DASOT.)

There are five SNAP tables, each containing 20 words. The first five words constitute the SNAP criteria: the key word address, threshold, type of key, and window size (range). The 15 remaining entries are the addresses of the data items to be printed by the SNAP. The SNAP tables are filled directly as the data are input.

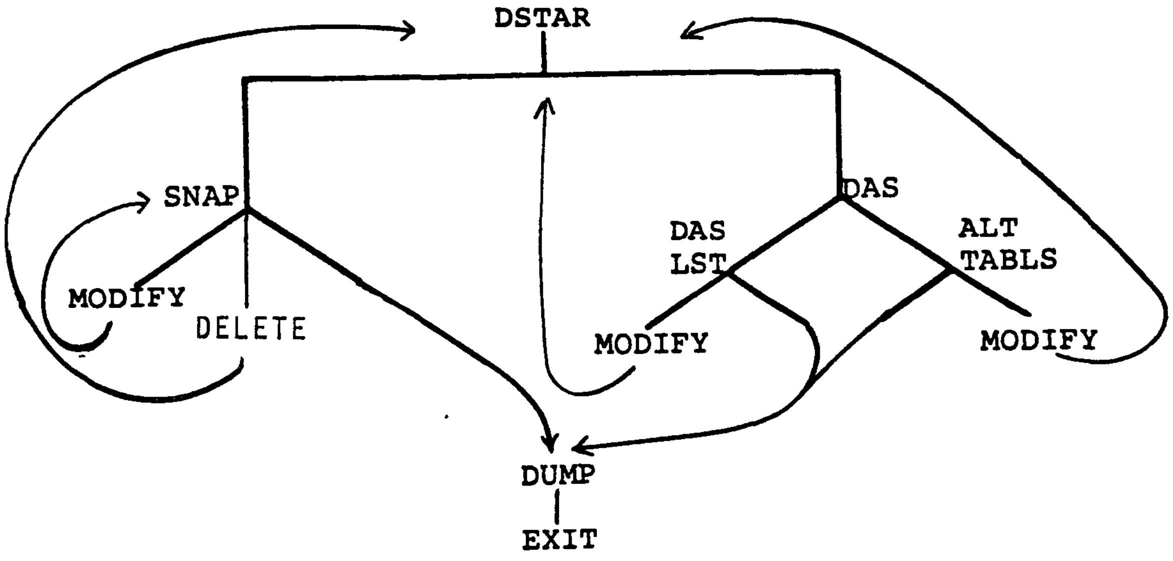
There are up to 150 entries in the DAS list, each consisting of a name, address, and scale factor. Nominally, this list is maintained in an external file, DSTDAT, which is task built with DSTAR. Within DSTDAT, the ASCII names of the variables are kept in the global block DNAME. The addresses and scale factors are kept in the global block DDATA. DSTDAT may be edited externally or modified interactively at run time. Entries may be changed, and/or new ones added up to the 150 entry limit. Entries 1 through 24 are reserved for strip chart parameters and are organized in three blocks of eight entries each. Each of these blocks corresponds with one of the 12 alternate tables which may be read into the block by subroutine DASOT. These alternate tables are maintained in the lower section of DSTDAT, each under its own global name (TABLO, TABL1, etc.) and each following the format of the primary list. Tables zero through seven relate to blocks one or two. Tables eight through 11 relate to block three and are limited to discrete data recording. The contents of DDATA and the parameters from the alternate tables are written to the global DASPAR and ALTPAR tables, respectively, during the DAS dump routine.

Therefore, after a system build, DSTAR must be run in order to fill these tables with whatever has been preset.

DSTAR has two modes of operation: manual and automatic. It is called by FAST on a cold start (COLDST) or on a fresh boot. For a cold start, DSTAR will already have been run and the various tables loaded. In this case only, the automatic mode is implemented. All I/O to the CRT and the printer is disabled and the dump routines are called to transfer all the tables. This mode is totally transparent to the user.

DSTAR is interactive and generally self-explanatory. The date must be entered on the first run after a system boot, after which a carriage return will suffice. The user is given the option to select SNAP or DAS processing, and in the latter case a sub-option to process the 12 alternate tables. Once in, the user may create, modify, delete, or add to the selected table. With DAS processing, whichever course is selected will, upon completion, return to the SNAP/DAS option. On the SNAP side, this will happen only when a SNAP table has been deleted -- all other activities end with a normal exit from the program. Therefore, if both SNAP and DAS processing are to be done, the DAS processing should be done first. See Figure 9-1.

FIGURE 9-1: FUNCTIONAL OVERVIEW.



When a name is requested, the input may be up to 10 characters and it may include a parenthetical index. E.G.: POSHAT(2). If the name matches one in SYMTAB, then the compool offset and data type will be calculated automatically, otherwise, they will be requested. If necessary to use different names to facilitate data reduction, or to name an array element, etc., the user may concoct a unique name and then enter the desired compool and offset information.

With SNAP processing, consecutive elements of a vector or an array may be specified by entering a "repeat" factor after the first element number, as follows: "POSHAT(1*3)". This will cause elements one, two and three of POSHAT to be entered into the SNAP table. The data entered for element one will be copied over for elements two and three

There are two normal ways to exit DSTAR: by selecting a dump through one of the option menus, or by entering CTRL-Z at any time after the date entry. In either case, dump activation is identical. If a dump flag is set, then the corresponding tables are dumped to the printer. The DAS and alternate table dump flags are initialized "ON" because these tables may have preset data which must be transferred to the DASPAR AND ALTPAR tables for DASOT. The SNAP tables can only be loaded interactively, at which time the flag will be set. Consequently, if the CTRL-Z exit is taken immediately after date entry, only the DAS and alternate tables will be dumped. The case by case results of dump activation are shown below in Figure 9-2.

Error checking is generally limited to identifying and avoiding gross errors, usually in input. Error messages are not displayed, but the last prompt or series of prompts is repeated. The user may correct erroneous entries through the modify options. However, if the error is in the SNAP key variable parameters, it will be necessary to re-enter the entire table.

FIGURE 9-2:

DUMP TO PRINTER: VARIATIONS

WHERE	TYPE	TABLES DUMPED		
INITIATED	INITIATION	DASLST	ALTERNATE	SNAP
DATE ENTRY	CTRL-Z	*	*	0
IN DAS MOD	CTRL-Z	X	*	0
"	"0"	X	X	0
IN ALT MOD	CTRL-Z	*	X	0
"	"Y"	*	X	0
IN SNAP MOD	CTRL-Z	*	*	X
"	"0"	*	*	X
ANYWHERE	CTRL-Z	*	*	*

* The DASLST and Alternate Tables will be dumped on the first call to DSTAR. Thereafter, a set of tables will be dumped only if the modification routine for that set was entered, causing the dump flag to be set.

GLOBAL OUTPUTS:
ALTPAR, DASPAR, DDATA, DNAME, DSTDAT, SCRIT1 thru SCRIT5, SDATA, TABLO thru TABL11

MODULES CONTAINED: DSTDAT, LABEL

VIRTUAL MEMORY MAP;

```
          . BLK.: 001334 030620 12688.
                  001374 020702 08642. DSTAR.OBJ
                  022236 007540 03936. DSTDAT.OBJ
                  031776 000156 00110. LABEL.OBJ
          BCKCOM: 160000 000252 00170.
          DISNAV: 140000 013200 05760.
          FCPOOL: 160252 000766 00502.
          FMBFCM: 153200 004410 02312.
          IOPOOL: 161240 001252 00682.
          NAVCOM: 162512 005034 02588.
          RECOM : 167546 003640 01952.
          SYMTAB: 120000 012457 05423.
```

MODULE NAME: DSTDAT

PURPOSE: To provide a list of data parameters for recording.

TASK: DSTAR

LANGUAGE: MACRO-11

CALLS TO: REAL & INTEG (internally)

CALLED BY: None (Components are addressed by their global names: DNAME, DDATA, TABLE0, TABLE1, etc.)

CALLING SEQUENCE: N/A

DESCRIPTION:

DSTDAT is the component of the DSTAR task which contains the default list of data from the Flight Controls/Flight Management computer to be recorded by the Data Acquisition System (DAS). It contains up to 150 names and corresponding scale factors. Of these, the first 24 specify the output to the strip chart recorders. There is also a group of 12 alternate tables with eight entries each. Three of these may be selected during flight to be read into the strip chart block entries one through twenty-four.

The first section of DSTDAT, labeled DNAME, consists of up to 150 ASCII names. These fields are used only for identification purposes. No calculations are based on them and the names need not be otherwise defined. The fields must include exactly 10 characters, including blanks. However, the fields may not include a right-leaning slash since this symbol terminates an ASCII declaration. An example follows:

```
.ASCII    /MLSSVCRNG /    ;
```

Two MACRO functions, REAL and INTEG, are included to convert the data declarations to floating point or integer format at assembly time. This is the only "functional" code in DSTDAT.

The next section, labeled DDATA, contains the data declarations which correspond to the names in the DNAME section. Each line entry consists of a function call to INTEG or REAL, the global name of the data, a scale factor, and a comment section. For example:

```
REAL      IDDXTK,10.          ; 83 IDDXTK     FPS2
INTEG     FOG,2048.           ; 84 FO (DME3)  PACKED DISCRETE
```

The first two fields are self-explanatory.

The third field, the scale factor, is a decimal number which determines how the data will appear on a strip chart, either on the aircraft or in the post-flight data reduction phase. Starting from a value of zero at the centerline of the chart, the scale is the number at which the needle will be at the edge of the chart. When this limit is exceded, the recorder "wraps-around"; the needle jumps to one side or the other and continues reflecting relative changes in the data. Thus, aircraft altitude, scaled at 500.0, would wrap quickly as the aircraft climbs or descends, but it would give a good record of small changes from level flight. Scaled at its maximum range, say 40,000 feet, the resolution of the altitude plot would be very poor.

Scale factor determination must consider the resolution available in the DAS and on the strip chart recorders. The DAS records the most significant 16 bits of data. The recorders can display only 12 bits, including the sign bit. The on-board recorder displays the most significant 12 bits. In post-flight analysis, the recorders can display any 12 bit string in the word.

If data of large magnitude is scaled to display small changes on the strip chart and if it is also necessary to record it at its actual magnitude, then it can be recorded twice. However, to permit post-flight reconstruction, the scale factors must be determined such that there is an overlap of significant bits. This can be done by relating the scale factors to some power of 2, up to 2 ** 15. For example:

```
REAL    POSHAT+10,100.        ; 53 ZHATF      FEET
REAL    POSHAT+10,204800.     ; 54 ZHATC      FEET
```

The 100 scale factor for ZHATF will produce good resolution for small changes. At 100 * (2**11) the scale for ZHATC, 204800 feet, is slightly more than the maximum range of ZHAT (32 miles) and it provides a 5 bit overlap in the 16 bit words.

Boolean data items are usually scaled at 2048, which equates to full displacement of the needle.

The comment section of a DDATA line also requires attention because some of the fields are parameters for one of the data reduction programs (CALDAS). The line length may not exceed 72 columns. The last word on the line specifies the unit of measurement. This field may not exceed 10 characters and it may not contain embedded blanks, commas, or slashes. Left-leaning slashes and underlines are acceptable. Any type of unit may be specified, but discretes must be indicated by the word "discrete". In the case of a "packed discrete", then those two words must be present. Abbreviations are not acceptable.

The alternate tables are short versions of DNAME and DDATA. Each table contains 8 ASCII name lines, followed by 8 global names with scale factors. Tables 0 through 7 are for real or integer data. Tables 8 through 11 may contain only booleans, defined as integers (INTEG). In these tables, comments are optional.

GLOBAL INPUTS: None

GLOBAL OUTPUTS: None

NAME: SNAP (SNAPshot recording routine)

PURPOSE: To record snapshot values of user specified variables according to user defined parameters.

LANGUAGE: MACRO-11

CALLED BY: FAST

CALLING SEQUENCE: CALL SNAP

CALLS TO: None

DESCRIPTION:

The SNAP routine records single-event values, called snapshots, for selected variables and stores them in the SDATA table in NAVCOM for subsequent output to the line printer by the SNPOUT routine. There are 5 snapshot criteria tables (SCRIT_), each of which contains a key variable address, the criteria under which that variable should cause a snapshot recording, and a list of up to 15 addresses for the data to be sampled when a snapshot occurs. (See the SCRIT1 comments in the RECOM listing.)

Snapshot variables and parameters are specified by the user through the task DSTAR.

On the first run after a system boot the local START flag will have been set. SNAP clears the flag and sets the appropriate index (0 - 4) in the SADR field of each SCRIT_ table. SNAP then checks the SNAP reset flag, SRST, and, if set, clears the store pointer (SPTR), the read pointer (RPTR), and SRST. All three are globals defined in RECOM.

SNAP then processes each of the 5 SCRIT tables in turn, or until it finds an empty key variable field (SVARA). If the key variable is an integer or a floating point value, it is procesed at the local labels INTG or FLTP. If not, it is assumed to be a boolean and is compared with the threshold SVART in the SCRIT table. If it matches, the snapshot is processed at the local label FLG.

At the label INTG, if the type of comparison specified in SCRIT_(STYPE) is "=", the value is checked for approximate equality with the threshold by incorporating the range from SCRIT_(SVARS). If within the window, the snapshot is processed at label FLG. If the type of comparison is a "<" or ">" the key and threshold are checked for that relationship and, if the condition is met, the snapshot is processed at the label FLG.

At label FLTP, floating point key variables are processed like integers except that floating point operations are forced to compute 16 bit values by setting a 16 bit floating point operand (eg., the threshold) in the second word of the floating point instruction.

At the label FLG, if bit 15 of SCRIT_(STYPE) is set, then that snapshot has already been done and control passes to the local label NXT2. If not done, the "done" flag is set, the title index is moved to SDATA, followed by the values of up to 15 variables listed in the address table SCRIT_(SADR). Processing stops at 15 or at the first empty address field. Unused buffer space is cleared, the storage pointer (SPTR) is incremented (Modulo-4), and, at NXT2, the next snapshot is initiated or SNAP terminates.

GLOBAL INPUTS: SCRIT1, SCRIT2, SCRIT3, SCRIT4, SCRIT5, SRST

GLOBAL OUTPUTS: SCRIT1, SCRIT2, SCRIT3. SCRIT4, SCRIT5, RPTR, SPTR, SRST, SDATA

NAME: SNPOUT (SNaPshot OUTput Routine)

PURPOSE: To format and print snapshot recordings on the aircraft line printer.

LANGUAGE: MACRO-11

TASK: SLOW

CALLED BY: SLOW

CALLING SEQUENCE: CALL SNPOUT

CALLS TO: None

DESCRIPTION:

SNPOUT prints out SNAP data whenever new snapshots have been added to the SNAP buffer (SDATA). The global counter SPTR is set by the SNAP routine when new SNAP data is stored. The global counter RPTR is incremented in SNPOUT when it is printed. If the two counters do not agree, then one or more SNAP lists remain to be printed. Both counters are Modulo 4. SNPOUT prints one SNAP list per call.

SNPOUT first increments the read counter RPTR and then formats a header line with the SNAP number and the system time, storing these in the output buffer. It then takes one entry at a time from the table SDATA, checks the form (floating point, boolean or integer), performs the necessary conversions, and stores the ASCII value in the buffer. It repeats this for 5 entries per line, for 3 lines, or until the data location in SDATA is empty. It prints the output buffer and returns.

GLOBAL INPUTS: HRSS, MINS, RPTR, SCRIT1, SCRIT2, SCRIT3, SCRIT4, SCRIT5, SDATA

GLOBAL OUTPUTS: IOACT, RPTR

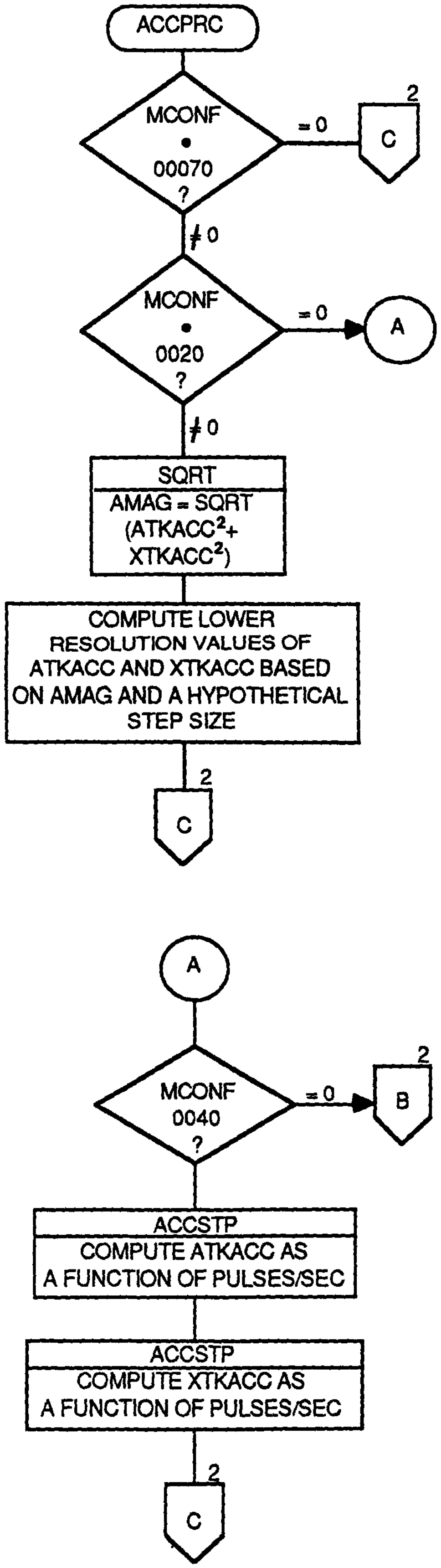
ADVANCED TRANSPORT OPERATING SYSTEM SOFTWARE UPGRADE

FLIGHT MANAGEMENT / FLIGHT CONTROLS SOFTWARE DESCRIPTION

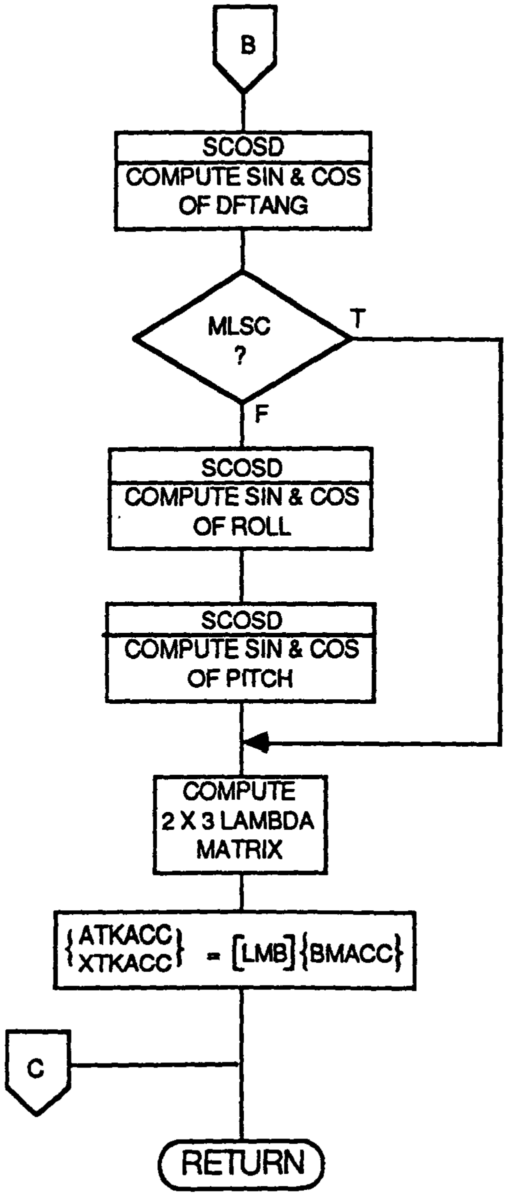
Appendix A
Flowcharts

Appendix B
Digital Systems Diagrams

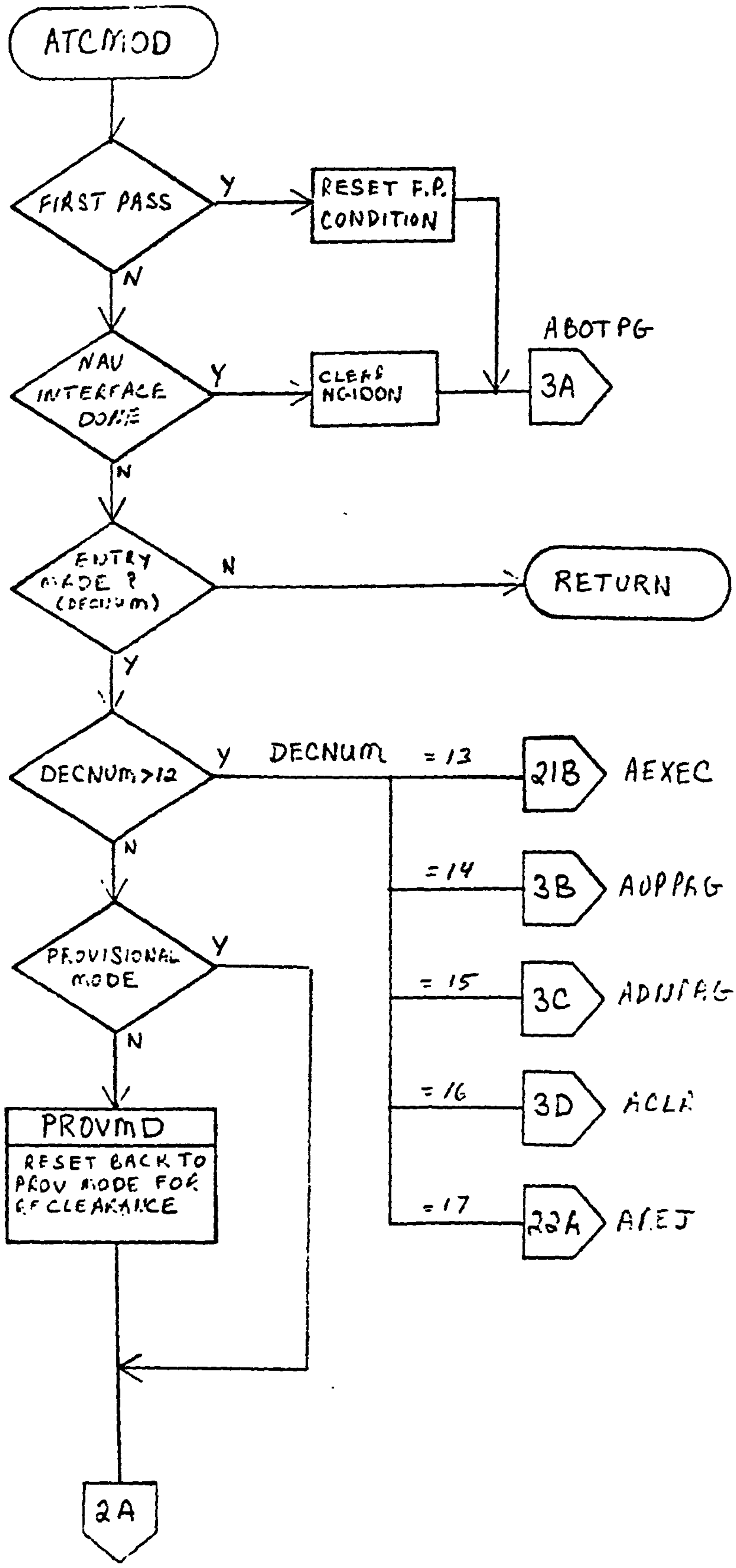
ALPHABETIC LIST OF FLOWCHARTS


ACCPRC
MCONF • 00070 ?
= 0
2
C
≠ 0
MCONF • 0020 ?
= 0
A
≠ 0
SQRT
AMAG = SQRT (ATKACC² + XTKACC²)
COMPUTE LOWER RESOLUTION VALUES OF ATKACC AND XTKACC BASED ON AMAG AND A HYPOTHETICAL STEP SIZE
2
C
A
MCONF 0040 ?
= 0
2
B
ACCSTP
COMPUTE ATKACC AS A FUNCTION OF PULSES/SEC
ACCSTP
COMPUTE XTKACC AS A FUNCTION OF PULSES/SEC
2
C

ACCPRC
(PAGE 1 OF 2)

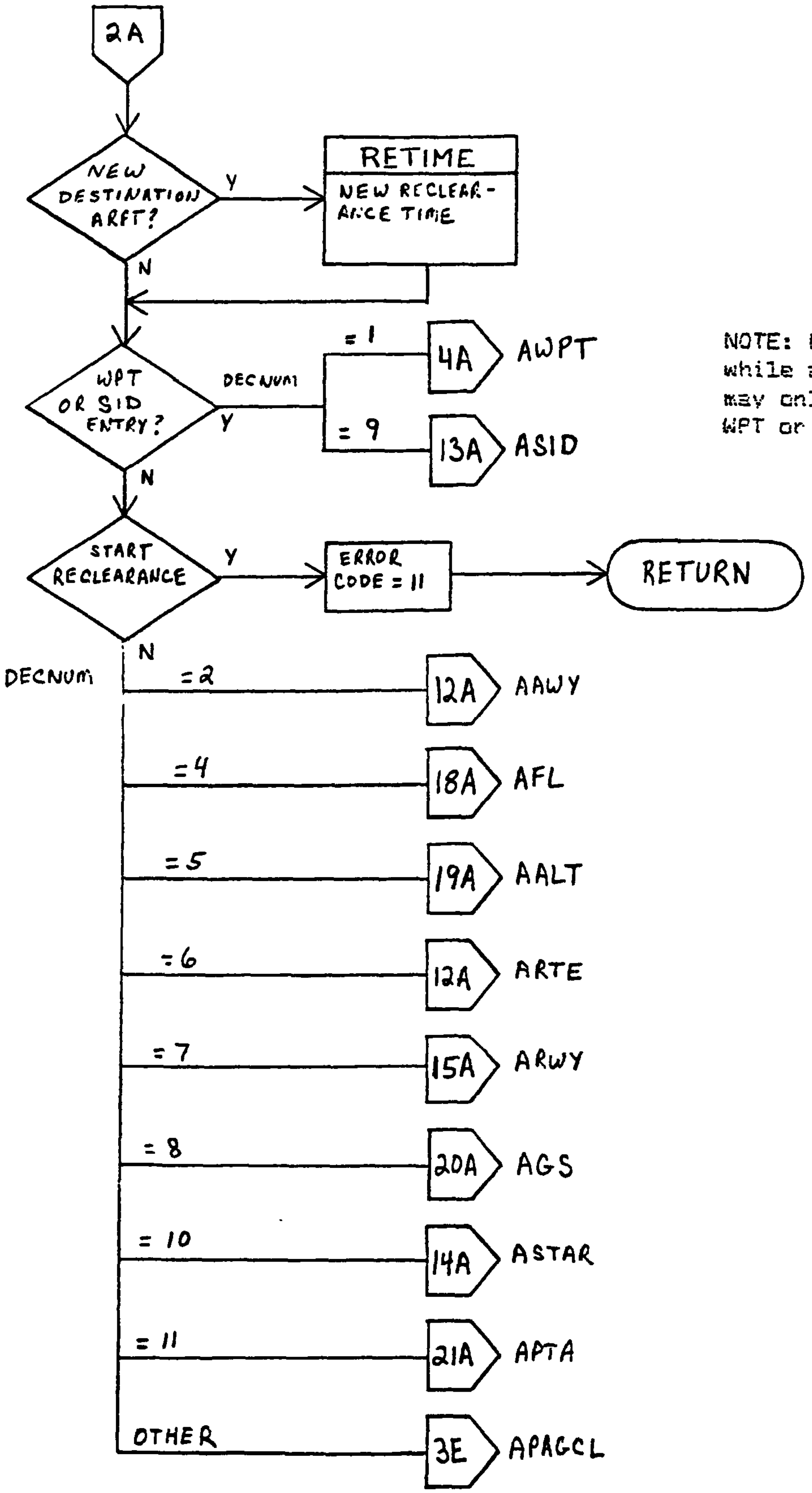

B
SCOSD
COMPUTE SIN & COS OF DFTANG
MLSC ?
T
F
SCOSD
COMPUTE SIN & COS OF ROLL
SCOSD
COMPUTE SIN & COS OF PITCH
COMPUTE 2 X 3 LAMBDA MATRIX
{ATKACC XTKACC} = [LMB]{BMACC}
C
RETURN

ACCPRC
(PAGE 2 OF 2)

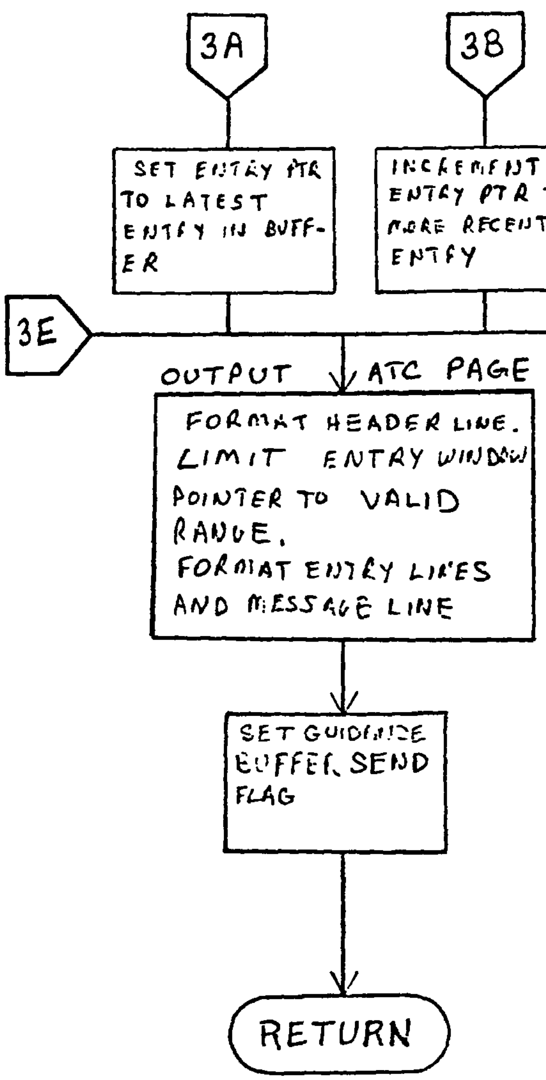


NOTE: Path definition functions are requested by ATCMOD. When they are completed, the NAV interface flag (NGIDON) is set so the busy message can be cleared and NCDU functions can continue.

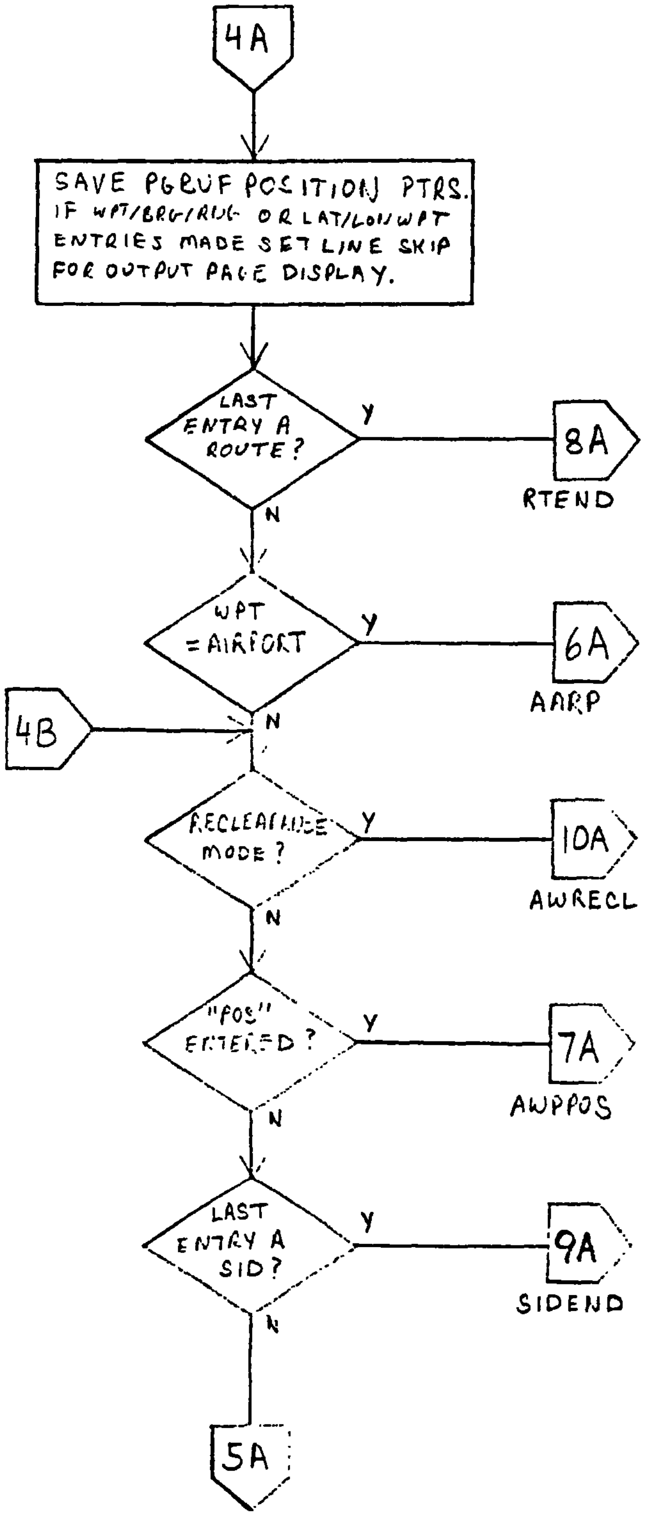
NOTE: All functions except REJ cause AREJ1 to be cleared. AREJ1 is a flag that is used to keep track of 2 consecutive REJ function presses.



NOTE: Reclearance (clearance while an active path exists) may only be initiated by the WPT or SID function keys.

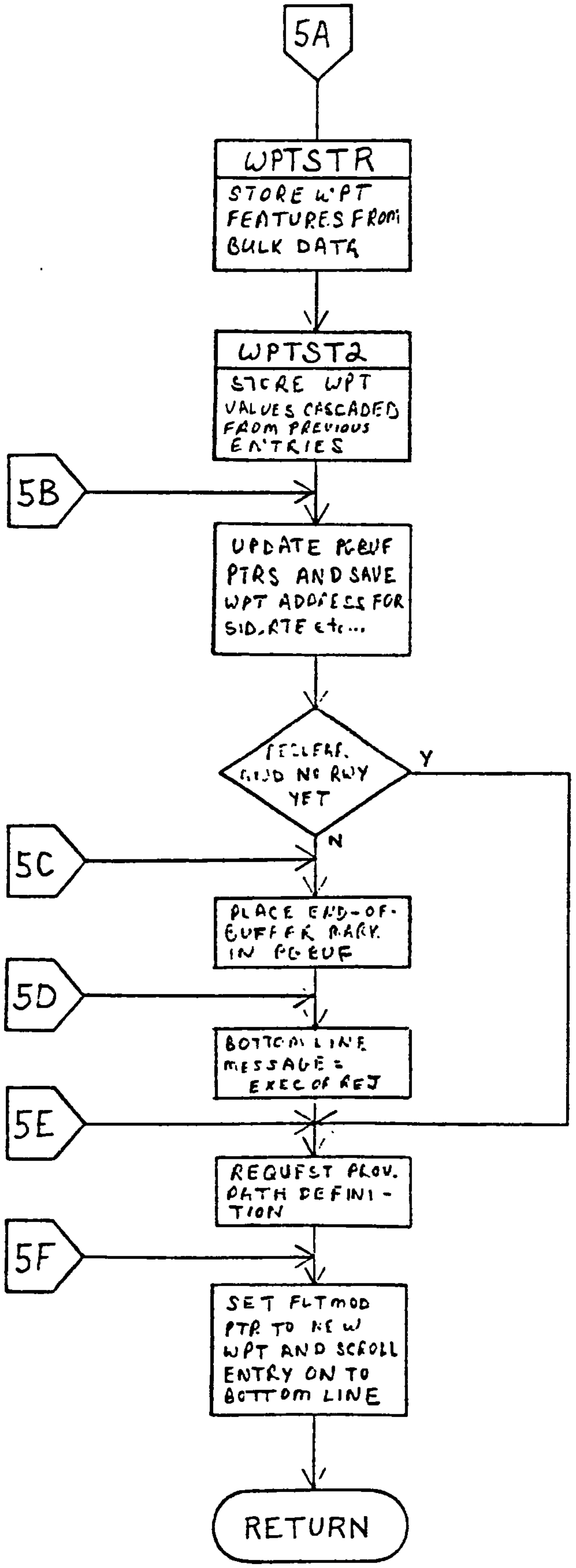

3A
3B
3C
3D
SET ENTRY PTR TO LATEST ENTRY IN BUFFER
INCREMENT ENTRY PTR TO MORE RECENT ENTRY
DECREMENT ENTRY PTR TO LESS RECENT ENTRY
CLEAR LINE #8 ERROR MESSAGE PTR
3E
OUTPUT ATC PAGE
FORMAT HEADER LINE.
LIMIT ENTRY WINDOW POINTER TO VALID RANGE.
FORMAT ENTRY LINES AND MESSAGE LINE
SET GUIDANCE BUFFER SEND FLAG
RETURN

NOTE: The NCDU display for the ATC page consists of a header line, 6 lines of user entries and the bottom message line. The user entry lines are scrolled upward, with the most recent user entry always appearimg on the sixth line. The ATC page remembers 19 lines of user entry, so scrolling can be done by using the UP/DOWN function keys. A pointer is used to mark the offset in the user entry buffer to designate which user entry is the current sixth line of the 6 line display window. The bottom line is used to display prompts and error messages.



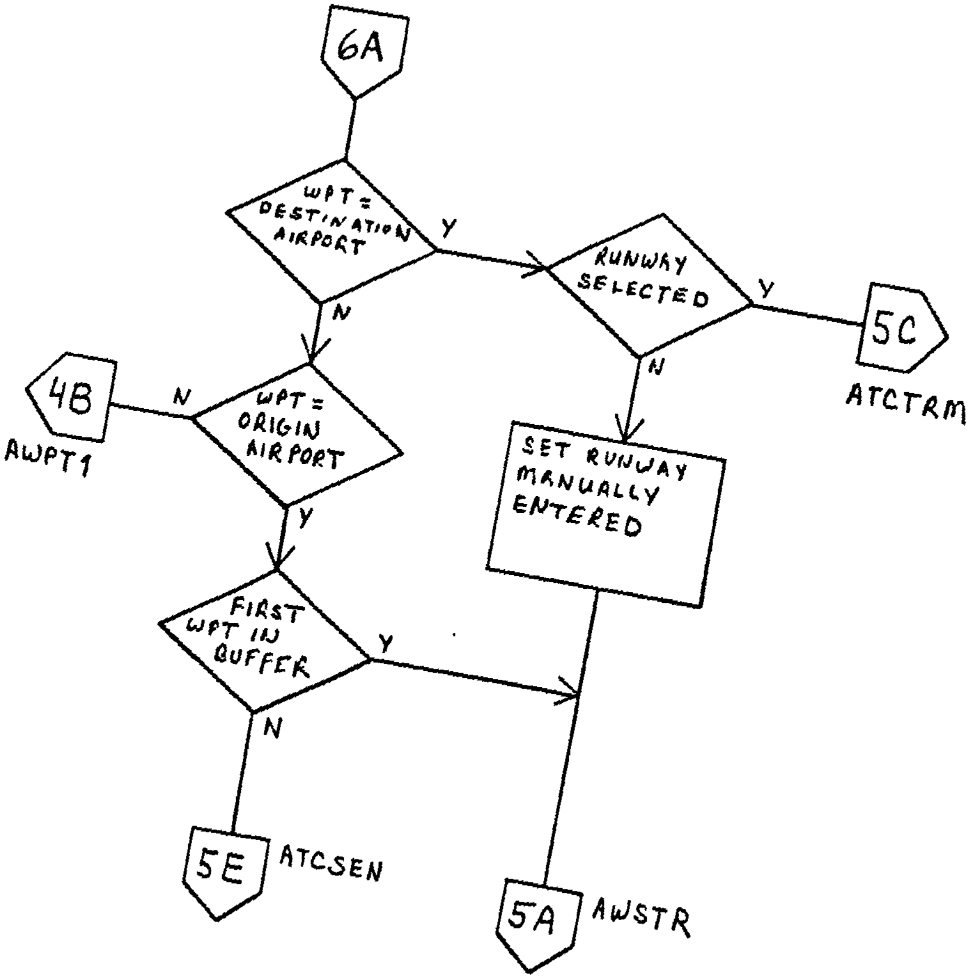
NOTE: ATCMOD stores waypoints in the provisional guidance buffer (PGBUF) and keeps track of the next insertion position with the pointers PPTR2D (byte offset) and PWPPTR (wpt number). Since many waypoints can be stored with one entry (STAR etc..), the last pointer positions must be saved in case of the last user entry being rejected.

NOTE: If the user entry filled much of the input line, line skip is set so wpt description entries such as ALT will appear on the line below the long entry.

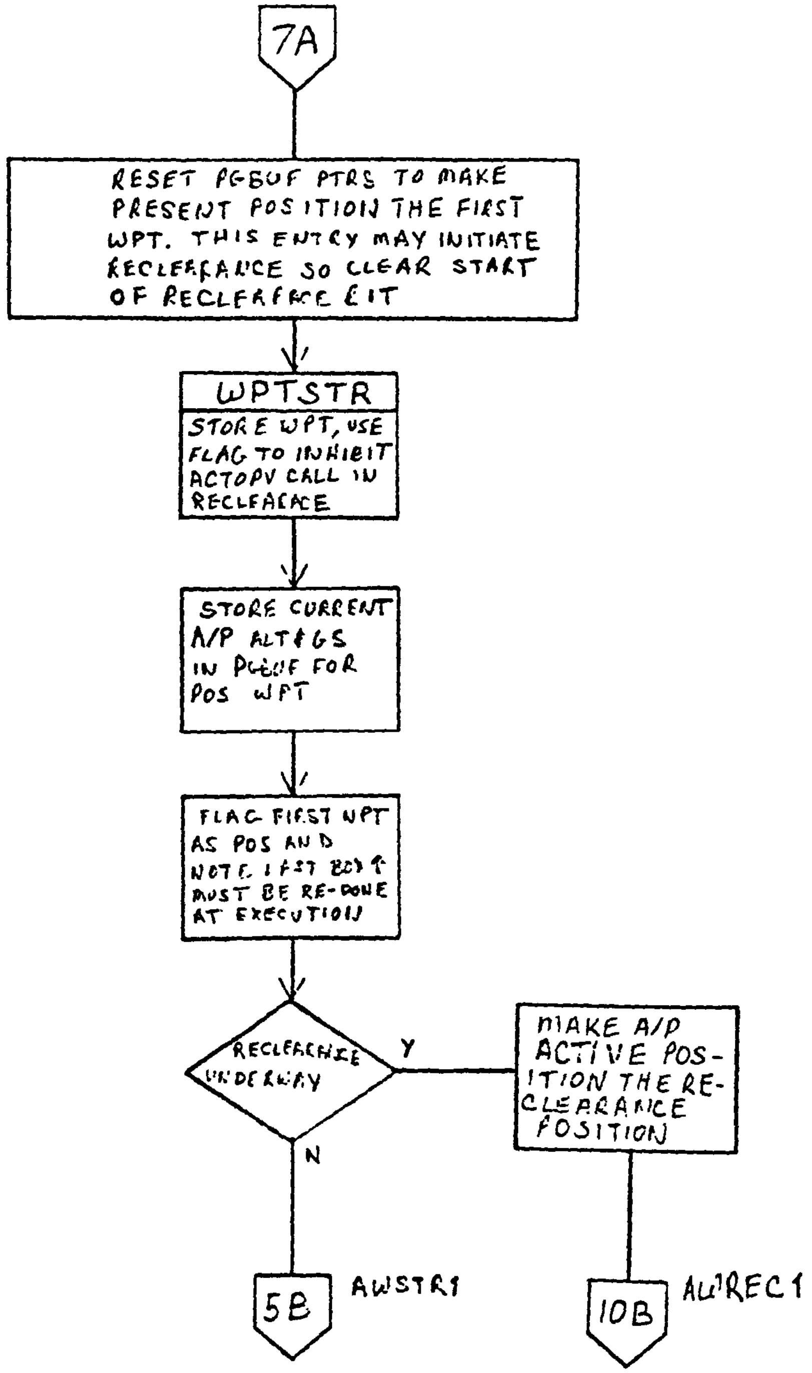

5A
WPTSTR
STORE WPT FEATURES FROM BULK DATA
WPTST2
STORE WPT VALUES CASCADED FROM PREVIOUS ENTRIES
5B
UPDATE PGBUF PTRS AND SAVE WPT ADDRESS FOR SID,RTE etc...
DECLEAR. GUID NO RWY YET
Y
N
5C
PLACE END-OF-BUFFER MARK IN PGBUF
5D
BOTTOM LINE MESSAGE = EXEC OR REJ
5E
REQUEST PROV. PATH DEFINITION
5F
SET FLTMOD PTR TO NEW WPT AND SCROLL ENTRY ON TO BOTTOM LINE
RETURN

ORIGINAL PAGE IS
OF POOR QUALITY

ATCMOD
(PAGE 5 OF 37)

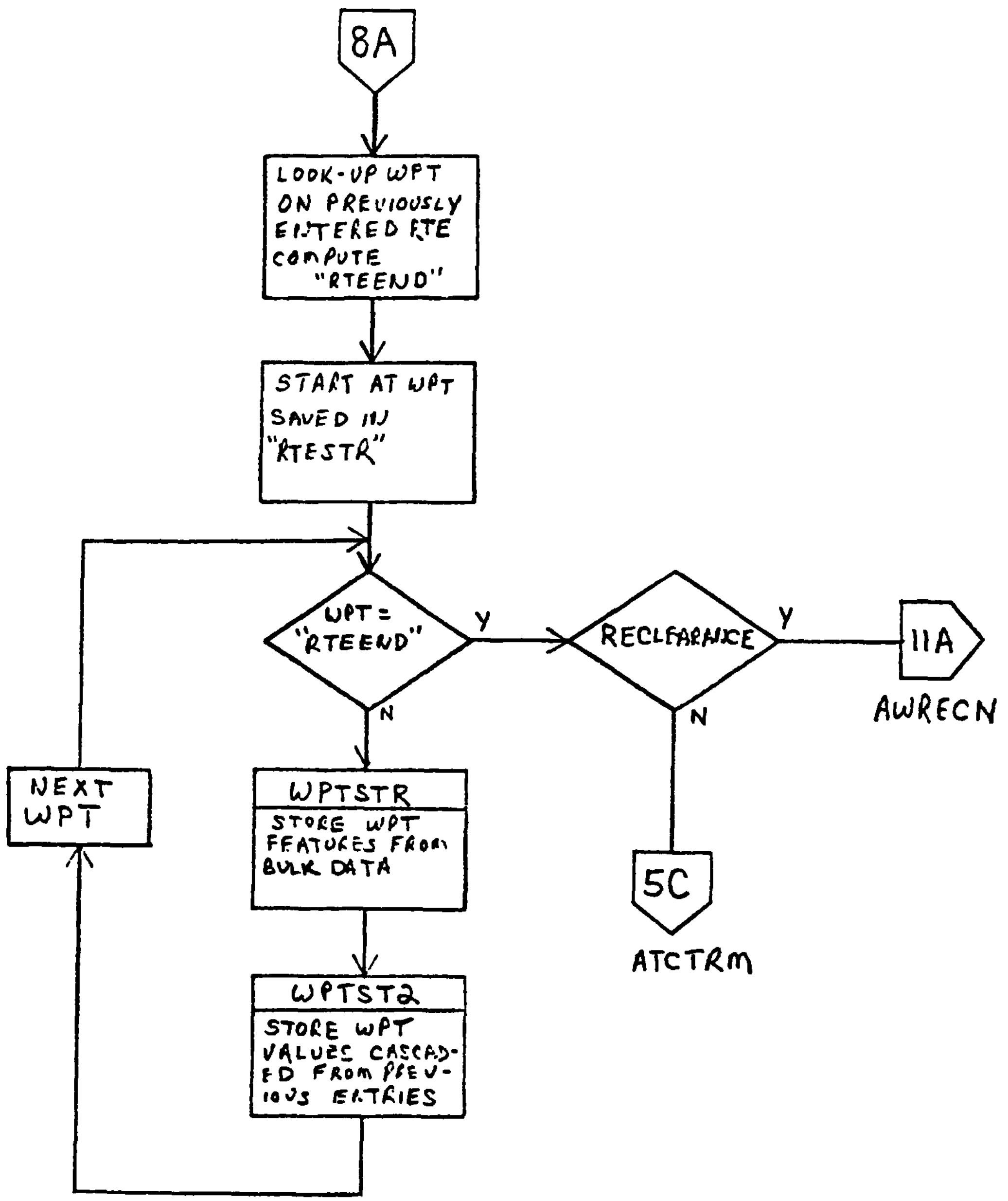


ORIGINAL PAGE IS OF POOR QUALITY

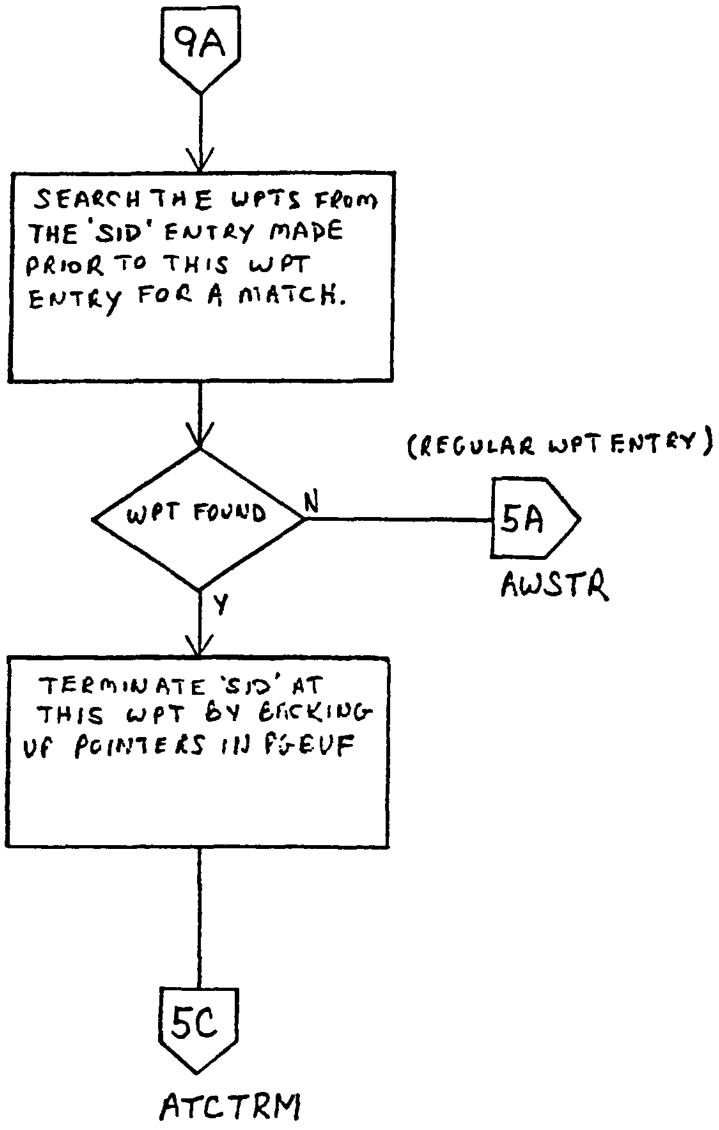

7A
RESET PGBUF PTRS TO MAKE PRESENT POSITION THE FIRST WPT. THIS ENTRY MAY INITIATE RECLEARANCE SO CLEAR START OF RECLEARANCE BIT
WPTSTR
STORE WPT, USE FLAG TO INHIBIT ACTOPV CALL IN RECLEARANCE
STORE CURRENT A/P ALT & GS IN PGBUF FOR POS WPT
FLAG FIRST WPT AS POS AND NOTE LAST BCN MUST BE RE-DONE AT EXECUTION
RECLEARANCE UNDERWAY
Y
N
MAKE A/P ACTIVE POSITION THE RECLEARANCE POSITION
5B
AWSTR1
10B
AWREC1

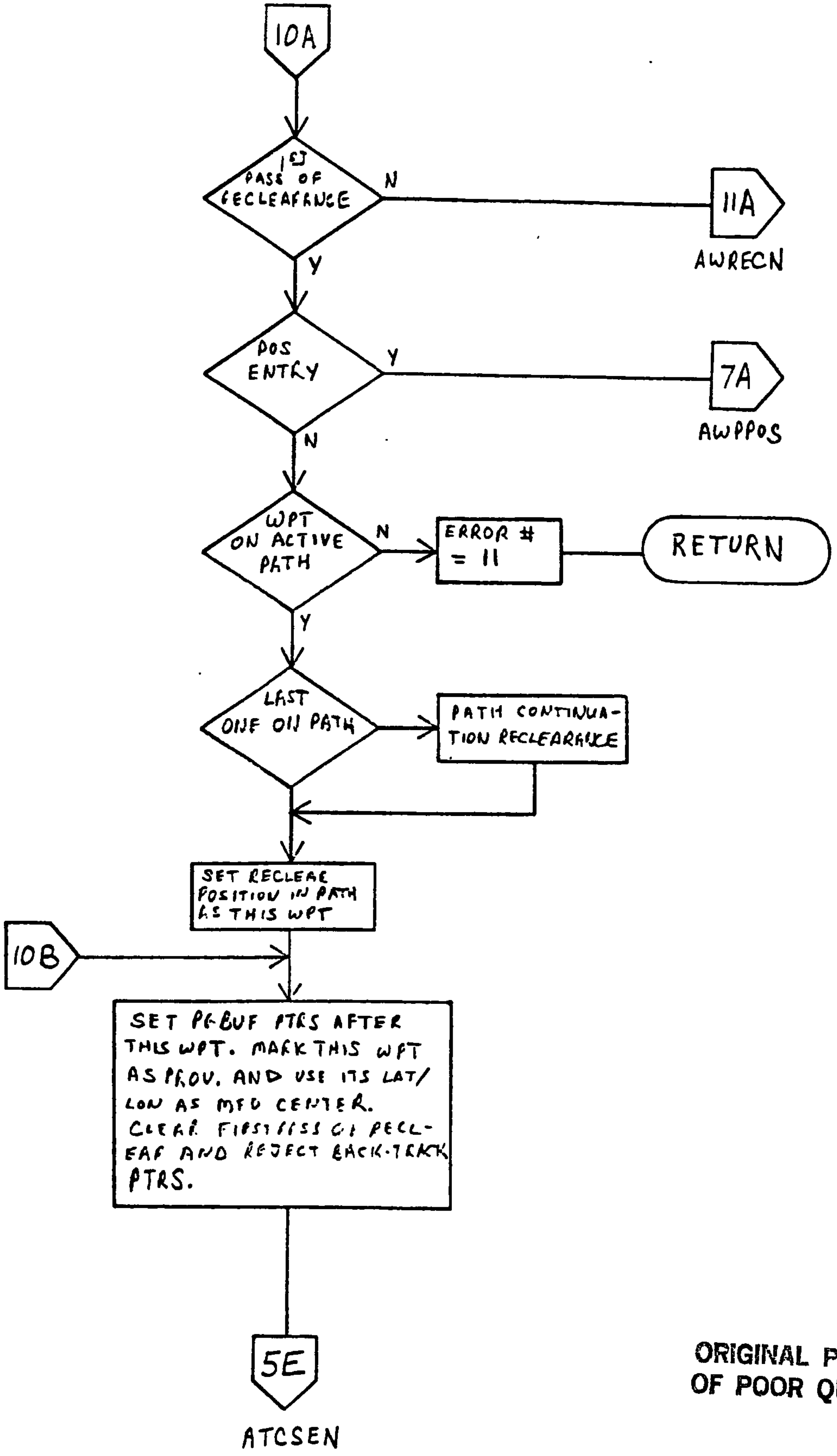
ORIGINAL PAGE IS
OF POOR QUALITY

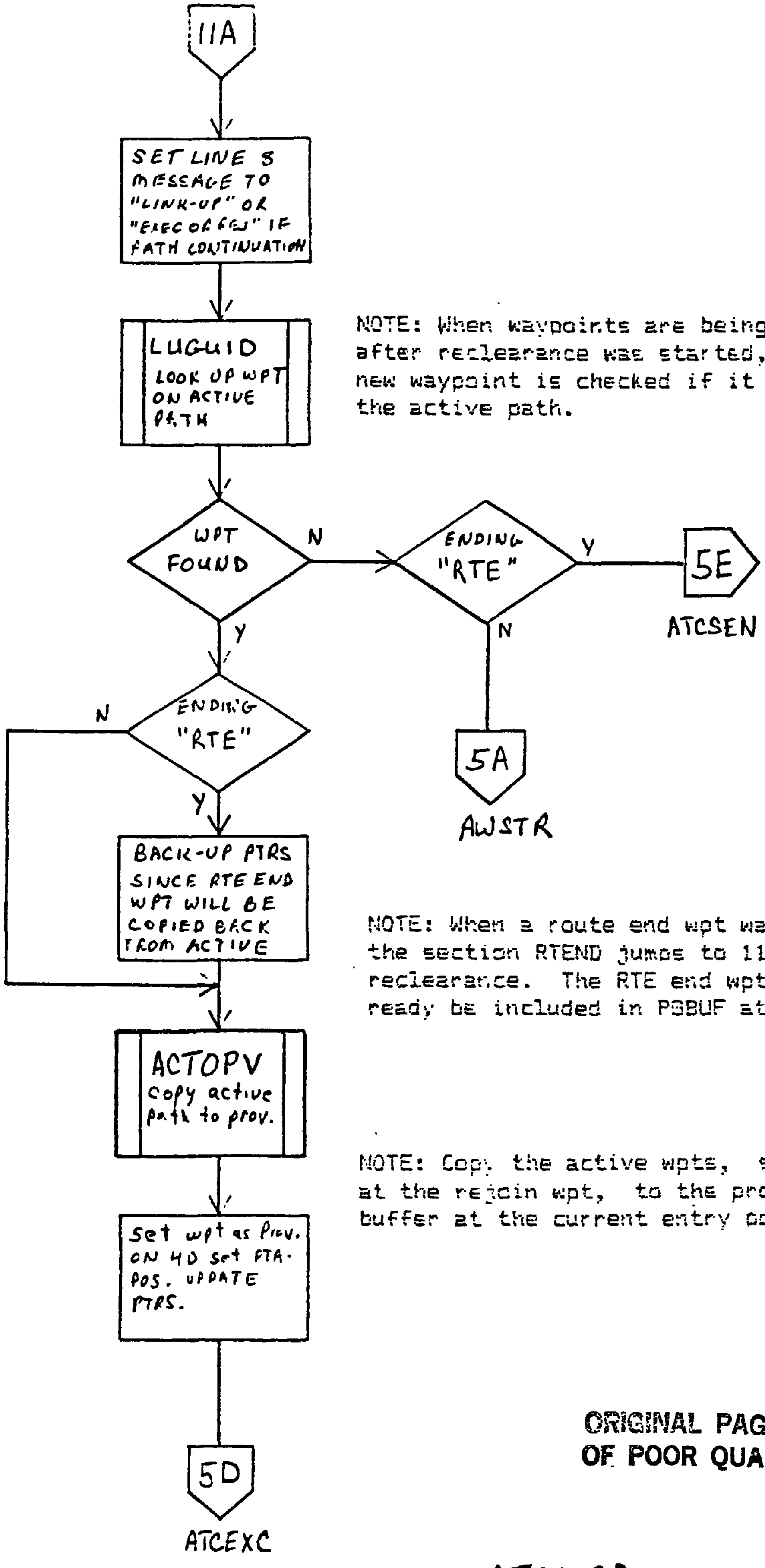
ATCMOD
(PAGE 7 OF 37)


8A
LOOK-UP WPT ON PREVIOUSLY ENTERED RTE COMPUTE "RTEEND"
START AT WPT SAVED IN "RTESTR"
WPT = "RTEEND"
Y
N
RECLEARANCE
Y
N
11A
AWRECN
5C
ATCTRM
NEXT WPT
WPTSTR
STORE WPT FEATURES FROM BULK DATA
WPTST2
STORE WPT VALUES CASCADED FROM PREVIOUS ENTRIES

SEE NOTE ON PAGE # 12


9A
SEARCH THE WPTS FROM THE 'SID' ENTRY MADE PRIOR TO THIS WPT ENTRY FOR A MATCH.
WPT FOUND
N
(REGULAR WPT ENTRY)
5A
AWSTR
Y
TERMINATE 'SID' AT THIS WPT BY BACKING UP POINTERS IN PGBUF
5C
ATCTRM

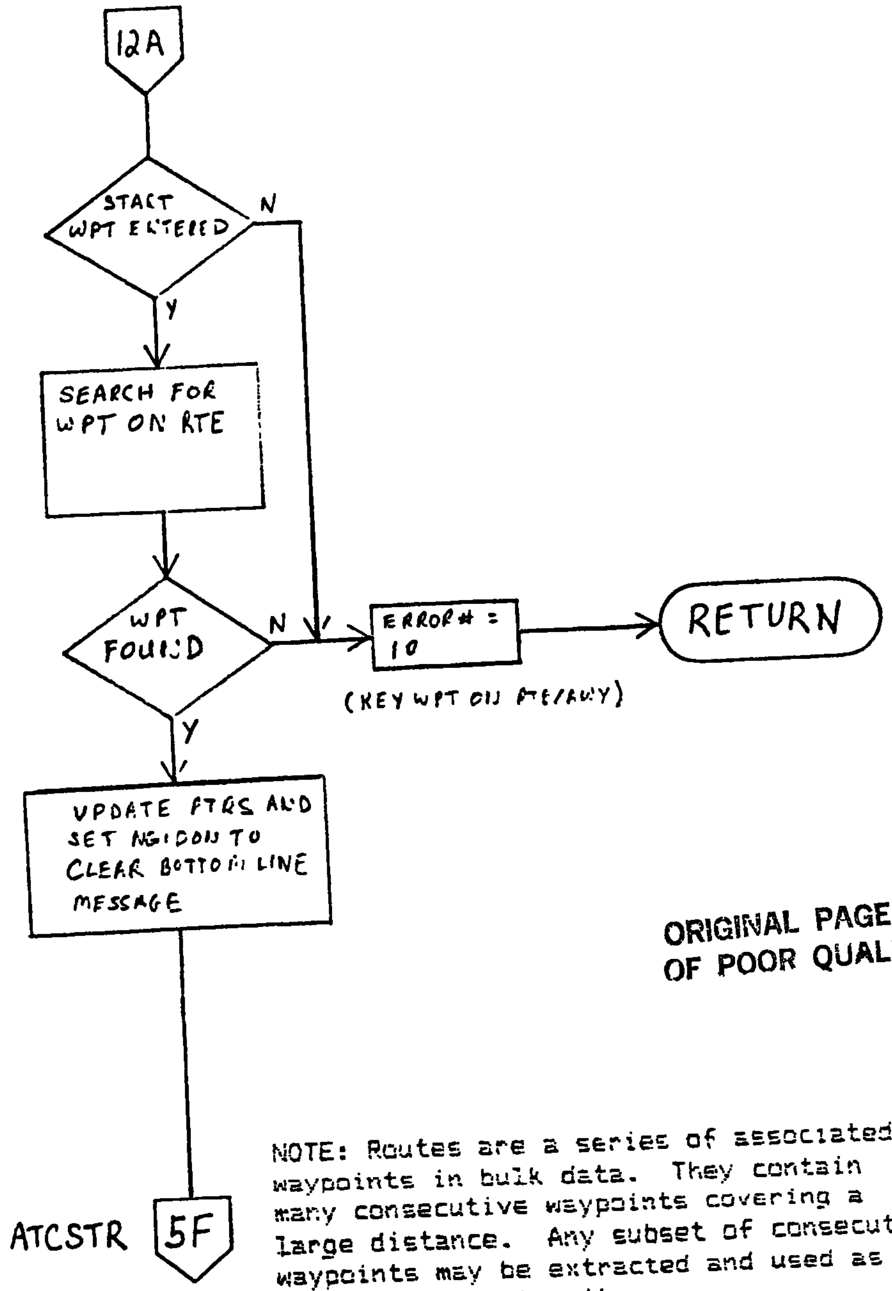

10A
1ST PASS OF RECLEARANCE
N
11A
AWRECN
Y
POS ENTRY
Y
7A
AWPPOS
N
WPT ON ACTIVE PATH
N
ERROR # = 11
RETURN
Y
LAST ONE ON PATH
PATH CONTINUATION RECLEARANCE
SET RECLEAR POSITION IN PATH AS THIS WPT
10B
SET PGBUF PTRS AFTER THIS WPT. MARK THIS WPT AS PROV. AND USE ITS LAT/LON AS MFD CENTER. CLEAR FIRSTPASS OF RECLEAR AND REJECT BACK-TRACK PTRS.
5E
ATCSEN


11A
SET LINE 8 MESSAGE TO "LINK-UP" OR "EXEC OR FCJ" IF PATH CONTINUATION
LUGUID
LOOK UP WPT ON ACTIVE PATH
WPT FOUND
N
ENDING "RTE"
Y
5E
ATCSEN
N
5A
AWSTR
Y
N
ENDING "RTE"
Y
BACK-UP PTRS SINCE RTE END WPT WILL BE COPIED BACK FROM ACTIVE
ACTOPV
copy active path to prov.
Set wpt as Prov. ON 4D set FTA-POS. UPDATE PTRS.
5D
ATCEXC

NOTE: When waypoints are being entered, after reclearance was started, each new waypoint is checked if it rejoins the active path.

NOTE: When a route end wpt was entered, the section RTEND jumps to 11A under reclearance. The RTE end wpt will already be included in PSBUF at this point.

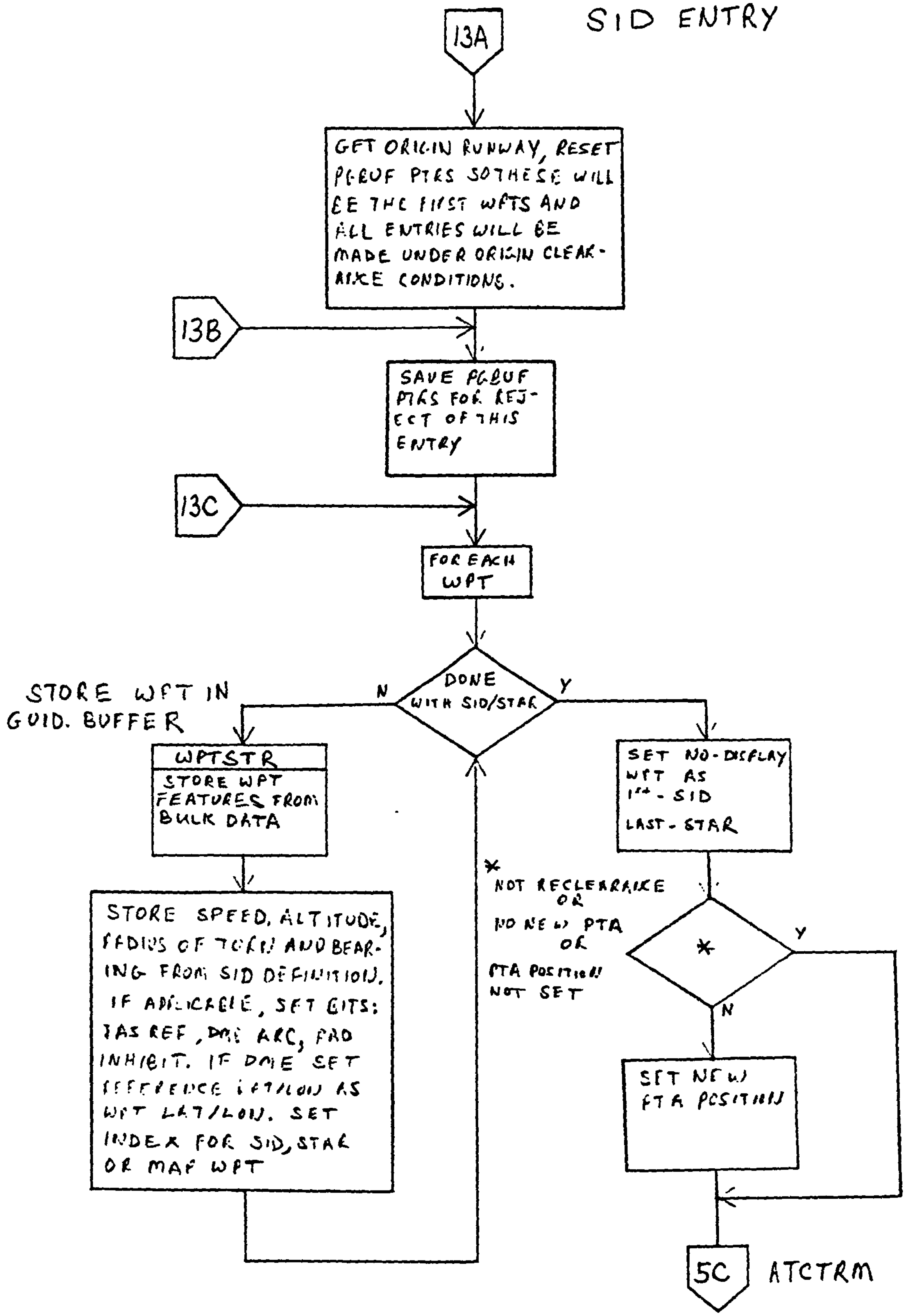
NOTE: Copy the active wpts, starting at the rejoin wpt, to the provisional buffer at the current entry position.

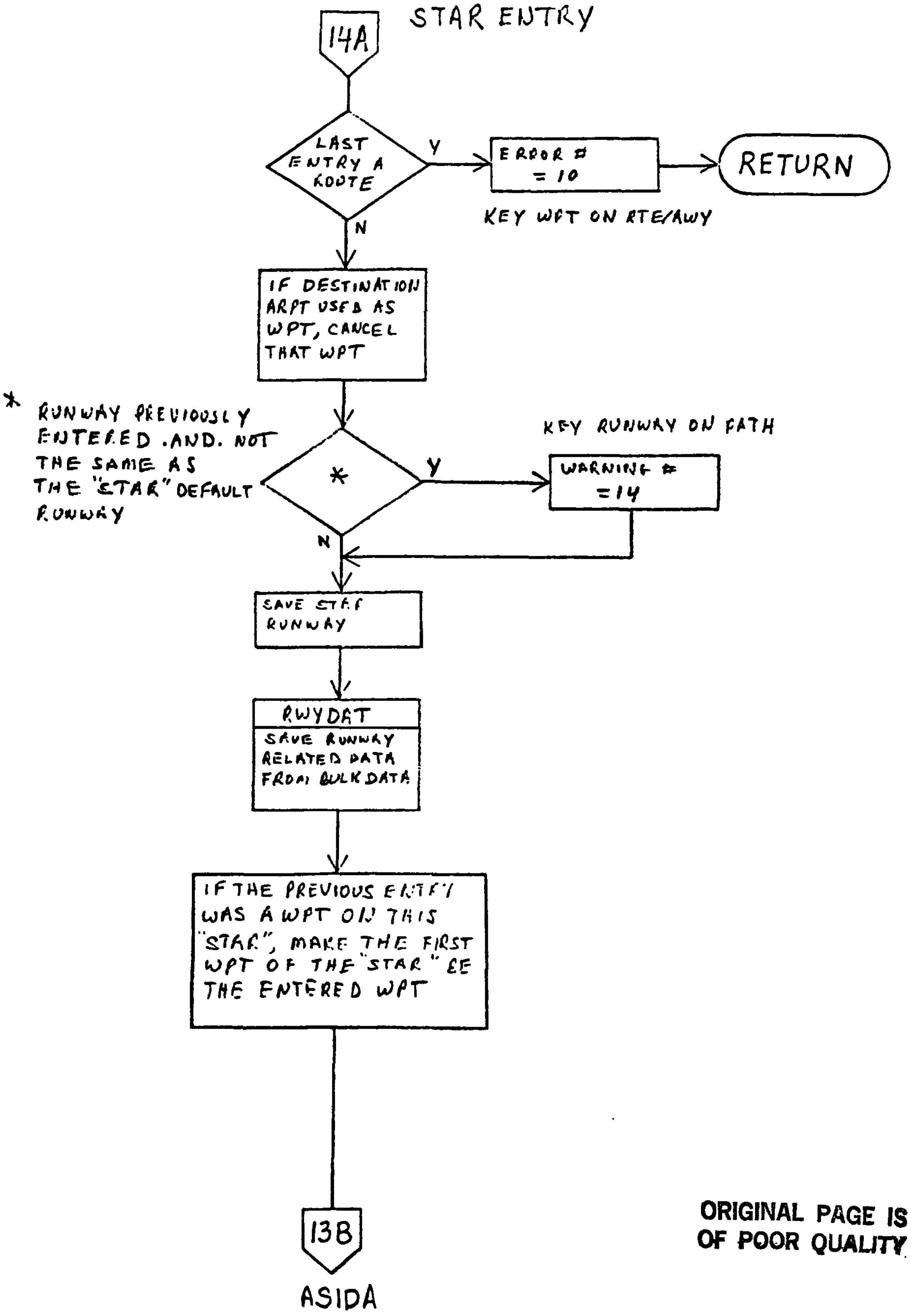


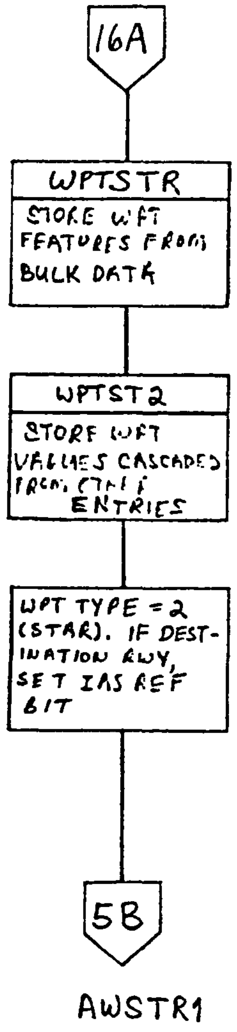
NOTE: Routes are a series of associated waypoints in bulk data. They contain many consecutive waypoints covering a large distance. Any subset of consecutive waypoints may be extracted and used as part of a flight path.

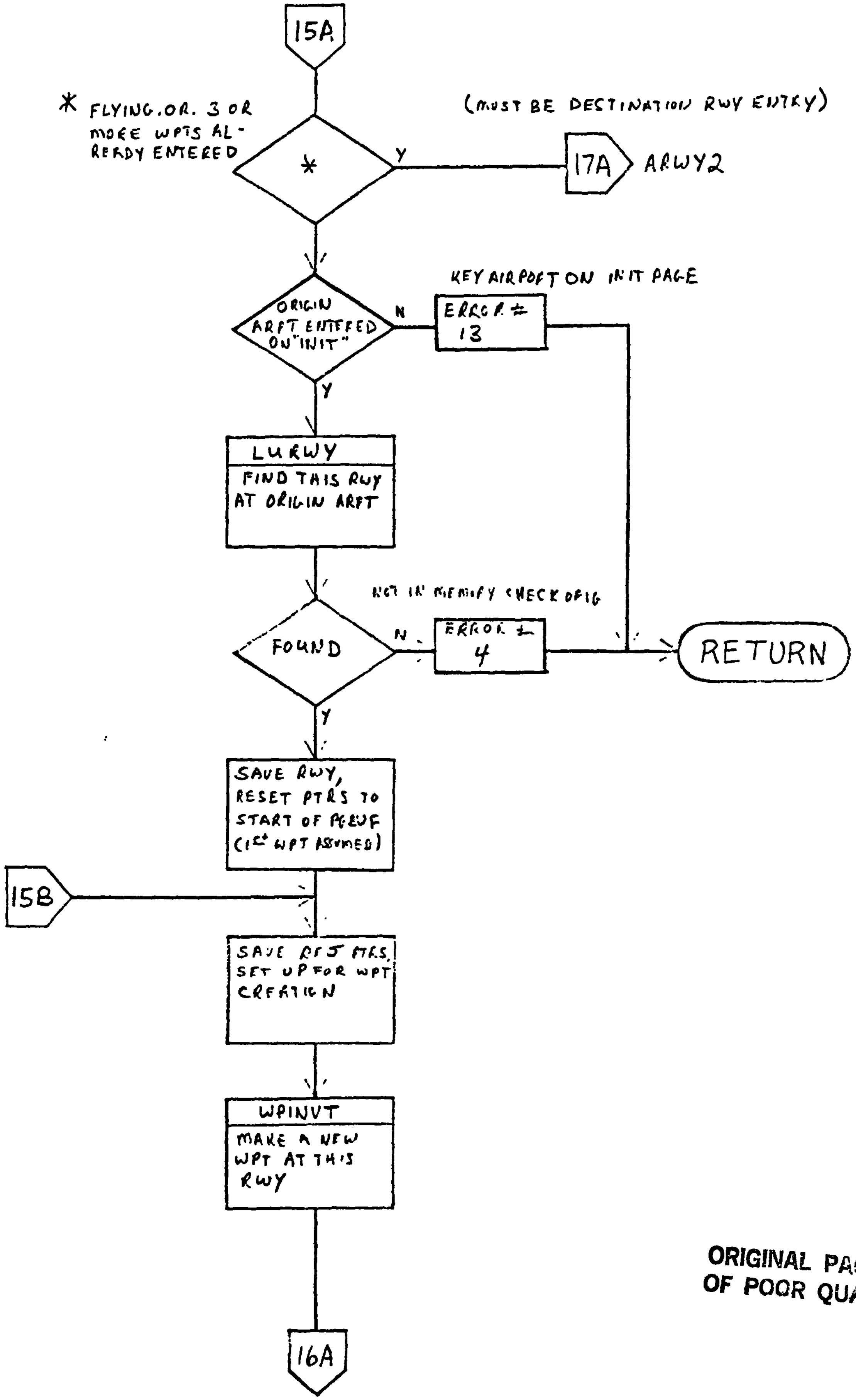
Route entries are made in 3 steps. First the name of a waypoint on the route is entered to designate where on the route to start. Next the route name is entered and finally the terminating waypoint name. The first entry is a normal waypoint entry, which saves the address of the waypoint in WPTENT. The route entry finds the offset of the first entry and stores it in RTESTR and also stores the route address in RTENTR to flag the next waypoint entry as a route terminater. The last entry (see page #8) causes the actual storing of the route waypoints in the provisional guidance buffer. All waypoints between the two waypoint entries are stored starting at the first entry and moving either forward or backward in BULK DATA to reach the last entered waypoint.

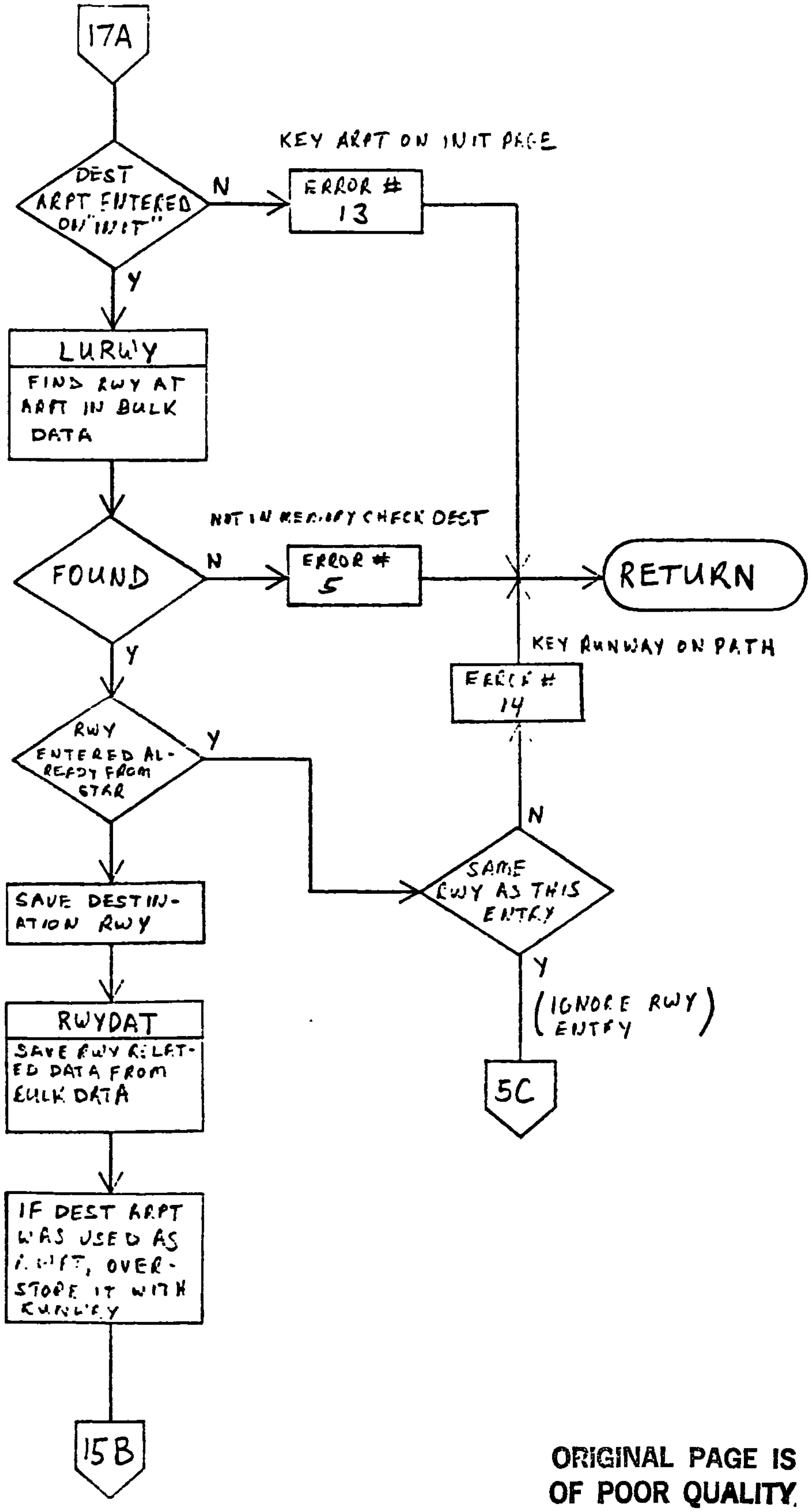
SID ENTRY


13A
GET ORIGIN RUNWAY, RESET PGBUF PTRS SO THESE WILL BE THE FIRST WPTS AND ALL ENTRIES WILL BE MADE UNDER ORIGIN CLEARANCE CONDITIONS.
13B
SAVE PGBUF PTRS FOR REJECT OF THIS ENTRY
13C
FOR EACH WPT
DONE WITH SID/STAR
N
Y
STORE WPT IN GUID. BUFFER
WPTSTR
STORE WPT FEATURES FROM BULK DATA
STORE SPEED, ALTITUDE, RADIUS OF TURN AND BEARING FROM SID DEFINITION. IF APPLICABLE, SET BITS: TAS REF, DME ARC, PAD INHIBIT. IF DME SET REFERENCE LAT/LON AS WPT LAT/LON. SET INDEX FOR SID, STAR OR MAP WPT
SET NO-DISPLAY WPT AS 1st - SID LAST - STAR
* NOT RECLEARANCE OR NO NEW PTA OR PTA POSITION NOT SET
*
Y
N
SET NEW PTA POSITION
5C
ATCTRM


14A
STAR ENTRY
LAST ENTRY A ROUTE
Y
ERROR # = 10
RETURN
KEY WPT ON RTE/AWY
N
IF DESTINATION ARPT USED AS WPT, CANCEL THAT WPT
* RUNWAY PREVIOUSLY ENTERED .AND. NOT THE SAME AS THE "STAR" DEFAULT RUNWAY
*
Y
KEY RUNWAY ON PATH
WARNING # = 14
N
SAVE STAR RUNWAY
RWYDAT
SAVE RUNWAY RELATED DATA FROM BULK DATA
IF THE PREVIOUS ENTRY WAS A WPT ON THIS "STAR", MAKE THE FIRST WPT OF THE "STAR" BE THE ENTERED WPT
13B
ASIDA


16A
WPTSTR
STORE WPT FEATURES FROM BULK DATA
WPTST2
STORE WPT VALUES CASCADED FROM CTRL ENTRIES
WPT TYPE = 2 (STAR). IF DESTINATION RWY, SET IAS REF BIT
5B
AWSTR1


15A
* FLYING.OR. 3 OR MORE WPTS ALREADY ENTERED
*
Y
(MUST BE DESTINATION RWY ENTRY)
17A
ARWY2
ORIGIN ARPT ENTERED ON "INIT"
N
KEY AIRPORT ON INIT PAGE
ERROR # 13
Y
LURWY
FIND THIS RWY AT ORIGIN ARPT
FOUND
N
NOT IN MEMORY CHECK ORIG
ERROR # 4
RETURN
Y
SAVE RWY, RESET PTRS TO START OF PGBUF (1ST WPT ASSUMED)
15B
SAVE REF PTRS. SET UP FOR WPT CREATION
WPINVT
MAKE A NEW WPT AT THIS RWY
16A



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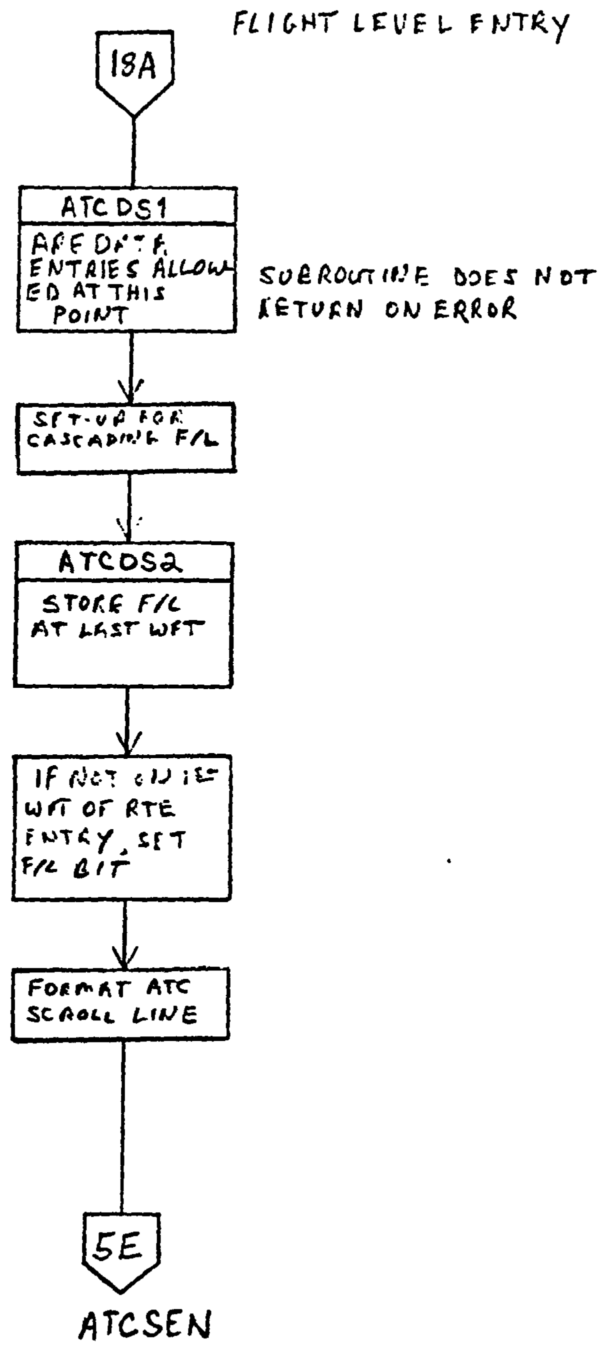
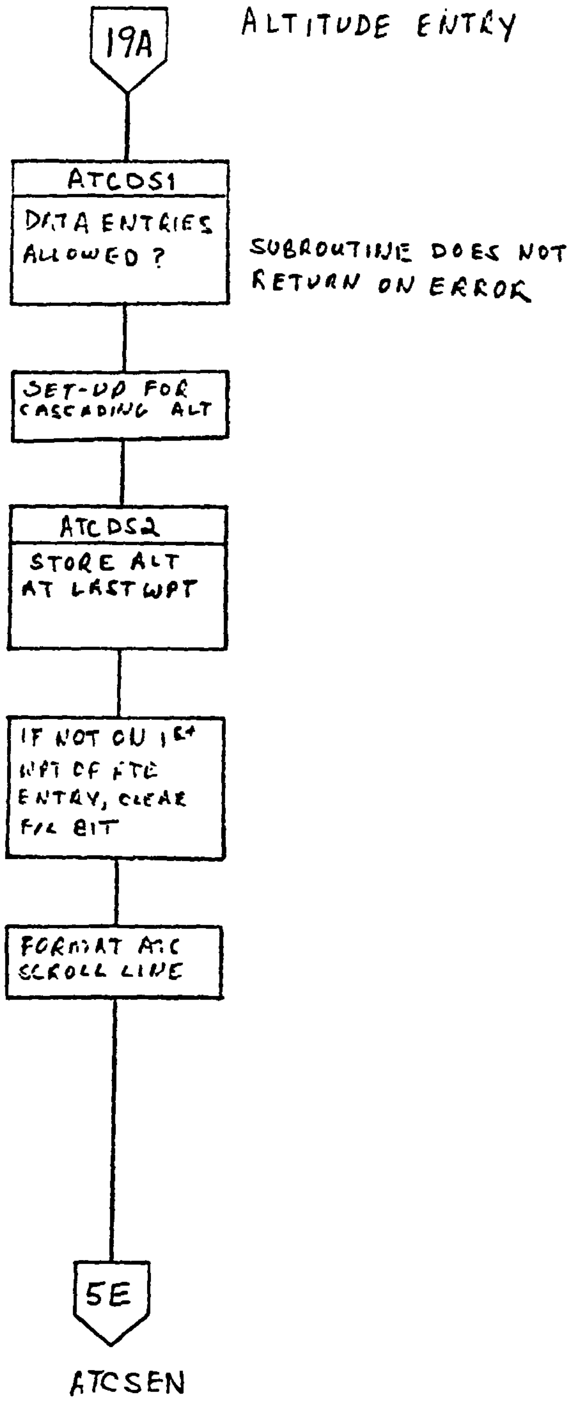
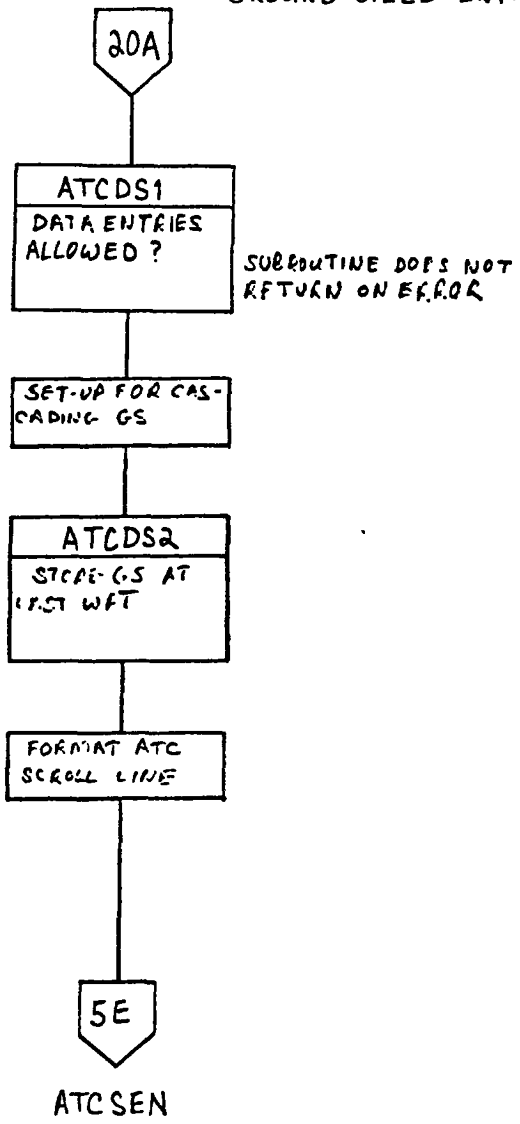
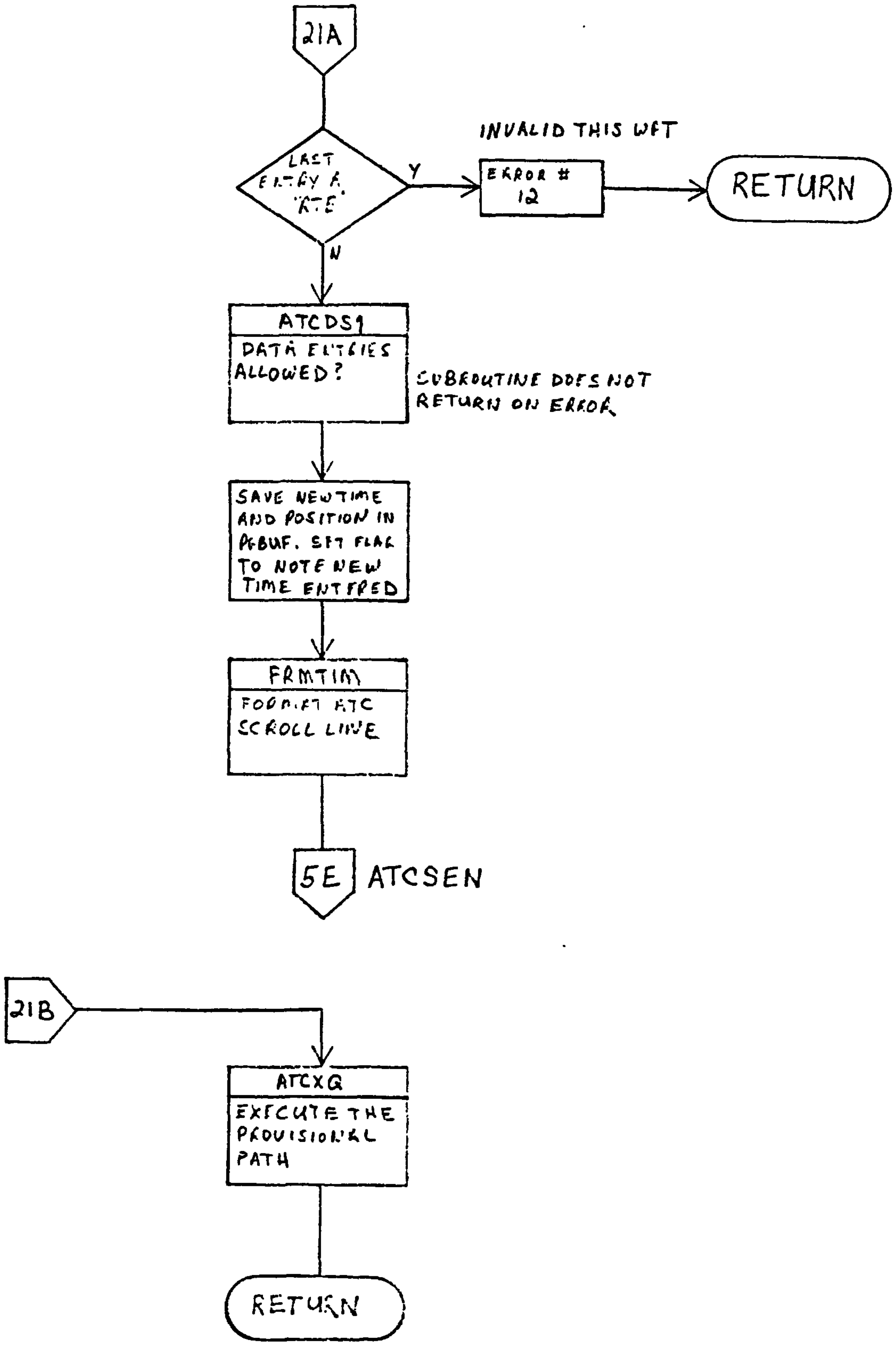
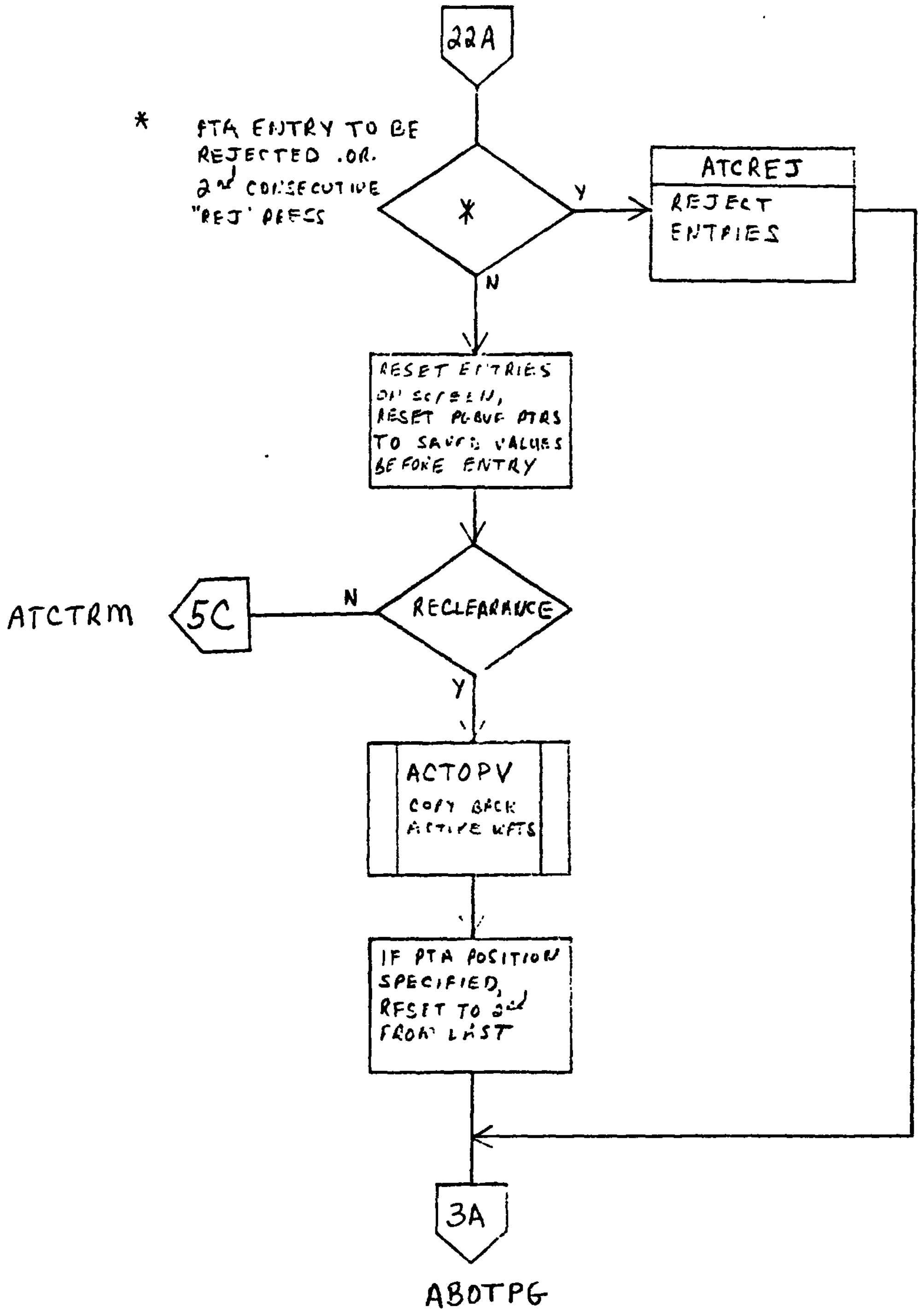

FLIGHT LEVEL ENTRY
18A
ATCDS1
ARE DATA ENTRIES ALLOWED AT THIS POINT
SUBROUTINE DOES NOT RETURN ON ERROR
SET-UP FOR CASCADING F/L
ATCDS2
STORE F/L AT LAST WPT
IF NOT ON 1ST WPT OF RTE ENTRY, SET F/L BIT
FORMAT ATC SCROLL LINE
5E
ATCSEN

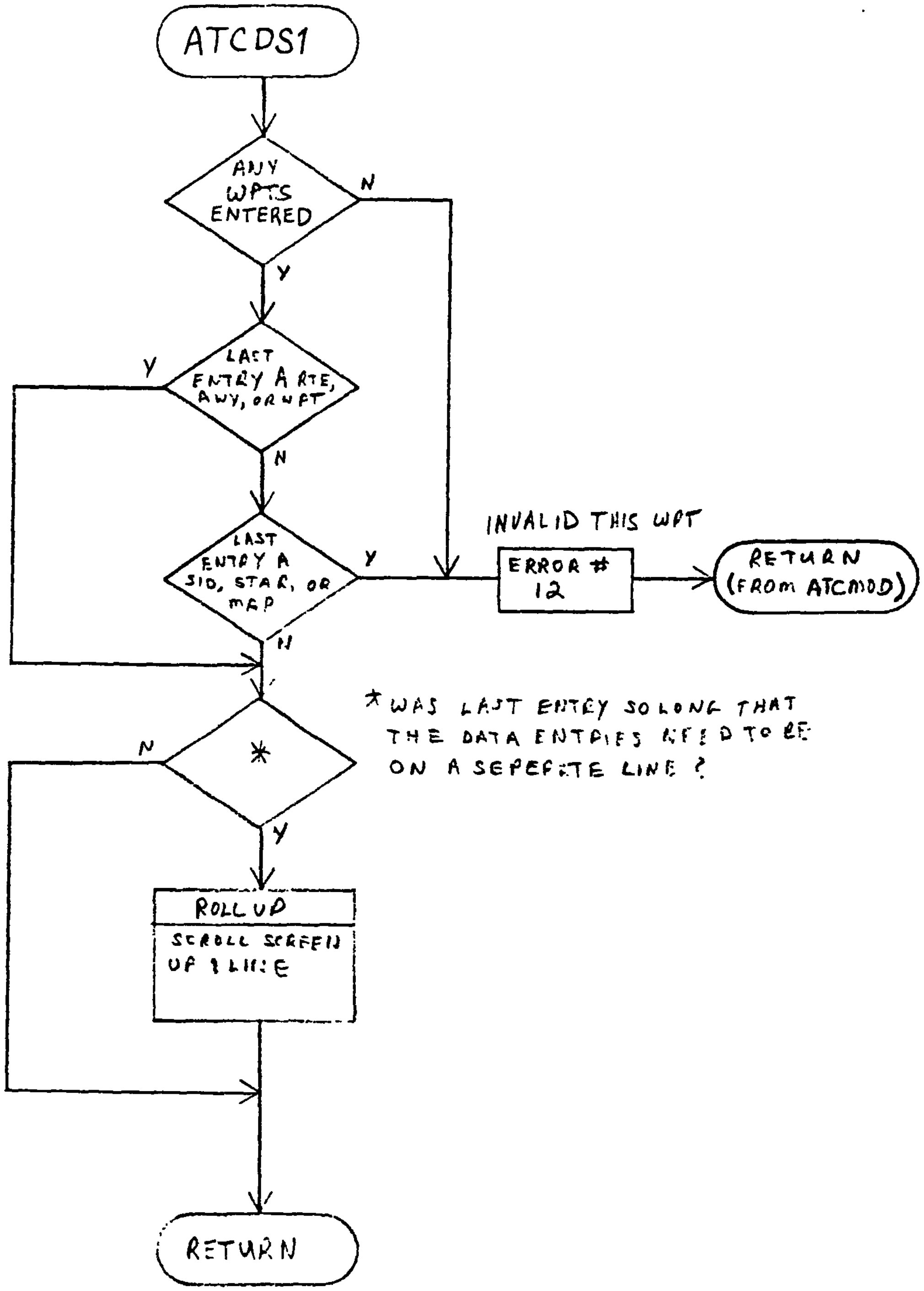

19A
ALTITUDE ENTRY
ATCDS1
DATA ENTRIES ALLOWED ?
SUBROUTINE DOES NOT RETURN ON ERROR
SET-UP FOR CASCADING ALT
ATCDS2
STORE ALT AT LAST WPT
IF NOT ON 1st WPT OF RTE ENTRY, CLEAR F/L BIT
FORMAT ATC SCROLL LINE
5E
ATCSEN

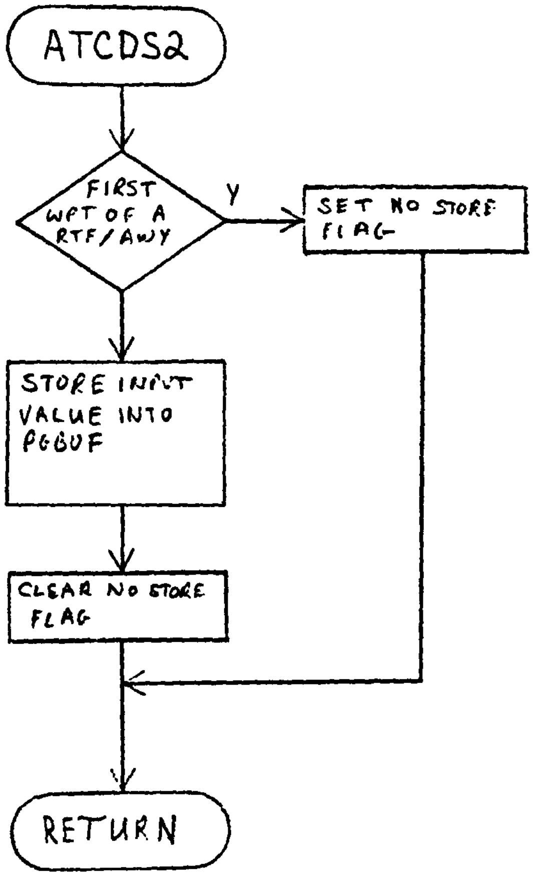
GROUND SPEED ENTRY



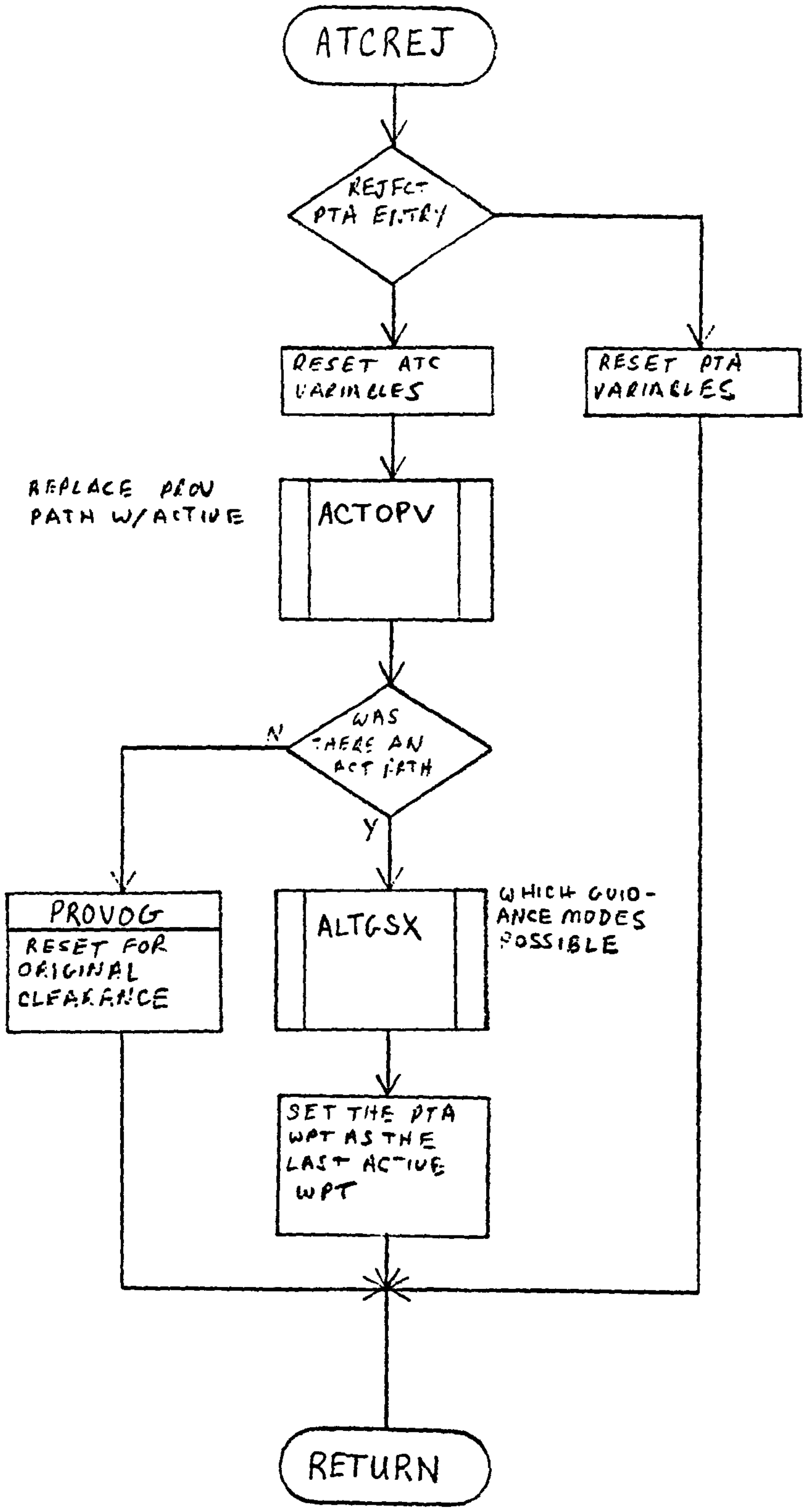

21A
LAST ENTRY A "RTE"
Y
N
INVALID THIS WPT
ERROR # 12
RETURN
ATCDS9
DATA ENTRIES ALLOWED?
SUBROUTINE DOES NOT RETURN ON ERROR
SAVE NEWTIME AND POSITION IN PGBUF. SET FLAG TO NOTE NEW TIME ENTERED
FRMTIM
FORMAT ATC SCROLL LINE
5E ATCSEN
21B
ATCXQ
EXECUTE THE PROVISIONAL PATH
RETURN

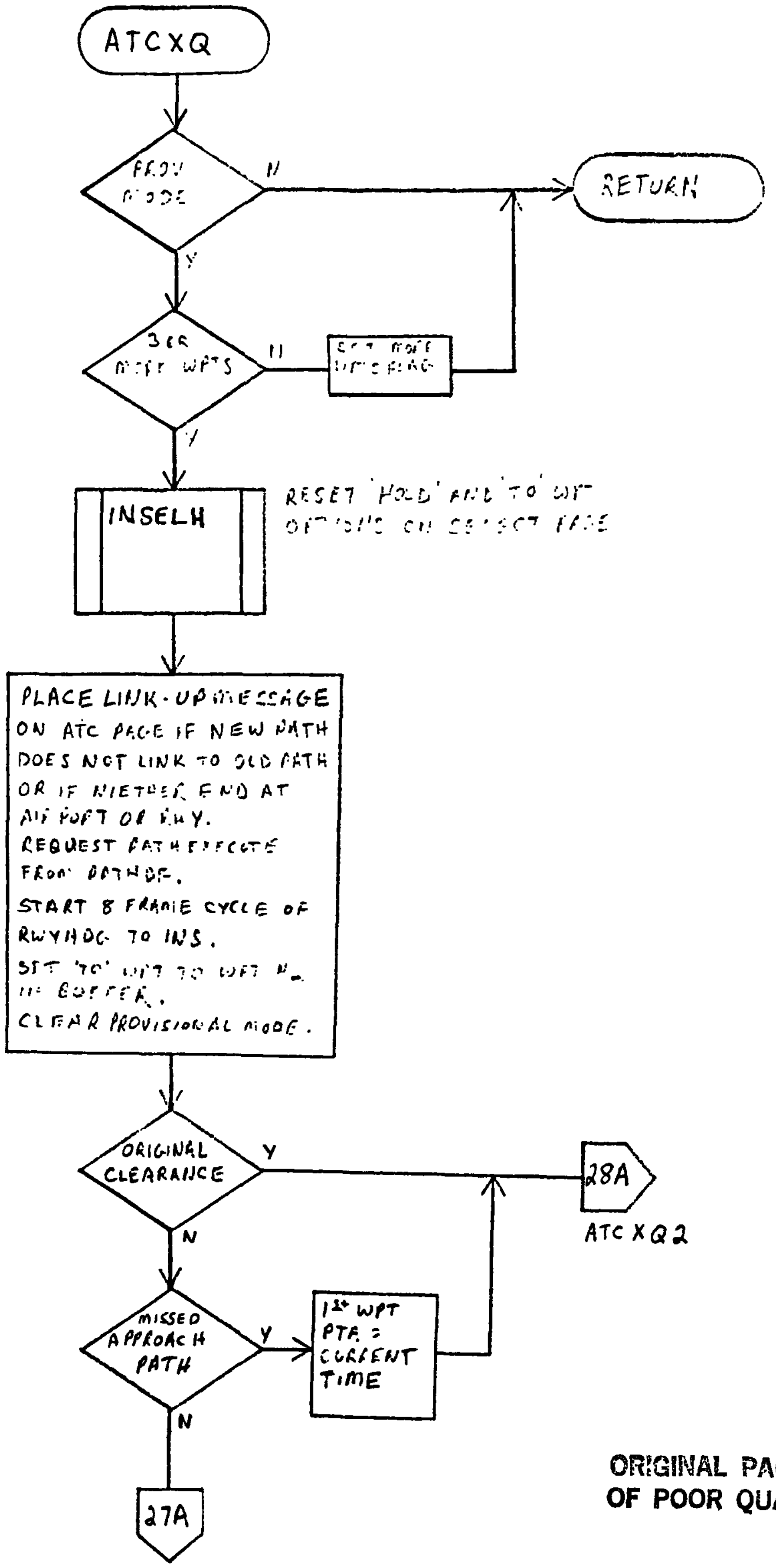

22A
* PTA ENTRY TO BE REJECTED .OR. 2nd CONSECUTIVE "REJ" PRESS
*
Y
ATCREJ
REJECT ENTRIES
N
RESET ENTRIES ON SCREEN, RESET PGBUF PTRS TO SAVED VALUES BEFORE ENTRY
RECLEARANCE
N
5C
ATCTRM
Y
ACTOPV
COPY BACK ACTIVE WPTS
IF PTA POSITION SPECIFIED, RESET TO 2nd FROM LAST
3A
ABOTPG

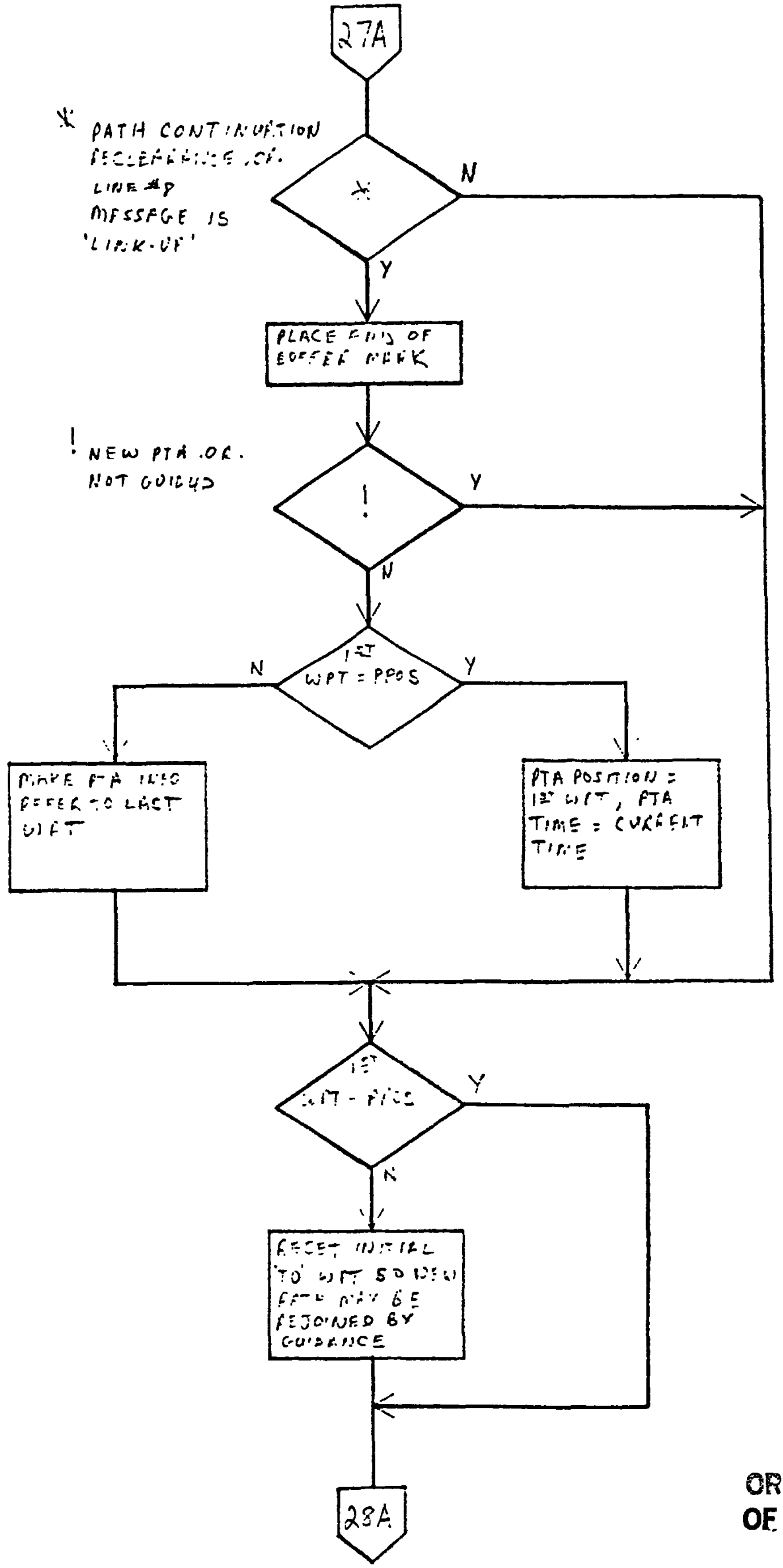

ATCDS1
ANY WPTS ENTERED
N
Y
LAST ENTRY A RTE, AWY, OR WPT
Y
N
LAST ENTRY A SID, STAR, OR MAP
Y
N
INVALID THIS WPT
ERROR # 12
RETURN (FROM ATCMOD)
*
N
Y
*WAS LAST ENTRY SO LONG THAT THE DATA ENTRIES NEED TO BE ON A SEPERATE LINE ?
ROLL UP
SCROLL SCREEN UP 1 LINE
RETURN

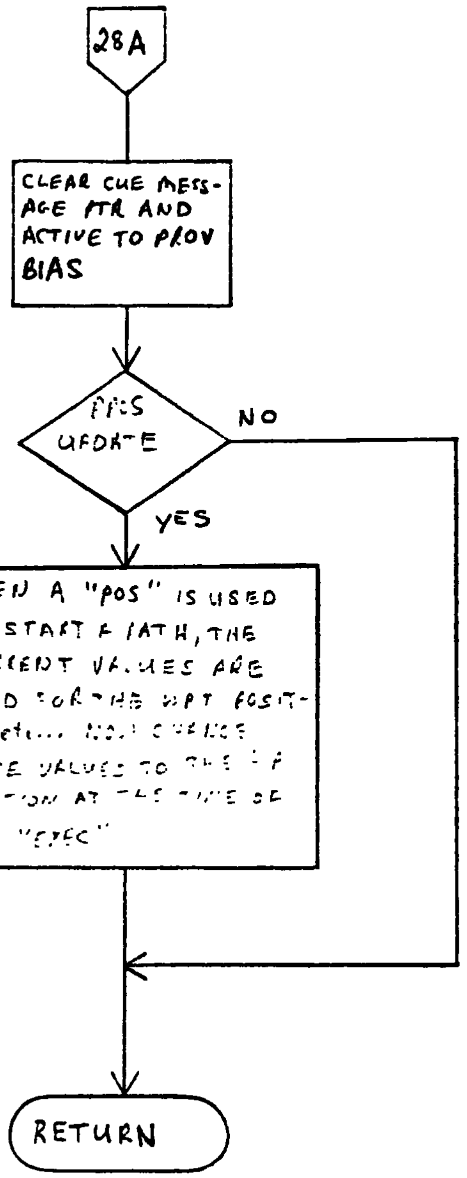


ORIGINAL PAGE IS
OF POOR QUALITY

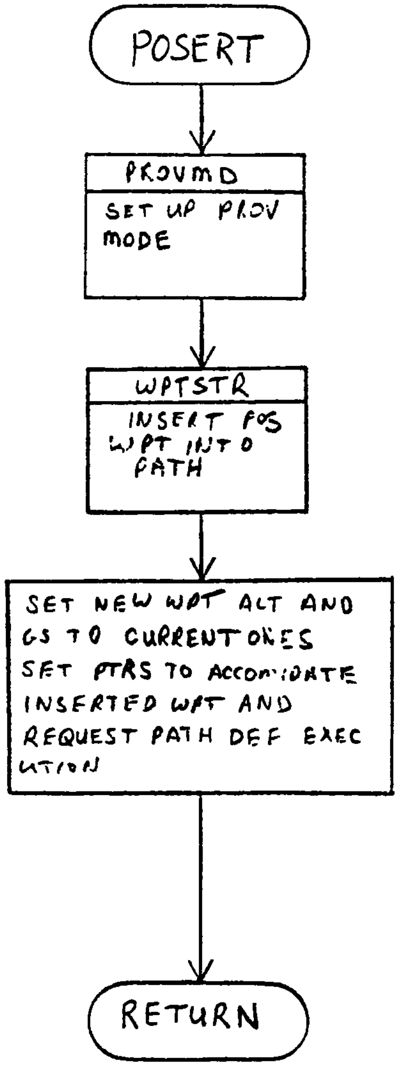

ATCREJ
REJECT PTA ENTRY
RESET ATC VARIABLES
RESET PTA VARIABLES
REPLACE PROV PATH W/ACTIVE
ACTOPV
WAS THERE AN ACT PATH
N
Y
PROVOG
RESET FOR ORIGINAL CLEARANCE
ALTGSX
WHICH GUIDANCE MODES POSSIBLE
SET THE PTA WPT AS THE LAST ACTIVE WPT
RETURN


ATCXQ
PROV MODE
N
Y
RETURN
3 OR MORE WPTS
N
SET MORE WPTS FLAG
Y
INSELH
RESET 'HOLD' AND 'TO' WPT
OPTIONS ON SELECT PAGE
PLACE LINK-UP MESSAGE ON ATC PAGE IF NEW PATH DOES NOT LINK TO OLD PATH OR IF NIETHER END AT AIRPORT OR RWY.
REQUEST PATH EXECUTE FROM PATHDF.
START 8 FRAME CYCLE OF RWYHDG TO INS.
SET 'TO' WPT TO WPT No IN BUFFER.
CLEAR PROVISIONAL MODE.
ORIGINAL CLEARANCE
Y
28A
ATCXQ2
N
MISSED APPROACH PATH
Y
1st WPT PTA = CURRENT TIME
N
27A

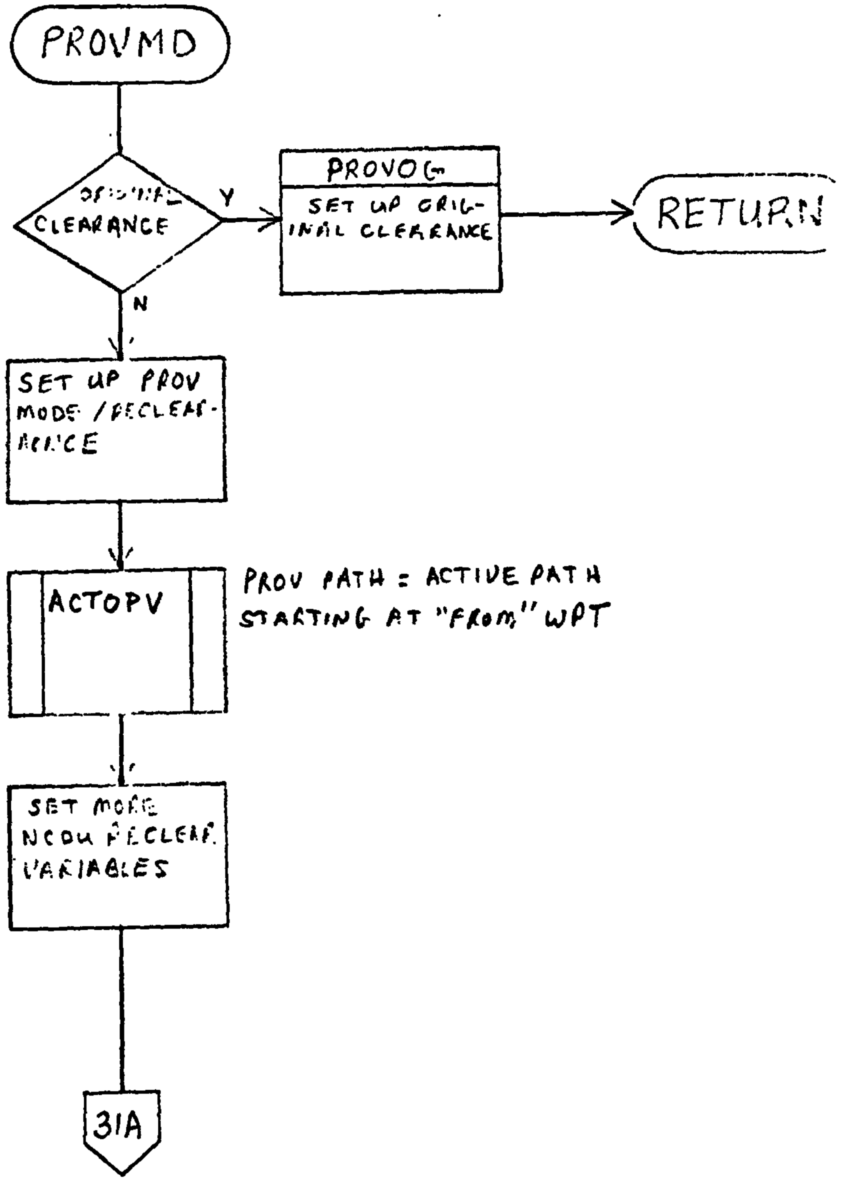

27A
* PATH CONTINUATION RECLEARANCE .OR. LINE #P MESSAGE IS 'LINK-UP'
*
N
Y
PLACE END OF BUFFER MARK
! NEW PTA .OR. NOT GUIDED
!
Y
N
1ST WPT = PPOS
N
Y
MAKE PTA INFO REFER TO LAST WPT
PTA POSITION = 1ST WPT, PTA TIME = CURRENT TIME
1ST WPT - PPOS
Y
N
RESET INITIAL TO WPT SO NEW PATH MAY BE REJOINED BY GUIDANCE
28A

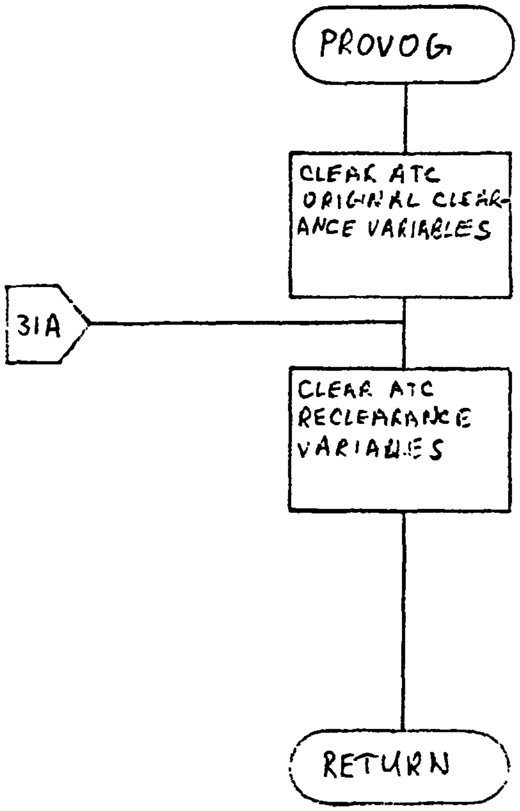

28A
CLEAR CUE MESSAGE PTR AND ACTIVE TO PROV BIAS
POS UPDATE
NO
YES
WHEN A "POS" IS USED TO START A PATH, THE CURRENT VALUES ARE USED FOR THE WPT POSITION ETC... NOW CHANGE THESE VALUES TO THE A/P POSITION AT THE TIME OF THE "EXEC"
RETURN

ORIGINAL PAGE IS
OF POOR QUALITY


POSERT
PROVMD
SET UP PROV MODE
WPTSTR
INSERT POS WPT INTO PATH
SET NEW WPT ALT AND GS TO CURRENT ONES SET PTRS TO ACCOMODATE INSERTED WPT AND REQUEST PATH DEF EXECUTION
RETURN

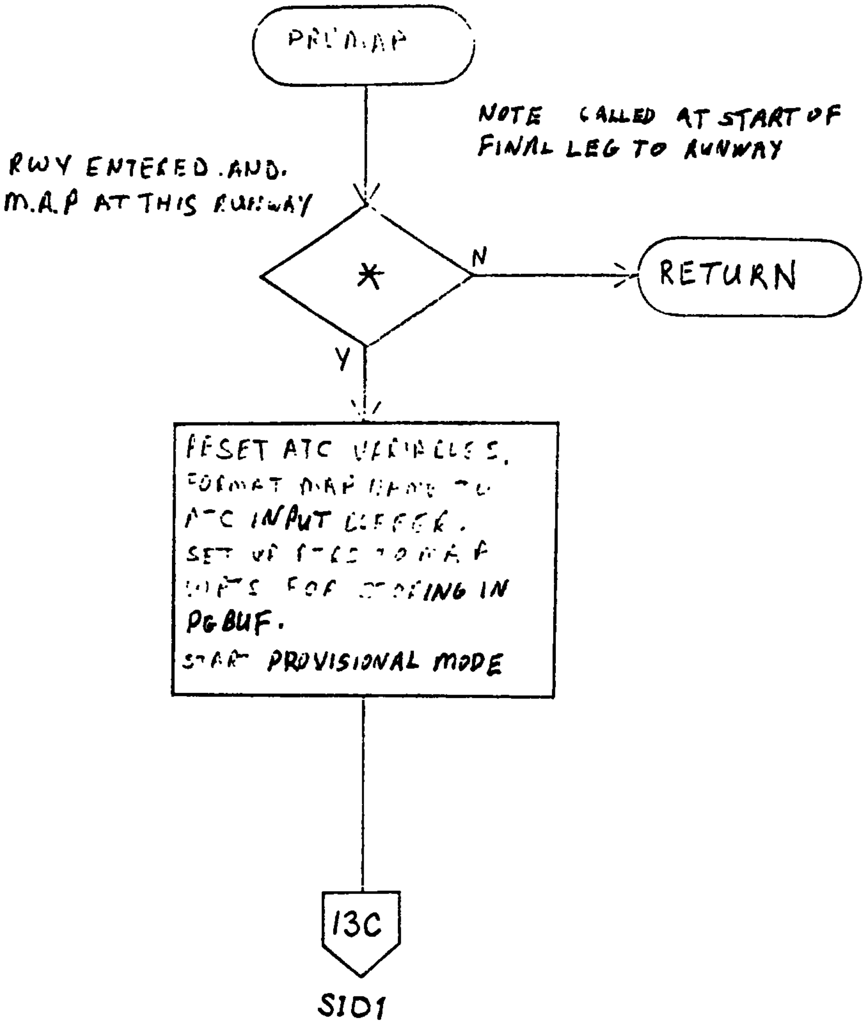
NOTE: This procedure is called when the pilot chooses the current position (POS) along the path as a HOLD waypoint. The active path is copied back ('FROM' wpt to end of path) to the provisional buffer in PROVMD and the pilot defined waypoint is inserted between the 'FROM' and 'TO' waypoints by WPTSTR.


PROVMD
ORIGINAL CLEARANCE
Y
PROVOG
SET UP ORIG-INAL CLEARANCE
RETURN
N
SET UP PROV MODE/RECLEAR-ANCE
ACTOPV
PROV PATH = ACTIVE PATH STARTING AT "FROM" WPT
SET MORE NCDU RECLEAR. VARIABLES
31A

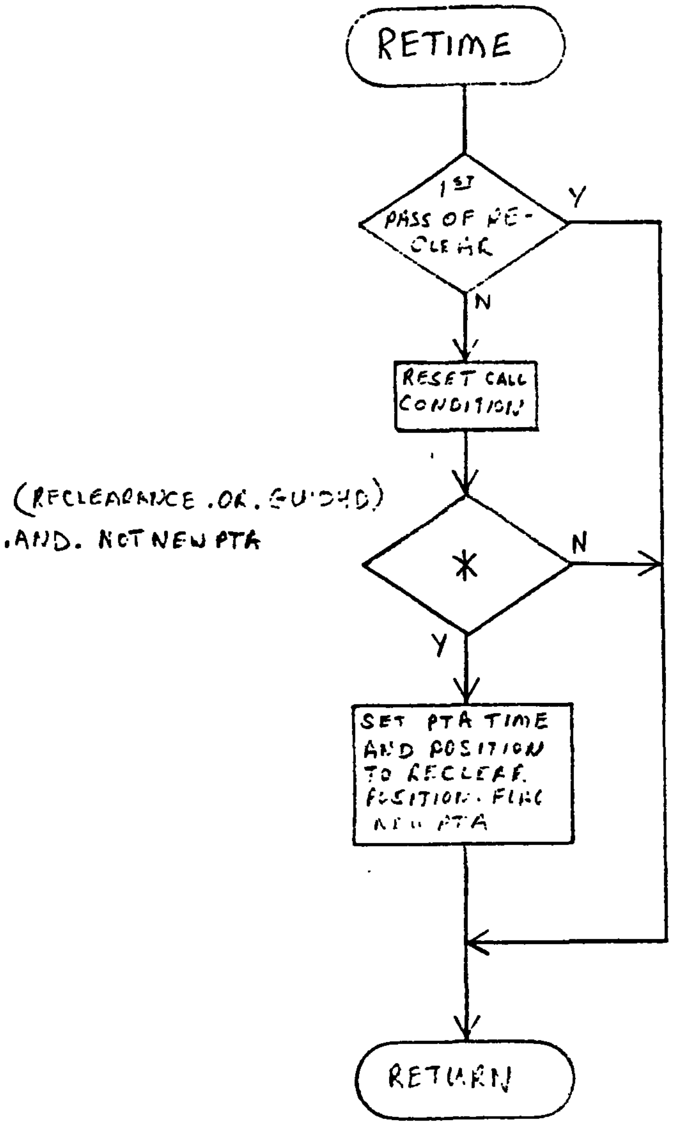

PROVOG
CLEAR ATC ORIGINAL CLEARANCE VARIABLES
31A
CLEAR ATC RECLEARANCE VARIABLES
RETURN

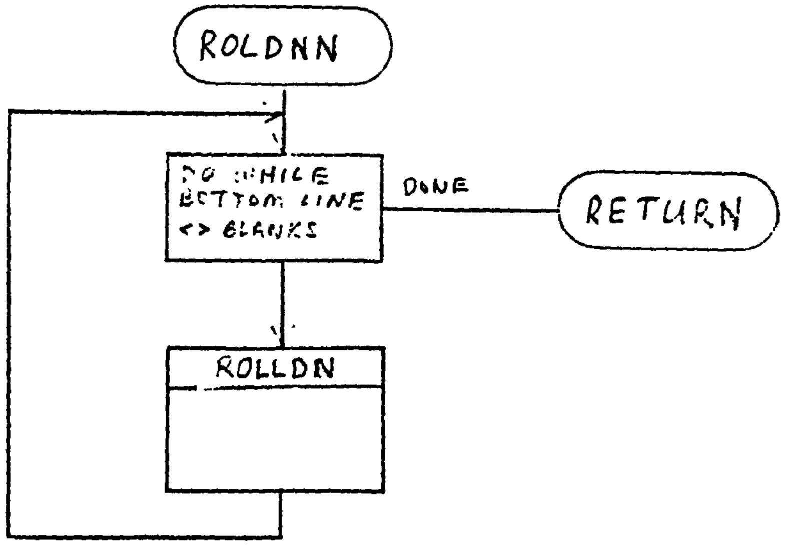
ORIGINAL PAGE IS
OF POOR QUALITY

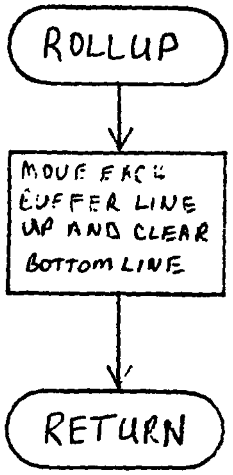
MISSED APPROACH PATH

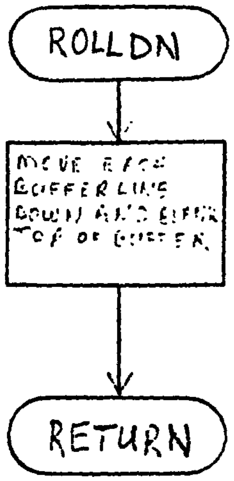

PREMAP
NOTE CALLED AT START OF FINAL LEG TO RUNWAY
RWY ENTERED .AND. M.A.P AT THIS RUNWAY
*
N
RETURN
Y
RESET ATC VARIABLES. FORMAT MAP DATA TO ATC INPUT BUFFER. SET UP PTRS TO M.A.P WPTS FOR STORING IN PGBUF. START PROVISIONAL MODE
13C
S1D1

ORIGINAL PAGE IS
OF POOR QUALITY

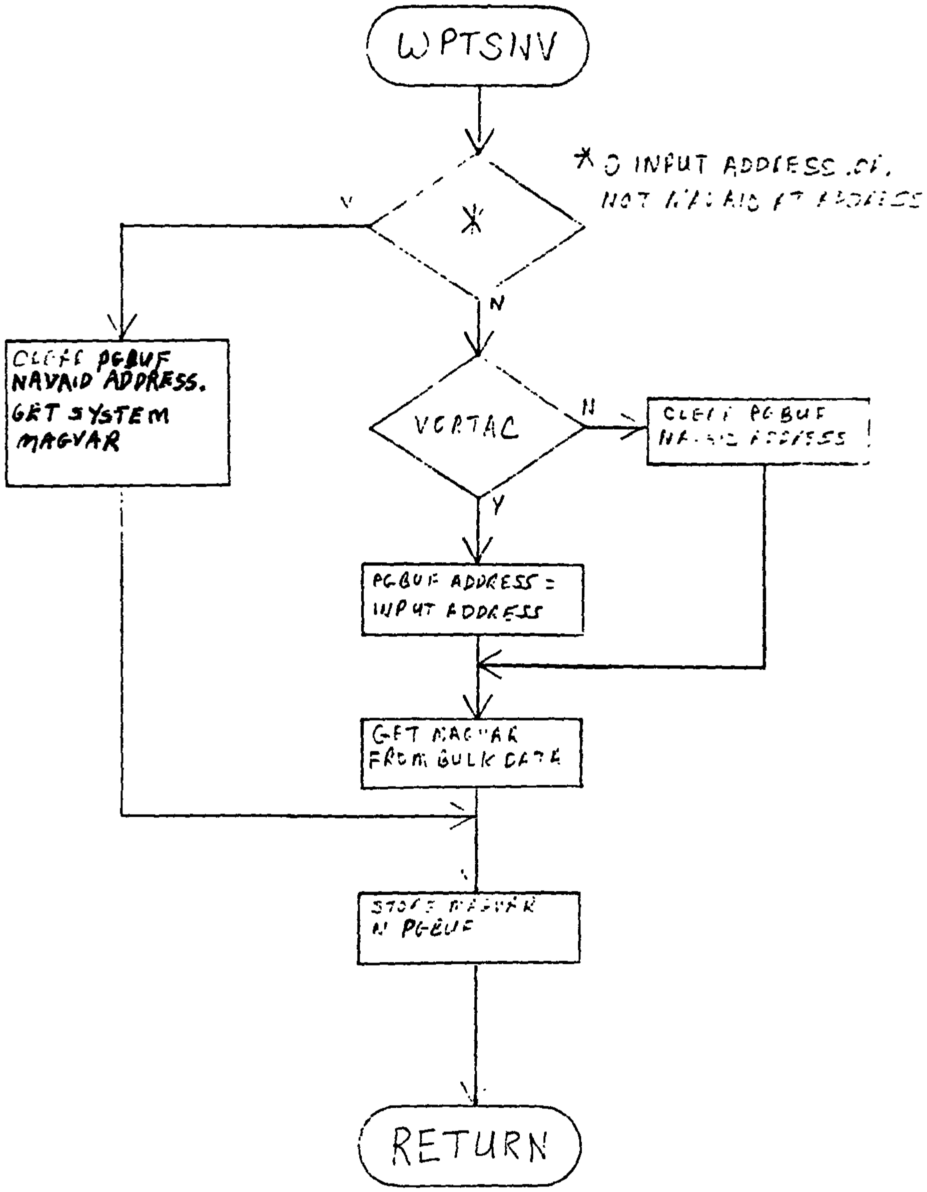

RETIME
1st PASS OF RE-CLEAR
Y
N
RESET CALL CONDITION
(RECLEARANCE .OR. GUIDED) .AND. NOT NEW PTA
*
N
Y
SET PTA TIME AND POSITION TO RECLEAR. POSITION. FLAG NEW PTA
RETURN

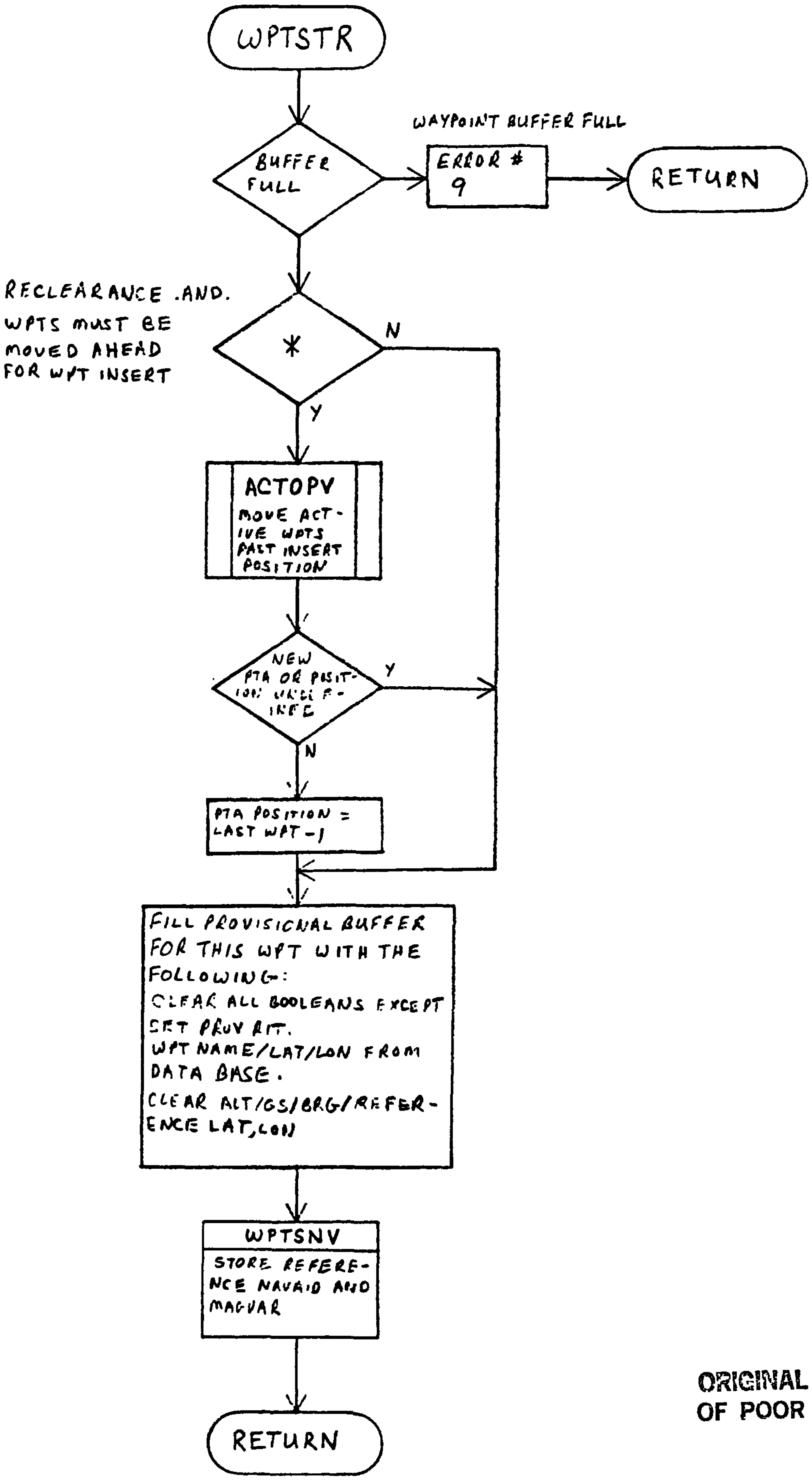


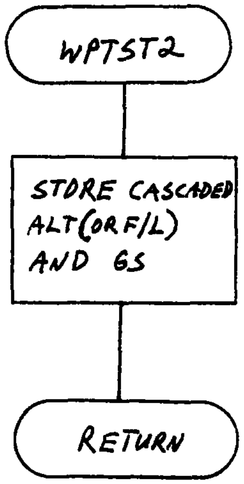


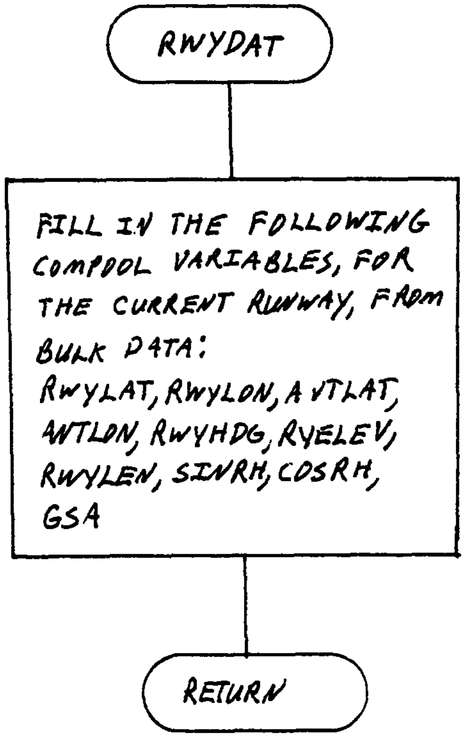


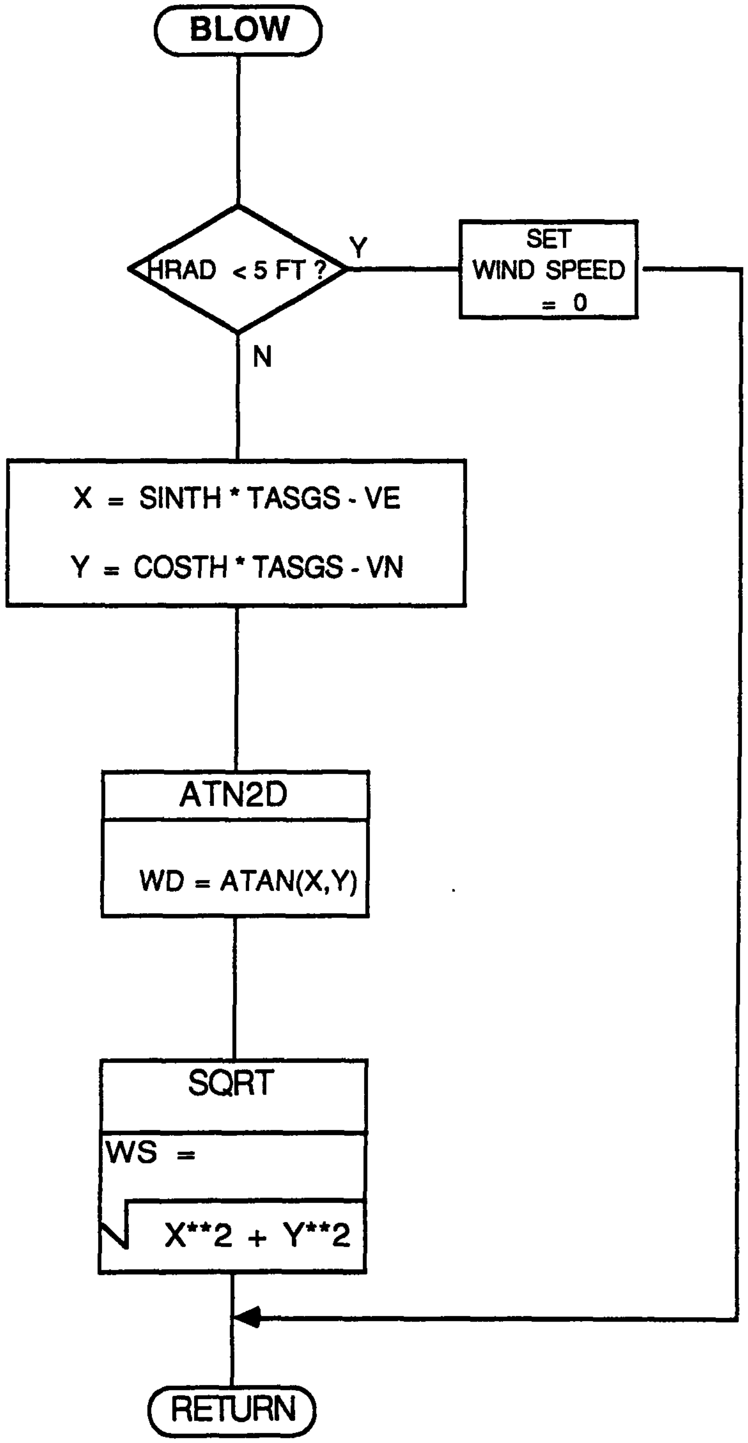
ORIGINAL PAGE IS
OF POOR QUALITY

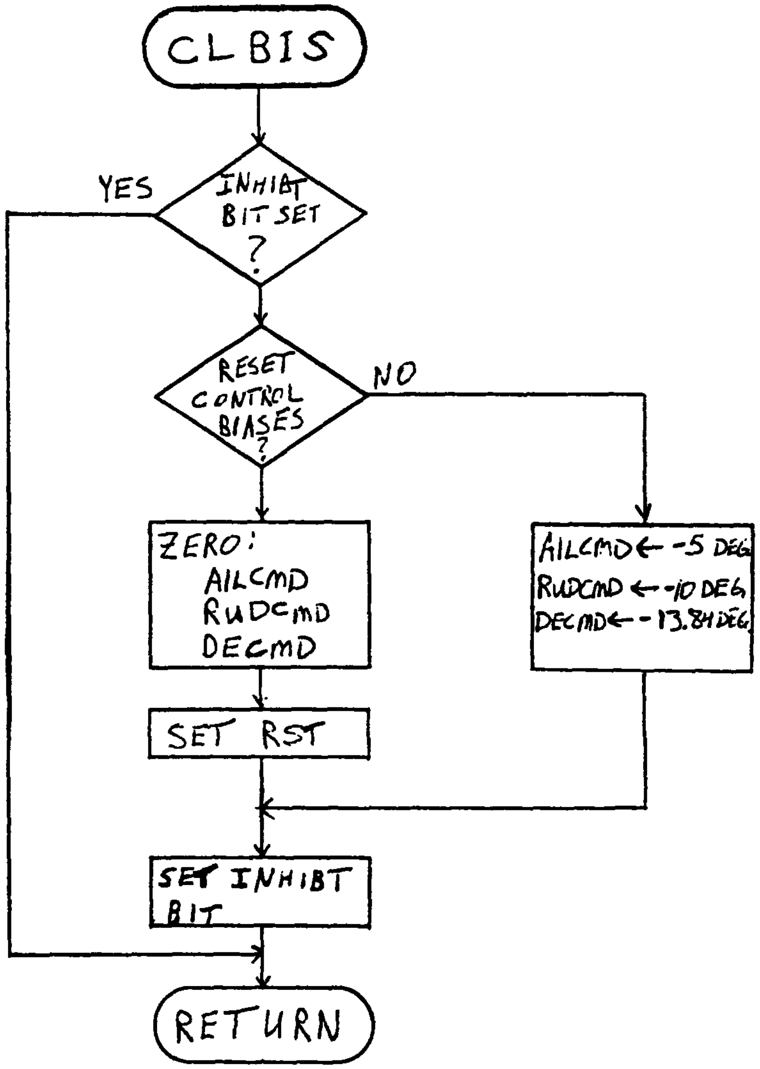

WPTSNV
* 0 INPUT ADDRESS OR,
NOT NAVAID AT ADDRESS
*
Y
N
CLEAR PGBUF
NAVAID ADDRESS.
GET SYSTEM
MAGVAR
VORTAC
N
CLEAR PGBUF
NAVAID ADDRESS
Y
PGBUF ADDRESS =
INPUT ADDRESS
GET MAGVAR
FROM BULK DATA
STORE MAGVAR
IN PGBUF
RETURN

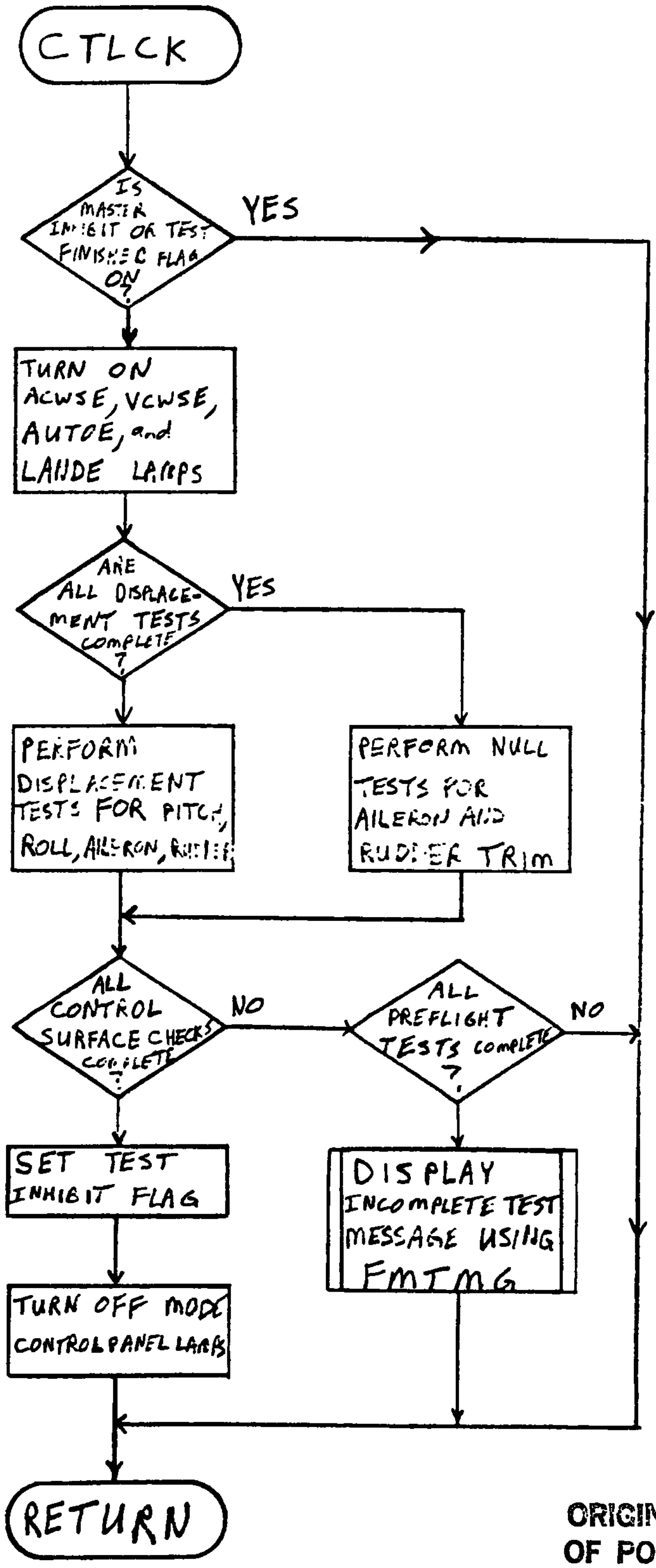

WPTSTR
BUFFER FULL
WAYPOINT BUFFER FULL
ERROR # 9
RETURN
RECLEARANCE .AND. WPTS MUST BE MOVED AHEAD FOR WPT INSERT
*
N
Y
ACTOPV
MOVE ACTIVE WPTS PAST INSERT POSITION
NEW PTA OR POSITION UNDEF- INED
Y
N
PTA POSITION = LAST WPT -1
FILL PROVISICNAL BUFFER FOR THIS WPT WITH THE FOLLOWING:
CLEAR ALL BOOLEANS EXCEPT SET PROV BIT.
WPT NAME/LAT/LON FROM DATA BASE.
CLEAR ALT/GS/BRG/REFER-ENCE LAT,LON
WPTSNV
STORE REFERENCE NAVAID AND MAGVAR
RETURN


WPTST2
STORE CASCADED ALT(OR F/L) AND GS
RETURN

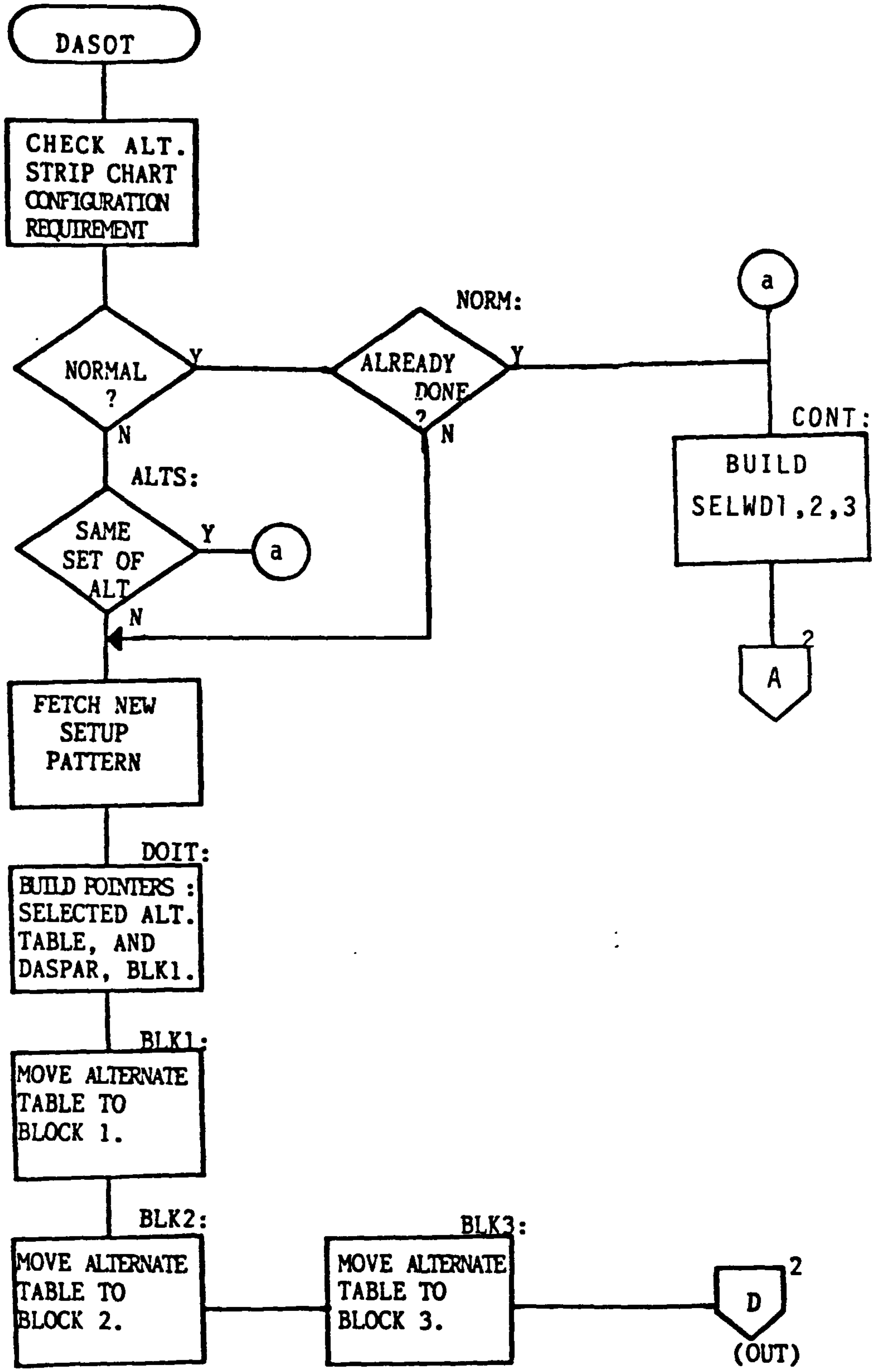

RWYDAT
FILL IN THE FOLLOWING COMPOOL VARIABLES, FOR THE CURRENT RUNWAY, FROM BULK DATA:
RWYLAT, RWYLON, AVTLAT, AVTLON, RWYHDG, RYELEV, RWYLEN, SINRH, COSRH, GSA
RETURN


BLOW
HRAD < 5 FT ?
Y
N
SET
WIND SPEED
= 0
X = SINTH * TASGS - VE
Y = COSTH * TASGS - VN
ATN2D
WD = ATAN(X,Y)
SQRT
WS =
X**2 + Y**2
RETURN

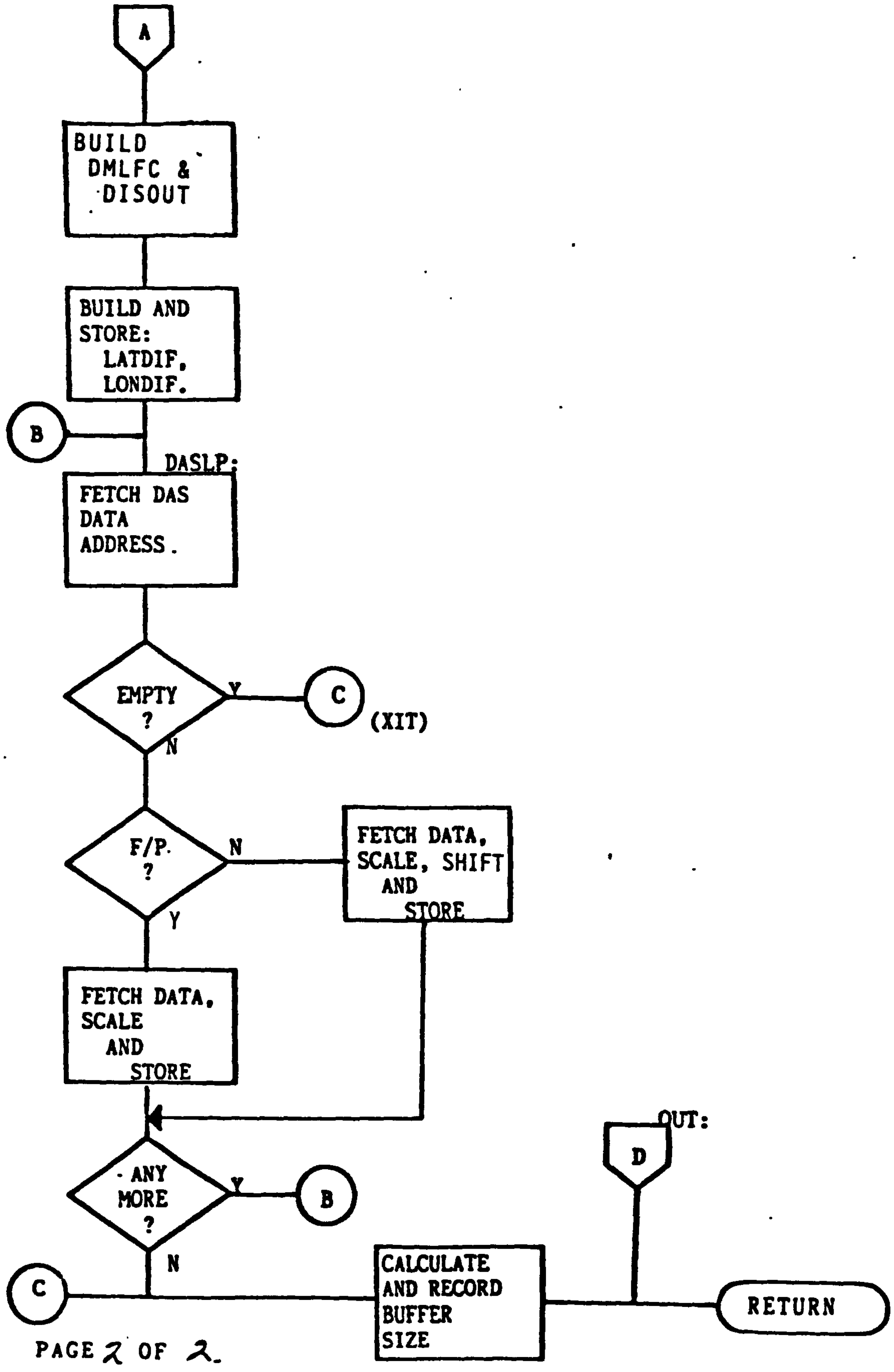

CLBIS
INHIBT BIT SET ?
YES
RESET CONTROL BIASES ?
NO
ZERO: AILCMD RUDCMD DECMD
AILCMD ← -5 DEG
RUDCMD ← -10 DEG
DECMD ← -13.84 DEG
SET RST
SET INHIBT BIT
RETURN

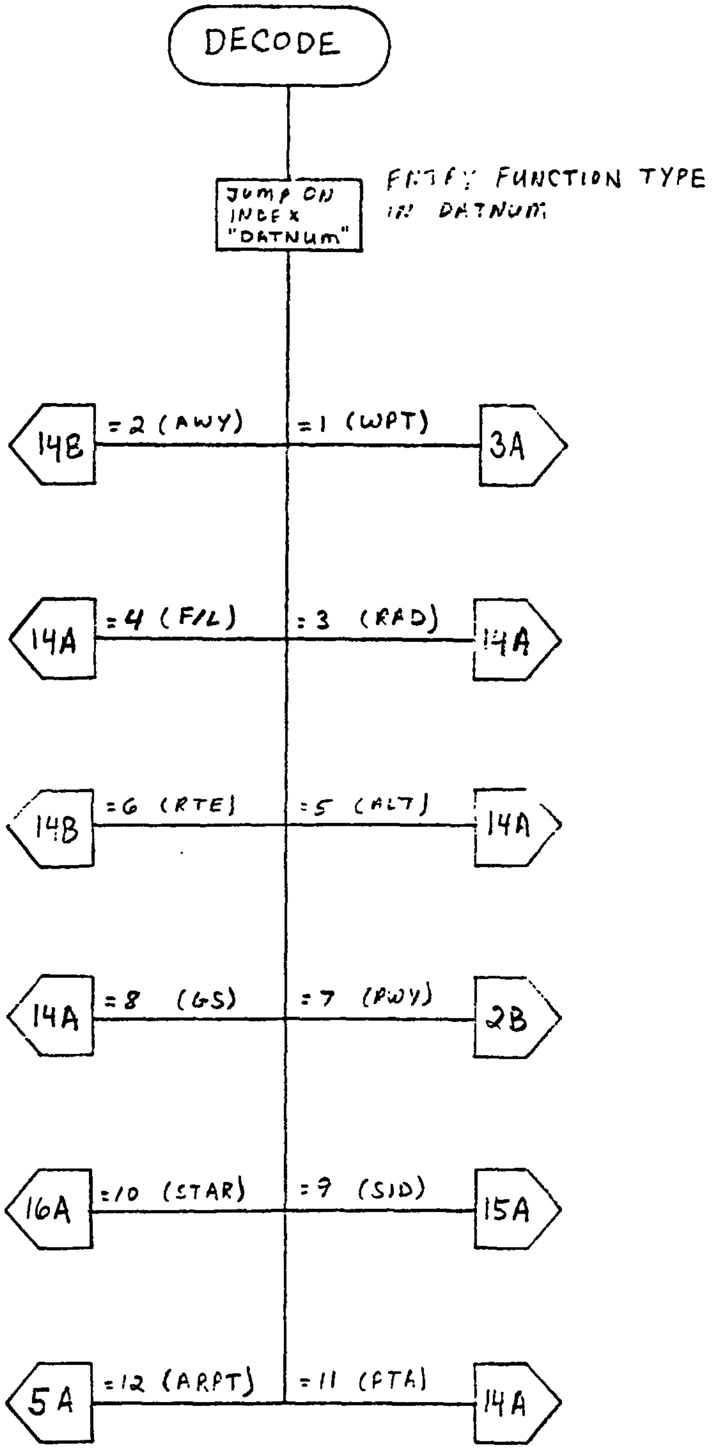

CTLCK
IS MASTER INHIBIT OR TEST FINISHED FLAG ON?
YES
TURN ON ACWSE, VCWSE, AUTOE, and LANDE LAMPS
ARE ALL DISPLACEMENT TESTS COMPLETE?
YES
PERFORM DISPLACEMENT TESTS FOR PITCH, ROLL, AILERON, RUDDER
PERFORM NULL TESTS FOR AILERON AND RUDDER TRIM
ALL CONTROL SURFACE CHECKS COMPLETE?
NO
ALL PREFLIGHT TESTS COMPLETE?
NO
SET TEST INHIBIT FLAG
DISPLAY INCOMPLETE TEST MESSAGE USING FMTMG
TURN OFF MODE CONTROL PANEL LAMPS
RETURN

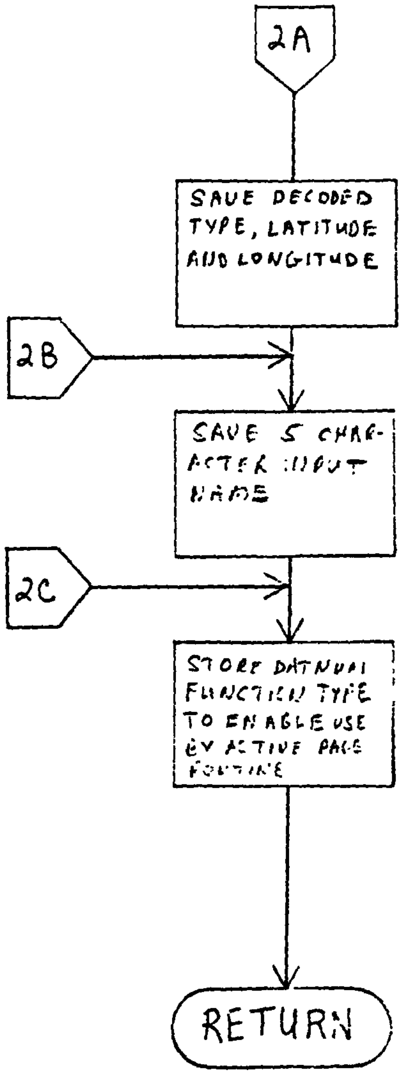
CTLCK
(PAGE 1 OF 1)


DASOT
CHECK ALT. STRIP CHART CONFIGURATION REQUIREMENT
NORMAL ?
Y
N
NORM:
ALREADY DONE ?
Y
N
a
CONT:
BUILD SELWD1,2,3
A
2
ALTS:
SAME SET OF ALT
Y
N
a
FETCH NEW SETUP PATTERN
DOIT:
BUILD POINTERS : SELECTED ALT. TABLE, AND DASPAR, BLK1.
BLK1:
MOVE ALTERNATE TABLE TO BLOCK 1.
BLK2:
MOVE ALTERNATE TABLE TO BLOCK 2.
BLK3:
MOVE ALTERNATE TABLE TO BLOCK 3.
D
2
(OUT)

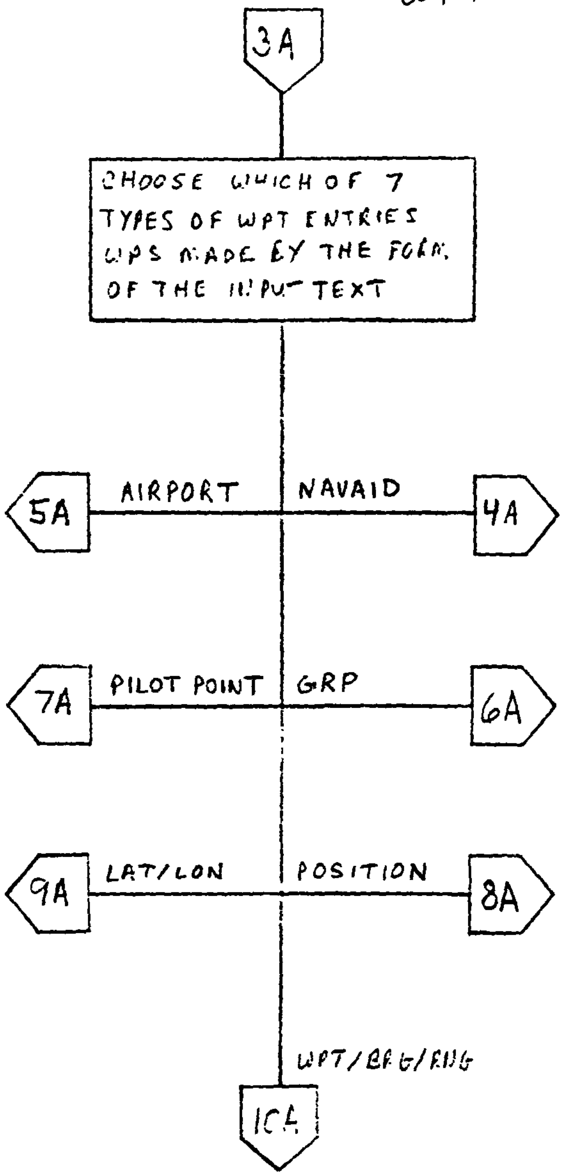
PAGE 1 OF 2


A
BUILD DMLFC & DISOUT
BUILD AND STORE: LATDIF, LONDIF.
B
DASLP:
FETCH DAS DATA ADDRESS.
EMPTY ?
Y
C
(XIT)
N
F/P. ?
N
FETCH DATA, SCALE, SHIFT AND STORE
Y
FETCH DATA, SCALE AND STORE
ANY MORE ?
Y
B
N
C
OUT:
D
CALCULATE AND RECORD BUFFER SIZE
RETURN
PAGE 2 OF 2.

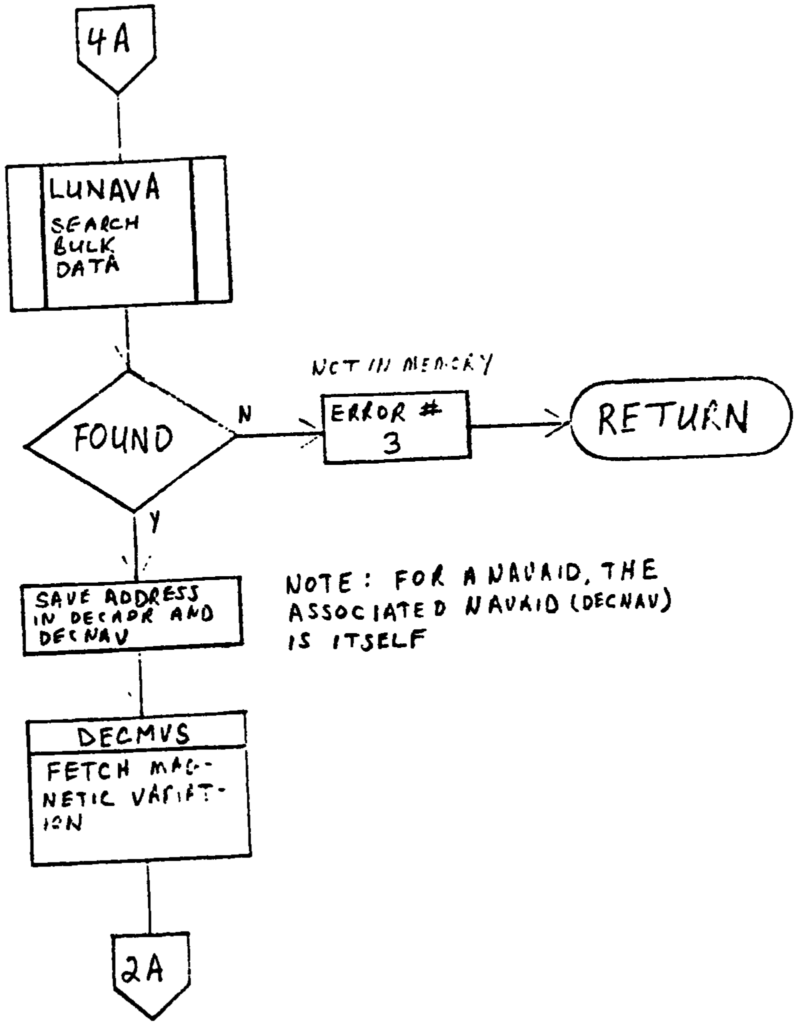

DECODE
JUMP ON INDEX "DATNUM"
ENTRY FUNCTION TYPE IN DATNUM
=1 (WPT)
3A
=2 (AWY)
14B
=3 (RAD)
14A
=4 (F/L)
14A
=5 (ALT)
14A
=6 (RTE)
14B
=7 (RWY)
2B
=8 (GS)
14A
=9 (SID)
15A
=10 (STAR)
16A
=11 (ETA)
14A
=12 (ARPT)
5A


2A
SAVE DECODED TYPE, LATITUDE AND LONGITUDE
2B
SAVE 5 CHARACTER INPUT NAME
2C
STORE DATNUM FUNCTION TYPE TO ENABLE USE BY ACTIVE PAGE ROUTINE
RETURN

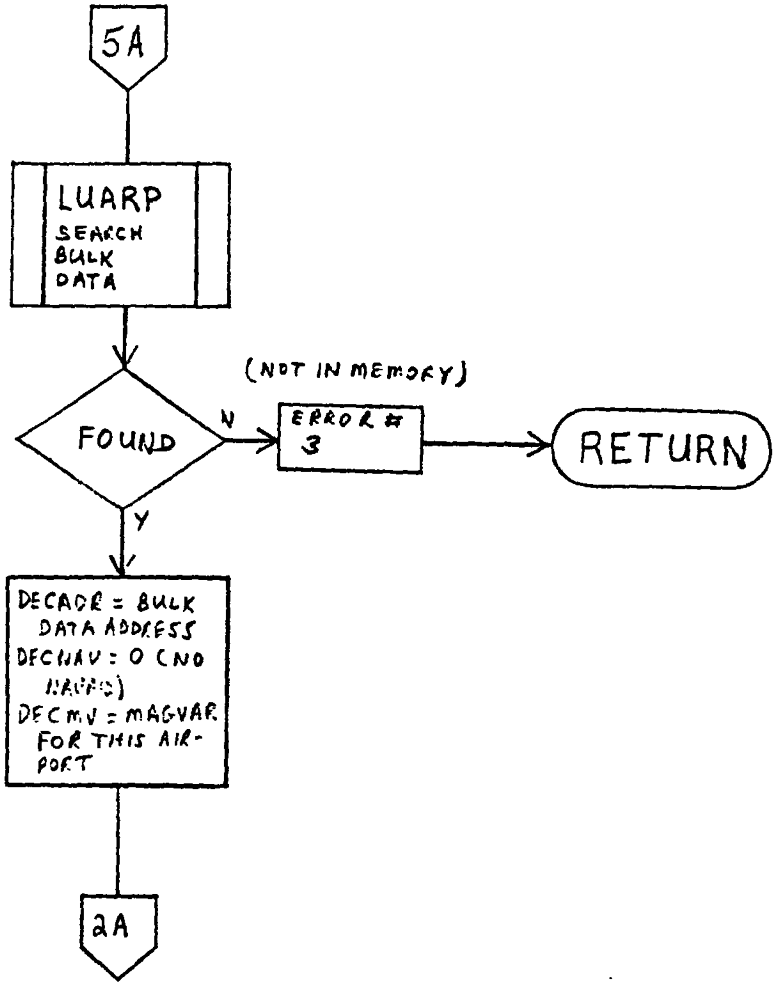
WPT ENTRY

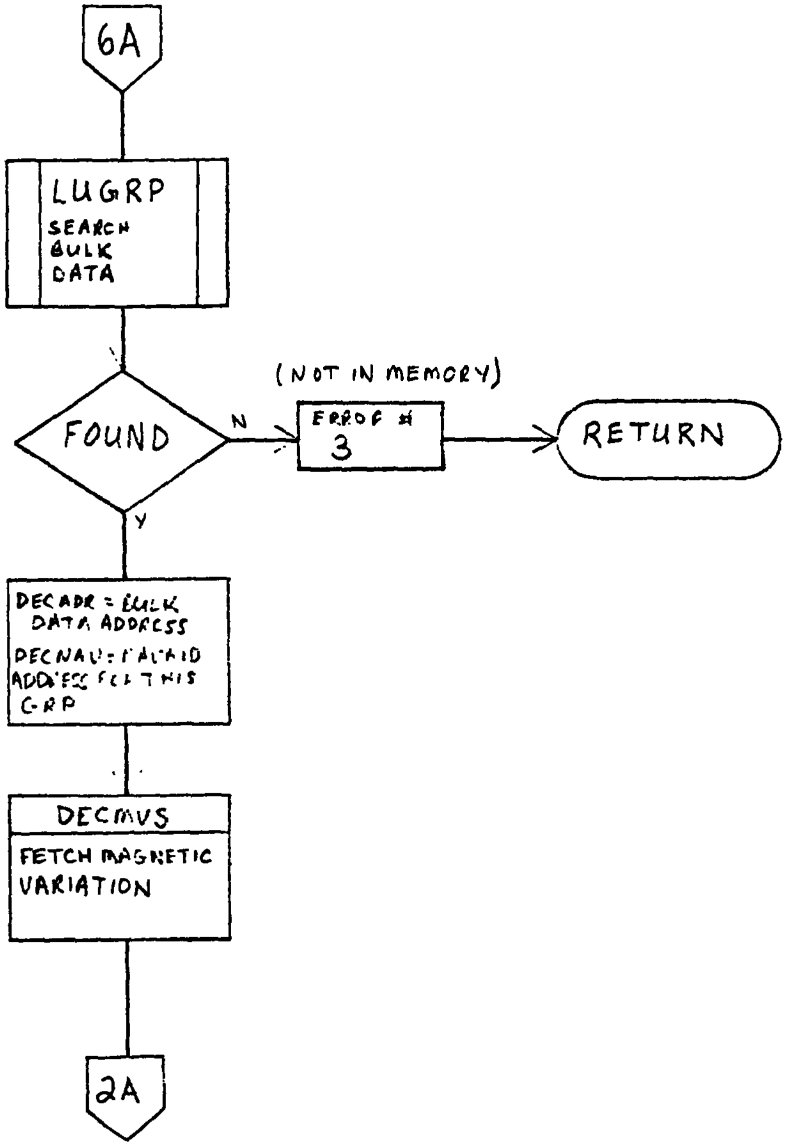

3A
CHOOSE WHICH OF 7 TYPES OF WPT ENTRIES WAS MADE BY THE FORM OF THE INPUT TEXT
5A
AIRPORT
NAVAID
4A
7A
PILOT POINT
GRP
6A
9A
LAT/LON
POSITION
8A
WPT/BRG/RNG
10A

NAVAID WAYPOINT



NOTE: FOR A NAVAID, THE ASSOCIATED NAVAID (DECNAV) IS ITSELF


5A
LUARP
SEARCH
BULK
DATA
FOUND
N
(NOT IN MEMORY)
ERROR #
3
RETURN
Y
DECADR = BULK
DATA ADDRESS
DECNAV = 0 (NO
NAVAID)
DECMV = MAGVAR
FOR THIS AIR-
PORT
2A



ORIGINAL PAGE IS
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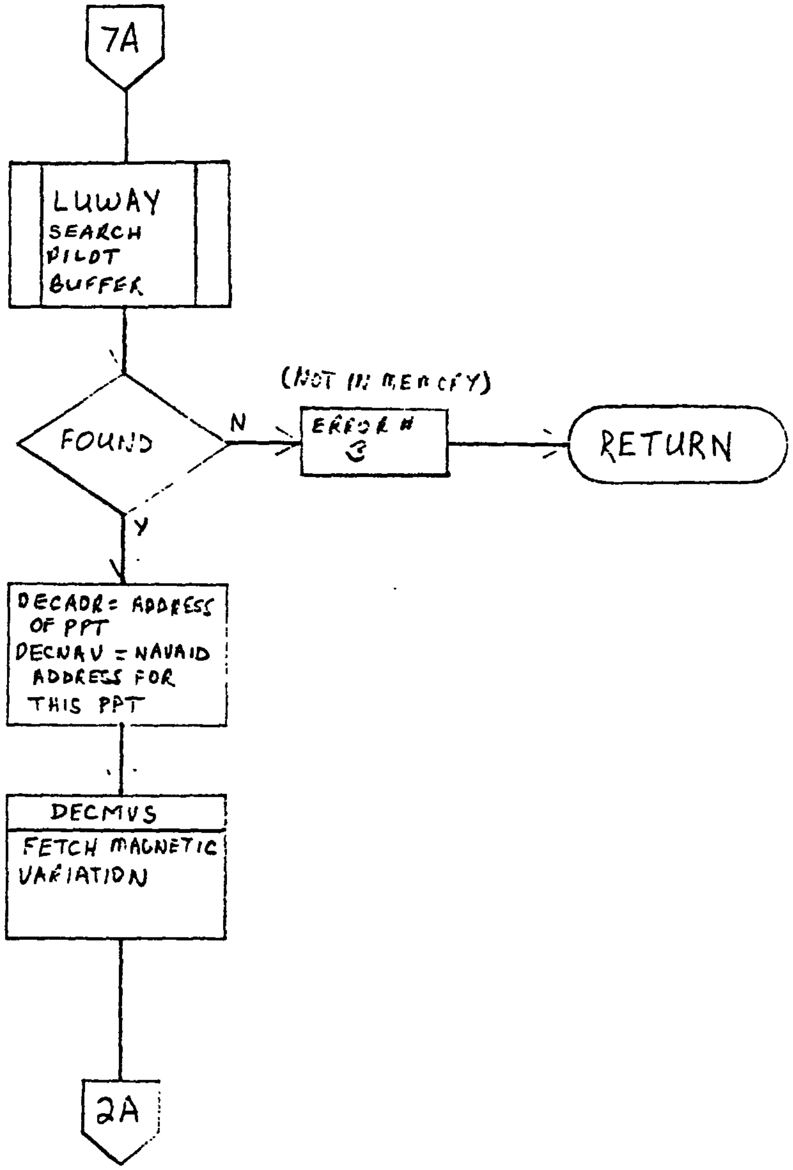
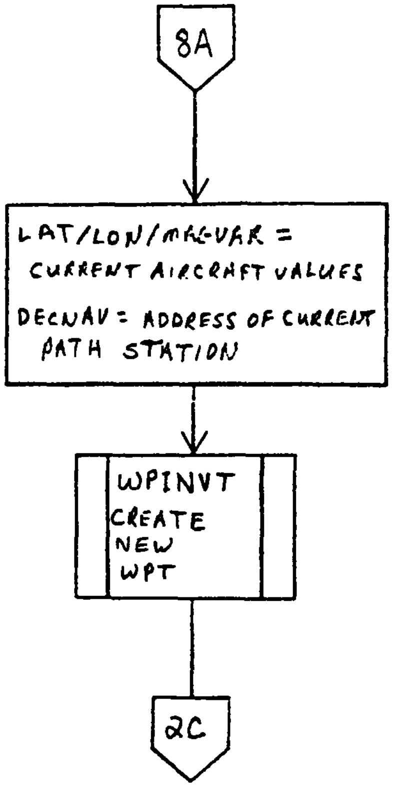
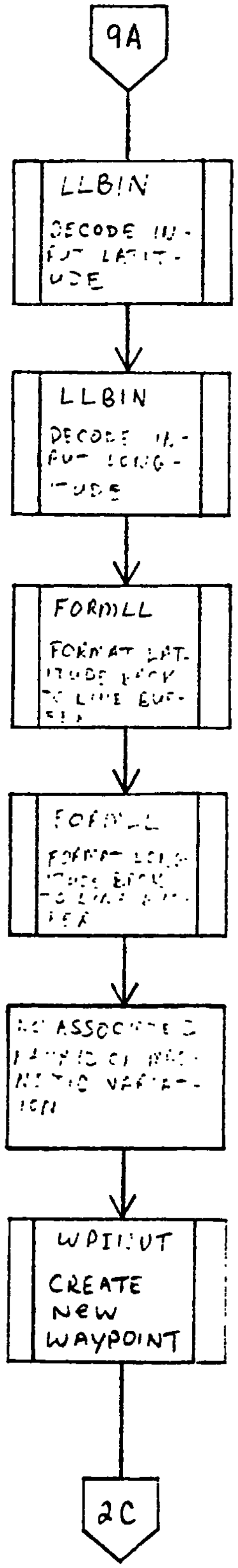
PILOT DEFINED WAYPOINT



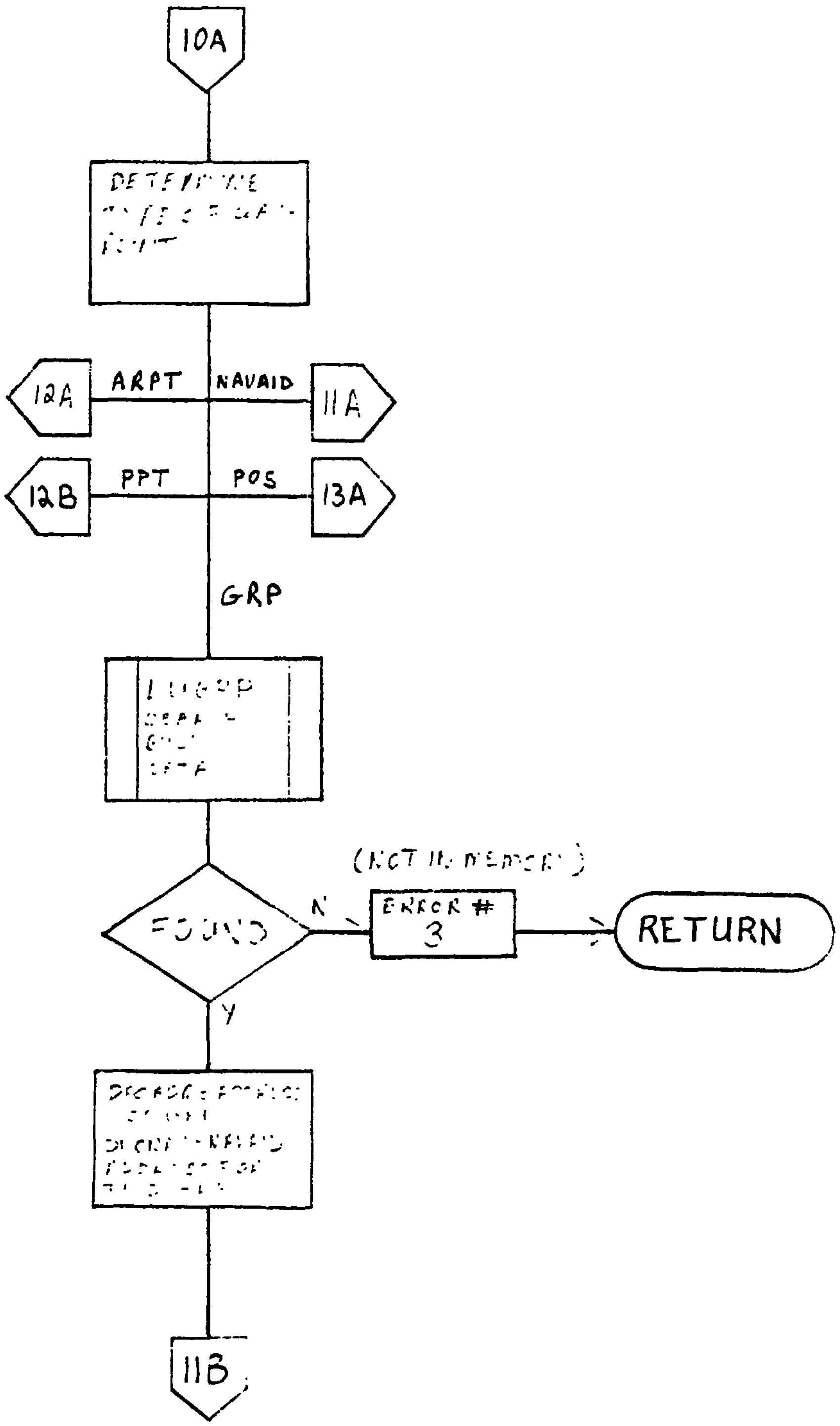
POSITION - CREATE NEW WAYPOINT


8A
LAT/LON/MAGVAR = CURRENT AIRCRAFT VALUES
DECNAV = ADDRESS OF CURRENT PATH STATION
WPINVT
CREATE NEW WPT
2C

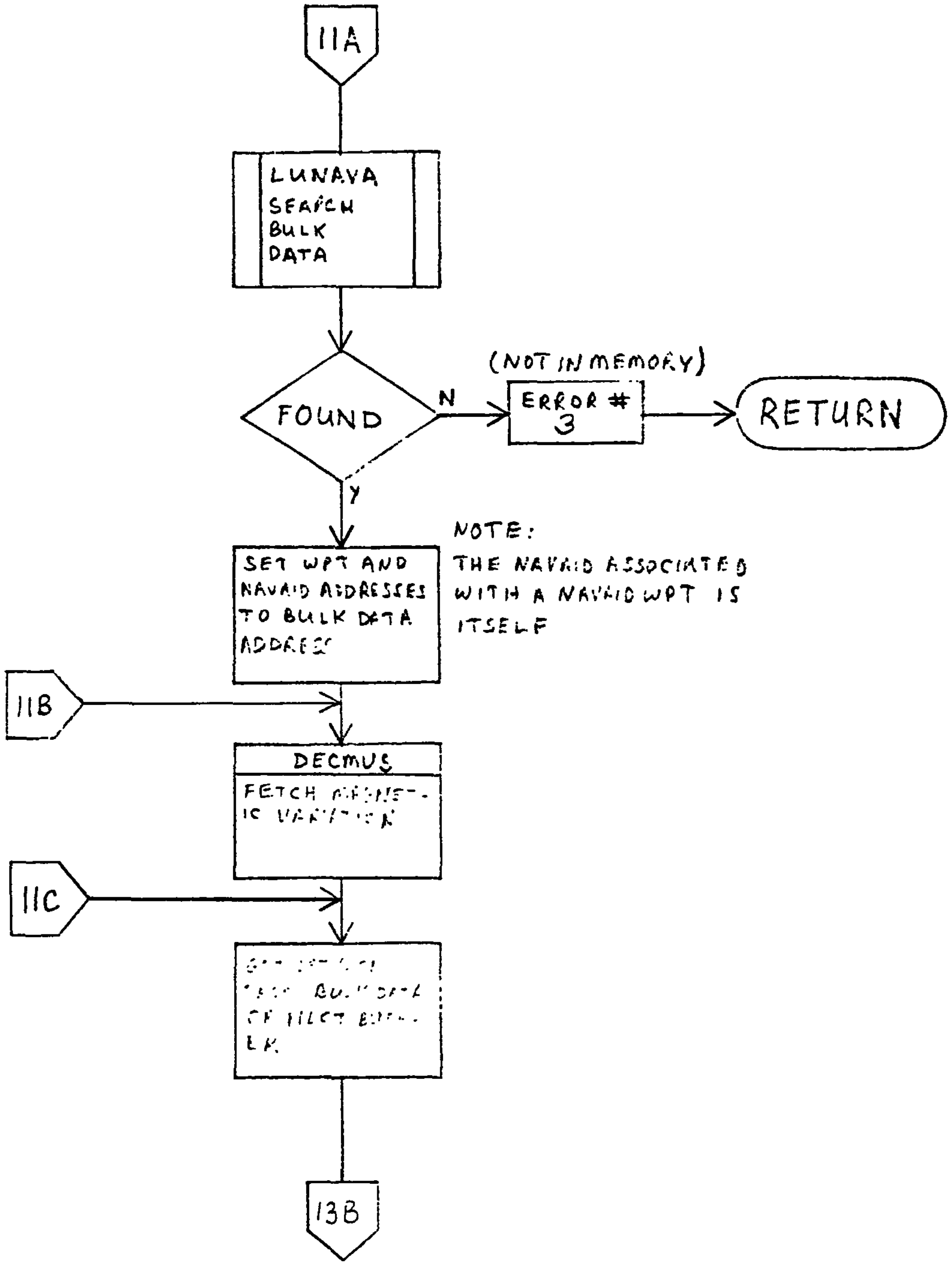
ORIGINAL PAGE IS
OF POOR QUALITY

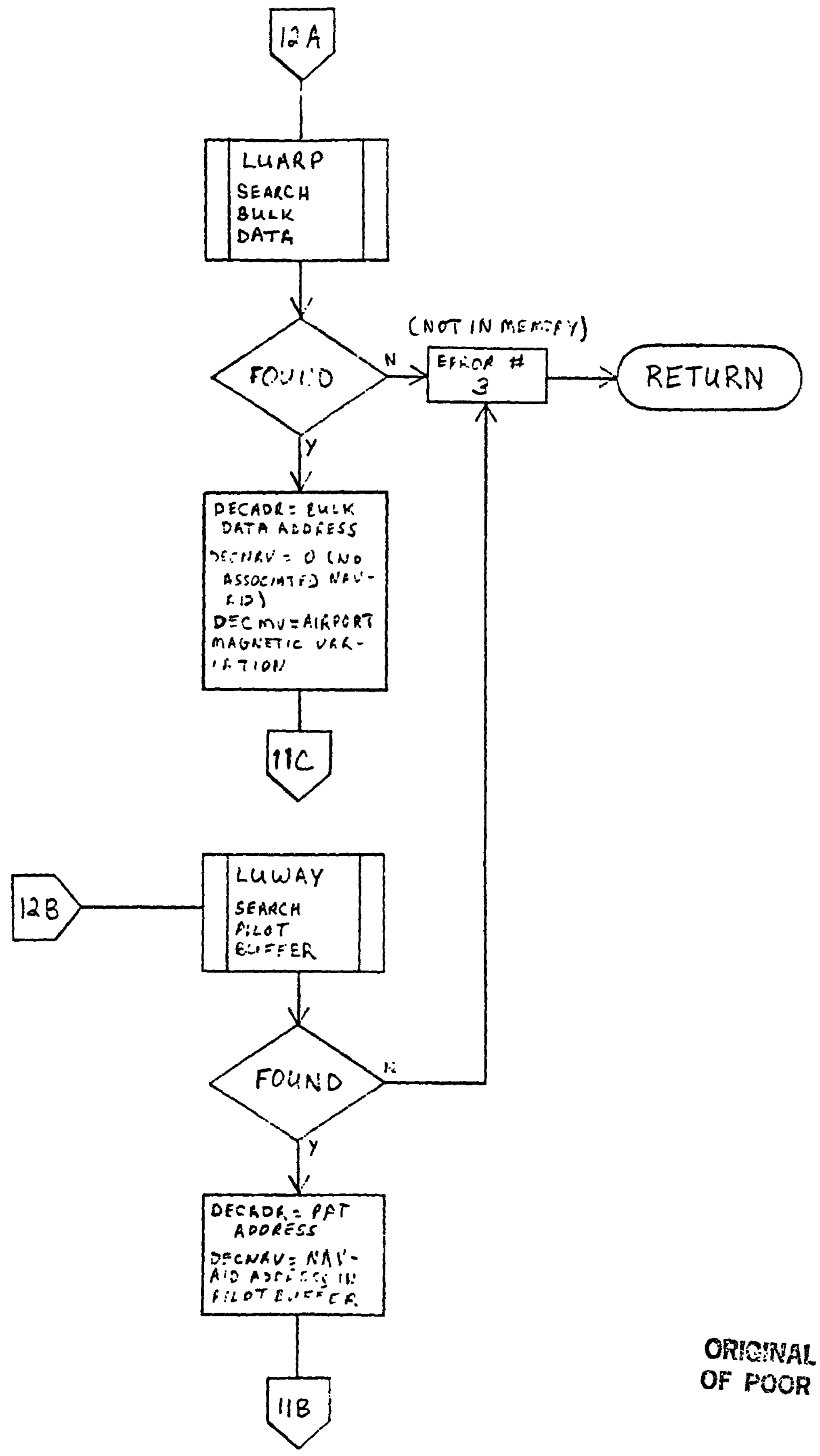

9A
LLBIN
DECODE INPUT LATITUDE
LLBIN
DECODE INPUT LONGITUDE
FORMLL
FORMAT LATITUDE BACK TO LINE BUFFER
FORMLL
FORMAT LONGITUDE BACK TO LINE BUFFER
NO ASSOCIATED NAVAID OR MAGNETIC VARIATION
WPINUT
CREATE NEW WAYPOINT
2C

WAYPOINT [illegible]/RANGE

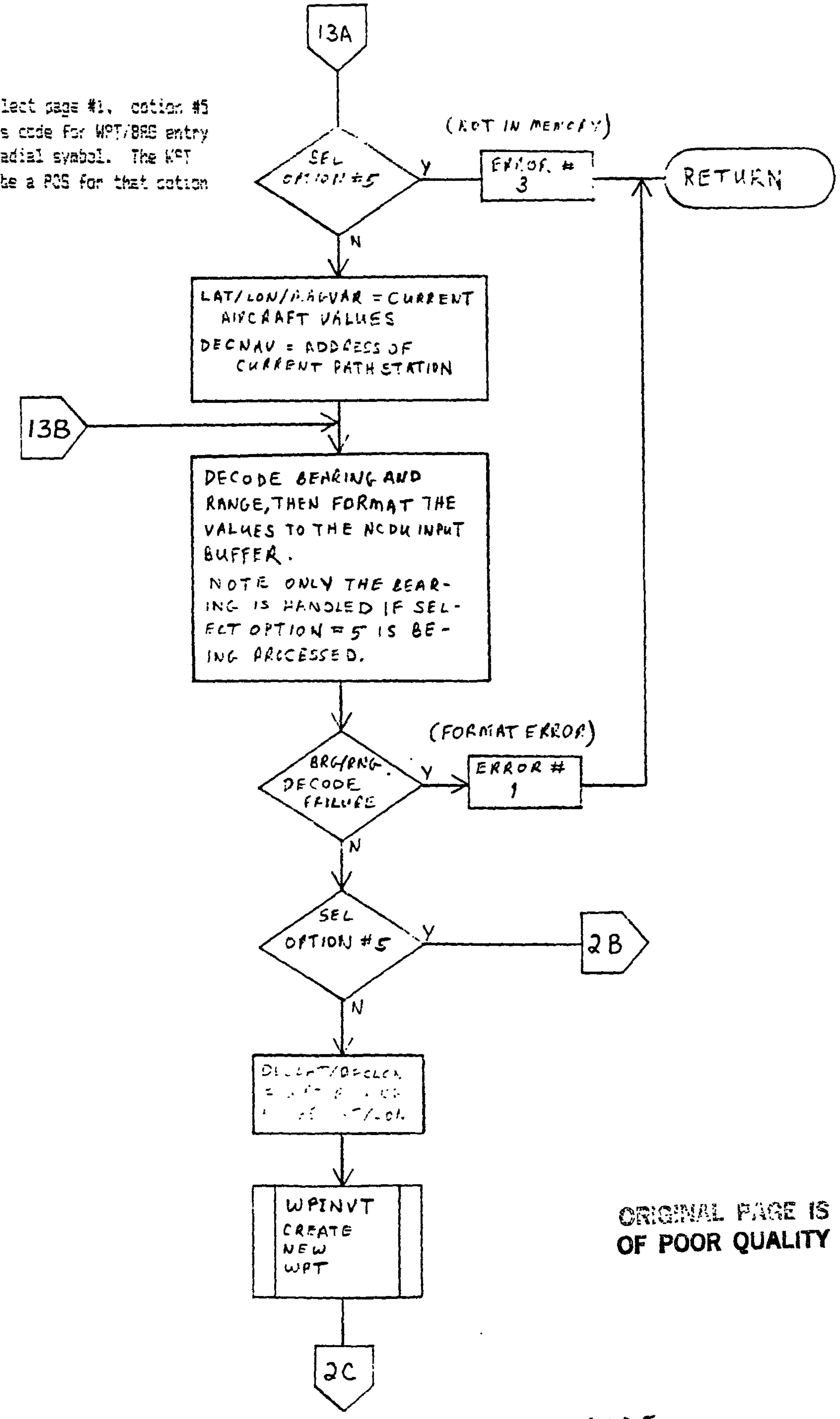


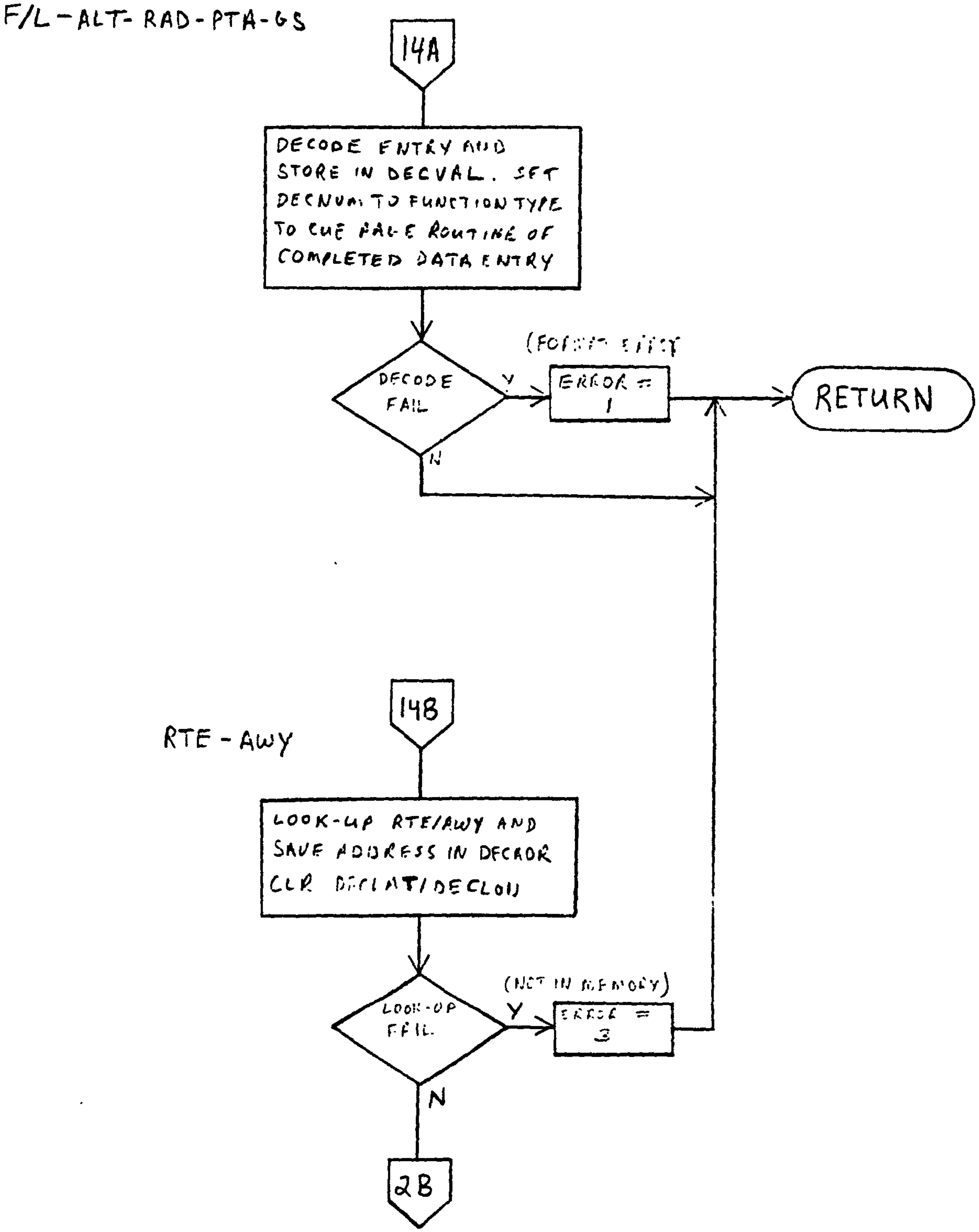
ORIGINAL PAGE IS
OF POOR QUALITY

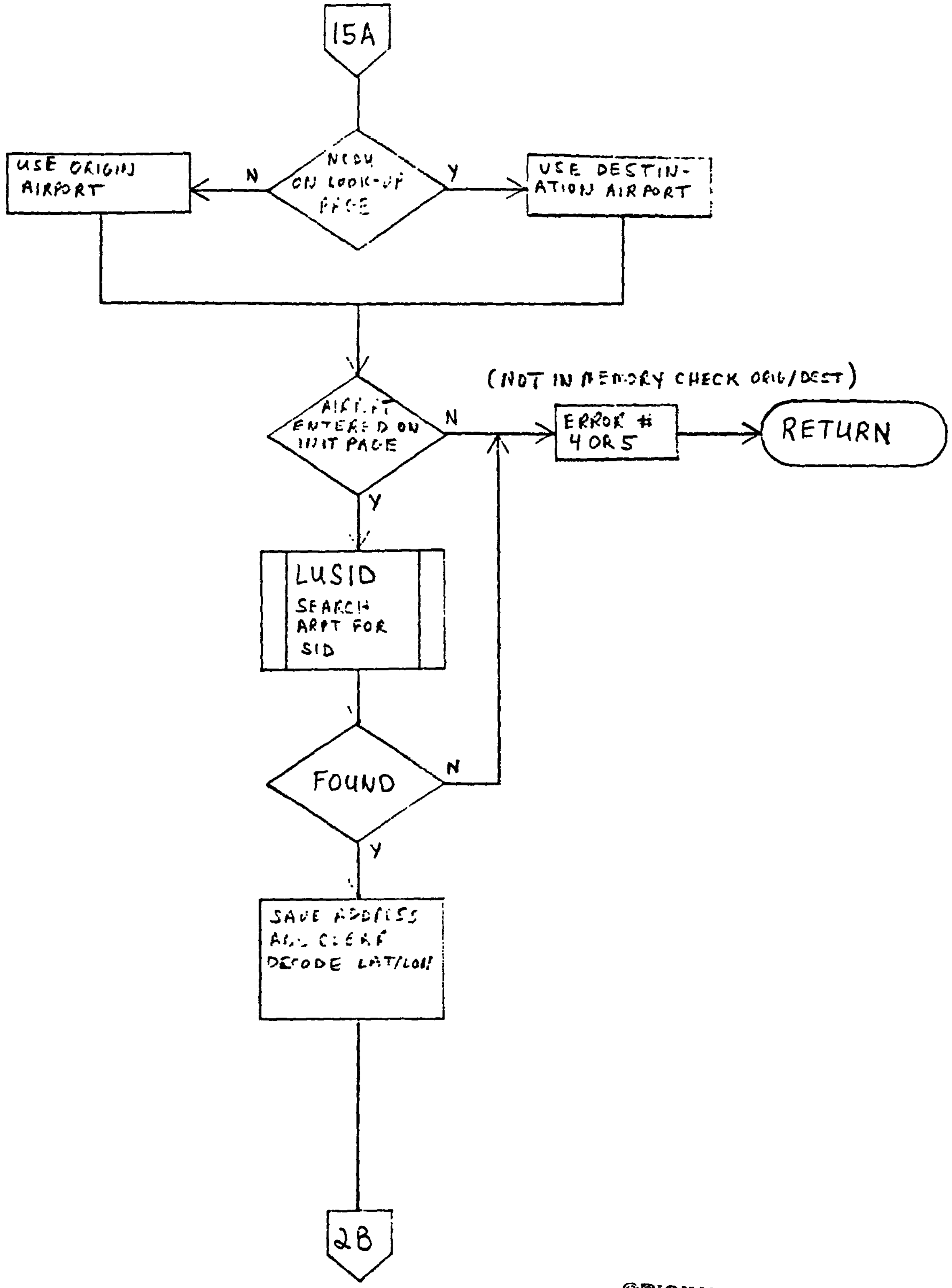

11A
LUNAVA
SEARCH
BULK
DATA
FOUND
N
(NOT IN MEMORY)
ERROR #
3
RETURN
Y
SET WPT AND
NAVAID ADDRESSES
TO BULK DATA
ADDRESS
NOTE:
THE NAVAID ASSOCIATED
WITH A NAVAID WPT IS
ITSELF
11B
DECMUS
FETCH MAGNET-
IC VARIATION
11C
GET SET ADR
FROM BULK DATA
OF PILOT BUFF-
ER.
13B


12A
LUARP
SEARCH
BULK
DATA
FOUND
N
(NOT IN MEMORY)
ERROR #
3
RETURN
Y
DECADR = BULK
DATA ADDRESS
DECNAV = 0 (NO
ASSOCIATED NAV-
AID)
DECMV = AIRPORT
MAGNETIC VAR-
IATION
11C
12B
LUWAY
SEARCH
PILOT
BUFFER
FOUND
N
Y
DECADR = PPT
ADDRESS
DECNAV = NAV-
AID ADDRESS IN
PILOT BUFFER
11B

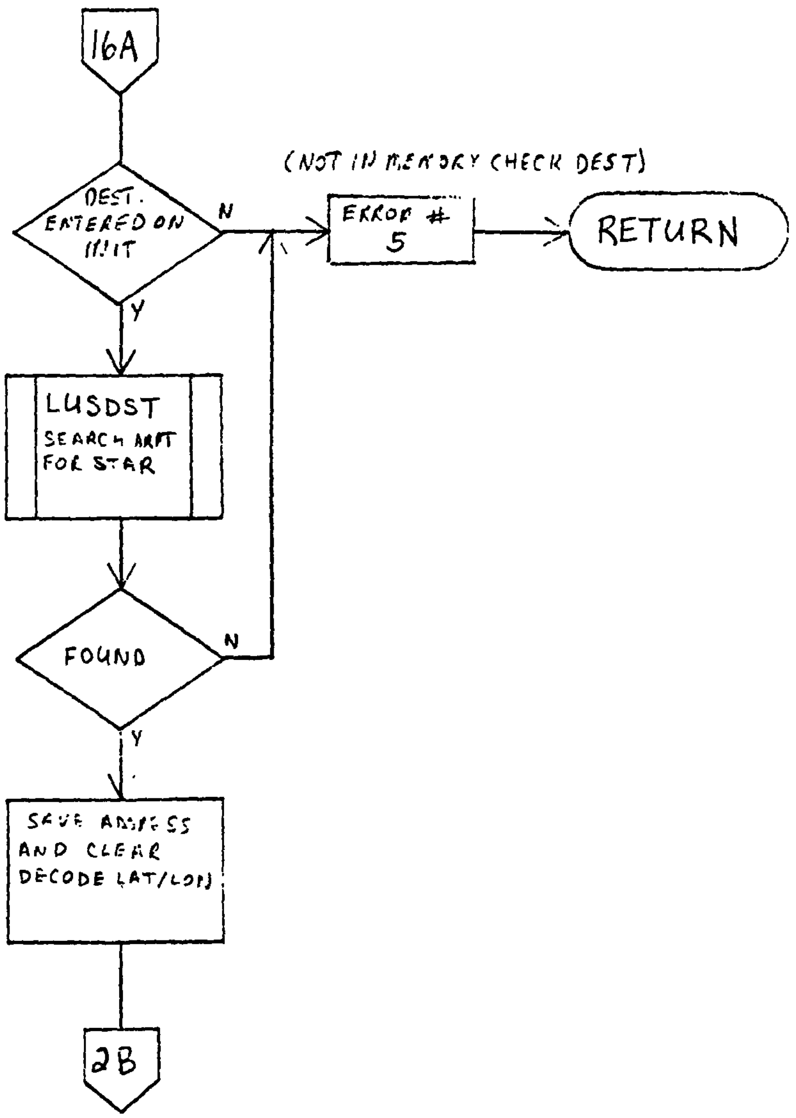
NOTE: Select page #1, option #5 uses this code for WPT/BRG entry of the radial symbol. The WPT may not be a POS for that option however.

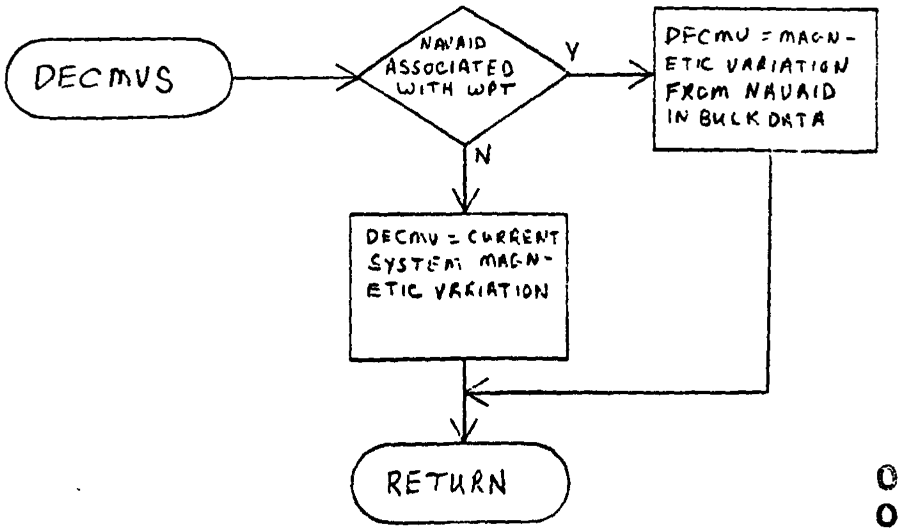

13A
SEL OPTION #5
Y
(NOT IN MEMORY)
ERROR # 3
RETURN
N
LAT/LON/MAGVAR = CURRENT AIRCRAFT VALUES
DECNAV = ADDRESS OF CURRENT PATH STATION
13B
DECODE BEARING AND RANGE, THEN FORMAT THE VALUES TO THE NCDU INPUT BUFFER.
NOTE ONLY THE BEARING IS HANDLED IF SELECT OPTION = 5 IS BEING PROCESSED.
BRG/RNG DECODE FAILURE
Y
(FORMAT ERROR)
ERROR # 1
N
SEL OPTION #5
Y
2B
N
DLLAT/DPCLON = [illegible]
WPINVT
CREATE NEW WPT
2C

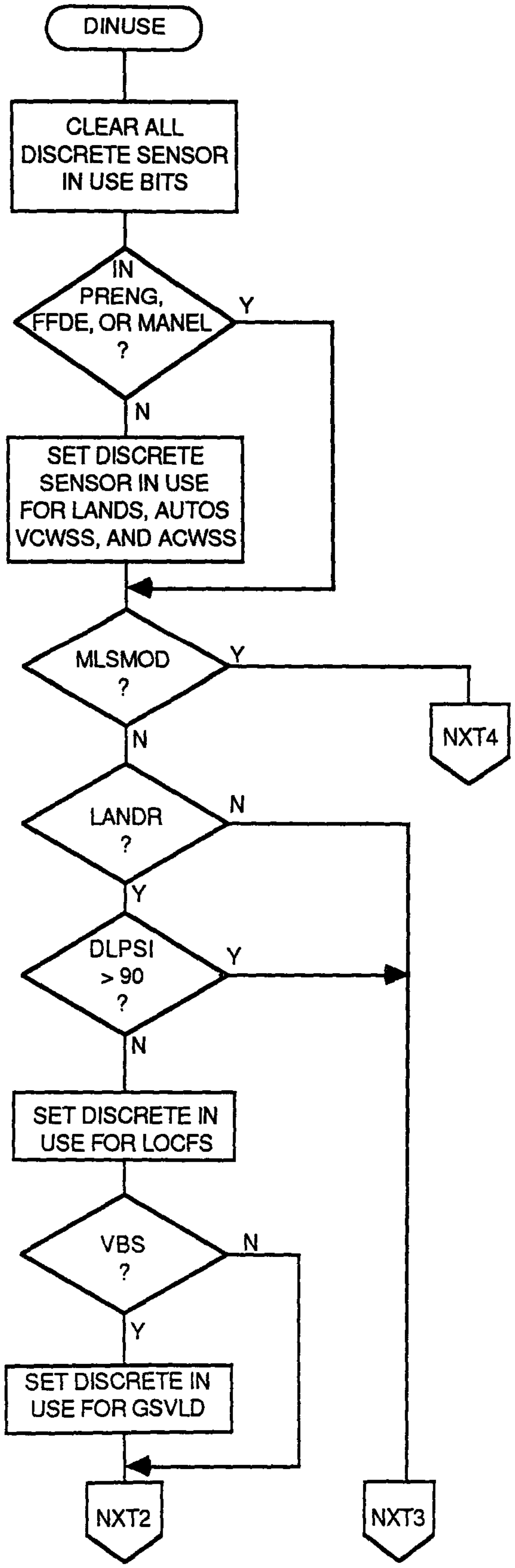

F/L-ALT-RAD-PTA-GS
14A
DECODE ENTRY AND STORE IN DECVAL. SET DECNUM TO FUNCTION TYPE TO CUE PAGE ROUTINE OF COMPLETED DATA ENTRY
DECODE FAIL
Y
N
(FORMAT ERROR
ERROR = 1
RETURN
RTE-AWY
14B
LOOK-UP RTE/AWY AND SAVE ADDRESS IN DECADR
CLR DECLAT/DECLON
LOOK-UP FAIL
Y
N
(NOT IN MEMORY)
ERROR = 3
2B



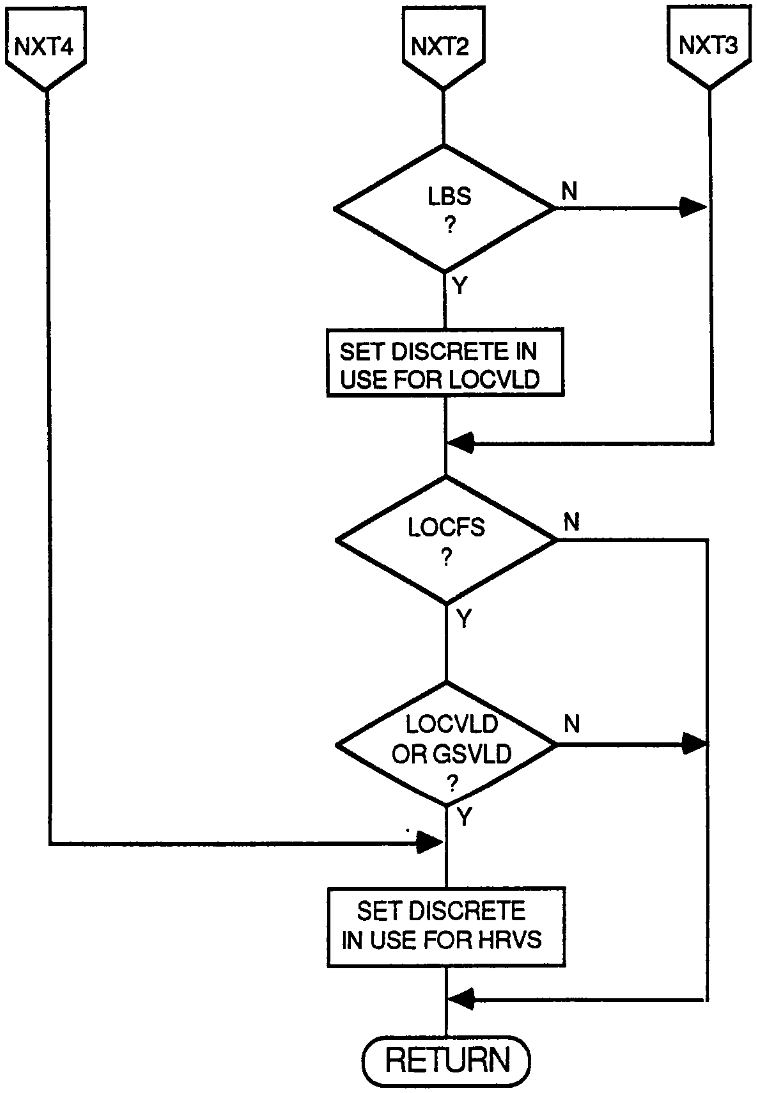
DECODE
(PAGE 15 OF 16)

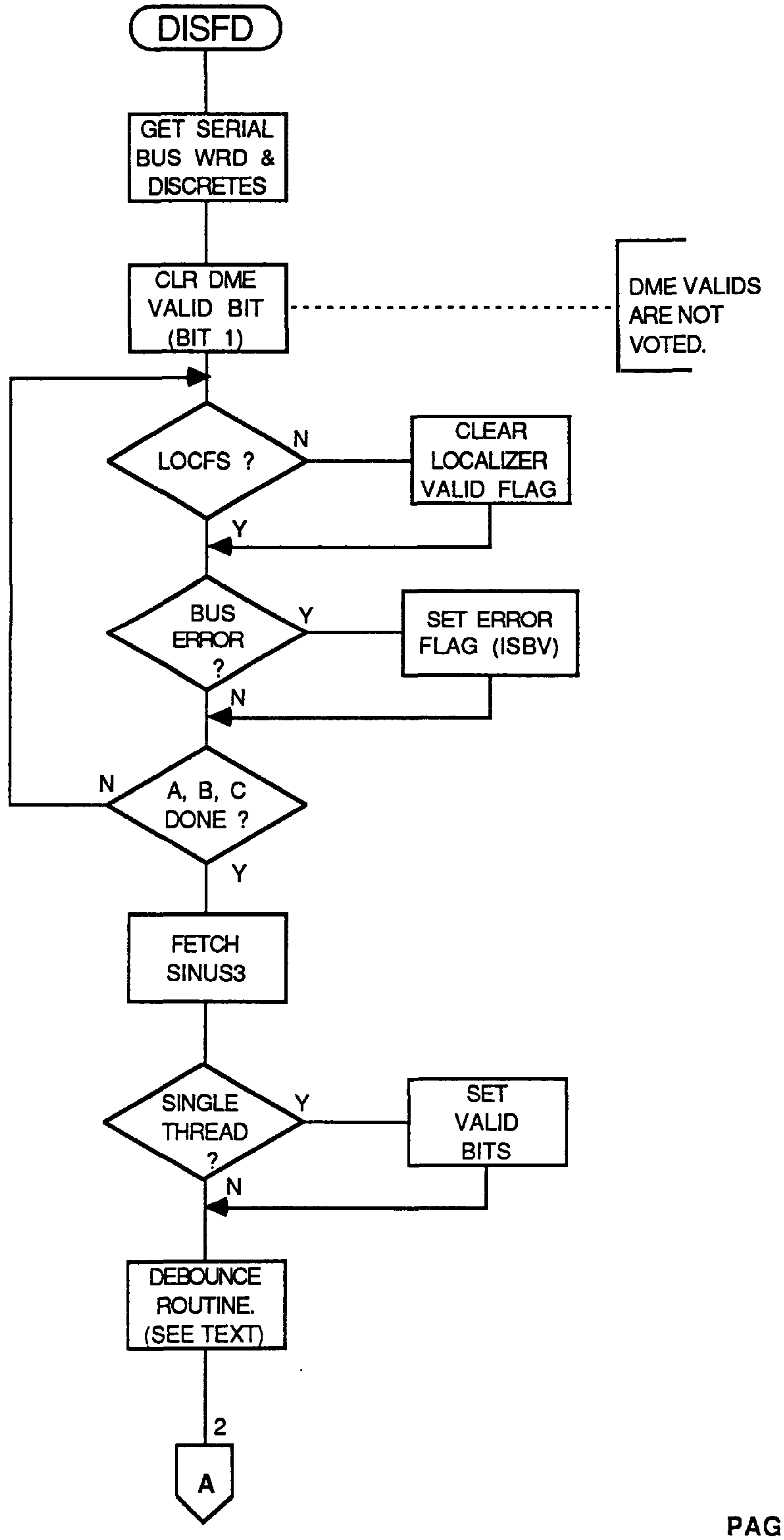

16A
(NOT IN MEMORY CHECK DEST)
DEST. ENTERED ON INIT
N
Y
ERROR # 5
RETURN
LUSDST
SEARCH ARPT FOR STAR
FOUND
N
Y
SAVE ADDRESS AND CLEAR DECODE LAT/LON
2B


DECMVS
NAVAID ASSOCIATED WITH WPT
Y
DECMV = MAGNETIC VARIATION FROM NAVAID IN BULK DATA
N
DECMV = CURRENT SYSTEM MAGNETIC VARIATION
RETURN

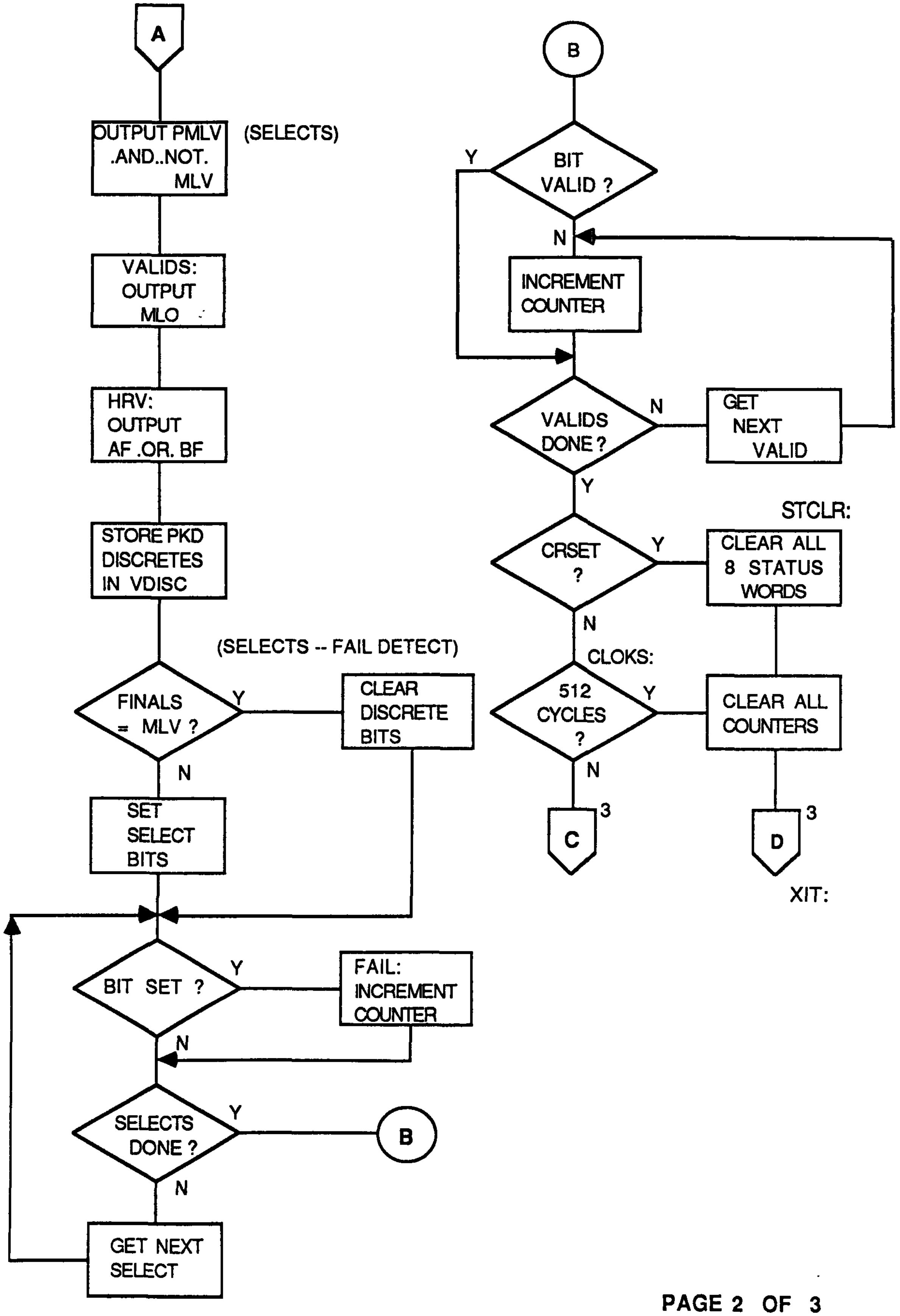

DINUSE
CLEAR ALL DISCRETE SENSOR IN USE BITS
IN PRENG, FFDE, OR MANEL ?
Y
N
SET DISCRETE SENSOR IN USE FOR LANDS, AUTOS VCWSS, AND ACWSS
MLSMOD ?
Y
NXT4
N
LANDR ?
N
Y
DLPSI > 90 ?
Y
N
SET DISCRETE IN USE FOR LOCFS
VBS ?
N
Y
SET DISCRETE IN USE FOR GSVLD
NXT2
NXT3

DINUSE
(PAGE 1 OF 2)

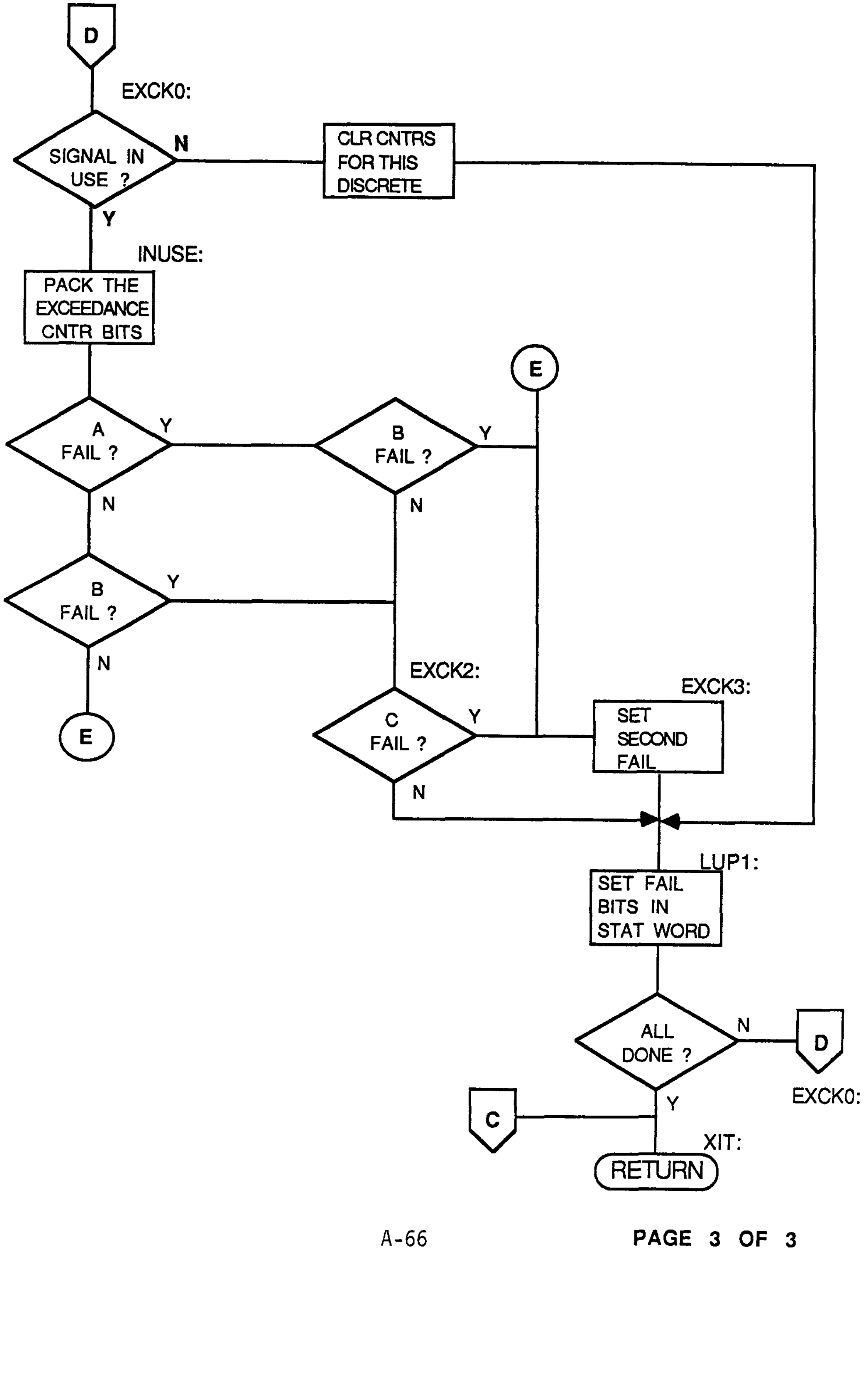

NXT4
NXT2
NXT3
LBS ?
N
Y
SET DISCRETE IN USE FOR LOCVLD
LOCFS ?
N
Y
LOCVLD OR GSVLD ?
N
Y
SET DISCRETE IN USE FOR HRVS
RETURN

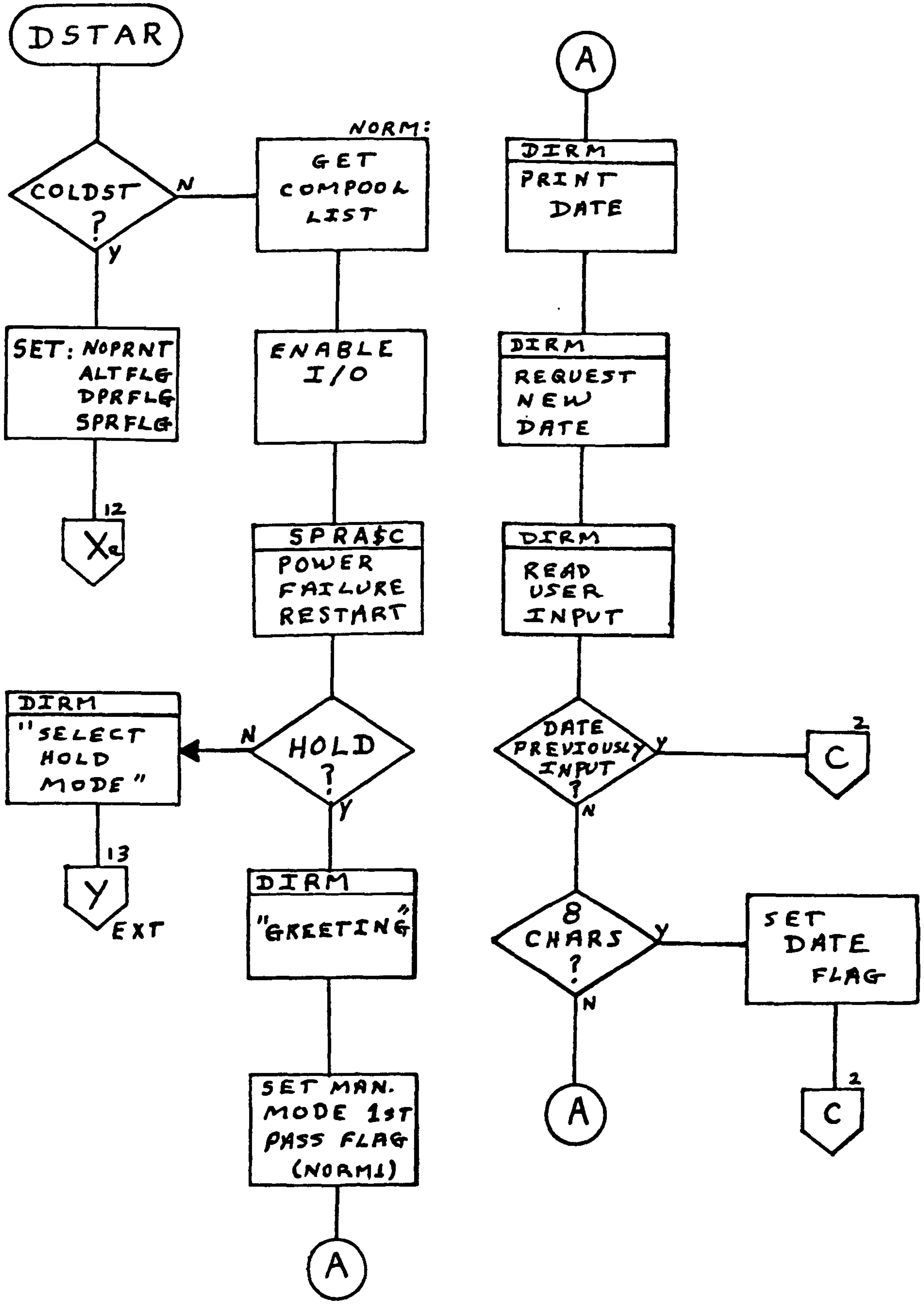

DISFD
GET SERIAL BUS WRD & DISCRETES
CLR DME VALID BIT (BIT 1)
DME VALIDS ARE NOT VOTED.
LOCFS ?
N
CLEAR LOCALIZER VALID FLAG
Y
BUS ERROR ?
Y
SET ERROR FLAG (ISBV)
N
A, B, C DONE ?
N
Y
FETCH SINUS3
SINGLE THREAD ?
Y
SET VALID BITS
N
DEBOUNCE ROUTINE. (SEE TEXT)
2
A

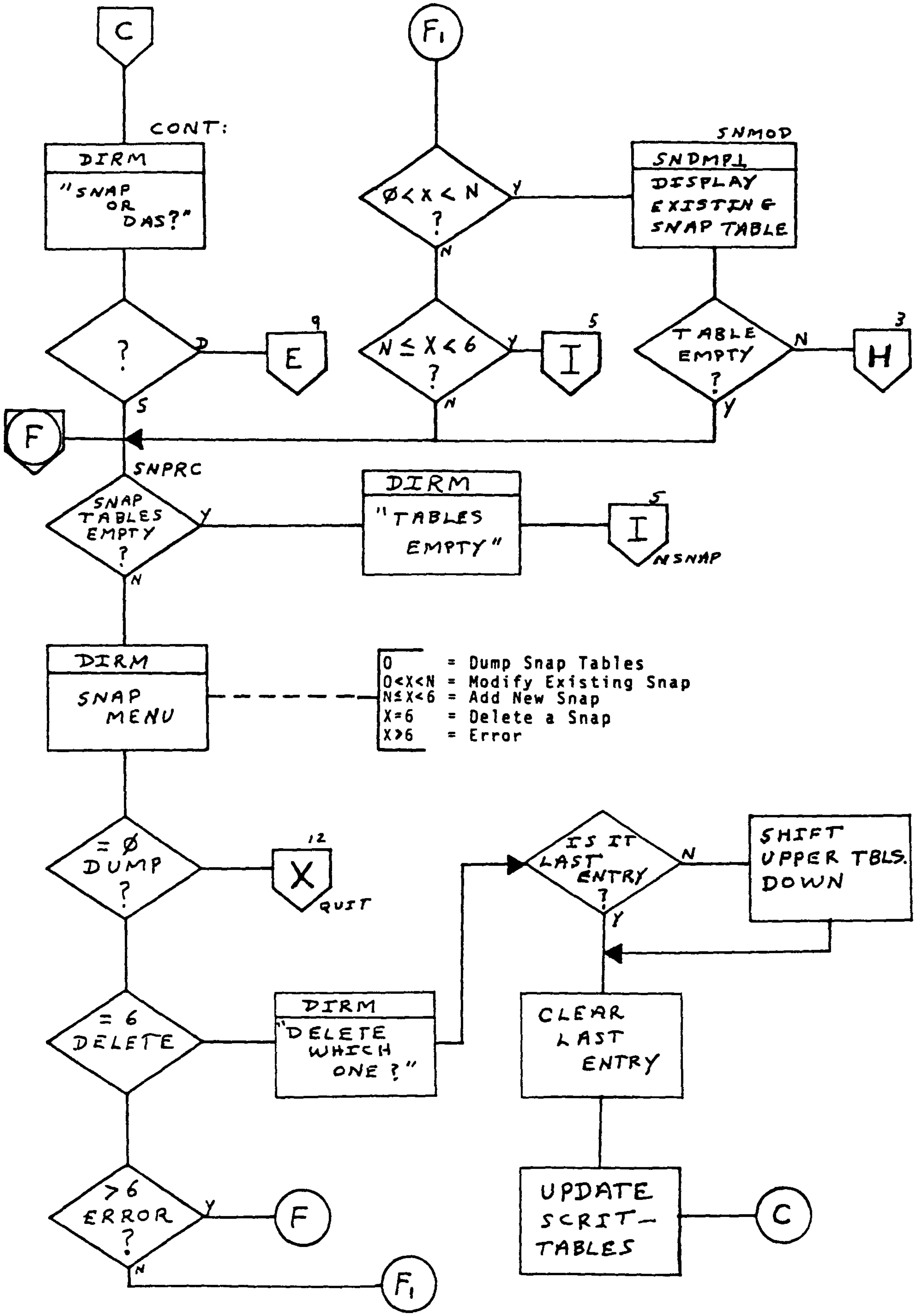
PAGE 1 OF 3


A
OUTPUT PMLV .AND..NOT. MLV
(SELECTS)
VALIDS: OUTPUT MLO
HRV: OUTPUT AF .OR. BF
STORE PKD DISCRETES IN VDISC
(SELECTS -- FAIL DETECT)
FINALS = MLV ?
Y
CLEAR DISCRETE BITS
N
SET SELECT BITS
BIT SET ?
Y
FAIL: INCREMENT COUNTER
N
SELECTS DONE ?
Y
B
N
GET NEXT SELECT
B
BIT VALID ?
Y
N
INCREMENT COUNTER
VALIDS DONE ?
N
GET NEXT VALID
Y
STCLR:
CRSET ?
Y
CLEAR ALL 8 STATUS WORDS
N
CLOKS:
512 CYCLES ?
Y
CLEAR ALL COUNTERS
N
C
3
D
3
XIT:

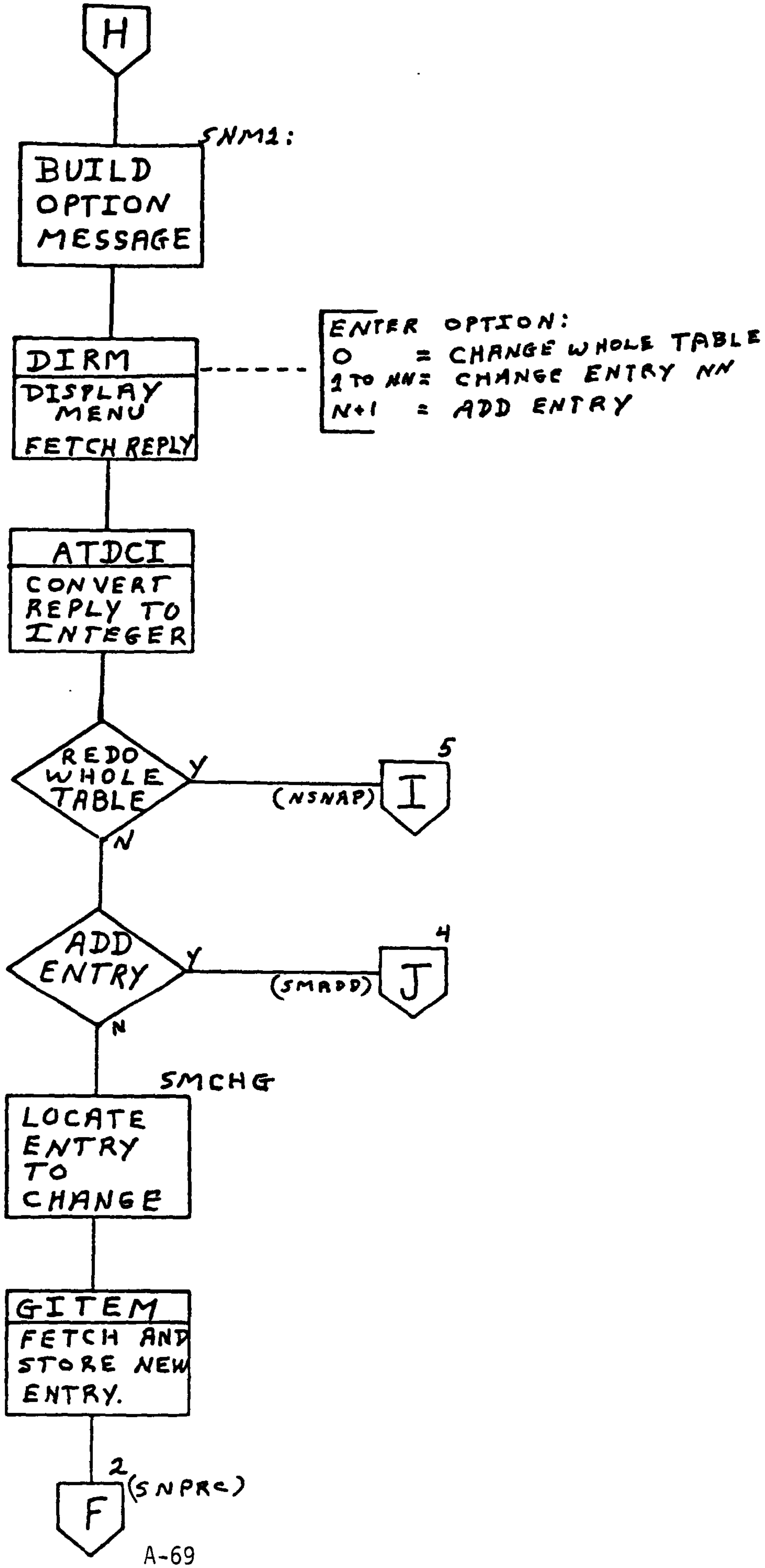
PAGE 2 OF 3

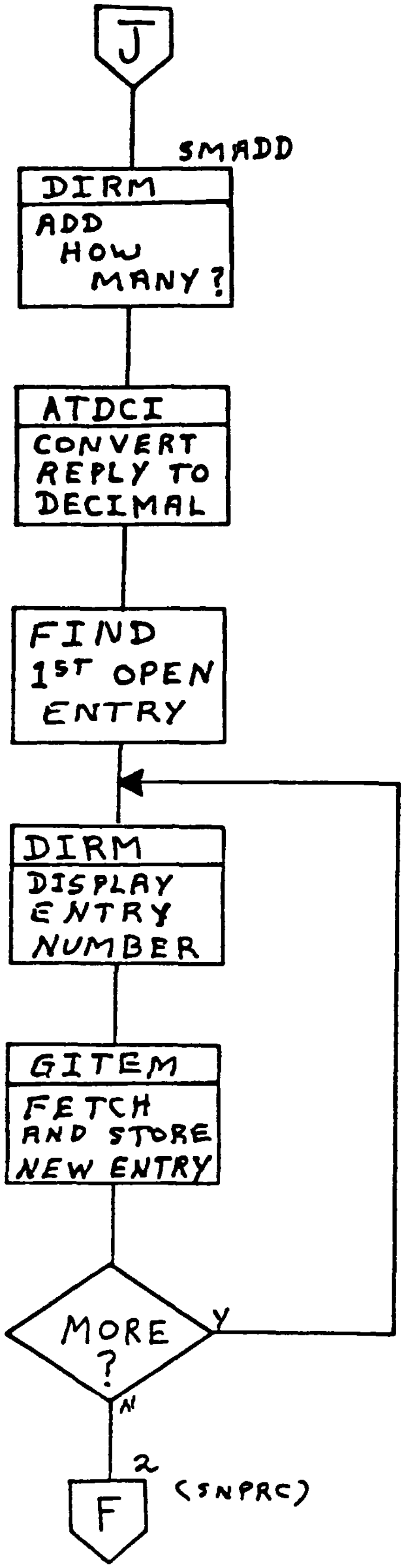

D
EXCK0:
SIGNAL IN USE ?
N
CLR CNTRS FOR THIS DISCRETE
Y
INUSE:
PACK THE EXCEEDANCE CNTR BITS
E
A FAIL ?
Y
B FAIL ?
Y
N
N
B FAIL ?
Y
N
E
EXCK2:
C FAIL ?
Y
N
EXCK3:
SET SECOND FAIL
LUP1:
SET FAIL BITS IN STAT WORD
ALL DONE ?
N
D
EXCK0:
Y
C
XIT:
RETURN

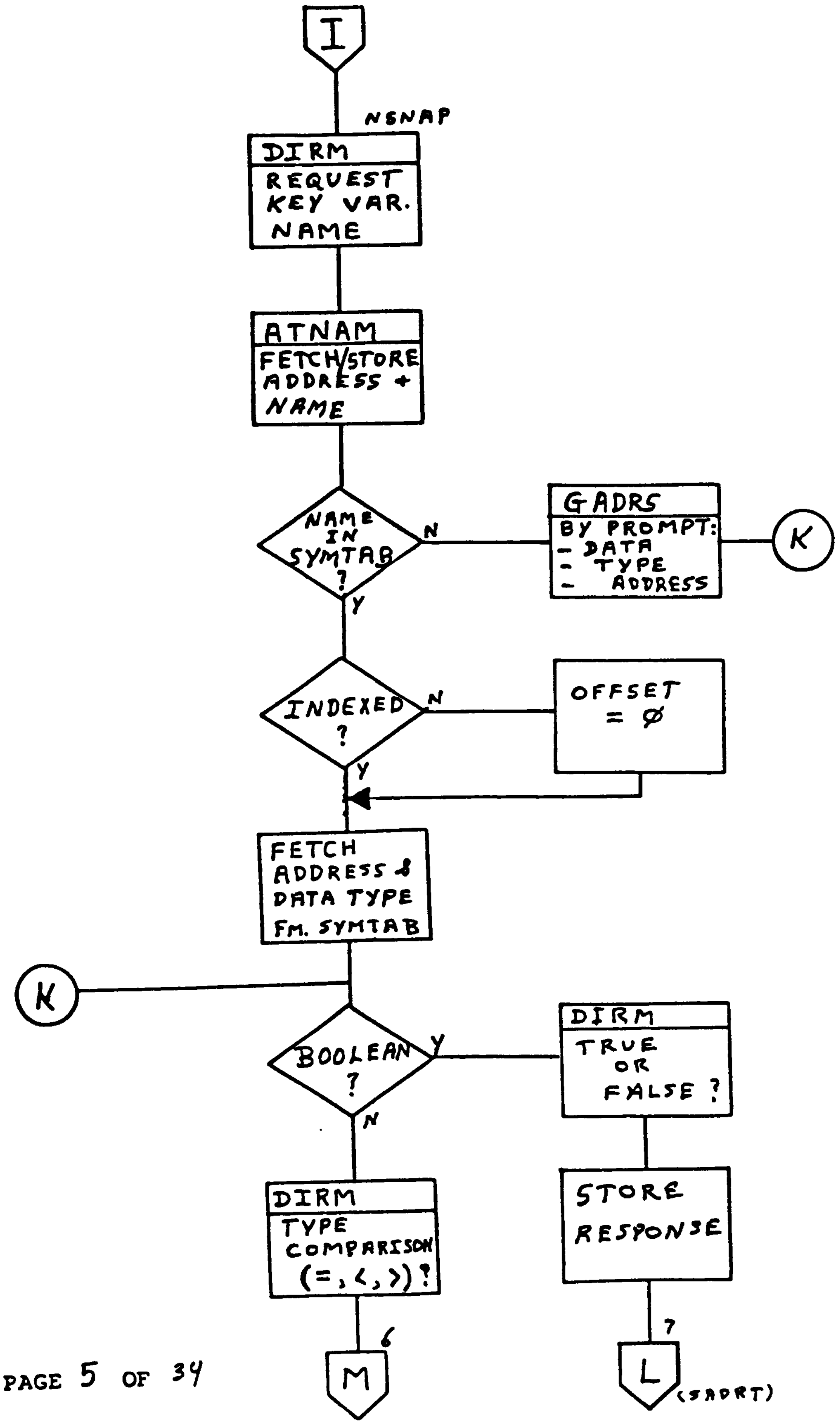

DSTAR
COLDST ?
N
Y
SET: NOPRNT
ALTFLG
DPRFLG
SPRFLG
12
X
NORM:
GET COMPOOL LIST
ENABLE I/O
SPRA$C
POWER FAILURE RESTART
HOLD ?
N
Y
DIRM
"SELECT HOLD MODE"
13
Y
EXT
DIRM
"GREETING"
SET MAN. MODE 1ST PASS FLAG (NORM1)
A
A
DIRM
PRINT DATE
DIRM
REQUEST NEW DATE
DIRM
READ USER INPUT
DATE PREVIOUSLY INPUT ?
Y
N
2
C
8 CHARS ?
Y
N
SET DATE FLAG
A
2
C



0 = Dump Snap Tables
0<X<N = Modify Existing Snap
N≤X<6 = Add New Snap
X=6 = Delete a Snap
X>6 = Error


H
SNM1:
BUILD OPTION MESSAGE
DIRM
DISPLAY MENU
FETCH REPLY
ENTER OPTION:
0 = CHANGE WHOLE TABLE
1 TO NN = CHANGE ENTRY NN
N+1 = ADD ENTRY
ATDCI
CONVERT REPLY TO INTEGER
REDO WHOLE TABLE
Y
(NSNAP)
I
5
N
ADD ENTRY
Y
(SMADD)
J
4
N
SMCHG
LOCATE ENTRY TO CHANGE
GITEM
FETCH AND STORE NEW ENTRY.
2
(SNPRC)
F


J
SMADD
DIRM
ADD HOW MANY?
ATDCI
CONVERT REPLY TO DECIMAL
FIND 1ST OPEN ENTRY
DIRM
DISPLAY ENTRY NUMBER
GITEM
FETCH AND STORE NEW ENTRY
MORE ?
Y
N
2
(SNPRC)
F


I
NSNAP
DIRM
REQUEST KEY VAR. NAME
ATNAM
FETCH/STORE ADDRESS + NAME
NAME IN SYMTAB ?
N
Y
GADRS
BY PROMPT:
- DATA
- TYPE
- ADDRESS
K
INDEXED ?
N
Y
OFFSET = Ø
FETCH ADDRESS & DATA TYPE FM. SYMTAB
K
BOOLEAN ?
Y
N
DIRM
TRUE OR FALSE ?
DIRM
TYPE COMPARISON (=, <, >) ?
STORE RESPONSE
6
M
7
L
(SHORT)

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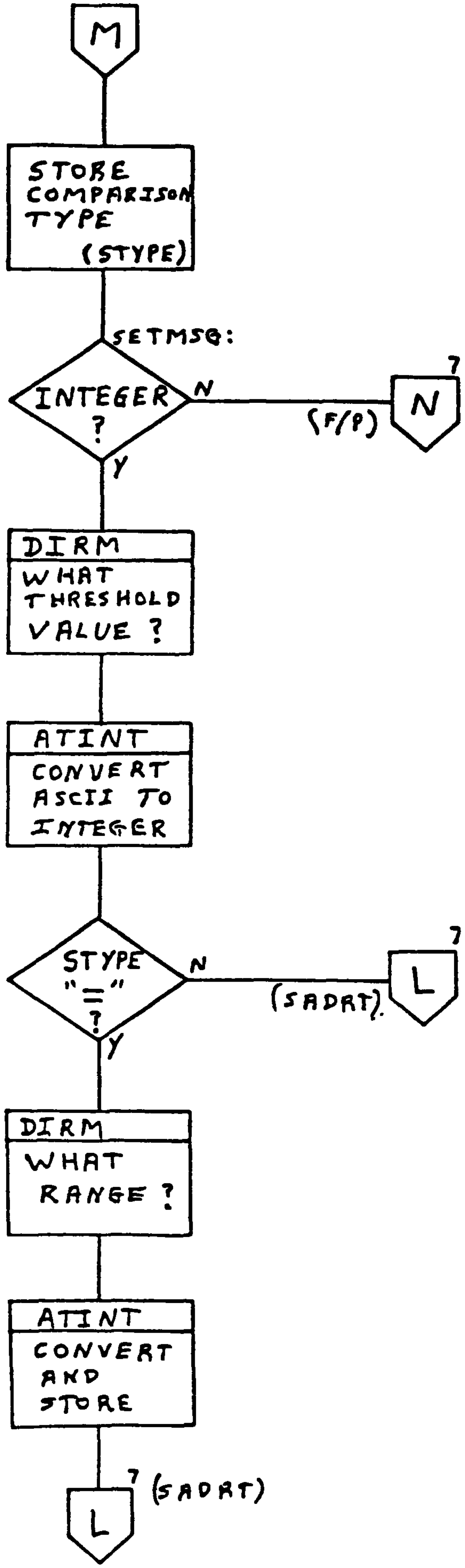
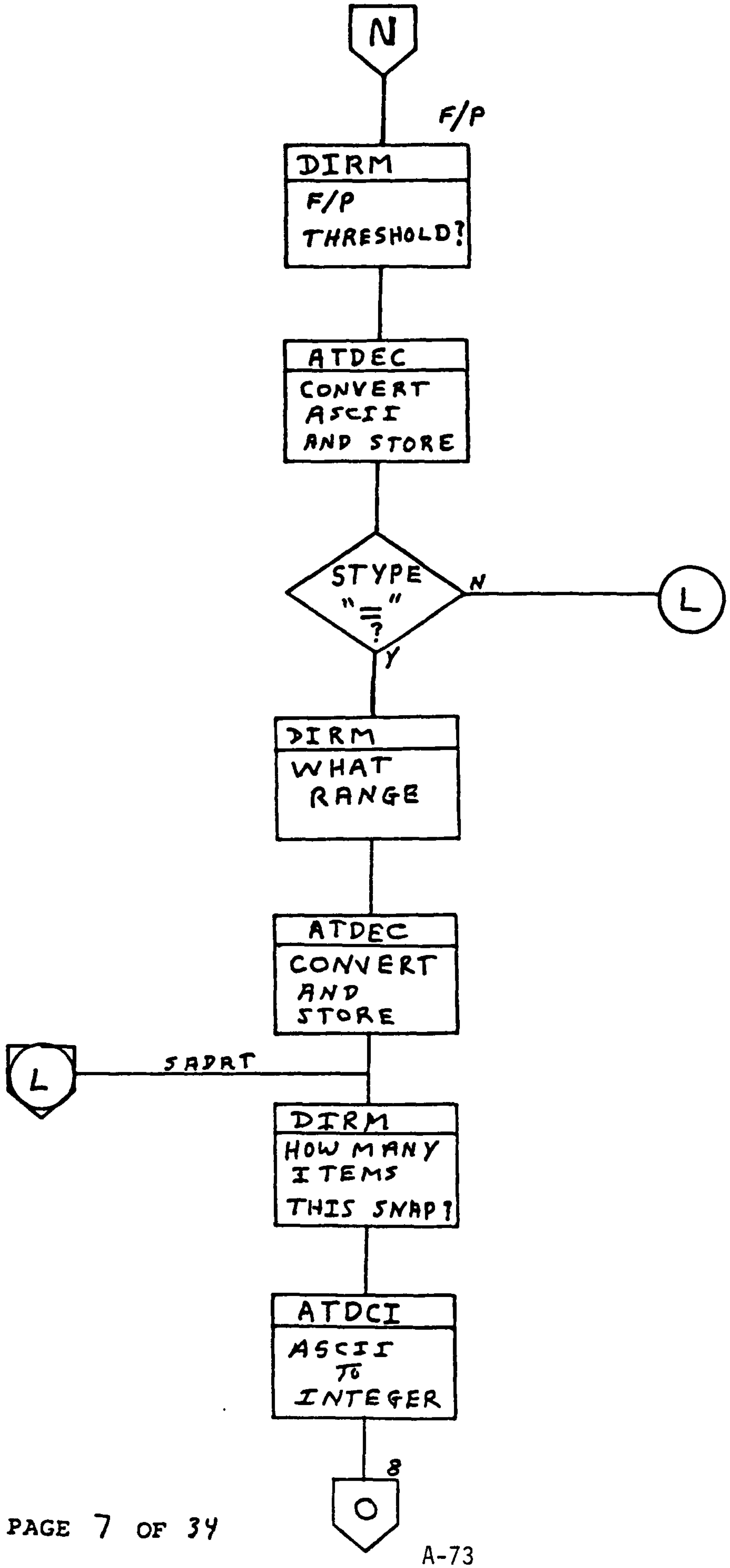
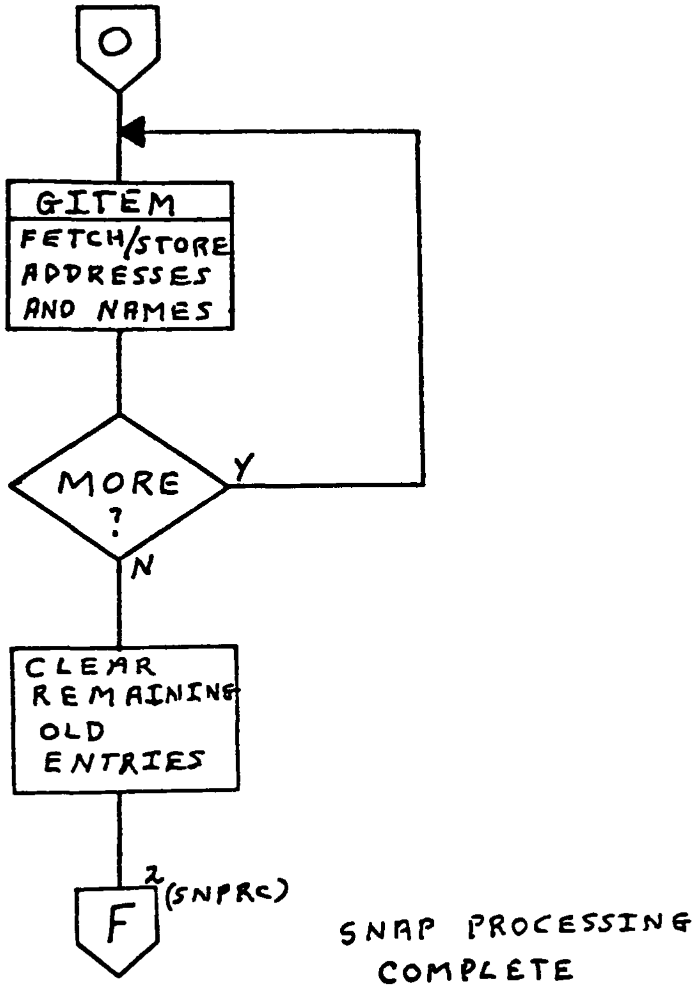
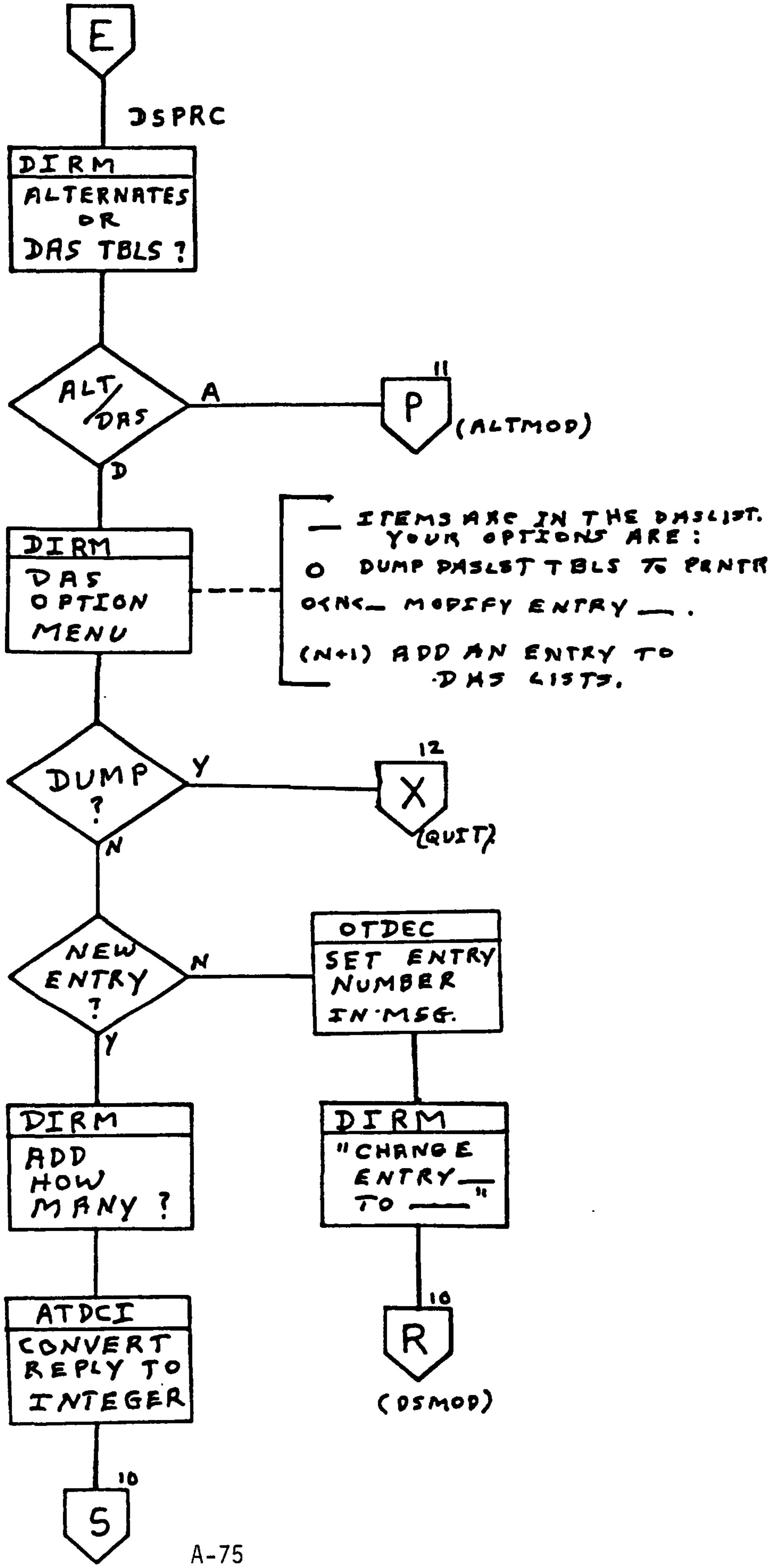
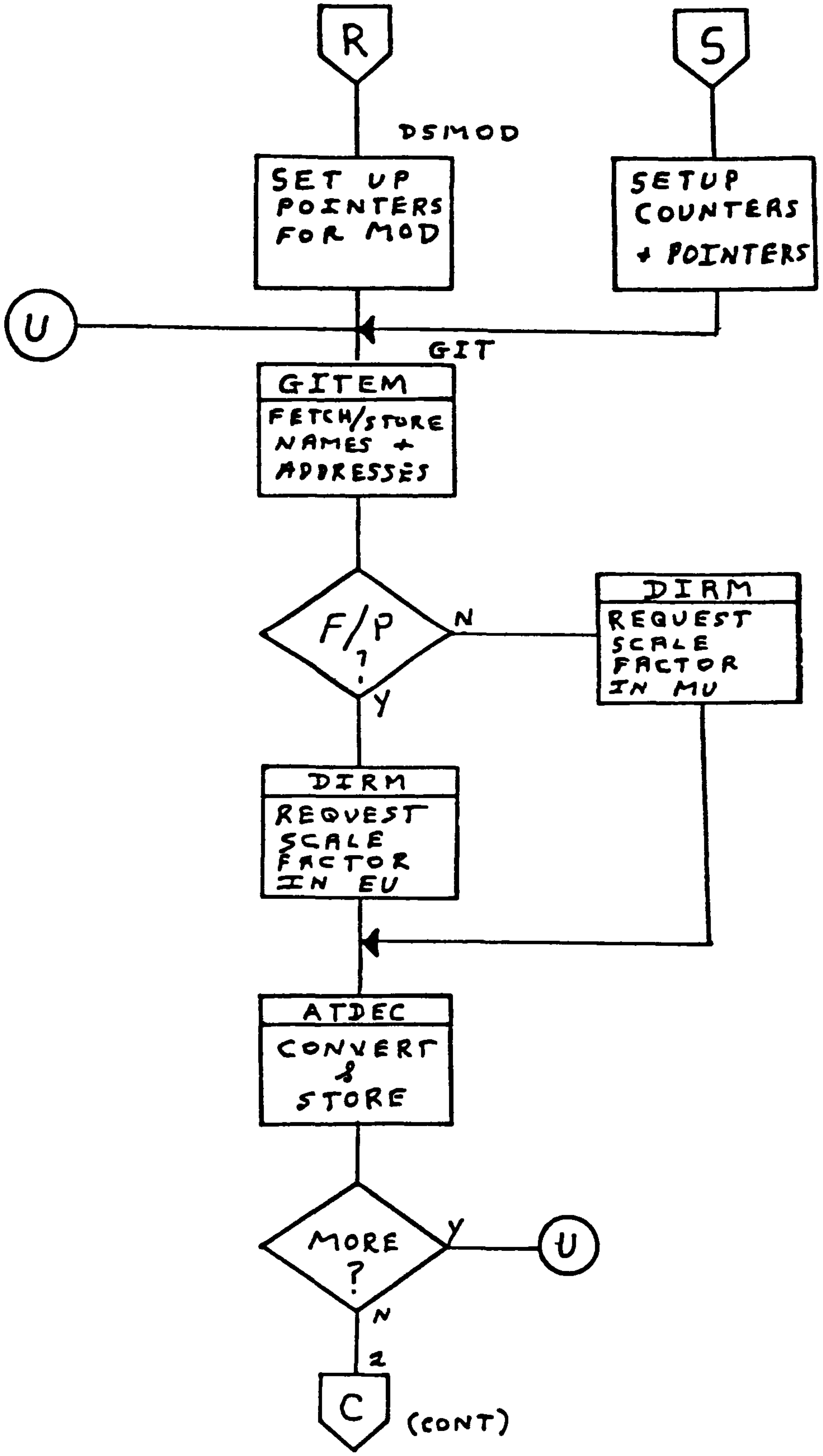

M
STORE
COMPARISON
TYPE
(STYPE)
SETMSG:
INTEGER
?
N
(F/P)
7
N
Y
DIRM
WHAT
THRESHOLD
VALUE ?
ATINT
CONVERT
ASCII TO
INTEGER
STYPE
"="
?
N
(SADRT)
7
L
Y
DIRM
WHAT
RANGE ?
ATINT
CONVERT
AND
STORE
7 (SADRT)
L


N
F/P
DIRM
F/P THRESHOLD?
ATDEC
CONVERT ASCII AND STORE
STYPE "=" ?
N
L
Y
DIRM
WHAT RANGE
ATDEC
CONVERT AND STORE
L
SADRT
DIRM
HOW MANY ITEMS THIS SNAP?
ATDCI
ASCII TO INTEGER
8
O


O
GITEM
FETCH/STORE ADDRESSES AND NAMES
MORE ?
Y
N
CLEAR REMAINING OLD ENTRIES
F
2 (SNPRC)
SNAP PROCESSING COMPLETE


E
DSPRC
DIRM
ALTERNATES OR DAS TBLS ?
ALT/DAS
A
D
11
P
(ALTMOD)
DIRM
DAS OPTION MENU
__ ITEMS ARE IN THE DASLIST. YOUR OPTIONS ARE:
0 DUMP DASLST TBLS TO PRNTR
0<N<__ MODIFY ENTRY __.
(N+1) ADD AN ENTRY TO DAS LISTS.
DUMP ?
Y
N
12
X
(QUIT)
NEW ENTRY ?
N
Y
OTDEC
SET ENTRY NUMBER IN MSG.
DIRM
ADD HOW MANY ?
DIRM
"CHANGE ENTRY__ TO __"
ATDCI
CONVERT REPLY TO INTEGER
10
R
(DSMOD)
10
S



R
S
DSMOD
SET UP POINTERS FOR MOD
SETUP COUNTERS + POINTERS
U
GIT
GITEM
FETCH/STORE NAMES + ADDRESSES
F/P ?
N
Y
DIRM
REQUEST SCALE FACTOR IN MU
DIRM
REQUEST SCALE FACTOR IN EU
ATDEC
CONVERT & STORE
MORE ?
Y
U
N
2
C
(CONT)

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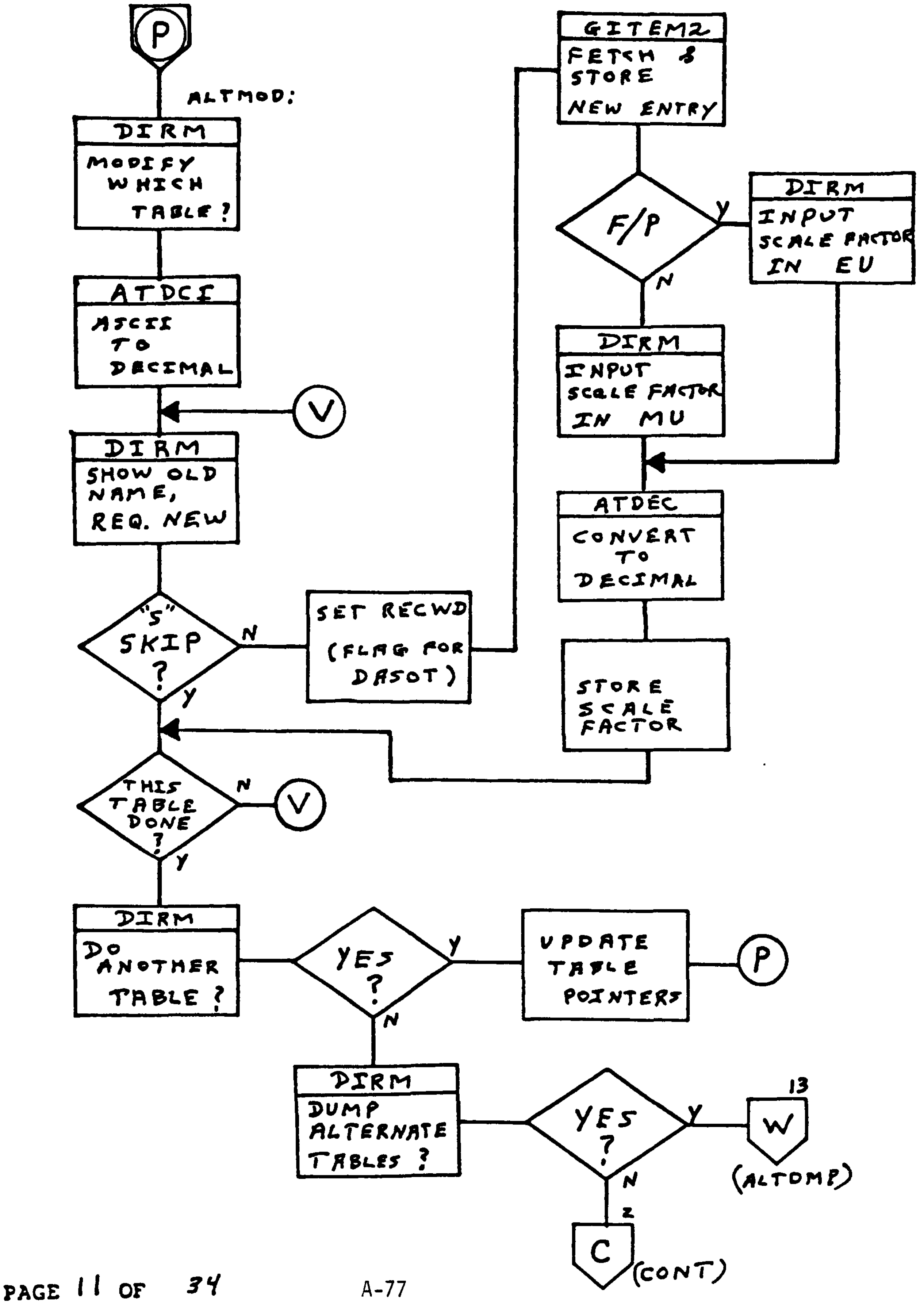
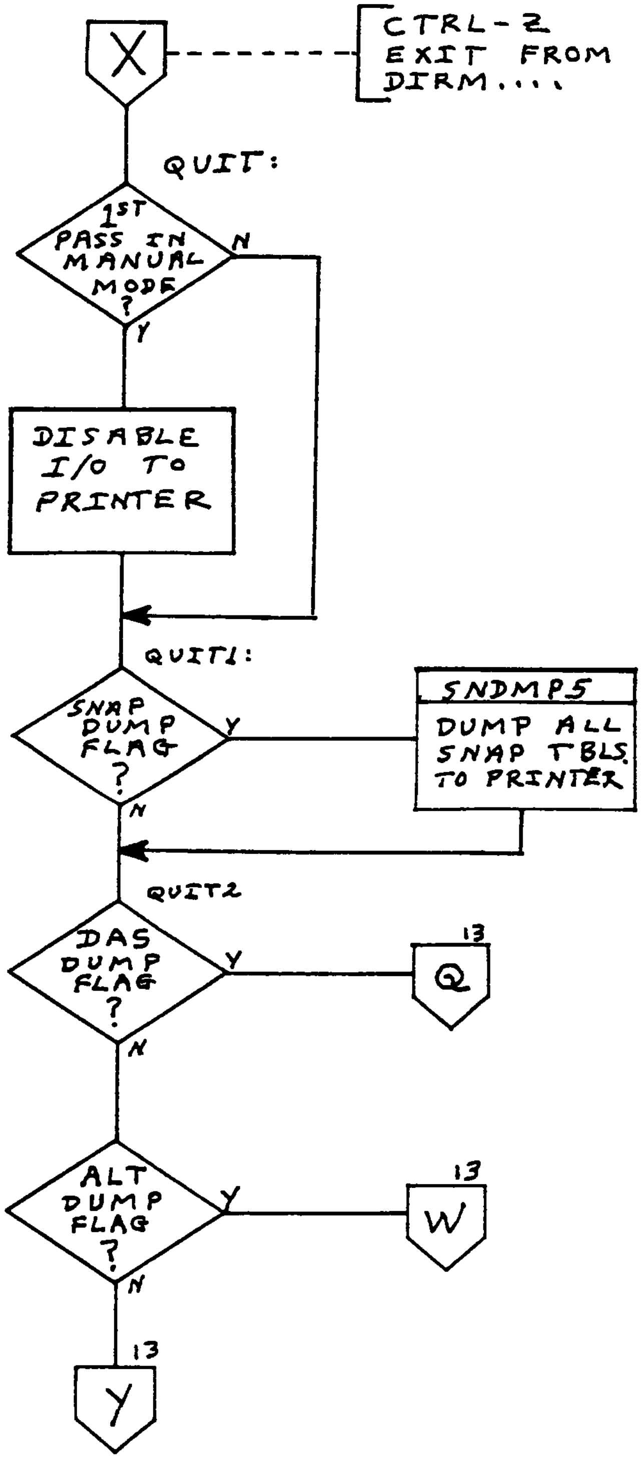
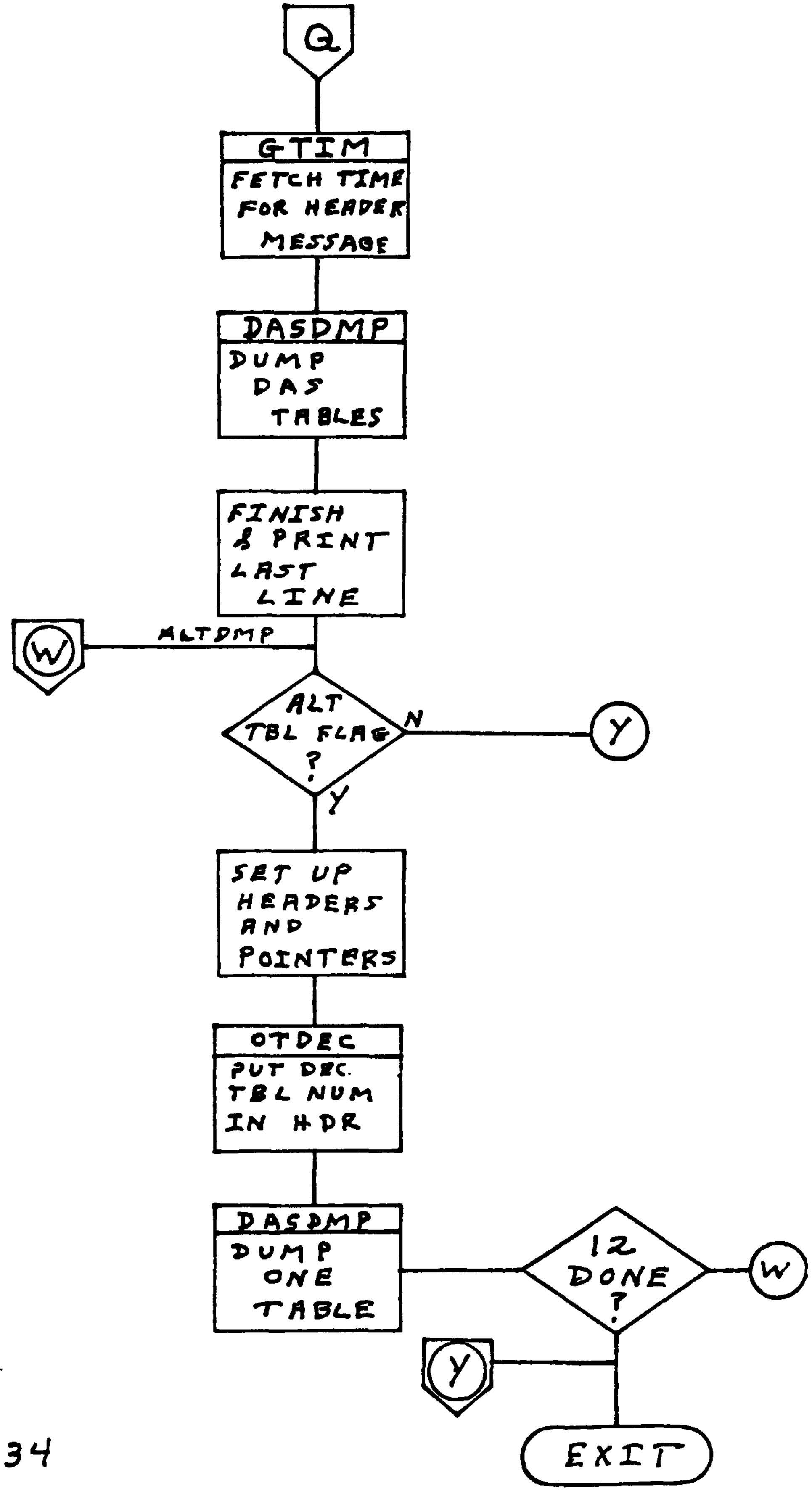

P
ALTMOD:
DIRM
MODIFY WHICH TABLE ?
ATDCI
ASCII TO DECIMAL
V
DIRM
SHOW OLD NAME, REQ. NEW
"S" SKIP ?
N
Y
SET RECWD (FLAG FOR DASOT)
GITEM2
FETCH & STORE NEW ENTRY
F/P
Y
N
DIRM
INPUT SCALE FACTOR IN EU
DIRM
INPUT SCALE FACTOR IN MU
ATDEC
CONVERT TO DECIMAL
STORE SCALE FACTOR
THIS TABLE DONE ?
N
V
Y
DIRM
DO ANOTHER TABLE ?
YES ?
Y
N
UPDATE TABLE POINTERS
P
DIRM
DUMP ALTERNATE TABLES ?
YES ?
Y
N
13
W
(ALTDMP)
2
C
(CONT)


X
CTRL-Z
EXIT FROM
DIRM....
QUIT:
1ST
PASS IN
MANUAL
MODE
?
N
Y
DISABLE
I/O TO
PRINTER
QUIT1:
SNAP
DUMP
FLAG
?
Y
N
SNDMP5
DUMP ALL
SNAP TBLS.
TO PRINTER
QUIT2
DAS
DUMP
FLAG
?
Y
N
13
Q
ALT
DUMP
FLAG
?
Y
N
13
W
13
Y


Q
GTIM
FETCH TIME FOR HEADER MESSAGE
DASDMP
DUMP DAS TABLES
FINISH & PRINT LAST LINE
W
ALTDMP
ALT TBL FLAG ?
N
Y
Y
SET UP HEADERS AND POINTERS
OTDEC
PUT DEC. TBL NUM IN HDR
DASDMP
DUMP ONE TABLE
12 DONE ?
W
Y
EXIT

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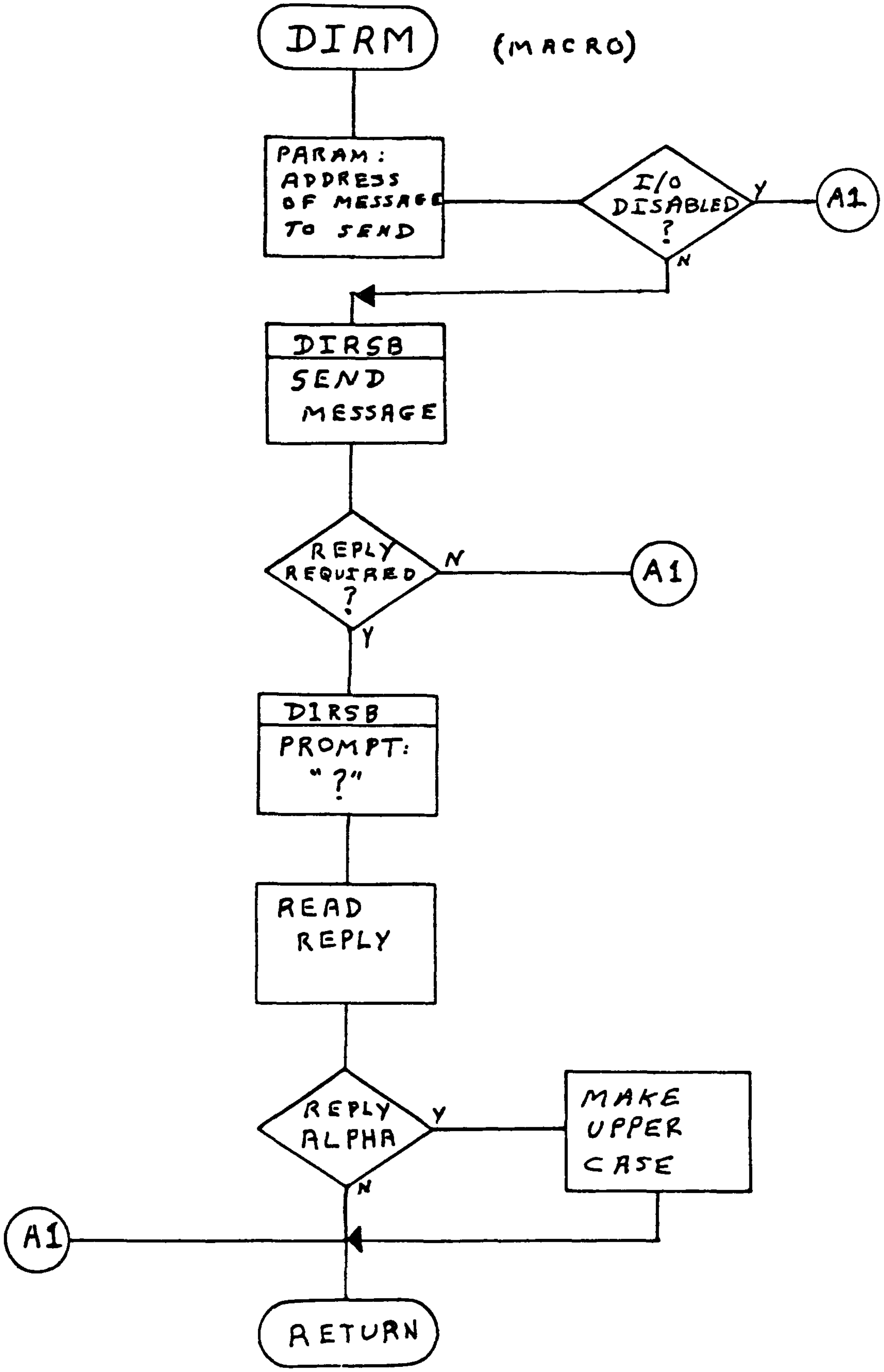
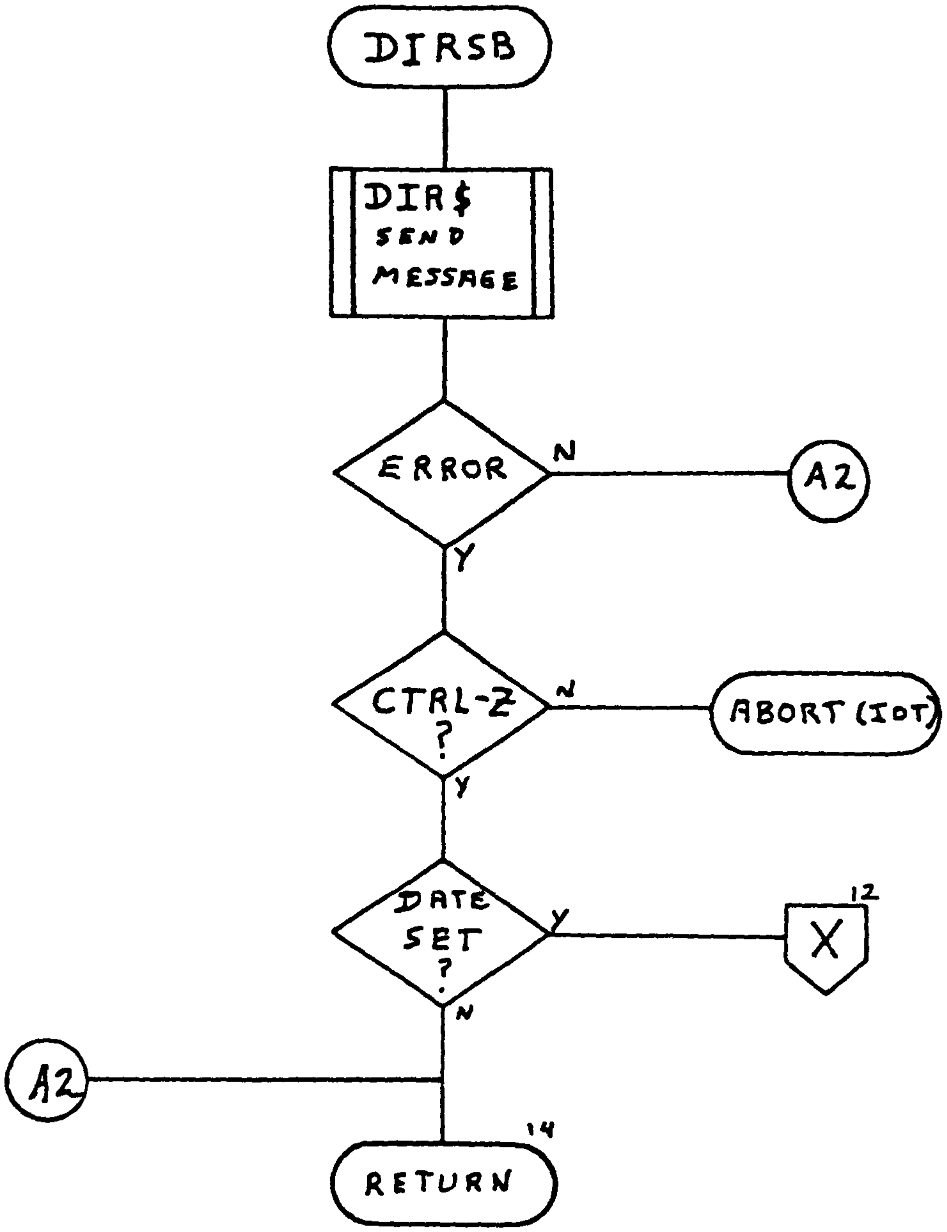
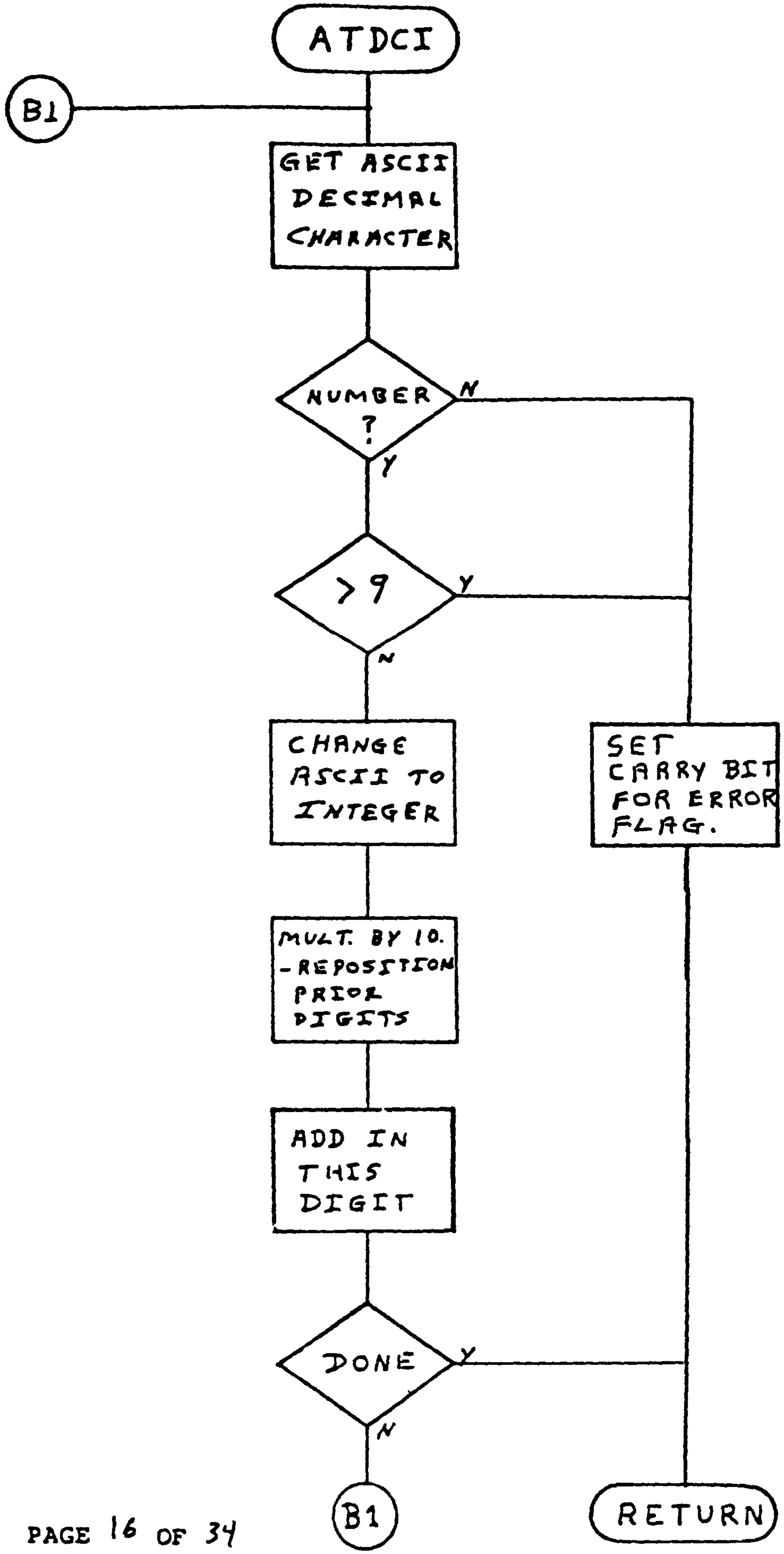

DIRM
(MACRO)
PARAM: ADDRESS OF MESSAGE TO SEND
I/O DISABLED ?
Y
N
A1
DIRSB
SEND MESSAGE
REPLY REQUIRED ?
N
Y
A1
DIRSB
PROMPT: "?"
READ REPLY
REPLY ALPHA
Y
N
MAKE UPPER CASE
A1
RETURN


DIRSB
DIR$ SEND MESSAGE
ERROR
N
A2
Y
CTRL-Z ?
N
ABORT (IOT)
Y
DATE SET ?
Y
X
12
N
A2
14
RETURN


ATDCI
B1
GET ASCII DECIMAL CHARACTER
NUMBER ?
N
Y
>9
Y
N
CHANGE ASCII TO INTEGER
SET CARRY BIT FOR ERROR FLAG.
MULT. BY 10. -REPOSITION PRIOR DIGITS
ADD IN THIS DIGIT
DONE
Y
N
B1
RETURN

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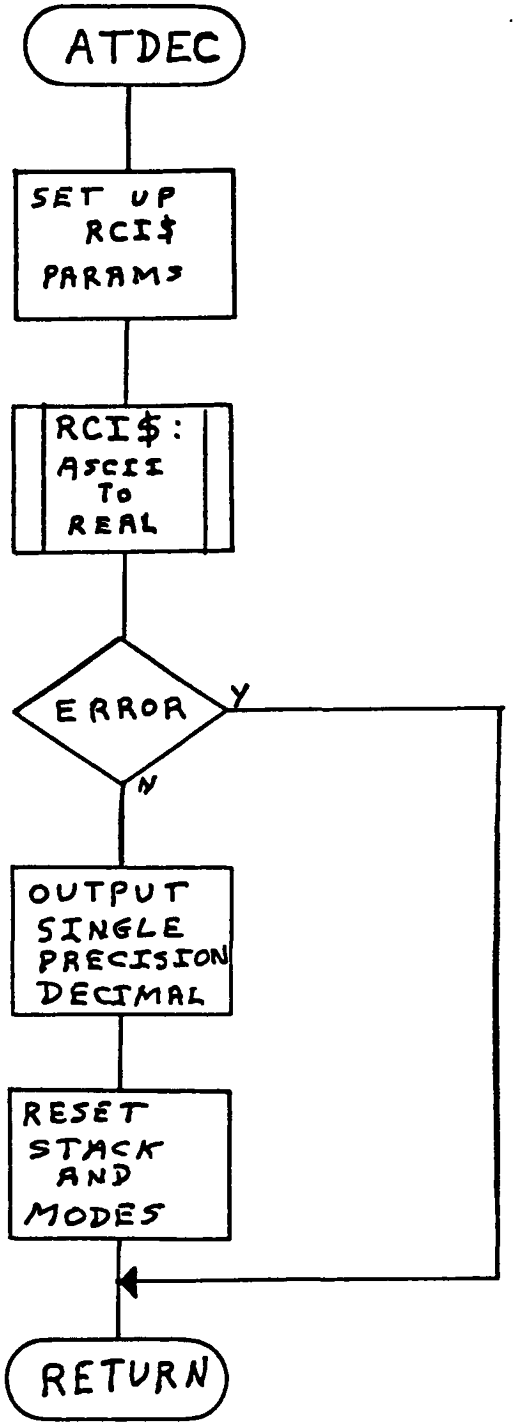
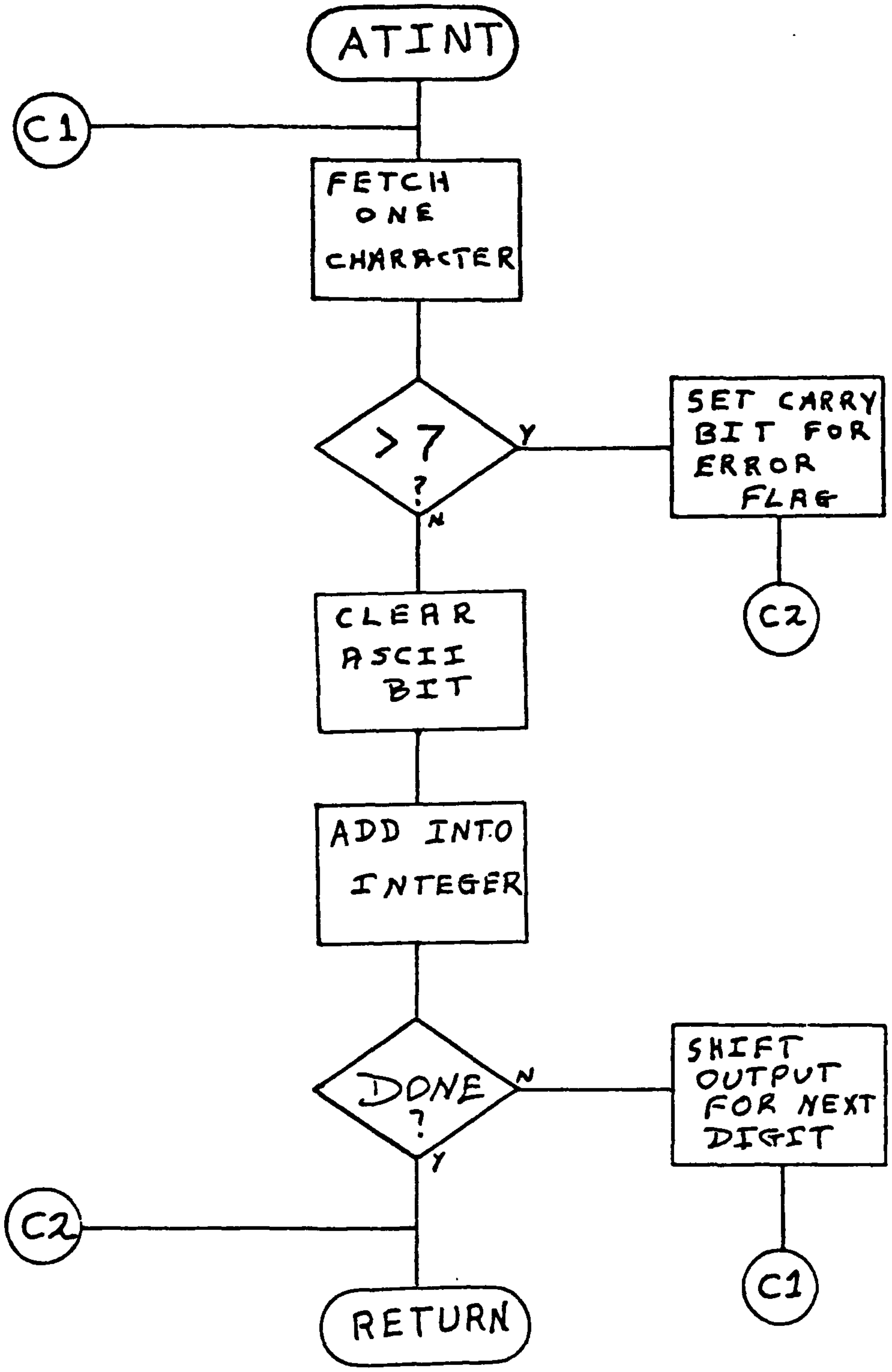
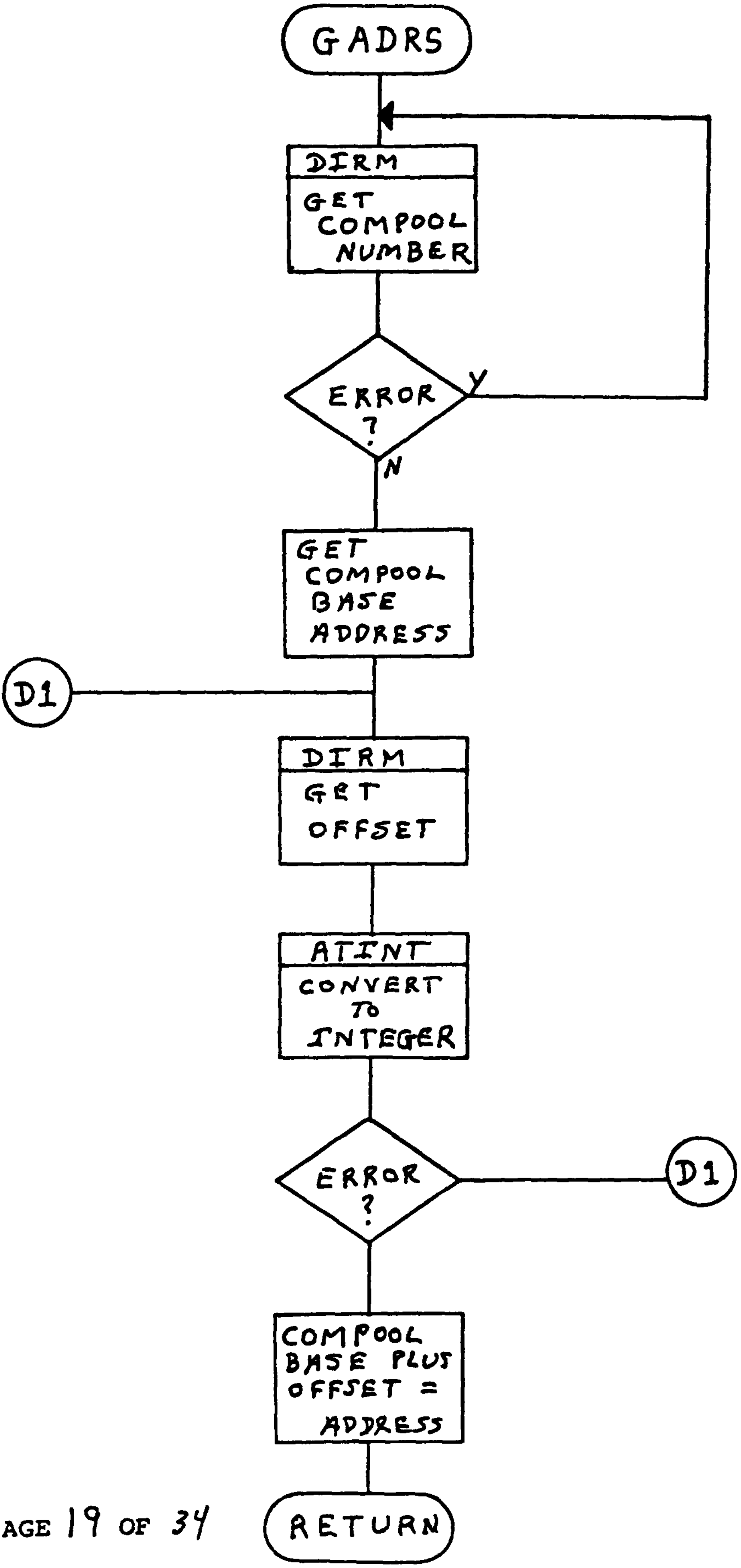
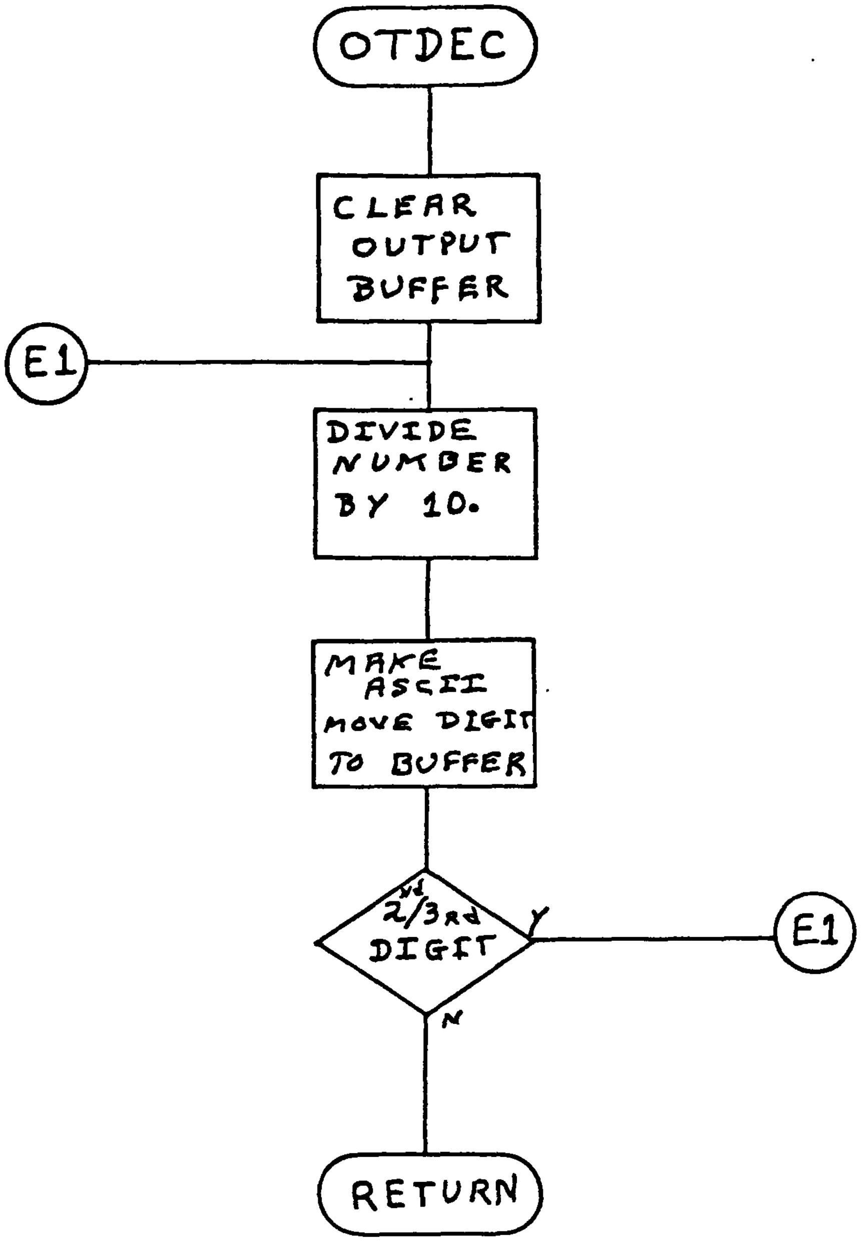
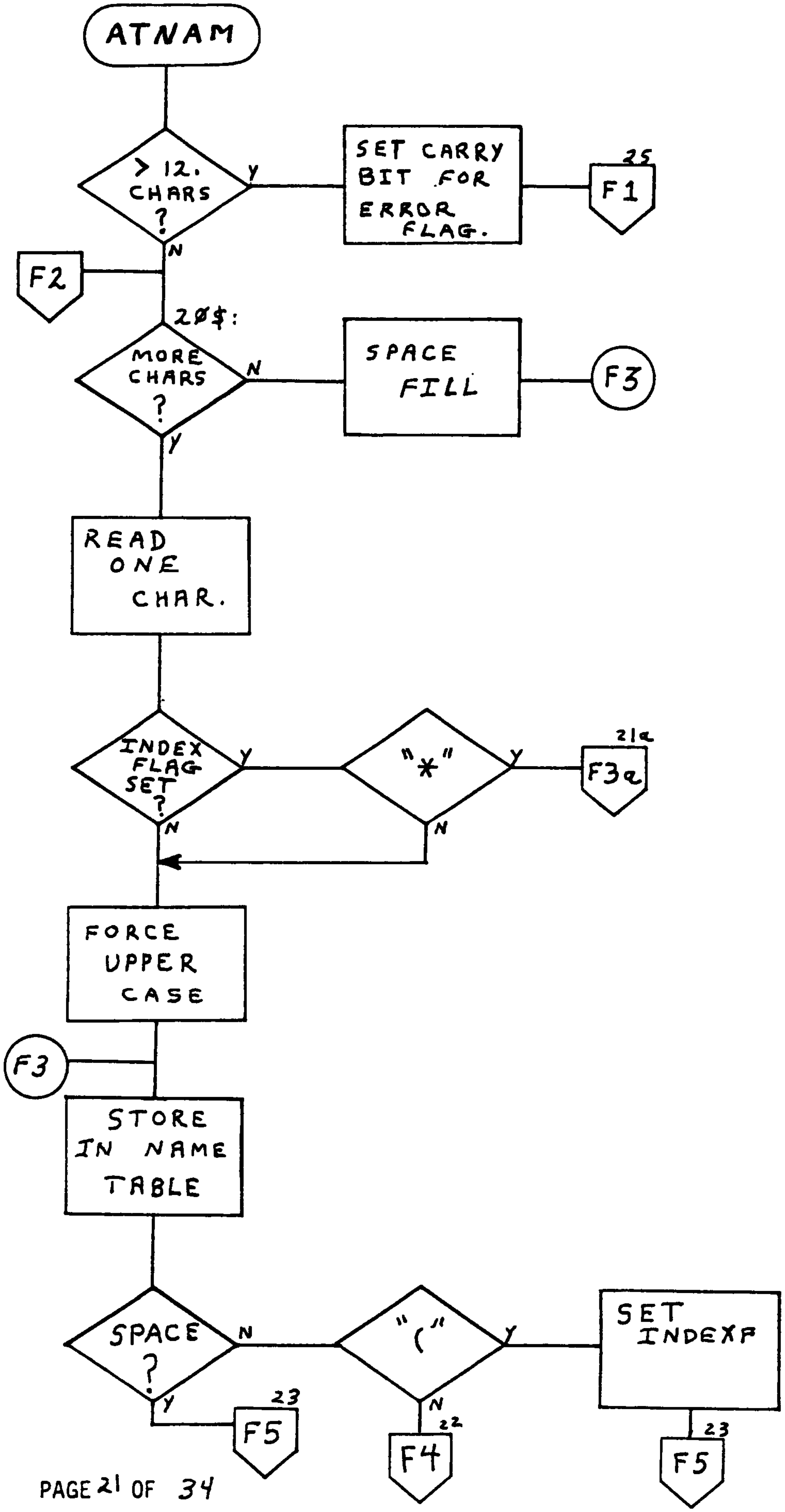
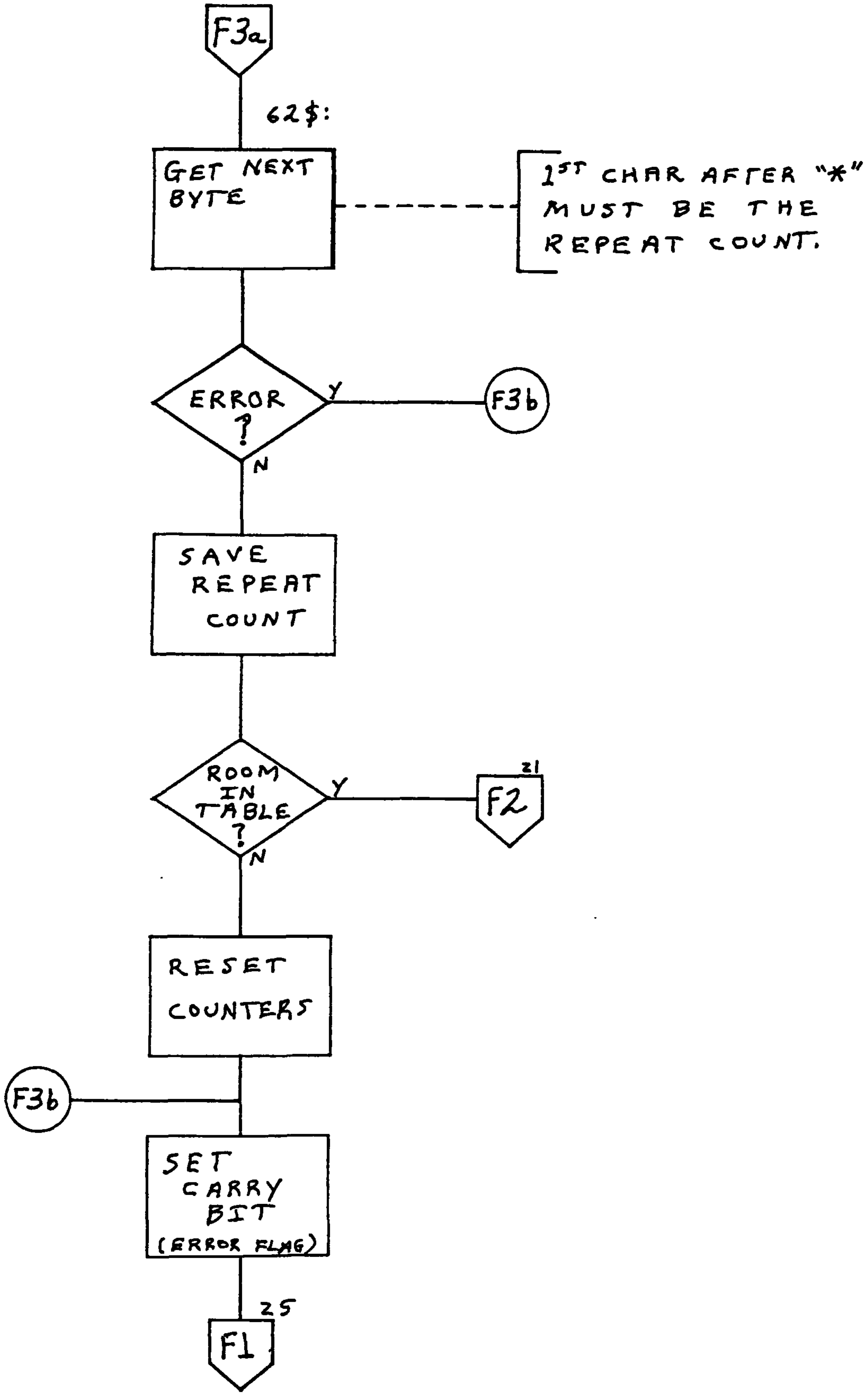

ATDEC
SET UP RCI$ PARAMS
RCI$: ASCII TO REAL
ERROR
Y
N
OUTPUT SINGLE PRECISION DECIMAL
RESET STACK AND MODES
RETURN

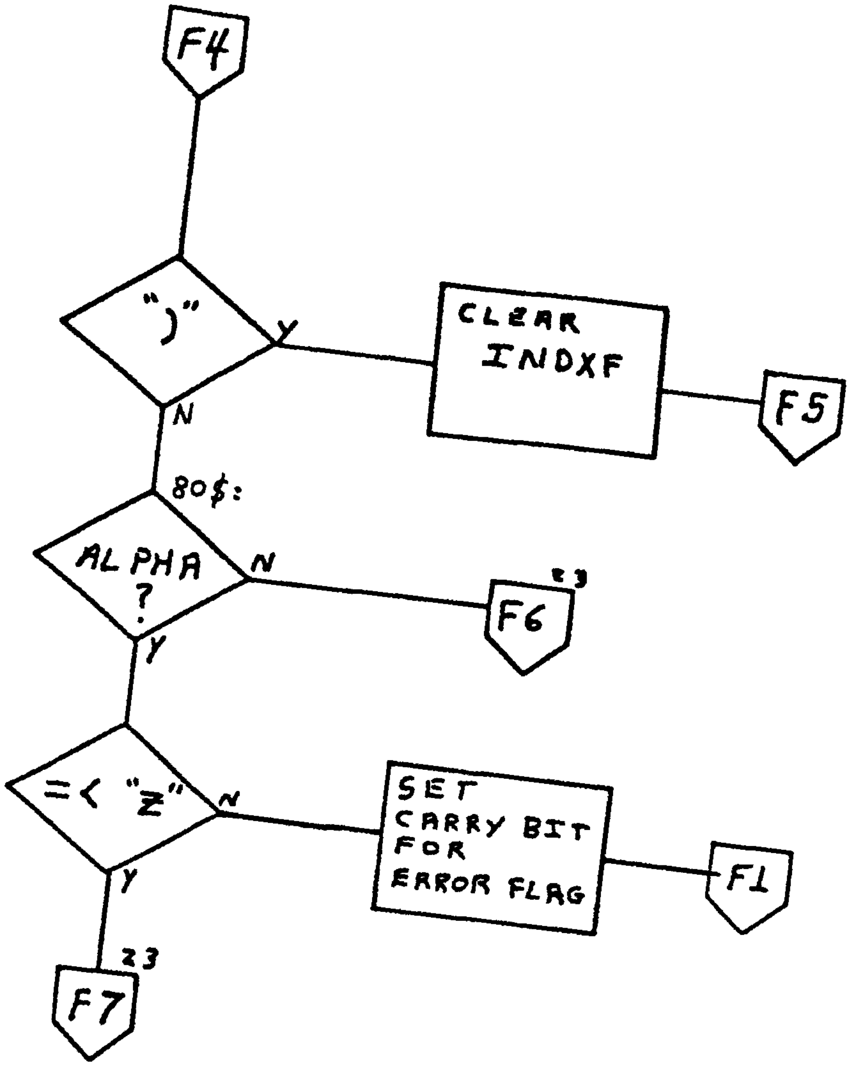

ATINT
C1
FETCH ONE CHARACTER
>7 ?
Y
N
SET CARRY BIT FOR ERROR FLAG
C2
CLEAR ASCII BIT
ADD INTO INTEGER
DONE ?
N
Y
SHIFT OUTPUT FOR NEXT DIGIT
C2
C1
RETURN

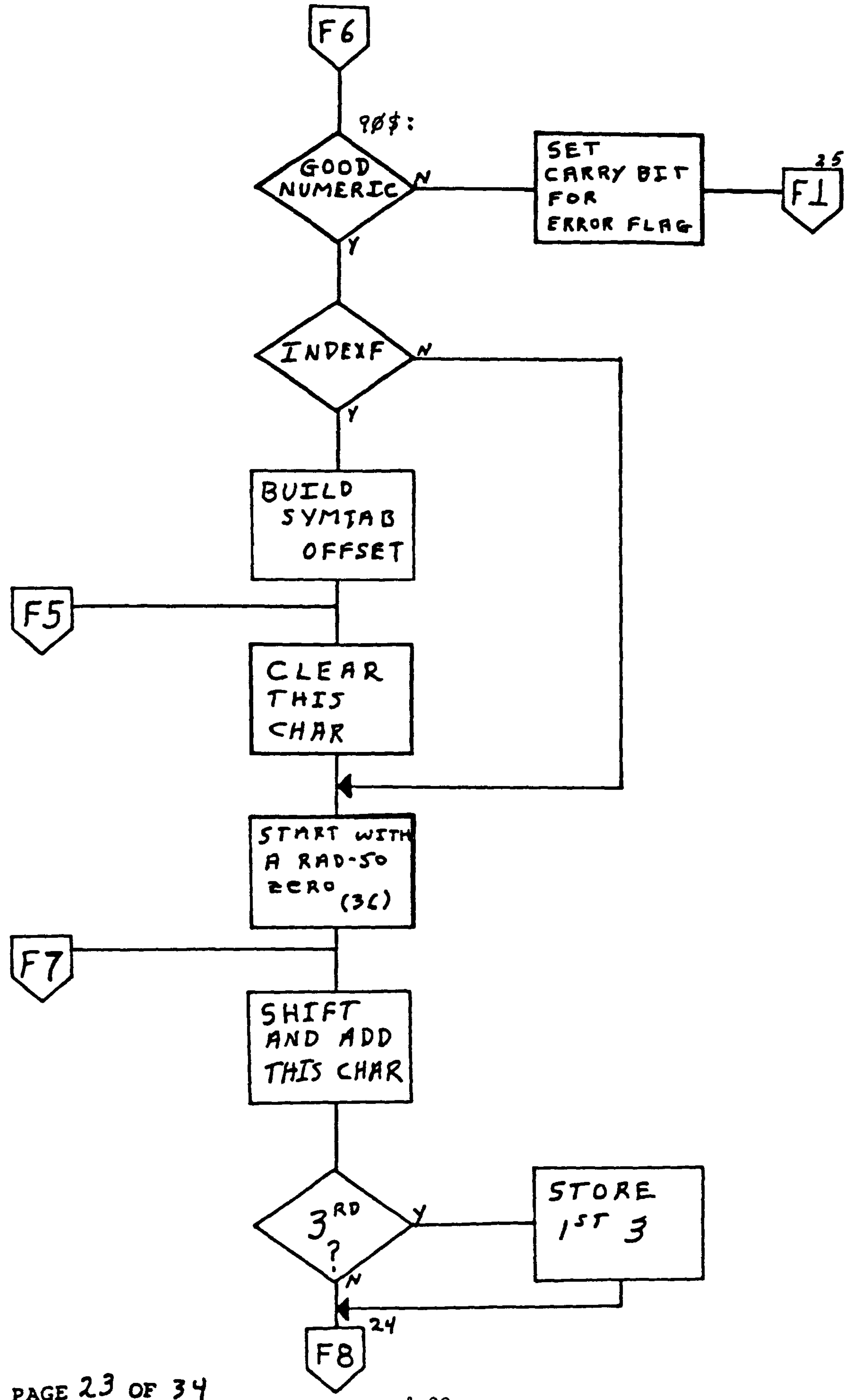

GADRS
DIRM
GET COMPOOL NUMBER
ERROR ?
Y
N
GET COMPOOL BASE ADDRESS
D1
DIRM
GET OFFSET
ATINT
CONVERT TO INTEGER
ERROR ?
D1
COMPOOL BASE PLUS OFFSET = ADDRESS
RETURN

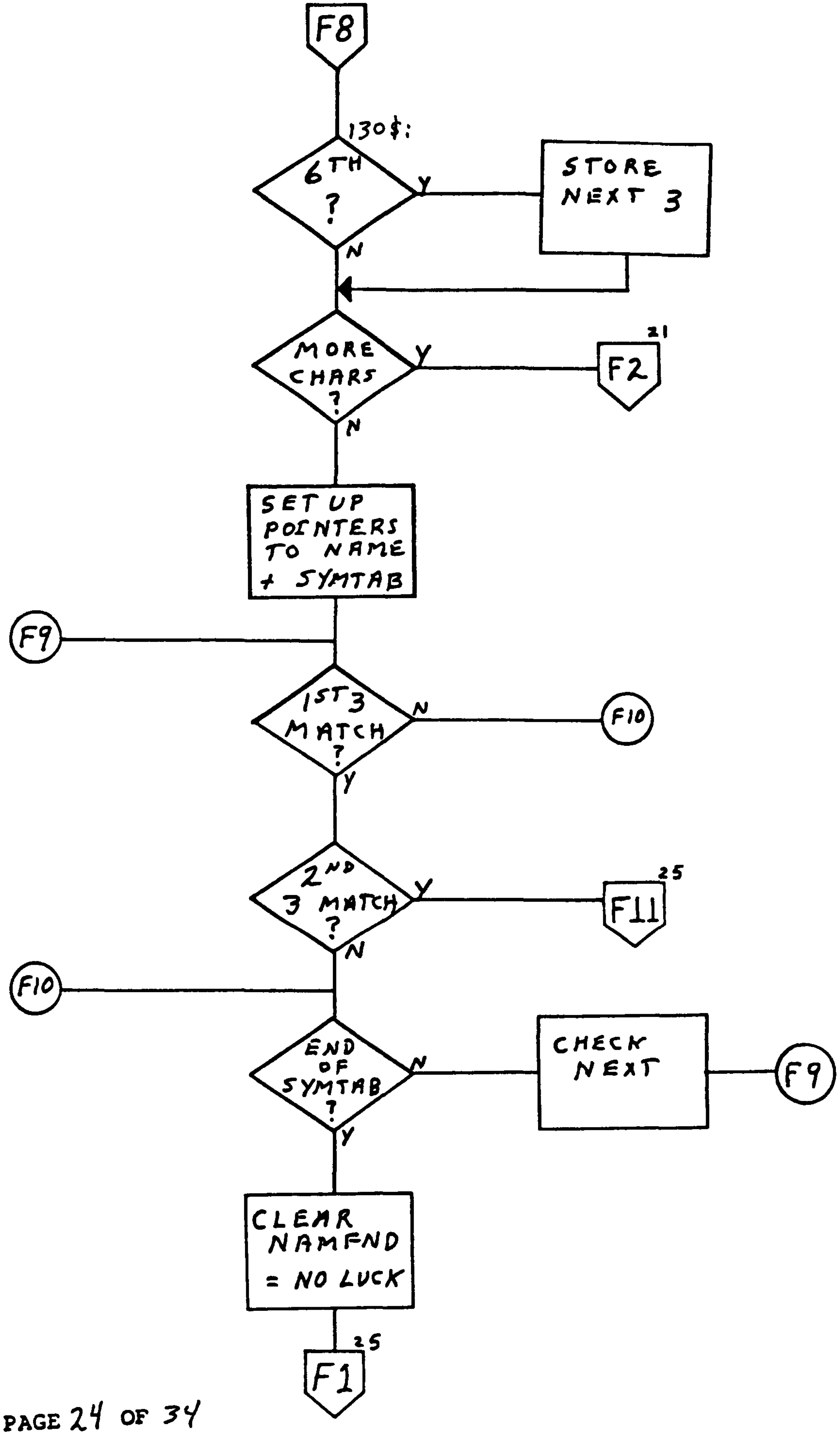

OTDEC
CLEAR OUTPUT BUFFER
E1
DIVIDE NUMBER BY 10.
MAKE ASCII
MOVE DIGIT TO BUFFER
2nd/3rd DIGIT
Y
E1
N
RETURN


ATNAM
> 12. CHARS ?
Y
SET CARRY BIT FOR ERROR FLAG.
25
F1
N
F2
20$:
MORE CHARS ?
N
SPACE FILL
F3
Y
READ ONE CHAR.
INDEX FLAG SET ?
Y
"*"
Y
21a
F3a
N
N
FORCE UPPER CASE
F3
STORE IN NAME TABLE
SPACE ?
N
"("
Y
SET INDEXF
Y
23
F5
N
22
F4
23
F5


F3a
62$:
GET NEXT BYTE
1ST CHAR AFTER "*" MUST BE THE REPEAT COUNT.
ERROR ?
Y
F3b
N
SAVE REPEAT COUNT
ROOM IN TABLE ?
Y
21
F2
N
RESET COUNTERS
F3b
SET CARRY BIT (ERROR FLAG)
25
F1


F4
")"
Y
CLEAR INDXF
F5
N
80$:
ALPHA ?
N
F6
23
Y
=< "Z"
N
SET CARRY BIT FOR ERROR FLAG
F1
Y
23
F7


F6
90$:
GOOD NUMERIC
N
Y
SET CARRY BIT FOR ERROR FLAG
25
F1
INDEXF
N
Y
BUILD SYMTAB OFFSET
F5
CLEAR THIS CHAR
START WITH A RAD-50 ZERO (36)
F7
SHIFT AND ADD THIS CHAR
3RD ?
Y
N
STORE 1ST 3
24
F8


F8
130$:
6TH ?
Y
STORE NEXT 3
N
MORE CHARS ?
Y
21
F2
N
SET UP POINTERS TO NAME + SYMTAB
F9
1ST 3 MATCH ?
N
F10
Y
2ND 3 MATCH ?
Y
25
F11
N
F10
END OF SYMTAB ?
N
CHECK NEXT
F9
Y
CLEAR NAMFND = NO LUCK
25
F1

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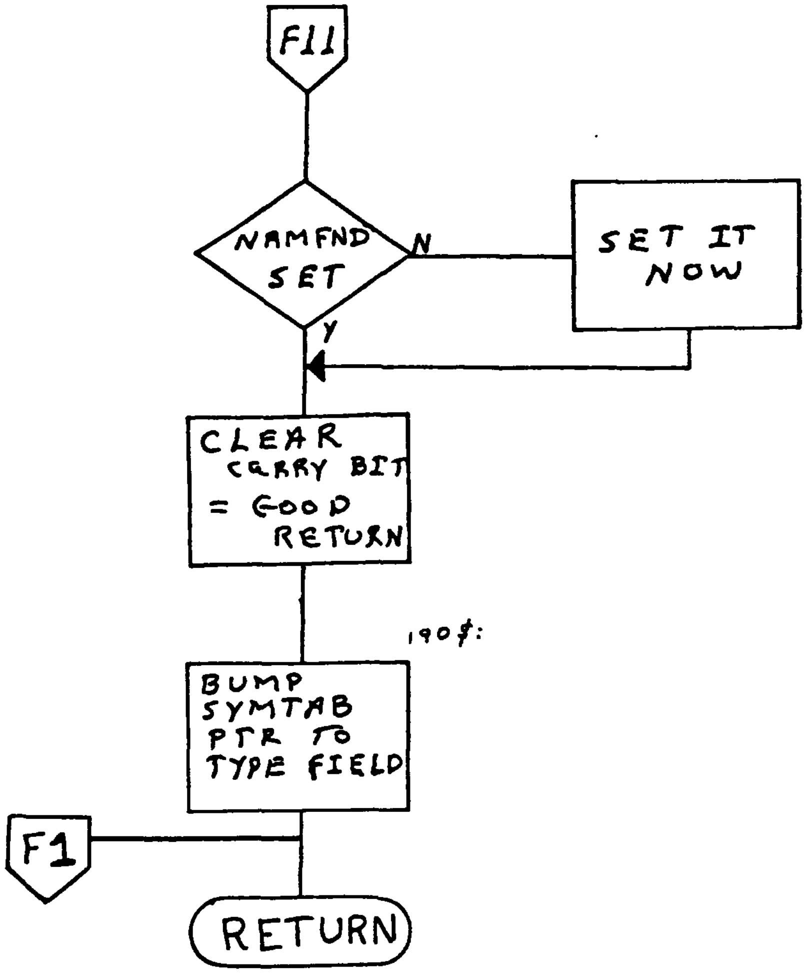
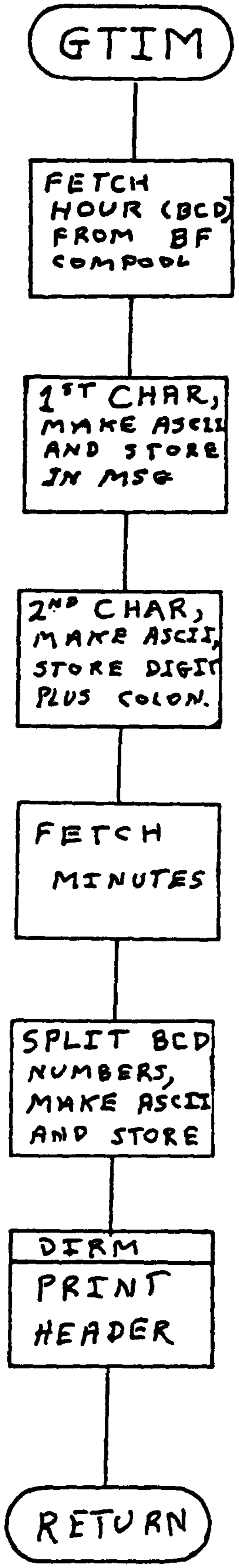
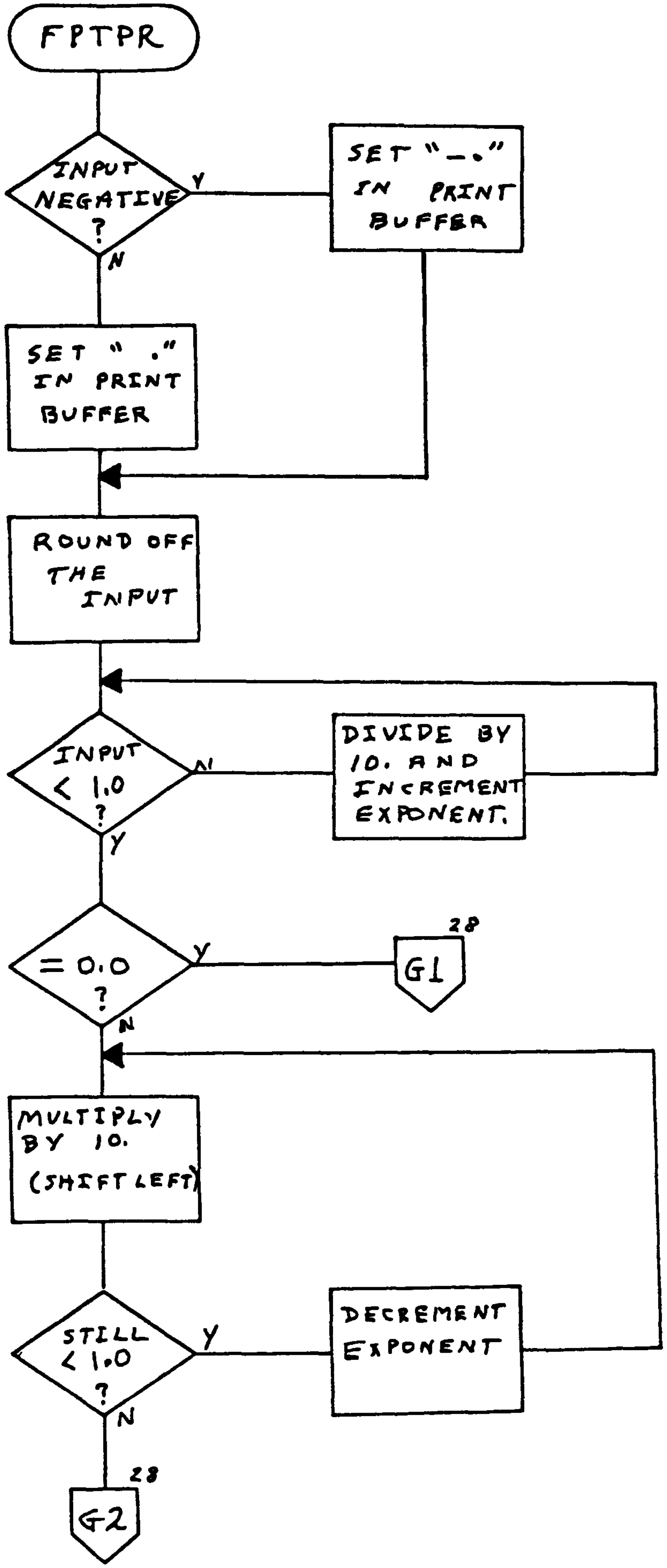
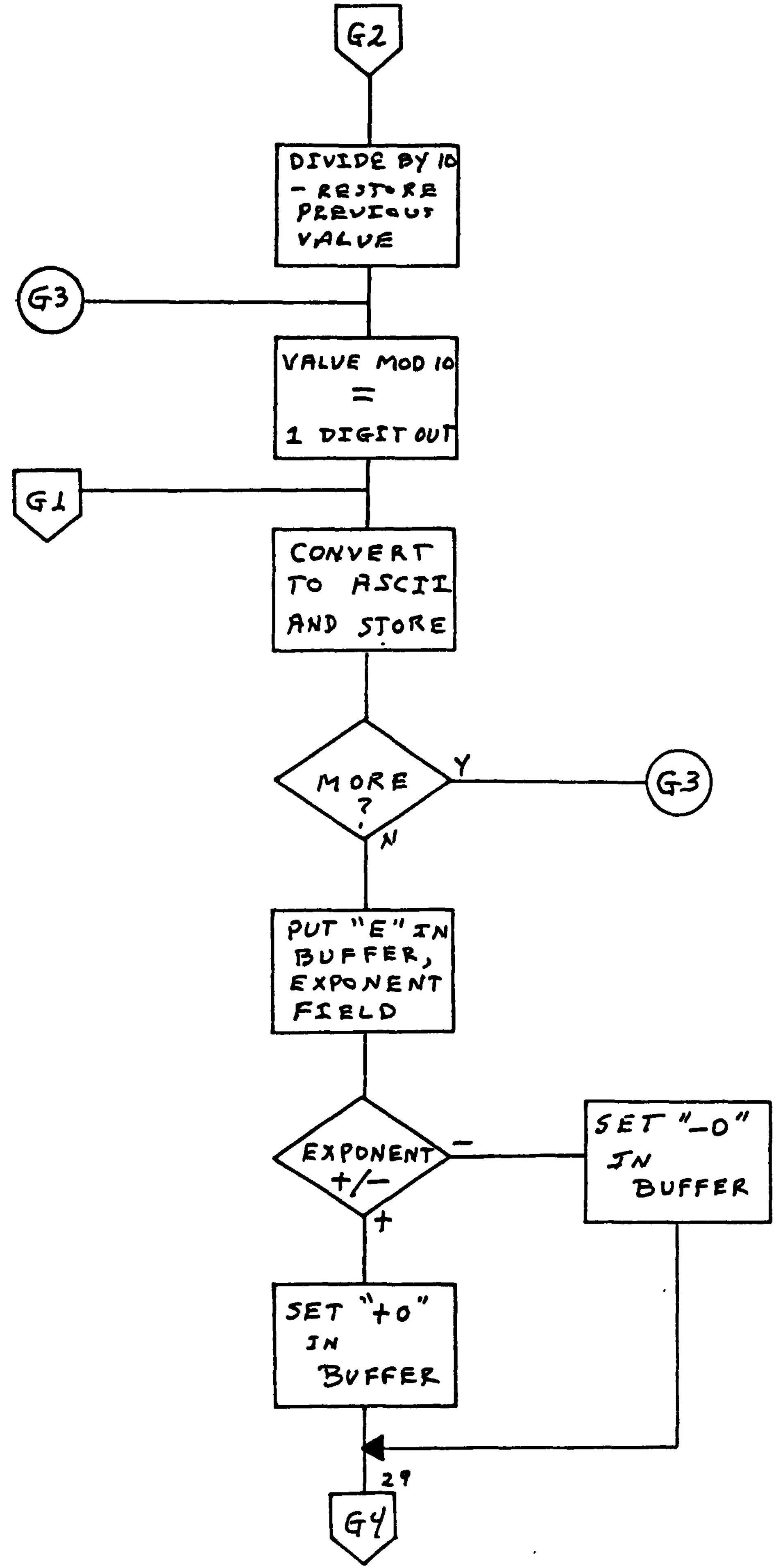
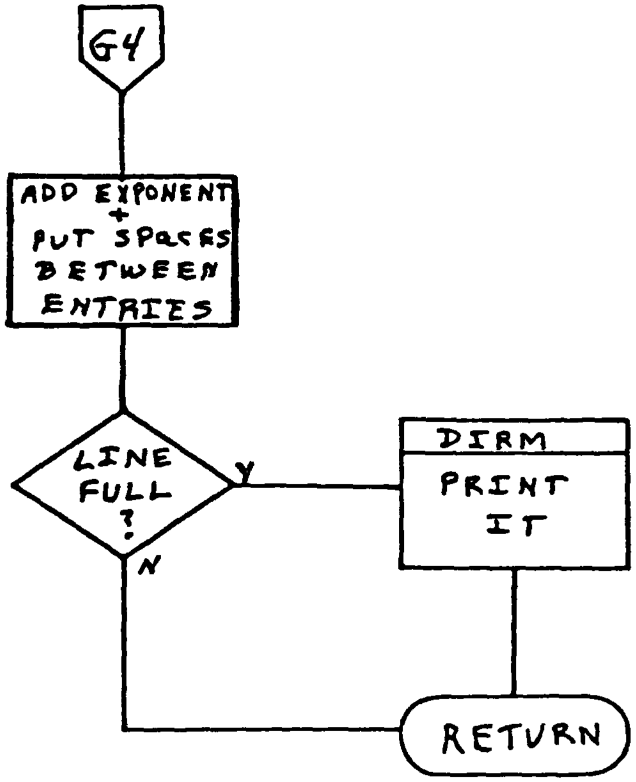
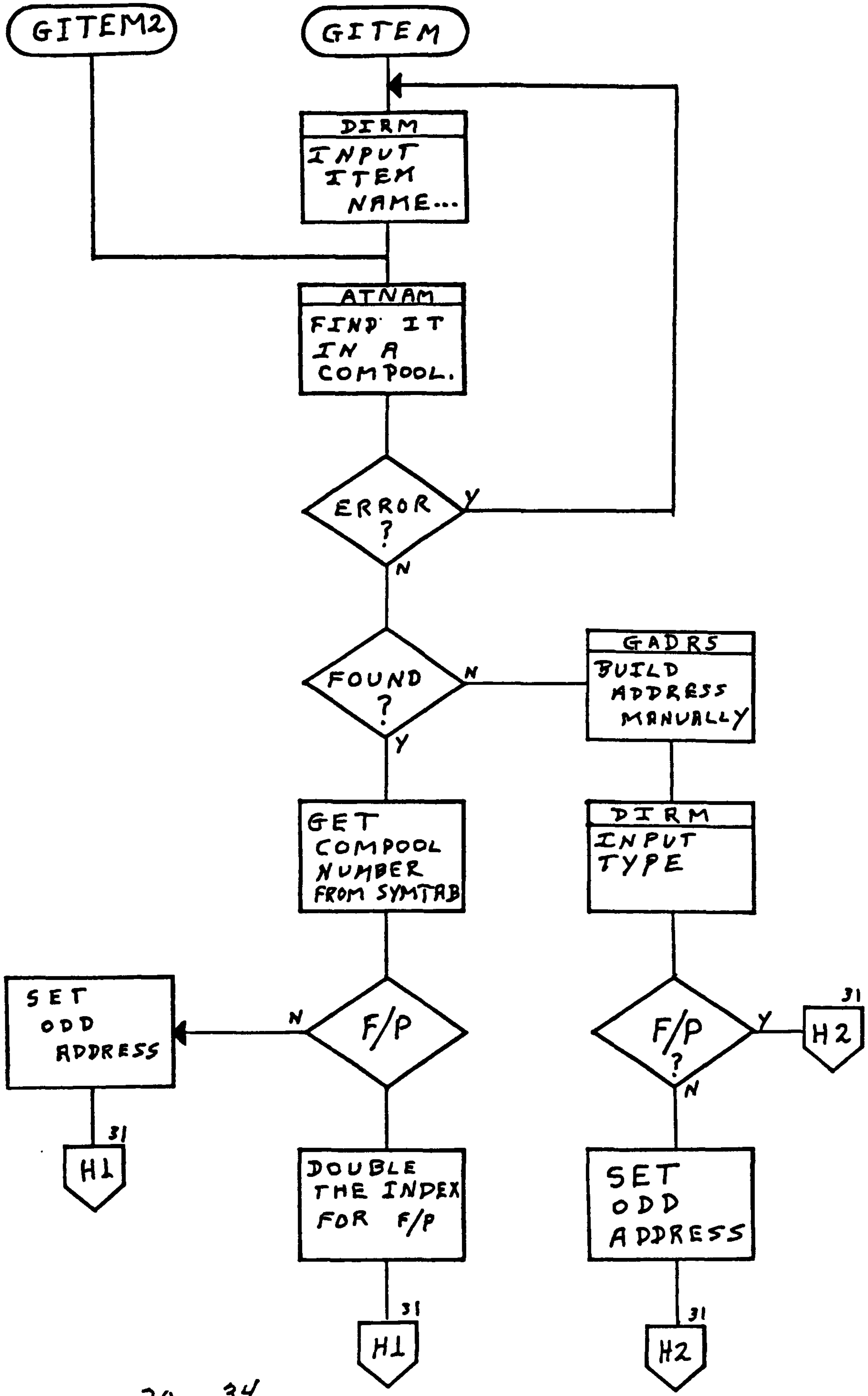

F11
NAMFND SET
N
SET IT NOW
Y
CLEAR CARRY BIT = GOOD RETURN
190∅:
BUMP SYMTAB PTR TO TYPE FIELD
F1
RETURN

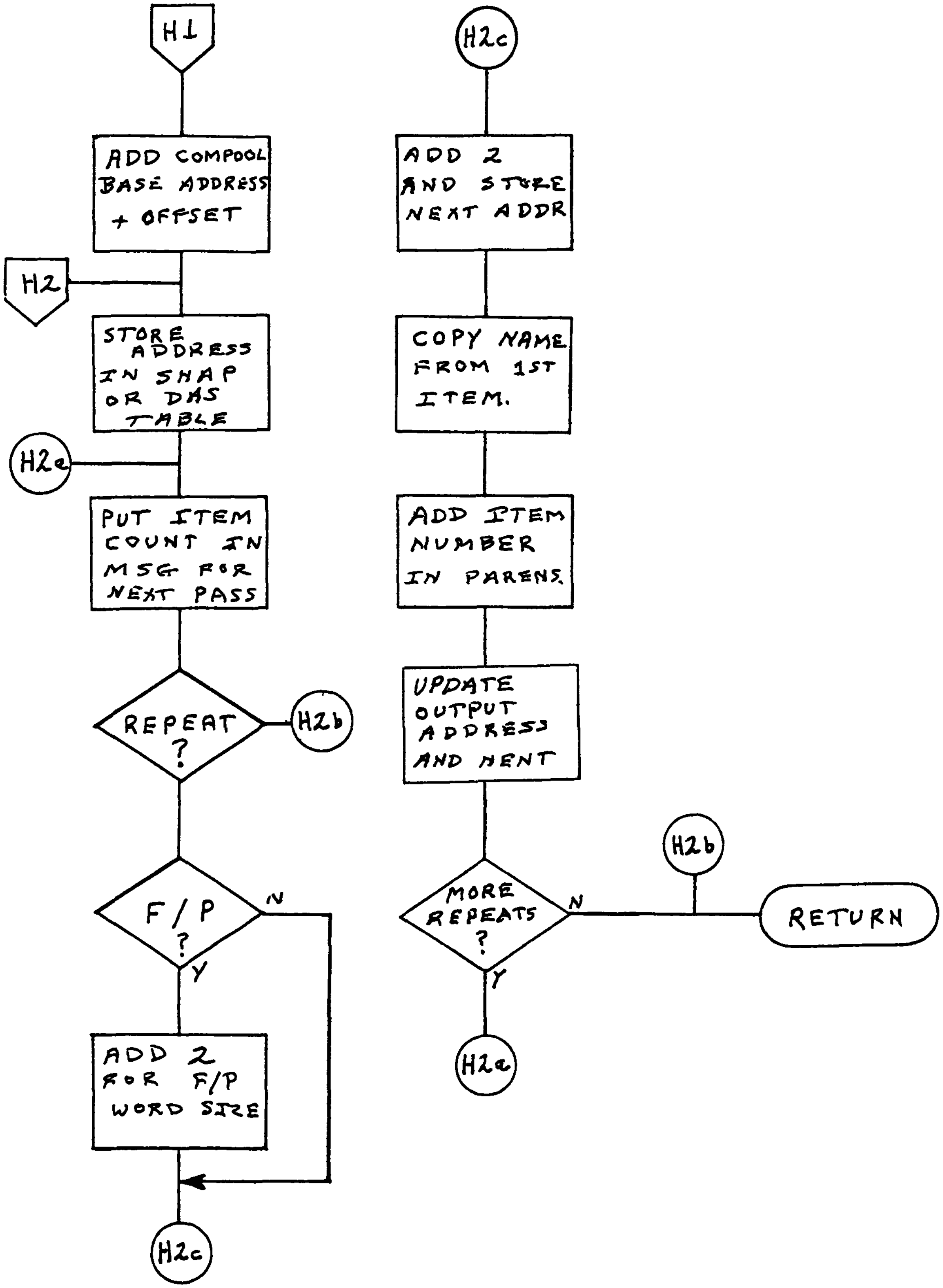

GTIM
FETCH HOUR (BCD) FROM BF COMPOOL
1ST CHAR, MAKE ASCII AND STORE IN MSG
2ND CHAR, MAKE ASCII, STORE DIGIT PLUS COLON.
FETCH MINUTES
SPLIT BCD NUMBERS, MAKE ASCII AND STORE
DIRM
PRINT HEADER
RETURN


FPTPR
INPUT NEGATIVE ?
Y
N
SET "-." IN PRINT BUFFER
SET " ." IN PRINT BUFFER
ROUND OFF THE INPUT
INPUT < 1.0 ?
N
Y
DIVIDE BY 10. AND INCREMENT EXPONENT.
= 0.0 ?
Y
N
28
G1
MULTIPLY BY 10. (SHIFT LEFT)
STILL < 1.0 ?
Y
N
DECREMENT EXPONENT
28
G2


G2
DIVIDE BY 10 - RESTORE PREVIOUS VALUE
G3
VALUE MOD 10 = 1 DIGIT OUT
G1
CONVERT TO ASCII AND STORE
MORE ?
Y
G3
N
PUT "E" IN BUFFER, EXPONENT FIELD
EXPONENT +/-
-
SET "-0" IN BUFFER
+
SET "+0" IN BUFFER
29
G4


G4
ADD EXPONENT + PUT SPACES BETWEEN ENTRIES
LINE FULL ?
Y
N
DIRM
PRINT IT
RETURN


GITEM2
GITEM
DIRM
INPUT ITEM NAME...
ATNAM
FIND IT IN A COMPOOL.
ERROR ?
Y
N
FOUND ?
N
Y
GADRS
BUILD ADDRESS MANUALLY
GET COMPOOL NUMBER FROM SYMTAB
DIRM
INPUT TYPE
SET ODD ADDRESS
N
F/P
F/P ?
Y
31
H2
N
31
H1
DOUBLE THE INDEX FOR F/P
SET ODD ADDRESS
31
H1
31
H2


H1
ADD COMPOOL BASE ADDRESS + OFFSET
H2
STORE ADDRESS IN SNAP OR DAS TABLE
H2e
PUT ITEM COUNT IN MSG FOR NEXT PASS
REPEAT ?
H2b
F/P ?
N
Y
ADD 2 FOR F/P WORD SIZE
H2c
H2c
ADD 2 AND STORE NEXT ADDR
COPY NAME FROM 1ST ITEM.
ADD ITEM NUMBER IN PARENS.
UPDATE OUTPUT ADDRESS AND NENT
MORE REPEATS ?
N
Y
H2b
RETURN
H2e

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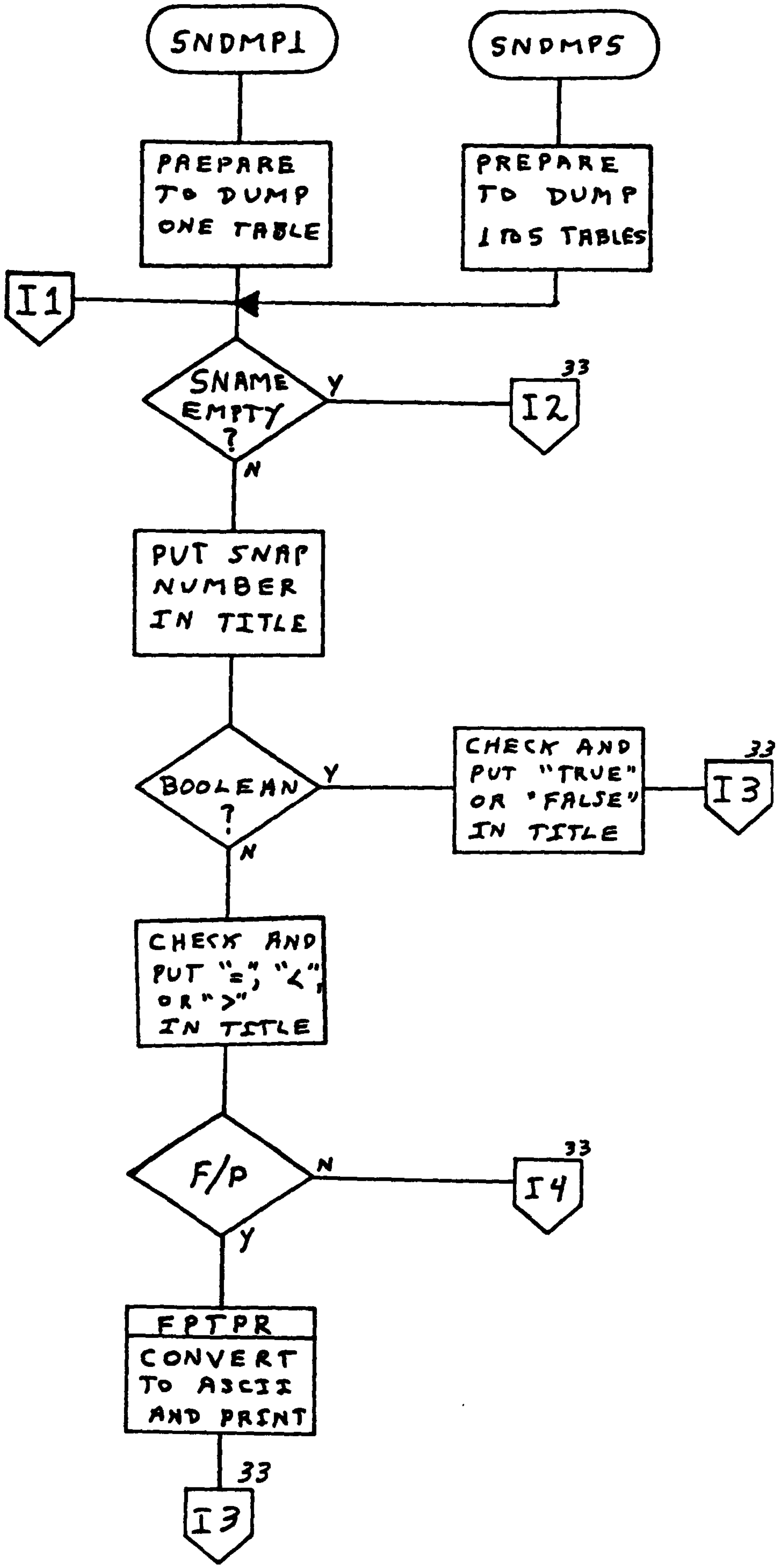
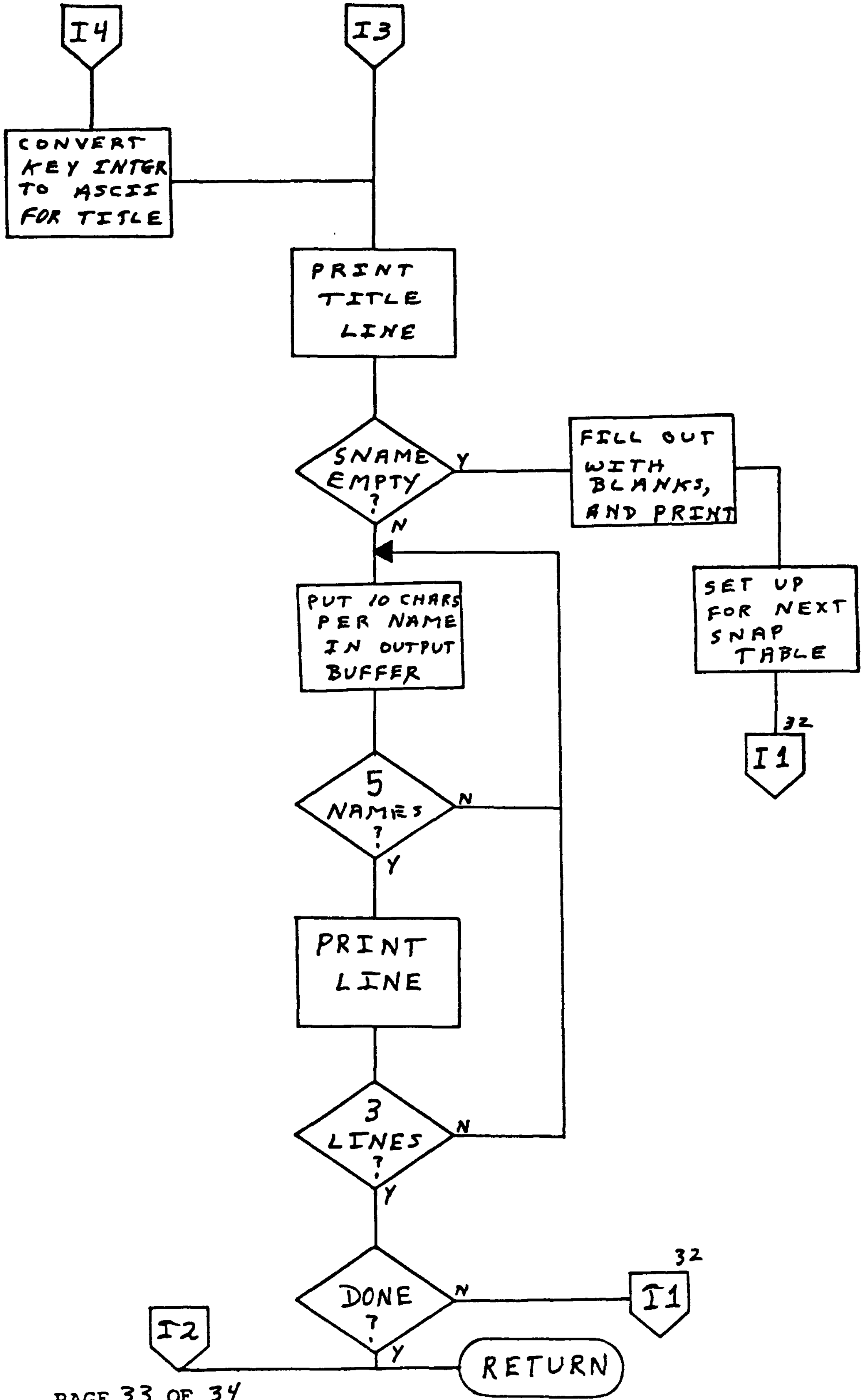
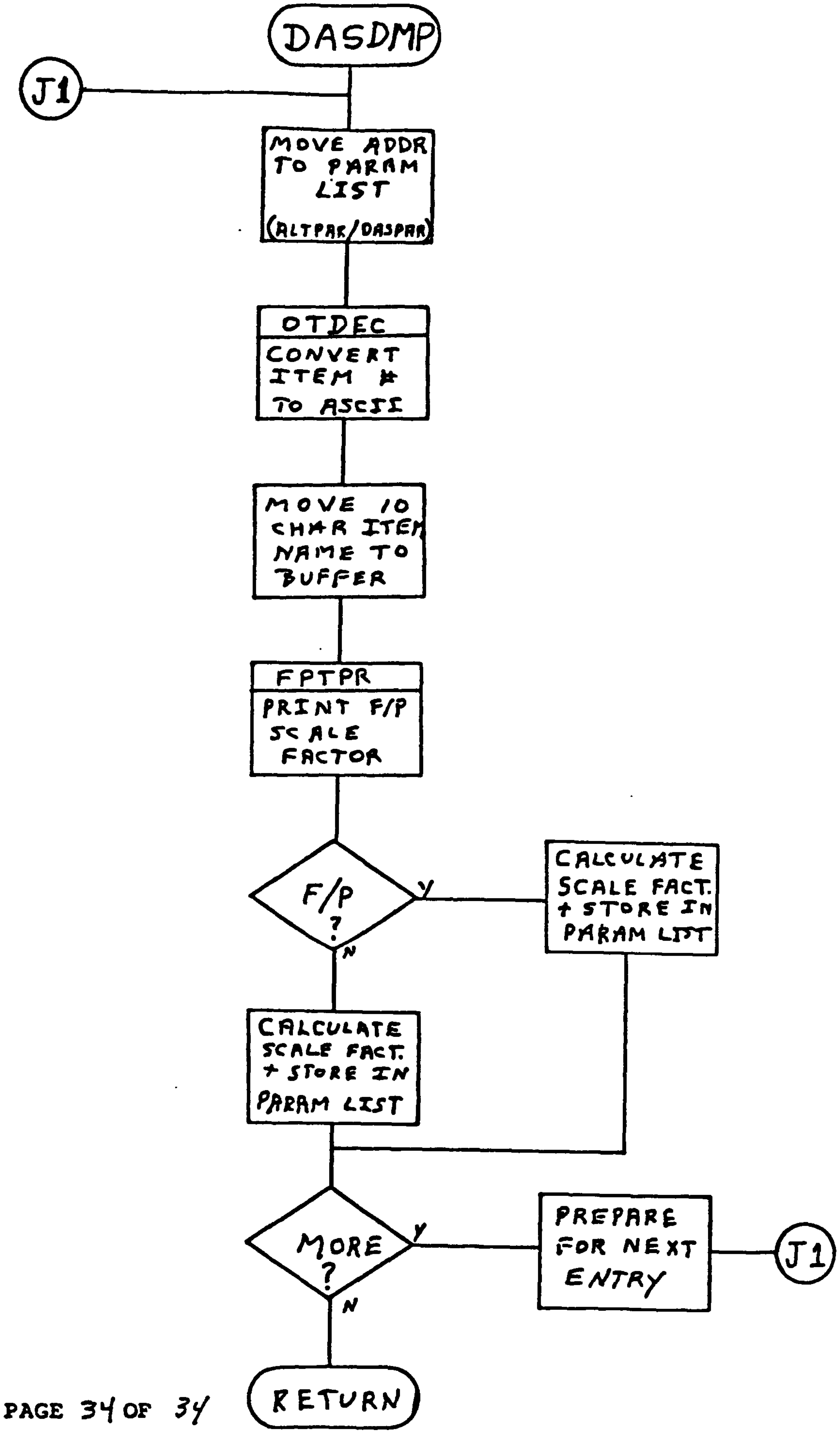
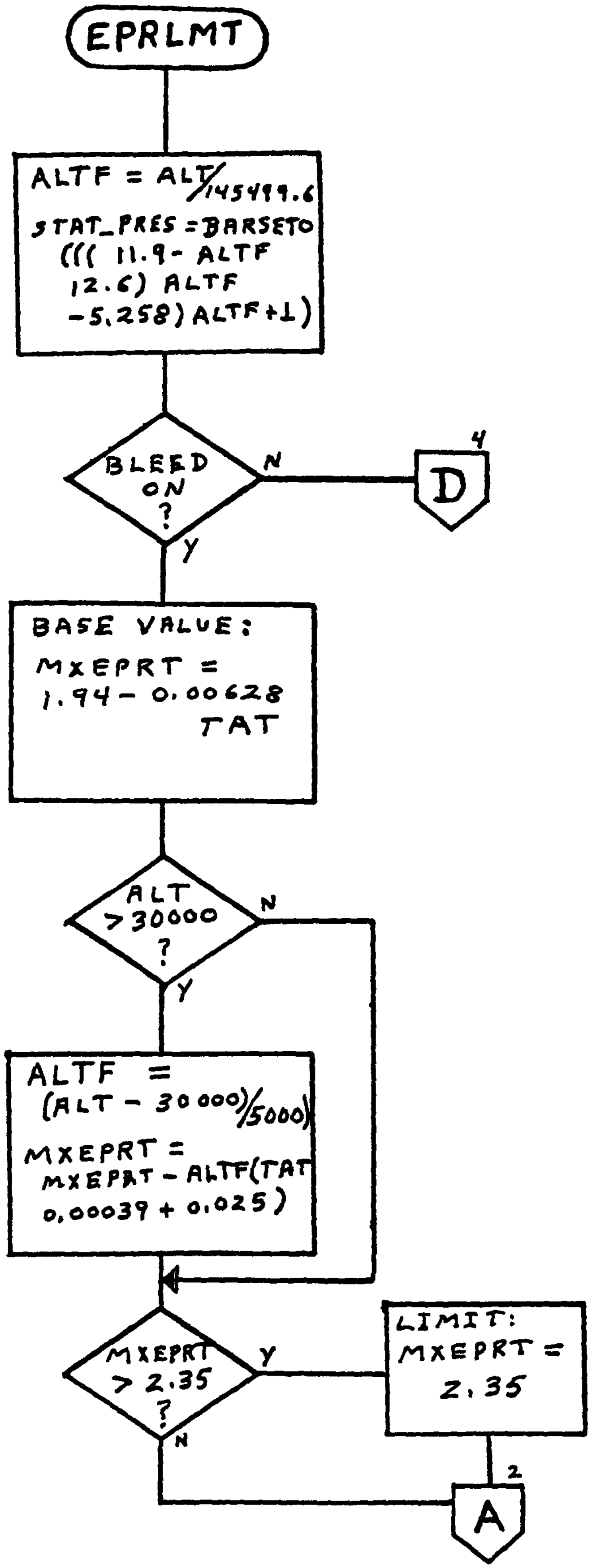
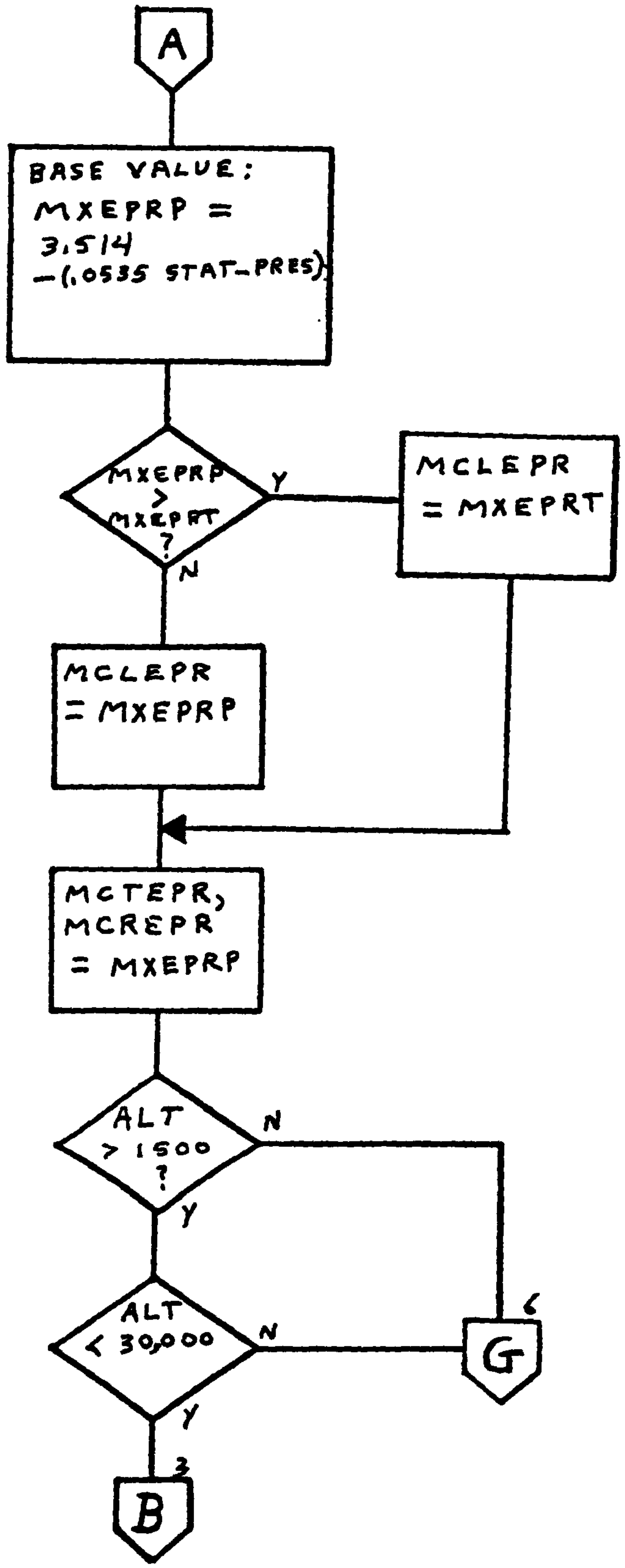

SNDMP1
SNDMPS
PREPARE TO DUMP ONE TABLE
PREPARE TO DUMP 1 TO 5 TABLES
I1
SNAME EMPTY ?
Y
33
I2
N
PUT SNAP NUMBER IN TITLE
BOOLEAN ?
Y
CHECK AND PUT "TRUE" OR "FALSE" IN TITLE
33
I3
N
CHECK AND PUT "=", "<", OR ">" IN TITLE
F/P
N
33
I4
Y
FPTPR
CONVERT TO ASCII AND PRINT
33
I3


I4
I3
CONVERT KEY INTGR TO ASCII FOR TITLE
PRINT TITLE LINE
SNAME EMPTY ?
Y
FILL OUT WITH BLANKS, AND PRINT
SET UP FOR NEXT SNAP TABLE
32
I1
N
PUT 10 CHARS PER NAME IN OUTPUT BUFFER
5 NAMES ?
N
Y
PRINT LINE
3 LINES ?
N
Y
DONE ?
N
32
I1
Y
I2
RETURN

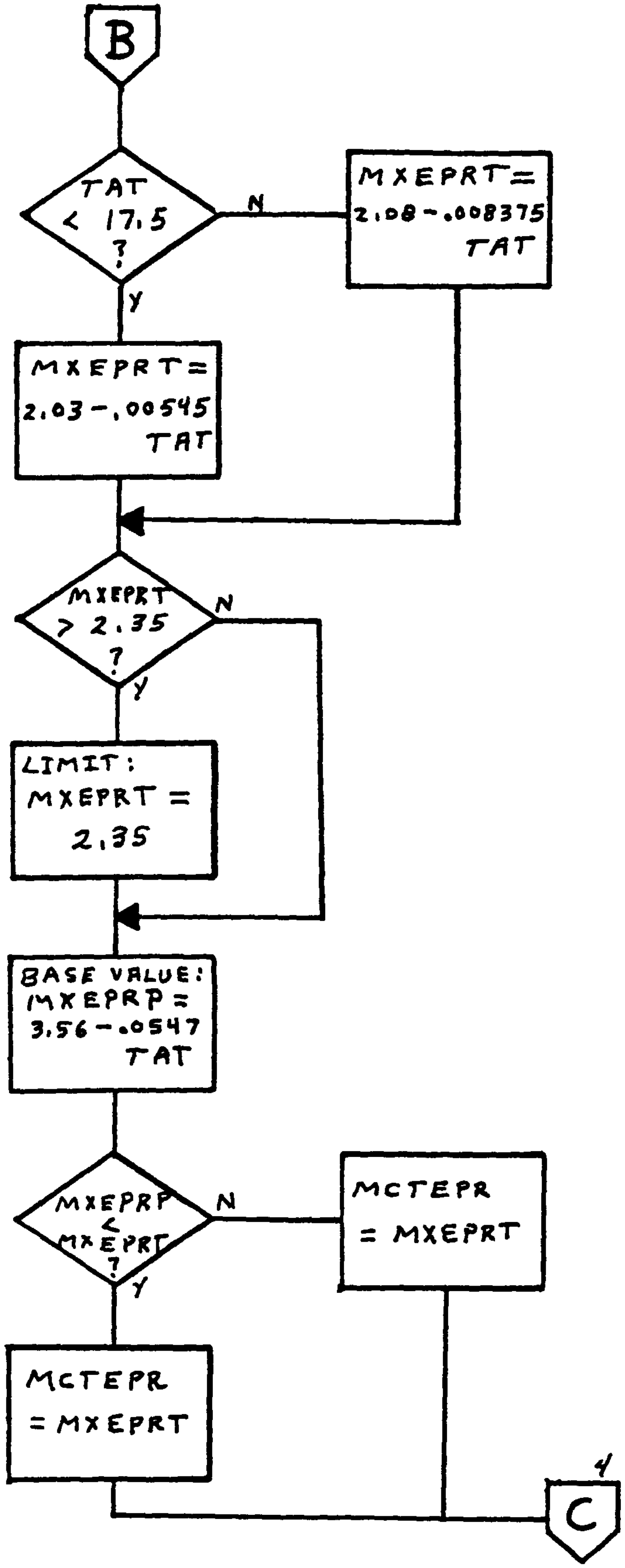

DASDMP
J1
MOVE ADDR TO PARAM LIST (ALTPAR/DASPAR)
OTDEC
CONVERT ITEM # TO ASCII
MOVE 10 CHAR ITEM NAME TO BUFFER
FPTPR
PRINT F/P SCALE FACTOR
F/P ?
Y
N
CALCULATE SCALE FACT. + STORE IN PARAM LIST
CALCULATE SCALE FACT. + STORE IN PARAM LIST
MORE ?
Y
N
PREPARE FOR NEXT ENTRY
J1
RETURN



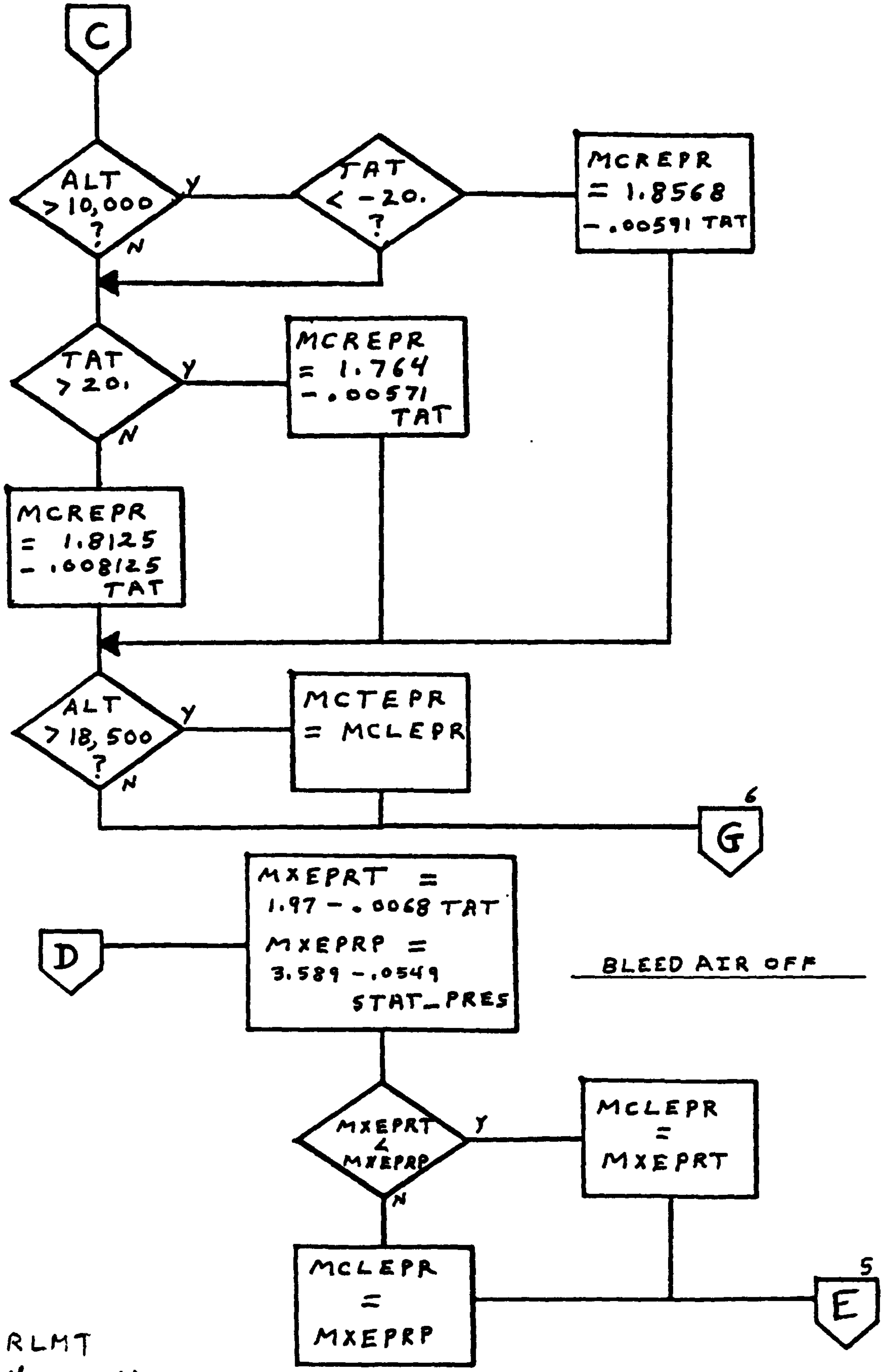
EPRLMT
(PAGE 1 OF 6)



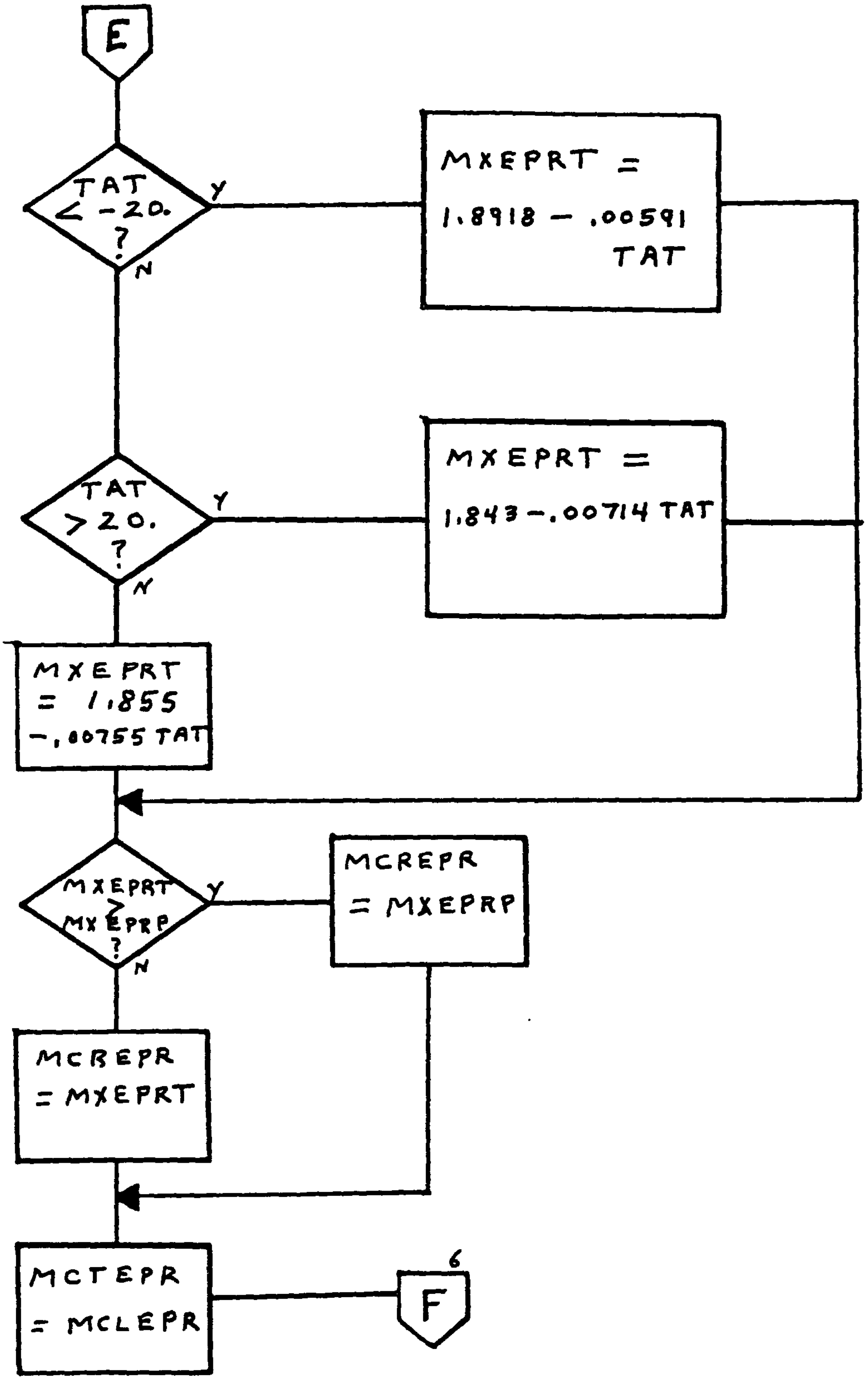
EPRLMT
(PAGE 2 OF 6)



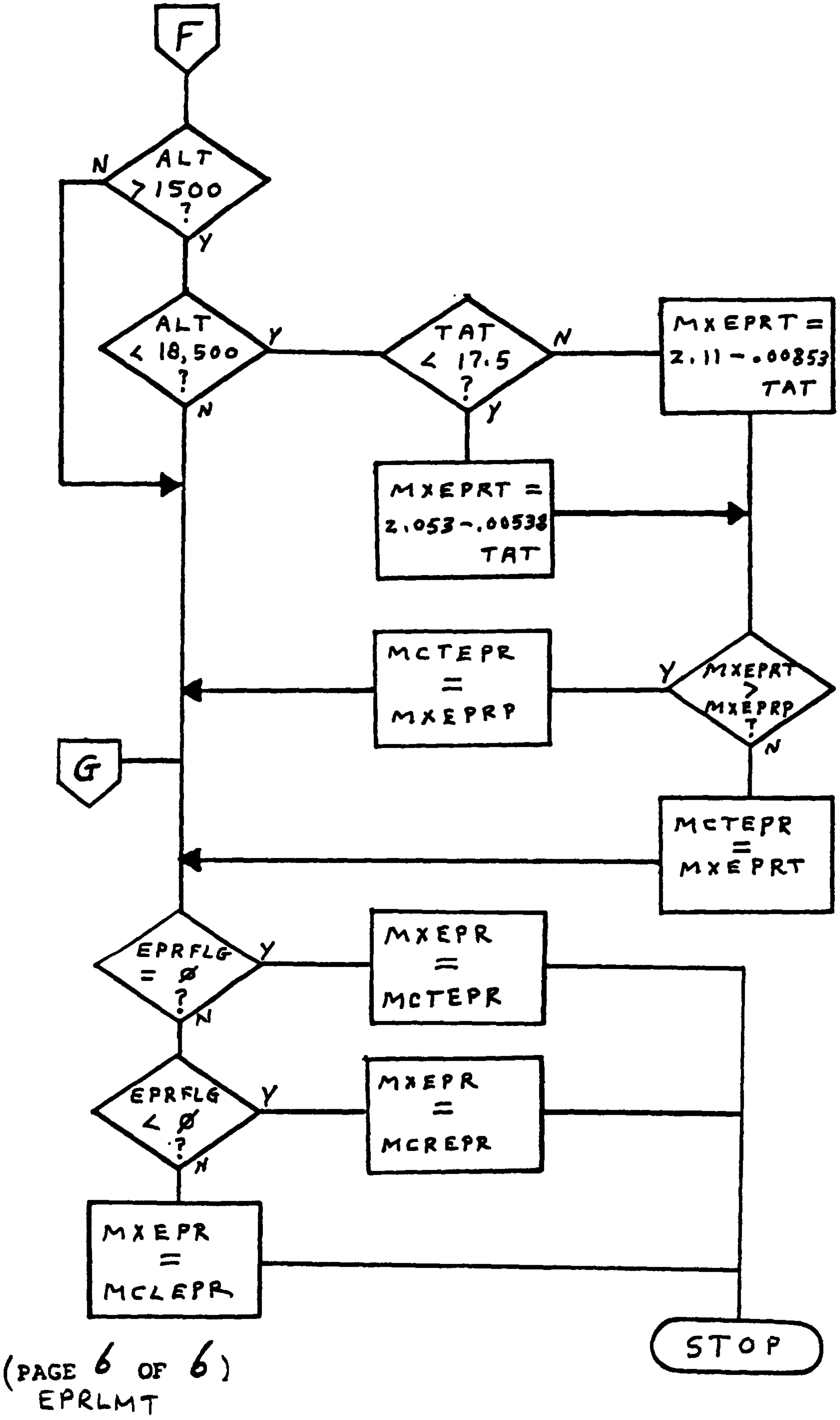
EPRLMT
(PAGE 3 OF 6)



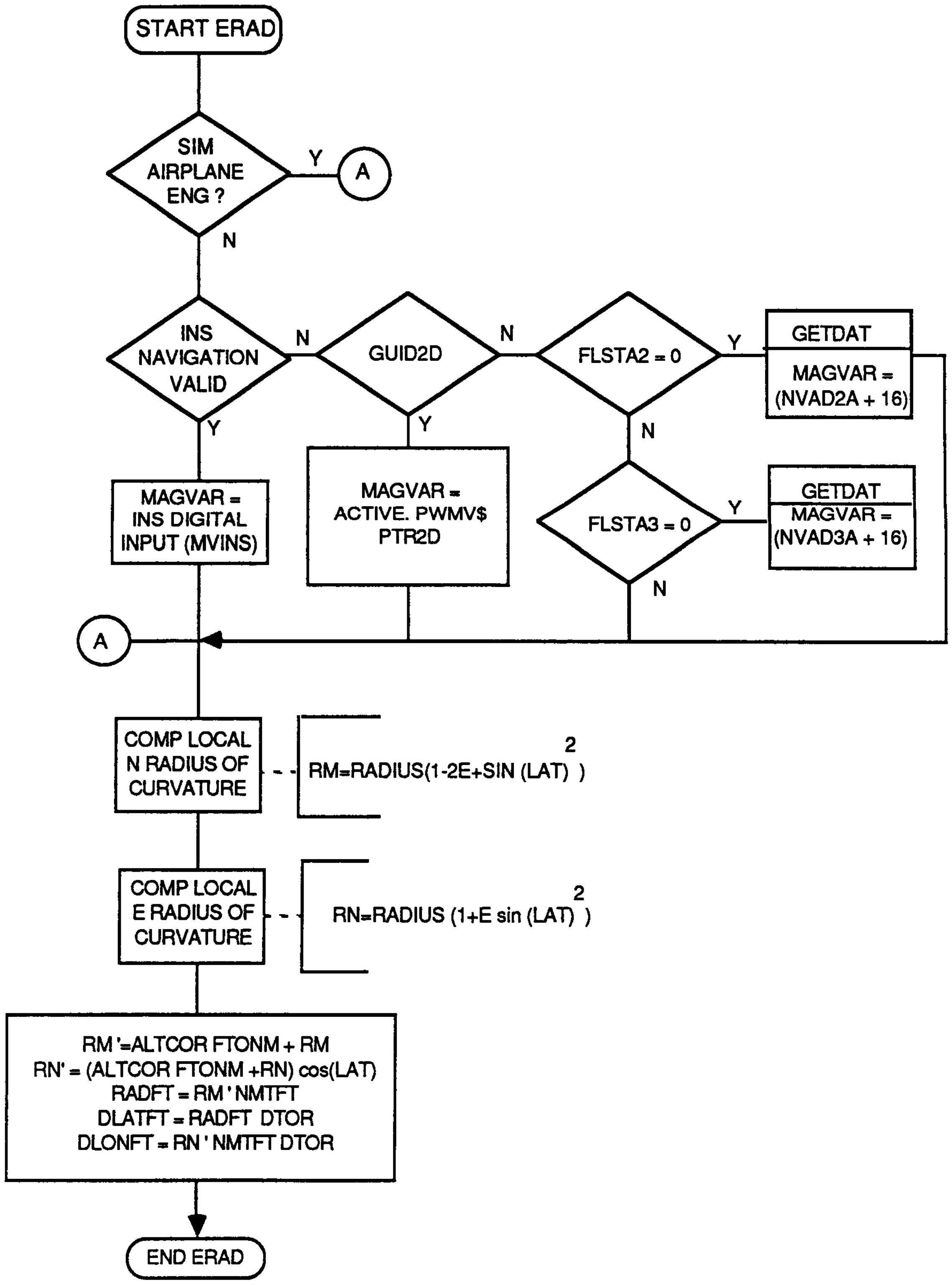
EPRLMT
(PAGE 4 OF 6)

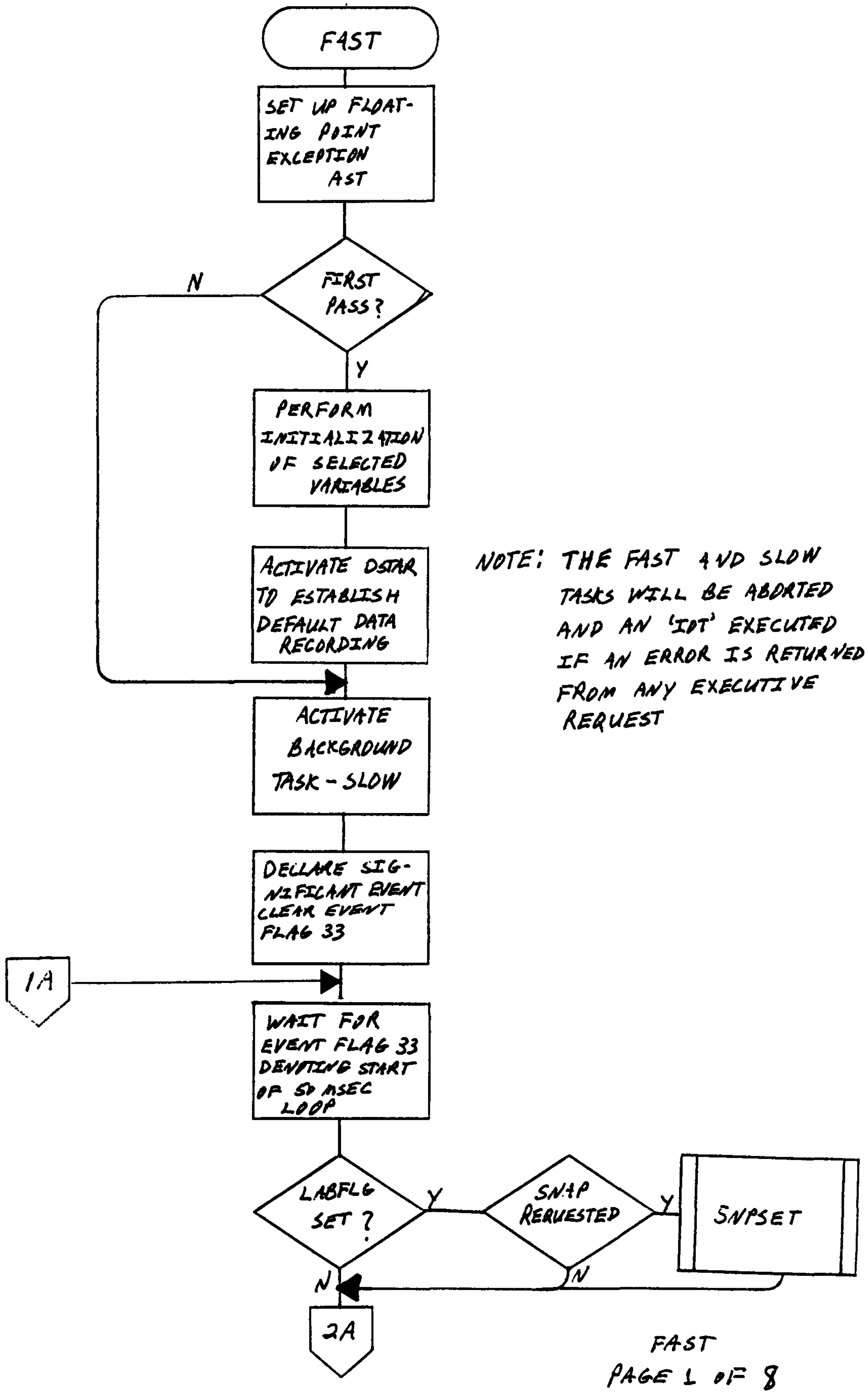


EPRLMT
(PAGE 5 OF 6)



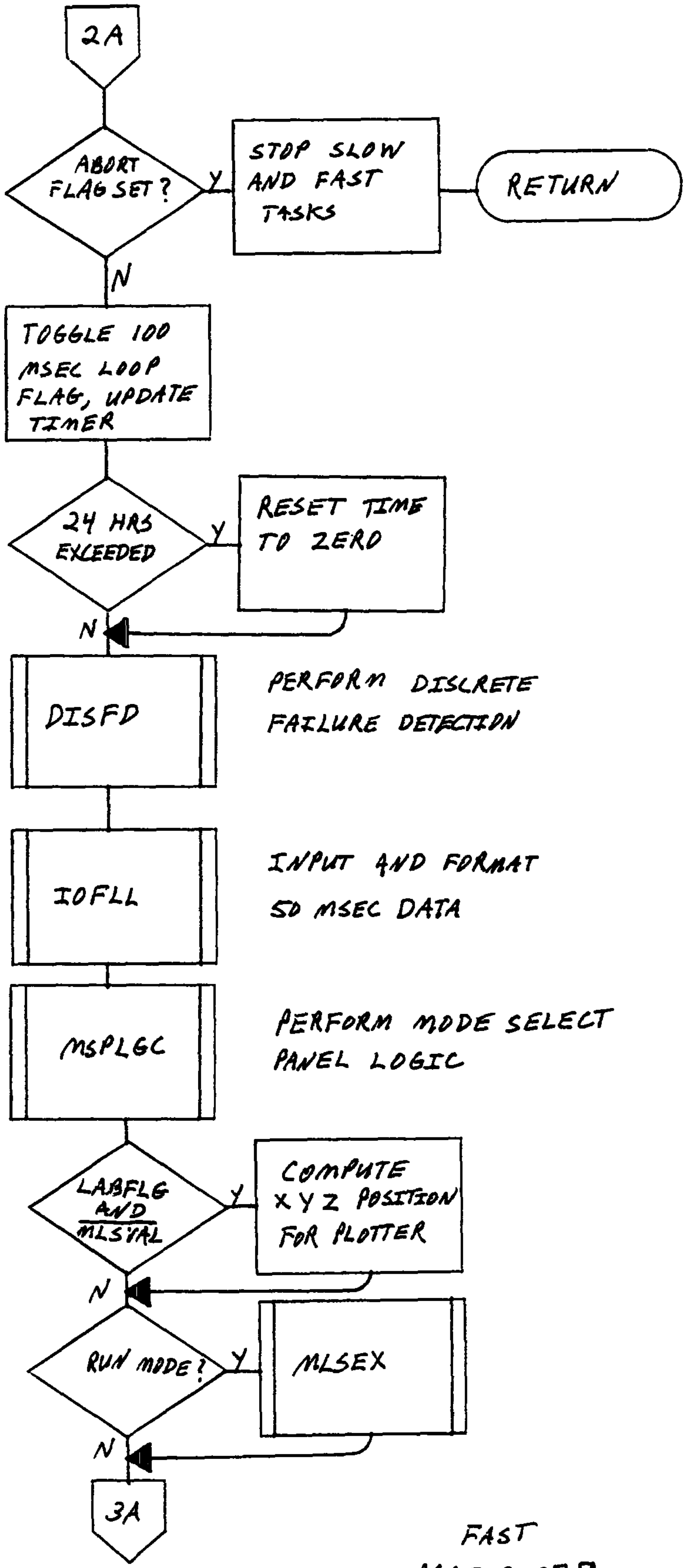
(PAGE 6 OF 6)
EPRLMT


START ERAD
SIM AIRPLANE ENG ?
Y
A
N
INS NAVIGATION VALID
N
GUID2D
N
FLSTA2 = 0
Y
GETDAT
MAGVAR = (NVAD2A + 16)
Y
MAGVAR = INS DIGITAL INPUT (MVINS)
Y
MAGVAR = ACTIVE. PWMV$ PTR2D
N
FLSTA3 = 0
Y
GETDAT
MAGVAR = (NVAD3A + 16)
N
A
COMP LOCAL N RADIUS OF CURVATURE
RM=RADIUS(1-2E+SIN (LAT)^2)
COMP LOCAL E RADIUS OF CURVATURE
RN=RADIUS (1+E sin (LAT)^2)
RM '=ALTCOR FTONM + RM
RN' = (ALTCOR FTONM +RN) cos(LAT)
RADFT = RM ' NMTFT
DLATFT = RADFT DTOR
DLONFT = RN ' NMTFT DTOR
END ERAD

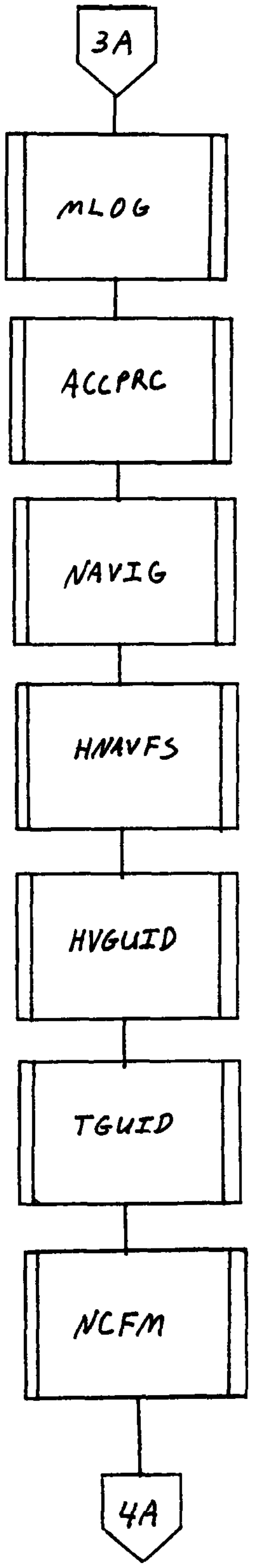

FAST
SET UP FLOATING POINT EXCEPTION AST
FIRST PASS?
N
Y
PERFORM INITIALIZATION OF SELECTED VARIABLES
ACTIVATE DSTAR TO ESTABLISH DEFAULT DATA RECORDING
ACTIVATE BACKGROUND TASK - SLOW
DECLARE SIGNIFICANT EVENT CLEAR EVENT FLAG 33
1A
WAIT FOR EVENT FLAG 33 DENOTING START OF 50 MSEC LOOP
LABFLG SET ?
Y
SNAP REQUESTED
Y
SNPSET
N
N
2A

NOTE: THE FAST AND SLOW TASKS WILL BE ABORTED AND AN 'IOT' EXECUTED IF AN ERROR IS RETURNED FROM ANY EXECUTIVE REQUEST

FAST
PAGE 1 OF 8


2A
ABORT FLAG SET?
Y
STOP SLOW AND FAST TASKS
RETURN
N
TOGGLE 100 MSEC LOOP FLAG, UPDATE TIMER
24 HRS EXCEEDED
Y
RESET TIME TO ZERO
N
DISFD
PERFORM DISCRETE FAILURE DETECTION
IOFLL
INPUT AND FORMAT 50 MSEC DATA
MSPLGC
PERFORM MODE SELECT PANEL LOGIC
LABFLG AND MLSVAL
Y
COMPUTE XYZ POSITION FOR PLOTTER
N
RUN MODE?
Y
MLSEX
N
3A

FAST
PAGE 2 OF 8



FAST
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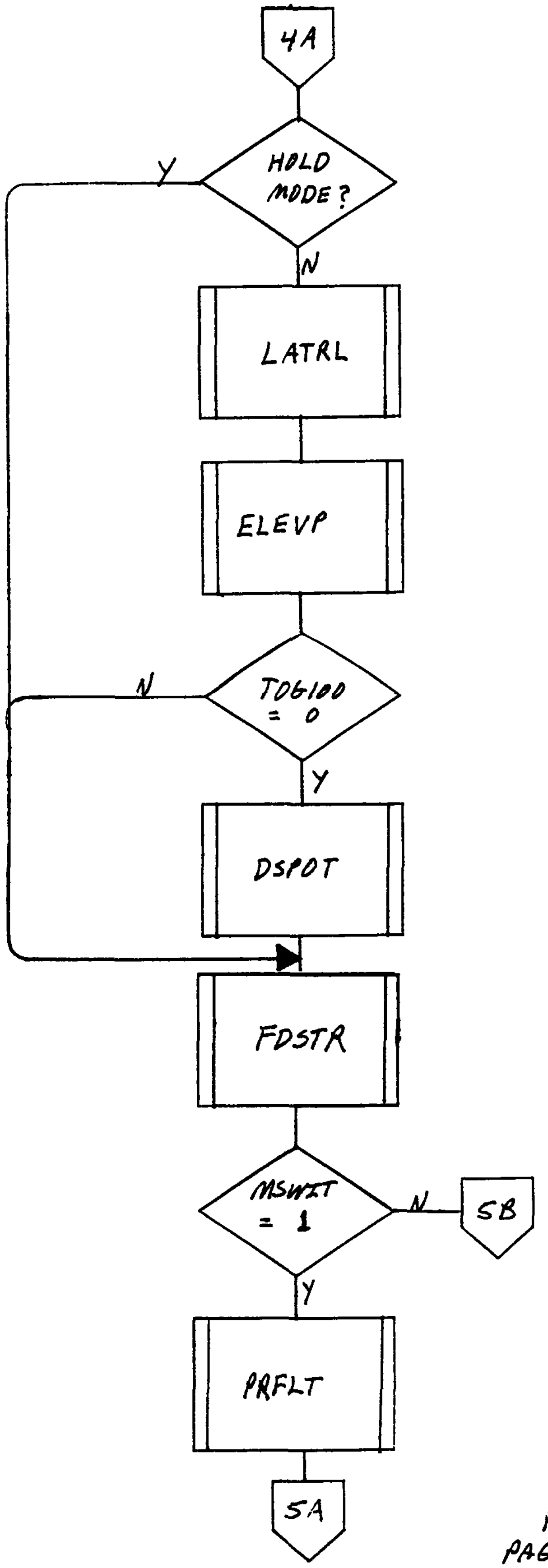

FAST
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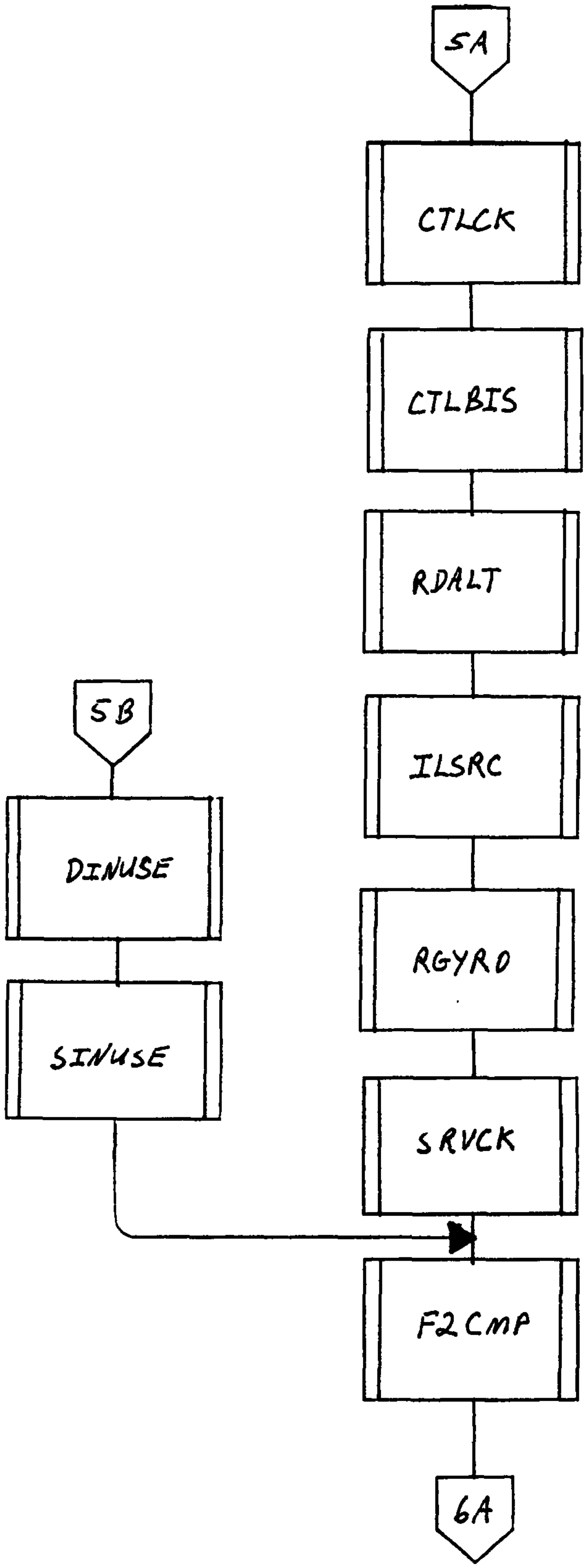
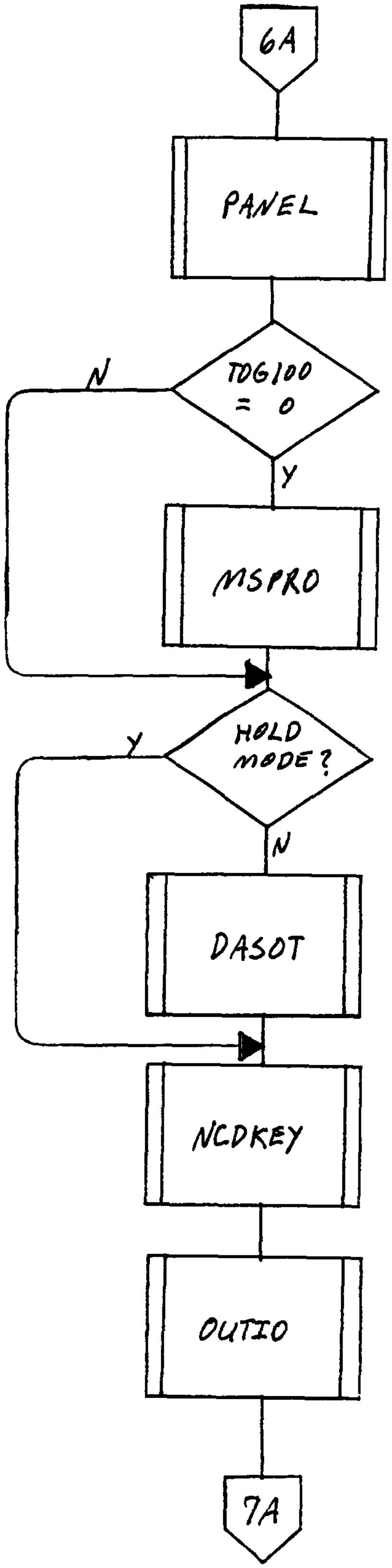


FAST
PAGE 5 OF 8



FAST
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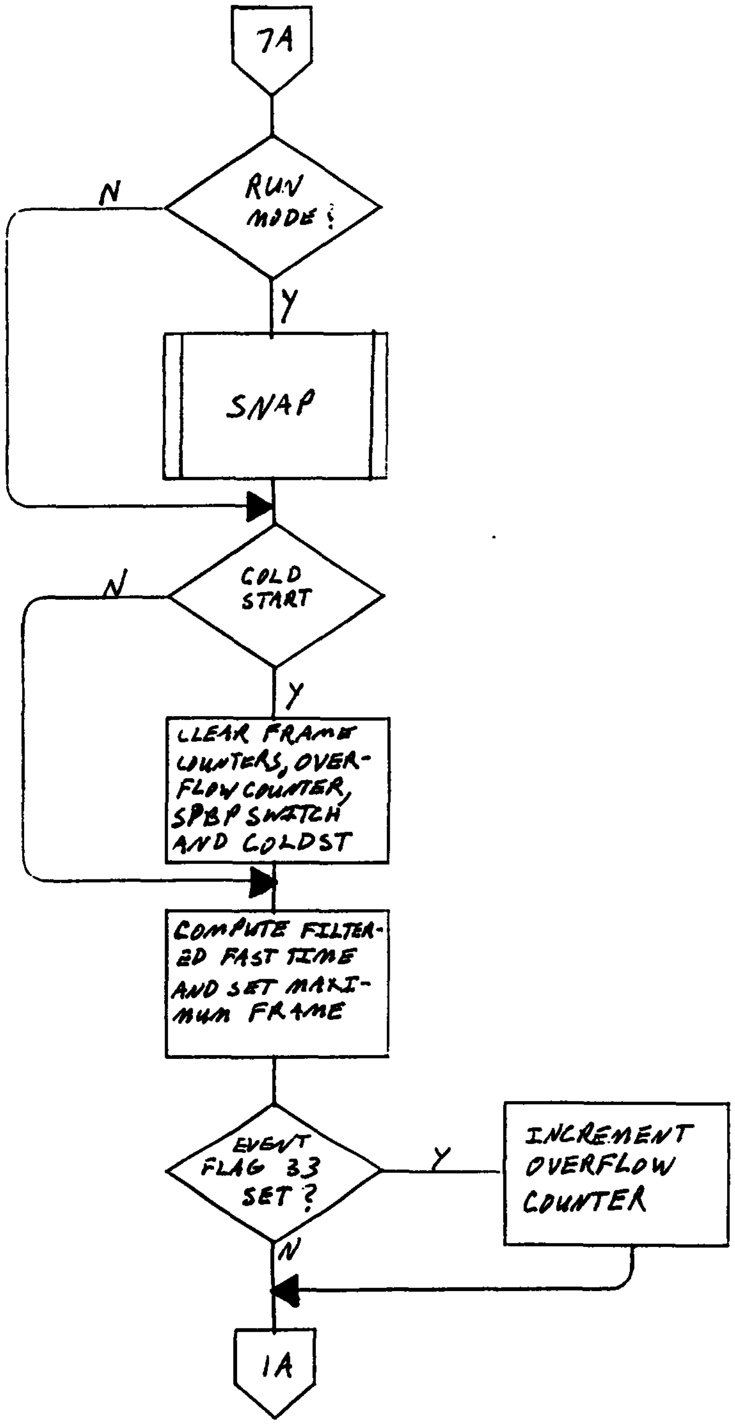
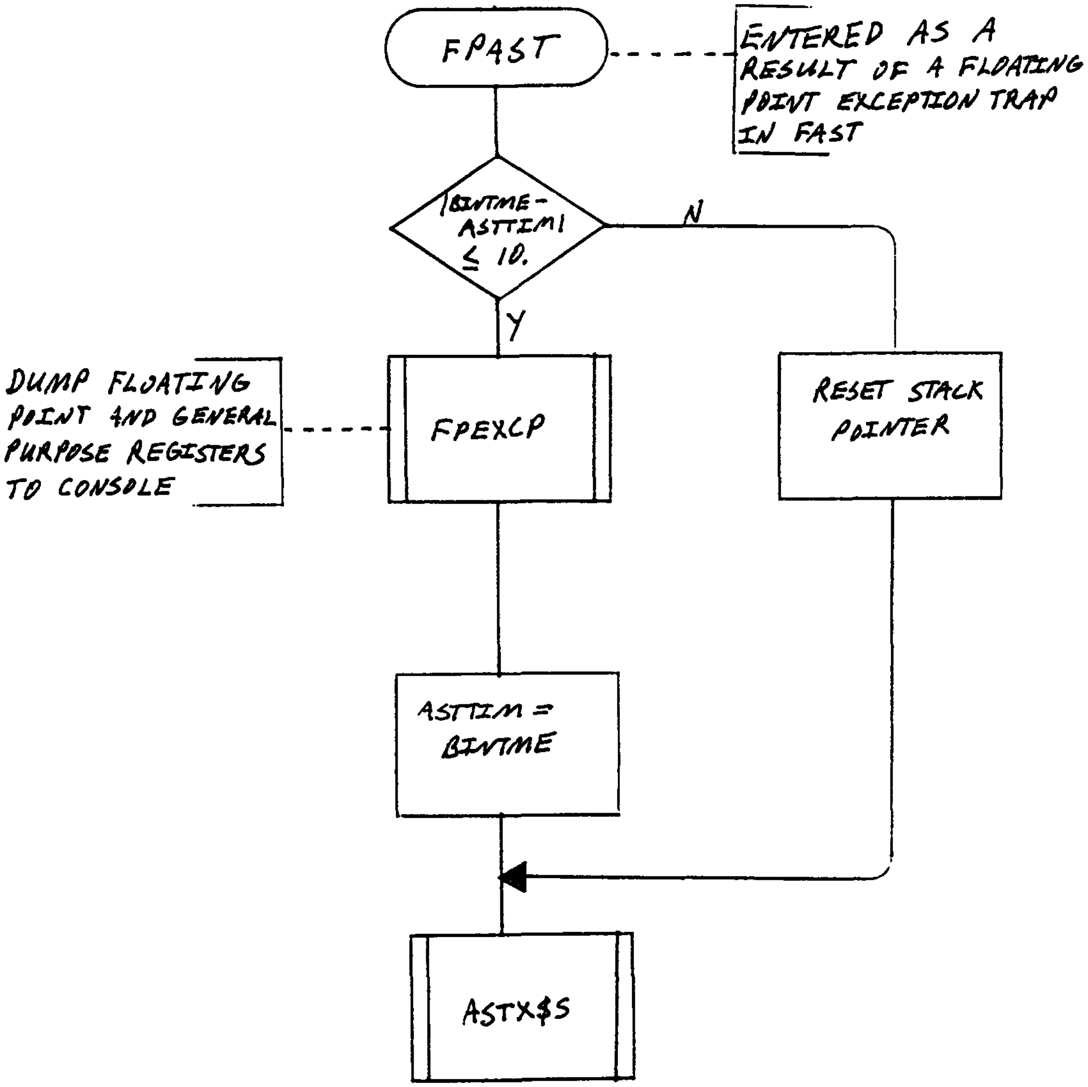
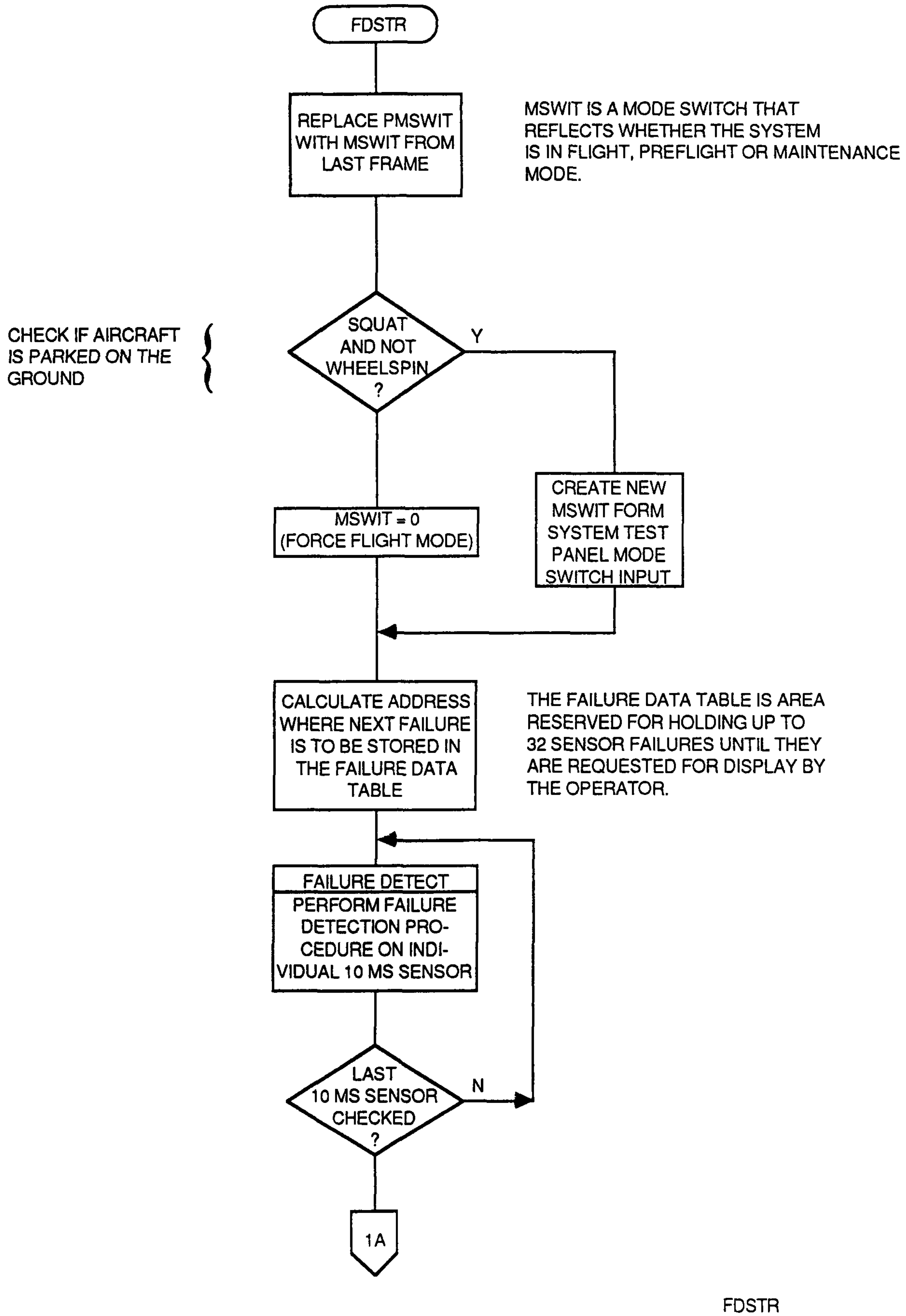

7A
RUN MODE?
N
Y
SNAP
COLD START
N
Y
CLEAR FRAME COUNTERS, OVERFLOW COUNTER, SPBP SWITCH AND COLDST
COMPUTE FILTERED FAST TIME AND SET MAXIMUM FRAME
EVENT FLAG 33 SET?
Y
INCREMENT OVERFLOW COUNTER
N
1A

FAST
PAGE 7 OF 8


FPAST
ENTERED AS A RESULT OF A FLOATING POINT EXCEPTION TRAP IN FAST
|BINTME-ASTTIM| ≤ 10.
N
Y
DUMP FLOATING POINT AND GENERAL PURPOSE REGISTERS TO CONSOLE
FPEXCP
RESET STACK POINTER
ASTTIM = BINTME
ASTX$S

FAST

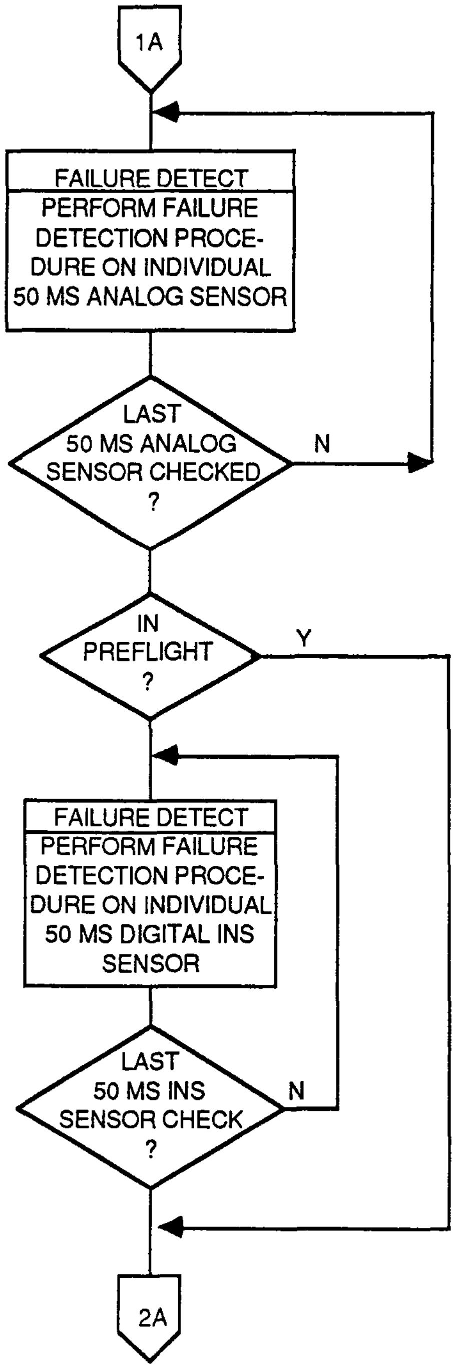
PAGE 8 OF 8

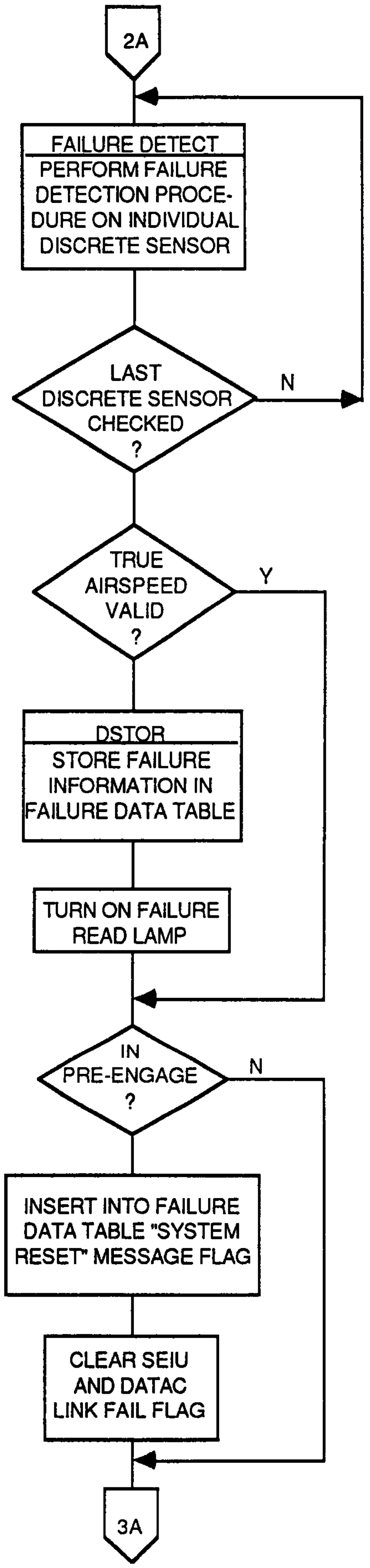

FDSTR
REPLACE PMSWIT WITH MSWIT FROM LAST FRAME
SQUAT AND NOT WHEELSPIN ?
Y
CREATE NEW MSWIT FORM SYSTEM TEST PANEL MODE SWITCH INPUT
MSWIT = 0 (FORCE FLIGHT MODE)
CALCULATE ADDRESS WHERE NEXT FAILURE IS TO BE STORED IN THE FAILURE DATA TABLE
FAILURE DETECT
PERFORM FAILURE DETECTION PROCEDURE ON INDIVIDUAL 10 MS SENSOR
LAST 10 MS SENSOR CHECKED ?
N
1A

MSWIT IS A MODE SWITCH THAT REFLECTS WHETHER THE SYSTEM IS IN FLIGHT, PREFLIGHT OR MAINTENANCE MODE.

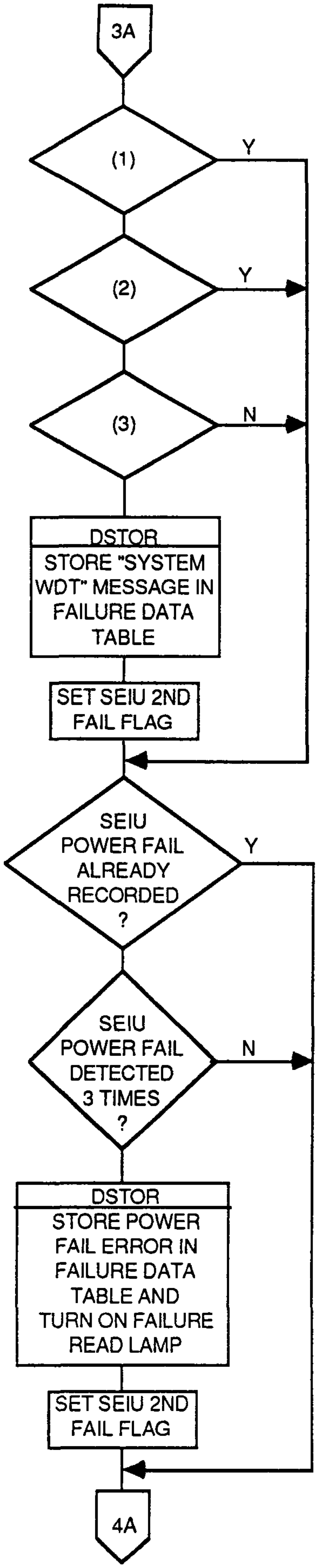
CHECK IF AIRCRAFT IS PARKED ON THE GROUND

THE FAILURE DATA TABLE IS AREA RESERVED FOR HOLDING UP TO 32 SENSOR FAILURES UNTIL THEY ARE REQUESTED FOR DISPLAY BY THE OPERATOR.


1A
FAILURE DETECT
PERFORM FAILURE DETECTION PROCEDURE ON INDIVIDUAL 50 MS ANALOG SENSOR
LAST 50 MS ANALOG SENSOR CHECKED ?
N
IN PREFLIGHT ?
Y
FAILURE DETECT
PERFORM FAILURE DETECTION PROCEDURE ON INDIVIDUAL 50 MS DIGITAL INS SENSOR
LAST 50 MS INS SENSOR CHECK ?
N
2A


2A
FAILURE DETECT
PERFORM FAILURE DETECTION PROCEDURE ON INDIVIDUAL DISCRETE SENSOR
LAST DISCRETE SENSOR CHECKED ?
N
TRUE AIRSPEED VALID ?
Y
DSTOR
STORE FAILURE INFORMATION IN FAILURE DATA TABLE
TURN ON FAILURE READ LAMP
IN PRE-ENGAGE ?
N
INSERT INTO FAILURE DATA TABLE "SYSTEM RESET" MESSAGE FLAG
CLEAR SEIU AND DATAC LINK FAIL FLAG
3A

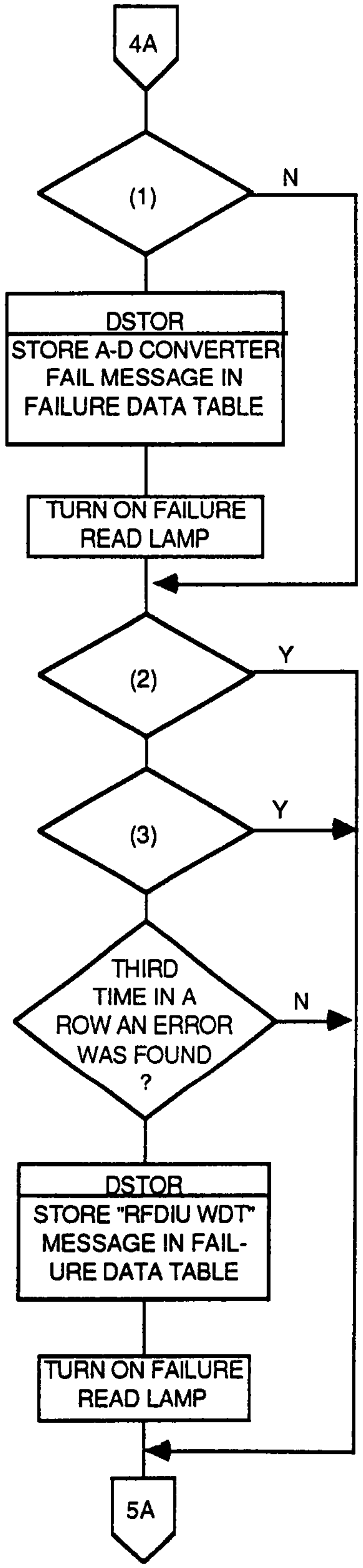
FDSTR
(PAGE 3 OF 8)


3A
(1)
Y
(2)
Y
(3)
N
DSTOR
STORE "SYSTEM WDT" MESSAGE IN FAILURE DATA TABLE
SET SEIU 2ND FAIL FLAG
SEIU POWER FAIL ALREADY RECORDED ?
Y
SEIU POWER FAIL DETECTED 3 TIMES ?
N
DSTOR
STORE POWER FAIL ERROR IN FAILURE DATA TABLE AND TURN ON FAILURE READ LAMP
SET SEIU 2ND FAIL FLAG
4A

(1) ANY SEIU COMMUNICATION FAILURES ALREADY LOGGED?

(2) IS WRAPAROUND FROM SIU THE SAME AS THAT SENT LAST FRAME?

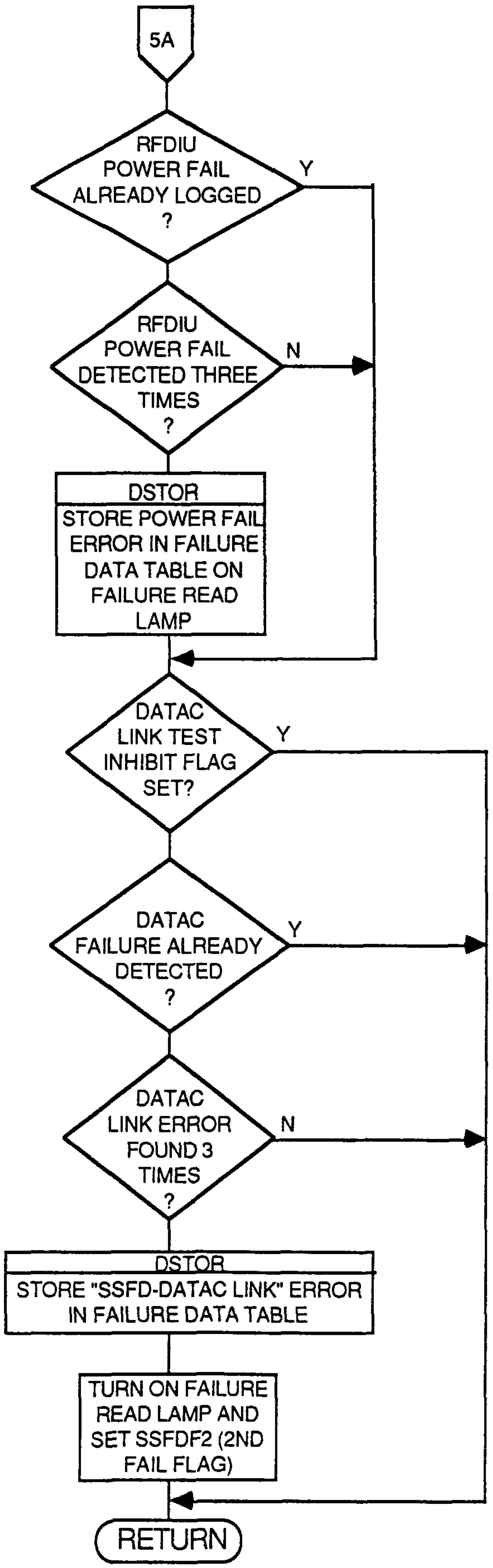
(3) THIRD TIME IN A ROW AN ERROR WAS FOUND?


4A
(1)
N
DSTOR
STORE A-D CONVERTER FAIL MESSAGE IN FAILURE DATA TABLE
TURN ON FAILURE READ LAMP
(2)
Y
(3)
Y
THIRD TIME IN A ROW AN ERROR WAS FOUND ?
N
DSTOR
STORE "RFDIU WDT" MESSAGE IN FAIL-URE DATA TABLE
TURN ON FAILURE READ LAMP
5A

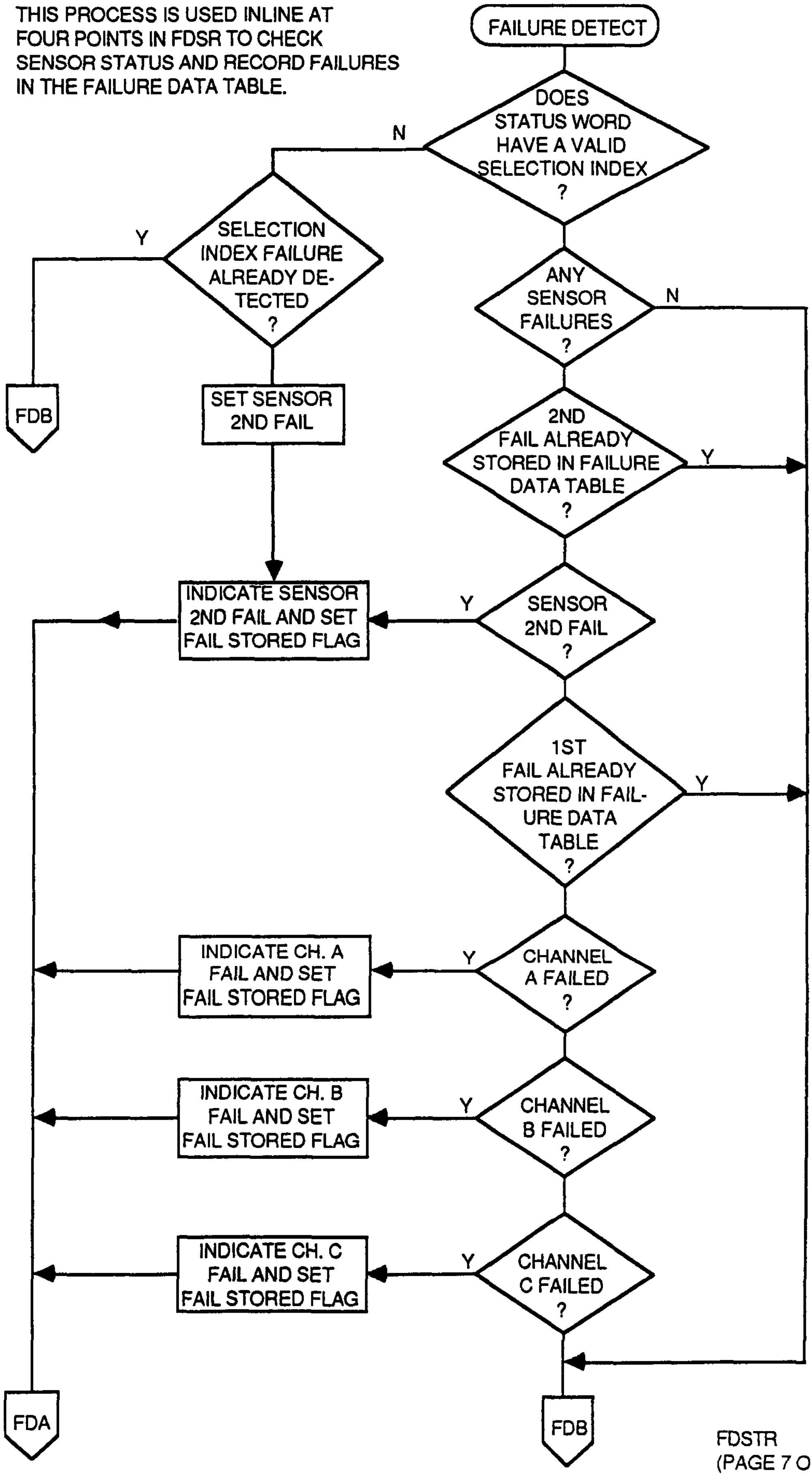
(1) SEIU A-D CONVERTER FAILED VALUE THREE TIMES IN A ROW?

(2) ANY RFDIU COMMUNICATION FAILURES LOGGED?

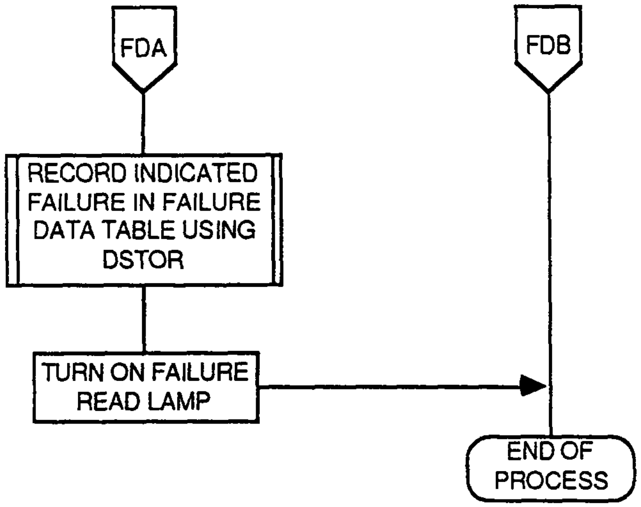
(3) IS WRAPAROUND FROM RFDIU SAME AS THAT SENT LAST FRAME?

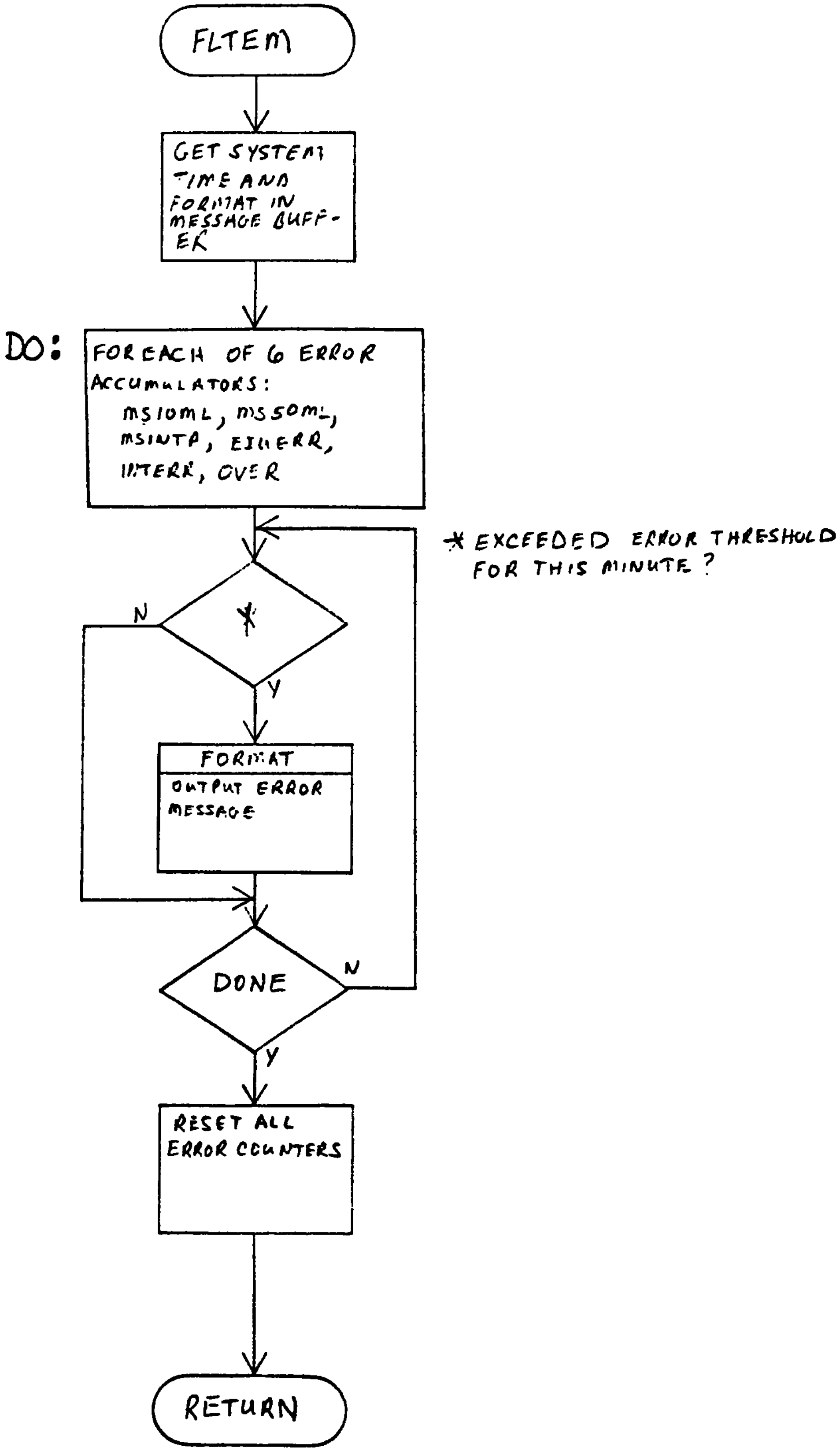

5A
RFDIU POWER FAIL ALREADY LOGGED ?
Y
RFDIU POWER FAIL DETECTED THREE TIMES ?
N
DSTOR
STORE POWER FAIL ERROR IN FAILURE DATA TABLE ON FAILURE READ LAMP
DATAC LINK TEST INHIBIT FLAG SET?
Y
DATAC FAILURE ALREADY DETECTED ?
Y
DATAC LINK ERROR FOUND 3 TIMES ?
N
DSTOR
STORE "SSFD-DATAC LINK" ERROR IN FAILURE DATA TABLE
TURN ON FAILURE READ LAMP AND SET SSFDF2 (2ND FAIL FLAG)
RETURN

THIS PROCESS IS USED INLINE AT FOUR POINTS IN FDSR TO CHECK SENSOR STATUS AND RECORD FAILURES IN THE FAILURE DATA TABLE.

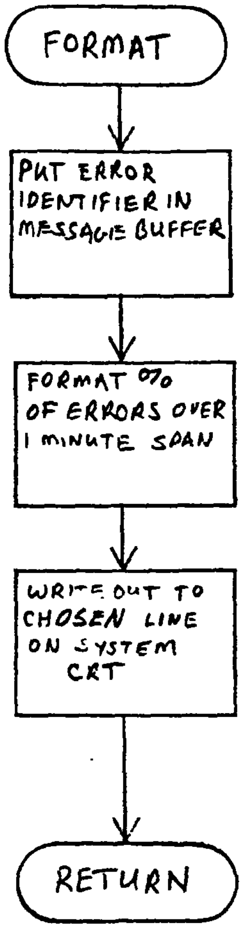

FAILURE DETECT
DOES STATUS WORD HAVE A VALID SELECTION INDEX ?
N
SELECTION INDEX FAILURE ALREADY DE-TECTED ?
Y
FDB
SET SENSOR 2ND FAIL
ANY SENSOR FAILURES ?
N
2ND FAIL ALREADY STORED IN FAILURE DATA TABLE ?
Y
SENSOR 2ND FAIL ?
Y
INDICATE SENSOR 2ND FAIL AND SET FAIL STORED FLAG
1ST FAIL ALREADY STORED IN FAIL-URE DATA TABLE ?
Y
CHANNEL A FAILED ?
Y
INDICATE CH. A FAIL AND SET FAIL STORED FLAG
CHANNEL B FAILED ?
Y
INDICATE CH. B FAIL AND SET FAIL STORED FLAG
CHANNEL C FAILED ?
Y
INDICATE CH. C FAIL AND SET FAIL STORED FLAG
FDA
FDB

FDSTR
(PAGE 7 OF 8)

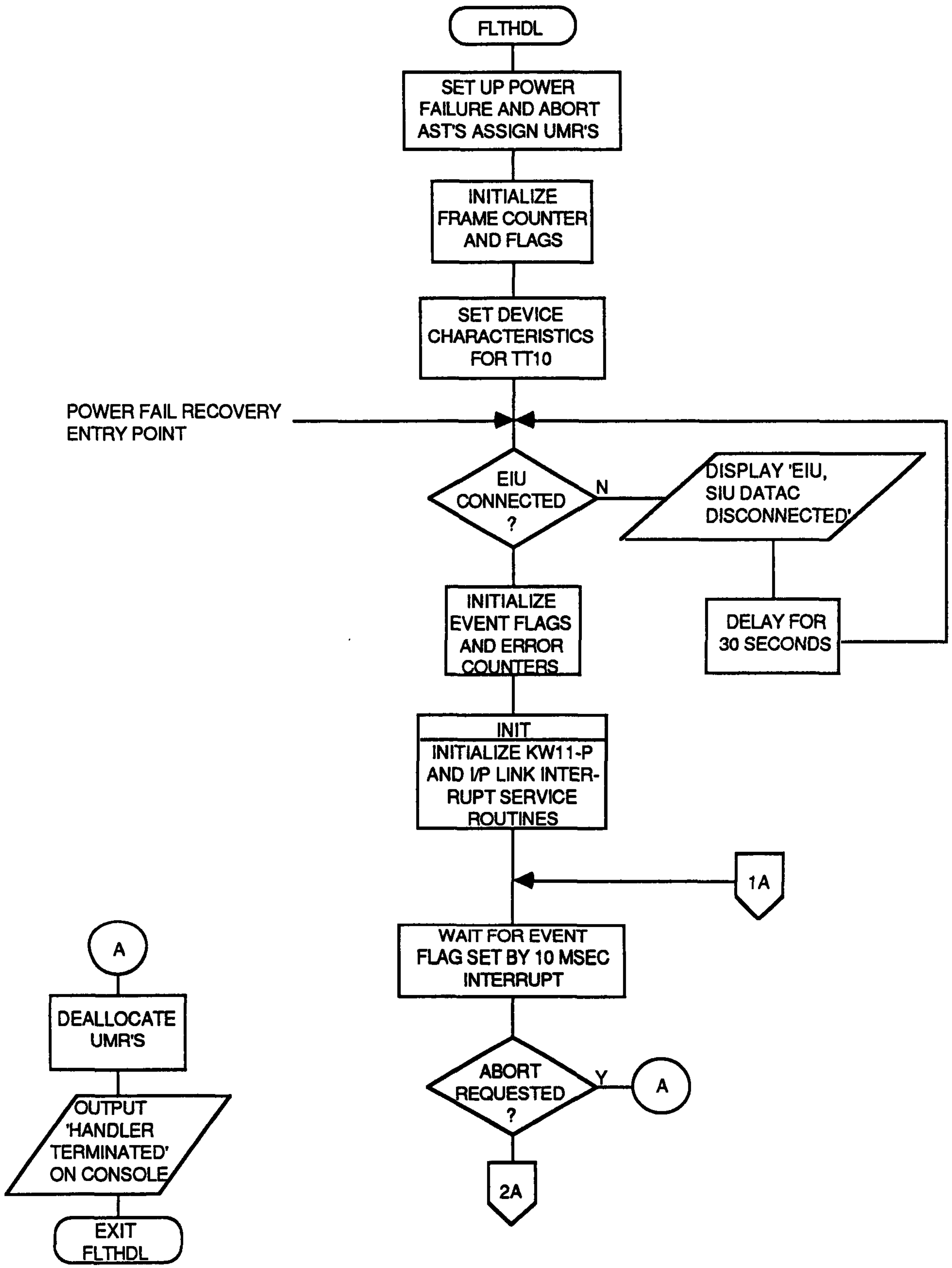

FDA
FDB
RECORD INDICATED FAILURE IN FAILURE DATA TABLE USING DSTOR
TURN ON FAILURE READ LAMP
END OF PROCESS


FLTEM
GET SYSTEM TIME AND FORMAT IN MESSAGE BUFF-ER
DO:
FOR EACH OF 6 ERROR ACCUMULATORS:
MS10ML, MS50ML,
MSINTP, EIUERR,
INTERR, OVER
* EXCEEDED ERROR THRESHOLD FOR THIS MINUTE?
*
N
Y
FORMAT
OUTPUT ERROR MESSAGE
DONE
N
Y
RESET ALL ERROR COUNTERS
RETURN

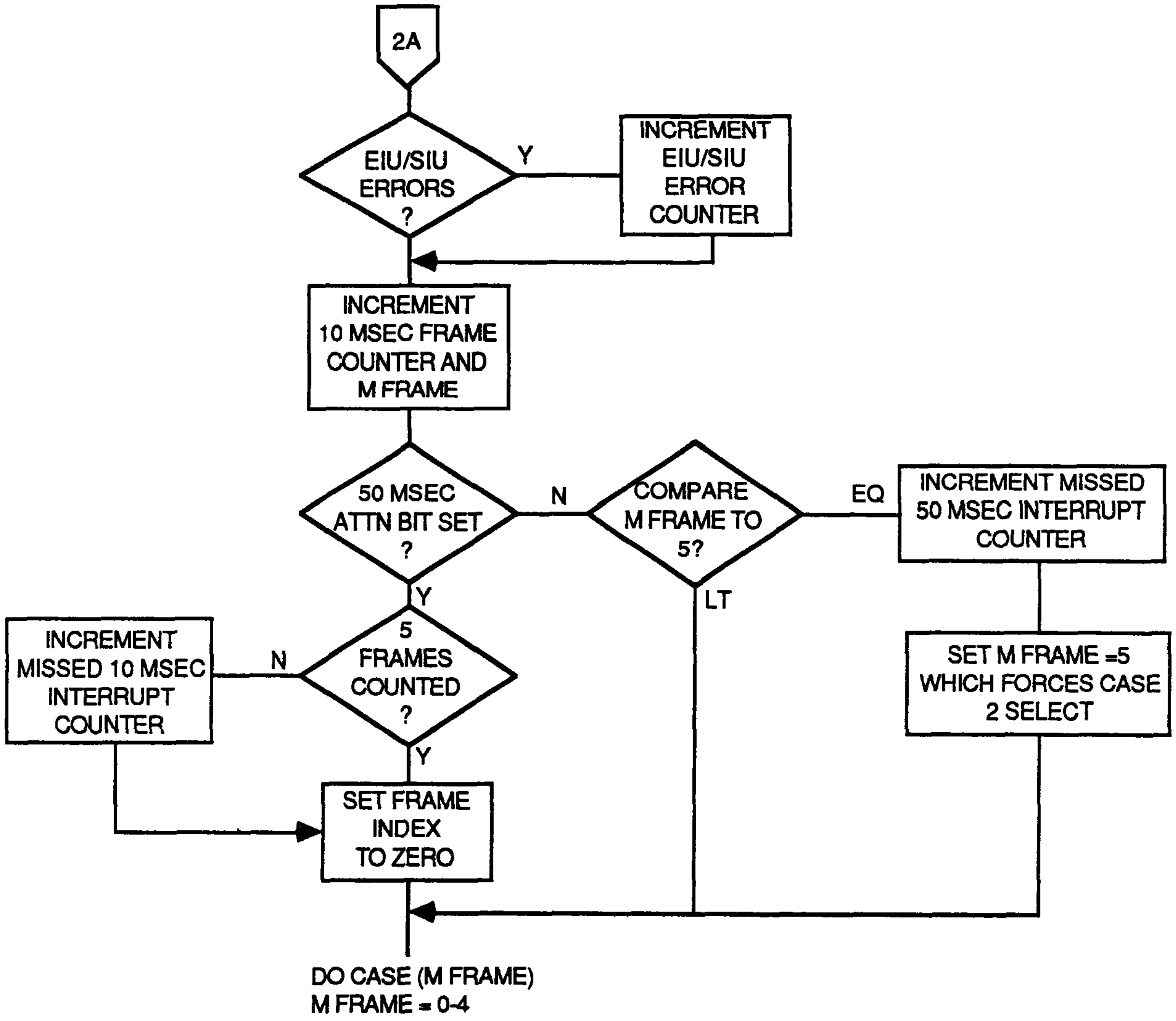
FLTEM
(PAGE 1 OF 2)


FORMAT
PUT ERROR IDENTIFIER IN MESSAGE BUFFER
FORMAT % OF ERRORS OVER 1 MINUTE SPAN
WRITE OUT TO CHOSEN LINE ON SYSTEM CRT
RETURN

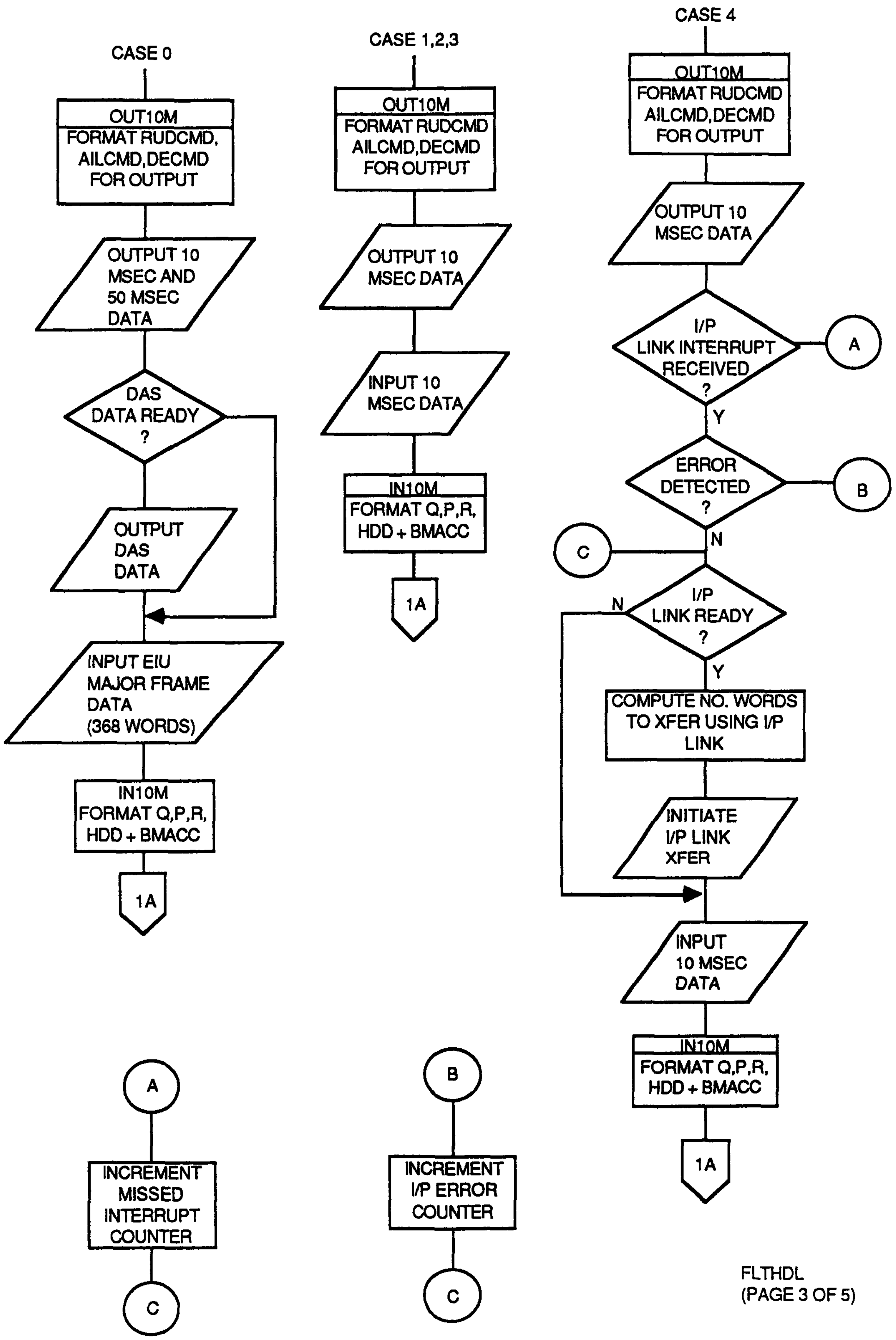
FLTEM
(PAGE 2 OF 2)


FLTHDL
SET UP POWER FAILURE AND ABORT AST'S ASSIGN UMR'S
INITIALIZE FRAME COUNTER AND FLAGS
SET DEVICE CHARACTERISTICS FOR TT10
POWER FAIL RECOVERY ENTRY POINT
EIU CONNECTED ?
N
DISPLAY 'EIU, SIU DATAC DISCONNECTED'
DELAY FOR 30 SECONDS
INITIALIZE EVENT FLAGS AND ERROR COUNTERS
INIT
INITIALIZE KW11-P AND I/P LINK INTER-RUPT SERVICE ROUTINES
1A
WAIT FOR EVENT FLAG SET BY 10 MSEC INTERRUPT
ABORT REQUESTED ?
Y
A
2A
A
DEALLOCATE UMR'S
OUTPUT 'HANDLER TERMINATED' ON CONSOLE
EXIT FLTHDL

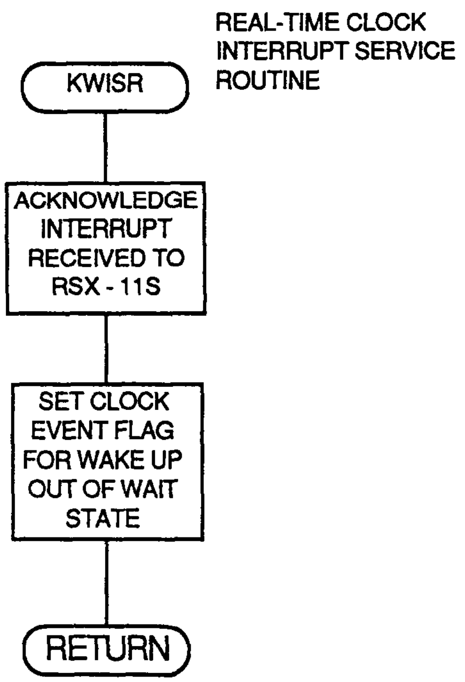
FLTHDL
(PAGE 1 OF 5)


2A
EIU/SIU ERRORS ?
Y
INCREMENT EIU/SIU ERROR COUNTER
INCREMENT 10 MSEC FRAME COUNTER AND M FRAME
50 MSEC ATTN BIT SET ?
N
COMPARE M FRAME TO 5?
EQ
INCREMENT MISSED 50 MSEC INTERRUPT COUNTER
LT
SET M FRAME =5 WHICH FORCES CASE 2 SELECT
Y
INCREMENT MISSED 10 MSEC INTERRUPT COUNTER
N
5 FRAMES COUNTED ?
Y
SET FRAME INDEX TO ZERO
DO CASE (M FRAME)
M FRAME = 0-4

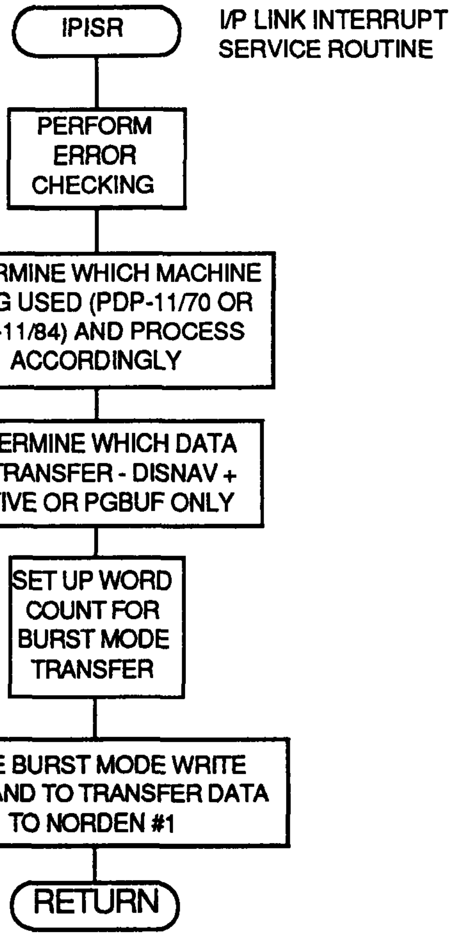
FLTHDL
(PAGE 2 OF 5)


CASE 0
OUT10M
FORMAT RUDCMD, AILCMD,DECMD FOR OUTPUT
OUTPUT 10 MSEC AND 50 MSEC DATA
DAS DATA READY ?
OUTPUT DAS DATA
INPUT EIU MAJOR FRAME DATA (368 WORDS)
IN10M
FORMAT Q,P,R, HDD + BMACC
1A
CASE 1,2,3
OUT10M
FORMAT RUDCMD AILCMD,DECMD FOR OUTPUT
OUTPUT 10 MSEC DATA
INPUT 10 MSEC DATA
IN10M
FORMAT Q,P,R, HDD + BMACC
1A
CASE 4
OUT10M
FORMAT RUDCMD AILCMD,DECMD FOR OUTPUT
OUTPUT 10 MSEC DATA
I/P LINK INTERRUPT RECEIVED ?
A
Y
ERROR DETECTED ?
B
N
C
I/P LINK READY ?
N
Y
COMPUTE NO. WORDS TO XFER USING I/P LINK
INITIATE I/P LINK XFER
INPUT 10 MSEC DATA
IN10M
FORMAT Q,P,R, HDD + BMACC
1A
A
INCREMENT MISSED INTERRUPT COUNTER
C
B
INCREMENT I/P ERROR COUNTER
C

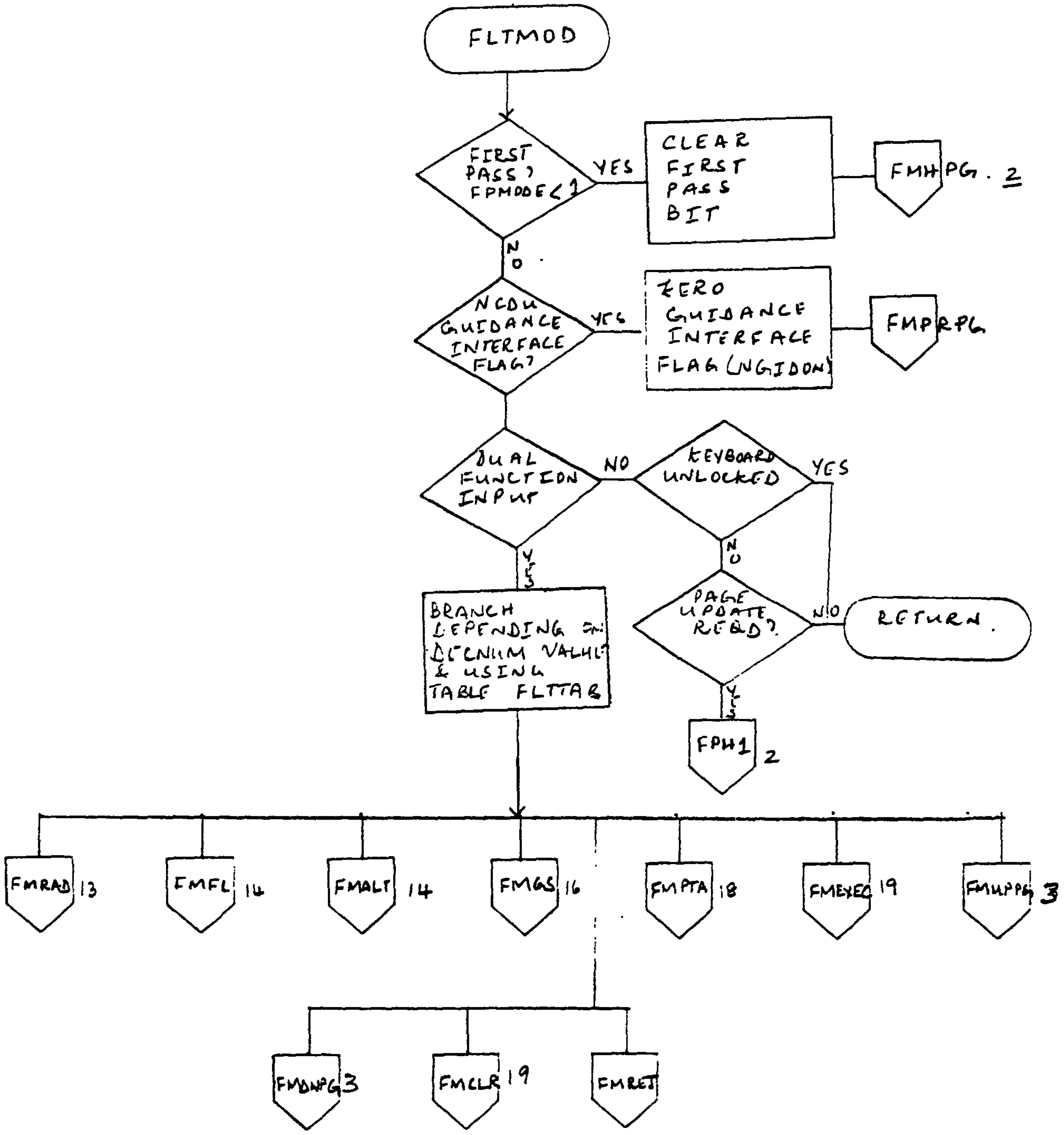
FLTHDL
(PAGE 3 OF 5)


REAL-TIME CLOCK INTERRUPT SERVICE ROUTINE
KWISR
ACKNOWLEDGE INTERRUPT RECEIVED TO RSX - 11S
SET CLOCK EVENT FLAG FOR WAKE UP OUT OF WAIT STATE
RETURN

FLTHDL
(PAGE 4 OF 5)


IPISR
I/P LINK INTERRUPT SERVICE ROUTINE
PERFORM ERROR CHECKING
DETERMINE WHICH MACHINE BEING USED (PDP-11/70 OR PDP-11/84) AND PROCESS ACCORDINGLY
DETERMINE WHICH DATA TO TRANSFER - DISNAV + ACTIVE OR PGBUF ONLY
SET UP WORD COUNT FOR BURST MODE TRANSFER
ISSUE BURST MODE WRITE COMMAND TO TRANSFER DATA TO NORDEN #1
RETURN

FLTHDL
(PAGE 5 OF 5)



FLTMOD
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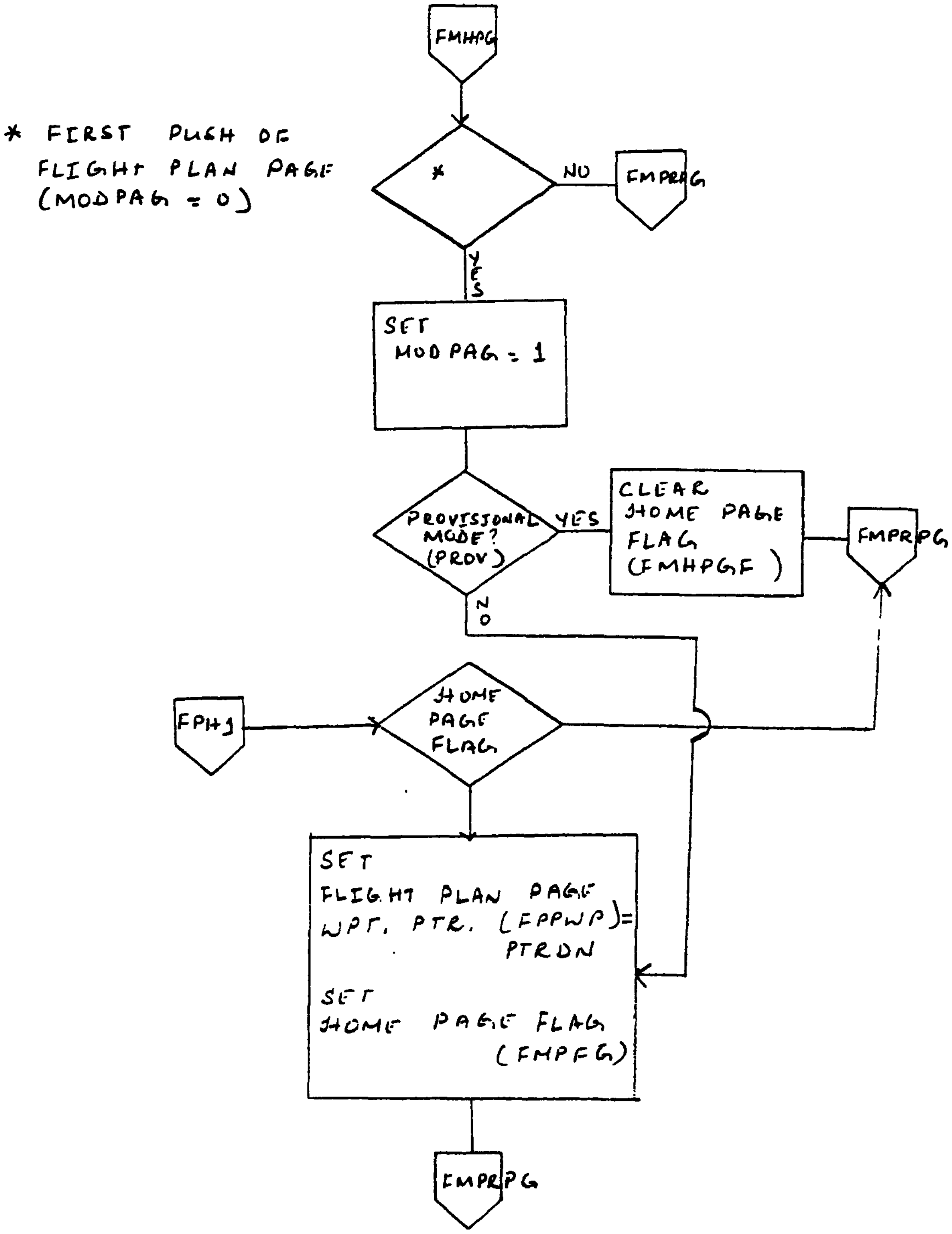

FLTMOD
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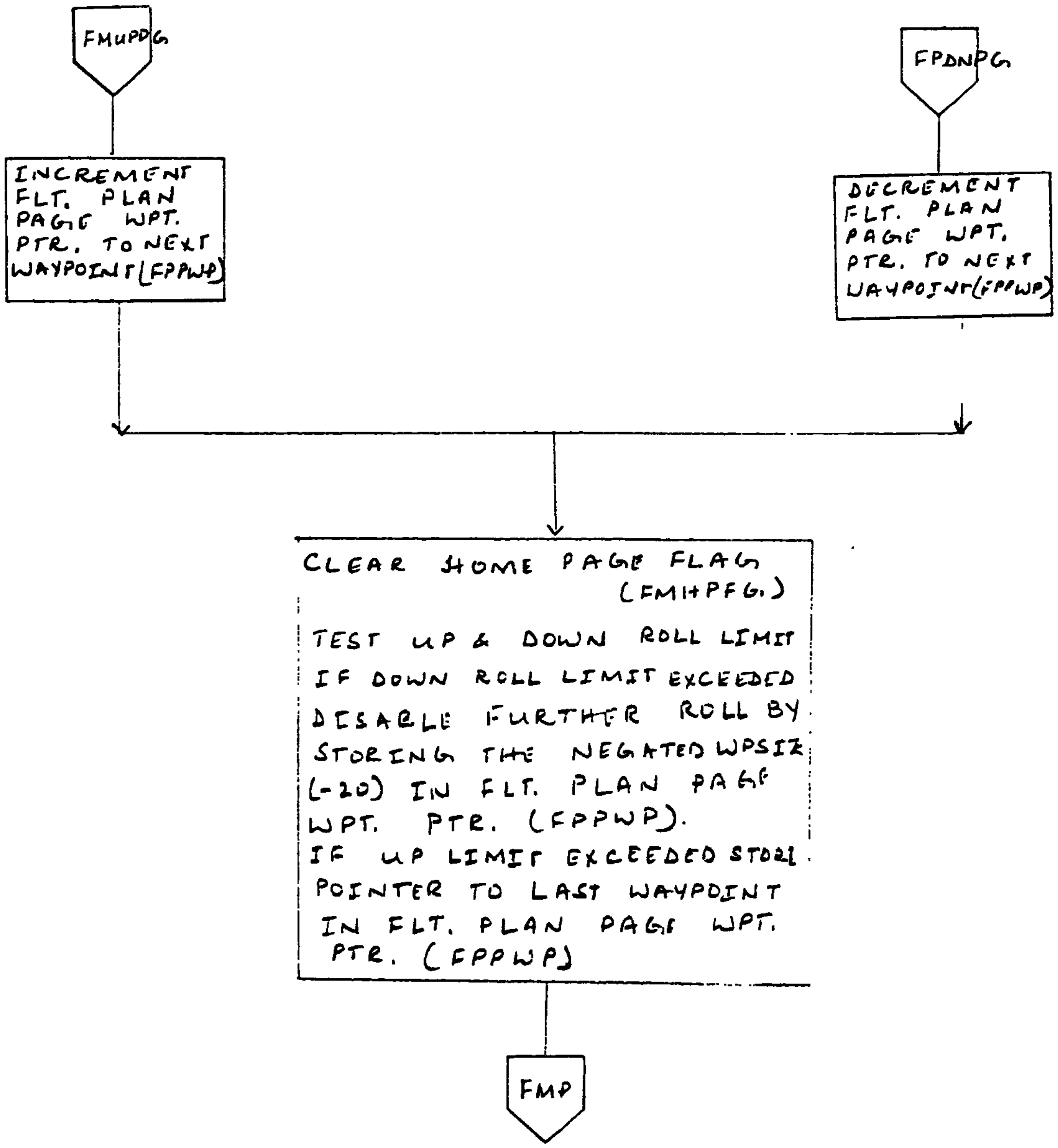
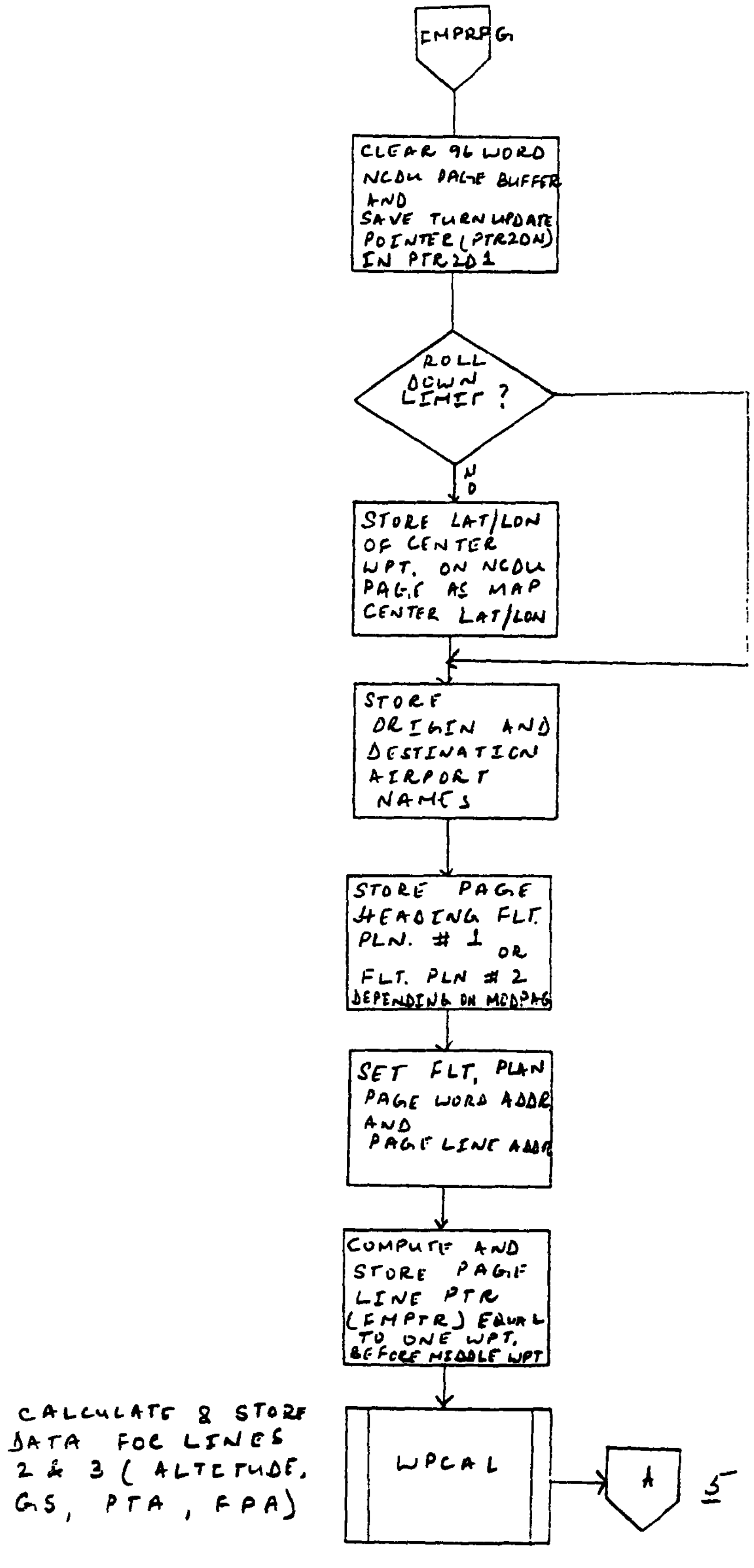
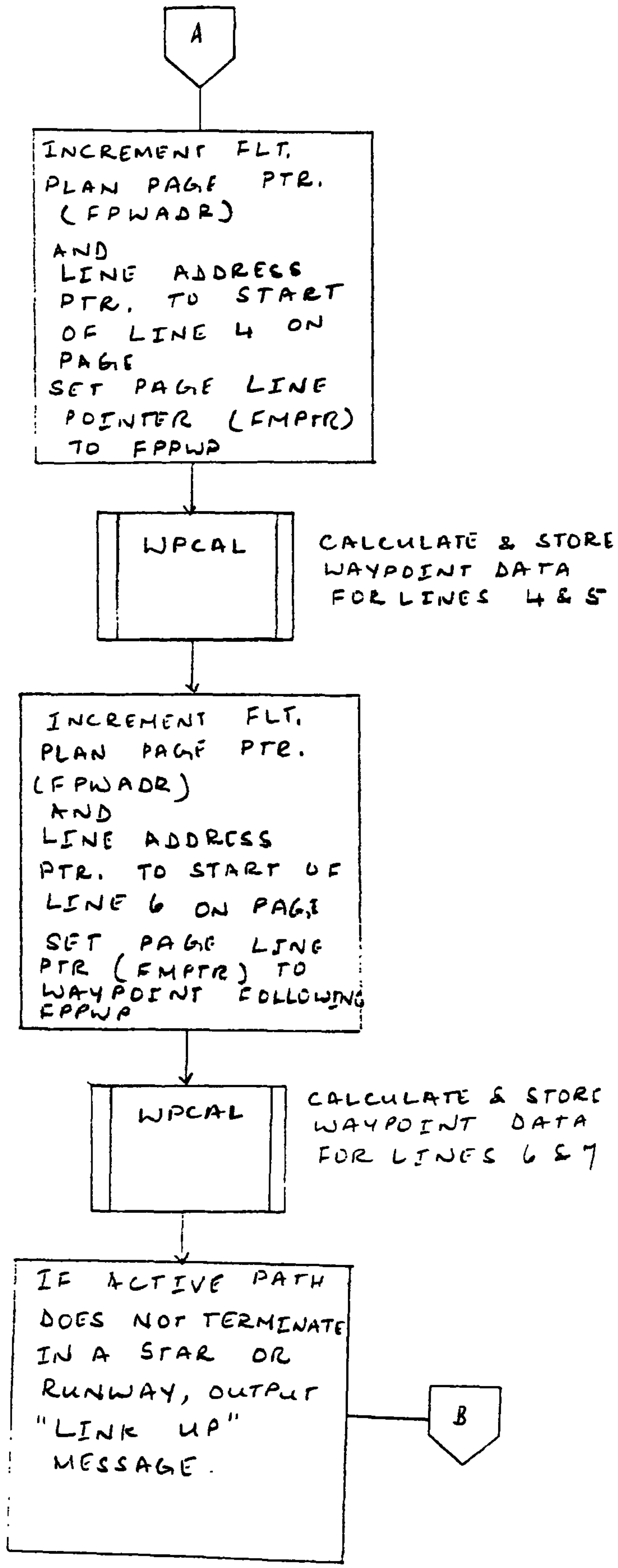
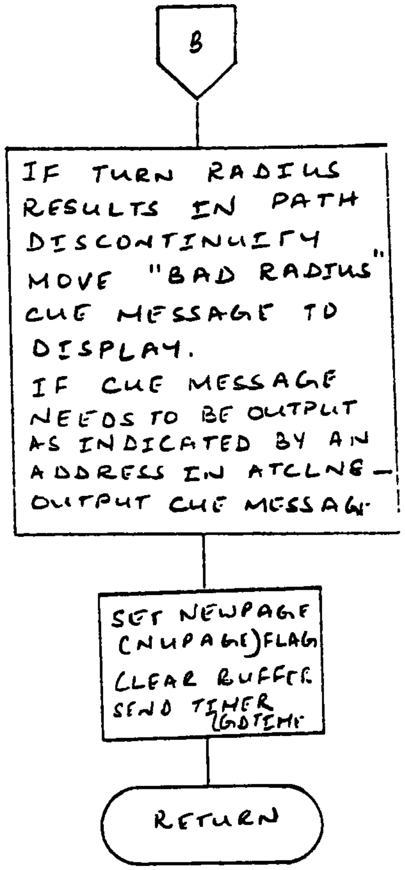

FMUPDG
INCREMENT FLT. PLAN PAGE WPT. PTR. TO NEXT WAYPOINT (FPPWP)
FPDNPG
DECREMENT FLT. PLAN PAGE WPT. PTR. TO NEXT WAYPOINT (FPPWP)
CLEAR HOME PAGE FLAG (FMHPFG.)
TEST UP & DOWN ROLL LIMIT
IF DOWN ROLL LIMIT EXCEEDED DISABLE FURTHER ROLL BY STORING THE NEGATED WPSIZ (-20) IN FLT. PLAN PAGE WPT. PTR. (FPPWP).
IF UP LIMIT EXCEEDED STORE POINTER TO LAST WAYPOINT IN FLT. PLAN PAGE WPT. PTR. (FPPWP)
FMP


EMPRPG
CLEAR 96 WORD NCDU PAGE BUFFER AND SAVE TURN UPDATE POINTER (PTR2ON) IN PTR2D1
ROLL DOWN LIMIT ?
NO
STORE LAT/LON OF CENTER WPT. ON NCDU PAGE AS MAP CENTER LAT/LON
STORE ORIGIN AND DESTINATION AIRPORT NAMES
STORE PAGE HEADING FLT. PLN. # 1 OR FLT. PLN # 2 DEPENDING ON MODPAG
SET FLT, PLAN PAGE WORD ADDR AND PAGE LINE ADDR
COMPUTE AND STORE PAGE LINE PTR (EMPTR) EQUAL TO ONE WPT. BEFORE MIDDLE WPT
CALCULATE & STORE DATA FOR LINES 2 & 3 (ALTITUDE, GS, PTA, FPA)
WPCAL
A
5


A
INCREMENT FLT. PLAN PAGE PTR. (FPWADR) AND LINE ADDRESS PTR. TO START OF LINE 4 ON PAGE
SET PAGE LINE POINTER (FMPTR) TO FPPWP
WPCAL
CALCULATE & STORE WAYPOINT DATA FOR LINES 4 & 5
INCREMENT FLT. PLAN PAGE PTR. (FPWADR) AND LINE ADDRESS PTR. TO START OF LINE 6 ON PAGE
SET PAGE LINE PTR (FMPTR) TO WAYPOINT FOLLOWING FPPWP
WPCAL
CALCULATE & STORE WAYPOINT DATA FOR LINES 6 & 7
IF ACTIVE PATH DOES NOT TERMINATE IN A STAR OR RUNWAY, OUTPUT "LINK UP" MESSAGE.
B

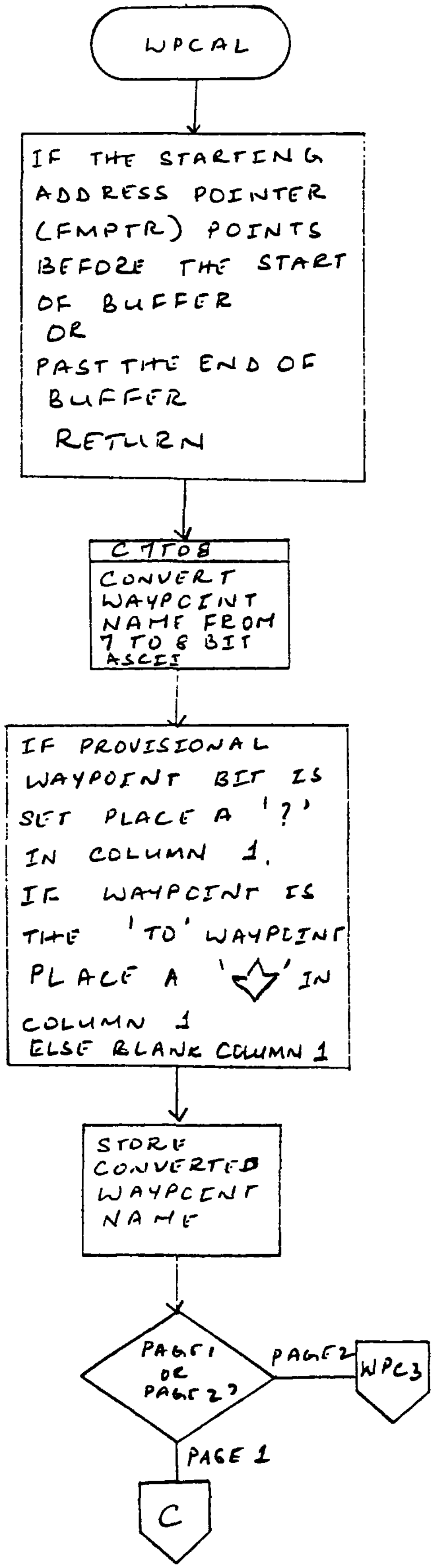
FLTMOD
(PAGE 5 OF 19)

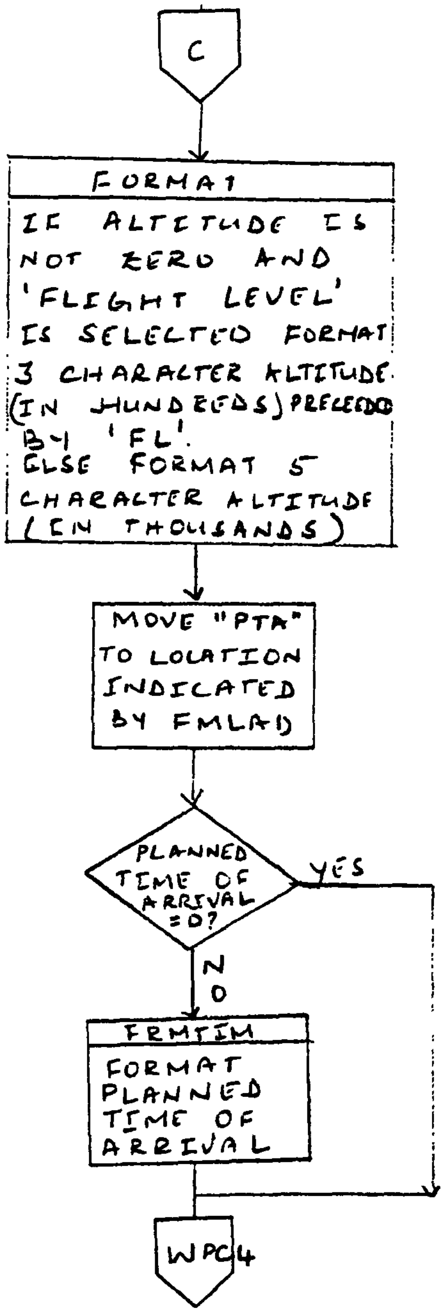


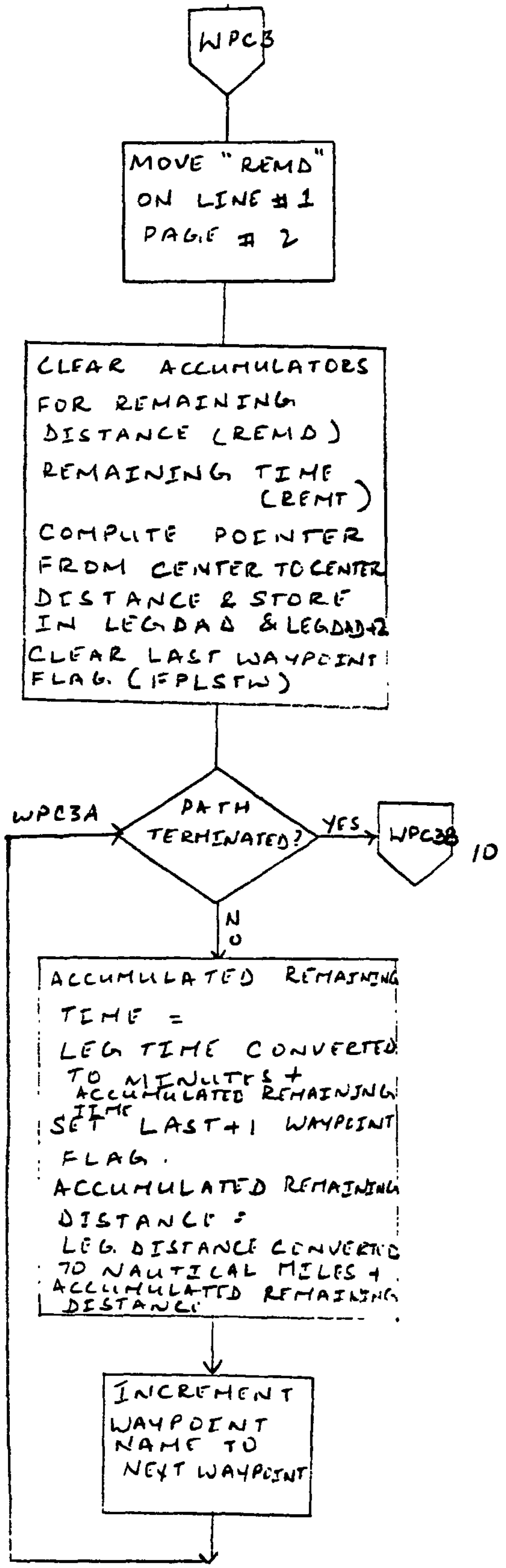
IF TURN RADIUS RESULTS IN PATH DISCONTINUITY MOVE "BAD RADIUS" CUE MESSAGE TO DISPLAY.
IF CUE MESSAGE NEEDS TO BE OUTPUT AS INDICATED BY AN ADDRESS IN ATCLNE — OUTPUT CUE MESSAGE

SET NEWPAGE (NUPAGE) FLAG
CLEAR BUFFER
SEND TIMER
(GDTIME

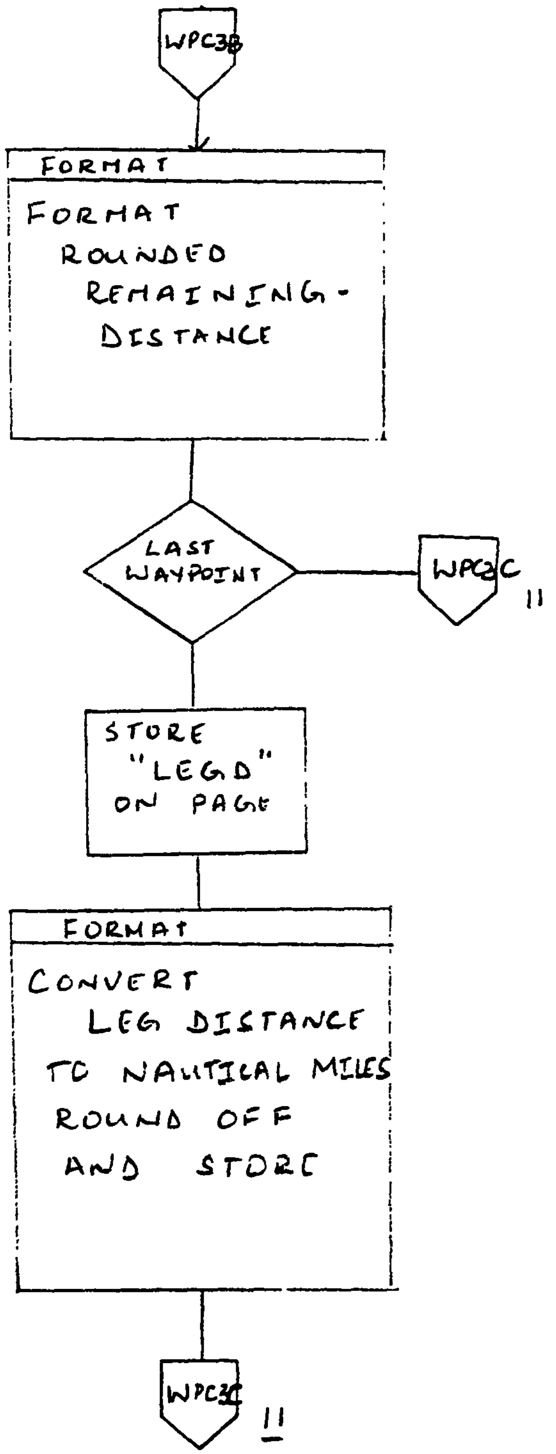
FLTMOD
(PAGE 6 OF 19)


WPCAL
IF THE STARTING ADDRESS POINTER (FMPTR) POINTS BEFORE THE START OF BUFFER OR PAST THE END OF BUFFER RETURN
C7TO8
CONVERT WAYPOINT NAME FROM 7 TO 8 BIT ASCII
IF PROVISIONAL WAYPOINT BIT IS SET PLACE A '?' IN COLUMN 1. IF WAYPOINT IS THE 'TO' WAYPOINT PLACE A '◇' IN COLUMN 1 ELSE BLANK COLUMN 1
STORE CONVERTED WAYPOINT NAME
PAGE 1 OR PAGE 2?
PAGE 2
WPC3
PAGE 1
C

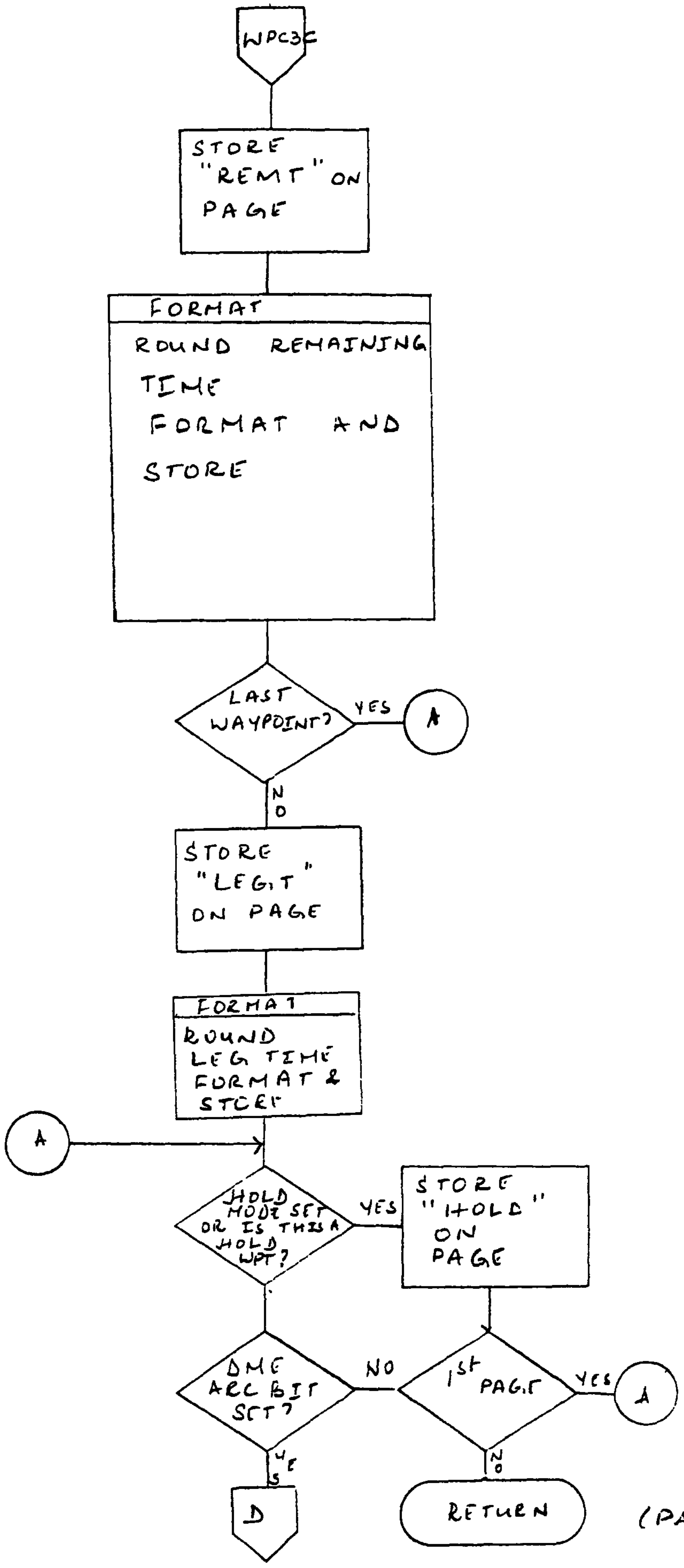

C
FORMAT
IF ALTITUDE IS NOT ZERO AND 'FLIGHT LEVEL' IS SELECTED FORMAT 3 CHARACTER ALTITUDE (IN HUNDREDS) PRECEDED BY 'FL'. ELSE FORMAT 5 CHARACTER ALTITUDE (IN THOUSANDS)
MOVE "PTA" TO LOCATION INDICATED BY FMLAD
PLANNED TIME OF ARRIVAL =0?
YES
NO
FRMTIM
FORMAT PLANNED TIME OF ARRIVAL
WPC4


WPC3
MOVE "REMD" ON LINE #1 PAGE # 2
CLEAR ACCUMULATORS FOR REMAINING DISTANCE (REMD) REMAINING TIME (REMT)
COMPUTE POINTER FROM CENTER TO CENTER DISTANCE & STORE IN LEGDAD & LEGDAD+2
CLEAR LAST WAYPOINT FLAG (FPLSTW)
WPC3A
PATH TERMINATED?
YES
WPC3B
10
NO
ACCUMULATED REMAINING TIME = LEG TIME CONVERTED TO MINUTES + ACCUMULATED REMAINING TIME
SET LAST+1 WAYPOINT FLAG.
ACCUMULATED REMAINING DISTANCE = LEG DISTANCE CONVERTED TO NAUTICAL MILES + ACCUMULATED REMAINING DISTANCE
INCREMENT WAYPOINT NAME TO NEXT WAYPOINT

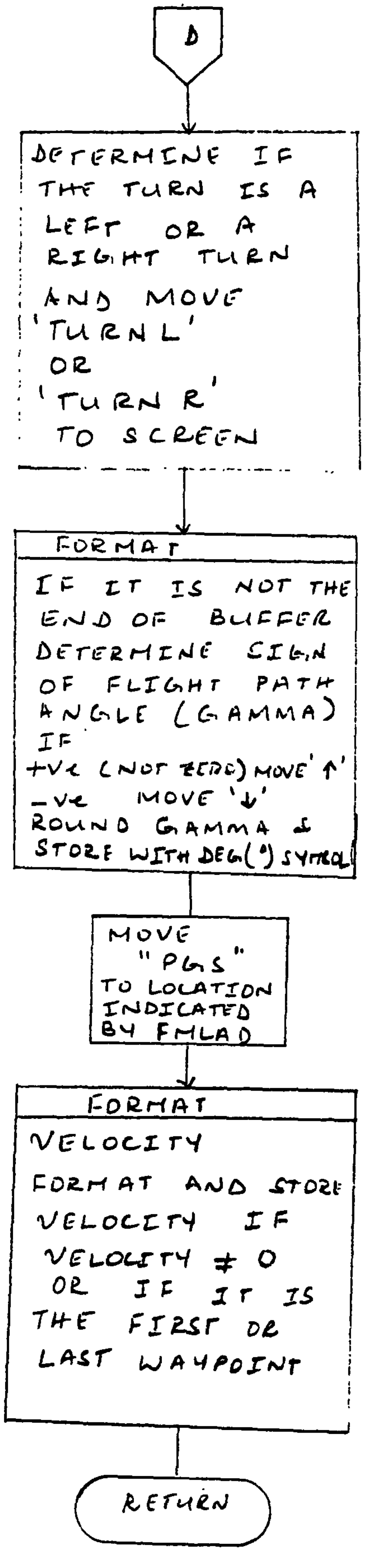
ORIGINAL PAGE IS
OF POOR QUALITY

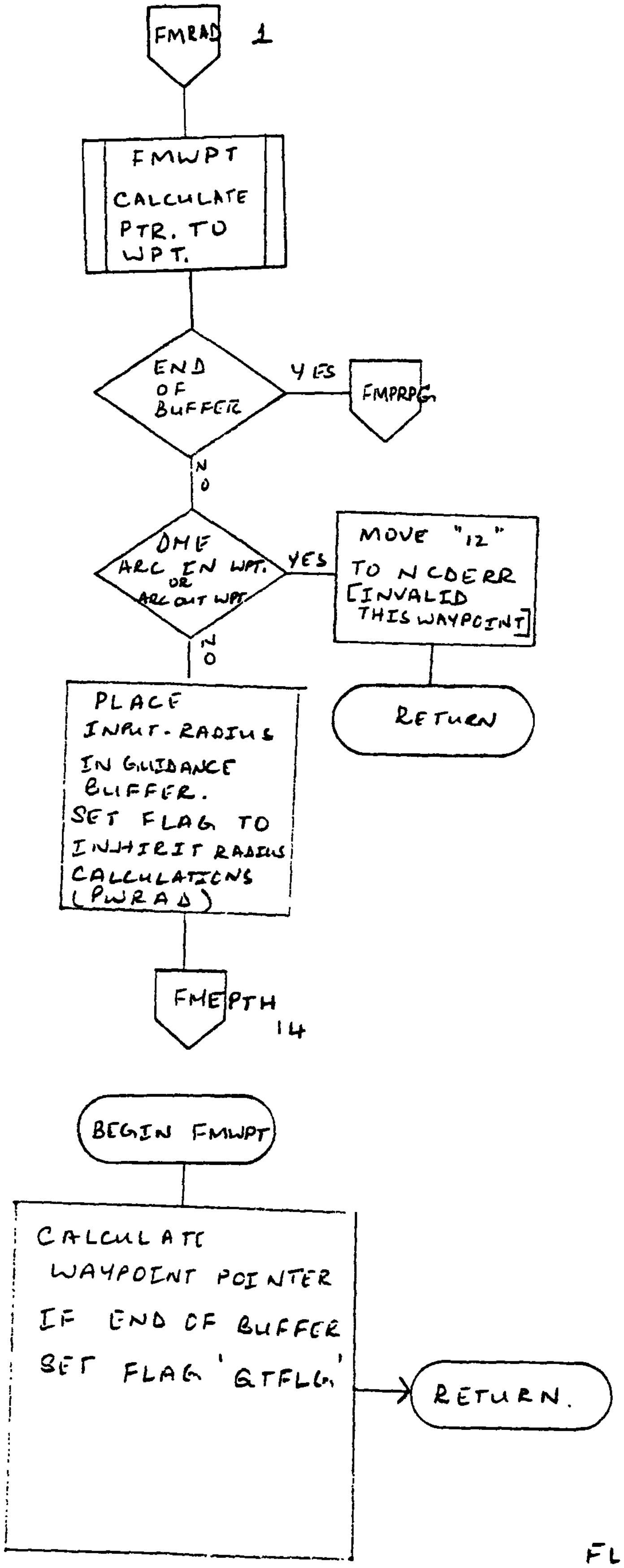

WPC3B
FORMAT
FORMAT ROUNDED REMAINING-DISTANCE
LAST WAYPOINT
WPC3C 11
STORE "LEGD" ON PAGE
FORMAT
CONVERT LEG DISTANCE TO NAUTICAL MILES ROUND OFF AND STORE
WPC3C 11

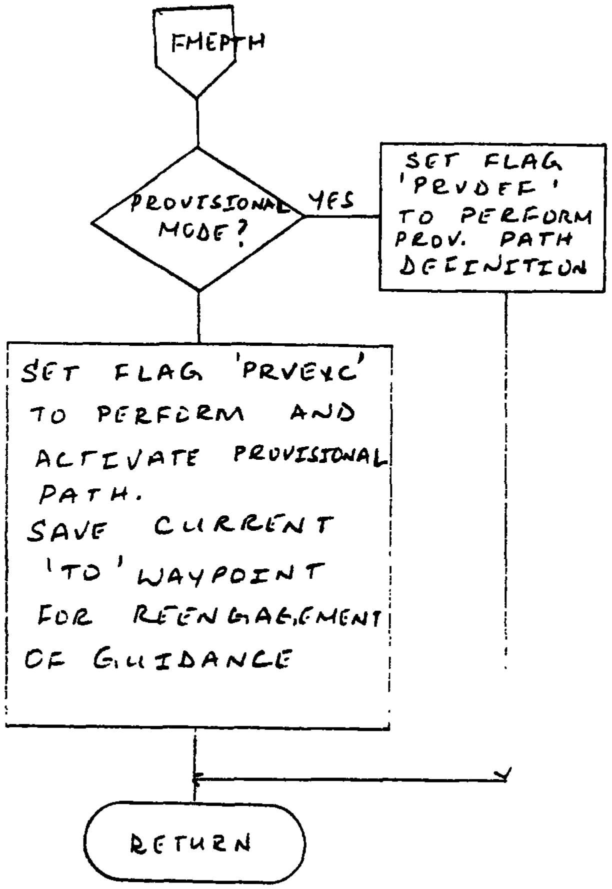
FLTMOD
(PAGE 10 OF 19)

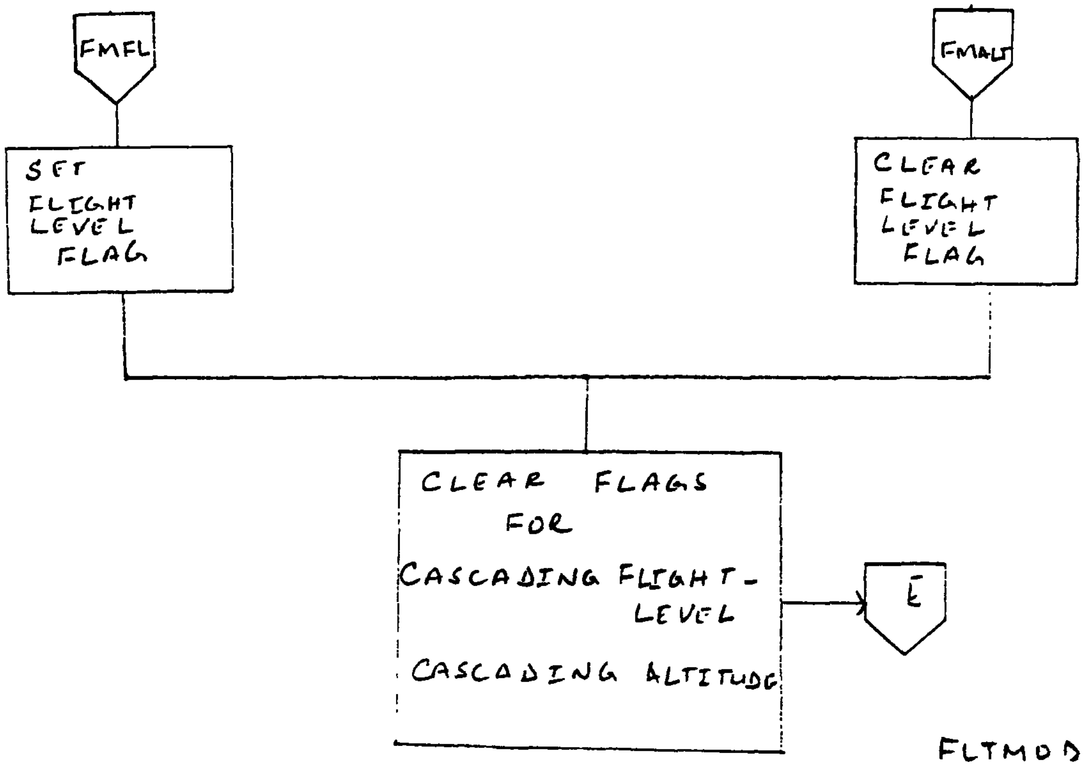


FLTMOD
(PAGE 11 OF 19)

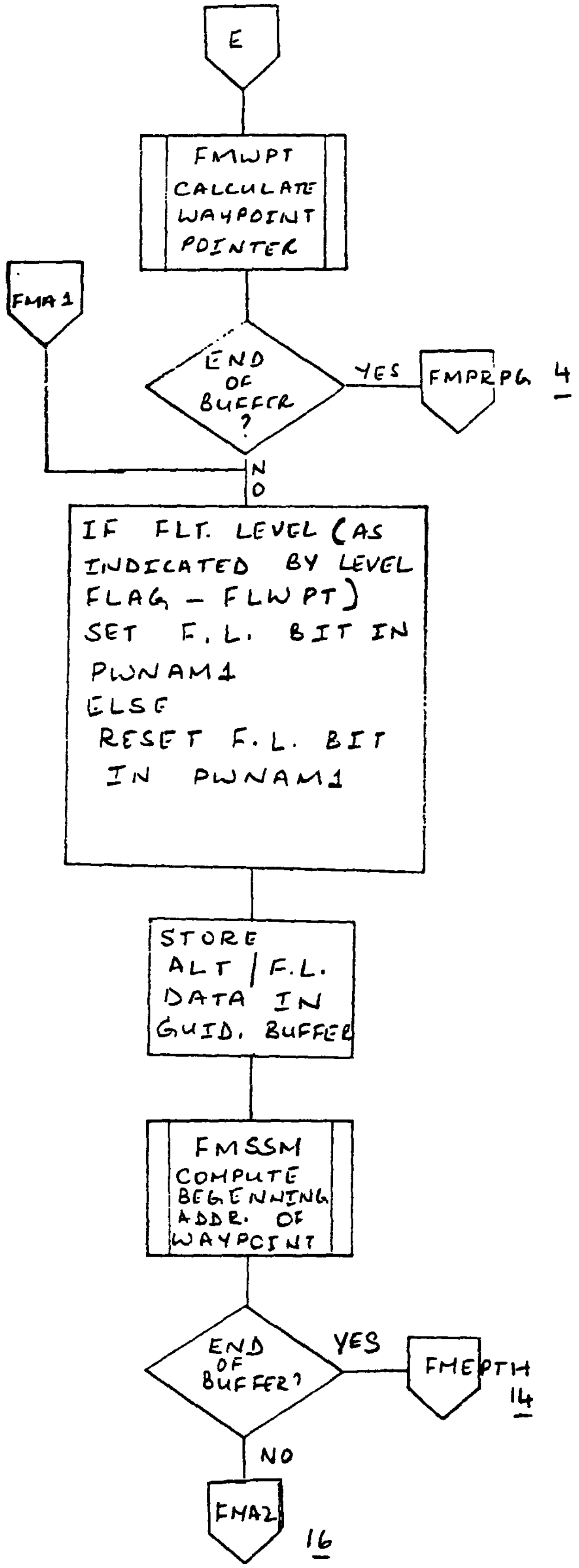

D
DETERMINE IF THE TURN IS A LEFT OR A RIGHT TURN AND MOVE 'TURN L' OR 'TURN R' TO SCREEN
FORMAT
IF IT IS NOT THE END OF BUFFER DETERMINE SIGN OF FLIGHT PATH ANGLE (GAMMA) IF +VE (NOT ZERO) MOVE '↑' -VE MOVE '↓' ROUND GAMMA & STORE WITH DEG(°) SYMBOL
MOVE "PGS" TO LOCATION INDICATED BY FMLAD
FORMAT
VELOCITY
FORMAT AND STORE VELOCITY IF VELOCITY ≠ 0 OR IF IT IS THE FIRST OR LAST WAYPOINT
RETURN


FMRAD 1
FMWPT
CALCULATE PTR. TO WPT.
END OF BUFFER
YES
FMPRPG
NO
DME ARC IN WPT. OR ARC OUT WPT.
YES
MOVE "12" TO NCDERR [INVALID THIS WAYPOINT]
RETURN
NO
PLACE INPUT-RADIUS IN GUIDANCE BUFFER. SET FLAG TO INHIBIT RADIUS CALCULATIONS (PWRAD)
FMEPTH 14
BEGIN FMWPT
CALCULATE WAYPOINT POINTER IF END OF BUFFER SET FLAG 'QTFLG'
RETURN.

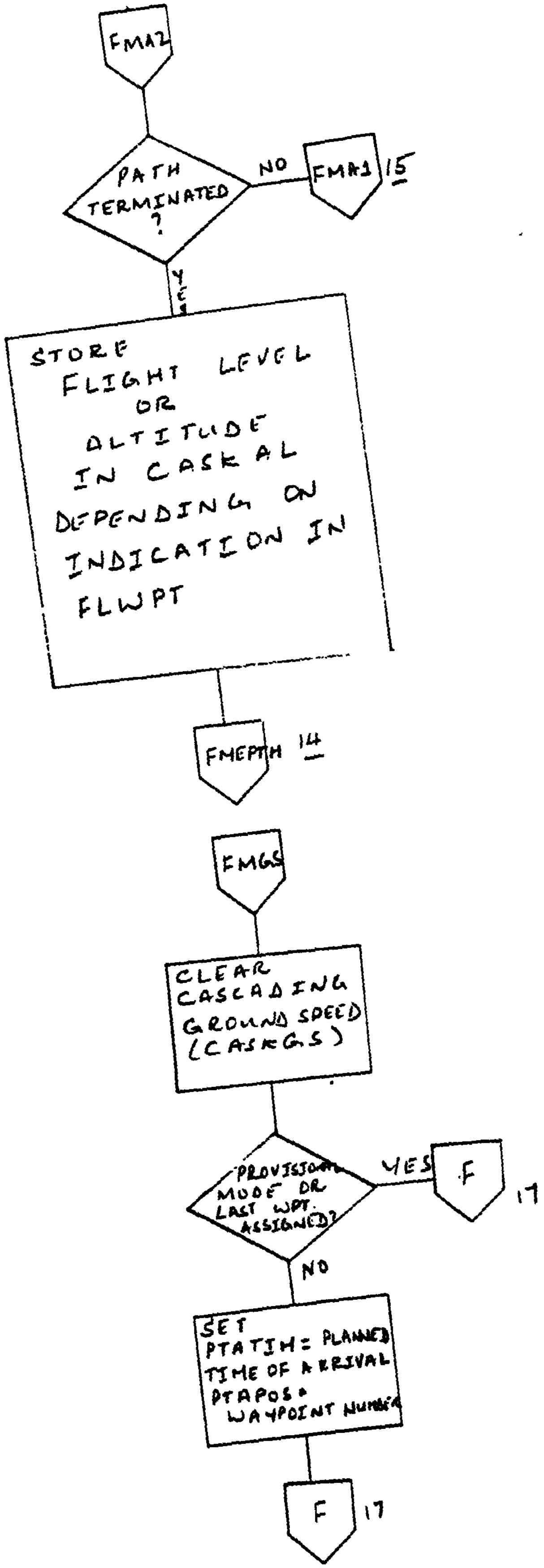

FMEPTH
PROVISIONAL MODE?
YES
SET FLAG 'PRVDEF' TO PERFORM PROV. PATH DEFINITION
SET FLAG 'PRVEXC' TO PERFORM AND ACTIVATE PROVISIONAL PATH. SAVE CURRENT 'TO' WAYPOINT FOR REENGAGEMENT OF GUIDANCE
RETURN



FLTMOD
(PAGE 14 OF 19)



FITMOD
(PAGE 15 OF 19)


FMA2
PATH TERMINATED ?
NO
FMA1 15
YES
STORE FLIGHT LEVEL OR ALTITUDE IN CASKAL DEPENDING ON INDICATION IN FLWPT
FMEPTH 14
FMGS
CLEAR CASCADING GROUND SPEED (CASKGS)
PROVISIONAL MODE OR LAST WPT. ASSIGNED?
YES
F 17
NO
SET PTATIM= PLANNED TIME OF ARRIVAL PTAPOS= WAYPOINT NUMBER
F 17

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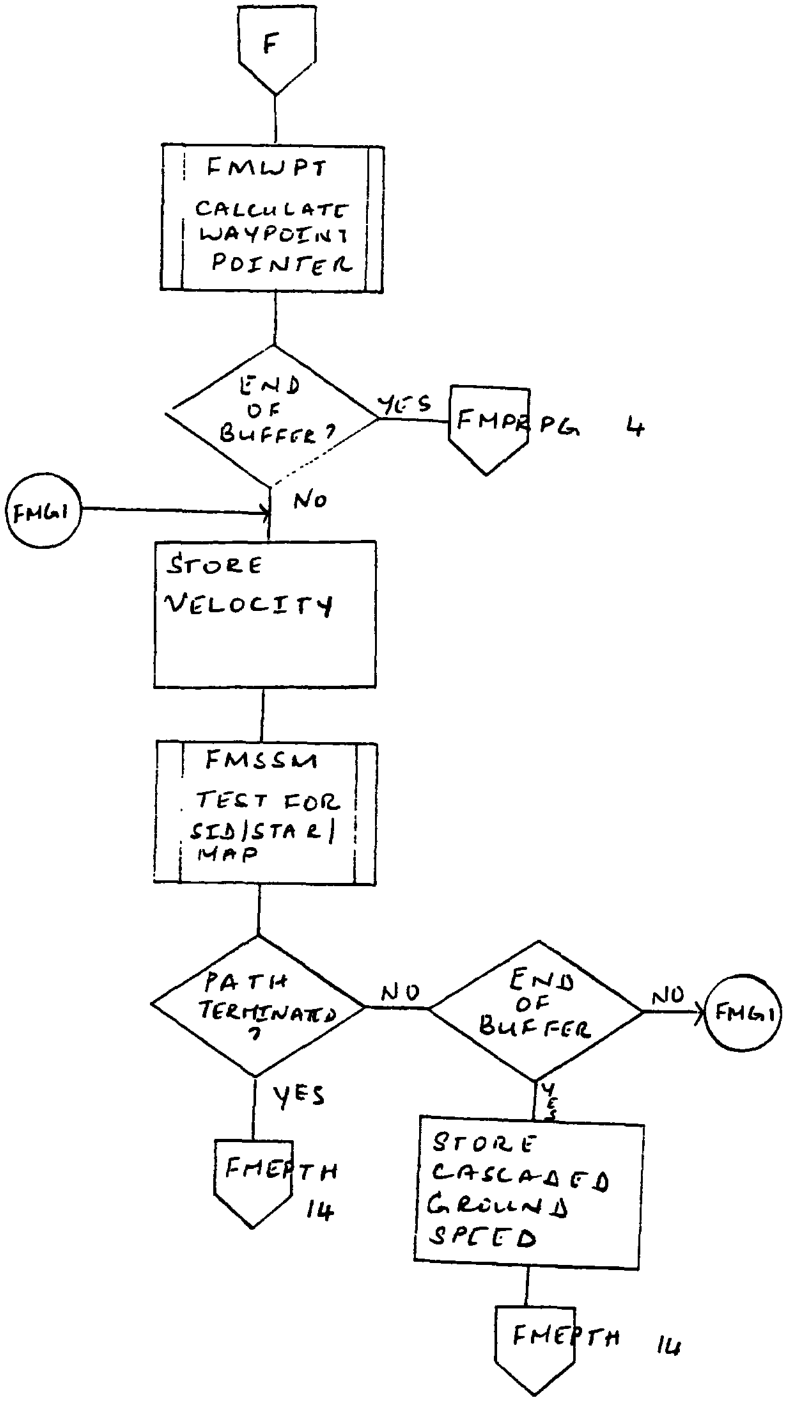
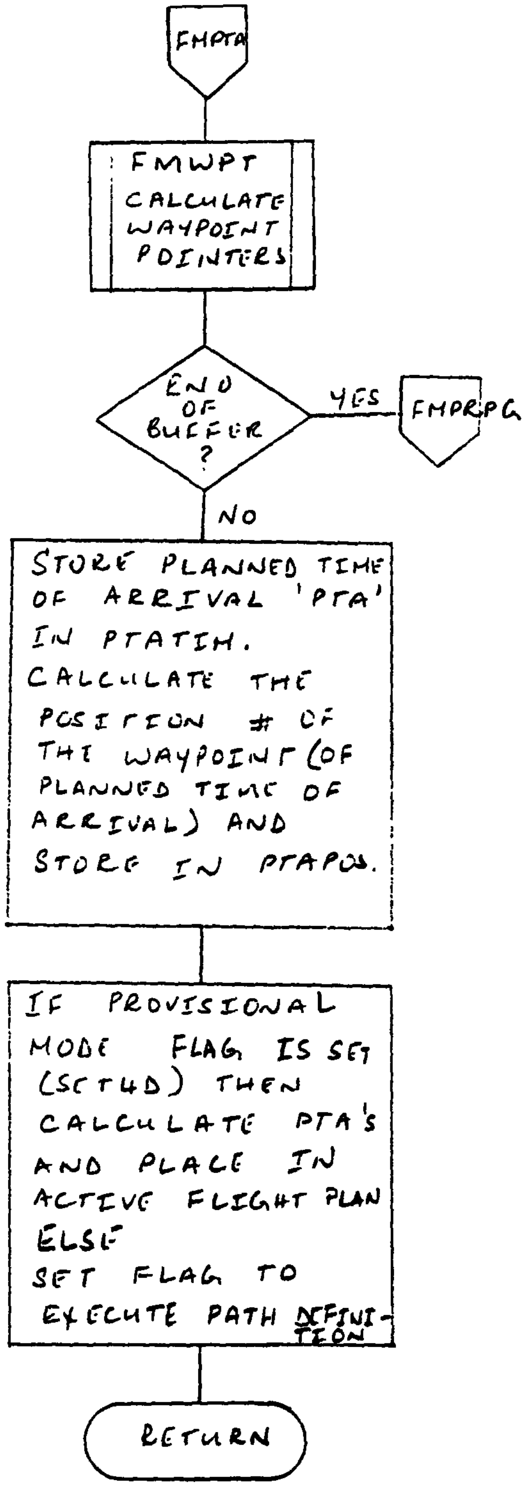
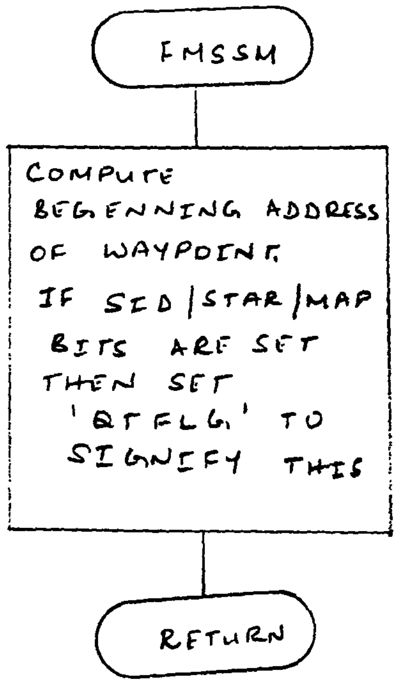
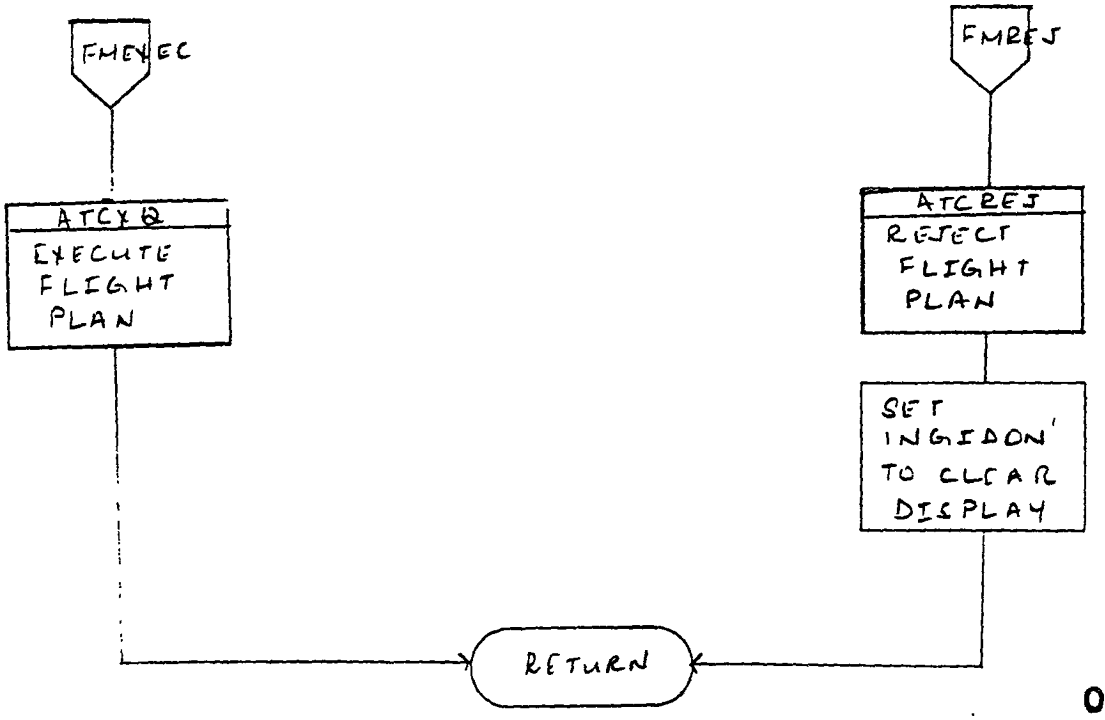
FLTMOD
(PAGE 16 OF 19)


F
FMWPT
CALCULATE WAYPOINT POINTER
END OF BUFFER?
YES
FMPR PG 4
NO
FMG1
STORE VELOCITY
FMSSM
TEST FOR SID/STAR/MAP
PATH TERMINATED ?
NO
END OF BUFFER
NO
FMG1
YES
FMEPTH 14
YES
STORE CASCADED GROUND SPEED
FMEPTH 14


FMPTA
FMWPT
CALCULATE WAYPOINT POINTERS
END OF BUFFER ?
YES
FMPRPG
NO
STORE PLANNED TIME OF ARRIVAL 'PTA' IN PTATIH.
CALCULATE THE POSITION # OF THE WAYPOINT (OF PLANNED TIME OF ARRIVAL) AND STORE IN PTAPOS.
IF PROVISIONAL MODE FLAG IS SET (SCT4D) THEN CALCULATE PTA's AND PLACE IN ACTIVE FLIGHT PLAN
ELSE
SET FLAG TO EXECUTE PATH DEFINITION
RETURN


FMSSM
COMPUTE BEGENNING ADDRESS OF WAYPOINT. IF SID|STAR|MAP BITS ARE SET THEN SET 'QTFLG' TO SIGNIFY THIS
RETURN



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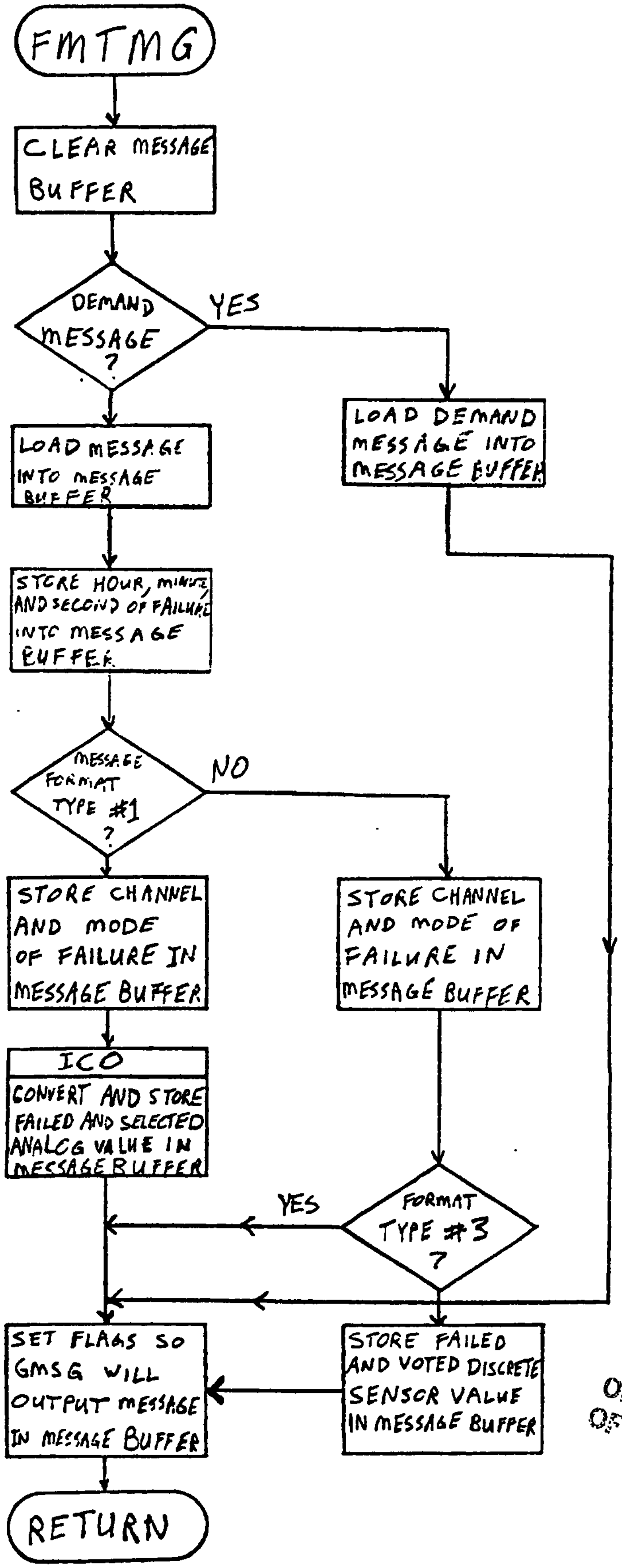
FLTMOD
(PAGE 19 OF 19)

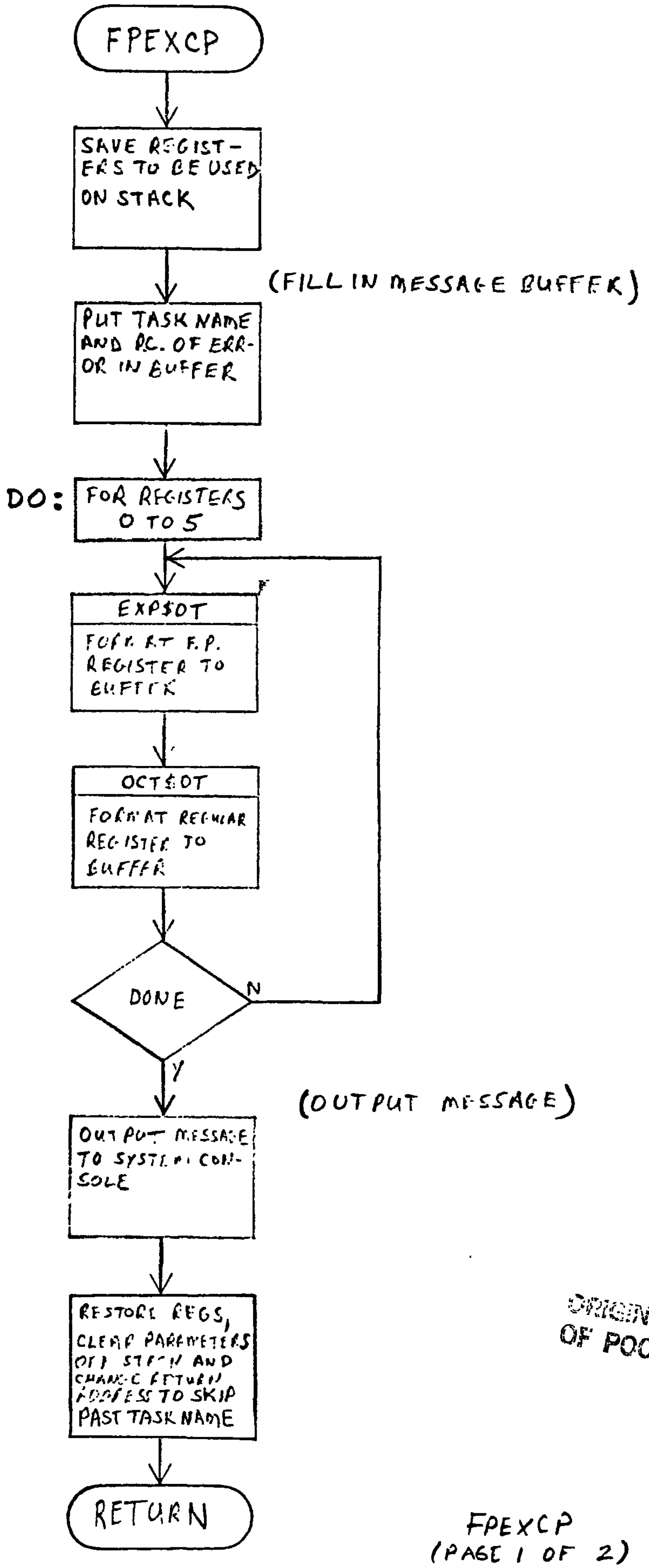
A demand message is one that is to be output immeadiatly without any request by the operator.

ICO is a local subroutine used to convert an integer number into ASCII for display.

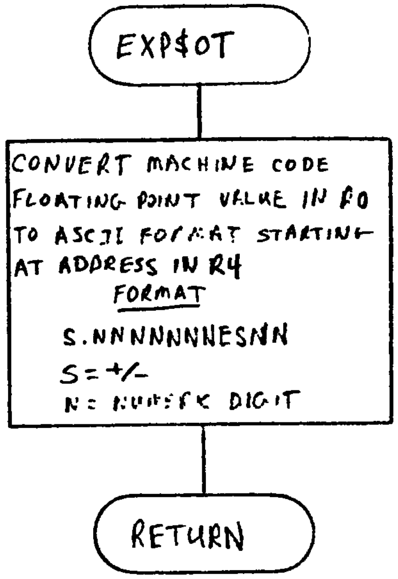

FMTMG
CLEAR MESSAGE BUFFER
DEMAND MESSAGE ?
YES
LOAD MESSAGE INTO MESSAGE BUFFER
LOAD DEMAND MESSAGE INTO MESSAGE BUFFER
STORE HOUR, MINUTE, AND SECOND OF FAILURE INTO MESSAGE BUFFER
MESSAGE FORMAT TYPE #1 ?
NO
STORE CHANNEL AND MODE OF FAILURE IN MESSAGE BUFFER
STORE CHANNEL AND MODE OF FAILURE IN MESSAGE BUFFER
ICO
CONVERT AND STORE FAILED AND SELECTED ANALOG VALUE IN MESSAGE BUFFER
YES
FORMAT TYPE #3 ?
SET FLAGS SO GMSG WILL OUTPUT MESSAGE IN MESSAGE BUFFER
STORE FAILED AND VOTED DISCRETE SENSOR VALUE IN MESSAGE BUFFER
RETURN

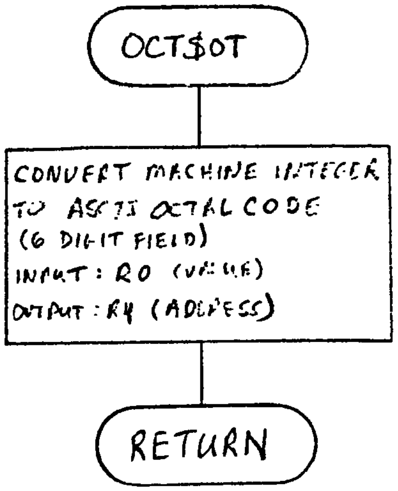
ORIGINAL PAGE IS OF POOR QUALITY

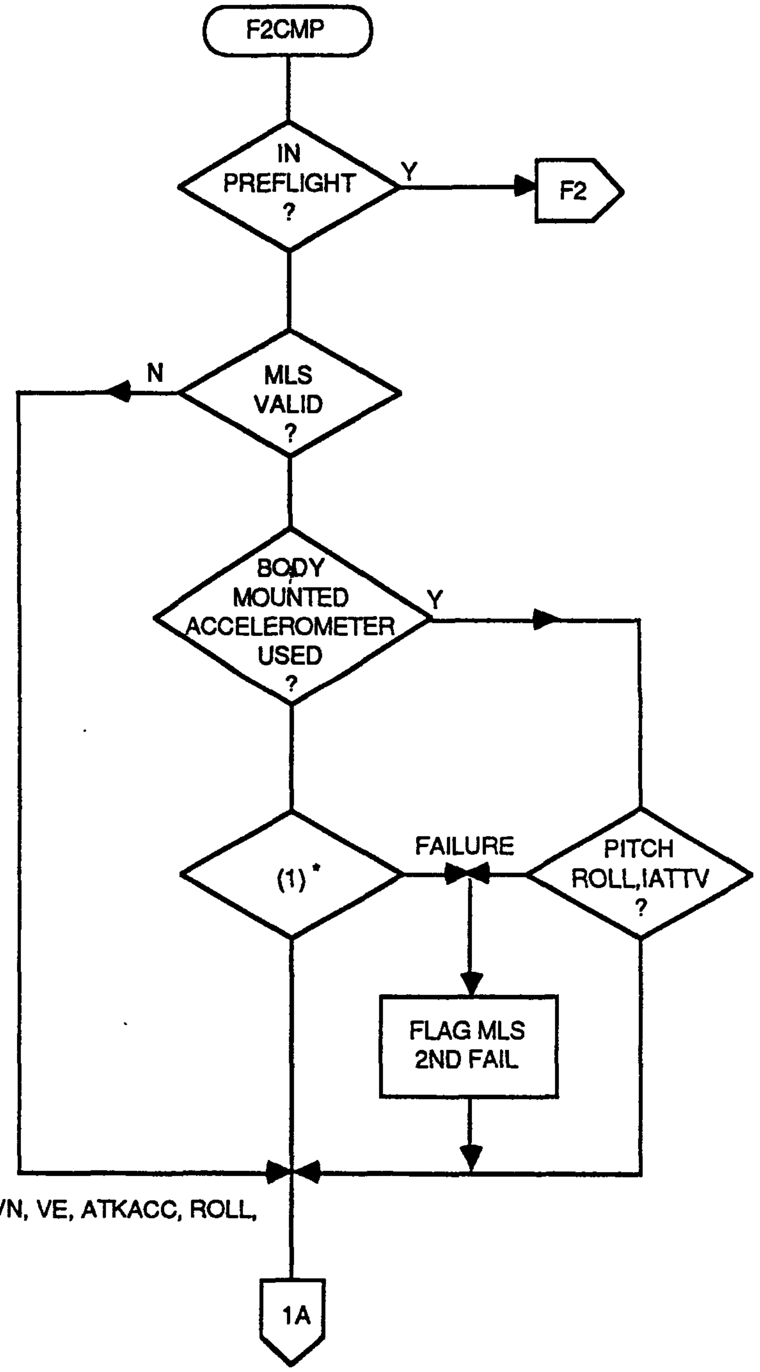
FMTMG 1/1


FPEXCP
SAVE REGISTERS TO BE USED ON STACK
(FILL IN MESSAGE BUFFER)
PUT TASK NAME AND P.C. OF ERROR IN BUFFER
DO:
FOR REGISTERS 0 TO 5
EXP$OT
FORMAT F.P. REGISTER TO BUFFER
OCT$OT
FORMAT REGULAR REGISTER TO BUFFER
DONE
N
Y
(OUTPUT MESSAGE)
OUTPUT MESSAGE TO SYSTEM CONSOLE
RESTORE REGS, CLEAR PARAMETERS OFF STACK AND CHANGE RETURN ADDRESS TO SKIP PAST TASK NAME
RETURN

FPEXCP
(PAGE 1 OF 2)


EXP$OT
CONVERT MACHINE CODE FLOATING POINT VALUE IN R0 TO ASCII FORMAT STARTING AT ADDRESS IN R4
FORMAT
S.NNNNNNNESNN
S=+/-
N= NUMBER DIGIT
RETURN

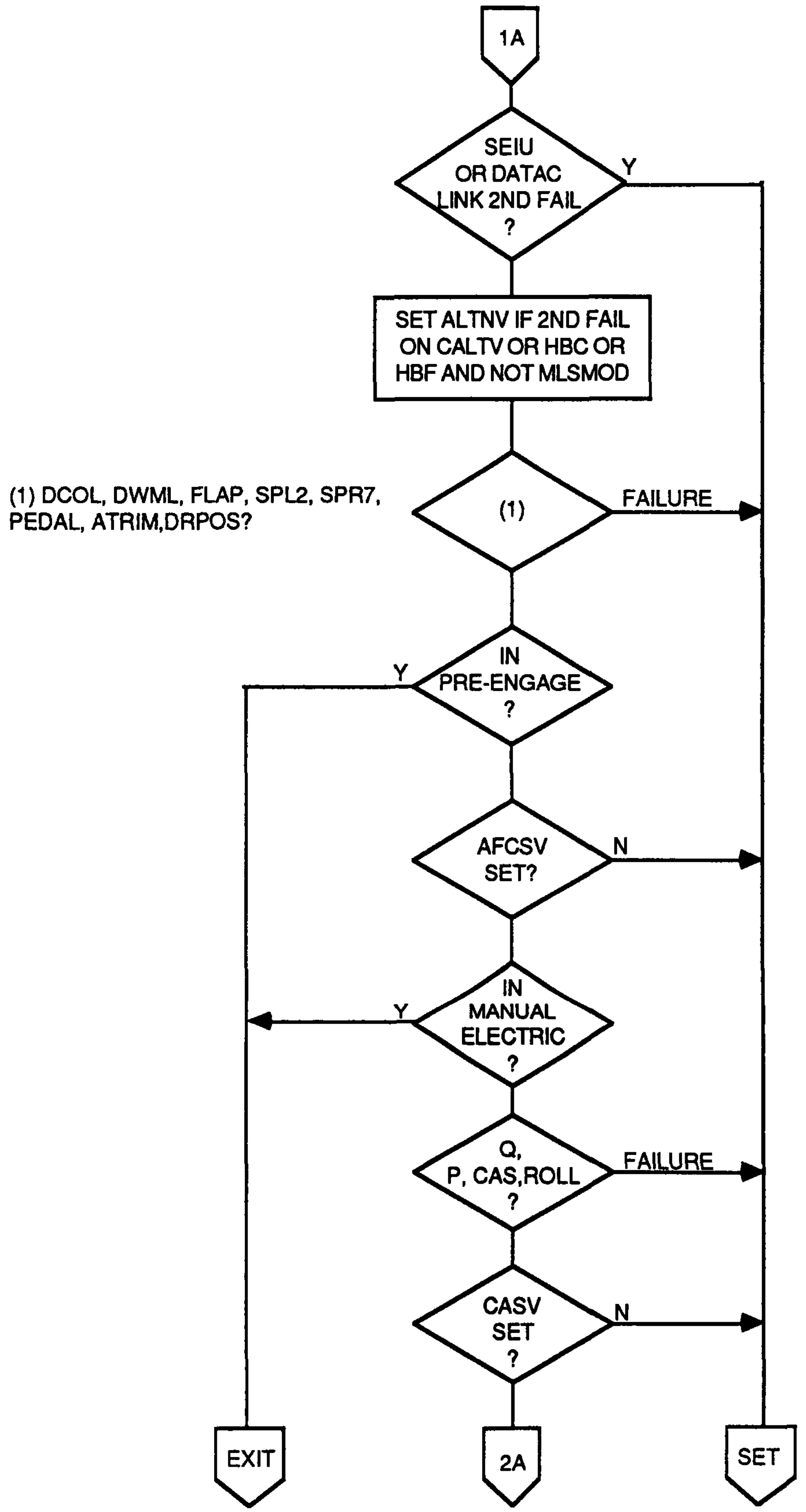

OCT$OT
CONVERT MACHINE INTEGER TO ASCII OCTAL CODE
(6 DIGIT FIELD)
INPUT: R0 (VALUE)
OUTPUT: R4 (ADDRESS)
RETURN



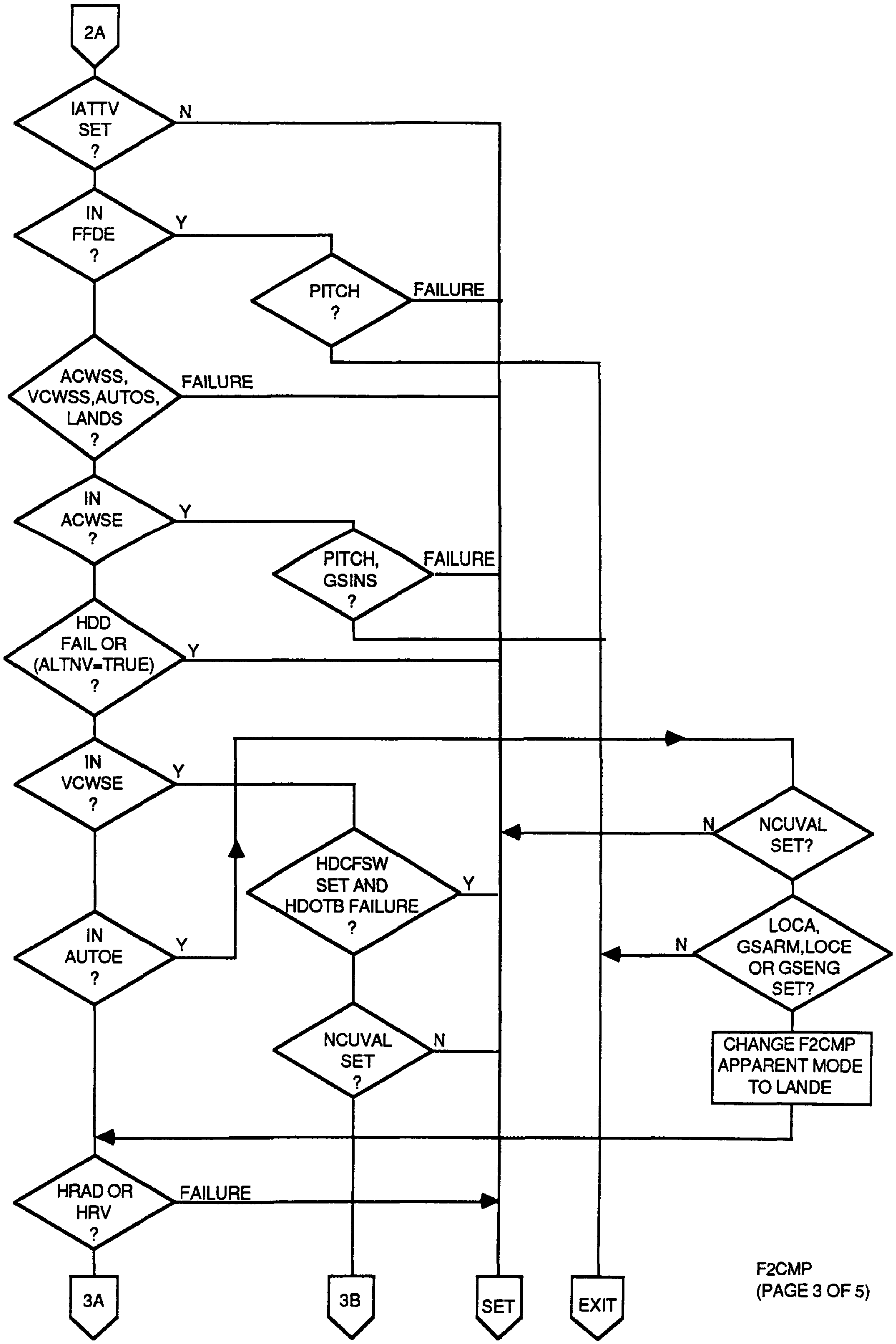
(1)* PITCH, HDD, XTKACC, VN, VE, ATKACC, ROLL, GSINS, INAVV, IATTV?

**THE FORMAT FOR THE DECISION SHOWN HERE IS USED THRUOUT THIS CHART. IT IMPLIES THAT THE INCLUDED SENSORS ARE TESTED FOR 2ND FAILURES AND IF ANY ARE FOUND, THE FAILURE BRANCH IS CHOSEN.

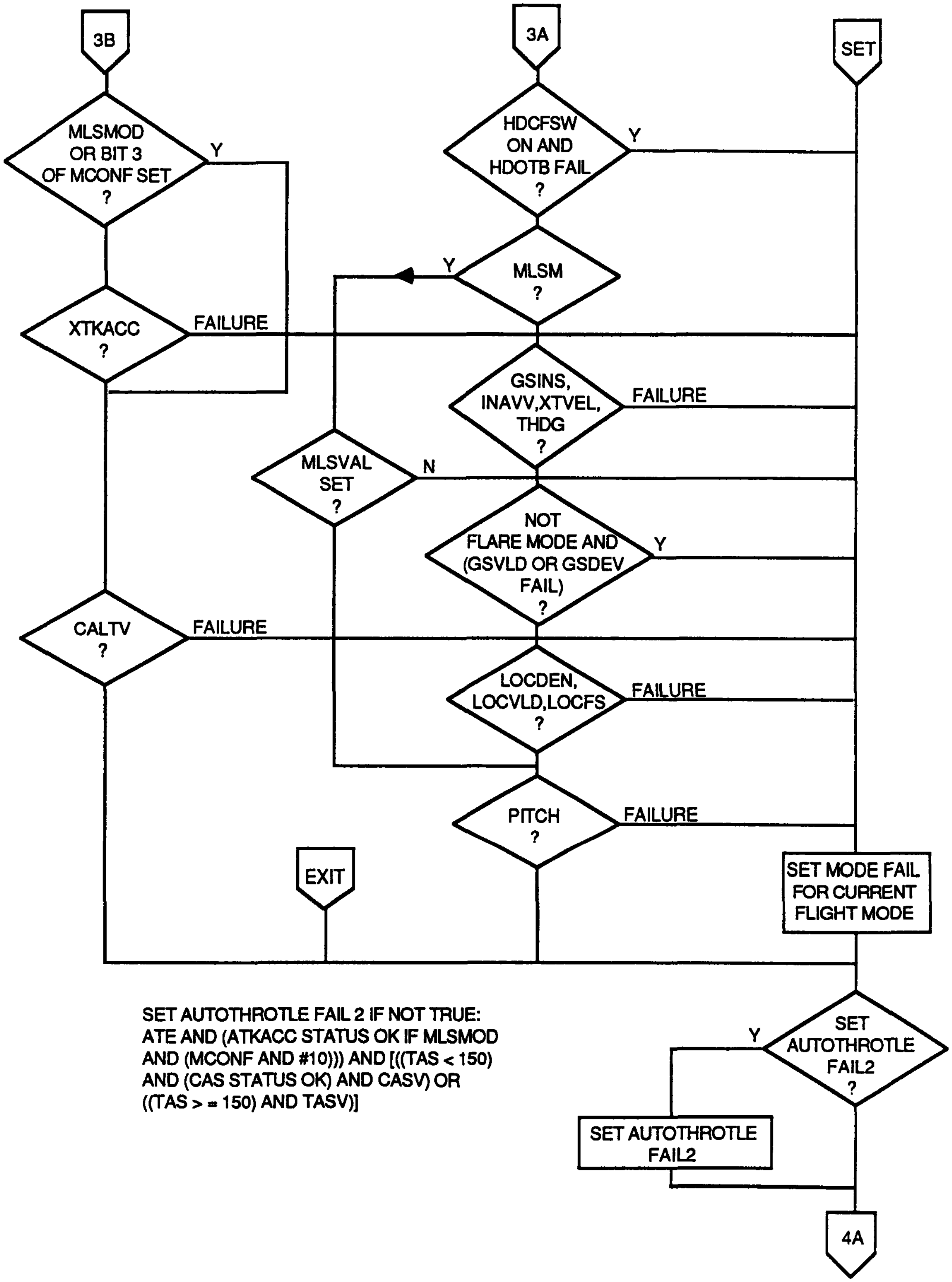
F2CMP
(PAGE 1 OF 5)


1A
SEIU OR DATAC LINK 2ND FAIL ?
Y
SET ALTNV IF 2ND FAIL ON CALTV OR HBC OR HBF AND NOT MLSMOD
(1) DCOL, DWML, FLAP, SPL2, SPR7, PEDAL, ATRIM,DRPOS?
(1)
FAILURE
Y
IN PRE-ENGAGE ?
AFCSV SET?
N
Y
IN MANUAL ELECTRIC ?
Q, P, CAS,ROLL ?
FAILURE
CASV SET ?
N
EXIT
2A
SET

F2CMP
(PAGE 2 OF 5)

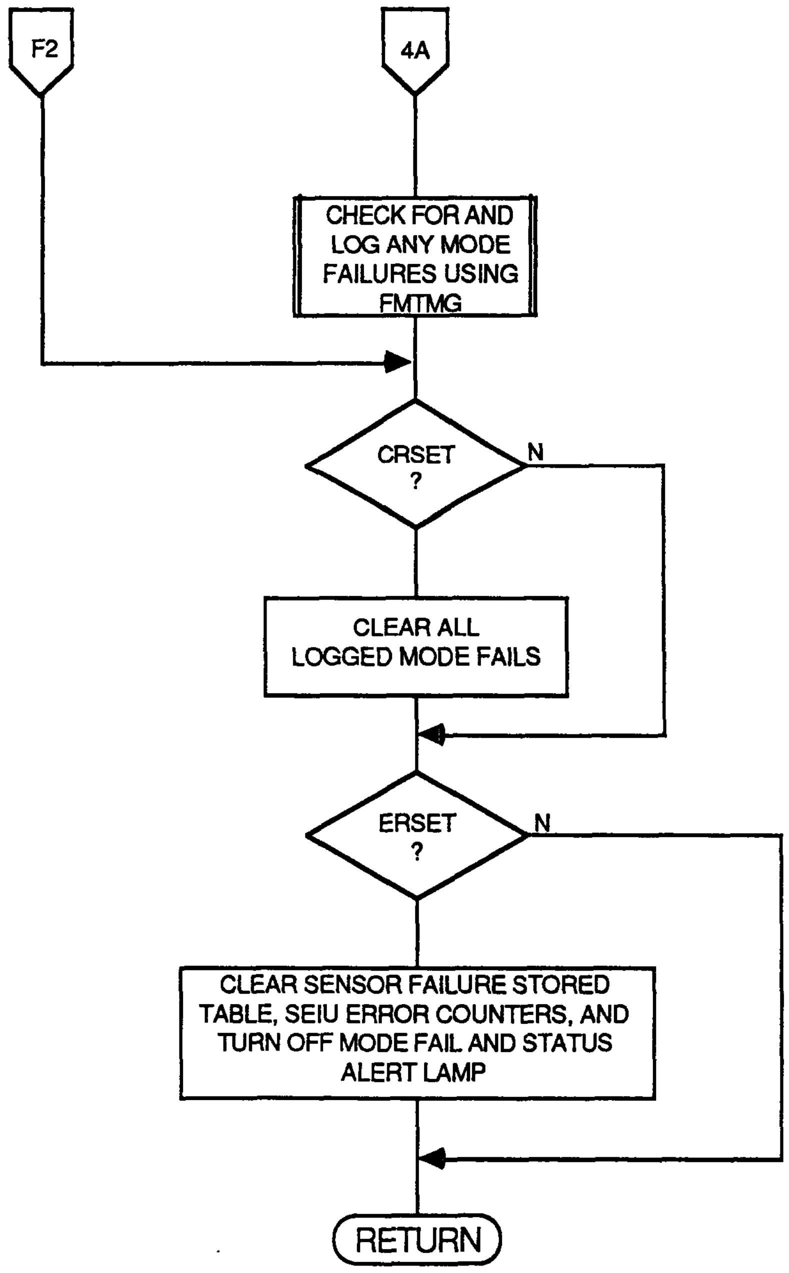


F2CMP
(PAGE 3 OF 5)

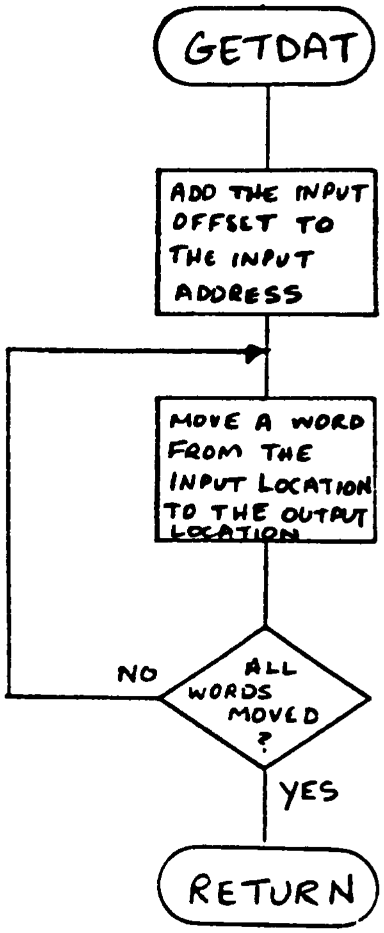

3B
3A
SET
MLSMOD OR BIT 3 OF MCONF SET ?
Y
HDCFSW ON AND HDOTB FAIL ?
Y
MLSM ?
Y
XTKACC ?
FAILURE
GSINS, INAVV,XTVEL, THDG ?
FAILURE
MLSVAL SET ?
N
NOT FLARE MODE AND (GSVLD OR GSDEV FAIL) ?
Y
CALTV ?
FAILURE
LOCDEN, LOCVLD,LOCFS ?
FAILURE
PITCH ?
FAILURE
EXIT
SET MODE FAIL FOR CURRENT FLIGHT MODE
SET AUTOTHROTLE FAIL2 ?
Y
SET AUTOTHROTLE FAIL2
4A

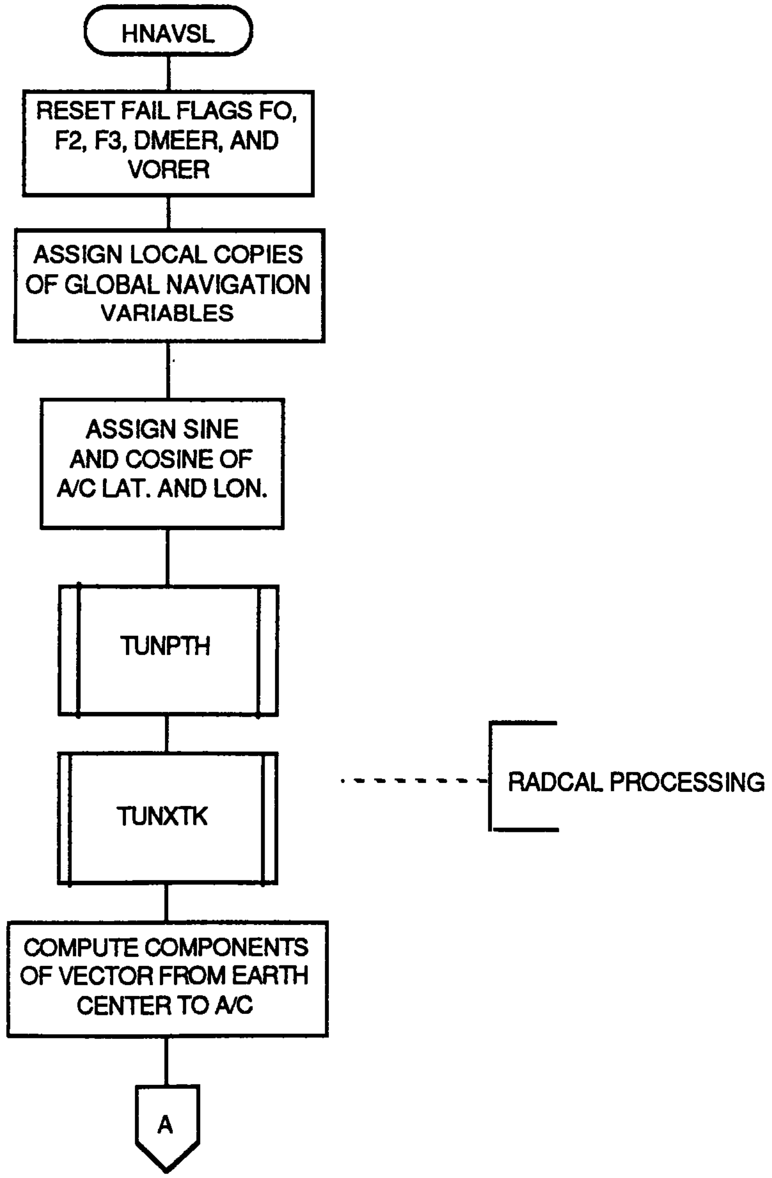
SET AUTOTHROTLE FAIL 2 IF NOT TRUE:
ATE AND (ATKACC STATUS OK IF MLSMOD
AND (MCONF AND #10))) AND [((TAS < 150)
AND (CAS STATUS OK) AND CASV) OR
((TAS > = 150) AND TASV)]

F2CMP
(PAGE 4 OF 5)


F2
4A
CHECK FOR AND LOG ANY MODE FAILURES USING FMTMG
CRSET ?
N
CLEAR ALL LOGGED MODE FAILS
ERSET ?
N
CLEAR SENSOR FAILURE STORED TABLE, SEIU ERROR COUNTERS, AND TURN OFF MODE FAIL AND STATUS ALERT LAMP
RETURN

F2CMP
(PAGE 5 OF 5)


GETDAT
ADD THE INPUT OFFSET TO THE INPUT ADDRESS
MOVE A WORD FROM THE INPUT LOCATION TO THE OUTPUT LOCATION
NO
ALL WORDS MOVED ?
YES
RETURN


HNAVSL
RESET FAIL FLAGS FO, F2, F3, DMEER, AND VORER
ASSIGN LOCAL COPIES OF GLOBAL NAVIGATION VARIABLES
ASSIGN SINE AND COSINE OF A/C LAT. AND LON.
TUNPTH
TUNXTK
RADCAL PROCESSING
COMPUTE COMPONENTS OF VECTOR FROM EARTH CENTER TO A/C
A

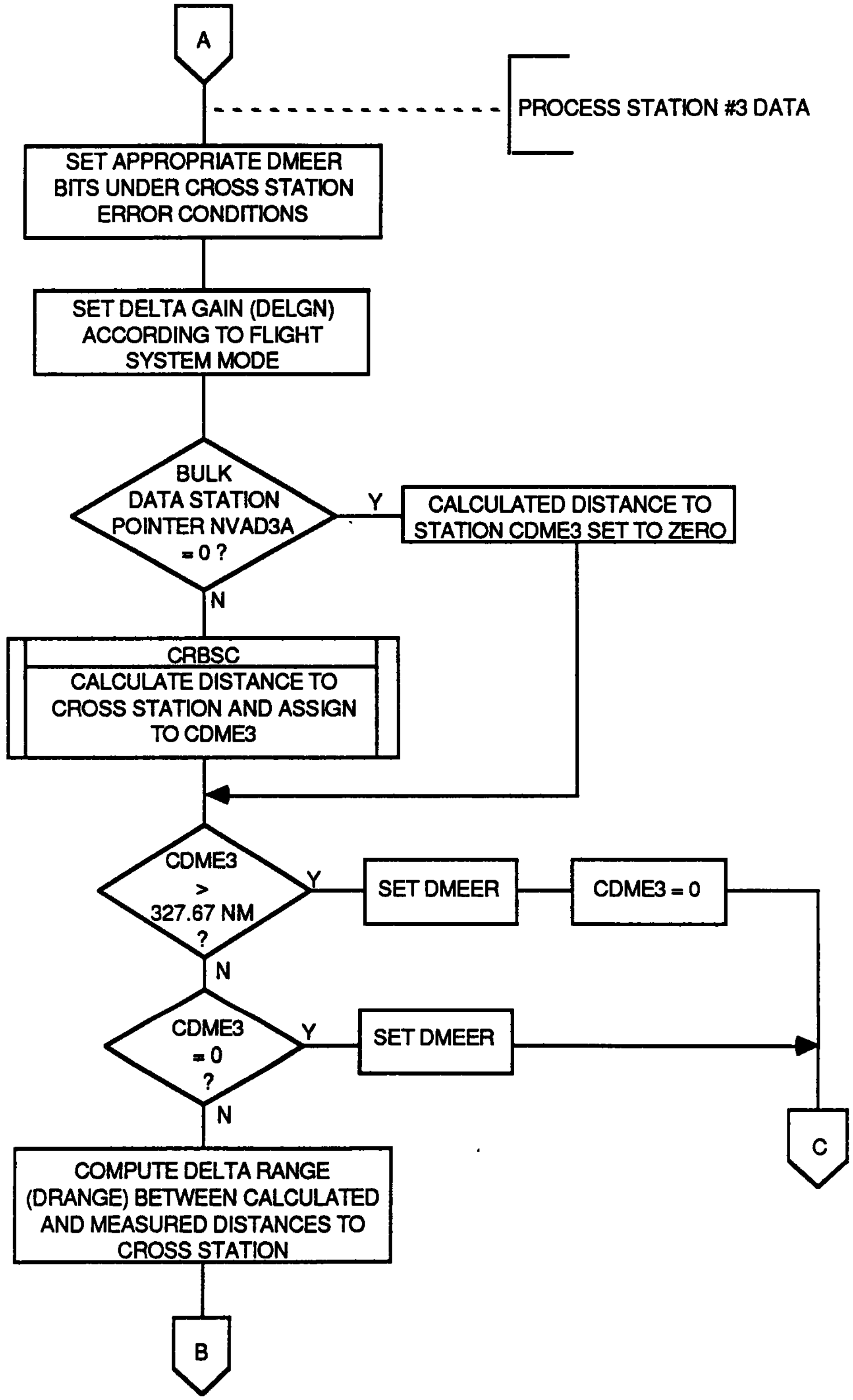
HNAVSL
(PAGE 1 OF 20)

ADVANCED TRANSPORT OPERATING SYSTEM SOFTWARE UPGRADE

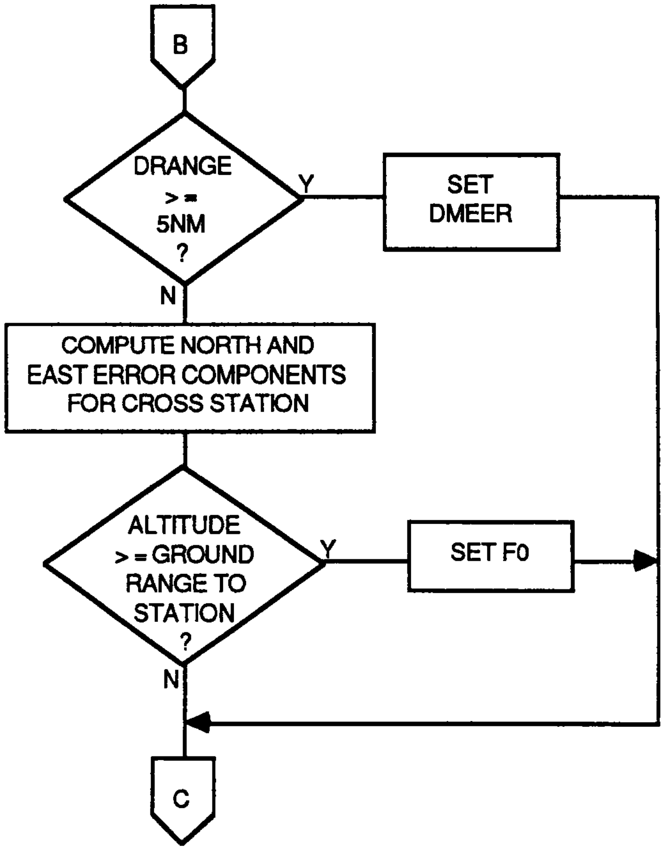
FLIGHT MANAGEMENT / FLIGHT CONTROLS SOFTWARE DESCRIPTION

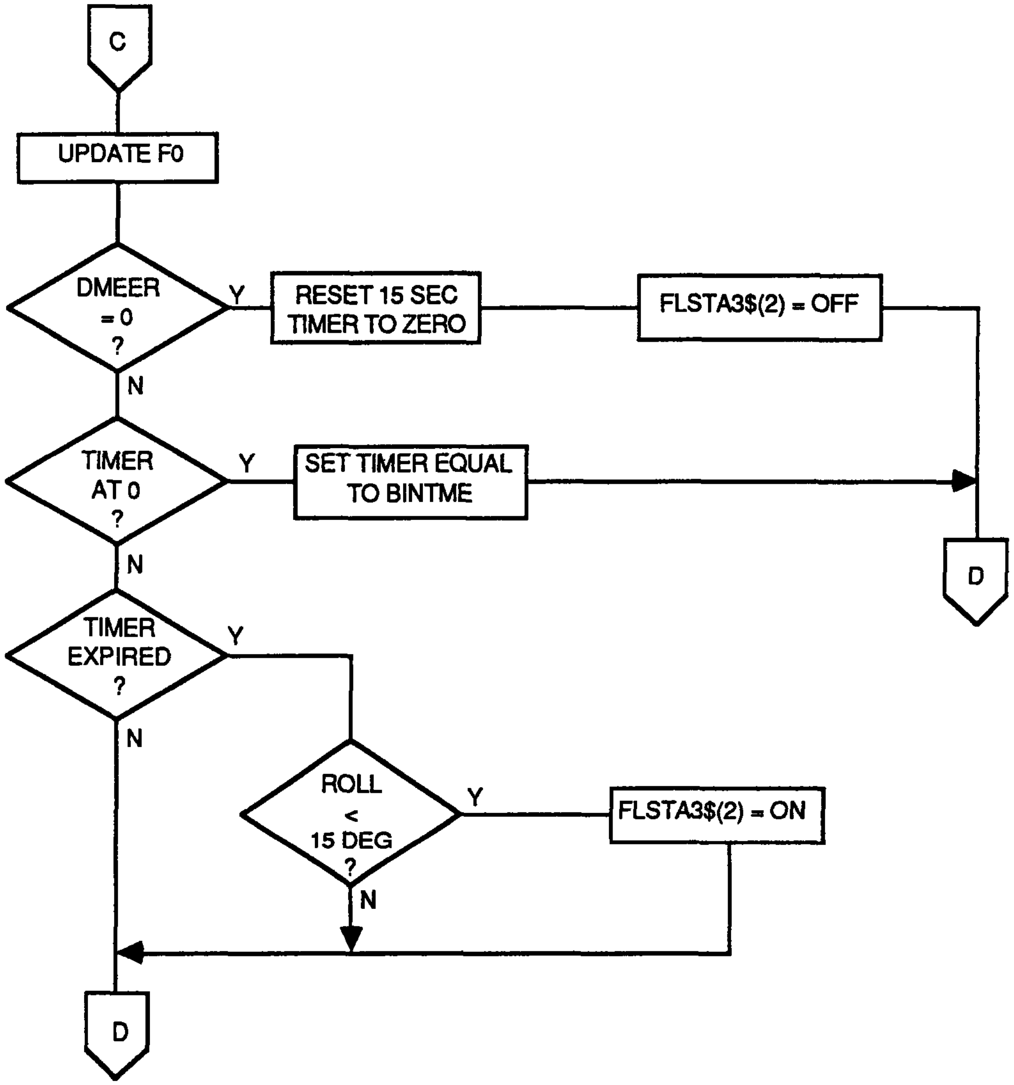
Appendix A
Flowcharts

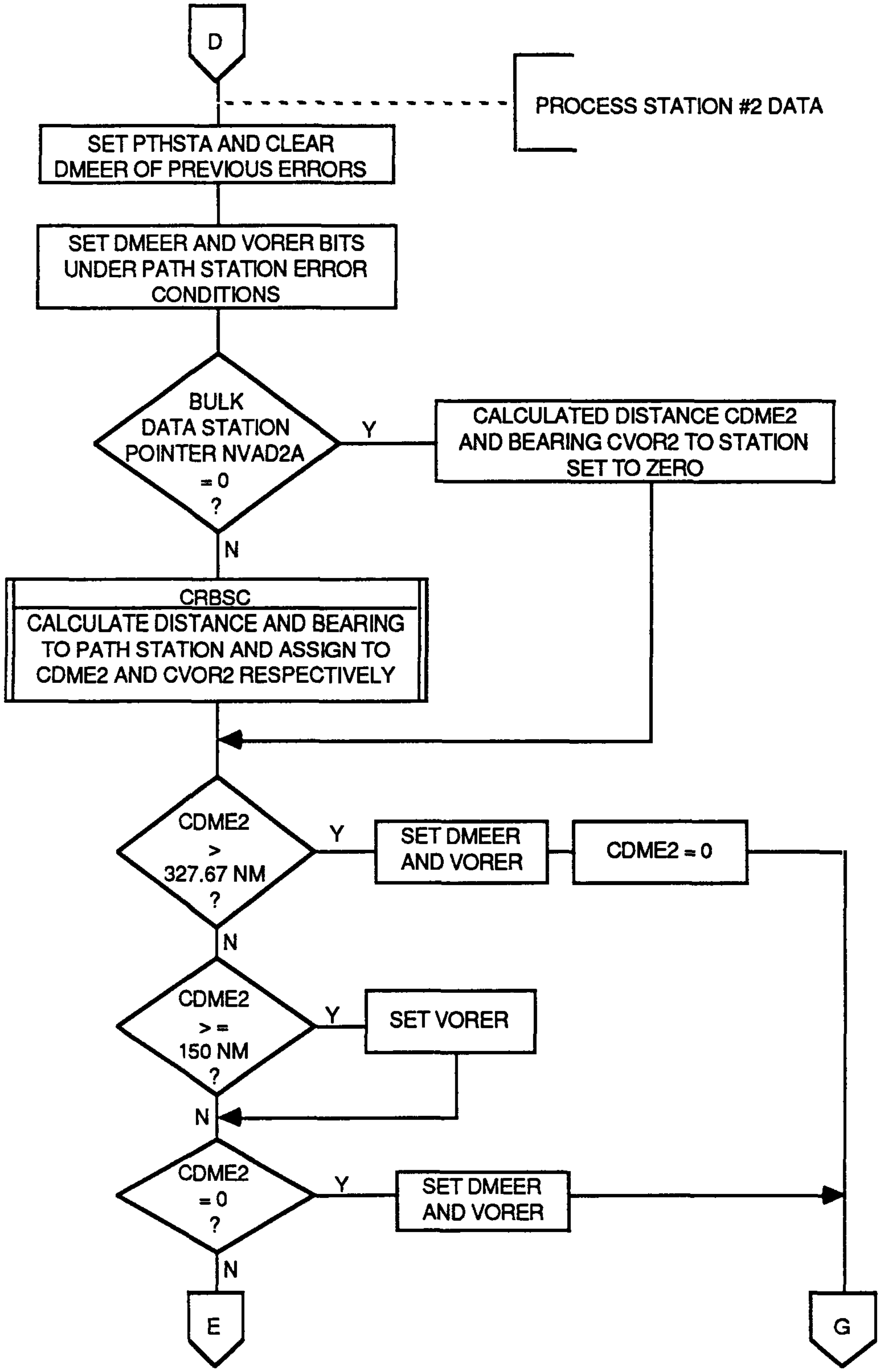
Appendix B
Digital Systems Diagrams


A
PROCESS STATION #3 DATA
SET APPROPRIATE DMEER BITS UNDER CROSS STATION ERROR CONDITIONS
SET DELTA GAIN (DELGN) ACCORDING TO FLIGHT SYSTEM MODE
BULK DATA STATION POINTER NVAD3A = 0 ?
Y
CALCULATED DISTANCE TO STATION CDME3 SET TO ZERO
N
CRBSC
CALCULATE DISTANCE TO CROSS STATION AND ASSIGN TO CDME3
CDME3 > 327.67 NM ?
Y
SET DMEER
CDME3 = 0
N
CDME3 = 0 ?
Y
SET DMEER
C
N
COMPUTE DELTA RANGE (DRANGE) BETWEEN CALCULATED AND MEASURED DISTANCES TO CROSS STATION
B

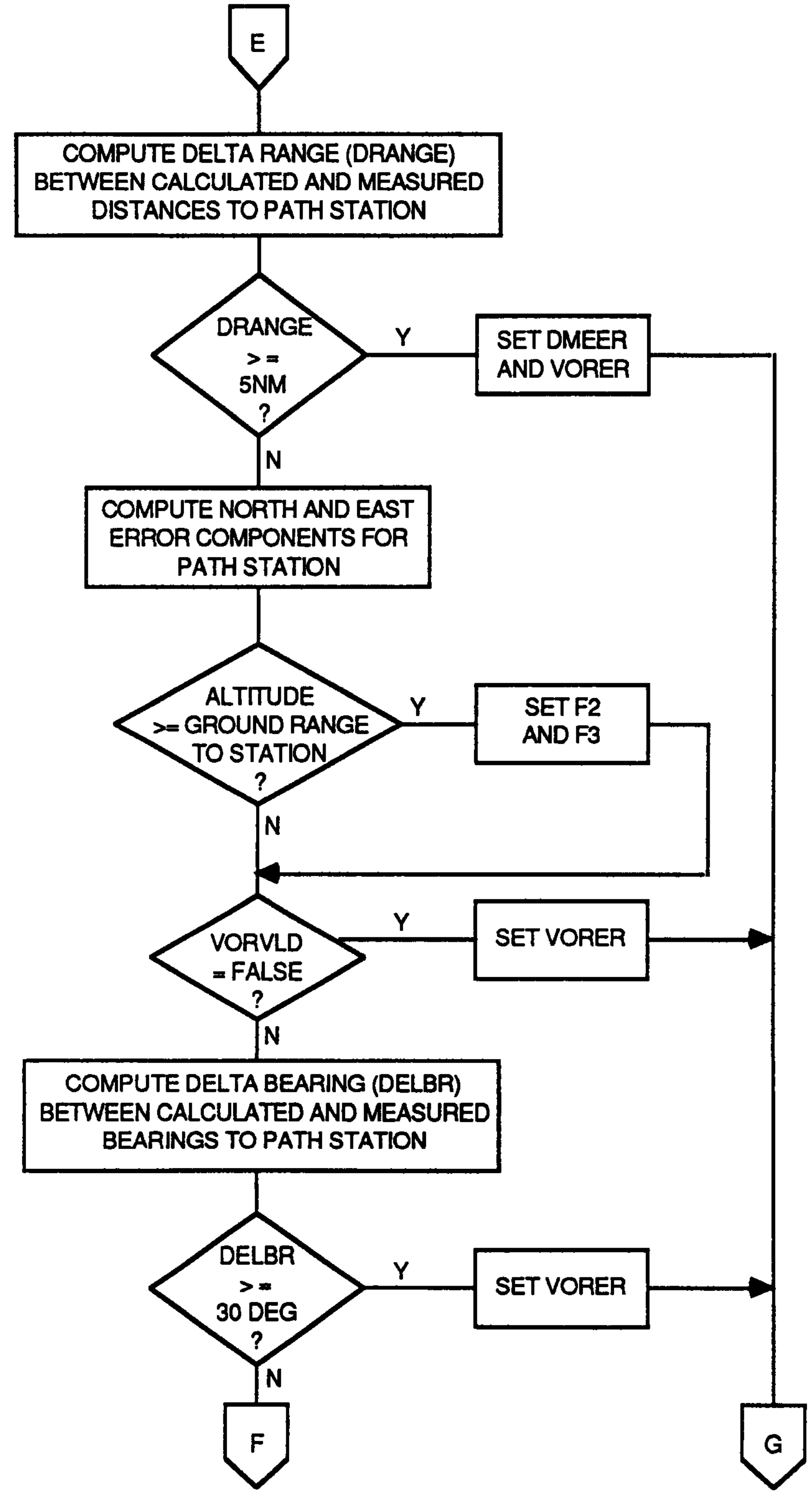
HNAVSL
(PAGE 2 OF 20)


B
DRANGE >= 5NM ?
Y
N
SET DMEER
COMPUTE NORTH AND EAST ERROR COMPONENTS FOR CROSS STATION
ALTITUDE >= GROUND RANGE TO STATION ?
Y
N
SET F0
C

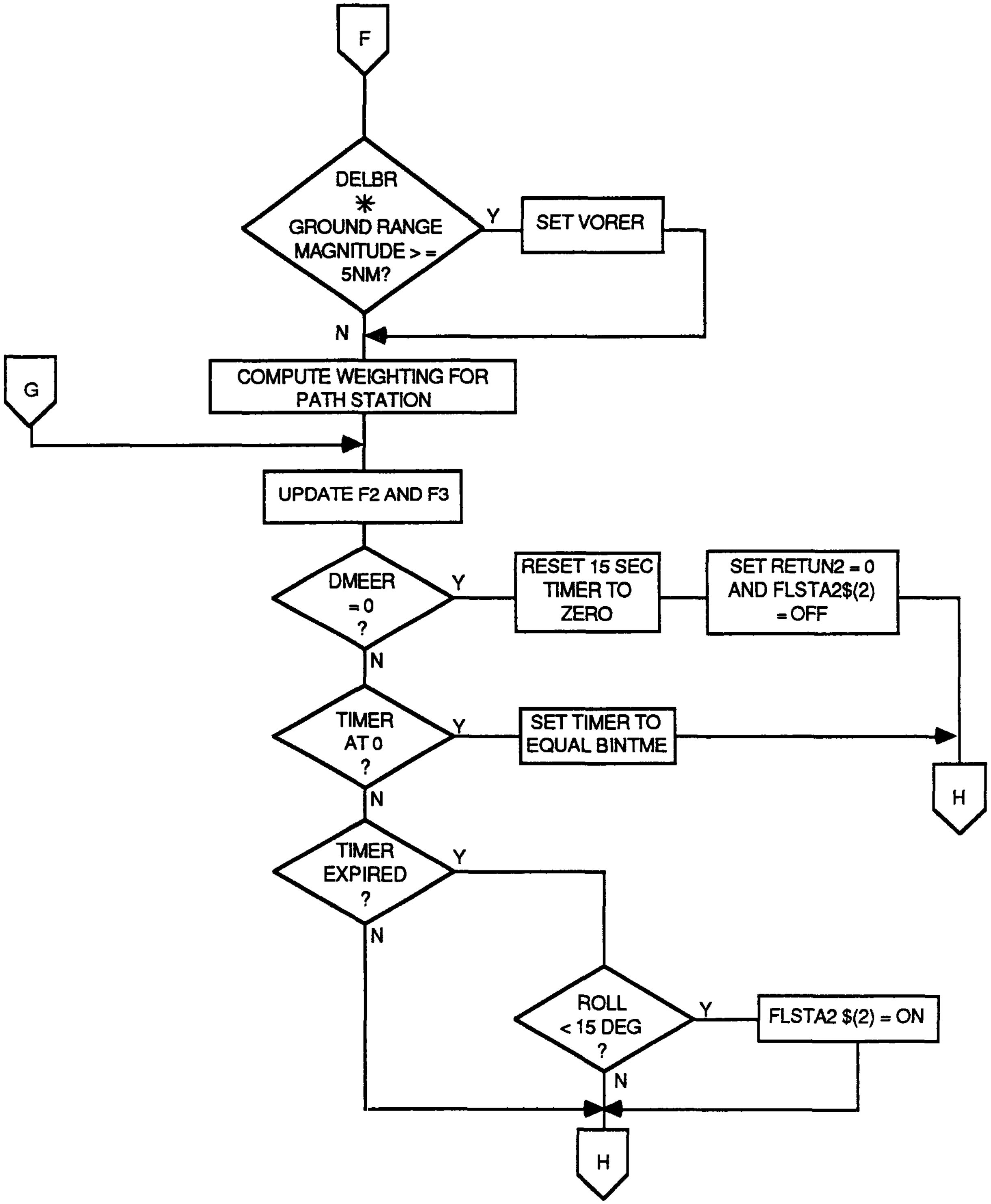

C
UPDATE F0
DMEER = 0 ?
Y
RESET 15 SEC TIMER TO ZERO
FLSTA3$(2) = OFF
N
TIMER AT 0 ?
Y
SET TIMER EQUAL TO BINTME
D
N
TIMER EXPIRED ?
Y
N
ROLL < 15 DEG ?
Y
FLSTA3$(2) = ON
N
D

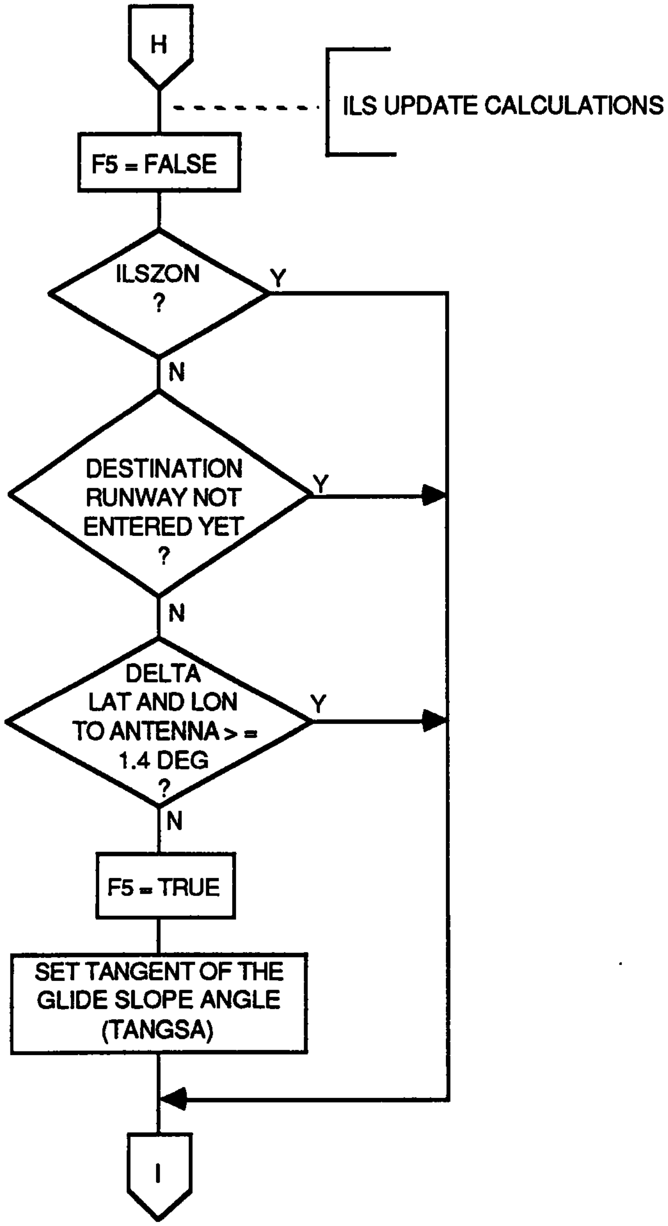

D
PROCESS STATION #2 DATA
SET PTHSTA AND CLEAR DMEER OF PREVIOUS ERRORS
SET DMEER AND VORER BITS UNDER PATH STATION ERROR CONDITIONS
BULK DATA STATION POINTER NVAD2A = 0 ?
Y
CALCULATED DISTANCE CDME2 AND BEARING CVOR2 TO STATION SET TO ZERO
N
CRBSC
CALCULATE DISTANCE AND BEARING TO PATH STATION AND ASSIGN TO CDME2 AND CVOR2 RESPECTIVELY
CDME2 > 327.67 NM ?
Y
SET DMEER AND VORER
CDME2 = 0
N
CDME2 > = 150 NM ?
Y
SET VORER
N
CDME2 = 0 ?
Y
SET DMEER AND VORER
N
E
G

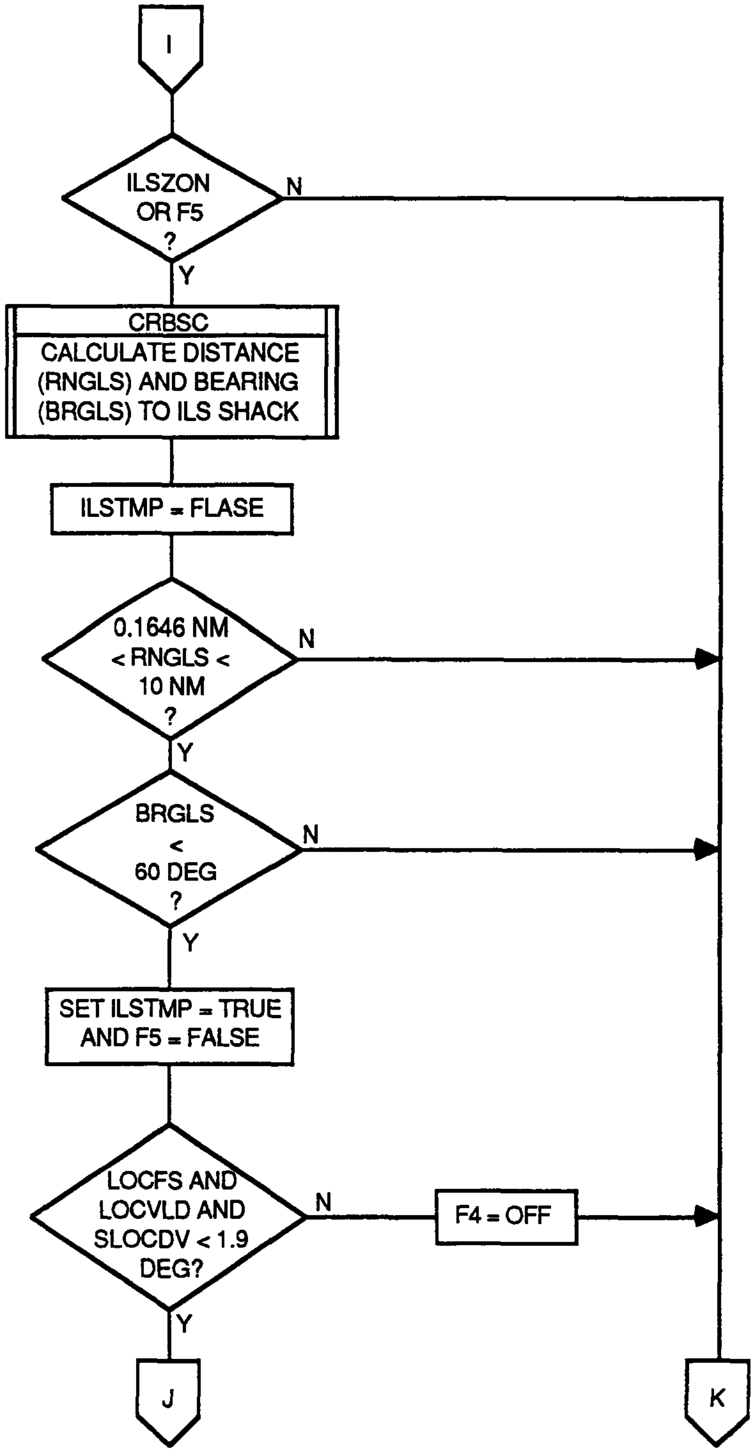
HNAVSL
(PAGE 5 OF 20)


E
COMPUTE DELTA RANGE (DRANGE) BETWEEN CALCULATED AND MEASURED DISTANCES TO PATH STATION
DRANGE >= 5NM ?
Y
SET DMEER AND VORER
N
COMPUTE NORTH AND EAST ERROR COMPONENTS FOR PATH STATION
ALTITUDE >= GROUND RANGE TO STATION ?
Y
SET F2 AND F3
N
VORVLD = FALSE ?
Y
SET VORER
N
COMPUTE DELTA BEARING (DELBR) BETWEEN CALCULATED AND MEASURED BEARINGS TO PATH STATION
DELBR >= 30 DEG ?
Y
SET VORER
N
F
G

HNAVSL
(PAGE 6 OF 20)


F
DELBR
*
GROUND RANGE
MAGNITUDE > =
5NM?
Y
SET VORER
N
COMPUTE WEIGHTING FOR
PATH STATION
G
UPDATE F2 AND F3
DMEER
= 0
?
Y
RESET 15 SEC
TIMER TO
ZERO
SET RETUN2 = 0
AND FLSTA2$(2)
= OFF
N
TIMER
AT 0
?
Y
SET TIMER TO
EQUAL BINTME
H
N
TIMER
EXPIRED
?
Y
N
ROLL
< 15 DEG
?
Y
FLSTA2 $(2) = ON
N
H


H
ILS UPDATE CALCULATIONS
F5 = FALSE
ILSZON
?
Y
N
DESTINATION
RUNWAY NOT
ENTERED YET
?
Y
N
DELTA
LAT AND LON
TO ANTENNA > =
1.4 DEG
?
Y
N
F5 = TRUE
SET TANGENT OF THE
GLIDE SLOPE ANGLE
(TANGSA)
I


I
ILSZON OR F5 ?
N
Y
CRBSC
CALCULATE DISTANCE (RNGLS) AND BEARING (BRGLS) TO ILS SHACK
ILSTMP = FLASE
0.1646 NM < RNGLS < 10 NM ?
N
Y
BRGLS < 60 DEG ?
N
Y
SET ILSTMP = TRUE AND F5 = FALSE
LOCFS AND LOCVLD AND SLOCDV < 1.9 DEG?
N
F4 = OFF
Y
J
K

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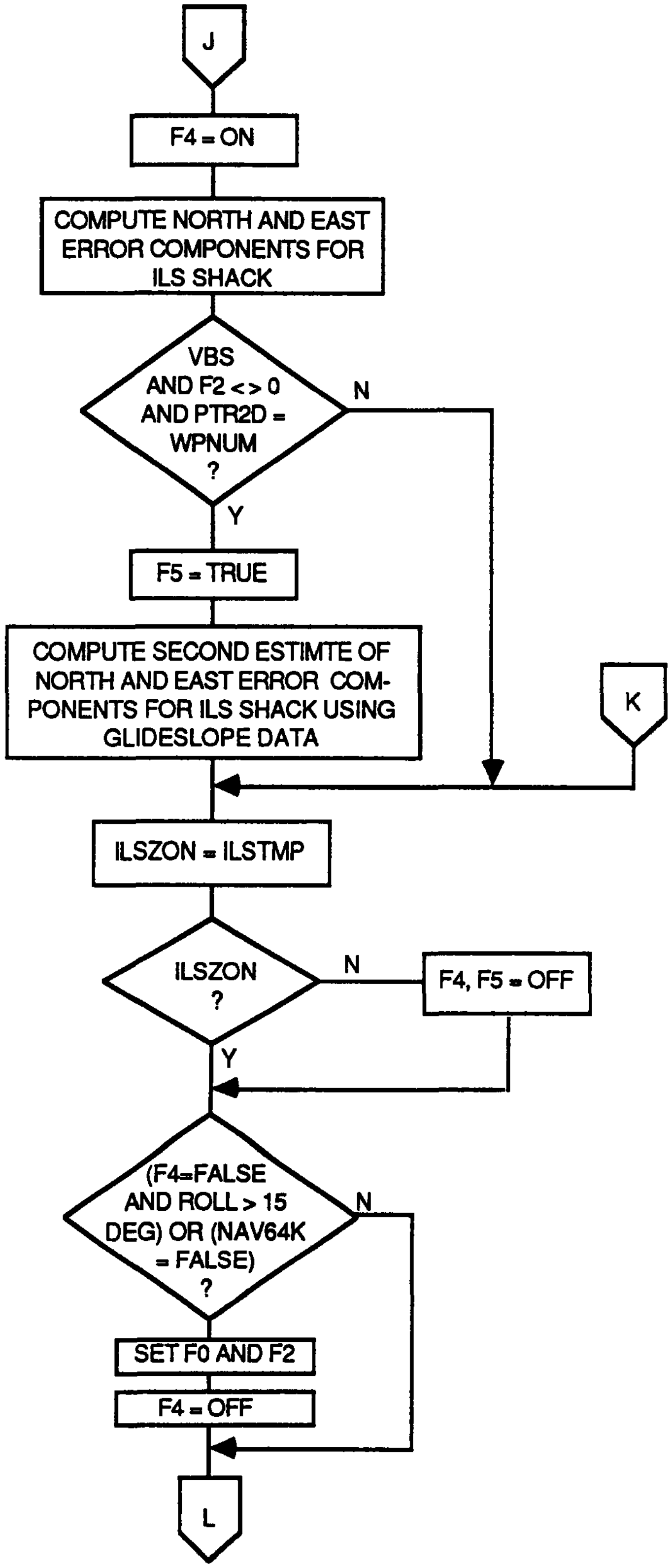
C·lr


J
F4 = ON
COMPUTE NORTH AND EAST ERROR COMPONENTS FOR ILS SHACK
VBS AND F2 <> 0 AND PTR2D = WPNUM ?
N
Y
F5 = TRUE
COMPUTE SECOND ESTIMTE OF NORTH AND EAST ERROR COMPONENTS FOR ILS SHACK USING GLIDESLOPE DATA
K
ILSZON = ILSTMP
ILSZON ?
N
F4, F5 = OFF
Y
(F4=FALSE AND ROLL > 15 DEG) OR (NAV64K = FALSE) ?
N
SET F0 AND F2
F4 = OFF
L

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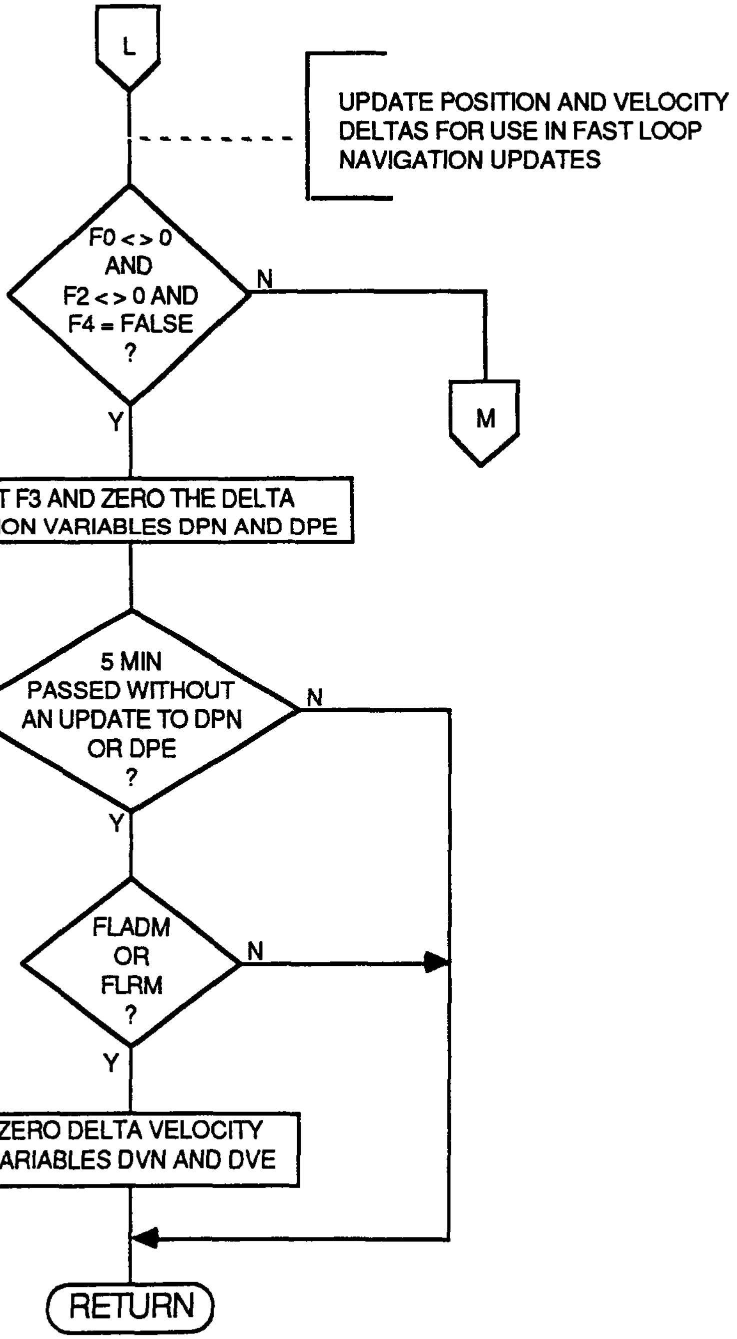
L
UPDATE POSITION AND VELOCITY DELTAS FOR USE IN FAST LOOP NAVIGATION UPDATES
F0 < > 0 AND F2 < > 0 AND F4 = FALSE ?
N
M
Y
SET F3 AND ZERO THE DELTA POSITION VARIABLES DPN AND DPE
5 MIN PASSED WITHOUT AN UPDATE TO DPN OR DPE ?
N
Y
FLADM OR FLRM ?
N
Y
ZERO DELTA VELOCITY VARIABLES DVN AND DVE
RETURN

HNAVSL
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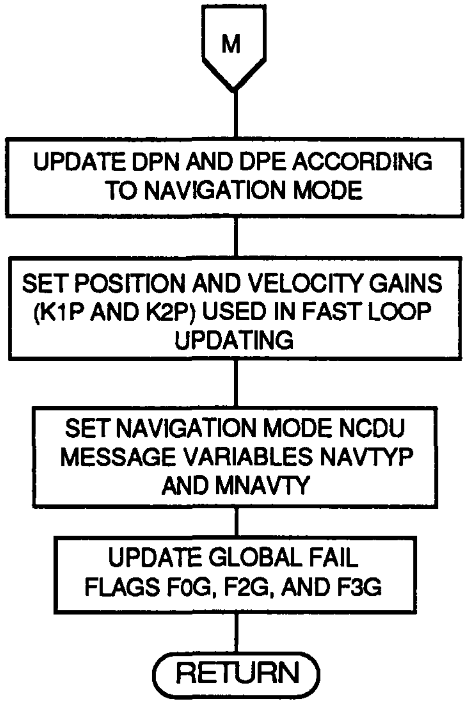
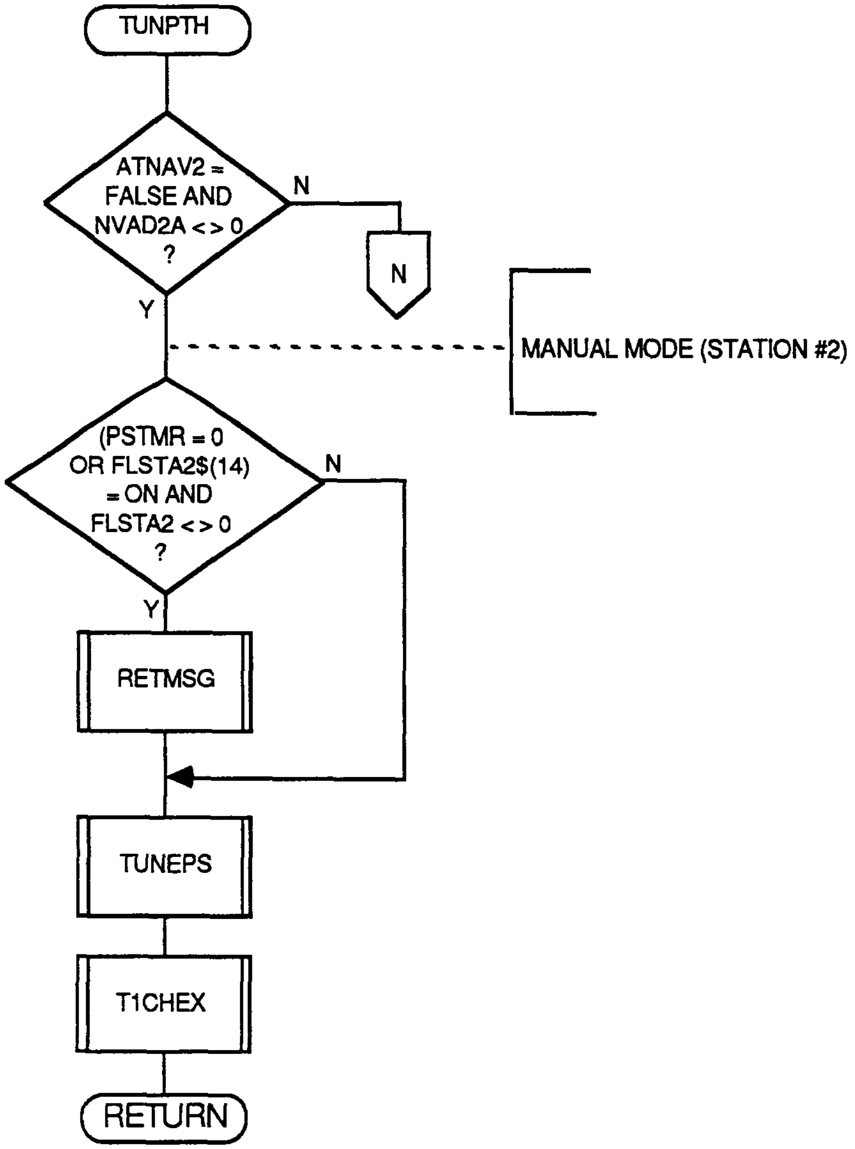
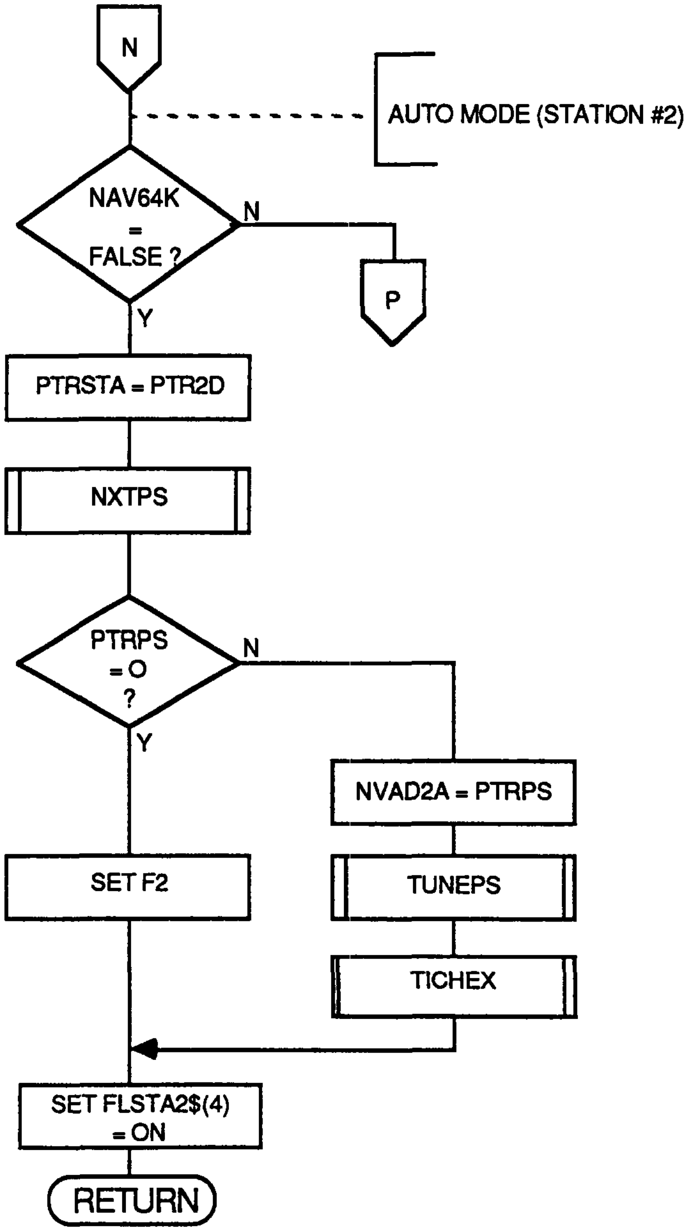
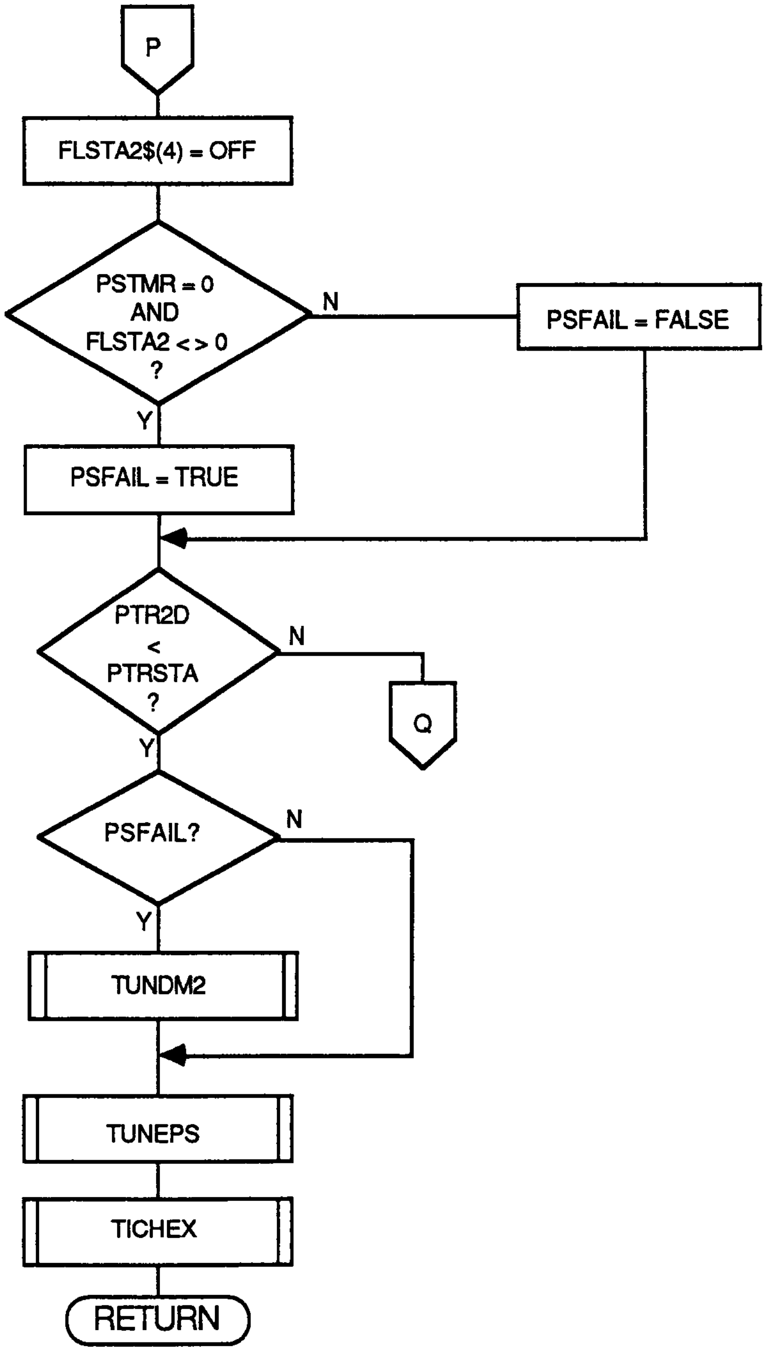

M
UPDATE DPN AND DPE ACCORDING TO NAVIGATION MODE
SET POSITION AND VELOCITY GAINS (K1P AND K2P) USED IN FAST LOOP UPDATING
SET NAVIGATION MODE NCDU MESSAGE VARIABLES NAVTYP AND MNAVTY
UPDATE GLOBAL FAIL FLAGS F0G, F2G, AND F3G
RETURN


TUNPTH
ATNAV2 = FALSE AND NVAD2A < > 0 ?
N
N
Y
MANUAL MODE (STATION #2)
(PSTMR = 0 OR FLSTA2$(14) = ON AND FLSTA2 < > 0 ?
N
Y
RETMSG
TUNEPS
T1CHEX
RETURN


N
AUTO MODE (STATION #2)
NAV64K = FALSE ?
N
P
Y
PTRSTA = PTR2D
NXTPS
PTRPS = O ?
N
Y
NVAD2A = PTRPS
SET F2
TUNEPS
TICHEX
SET FLSTA2$(4) = ON
RETURN



HNAVSL
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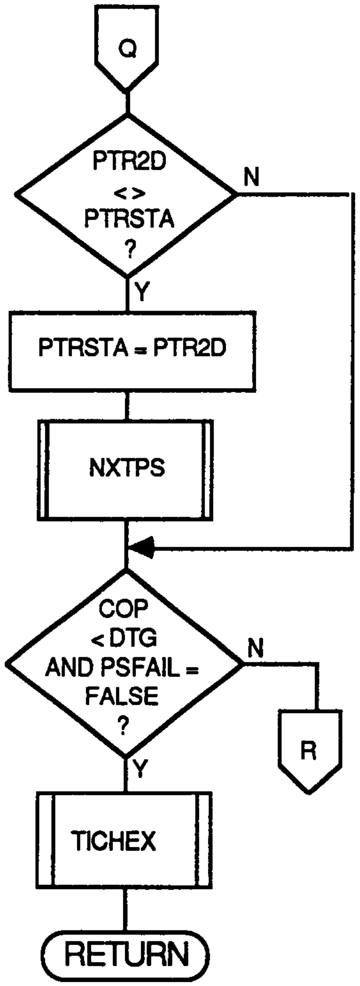
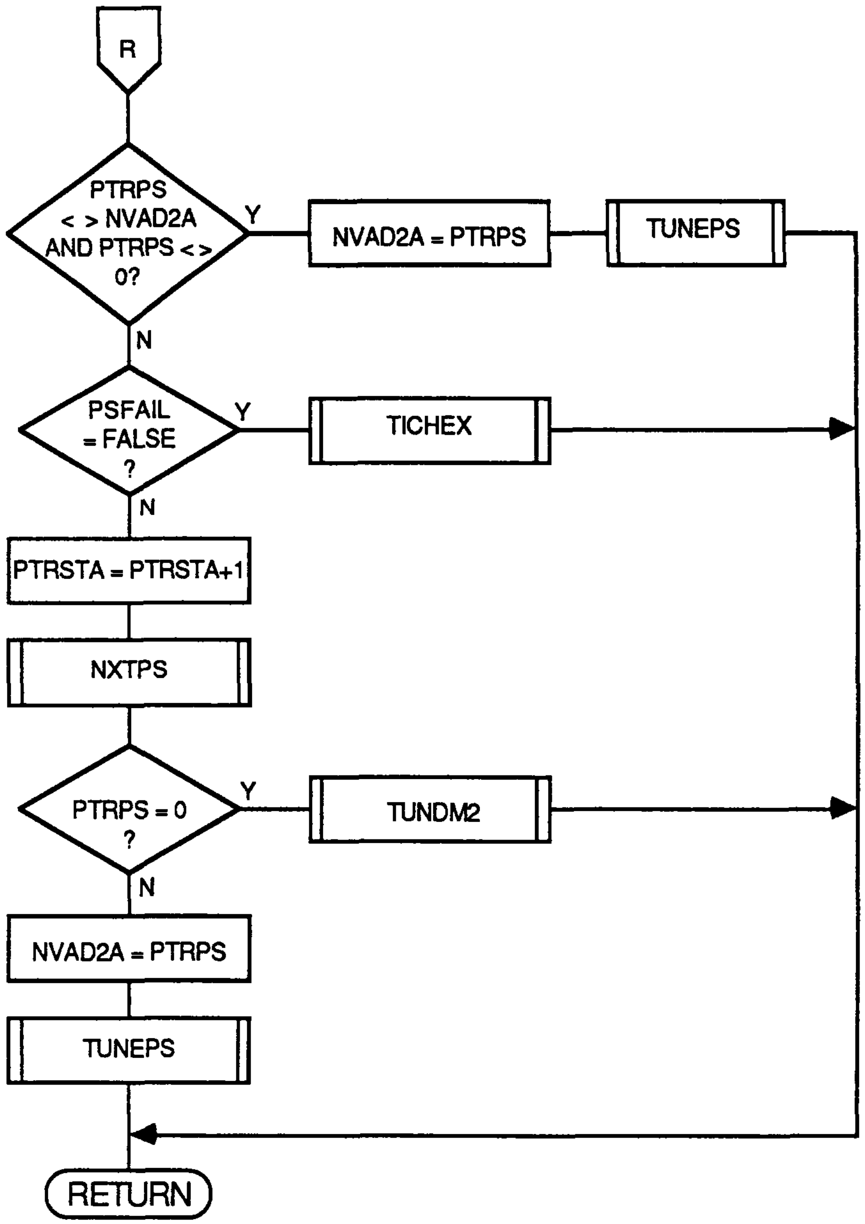
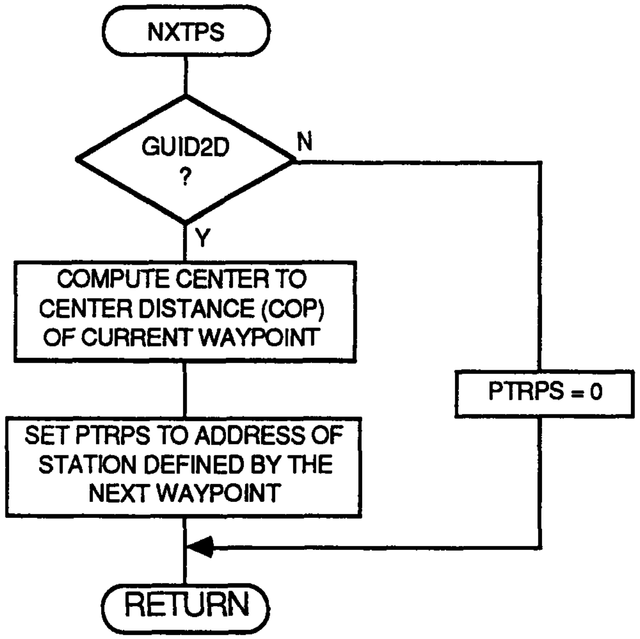
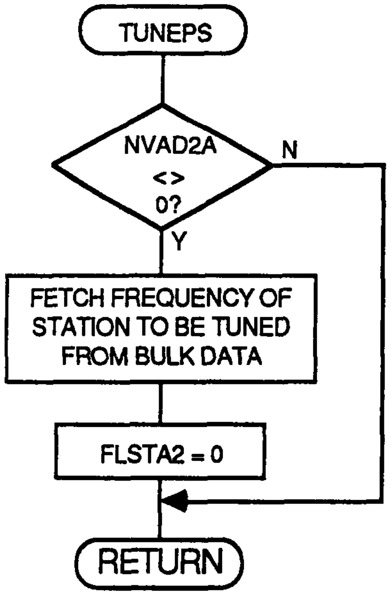
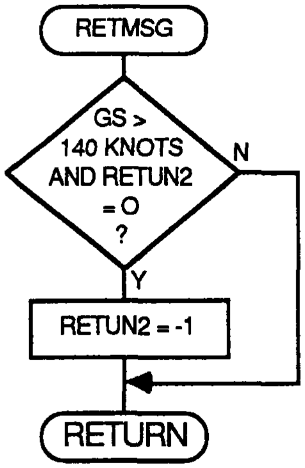
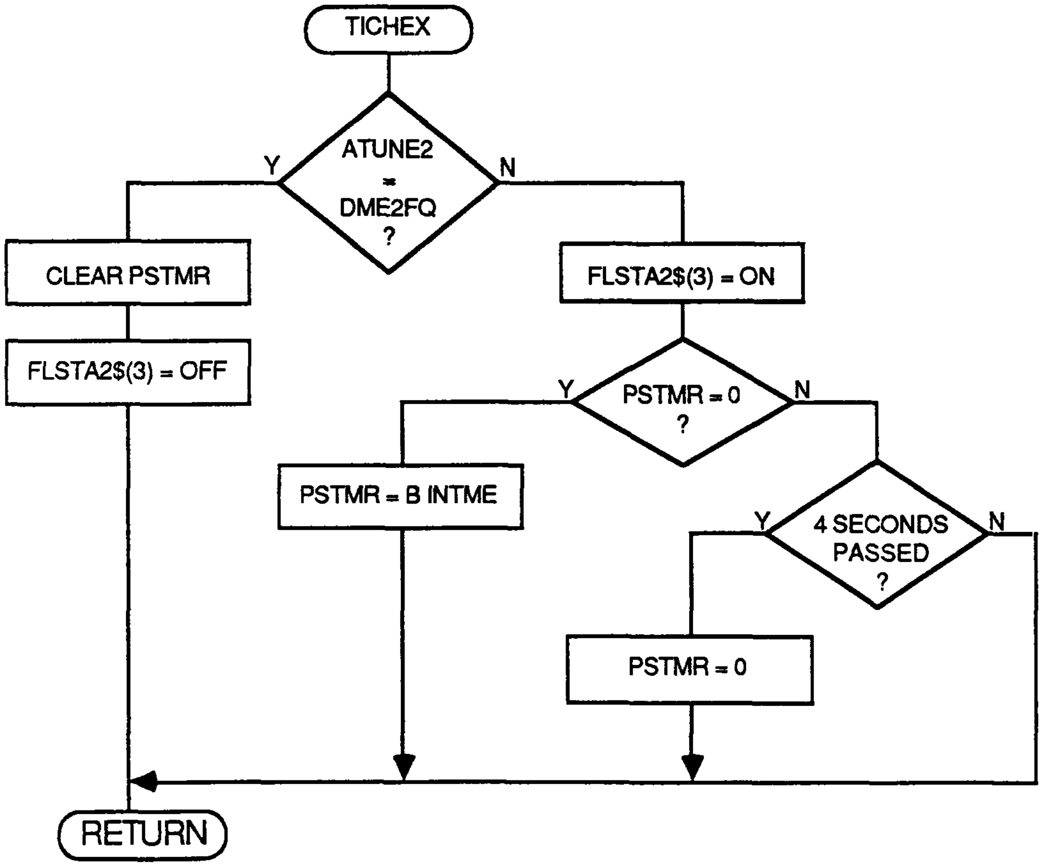

Q
PTR2D
< >
PTRSTA
?
N
Y
PTRSTA = PTR2D
NXTPS
COP
< DTG
AND PSFAIL =
FALSE
?
N
R
Y
TICHEX
RETURN

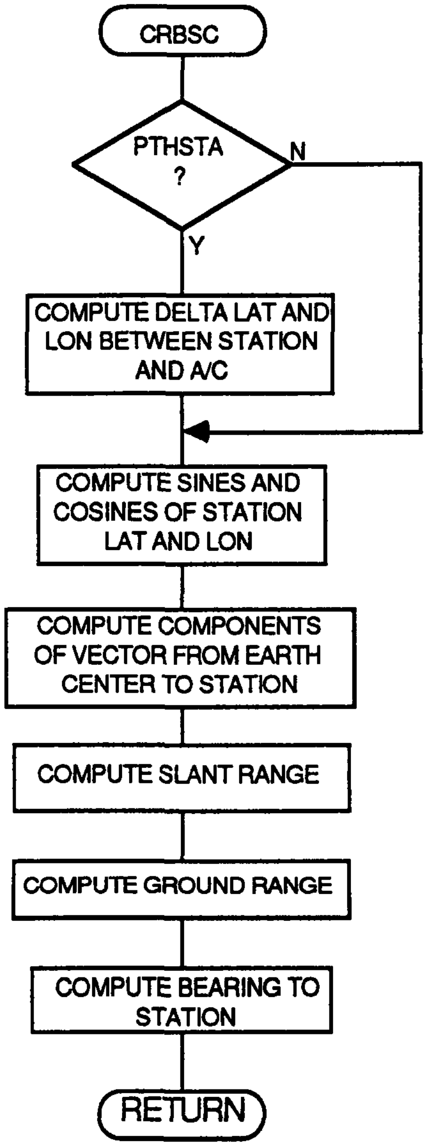

R
PTRPS
< > NVAD2A
AND PTRPS < >
0?
Y
NVAD2A = PTRPS
TUNEPS
N
PSFAIL
= FALSE
?
Y
TICHEX
N
PTRSTA = PTRSTA+1
NXTPS
PTRPS = 0
?
Y
TUNDM2
N
NVAD2A = PTRPS
TUNEPS
RETURN


NXTPS
GUID2D ?
N
Y
COMPUTE CENTER TO CENTER DISTANCE (COP) OF CURRENT WAYPOINT
PTRPS = 0
SET PTRPS TO ADDRESS OF STATION DEFINED BY THE NEXT WAYPOINT
RETURN


TUNEPS
NVAD2A <> 0?
N
Y
FETCH FREQUENCY OF STATION TO BE TUNED FROM BULK DATA
FLSTA2 = 0
RETURN


RETMSG
GS > 140 KNOTS AND RETUN2 = O ?
N
Y
RETUN2 = -1
RETURN


TICHEX
ATUNE2 = DME2FQ ?
Y
N
CLEAR PSTMR
FLSTA2$(3) = OFF
FLSTA2$(3) = ON
PSTMR = 0 ?
Y
N
PSTMR = B INTME
4 SECONDS PASSED ?
Y
N
PSTMR = 0
RETURN


CRBSC
PTHSTA ?
N
Y
COMPUTE DELTA LAT AND LON BETWEEN STATION AND A/C
COMPUTE SINES AND COSINES OF STATION LAT AND LON
COMPUTE COMPONENTS OF VECTOR FROM EARTH CENTER TO STATION
COMPUTE SLANT RANGE
COMPUTE GROUND RANGE
COMPUTE BEARING TO STATION
RETURN

HNAVSL
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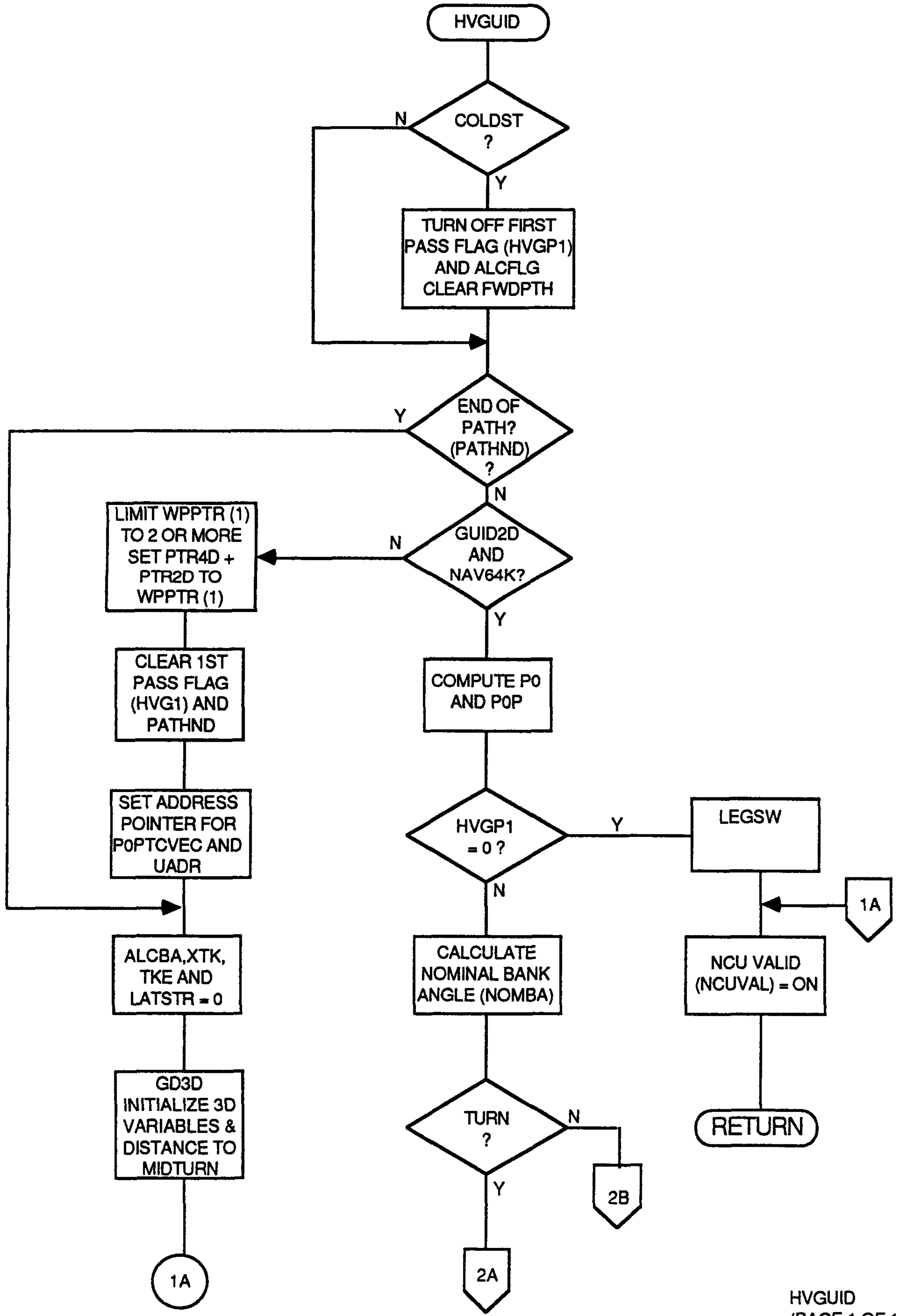
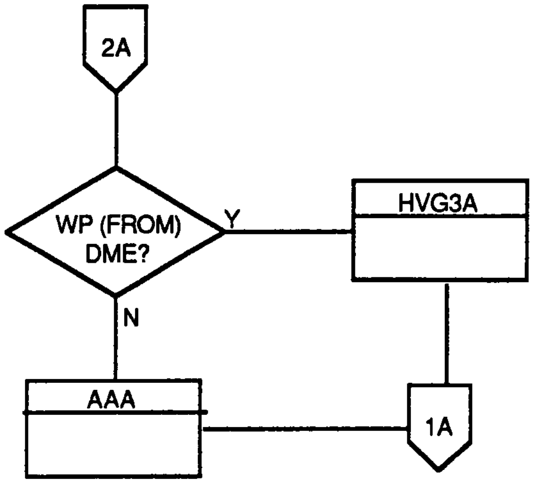
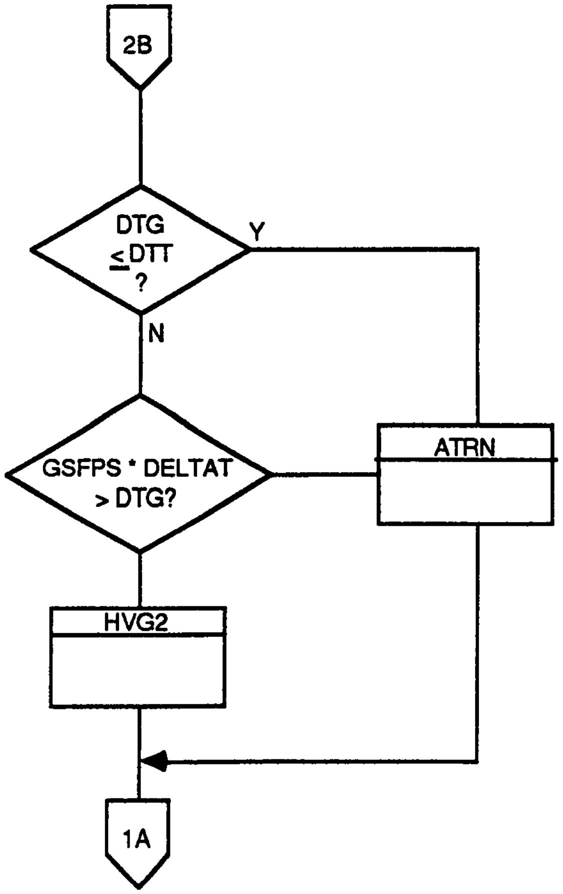
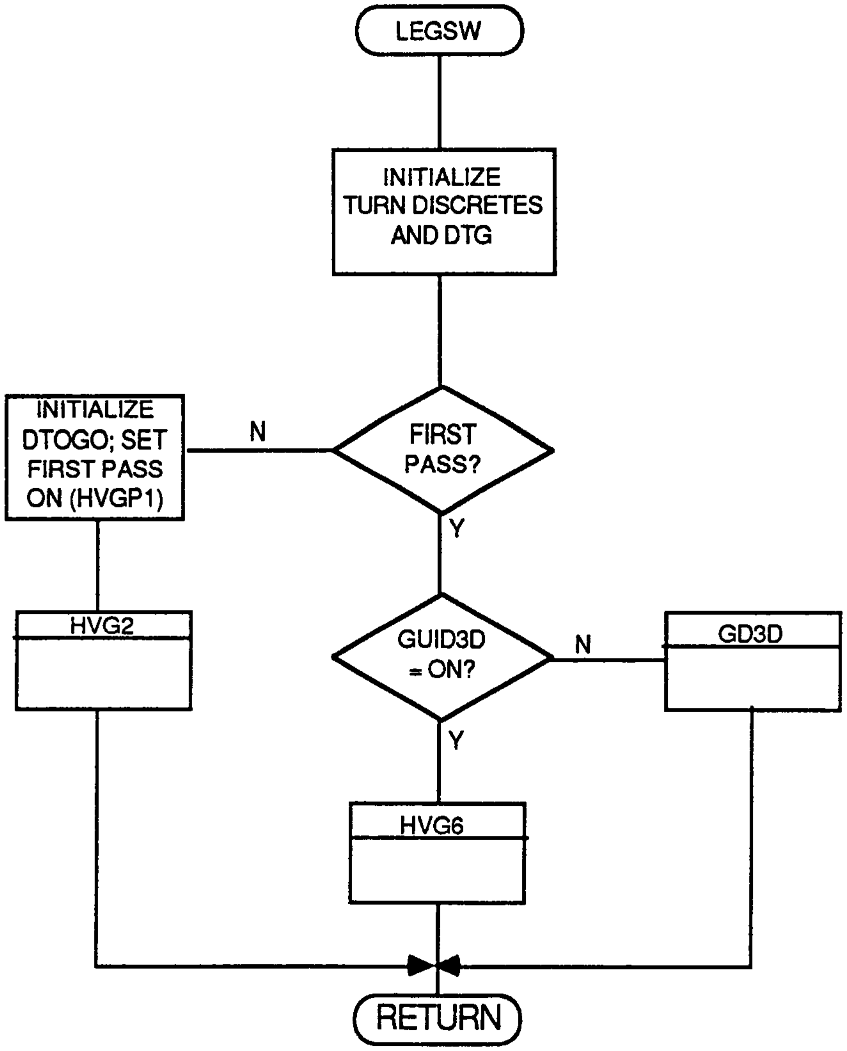
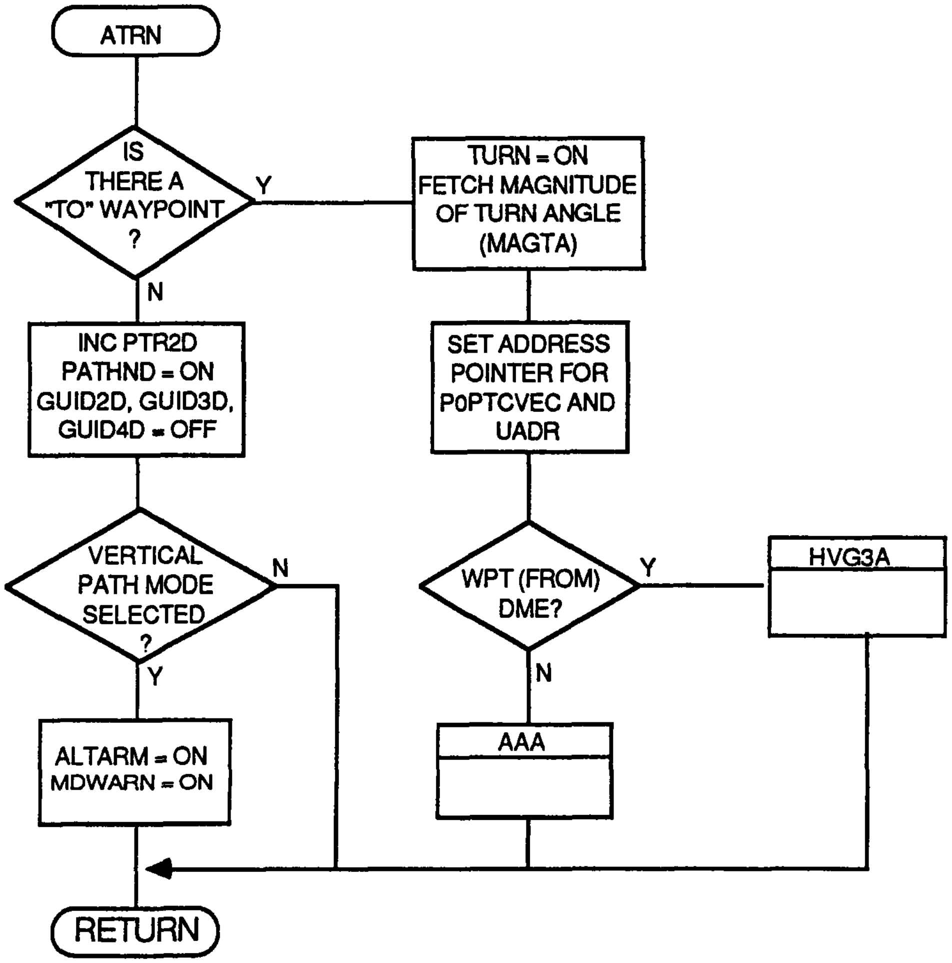

HVGUID
COLDST ?
N
Y
TURN OFF FIRST PASS FLAG (HVGP1) AND ALCFLG CLEAR FWDPTH
END OF PATH? (PATHND) ?
Y
N
GUID2D AND NAV64K?
N
Y
LIMIT WPPTR (1) TO 2 OR MORE SET PTR4D + PTR2D TO WPPTR (1)
CLEAR 1ST PASS FLAG (HVG1) AND PATHND
SET ADDRESS POINTER FOR P0PTCVEC AND UADR
ALCBA,XTK, TKE AND LATSTR = 0
GD3D INITIALIZE 3D VARIABLES & DISTANCE TO MIDTURN
1A
COMPUTE P0 AND P0P
HVGP1 = 0 ?
Y
N
LEGSW
1A
NCU VALID (NCUVAL) = ON
RETURN
CALCULATE NOMINAL BANK ANGLE (NOMBA)
TURN ?
N
Y
2B
2A

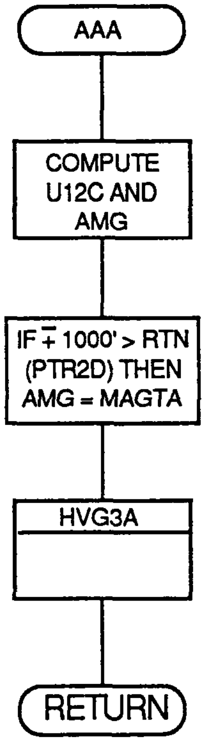
HVGUID
(PAGE 1 OF 14)


2A
WP (FROM) DME?
Y
N
HVG3A
AAA
1A

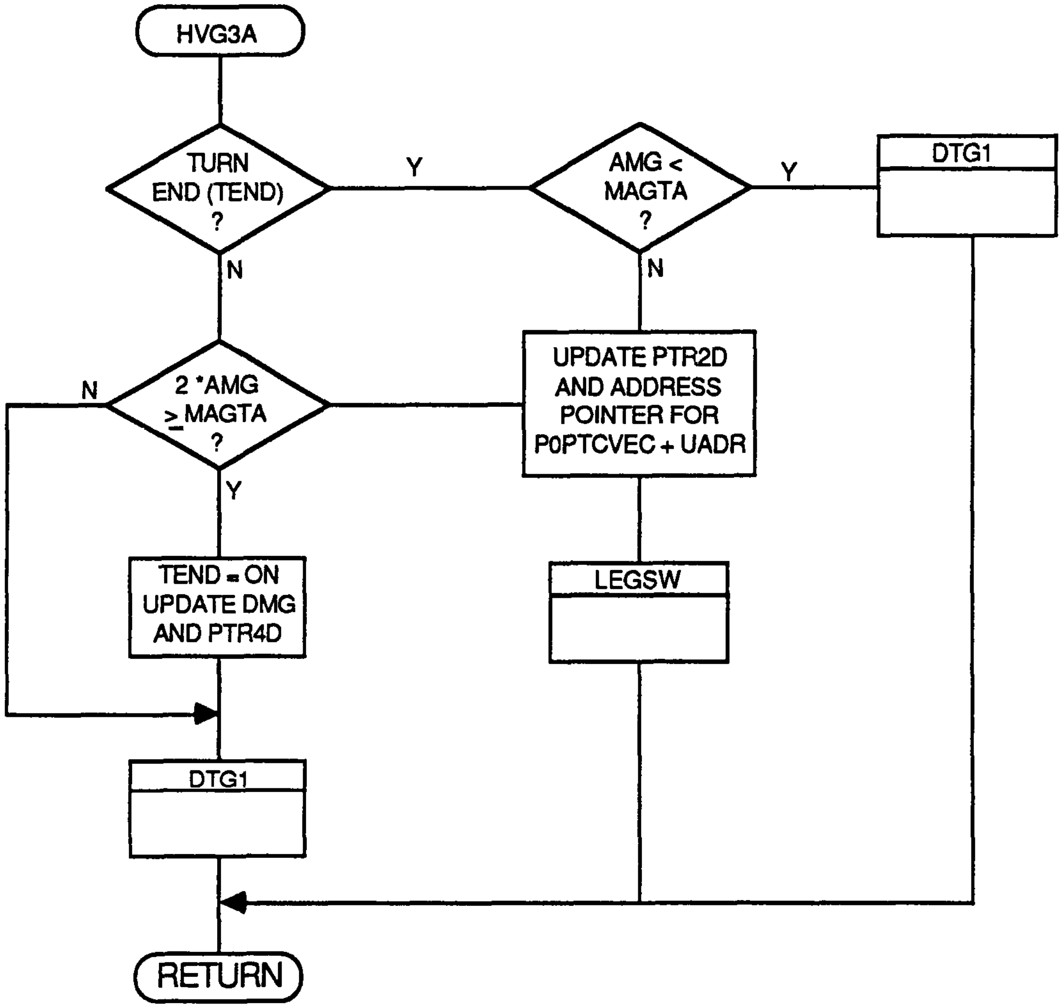

2B
DTG ≤ DTT ?
Y
N
GSFPS * DELTAT > DTG?
ATRN
HVG2
1A

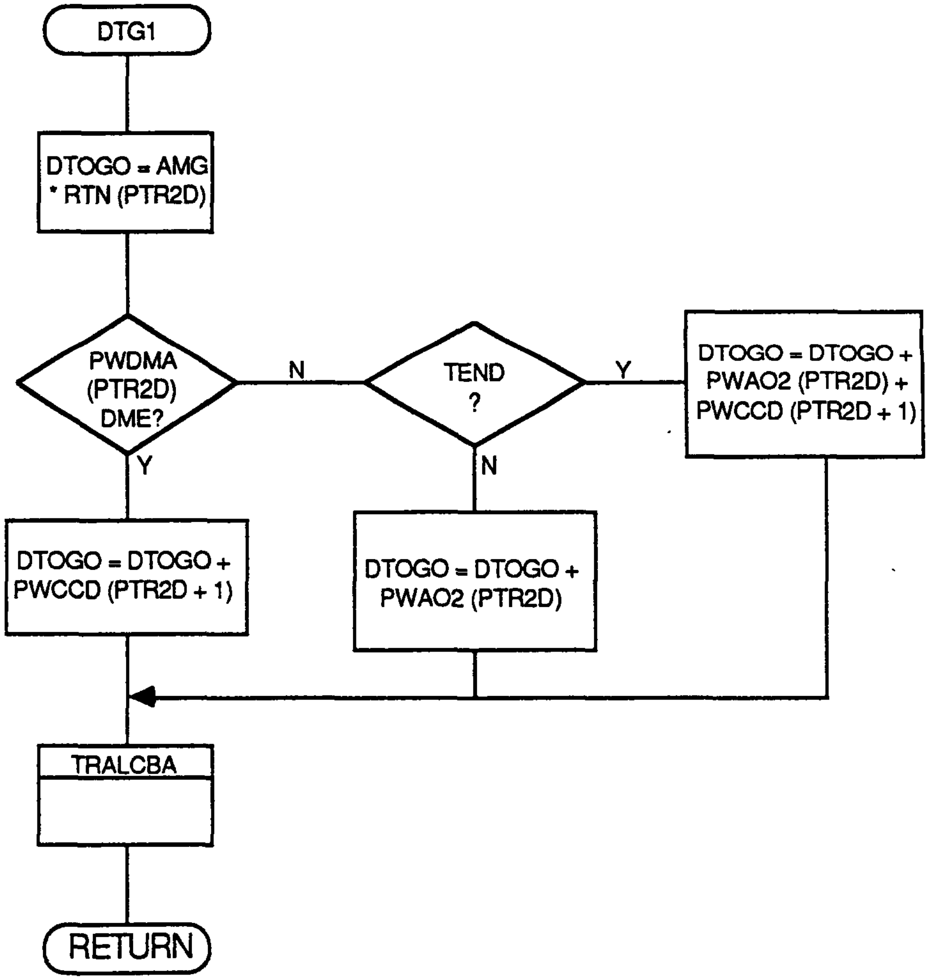

LEGSW
INITIALIZE TURN DISCRETES AND DTG
FIRST PASS?
N
INITIALIZE DTOGO; SET FIRST PASS ON (HVGP1)
Y
HVG2
GUID3D = ON?
N
GD3D
Y
HVG6
RETURN

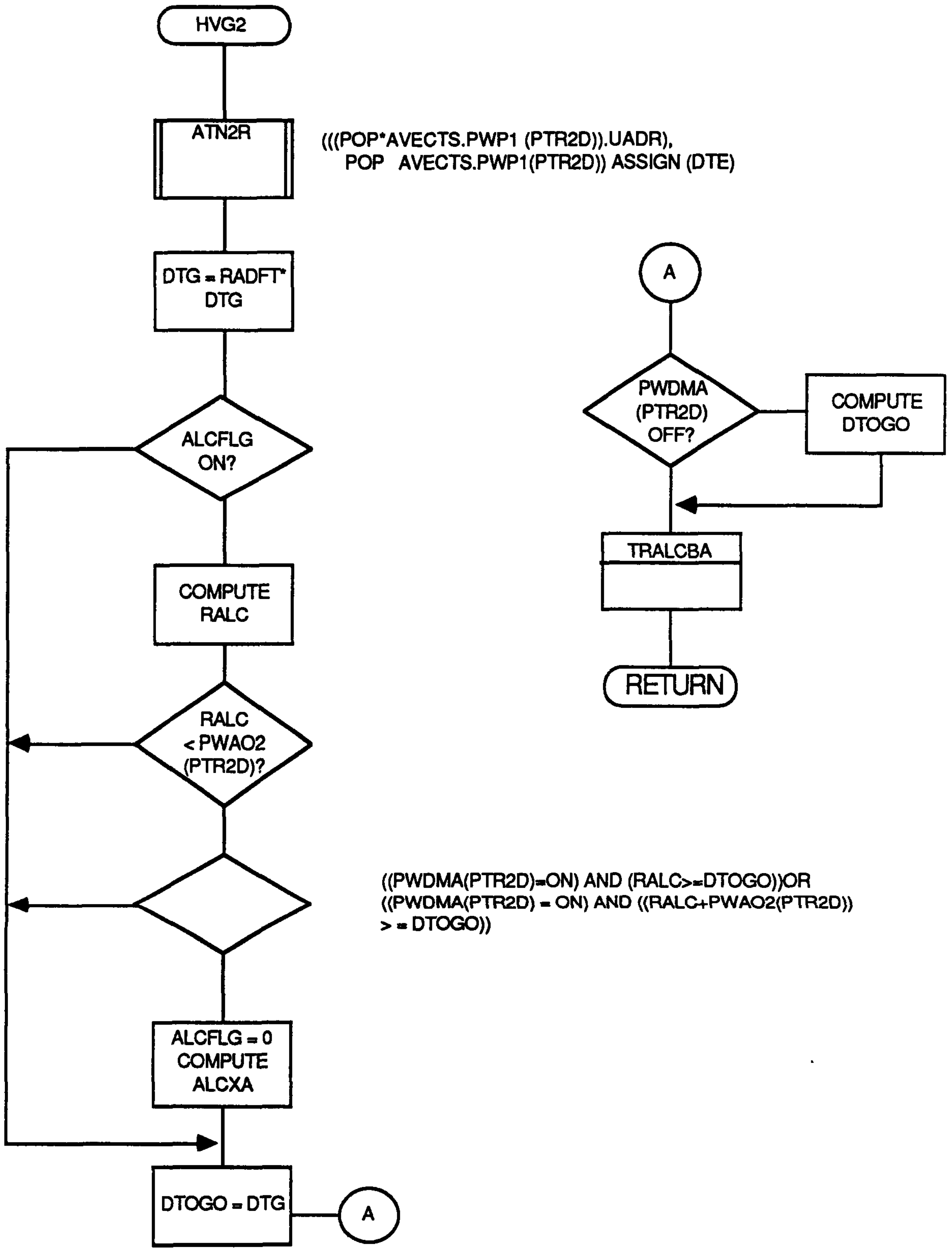

ATRN
IS THERE A "TO" WAYPOINT ?
Y
N
TURN = ON
FETCH MAGNITUDE OF TURN ANGLE (MAGTA)
INC PTR2D
PATHND = ON
GUID2D, GUID3D, GUID4D = OFF
SET ADDRESS POINTER FOR P0PTCVEC AND UADR
VERTICAL PATH MODE SELECTED ?
N
Y
WPT (FROM) DME?
Y
N
HVG3A
AAA
ALTARM = ON
MDWARN = ON
RETURN



IF THE AIRPLANE IS OFF THE PATH
(RIGHT OR LEFT) SUCH THAT XTK∓1000 FT.
IS > THE RADIUS OF TURN, FORCE THE
TURN COMPLETION BY SETTING AMG = MAGTA


HVG3A
TURN END (TEND) ?
Y
N
AMG < MAGTA ?
Y
N
DTG1
2 *AMG ≥ MAGTA ?
N
Y
UPDATE PTR2D AND ADDRESS POINTER FOR P0PTCVEC + UADR
TEND = ON UPDATE DMG AND PTR4D
LEGSW
DTG1
RETURN


DTG1
DTOGO = AMG * RTN (PTR2D)
PWDMA (PTR2D) DME?
N
Y
TEND ?
Y
N
DTOGO = DTOGO + PWAO2 (PTR2D) + PWCCD (PTR2D + 1)
DTOGO = DTOGO + PWCCD (PTR2D + 1)
DTOGO = DTOGO + PWAO2 (PTR2D)
TRALCBA
RETURN


HVG2
ATN2R
(((POP*AVECTS.PWP1 (PTR2D)).UADR),
POP AVECTS.PWP1(PTR2D)) ASSIGN (DTE)
DTG = RADFT*
DTG
ALCFLG
ON?
COMPUTE
RALC
RALC
< PWAO2
(PTR2D)?
((PWDMA(PTR2D)=ON) AND (RALC>=DTOGO))OR
((PWDMA(PTR2D) = ON) AND ((RALC+PWAO2(PTR2D))
> = DTOGO))
ALCFLG = 0
COMPUTE
ALCXA
DTOGO = DTG
A
A
PWDMA
(PTR2D)
OFF?
COMPUTE
DTOGO
TRALCBA
RETURN

HVGUID
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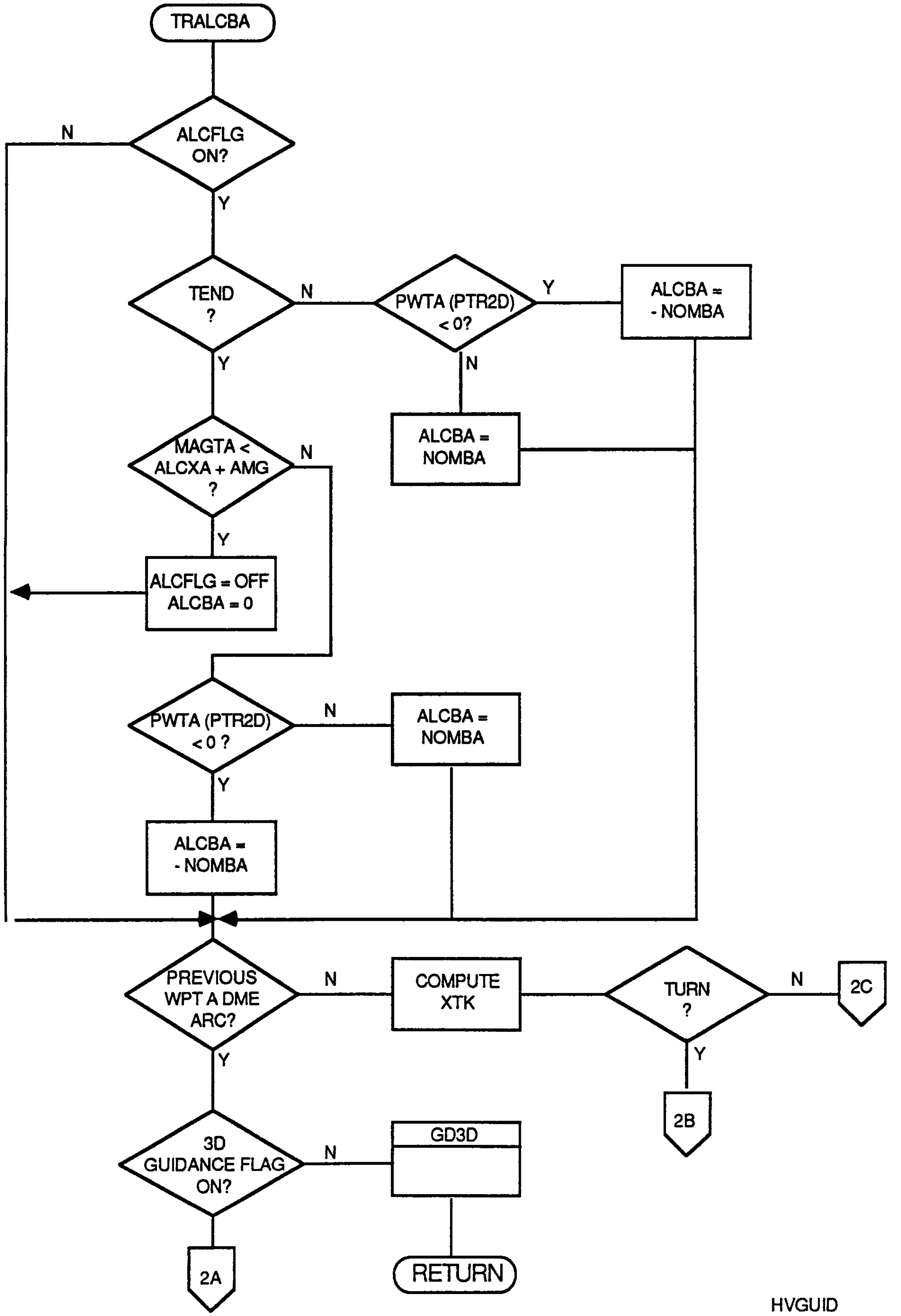

HVGUID
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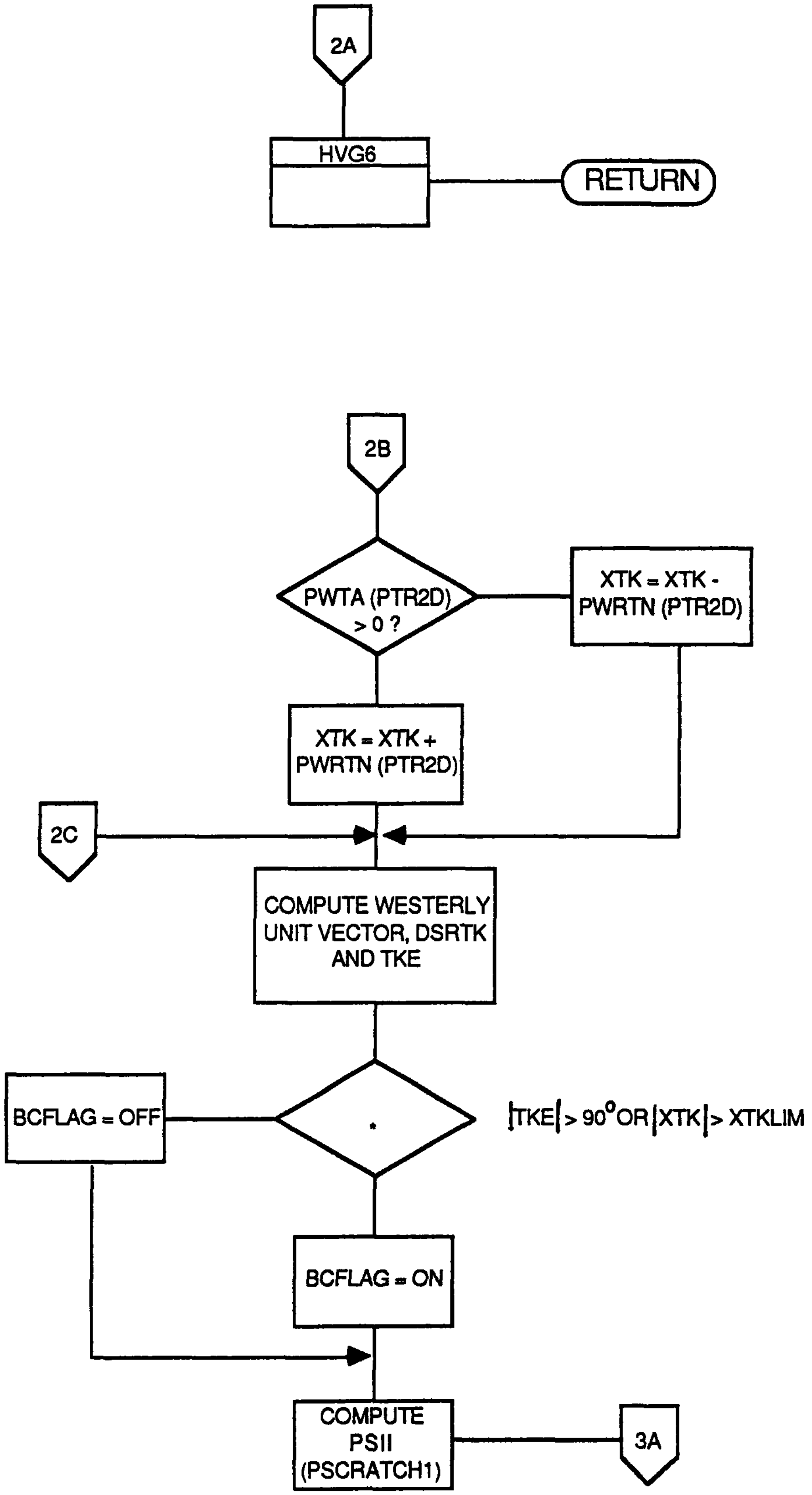
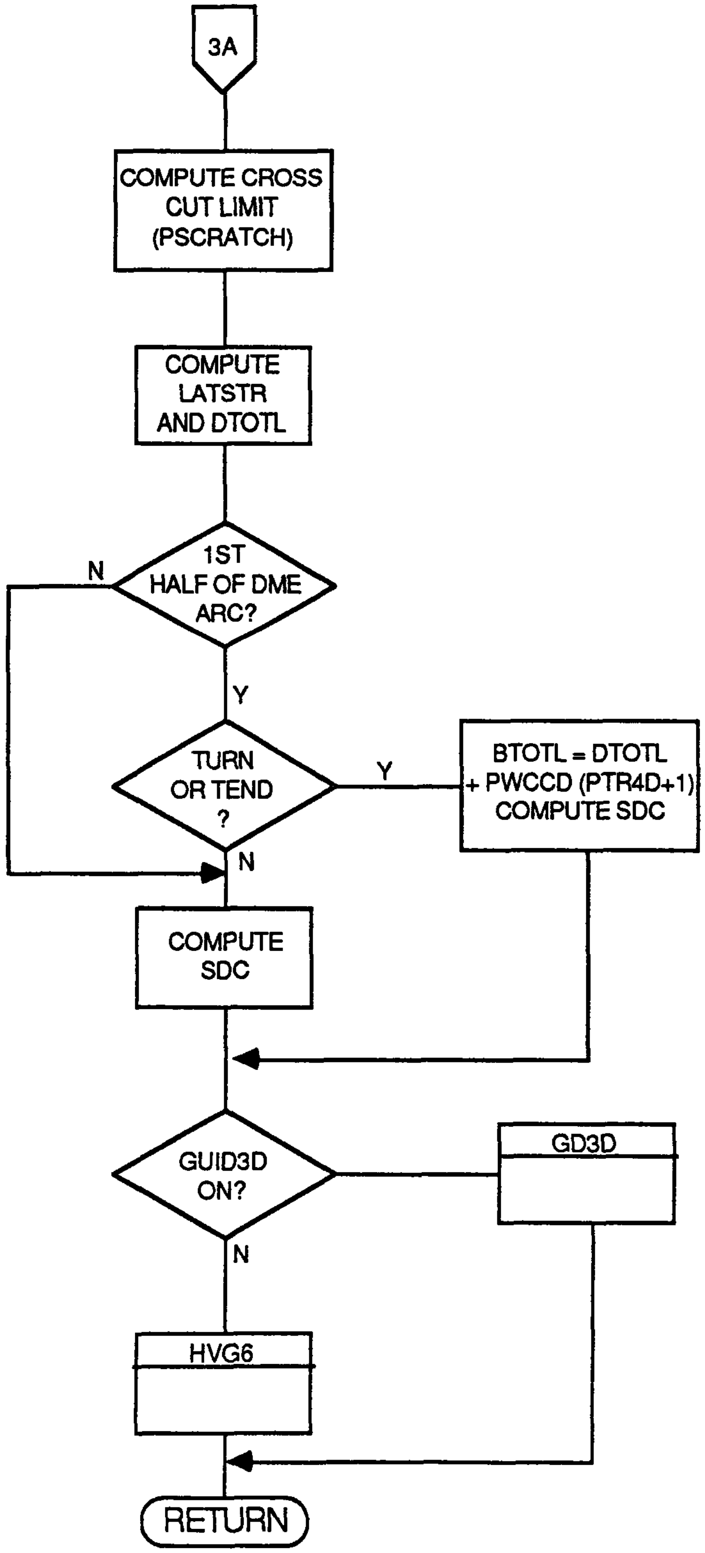
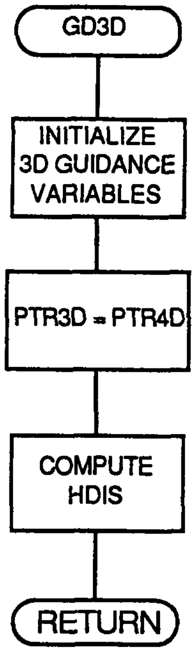
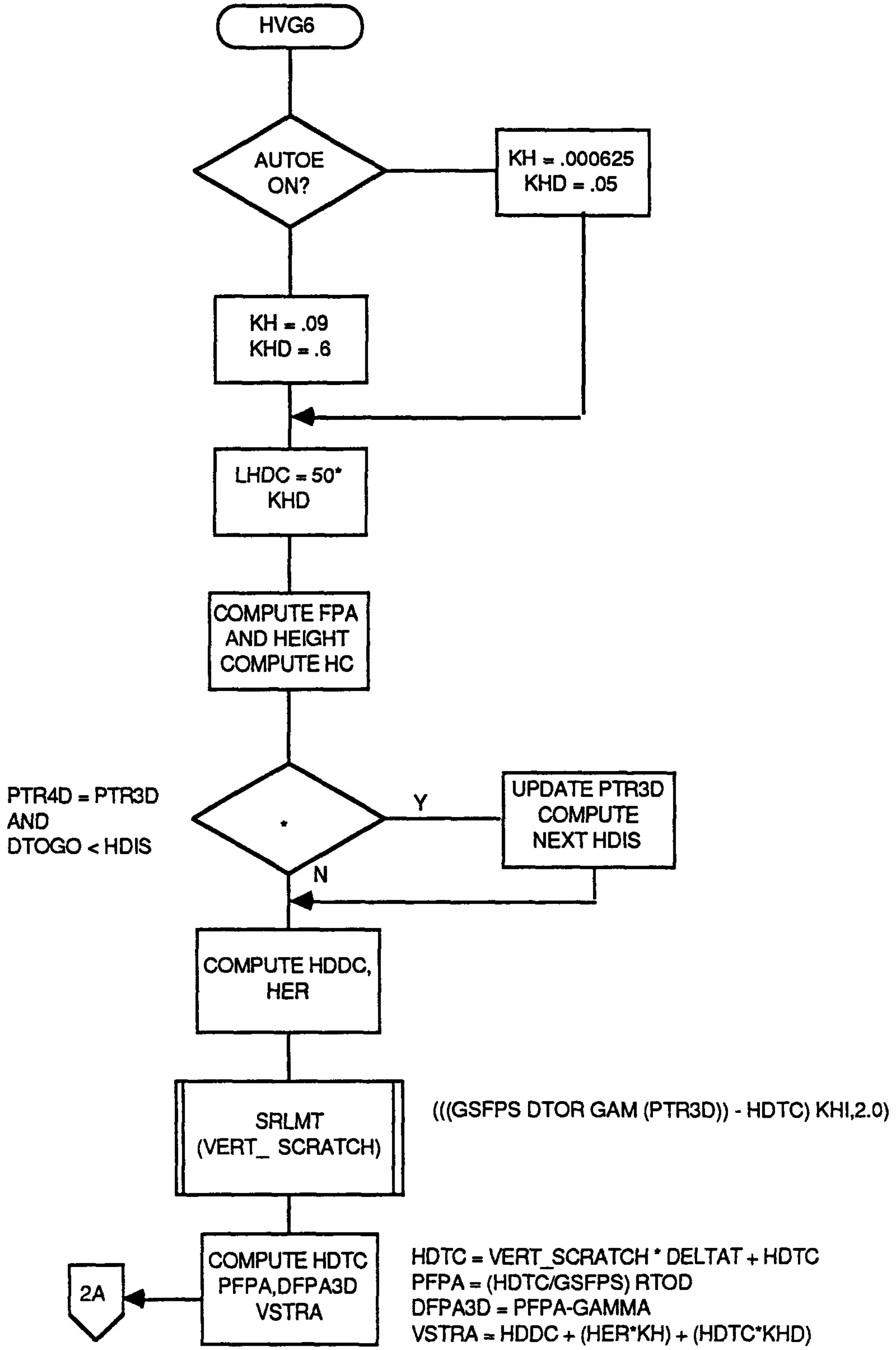
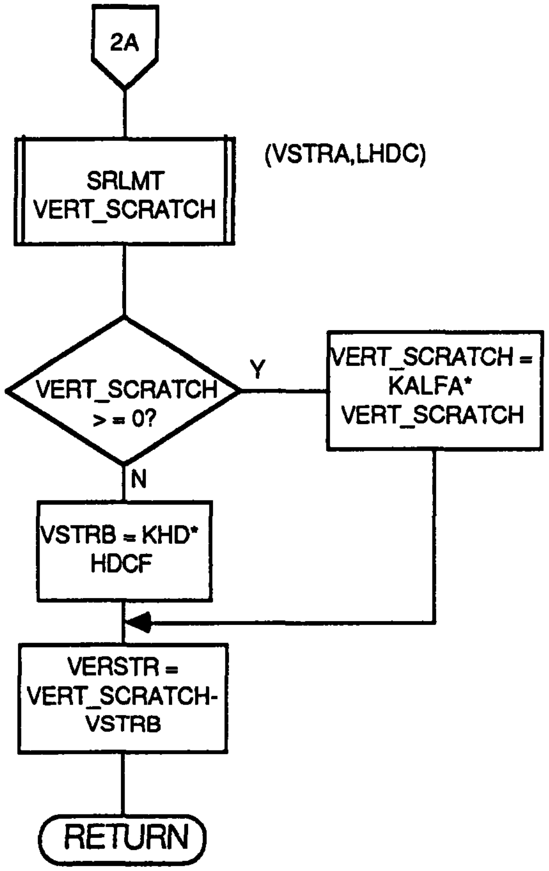
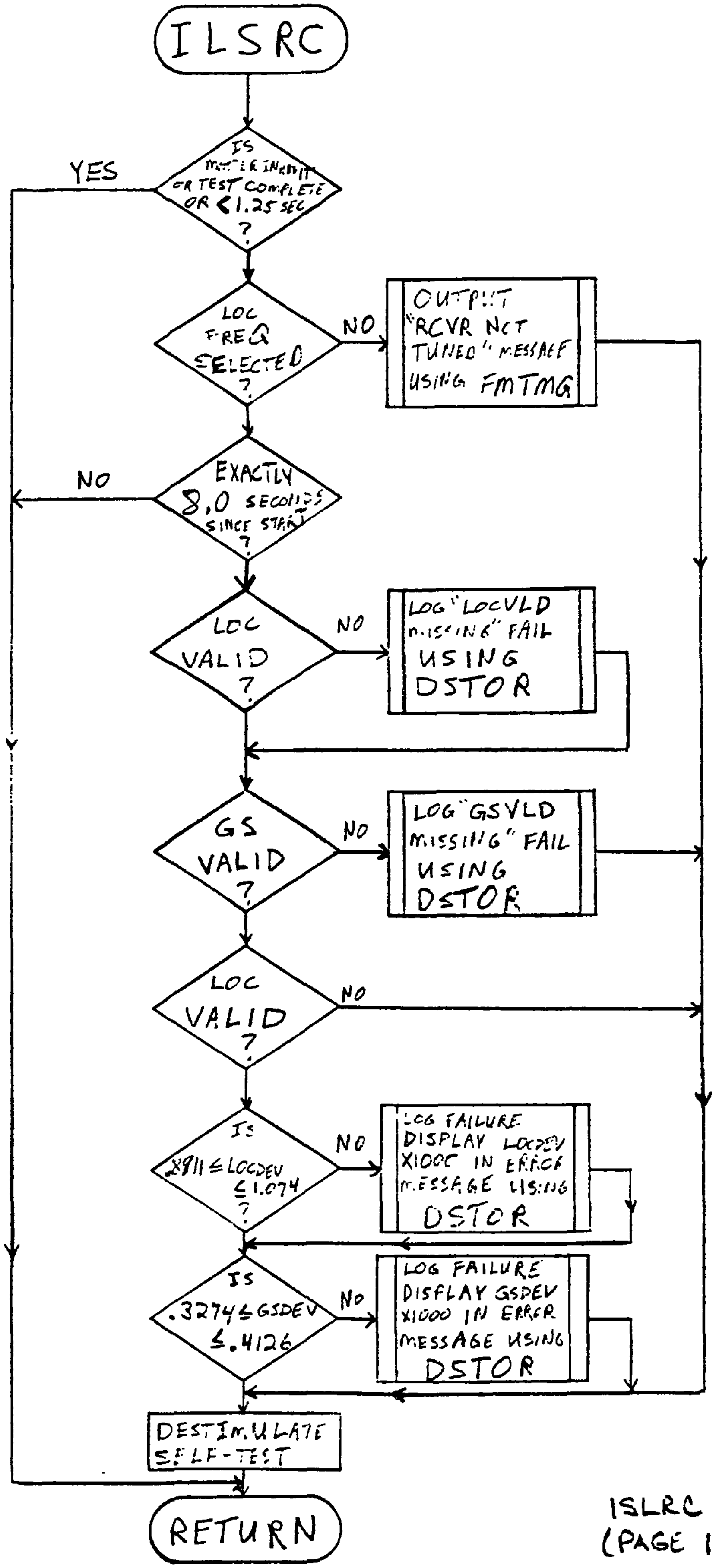

2A
HVG6
RETURN
2B
PWTA (PTR2D) > 0 ?
XTK = XTK - PWRTN (PTR2D)
XTK = XTK + PWRTN (PTR2D)
2C
COMPUTE WESTERLY UNIT VECTOR, DSRTK AND TKE
BCFLAG = OFF
*
|TKE| > 90°OR |XTK| > XTKLIM
BCFLAG = ON
COMPUTE PSII (PSCRATCH1)
3A


3A
COMPUTE CROSS CUT LIMIT (PSCRATCH)
COMPUTE LATSTR AND DTOTL
1ST HALF OF DME ARC?
N
Y
TURN OR TEND ?
Y
BTOTL = DTOTL + PWCCD (PTR4D+1) COMPUTE SDC
N
COMPUTE SDC
GUID3D ON?
GD3D
N
HVG6
RETURN


GD3D
INITIALIZE 3D GUIDANCE VARIABLES
PTR3D = PTR4D
COMPUTE HDIS
RETURN

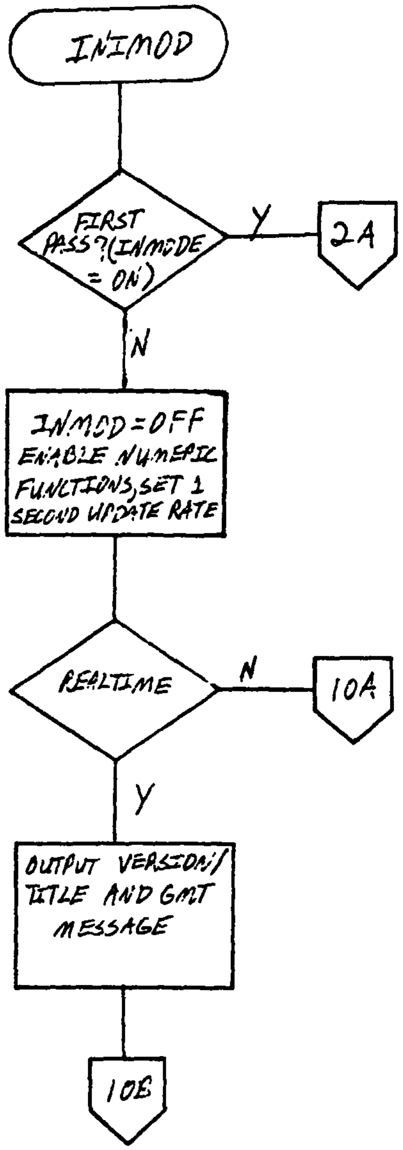

HVG6
AUTOE ON?
KH = .000625
KHD = .05
KH = .09
KHD = .6
LHDC = 50*
KHD
COMPUTE FPA
AND HEIGHT
COMPUTE HC
PTR4D = PTR3D
AND
DTOGO < HDIS
*
Y
N
UPDATE PTR3D
COMPUTE
NEXT HDIS
COMPUTE HDDC,
HER
SRLMT
(VERT_ SCRATCH)
(((GSFPS DTOR GAM (PTR3D)) - HDTC) KHI,2.0)
COMPUTE HDTC
PFPA,DFPA3D
VSTRA
HDTC = VERT_SCRATCH * DELTAT + HDTC
PFPA = (HDTC/GSFPS) RTOD
DFPA3D = PFPA-GAMMA
VSTRA = HDDC + (HER*KH) + (HDTC*KHD)
2A

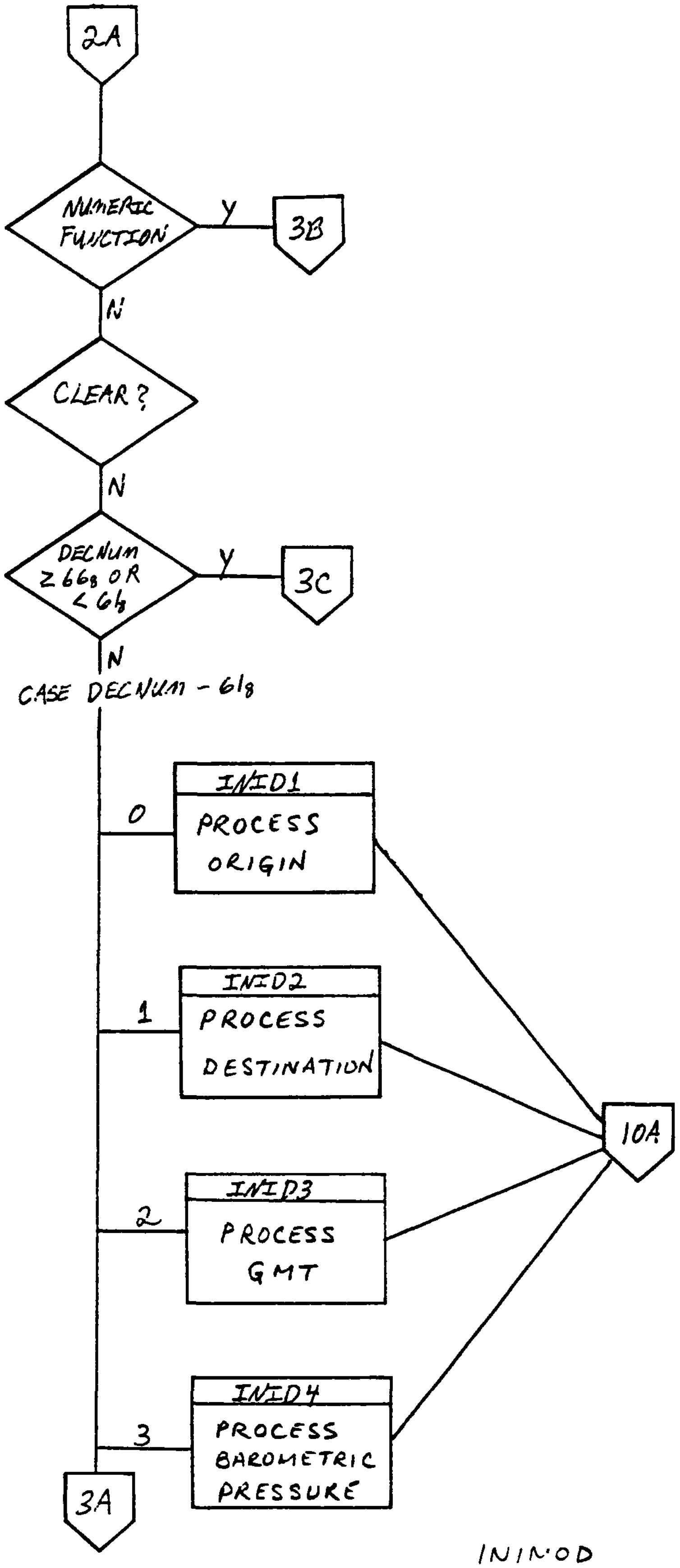

2A
SRLMT
VERT_SCRATCH
(VSTRA,LHDC)
VERT_SCRATCH
> = 0?
Y
N
VERT_SCRATCH =
KALFA*
VERT_SCRATCH
VSTRB = KHD*
HDCF
VERSTR =
VERT_SCRATCH-
VSTRB
RETURN


ILSRC
IS MASTER INHIBIT OR TEST COMPLETE OR < 1.25 SEC ?
YES
LOC FREQ SELECTED ?
NO
OUTPUT "RCVR NOT TUNED" MESSAGE USING FMTMG
EXACTLY 8.0 SECONDS SINCE START ?
NO
LOC VALID ?
NO
LOG "LOCVLD MISSING" FAIL USING DSTOR
GS VALID ?
NO
LOG "GSVLD MISSING" FAIL USING DSTOR
LOC VALID ?
NO
IS .8911 ≤ LOCDEV ≤ 1.074 ?
NO
LOG FAILURE DISPLAY LOCDEV X1000 IN ERROR MESSAGE USING DSTOR
IS .3274 ≤ GSDEV ≤ .4126
NO
LOG FAILURE DISPLAY GSDEV X1000 IN ERROR MESSAGE USING DSTOR
DESTIMULATE SELF-TEST
RETURN

ISLRC
(PAGE 1 OF 1)

ORIGINAL PAGE IS
OF POOR QUALITY


INIMOD
FIRST PASS?(INMODE = ON)
Y
2A
N
INMOD=OFF ENABLE NUMERIC FUNCTIONS,SET 1 SECOND UPDATE RATE
REALTIME
N
10A
Y
OUTPUT VERSION/ TITLE AND GMT MESSAGE
10B



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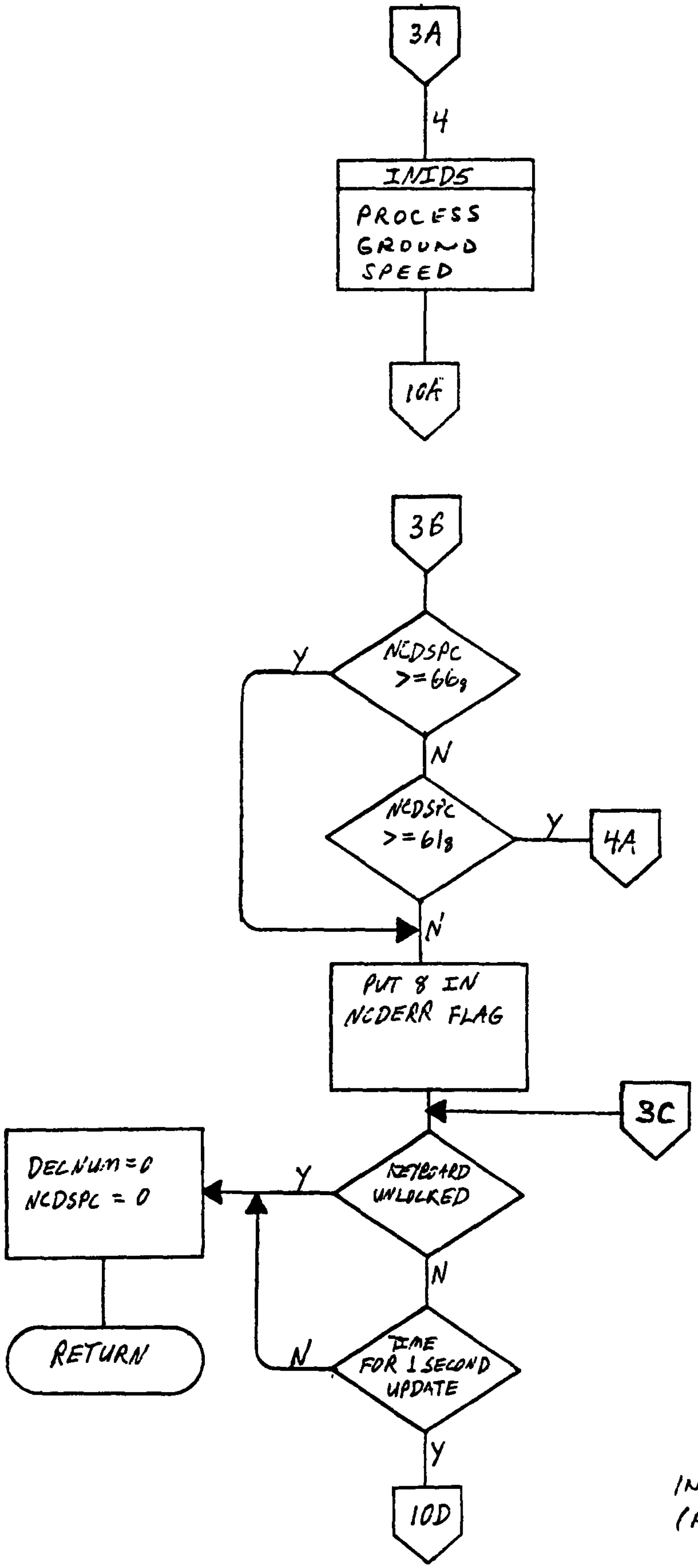

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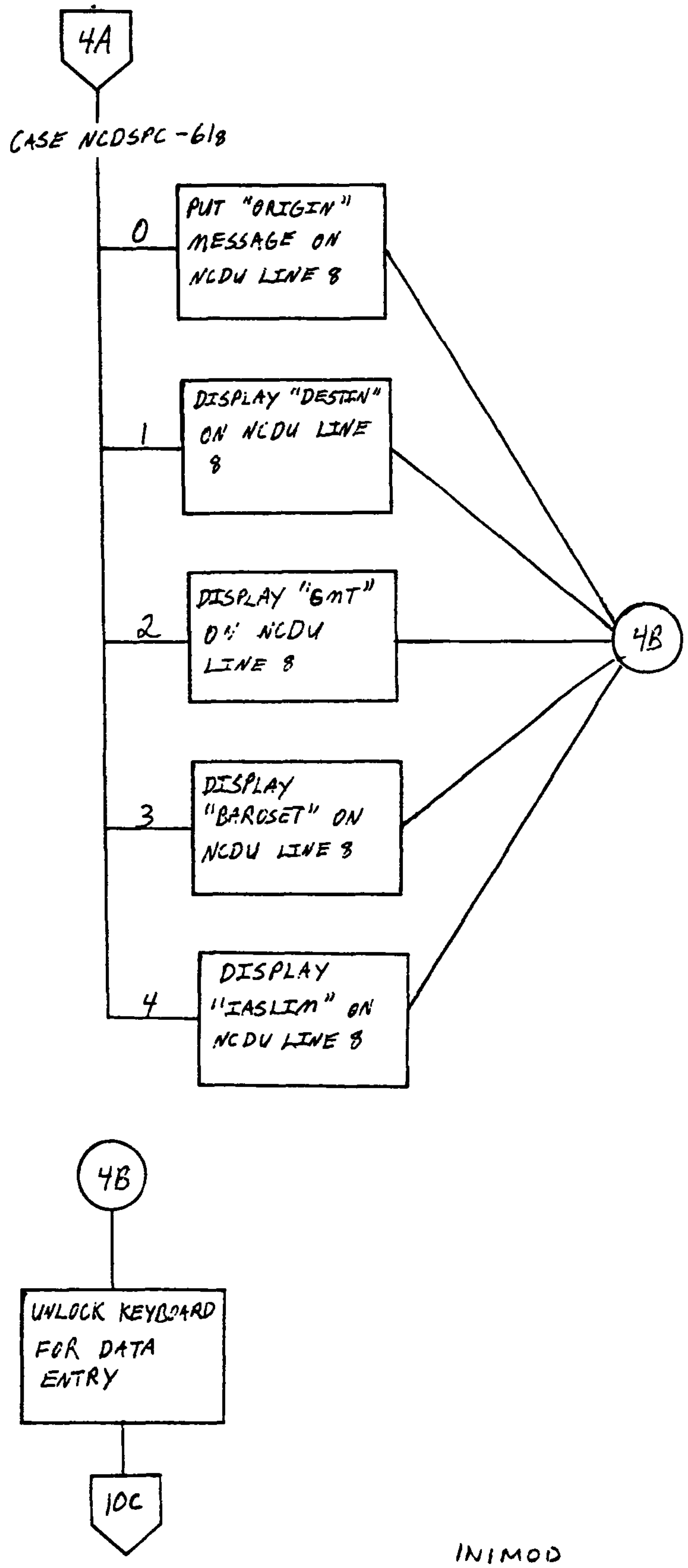
4A
CASE NCDSPC -61₈
0
PUT "ORIGIN" MESSAGE ON NCDU LINE 8
1
DISPLAY "DESTIN" ON NCDU LINE 8
2
DISPLAY "GMT" ON NCDU LINE 8
3
DISPLAY "BAROSET" ON NCDU LINE 8
4
DISPLAY "IASLIM" ON NCDU LINE 8
4B
4B
UNLOCK KEYBOARD FOR DATA ENTRY
10C

INIMOD
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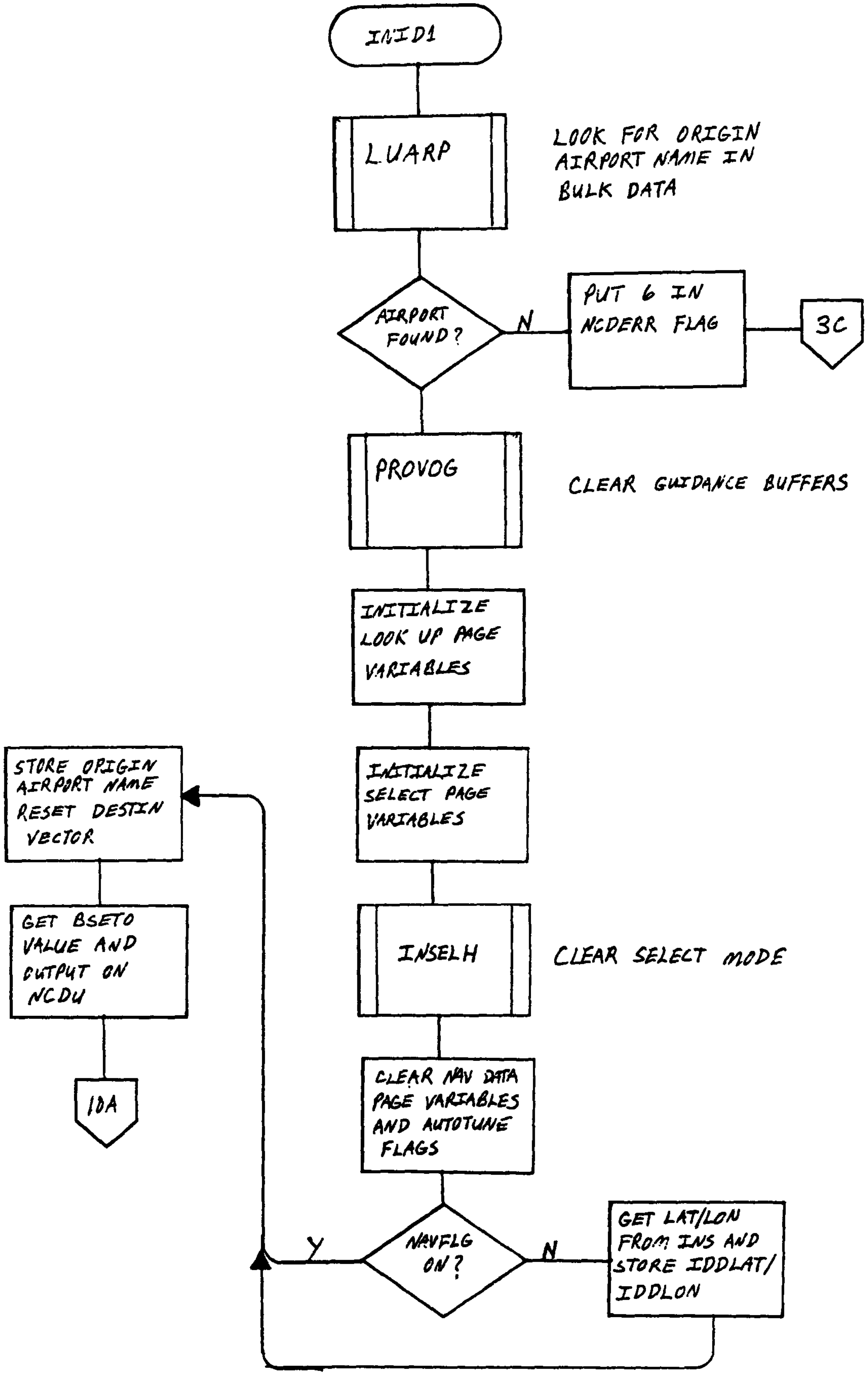
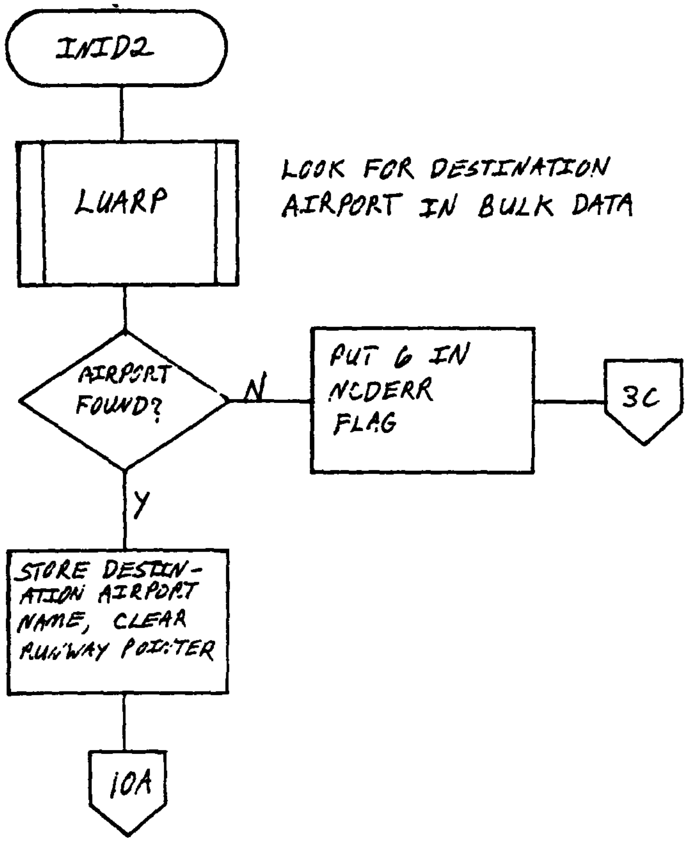
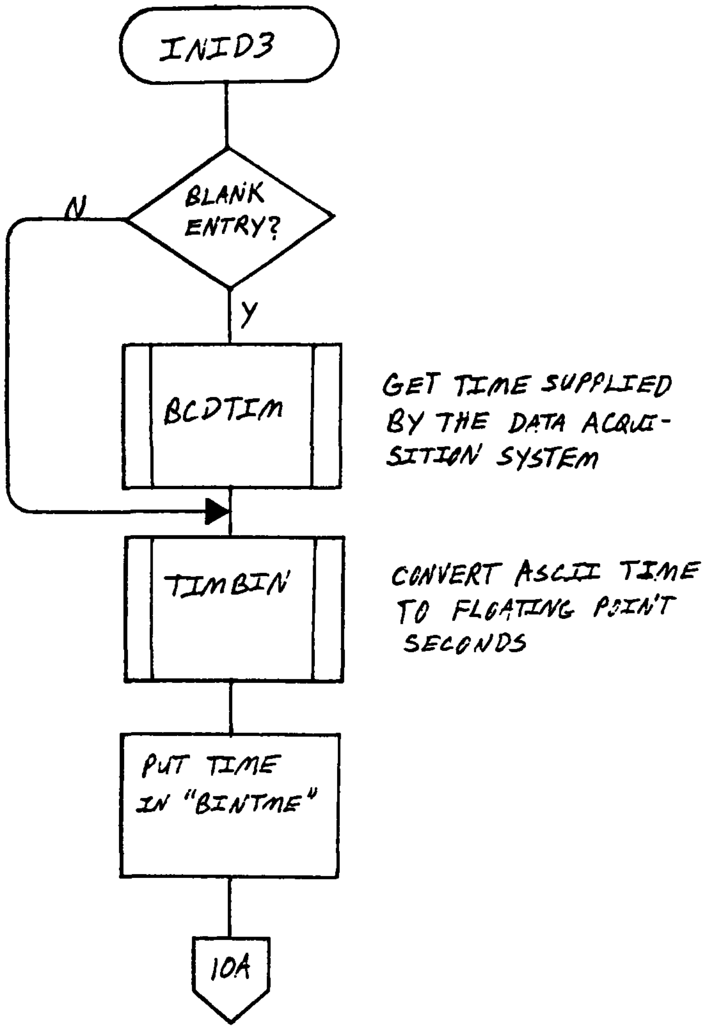
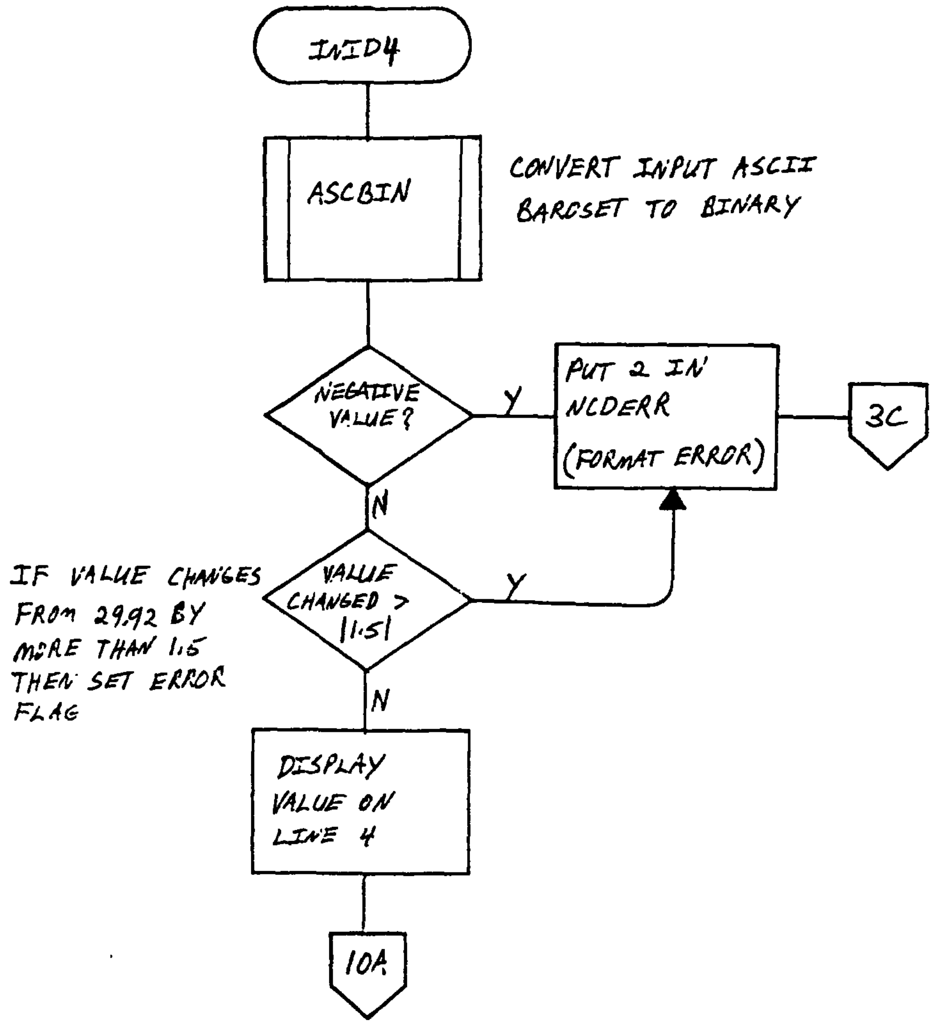

INID1
LUARP
LOOK FOR ORIGIN AIRPORT NAME IN BULK DATA
AIRPORT FOUND?
N
PUT 6 IN NCDERR FLAG
3C
PROVOG
CLEAR GUIDANCE BUFFERS
INITIALIZE LOOK UP PAGE VARIABLES
INITIALIZE SELECT PAGE VARIABLES
INSELH
CLEAR SELECT MODE
CLEAR NAV DATA PAGE VARIABLES AND AUTOTUNE FLAGS
NAVFLG ON?
Y
N
GET LAT/LON FROM INS AND STORE IDDLAT/IDDLON
STORE ORIGIN AIRPORT NAME RESET DESTIN VECTOR
GET BSETO VALUE AND OUTPUT ON NCDU
IDA

INIMOD
(PAGE 5 OF 10)

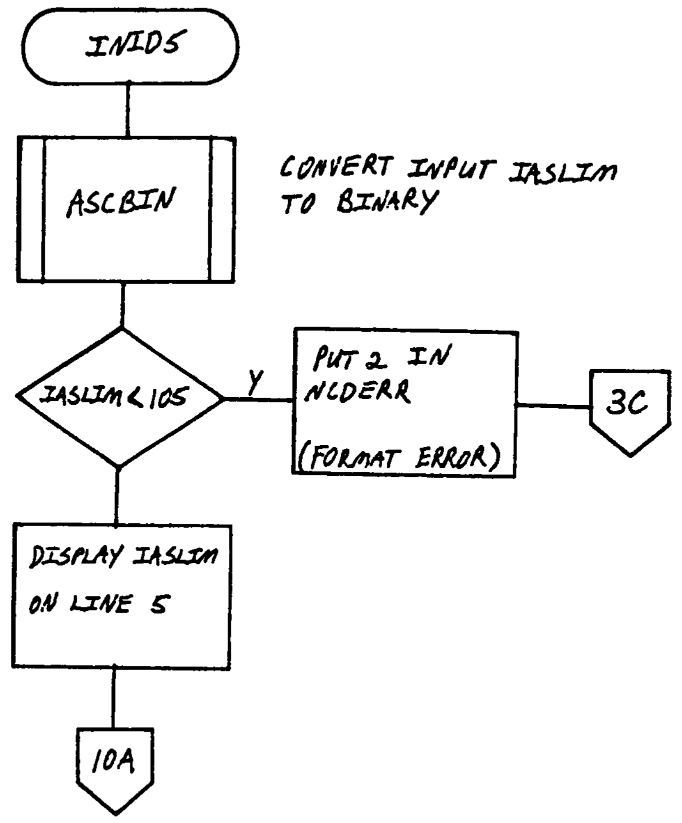

INID2
LUARP
LOOK FOR DESTINATION AIRPORT IN BULK DATA
AIRPORT FOUND?
N
PUT 6 IN NCDERR FLAG
3C
Y
STORE DESTIN-ATION AIRPORT NAME, CLEAR RUNWAY POINTER
10A


INID3
BLANK ENTRY?
N
Y
BCDTIM
GET TIME SUPPLIED BY THE DATA ACQUISITION SYSTEM
TIMBIN
CONVERT ASCII TIME TO FLOATING POINT SECONDS
PUT TIME IN "BINTME"
10A

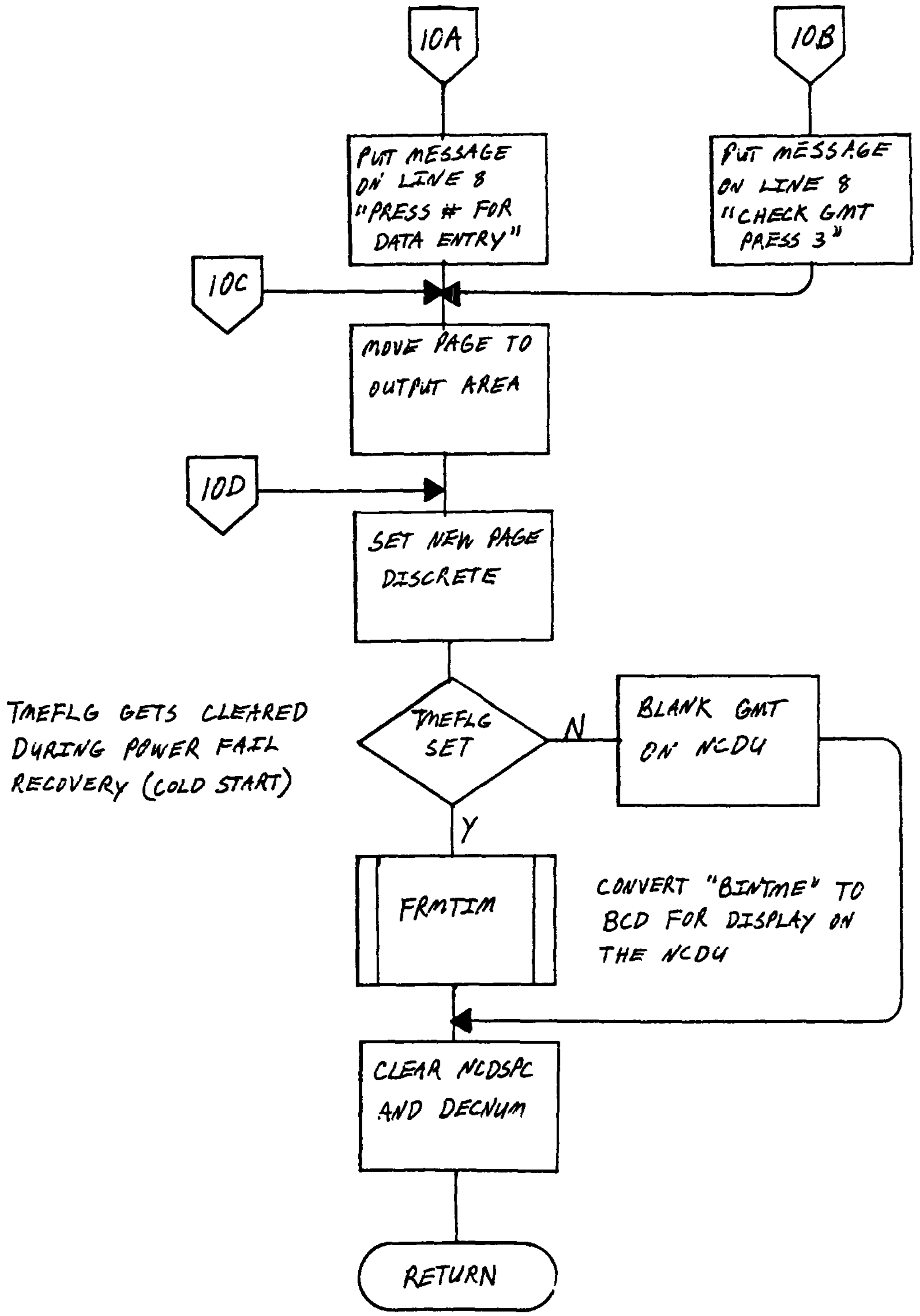
INIMOD
(PAGE 7 OF 10)

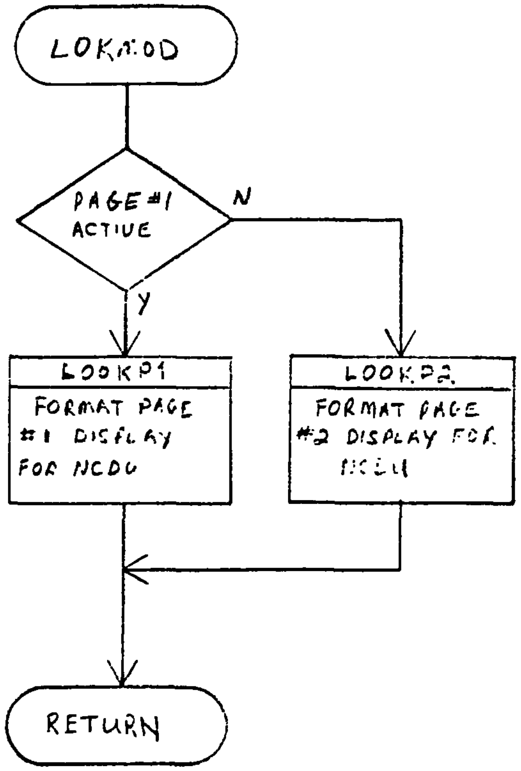

INID4
ASCBIN
CONVERT INPUT ASCII BAROSET TO BINARY
NEGATIVE VALUE?
Y
PUT 2 IN NCDERR (FORMAT ERROR)
3C
N
IF VALUE CHANGES FROM 29.92 BY MORE THAN 1.5 THEN SET ERROR FLAG
VALUE CHANGED > |1.5|
Y
N
DISPLAY VALUE ON LINE 4
10A

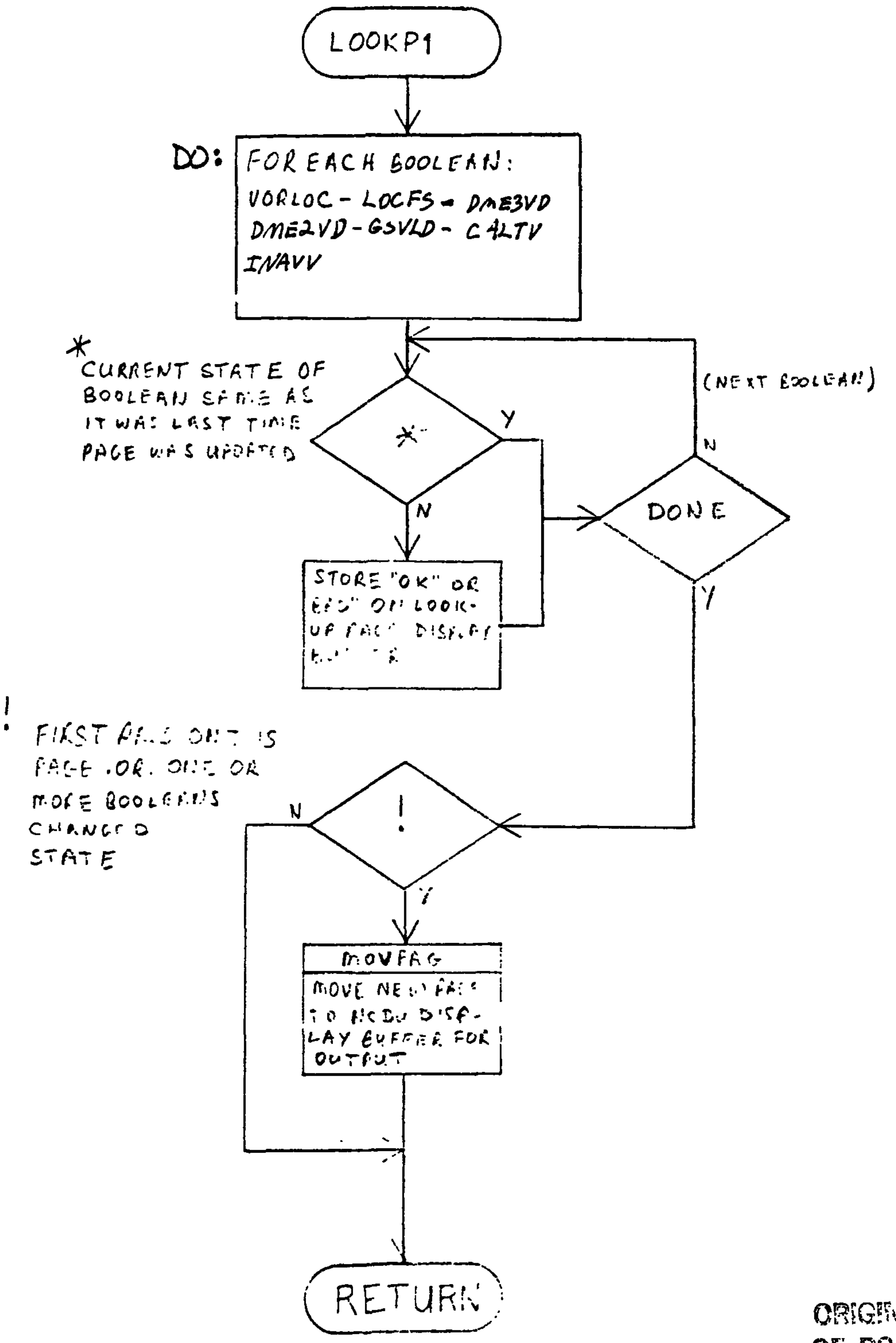
INIMOD
(PAGE 8 OF 10)



INIMOD
(PAGE 9 OF 10)

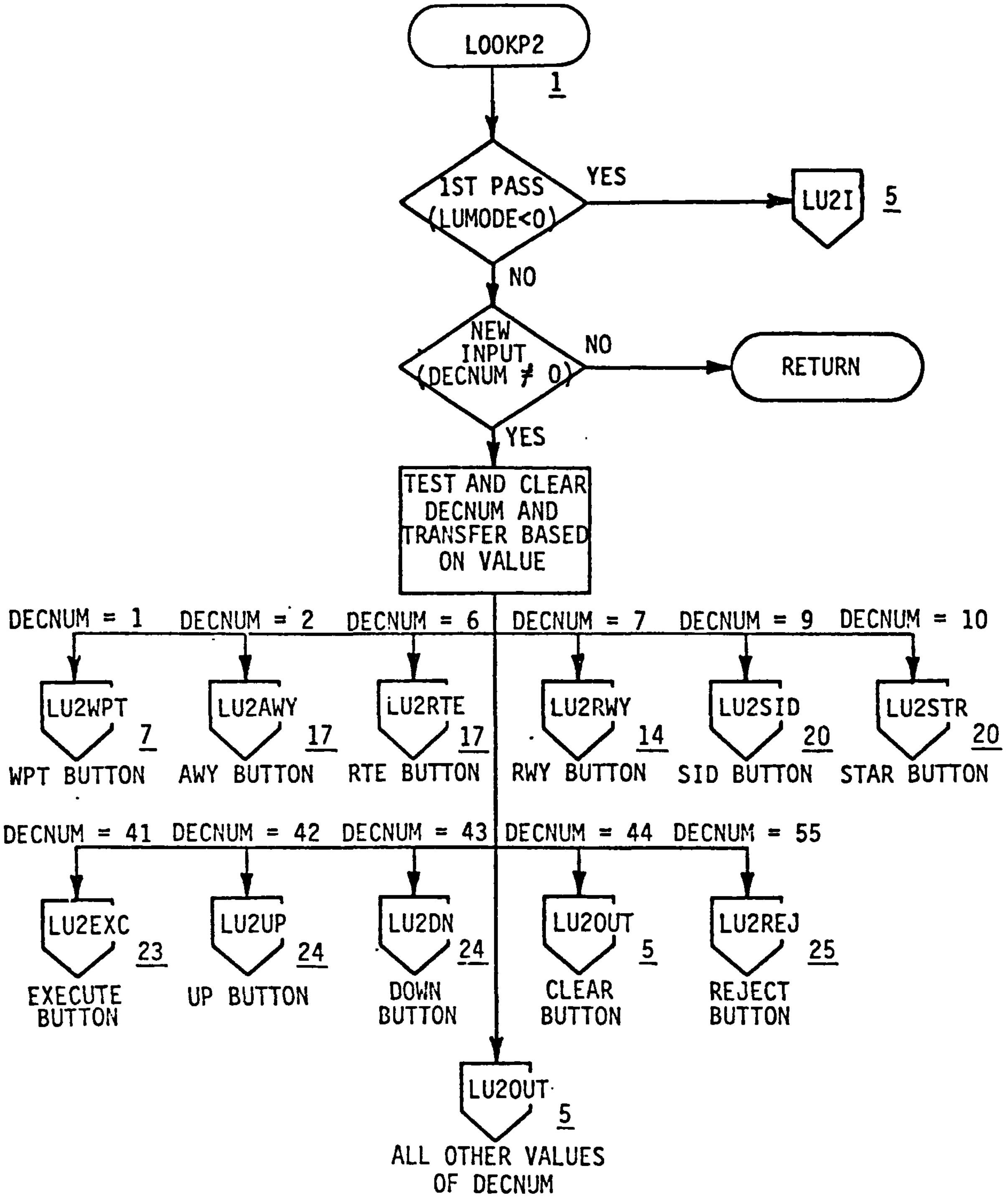

10A
10B
PUT MESSAGE ON LINE 8 "PRESS # FOR DATA ENTRY"
PUT MESSAGE ON LINE 8 "CHECK GMT PRESS 3"
10C
MOVE PAGE TO OUTPUT AREA
10D
SET NEW PAGE DISCRETE
TMEFLG GETS CLEARED DURING POWER FAIL RECOVERY (COLD START)
TMEFLG SET
N
BLANK GMT ON NCDU
Y
FRMTIM
CONVERT "BINTME" TO BCD FOR DISPLAY ON THE NCDU
CLEAR NCDSPC AND DECNUM
RETURN


LOKMOD
PAGE #1 ACTIVE
N
Y
LOOKP1
FORMAT PAGE #1 DISPLAY FOR NCDU
LOOKP2
FORMAT PAGE #2 DISPLAY FOR NCDU
RETURN


LOOKP1
DO:
FOR EACH BOOLEAN:
VORLOC - LOCFS - DME3VD
DME2VD - GSVLD - C4LTV
INAVV
*
CURRENT STATE OF
BOOLEAN SAME AS
IT WAS LAST TIME
PAGE WAS UPDATED
*
Y
N
(NEXT BOOLEAN)
N
DONE
Y
STORE "OK" OR
"BAD" ON LOOK-
UP PAGE DISPLAY
BUFFER
!
FIRST PASS ONTO
PAGE .OR. ONE OR
MORE BOOLEANS
CHANGED
STATE
!
N
Y
MOVPAG
MOVE NEW PAGE
TO MCDU DISP-
LAY BUFFER FOR
OUTPUT
RETURN

THIS PAGE INTENTIONALLY

LEFT BLANK



LOKMOD
(PAGE 4 OF 32)

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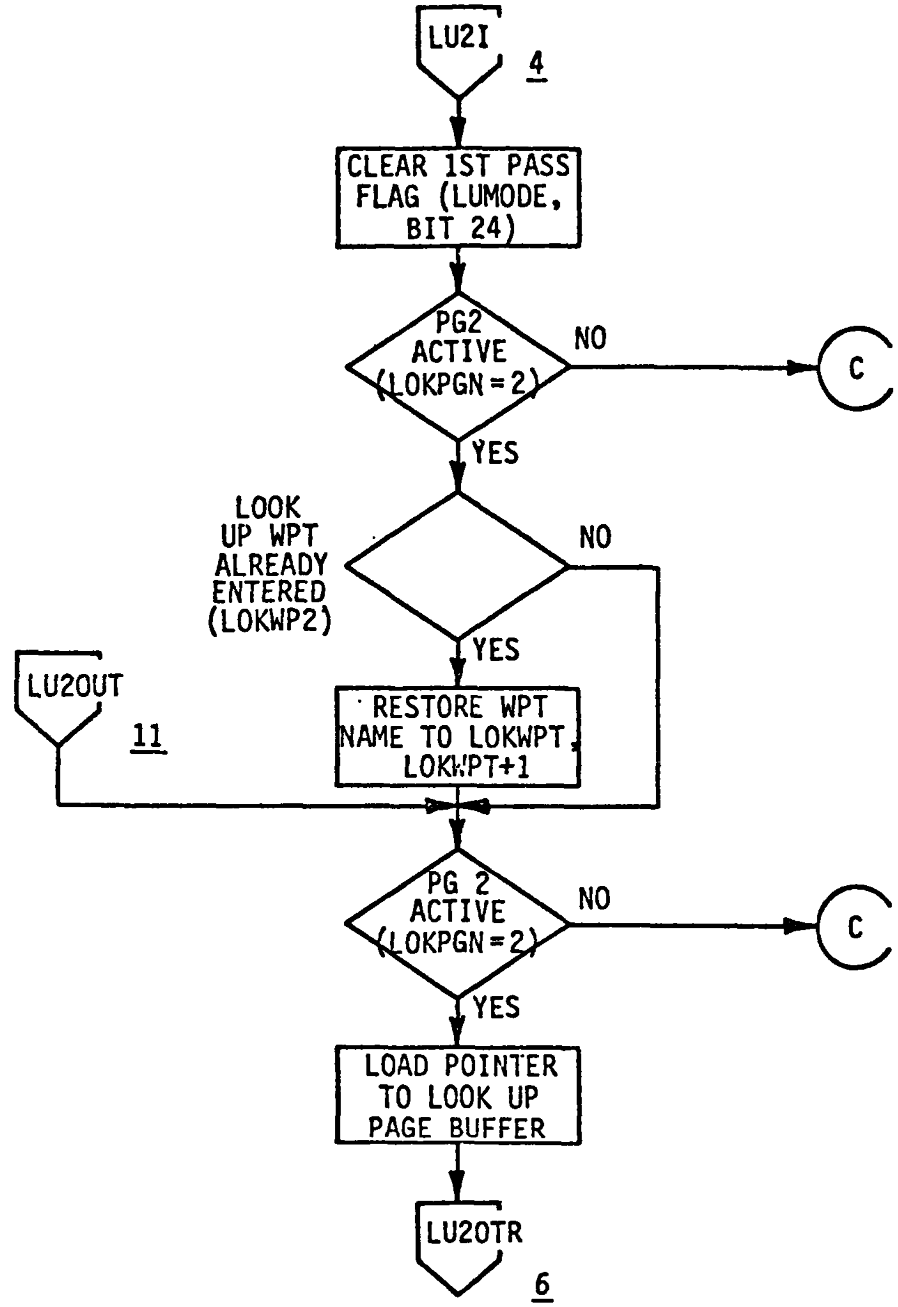
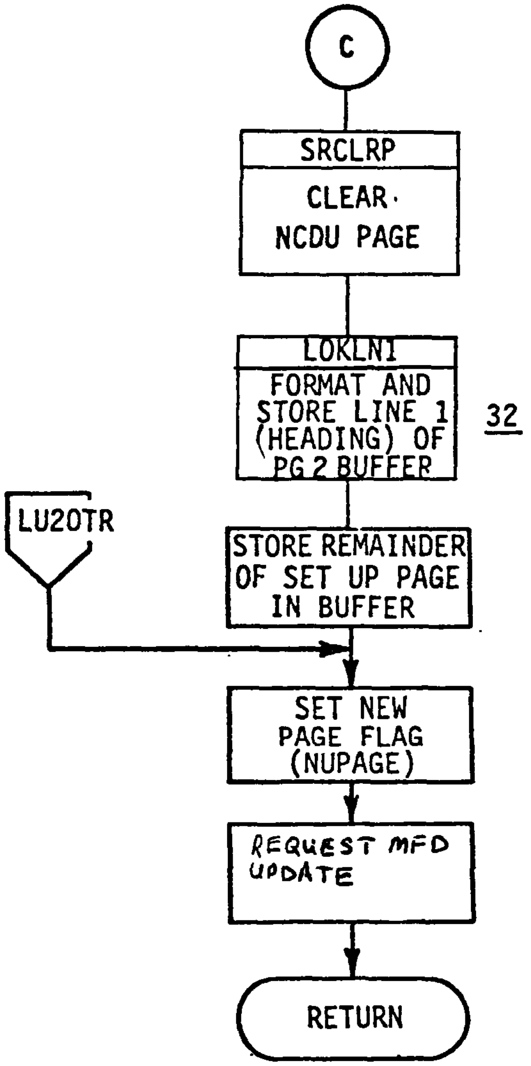
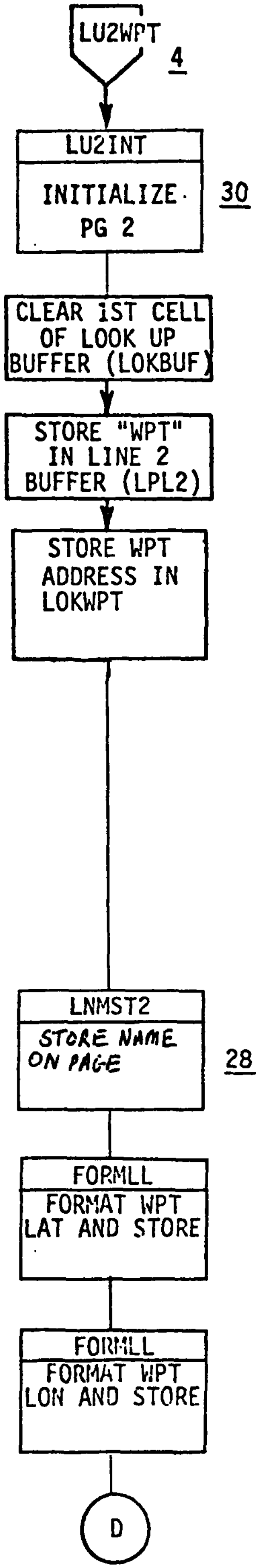
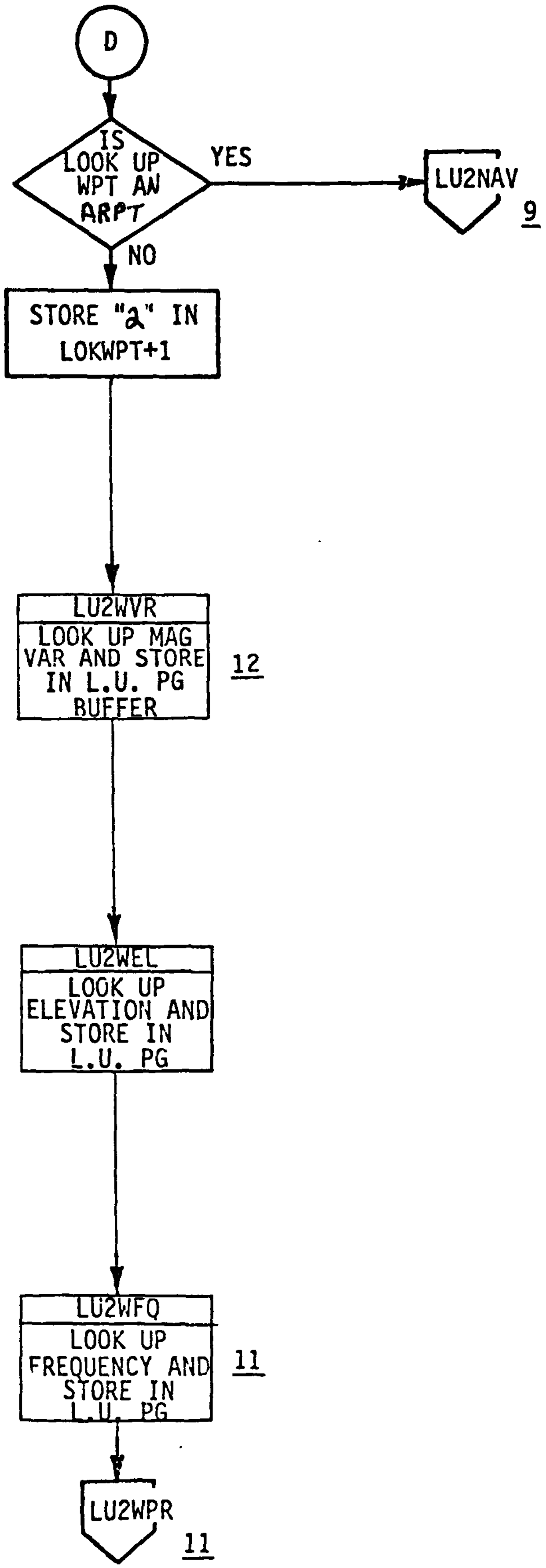
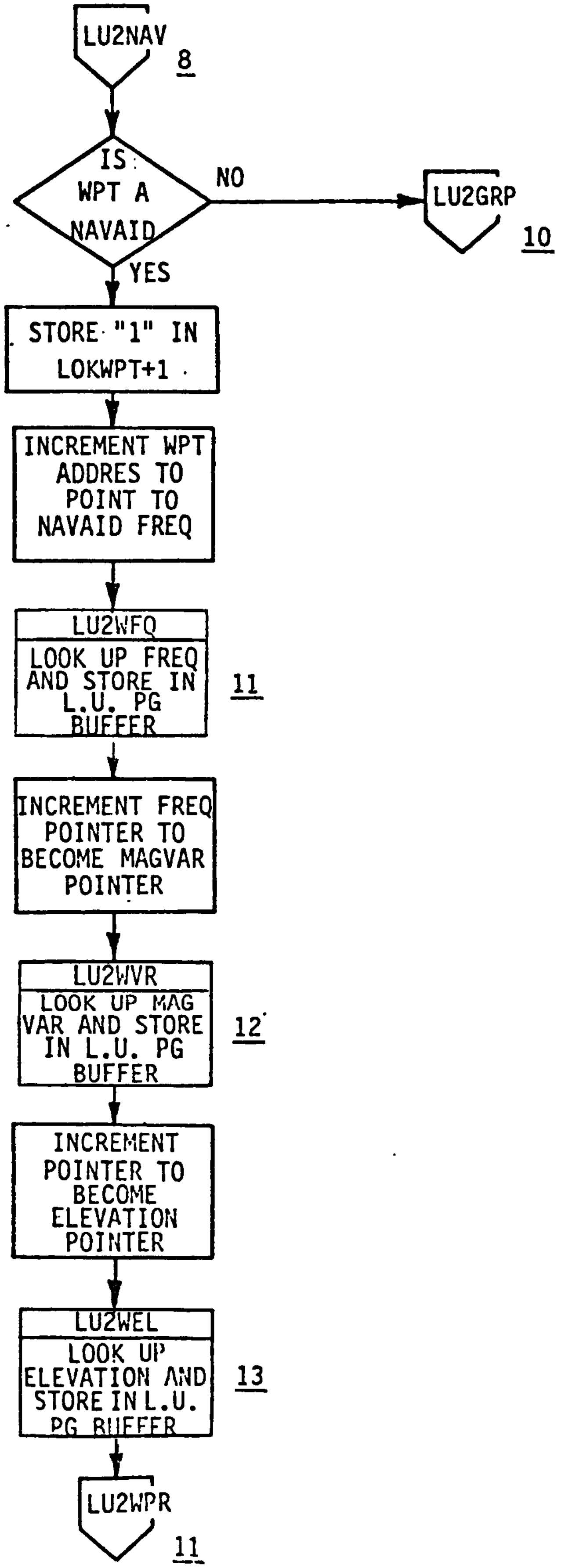
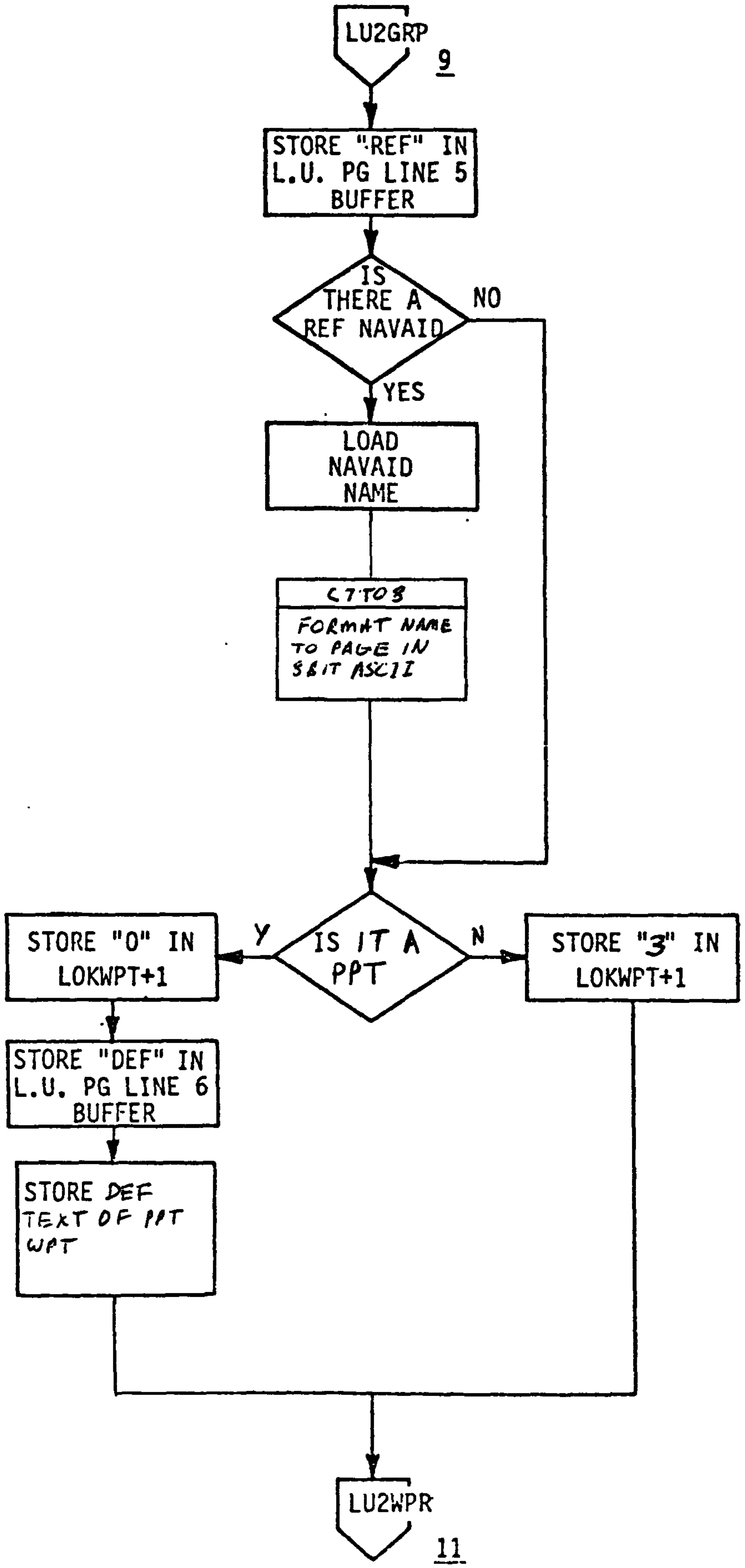

LU2I
4
CLEAR 1ST PASS FLAG (LUMODE, BIT 24)
PG2 ACTIVE (LOKPGN=2)
NO
C
YES
LOOK UP WPT ALREADY ENTERED (LOKWP2)
NO
YES
LU2OUT
11
RESTORE WPT NAME TO LOKWPT, LOKWPT+1
PG 2 ACTIVE (LOKPGN=2)
NO
C
YES
LOAD POINTER TO LOOK UP PAGE BUFFER
LU2OTR
6

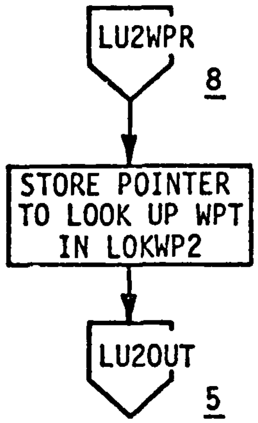

C
SRCLRP
CLEAR
NCDU PAGE
LOKLN1
FORMAT AND
STORE LINE 1
(HEADING) OF
PG 2 BUFFER
32
LU2OTR
STORE REMAINDER
OF SET UP PAGE
IN BUFFER
SET NEW
PAGE FLAG
(NUPAGE)
REQUEST MFD
UPDATE
RETURN

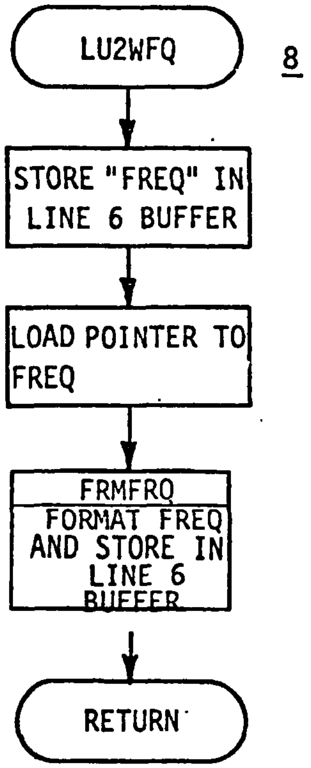

LU2WPT
4
LU2INT
INITIALIZE PG 2
30
CLEAR 1ST CELL OF LOOK UP BUFFER (LOKBUF)
STORE "WPT" IN LINE 2 BUFFER (LPL2)
STORE WPT ADDRESS IN LOKWPT
LNMST2
STORE NAME ON PAGE
28
FORMLL
FORMAT WPT LAT AND STORE
FORMLL
FORMAT WPT LON AND STORE
D

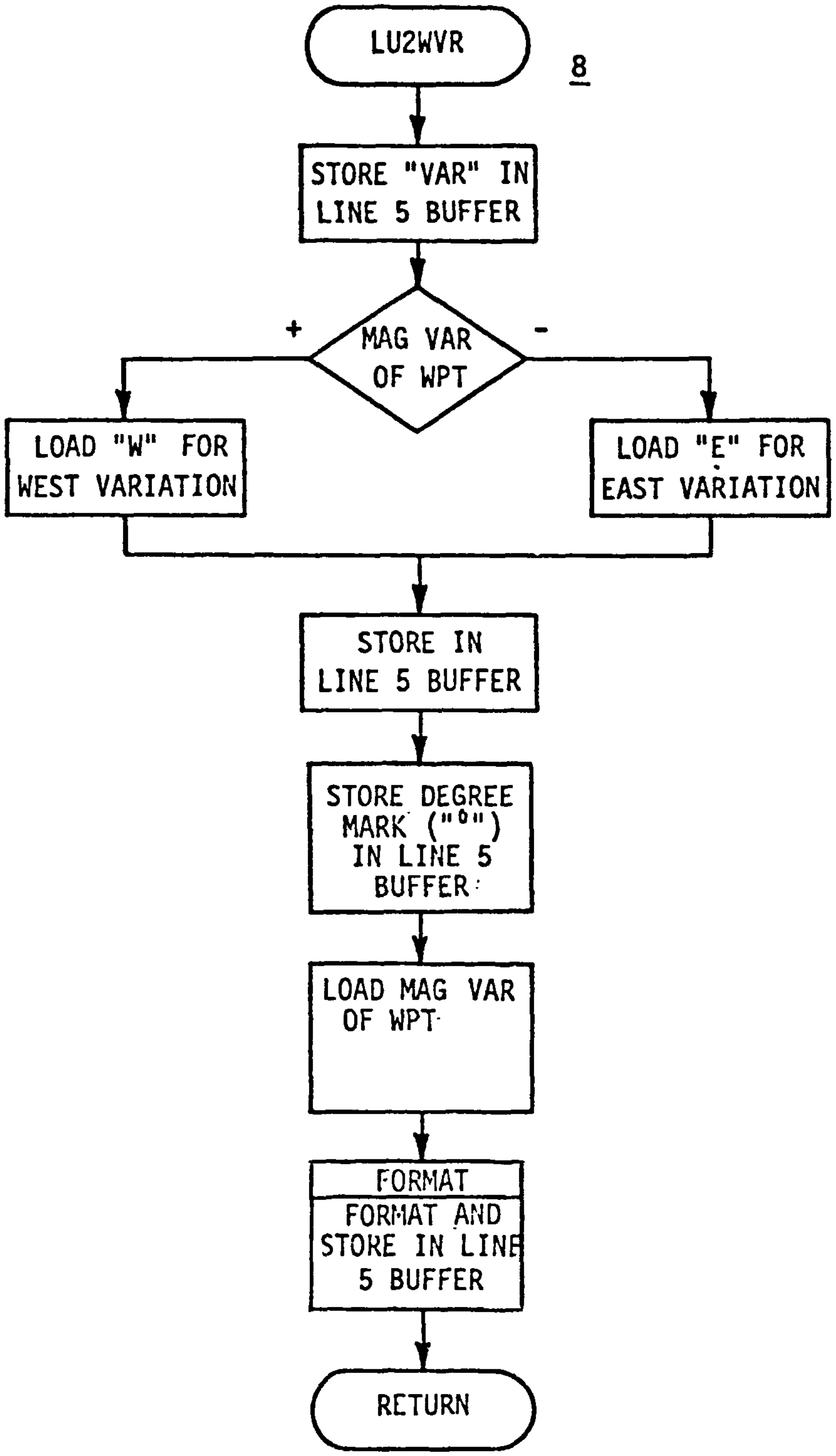

D
IS LOOK UP WPT AN ARPT
YES
NO
LU2NAV
9
STORE "2" IN LOKWPT+1
LU2WVR
LOOK UP MAG VAR AND STORE IN L.U. PG BUFFER
12
LU2WEL
LOOK UP ELEVATION AND STORE IN L.U. PG
LU2WFQ
LOOK UP FREQUENCY AND STORE IN L.U. PG
11
LU2WPR
11

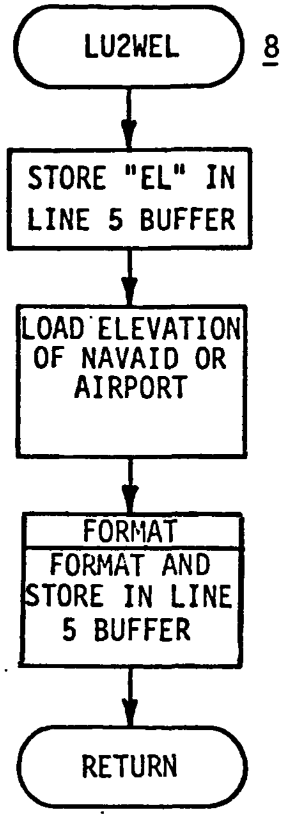

LU2NAV
8
IS WPT A NAVAID
NO
LU2GRP
10
YES
STORE "1" IN LOKWPT+1
INCREMENT WPT ADDRES TO POINT TO NAVAID FREQ
LU2WFQ
LOOK UP FREQ AND STORE IN L.U. PG BUFFER
11
INCREMENT FREQ POINTER TO BECOME MAGVAR POINTER
LU2WVR
LOOK UP MAG VAR AND STORE IN L.U. PG BUFFER
12
INCREMENT POINTER TO BECOME ELEVATION POINTER
LU2WEL
LOOK UP ELEVATION AND STORE IN L.U. PG BUFFER
13
LU2WPR
11

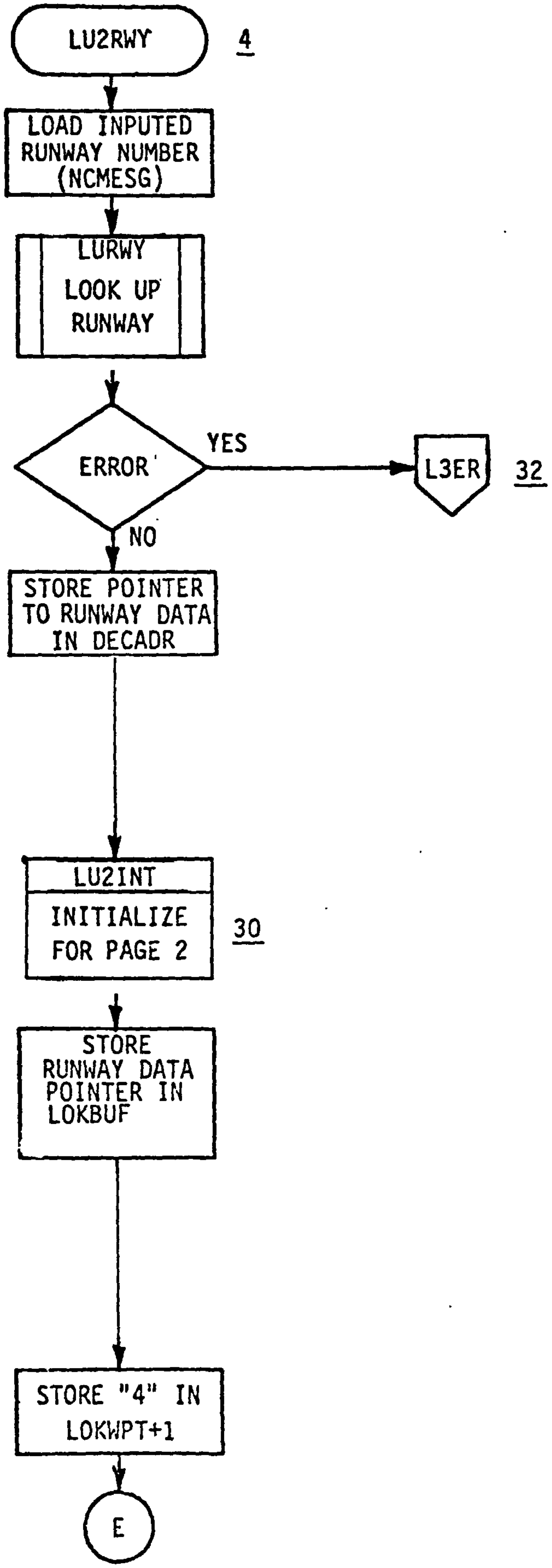

LU2GRP
9
STORE "REF" IN L.U. PG LINE 5 BUFFER
IS THERE A REF NAVAID
NO
YES
LOAD NAVAID NAME
C7TO8
FORMAT NAME TO PAGE IN 8BIT ASCII
Y
IS IT A PPT
N
STORE "0" IN LOKWPT+1
STORE "3" IN LOKWPT+1
STORE "DEF" IN L.U. PG LINE 6 BUFFER
STORE DEF TEXT OF PPT WPT
LU2WPR
11

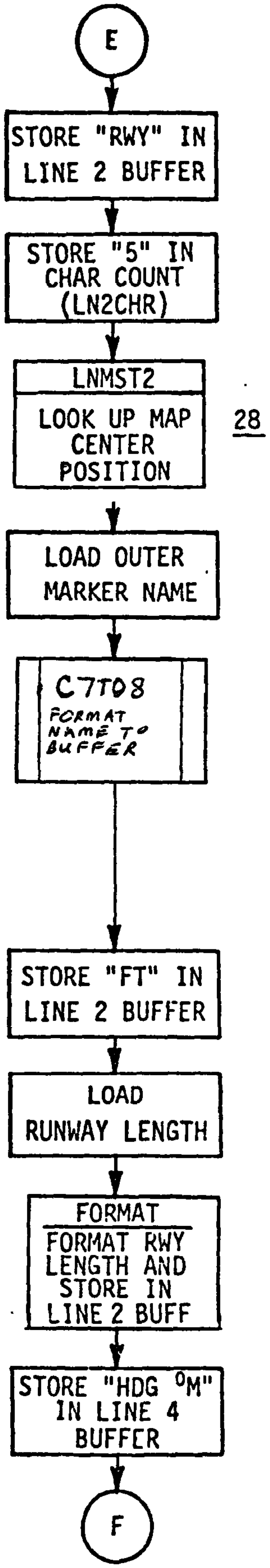

LU2WPR
8
STORE POINTER TO LOOK UP WPT IN LOKWP2
LU2OUT
5

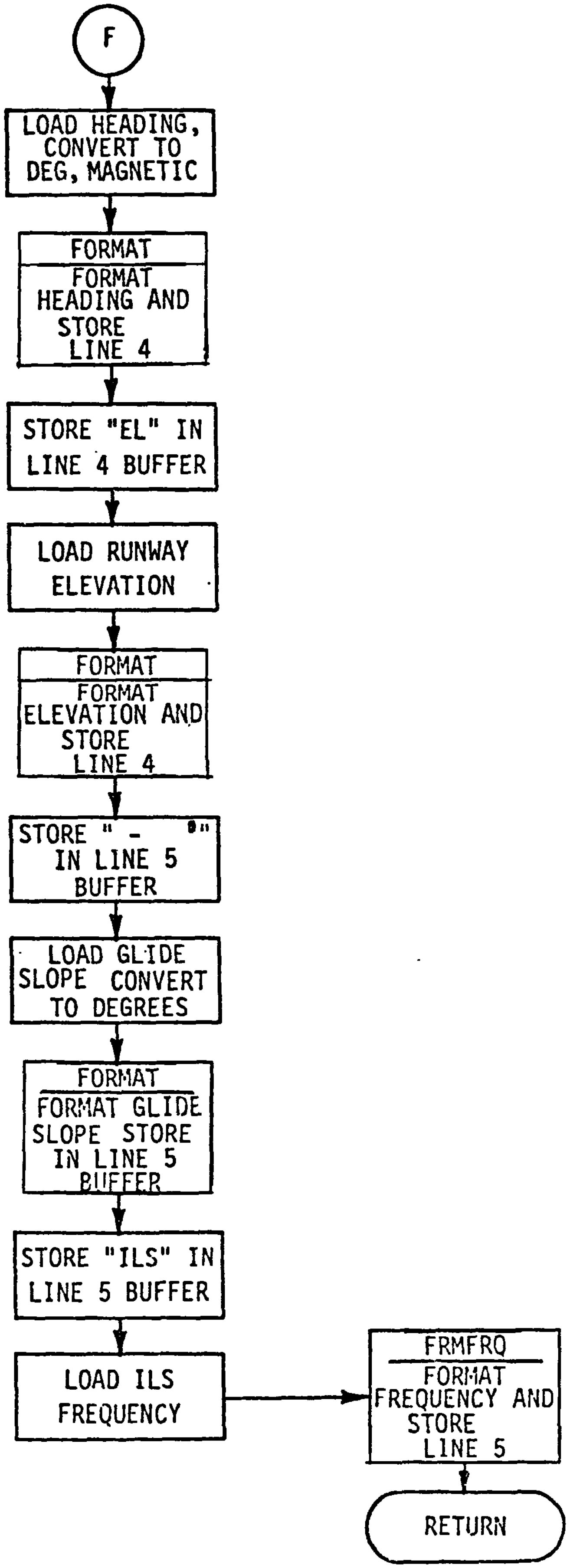

LU2WFQ
8
STORE "FREQ" IN LINE 6 BUFFER
LOAD POINTER TO FREQ
FRMFRQ
FORMAT FREQ AND STORE IN LINE 6 BUFFER
RETURN

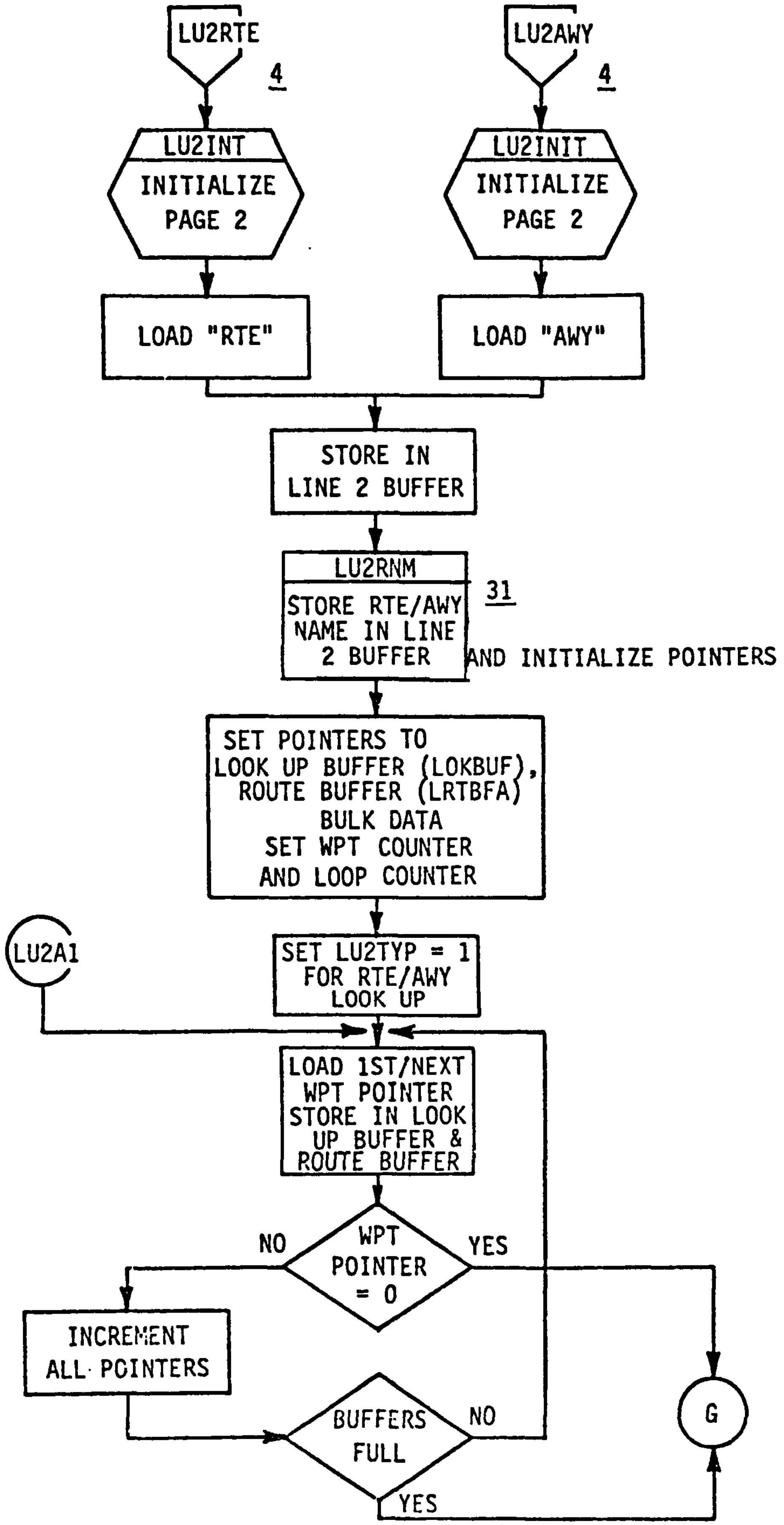

LU2WVR
8
STORE "VAR" IN LINE 5 BUFFER
MAG VAR OF WPT
+
-
LOAD "W" FOR WEST VARIATION
LOAD "E" FOR EAST VARIATION
STORE IN LINE 5 BUFFER
STORE DEGREE MARK ("°") IN LINE 5 BUFFER
LOAD MAG VAR OF WPT
FORMAT
FORMAT AND STORE IN LINE 5 BUFFER
RETURN

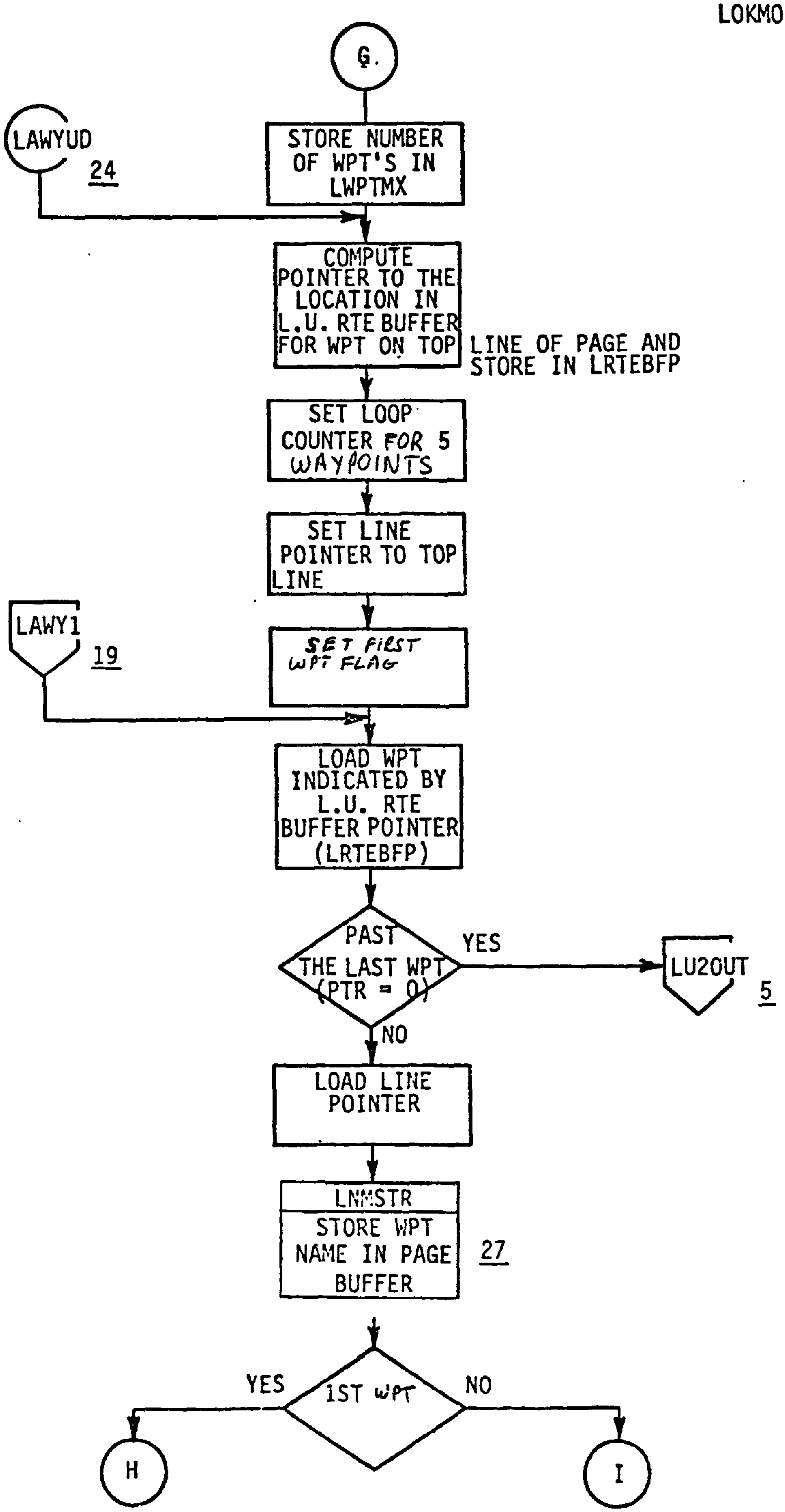

LU2WEL
8
STORE "EL" IN LINE 5 BUFFER
LOAD ELEVATION OF NAVAID OR AIRPORT
FORMAT
FORMAT AND STORE IN LINE 5 BUFFER
RETURN

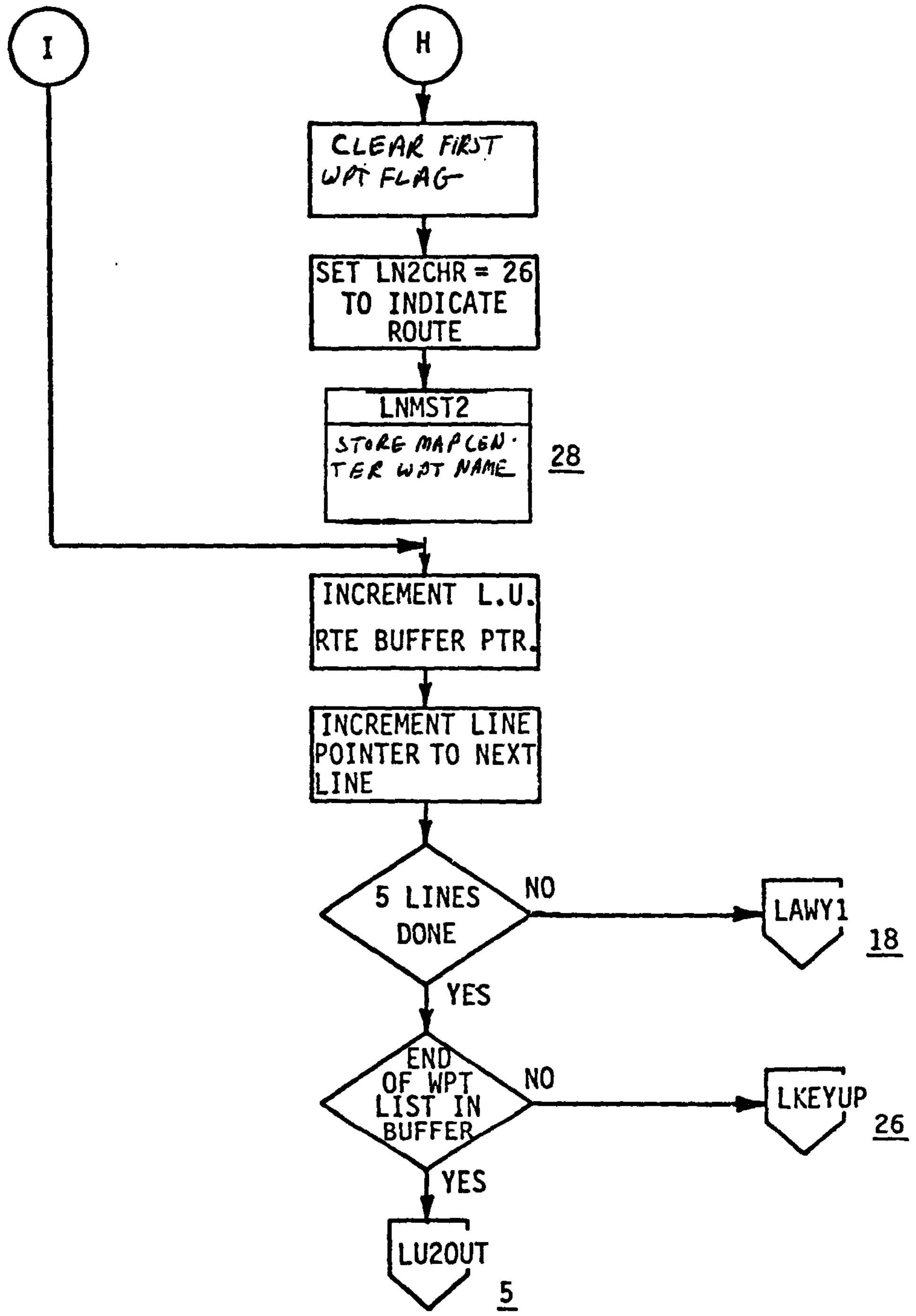

LU2RWY
4
LOAD INPUTED RUNWAY NUMBER (NCMESG)
LURWY
LOOK UP RUNWAY
ERROR
YES
L3ER
32
NO
STORE POINTER TO RUNWAY DATA IN DECADR
LU2INT
INITIALIZE FOR PAGE 2
30
STORE RUNWAY DATA POINTER IN LOKBUF
STORE "4" IN LOKWPT+1
E

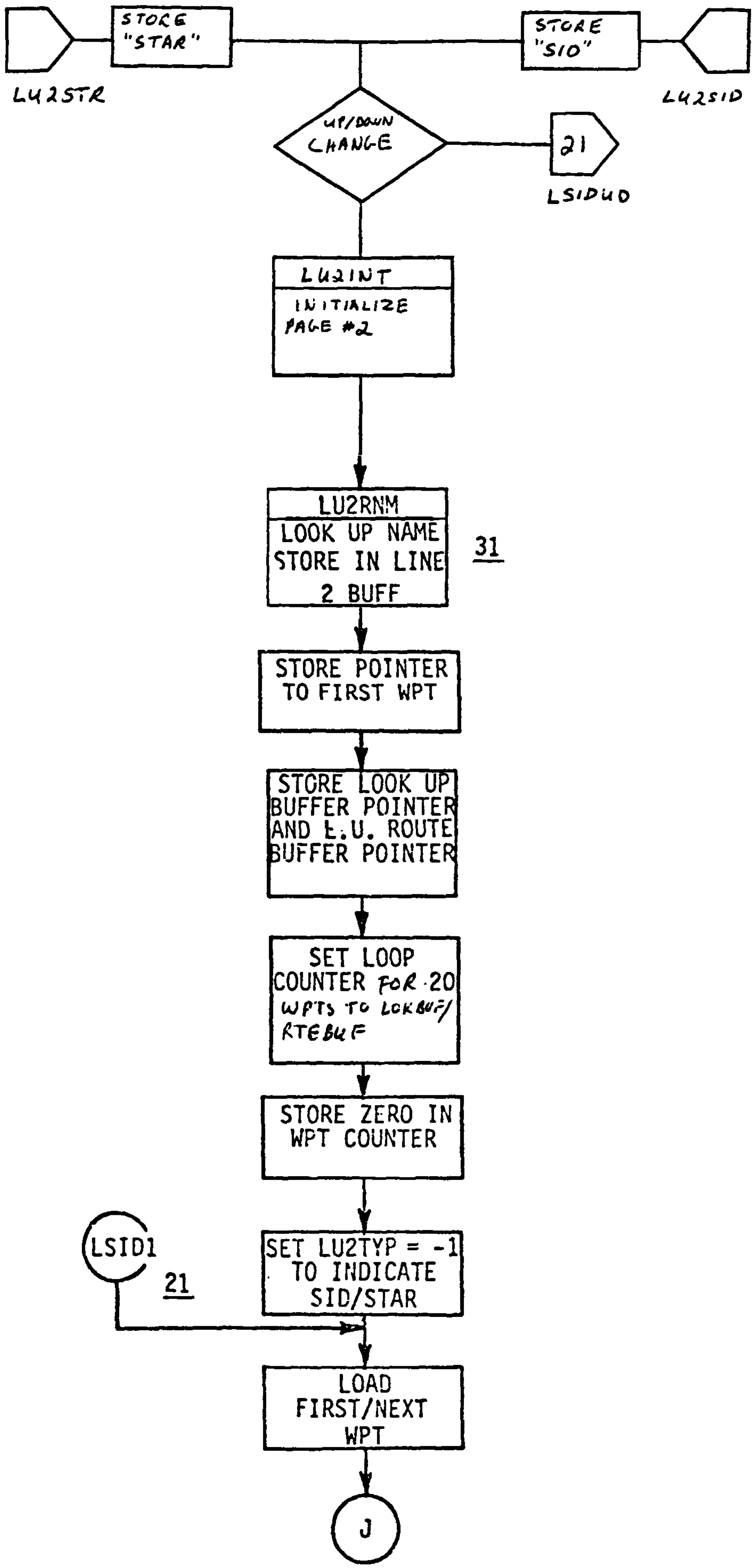

E
STORE "RWY" IN LINE 2 BUFFER
STORE "5" IN CHAR COUNT (LN2CHR)
LNMST2
LOOK UP MAP CENTER POSITION
28
LOAD OUTER MARKER NAME
C7T08
FORMAT NAME TO BUFFER
STORE "FT" IN LINE 2 BUFFER
LOAD RUNWAY LENGTH
FORMAT
FORMAT RWY LENGTH AND STORE IN LINE 2 BUFF
STORE "HDG °M" IN LINE 4 BUFFER
F

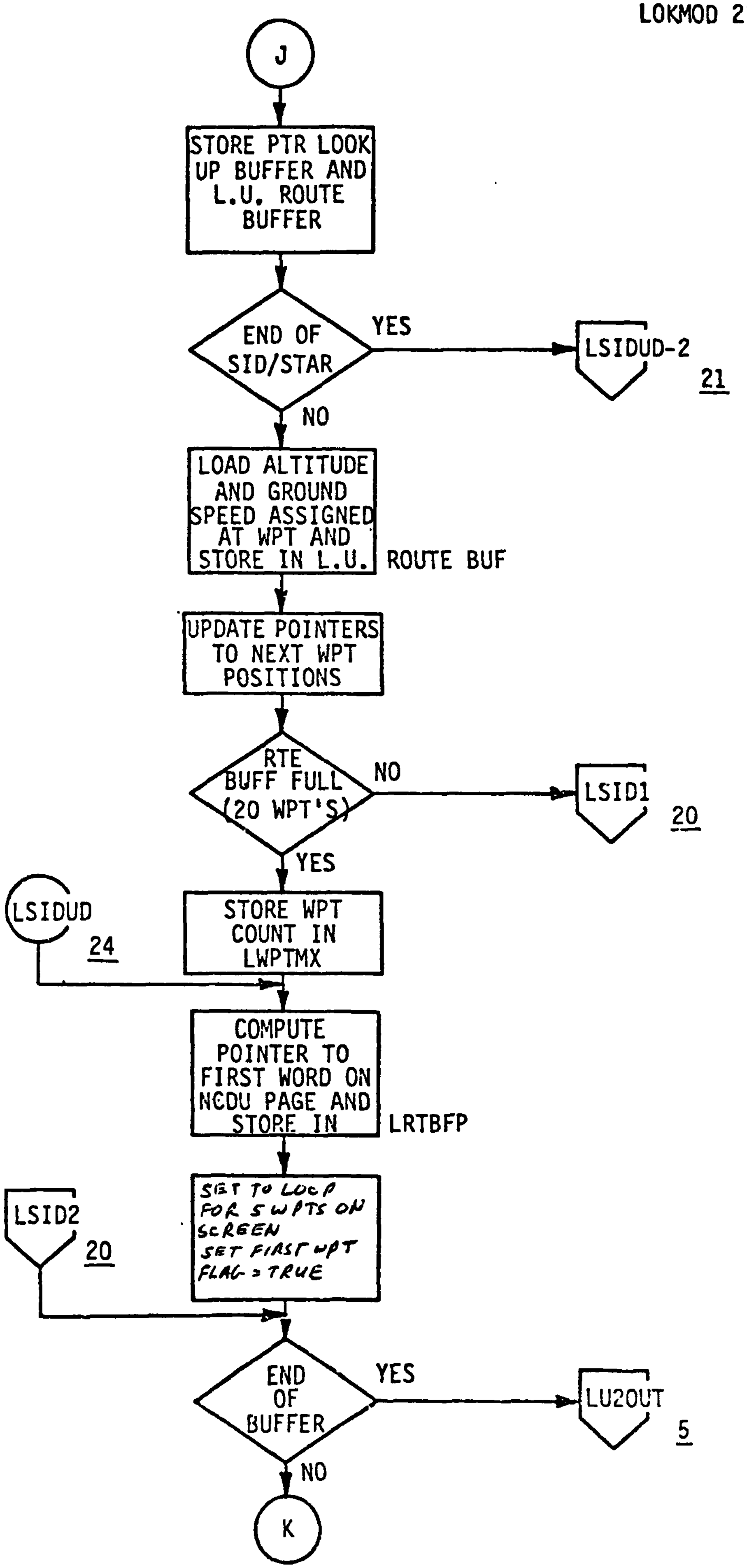

F
LOAD HEADING, CONVERT TO DEG, MAGNETIC
FORMAT
FORMAT HEADING AND STORE LINE 4
STORE "EL" IN LINE 4 BUFFER
LOAD RUNWAY ELEVATION
FORMAT
FORMAT ELEVATION AND STORE LINE 4
STORE " -   °" IN LINE 5 BUFFER
LOAD GLIDE SLOPE CONVERT TO DEGREES
FORMAT
FORMAT GLIDE SLOPE STORE IN LINE 5 BUFFER
STORE "ILS" IN LINE 5 BUFFER
LOAD ILS FREQUENCY
FRMFRQ
FORMAT FREQUENCY AND STORE LINE 5
RETURN

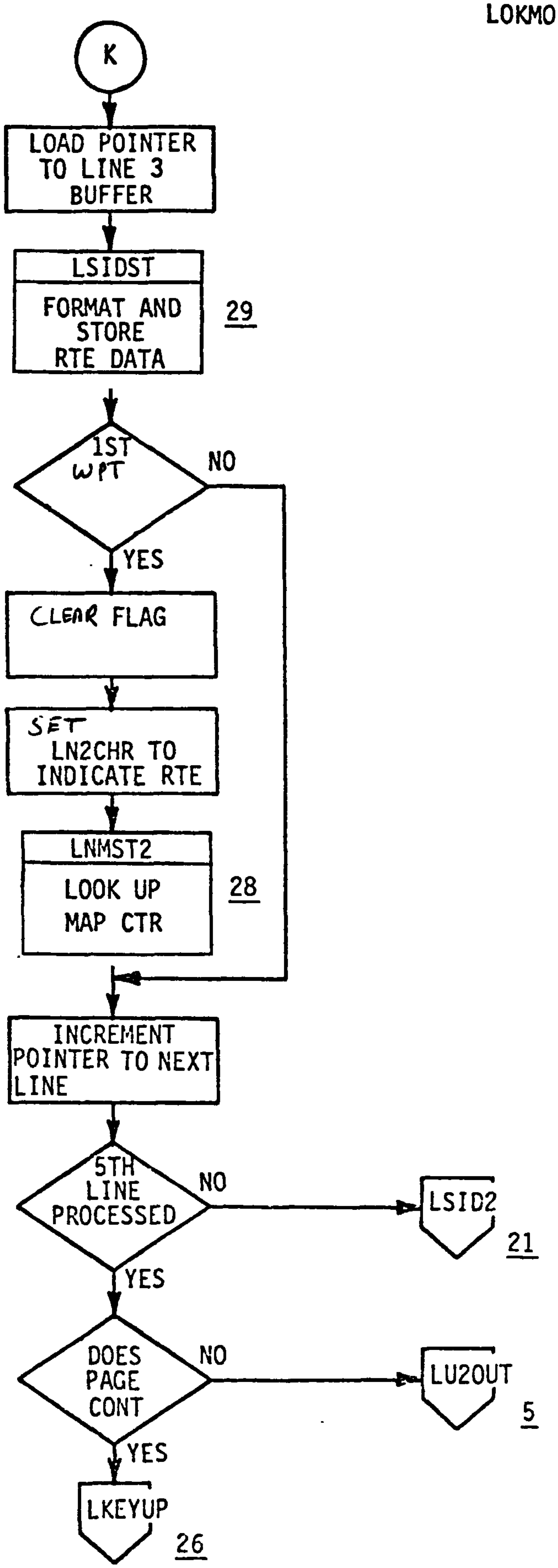

LU2RTE
4
LU2AWY
4
LU2INT
INITIALIZE PAGE 2
LU2INIT
INITIALIZE PAGE 2
LOAD "RTE"
LOAD "AWY"
STORE IN LINE 2 BUFFER
LU2RNM
31
STORE RTE/AWY NAME IN LINE 2 BUFFER AND INITIALIZE POINTERS
SET POINTERS TO LOOK UP BUFFER (LOKBUF), ROUTE BUFFER (LRTBFA) BULK DATA SET WPT COUNTER AND LOOP COUNTER
LU2A1
SET LU2TYP = 1 FOR RTE/AWY LOOK UP
LOAD 1ST/NEXT WPT POINTER STORE IN LOOK UP BUFFER & ROUTE BUFFER
WPT POINTER = 0
NO
YES
INCREMENT ALL POINTERS
BUFFERS FULL
NO
YES
G

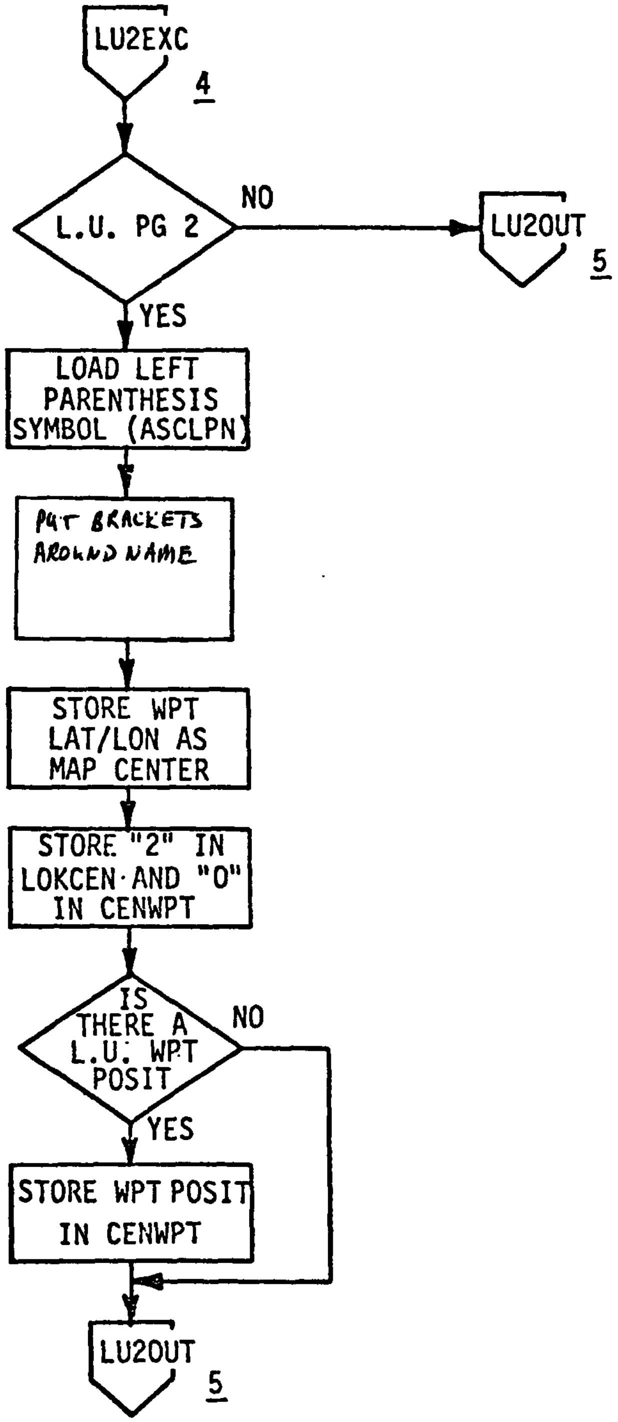

G.
LAWYUD
24
STORE NUMBER OF WPT'S IN LWPTMX
COMPUTE POINTER TO THE LOCATION IN L.U. RTE BUFFER FOR WPT ON TOP LINE OF PAGE AND STORE IN LRTEBFP
SET LOOP COUNTER FOR 5 WAYPOINTS
SET LINE POINTER TO TOP LINE
LAWY1
19
SET FIRST WPT FLAG
LOAD WPT INDICATED BY L.U. RTE BUFFER POINTER (LRTEBFP)
PAST THE LAST WPT (PTR = 0)
YES
LU2OUT
5
NO
LOAD LINE POINTER
LNMSTR
STORE WPT NAME IN PAGE BUFFER
27
1ST WPT
YES
NO
H
I

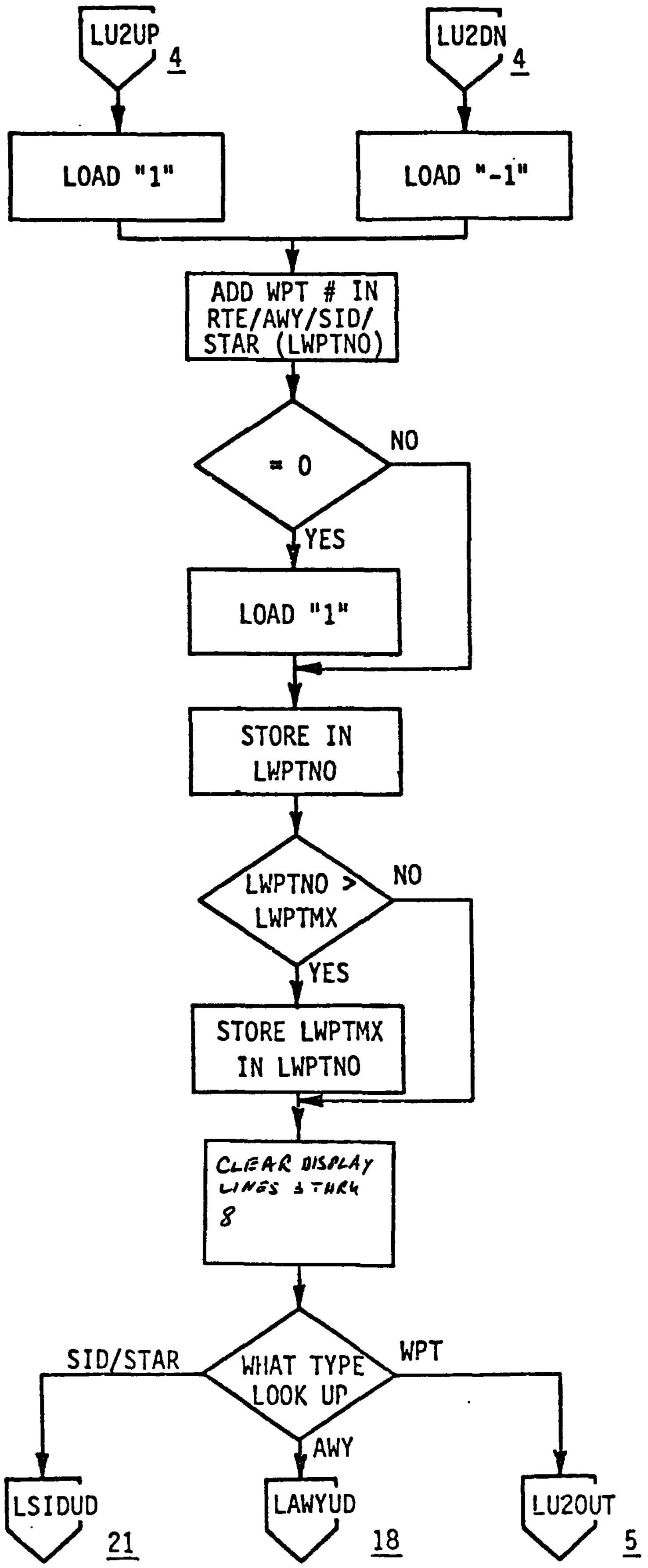

I
H
CLEAR FIRST WPT FLAG
SET LN2CHR = 26 TO INDICATE ROUTE
LNMST2
STORE MAPCEN-TER WPT NAME
28
INCREMENT L.U. RTE BUFFER PTR.
INCREMENT LINE POINTER TO NEXT LINE
5 LINES DONE
NO
LAWY1
18
YES
END OF WPT LIST IN BUFFER
NO
LKEYUP
26
YES
LU2OUT
5

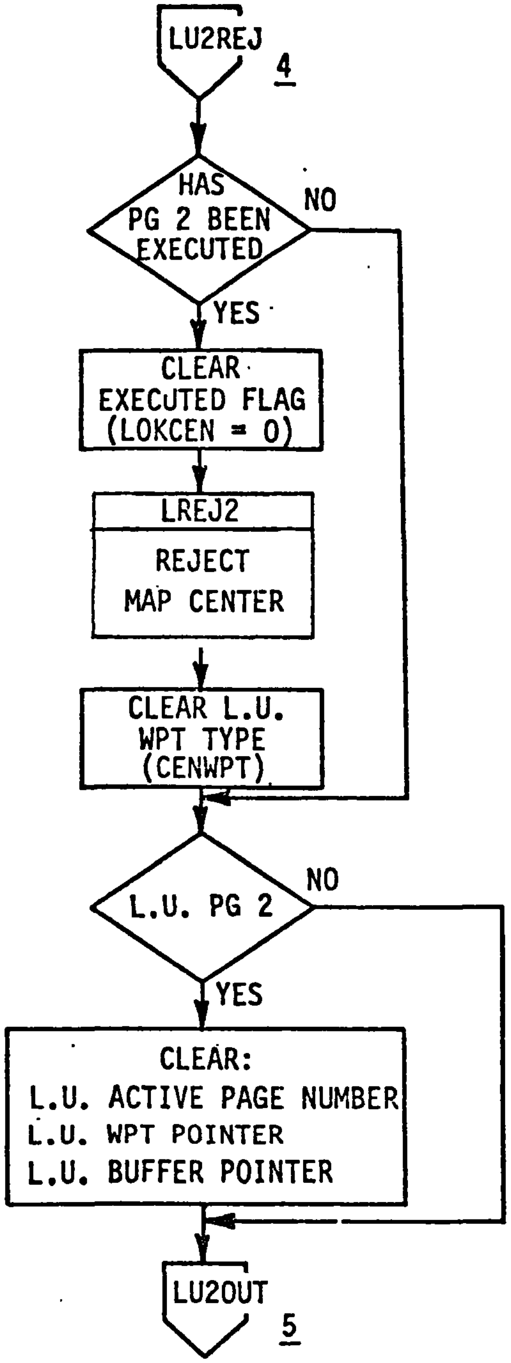

STORE "STAR"
LU2STR
STORE "SID"
LU2SID
UP/DOWN CHANGE
21
LSIDUD
LU2INT
INITIALIZE PAGE #2
LU2RNM
LOOK UP NAME STORE IN LINE 2 BUFF
31
STORE POINTER TO FIRST WPT
STORE LOOK UP BUFFER POINTER AND L.U. ROUTE BUFFER POINTER
SET LOOP COUNTER FOR 20 WPTS TO LOKBUF/RTEBUF
STORE ZERO IN WPT COUNTER
LSID1
21
SET LU2TYP = -1 TO INDICATE SID/STAR
LOAD FIRST/NEXT WPT
J

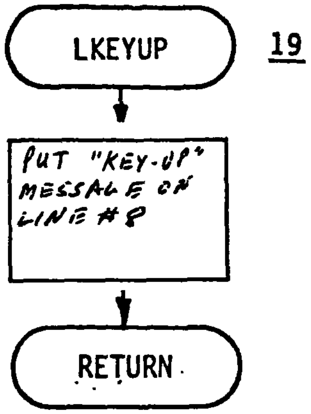

J
STORE PTR LOOK UP BUFFER AND L.U. ROUTE BUFFER
END OF SID/STAR
YES
LSIDUD-2
21
NO
LOAD ALTITUDE AND GROUND SPEED ASSIGNED AT WPT AND STORE IN L.U. ROUTE BUF
UPDATE POINTERS TO NEXT WPT POSITIONS
RTE BUFF FULL (20 WPT'S)
NO
LSID1
20
YES
LSIDUD
24
STORE WPT COUNT IN LWPTMX
COMPUTE POINTER TO FIRST WORD ON NCDU PAGE AND STORE IN LRTBFP
LSID2
20
SET TO LOOP FOR 5 WPTS ON SCREEN
SET FIRST WPT FLAG = TRUE
END OF BUFFER
YES
LU2OUT
5
NO
K

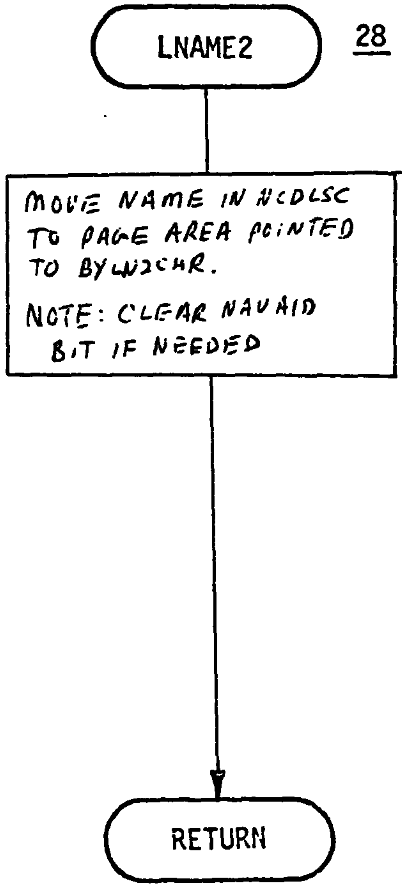

K
LOAD POINTER TO LINE 3 BUFFER
LSIDST
FORMAT AND STORE RTE DATA
29
1ST WPT
NO
YES
CLEAR FLAG
SET LN2CHR TO INDICATE RTE
LNMST2
LOOK UP MAP CTR
28
INCREMENT POINTER TO NEXT LINE
5TH LINE PROCESSED
NO
LSID2
21
YES
DOES PAGE CONT
NO
LU2OUT
5
YES
LKEYUP
26

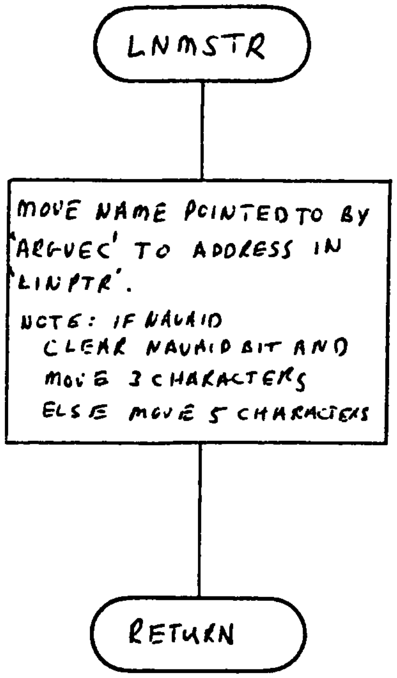

LU2EXC
4
L.U. PG 2
NO
LU2OUT
5
YES
LOAD LEFT PARENTHESIS SYMBOL (ASCLPN)
PUT BRACKETS AROUND NAME
STORE WPT LAT/LON AS MAP CENTER
STORE "2" IN LOKCEN AND "0" IN CENWPT
IS THERE A L.U. WPT POSIT
NO
YES
STORE WPT POSIT IN CENWPT
LU2OUT
5


LU2UP
4
LU2DN
4
LOAD "1"
LOAD "-1"
ADD WPT # IN RTE/AWY/SID/STAR (LWPTNO)
= 0
NO
YES
LOAD "1"
STORE IN LWPTNO
LWPTNO > LWPTMX
NO
YES
STORE LWPTMX IN LWPTNO
CLEAR DISPLAY LINES 3 THRU 8
WHAT TYPE LOOK UP
SID/STAR
WPT
AWY
LSIDUD
21
LAWYUD
18
LU2OUT
5

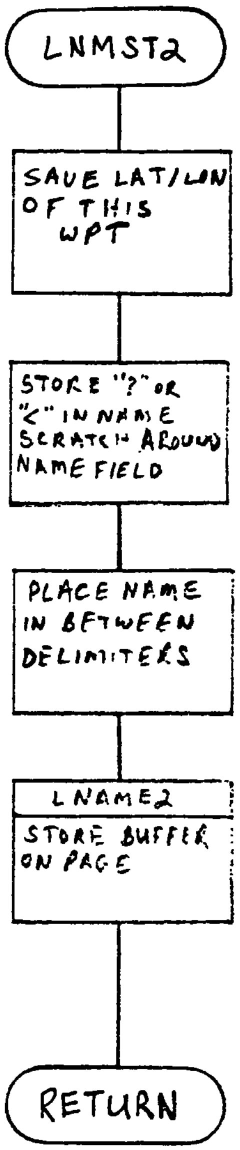

LU2REJ
4
HAS PG 2 BEEN EXECUTED
NO
YES
CLEAR EXECUTED FLAG (LOKCEN = 0)
LREJ2
REJECT MAP CENTER
CLEAR L.U. WPT TYPE (CENWPT)
L.U. PG 2
NO
YES
CLEAR:
L.U. ACTIVE PAGE NUMBER
L.U. WPT POINTER
L.U. BUFFER POINTER
LU2OUT
5


LKEYUP
19
PUT "KEY-UP" MESSAGE ON LINE #8
RETURN


LNAME2
28
MOVE NAME IN NCDLSC TO PAGE AREA POINTED TO BY LN2CHR.
NOTE: CLEAR NAVAID BIT IF NEEDED
RETURN

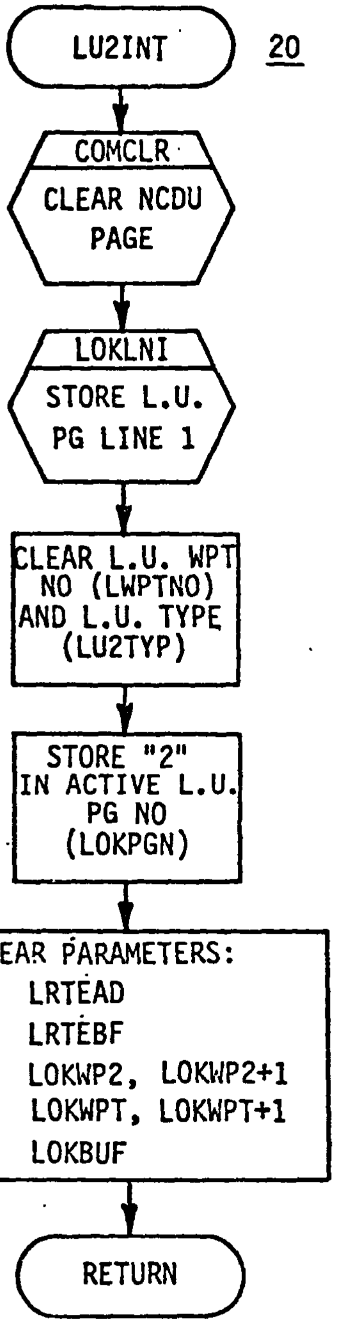

LNMSTR
MOVE NAME POINTED TO BY 'ARGVEC' TO ADDRESS IN 'LINPTR'.
NOTE: IF NAVAID
CLEAR NAVAID BIT AND
MOVE 3 CHARACTERS
ELSE MOVE 5 CHARACTERS
RETURN

[redacted]


LNMST2
SAVE LAT/LON OF THIS WPT
STORE "?" OR "<" IN NAME SCRATCH AROUND NAME FIELD
PLACE NAME IN BETWEEN DELIMITERS
LNAME2
STORE BUFFER ON PAGE
RETURN

THIS PAGE INTENTIONALLY

LEFT BLANK



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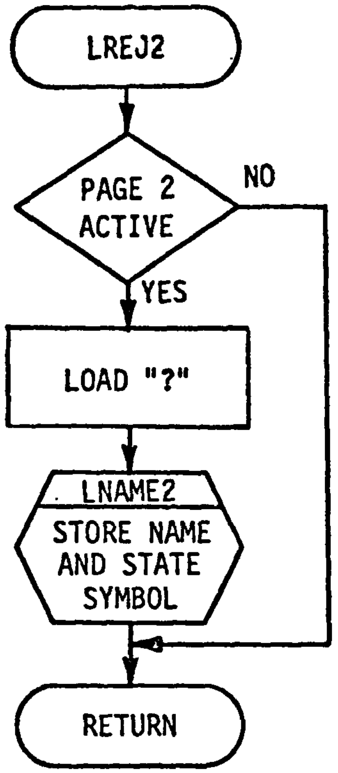
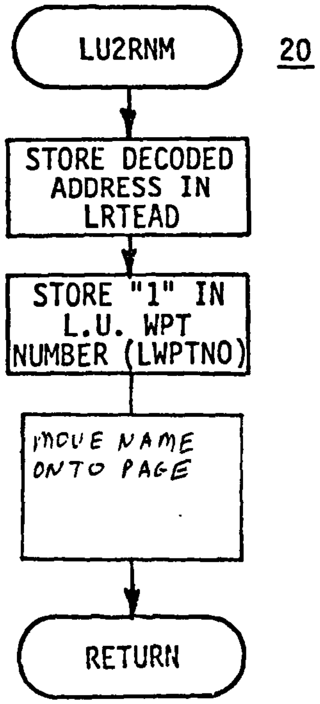
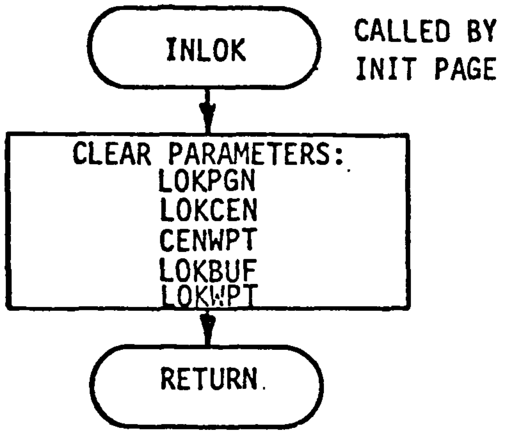
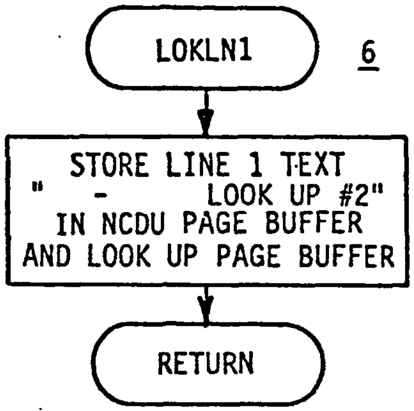
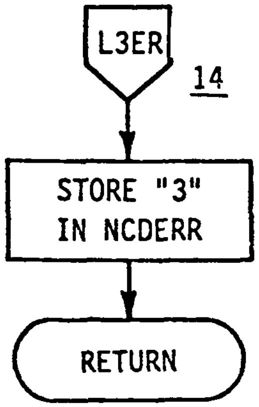
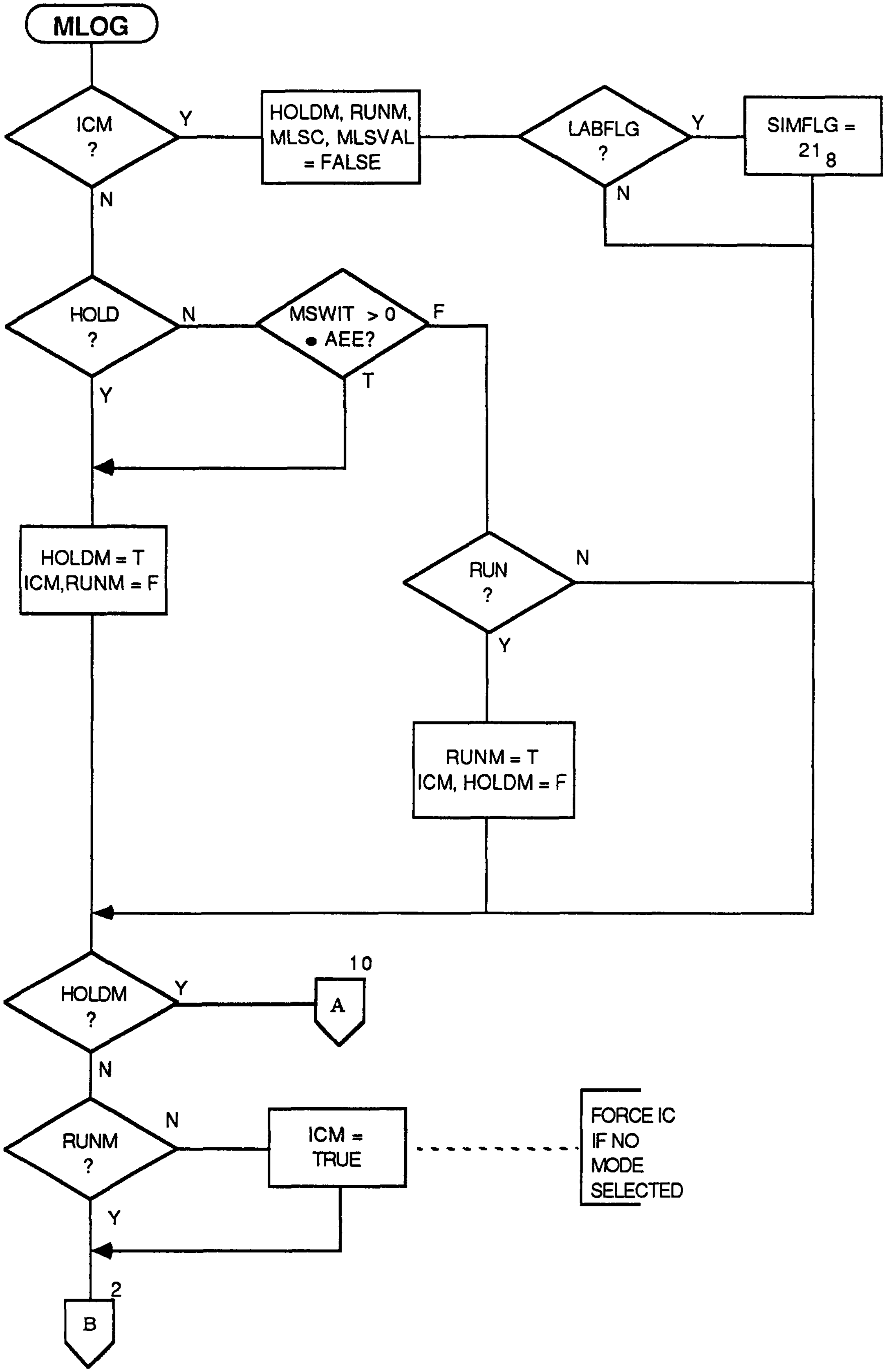

LREJ2
PAGE 2 ACTIVE
NO
YES
LOAD "?"
LNAME2
STORE NAME AND STATE SYMBOL
RETURN

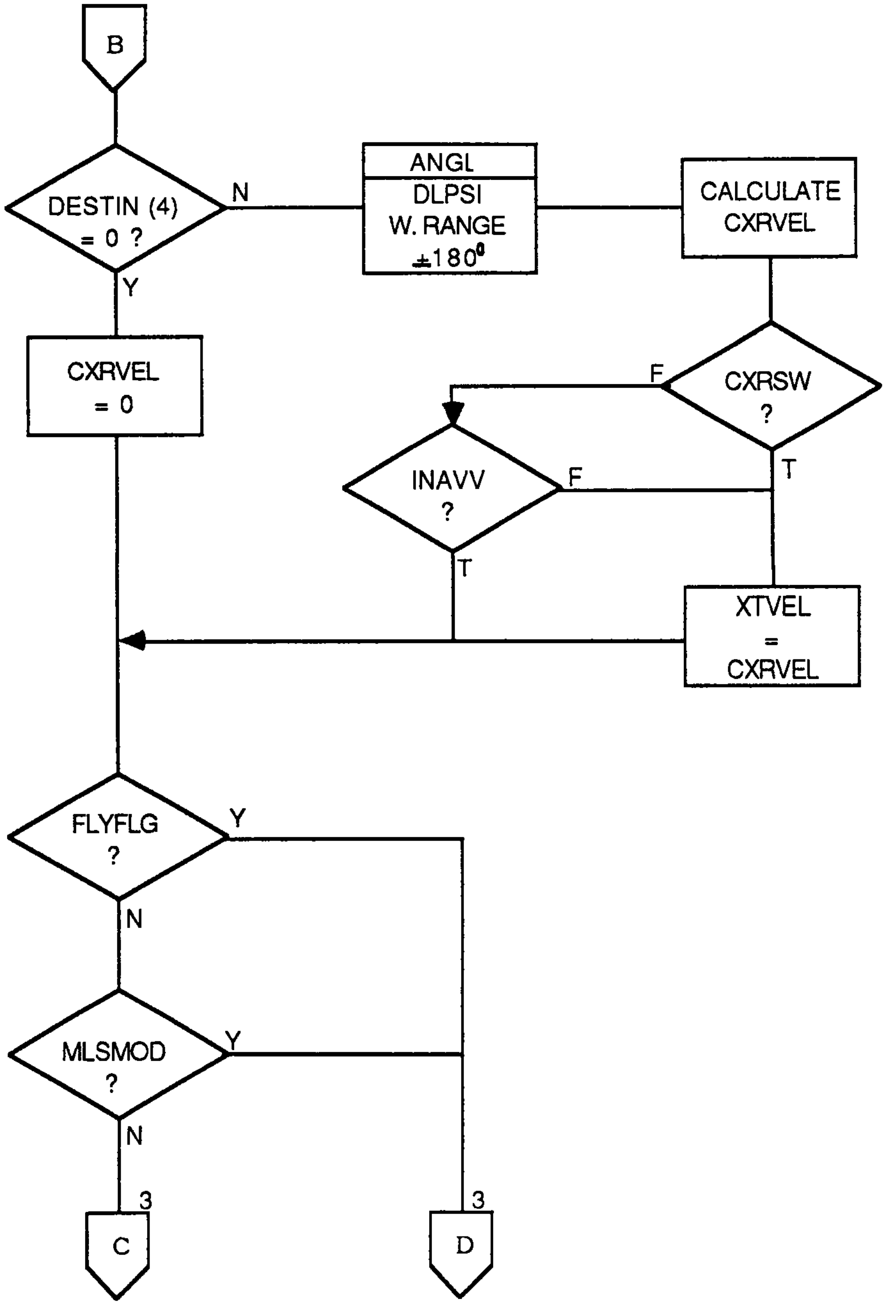

LU2RNM
20
STORE DECODED ADDRESS IN LRTEAD
STORE "1" IN L.U. WPT NUMBER (LWPTNO)
MOVE NAME ONTO PAGE
RETURN

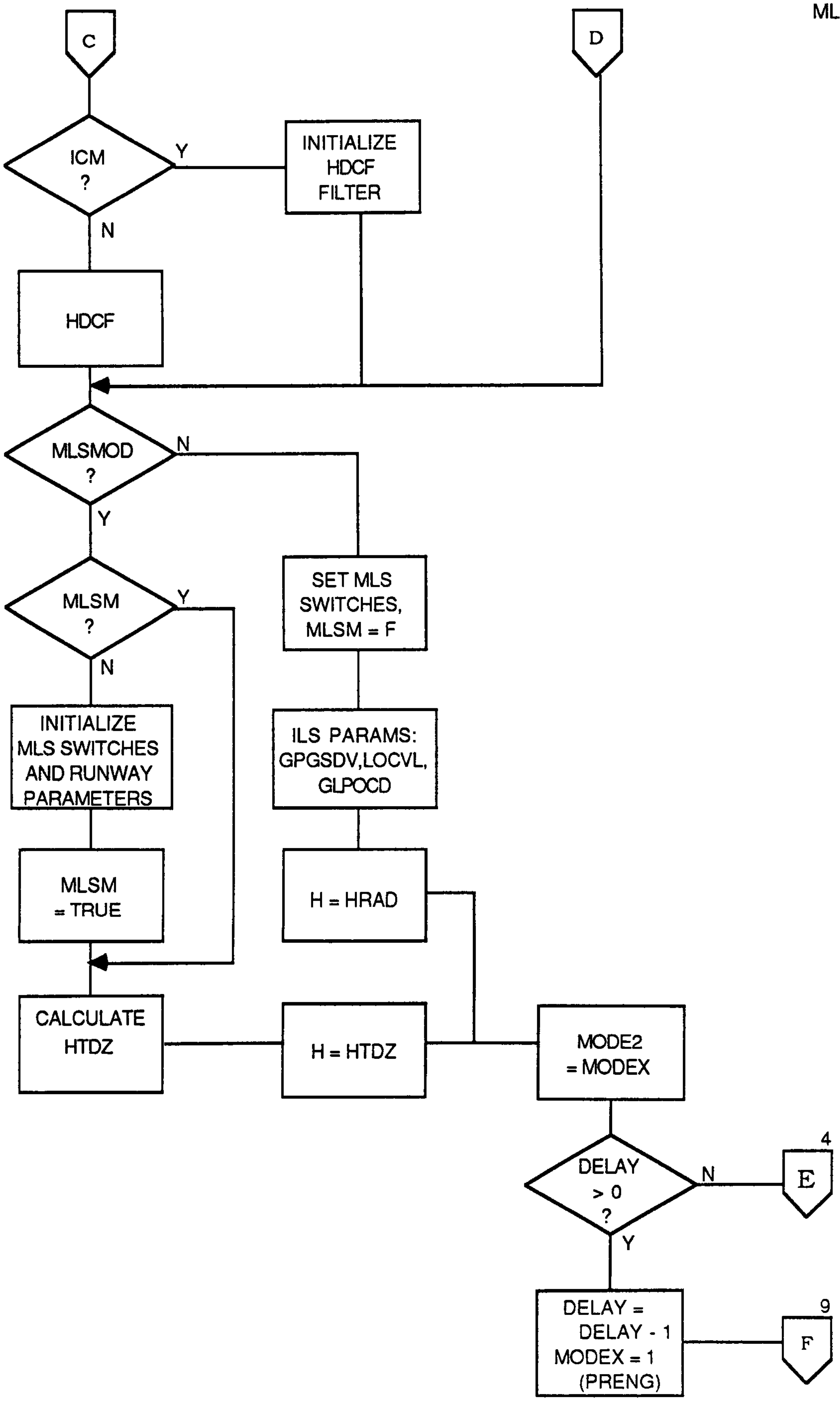

INLOK
CALLED BY
INIT PAGE
CLEAR PARAMETERS:
LOKPGN
LOKCEN
CENWPT
LOKBUF
LOKWPT
RETURN

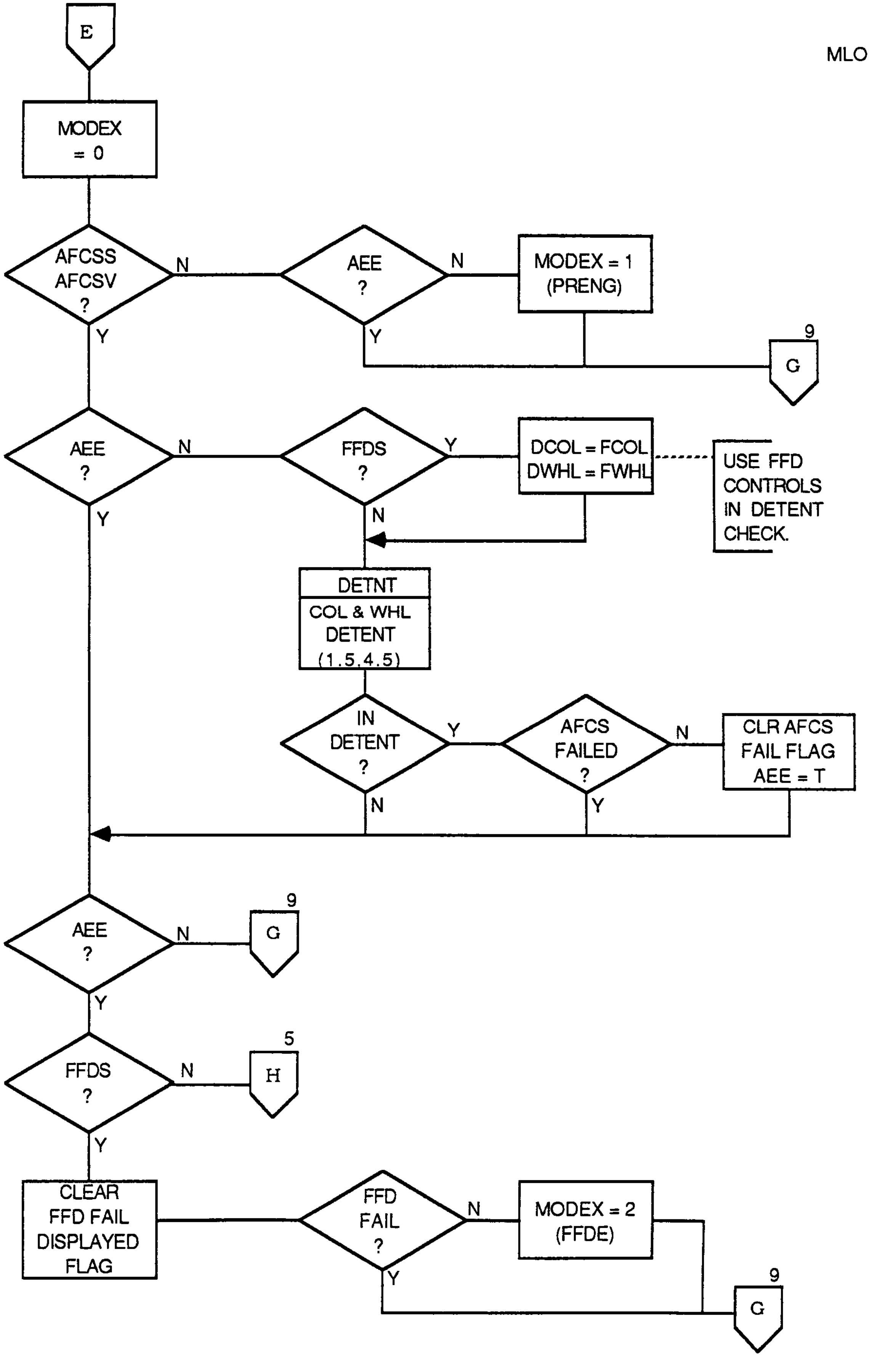

LOKLN1
6
STORE LINE 1 TEXT
"   -   LOOK UP #2"
IN NCDU PAGE BUFFER
AND LOOK UP PAGE BUFFER
RETURN

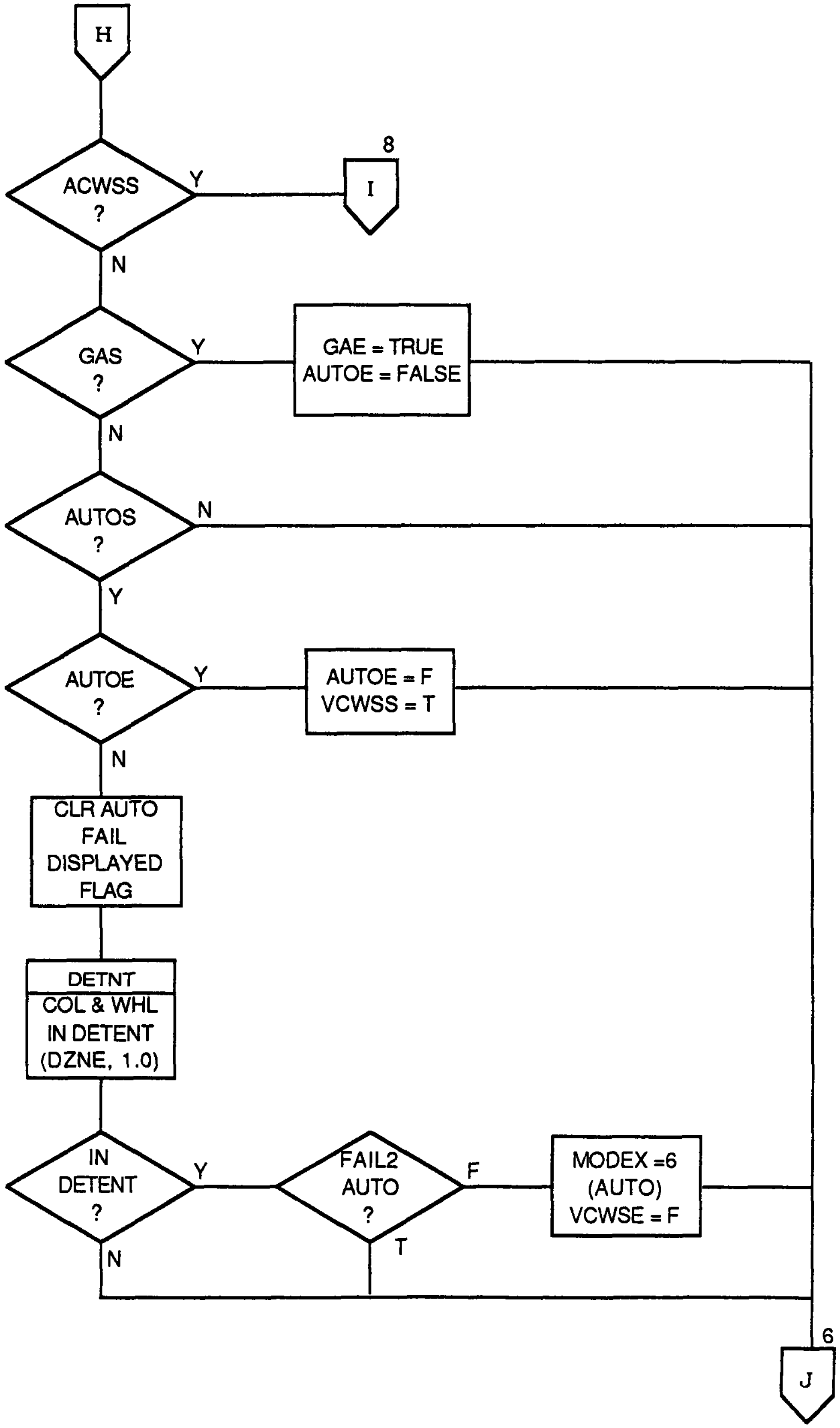

L3ER
14
STORE "3"
IN NCDERR
RETURN


MLOG
ICM ?
Y
N
HOLDM, RUNM, MLSC, MLSVAL = FALSE
LABFLG ?
Y
N
SIMFLG = 21_8
HOLD ?
N
Y
MSWIT > 0 • AEE?
F
T
HOLDM = T ICM,RUNM = F
RUN ?
N
Y
RUNM = T ICM, HOLDM = F
HOLDM ?
Y
10
A
N
RUNM ?
N
ICM = TRUE
FORCE IC IF NO MODE SELECTED
Y
2
B

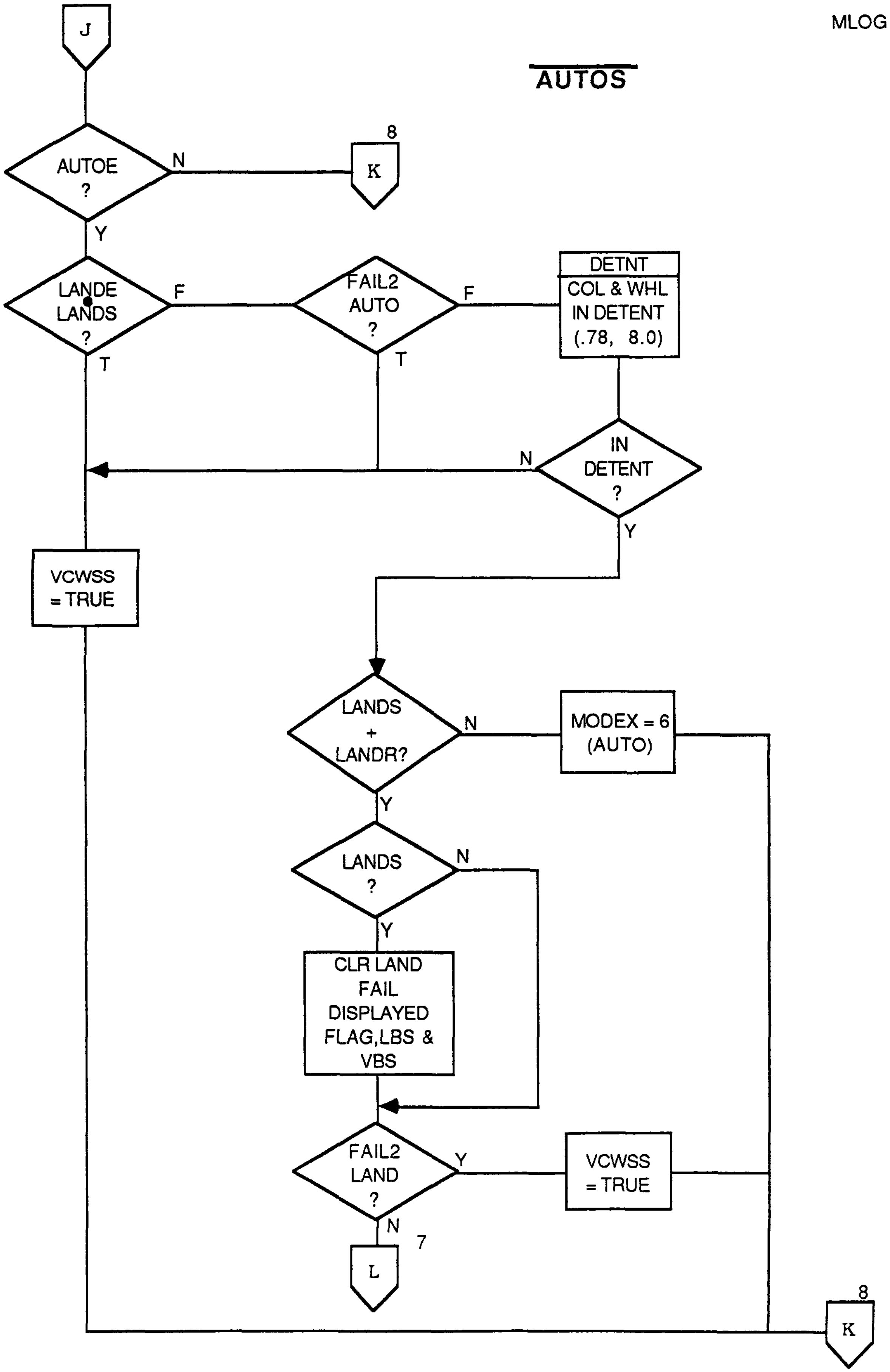

B
DESTIN (4) = 0 ?
N
Y
ANGL
DLPSI
W. RANGE
±180°
CALCULATE CXRVEL
CXRVEL = 0
CXRSW ?
F
T
INAVV ?
F
T
XTVEL = CXRVEL
FLYFLG ?
Y
N
MLSMOD ?
Y
N
3
C
3
D

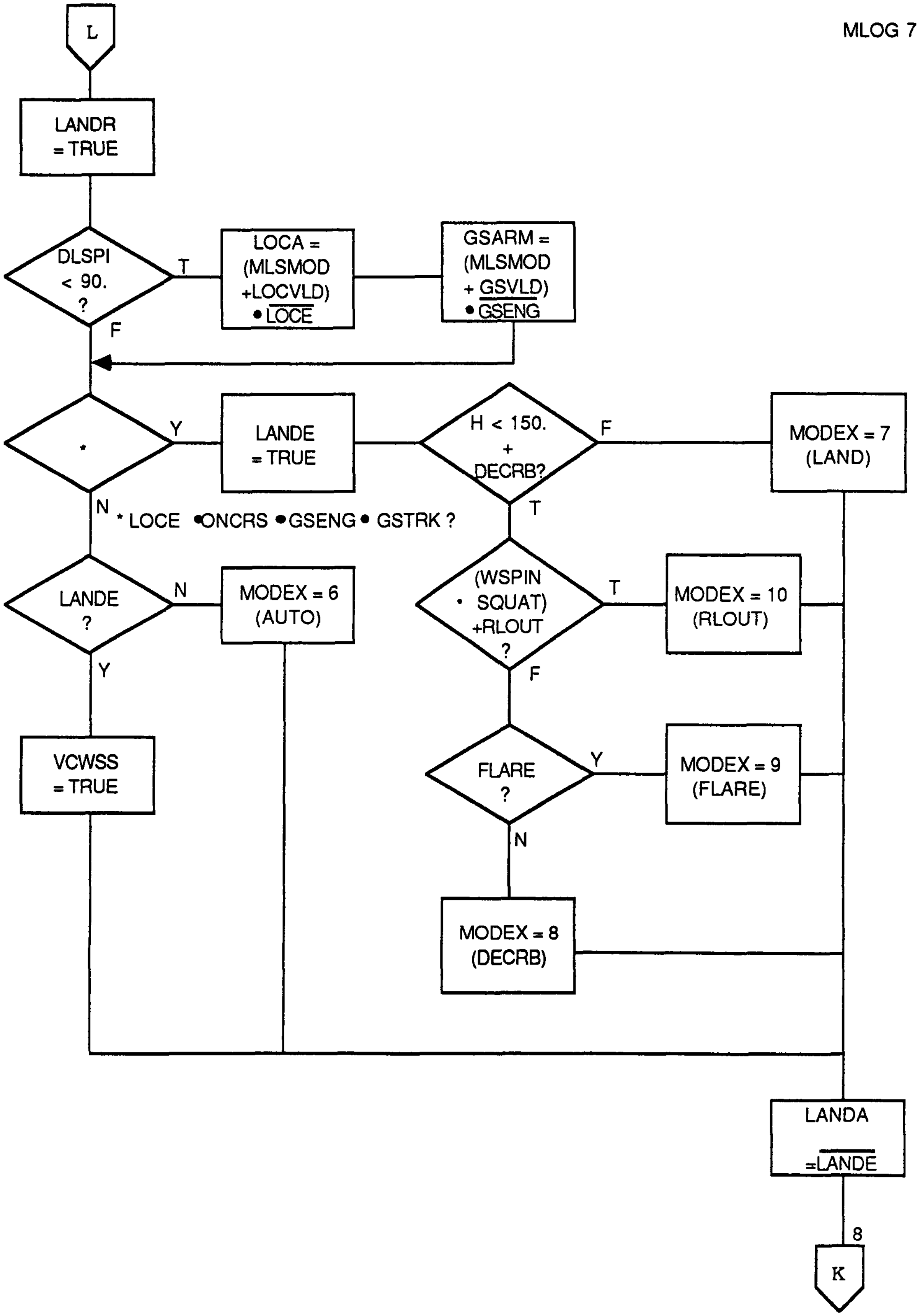

C
D
ICM ?
Y
N
INITIALIZE HDCF FILTER
HDCF
MLSMOD ?
N
Y
MLSM ?
Y
N
SET MLS SWITCHES, MLSM = F
INITIALIZE MLS SWITCHES AND RUNWAY PARAMETERS
ILS PARAMS: GPGSDV,LOCVL, GLPOCD
MLSM = TRUE
H = HRAD
CALCULATE HTDZ
H = HTDZ
MODE2 = MODEX
DELAY > 0 ?
N
4
E
Y
DELAY = DELAY - 1 MODEX = 1 (PRENG)
9
F

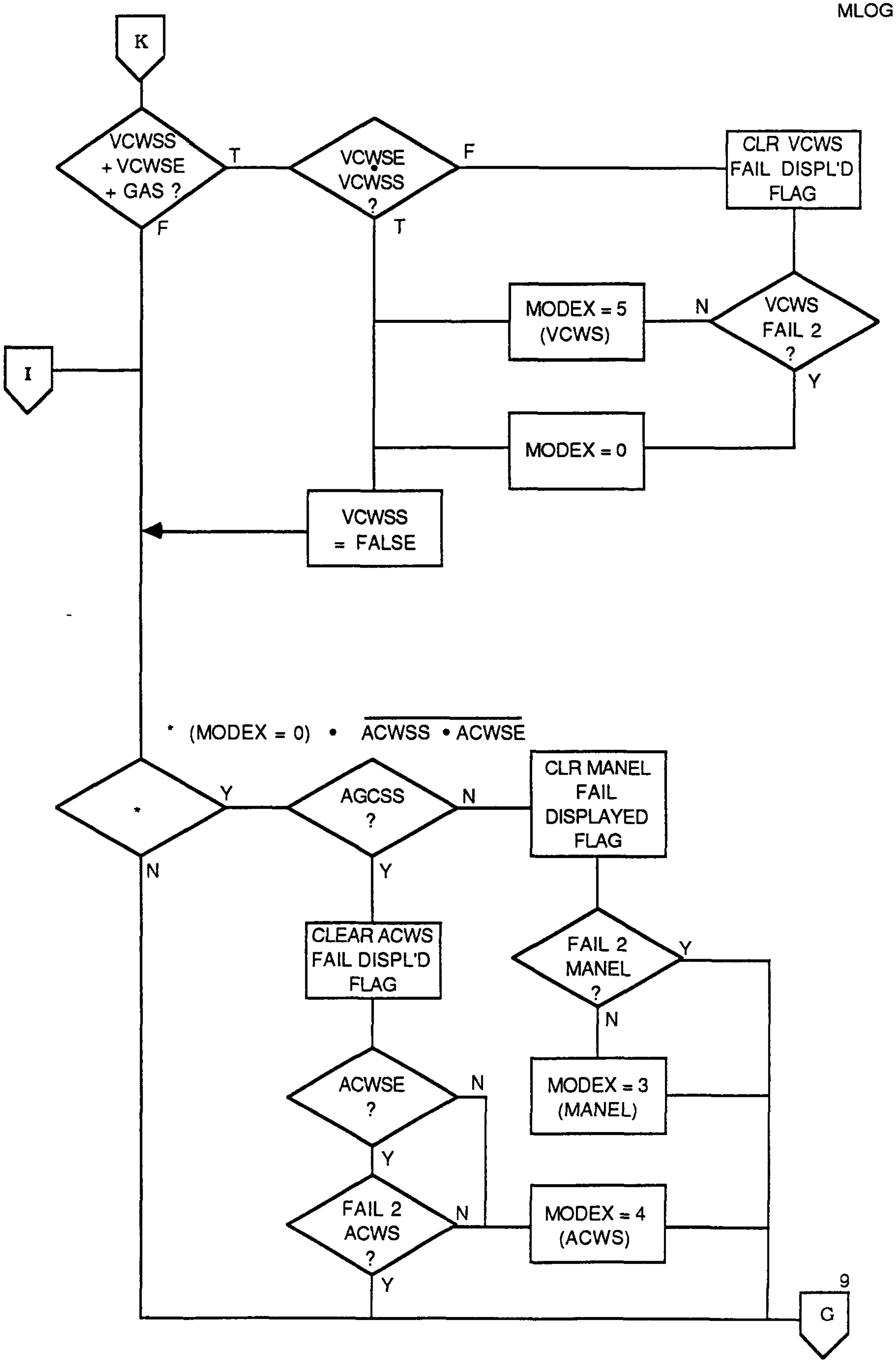

E
MODEX = 0
AFCSS AFCSV ?
N
AEE ?
N
MODEX = 1 (PRENG)
Y
Y
9
G
AEE ?
N
FFDS ?
Y
DCOL = FCOL DWHL = FWHL
USE FFD CONTROLS IN DETENT CHECK.
N
Y
DETNT
COL & WHL DETENT (1.5.4.5)
IN DETENT ?
Y
AFCS FAILED ?
N
CLR AFCS FAIL FLAG AEE = T
N
Y
AEE ?
N
9
G
Y
FFDS ?
N
5
H
Y
CLEAR FFD FAIL DISPLAYED FLAG
FFD FAIL ?
N
MODEX = 2 (FFDE)
Y
9
G

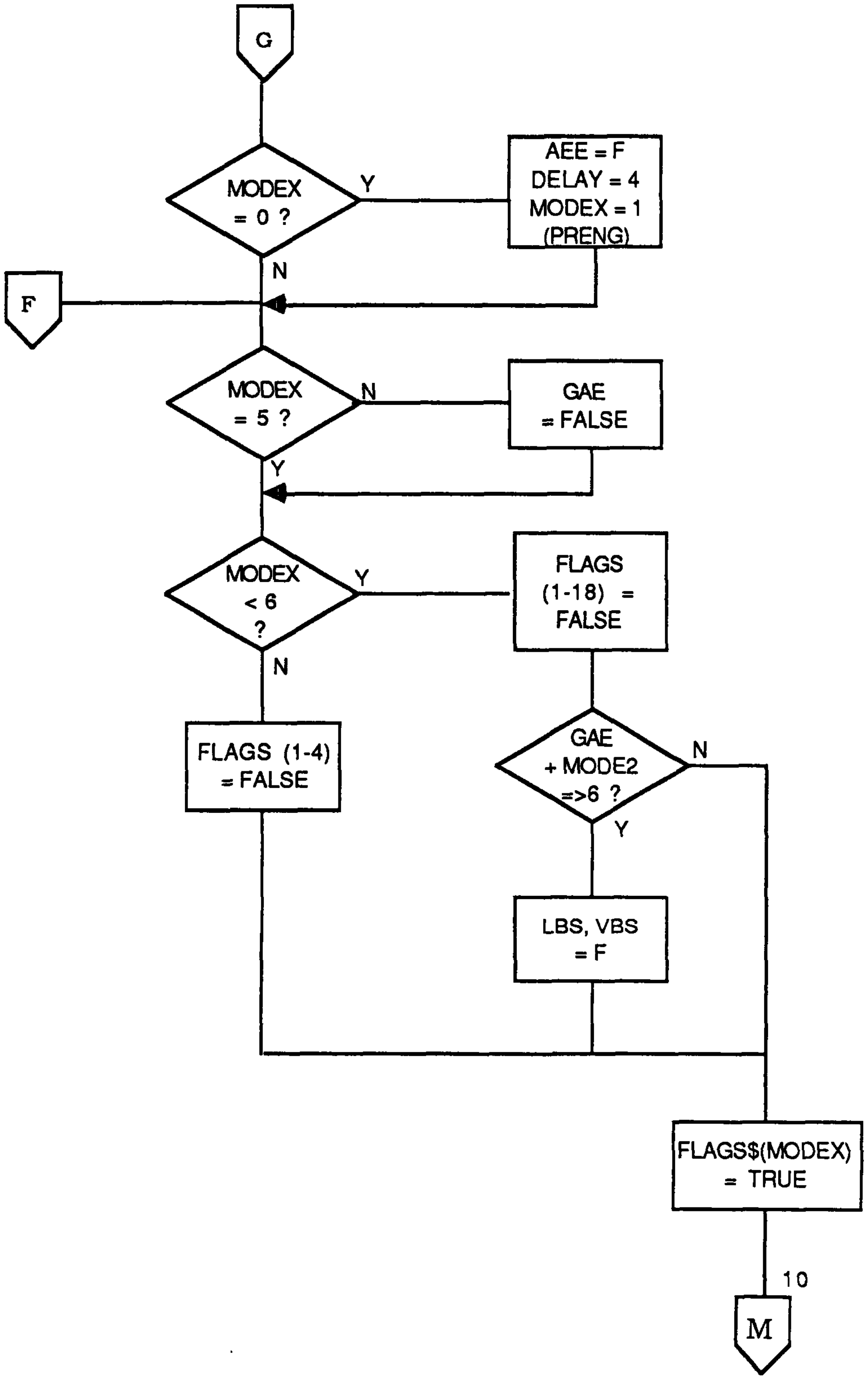

H
ACWSS
?
Y
8
I
N
GAS
?
Y
GAE = TRUE
AUTOE = FALSE
N
AUTOS
?
N
Y
AUTOE
?
Y
AUTOE = F
VCWSS = T
N
CLR AUTO
FAIL
DISPLAYED
FLAG
DETNT
COL & WHL
IN DETENT
(DZNE, 1.0)
IN
DETENT
?
Y
FAIL2
AUTO
?
F
MODEX =6
(AUTO)
VCWSE = F
T
N
6
J

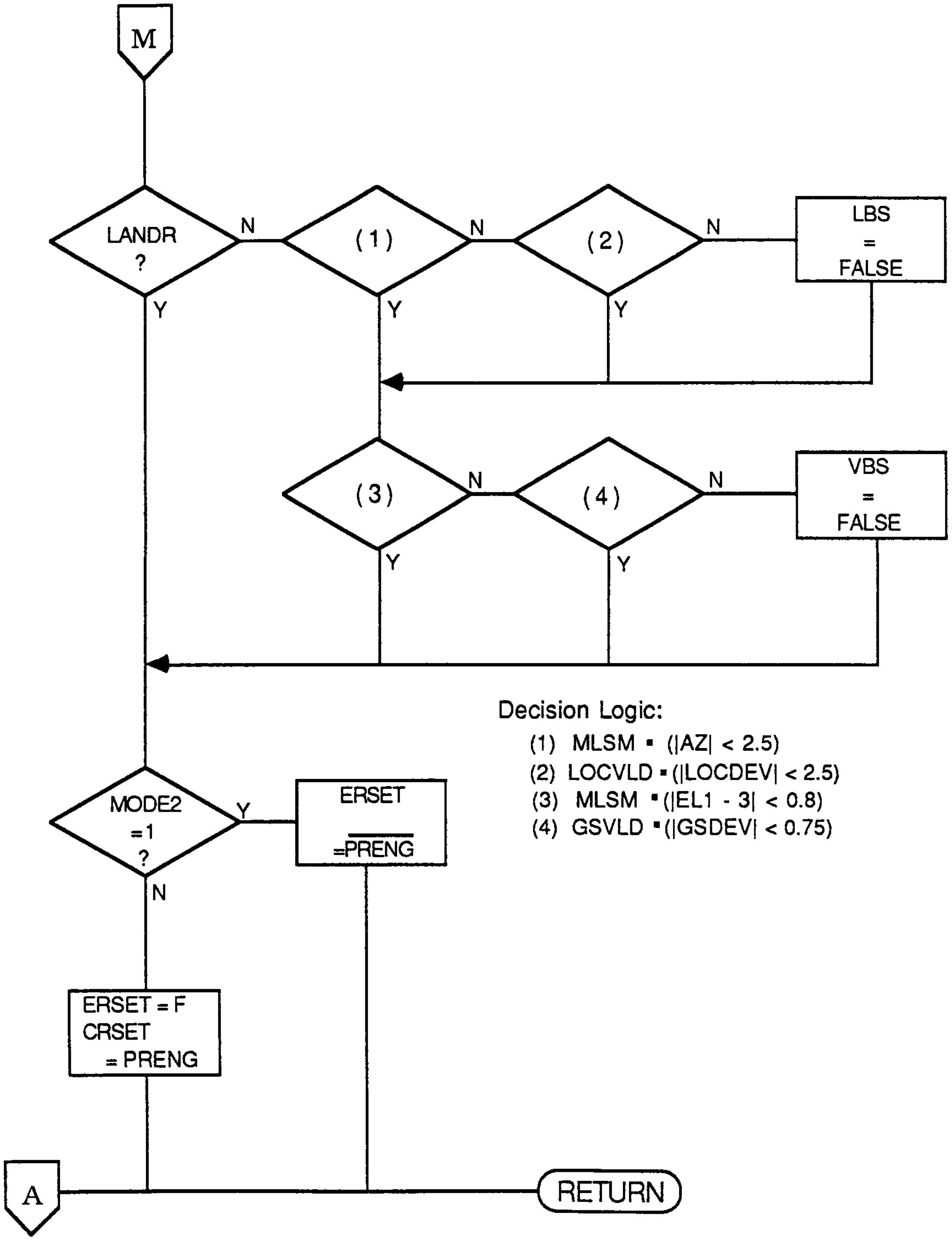
AUTOS


J
AUTOE ?
N
8
K
Y
LANDE • LANDS ?
F
FAIL2 AUTO ?
F
DETNT
COL & WHL IN DETENT (.78, 8.0)
T
T
IN DETENT ?
N
Y
VCWSS = TRUE
LANDS + LANDR?
N
MODEX = 6 (AUTO)
Y
LANDS ?
N
Y
CLR LAND FAIL DISPLAYED FLAG,LBS & VBS
FAIL2 LAND ?
Y
VCWSS = TRUE
N
7
L
8
K


L
LANDR = TRUE
DLSPI < 90. ?
T
F
LOCA = (MLSMOD +LOCVLD) • LOCE
GSARM = (MLSMOD + GSVLD) • GSENG
*
Y
N
* LOCE •ONCRS •GSENG • GSTRK ?
LANDE = TRUE
H < 150. + DECRB?
F
T
MODEX = 7 (LAND)
LANDE ?
N
Y
MODEX = 6 (AUTO)
(WSPIN • SQUAT) +RLOUT ?
T
F
MODEX = 10 (RLOUT)
VCWSS = TRUE
FLARE ?
Y
N
MODEX = 9 (FLARE)
MODEX = 8 (DECRB)
LANDA =LANDE
8
K

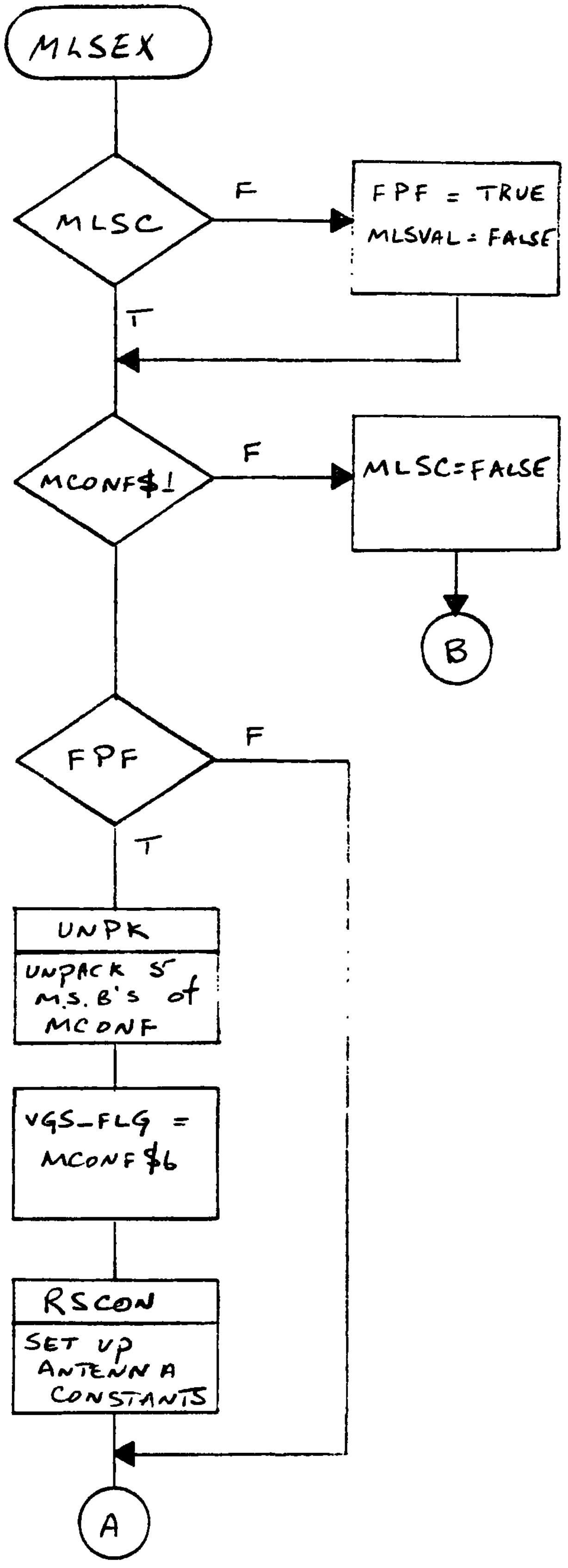

K
VCWSS + VCWSE + GAS ?
T
F
VCWSE • VCWSS ?
F
T
CLR VCWS FAIL DISPL'D FLAG
VCWS FAIL 2 ?
N
Y
MODEX = 5 (VCWS)
MODEX = 0
I
VCWSS = FALSE
* (MODEX = 0) • ACWSS • ACWSE
*
Y
N
AGCSS ?
N
Y
CLR MANEL FAIL DISPLAYED FLAG
CLEAR ACWS FAIL DISPL'D FLAG
FAIL 2 MANEL ?
Y
N
MODEX = 3 (MANEL)
ACWSE ?
N
Y
FAIL 2 ACWS ?
N
Y
MODEX = 4 (ACWS)
9
G

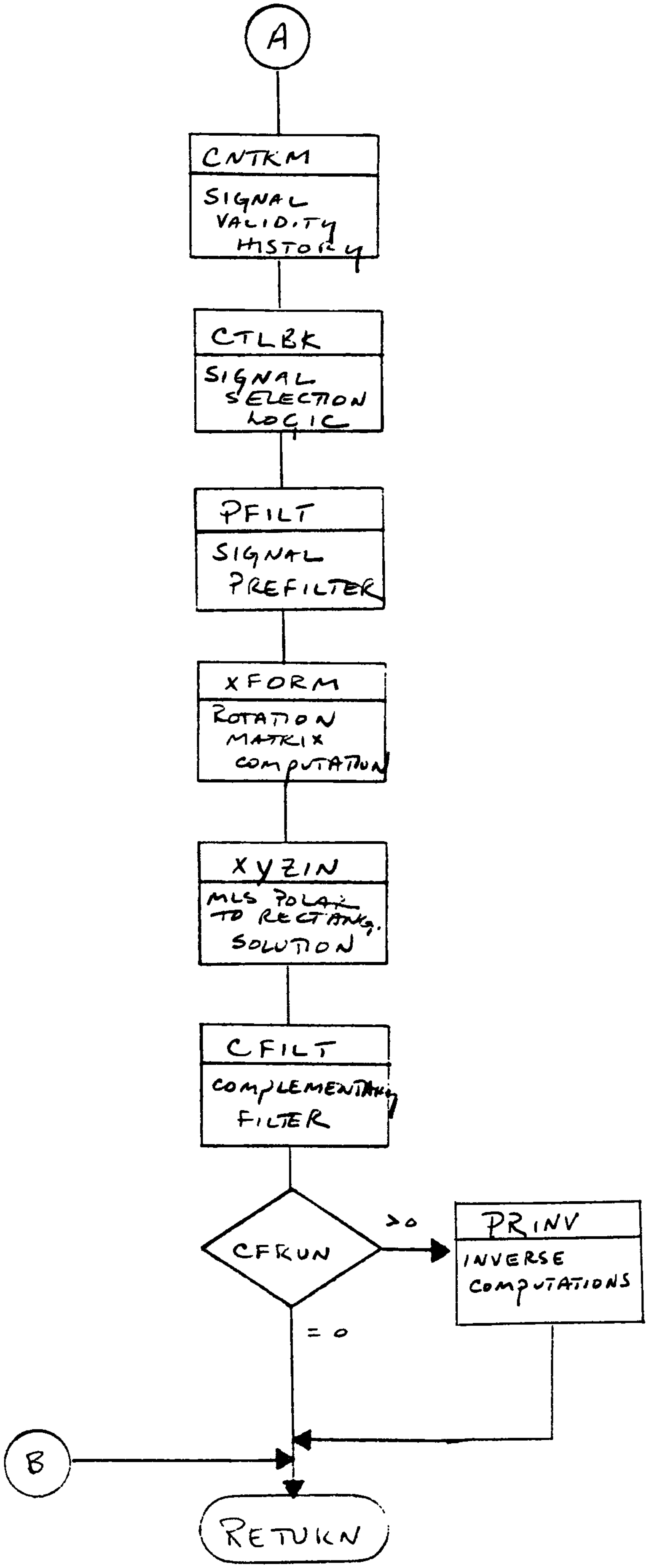

G
MODEX = 0 ?
Y
AEE = F
DELAY = 4
MODEX = 1
(PRENG)
N
F
MODEX = 5 ?
N
GAE = FALSE
Y
MODEX < 6 ?
Y
FLAGS (1-18) = FALSE
N
FLAGS (1-4) = FALSE
GAE + MODE2 =>6 ?
N
Y
LBS, VBS = F
FLAGS$(MODEX) = TRUE
10
M

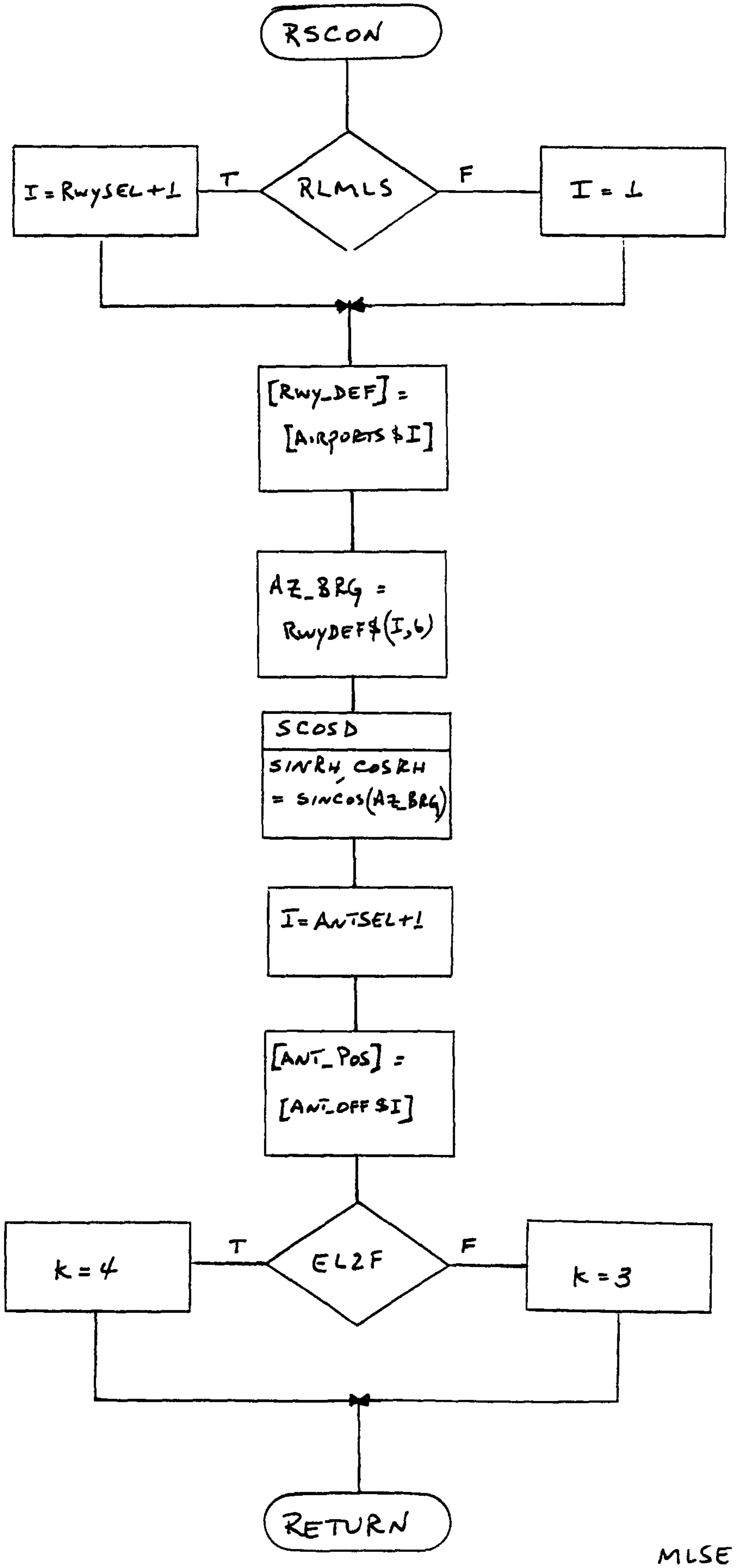


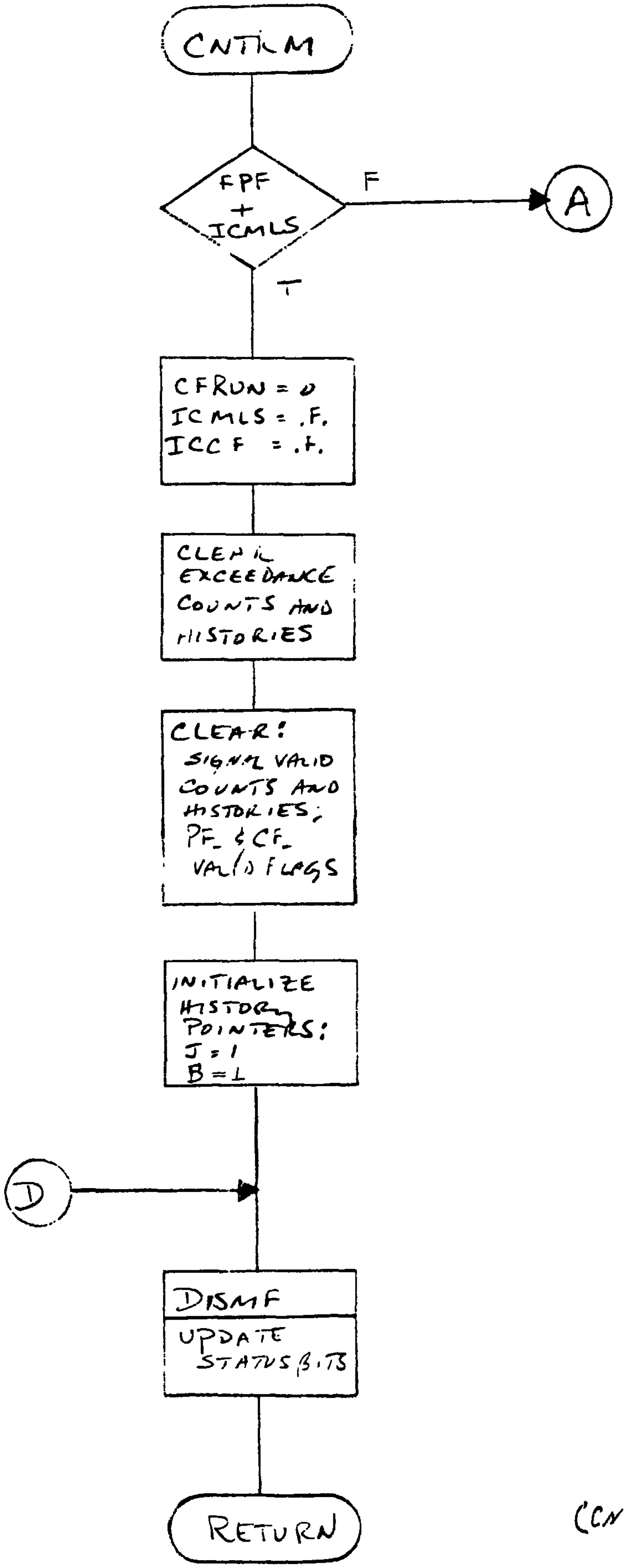
Decision Logic:

(1) MLSM ▪ (|AZ| < 2.5)
(2) LOCVLD ▪ (|LOCDEV| < 2.5)
(3) MLSM ▪ (|EL1 - 3| < 0.8)
(4) GSVLD ▪ (|GSDEV| < 0.75)

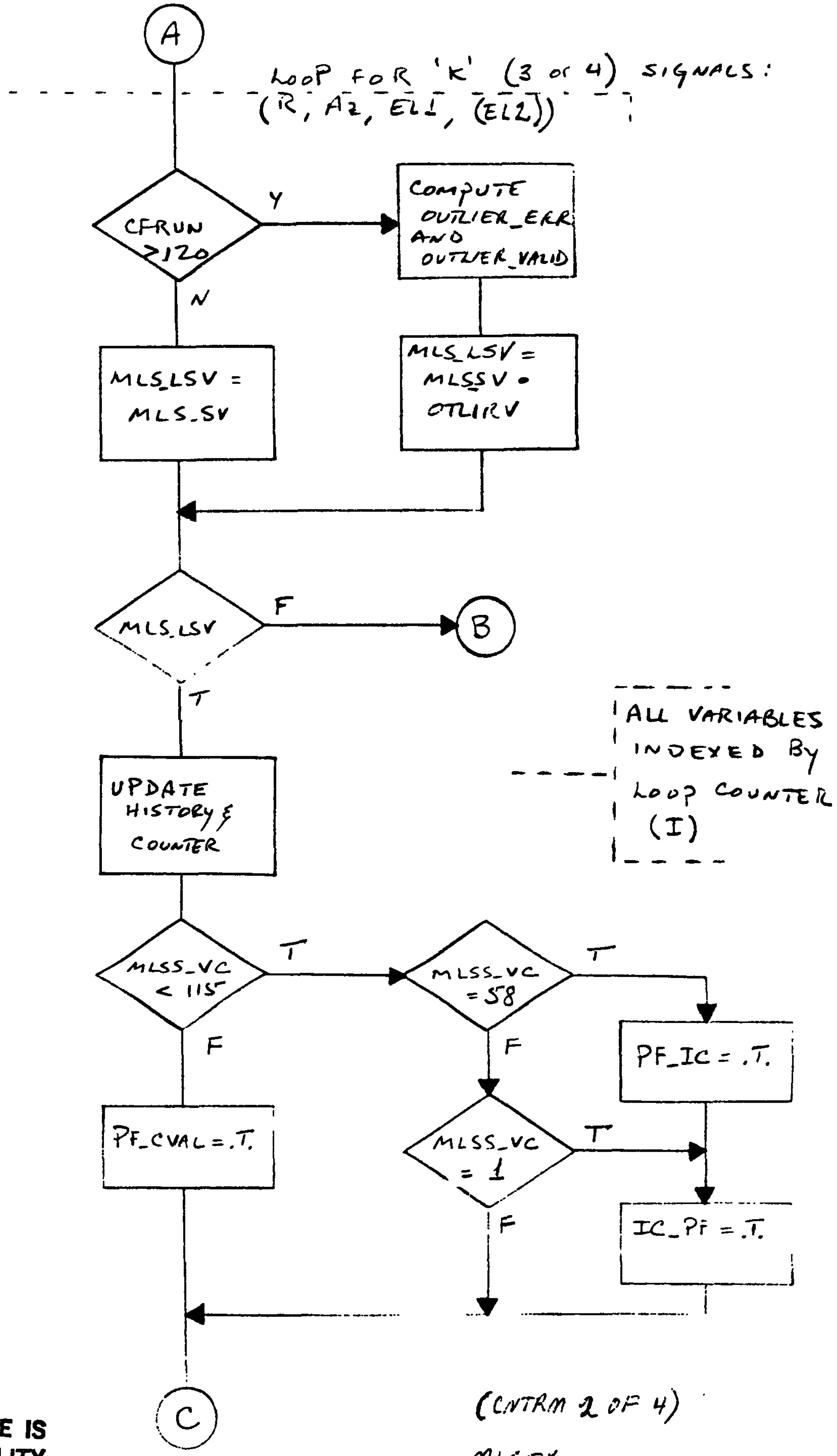

MLSEX
MLSC
F
FPF = TRUE
MLSVAL = FALSE
T
MCONF$1
F
MLSC=FALSE
B
FPF
F
T
UNPK
UNPACK 5 M.S.B's of MCONF
VGS_FLG = MCONF$6
RSCON
SET UP ANTENNA CONSTANTS
A

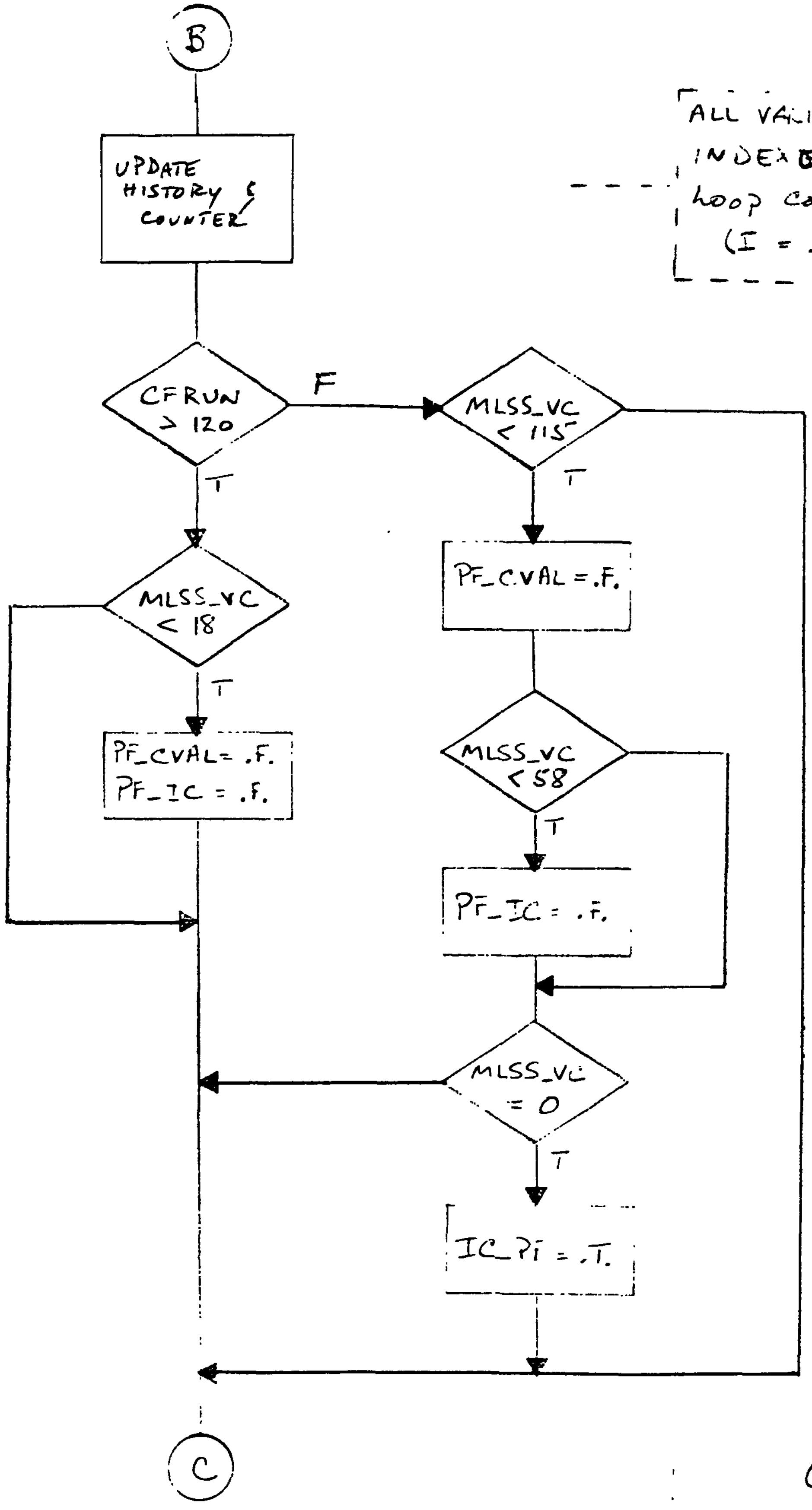

A
CNTKM
SIGNAL VALIDITY HISTORY
CTLBK
SIGNAL SELECTION LOGIC
PFILT
SIGNAL PREFILTER
XFORM
ROTATION MATRIX COMPUTATION
XYZIN
MLS POLAR TO RECTANG. SOLUTION
CFILT
COMPLEMENTARY FILTER
CFRUN
>0
PRINV
INVERSE COMPUTATIONS
=0
B
RETURN


RSCON
I = RwySEL+1
T
RLMLS
F
I = 1
[Rwy_DEF] = [AirPORTS $I]
AZ_BRG = RwyDEF$(I,6)
SCOSD
SINRH, COSRH = SINCOS(AZ_BRG)
I = ANTSEL+1
[ANT_POS] = [ANT_OFF $I]
k = 4
T
EL2F
F
k = 3
RETURN


CNTRM
FPF + ICMLS
F
A
T
CFRUN = 0
ICMLS = .F.
ICCF = .F.
CLEAR EXCEEDANCE COUNTS AND HISTORIES
CLEAR:
SIGNAL VALID COUNTS AND HISTORIES;
PF_ & CF_ VALID FLAGS
INITIALIZE HISTORY POINTERS:
J = 1
B = L
D
DISMF
UPDATE STATUS BITS
RETURN

(CNTRM 1 OF 4)

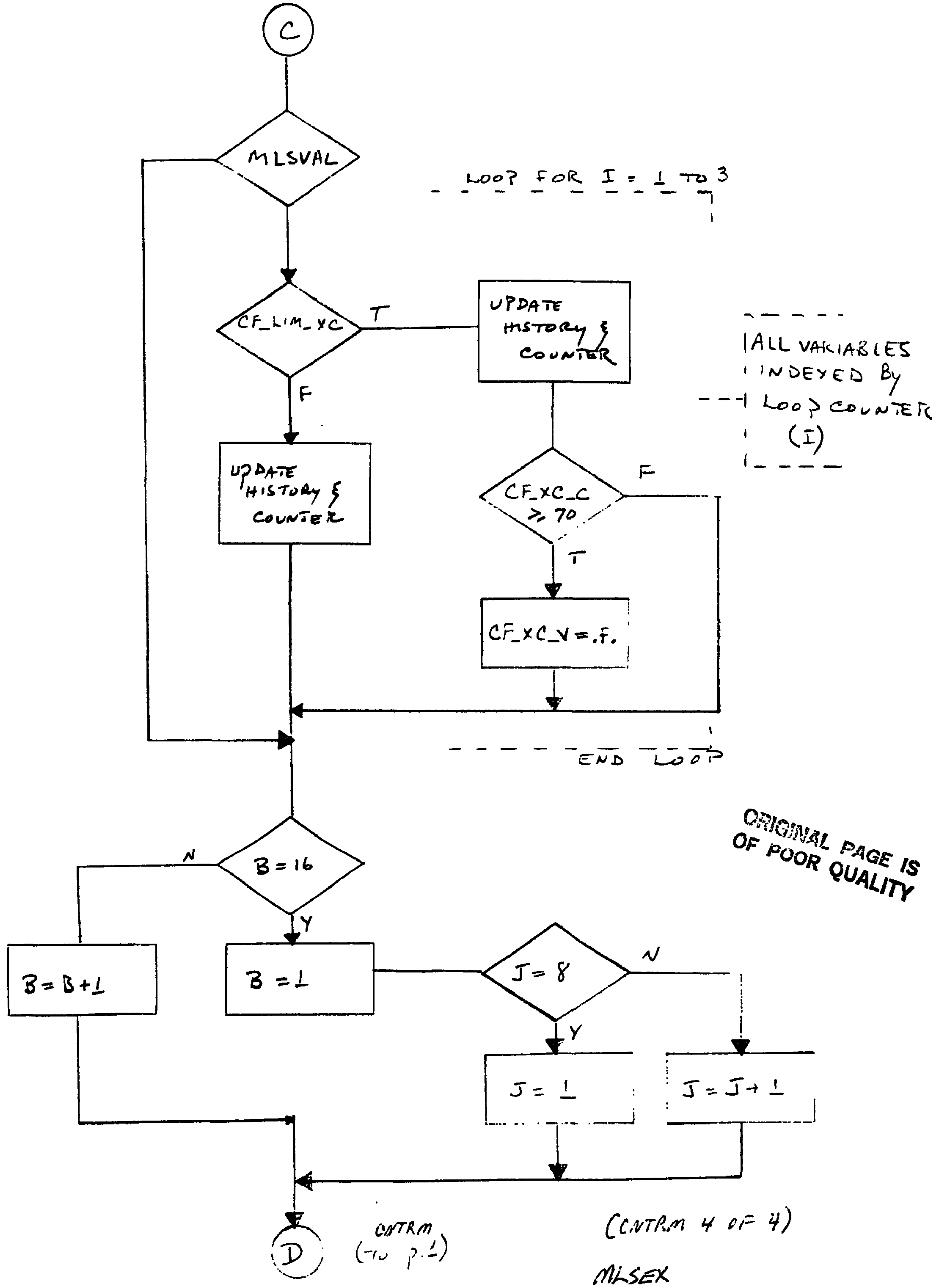

A
LOOP FOR 'K' (3 or 4) SIGNALS:
(R, AZ, EL1, (EL2))
CFRUN >120
Y
COMPUTE OUTLIER_ERR AND OUTLIER_VALID
N
MLS_LSV = MLS_SV
MLS_LSV = MLSSV • OTLIRV
MLS_LSV
F
B
T
UPDATE HISTORY & COUNTER
ALL VARIABLES INDEXED BY LOOP COUNTER (I)
MLSS_VC < 115
T
MLSS_VC = 58
T
F
PF_IC = .T.
F
PF_CVAL = .T.
MLSS_VC = 1
T
IC_PF = .T.
F
C



ALL VARIABLES INDEXED BY LOOP COUNTER (I = 1 TO K)

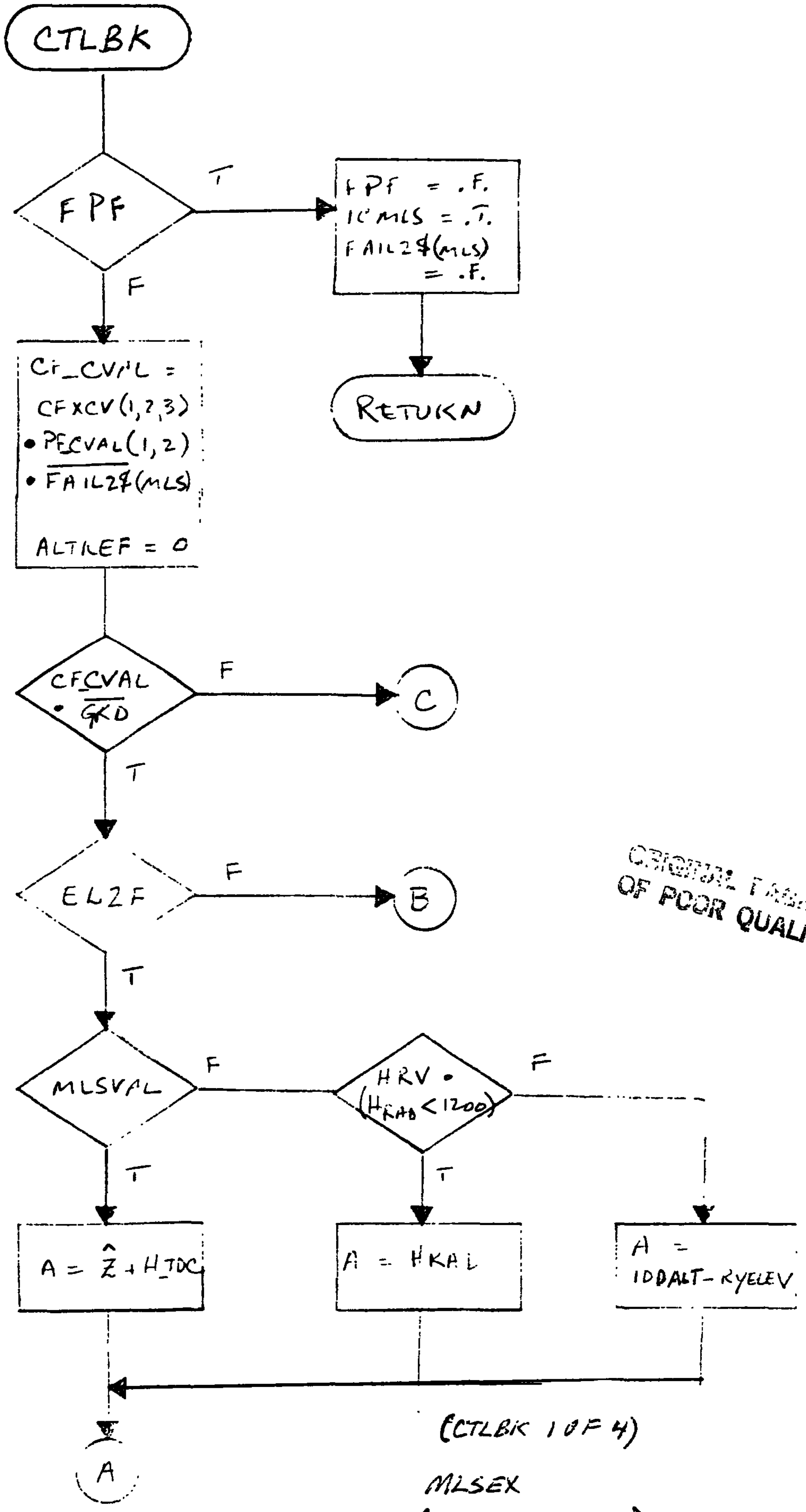
(CNTRM 3 OF 4)

END OF LOOP FOR 'K' SIGNALS



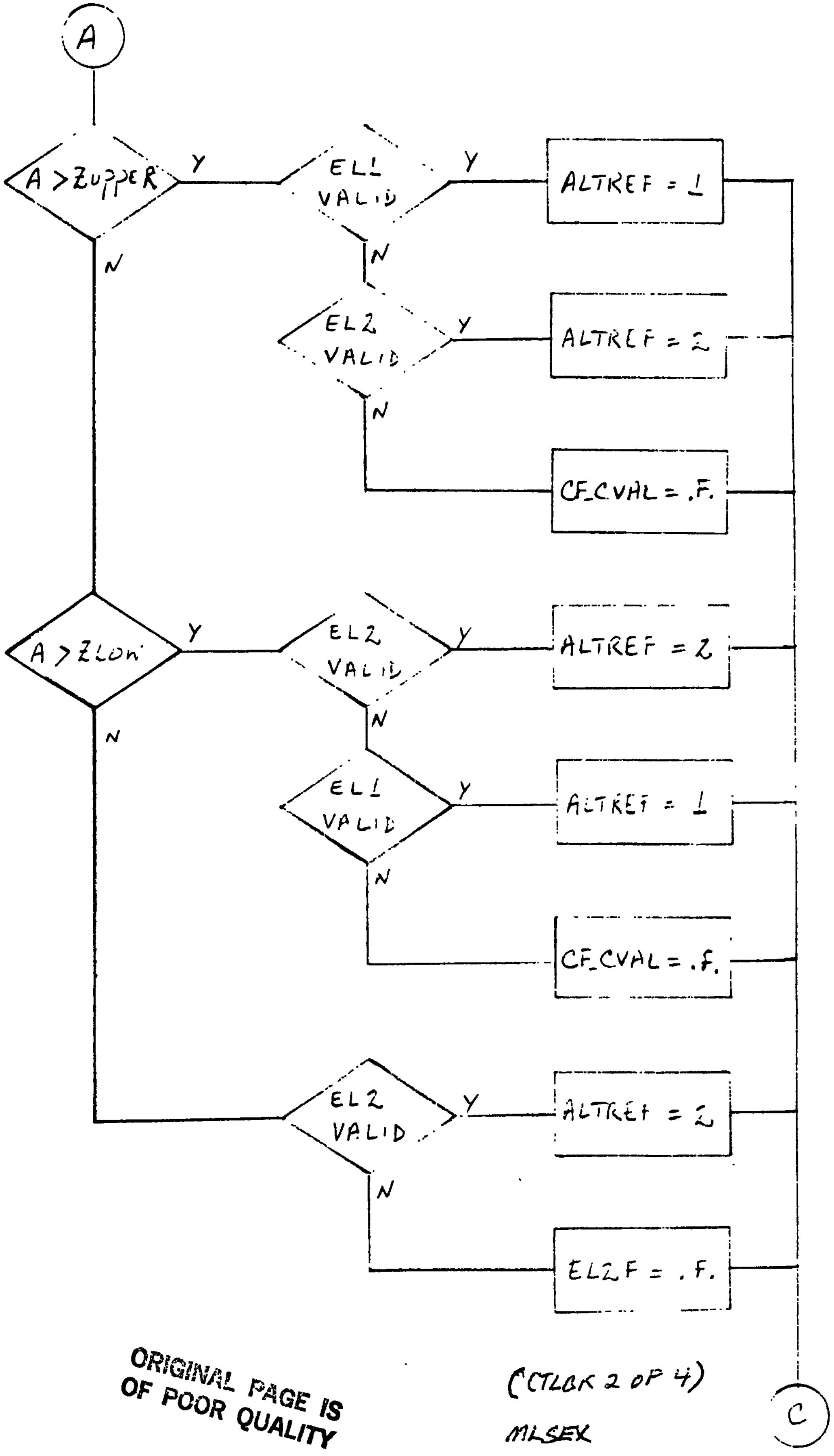
(CNTRM 4 OF 4)

MLSEX
(PAGE 7 OF 20)

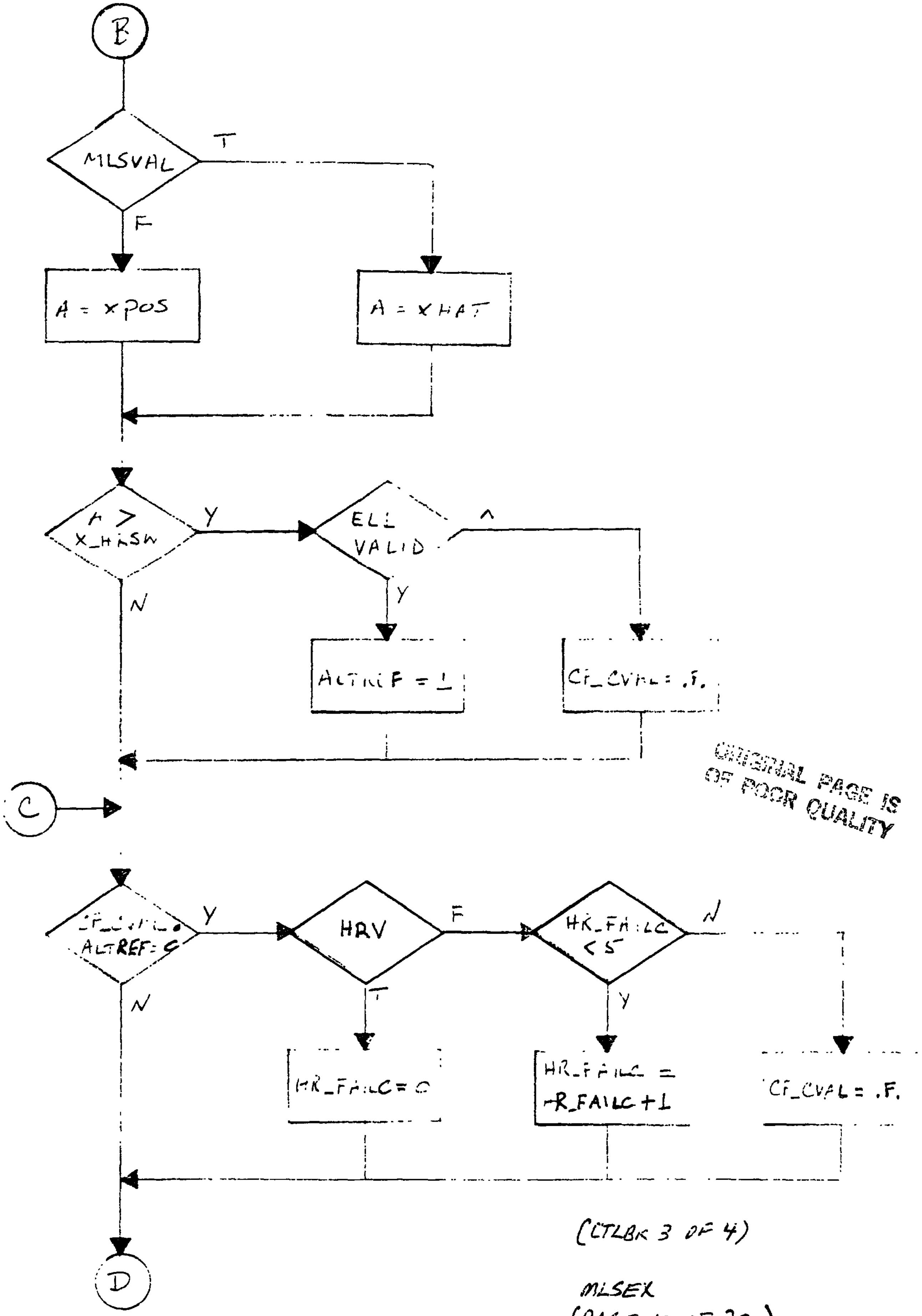


(CTLBK 1 OF 4)

MLSEX
(PAGE 8 OF 20)



(CTLBK 2 OF 4)
MLSEX
(PAGE 9 OF 20)



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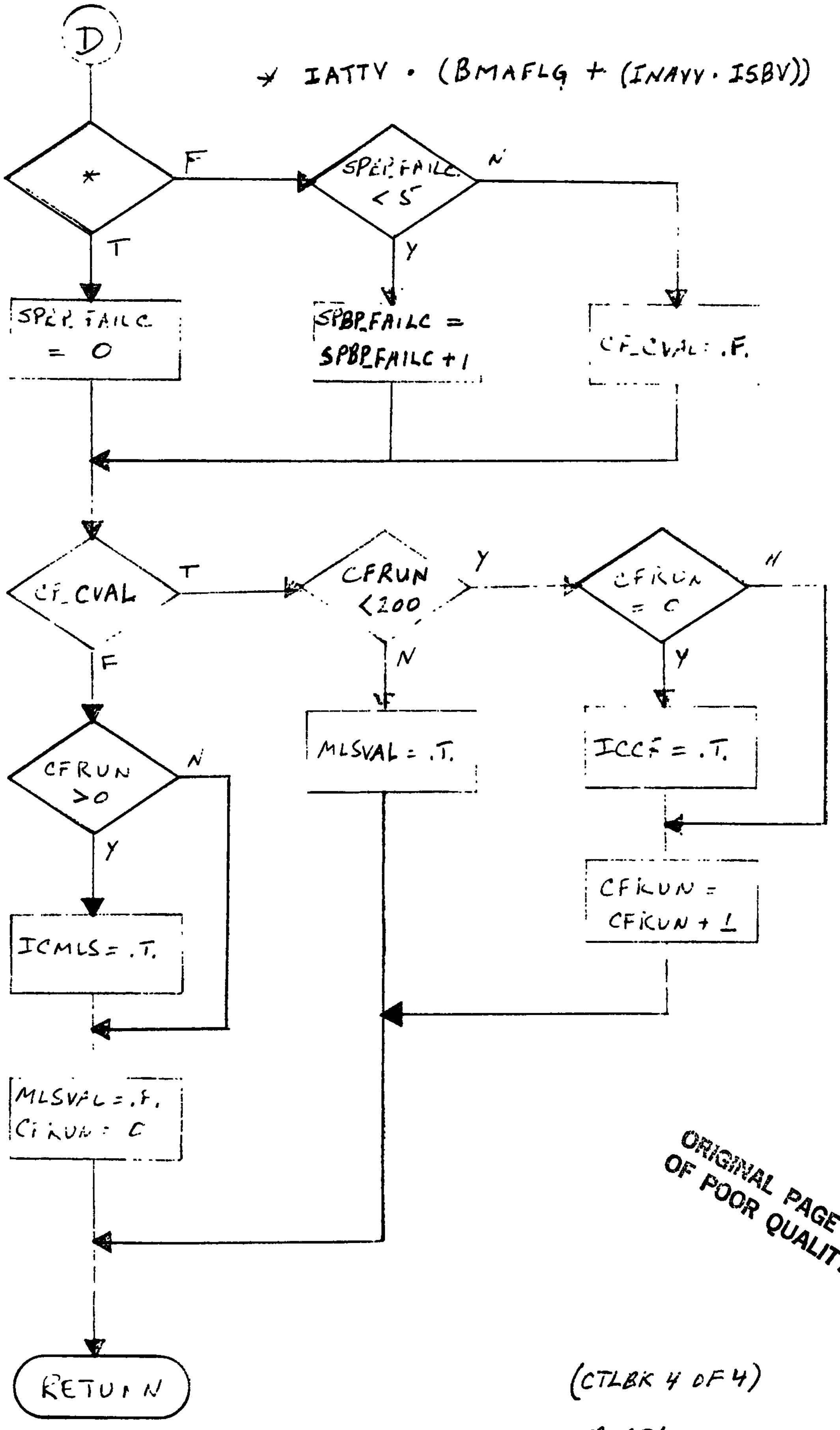
(CTLBK 3 OF 4)

MLSEX
(PAGE 10 OF 20)



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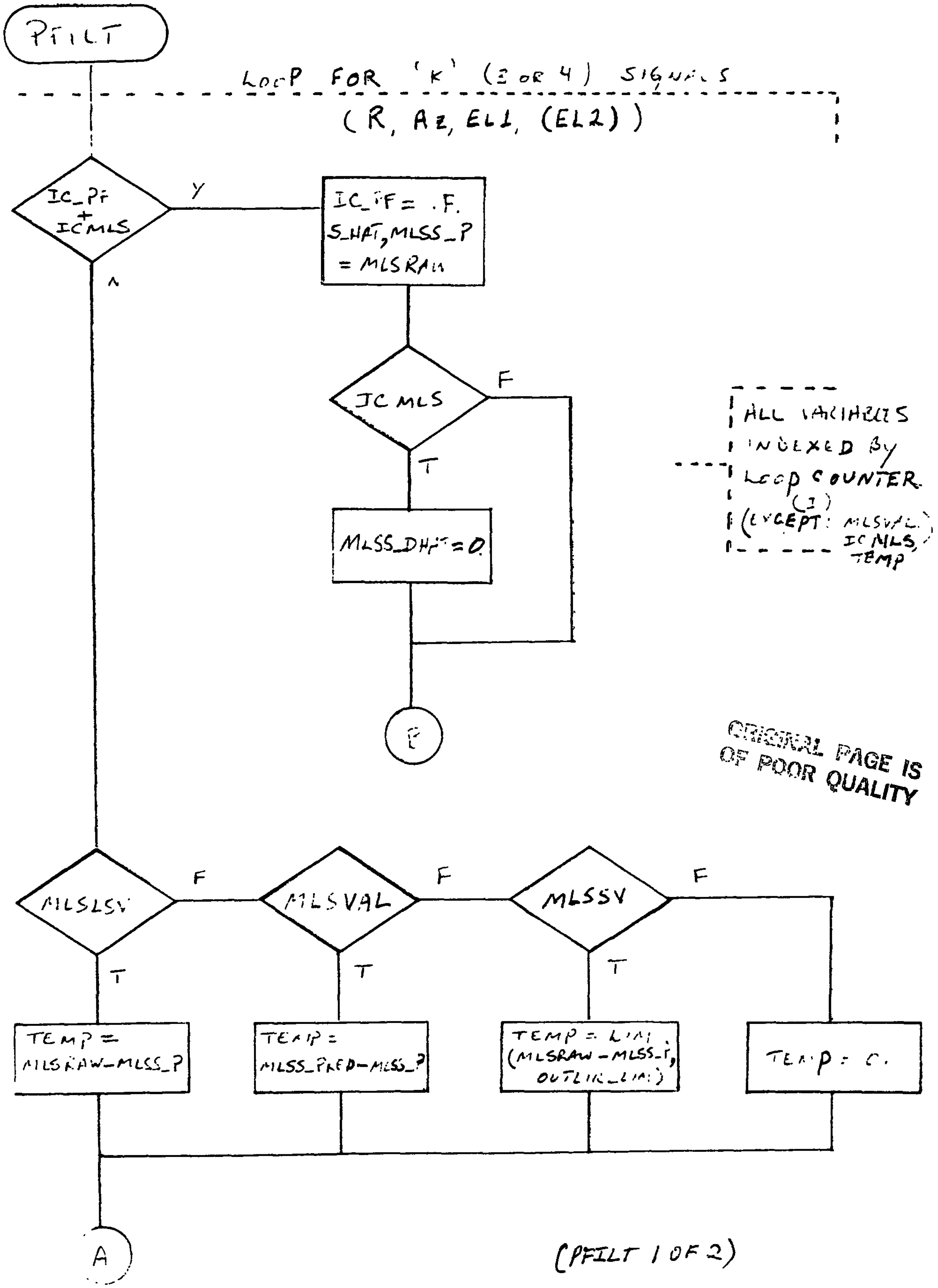
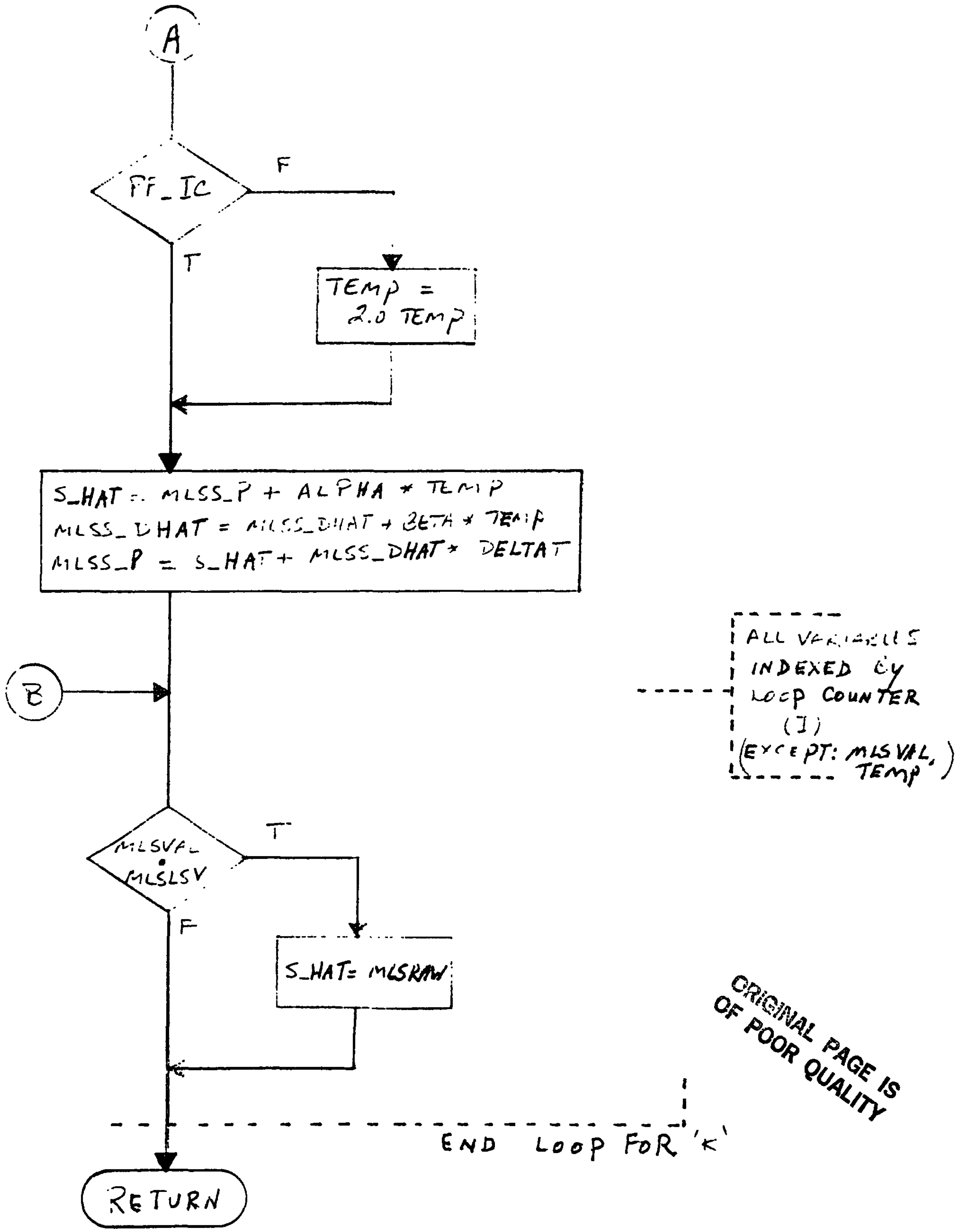
(CTLBK 4 OF 4)

MLSEX
(PAGE 11 OF 20)

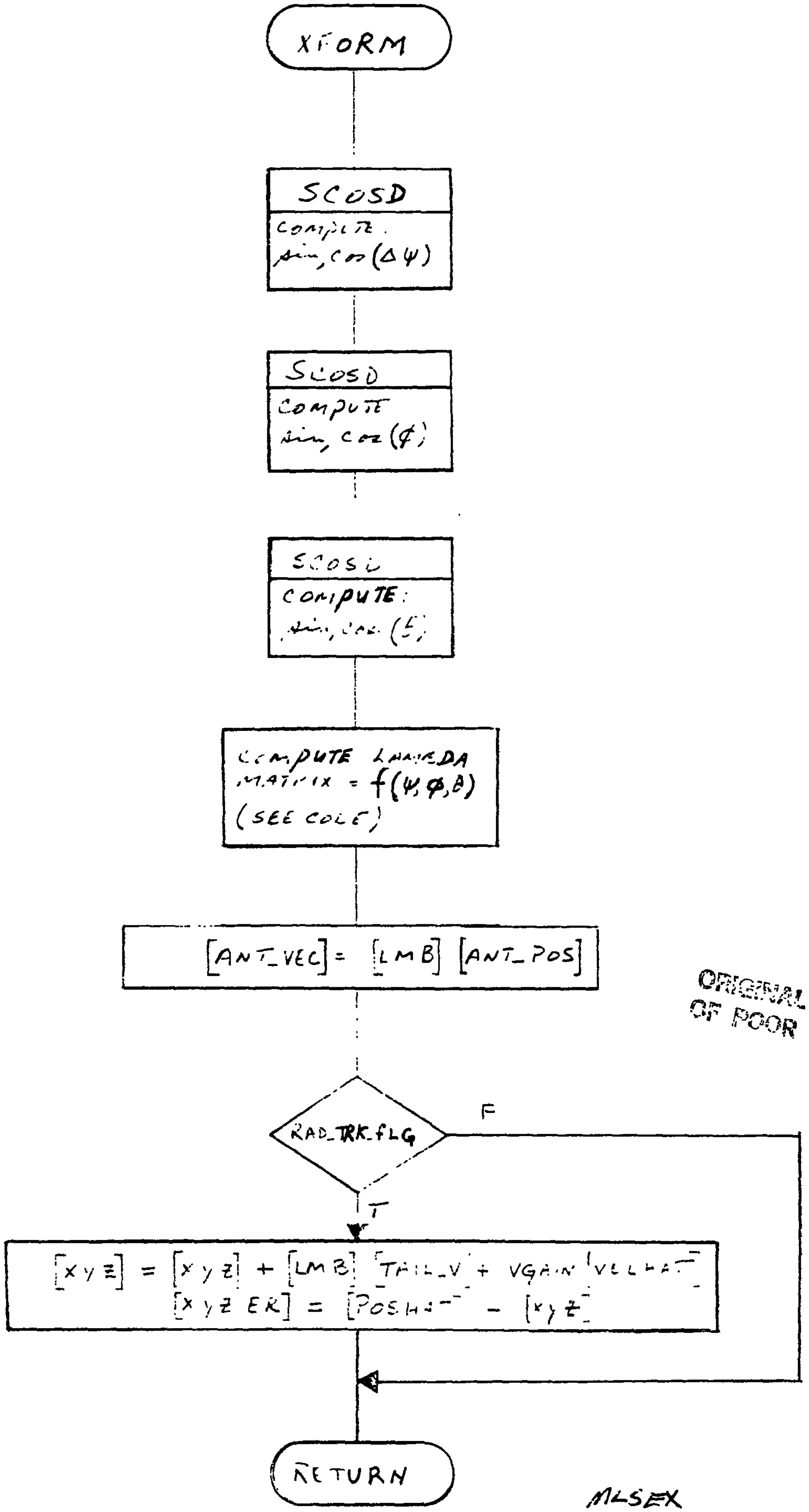


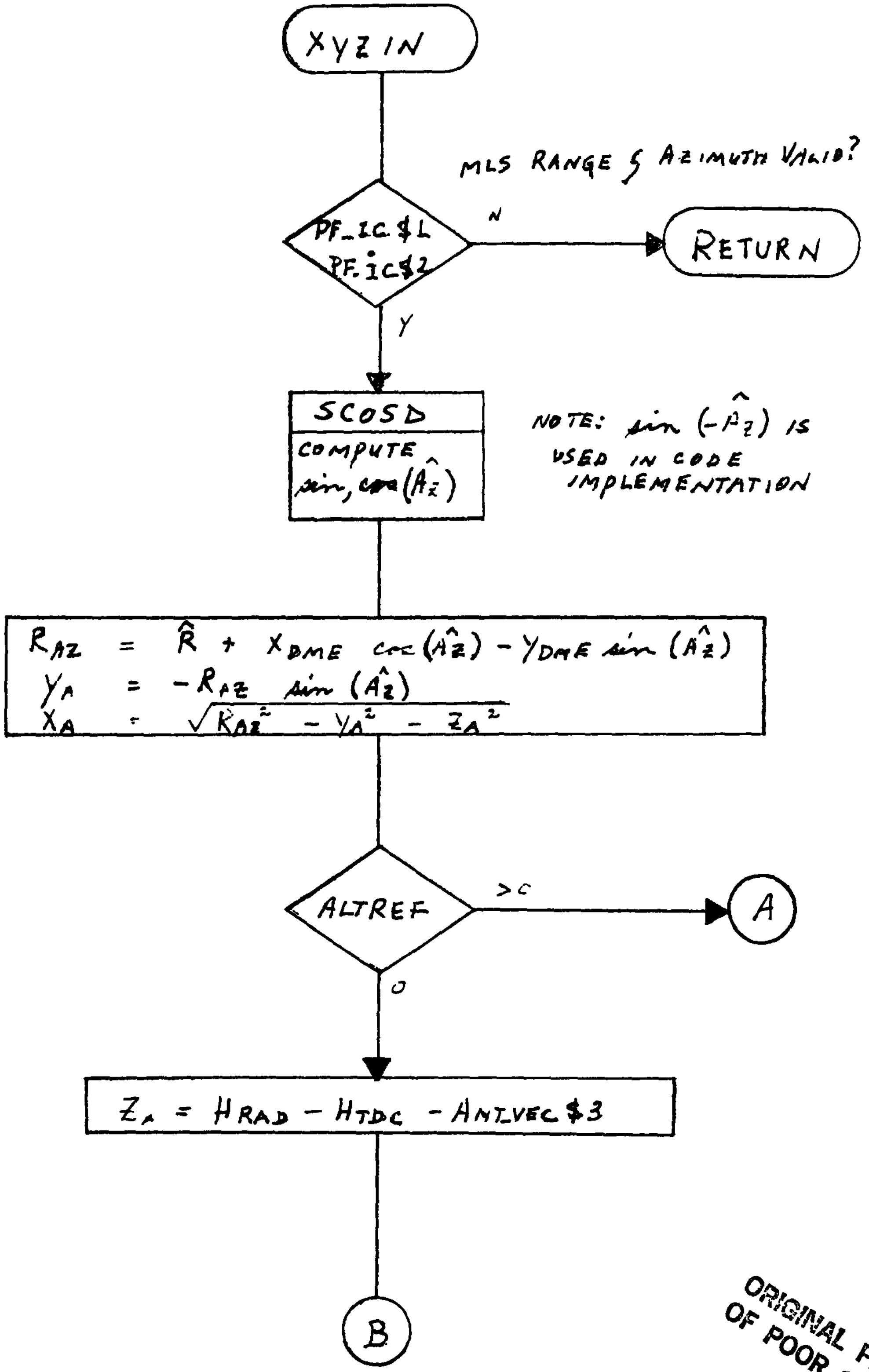
(PFILT 1 OF 2)

MLSEX
(PAGE 12 OF 20)


A
PF_IC
F
T
TEMP =
2.0 TEMP
S_HAT = MLSS_P + ALPHA * TEMP
MLSS_DHAT = MLSS_DHAT + BETA * TEMP
MLSS_P = S_HAT + MLSS_DHAT * DELTAT
B
ALL VARIABLES
INDEXED BY
LOOP COUNTER
(I)
(EXCEPT: MLSVAL,
TEMP)
MLSVAL
•
MLSLSV
T
F
S_HAT = MLSRAW
END LOOP FOR 'K'
RETURN

(PFILT 2 OF 2)


XFORM
SCOSD
COMPUTE
sin, cos (Δψ)
SCOSD
COMPUTE
sin, cos (φ)
SCOSD
COMPUTE:
sin, cos (θ)
COMPUTE LAMBDA MATRIX = f(ψ,φ,θ) (SEE CODE)
[ANT_VEC] = [LMB] [ANT_POS]
RAD_TRK_FLG
F
T
[xyz] = [xyz] + [LMB] [TAIL_V + VGAIN VELHAT]
[xyz ER] = [POSHAT] - [xyz]
RETURN


XYZIN
MLS RANGE & AZIMUTH VALID?
PF_IC$1
PF_IC$2
N
RETURN
Y
SCOSD
COMPUTE
sin, cos(Â_z)
NOTE: sin (-Â_z) IS USED IN CODE IMPLEMENTATION
R_AZ = R̂ + X_DME cos(Â_z) - Y_DME sin (Â_z)
Y_A = -R_AZ sin (Â_z)
X_A = √(R_AZ² - Y_A² - Z_A²)
ALTREF
>0
A
0
Z_A = H_RAD - H_TDC - ANT_VEC$3
B

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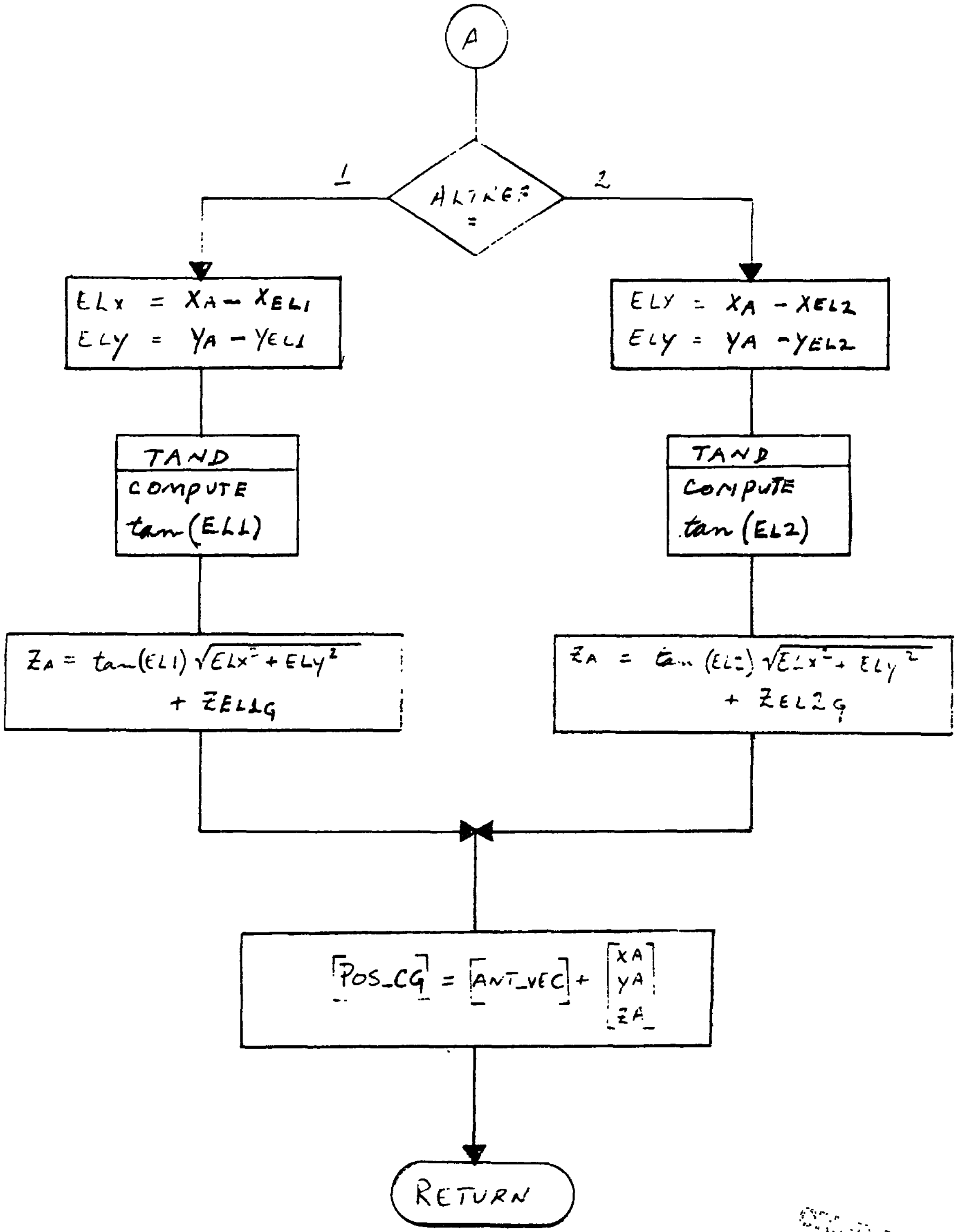
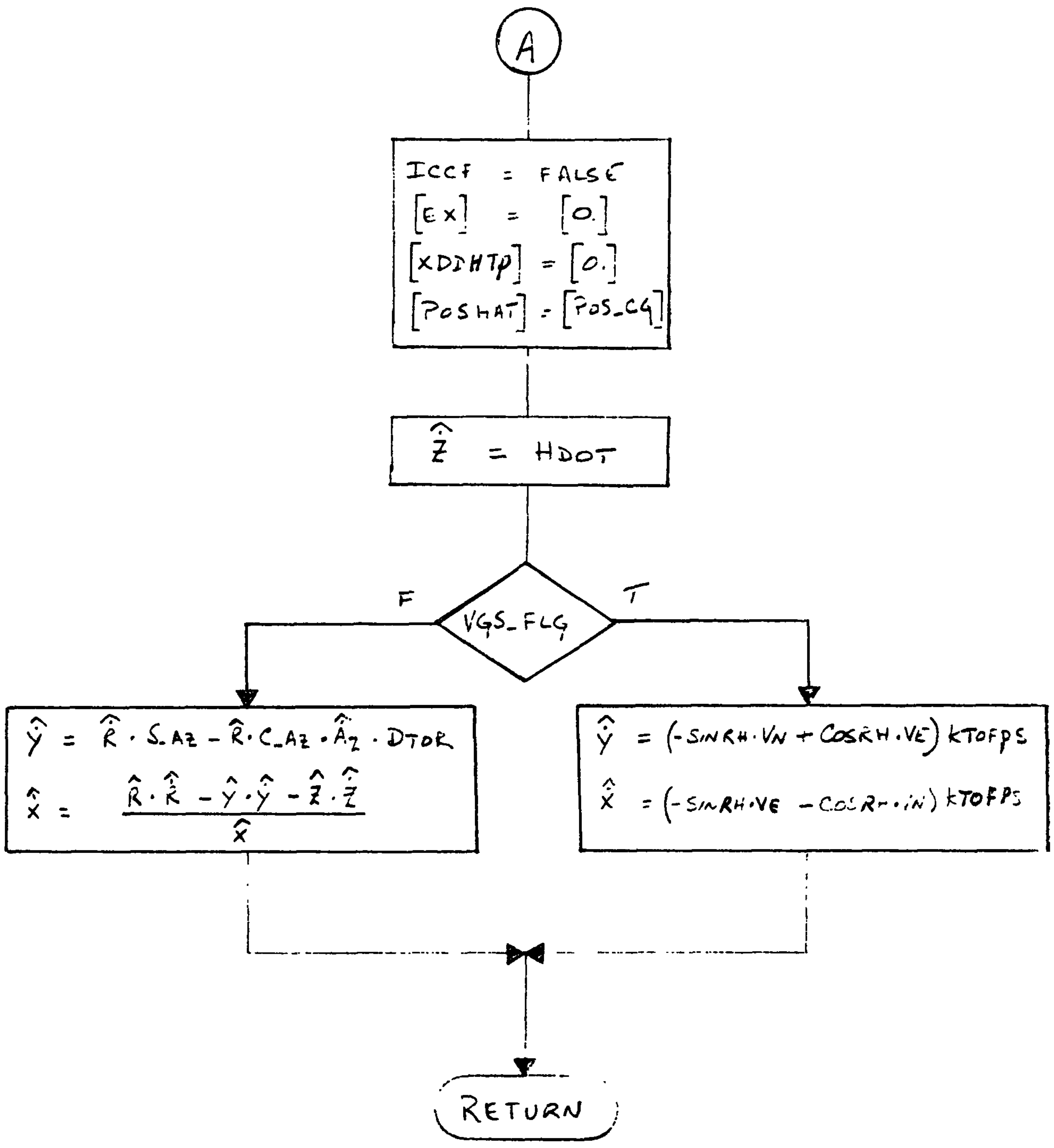
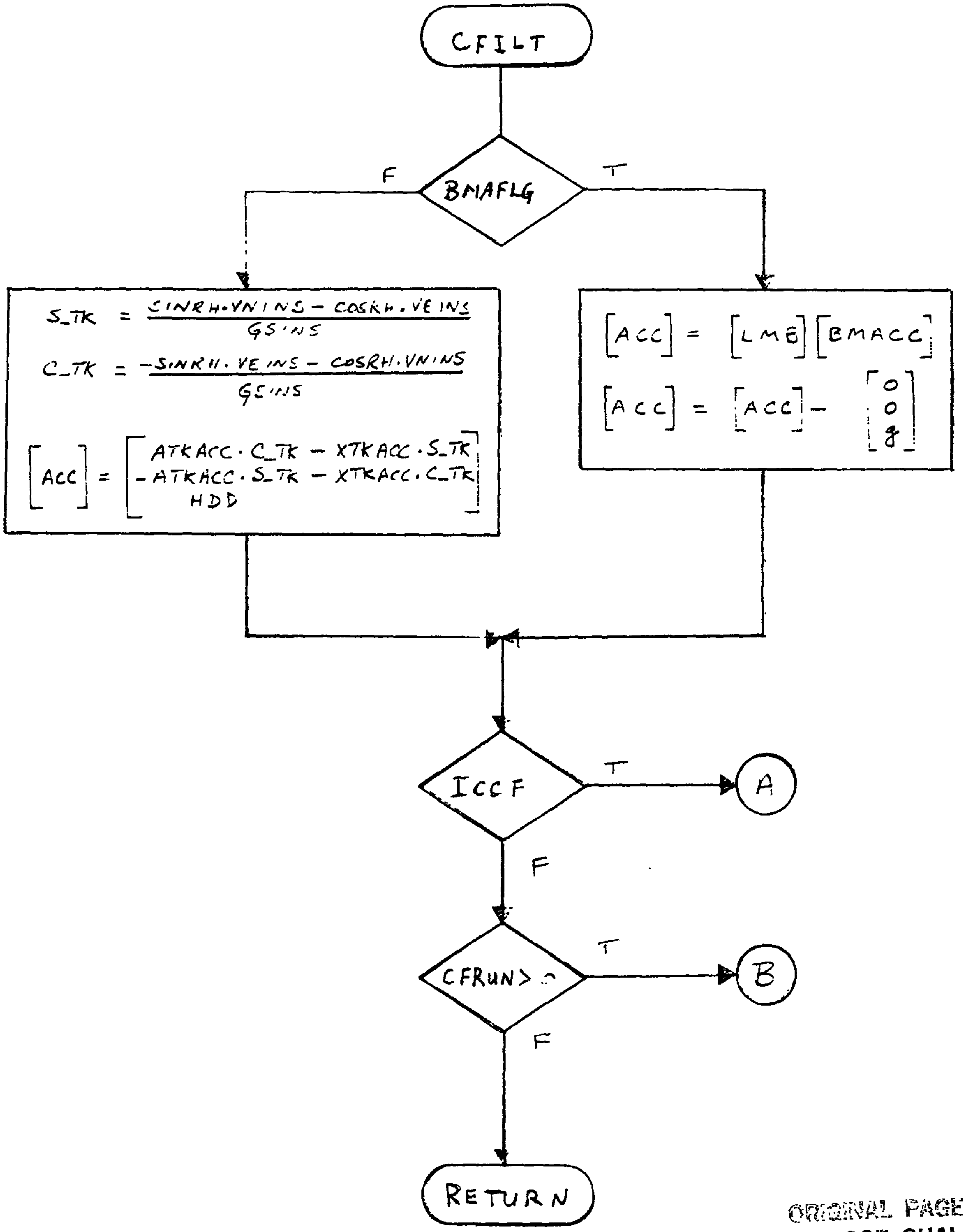
(XYZIN 1 OF 2)

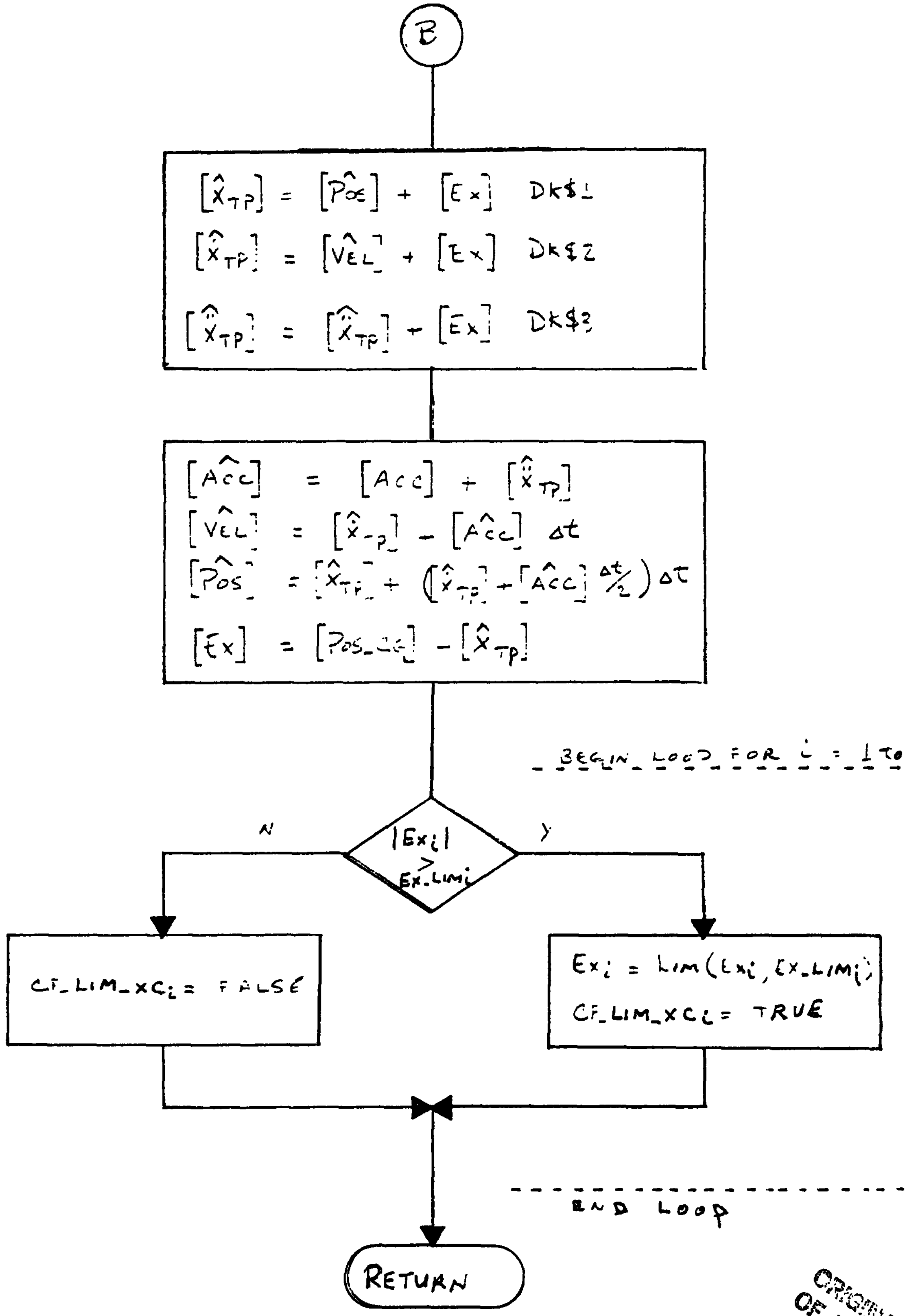

A
ALTREF =
1
2
ELX = XA − XEL1
ELY = YA − YEL1
ELY = XA − XEL2
ELY = YA − YEL2
TAND
COMPUTE
tan(EL1)
TAND
COMPUTE
tan(EL2)
ZA = tan(EL1) √ELX² + ELY²
+ ZEL1G
ZA = tan(EL2) √ELX² + ELY²
+ ZEL2G
[POS_CG] = [ANT_VEC] + [XA YA ZA]
RETURN

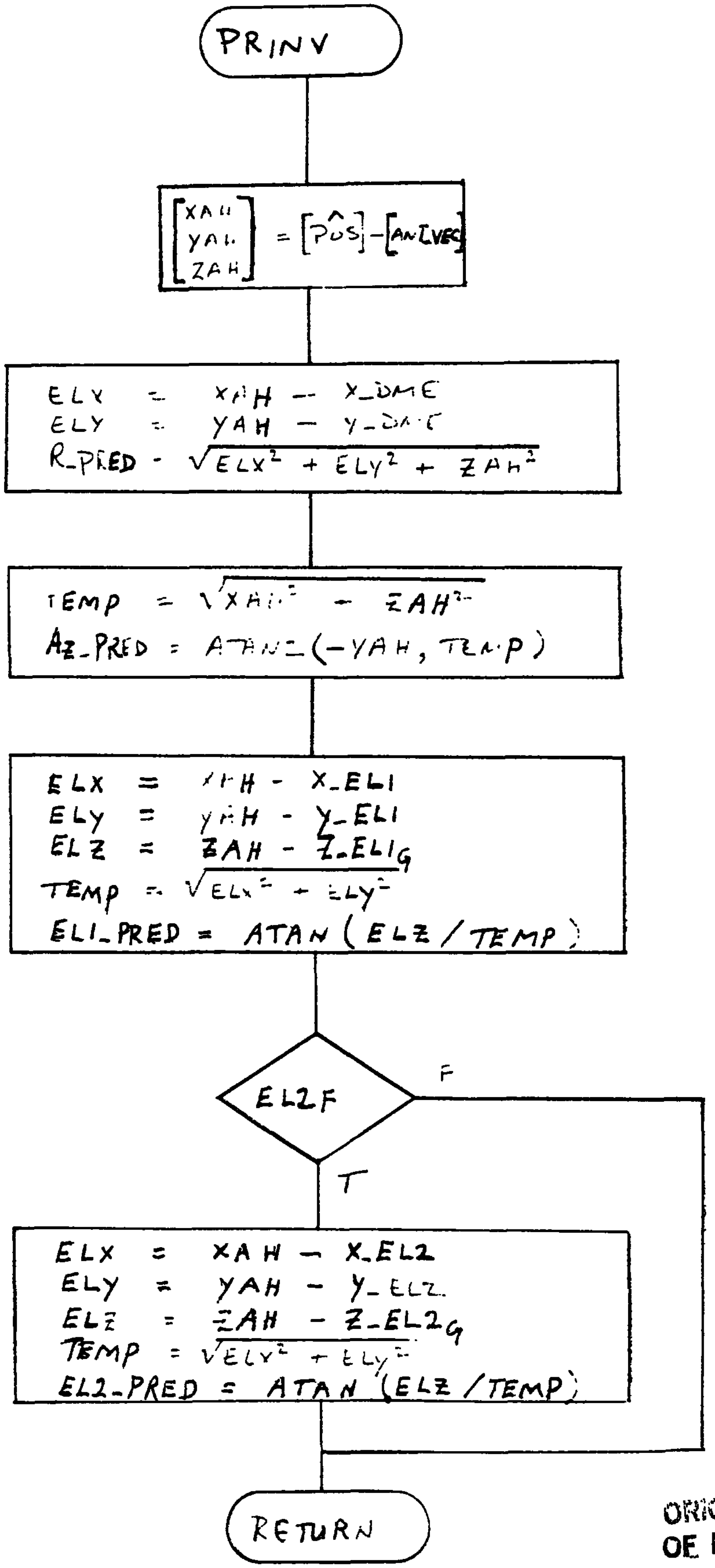

A
ICCF = FALSE
[EX] = [0.]
[XDIHTP] = [0.]
[POSHAT] = [POS_CG]
$\hat{\dot{Z}}$ = HDOT
F
VGS_FLG
T
$\hat{\dot{Y}} = \dot{\hat{R}} \cdot S\_AZ - \hat{R} \cdot C\_AZ \cdot \hat{\dot{A}}_Z \cdot DTOR$
$\hat{\dot{X}} = \dfrac{\hat{R} \cdot \hat{\dot{R}} - \hat{Y} \cdot \hat{\dot{Y}} - \hat{Z} \cdot \hat{\dot{Z}}}{\hat{X}}$
$\hat{\dot{Y}}$ = (-SINRH·VN + COSRH·VE) KTOFPS
$\hat{\dot{X}}$ = (-SINRH·VE - COSRH·VN) KTOFPS
RETURN


CFILT
BMAFLG
F
T
$S\_TK = \frac{SINRH \cdot VNINS - COSRH \cdot VEINS}{GSINS}$
$C\_TK = \frac{-SINRH \cdot VEINS - COSRH \cdot VNINS}{GSINS}$
$\begin{bmatrix} ACC \end{bmatrix} = \begin{bmatrix} ATKACC \cdot C\_TK - XTKACC \cdot S\_TK \\ -ATKACC \cdot S\_TK - XTKACC \cdot C\_TK \\ HDD \end{bmatrix}$
$\begin{bmatrix} ACC \end{bmatrix} = \begin{bmatrix} LMB \end{bmatrix} \begin{bmatrix} BMACC \end{bmatrix}$
$\begin{bmatrix} ACC \end{bmatrix} = \begin{bmatrix} ACC \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ g \end{bmatrix}$
ICCF
T
A
F
CFRUN > 0
T
B
F
RETURN

(CFILT 1 OF 3)

MLSEX
(PAGE 17 OF 20)


B
$[\hat{X}_{TP}] = [\hat{Pos}] + [Ex]$ DK$1
$[\hat{\dot{X}}_{TP}] = [\hat{VEL}] + [Ex]$ DK$2
$[\hat{\ddot{X}}_{TP}] = [\hat{\dot{X}}_{TP}] + [Ex]$ DK$3
$[\hat{Acc}] = [Acc] + [\hat{\ddot{X}}_{TP}]$
$[\hat{VEL}] = [\hat{\dot{X}}_{TP}] - [\hat{Acc}]\ \Delta t$
$[\hat{Pos}] = [\hat{X}_{TP}] + ([\hat{\dot{X}}_{TP}] - [\hat{Acc}]\frac{\Delta t}{2})\Delta t$
$[Ex] = [Pos\_CC] - [\hat{X}_{TP}]$
BEGIN LOOP FOR i = 1 TO 3
N
Y
$|Ex_i| > EX\_LIM_i$
CF_LIM_XC_i = FALSE
Ex_i = LIM(Ex_i, EX_LIM_i)
CF_LIM_XC_i = TRUE
END LOOP
RETURN



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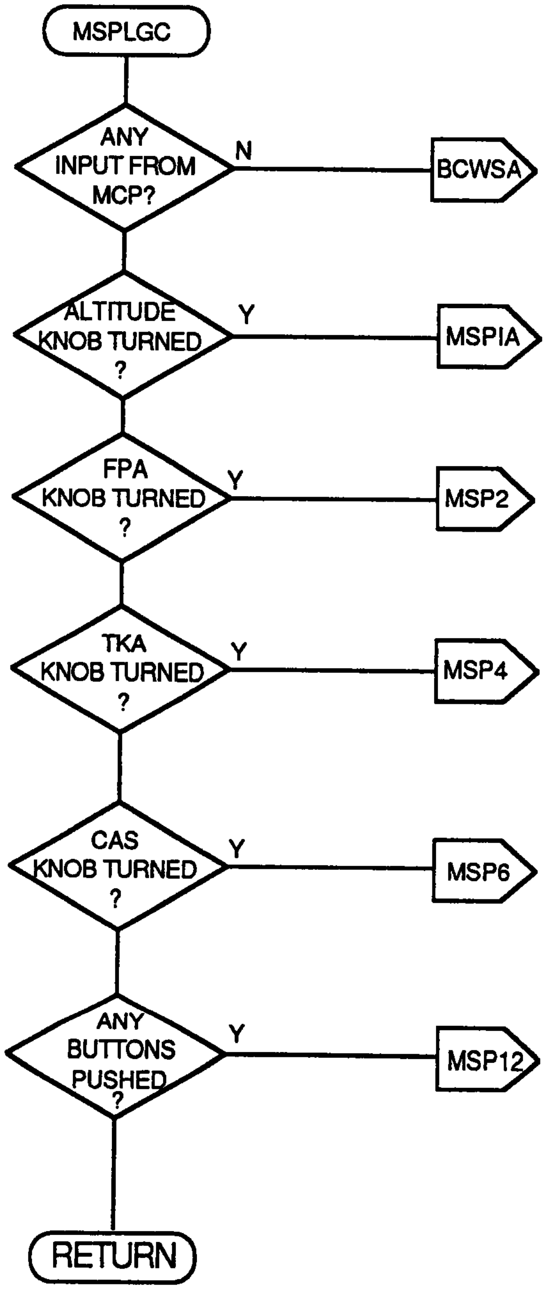
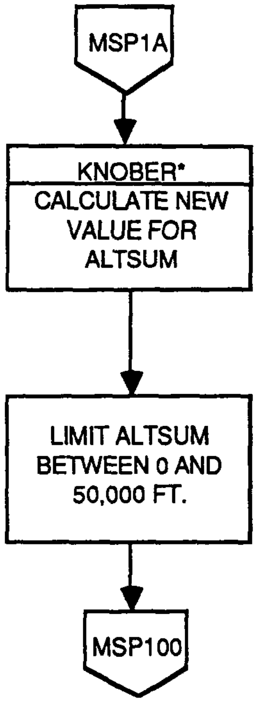
MLSEX
(PAGE 2[illegible] OF 20)

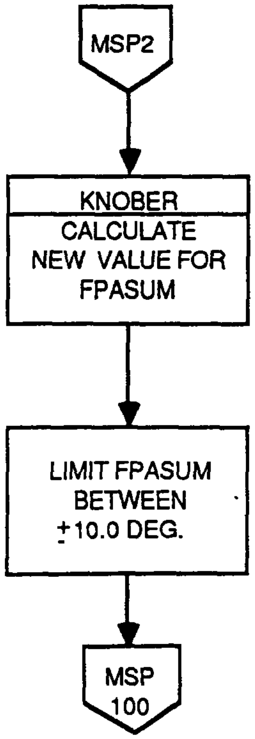

MSPLGC
ANY INPUT FROM MCP?
N
BCWSA
ALTITUDE KNOB TURNED ?
Y
MSPIA
FPA KNOB TURNED ?
Y
MSP2
TKA KNOB TURNED ?
Y
MSP4
CAS KNOB TURNED ?
Y
MSP6
ANY BUTTONS PUSHED ?
Y
MSP12
RETURN

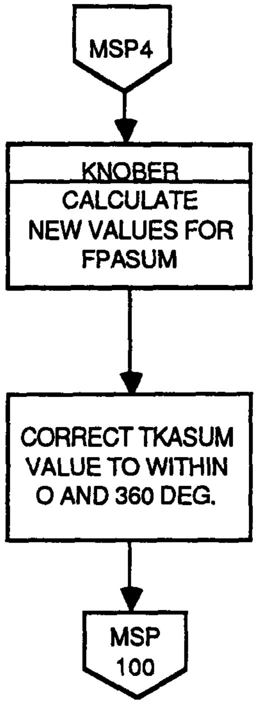
MSPLGC 1/9

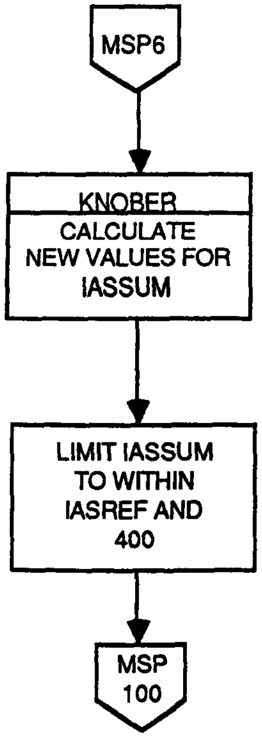

MSP1A
KNOBER*
CALCULATE NEW VALUE FOR ALTSUM
LIMIT ALTSUM BETWEEN 0 AND 50,000 FT.
MSP100

*KNOBER is a local subroutine which increments or decrements the input parameter based on the knob input. It also sets a Boolean corresponding to the knob turned. These Booleans are the following:

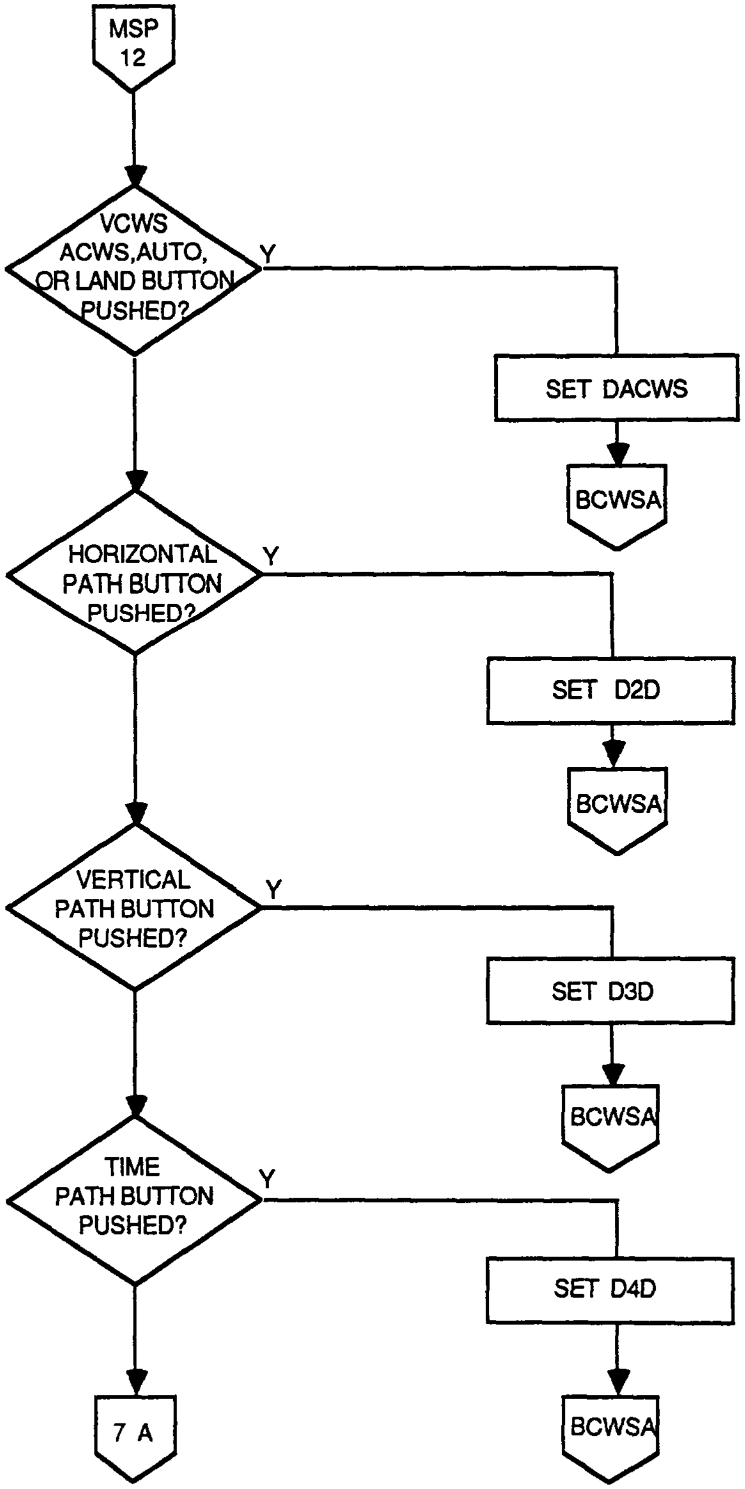
RAKNOB -	Altitude
RFKNOB -	Flight path angle
RTKNOB -	Track angle
RCKNOB -	Airspeed

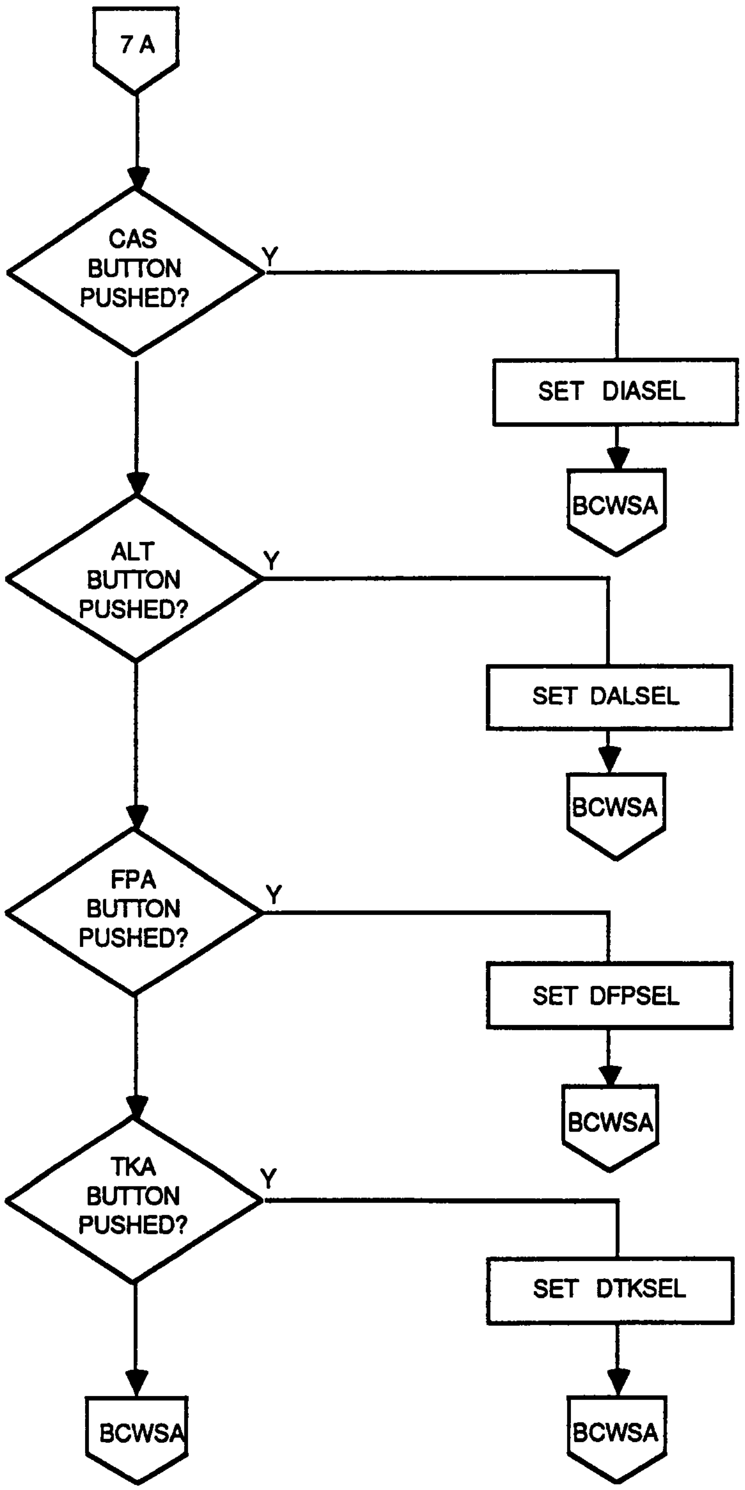

MSP2
KNOBER
CALCULATE NEW VALUE FOR FPASUM
LIMIT FPASUM BETWEEN ±10.0 DEG.
MSP 100


MSP4
KNOBER
CALCULATE NEW VALUES FOR FPASUM
CORRECT TKASUM VALUE TO WITHIN O AND 360 DEG.
MSP 100

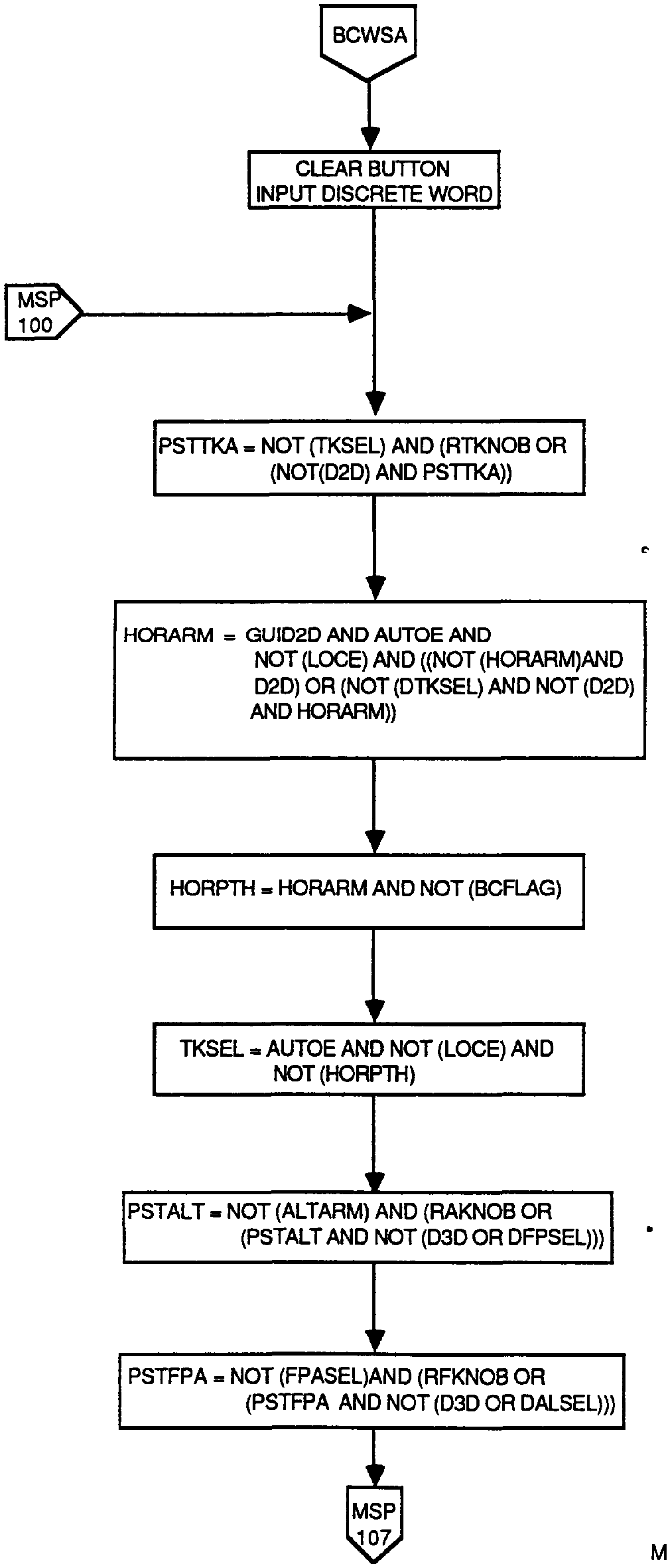

MSP6
KNOBER
CALCULATE NEW VALUES FOR IASSUM
LIMIT IASSUM TO WITHIN IASREF AND 400
MSP 100

MSPLGC 3/9

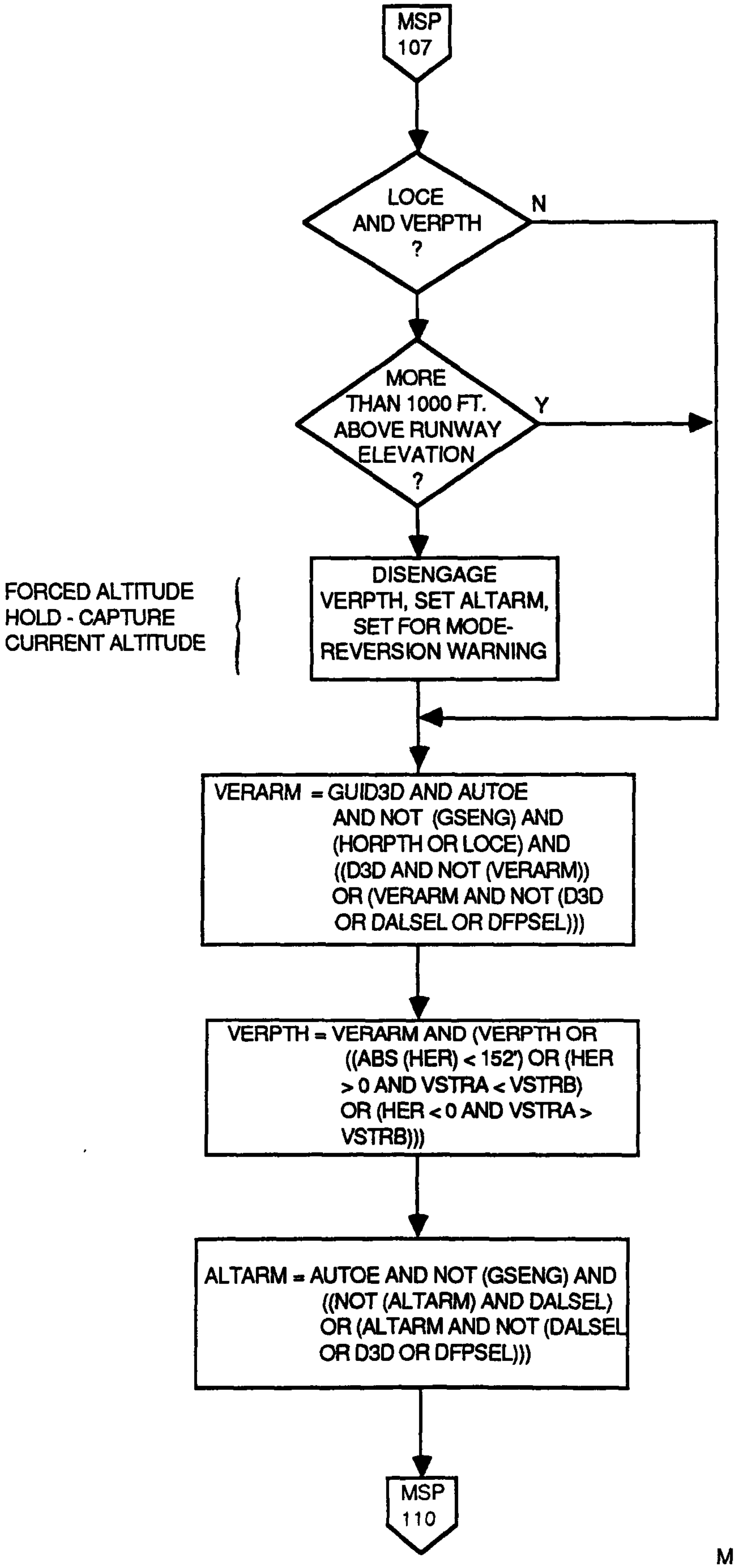

MSP 12
VCWS ACWS,AUTO, OR LAND BUTTON PUSHED?
Y
SET DACWS
BCWSA
HORIZONTAL PATH BUTTON PUSHED?
Y
SET D2D
BCWSA
VERTICAL PATH BUTTON PUSHED?
Y
SET D3D
BCWSA
TIME PATH BUTTON PUSHED?
Y
SET D4D
BCWSA
7 A


7 A
CAS BUTTON PUSHED?
Y
SET DIASEL
BCWSA
ALT BUTTON PUSHED?
Y
SET DALSEL
BCWSA
FPA BUTTON PUSHED?
Y
SET DFPSEL
BCWSA
TKA BUTTON PUSHED?
Y
SET DTKSEL
BCWSA
BCWSA

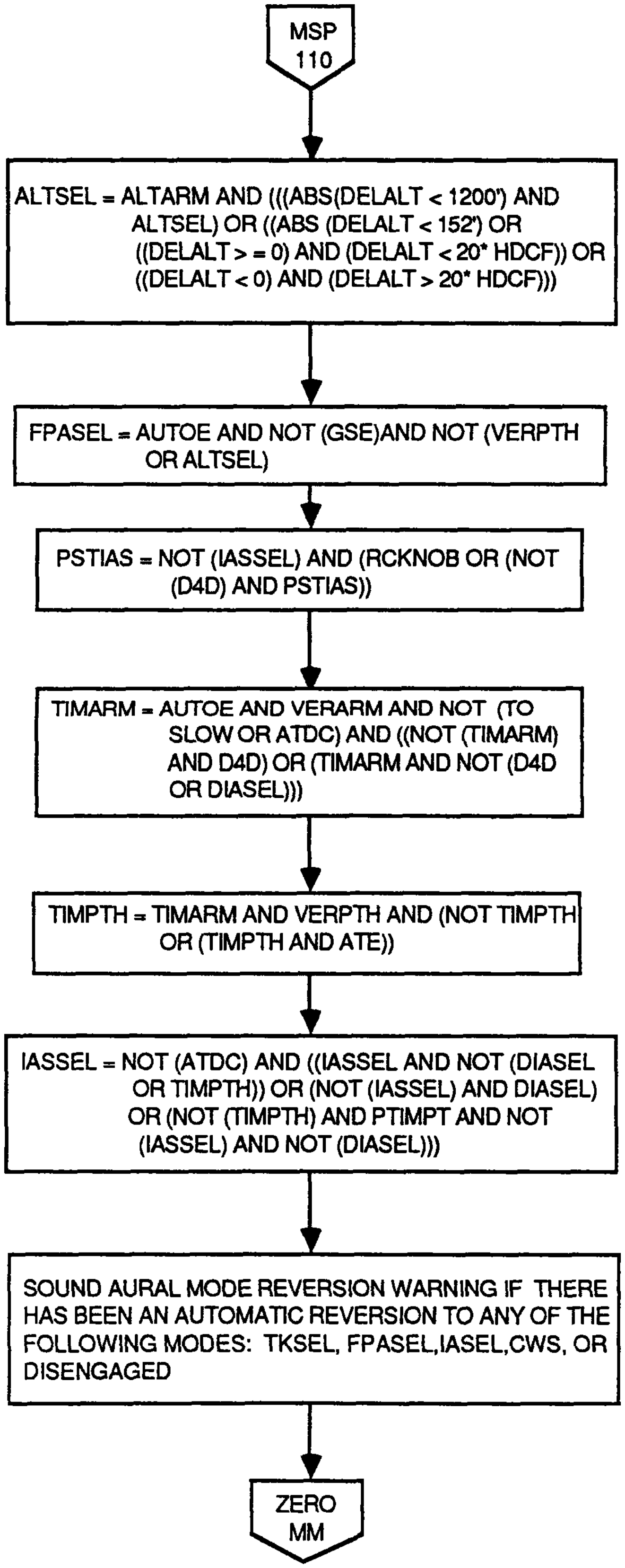
MSPLGC 5/9


BCWSA
CLEAR BUTTON INPUT DISCRETE WORD
MSP 100
PSTTKA = NOT (TKSEL) AND (RTKNOB OR (NOT(D2D) AND PSTTKA))
HORARM = GUID2D AND AUTOE AND NOT (LOCE) AND ((NOT (HORARM)AND D2D) OR (NOT (DTKSEL) AND NOT (D2D) AND HORARM))
HORPTH = HORARM AND NOT (BCFLAG)
TKSEL = AUTOE AND NOT (LOCE) AND NOT (HORPTH)
PSTALT = NOT (ALTARM) AND (RAKNOB OR (PSTALT AND NOT (D3D OR DFPSEL)))
PSTFPA = NOT (FPASEL)AND (RFKNOB OR (PSTFPA AND NOT (D3D OR DALSEL)))
MSP 107

MSPLGC 6/9


MSP 107
LOCE AND VERPTH ?
N
MORE THAN 1000 FT. ABOVE RUNWAY ELEVATION ?
Y
FORCED ALTITUDE HOLD - CAPTURE CURRENT ALTITUDE
DISENGAGE VERPTH, SET ALTARM, SET FOR MODE-REVERSION WARNING
VERARM = GUID3D AND AUTOE AND NOT (GSENG) AND (HORPTH OR LOCE) AND ((D3D AND NOT (VERARM)) OR (VERARM AND NOT (D3D OR DALSEL OR DFPSEL)))
VERPTH = VERARM AND (VERPTH OR ((ABS (HER) < 152') OR (HER > 0 AND VSTRA < VSTRB) OR (HER < 0 AND VSTRA > VSTRB)))
ALTARM = AUTOE AND NOT (GSENG) AND ((NOT (ALTARM) AND DALSEL) OR (ALTARM AND NOT (DALSEL OR D3D OR DFPSEL)))
MSP 110

MSPLGC 7/9



ALTSEL = ALTARM AND (((ABS(DELALT < 1200') AND
ALTSEL) OR ((ABS (DELALT < 152') OR
((DELALT > = 0) AND (DELALT < 20* HDCF)) OR
((DELALT < 0) AND (DELALT > 20* HDCF)))

FPASEL = AUTOE AND NOT (GSE)AND NOT (VERPTH
OR ALTSEL)

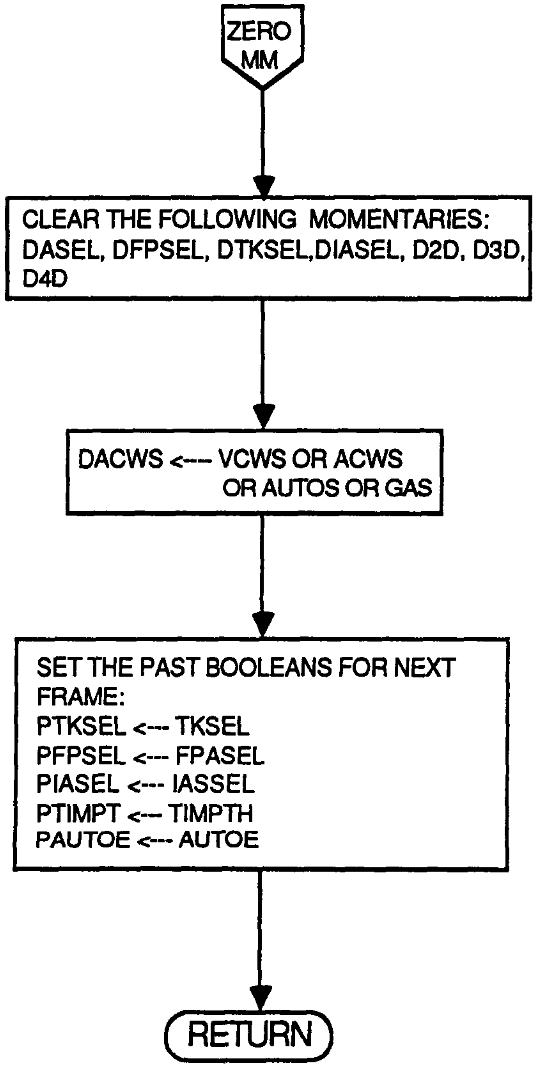
PSTIAS = NOT (IASSEL) AND (RCKNOB OR (NOT
(D4D) AND PSTIAS))

TIMARM = AUTOE AND VERARM AND NOT (TO
SLOW OR ATDC) AND ((NOT (TIMARM)
AND D4D) OR (TIMARM AND NOT (D4D
OR DIASEL)))

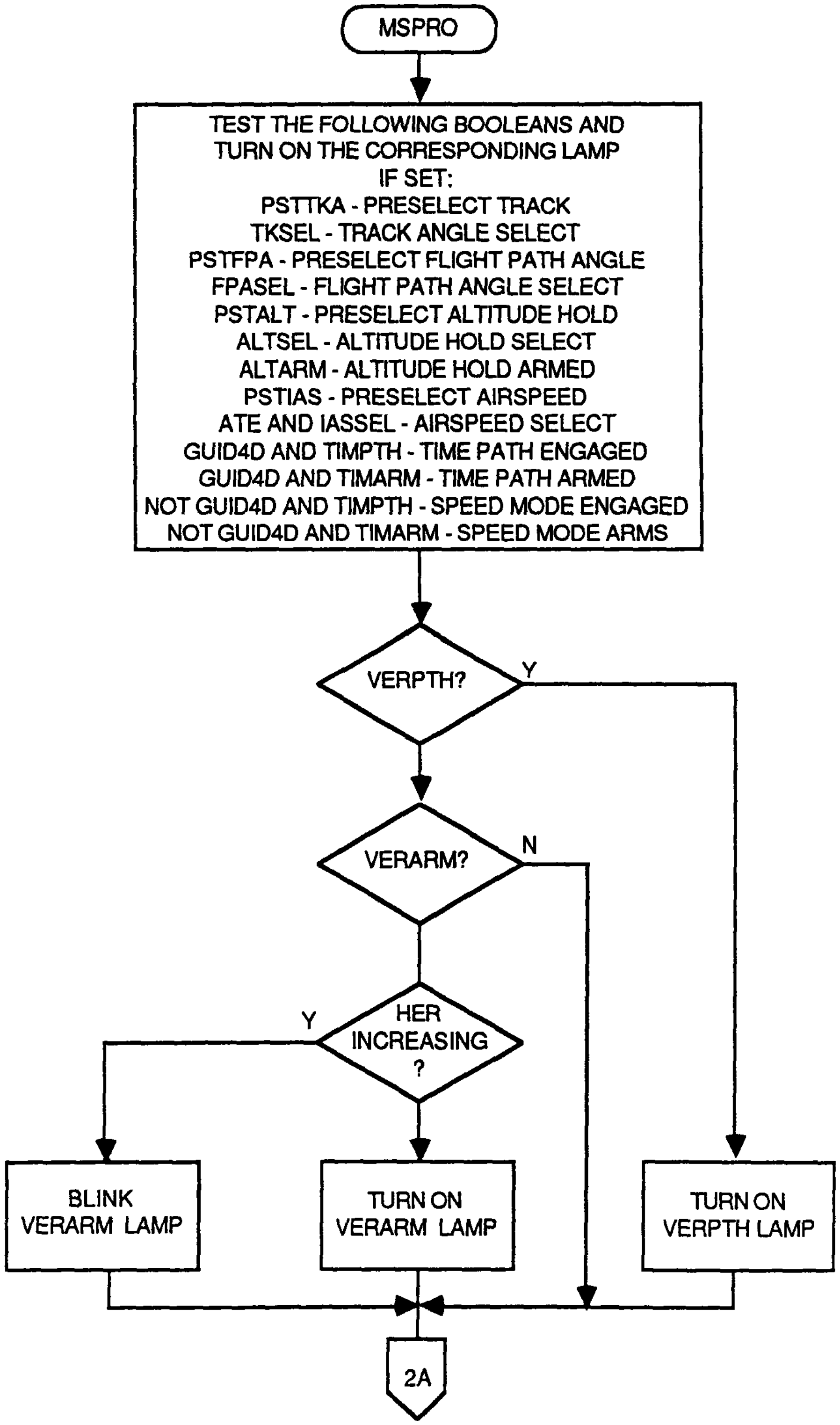
TIMPTH = TIMARM AND VERPTH AND (NOT TIMPTH
OR (TIMPTH AND ATE))

IASSEL = NOT (ATDC) AND ((IASSEL AND NOT (DIASEL
OR TIMPTH)) OR (NOT (IASSEL) AND DIASEL)
OR (NOT (TIMPTH) AND PTIMPT AND NOT
(IASSEL) AND NOT (DIASEL)))

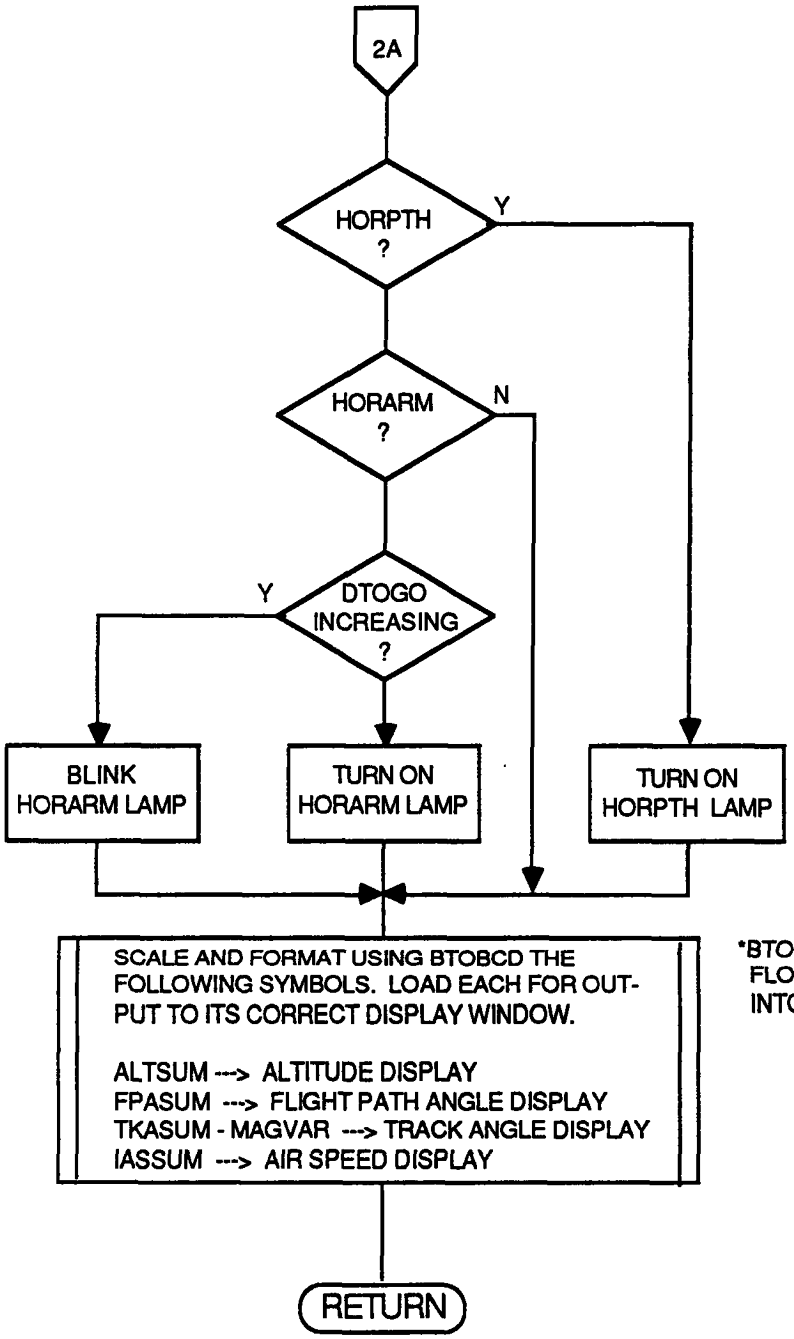
SOUND AURAL MODE REVERSION WARNING IF THERE HAS BEEN AN AUTOMATIC REVERSION TO ANY OF THE FOLLOWING MODES: TKSEL, FPASEL,IASEL,CWS, OR DISENGAGED


ZERO MM
CLEAR THE FOLLOWING MOMENTARIES: DASEL, DFPSEL, DTKSEL,DIASEL, D2D, D3D, D4D
DACWS <--- VCWS OR ACWS OR AUTOS OR GAS
SET THE PAST BOOLEANS FOR NEXT FRAME:
PTKSEL <--- TKSEL
PFPSEL <--- FPASEL
PIASEL <--- IASSEL
PTIMPT <--- TIMPTH
PAUTOE <--- AUTOE
RETURN

MSPLGC 9/9

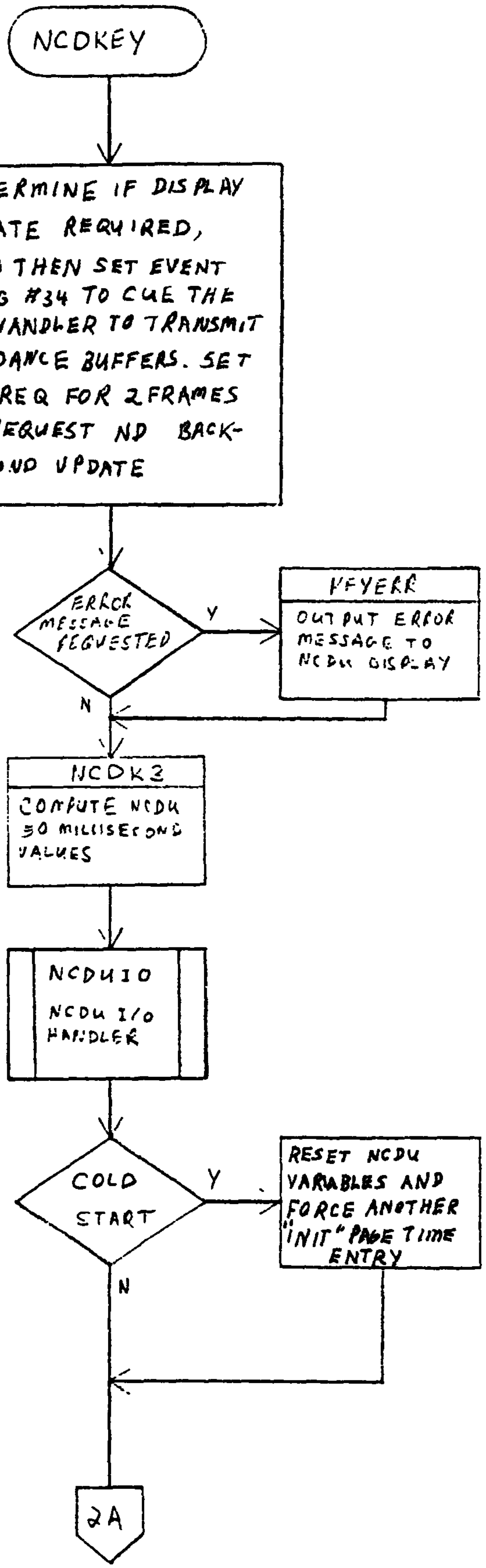

MSPRO
TEST THE FOLLOWING BOOLEANS AND
TURN ON THE CORRESPONDING LAMP
IF SET:
PSTTKA - PRESELECT TRACK
TKSEL - TRACK ANGLE SELECT
PSTFPA - PRESELECT FLIGHT PATH ANGLE
FPASEL - FLIGHT PATH ANGLE SELECT
PSTALT - PRESELECT ALTITUDE HOLD
ALTSEL - ALTITUDE HOLD SELECT
ALTARM - ALTITUDE HOLD ARMED
PSTIAS - PRESELECT AIRSPEED
ATE AND IASSEL - AIRSPEED SELECT
GUID4D AND TIMPTH - TIME PATH ENGAGED
GUID4D AND TIMARM - TIME PATH ARMED
NOT GUID4D AND TIMPTH - SPEED MODE ENGAGED
NOT GUID4D AND TIMARM - SPEED MODE ARMS
VERPTH?
Y
VERARM?
N
HER INCREASING ?
Y
BLINK VERARM LAMP
TURN ON VERARM LAMP
TURN ON VERPTH LAMP
2A

MSPRO 1/2

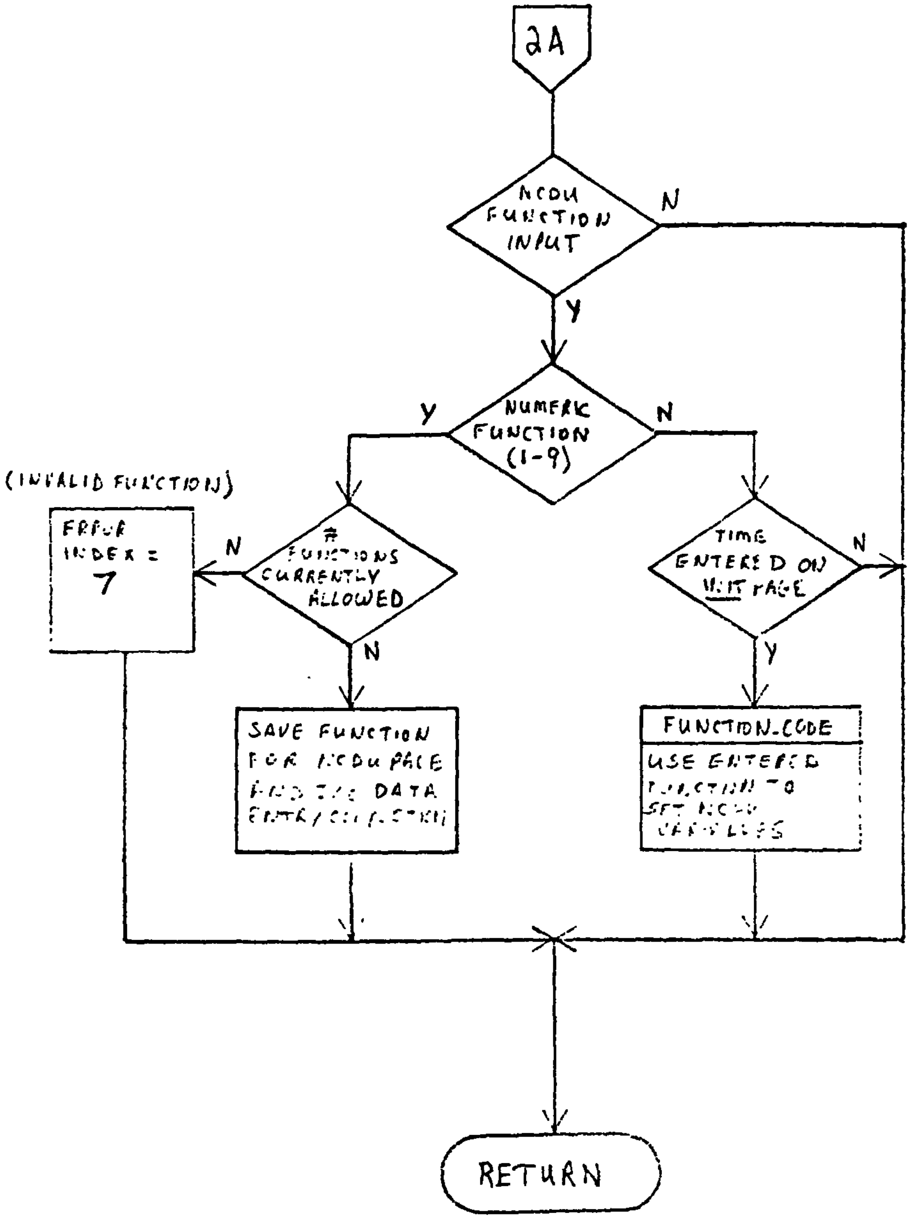

2A
HORPTH ?
Y
HORARM ?
N
DTOGO INCREASING ?
Y
BLINK HORARM LAMP
TURN ON HORARM LAMP
TURN ON HORPTH LAMP
SCALE AND FORMAT USING BTOBCD THE FOLLOWING SYMBOLS. LOAD EACH FOR OUTPUT TO ITS CORRECT DISPLAY WINDOW.
ALTSUM ---> ALTITUDE DISPLAY
FPASUM ---> FLIGHT PATH ANGLE DISPLAY
TKASUM - MAGVAR ---> TRACK ANGLE DISPLAY
IASSUM ---> AIR SPEED DISPLAY
RETURN

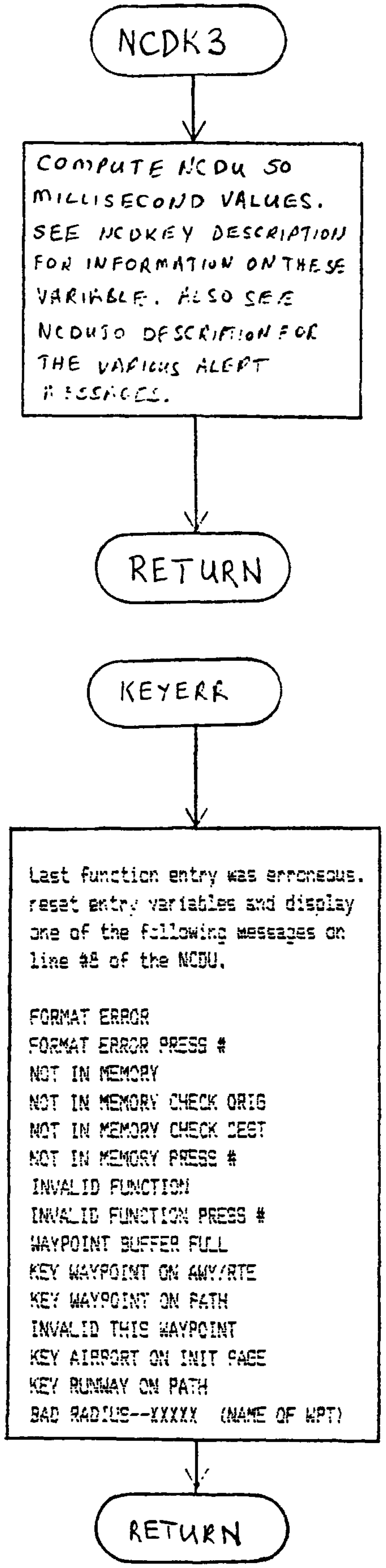
*BTOBCD CONVERTS A FLOATING POINT NUMBER INTO BINARY CODED DECIMAL.

MSPRO 2/2


NCDKEY
DETERMINE IF DISPLAY UPDATE REQUIRED, IF SO THEN SET EVENT FLAG #34 TO CUE THE I/O HANDLER TO TRANSMIT GUIDANCE BUFFERS. SET MFDREQ FOR 2FRAMES TO REQUEST ND BACK-GROUND UPDATE
ERROR MESSAGE REQUESTED
Y
N
KEYERR
OUTPUT ERROR MESSAGE TO NCDU DISPLAY
NCDK3
COMPUTE NCDU 50 MILLISECOND VALUES
NCDUIO
NCDU I/O HANDLER
COLD START
Y
N
RESET NCDU VARABLES AND FORCE ANOTHER "INIT" PAGE TIME ENTRY
2A

NCDKEY
(PAGE 1 OF 4)

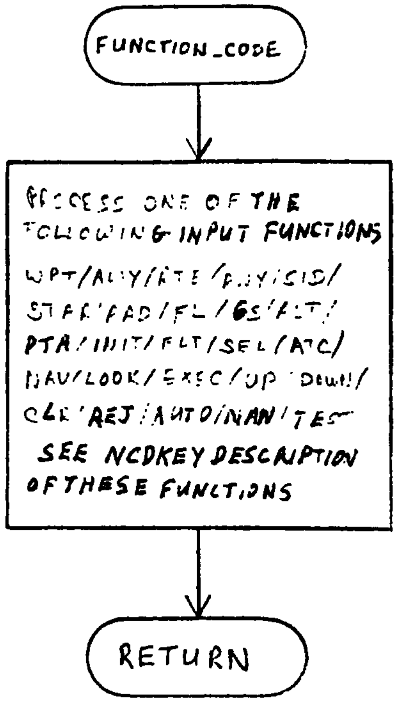

2A
NCDU FUNCTION INPUT
N
Y
NUMERIC FUNCTION (1-9)
Y
N
(INVALID FUNCTION)
ERROR INDEX = 7
N
# FUNCTIONS CURRENTLY ALLOWED
N
TIME ENTERED ON INIT PAGE
N
Y
SAVE FUNCTION FOR NCDU PAGE AND THE DATA ENTRY/COLLECTION
FUNCTION_CODE
USE ENTERED FUNCTION TO SET NCDU VARIABLES
RETURN

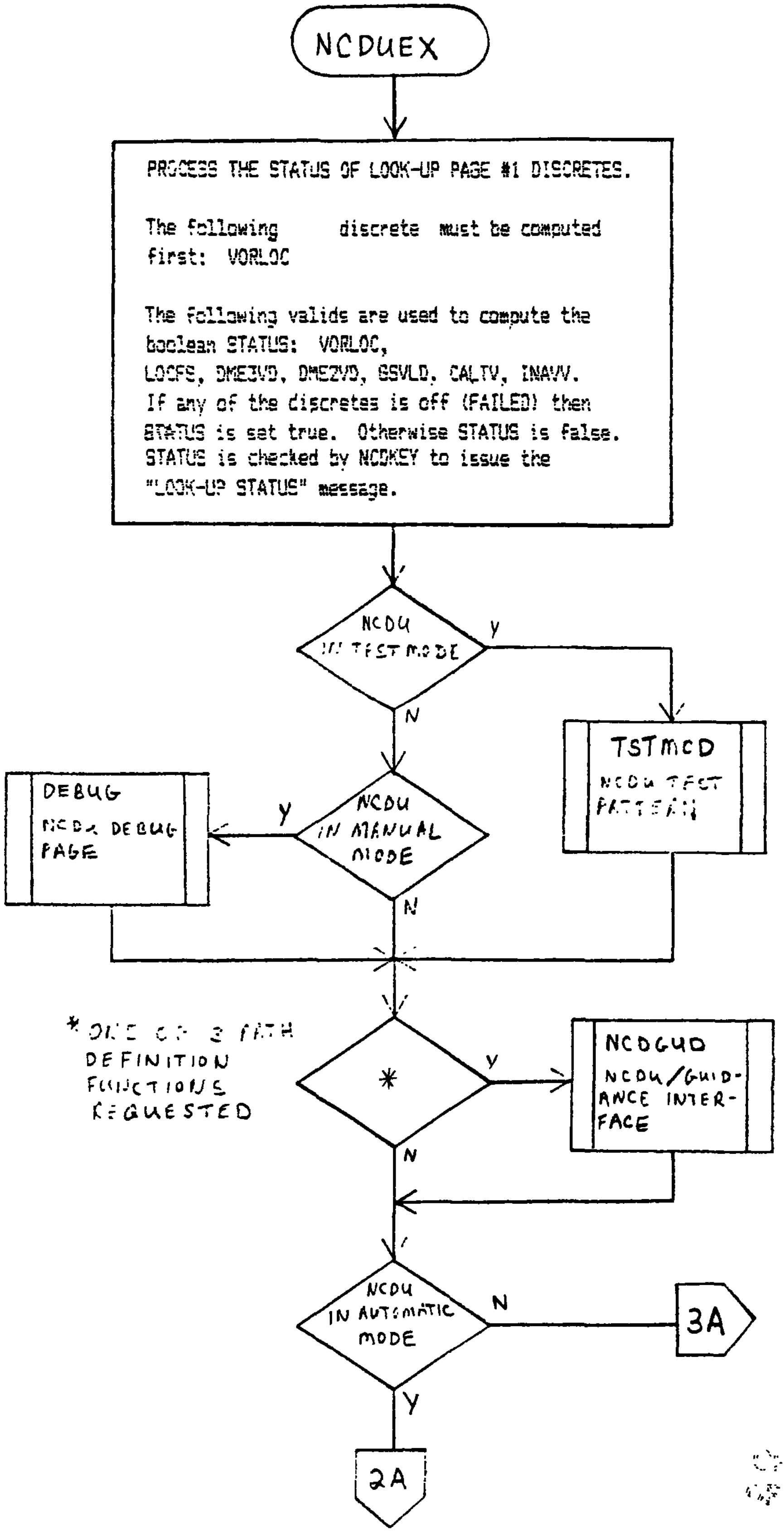


COMPUTE NCDU 50 MILLISECOND VALUES. SEE NCDKEY DESCRIPTION FOR INFORMATION ON THESE VARIABLE. ALSO SEE NCDU50 DESCRIPTION FOR THE VARIOUS ALERT MESSAGES.

Last function entry was erroneous. reset entry variables and display one of the following messages on line #8 of the NCDU.

FORMAT ERROR
FORMAT ERROR PRESS #
NOT IN MEMORY
NOT IN MEMORY CHECK ORIG
NOT IN MEMORY CHECK DEST
NOT IN MEMORY PRESS #
INVALID FUNCTION
INVALID FUNCTION PRESS #
WAYPOINT BUFFER FULL
KEY WAYPOINT ON AWY/RTE
KEY WAYPOINT ON PATH
INVALID THIS WAYPOINT
KEY AIRPORT ON INIT PAGE
KEY RUNWAY ON PATH
BAD RADIUS--XXXXX (NAME OF WPT)

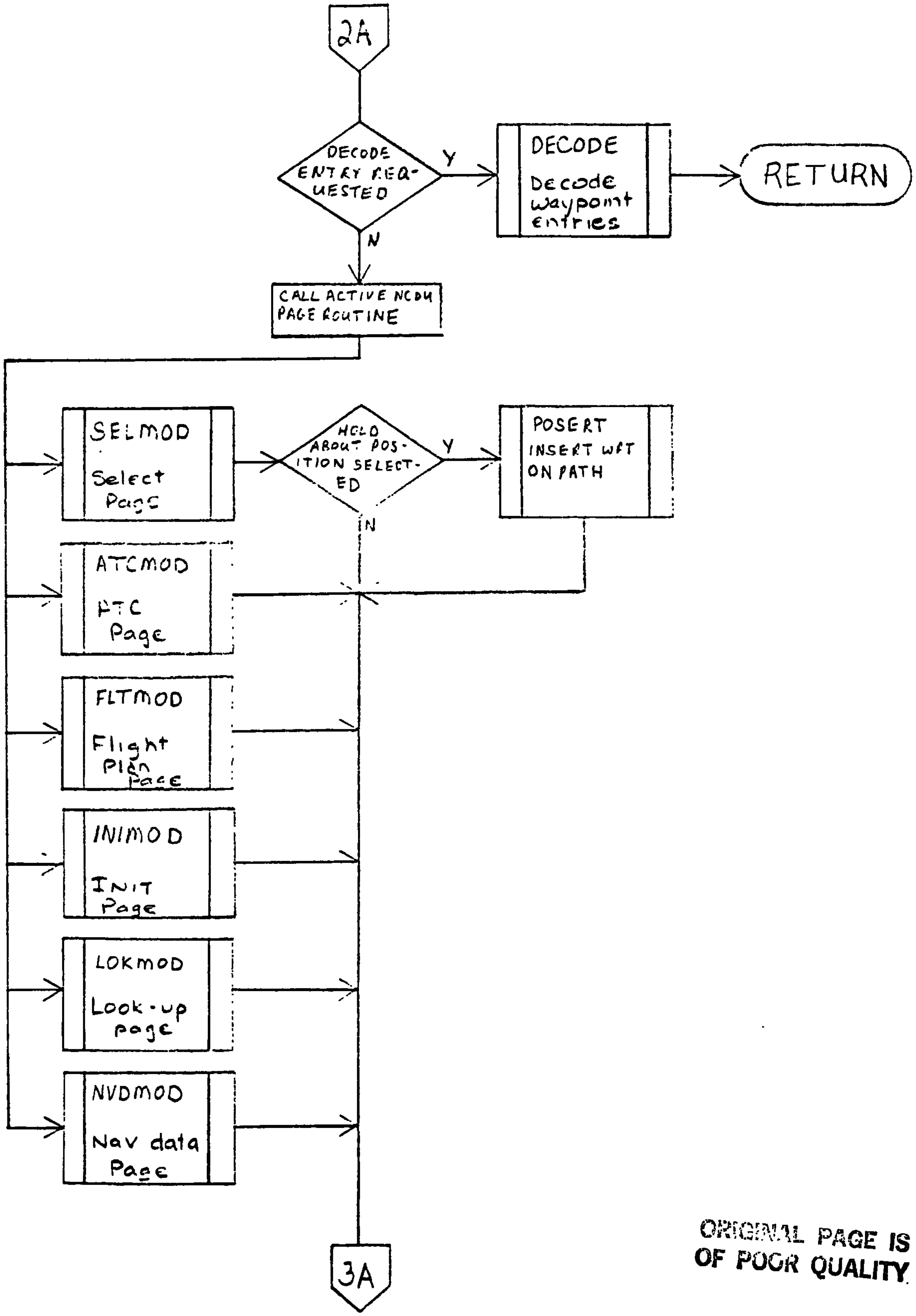

FUNCTION_CODE
PROCESS ONE OF THE FOLLOWING INPUT FUNCTIONS
WPT/ALY/RTE/RWY/SID/
STAR/RAD/FL/GS/ALT/
PTA/INIT/FLT/SEL/ATC/
NAV/LOOK/EXEC/UP/DOWN/
CLR/REJ/AUTO/MAN/TEST
SEE NCDKEY DESCRIPTION OF THESE FUNCTIONS
RETURN



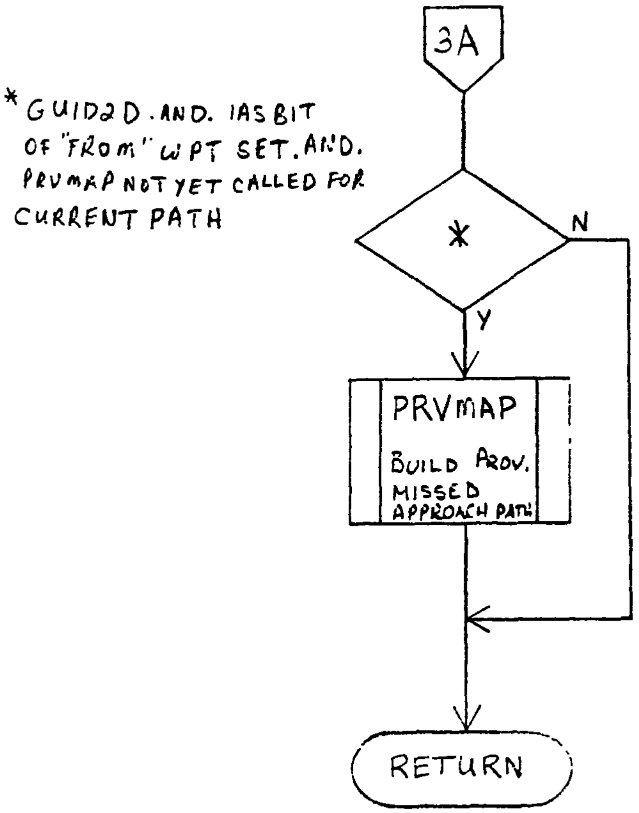
PROCESS THE STATUS OF LOOK-UP PAGE #1 DISCRETES.

The following discrete must be computed first: VORLOC

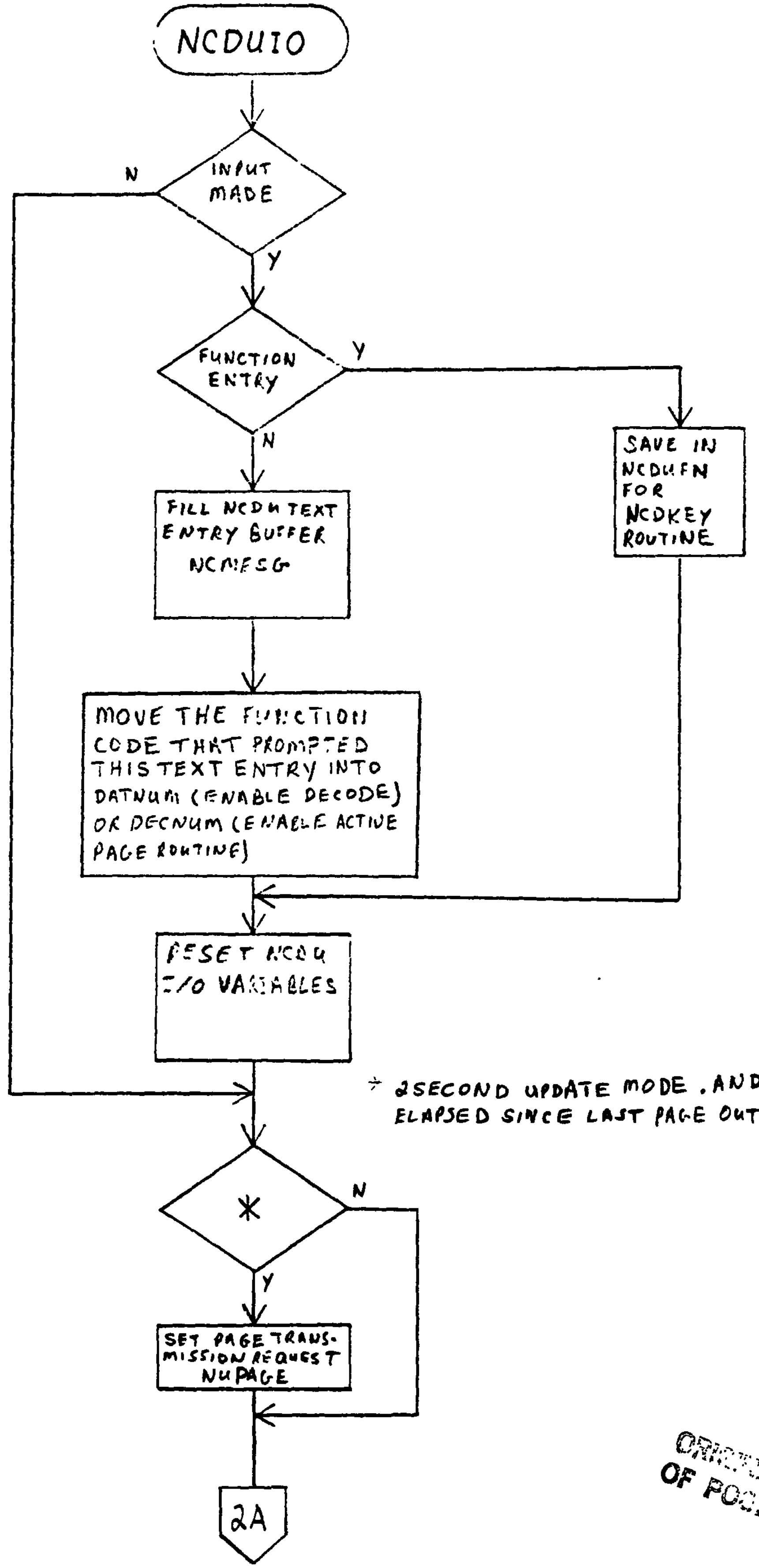
The following valids are used to compute the boolean STATUS: VORLOC, LOCFS, DMEJVD, DMEZVD, GSVLD, CALTV, INAVV. If any of the discretes is off (FAILED) then STATUS is set true. Otherwise STATUS is false. STATUS is checked by NCDKEY to issue the "LOOK-UP STATUS" message.



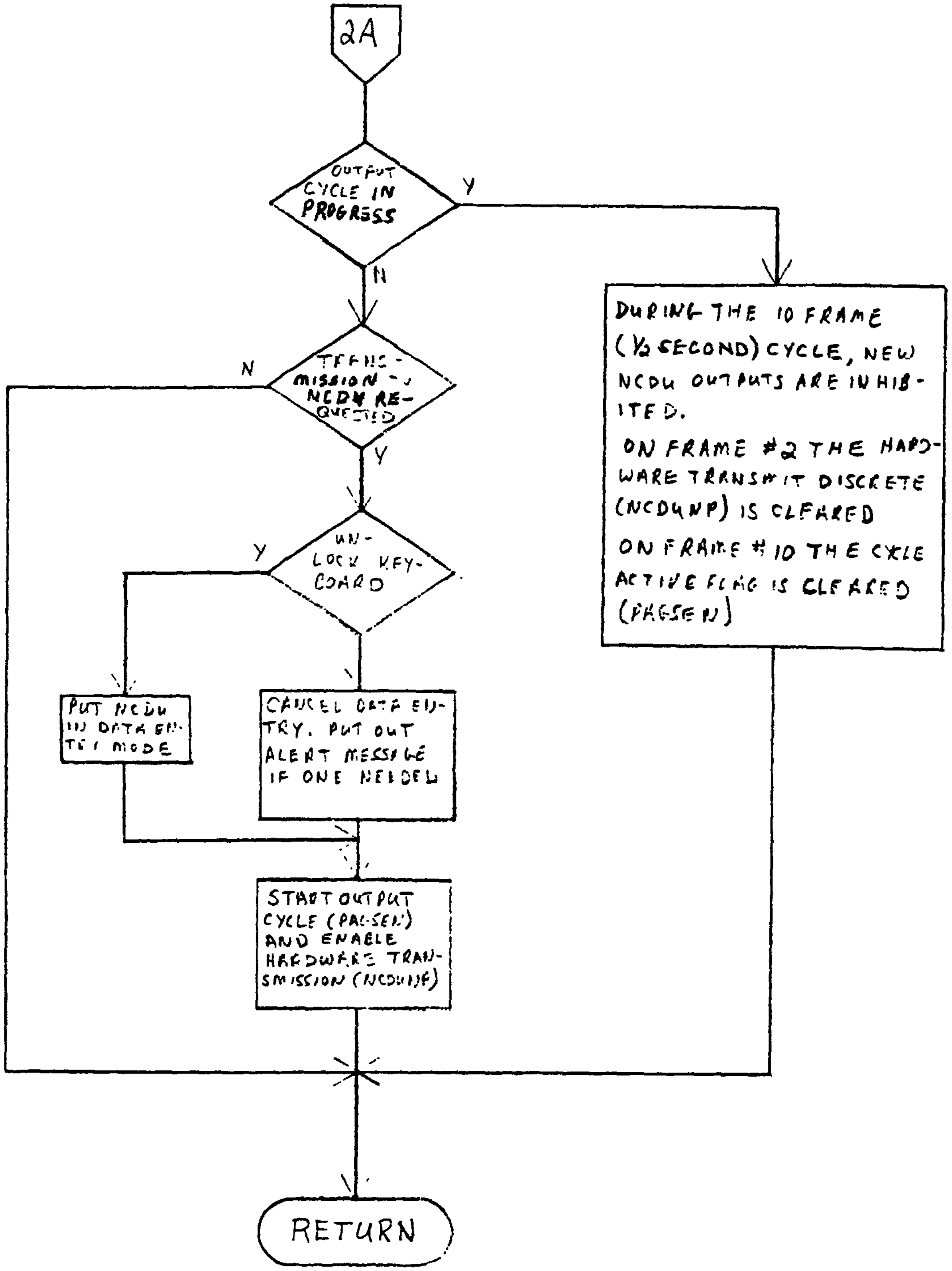
NCDUEX
(PAGE 2 OF 3)


3A
*GUID2D .AND. IASBIT OF "FROM" WPT SET .AND. PRVMAP NOT YET CALLED FOR CURRENT PATH
*
N
Y
PRVMAP
BUILD PROV. MISSED APPROACH PATH
RETURN

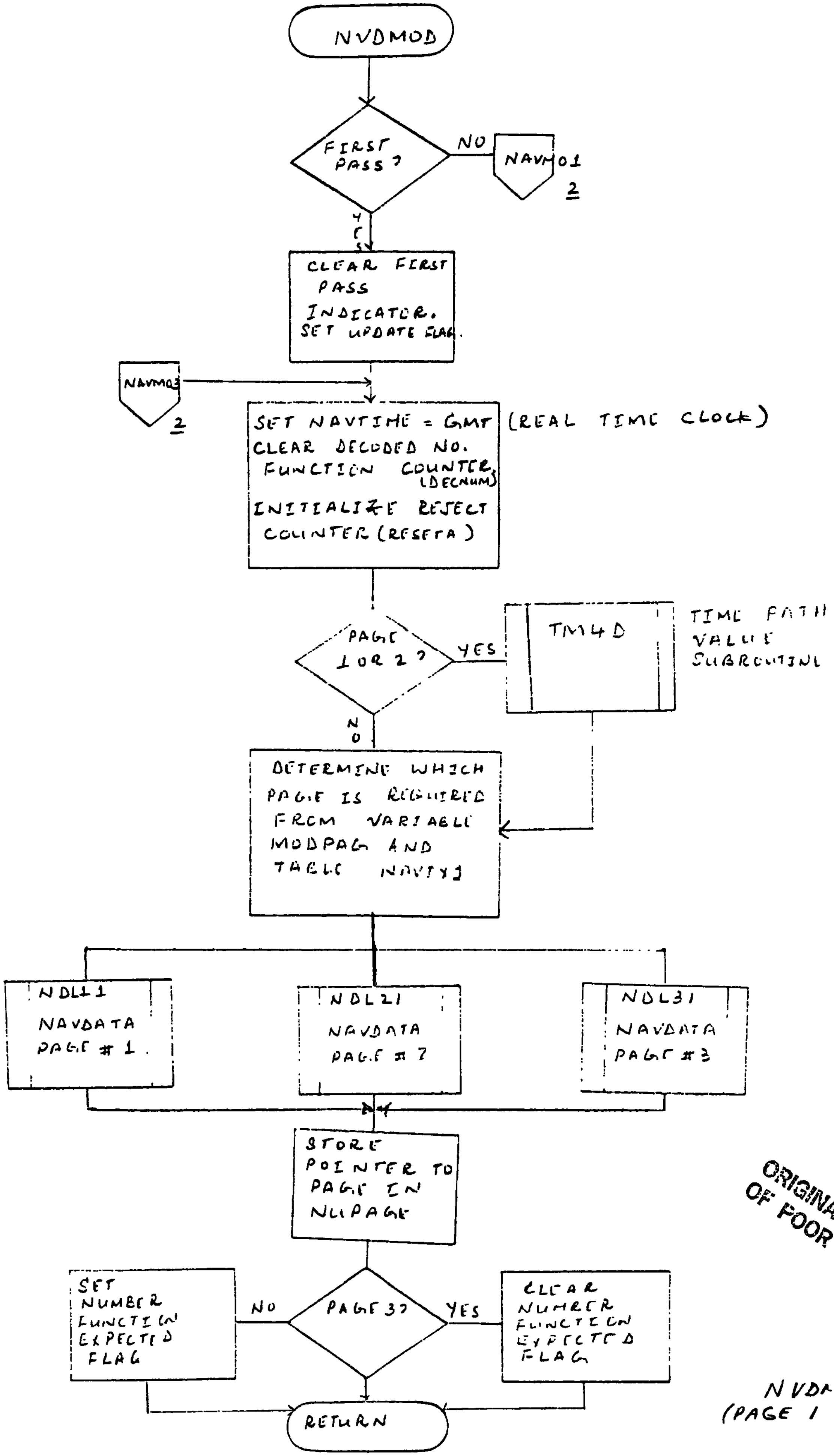
NCDUEX


NCDUIO
INPUT MADE
N
Y
FUNCTION ENTRY
Y
N
SAVE IN NCDUFN FOR NCDKEY ROUTINE
FILL NCDU TEXT ENTRY BUFFER NCMESG
MOVE THE FUNCTION CODE THAT PROMPTED THIS TEXT ENTRY INTO DATNUM (ENABLE DECODE) OR DECNUM (ENABLE ACTIVE PAGE ROUTINE)
RESET NCDU I/O VARIABLES
*
N
Y
SET PAGE TRANSMISSION REQUEST NUPAGE
2A

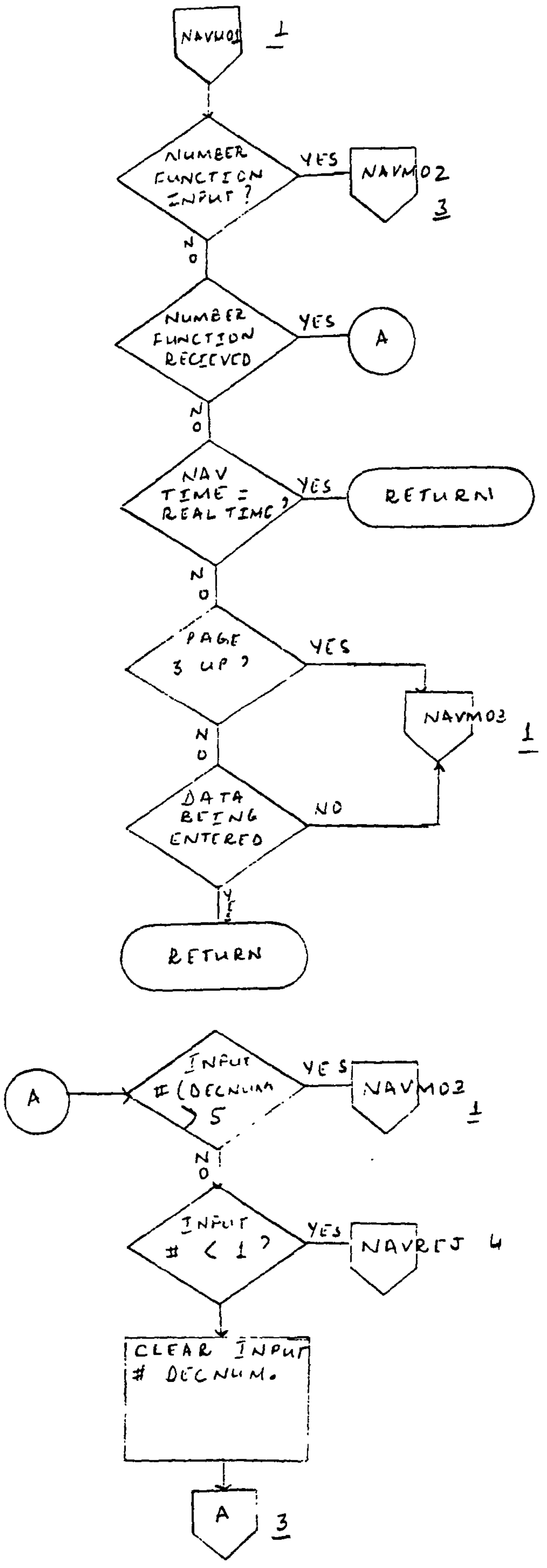
* 2SECOND UPDATE MODE .AND. 2 SECONDS ELAPSED SINCE LAST PAGE OUTPUT


2A
OUTPUT CYCLE IN PROGRESS
Y
N
DURING THE 10 FRAME (½ SECOND) CYCLE, NEW NCDU OUTPUTS ARE INHIBITED.
ON FRAME #2 THE HARDWARE TRANSMIT DISCRETE (NCDUNP) IS CLEARED
ON FRAME #10 THE CYCLE ACTIVE FLAG IS CLEARED (PAGSEN)
N
TRANSMISSION NCDU REQUESTED
Y
Y
UNLOCK KEYBOARD
PUT NCDU IN DATA ENTRY MODE
CANCEL DATA ENTRY. PUT OUT ALERT MESSAGE IF ONE NEEDED
START OUTPUT CYCLE (PAGSEN) AND ENABLE HARDWARE TRANSMISSION (NCDUNP)
RETURN

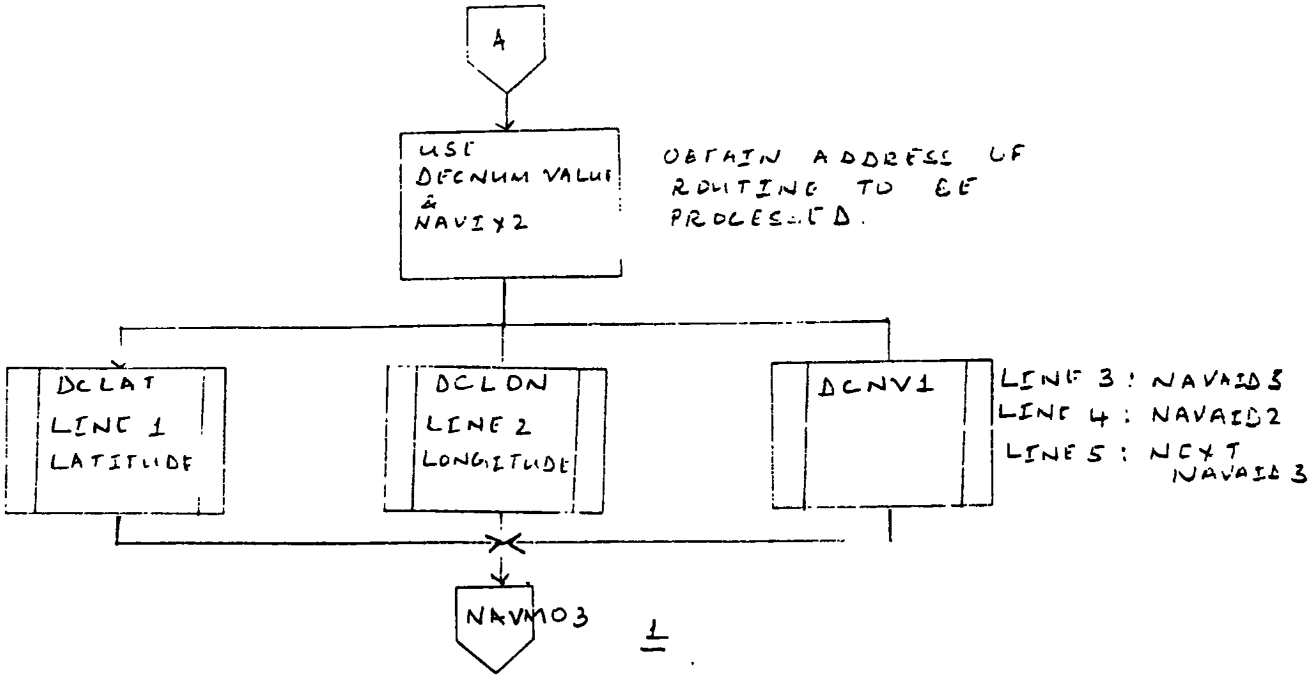
ORIGINAL PAGE IS OF POOR QUALITY

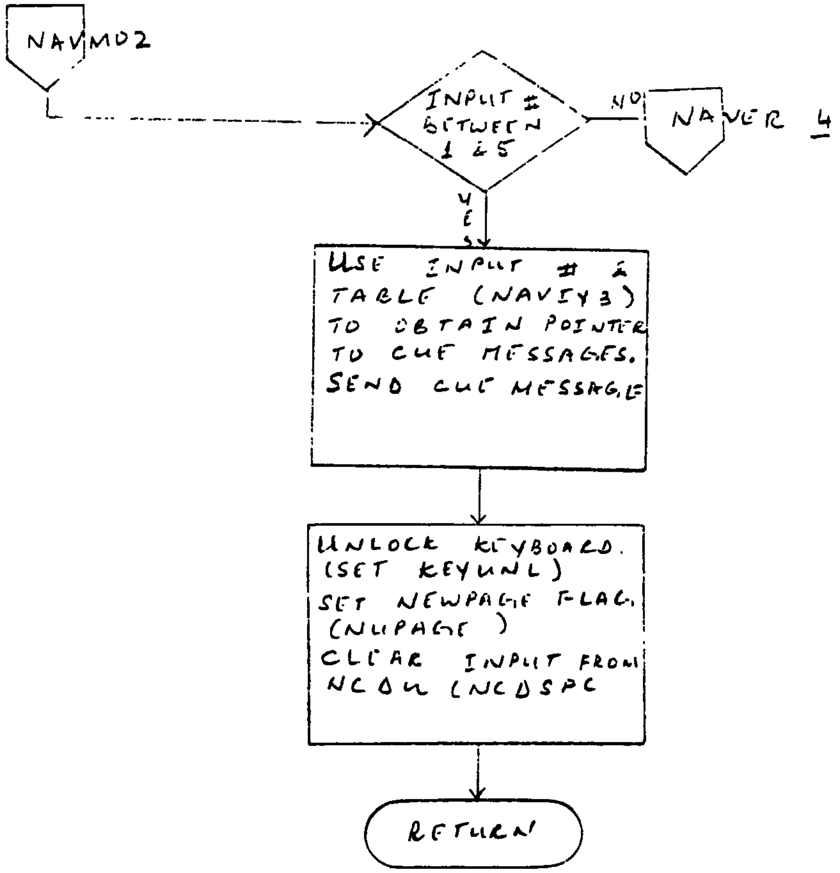

NVDMOD
FIRST PASS?
NO
NAVM01
2
YES
CLEAR FIRST PASS INDICATOR. SET UPDATE FLAG.
NAVM03
2
SET NAVTIME = GMT (REAL TIME CLOCK)
CLEAR DECODED NO. FUNCTION COUNTER (DECNUM)
INITIALIZE REJECT COUNTER (RESETA)
PAGE 1 OR 2?
YES
TM4D
TIME PATH VALUE SUBROUTINE
NO
DETERMINE WHICH PAGE IS REQUIRED FROM VARIABLE MODPAG AND TABLE NAVTX1
NDL11
NAVDATA PAGE # 1.
NDL21
NAVDATA PAGE # 2
NDL31
NAVDATA PAGE # 3
STORE POINTER TO PAGE IN NUPAGE
PAGE 3?
NO
SET NUMBER FUNCTION EXPECTED FLAG
YES
CLEAR NUMBER FUNCTION EXPECTED FLAG
RETURN

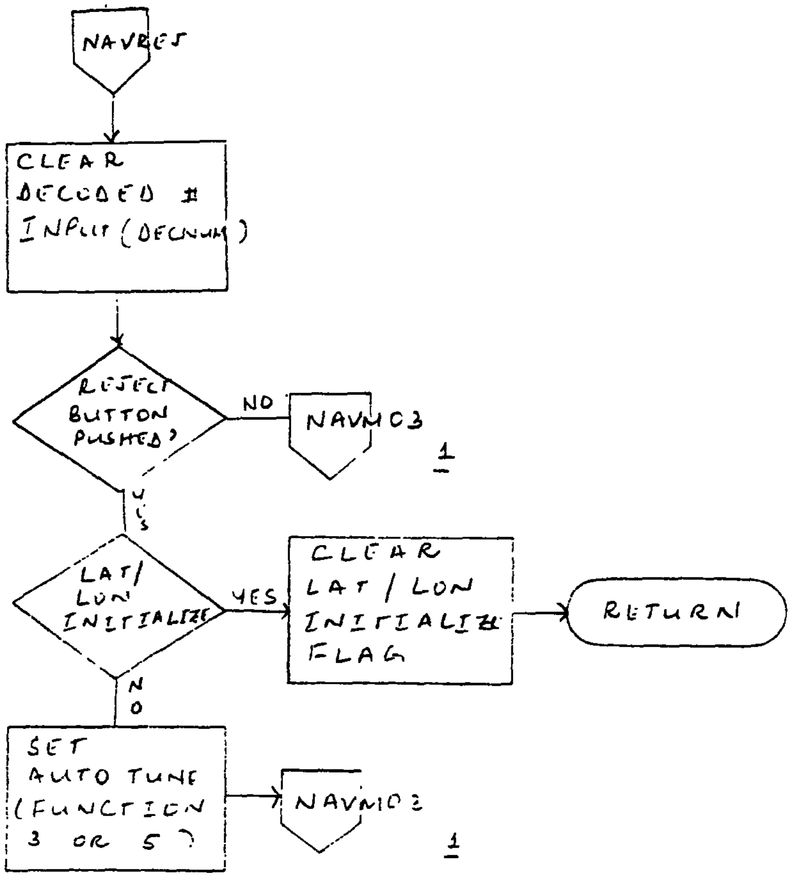
NVDMOD
(PAGE 1 OF 17)

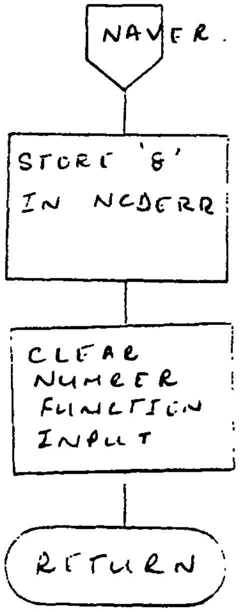


NVDMCD
(PAGE 2 OF 17)


A
USE DECNUM VALUE & NAVIX2
OBTAIN ADDRESS OF ROUTINE TO BE PROCESSED.
DCLAT
LINE 1
LATITUDE
DCLON
LINE 2
LONGITUDE
DCNV1
LINE 3 : NAVAID3
LINE 4 : NAVAID2
LINE 5 : NEXT NAVAID 3
NAVM03
1

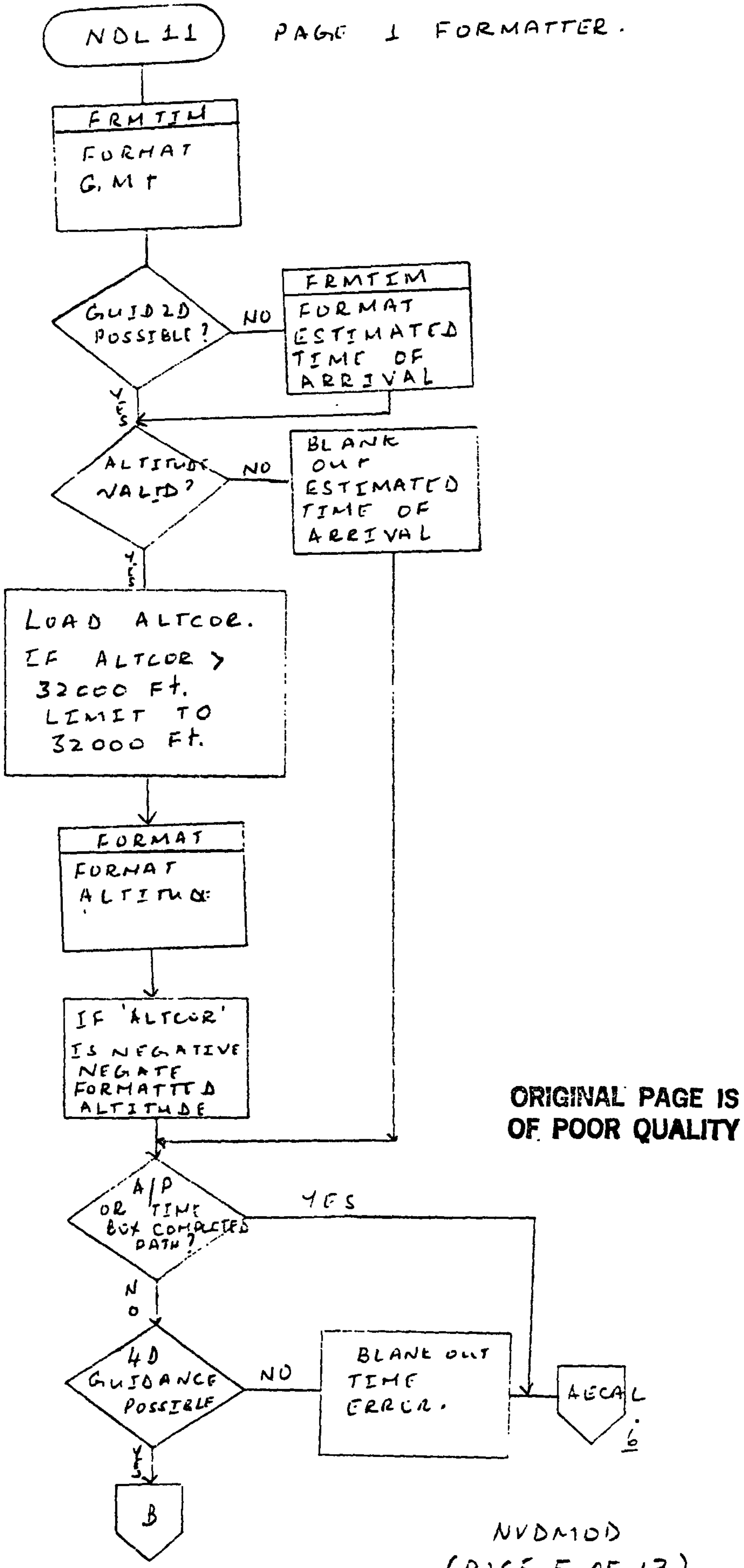

NAVM02
INPUT # BETWEEN 1 & 5
NO
NAVER
4
YES
USE INPUT # & TABLE (NAVIX3) TO OBTAIN POINTER TO CUE MESSAGES. SEND CUE MESSAGE
UNLOCK KEYBOARD. (SET KEYUNL) SET NEWPAGE FLAG (NUPAGE) CLEAR INPUT FROM NCDU (NCDSPC
RETURN


NAVRES
CLEAR DECODED # INPUT (DECNUM)
REJECT BUTTON PUSHED?
NO
NAVMO3
1
YES
LAT/LON INITIALIZE
YES
CLEAR LAT / LON INITIALIZE FLAG
RETURN
NO
SET AUTO TUNE (FUNCTION 3 OR 5)
NAVMO3
1

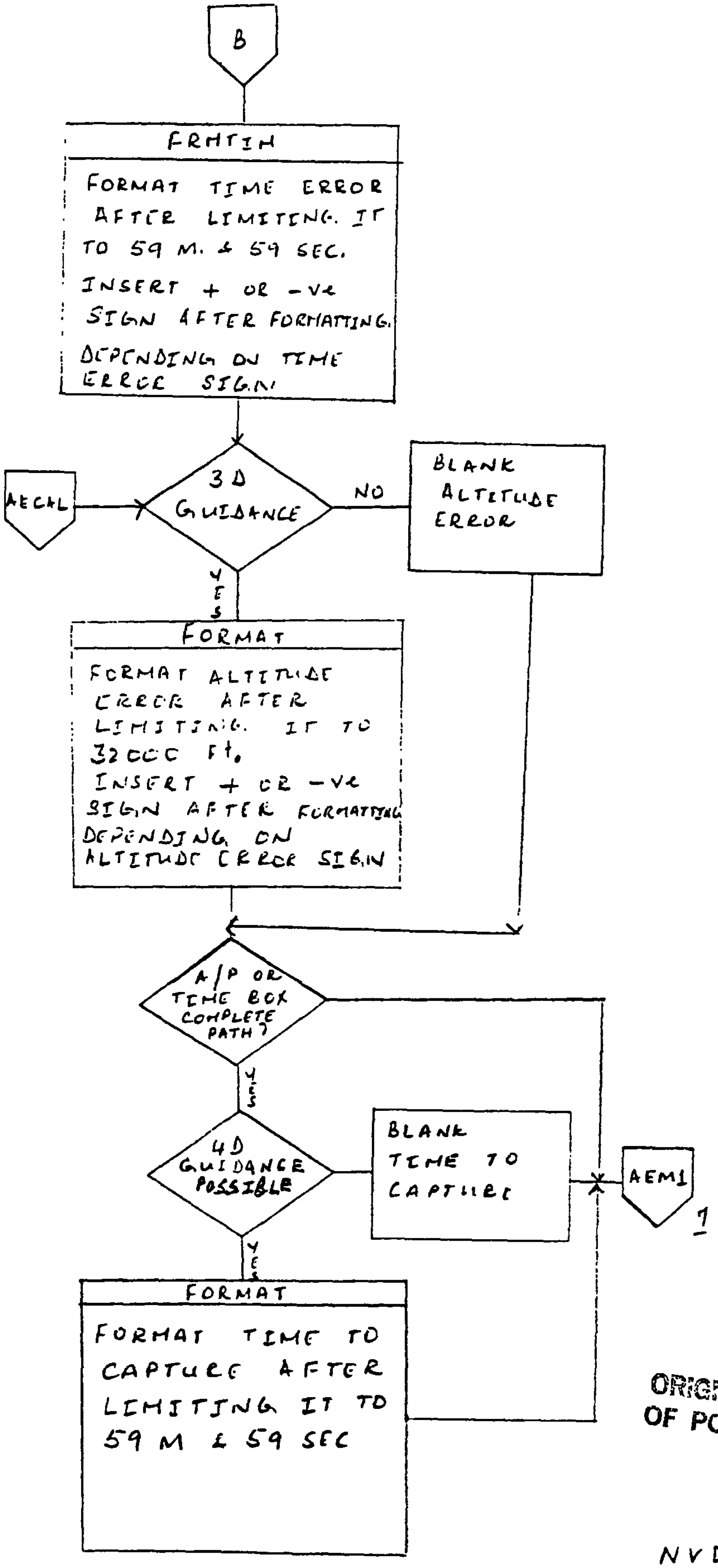


'8' WILL CAUSE CUE. MESSAGE "INVALID FUNCTION PRESS #" TO BE DISPLAYED.

ORIGINAL PAGE IS OF POOR QUALITY

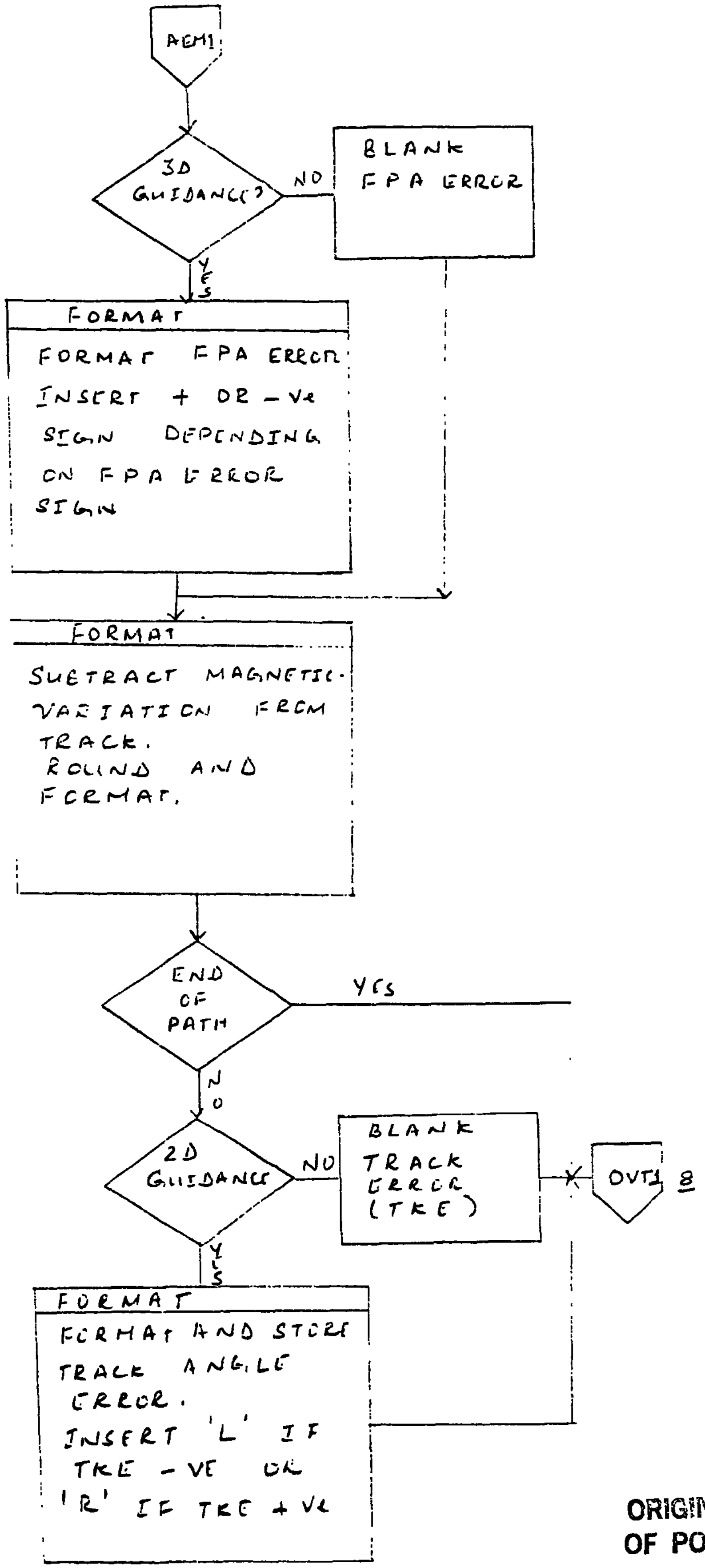

NDL11
PAGE 1 FORMATTER.
FRMTIM
FORMAT G.MT
GUID2D POSSIBLE?
NO
YES
FRMTIM
FORMAT ESTIMATED TIME OF ARRIVAL
ALTITUDE VALID?
NO
YES
BLANK OUT ESTIMATED TIME OF ARRIVAL
LOAD ALTCOR. IF ALTCOR > 32000 Ft. LIMIT TO 32000 Ft.
FORMAT
FORMAT ALTITUDE
IF 'ALTCOR' IS NEGATIVE NEGATE FORMATTED ALTITUDE
A/P OR TIME BOX COMPLETED PATH?
YES
NO
4D GUIDANCE POSSIBLE
NO
YES
BLANK OUT TIME ERROR.
AECAL
6
B

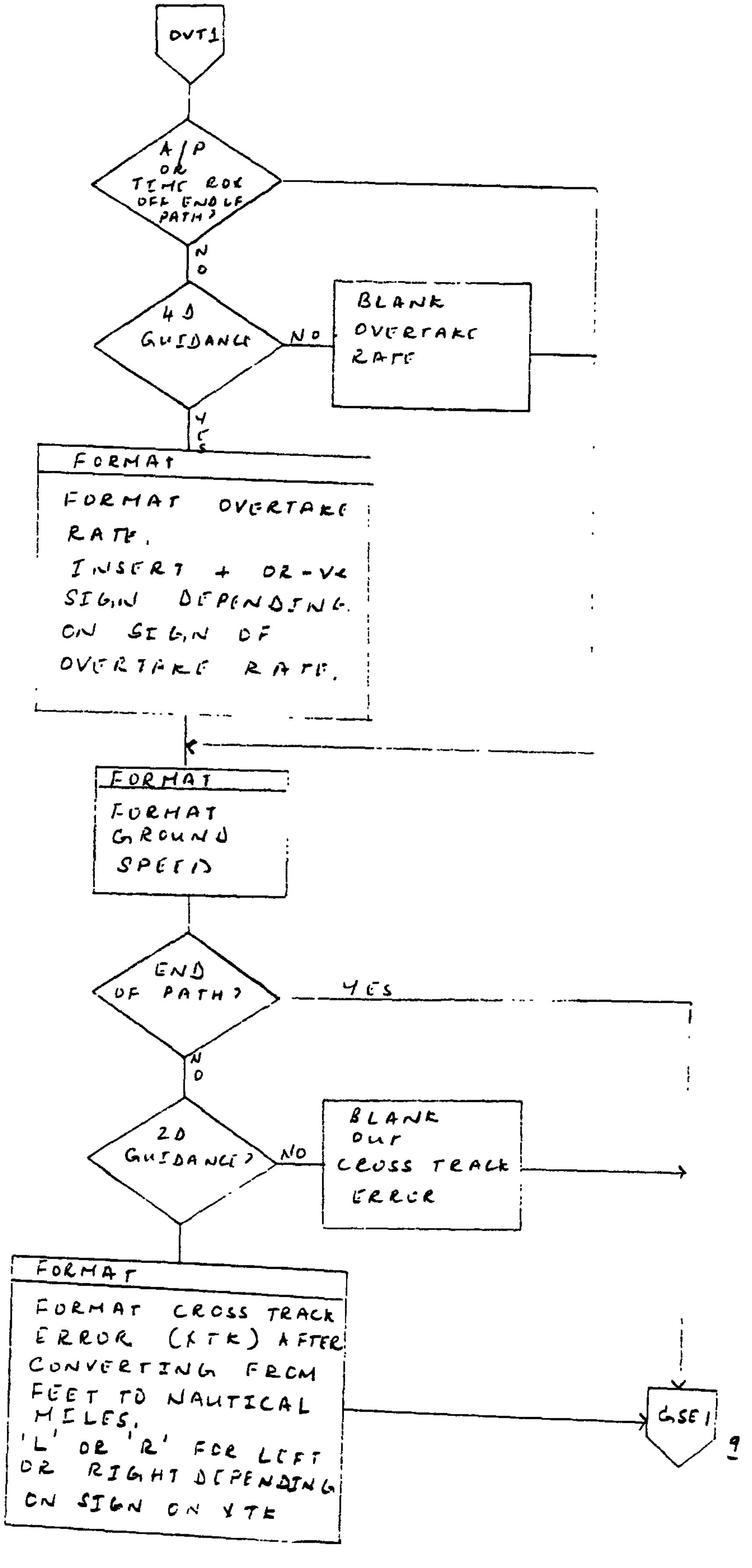
NVDMOD
(PAGE 5 OF 17)


B
FRMTIM
FORMAT TIME ERROR AFTER LIMITING IT TO 59 M. & 59 SEC.
INSERT + OR -ve SIGN AFTER FORMATTING DEPENDING ON TIME ERROR SIGN
AECAL
3D GUIDANCE
NO
BLANK ALTITUDE ERROR
YES
FORMAT
FORMAT ALTITUDE ERROR AFTER LIMITING IT TO 32000 Ft.
INSERT + OR -ve SIGN AFTER FORMATTING DEPENDING ON ALTITUDE ERROR SIGN
A/P OR TIME BOX COMPLETE PATH?
YES
4D GUIDANCE POSSIBLE
BLANK TIME TO CAPTURE
AEM1
1
YES
FORMAT
FORMAT TIME TO CAPTURE AFTER LIMITING IT TO 59 M & 59 SEC

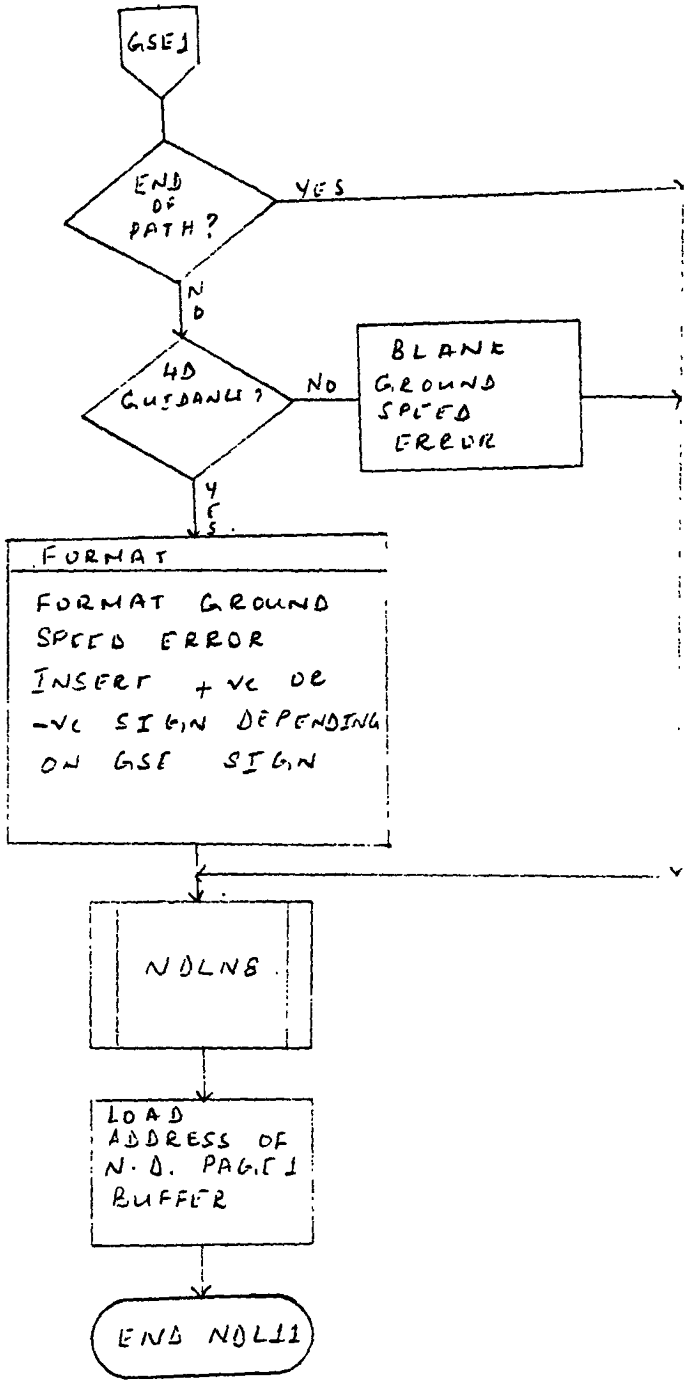
ORIGINAL PAGE IS
OF POOR QUALITY

NVDMOD
(PAGE 6 OF 17)

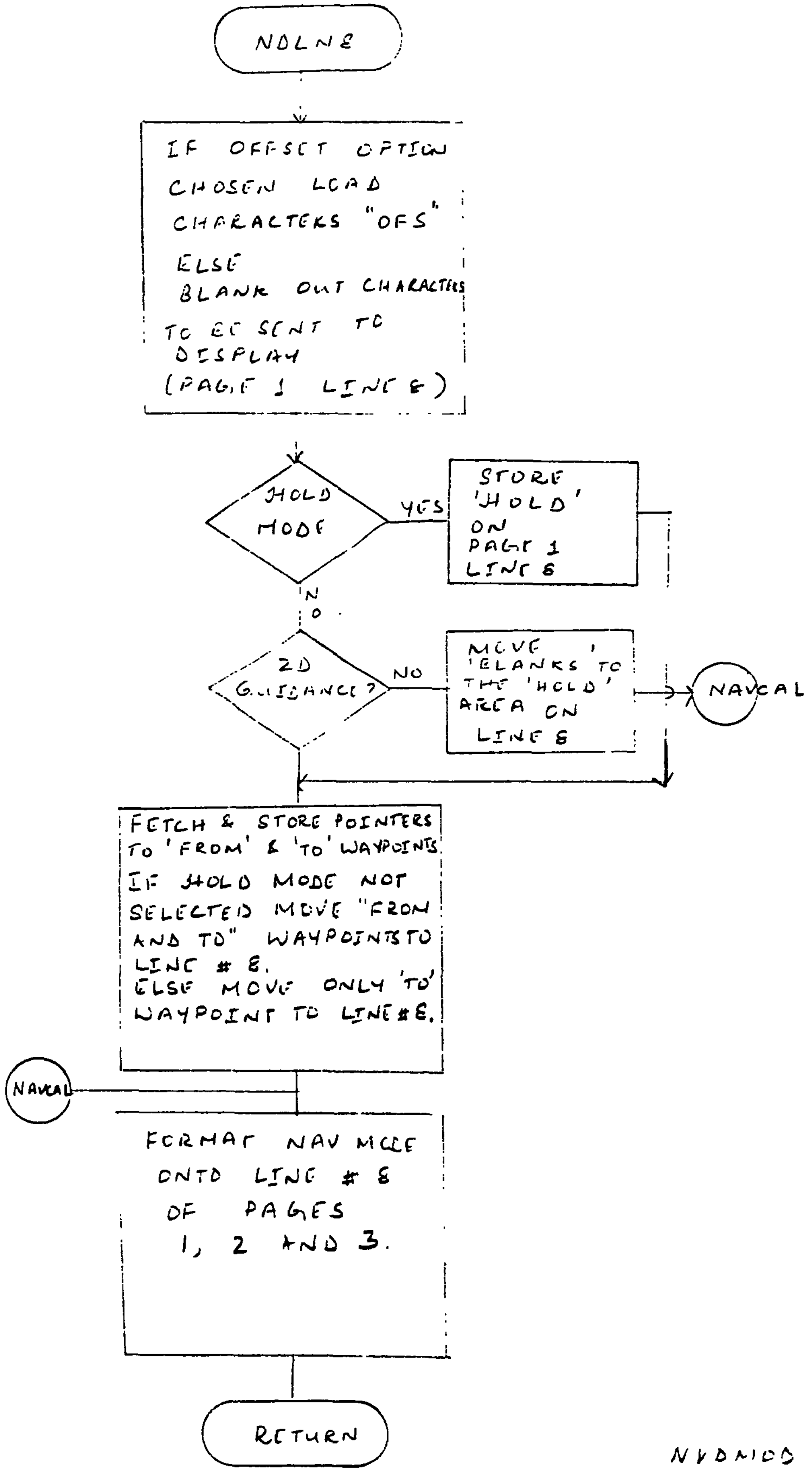

AEM1
3D GUIDANCE?
NO
BLANK FPA ERROR
YES
FORMAT
FORMAT FPA ERROR INSERT + OR -VE SIGN DEPENDING ON FPA ERROR SIGN
FORMAT
SUBTRACT MAGNETIC VARIATION FROM TRACK. ROUND AND FORMAT.
END OF PATH
YES
NO
2D GUIDANCE
NO
BLANK TRACK ERROR (TKE)
OVT1
8
YES
FORMAT
FORMAT AND STORE TRACK ANGLE ERROR. INSERT 'L' IF TKE -VE OR 'R' IF TKE +VE

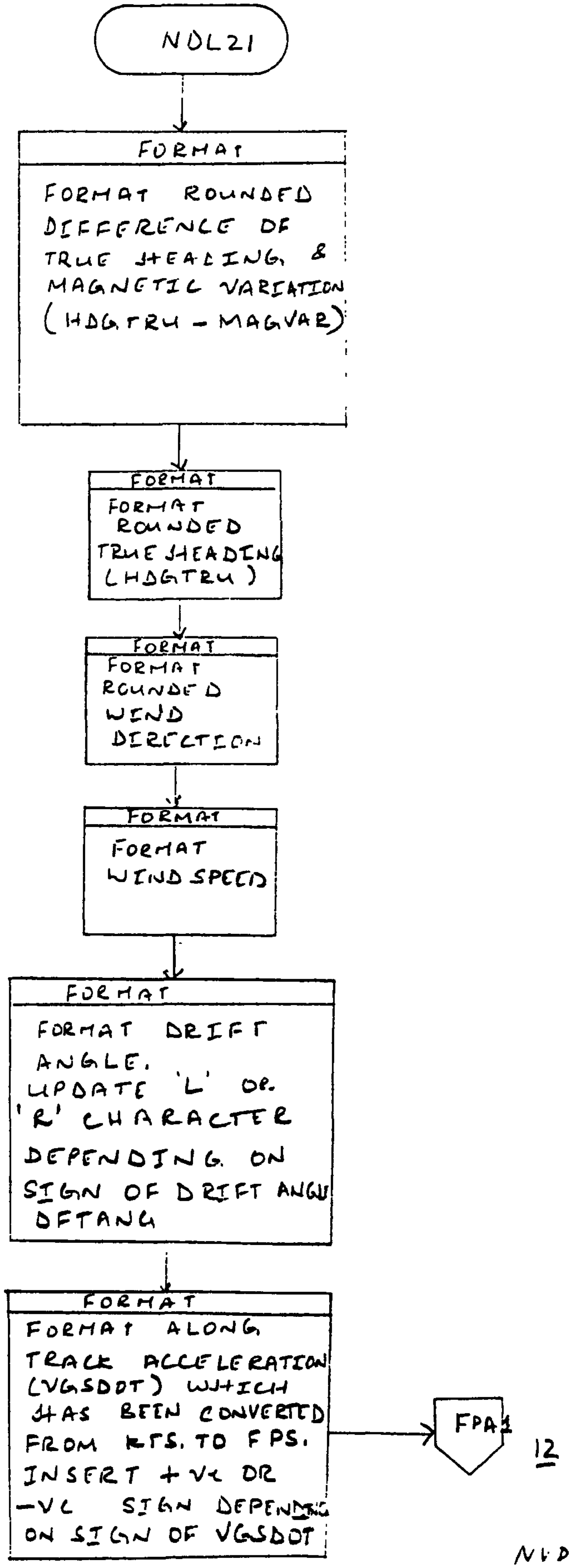

OVT1
A/P OR TIME ROR OFF END OF PATH?
NO
4D GUIDANCE
NO
BLANK OVERTAKE RATE
YES
FORMAT
FORMAT OVERTAKE RATE. INSERT + OR -VE SIGN DEPENDING ON SIGN OF OVERTAKE RATE.
FORMAT
FORMAT GROUND SPEED
END OF PATH?
YES
NO
2D GUIDANCE?
NO
BLANK OUT CROSS TRACK ERROR
FORMAT
FORMAT CROSS TRACK ERROR (XTK) AFTER CONVERTING FROM FEET TO NAUTICAL MILES. 'L' OR 'R' FOR LEFT OR RIGHT DEPENDING ON SIGN ON XTE
GSE1
9

NVDMOD
(PAGE 8 OF 17)

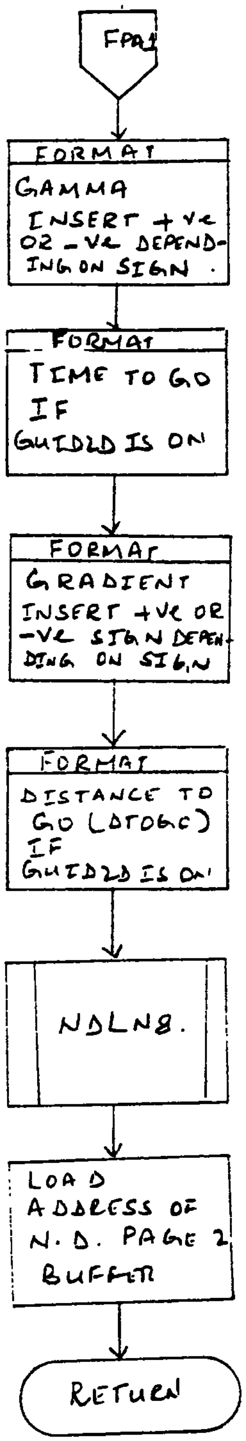

GSE1
END OF PATH?
YES
NO
4D GUIDANCE?
NO
BLANK GROUND SPEED ERROR
YES
FORMAT
FORMAT GROUND SPEED ERROR INSERT +VE OR -VE SIGN DEPENDING ON GSE SIGN
NDLN8
LOAD ADDRESS OF N.D. PAGE1 BUFFER
END NDL11

NVDMOD
(PAGE 9 OF 17)

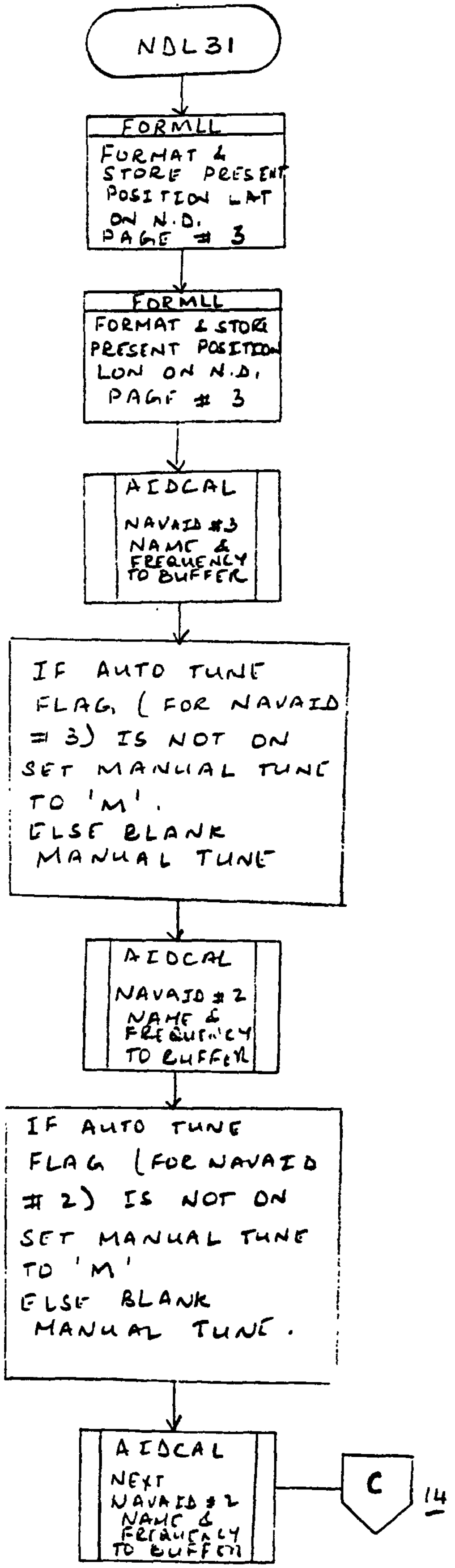

NDLNE
IF OFFSET OPTION CHOSEN LOAD CHARACTERS "OFS" ELSE BLANK OUT CHARACTERS TO BE SENT TO DISPLAY (PAGE 1 LINE 8)
HOLD MODE
YES
STORE 'HOLD' ON PAGE 1 LINE 8
NO
2D GUIDANCE?
NO
MOVE ' BLANKS TO THE 'HOLD' AREA ON LINE 8
NAVCAL
FETCH & STORE POINTERS TO 'FROM' & 'TO' WAYPOINTS IF HOLD MODE NOT SELECTED MOVE "FROM AND TO" WAYPOINTS TO LINE # 8. ELSE MOVE ONLY 'TO' WAYPOINT TO LINE # 8.
NAVCAL
FORMAT NAV MCLE ONTO LINE # 8 OF PAGES 1, 2 AND 3.
RETURN


NDL21
FORMAT
FORMAT ROUNDED DIFFERENCE OF TRUE HEADING & MAGNETIC VARIATION (HDGTRU - MAGVAR)
FORMAT
FORMAT ROUNDED TRUE HEADING (HDGTRU)
FORMAT
FORMAT ROUNDED WIND DIRECTION
FORMAT
FORMAT WIND SPEED
FORMAT
FORMAT DRIFT ANGLE. UPDATE 'L' OR 'R' CHARACTER DEPENDING ON SIGN OF DRIFT ANGLE DFTANG
FORMAT
FORMAT ALONG TRACK ACCELERATION (VGSDOT) WHICH HAS BEEN CONVERTED FROM KTS. TO FPS. INSERT +VE OR -VE SIGN DEPENDING ON SIGN OF VGSDOT
FPA1
12

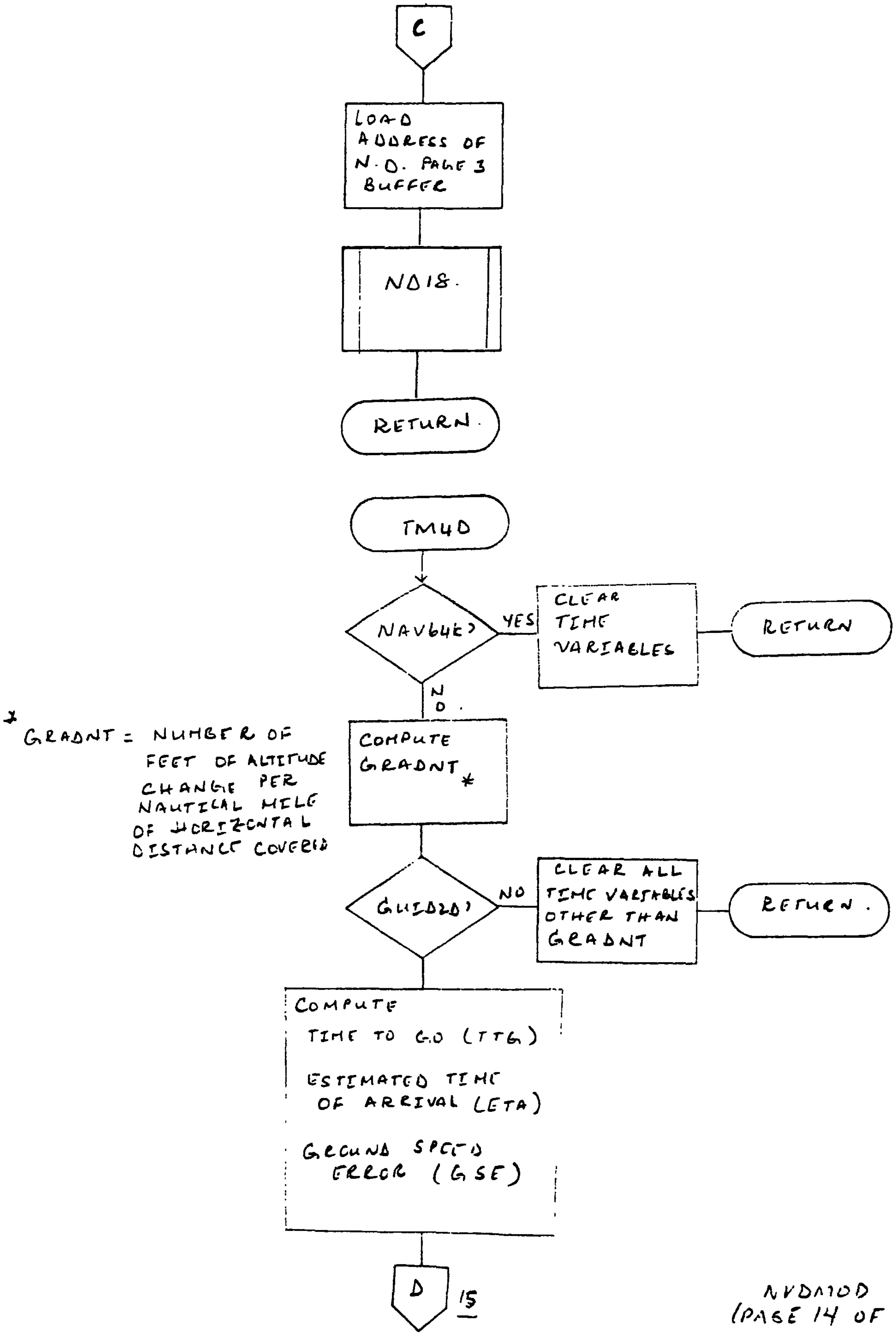
NVDMOD
(PAGE 11 OF 17)



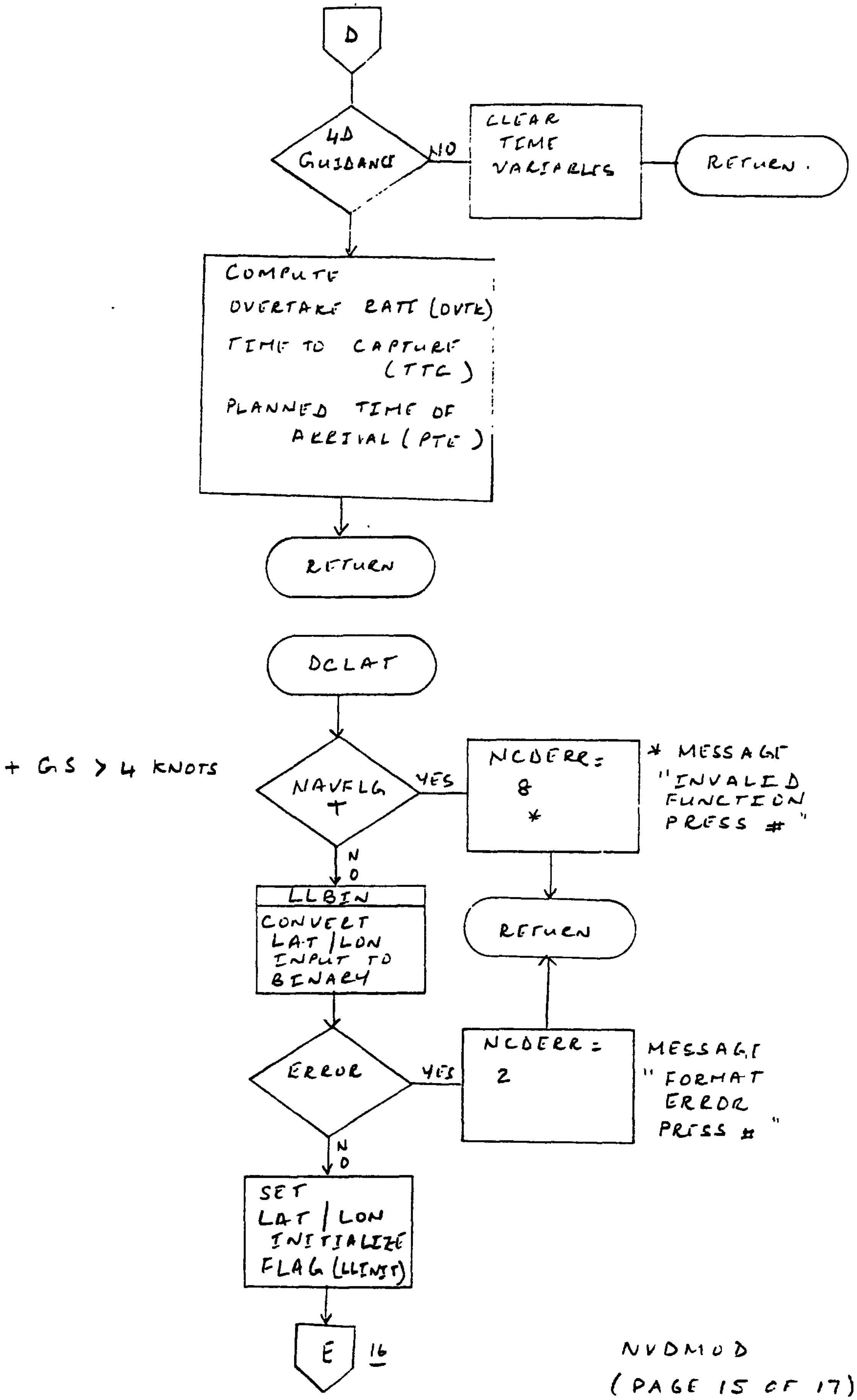
NVDMOD
(PAGE 12 OF 17)


NDL31
FORMLL
FORMAT & STORE PRESENT POSITION LAT ON N.D. PAGE # 3
FORMLL
FORMAT & STORE PRESENT POSITION LON ON N.D. PAGE # 3
AIDCAL
NAVAID #3 NAME & FREQUENCY TO BUFFER
IF AUTO TUNE FLAG (FOR NAVAID # 3) IS NOT ON SET MANUAL TUNE TO 'M'. ELSE BLANK MANUAL TUNE
AIDCAL
NAVAID # 2 NAME & FREQUENCY TO BUFFER
IF AUTO TUNE FLAG (FOR NAVAID # 2) IS NOT ON SET MANUAL TUNE TO 'M' ELSE BLANK MANUAL TUNE.
AIDCAL
NEXT NAVAID # 2 NAME & FREQUENCY TO BUFFER
C
14

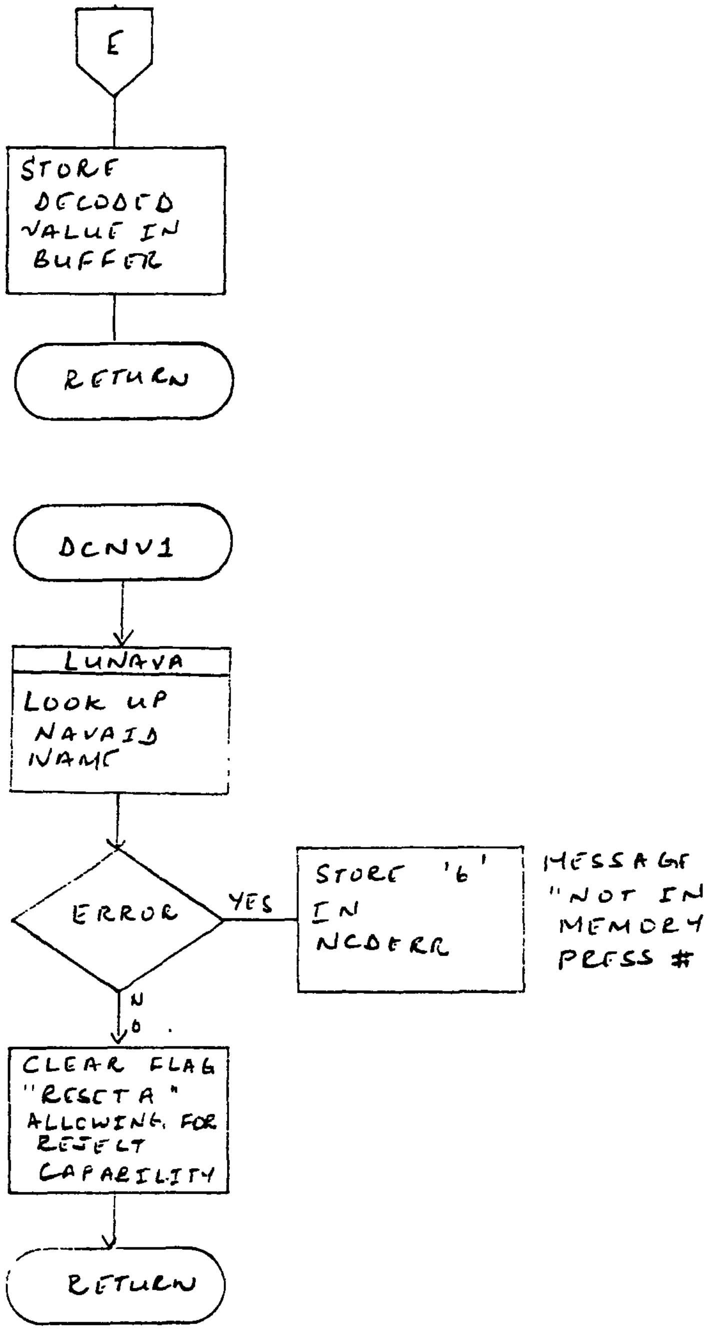
NVDMOD
(PAGE 13 OF 17)

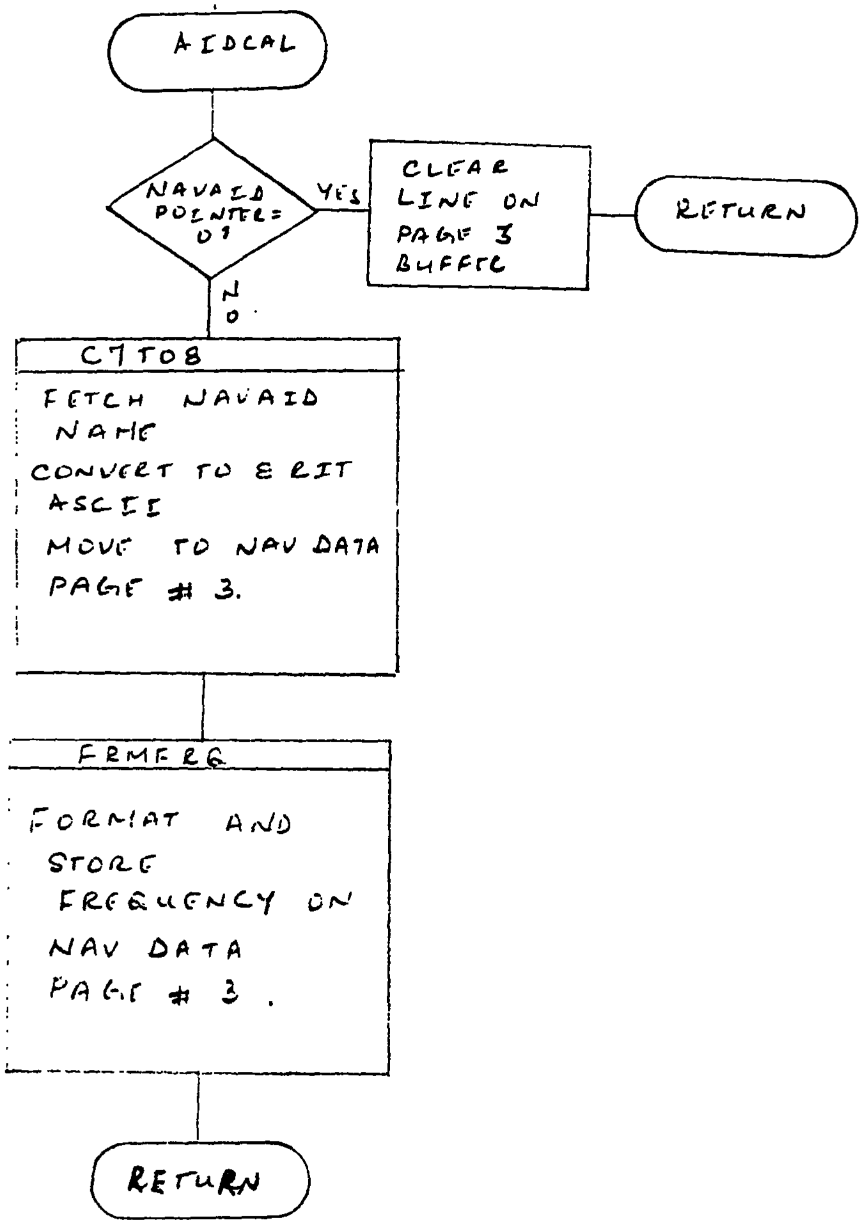

C
LOAD ADDRESS OF N.D. PAGE 3 BUFFER
ND18.
RETURN.
TM4D
NAV64E?
YES
CLEAR TIME VARIABLES
RETURN
NO.
COMPUTE GRADNT*
*GRADNT = NUMBER OF FEET OF ALTITUDE CHANGE PER NAUTICAL MILE OF HORIZONTAL DISTANCE COVERED
GUID2D?
NO
CLEAR ALL TIME VARIABLES OTHER THAN GRADNT
RETURN.
COMPUTE
TIME TO GO (TTG)
ESTIMATED TIME OF ARRIVAL (ETA)
GROUND SPEED ERROR (GSE)
D
15

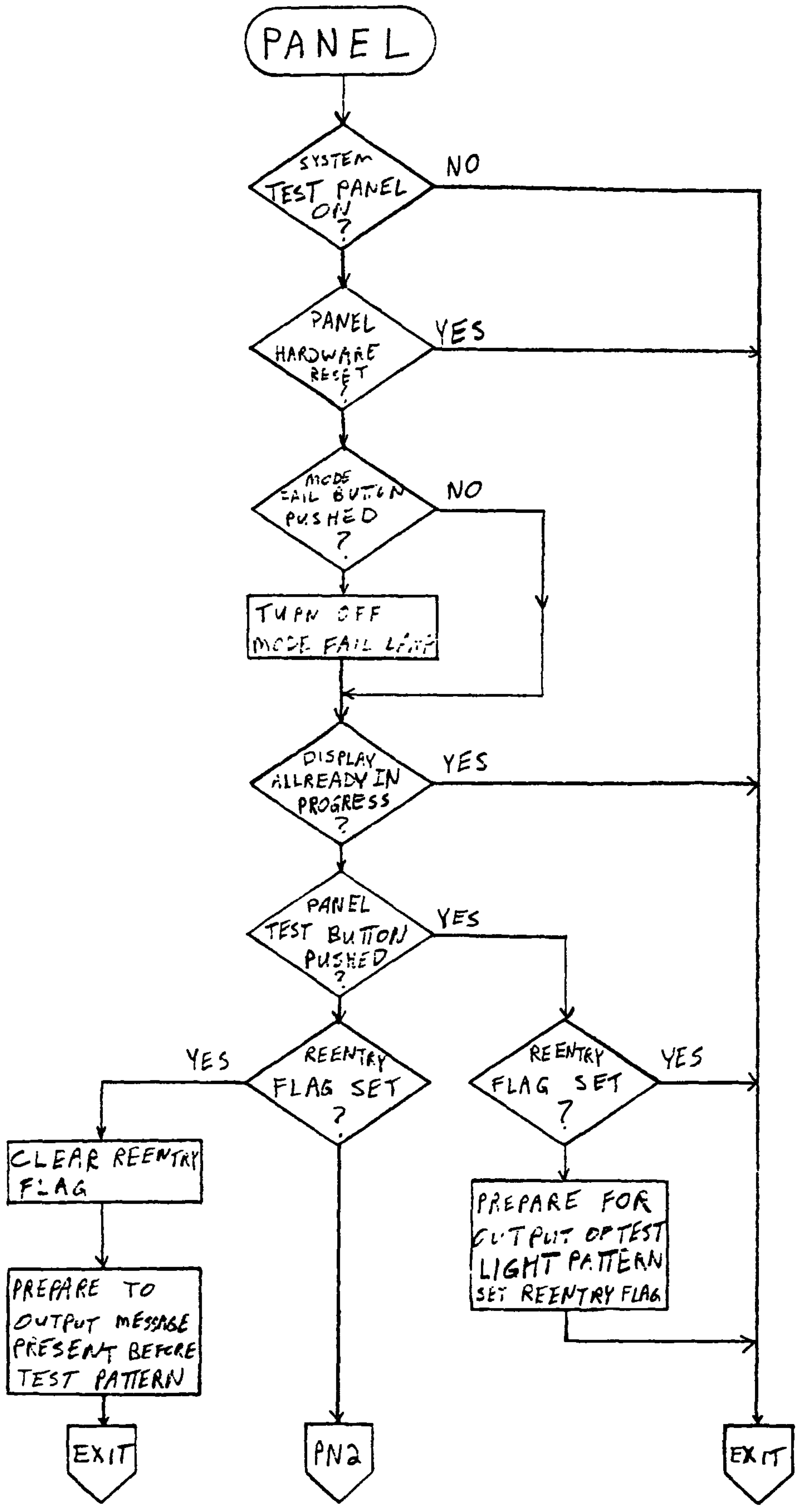
NVDM0D
(PAGE 14 OF 17)

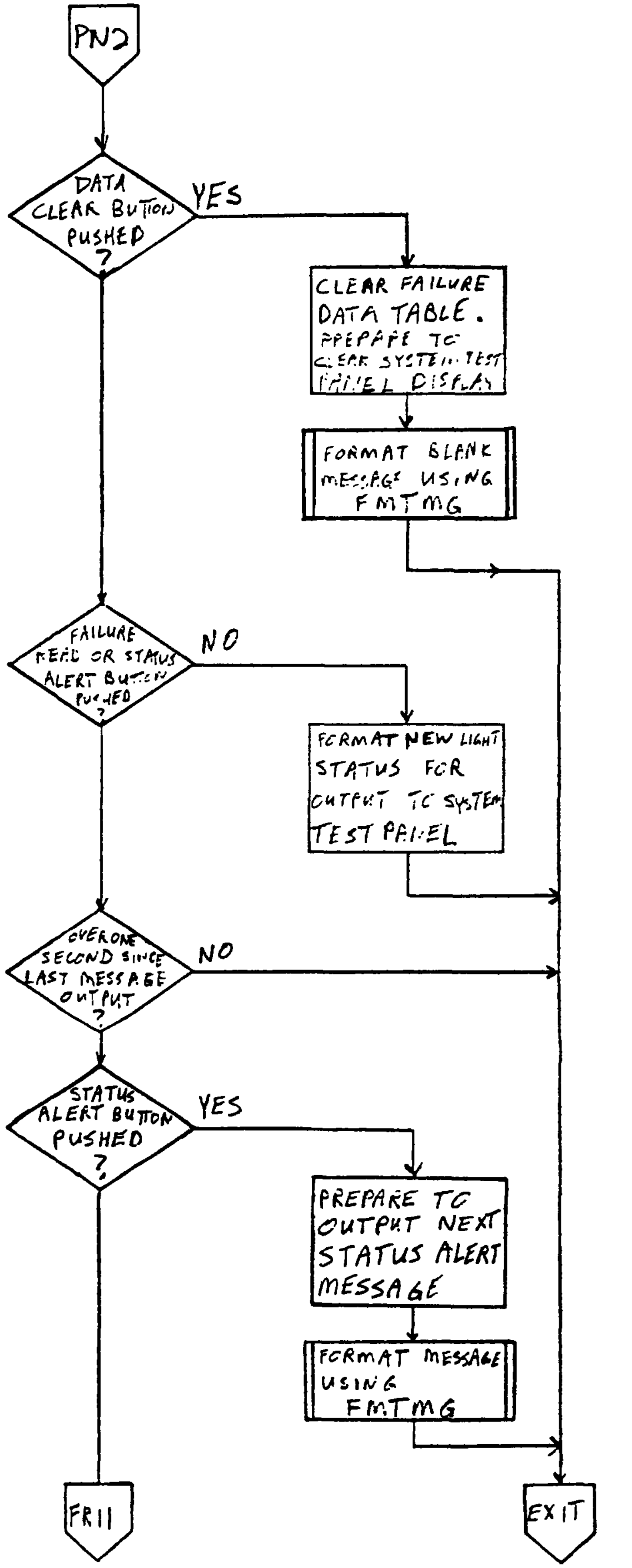


NVDMOD
(PAGE 15 OF 17)

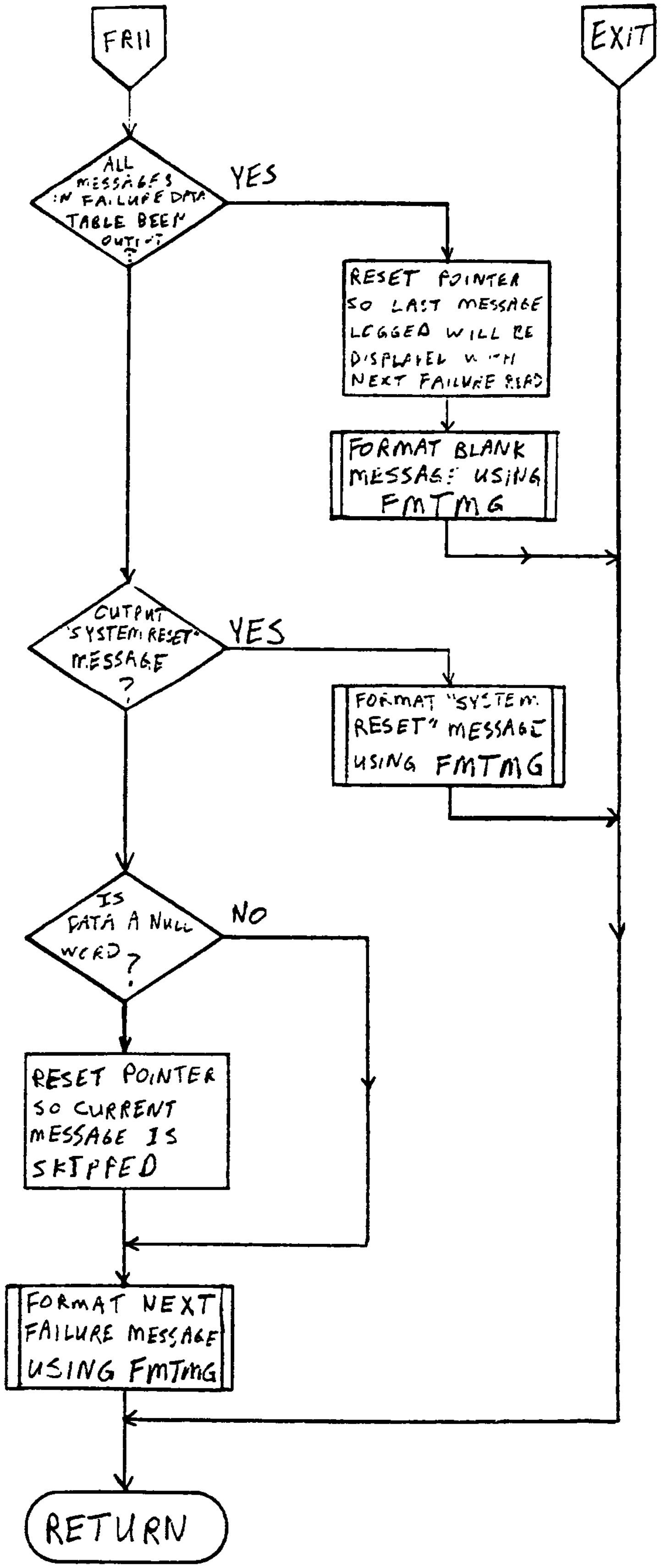

E
STORE DECODED VALUE IN BUFFER
RETURN
DCNV1
LUNAVA
LOOK UP NAVAID NAME
ERROR
YES
STORE '6' IN NCDERR
MESSAGE "NOT IN MEMORY PRESS #
NO
CLEAR FLAG "RESETA" ALLOWING FOR REJECT CAPABILITY
RETURN


AIDCAL
NAVAID POINTER= 0?
YES
CLEAR LINE ON PAGE 3 BUFFER
RETURN
NO
C7TO8
FETCH NAVAID NAME
CONVERT TO 8 BIT ASCII
MOVE TO NAV DATA PAGE # 3.
FRMFRQ
FORMAT AND STORE FREQUENCY ON NAV DATA PAGE # 3.
RETURN


PANEL
SYSTEM TEST PANEL ON ?
NO
PANEL HARDWARE RESET ?
YES
MODE FAIL BUTTON PUSHED ?
NO
TURN OFF MODE FAIL LAMP
DISPLAY ALLREADY IN PROGRESS ?
YES
PANEL TEST BUTTON PUSHED ?
YES
REENTRY FLAG SET ?
YES
REENTRY FLAG SET ?
YES
CLEAR REENTRY FLAG
PREPARE TO OUTPUT MESSAGE PRESENT BEFORE TEST PATTERN
PREPARE FOR OUTPUT OF TEST LIGHT PATTERN SET REENTRY FLAG
EXIT
PN2
EXIT

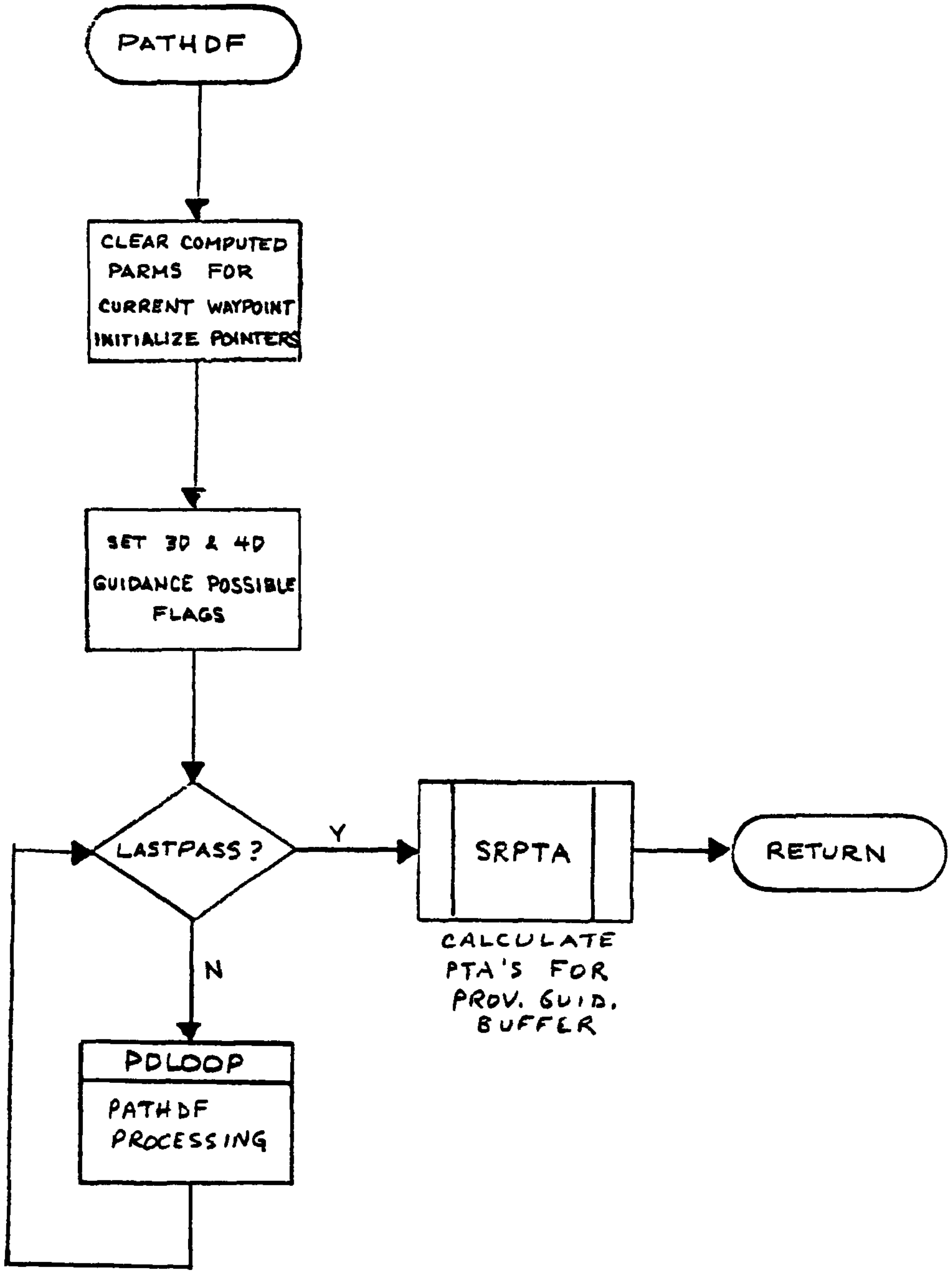

PN2
DATA CLEAR BUTTON PUSHED ?
YES
CLEAR FAILURE DATA TABLE. PREPARE TO CLEAR SYSTEM TEST PANEL DISPLAY
FORMAT BLANK MESSAGE USING FMTMG
FAILURE READ OR STATUS ALERT BUTTON PUSHED ?
NO
FORMAT NEW LIGHT STATUS FOR OUTPUT TO SYSTEM TEST PANEL
OVER ONE SECOND SINCE LAST MESSAGE OUTPUT ?
NO
STATUS ALERT BUTTON PUSHED ?
YES
PREPARE TO OUTPUT NEXT STATUS ALERT MESSAGE
FORMAT MESSAGE USING FMTMG
FR11
EXIT

PANEL 2/3


FR11
EXIT
ALL MESSAGES IN FAILURE DATA TABLE BEEN OUTPUT ?
YES
RESET POINTER SO LAST MESSAGE LOGGED WILL BE DISPLAYED WITH NEXT FAILURE READ
FORMAT BLANK MESSAGE USING FMTMG
OUTPUT "SYSTEM RESET" MESSAGE ?
YES
FORMAT "SYSTEM RESET" MESSAGE USING FMTMG
IS DATA A NULL WORD ?
NO
RESET POINTER SO CURRENT MESSAGE IS SKIPPED
FORMAT NEXT FAILURE MESSAGE USING FMTMG
RETURN

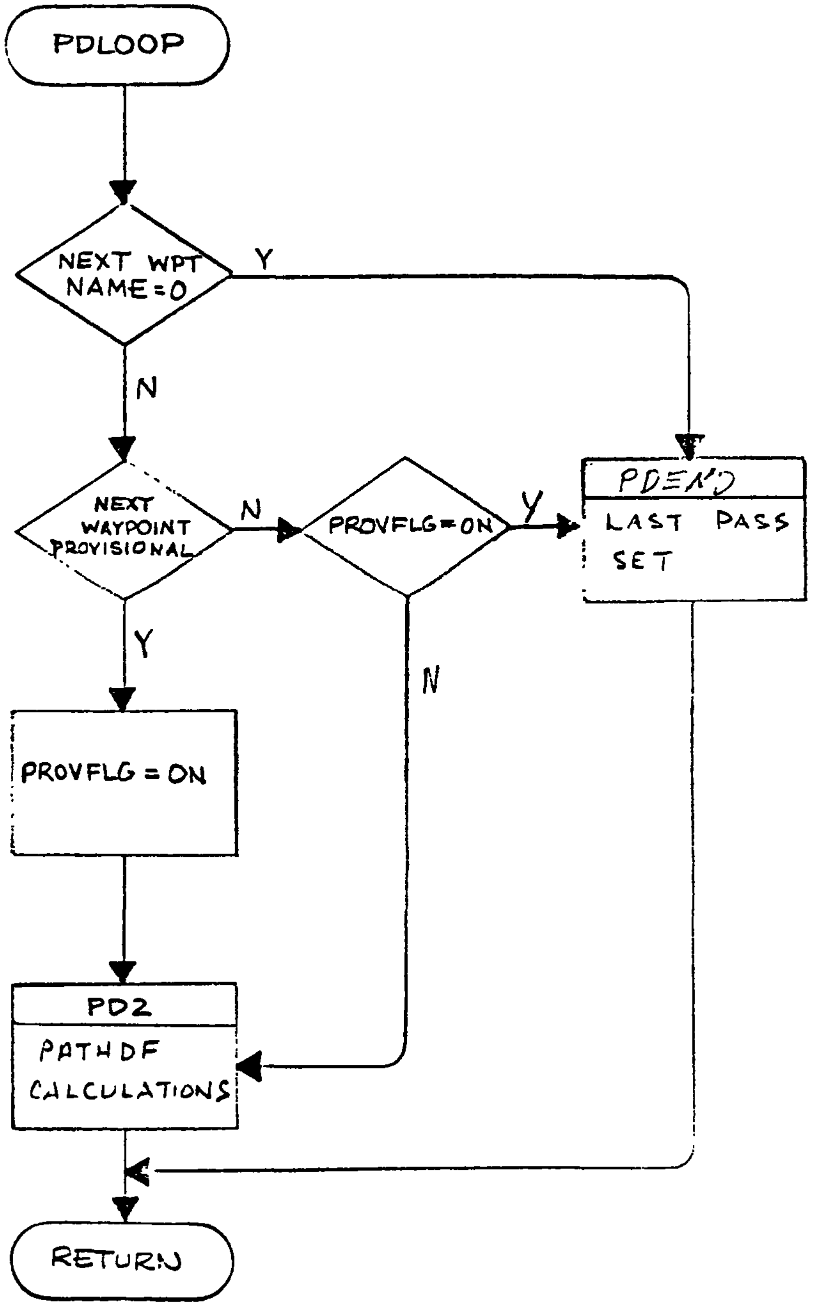
The need for a "SYSTEM RESET" message is indicated by a Boolean true in the null word (word 8) of the eight words stored for each message in the failure data table.

PANEL 3/3

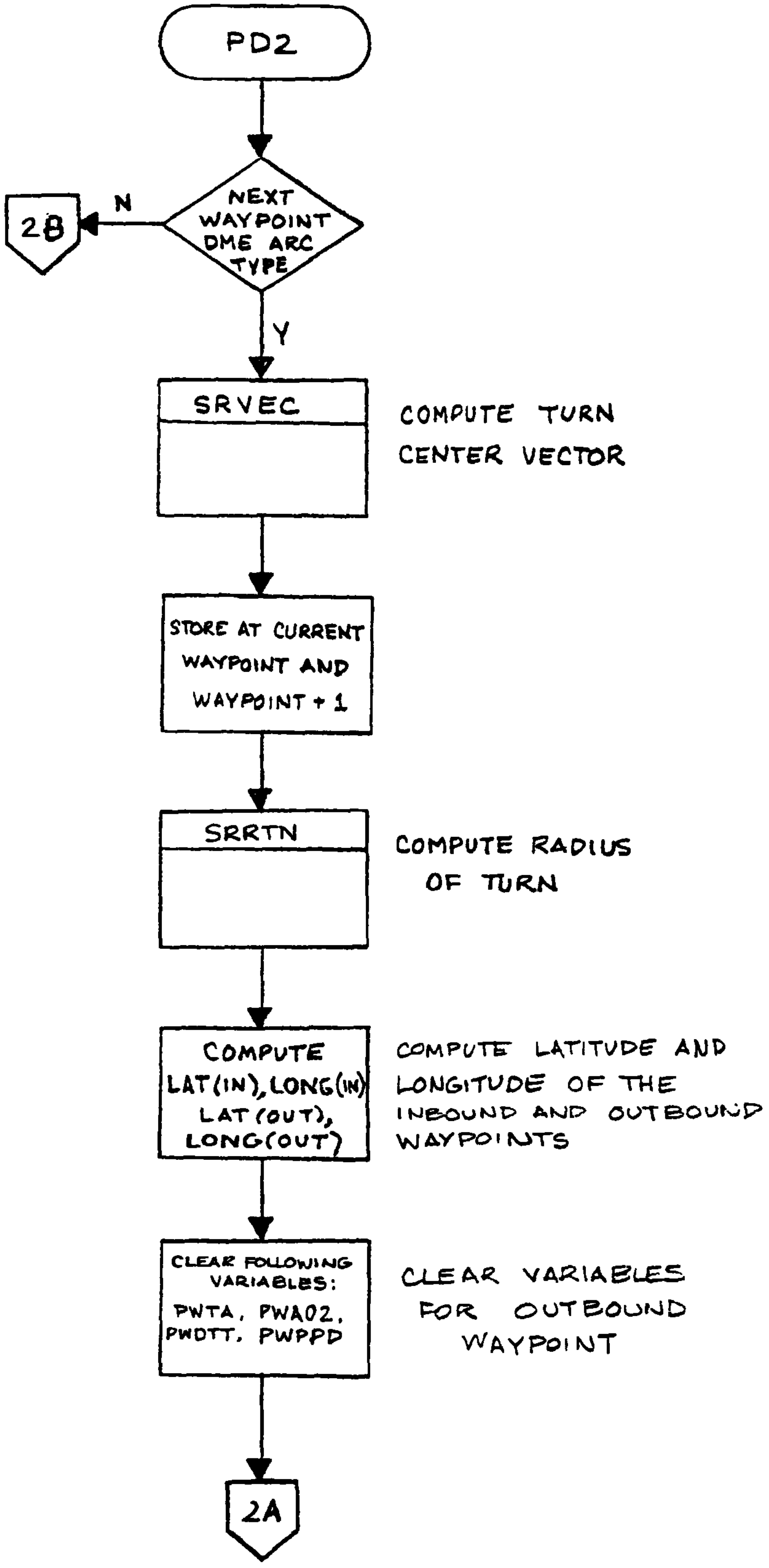

PATHDF
CLEAR COMPUTED PARMS FOR CURRENT WAYPOINT INITIALIZE POINTERS
SET 3D & 4D GUIDANCE POSSIBLE FLAGS
LASTPASS ?
Y
N
SRPTA
CALCULATE PTA'S FOR PROV. GUID. BUFFER
RETURN
PDLOOP
PATHDF PROCESSING

PATHDF
(PAGE 1 OF 11)

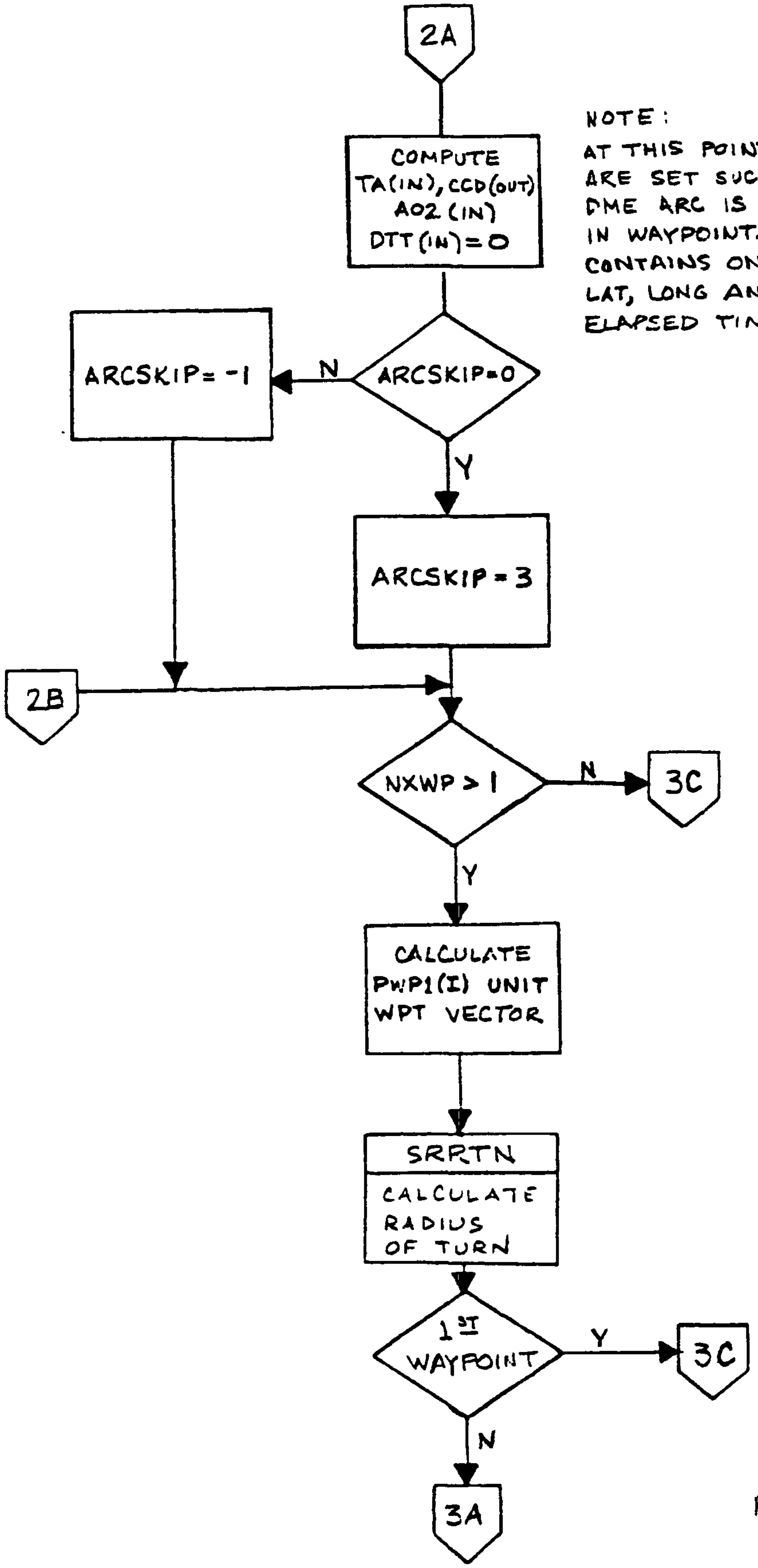
ORIGINAL PAGE IS
OF POOR QUALITY



PATHDF
(PAGE 2 OF 11)

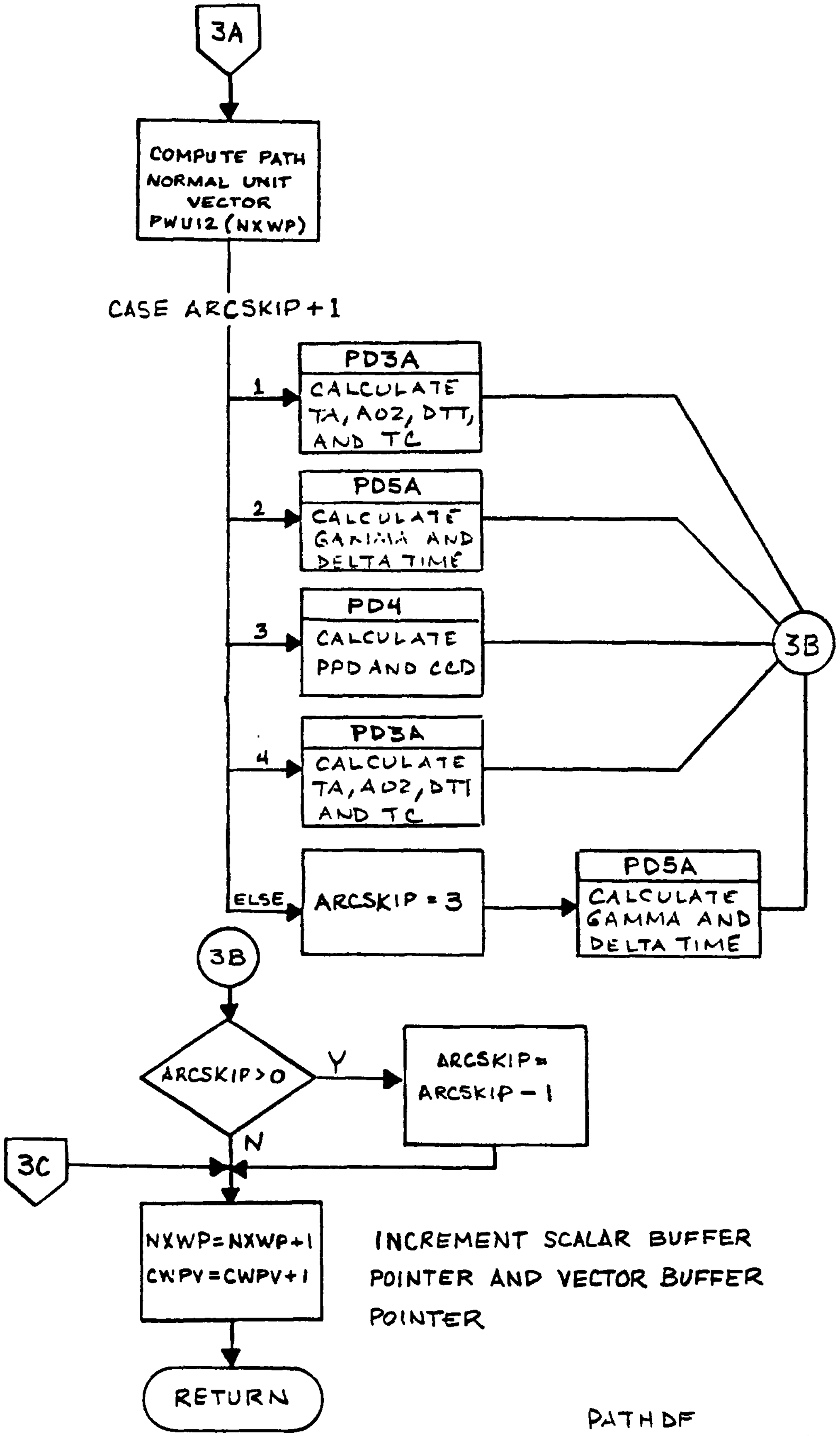

PD2
NEXT WAYPOINT DME ARC TYPE
N
2B
Y
SRVEC
COMPUTE TURN CENTER VECTOR
STORE AT CURRENT WAYPOINT AND WAYPOINT + 1
SRRTN
COMPUTE RADIUS OF TURN
COMPUTE LAT(IN), LONG(IN) LAT(OUT), LONG(OUT)
COMPUTE LATITUDE AND LONGITUDE OF THE INBOUND AND OUTBOUND WAYPOINTS
CLEAR FOLLOWING VARIABLES: PWTA, PWA02, PWDTT, PWPPD
CLEAR VARIABLES FOR OUTBOUND WAYPOINT
2A

PATHDF
(PAGE 3 OF 11)

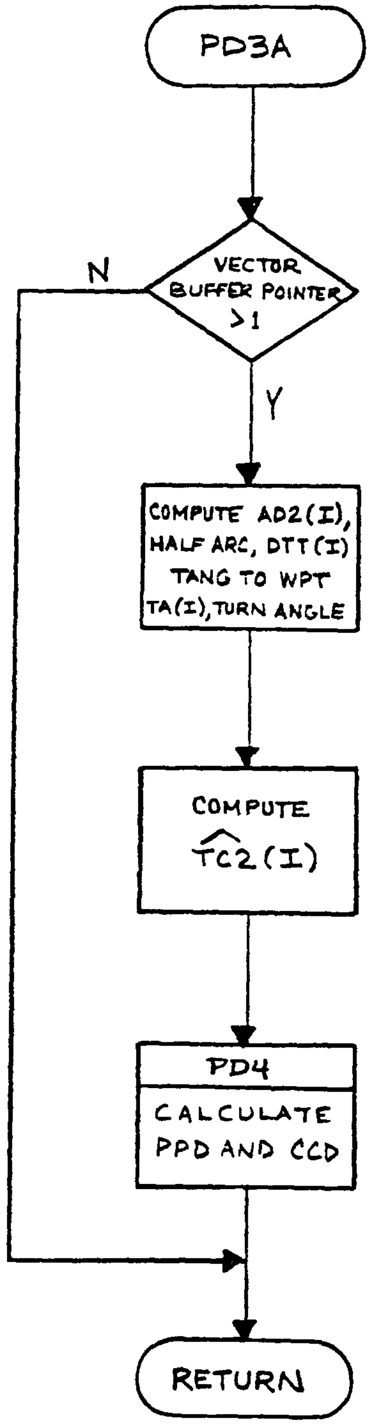


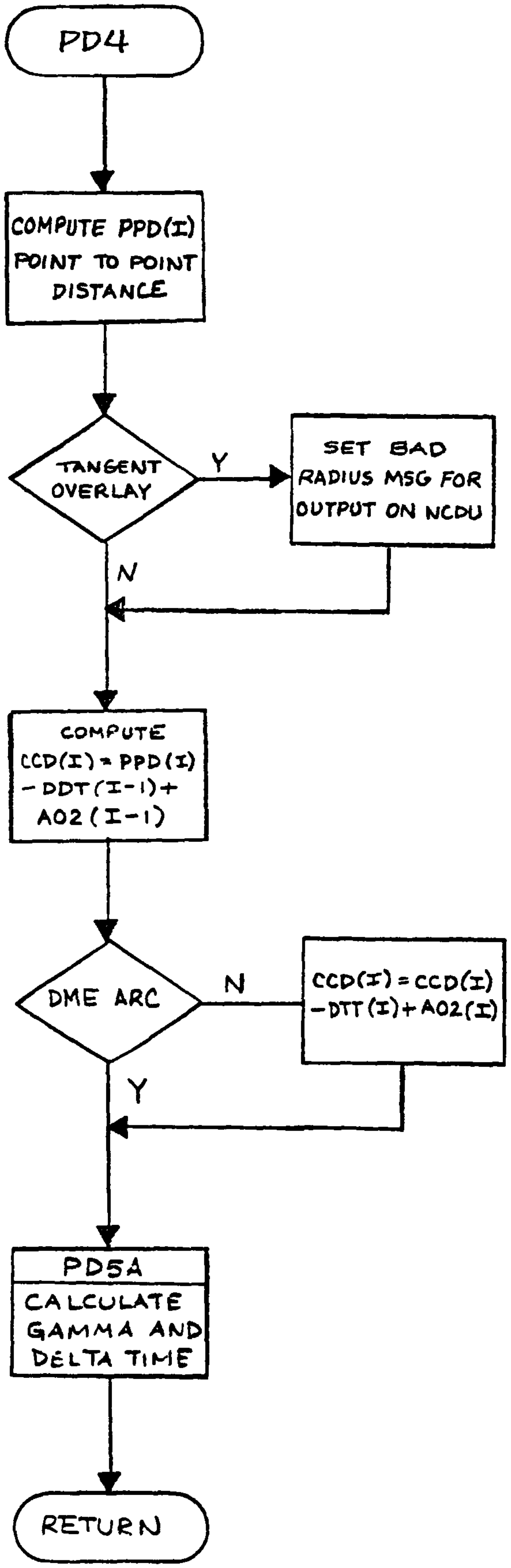
NOTE:
AT THIS POINT THE BUFFERS ARE SET SUCH THAT THE TOTAL DME ARC IS ATTACHED TO THE IN WAYPOINT. THE OUT WAYPOINT CONTAINS ONLY THE END OF ARC LAT, LONG AND THE CCD FOR ELAPSED TIME CALCULATIONS.

PATHDF
(PAGE 4 OF 11)

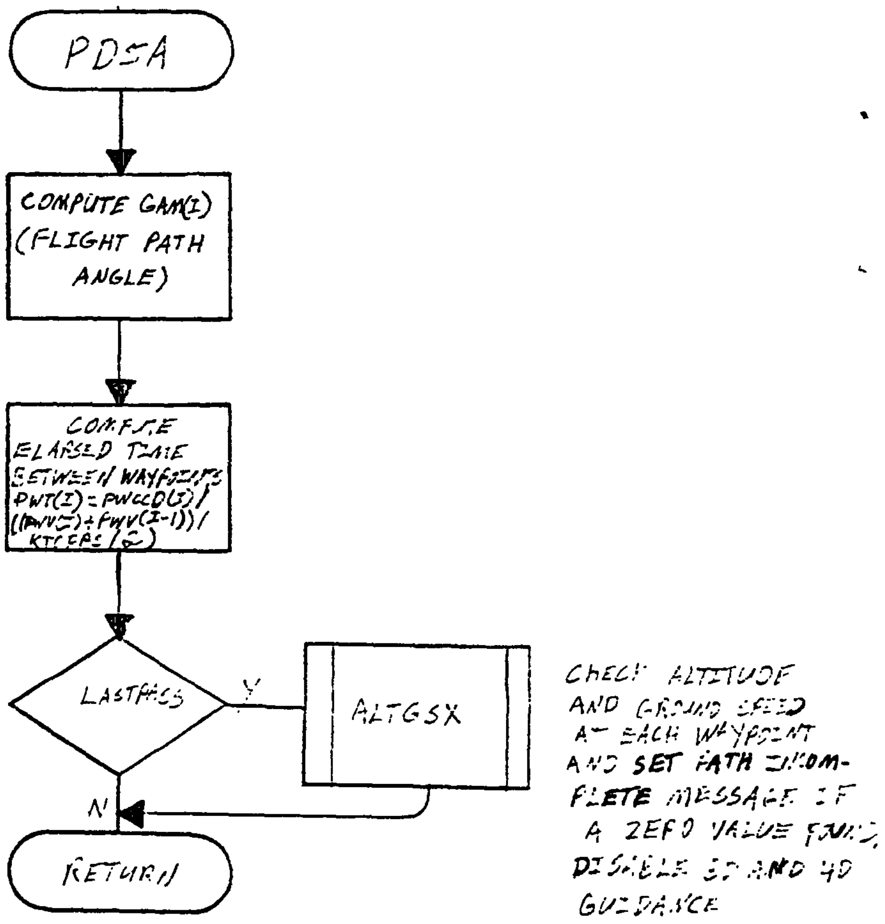

3A
COMPUTE PATH NORMAL UNIT VECTOR PWU12(NXWP)
CASE ARCSKIP+1
1
PD3A
CALCULATE TA, A02, DTT, AND TC
2
PD5A
CALCULATE GAMMA AND DELTA TIME
3
PD4
CALCULATE PPD AND CCD
4
PD3A
CALCULATE TA, A02, DTT AND TC
ELSE
ARCSKIP = 3
PD5A
CALCULATE GAMMA AND DELTA TIME
3B
3B
ARCSKIP>0
Y
ARCSKIP= ARCSKIP - 1
N
3C
NXWP=NXWP+1
CWPV=CWPV+1
INCREMENT SCALAR BUFFER POINTER AND VECTOR BUFFER POINTER
RETURN

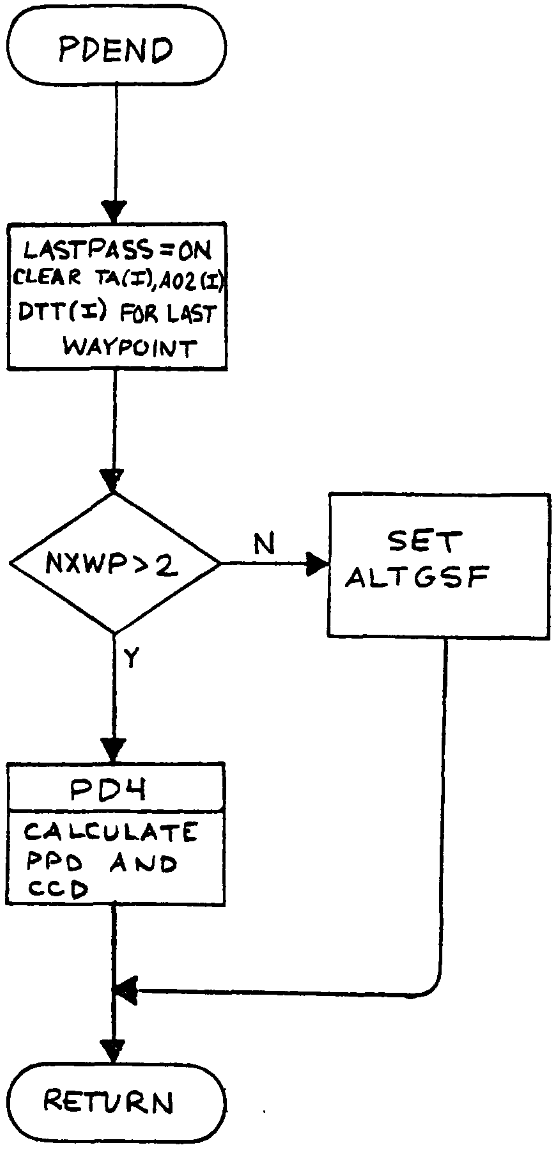
PATHDF
(PAGE 5 OF 11)

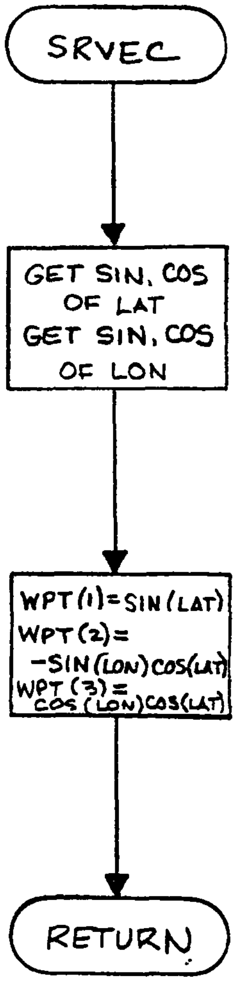

PD3A
VECTOR BUFFER POINTER >1
N
Y
COMPUTE AD2(I), HALF ARC, DTT(I) TANG TO WPT TA(I), TURN ANGLE
COMPUTE $\widehat{TC2}(I)$
PD4
CALCULATE PPD AND CCD
RETURN


PD4
COMPUTE PPD(I) POINT TO POINT DISTANCE
TANGENT OVERLAY
Y
SET BAD RADIUS MSG FOR OUTPUT ON NCDU
N
COMPUTE CCD(I) = PPD(I) − DDT(I−1) + A02(I−1)
DME ARC
N
CCD(I) = CCD(I) −DTT(I) + A02(I)
Y
PD5A
CALCULATE GAMMA AND DELTA TIME
RETURN

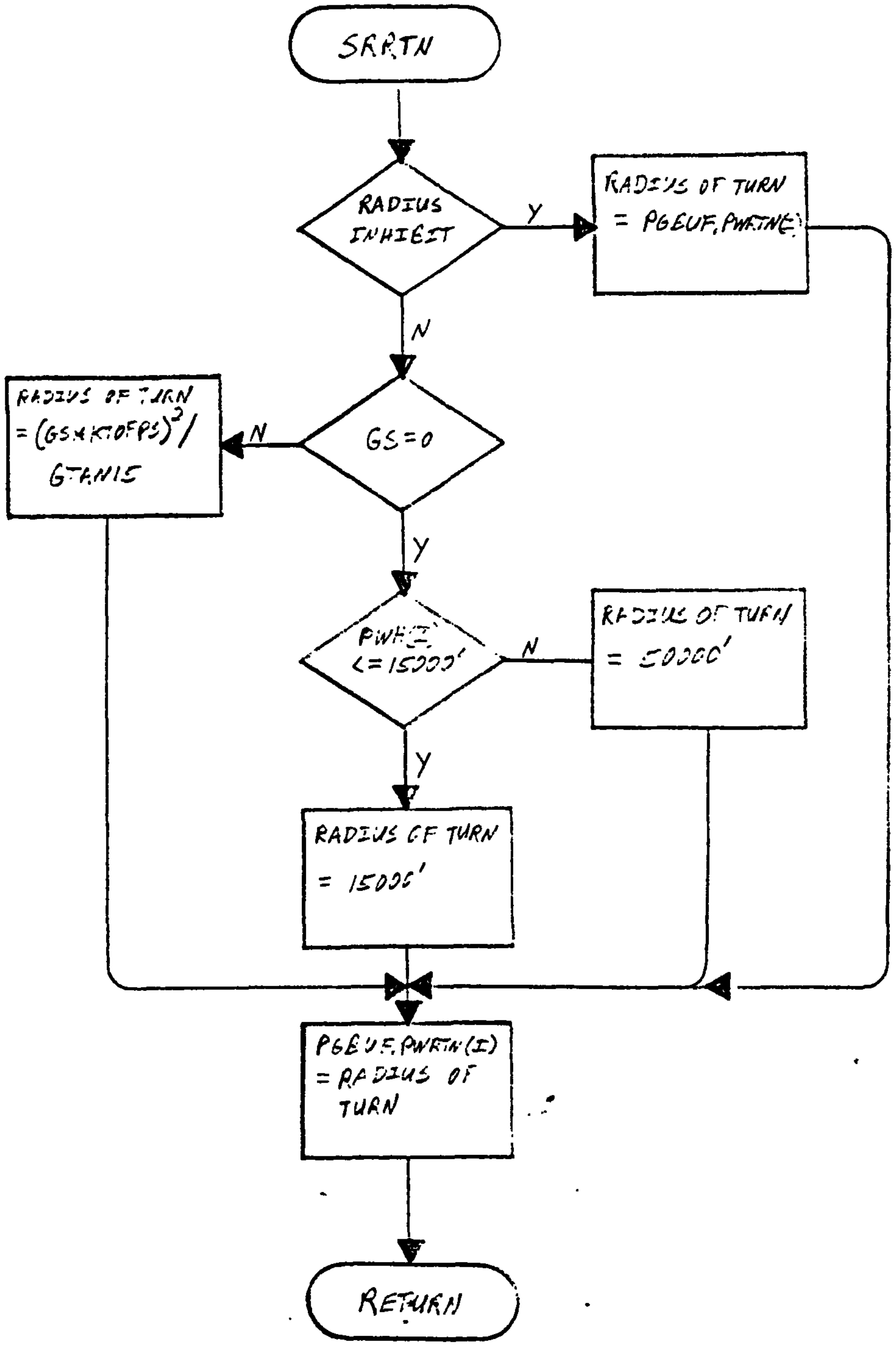
PATHDF
(PAGE 7 OF 11)


PDSA
COMPUTE GAM(I) (FLIGHT PATH ANGLE)
COMPUTE ELAPSED TIME BETWEEN WAYPOINTS PWT(I)=PWCOD(I)/((PWV(I)+PWV(I-1))/KTOFPS/2)
LASTPASS
Y
ALTGSX
N
RETURN
CHECK ALTITUDE AND GROUND SPEED AT EACH WAYPOINT AND SET PATH INCOMPLETE MESSAGE IF A ZERO VALUE FOUND, DISABLE 3D AND 4D GUIDANCE


PDEND
LASTPASS = ON
CLEAR TA(I), A02(I)
DTT(I) FOR LAST
WAYPOINT
NXWP>2
N
Y
SET
ALTGSF
PD4
CALCULATE
PPD AND
CCD
RETURN

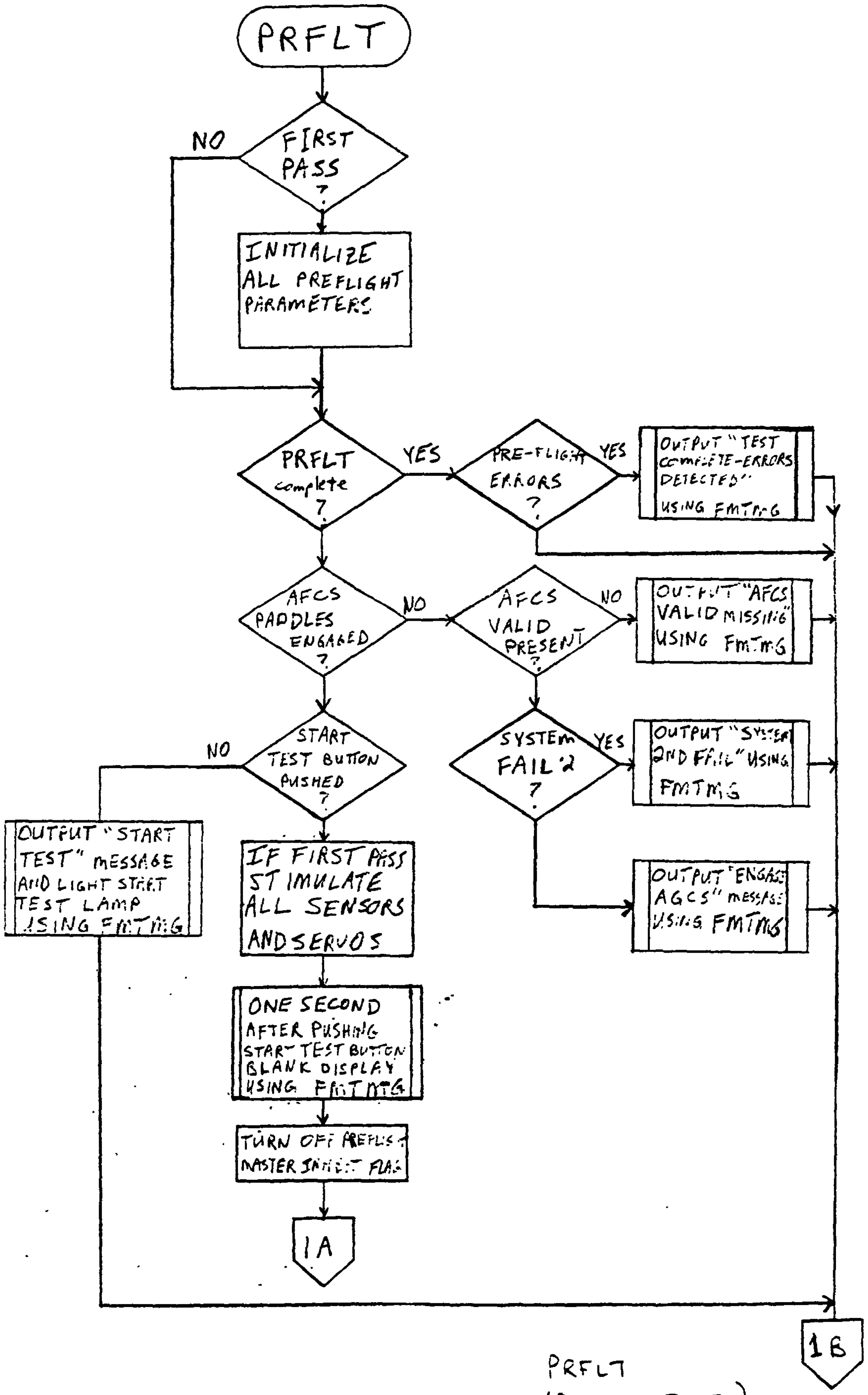

SRVEC
GET SIN, COS OF LAT GET SIN, COS OF LON
WPT(1)=SIN(LAT) WPT(2)= -SIN(LON)COS(LAT) WPT(3)= COS(LON)COS(LAT)
RETURN

ARGUMENTS TO THIS ROUTINE
ARE LAT, LON, ASSIGN (WPT)
E.G.
CALL SRVEC(LAT, LON) ASSIGN(WPT)

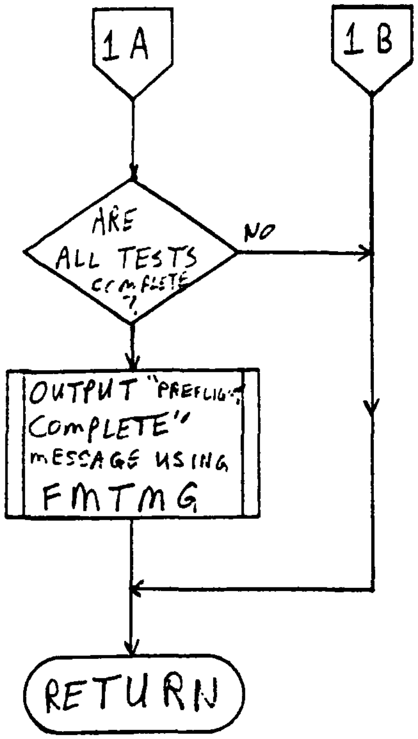

SRRTN
RADIUS INHIBIT
Y
RADIUS OF TURN = PGEUF.PWRTN(I)
N
GS=0
N
RADIUS OF TURN = (GS*KTOFPS)^2/ GTAN15
Y
PWR(I) <=15000'
N
RADIUS OF TURN = 50000'
Y
RADIUS OF TURN = 15000'
PGEUF.PWRTN(I) = RADIUS OF TURN
RETURN

GTAN15= TAN 15° * NOMINAL ACCELERATION OF GRAVITY (8.62097522)

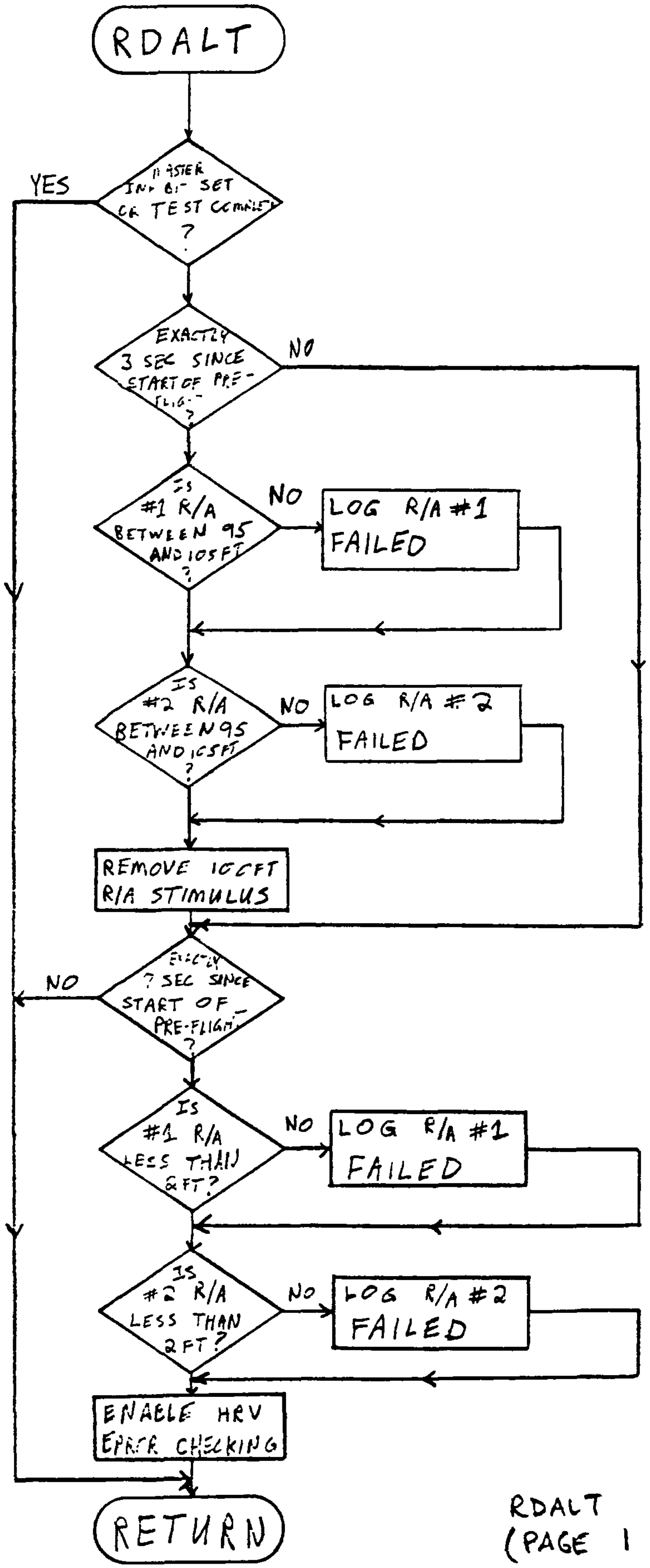
PATHDF
(PAGE 11 OF 11)


PRFLT
FIRST PASS ?
NO
INITIALIZE ALL PREFLIGHT PARAMETERS
PRFLT complete ?
YES
PRE-FLIGHT ERRORS ?
YES
OUTPUT "TEST COMPLETE-ERRORS DETECTED" USING FMTMG
AFCS PADDLES ENGAGED ?
NO
AFCS VALID PRESENT ?
NO
OUTPUT "AFCS VALID MISSING" USING FMTMG
START TEST BUTTON PUSHED ?
NO
SYSTEM FAIL 2 ?
YES
OUTPUT "SYSTEM 2ND FAIL" USING FMTMG
OUTPUT "START TEST" MESSAGE AND LIGHT START TEST LAMP USING FMTMG
IF FIRST PASS STIMULATE ALL SENSORS AND SERVOS
OUTPUT "ENGAGE AGCS" MESSAGE USING FMTMG
ONE SECOND AFTER PUSHING START TEST BUTTON BLANK DISPLAY USING FMTMG
TURN OFF PREFLIGHT MASTER INHIBIT FLAG
1A
1B

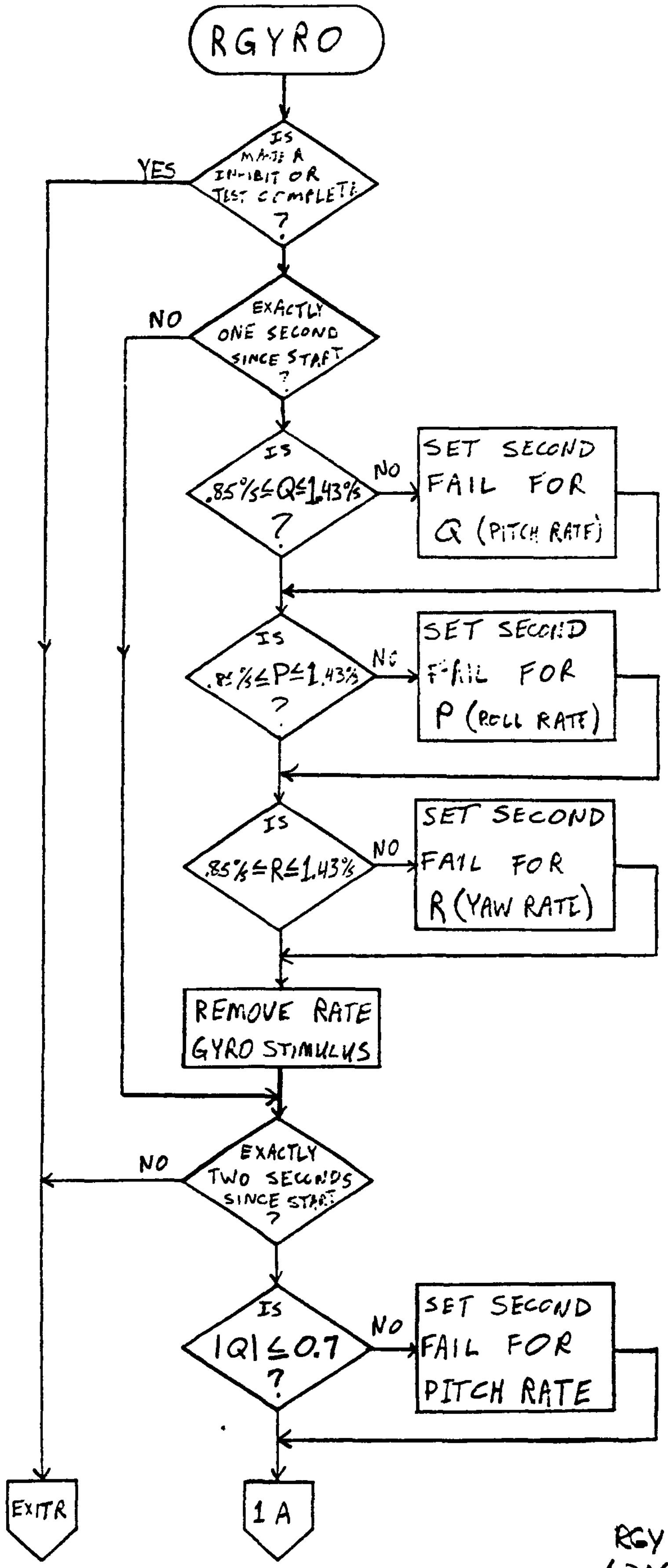
PRFLT
(PAGE 1 OF 2)



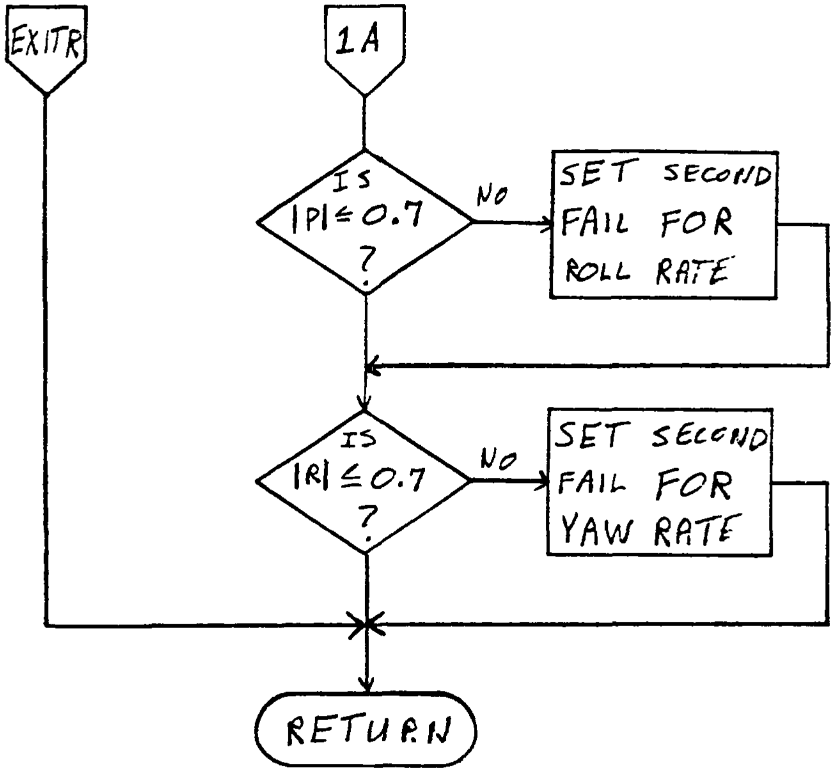
PRFLT
(PAGE 2 OF 2)


RDALT
MASTER INH BIT SET OR TEST COMPLETE ?
YES
EXACTLY 3 SEC SINCE START OF PRE-FLIGHT ?
NO
IS #1 R/A BETWEEN 95 AND 105 FT ?
NO
LOG R/A #1 FAILED
IS #2 R/A BETWEEN 95 AND 105 FT ?
NO
LOG R/A #2 FAILED
REMOVE 100 FT R/A STIMULUS
EXACTLY 7 SEC SINCE START OF PRE-FLIGHT ?
NO
IS #1 R/A LESS THAN 2 FT?
NO
LOG R/A #1 FAILED
IS #2 R/A LESS THAN 2 FT?
NO
LOG R/A #2 FAILED
ENABLE HRV ERROR CHECKING
RETURN

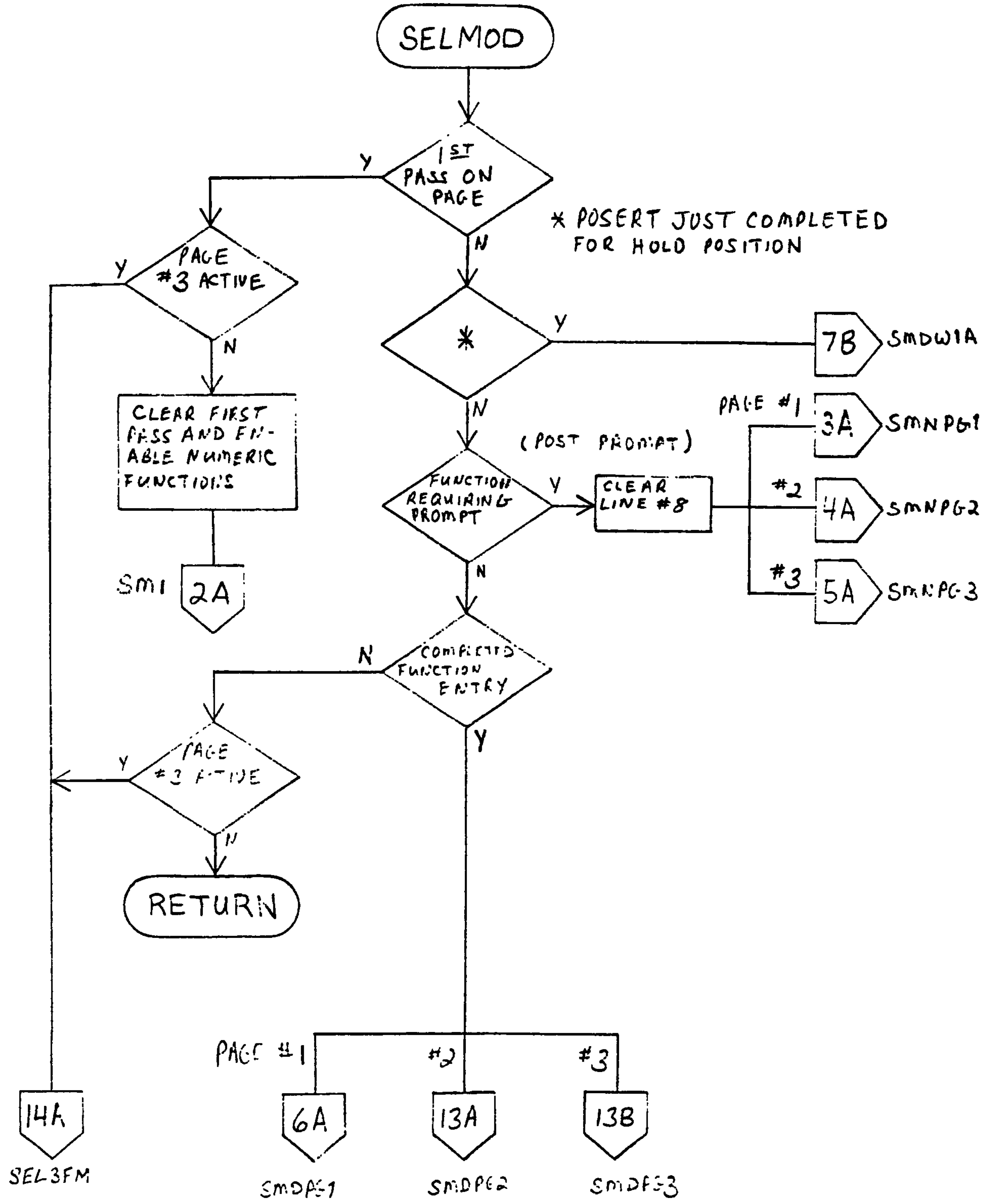
RDALT
(PAGE 1 OF 1)

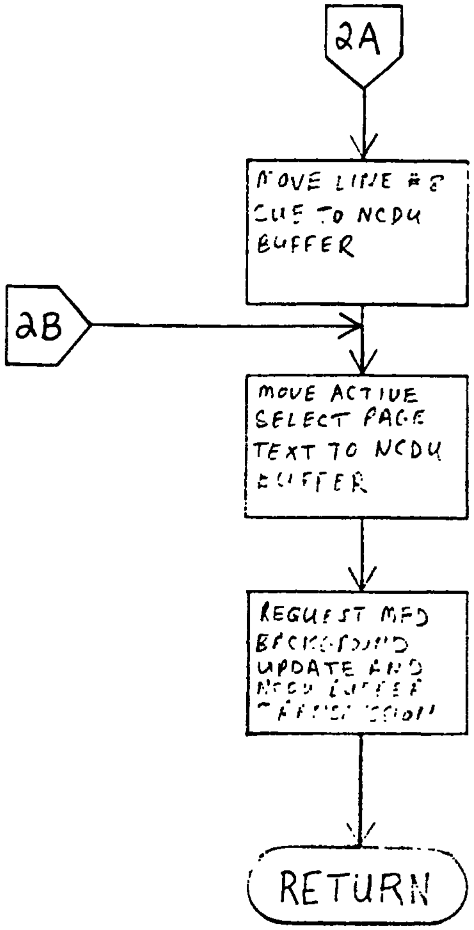

RGYRO
IS MATE A INHIBIT OR TEST COMPLETE ?
YES
EXACTLY ONE SECOND SINCE START ?
NO
IS .85%/S≤Q≤1.43%/S ?
NO
SET SECOND FAIL FOR Q (PITCH RATE)
IS .85%/S≤P≤1.43%/S ?
NO
SET SECOND FAIL FOR P (ROLL RATE)
IS .85%/S≤R≤1.43%/S
NO
SET SECOND FAIL FOR R (YAW RATE)
REMOVE RATE GYRO STIMULUS
EXACTLY TWO SECONDS SINCE START ?
NO
IS |Q|≤0.7 ?
NO
SET SECOND FAIL FOR PITCH RATE
EXITR
1 A

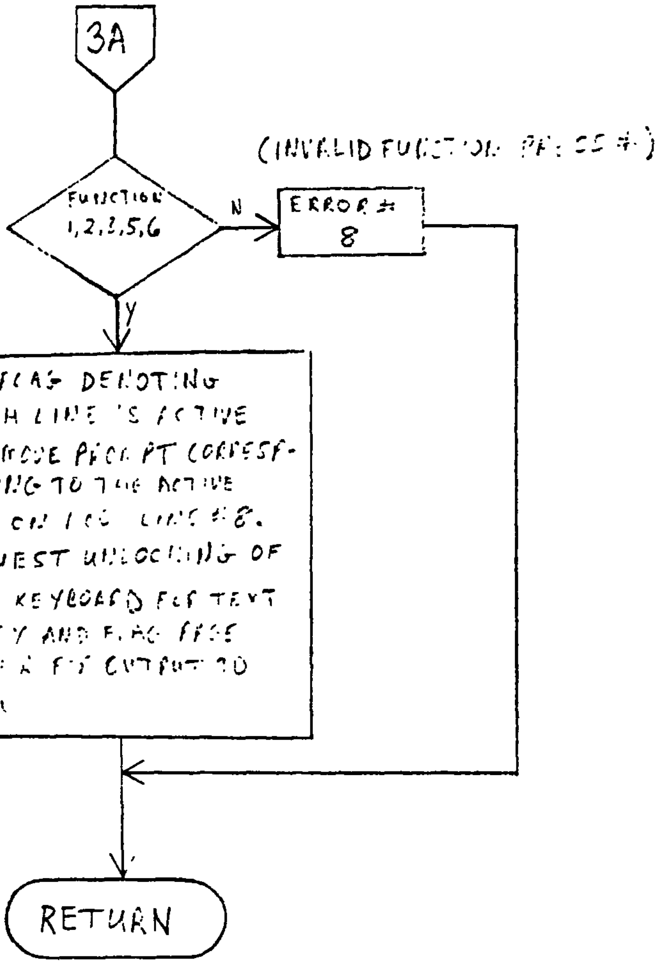
RGYRO
(PAGE 1 OF 2)

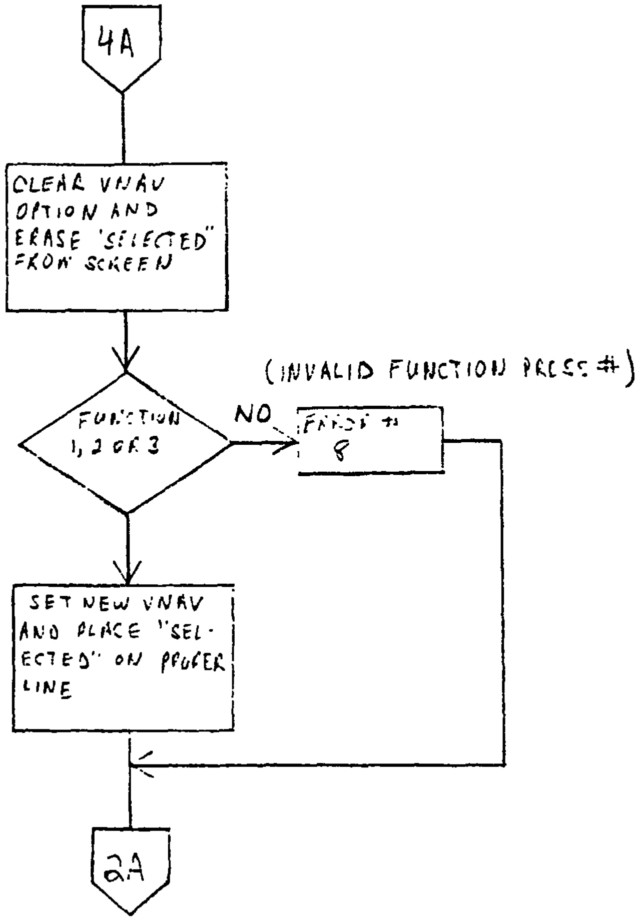


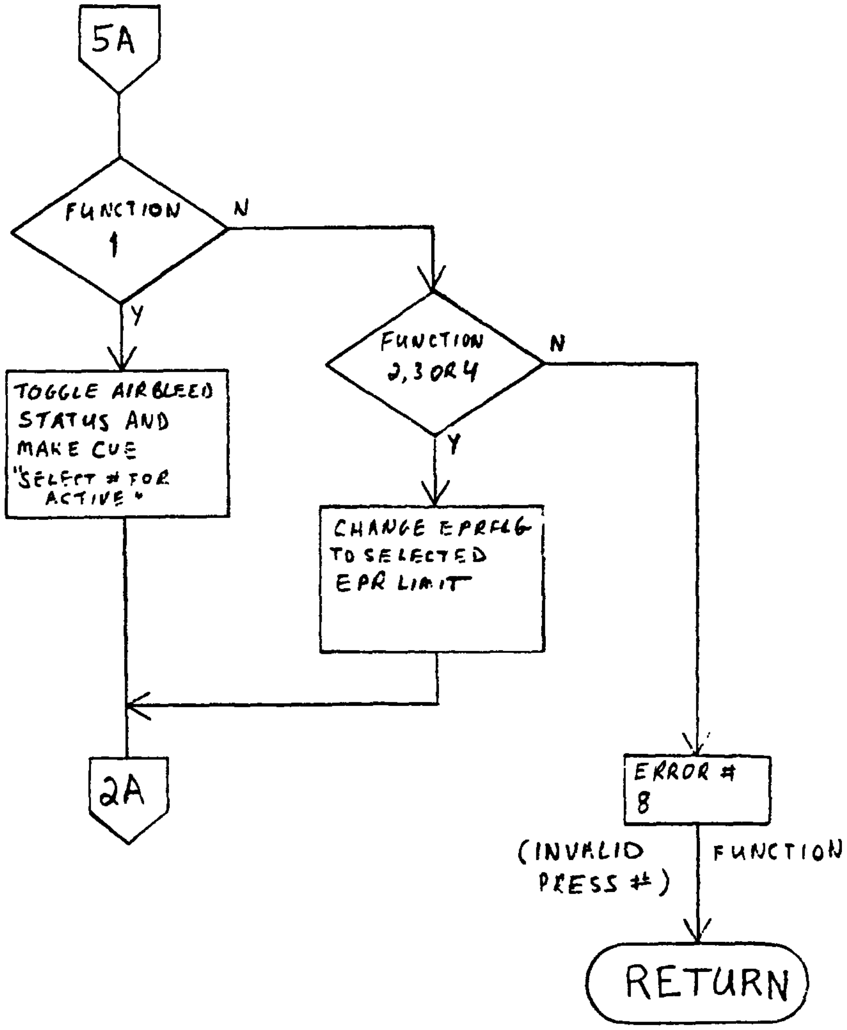
RGYRO
(PAGE 2 OF 2)

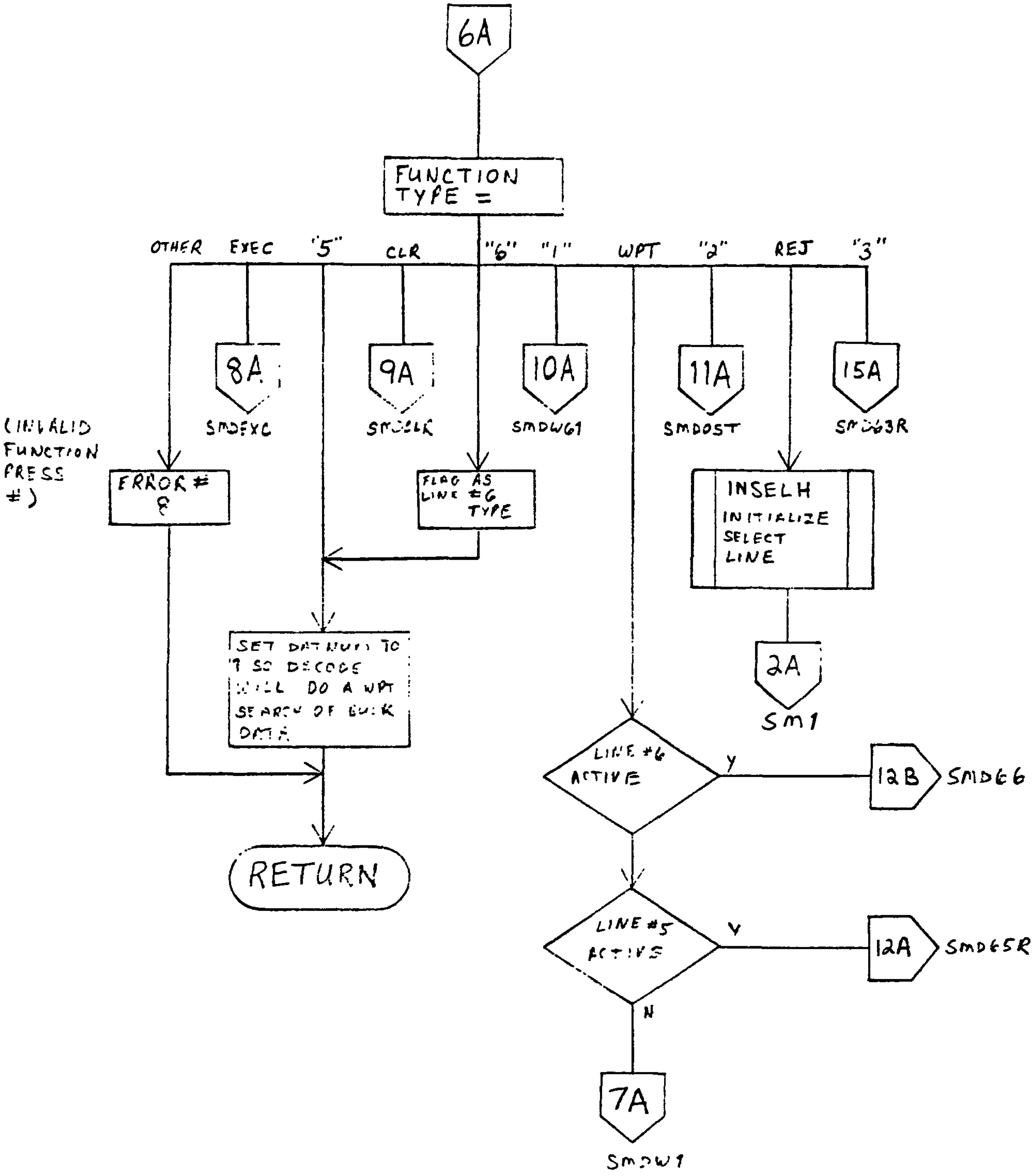

SELMOD
1ST PASS ON PAGE
Y
N
* POSERT JUST COMPLETED FOR HOLD POSITION
PAGE #3 ACTIVE
Y
N
CLEAR FIRST PASS AND EN-ABLE NUMERIC FUNCTIONS
SM1
2A
*
Y
7B
SMDW1A
N
(POST PROMPT)
FUNCTION REQUIRING PROMPT
Y
CLEAR LINE #8
PAGE #1
3A
SMNPG1
#2
4A
SMNPG2
#3
5A
SMNPG3
N
COMPLETED FUNCTION ENTRY
N
Y
PAGE #3 ACTIVE
Y
N
RETURN
14A
SEL3FM
PAGE #1
6A
SMDPG1
#2
13A
SMDPG2
#3
13B
SMDPG3

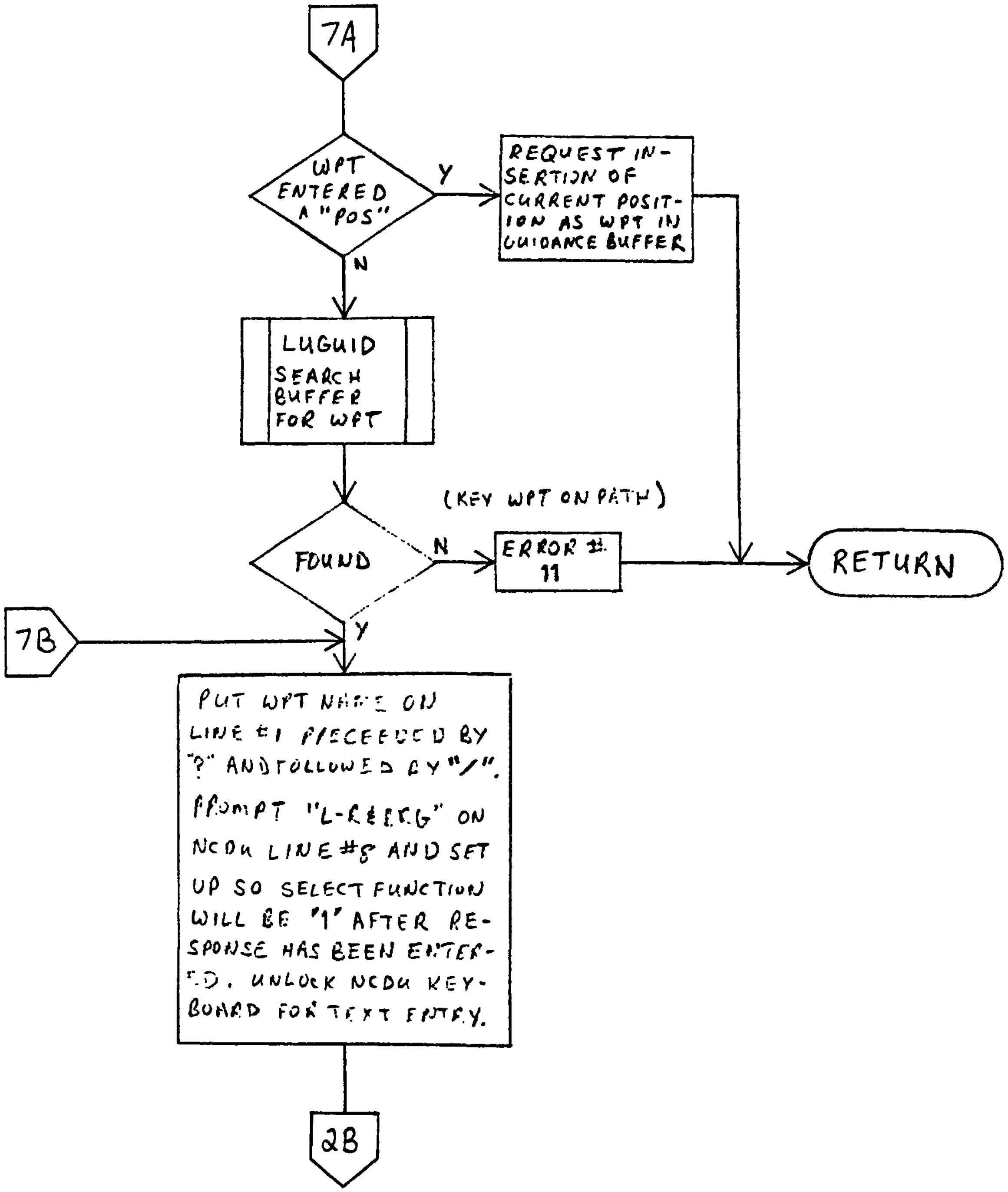

2A
MOVE LINE #8 CUE TO NCDU BUFFER
2B
MOVE ACTIVE SELECT PAGE TEXT TO NCDU BUFFER
REQUEST MFD BACKGROUND UPDATE AND NCDU BUFFER TRANSMISSION
RETURN

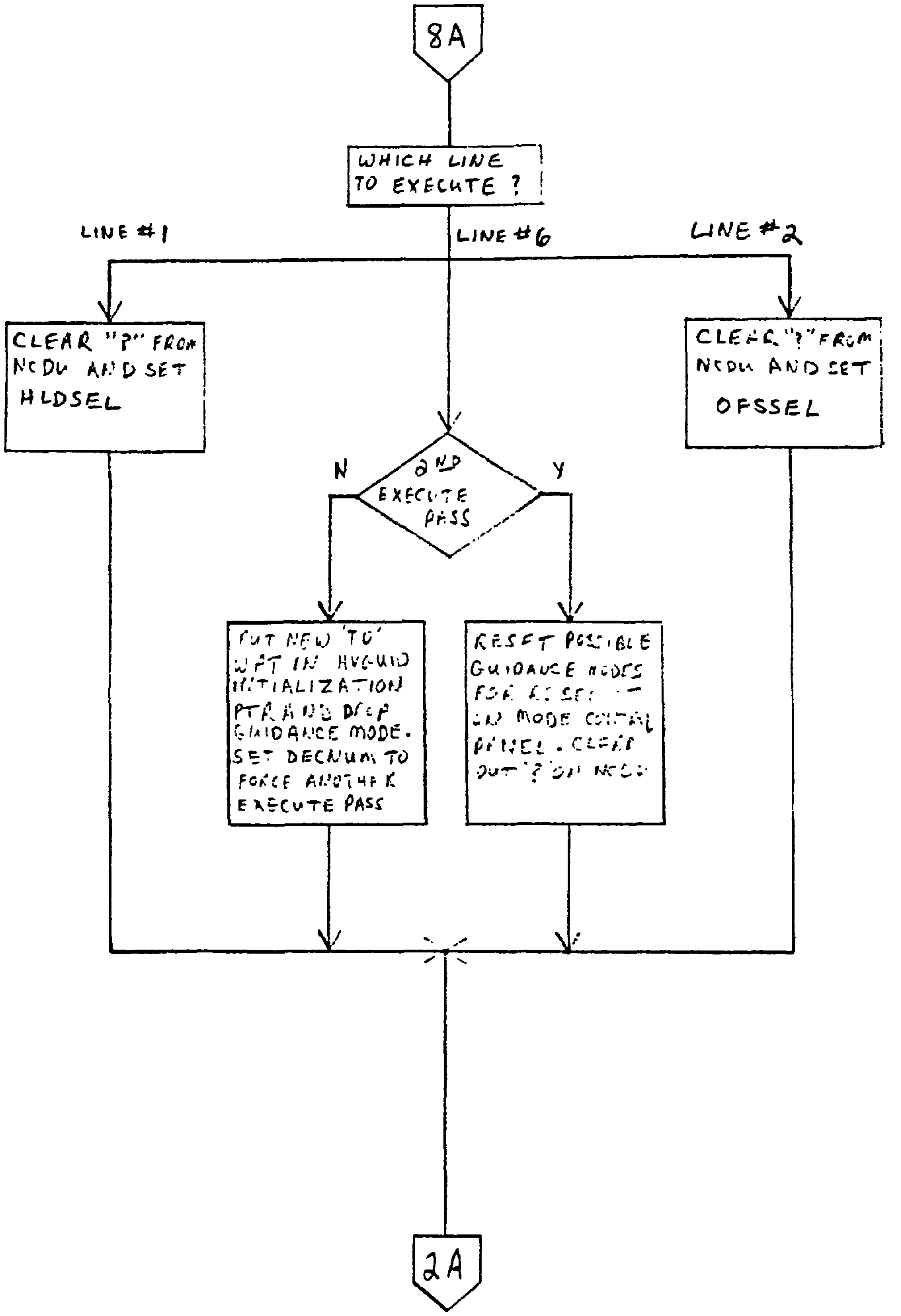

3A
(INVALID FUNCTION PRESS #)
FUNCTION 1,2,3,5,6
N
ERROR # 8
Y
SET FLAG DENOTING WHICH LINE IS ACTIVE AND MOVE PROMPT CORRESPONDING TO THE ACTIVE LINE ON NCDU LINE #8. REQUEST UNLOCKING OF NCDU KEYBOARD FOR TEXT ENTRY AND FLAG FREE BUFFER FOR OUTPUT TO NCDU
RETURN


4A
CLEAR VNAV OPTION AND ERASE 'SELECTED' FROM SCREEN
FUNCTION 1, 2 OR 3
NO
(INVALID FUNCTION PRESS #)
ERROR # 8
SET NEW VNAV AND PLACE "SELECTED" ON PROPER LINE
2A


5A
FUNCTION 1
N
Y
TOGGLE AIRBLEED STATUS AND MAKE CUE "SELECT # FOR ACTIVE"
FUNCTION 2,3 OR 4
N
Y
CHANGE EPRFLG TO SELECTED EPR LIMIT
2A
ERROR # 8
(INVALID PRESS #)
FUNCTION
RETURN

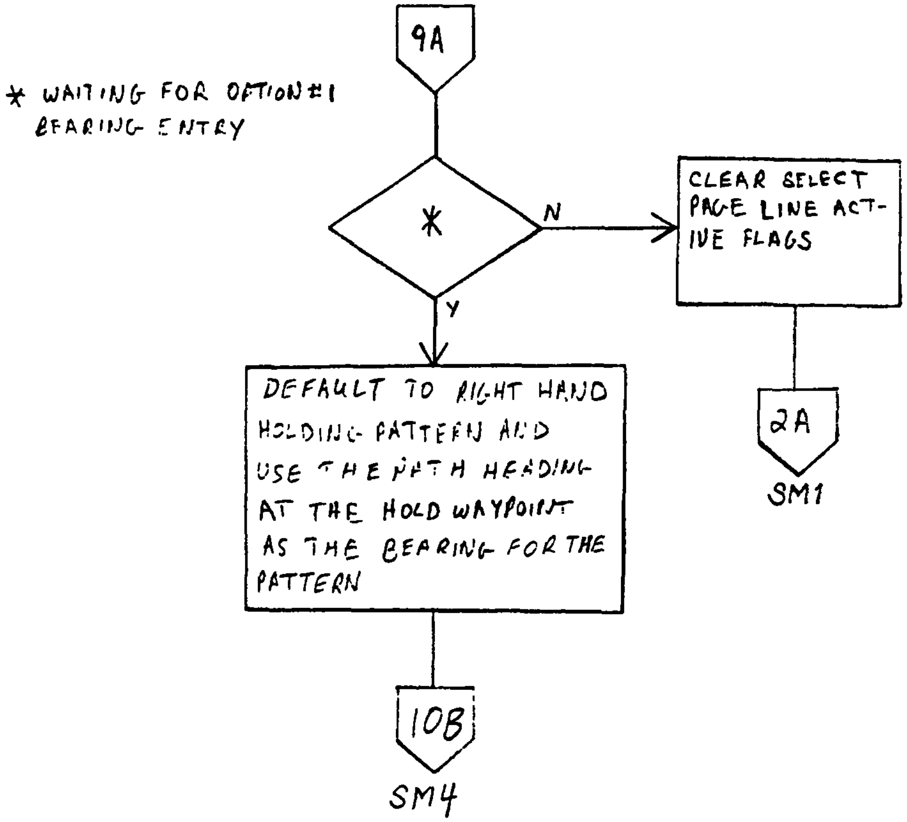

6A
FUNCTION TYPE =
OTHER
EXEC
"5"
CLR
"6"
"1"
WPT
"2"
REJ
"3"
8A
SMDEXC
9A
SMDCLR
10A
SMDW61
11A
SMDOST
15A
SMD63R
(INVALID FUNCTION PRESS #)
ERROR # 8
FLAG AS LINE #6 TYPE
INSELH
INITIALIZE SELECT LINE
2A
SM1
SET DATNUM TO 7 SO DECODE WILL DO A WPT SEARCH OF BULK DATA
RETURN
LINE #6 ACTIVE
Y
12B
SMD66
LINE #5 ACTIVE
Y
12A
SMD65R
N
7A
SMDW1


7A
WPT ENTERED A "POS"
Y
REQUEST INSERTION OF CURRENT POSITION AS WPT IN GUIDANCE BUFFER
N
LUGUID
SEARCH BUFFER FOR WPT
(KEY WPT ON PATH)
FOUND
N
ERROR # 11
RETURN
7B
Y
PUT WPT NAME ON LINE #1 PRECEEDED BY "?" AND FOLLOWED BY "/".
PROMPT "L-REERG" ON NCDU LINE #8 AND SET UP SO SELECT FUNCTION WILL BE "1" AFTER RESPONSE HAS BEEN ENTERED. UNLOCK NCDU KEYBOARD FOR TEXT ENTRY.
2B

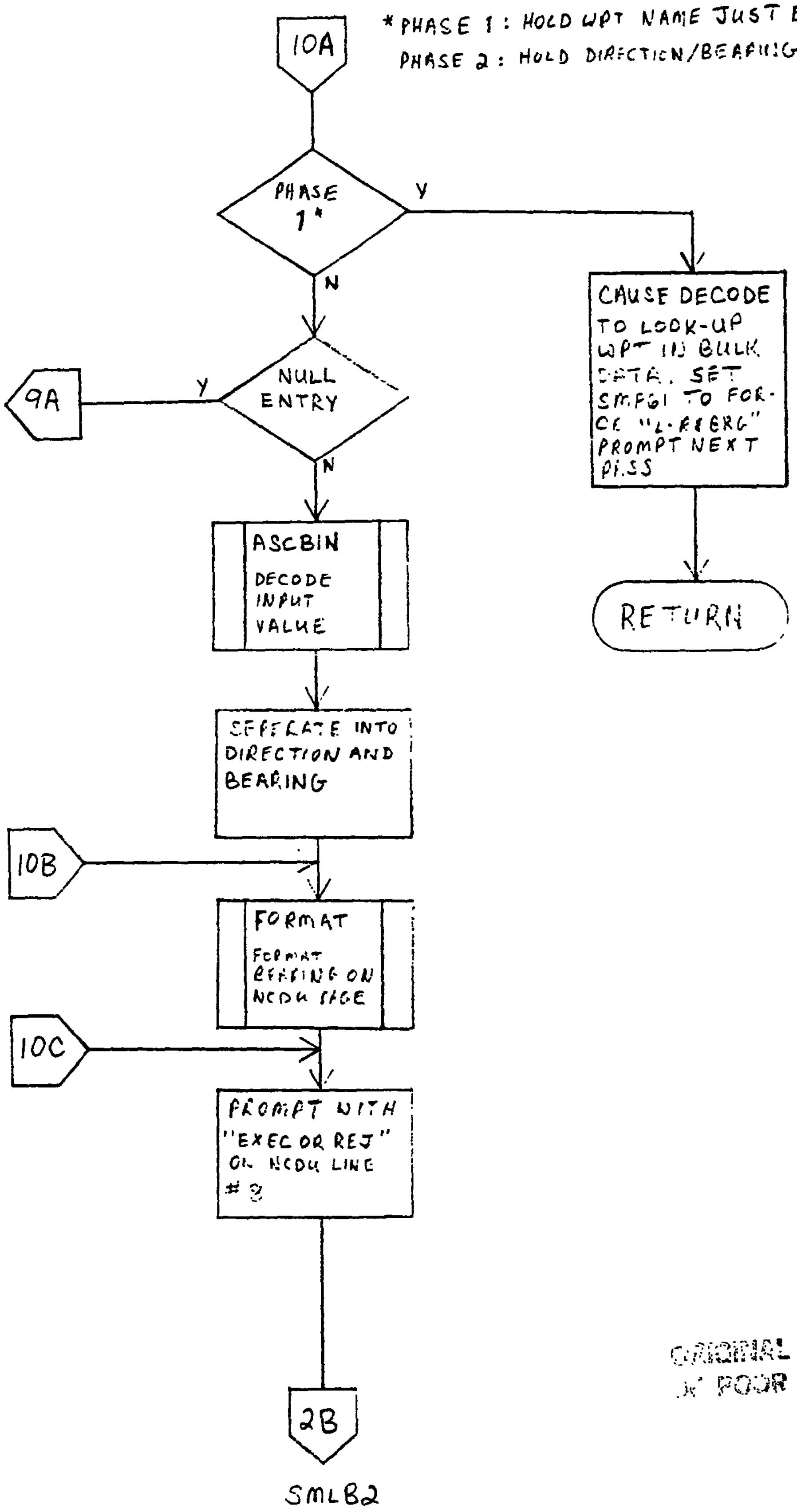

8A
WHICH LINE TO EXECUTE ?
LINE #1
LINE #6
LINE #2
CLEAR "?" FROM NCDU AND SET HLDSEL
CLEAR "?" FROM NCDU AND SET OFSSEL
N
Y
2ND EXECUTE PASS
PUT NEW 'TO' WPT IN HVGUID INITIALIZATION PTR AND DROP GUIDANCE MODE. SET DECNUM TO FORCE ANOTHER EXECUTE PASS
RESET POSSIBLE GUIDANCE MODES FOR RESET - ON MODE CONTROL PANEL. CLEAR OUT '?' ON NCDU
2A

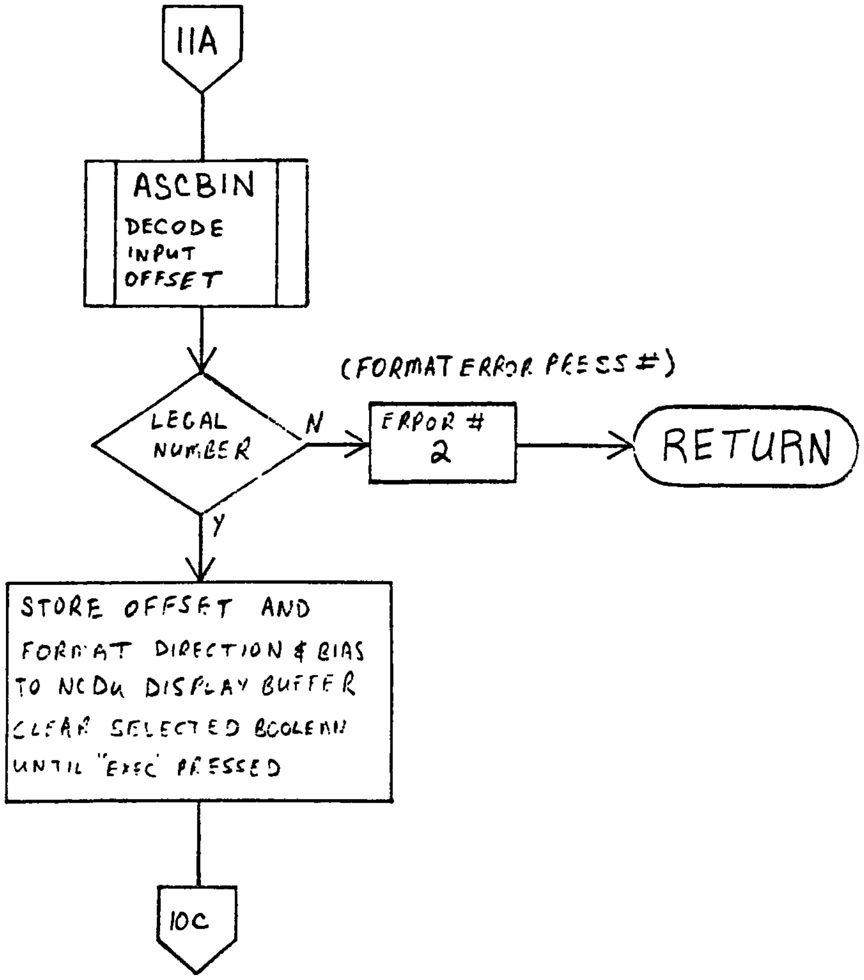
ORIGINAL PAGE IS
OF POOR QUALITY

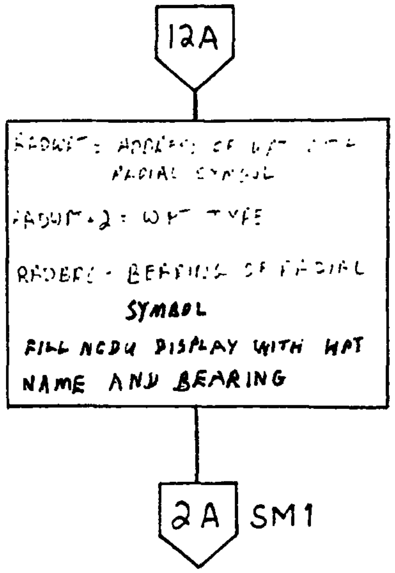
SELMOD
(PAGE 8 OF 15)

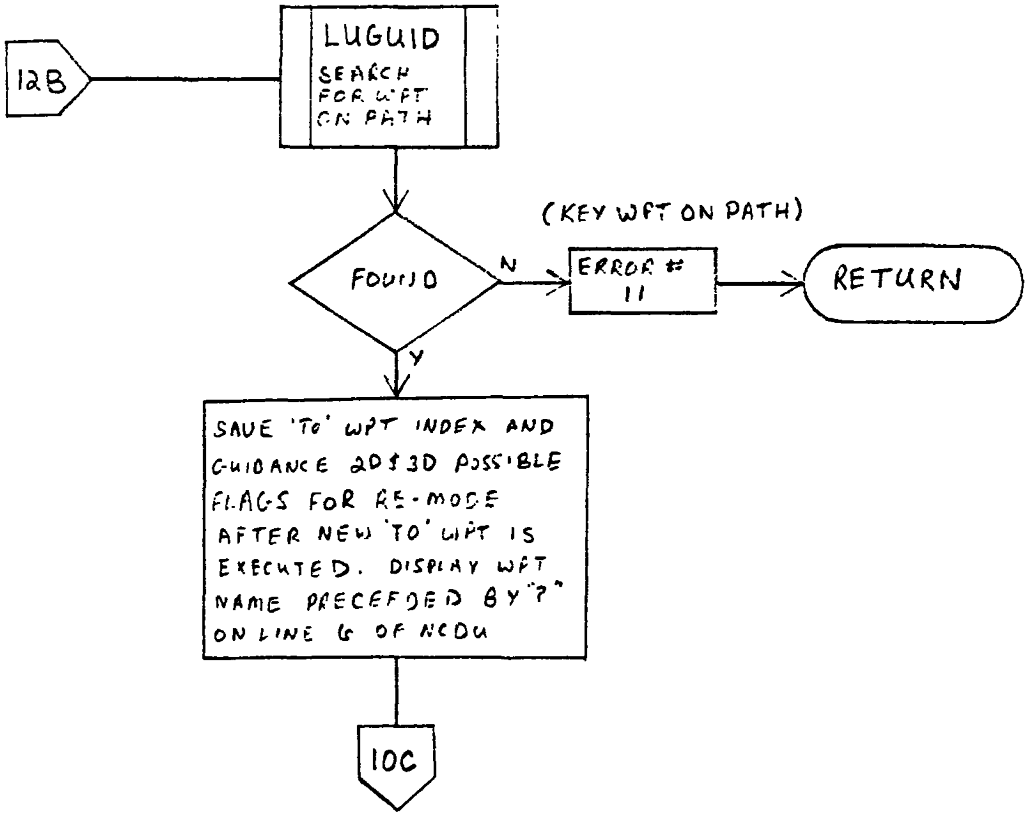

9A
* WAITING FOR OPTION#1 BEARING ENTRY
*
N
Y
CLEAR SELECT PAGE LINE ACTIVE FLAGS
2A
SM1
DEFAULT TO RIGHT HAND HOLDING PATTERN AND USE THE PATH HEADING AT THE HOLD WAYPOINT AS THE BEARING FOR THE PATTERN
10B
SM4

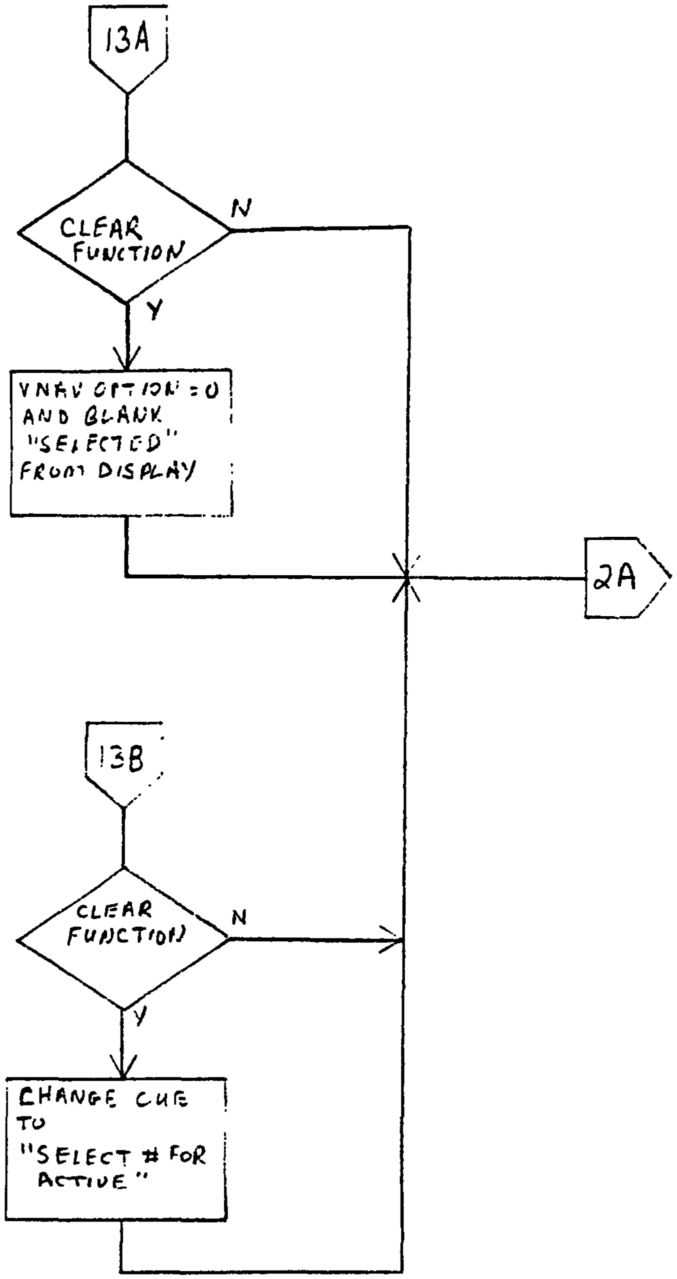
*PHASE 1: HOLD WPT NAME JUST ENTERED
PHASE 2: HOLD DIRECTION/BEARING JUST ENTERED

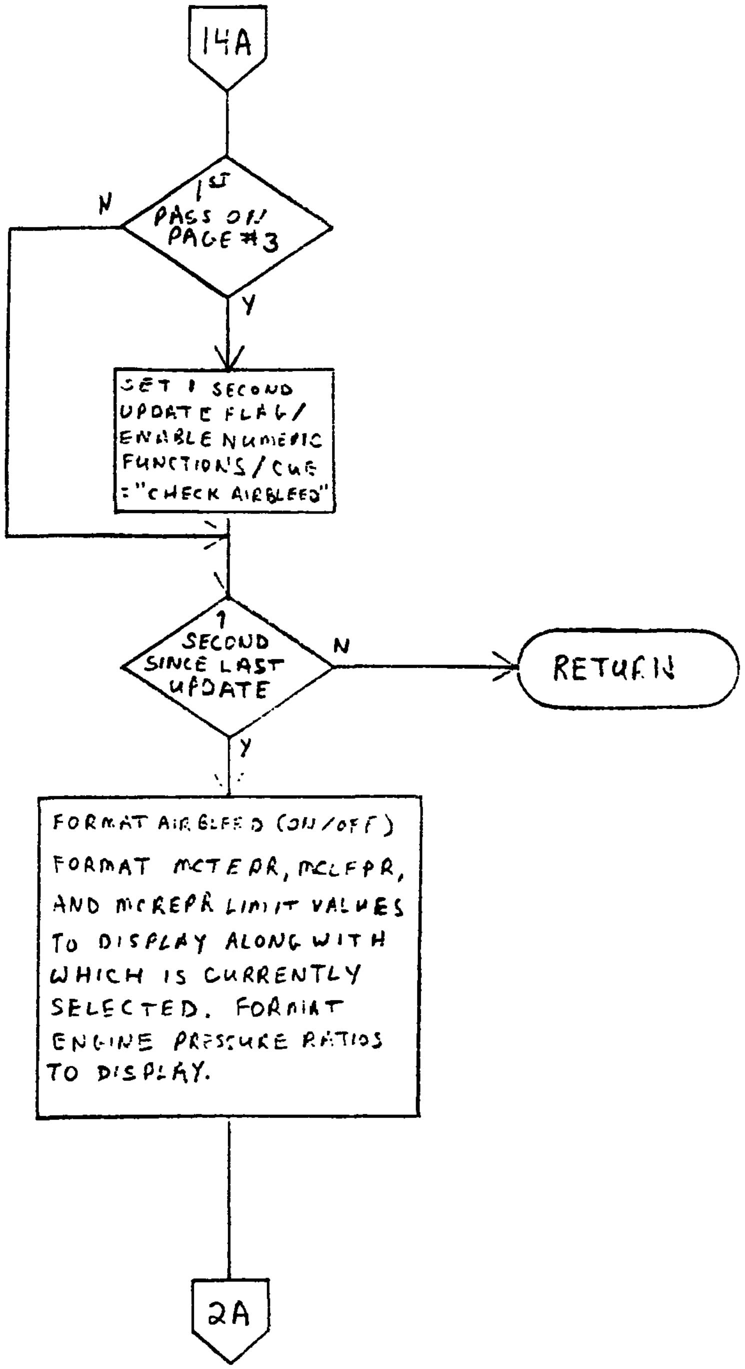

10A
PHASE 1*
Y
N
CAUSE DECODE TO LOOK-UP WPT IN BULK DATA. SET SMF61 TO FORCE "L-BEARG" PROMPT NEXT PASS
RETURN
9A
Y
NULL ENTRY
N
ASCBIN
DECODE INPUT VALUE
SEPERATE INTO DIRECTION AND BEARING
10B
FORMAT
FORMAT BEARING ON MCDU PAGE
10C
PROMPT WITH "EXEC OR REJ" ON MCDU LINE #3
2B
SMLB2

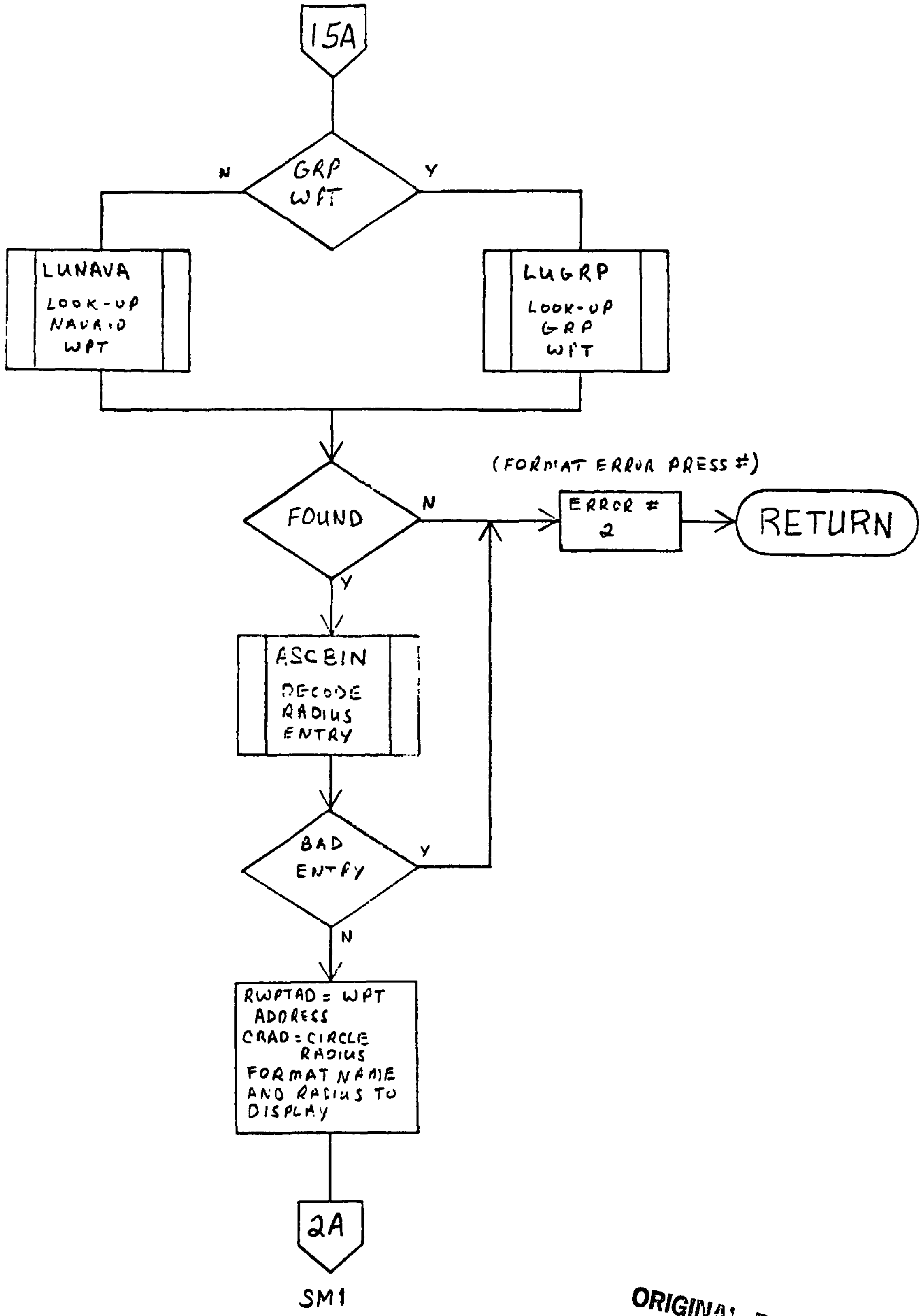

11A
ASCBIN
DECODE
INPUT
OFFSET
(FORMAT ERROR PRESS #)
LEGAL
NUMBER
N
ERROR #
2
RETURN
Y
STORE OFFSET AND
FORMAT DIRECTION & BIAS
TO NCDU DISPLAY BUFFER
CLEAR SELECTED BOOLEAN
UNTIL "EXEC" PRESSED
10C

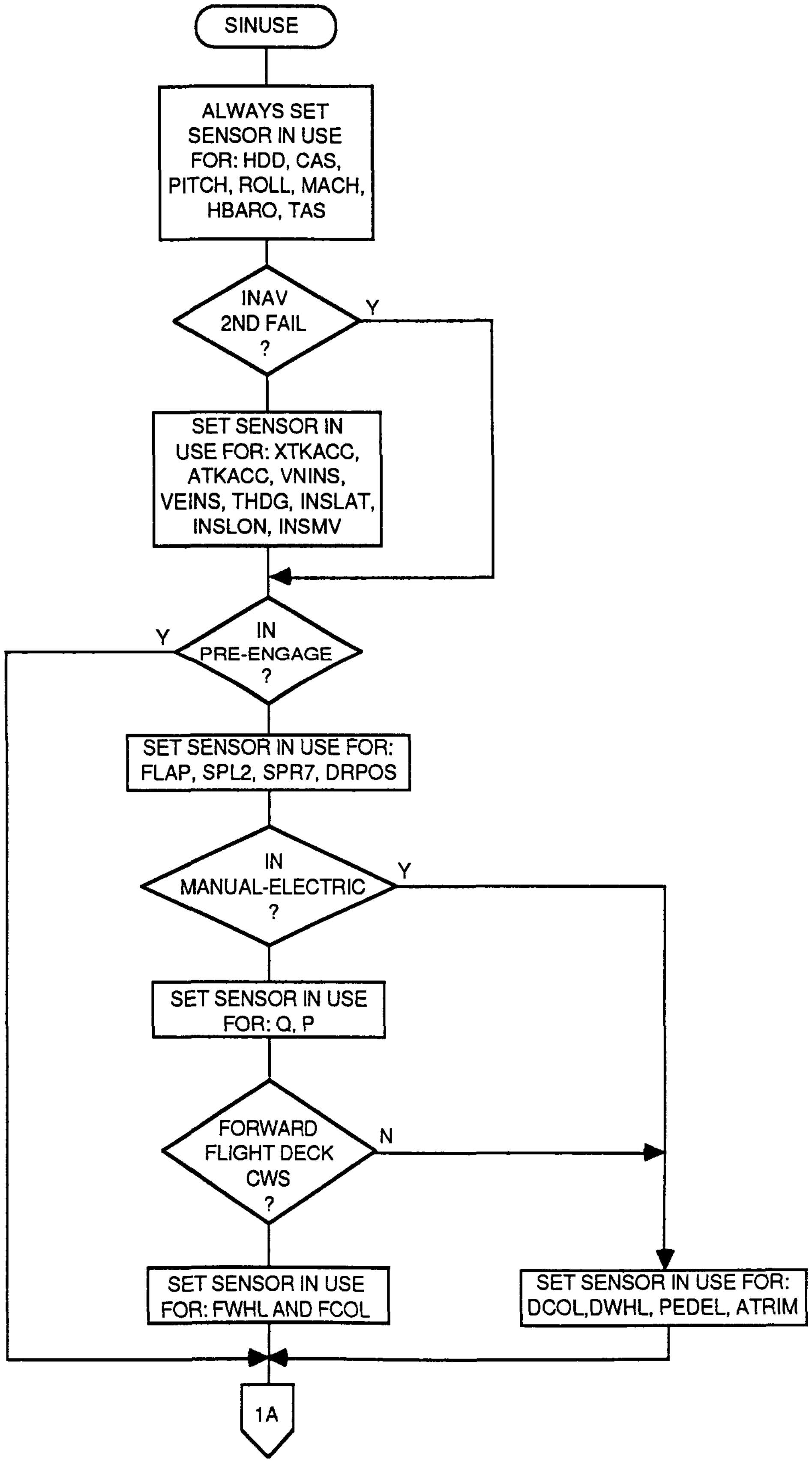

12A
RADWPT = ADDRESS OF WPT WITH RADIAL SYMBOL
RADWPT+2 = WPT TYPE
RADBRG = BEARING OF RADIAL SYMBOL
FILL NCDU DISPLAY WITH WPT NAME AND BEARING
2A
SM1


12B
LUGUID
SEARCH FOR WPT ON PATH
FOUND
N
(KEY WPT ON PATH)
ERROR # 11
RETURN
Y
SAVE 'TO' WPT INDEX AND GUIDANCE 2D$3D POSSIBLE FLAGS FOR RE-MODE AFTER NEW 'TO' WPT IS EXECUTED. DISPLAY WPT NAME PRECEDED BY "?" ON LINE 6 OF NCDU
10C

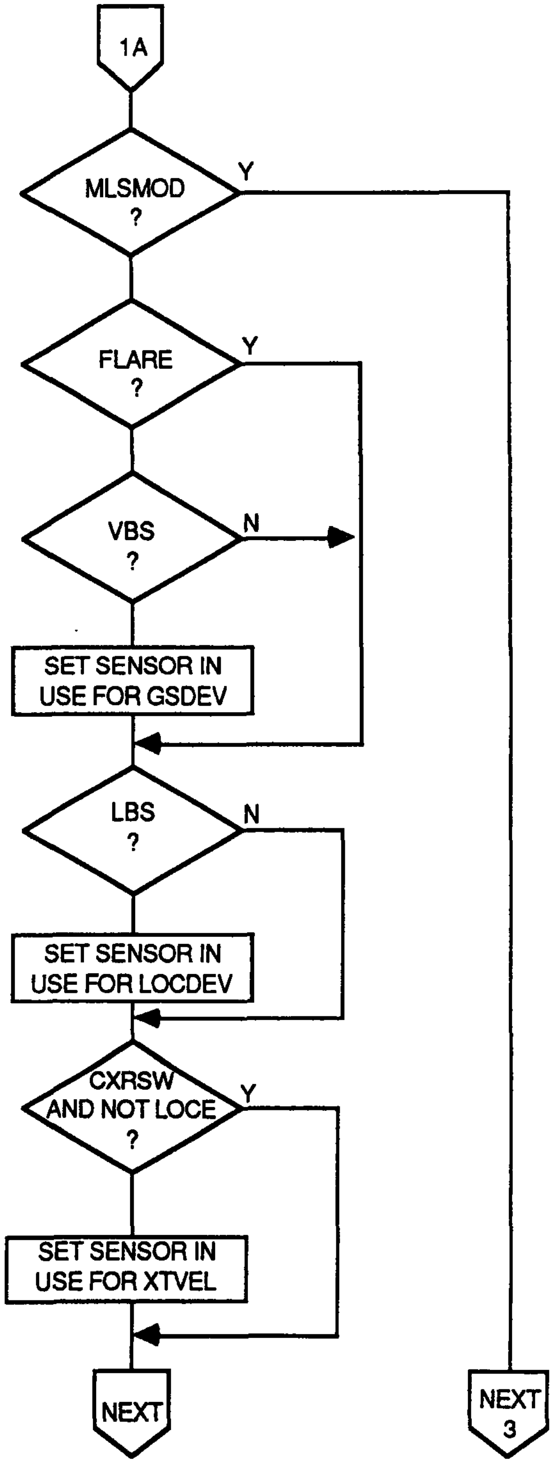

13A
CLEAR FUNCTION
N
Y
VNAV OPTION = 0 AND BLANK "SELECTED" FROM DISPLAY
2A
13B
CLEAR FUNCTION
N
Y
CHANGE CUE TO "SELECT # FOR ACTIVE"


14A
1st PASS ON PAGE #3
N
Y
SET 1 SECOND UPDATE FLAG/ ENABLE NUMERIC FUNCTIONS/CUE ="CHECK AIRBLEED"
1 SECOND SINCE LAST UPDATE
N
RETURN
Y
FORMAT AIRBLEED (ON/OFF)
FORMAT MCTEPR, MCLEPR, AND MCREPR LIMIT VALUES TO DISPLAY ALONG WITH WHICH IS CURRENTLY SELECTED. FORMAT ENGINE PRESSURE RATIOS TO DISPLAY.
2A

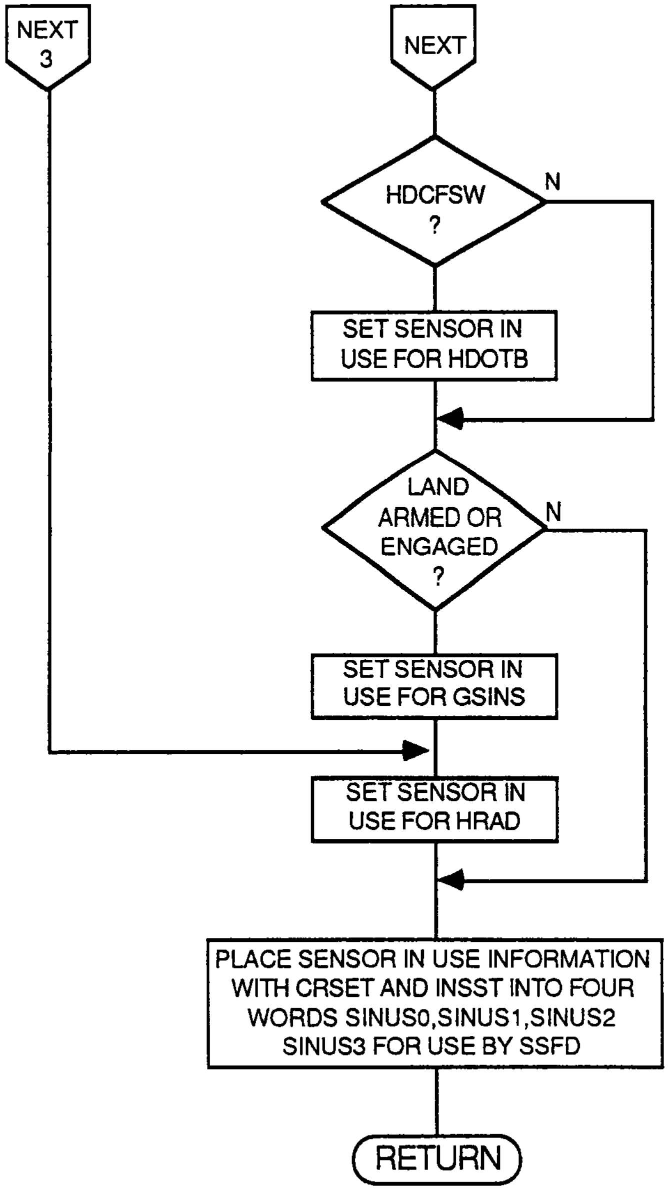

15A
GRP WPT
N
Y
LUNAVA
LOOK-UP NAVAID WPT
LUGRP
LOOK-UP GRP WPT
FOUND
N
Y
(FORMAT ERROR PRESS #)
ERROR # 2
RETURN
ASCBIN
DECODE RADIUS ENTRY
BAD ENTRY
Y
N
RWPTAD = WPT ADDRESS
CRAD = CIRCLE RADIUS
FORMAT NAME AND RADIUS TO DISPLAY
2A
SM1


SINUSE
ALWAYS SET SENSOR IN USE FOR: HDD, CAS, PITCH, ROLL, MACH, HBARO, TAS
INAV 2ND FAIL ?
Y
SET SENSOR IN USE FOR: XTKACC, ATKACC, VNINS, VEINS, THDG, INSLAT, INSLON, INSMV
IN PRE-ENGAGE ?
Y
SET SENSOR IN USE FOR: FLAP, SPL2, SPR7, DRPOS
IN MANUAL-ELECTRIC ?
Y
SET SENSOR IN USE FOR: Q, P
FORWARD FLIGHT DECK CWS ?
N
SET SENSOR IN USE FOR: FWHL AND FCOL
SET SENSOR IN USE FOR: DCOL,DWHL, PEDEL, ATRIM
1A

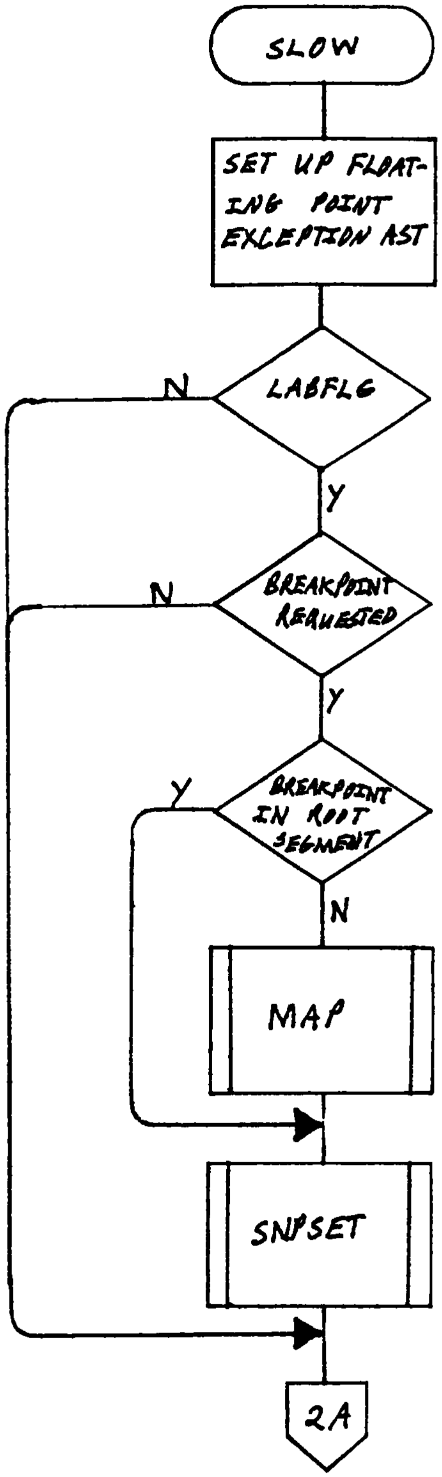
SINUSE
(PAGE 1 OF 3)


1A
MLSMOD ?
Y
FLARE ?
Y
VBS ?
N
SET SENSOR IN USE FOR GSDEV
LBS ?
N
SET SENSOR IN USE FOR LOCDEV
CXRSW AND NOT LOCE ?
Y
SET SENSOR IN USE FOR XTVEL
NEXT
NEXT 3

SINUSE
(PAGE 2 OF 3)


NEXT 3
NEXT
HDCFSW ?
N
SET SENSOR IN USE FOR HDOTB
LAND ARMED OR ENGAGED ?
N
SET SENSOR IN USE FOR GSINS
SET SENSOR IN USE FOR HRAD
PLACE SENSOR IN USE INFORMATION WITH CRSET AND INSST INTO FOUR WORDS SINUS0,SINUS1,SINUS2 SINUS3 FOR USE BY SSFD
RETURN

SINUSE
(PAGE 3 OF 3)

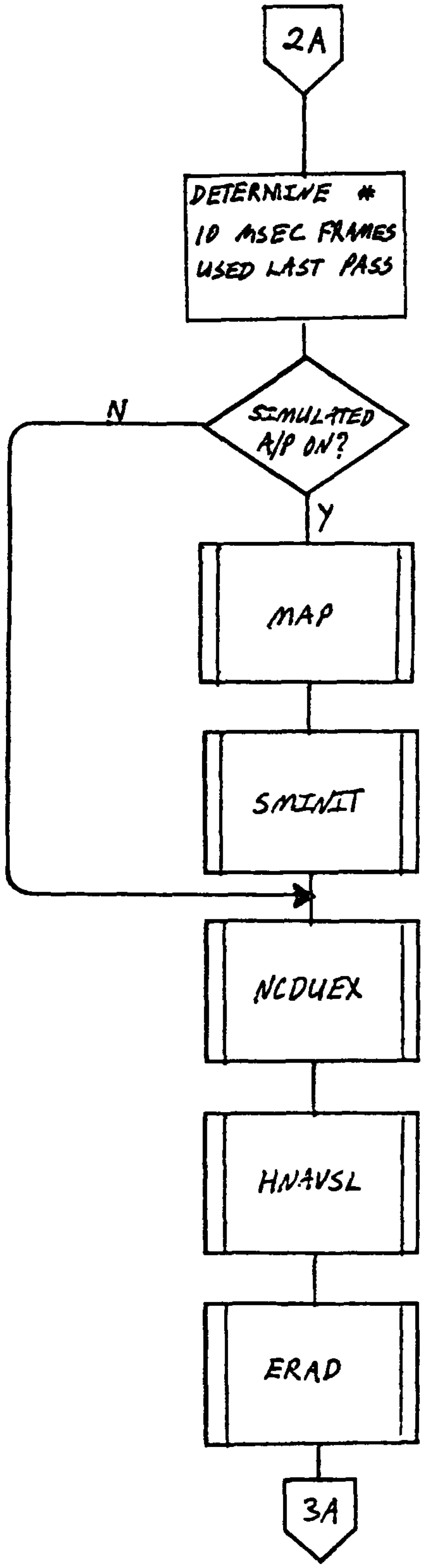

SLOW
SET UP FLOATING POINT EXCEPTION AST
LABFLG
N
Y
BREAKPOINT REQUESTED
N
Y
BREAKPOINT IN ROOT SEGMENT
Y
N
MAP
SNPSET
2A

NOTE: SLOW WILL BE ABORTED VIA AN 'IOT' EXECUTION IF AN ERROR IS DETECTED IN THE MRKT$C EXECUTIVE REQUEST

MAP OVERLAY SEGMENT IN WHICH BREAKPOINT IS TO BE INSERTED

SET BREAKPOINT INSTRUCTION

PAGE 1 OF 4



MAP APPROPRIATE OVERLAY SEGMENT FOR SIMULATED A/P INITIALIZATION

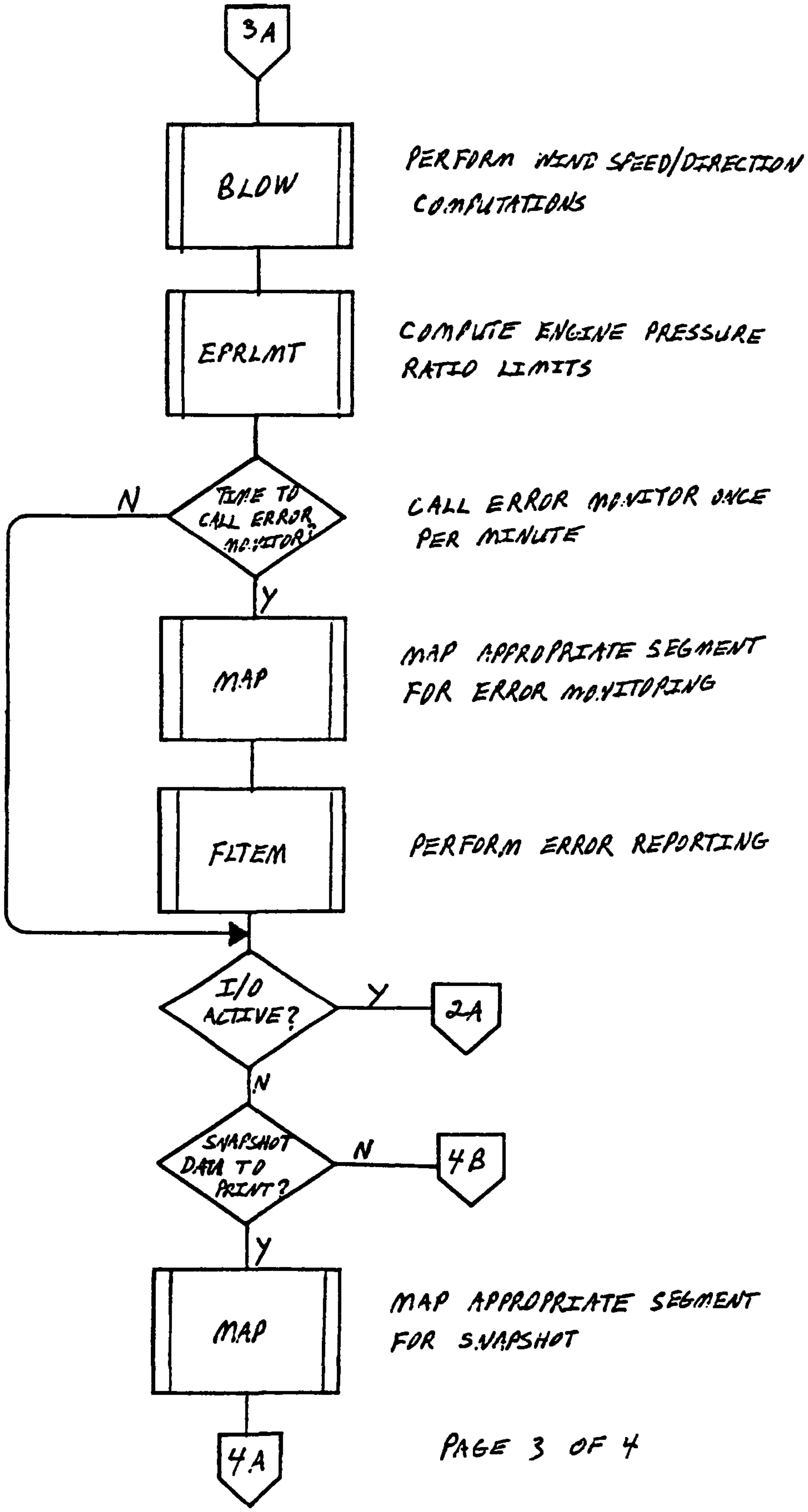
INITIALIZE A/P

CALL NCDU EXECUTIVE

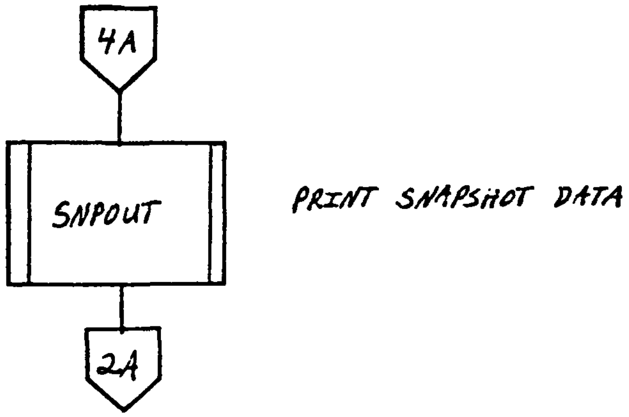
PERFORM SLOW LOOP NAVIGATION

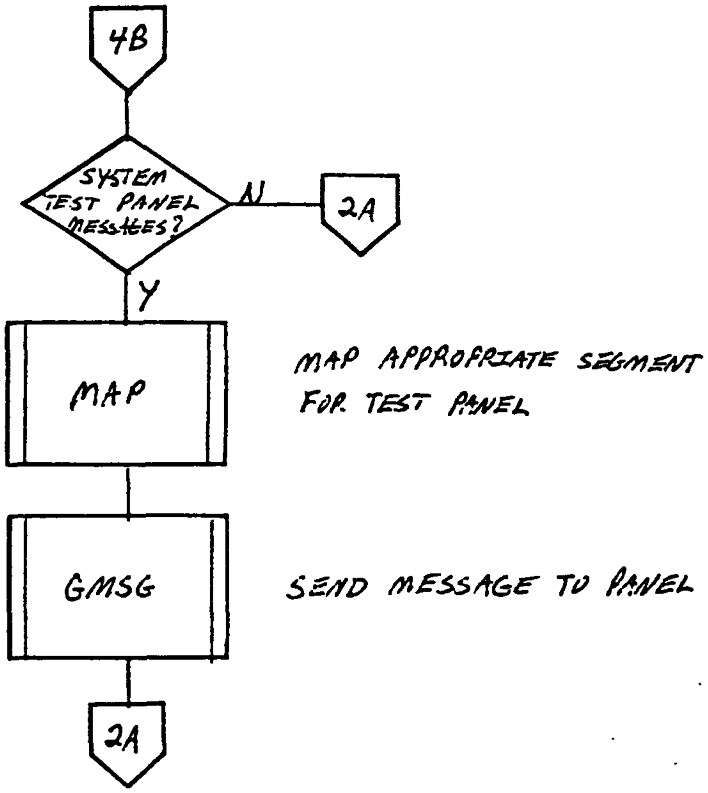
PERFORM EARTH'S RADIUS COMPUTATIONS

PAGE 2 OF 4

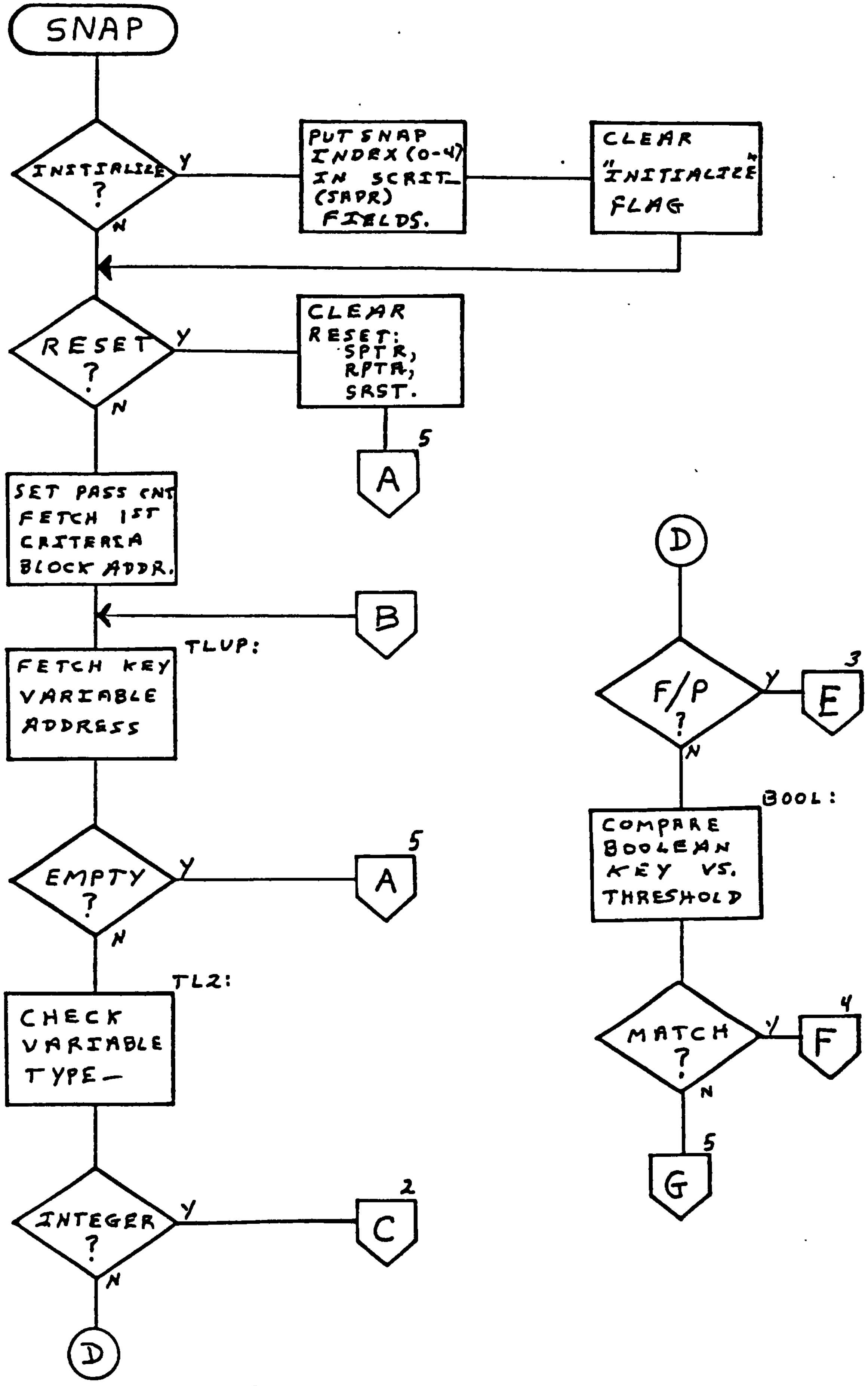

3A
BLOW
PERFORM WIND SPEED/DIRECTION COMPUTATIONS
EPRLMT
COMPUTE ENGINE PRESSURE RATIO LIMITS
TIME TO CALL ERROR MONITOR?
N
Y
CALL ERROR MONITOR ONCE PER MINUTE
MAP
MAP APPROPRIATE SEGMENT FOR ERROR MONITORING
FLTEM
PERFORM ERROR REPORTING
I/O ACTIVE?
Y
2A
N
SNAPSHOT DATA TO PRINT?
N
4B
Y
MAP
MAP APPROPRIATE SEGMENT FOR SNAPSHOT
4A

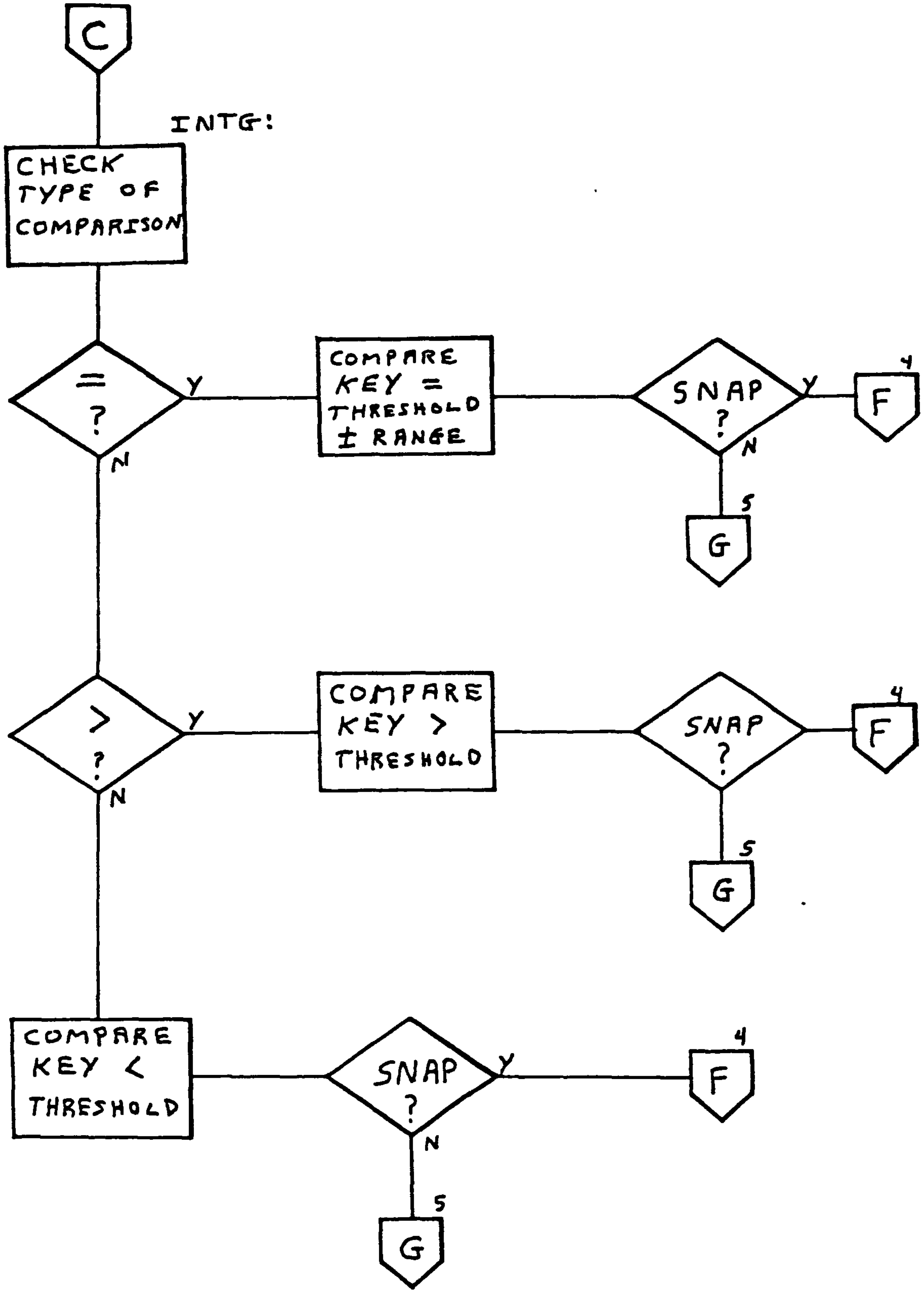
PAGE 3 OF 4

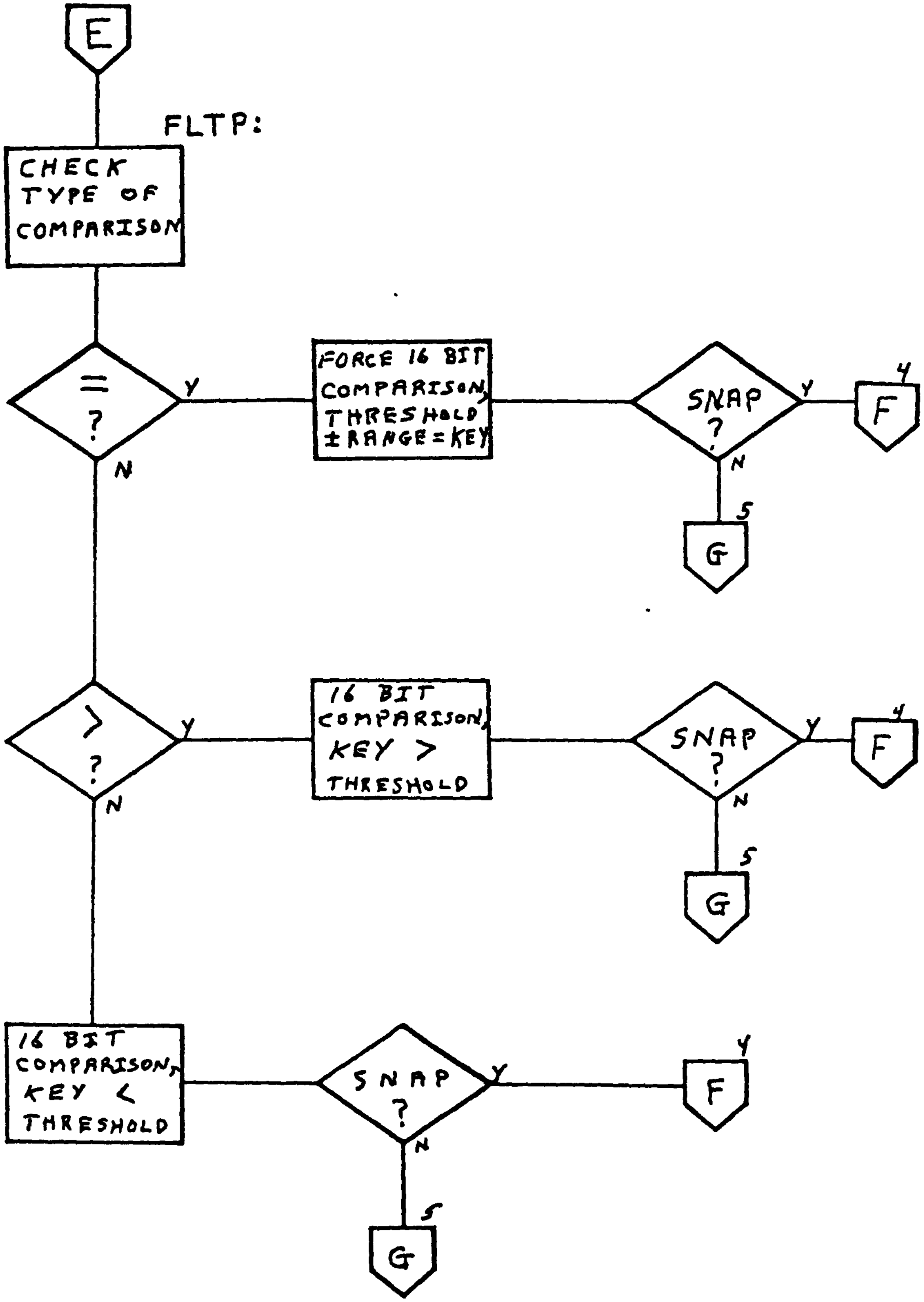

4A
SNPOUT
PRINT SNAPSHOT DATA
2A

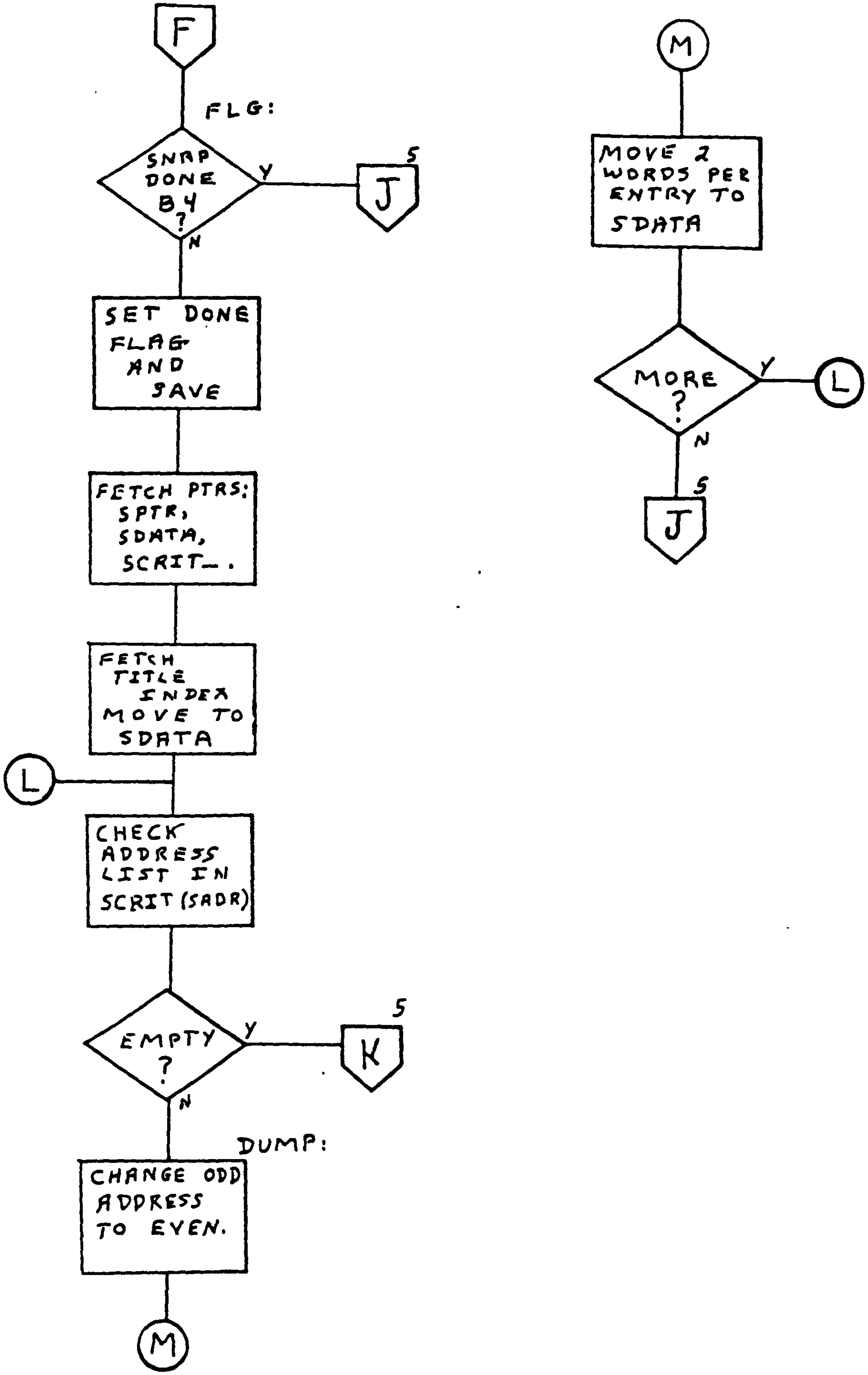

4B
SYSTEM TEST PANEL MESSAGES?
N
2A
Y
MAP
MAP APPROPRIATE SEGMENT FOR TEST PANEL
GMSG
SEND MESSAGE TO PANEL
2A

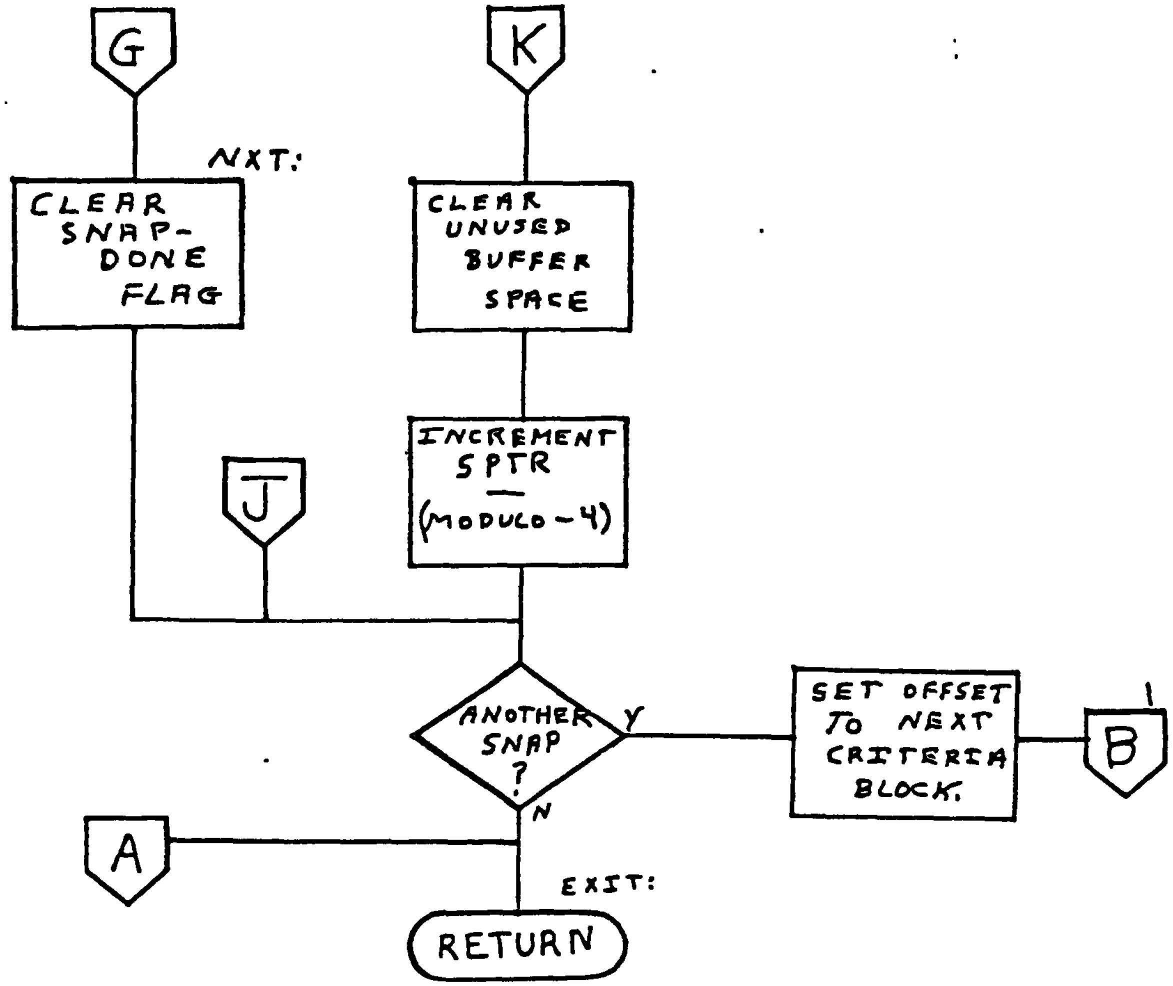
PAGE 4 OF 4


SNAP
INITIALIZE ?
Y
N
PUT SNAP INDEX (0-4) IN SCRIT_ (SAPR) FIELDS.
CLEAR "INITIALIZE" FLAG
RESET ?
Y
N
CLEAR RESET: SPTR, RPTR; SRST.
5
A
SET PASS CNT FETCH 1ST CRITERIA BLOCK ADDR.
B
TLUP:
FETCH KEY VARIABLE ADDRESS
EMPTY ?
Y
N
5
A
TL2:
CHECK VARIABLE TYPE—
INTEGER ?
Y
N
2
C
D
D
F/P ?
Y
N
3
E
BOOL:
COMPARE BOOLEAN KEY VS. THRESHOLD
MATCH ?
Y
N
4
F
5
G

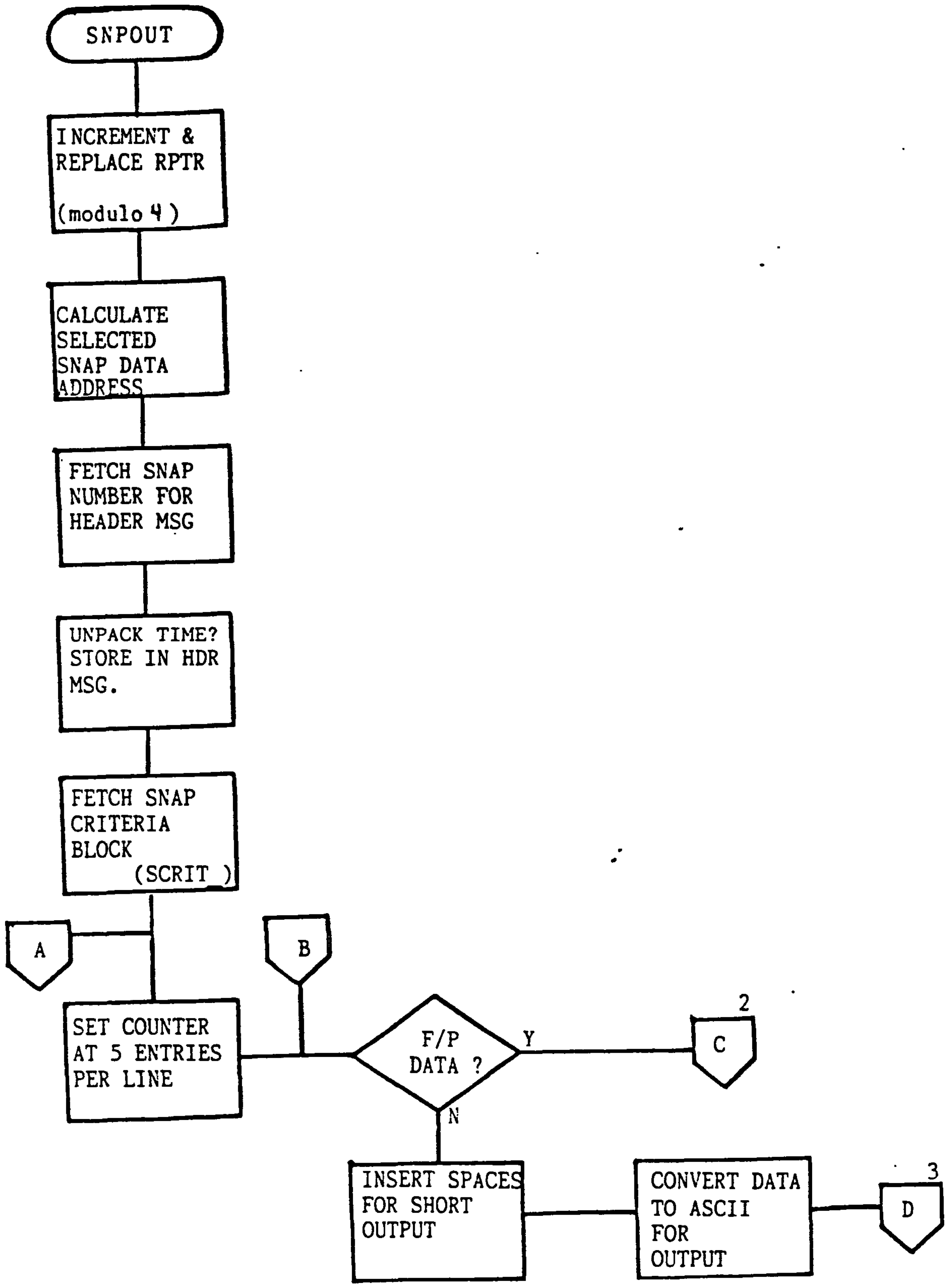

C
INTG:
CHECK TYPE OF COMPARISON
= ?
Y
N
COMPARE KEY = THRESHOLD ± RANGE
SNAP ?
Y
N
4
F
5
G
> ?
Y
N
COMPARE KEY > THRESHOLD
SNAP ?
4
F
5
G
COMPARE KEY < THRESHOLD
SNAP ?
Y
N
4
F
5
G


E
FLTP:
CHECK TYPE OF COMPARISON
=
?
Y
N
FORCE 16 BIT COMPARISON, THRESHOLD ± RANGE = KEY
SNAP ?
Y
N
4
F
5
G
>
?
Y
N
16 BIT COMPARISON, KEY > THRESHOLD
SNAP ?
Y
N
4
F
5
G
16 BIT COMPARISON, KEY < THRESHOLD
SNAP ?
Y
N
4
F
5
G

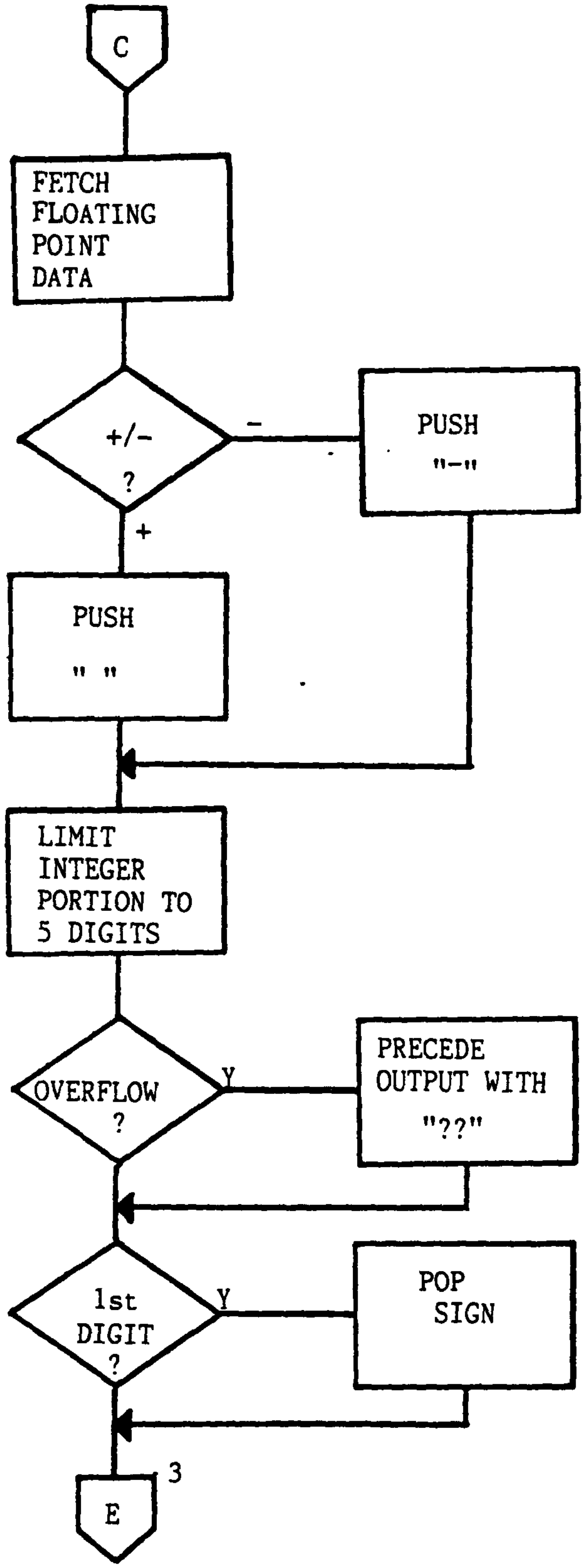

F
FLG:
SNAP DONE B4 ?
Y
N
5
J
SET DONE FLAG AND SAVE
FETCH PTRS: SPTR, SDATA, SCRIT—.
FETCH TITLE INDEX MOVE TO SDATA
L
CHECK ADDRESS LIST IN SCRIT (SADR)
EMPTY ?
Y
N
5
K
DUMP:
CHANGE ODD ADDRESS TO EVEN.
M
M
MOVE 2 WORDS PER ENTRY TO SDATA
MORE ?
Y
L
N
5
J


G
K
NXT:
CLEAR SNAP-DONE FLAG
CLEAR UNUSED BUFFER SPACE
INCREMENT SPTR (MODULO-4)
J
ANOTHER SNAP ?
Y
N
SET OFFSET TO NEXT CRITERIA BLOCK.
B
A
EXIT:
RETURN

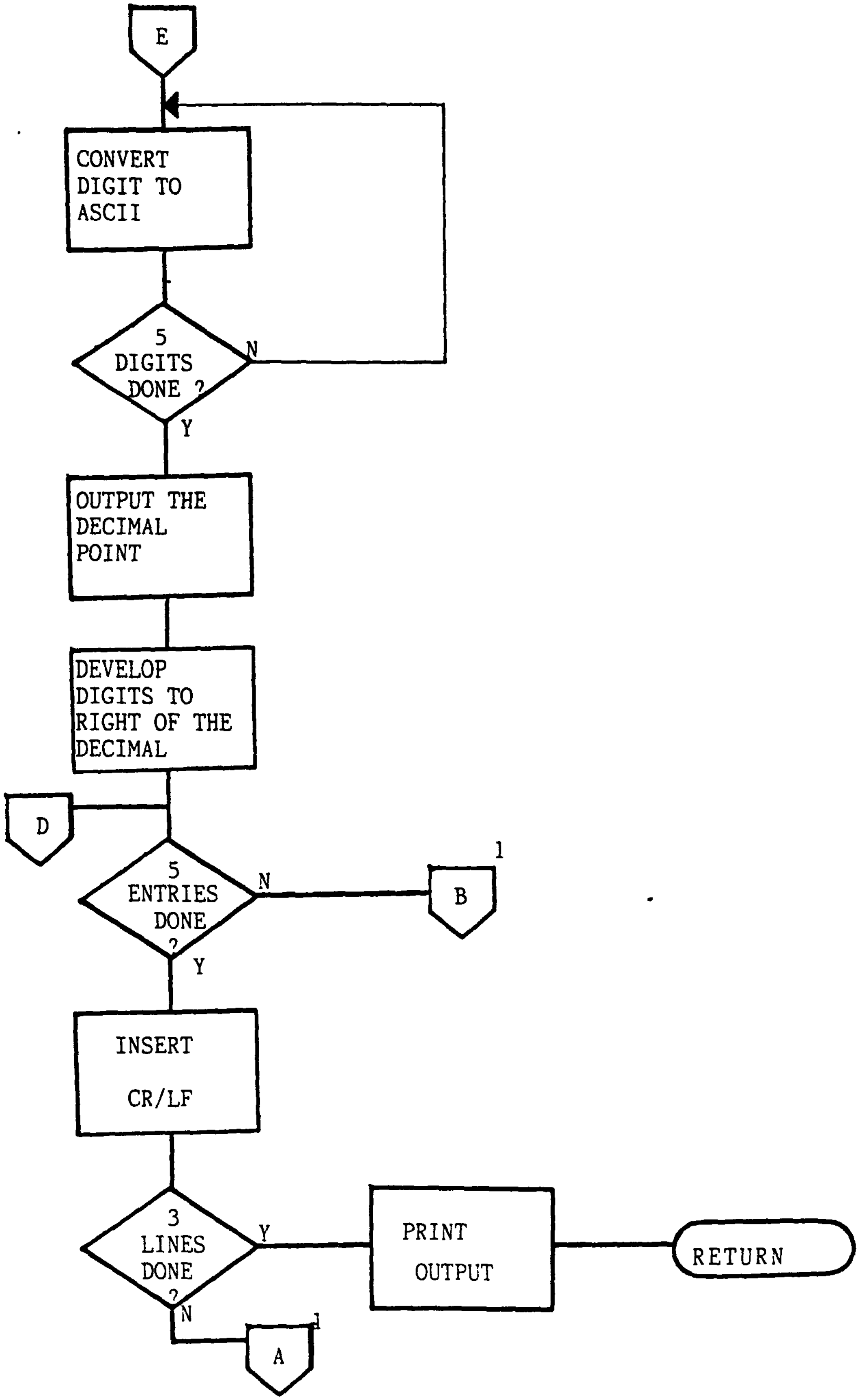
PAGE 5 OF 5


SNPOUT
INCREMENT & REPLACE RPTR (modulo 4)
CALCULATE SELECTED SNAP DATA ADDRESS
FETCH SNAP NUMBER FOR HEADER MSG
UNPACK TIME? STORE IN HDR MSG.
FETCH SNAP CRITERIA BLOCK (SCRIT_)
A
B
SET COUNTER AT 5 ENTRIES PER LINE
F/P DATA ?
Y
N
2
C
INSERT SPACES FOR SHORT OUTPUT
CONVERT DATA TO ASCII FOR OUTPUT
3
D

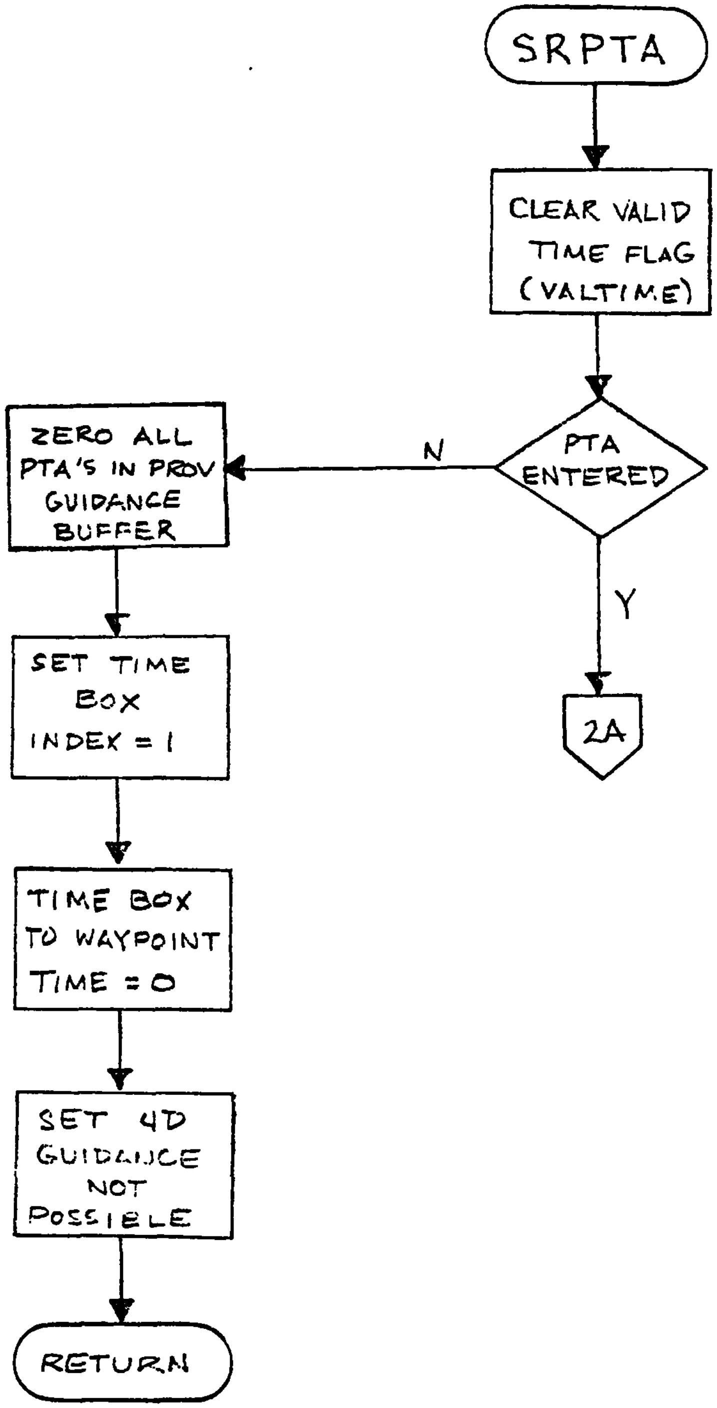
PAGE 1 OF 3

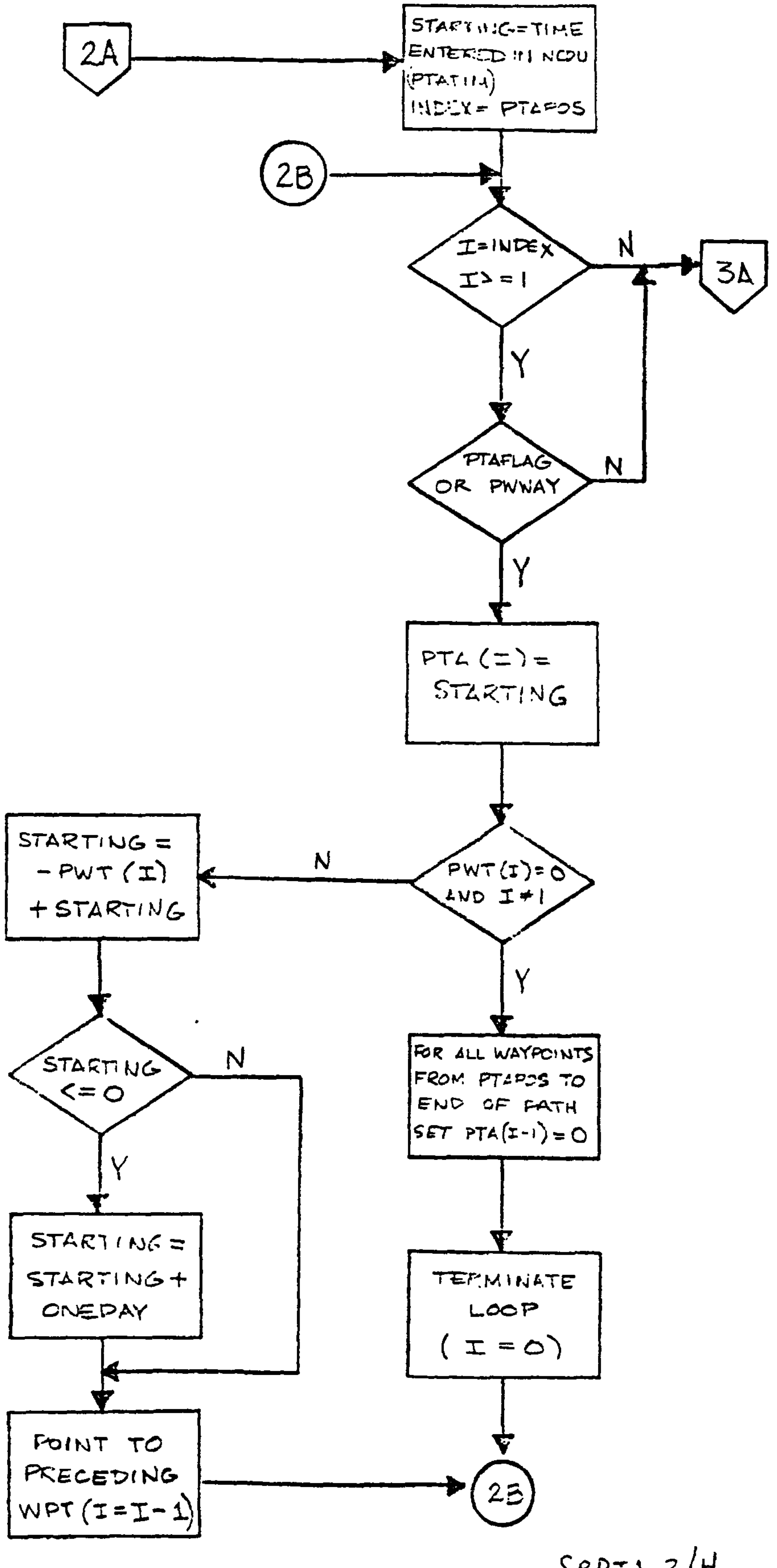

C
FETCH FLOATING POINT DATA
+/- ?
-
PUSH "-"
+
PUSH " "
LIMIT INTEGER PORTION TO 5 DIGITS
OVERFLOW ?
Y
PRECEDE OUTPUT WITH "??"
1st DIGIT ?
Y
POP SIGN
3
E

PAGE 2 OF 3


E
CONVERT DIGIT TO ASCII
5 DIGITS DONE ?
N
Y
OUTPUT THE DECIMAL POINT
DEVELOP DIGITS TO RIGHT OF THE DECIMAL
D
5 ENTRIES DONE ?
N
B
1
Y
INSERT CR/LF
3 LINES DONE ?
Y
PRINT OUTPUT
RETURN
N
A
1

PAGE 3 OF 3


SRPTA
CLEAR VALID TIME FLAG (VALTIME)
PTA ENTERED
N
Y
2A
ZERO ALL PTA'S IN PROV GUIDANCE BUFFER
SET TIME BOX INDEX = 1
TIME BOX TO WAYPOINT TIME = 0
SET 4D GUIDANCE NOT POSSIBLE
RETURN



SRPTA 2/4

ORIGINAL PAGE IS
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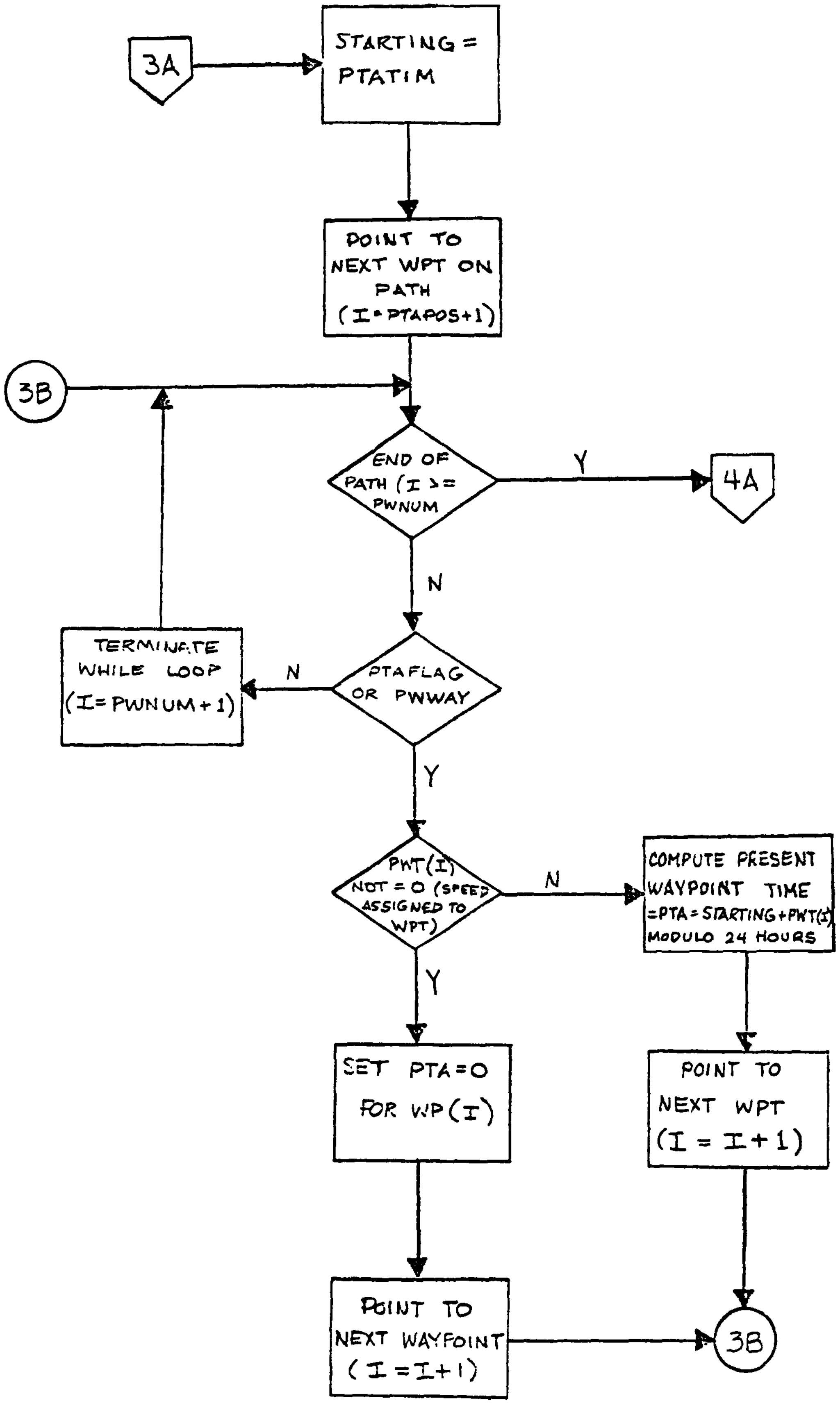
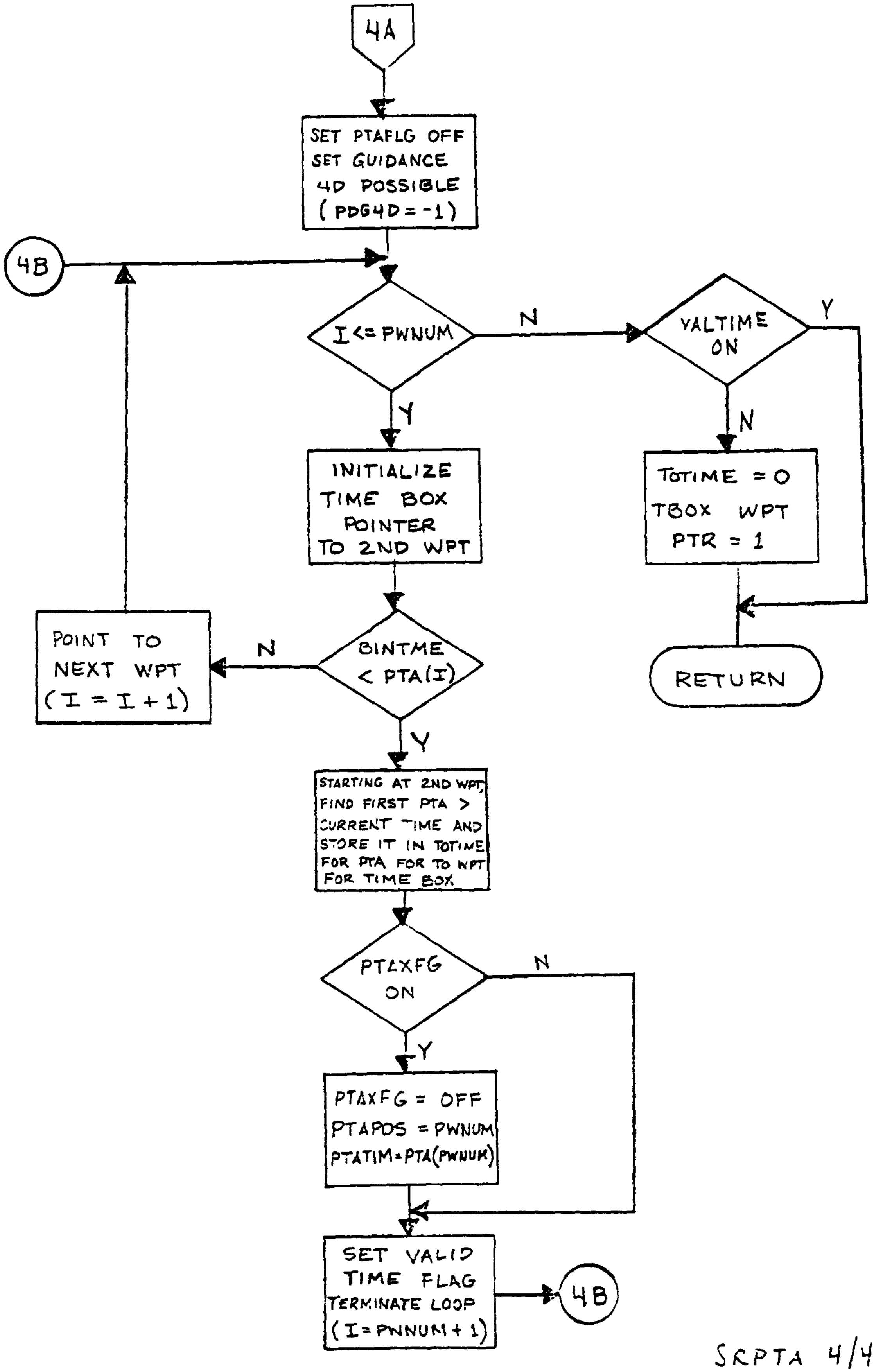
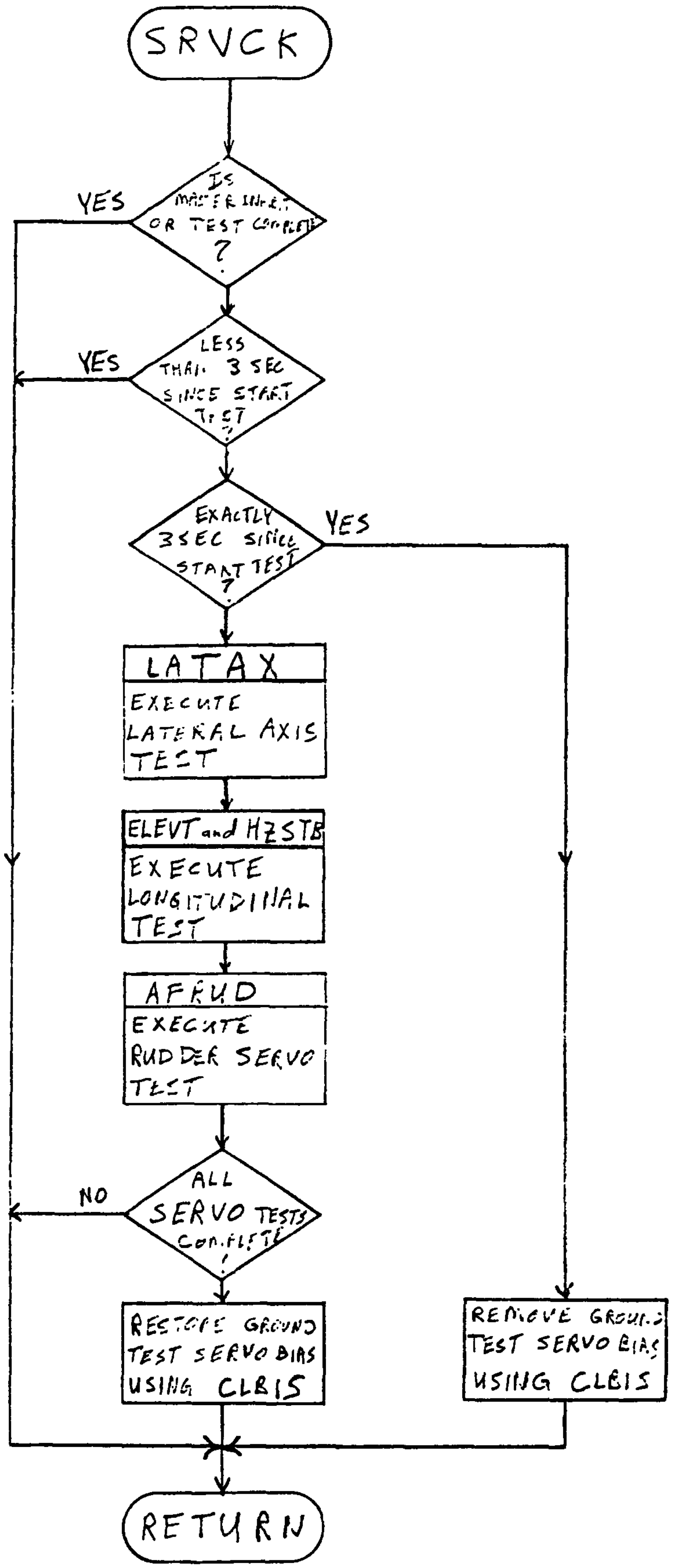

3A
STARTING = PTATIM
POINT TO NEXT WPT ON PATH (I=PTAPOS+1)
3B
END OF PATH (I >= PWNUM
Y
4A
N
PTAFLAG OR PWWAY
N
TERMINATE WHILE LOOP (I=PWNUM+1)
Y
PWT(I) NOT = 0 (SPEED ASSIGNED TO WPT)
N
COMPUTE PRESENT WAYPOINT TIME =PTA=STARTING+PWT(I) MODULO 24 HOURS
Y
SET PTA=0 FOR WP(I)
POINT TO NEXT WPT (I = I+1)
POINT TO NEXT WAYPOINT (I=I+1)
3B

SRPTA 3/4

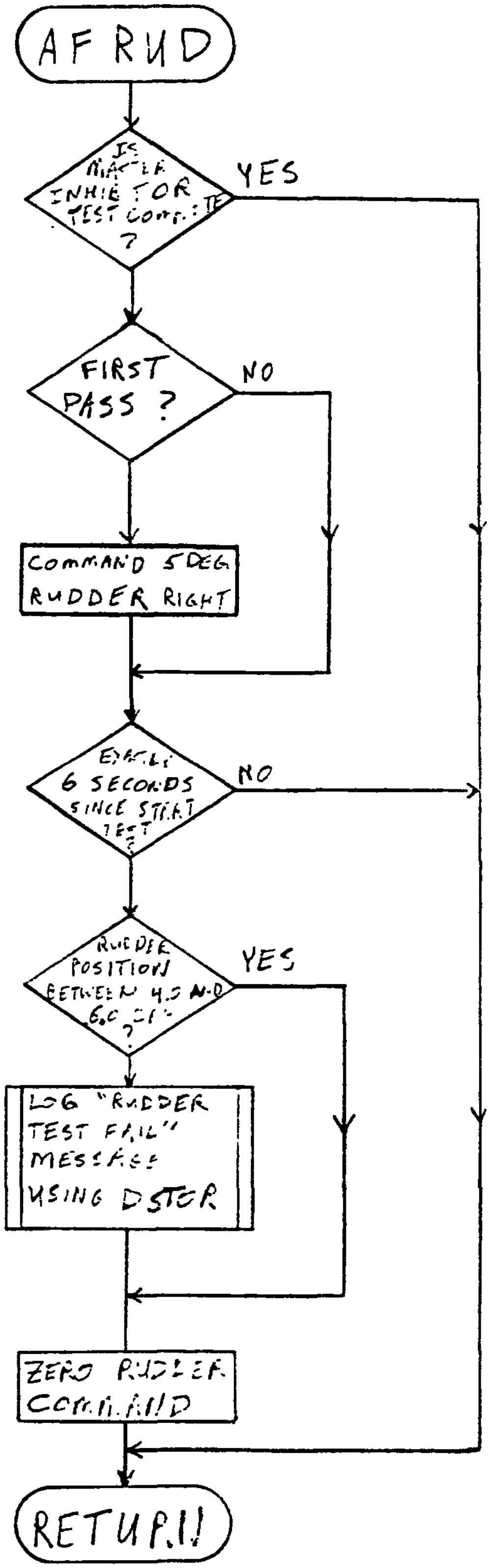
ORIGINAL PAGE IS OF POOR QUALITY


4A
SET PTAFLG OFF
SET GUIDANCE
4D POSSIBLE
(PDG4D=-1)
4B
I<=PWNUM
N
VALTIME ON
Y
Y
N
INITIALIZE TIME BOX POINTER TO 2ND WPT
TOTIME =0
TBOX WPT PTR = 1
POINT TO NEXT WPT (I = I + 1)
N
BINTME < PTA(I)
RETURN
Y
STARTING AT 2ND WPT, FIND FIRST PTA > CURRENT TIME AND STORE IT IN TOTIME FOR PTA FOR TO WPT FOR TIME BOX
PTAXFG ON
N
Y
PTAXFG = OFF
PTAPOS = PWNUM
PTATIM=PTA(PWNUM)
SET VALID TIME FLAG
TERMINATE LOOP
(I=PWNUM+1)
4B

SRPTA 4/4


SRVCK
IS MASTER INHBT OR TEST COMPLETE ?
YES
LESS THAN 3 SEC SINCE START TEST ?
YES
EXACTLY 3SEC SINCE START TEST ?
YES
LATAX
EXECUTE LATERAL AXIS TEST
ELEVT and HZSTB
EXECUTE LONGITUDINAL TEST
AFRUD
EXECUTE RUDDER SERVO TEST
ALL SERVO TESTS COMPLETE ?
NO
RESTORE GROUND TEST SERVO BIAS USING CLBIS
REMOVE GROUND TEST SERVO BIAS USING CLBIS
RETURN

SRVCK
(PAGE 1 OF 6)


AFRUD
IS MASTER INHIBIT OR TEST COMPLETE ?
YES
FIRST PASS ?
NO
COMMAND 5 DEG RUDDER RIGHT
EXACTLY 6 SECONDS SINCE START TEST ?
NO
RUDDER POSITION BETWEEN 4.5 AND 6.0 DEG ?
YES
LOG "RUDDER TEST FAIL" MESSAGE USING DSTOR
ZERO RUDDER COMMAND
RETURN

ORIGINAL PAGE IS
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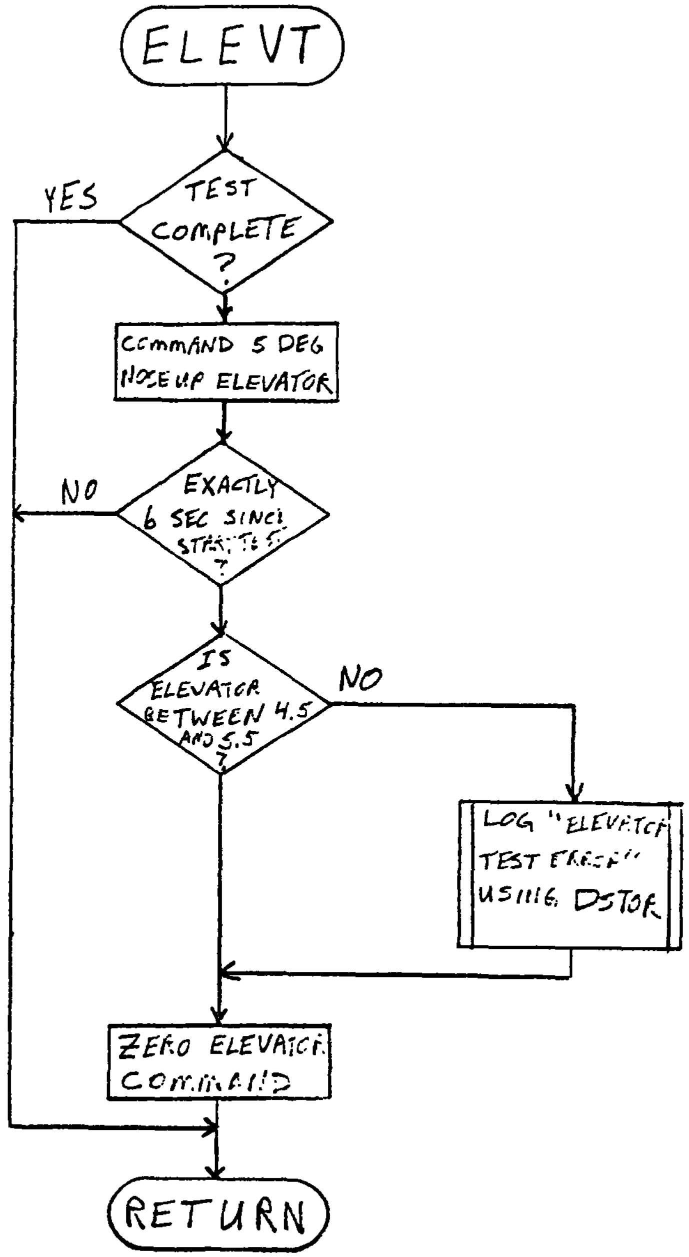
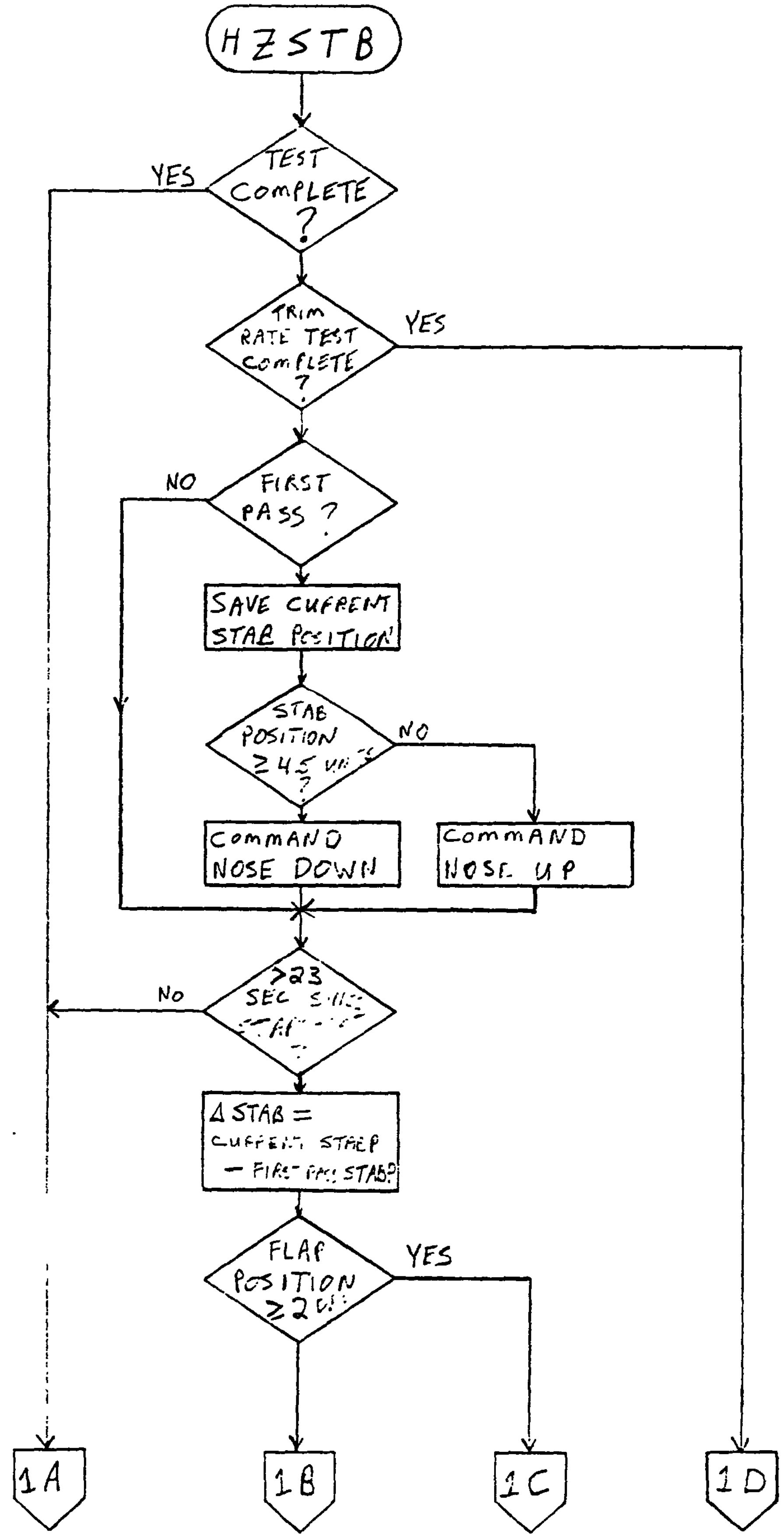
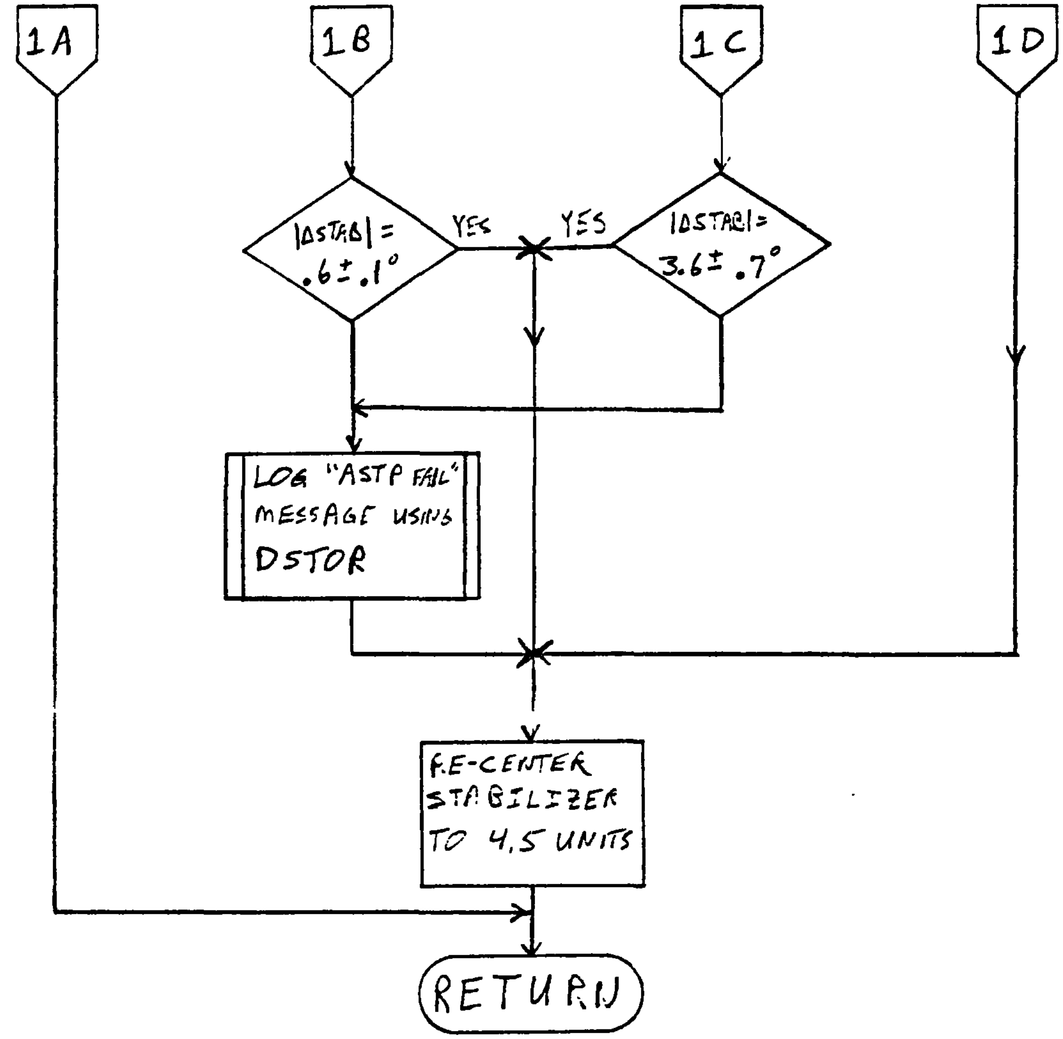
SRUCK
(PAGE 2 OF 6)


ELEVT
TEST COMPLETE ?
YES
COMMAND 5 DEG NOSE UP ELEVATOR
EXACTLY 6 SEC SINCE START TEST ?
NO
IS ELEVATOR BETWEEN 4.5 AND 5.5 ?
NO
LOG "ELEVATOR TEST ERROR" USING DSTOR
ZERO ELEVATOR COMMAND
RETURN

SRVCK
(PAGE 3 OF 6)



SRVCK
(PAGE 4 OF 6)


1A
1B
1C
1D
|ΔSTAB| = .6± .1°
YES
YES
|ΔSTAB| = 3.6± .7°
LOG "ASTP FAIL" MESSAGE USING DSTOR
RE-CENTER STABILIZER TO 4.5 UNITS
RETURN

SRVCK
(PAGE 5 OF 6)

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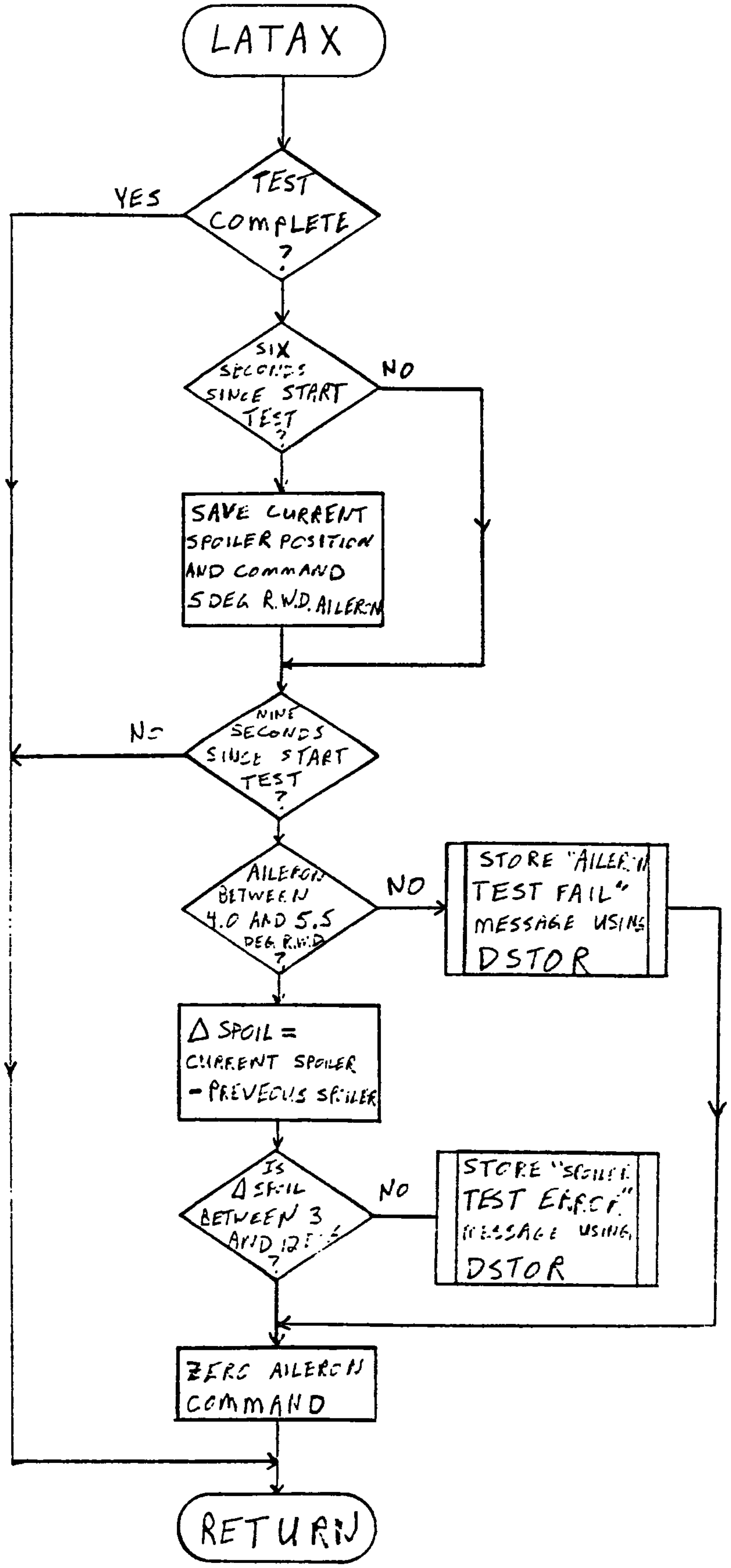
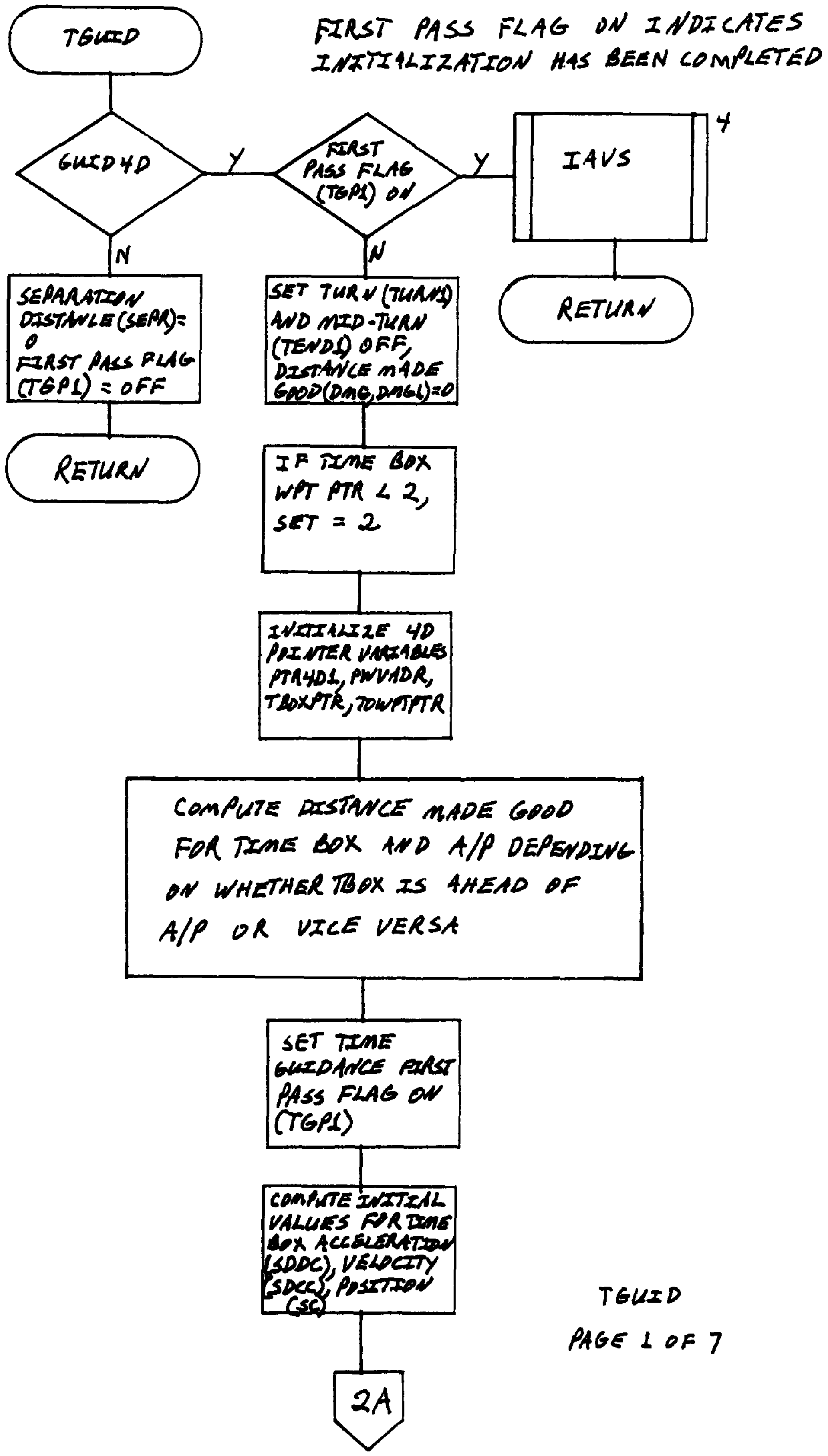
OF POOR QUALITY


LATAX
TEST COMPLETE ?
YES
SIX SECONDS SINCE START TEST ?
NO
SAVE CURRENT SPOILER POSITION AND COMMAND 5 DEG R.W.D. AILERON
NINE SECONDS SINCE START TEST ?
NO
AILERON BETWEEN 4.0 AND 5.5 DEG R.W.D ?
NO
STORE "AILERON TEST FAIL" MESSAGE USING DSTOR
Δ SPOIL = CURRENT SPOILER - PREVIOUS SPOILER
IS Δ SPOIL BETWEEN 3 AND 12 DEG ?
NO
STORE "SPOILER TEST ERROR" MESSAGE USING DSTOR
ZERO AILERON COMMAND
RETURN

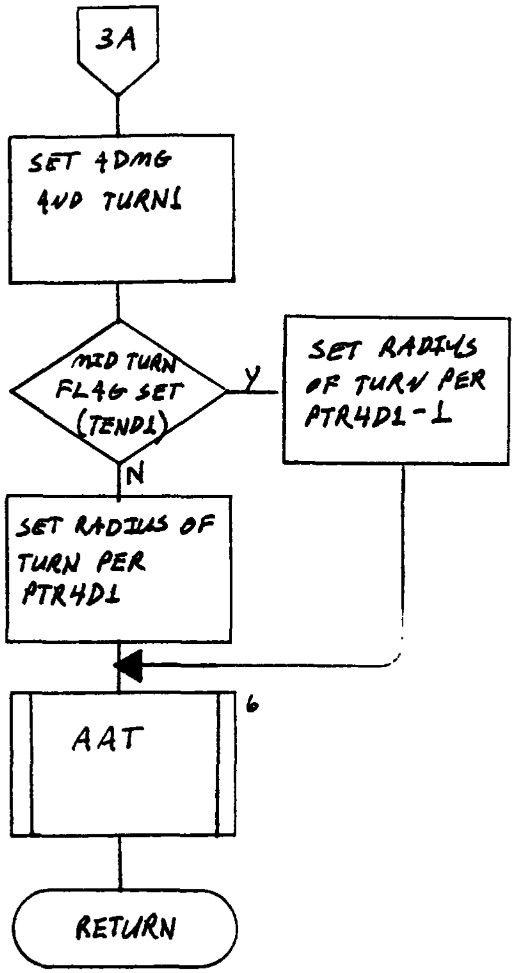
SRVCK
(PAGE 6 OF 6)


TGUID
GUID4D
Y
N
SEPARATION DISTANCE (SEPR) = 0
FIRST PASS FLAG (TGP1) = OFF
RETURN
FIRST PASS FLAG (TGP1) ON
Y
N
IAVS
4
RETURN
SET TURN (TURN1) AND MID-TURN (TEND1) OFF, DISTANCE MADE GOOD (DMG, DMG1) = 0
IF TIME BOX WPT PTR ∠ 2, SET = 2
INITIALIZE 4D POINTER VARIABLES PTR4D1, PWVADR, TBOXPTR, TOWPTPTR
COMPUTE DISTANCE MADE GOOD FOR TIME BOX AND A/P DEPENDING ON WHETHER TBOX IS AHEAD OF A/P OR VICE VERSA
SET TIME GUIDANCE FIRST PASS FLAG ON (TGP1)
COMPUTE INITIAL VALUES FOR TIME BOX ACCELERATION (SDDC), VELOCITY (SDCC), POSITION (SC)
2A

FIRST PASS FLAG ON INDICATES INITIALIZATION HAS BEEN COMPLETED

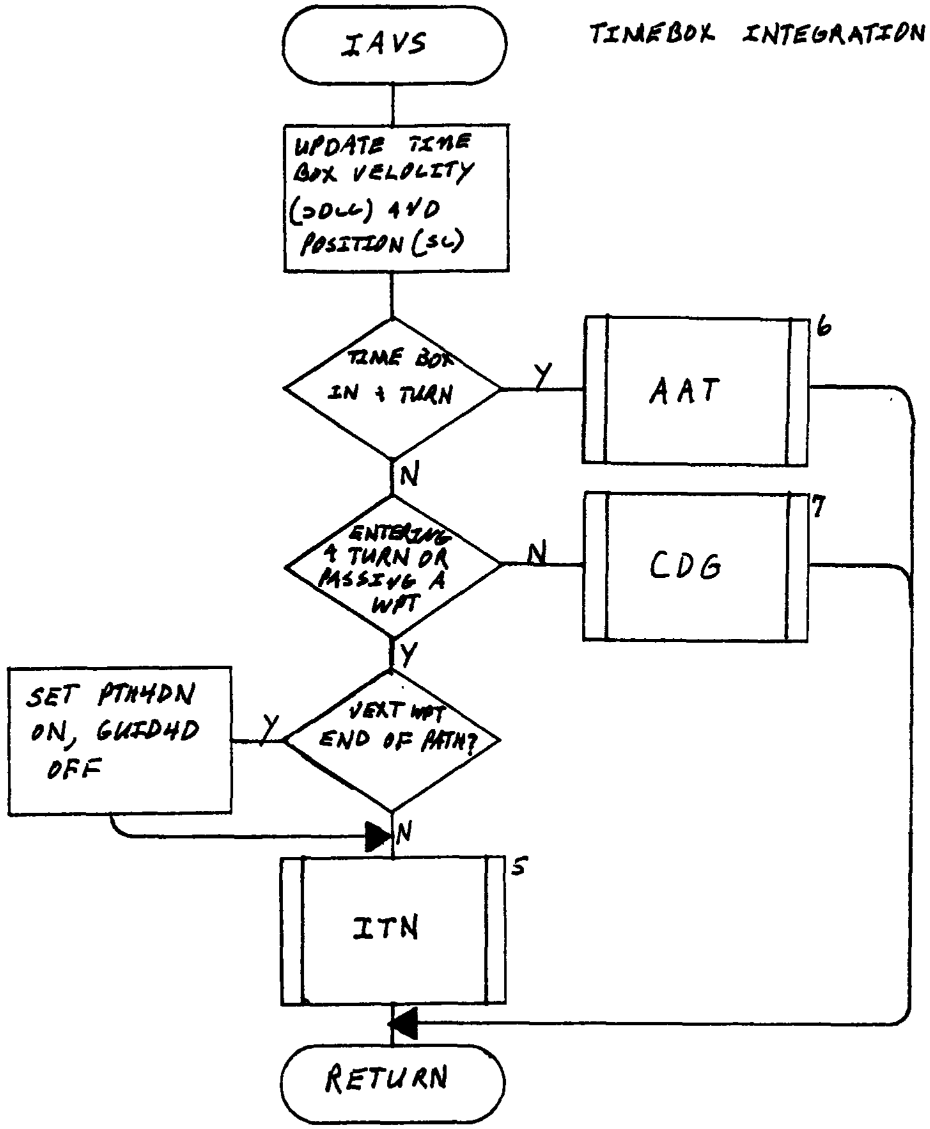
TGUID

PAGE 1 OF 7


3A
SET ADMG AND TURN1
MID TURN FLAG SET (TEND1)
Y
SET RADIUS OF TURN PER PTR4D1-1
N
SET RADIUS OF TURN PER PTR4D1
AAT
6
RETURN

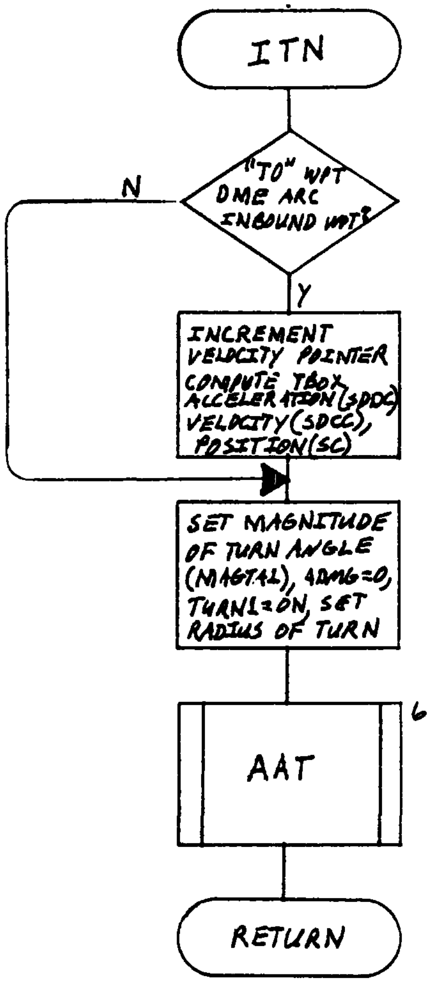
TGUID
PAGE 3 OF 7

TIMEBOX INTEGRATION


IAVS
UPDATE TIME BOX VELOCITY (SDLL) AND POSITION (SL)
TIME BOX IN A TURN
Y
AAT
6
N
ENTERING A TURN OR PASSING A WPT
N
CDG
7
Y
NEXT WPT END OF PATH?
Y
SET PTHHDN ON, GUIDHD OFF
N
ITN
5
RETURN

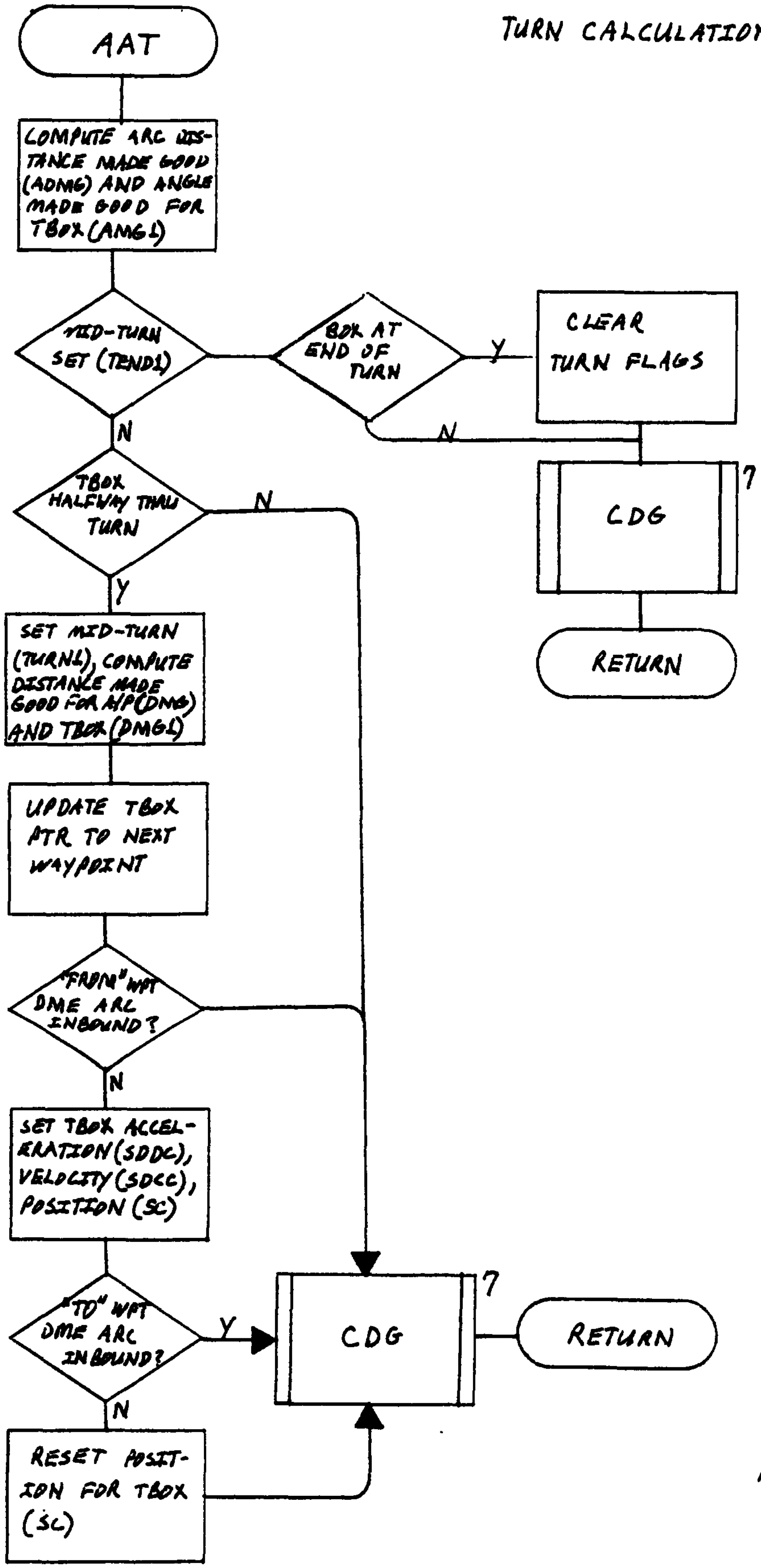
TGUID
PAGE 4 OF 7

TURN INITIALIZATION


ITN
"TO" WPT DME ARC INBOUND WPT?
N
Y
INCREMENT VELOCITY POINTER
COMPUTE TBOX ACCELERATION(SDDC) VELOCITY(SDCC), POSITION(SC)
SET MAGNITUDE OF TURN ANGLE (MAGTAL), ADMG=0, TURN1=ON, SET RADIUS OF TURN
6
AAT
RETURN

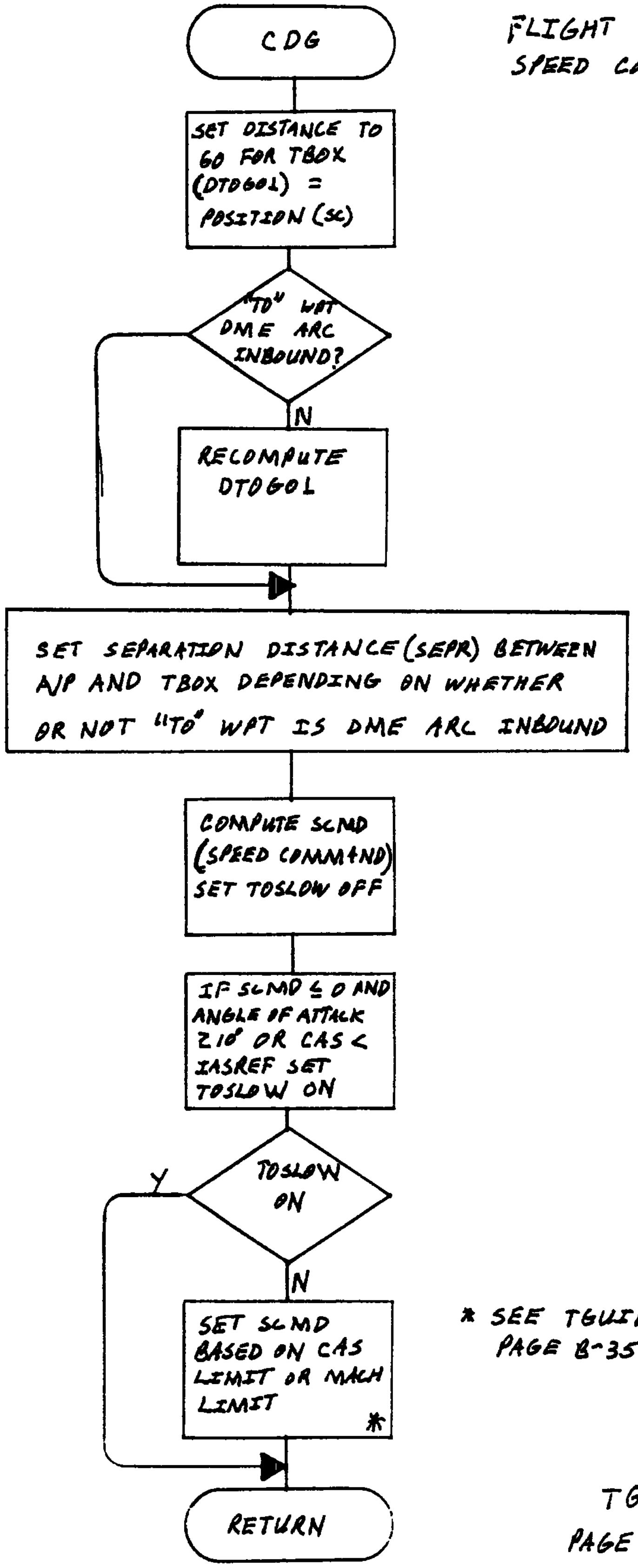
TGUID
PAGE 5 OF 7

TURN CALCULATIONS


AAT
COMPUTE ARC DISTANCE MADE GOOD (ADMG) AND ANGLE MADE GOOD FOR TBOX (AMGL)
MID-TURN SET (TEND1)
N
BOX AT END OF TURN
Y
CLEAR TURN FLAGS
N
CDG
7
RETURN
TBOX HALFWAY THRU TURN
N
Y
SET MID-TURN (TURNL), COMPUTE DISTANCE MADE GOOD FOR A/P (DMG) AND TBOX (DMGL)
UPDATE TBOX PTR TO NEXT WAYPOINT
"FROM" WPT DME ARC INBOUND?
N
SET TBOX ACCELERATION (SDDC), VELOCITY (SDCC), POSITION (SC)
"TO" WPT DME ARC INBOUND?
Y
CDG
7
RETURN
N
RESET POSITION FOR TBOX (SC)

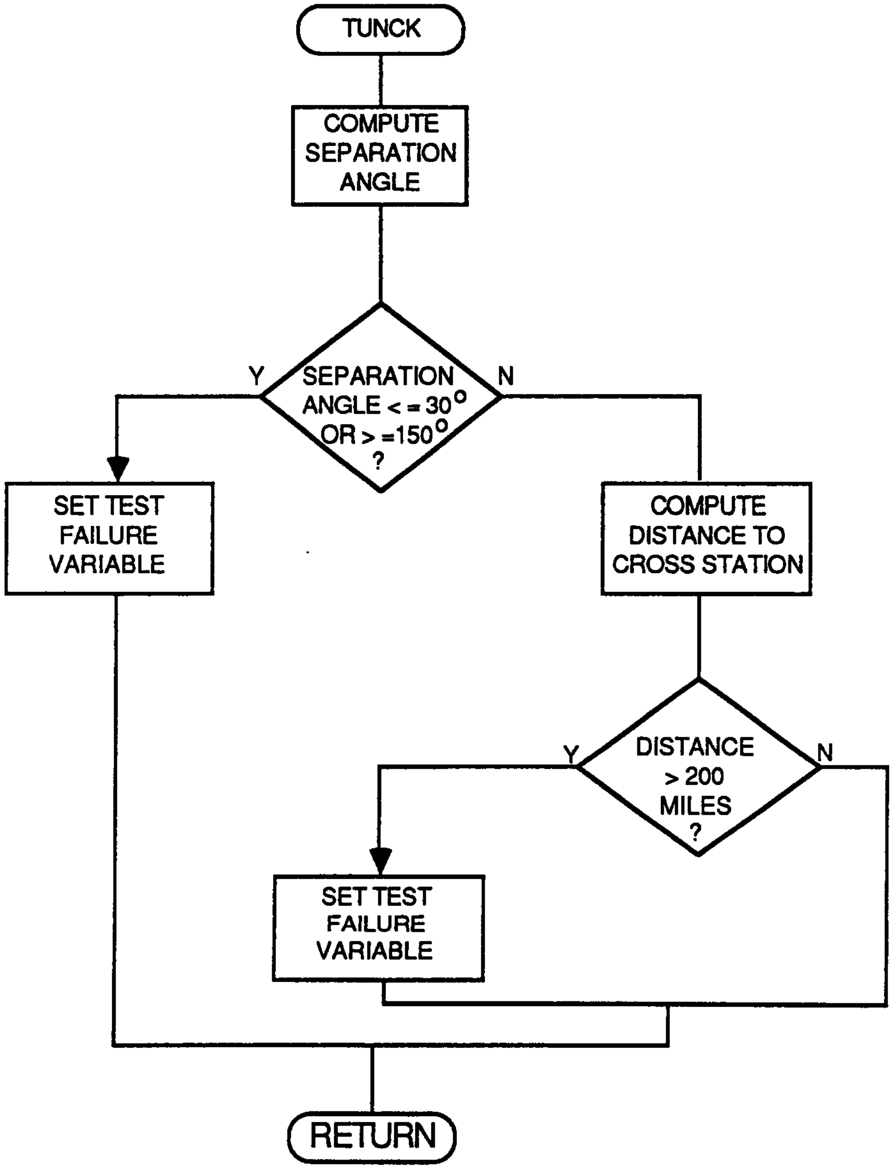
TGUID
PAGE 6 OF 7

FLIGHT DIRECTOR
SPEED COMAND

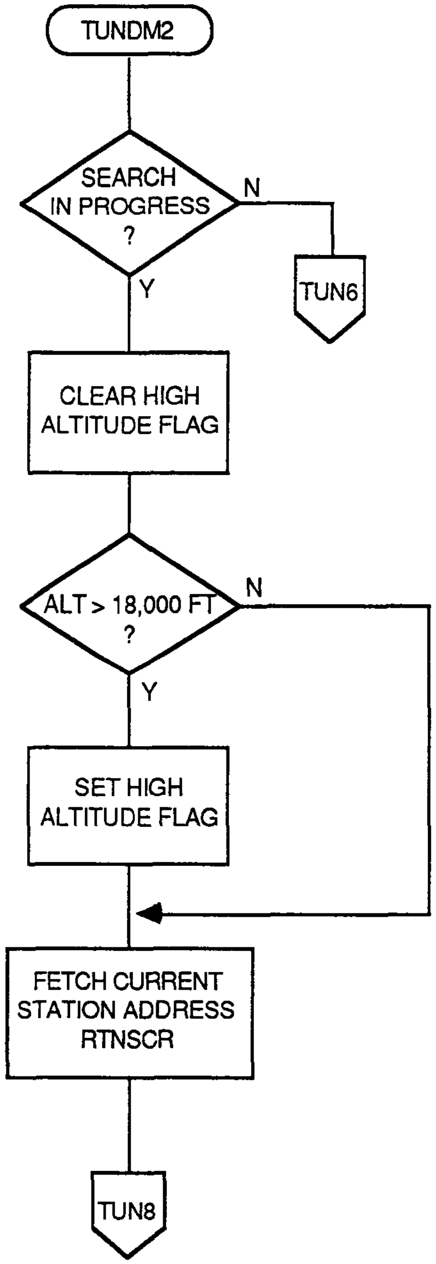

CDG
SET DISTANCE TO GO FOR TBOX (DTOGOL) = POSITION (SC)
"TO" WPT DME ARC INBOUND?
N
RECOMPUTE DTOGOL
SET SEPARATION DISTANCE (SEPR) BETWEEN A/P AND TBOX DEPENDING ON WHETHER OR NOT "TO" WPT IS DME ARC INBOUND
COMPUTE SCMD (SPEED COMMAND) SET TOSLOW OFF
IF SCMD ≤ 0 AND ANGLE OF ATTACK ≥ 10° OR CAS < IASREF SET TOSLOW ON
TOSLOW ON
Y
N
SET SCMD BASED ON CAS LIMIT OR MACH LIMIT
*
RETURN

* SEE TGUID DSD
PAGE B-35

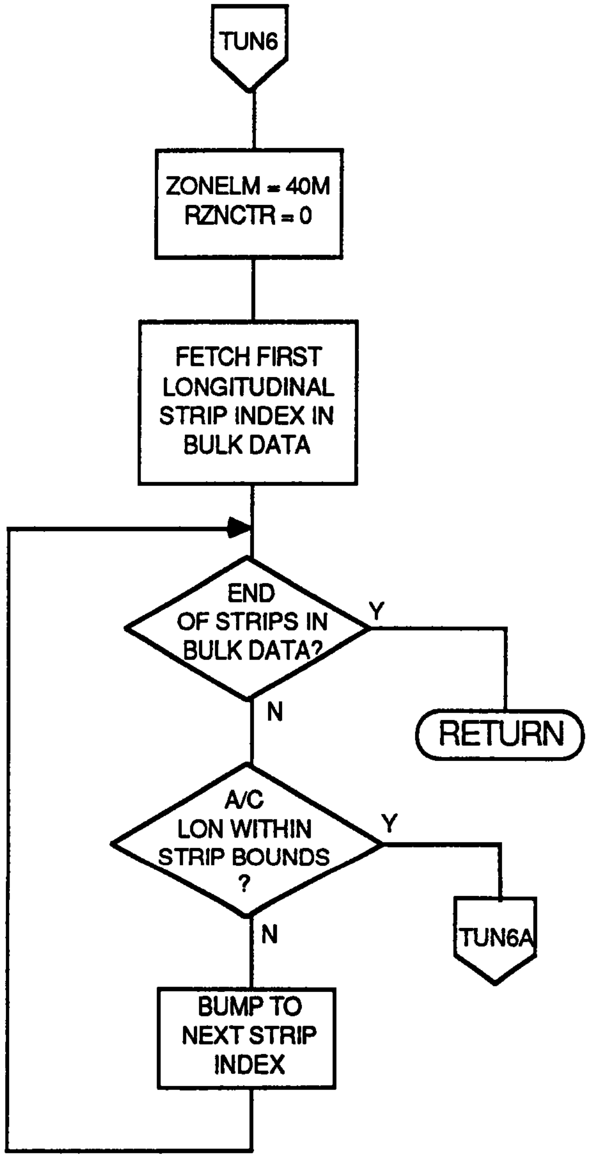
TGUID
PAGE 7 OF 7

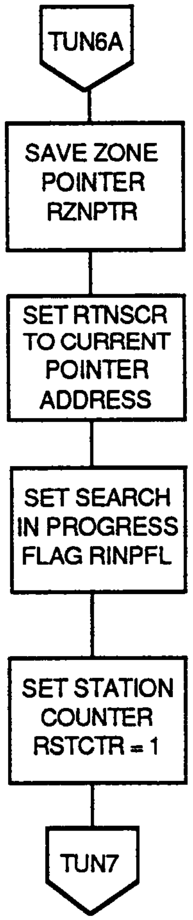

TUNCK
COMPUTE SEPARATION ANGLE
SEPARATION ANGLE < = 30° OR > =150° ?
Y
N
SET TEST FAILURE VARIABLE
COMPUTE DISTANCE TO CROSS STATION
DISTANCE > 200 MILES ?
Y
N
SET TEST FAILURE VARIABLE
RETURN

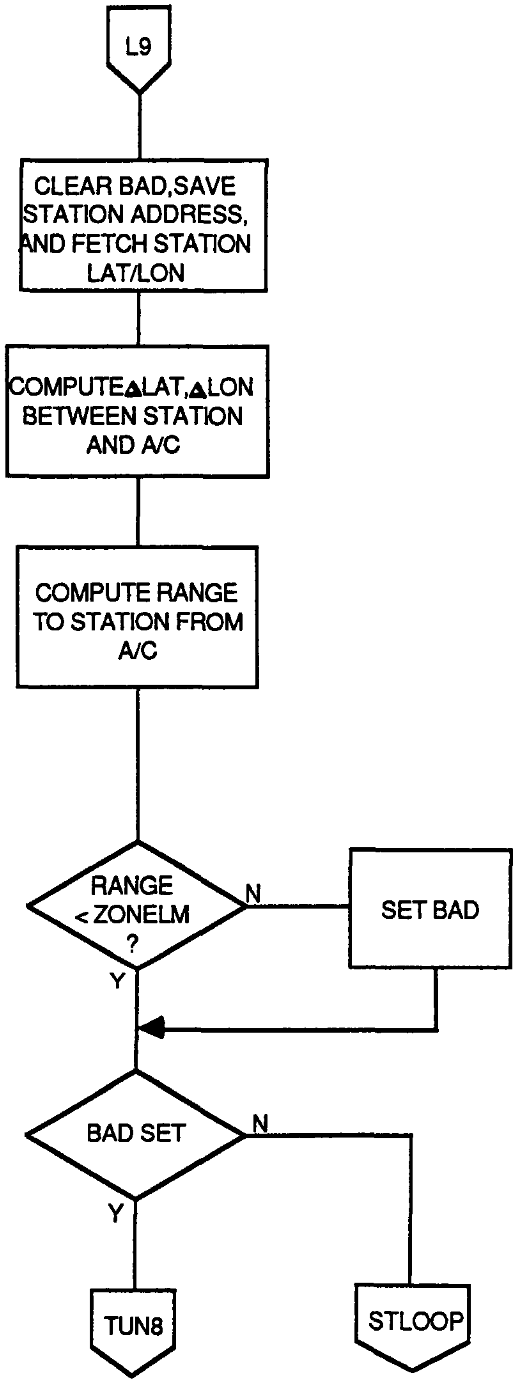
TUNCK 1/1

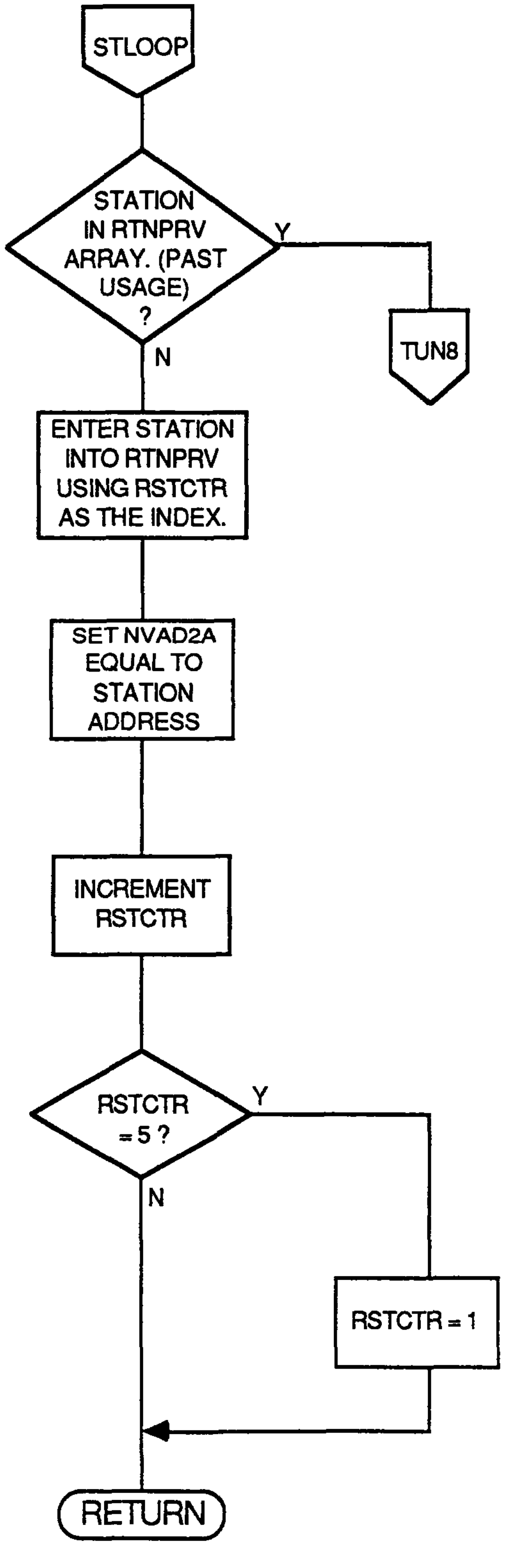


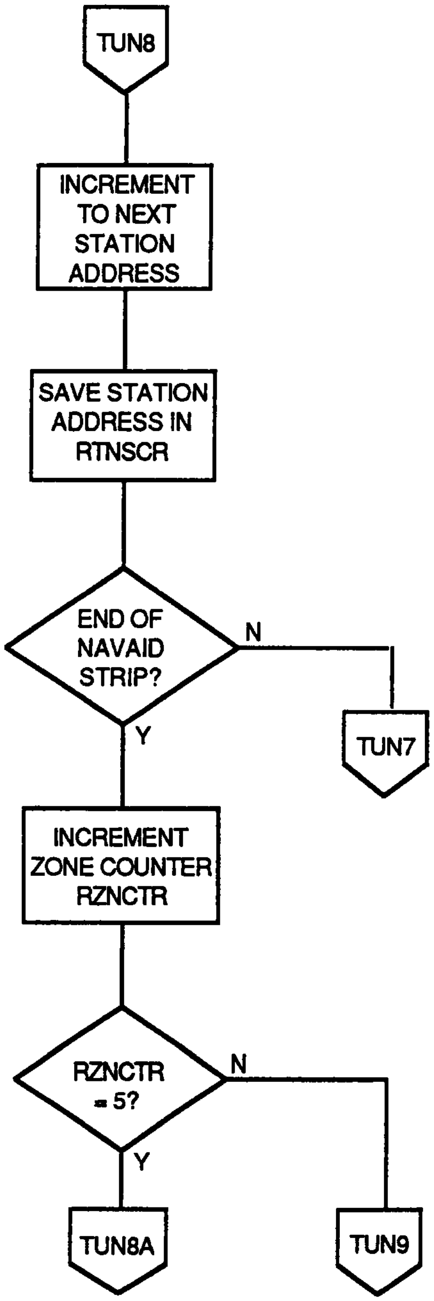
TUNDM2
(PAGE 1 OF 12)

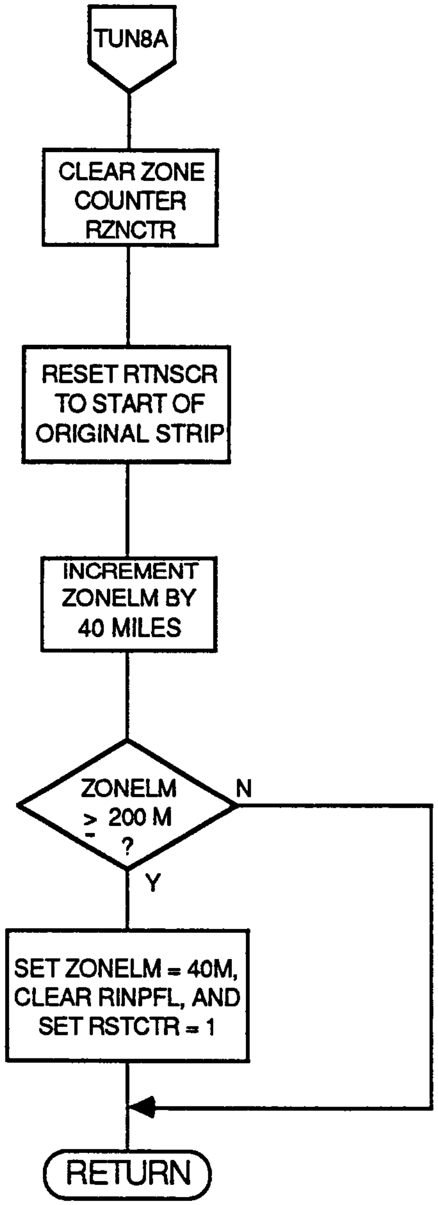

TUN6
ZONELM = 40M
RZNCTR = 0
FETCH FIRST LONGITUDINAL STRIP INDEX IN BULK DATA
END OF STRIPS IN BULK DATA?
Y
RETURN
N
A/C LON WITHIN STRIP BOUNDS ?
Y
TUN6A
N
BUMP TO NEXT STRIP INDEX

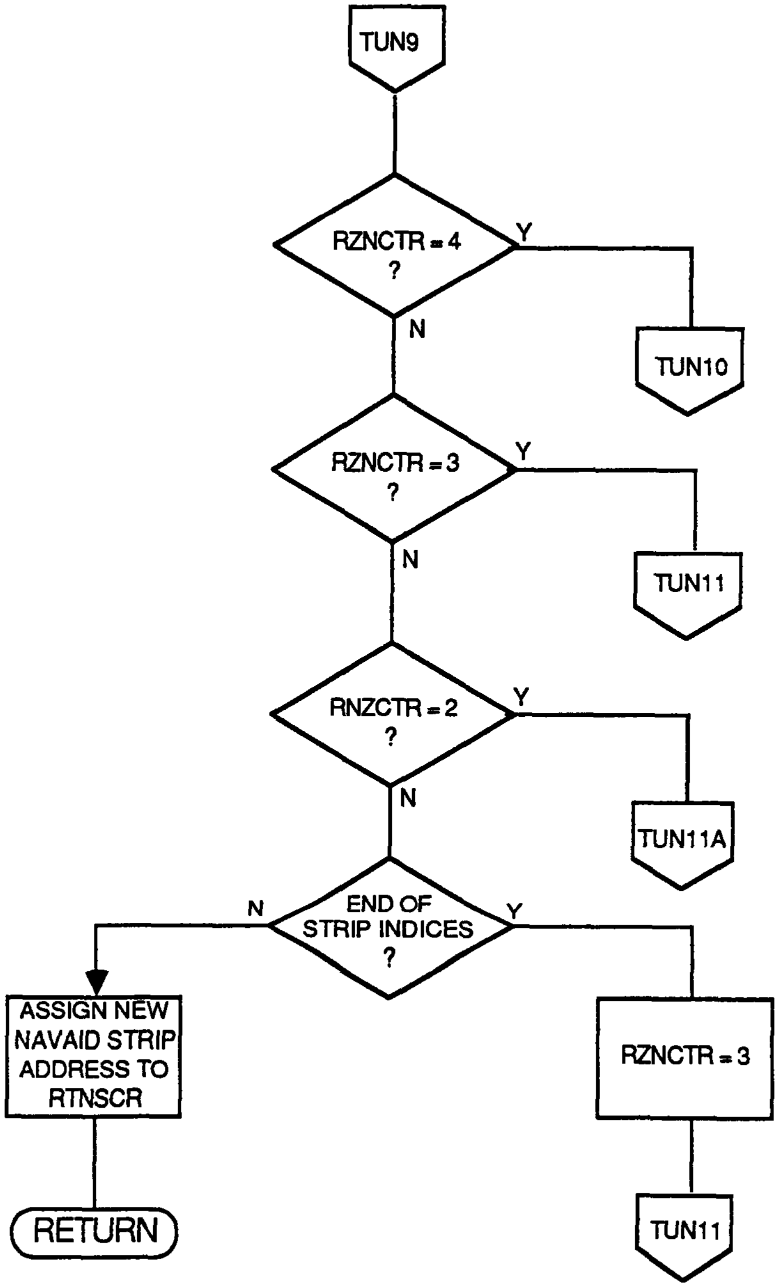

TUN6A
SAVE ZONE POINTER RZNPTR
SET RTNSCR TO CURRENT POINTER ADDRESS
SET SEARCH IN PROGRESS FLAG RINPFL
SET STATION COUNTER RSTCTR = 1
TUN7

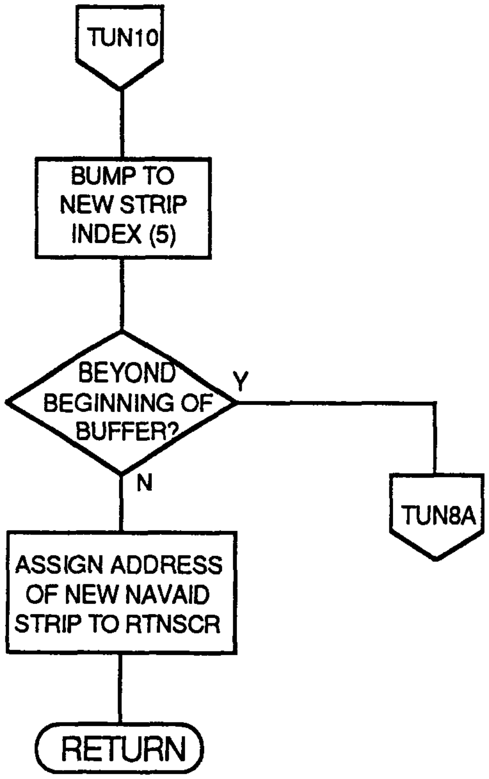

L9
CLEAR BAD,SAVE STATION ADDRESS, AND FETCH STATION LAT/LON
COMPUTE▲LAT,▲LON BETWEEN STATION AND A/C
COMPUTE RANGE TO STATION FROM A/C
RANGE < ZONELM ?
N
SET BAD
Y
BAD SET
N
Y
TUN8
STLOOP

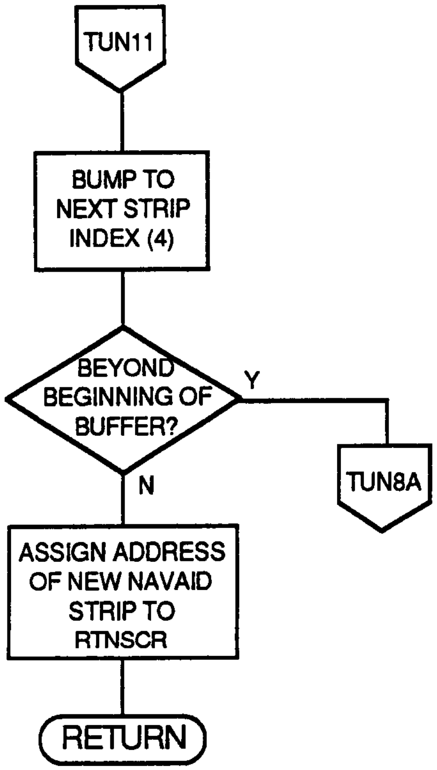

STLOOP
STATION IN RTNPRV ARRAY. (PAST USAGE) ?
Y
TUN8
N
ENTER STATION INTO RTNPRV USING RSTCTR AS THE INDEX.
SET NVAD2A EQUAL TO STATION ADDRESS
INCREMENT RSTCTR
RSTCTR = 5 ?
Y
N
RSTCTR = 1
RETURN

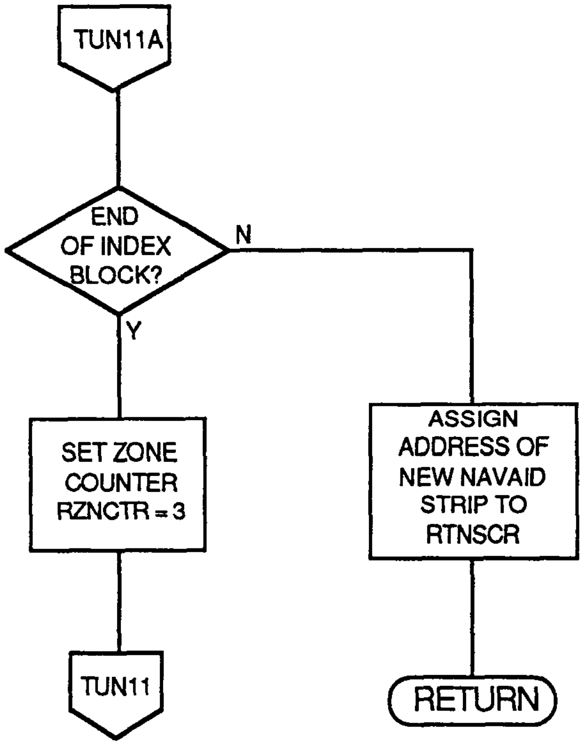

TUN8
INCREMENT TO NEXT STATION ADDRESS
SAVE STATION ADDRESS IN RTNSCR
END OF NAVAID STRIP?
N
TUN7
Y
INCREMENT ZONE COUNTER RZNCTR
RZNCTR = 5?
N
Y
TUN8A
TUN9

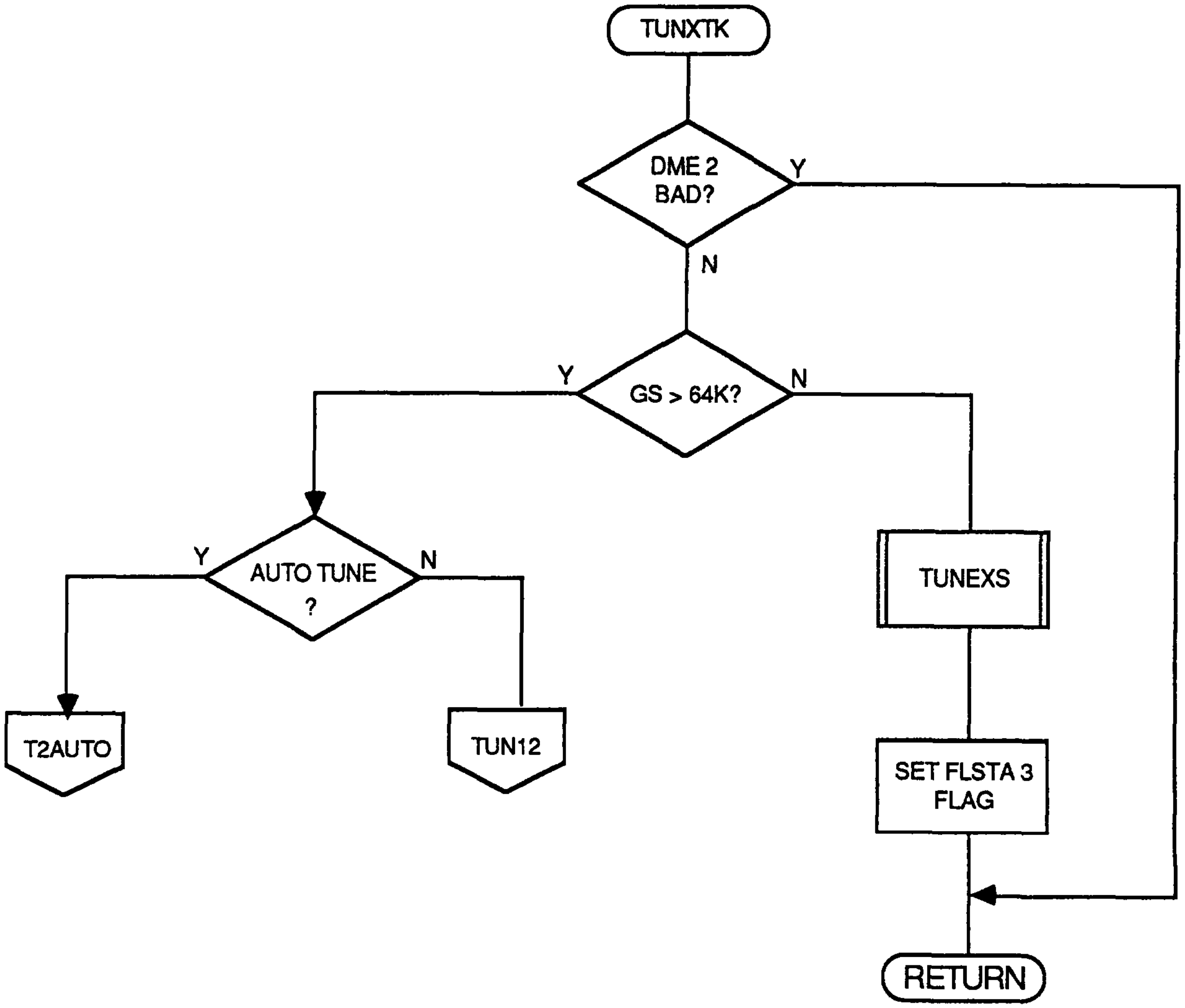

TUN8A
CLEAR ZONE COUNTER RZNCTR
RESET RTNSCR TO START OF ORIGINAL STRIP
INCREMENT ZONELM BY 40 MILES
ZONELM ≥ 200 M ?
N
Y
SET ZONELM = 40M, CLEAR RINPFL, AND SET RSTCTR = 1
RETURN

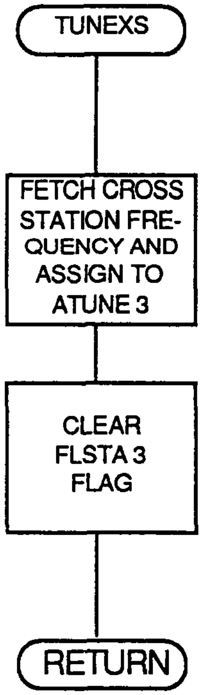

TUN9
RZNCTR = 4
?
Y
N
TUN10
RZNCTR = 3
?
Y
N
TUN11
RNZCTR = 2
?
Y
N
TUN11A
N
END OF
STRIP INDICES
?
Y
ASSIGN NEW NAVAID STRIP ADDRESS TO RTNSCR
RETURN
RZNCTR = 3
TUN11

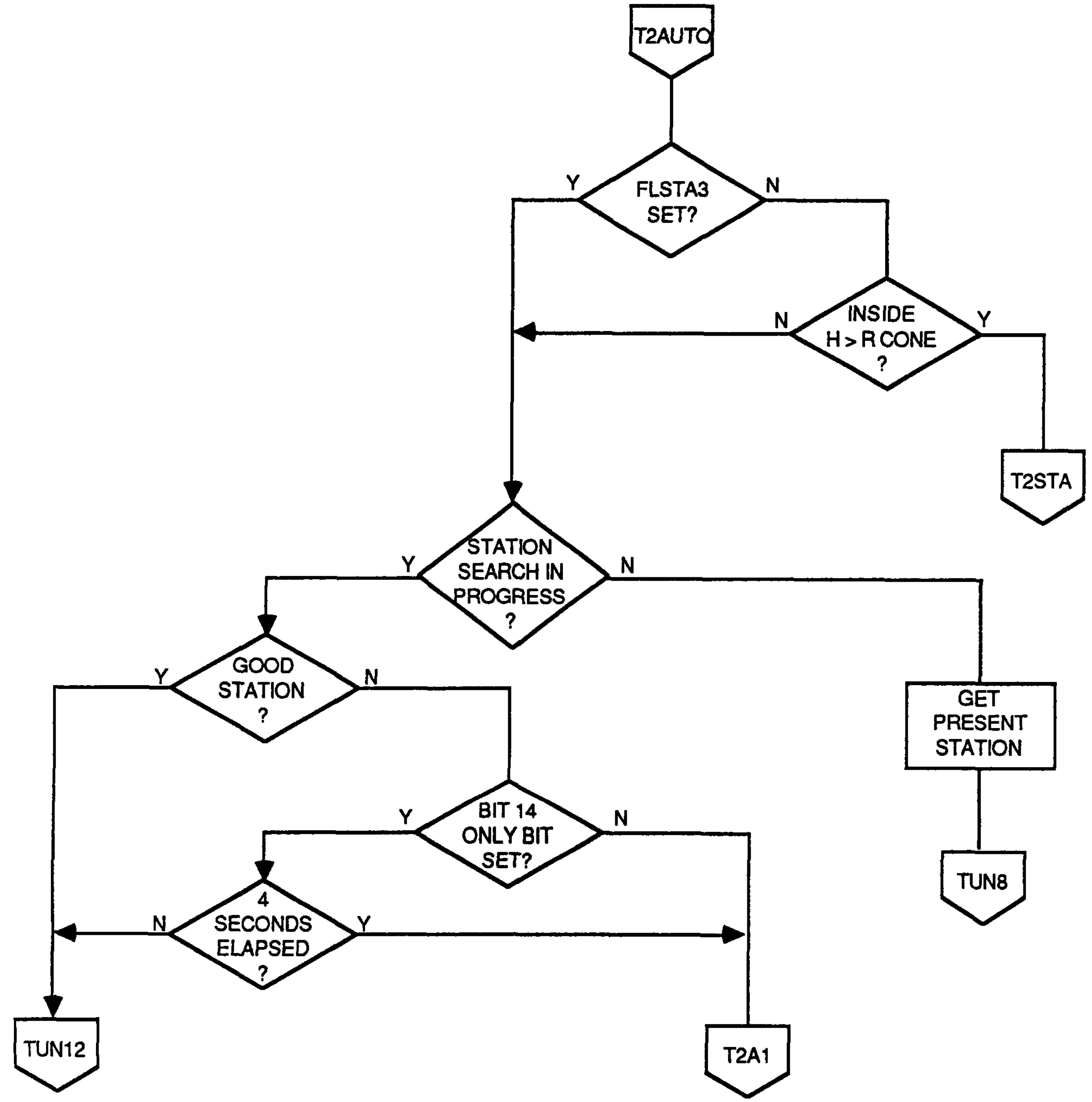

TUN10
BUMP TO NEW STRIP INDEX (5)
BEYOND BEGINNING OF BUFFER?
Y
N
TUN8A
ASSIGN ADDRESS OF NEW NAVAID STRIP TO RTNSCR
RETURN

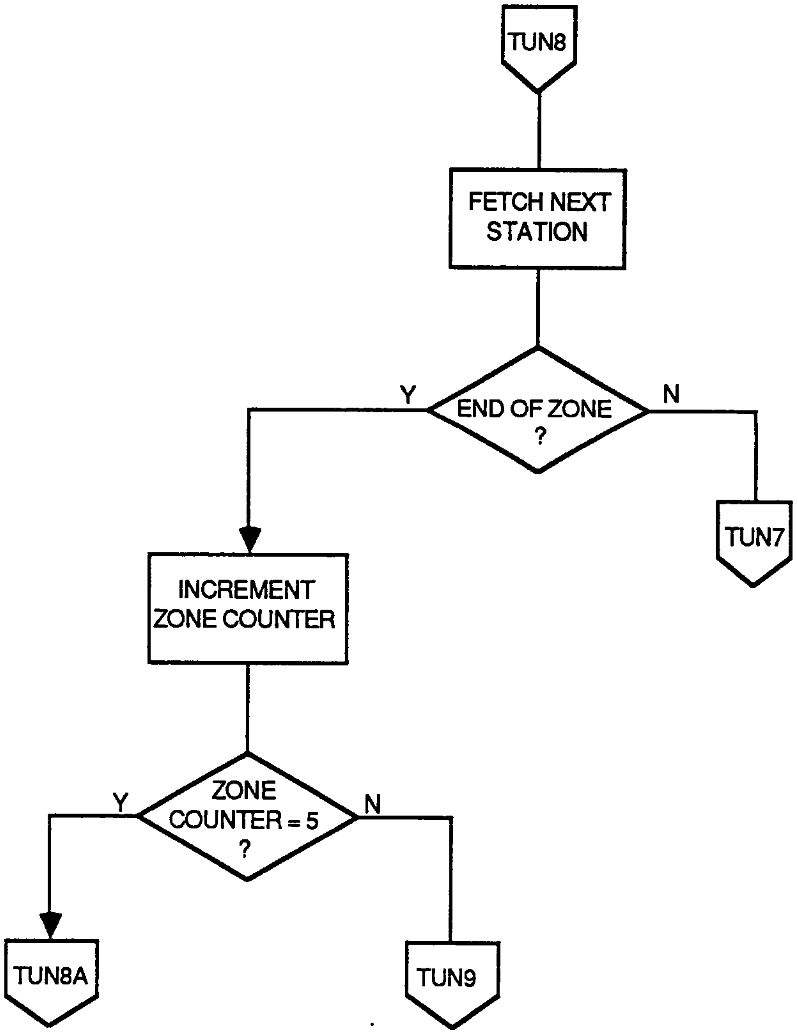

TUN11
BUMP TO NEXT STRIP INDEX (4)
BEYOND BEGINNING OF BUFFER?
Y
TUN8A
N
ASSIGN ADDRESS OF NEW NAVAID STRIP TO RTNSCR
RETURN

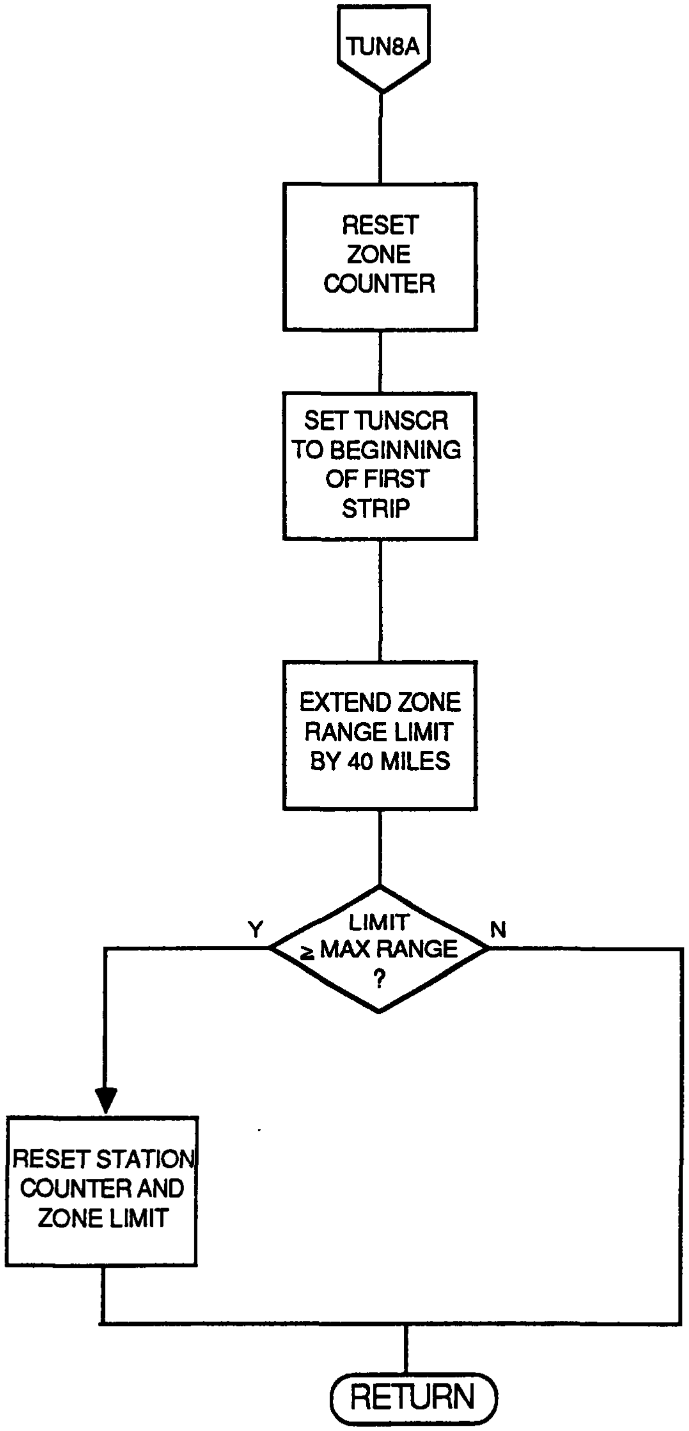

TUN11A
END OF INDEX BLOCK?
N
Y
SET ZONE COUNTER RZNCTR = 3
ASSIGN ADDRESS OF NEW NAVAID STRIP TO RTNSCR
TUN11
RETURN

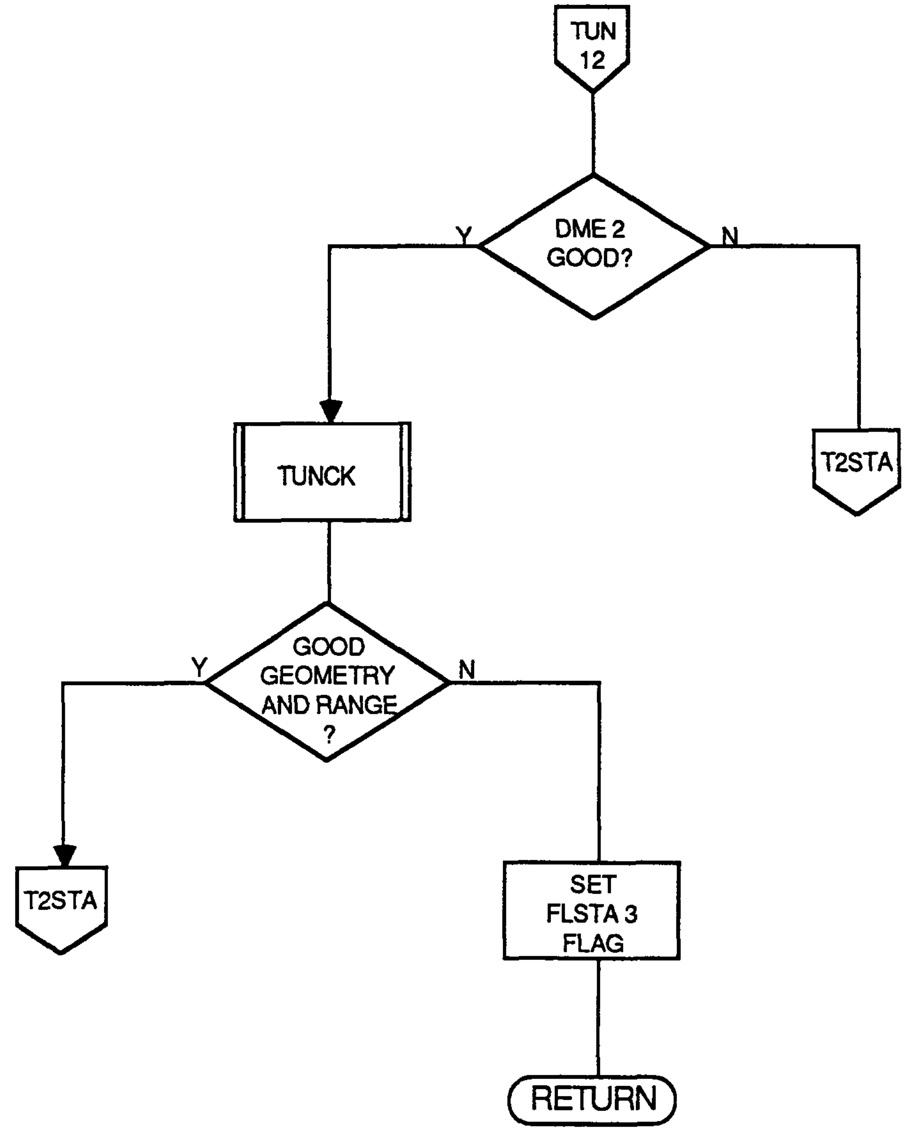

TUNXTK
DME 2 BAD?
Y
N
GS > 64K?
Y
N
AUTO TUNE ?
Y
N
TUNEXS
T2AUTO
TUN12
SET FLSTA 3 FLAG
RETURN

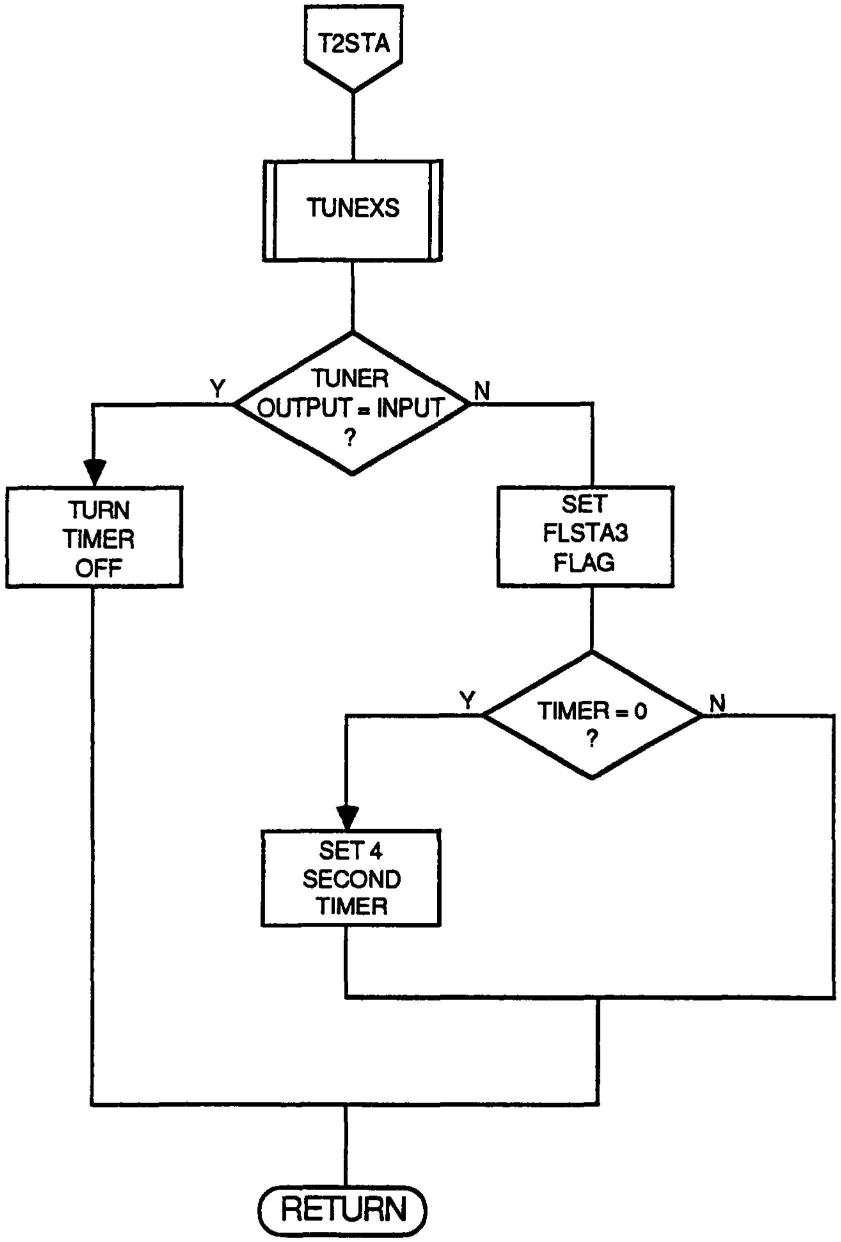

TUNEXS
FETCH CROSS STATION FRE-QUENCY AND ASSIGN TO ATUNE 3
CLEAR FLSTA 3 FLAG
RETURN

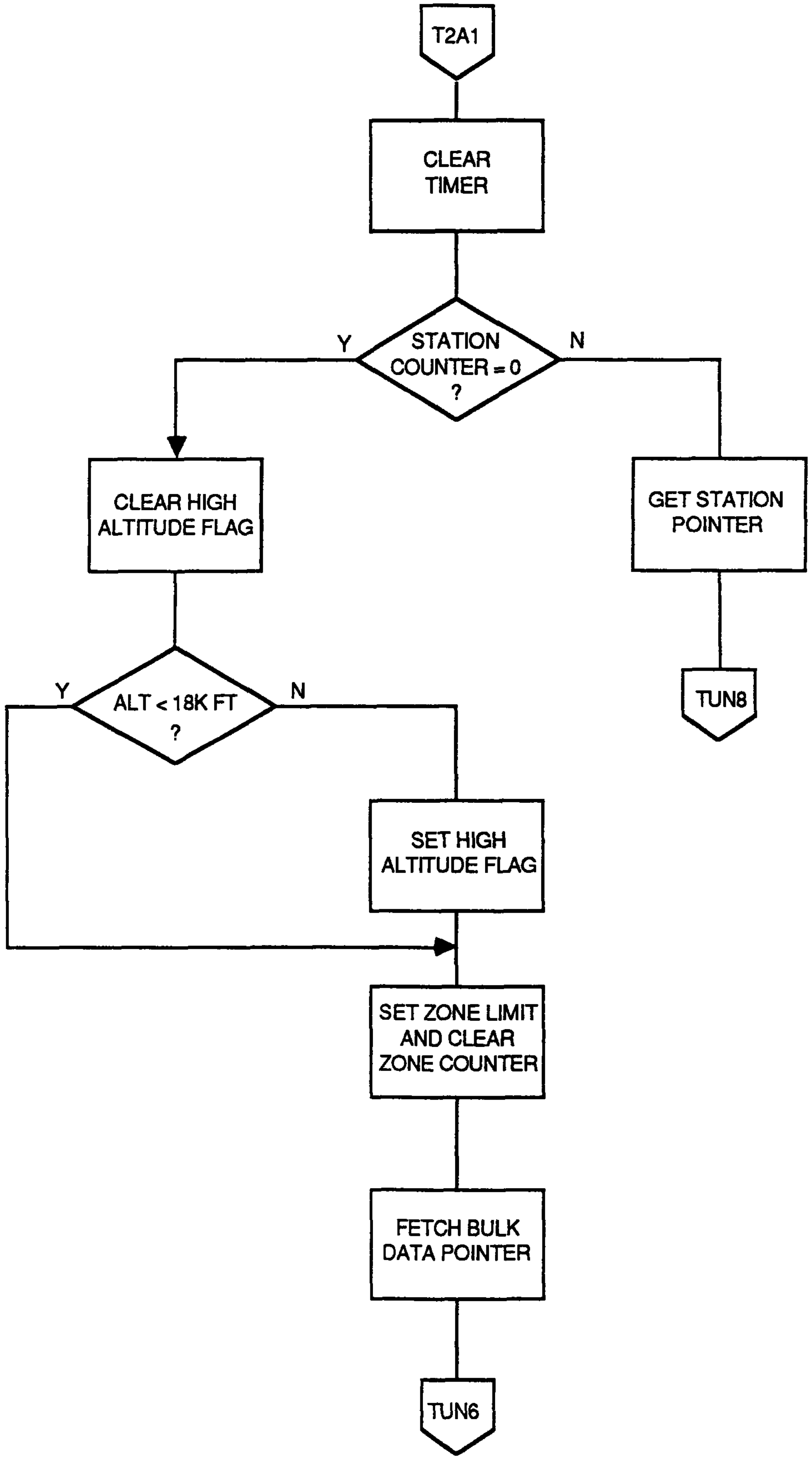

T2AUTO
FLSTA3 SET?
Y
N
INSIDE H > R CONE ?
N
Y
T2STA
STATION SEARCH IN PROGRESS ?
Y
N
GOOD STATION ?
Y
N
GET PRESENT STATION
TUN8
BIT 14 ONLY BIT SET?
Y
N
4 SECONDS ELAPSED ?
N
Y
TUN12
T2A1

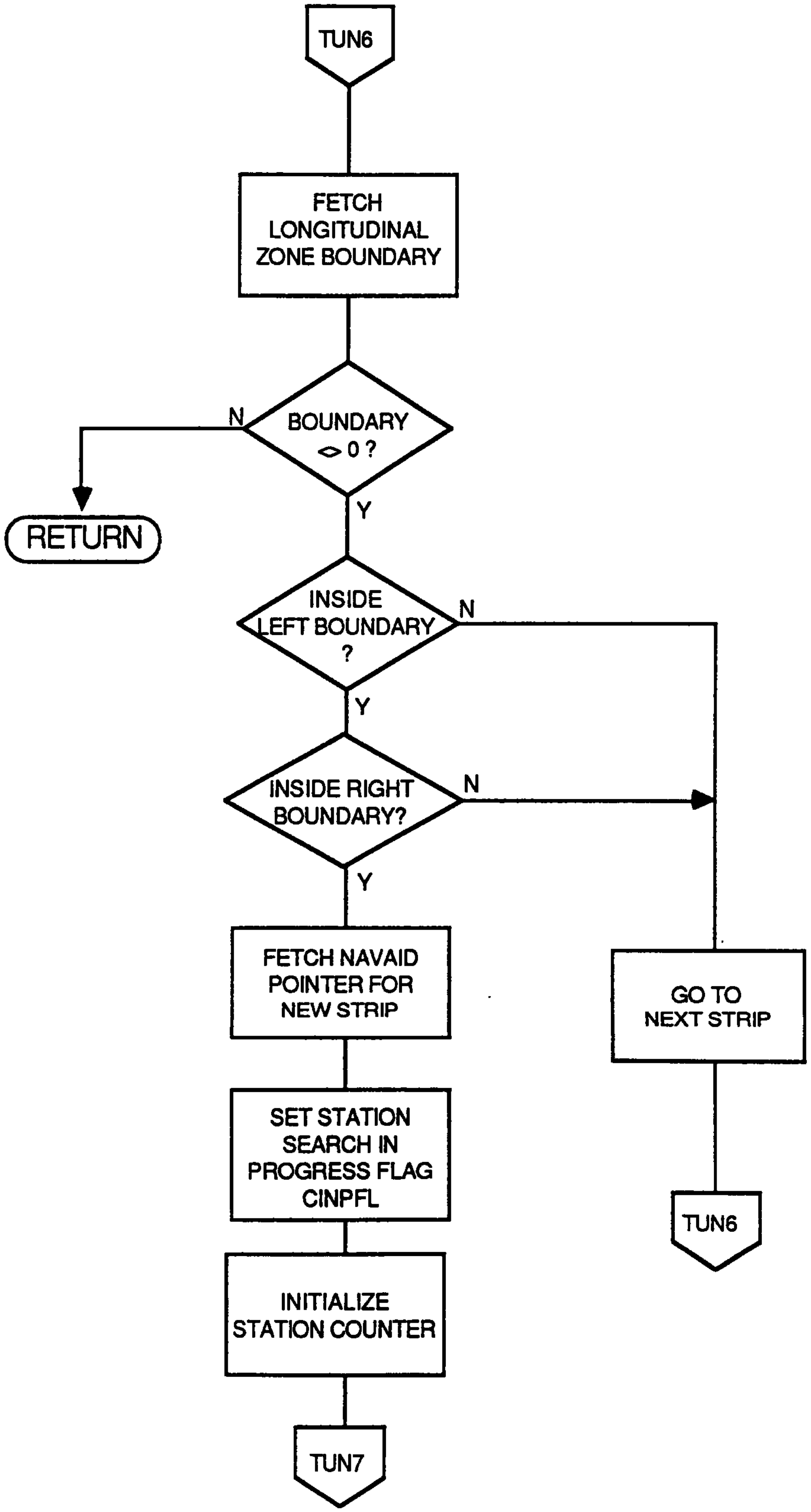

TUN8
FETCH NEXT STATION
END OF ZONE ?
Y
N
TUN7
INCREMENT ZONE COUNTER
ZONE COUNTER = 5 ?
Y
N
TUN8A
TUN9

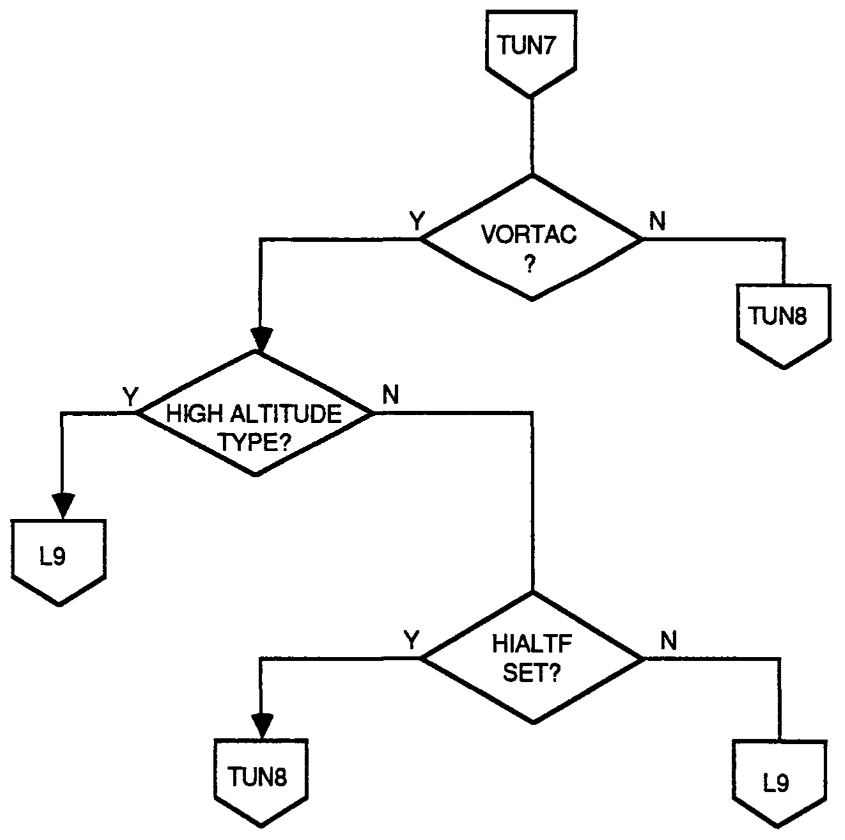

TUN8A
RESET ZONE COUNTER
SET TUNSCR TO BEGINNING OF FIRST STRIP
EXTEND ZONE RANGE LIMIT BY 40 MILES
LIMIT ≥ MAX RANGE ?
Y
N
RESET STATION COUNTER AND ZONE LIMIT
RETURN


TUN 12
DME 2 GOOD?
Y
N
TUNCK
T2STA
GOOD GEOMETRY AND RANGE ?
Y
N
T2STA
SET FLSTA 3 FLAG
RETURN

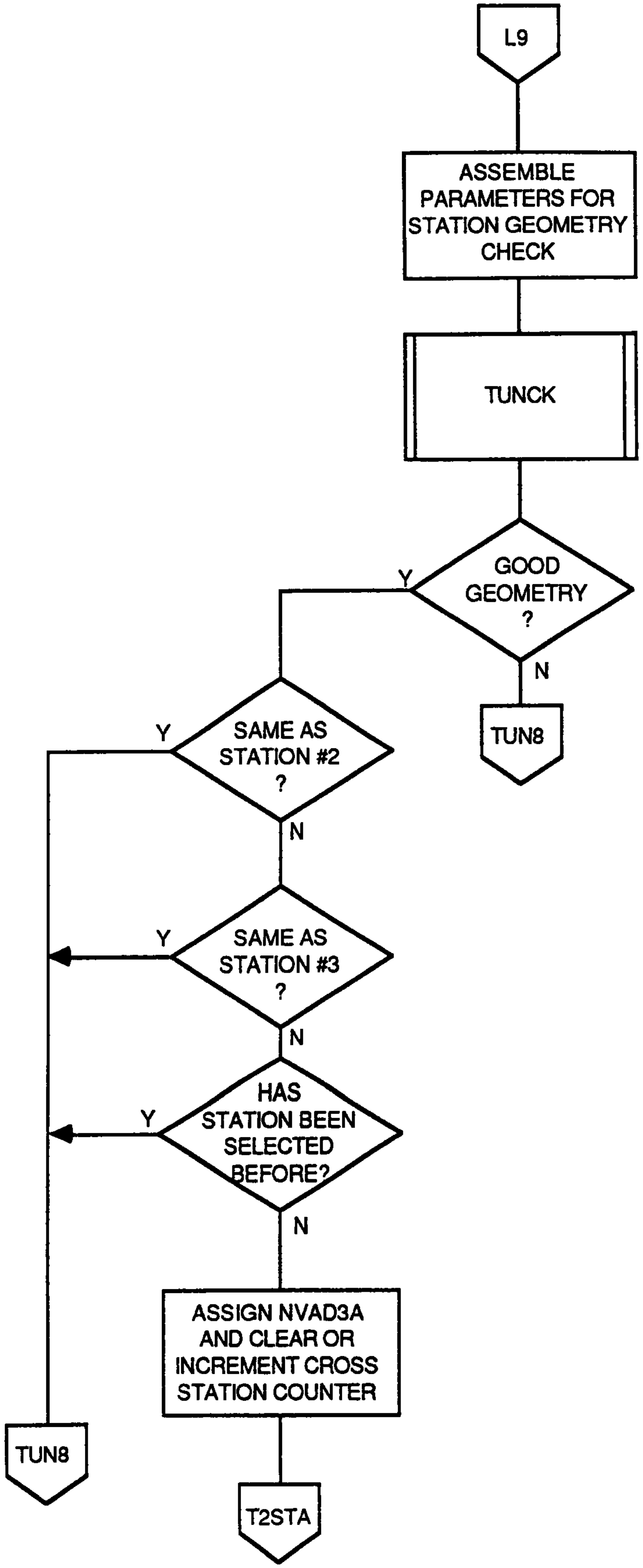

T2STA
TUNEXS
TUNER OUTPUT = INPUT ?
Y
N
TURN TIMER OFF
SET FLSTA3 FLAG
Y
TIMER = 0 ?
N
SET 4 SECOND TIMER
RETURN

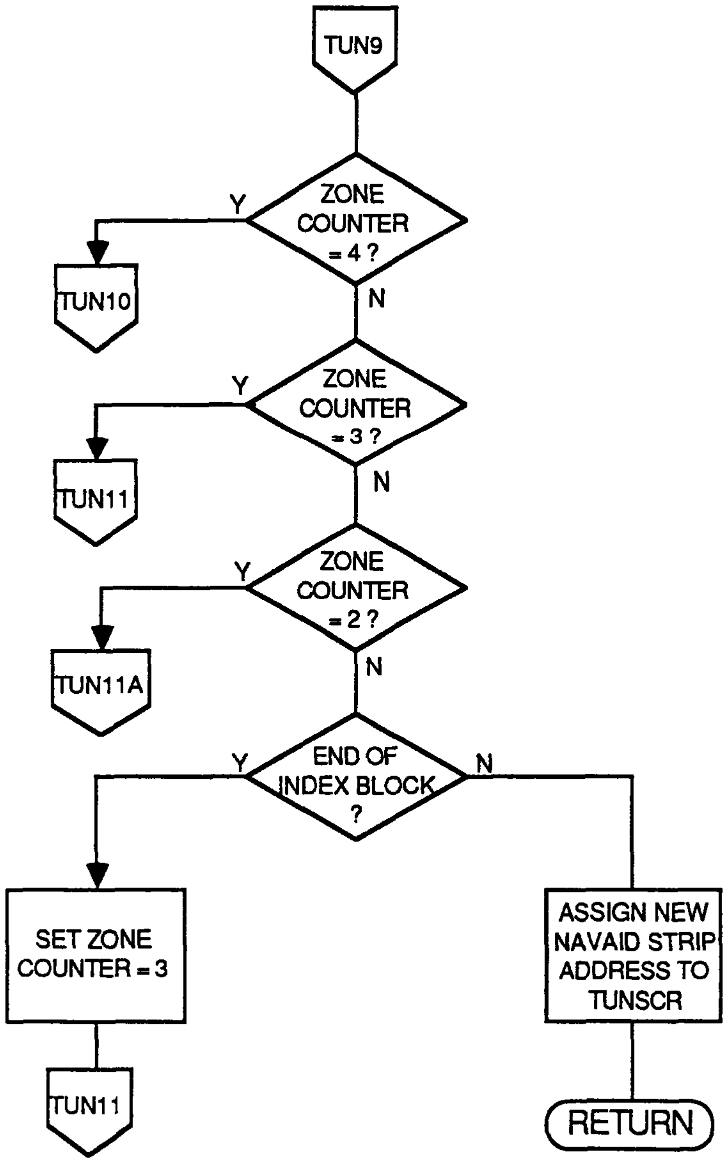

T2A1
CLEAR TIMER
STATION COUNTER = 0 ?
Y
N
CLEAR HIGH ALTITUDE FLAG
GET STATION POINTER
TUN8
ALT < 18K FT ?
Y
N
SET HIGH ALTITUDE FLAG
SET ZONE LIMIT AND CLEAR ZONE COUNTER
FETCH BULK DATA POINTER
TUN6

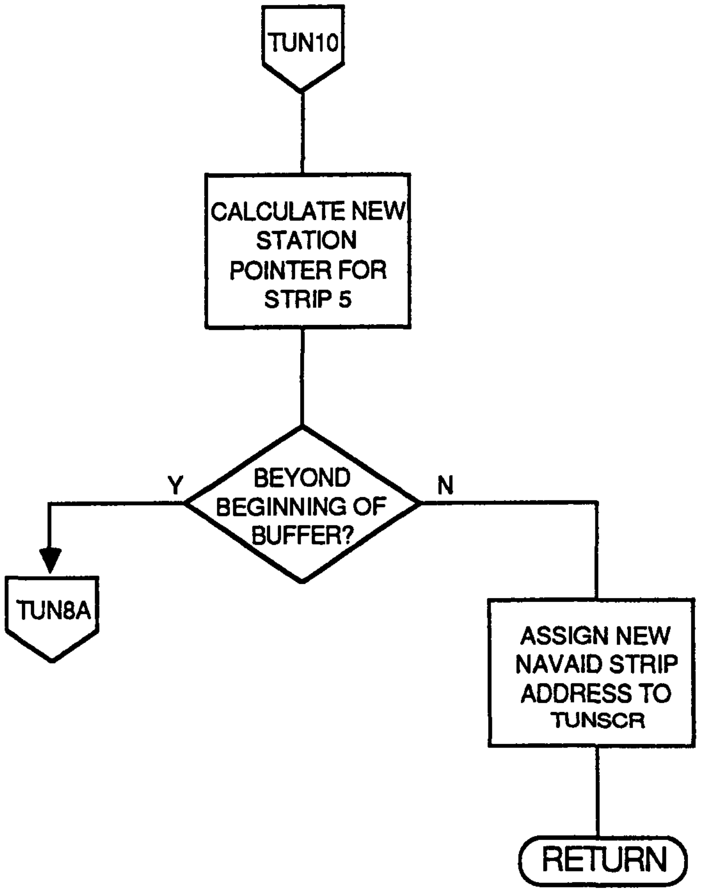

TUN6
FETCH LONGITUDINAL ZONE BOUNDARY
BOUNDARY <> 0 ?
N
RETURN
Y
INSIDE LEFT BOUNDARY ?
N
Y
INSIDE RIGHT BOUNDARY?
N
Y
FETCH NAVAID POINTER FOR NEW STRIP
SET STATION SEARCH IN PROGRESS FLAG CINPFL
INITIALIZE STATION COUNTER
TUN7
GO TO NEXT STRIP
TUN6

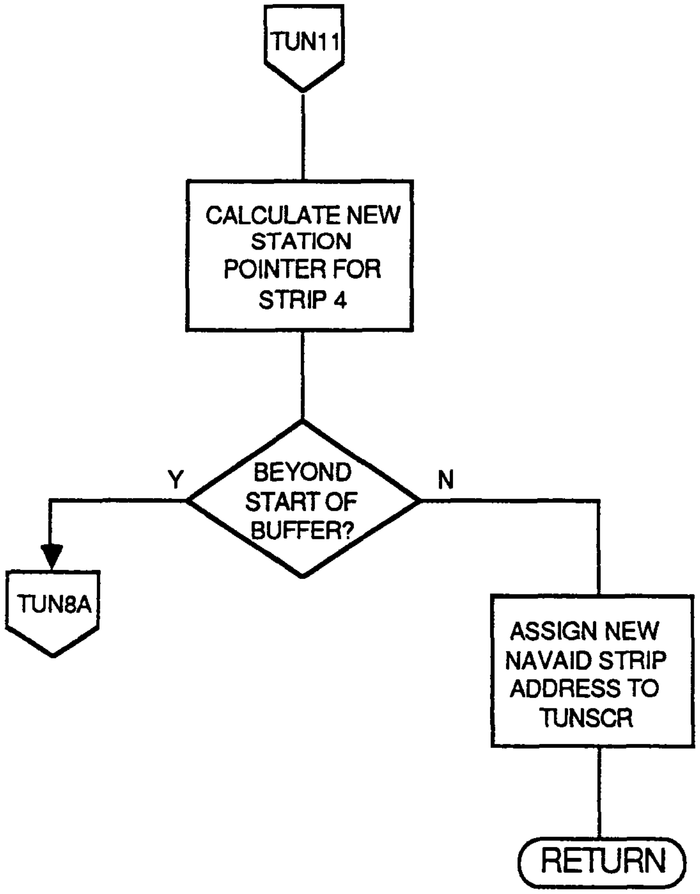


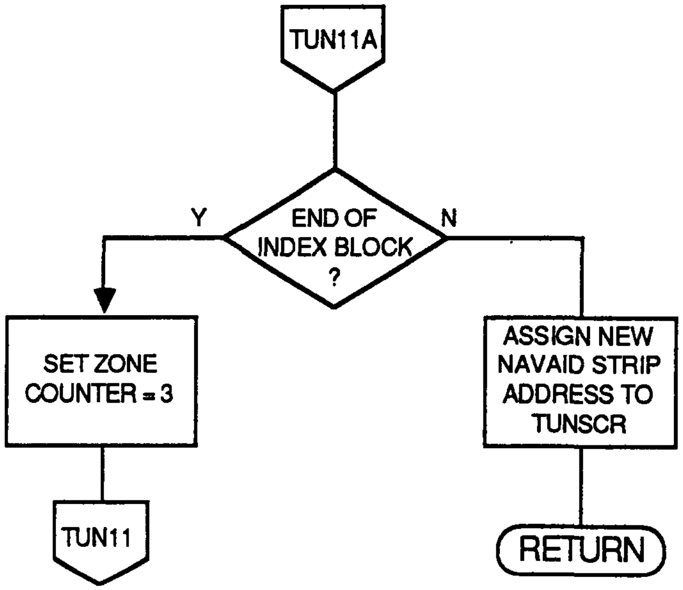
TUNXTK
(PAGE 10 OF 15)


L9
ASSEMBLE PARAMETERS FOR STATION GEOMETRY CHECK
TUNCK
GOOD GEOMETRY ?
Y
N
TUN8
SAME AS STATION #2 ?
Y
N
SAME AS STATION #3 ?
Y
N
HAS STATION BEEN SELECTED BEFORE?
Y
N
ASSIGN NVAD3A AND CLEAR OR INCREMENT CROSS STATION COUNTER
TUN8
T2STA


TUN9
ZONE COUNTER = 4 ?
Y
TUN10
N
ZONE COUNTER = 3 ?
Y
TUN11
N
ZONE COUNTER = 2 ?
Y
TUN11A
N
END OF INDEX BLOCK ?
Y
N
SET ZONE COUNTER = 3
TUN11
ASSIGN NEW NAVAID STRIP ADDRESS TO TUNSCR
RETURN


TUN10
CALCULATE NEW STATION POINTER FOR STRIP 5
BEYOND BEGINNING OF BUFFER?
Y
N
TUN8A
ASSIGN NEW NAVAID STRIP ADDRESS TO TUNSCR
RETURN

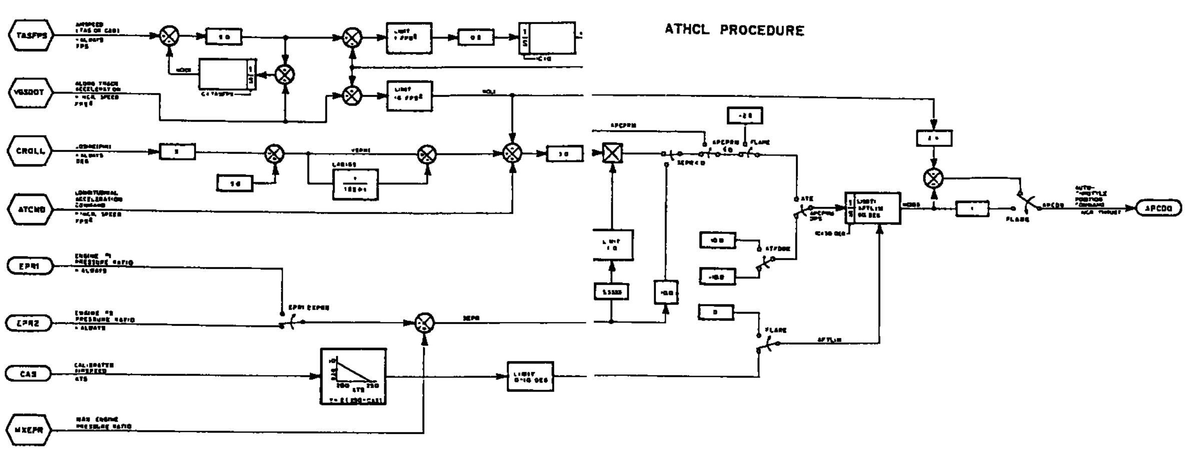

TUN11
CALCULATE NEW STATION POINTER FOR STRIP 4
BEYOND START OF BUFFER?
Y
N
TUN8A
ASSIGN NEW NAVAID STRIP ADDRESS TO TUNSCR
RETURN


TUN11A
END OF INDEX BLOCK ?
Y
N
SET ZONE COUNTER = 3
TUN11
ASSIGN NEW NAVAID STRIP ADDRESS TO TUNSCR
RETURN

DIGITAL SYSTEMS DIAGRAMS

FOLDOUT FRAME 1

FOLDOUT FRAME 2


ATHCL PROCEDURE

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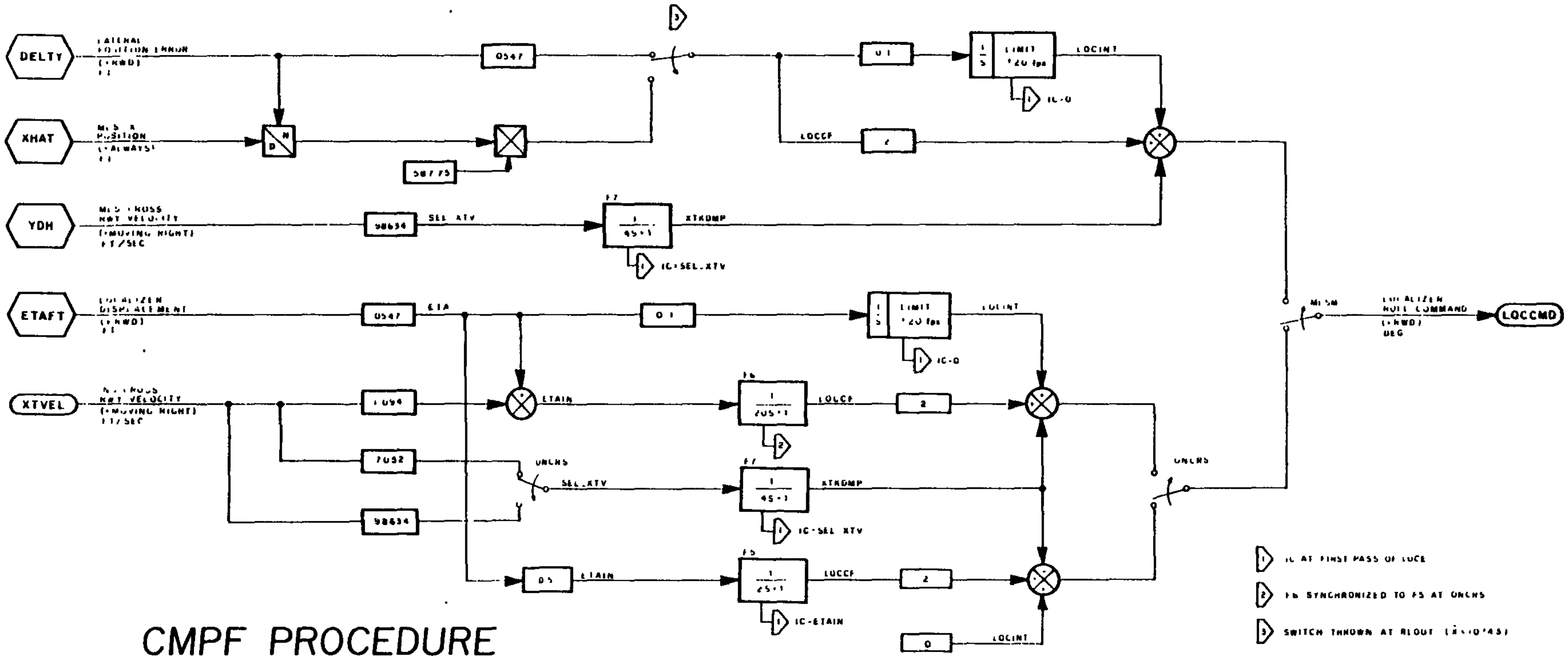
ORIGINAL PAGE IS
OF POOR QUALITY



CMPF PROCEDURE

COMPLEMENTARY FILTER

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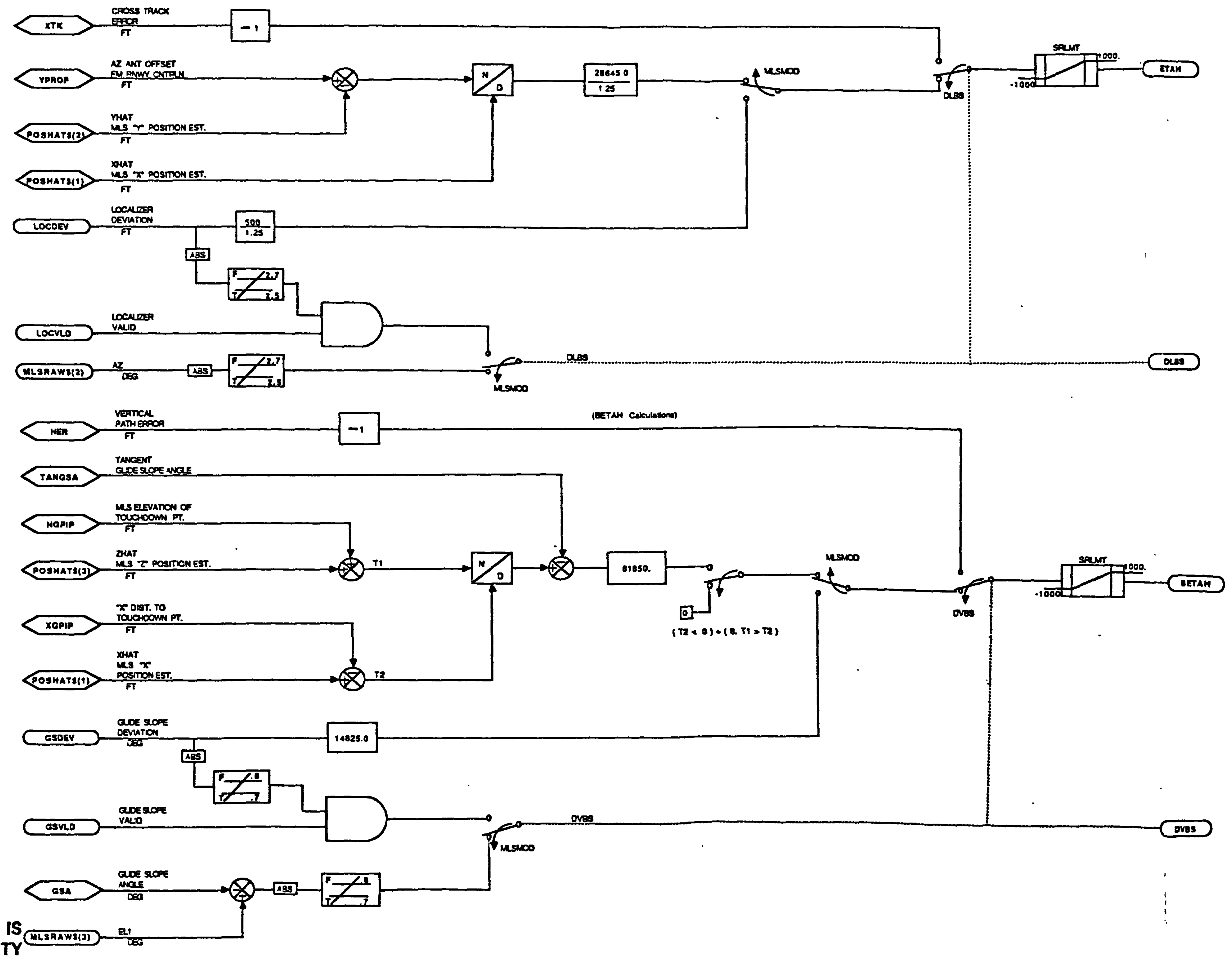
FOLDOUT FRAME 2.

FOLDOUT FRAME 1

PROCEDURE DSPOT

(ETAH Calculations)



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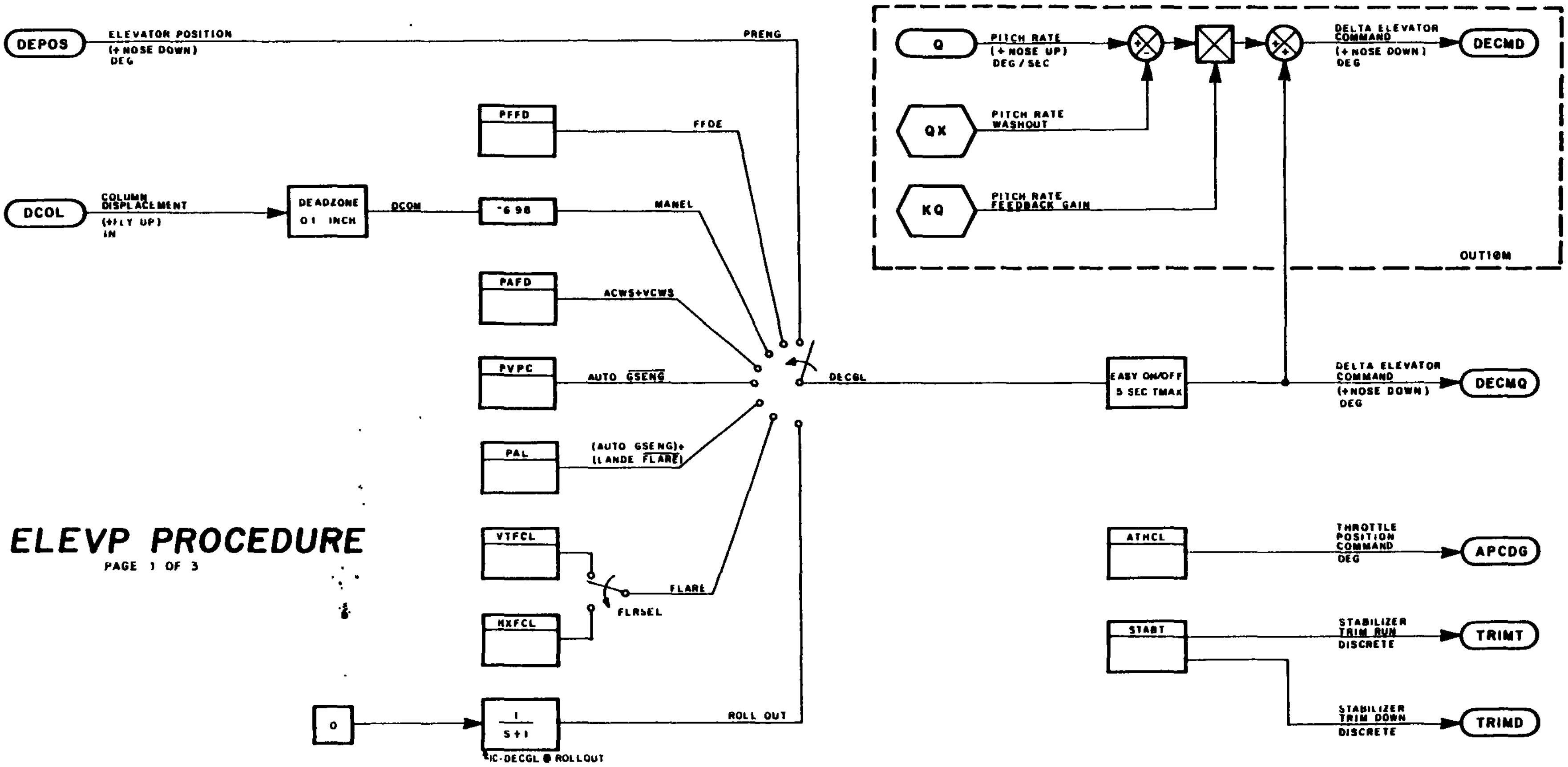
B4



ELEVP PROCEDURE

PAGE 1 OF 3

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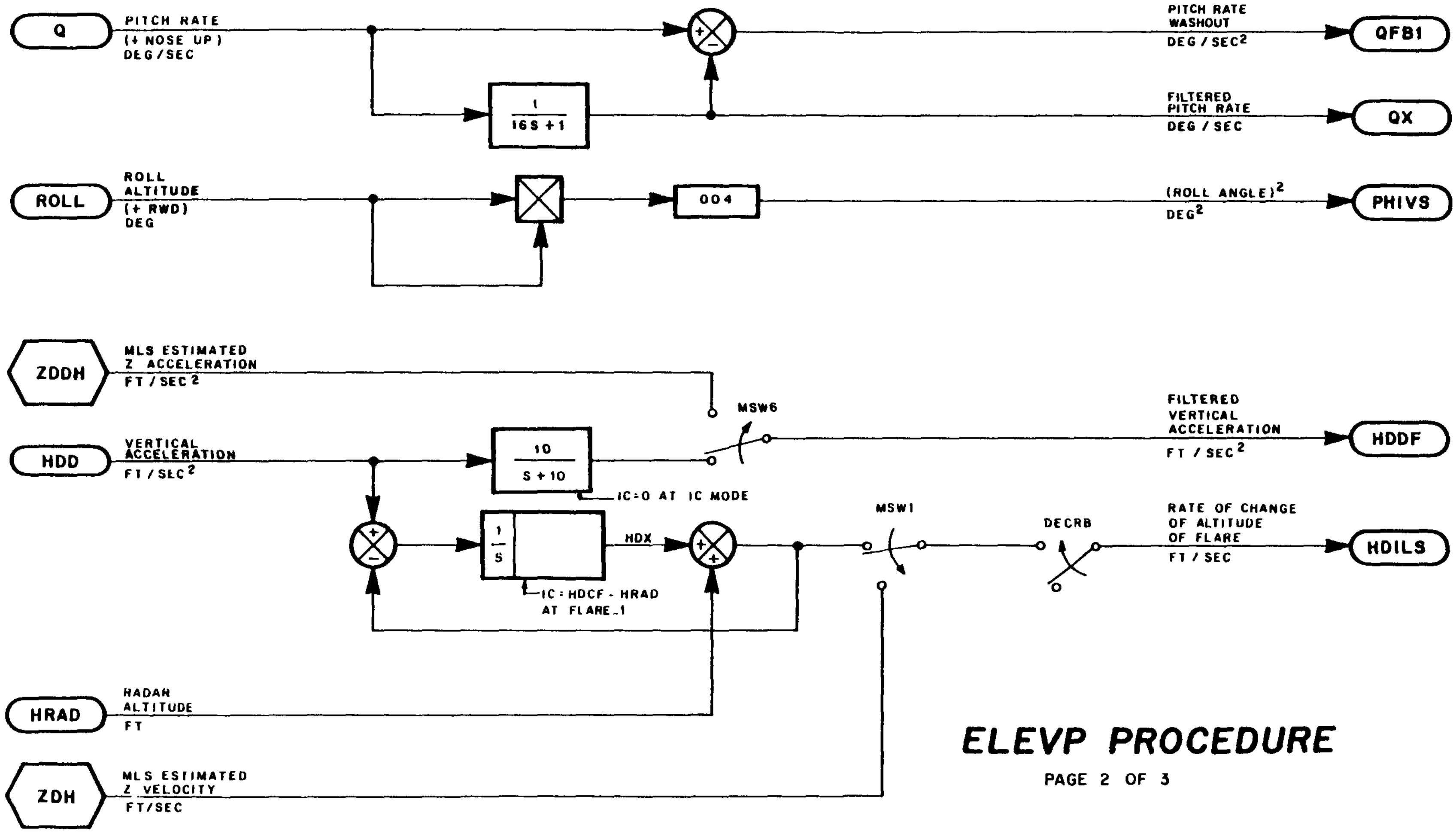
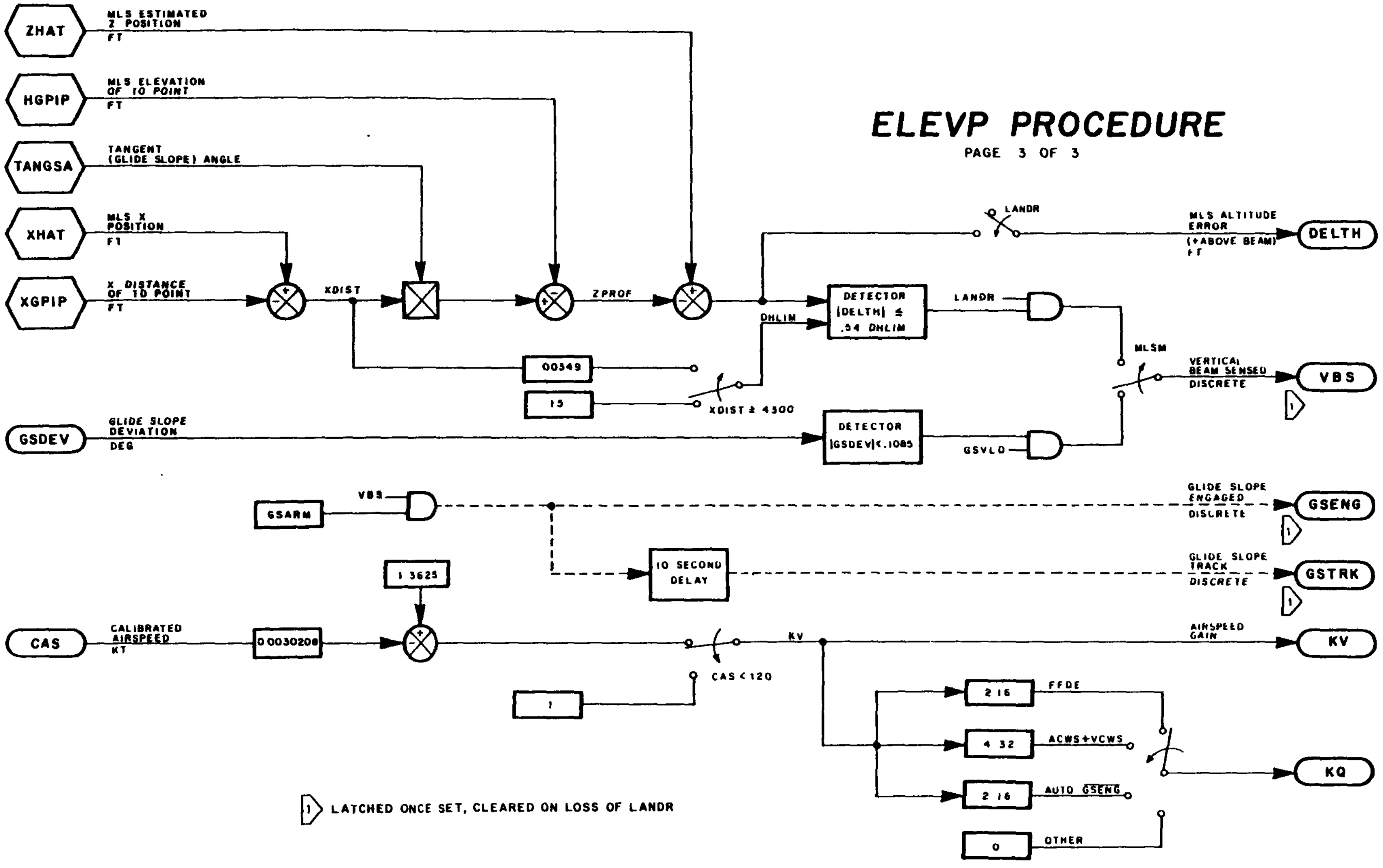


ELEVP PROCEDURE

PAGE 2 OF 3

ELEVP PROCEDURE

PAGE 3 OF 3


ZHAT
MLS ESTIMATED Z POSITION FT
HGPIP
MLS ELEVATION OF 10 POINT FT
TANGSA
TANGENT (GLIDE SLOPE) ANGLE
XHAT
MLS X POSITION FT
XGPIP
X DISTANCE OF 1D POINT FT
XDIST
ZPROF
00349
15
XDIST ≥ 4300
DHLIM
DETECTOR |DELTH| ≤ .54 DHLIM
LANDR
LANDR
MLS ALTITUDE ERROR (+ABOVE BEAM) FT
DELTH
MLSM
VERTICAL BEAM SENSED DISCRETE
VBS
GSDEV
GLIDE SLOPE DEVIATION DEG
DETECTOR |GSDEV|<.1085
GSVLD
GSARM
VBS
GLIDE SLOPE ENGAGED DISCRETE
GSENG
10 SECOND DELAY
GLIDE SLOPE TRACK DISCRETE
GSTRK
CAS
CALIBRATED AIRSPEED KT
0.0030208
1.3625
KV
CAS < 120
1
AIRSPEED GAIN
KV
2.16
FFDE
4.32
ACWS+VCWS
2.16
AUTO GSENG
0
OTHER
KQ
1

1 LATCHED ONCE SET, CLEARED ON LOSS OF LANDR

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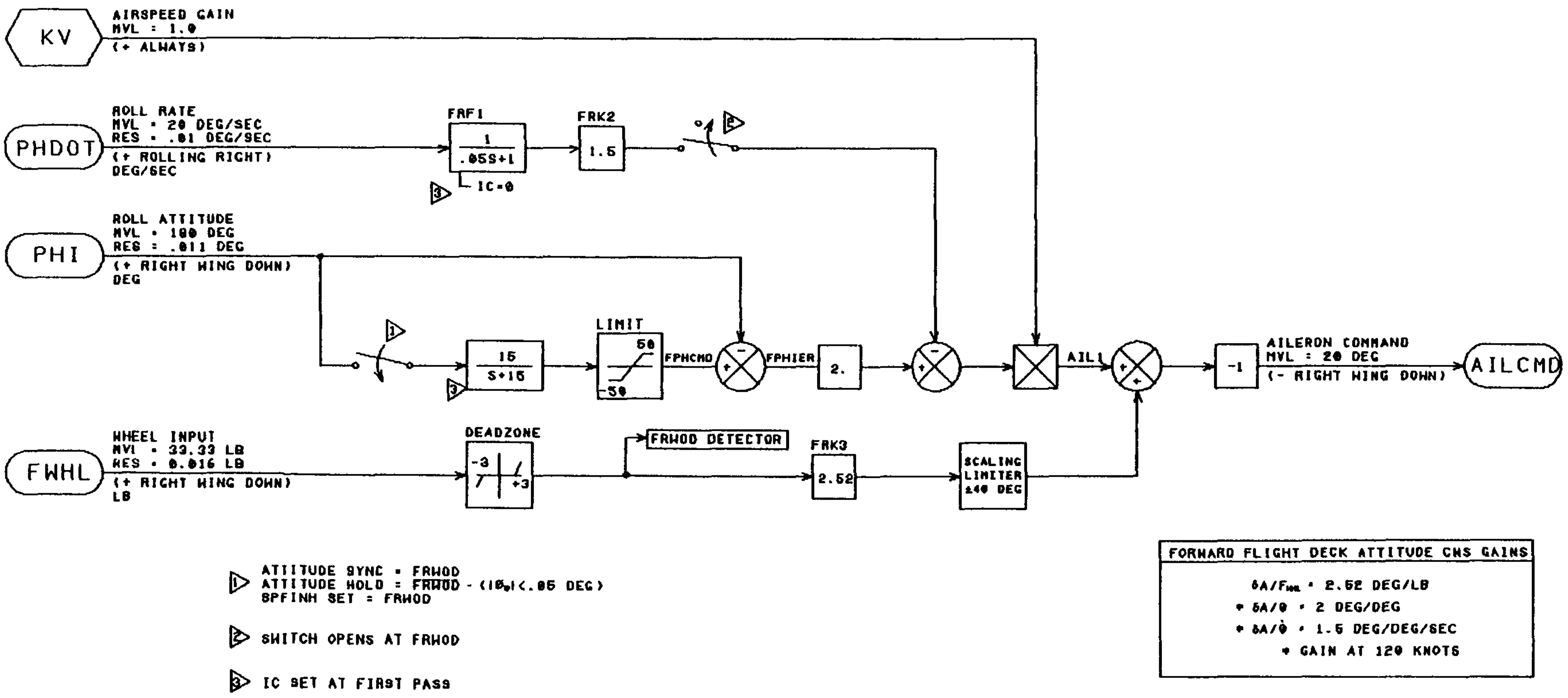
FRCWS SUBROUTINE



1 ATTITUDE SYNC = FRWOD
ATTITUDE HOLD = ~~FRWOD~~ - (|Ṗ|<.05 DEG)
SPFINH SET = FRWOD

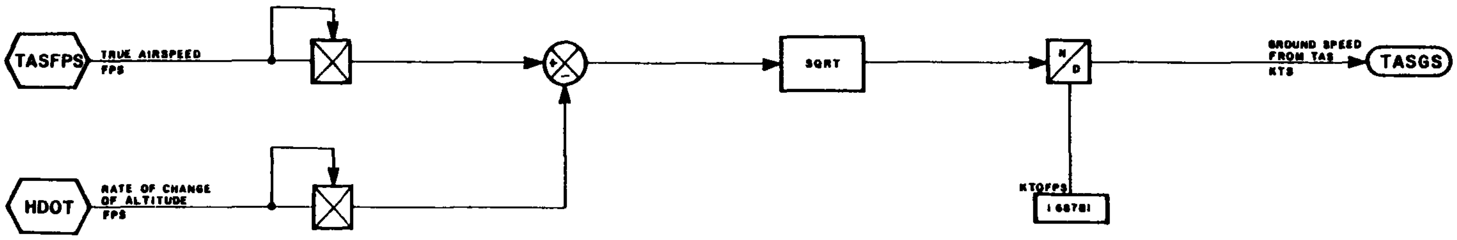
2 SWITCH OPENS AT FRWOD

3 IC SET AT FIRST PASS

FORWARD FLIGHT DECK ATTITUDE CWS GAINS

$\delta A/F_{WHL}$ = 2.52 DEG/LB
* $\delta A/\phi$ = 2 DEG/DEG
* $\delta A/\dot{\phi}$ = 1.5 DEG/DEG/SEC
* GAIN AT 120 KNOTS

MODE DETERMINATION AND INITIALIZATION:



INS MODE (INAVV)	AIR DATA OR RADIO MODE (FLYFLG + INAVV)	SIMULATED AIRPLANE (FLYFLG)	
ATKACC	ATKACC * $\overline{\text{MCONFS(13)}}$*	0	INS ALONG TRACK ACCELERATION FPS^2 → IDDATK
XTKACC	XTKACC * MCONFS(13)*	IDDXTK COMPUTED BY NAVIG	INS CROSS TRACK ACCELERATION FPS^2 → IDDXTK
THDG	MAGVAR + MAGHDG	SMUHDG	TRUE HEADING DEG → HDGTRU
VEINS	(TASGS * SIN (HDGTRU)) TASV ELSE = 0	CAS * SIN (HDGTRU)	INS EAST VELOCITY KTS → EWVAVE
VNINS	(TASGS * COS (HDGTRU)) TASV ELSE = 0	CAS * COS (HDGTRU)	INS NORTH VELOCITY KTS → NSVAVE
OFF	TASV	OFF	AIR DATA MODE FLAG → FLADM
OFF	$\overline{\text{TASV}}$	OFF	RADIO MODE FLAG → FLRM
ON	OFF	ON	INS VALID FLAG → INSVAL

* MCONFS(13): EXPERIMENTAL SWITCH

SET = BODY MOUNTED ACCELEROMETER IN USE FOR ATKACC/XTKACC

MLSVLD = MLSVAL RUNM

MLSMOD = $\overline{\text{FLYFLG}}$ MLSSLI MLSVLD (DESTINS(4) ≠ 0) (ANTLAT ≠ 0)

LATCHED ONCE SET

CLEARED BY FLYFLG + $\overline{\text{MLSSLI}}$ + $\overline{\text{MLSVAL}}$

NAVFLG = $\overline{\text{COLDST}}$ (GS > 4)

LLINIT = ON, IF NAV64K

OFF, IF COLDST

LLINIT OTHERWISE

PROCEDURE HNAVFS

PAGE 1 OF 11

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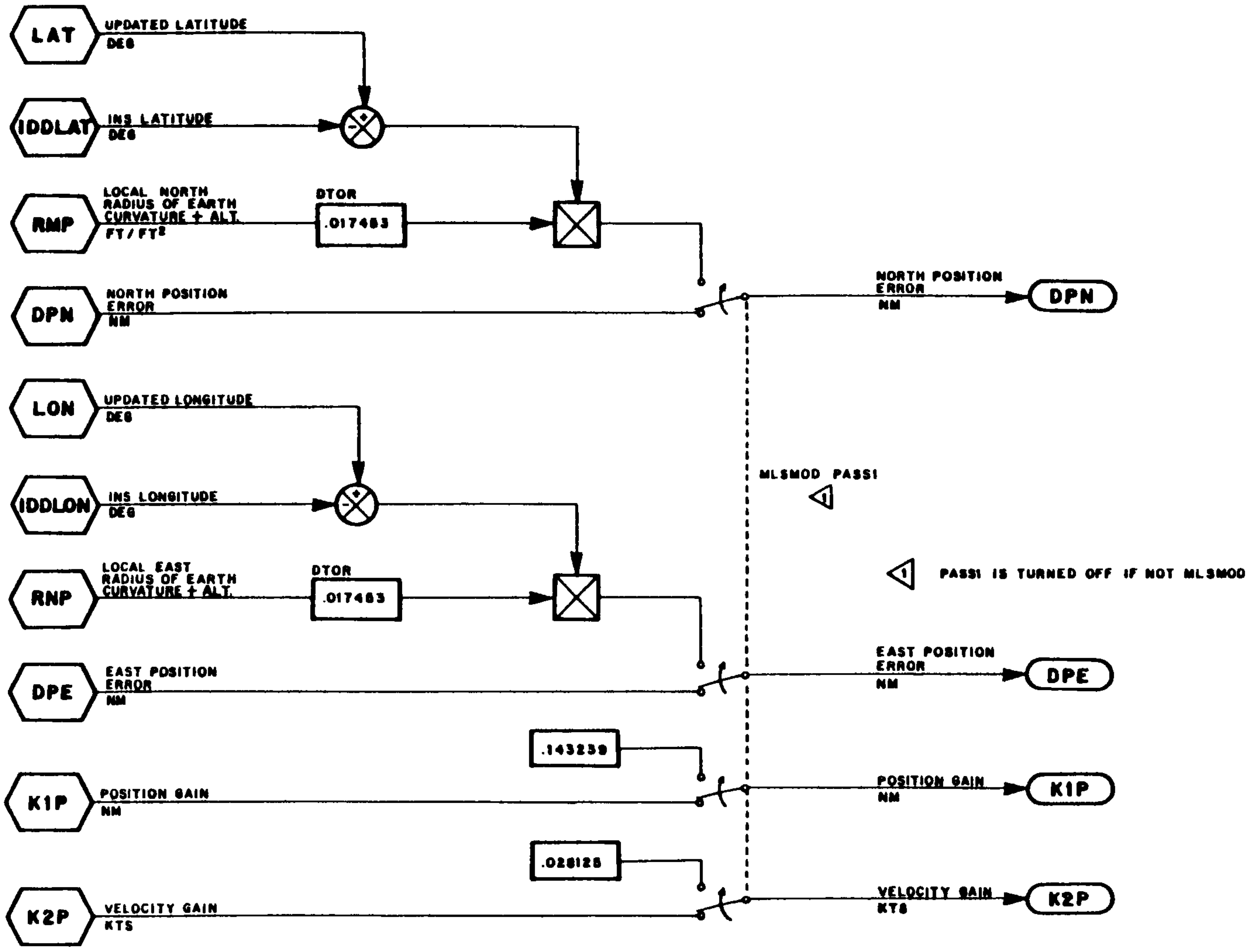
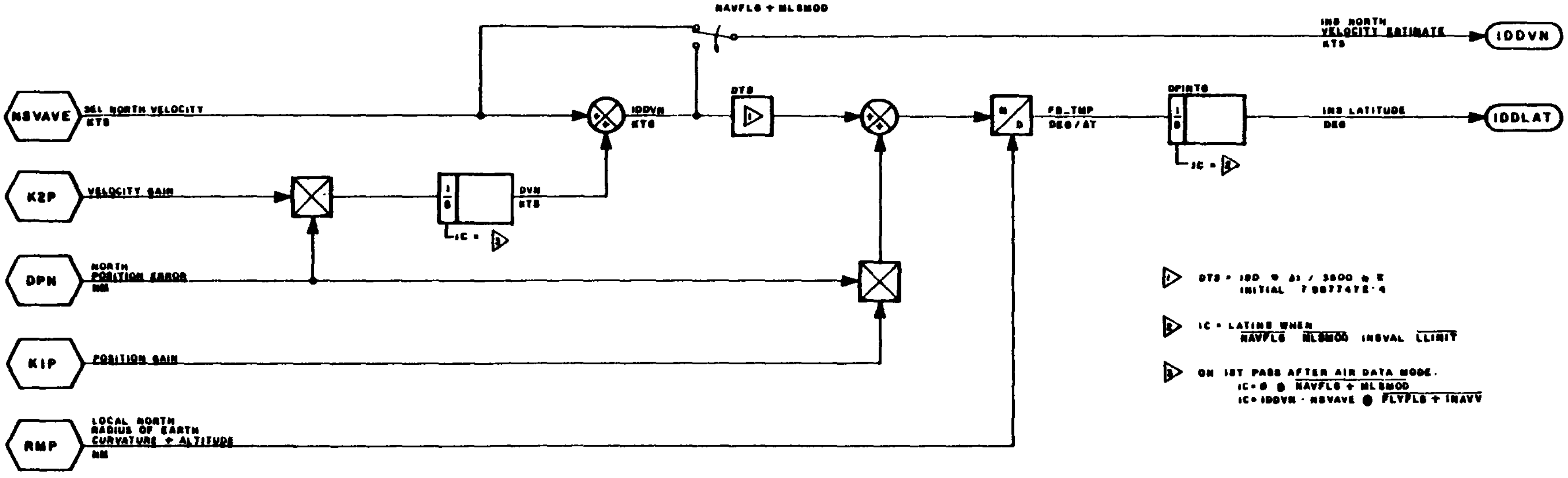


PROCEDURE HNAVB (HNAVFS)

PAGE 1 OF 4

UPDATE CALCULATIONS. FOLLOWING SIGNAL SELECTION PROCESS, HNAVB IS CALLED UNCONDITIONALLY. PROCEDURE HNAVML IS NEXT CALLED IF MLSMOD IS TRUE

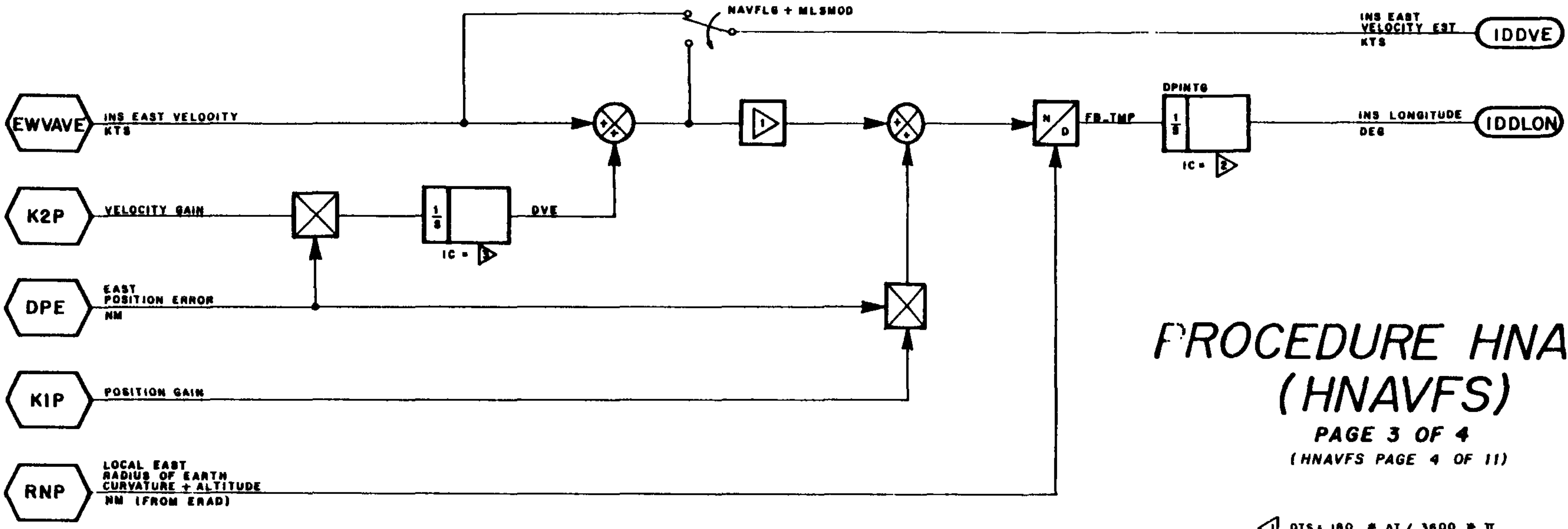
LATITUDE UPDATE CALCULATIONS:



PROCEDURE HNAVB (HNAVFS)

PAGE 2 OF 4

LONGITUDE UPDATE CALCULATIONS:



PROCEDURE HNAVB (HNAVFS)

PAGE 3 OF 4

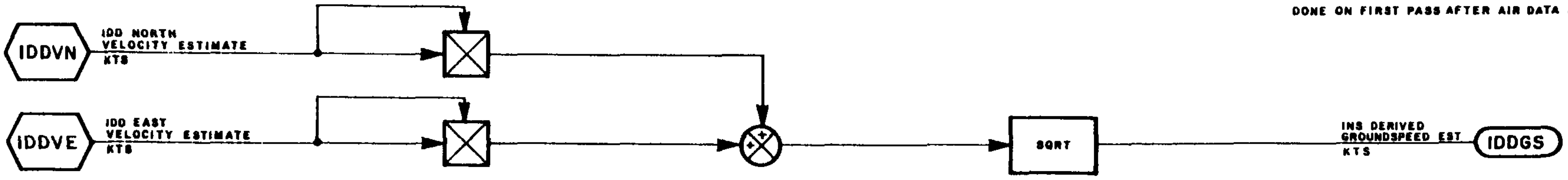
(HNAVFS PAGE 4 OF 11)

1. DTS = 180 * ΔT / 3600 * π
INITIAL 7 957747E-4

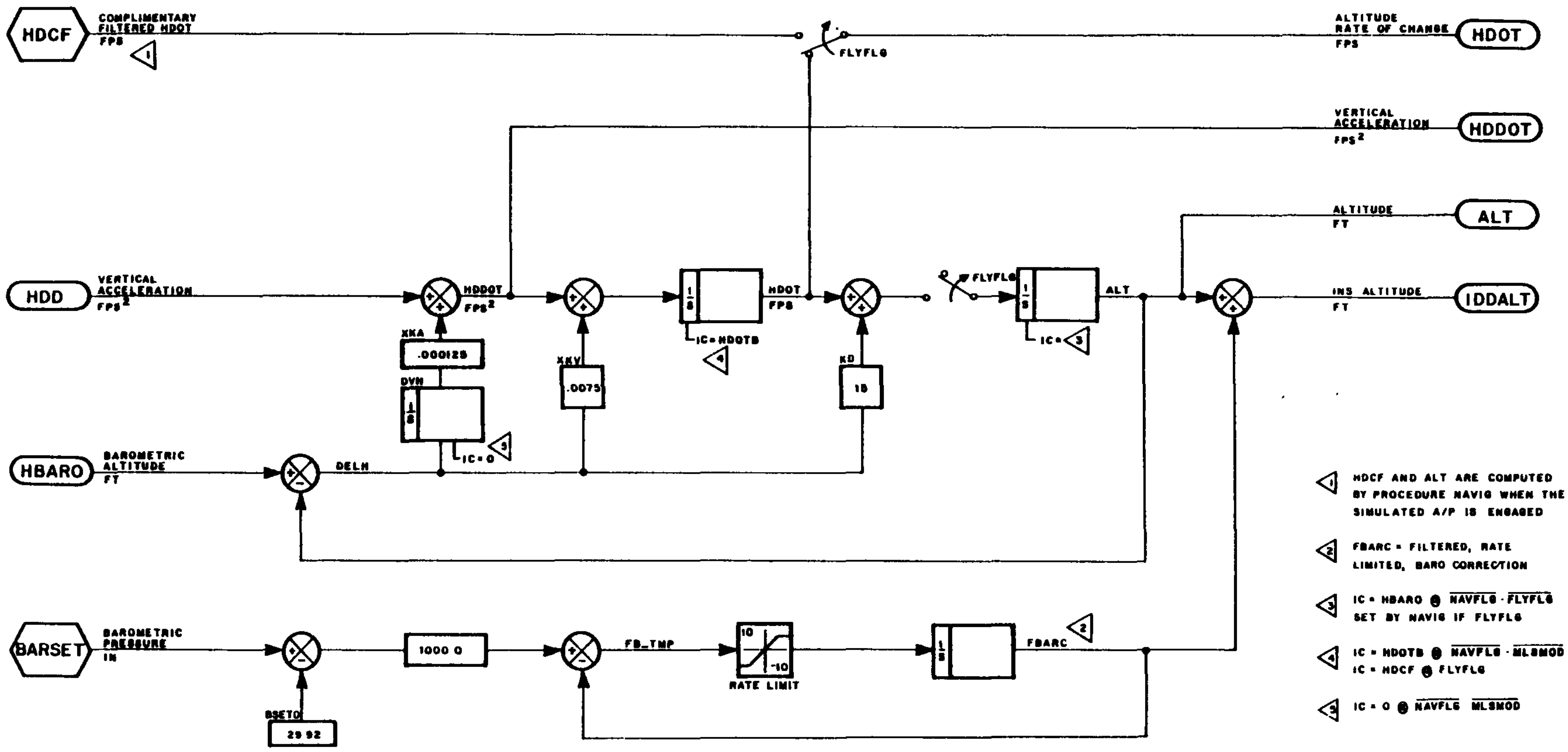
2. IC = LONINS WHEN
$\overline{NAVFLG}$ · $\overline{MLSMOD}$ INSVAL · $\overline{LLINIT}$

3. IC = 0 @ $\overline{NAVFLG}$ $\overline{MLSMOD}$
IC = IDDVE − EWVAVE @ $\overline{FLYFLG + INAVV}$
DONE ON FIRST PASS AFTER AIR DATA MODE

GROUNDSPEED UPDATE CALCULATIONS:


IDDVN
IDD NORTH VELOCITY ESTIMATE KTS
IDDVE
IDD EAST VELOCITY ESTIMATE KTS
SQRT
INS DERIVED GROUNDSPEED EST KTS
IDDGS

VERTICAL UPDATE CALCULATIONS:



1 HDCF AND ALT ARE COMPUTED BY PROCEDURE NAVIG WHEN THE SIMULATED A/P IS ENGAGED

2 FBARC = FILTERED, RATE LIMITED, BARO CORRECTION

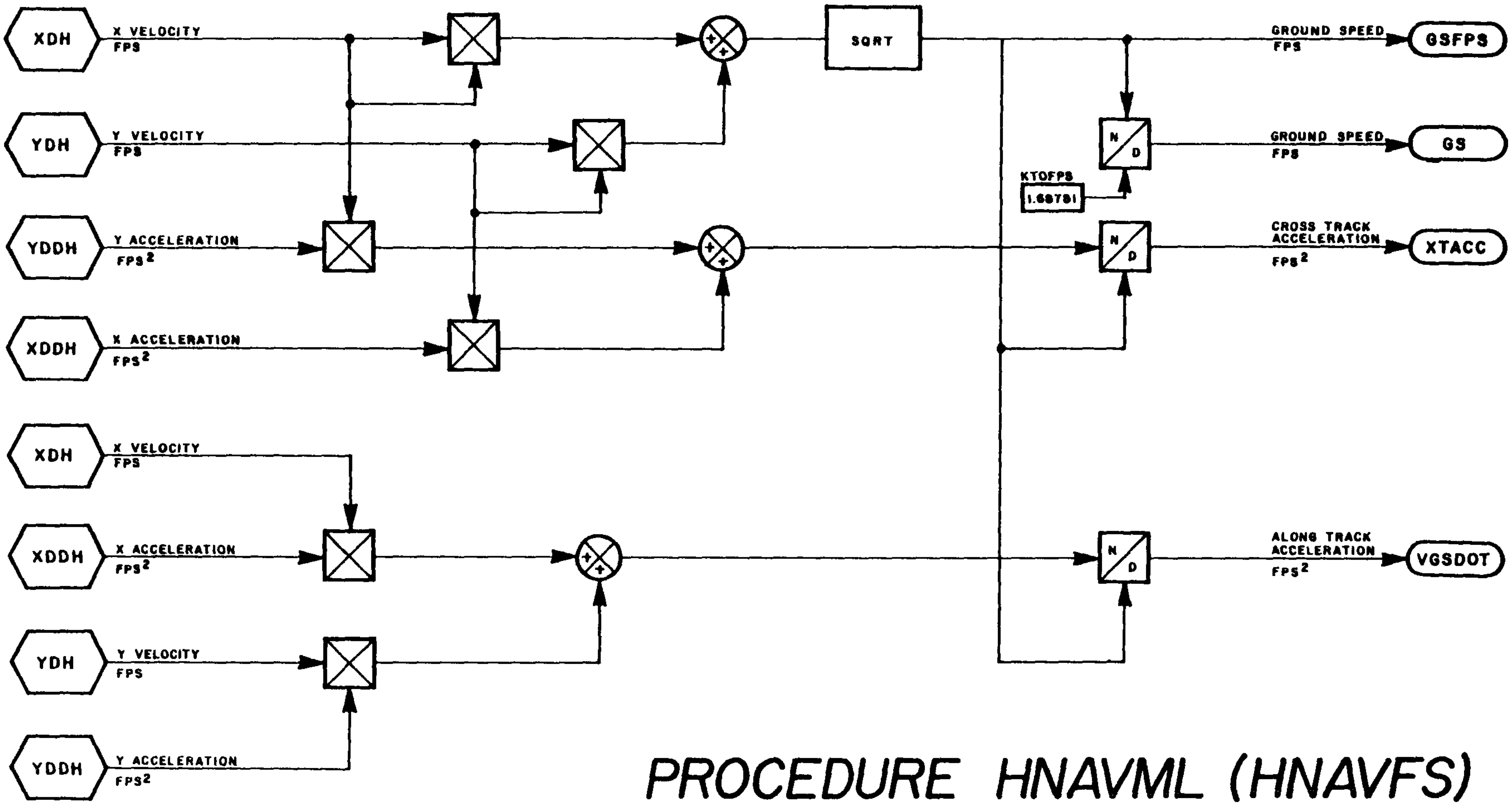
3 IC = HBARO @ $\overline{NAVFLG}$ · $\overline{FLYFLG}$
SET BY NAVIG IF FLYFLG

4 IC = HDOTB @ $\overline{NAVFLG}$ · $\overline{MLSMOD}$
IC = HDCF @ FLYFLG

5 IC = 0 @ $\overline{NAVFLG}$ $\overline{MLSMOD}$

PROCEDURE HNAVB (HNAVFS)

PAGE 4 OF 4
(HNAVFS PAGE 5 OF 11)

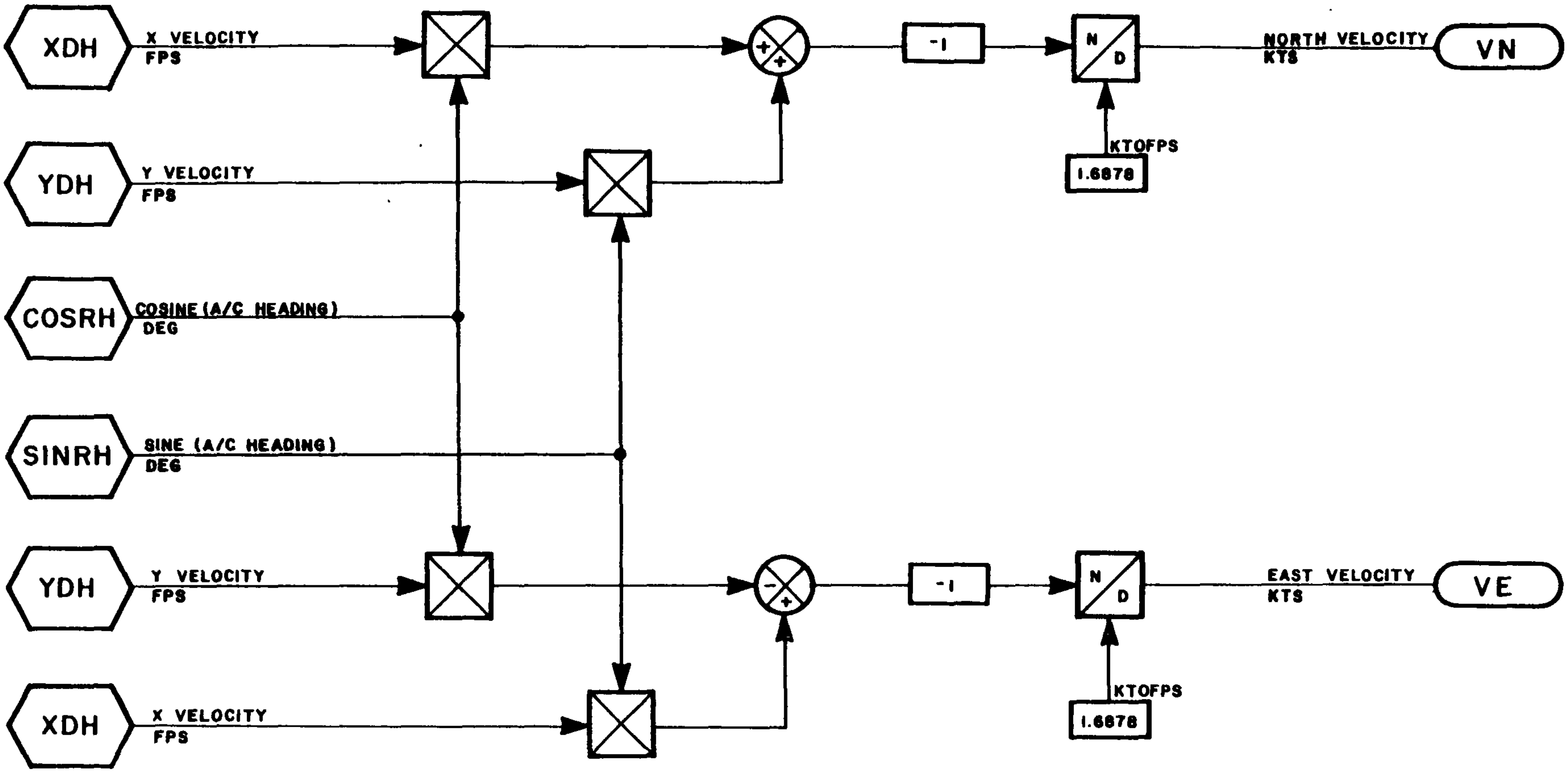


PROCEDURE HNAVML (HNAVFS)

PAGE 1 OF 4

(HNAVML IS CALLED AFTER HNAVB, IF MLSMOD IS TRUE)

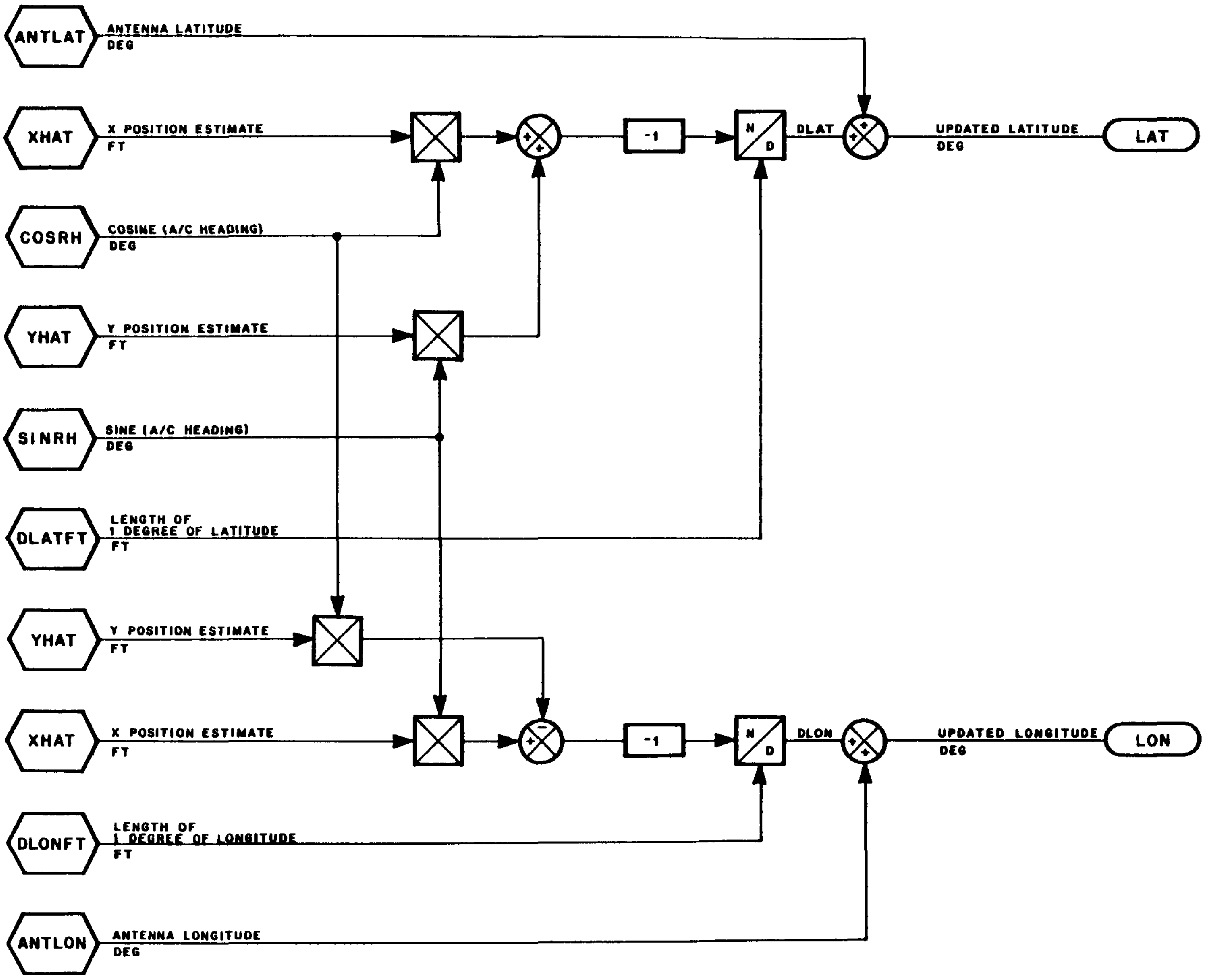
(HNAVFS PAGE 6 OF 11)



PROCEDURE HNAVML (HNAVFS)

PAGE 2 OF 4

(HNAVFS PAGE 7 OF 11)



PROCEDURE HNAVML (HNAVFS)

PAGE 3 OF 4
(HNAVFS PAGE 8 OF 11)

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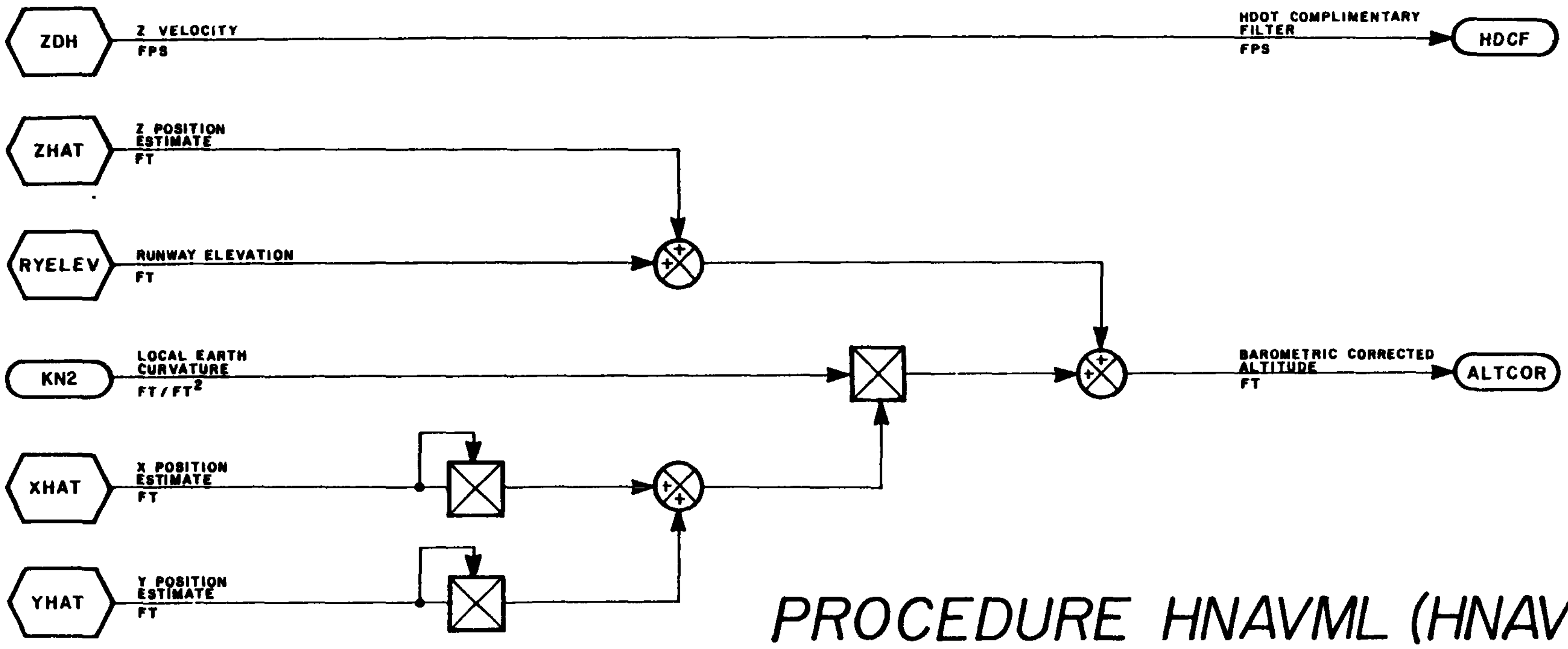
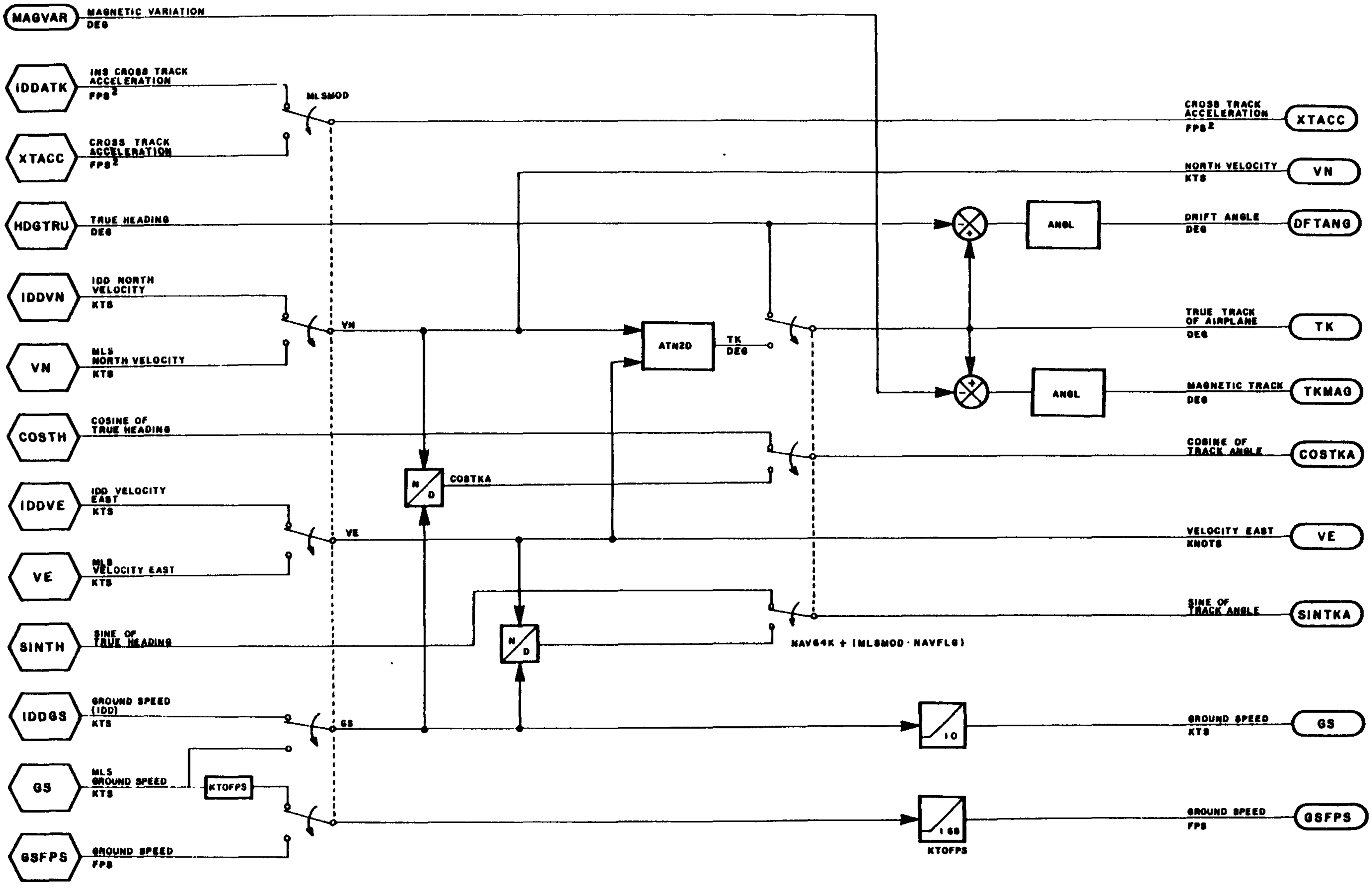


PROCEDURE HNAVML (HNAVFS)

PAGE 4 OF 4
(HNAVFS PAGE 9 OF 11)

OUTPUT SELECTION: SELECT HNAVML OR HNAVB OUTPUTS AS SOURCES AND PERFORM FINAL CALCULATIONS



PROCEDURE HNAVFS

PAGE 10 OF 11

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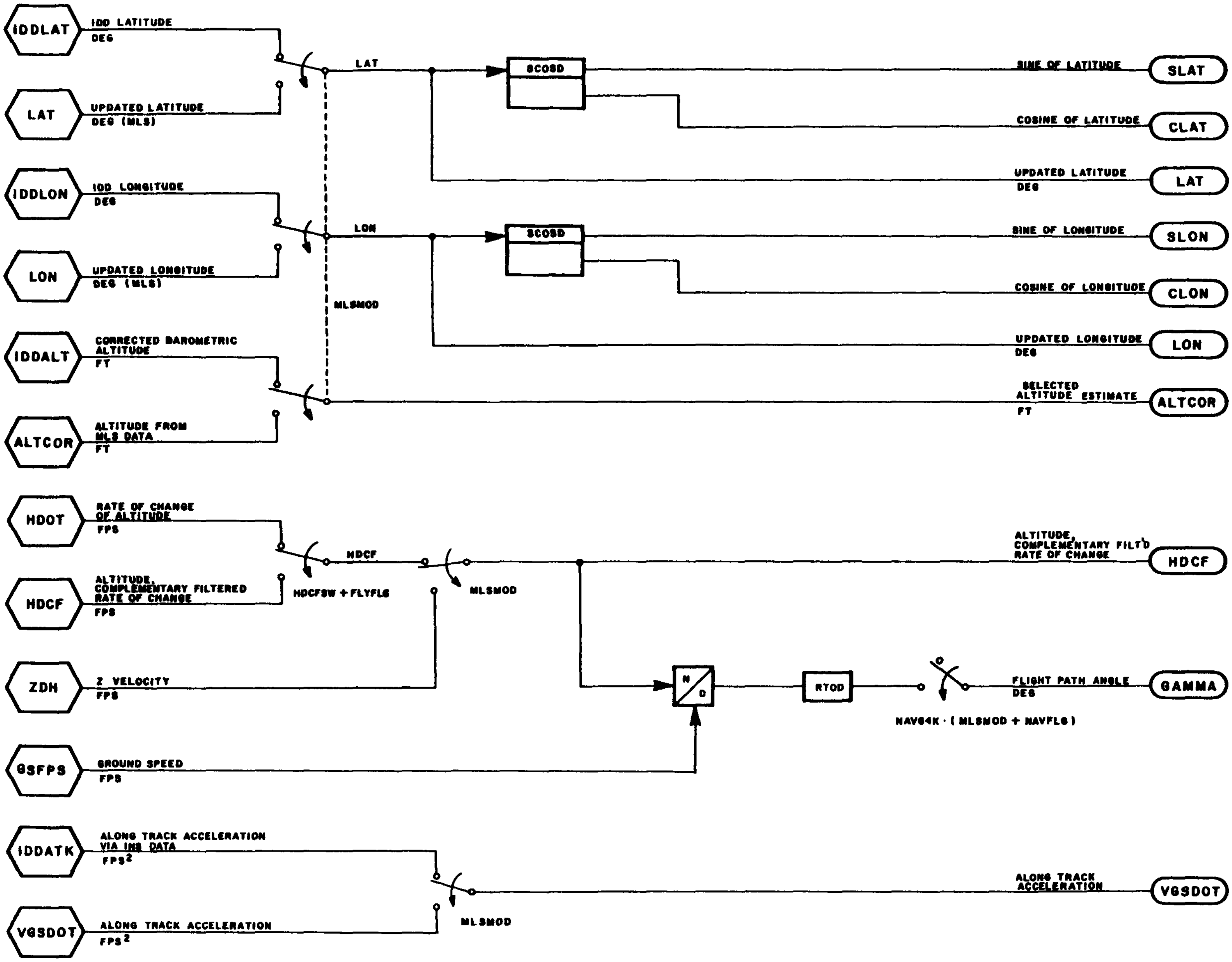
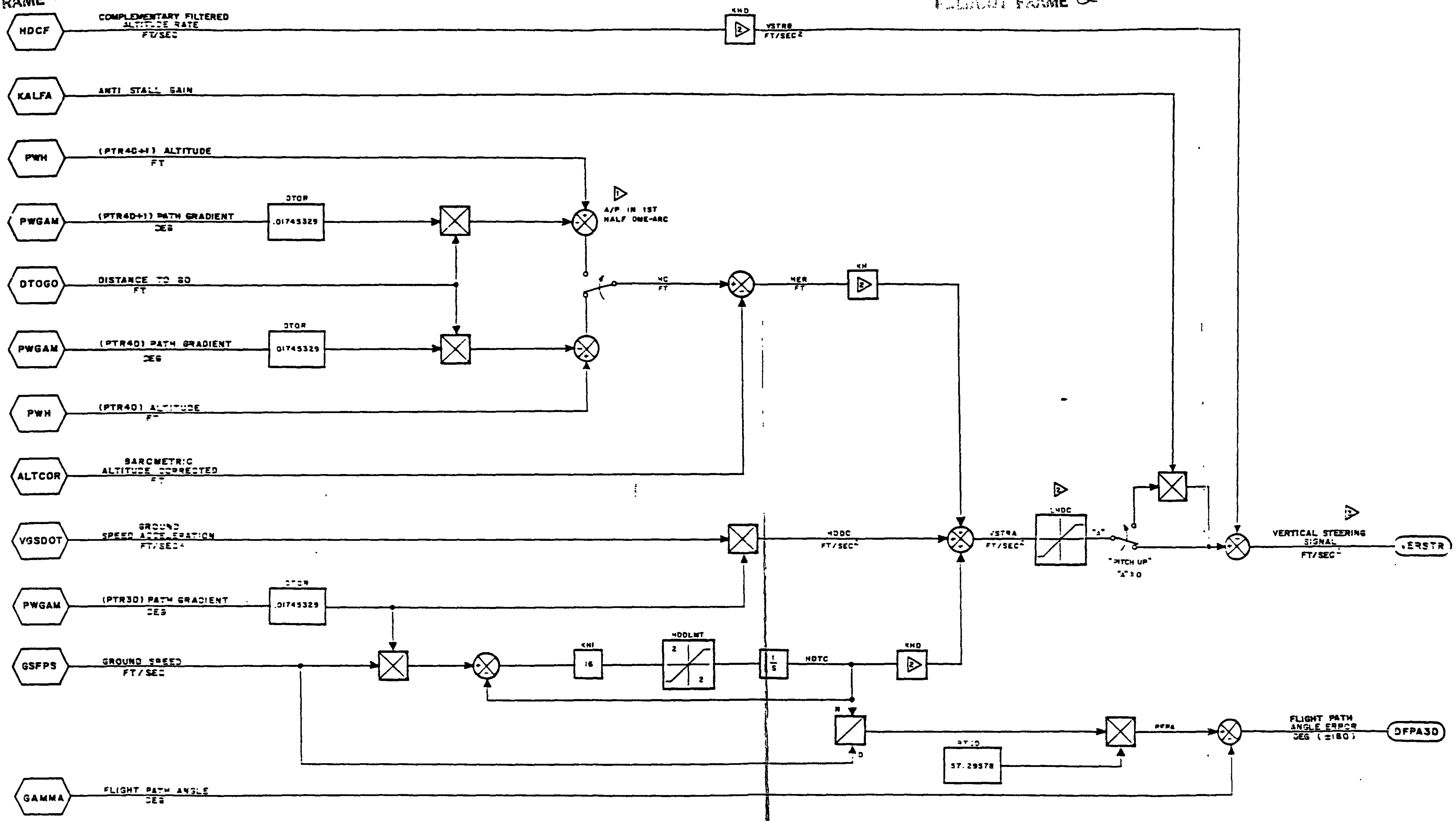


PROCEDURE HNAVFS

PAGE 11 OF 11

FOLDOUT FRAME 1

FOLDOUT FRAME 2



1. THE LOGIC FOR DETERMINING IF THE AIRPLANE IS IN THE 1ST HALF OF A DME ARC IS: ACTIVE.PWDMA (PTR4D) ON AND TURN AND $\overline{\text{TEND}}$

2. THE VALUES OF KH, KHD, AND LHDC DEPEND ON THE AUTO DISCRETE
IF AUTOE IS SET (-1) THEN KH=.09 KHD=.6 LHDC=50 * KHD
IF AUTOE IS NOT SET (0) THEN KH=.000625 KHD=.05 LHDC=50 * KHD

3. THE EQUATION IMPLEMENTED IS: $\ddot{H}_C = K_H(\Delta H) + K_{\dot{H}}(\Delta\dot{H}) + \ddot{H}$
VSTRA = KH(HER) + KHD(HDTC) + HDDC
VSTRB = KHD(HDCF)
VERSTR = VSTRA - VSTRB

HVG6 SUBROUTINE

VERTICAL STEERING COMPUTATIONS

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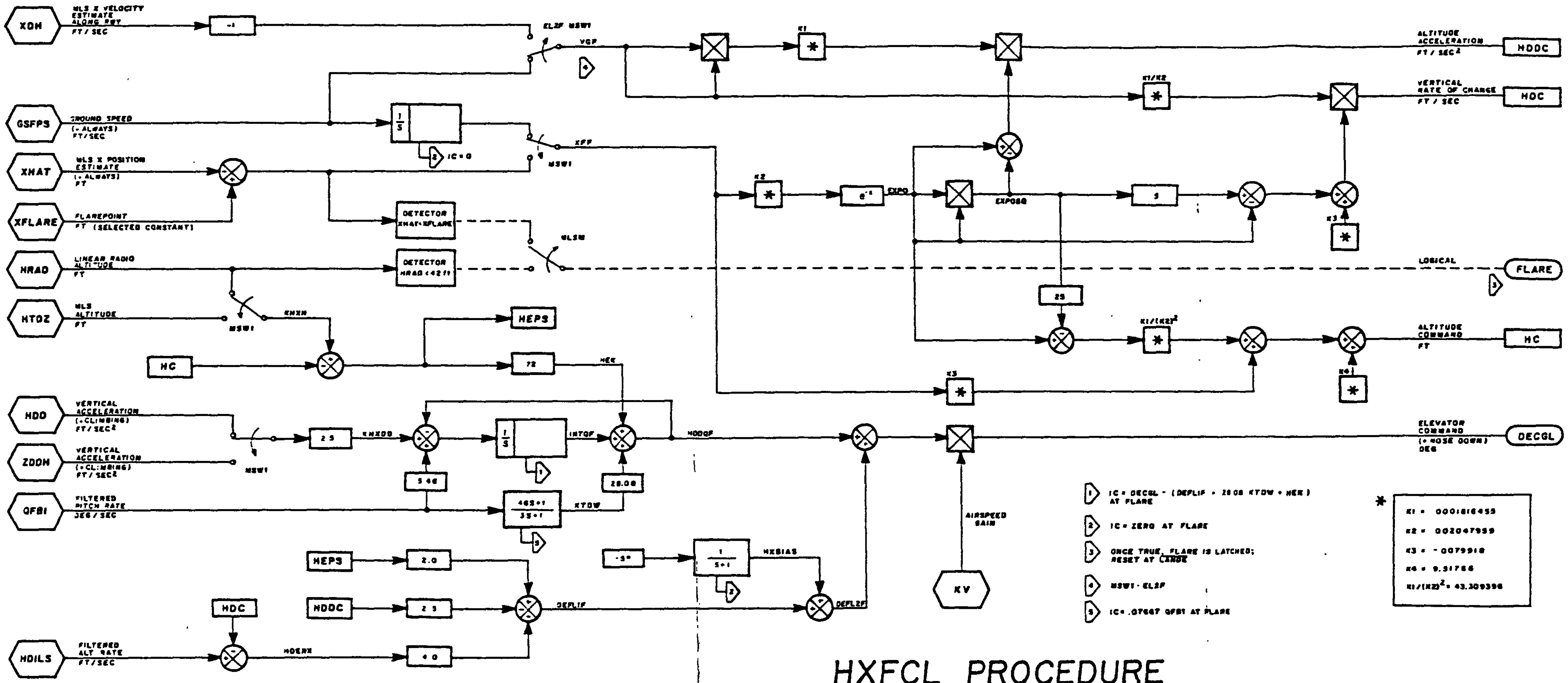
FOLDOUT FRAME 2.



1. IC = DECGL - (DEFLIF + 28.08 KTDW + HEK) AT FLARE
2. IC = ZERO AT FLARE
3. ONCE TRUE, FLARE IS LATCHED; RESET AT LANDE
4. MSW1 · EL2F
5. IC = .07667 QFBI AT FLARE

*

K1 = .0001816455

K2 = .002047959

K3 = -.0079918

K4 = 9.51766

K1/(K2)² = 43.309396

HXFCL PROCEDURE

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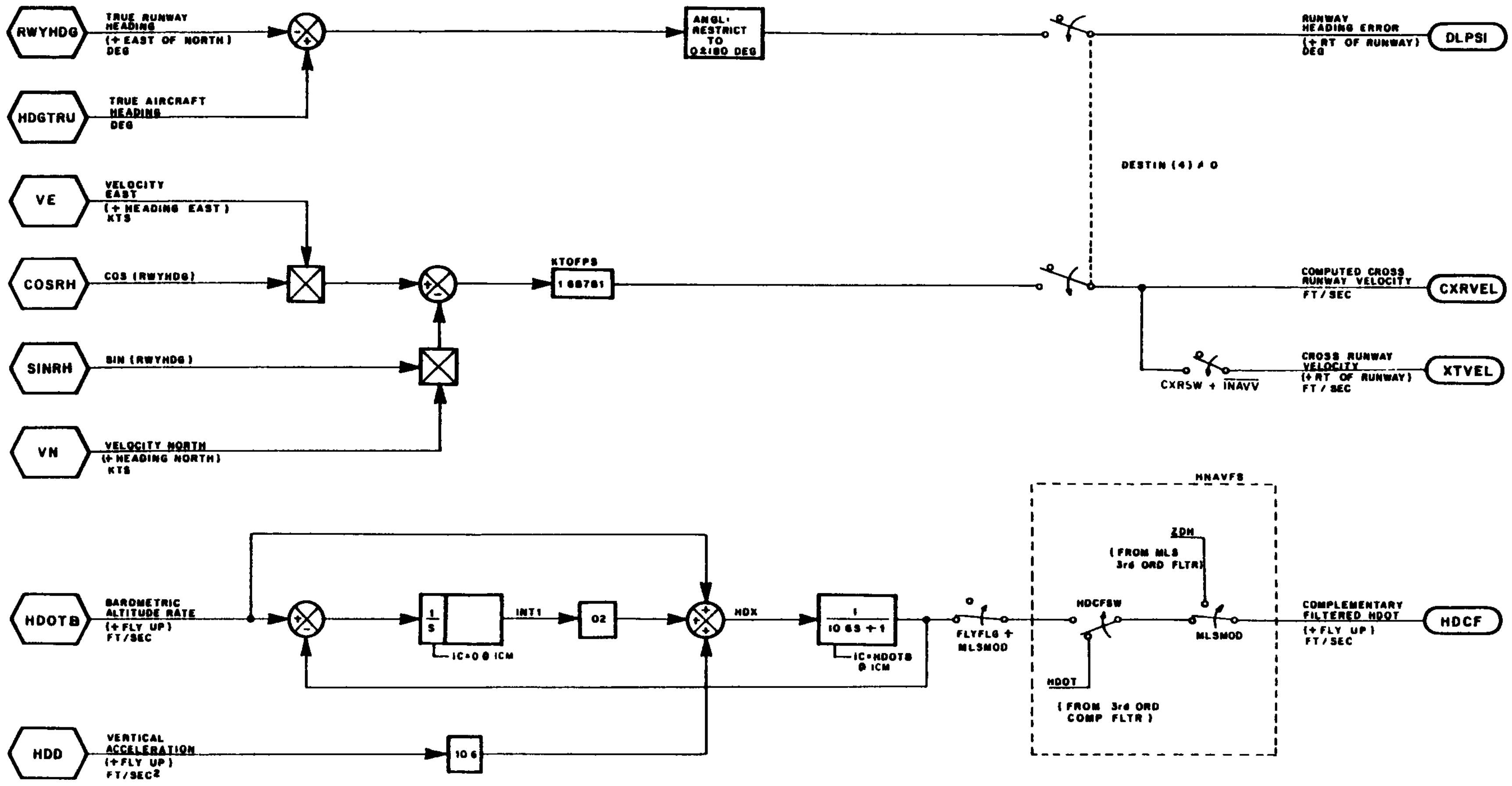

MLOG PROCEDURE
(LAND COMPUTATIONS)
PAGE 1 OF 2

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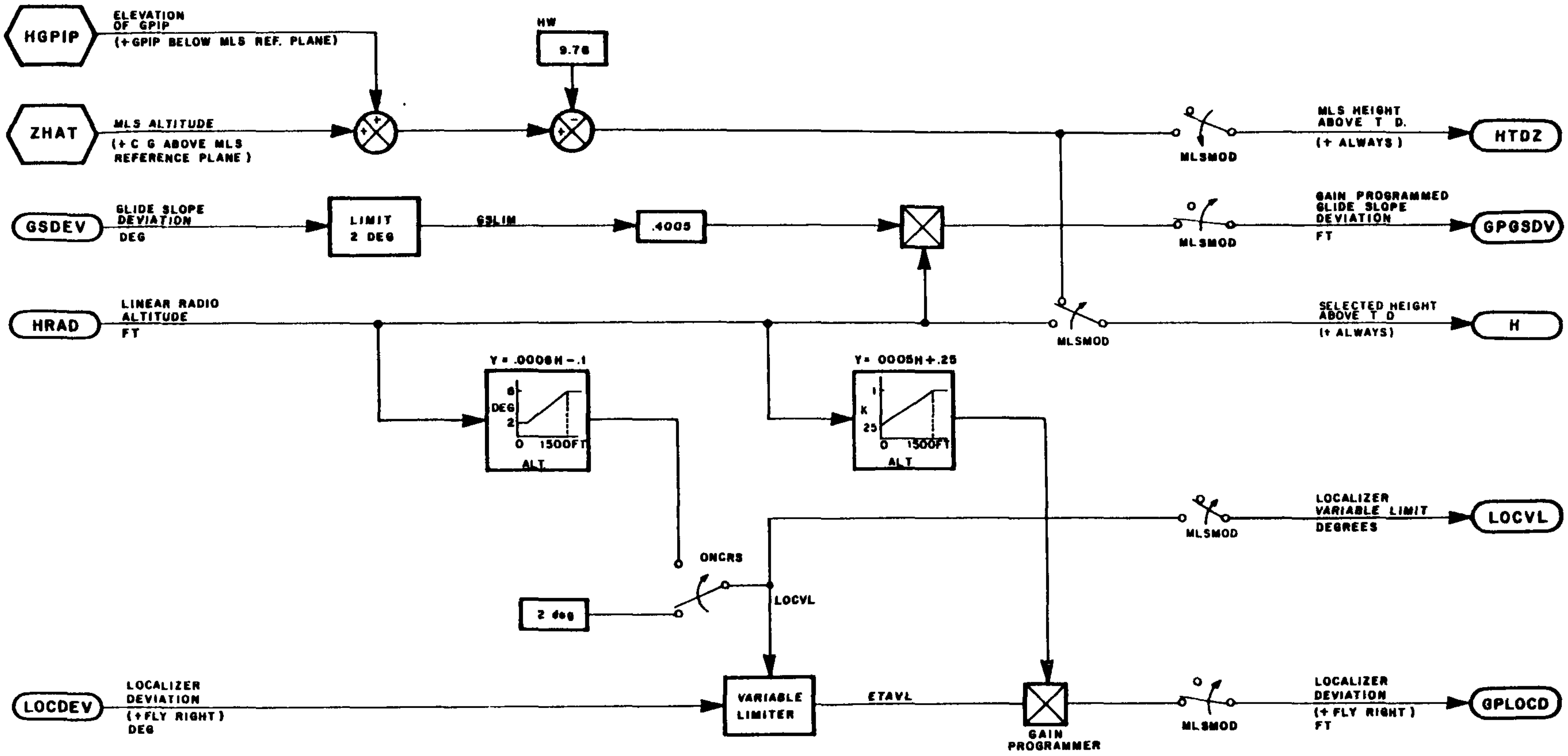

MLOG PROCEDURE

(LAND COMPUTATIONS)

PAGE 2 OF 2

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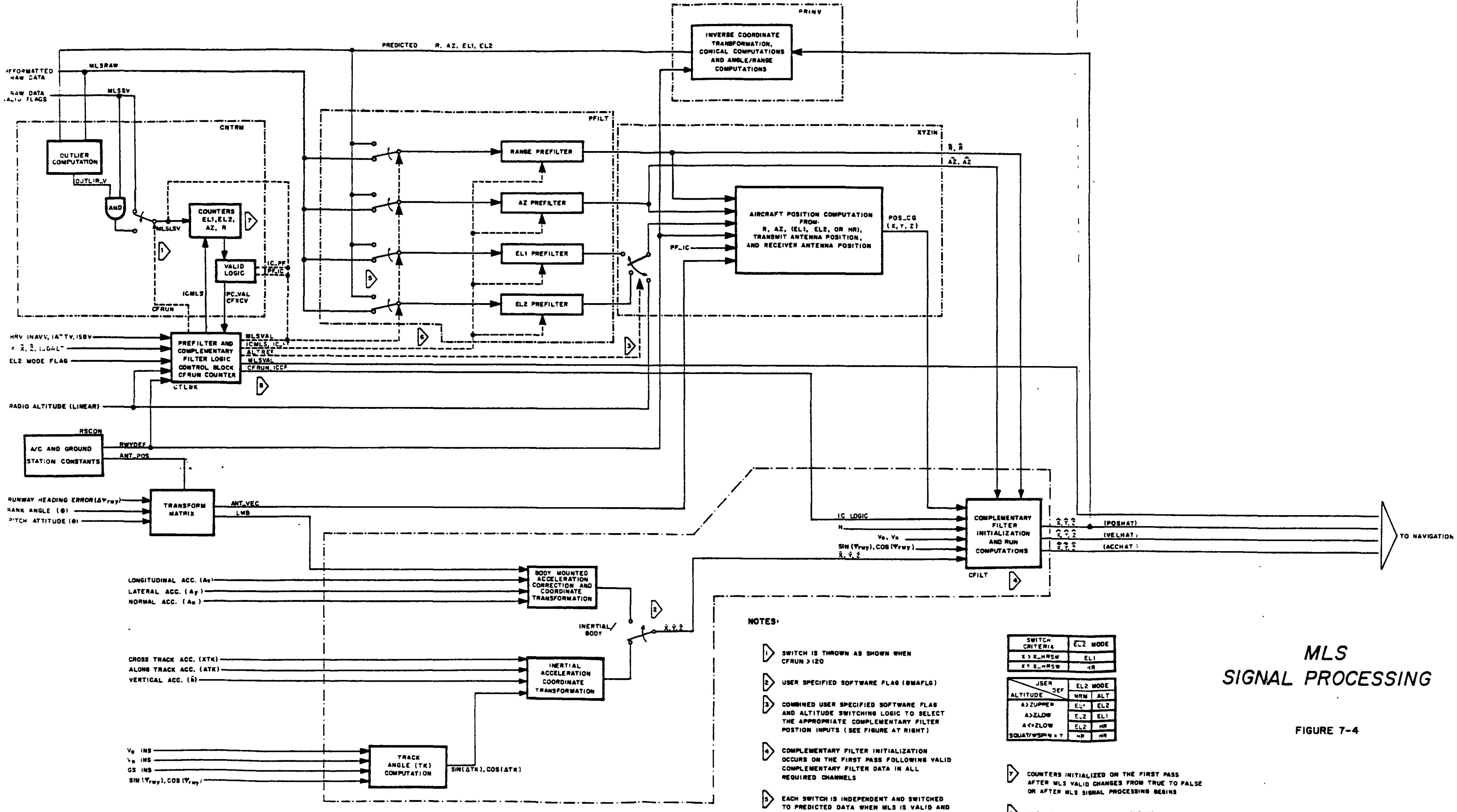
FOLDOUT FRAME 2.



NOTES:

1. SWITCH IS THROWN AS SHOWN WHEN CFRUN > 120

2. USER SPECIFIED SOFTWARE FLAG (BMAFLG)

3. COMBINED USER SPECIFIED SOFTWARE FLAG AND ALTITUDE SWITCHING LOGIC TO SELECT THE APPROPRIATE COMPLEMENTARY FILTER POSTION INPUTS (SEE FIGURE AT RIGHT)

4. COMPLEMENTARY FILTER INITIALIZATION OCCURS ON THE FIRST PASS FOLLOWING VALID COMPLEMENTARY FILTER DATA IN ALL REQUIRED CHANNELS

5. EACH SWITCH IS INDEPENDENT AND SWITCHED TO PREDICTED DATA WHEN MLS IS VALID AND THE OUTLIER IS EXCEEDED

6. EACH PREFILTER IS INITIALIZED ON THE FIRST PASS AFTER ICMLS OR IC_PF BECOMES TRUE

SWITCH CRITERIA	$\overline{EL2}$ MODE
X > X_HRSW	EL1
X ≤ X_HRSW	HR

USER DEF / ALTITUDE	EL2 MODE	
	NRM	ALT
A>ZUPPER	EL1	EL2
A>ZLOW	EL2	EL1
A<=ZLOW	EL2	HR
SQUAT/WSPIN = T	HR	HR

7. COUNTERS INITIALIZED ON THE FIRST PASS AFTER MLS VALID CHANGES FROM TRUE TO FALSE OR AFTER MLS SIGNAL PROCESSING BEGINS

8. MLS VALID SET TO FALSE WHENEVER MLS SIGNAL PROCESSING NOT EXECUTED

MLS
SIGNAL PROCESSING

FIGURE 7-4

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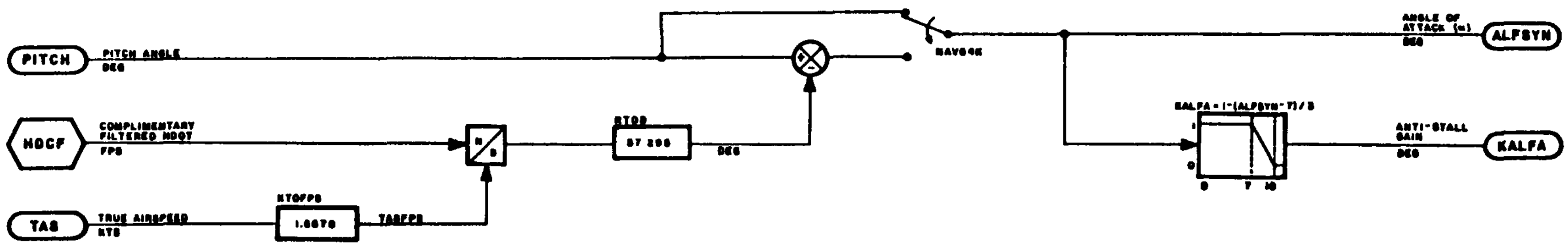
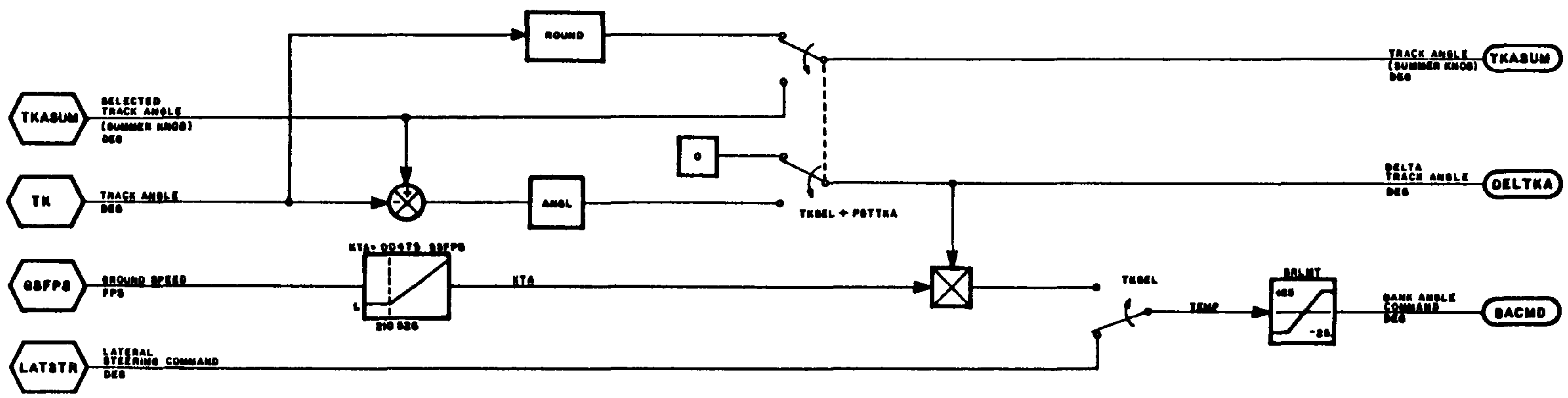
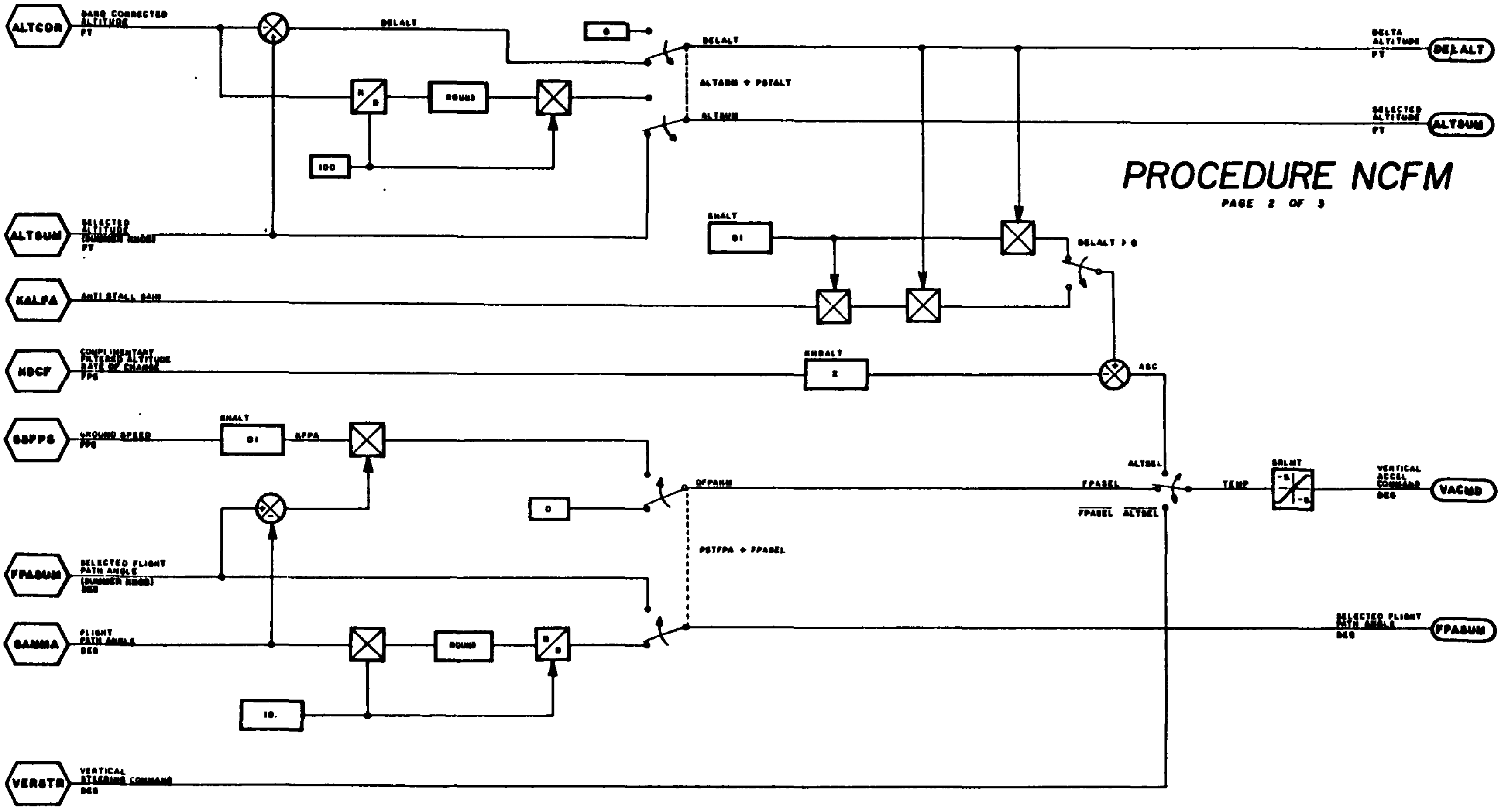


HORIZONTAL MODE CALCULATIONS:



PROCEDURE NCFM

PAGE 1 OF 3



PROCEDURE NCFM

PAGE 2 OF 3

VERTICAL MODE CALCULATIONS

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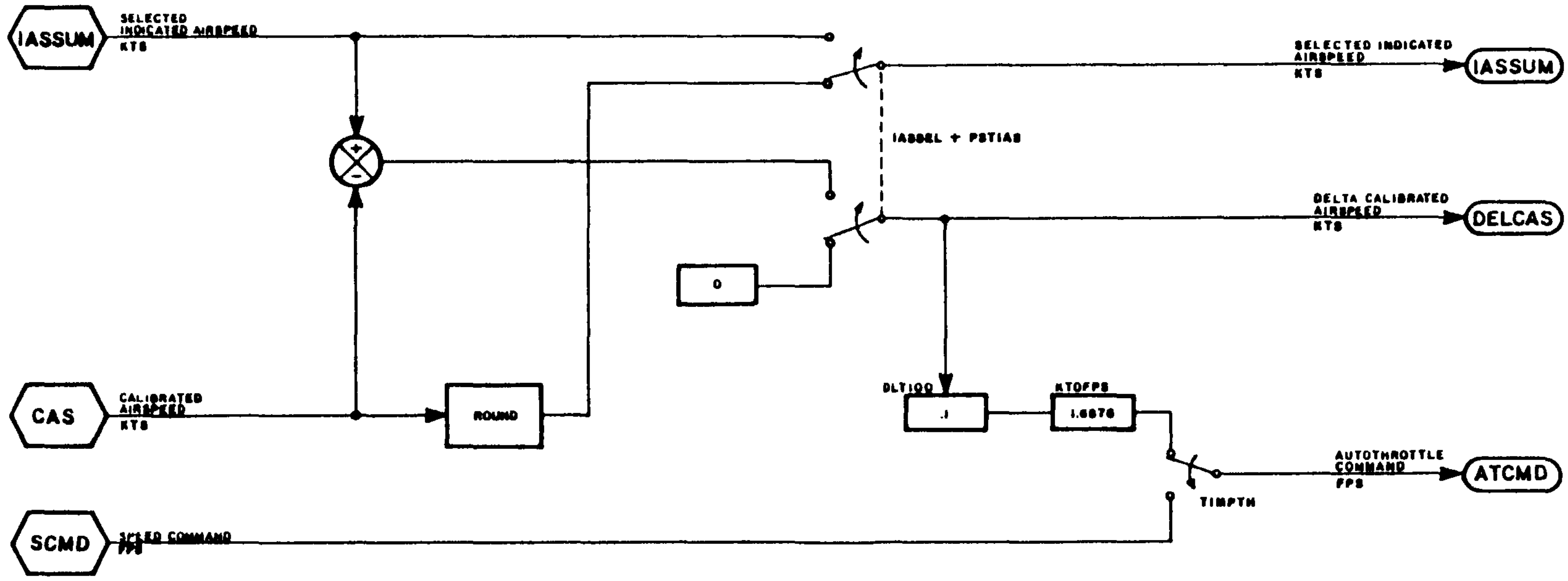

PROCEDURE NCFM

PAGE 3 OF 3

FOLDOUT FRAME 1

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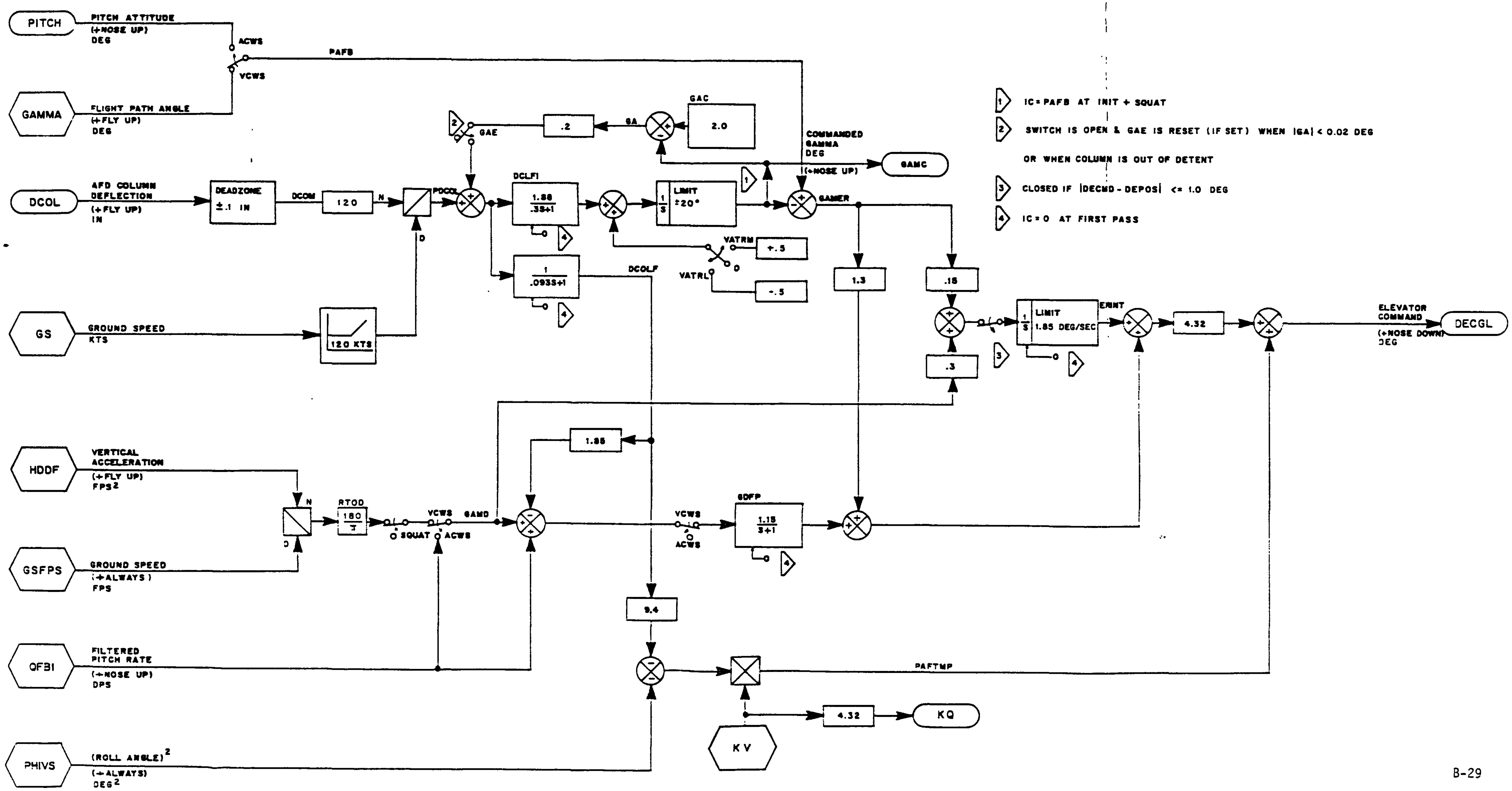
PAFD PROCEDURE

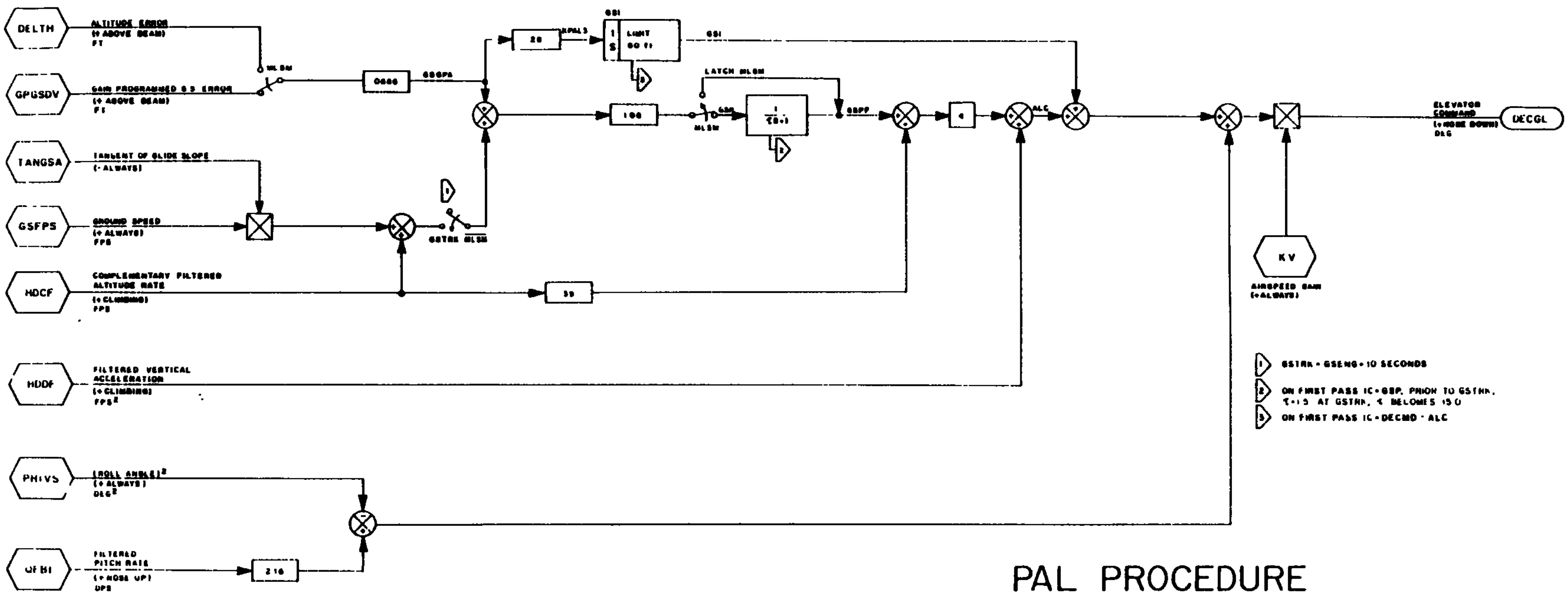


1 IC = PAFB AT INIT + SQUAT

2 SWITCH IS OPEN & GAE IS RESET (IF SET) WHEN |GA| < 0.02 DEG OR WHEN COLUMN IS OUT OF DETENT

3 CLOSED IF |DECMD - DEPOS| <= 1.0 DEG

4 IC = 0 AT FIRST PASS



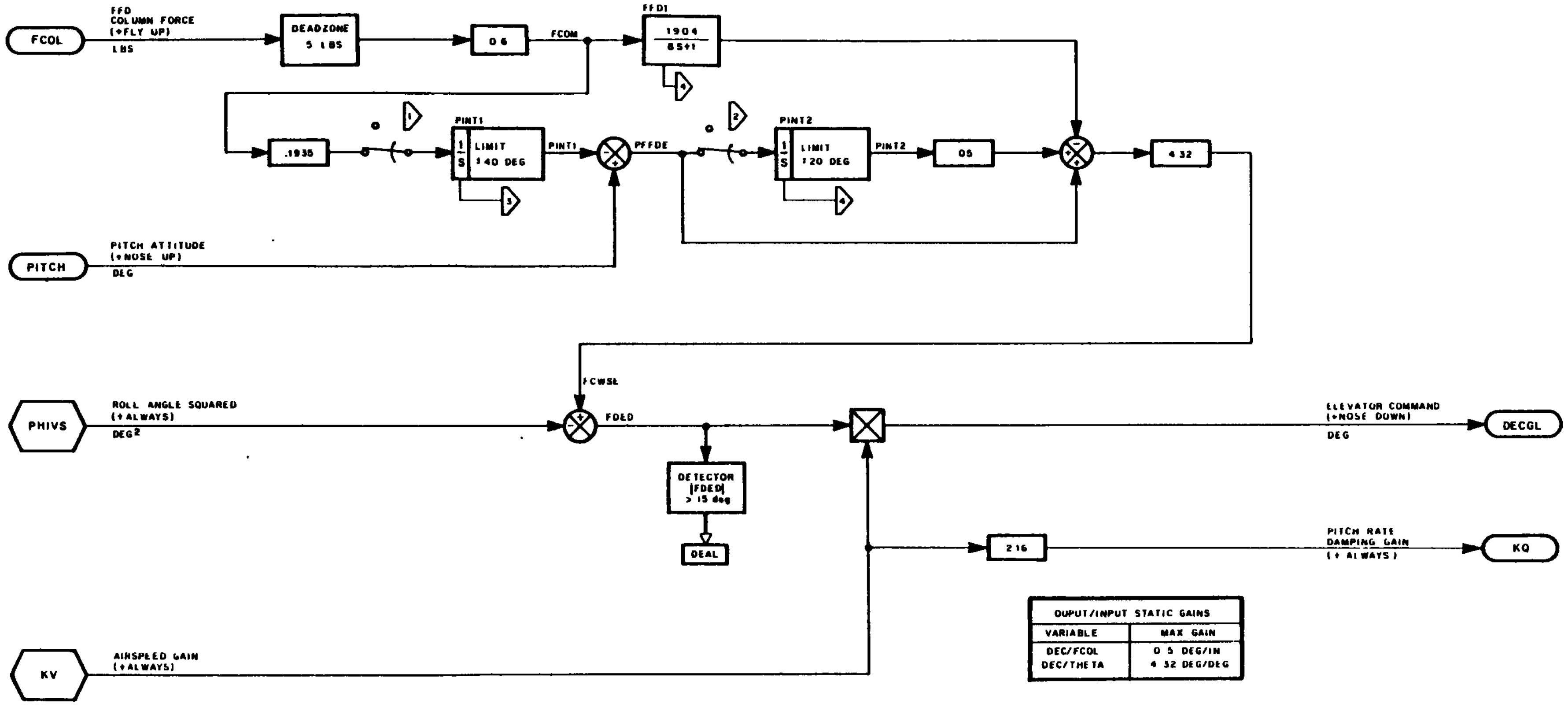
1 GSTRK = GSENG + 10 SECONDS

2 ON FIRST PASS IC = GSP. PRIOR TO GSTRK, τ = 1.5 AT GSTRK, τ BECOMES 15.0

3 ON FIRST PASS IC = DECMD - ALC

PAL PROCEDURE

PFFD PROCEDURE



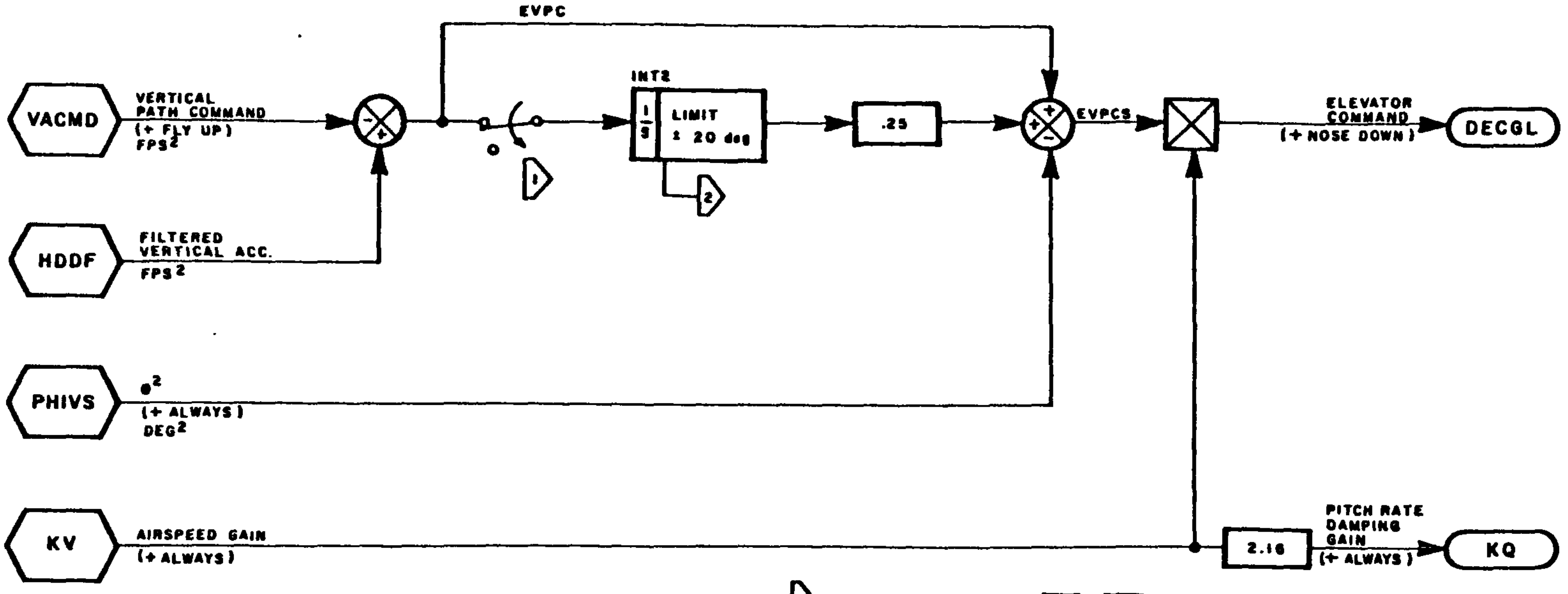
OUPUT/INPUT STATIC GAINS	
VARIABLE	MAX GAIN
DEC/FCOL	0 5 DEG/IN
DEC/THETA	4 32 DEG/DEG

1 OPEN AT (DEAL $\overline{\text{FIRST PASS}}$)

2 OPEN AT ((PCWOD+(PHICMD>5 DEG)) $\overline{\text{FIRST PASS}}$)

3 IC=PITCH AT FIRST PASS

4 IC=0 AT FIRST PASS


EVPC
VACMD
VERTICAL PATH COMMAND (+ FLY UP) FPS^2
INT2
$\frac{1}{S}$
LIMIT ± 20 deg
.25
EVPCS
ELEVATOR COMMAND (+ NOSE DOWN)
DECGL
1
2
HDDF
FILTERED VERTICAL ACC. FPS^2
PHIVS
ϕ^2 (+ ALWAYS) DEG^2
KV
AIRSPEED GAIN (+ ALWAYS)
2.16
PITCH RATE DAMPING GAIN (+ ALWAYS)
KQ

PVPC PROCEDURE

1 INTEGRATE AT AUTO · $\overline{\text{INIT}}$ · $\overline{\text{HOLD}}$

HOLD AT TRIMT · (SIGN (EVPC) = SIGN (INT2))

2 IC TO ZERO ON FIRST PASS

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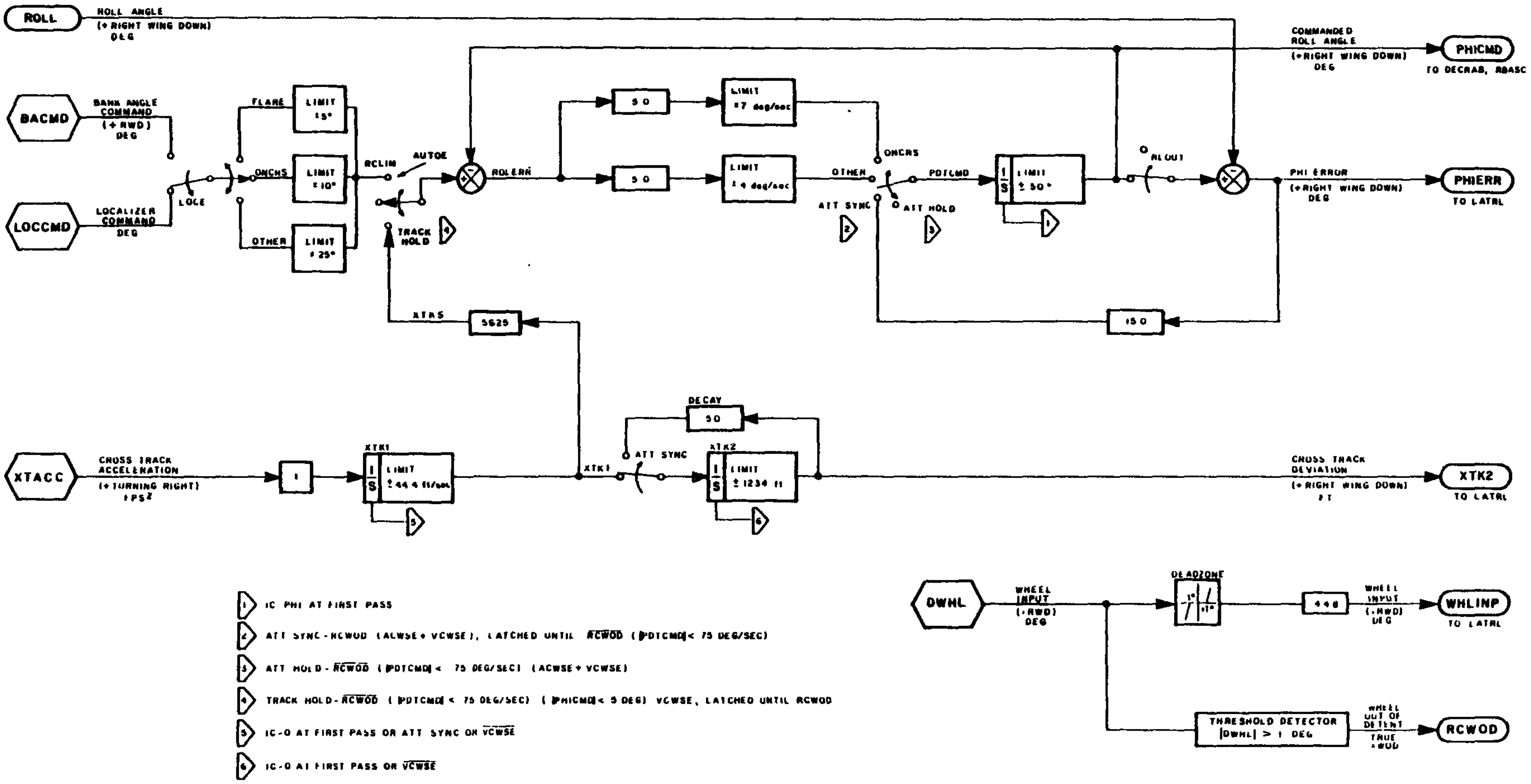
RCOM SUBROUTINE

ROLL COMPUTER



1 IC PHI AT FIRST PASS

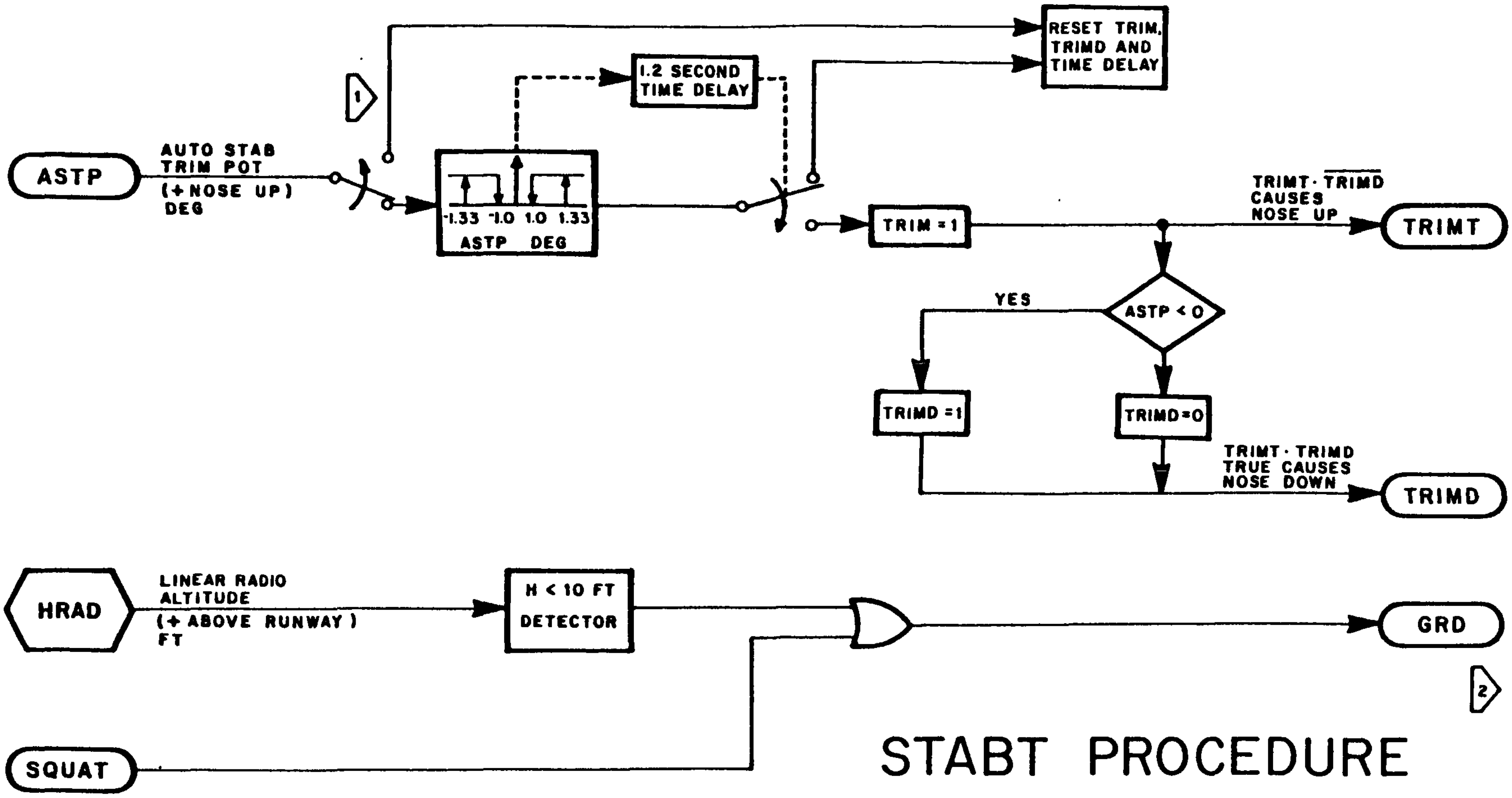
2 ATT SYNC - RCWOD (ACWSE + VCWSE), LATCHED UNTIL $\overline{\text{RCWOD}}$ (|PDTCMD| < 75 DEG/SEC)

3 ATT HOLD - $\overline{\text{RCWOD}}$ (|PDTCMD| < 75 DEG/SEC) (ACWSE + VCWSE)

4 TRACK HOLD - $\overline{\text{RCWOD}}$ (|PDTCMD| < 75 DEG/SEC) (|PHICMD| < 5 DEG) VCWSE, LATCHED UNTIL RCWOD

5 IC-0 AT FIRST PASS OR ATT SYNC OR $\overline{\text{VCWSE}}$

6 IC-0 AT FIRST PASS OR $\overline{\text{VCWSE}}$

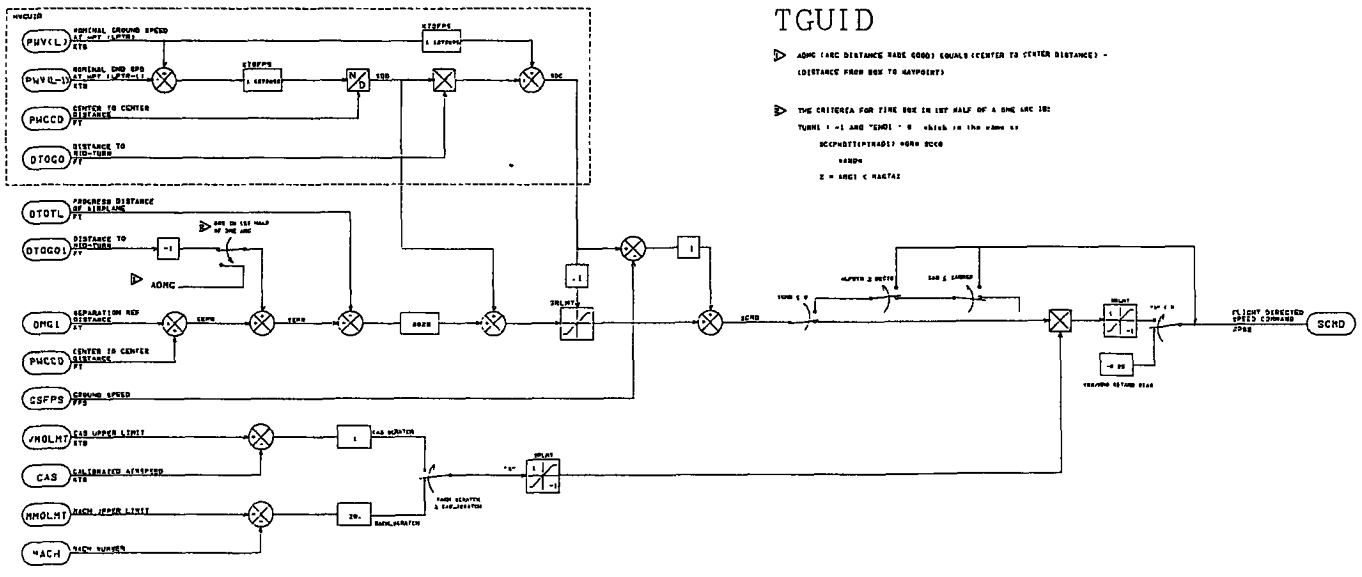


STABT PROCEDURE

1. GRD + MANEL + PRENG

2. GRD IS SET ON SQUAT, CLEARED ON HRAD>10

TGUID



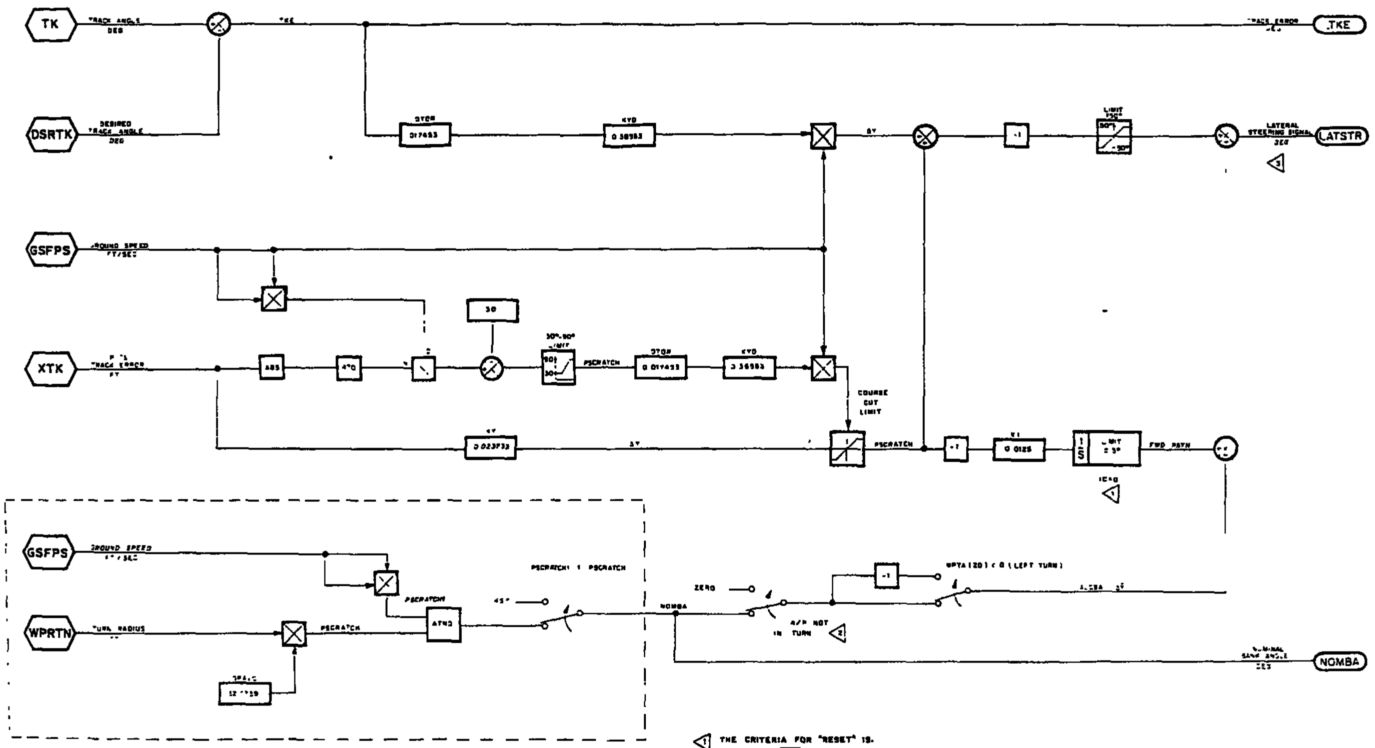
ADMG (ARC DISTANCE MADE GOOD) EQUALS (CENTER TO CENTER DISTANCE) - (DISTANCE FROM BOX TO WAYPOINT)

THE CRITERIA FOR TIME BOX IN 1ST HALF OF A DME ARC IS:
TURN1 = -1 AND TEND1 = 0 which is the same as
SC(PHDT)(PTRAD1) [illegible] SCC0
.AND.
Z = ANG1 < MAGTA1

B-35

FOLDOUT FRAME /

FOLDOUT FRAME 2



TRALCBA SUBROUTINE

LATERAL STEERING COMPUTATIONS

<1> THE CRITERIA FOR "RESET" IS.
TKSEL OR $\overline{\text{AUTO}}$ OR ((XTK(> 1000 FT) OR ((TKE(> 5 DEG)

<2> THE CRITERIA FOR THE A/P
NOT IN A TURN IS. TURN=0

<3> LATSTR = ΔY (KY) + ΔY (KYD) + $\Delta\dot{Y}$
= XTK (KY) + TKE * VGS * DTOR * KYD + ALCBA

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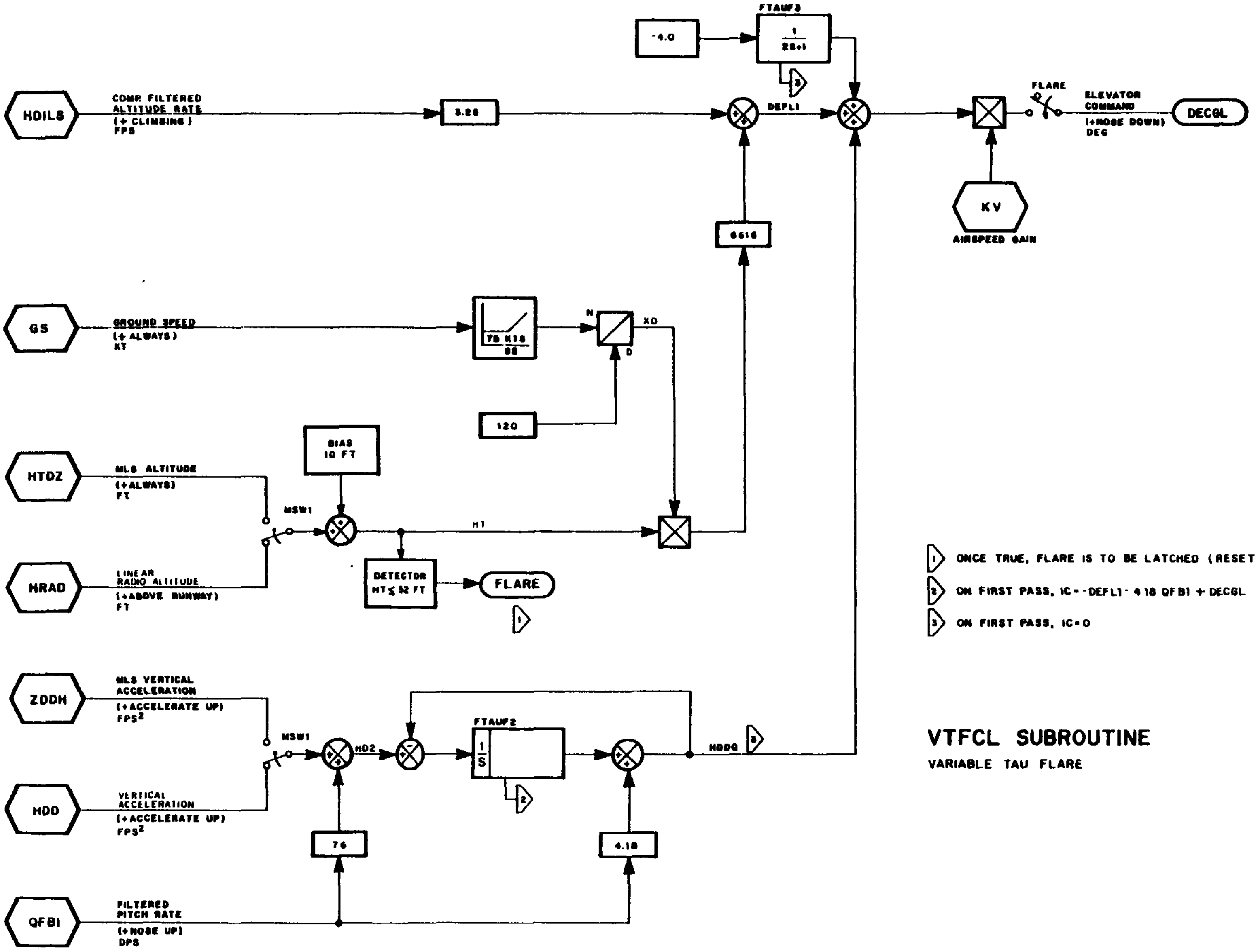

1 ONCE TRUE, FLARE IS TO BE LATCHED (RESET AT $\overline{\text{LANDE}}$)

2 ON FIRST PASS, IC = -DEFL1 - 4.18 QFBI + DECGL

3 ON FIRST PASS, IC = 0

VTFCL SUBROUTINE

VARIABLE TAU FLARE

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NASA
National Aeronautics and Space Administration

Report Documentation Page

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Langley Technical Monitor: John E. Hogge

16. Abstract

This document describes the Flight Management/Flight Controls (FM/FC) software for the Norden #2 (PDP-11/70M) computer installed on the NASA 737 airplane. The software computes the navigation position estimates, guidance commands, and those commands to be issued to the control surfaces to direct the airplane in flight based on the modes selected on the Advanced Guidance Control System (AGCS) mode panel, and the flight path selected via the Navigation Control/Display Unit (NCDU).

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Flight Management
Flight Controls

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22. Price
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Teamwork Reasoning and Multi-Satellite Missions

NASA Agreement
Investigating Teamwork Among Spacecraft
Number
NAG 2-1489
Period of Performance: 7/1/01- 4/30/02

Stacy C. Marsella
Information Sciences Institute
University of Southern California

Abstract

NASA is rapidly moving towards the use of spatially distributed multiple satellites operating in near Earth orbit and Deep Space. Effective operation of such multi-satellite constellations raises many key research issues. In particular, the satellites will be required to cooperate with each other as a team that must achieve common objectives with a high degree of autonomy from ground based operations. The multi-agent research community has made considerable progress in investigating the challenges of realizing such teamwork. In this report, we discuss some of the teamwork issues that will be faced by multi-satellite operations. The basis of the discussion is a particular proposed mission, the Magnetospheric MultiScale mission to explore Earth's magnetosphere. We describe this mission and then consider how multi-agent technologies might be applied in the design and operation of these missions. We consider the potential benefits of these technologies as well as the research challenges that will be raised in applying them to NASA multi-satellite missions. We conclude with some recommendations for future work.

Contents

1 Introduction

NASA is rapidly moving towards the use of spatially distributed multiple satellites operating in near Earth orbit and Deep Space. The satellites will be required to cooperate with each other as a *team* that must achieve common objectives with a high degree of autonomy from ground based operations. Such satellite teams will be able to perform spatially separated, synchronized observations that are currently not feasible in single satellite missions. This will enable or improve multi-point observations of large scale phenomenon, co-observation of single phenomenon and interferometry. Autonomous operations will reduce the need for ground based support that would otherwise be prohibitively expensive in such missions. However, the underlying control systems necessary to enable such missions will raise many new challenges in autonomous, multi-platform operations.

In particular, a critical requirement for these satellite constellations is that they must act coherently as a coordinated, often autonomous team, and to do so even in the face of unanticipated events. This ability to operate as an autonomous team will need to be satisfied in many of the multi-satellite missions being planned. Therefore, it is important to understand this requirement, elucidate the research challenges it presents and consider approaches to satisfying it.

For example, consider the Magnetospheric Multiscale (MMS) mission. The mission involves 5 satellites flying in various formation configurations while making coordinated, simultaneous observations of the three dimensional structure of the magnetosphere. MMS's observation plan has a projected 2 year life span involving multiple phases with different orbits and formation scales. The satellite "constellation" will face and need to respond in a timely fashion to hard to predict and unexpected events such as solar flare observation opportunities or equipment failures. The constellation will likely have to address most of these events without human operator intervention; there will be limited and delayed communication with earth based human operators.

If an observation event occurs, the constellation may need to make a coordinated decision concerning the onset of observations and which sensor to use, decisions which in turn may be impacted by the status of each craft's sensor equipment. To realize this coordination, the satellites will need to communicate with each other. An effective policy for that communication is clearly a key requirement for the success of the mission. MMS also raises key issues about coordination between the constellation and ground-based operations. For example, in the face of unexpected events, the satellites must balance the need to react coherently in a timely fashion against the need for human oversight at critical junctures. At times, it may be best for the constellation to make an autonomous decision as how to proceed. At other times it may be best to seek human operator intervention. If that intervention does not come in a timely fashion, the constellation may still need to make an autonomous decision. An effective policy for such adjustable autonomy will be critical to the long-term survivability and success of the mission.

Of course, the question of how to achieve the necessary coordination between these craft and the adjustable autonomy with ground operations are requirements that are not unique to MMS or even multi-satellite operations in general. The multi-agent research community has been investigating these issues and has made considerable progress in addressing them. Various general approaches to coordinated teamwork and adjustable autonomy have been proposed, have been implemented in a variety of domains and have demonstrated considerable robustness. These approaches, for example, lay out prescriptions for when teammates should communicate and what they should communicate in order to achieve effective coordination on a team task such as a multi-point observation of an event. The design of multi-satellite missions will likely benefit greatly from this research. At the same time, a multi-satellite constellation will face difficult challenges that raise research questions which are not only at the frontiers of multi-agent research but will likely push that frontier forward.

One of these research challenges concerns the complexity of the process by which the satellites come to some coordinated decision and the quality of the resulting decision. For example, we might consider how MMS decides to make a joint observation with some sensor and whether it is the best decision they could make. Any approach will require certain communications, which consume power and time, and result in a specific decision that is, more or less, the optimal decision given the situation, the time it took to make the decision, etc. Furthermore, the MMS craft must make decisions in the context of a mission that has a 2 year lifespan, therefore the optimal decision for a specific observation event, for example, may be far from optimal in the context of subsequent tasks that must be performed. Indeed the very concept of optimal must take into account that the tasks the mission faces cannot be a priori specified with certainty, given the opportunistic nature of the observations, unexpected equipment failures, etc.

To address this challenge, it is useful to know certain baselines, such as what is the *optimal* decision for the team to make in any given situation and what is the *complexity* of finding that decision. However, to date insufficient progress has been made in precisely characterizing what constitutes an optimal decision and understanding the complexity of finding such optimal decisions. Given the lack of such baselines, it is not surprising that the various practical approaches to making teamwork decisions that have been proposed by the research community have also not been comparatively analyzed in terms of their optimality or complexity. Thus the optimality/complexity tradeoffs of proposed approaches cannot be determined, making it difficult to evaluate alternative approaches. Indeed, the optimal policy for a particular domain or application is typically unknown. This lack of progress in evaluating alternative approaches to central problems in teamwork is particularly worrisome in high cost, critical applications such as satellite constellations.

A second, closely related, research question concerns the *limited resources* any multi-satellite mission faces. Only limited progress has been made by the multi-agent research in explicitly modeling the real world constraints that are fundamental to the success of a satellite mission. For example, communication is in general a cornerstone of effective teamwork and will likely be key to maintaining MMS satellite coordination. However, communication has a cost. It can consume considerable power, can impact certain kinds of data collection and can delay other actions if for example one member of team communicates and waits for a response from other teammates. Similar real world issues arise in the case of adjustable autonomy. Traditionally, the adjustable autonomy issue has been framed as a one-shot decision to either make an autonomous decision or pass control to a human (e.g., ground controllers). However, the decision to pass control may lead to costly delays which ideally should be factored into the decision to transfer control. But in the real world the length of the delay is typically indeterminate, drawing into question the advisability of making such a one-shot decision.

However, recent advances in *formal models* of teamwork and adjustable autonomy have begun to address these challenges. For example, work in casting teamwork into a formal framework, what we call an MTDP (*multi-agent team decision problem)*, provides a tool to address a range of analyses critical to fielding teams in real world applications. Using the MTDP framework, the complexity of deriving optimal teamwork policies across various classes of problem domains can be determined. The framework also provides a means of contrasting the optimality of alternative approaches to key teamwork issues like role replacement. Finally, the framework also allows us to empirically analyze a specific problem domain or application of interest. To that end, a suite of domain independent algorithms has been developed that allow a problem domain to be cast into the MTDP framework. This allows the empirical comparison of alternative teamwork approaches in that domain. Derivation of the optimal policy for the problem domain serves not only as the basis of comparison but also can inform the design of more practical policies. Most recently, progress is being made in addressing how real world operating constraints like power consumption can be modeled in this framework.

Another critical research question concerns *integration*. Clearly, these teamwork and autonomy decisions cannot be made independently from the rest of the operational decisions being made on the craft. But the question of how they integrate is yet another research question.

In this report, our goal is to illuminate several basic issues in the application of multi-agent research to multi-satellite missions. We discuss the need to develop robust and effective coordination prescriptions for multi-satellite teamwork. Rather than mission-by-mission ad hoc approaches to coordination, we focus on a general approach to teamwork that will be both more robust in a particular mission while also building across mission teamwork infrastructure. We also stress the need for analysis and suggest an approach to assessing the quality of alternative prescriptions, based on MTDPs, that allows both formal and empirical evaluation. We illustrate how the approach could be applied to MMS and discuss how it could be extended to provide a faithful rendering of difficult resource limits that such missions will operate under. In addition, we discuss alternatives to realizing the teamwork reasoning and how teamwork and autonomy is integrated into a craft's overall software architecture.

The discussion of these issues begins in Section 2, by describing the MMS mission and pointing out some of the technical challenges it raises for teamwork and adjustable autonomy. But of course, teamwork and autonomy reasoning are just one part of the constellation's operation, which must include various flying, observation, communication and maintenance tasks over the duration of the mission. So we briefly introduce the supervisory control software that manages and schedules these tasks. In particular, we discuss one approach to the design of this supervisory software in order to facilitate later discussions. We then discuss in Section 4 the issue of realizing robust teamwork, as the problem is approached by the STEAM architecture. Section 5, *Analysis and Synthesis of Teamwork*, presents one of the central proposals of this report, the use of formal models for analyzing teamwork. Section 6 presents some prior work in teamwork analysis. Sections 7 and 8 discuss in turn adjustable autonomy and the integration of teamwork reasoning with the supervisory control software. Finally, Section 9, *Recommendations*, suggests several directions for the research and also potential collaborations with NASA.

2 Magnetospheric Multiscale

The Magnetospheric Multiscale (MMS) mission is being designed to investigate the processes of magnetic reconnection, charged particle acceleration and turbulence in the Earth's magnetosphere. The study is concerned with the dynamic and spatial structure of these processes and thus it can not feasibly be undertaken by a single craft. A multi-satellite mission design is being developed that uses identical spacecraft capable of flying in formation and making the simultaneous, coordinated observations required. The 5 satellites of MMS will fly in a hexahedral formation near apogee, comprising two tetrahedral with three of the satellites in a plane with the fourth satellite above and a fifth below that plane. See Figure 1. An alternative design will have four craft defining a tetradron with the fifth craft (potentially) placed within that tetrahedron. See Figure 2. The formation will at times elongate into a string of pearls, depending on where it is in the orbit and the temporal/spatial goals of the observations. Whereas observations that could separate spatial and temporal characteristics of observed phenomenon could be done by two craft, the ability to resolve these characteristics are significantly improved by 5 craft. In order to capture data from different regions of the magnetosphere, there are multiple phases to the mission with different orbits and different inter-satellite distances. Specifically, Phase 3 and Phase 4 will involve more distant observations, including magnetotail studies at up to 120 RE. Depending on the phase of the mission, the spacing between satellites will range for from tens of kilometers to tens of thousands of kilometers, with separations sometimes increasing or decreasing over orbital phase. The MMS mission has an operational duration of 2 years.

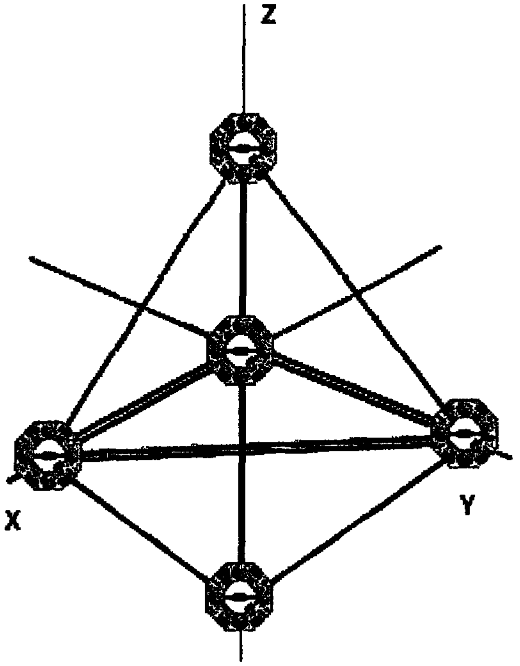

Figure 1. MMS Spacecraft in hexahedral configuration.

Each craft has memory on board to record data which must be transferred to ground stations at appropriate times. As of early 2002, the craft design proposed a sensor system that has two data rates, high and low, which give them different resolution observations. At interesting events, such as a solar flare, the craft should go into high data rate to get the greatest amount/resolution of data. However, some highly desired events happen quickly enough that they can be missed, at least partially. The memory also fills quickly at high data rates. Plus the buffers on the craft may have different amounts of free memory at any time, making it more or less feasible for them to go into high data rate. Not all craft need to be at the same rate during an observation, surprisingly, but the more the better. Also, Phase 3 and 4 of the mission will require the DSN 34-meter dish. Since the downlink of data is sensitive to distance and ground station cost can be prohibitive, the craft will be required to store weeks of data until their orbit brings them close enough for high speed downlinks.

Additionally, the MMS satellites will carry a range of instruments, including plasma instrumentation, energetic particle detector, electric field/plasma wave instruments and magnetometer. For various reasons, a craft's instruments may not be operable simultaneously. For example, they may share electronics. The operation of the sensors will also need to be coordinated between craft.

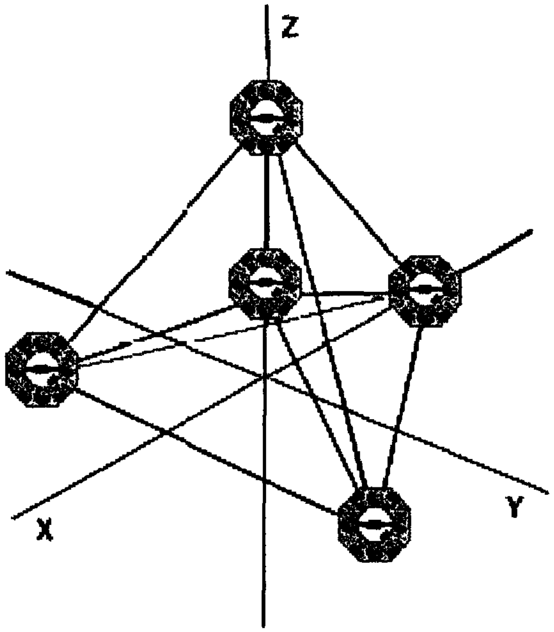

Figure 2. MMS Spacecraft, five tetrahedral configuration.

Finally, the formation is not designed to dynamically reconfigure - the reconfiguration is preplanned depending on where they are in orbit and which phase of the mission it is. Apparently, it is too expensive to consider dynamic reconfiguration - it costs too much in fuel (and consequently liftoff weight). This in principle limits the kinds of coordination tasks that need to be addressed, but does not eliminate the need for coordination. Because of this limitation, however, this document will not address in great detail possible relations between teamwork reasoning or adjustable autonomy and low-level control algorithms that will be used to maintain the crafts' formation. Rather the focus will in large measure be on the science operations.

2.1 MMS and Teamwork.

A decision to make an observation potentially faces various tradeoffs with respect to the interestingness of the observation, the feasibility of any particular satellite going into high rate given its free memory, the quality of the observations that results or when the next downlink is feasible. Additional factors may arise that affect the high/low data rate decision. It is also not clear when to turn back to low data rate - presumably because it is not clear when the observation of an event should end. Closely related is the possibility of foregone future observations due to too full memory prior to any downlink. Or for that matter some satellite could run out of memory mid-observation. The state/precision of the constellation's formation will also impact observation quality and arguably should be factored into the high and low data rate decision.

Related to this observation decision, there are also interesting coordination issues and tradeoffs to be considered. The current proposed coordination approach is an alarm system. A satellite individually detects interesting events and signals others that it spot the event and is going into high data rate, other satellites should in turn signal that they are going into high data rate, assuming they have the buffer space. This is "what's my state" coordination technique that appears topreclude the possibility of coordinating the high/low data rate decision as a team decision which arguably might be a better approach --- since the individual decision may need to take into account the state of the team such as the other satellites state of memory, value of only part of the formation going into high rate, the teams current formation, the possibility of false alerts, whether all craft's sensors are working, power levels in the various craft, etc.

Moreover, the high/low data rate decision is clearly just one decision to coordinate. For example, which instruments will be activated to perform an observation clearly must be coordinated between craft. Again, there may be many factors that could impact this decision and might argue that a coordinated, team decision is preferable. For example, if one or more craft has an instrument failure, then this might argue for changing the observation to other instruments. Since useful, but degraded, observations of spatial/temporal characteristics can possibly be made by even two craft, the appropriate decision may not be obvious.

There also is another planned mission, solar sentinel, that will be closer to the sun that could coordinate with MMS. Specifically, it could be used as early warning sensors for interesting events.

Finally autonomy is critical here. Ground links in general are expensive, especially when, in Phase 3 and 4, DSN is required. Communication would thus drive up costs astronomically and will be relatively infrequent. The uplink of data is designed to be quite contained, one design for the mission specifies that commanding for the instruments will be 100 bytes per day per craft.

2.2 MMS, Formation Flying Testbed and Distributed Satellite Simulation.

The MMS mission has been chosen as the first mission design to be explored within the Formation Flying TestBed (FFTB) being developed at Goddard. FFTB is specifically designed to evaluate the low-level distributed control algorithm (DCA) and hardware involved in realizing the low-level formation maintenance and station-keeping necessary for a mission like MMS. However, the FFTB is also becoming the kernel of a distributed satellite simulation system (DSS) that will bring software and hardware together within a distributed system that will allow the simulation of an entire mission. Since the FFTB and DSS presents special opportunities for evaluating the constellations control software, we briefly describe these components here and raise certain implications of their design for the teamwork research.

The Formation Flying Testbed (FFTB) at NASA GSFC is a modular, hybrid dynamic simulation facility being developed as a platform for the evaluation of guidance, navigation, and control of formation flying clusters and constellations of satellites. The FFTB is being developed to support both hardware and software development for a wide range of missions involving distributed spacecraft operations.

The FFTB has several features of special note here. It is being designed to realize very high fidelity simulations of a constellations formation flying that will provide a strong test for software design. It is a hybrid simulation system that can employ a blend of hardware of software components. The use of hardware within the simulation system can constrain the simulation to run in real time. However, the FFTB design is modular. Software modules can be swapped in for the hardware modules, which would allow faster than real time simulation but at the cost of some loss in the fidelity of the simulation.

Most critically, FFTB is the core of an evolving distributed simulation system/environment (DSS) for satellite constellations. DSS could potentially support the simulation of all aspects of a mission, including the multiple sensors, absolute and relative position determination and control, in all (attitude and orbit) degrees of freedom, information management, high-level supervisory control as well as the underlying physical phenomenon the constellation is designed to observe.

This implementation is therefore an ideal framework for exploring and evaluating alternative approaches to the high-level supervisory control of the craft and its coordination with other craft in the constellation and ground control. The supervisory control has the general functions of validating the data in the navigation system, switching the modes of operation of the vehicle based on either events or schedules, and interfacing the on-board functions with ground functions. Thus teamwork reasoning will need to play some integrated role in supervisory control.

3 Supervisory Control

The main focus of this paper is the adjustable autonomy and teamwork decision-making that arise in missions like MMS. However, these capabilities are realized within the context of each crafts supervisory control software that overall decides what tasks are performed and when they are performed. Thus the relation between the teamwork reasoning and supervisory control is a central issue. For example, one issue that will arise in later discussions concerns the tradeoffs between realizing teamwork reasoning as a separate module versus a tighter integration.

In order to help set the context for that subsequent discussion, we introduce here an example of a general purpose architecture for supervisory control of remote craft that has been proposed by NASA Ames. We leave out many architectural specifics such as the relation of supervisory control to the distributed control algorithms used for formation maintenance.

3.1 Planning and Scheduling

NASA Ames's Intelligent Deployable Execution Agents (IDEA) [14] framework for planning and scheduling, which is a continuation of the work begun for the Remote Agent. IDEA has four main components; (1) a plan database which represents all possible plans that are consistent with the current set of instantiated constraints, (2) a domain model which defines the operational constraints for the craft, (3) a set of planners that generate plans in the plan database and (4) the plan runner which performs execution. Figure 1, borrowed from a NASA report, depicts IDEA.

The IDEA has many interesting capabilities but for our subsequent discussions, two features are most relevant. IDEA allows for multiple planners with different planning time responses, some of which may be more deliberative while others may be more reactive or scripted. The plan database provides a uniform representation for these planners and the execution of the resulting (partial) plan. Within the plan database, it is possible to represent not only partial plans for execution tasks but also flexibly represent planning tasks and reason about the scheduling constraints on those planning tasks. For example, IDEA could schedule a planning task, based on other operational constraints (e.g., whether the cpu is available). IDEA could also choose between alternative planning strategies based on scheduling constraints or modify other mission tasks to ensure time for planning (e.g., go into a wait loop).

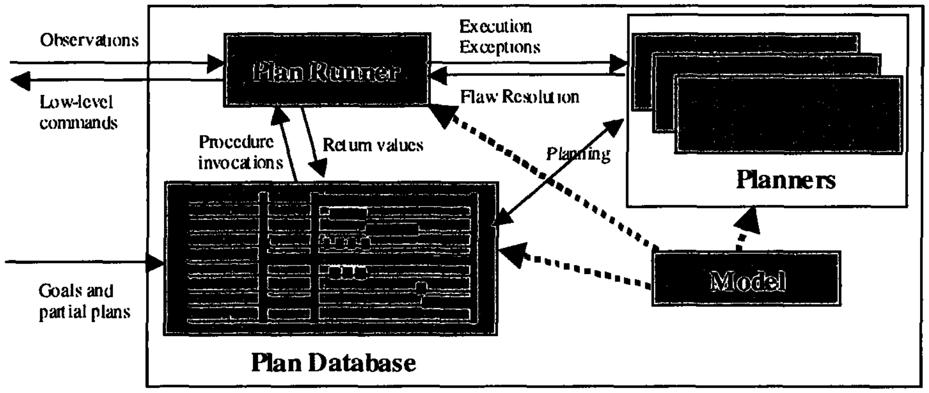

Figure 3. The IDEA Framework (from NASA report)

4 Teamwork

Although there is an increasing demand for multi-agent systems that enable a team of agents to work together, getting the team to perform well in a dynamic environment remains a difficult challenge. It is particularly difficult to ensure robust and flexible performance in the face of unexpected events. Individual agents may fail and there may also be coordination breakdowns, due to agent's not having a shared mental model. Building a system may require a potentially large number of special purpose coordination plans to cover all the low-level coordination details. If the underlying system tasks change or new agents are added, new coordination plans will be needed.

Considerable progress has been made over the years in developing and implementing practical models of teamwork that address these design challenges. Theoretical work on teamwork [Cohen & Levesque, Grosz, etc] laid the solid basis for implemented systems, such as STEAM [Jair], a general model of teamwork that explicitly reasons about commitments in teamwork. STEAM demonstrated the real-world utility of explicit reasoning about teamwork commitments for designing robust organizations of agents that coordinate amongst themselves. In a STEAM system, each team member has general purpose teamwork reasoning skills as well as an explict model of the team plan and its commitments to teammates. Thus each teammate knows that it is in a team and it has commitments to achieve team goals. Plus they possess rules for achieving the coordination required by those commitments in the face of unforeseen events. So, for example, if a teammate sees another teammate fail in a key task, it will reason about whether to warn teammates.

In particular, STEAM contains maintenance-and-repair rules that enable team members to monitor the impact of failing teammates and suggest recovery for such failures (e.g., by substitution of a failing team member with another). It also contains coherence-preserving rules which enable team members to supply each other key information to maintain coherence within a team, and communication-selectivity rules that help agents limit their communication using decision-theoretic reasoning. For example, one coherency preserving rule is that teammates need to know when a team task is achievable. Therefore, if an agent observes that a team task is achievable, this rule comes into play and the agent will decide to communicate the information, based on the communication-selectivity rules.

These rules realize general teamwork reasoning and therefore apply across any team task. They are as well practical in the sense that they take into account tradeoffs. In particular, the communication-selectivity rules take into account the criticality of the task, the cost of the communication and the likelihood that teammates already know. Our experience in a host of difficult domains is that this combination of general teamwork reasoning skills, explicit team plans and decision-theoretic reasoning about tradeoffs is robust. It's robustness follows from the emphasis on giving general teamwork reasoning skills to each teammate. The underlying assumption is that the world is "open", that the unexpected event can happen in the world. The designer of the team cannot pre-plan for every such event but rather must design general methods for teamwork reasoning about failures that allow the teamwork to maintain a coordinated, effective response.

STEAM's successful applications of teamwork to multi-agent systems lead to the Teamcore architecture. The key hypothesis behind Teamcore is that teamwork among agents can enhance robust execution even among heterogeneous agents in an open environment. The Teamcore architecture enables teamwork among agents with no coordination capabilities, and it establishes and automates consistent teamwork among agents with some coordination capabilities, by providing each agent with a proxy capable of general teamwork reasoning. At the heart of each Teamcore proxy is the STEAM teamwork model, which provides the set of rules that enable heterogeneous agents to act as responsible team members. The power of the resulting architecture stems from these built-in teamwork capabilities that provide the required robustness and flexibility in agent integration, without requiring modification of the agents themselves.

The Teamcore/STEAM framework has been successfully applied in several different domains. STEAM's original application was in the battlefield simulation environment where it was successfully used to build a team of synthetic helicopter pilots that participated in DARPA's synthetic theater of war (STOW'97) exercise, a large scale exercise involving virtual and real entities, including human pilots. STEAM was later reused in RoboCup Soccer, where it led to top performing teams in International RoboCup Soccer tournaments. STEAM is at the heart of the Teamcore proxies, which now enable distributed heterogeneous agents to be integrated in teams. Teamcore has been applied to bring together agents developed by different developers in DARPA's COABS program; these agents had no teamwork capabilities to begin with, but Teamcore allowed their smooth integration. Finally, Teamcore is also being used in the "Electric Elves" project, a deployed agent system at USC/ISI, which has been running 24/7 since June, 2000. This system provides Teamcore proxies for individual researchers and students at USC/ISI, as well as proxies for a variety of schedulers, matchmakers, information agents. The resulting team of 15-20 agents helps to reschedule meetings, decide presenters for our research meetings, track people and even order our meals.

4.1 TEAMCORE and MMS

It is useful to consider how we might apply Teamcore to MMS. Consider the previously discussed observation coordination example. To realize coordinated observations, observations would be defined as a team task, which would be achievable, for instance, when a solar flare happened. If a satellite now observed a solar flare, the coherency-preserving and communication rules would lead it to communicate to its teammate satellites that observation was now achievable (i.e., should be jointly executed). This would lead them to turn on high data rate as a team.

We can also consider somewhat more ambitious, speculative scenarios based on general teamwork reasoning and **team reformation**. For instance, assume MMS is in operation when some other mission is launched, enabling in some way better or earlier sensing of interesting events. For example, Solar Sentinel would be such a mission. To exploit this new capability, the already in-flight MMS craft, in principle, would not have to be modified (which would be risky and costly to do via command uplink). The new craft would just be added as a member of the MMS observation team, using the same Teamcore reasoning and observation team task. When it sensed an event, it would inform its teammates, the original MMS team. In practice, of course, this flexibility presumes that the new craft has some communication channel with the MMS craft, a network in some sense. Although such a network may not be currently feasible, if it were one can envision such plug and play teams of heterogenous satellites helping each other on their missions by dynamically taking on new roles in each other's tasks.

Let's also consider the case of failures. Assume some planned action by the supervisory control software, such as an attitude adjustment, suffers a failure of some kind. If the failure impacts a team task such as an observation, then the agent will signal its Teamcore proxy teamwork layer that it cannot perform its role in the team task as planned. The proxy will communicate with the other satellites in the team which will attempt to adjust their plans. If they cannot, they will in turn communicate failure on the team task that will in turn lead to a coordinated response to the initial failure.

5 Analysis and Synthesis of Teamwork

Based on systems like Teamcore/STEAM, multi-agent systems have moved out of the research lab into a wide range of applications areas. But of course, multi-satellite control is a highly critical application, where seemingly minor control decisions can have drastic consequences when made incorrectly. To meet the challenge of such a bold application, multi-agent research will need to provide high-performing, robust designs that performs such control as optimally as feasible given the inherent uncertainty of the domain. Unfortunately, in practice, research on implemented systems has often fallen short in assessing the optimality of their proposed approaches with respect to mission-level performance criteria.

To address this shortcoming, researchers have increasingly resorted to decision-theoretic models as a framework in which to formulate and evaluate multi-agent designs. Given some group of agents, the problem of deriving separate policies for them that maximize some joint reward (i.e., performance metric) can be modeled as a decentralized partially observable Markov decision process (DEC-POMDP). In particular, the DEC-POMDP model is a generalization of a POMDP to the case where there are multiple, distributed agents basing their actions on their separate observations. POMDP is in turn a generalization of a single agent Markov decision process, or MDP, whereby the agent makes decisions based on only partial observations of the state.

The Com-MTDP model is a closely related framework that extends DEC-POMDP by explicitly modeling communication. R-COM-MTDP in turn extends Com-MTDP to enable explicit reasoning about Team Formation and Re-Formation.

These MTDP frameworks allow a variety of key issues to be posed and answered. Of particular interest here, these frameworks allow us to formulate what constitutes an optimal policy for a multi-agent system and in principle to derive that policy.

For example, the COMmunicative Multiagent Team Decision Problem (COM-MTDP) provides a general-purpose language for representing the interactions among intelligent agents sharing a complex environment. The COM-MTDP can capture the different capabilities of the various agents in the world to perform actions and send messages. The model can represent the uncertainty in the occurrence of events, in the ability of the agents to observe such events, and in the effects of those events on the state of the world. The model also uses a reward function to quantify fine-grained preferences over various states of the world. The overall model provides a decision-theoretic basis for examining and evaluating possible courses of action and communication for the agents so as to maximize the expected reward in the face of their environment's ubiquitous uncertainty.

In a COM-MTDP, the behavior of the team is modeled as a joint policy that determines each agent's action based on its observations. There is also a reward function that assigns a value for an agent performing that action in the current state of the world. This framework allows us to determine what is the expected utility of any policy and in principle derive the optimal policy for a team of agents. It may also be a robust policy but only if the probabilistic models have done a faithful rendering of what could happen in the world. Note that in this analysis framework the individual agent knows nothing about being in a team. Knowledge about being in a team is not explicitly being modeled. Rather, a central planner derives a joint policy and each agent only has its part of the policy which tells it what to do next based on its current beliefs. This is quite different from the STEAM teamwork reasoning where each teammate knows it is in a team and can reason individually and as a team about how to best maintain team coordination in pursuit of team goals.

5.1 Technical Details

The COMmunicative Multiagent Team Decision Problem (COM-MTDP)} model subsumes previous distributed models in control theory, decision-theoretic planning, multiagent systems, and game theory. An instantiated COM-MTDP model represents a team of selfless agents who intend to perform some joint task. This COM-MTDP is specified as a tuple, <S,A,O,B,R>.

S is a set of world states which describes the state of the overall system at a particular point in time. For example, the state of a typical COM_MTDP system would capture the status of the agents (e.g., satellites) themselves, including their positions, their available power, their communication queue, etc. The state would also represent the current environment, external to the agents themselves (e.g., position of other satellites or observation targets).

A_i, is the set of control decisions that each agent i can make to change itself or its environment, implicitly defining a set of combined system actions, A. The actions of an individual agent/satellite, for example, may include choice of sensor, choice of orientation, choice of power consumption (perhaps selecting between high- and low-quality sensing), and potentially even a choice to do no sensing at all (e.g., to maximize power conservation).

The state of the world evolves in stages that represents the progression of the system over time. For nontrivial domains, the state transitions are non-deterministic and depend on the actions selected by the agents in the interval. The non-determinism inherent in these transitions is quantified by specifying transitions as a probabilistic distribution. The transition probability function can represent the non-deterministic effects of each agent's choice of action.

O_i is a set of observations that each agent, i, can experience of its world, implicitly defining a combined observation. O_i may include elements corresponding to indirect evidence of the state (e.g., sensor readings) and actions of other agents (e.g., movement of other satellites or robots). The observations that a particular agent receives are non-deterministic (e.g., due to sensor noise), and this non-determinism is quantified with a set of observation functions. Each such observation function defines a distribution over possible observations that an agent can make. Each observation function represent the noise model of a node's sensors, so that we can determine the relative likelihood of the various possible sensor readings for that node, conditioned on the real state of the system and its environment.

C_i is a set of possible messages for each agent, i, implicitly defining a set of combined communications. An agent may communicate messages to its teammates.

Each agent forms a belief state based on its observations seen and messages received through time, where B_i circumscribes the set of possible belief states for the agent. The agents update their belief states at two distinct points within each decision epoch: once upon receiving observation (producing the *pre-communication* belief state) and again upon receiving the other agents' messages (producing the *post-communication* belief state). The distinction allows us to differentiate between the belief state used by the agents in selecting their communication actions and the more ``up-to-date" belief state used in selecting their domain-level actions.

An agent's belief state forms the basis of its decision-making in selecting both domain-level actions and communication. This decision-making is summarized by mappings from belief states into actions and messages, using a domain-level *policy* that maps an agent's belief state to an action and a communication-level policy.

A common reward function R is central to the notion of teamwork in this model. This function represents the performance metric by which the system's overall performance is evaluated. The reward function represents the team's joint preferences over states, the cost of domain-level actions and the cost of communicative acts (e.g., communication channels may have associated cost).

5.2 An MTDP - MMS analysis example

The COM-MTDP work was originally envisioned as a framework for analyzing teamwork strategies but increasingly we have begun to explore its use in synthesizing teamwork strategies. However, let's first exemplify its use in analysis.

MTDP can be applied to represent the MMS spacecraft's data acquisition discussed earlier. To do this, we would represent each of the spacecraft as an agent, with state features representing the status of each spacecraft. We could also potentially represent a spacecraft's power limitations and consumption within the MTDP model's state space and transition probability. In particular, for each spacecraft, there would be a corresponding state feature representing its available power. The transition probability function would model the dynamics of this available power as a stochastic process, with the change in available power as a function of the spacecraft's choice of action (e.g., data transmission accelerates the rate of power consumption). We can use similar state features to represent the position, orientation, amount of data recorded for each spacecraft, as well as a similar transition probability function to represent the dynamics of each. Such state-based representations have proven successful in modeling distributed systems, and we have had similar success ourselves in applying them to multiagent systems.

There would be additional state features to represent the state of the magnetosphere around them. These features would capture the presence/absence of the various phenomena of interest to the mission. The transition probability function would capture the stochastic evolution of the magnetosphere state, perhaps by incorporating existing models (e.g., MHD models). An agent's observation function would provide a probabilistic model of its corresponding spacecraft's sensors in relation to the state of the surrounding magnetosphere.

Each agent would have a choice of recording or not recording data. The MTDP reward function represents the relative value of its choice after taking into consideration the magnetosphere state. In other words, recording data will have a high value when phenomena of interest are present in the current state. The magnitude of the value will correspond to the relative value of the present phenomena. When an agent decides to record data, the transition probability function will represent the change in the spacecraft's state (i.e., it will have less memory left for recording data).

Given such an MTDP model, we can evaluate data acquisition procedures by encoding them as agent policies. In other words, each agent's policy would represent its corresponding spacecraft's decision process in deciding when to record data, based on its sensor readings. We can then use MTDP algorithms to simulate the behavior of these policies over the possible magnetosphere events. By evaluating the reward earned by the agents over these possible events, weighed against their likelihood, we can derive an expected reward of the policies selected, which in turn allows us to characterize the various performance tradeoffs. We can manipulate the MTDP reward function to isolate the dimensions of interest for each such tradeoff. For instance, if we wish to quantify the ability of an acquisition procedure to avoid running out of power, we can define a reward function that has value 1 in a state where a spacecraft has no available power and 0 in all other states. We can then use our evaluation algorithm to compute the expected reward earned by the nodes, which, with this reward function, will exactly measure the probability that a spacecraft runs out of power. We can make similar reward function definitions that allow our evaluation algorithm to compute expected amount of data recorded, amount of data transmitted, expected number of interesting phenomena *missed*, etc. We can combine reward functions over different dimensions into a single reward function to consider the two dimensions simultaneously and thus quantify the tradeoffs between them. Furthermore, by replacing the expectation in these algorithms with minimization and maximization, we can compute best- and worst-case statistics as well.

This provides a potential basis for selecting between various candidate data acquisition policies. The MTDP model can also potentially provide feedback into the design process underlying data acquisition. A system designer can consider the output of our evaluation algorithms (i.e., the separate predictions and the tradeoffs between them) when choosing among various candidate data-acquisition procedures. These performance predictions will provide the algorithm designers with concrete performance profiles of their algorithms' performance under realistic conditions. The designers can then take these profiles (e.g., too many messages, low probability of success) and use them to make informed improvements to the means by which they achieve data acquisition. This will help our research but in addition provide useful, practical information and software tools (the MTDP analysis framework in particular) for developing these missions.

5.3 Modeling Real World Constraints

Formal models of distributed systems have typically neglected to model real world resource limits. In contrast, one of the features of the previous example use of MTDP was the proposal to model power consumption dynamics. This represents current research in which we are investigating how various real world resource limits such as power consumption can be modeled as first class entities. Since one of the difficult challenges faced by many NASA missions and MMS in particular is the tight resource constraints they operate under, this added capability will clearly have special relevance for using the MTDP framework for NASA mission analyses.

5.4 Synthesis and Re-Synthesis potential.

As commented earlier, the MTDP work was originally envisioned as a framework for analyzing teamwork algorithms. Our experiences to date have also revealed an extremely interesting potential for synthesis. For example, we can use the MTDP work to derive an optimal policy for some team mission by simply simulating all possible policies out to some bounded point in the simulation and picking the best one. This optimal policy is of course only optimal under the assumptions about the world built into the probabilistic models used in the simulation. And it is not a tractable simulation to perform in general. Nevertheless, it does provide a benchmark against which to measure the optimality of alternative teamwork reasoning approaches such as the TEAMCORE work mentioned above. When we have done this kind of benchmarking, we found that the MTDP may generate optimal policies that were entirely unexpected. For example, the optimal policy might replace "failed" teammates before they fail - in essence employing a redundancy approach in high-risk situations. The optimal policy might flexibly decide to replace or not replace based on the expected utility. Finally in some cases it might choose to abandon the mission. None of these capabilities were built into the experiments by the designers - they were discovered by deriving and then inspecting the optimal policy.

This discovery suggests a third approach to building agent teams – the iterative combined approach. Here the domain is modeled probabilistically, the optimal policy is derived and this policy is analyzed to suggest possible improvements to the more general-purpose teamwork reasoning strategies such as employed in TEAMCORE. In other words, by examining the optimal policy (which may be infeasible with real-world resource constraints), we could identify deviations made by our more practical TEAMCORE architecture. We can then modify the architecture to be more in line with the ideal behavior specified by the optimal policy, and thus minimize the suboptimality that we achieve in practice.

5.5 Effective policy derivation algorithms

COM-MTDP and decentralized POMDPs clearly show considerable promise for multi-agent research as well as the application of that research. One key step to using these formalisms is the derivation of the policies. However effective algorithms for deriving policies for decentralized POMDPS is ongoing research. Significant progress has been achieved in efficient single-agent POMDP policy generation algorithms (refs, Monahan, etc). However, it is unlikely such research can be directly carried over to the decentralized case. Finding an optimal policies for decentralized POMDPs is NEXP-complete and therefore provably does not admit a polynomial time algorithm (Bernstein, Zilberstein and Immerman). In contrast, solving a POMDP is PSPACE-complete (Papadimitriou and Tsitsiklis). As Bernstein et al. note (ref), this suggests a fundamental difference in the nature of the problems. Since the reward function is a joint one, the decentralized problem can not be treated as one of separate POMDPs in which individual policies can be generated for individual agents. (For any one action of one agent, there may be many different rewards possible, based on the actions that other agents may take.)

In our own work, we have developed several policy derivation algorithms. Among these is an exact algorithm that generates optimal policies via a full search of the space of policies. This exact algorithm is of course expensive to compute which limits its applicability to problems for which there is sufficient time to offline pre-compute such an exact solution or some way of decomposing the problem a priori. Therefore, we have also developed approximate algorithms. For example, one approach is to search the space of policies incrementally. This algorithm iterates through the agents, finding an optimal policy for each agent assuming the policies of the other agents are fixed. The algorithm terminates when no improvements to the joint reward is achieved, thus achieving a local optimum similar to a Nash Equilibrium.

This question of effective algorithms will likely be of special relevance to the application of these formalisms to MMS. Given its projected mission duration of two years, a brute force search for the optimal policy would not be feasible. However, although the resource constraints of such missions will complicate our representation, they may actually *simplify* such algorithms by restricting the search space of implementable policies. For example, the optimal policy for many COM-MTDP problems requires that the agents remember *all* of their observations throughout their lifetime and then choose different actions based on all possible such observation sequences. Spacecraft with the limited memory resources cannot store such a policy, let alone execute it. The number of possible policies that are executable is much smaller than the number of unrestricted policies, which suggests that finding optimal policies *subject to the mission resource constraints* may be feasible through novel COM-MTDP synthesis algorithms.

6 An aside: Data-driven analysis

The COM-MTDP work provides an approach to analyzing team performance. A key requirement for the analysis is the probabilistic models of the domain and task, for example the state transition probabilities and the observation function. This begs the question of where these models come from.

In the case of MMS, these models could be derived directly or indirectly from the models of the magnetosphere, of the low-level flight control, etc. that are part of the Formation Flying Test Bed (FFTB) and Distributed Satellite Simulation (DSS) mentioned earlier which are being developed at Goddard. For example, an indirect derivation would rely on the simulation of these models within the DSS that could be sampled to derive estimates of the probabilistic models needed for COM-MTDP. By combining the COM-MTDP framework and the DSS simulation, the overall approach to the analysis would be more driven by the data in the simulations. More generally, we envision such combinations of analytical analysis and simulation to be a particularly fruitful research path.

This optimism stems from our prior experiences in researching data-driven approaches to analysis that used simulation data to derive models that were subsequently used for teamwork analysis. In particular, such an approach was used by the ISAAC teamwork analysis tool (ref). ISAAC performs post-hoc, off-line analysis of teams using agent-behavior traces derived from the team's performance in the domain or simulation of the domain. This analysis is performed using data mining and inductive learning techniques to derive models of the team's performance in the domain.. Using data from the agents' external behavior traces, ISAAC is able to analyze a team with very little in the way of pre-existing models of the domain or the team's internals.

In fact, ISAAC develops multiple models of a team. To fully understand team performance, multiple levels of analysis are criticial. One must understand individual agent behavior at critical junctures, how agents interact with each other at critical junctures as well as the overall trends and consequences of team behavior throughout the life of a mission. Thus ISAAC is similarly capable of analyzing from multiple perspectives and multiple levels of granularity. To support such analyses, ISAAC derives multiple models of team behavior, each covering a different level of granularity. More specifically, ISAAC relies on three heterogeneous models that analyze events at three separate levels of granularity: an individual agent action, agent interactions, and overall team behavior. These models are automatically acquired using different methods (inductive learning and pattern matching) -- indeed, with multiple models, the method of acquisition can be tailored to the model being acquired.

Yet, team analysts such as ISAAC must not only be experts in team analysis, they must also be experts in conveying this information to humans. The constraint of multiple models has strong implications for the type of presentation as well. Analysis of an agent action can show the action and highlight features of that action that played a prominent role in its success or failure, but a similar presentation would be incongruous for a global analysis, since no single action would suffice. Global analysis requires a more comprehensive explanation that ties together seemingly unconnected aspects and trends of team behavior. ISAAC uses a natural language summary to explain the team's overall performance, using its multimedia viewer to show examples where appropriate. The content for the summary is chosen based on ISAAC's analysis of key factors determining the outcome of the engagement.

Additionally, ISAAC presents alternative courses of action to improve a team using a technique called 'perturbation analysis'. A key feature of perturbation analysis is that it finds actions within the agents' skill set, such that recommendations are plausible. In particular, this analysis mines data from actions that the team has already performed.

ISAAC has been applied to all of the teams from several RoboCup tournaments in a fully automated fashion. This analysis has revealed many interesting results including surprising weaknesses of the leading teams in both the RoboCup '97 and RoboCup '98 tournaments and provided natural language summaries at RoboCup '99. ISAAC was also awarded the 'Scientific Challenge Award' at the RoboCup '99 international tournament. ISAAC is available on the web at http://coach.isi.edu and has been used remotely by teams preparing for these competitions.

While ISAAC is currently applied in RoboCup, ISAAC's techniques are intended to apply in other team domains such as agent-teams in satellite constellations. For example, ISAAC could produce a similar analysis for the DSS simulation system and use similar presentation techniques as well. Indeed, we believe that the COM-MTDP analysis work could be incorporated into a ISAAC-like tool for the DSS system.

6.1 OVERVIEW OF ISAAC

(Perhaps delete this section)

ISAAC uses a two-tiered approach to the team analysis problem. The first step is acquiring models that will compactly describe team behavior, providing a basis for analyzing the behavior of the team. As mentioned earlier, this involves using multiple models at different levels of granularity to capture various aspects of team performance. The second step is to make efficient use of these models in analyzing the team and presenting this analysis to the user An overview of the entire process is shown in Figure 4.

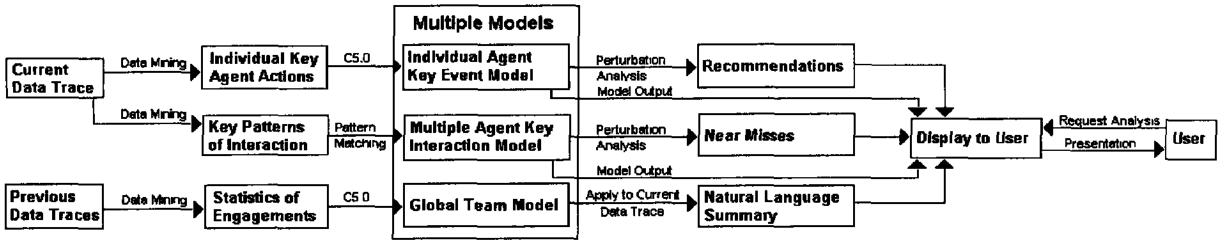

Figure 3. ISAAC analysis process.

Input to all models comes in the form of data traces of agent behaviors. In the current implementation of ISAAC, these traces have been uploaded from users around the world through the Internet.

As shown in figure 4, acquiring the models involves a mix of data mining and inductive learning but is specific to the granularity of analysis being modeled. Analysis of an individual agent action (*individual agent key event model*) uses the C5.0 decision tree inductive learning algorithm, an extension to C4.5, to create rules of success or failure [ref]. For analysis of agent interactions (*multiple agent key interaction model*), pre-defined patterns are matched to find prevalent patterns of success. To develop rules of team successes or failures (*global team model*), game level statistics are mined from all available previous games and again inductive learning is used to determine reasons for success and failure.

Utilizing the models involves catering the presentation to the granularity of analysis to maximize human understandability. ISAAC uses different presentation techniques in each situation. For the individual agent key event model, the rules and the cases they govern are displayed to the user who is free to make the final determination about the validity of the analysis. By themselves, the features that compose a rule provide implicit advice for improving the team. To further elucidate, a multimedia viewer is used to show cases matching the rule, allowing the user to better understand the situation and to validate the rules (See figure 5). A *perturbation analysis* is then performed to recommend changes to the team by changing the rule condition by condition and mining cases of success and failure for this perturbed rule. The cases of this analysis are also displayed in the multimedia viewer, enabling the user to verify or refute the analysis.

For the multiple agent key interaction model, patterns of agent actions are analyzed similar to the individual agent actions. A perturbation analysis is also performed here, to find patterns that are similar to successful patterns but were unsuccessful. Both successful patterns and these 'near misses' are displayed to the user as implicit advice. This model makes no recommendations, but does allow the user to scrutinize these cases.

The global team model requires a different method of presentation. For the analysis of overall team performance, the current engagement is matched against previous rules, and if there are any matches, ISAAC concludes that the reasons given by the rule were the determining factors in the result of the engagement. A natural language summary of the engagement is generated using this rule for content selection and sentence planning. ISAAC makes use of the multimedia display here as well, linking text in the summary to corresponding selected highlights.

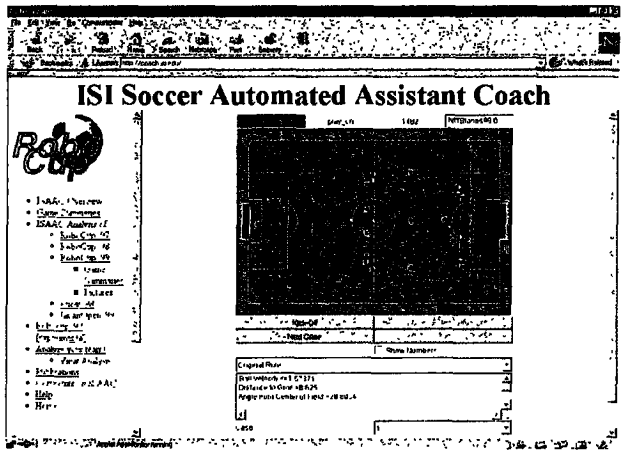

Figure 5: Multimedia viewer highlighting key features

7 Adjustable Autonomy

One of the interesting issues raised by MMS is how the team of satellites interact with ground control. Recall that at various times, the constellation is quite distant from Earth and requires the DSN to communicate (and then only when the orbit takes them close enough high speed data links). This makes communication more costly and harder to schedule. The planned daily uplink of command data has been estimated in one report (1999) to be 100 bytes. Clearly, the MMS satellite will need to exhibit considerable autonomy but nevertheless it is not hard to imagine that system anomalies may occur that require human intervention.

Increasing interest in applications where humans must act as part of agent teams, has led to a burgeoning of research in adjustable autonomy, i.e., in agents that dynamically adjust their own level of autonomy. Essentially, for effective task performance, an agent may act with full autonomy or with reduced autonomy --- harnessing human knowledge or skills when needed, but without overly burdening the humans. The results of this research are both practically important and theoretically significant.

The need for agent teamwork and coordination in a multi-satellite mission leads to critical and novel challenges in adjustable autonomy --- challenges not addressed in previous work, given that it has mostly focused on individual agents' interactions with individual humans. For instance, consider one of the central problems in adjustable autonomy: when should an agent transfer decision-making control to a human (or vice versa). The presence of agent teams adds a novel challenge of avoiding team miscoordination during such transfer.

To get a more concrete sense of the Adjustable Autonomy Issues here, consider a simple example. If the MMS constellation's formation deteriorates beyond some safe bound, the side-effects of making the adjustment may make it undesirable to leave it to the low-level distributed control algorithm (DCA) to make adjustments. There may be more than one way for the individual satellites to adjust with different fuel requirements across satellites, while the satellites may differ in amount of fuel they have. One of the satellites may have a persistent but not detected/diagnosed anomaly in its attitude control that is leading to the formation degradation, which should be factored into the decision-making. The necessary adjustments may also subsequently impact the transformations of the orbits over time, which are part of the planned mission phase transitions. Finally, these factors are happening in some part of the orbit/mission that makes communication with ground more or less feasible in some amount of time.

Clearly, if a single agent were to transfer control for this decision to the human user involved, and the human fails to respond, the agent may end up mis-coordinating with its teammates who may need to act urgently. Yet, given the risks in the decision, acting autonomously may be problematic as well. Clearly, the adjustable autonomy in this context applies to the entire team of agents rather than any individual spacecraft. Further, if the decision is to transfer control, the team could not expect to wait indefinitely for a response from a human operator.

Clearly, the need for real-time response, the serious potential costs of errors, and the inability of the human to directly monitor the state of the different spacecraft add to the complexity of the adjustable autonomy problem. In addressing such challenges, on-going work in adjustable autonomy will play a critical role.

For example, one approach to avoid team miscoordination due to transfer of control decisions is for an agent to take into account the cost of potential mis-coordination with teammates before transferring decision-making control. For example, if a satellite is having persistent difficulty maintaining formation, one response might be to ask ground control what to do and go into a wait loop waiting for a response. But such a response needs to take into account the miscoordination consequences before it decided to transfer the control decision to ground. This would avoid rigidly committing to a transfer of control decision and allow the craft to continual reevaluating the situation, reversing control and taking autonomous action when needed. This suggests that transfer of control must be more strategic.

7.1 Transfer of Control Strategies

Previous approaches to transfer-of-control were quite too rigid, employing one-shot transfers-of-control that can result in unacceptable coordination failures. Furthermore, the previous approaches ignore potential costs (e.g., from delays) to an agent's team due to such transfers of control.

To remedy such problems, more recent work (ref to Scerri et al) emphasizes the notion of a transfer-of-control strategy. A transfer-of-control strategy consists of a conditional sequence of two types of actions: (i) actions to transfer decision-making control (e.g., from the agent to the user or vice versa) and (ii) actions to change an agent's pre-specified coordination constraints with team members, aimed at minimizing mis-coordination costs. An agent executes such a strategy by performing the actions in sequence, transferring control to the specified entity and changing coordination as required, until some point in time when the entity currently in control exercises that control and makes the decision. When the agent transfers decision-making control to an entity, it may stipulate a limit on the time that it will wait for a response from that entity.

Since the outcome of a transfer-of-control action is uncertain and some potential outcomes are undesirable, an agent needs to carefully consider the potential consequences of its actions and plan for the various contingencies that might arise. Moreover, the agent needs to consider sequences of transfer-of-control actions to properly deal with a single decision. Considering multi-step strategies can allow an agent to attempt to exploit decision making sources that might be too risky to exploit without the possibility of retaking control. For example, control could be transferred to a very capable but not always available decision maker then taken back if the decision was not made before serious miscoordination occurred. More complex strategies, possibly including several changes in coordination constraints, can provide even more opportunity for obtaining high quality input.

7.2 Implications of Strategies

The goal for a transfer of control strategy is for high quality individual decisions to be made with minimal disruption to the coordination of the team. Clearly however there are dependencies. Transfer of control actions, whether they are one-shot or strategies, take time. Further the decision to use a particular transfer of control strategies may not be independent from the other task facing the team and individual craft. This clearly factors in to the question of how adjustable autonomy is realized within the overall software architecture and in particular its relation to supervisory control – a question we return to later.

Of course, one approach to deriving good transfer of control strategies is to conjoin decision-making about adjustable autonomy with the other planning and scheduling decisions. For example, one can operationalize transfer of control strategies via Markov decision processes (MDPs) which select the optimal strategy given an uncertain environment and costs to individuals and teams. Scerri et al. have also developed a general reward function and state representation for such an MDP, to facilitate application of the approach to different domains.

7.3 MMS and AA

Currently, it is not clear to what extent adjustable autonomy will play a major role in MMS. MMS is being planned with an apparent high degree of autonomy. However, it is interesting to note that the costs in time and money of any transfer of control to human operators on the ground will vary over the course of an orbit as well as the phase of the mission. For example, in phases 3 and 4 of the mission, as noted earlier, MMS will be quite distant at times and require scheduling time on the DSN for communication. This would make any interaction with ground more costly and more time consuming. The implication of this is that if Adjustable Autonomy becomes part of the mission design, the transfer of control strategies will be quite different over the course of the mission.

8 Integration

Until now, we have only briefly touched on how the teamwork reasoning and adjustable autonomy reasoning could be folded into each craft's supervisory control procedures. However, the discussions of the underlying decision-making and communication involved in teamwork and adjustable autonomy made it clear that these processes take time. For that reason, they may interact with the scheduling of other tasks. For example, the decision to turn on a sensor could be made autonomously by a craft, negotiated with other craft, transferred to ground or decided by executing some transfer of control strategy. Each of these strategies will have some kind of temporal footprint with potential tradeoffs on whether the conjoined sensing acting succeeds, whether other mission critical tasks are delayed, which tasks need to be performed, how the power levels are impacted and how much the data buffer is filled. The tradeoffs in principle might work both ways. Thus, the teamwork and autonomy decision-making processes may impact the scheduling decisions made by the supervisory control and conversely the scheduling decisions may impact which teamwork strategy is preferred. And overall solution quality may, in fact likely will, depend on the teamwork, autonomy and supervisory control decisions.

This argues for a tight integration of these teamwork and supervisory procedures, for an integration that makes teamwork decisions part of the supervisor's planning, scheduling and execution. Of course, this need for tight, uniform integration is precisely the kind of need that architectures like IDEA, specifically its plan database, are supposed to address. IDEA gives planning decisions first class status in its plan database and it could likewise incorporate teamwork and adjustable autonomy decisions. Thus, one model of a general software architecture for multi-satellite missions like MMS is to integrate the teamwork and adjustable autonomy reasoning into the rest of the decision-making. The constraints that the alternative decision choices impose on each other can then be explicitly reasoned about. For example, in such a system, the planning/scheduling decides which transfer of control strategy to use in concert with decisions being made about other tasks.

An alternative is to treat these decision-making processes as separate modules. Indeed this is often the norm in the design of multi-agent teams. Teamcore in particular is an architecture designed around the assumption that teamwork reasoning can be a distinct module or wrapper around the rest of the agent's individual task reasoning. This approach has many benefits. The separation has no doubt played a key role in the advances made in multi-agent teamwork theory. More pragmatically, the separation provides a strong decomposition that greatly simplifies the software engineering task. It also allows existing agent designs to be wrapped. It would likely work well in many multi-satellite missions. But it does, by design, enforce a separation between individual task reasoning and team task reasoning. If the tradeoffs between these tasks are inconsequential, then there needs to be someway to make those tradeoffs explicit in the interactions between decision modules. For example, supervisory control might communicate to the teamwork reasoning various time windows available to make a decision along with its estimate of their impact on solution quality. The teamwork reasoning module would make a decision on the appropriate coordination strategy based on this information and its own estimates. One might also imagine some form of iterative communication between a single craft's modules, or even negotiation, to come to a joint decision.

A third alternative is arguably more radical. We mention it here only since we earlier discussed decentralized POMDPs as a framework of analysis. This naturally raises the question of why not consider them for synthesis. In this approach, there is no flexible supervisory control and no teamwork reasoning module. Rather a decentralized policy is derived for all the craft. Each craft's software simply implements that policy that drives their behavior based on the history of their observations. The individual craft sense, communicate, make attitude adjustments, uplink and downlink because their individual policies informed them to perform these actions. We do not envision this approach being feasible for anything but perhaps the shorter, simpler missions. Given the complexity of generating Dec-Pomdp algorithms, it may not be feasible to derive the policy for longer, more complex missions in the first place. Further, the probabilistic models for state transitions, observations, etc. are not known with sufficient accuracy to entrust mission success to them. The policies themselves may be too large to store on board. Arguably most important is the fact that there are alternative approaches with well-demonstrated track records. IDEA is the follow-on to Remote Agent which has mission experience. STEAM has been used in many applications where it is has demonstrated its robustness and has even evaluated in several domains within the COM-MTDP framework where it has demonstrated that it can provide a cheaper-to-compute good approximation to optimal performance.

9 Recommendations

It is a difficult challenge to design a team of agents that can coherently and efficiently pursue common goals in dynamic, uncertain environments. Indeed, the magnitude of the challenge is often underestimated. However considerable progress has been made by the multi-agent research community in understanding this challenge, designing teamwork algorithms and implementing agent teams. Clearly, this research could play an important role in facilitating the development of NASA multi-satellite missions. As has been noted throughout this paper, the application of this research to NASA missions like MMS raises several issues and opportunities. In this conclusion, we summarize these issues and make suggestions for future directions.

NASA is embarking on a wide range of ambitious multi-satellite mission designs. By establishing FFTB and DSS, NASA has already recognized and acted on the pressing need for systematic evaluation and experimentation of any distributed spacecraft system. This presents a clear opportunity for NASA and the multi-agent research community to collaborate. In particular, models of teamwork reasoning could be part of this experimentation. Without such models, key questions about satellite coordination and performance will remain unanswered. Incorporating a teamwork module would be relatively straightforward. Indeed, there are no technological barriers to incorporating Teamcore into DSS since Teamcore, like FFTB and the DSS system, is designed to be a modular component.

In particular, the formal MTDP work can and should play a key role in analyzing designs for distributed satellite missions. These formal frameworks will likely have a major impact on multi-agent research. For example, the best-case, worst-case and average case analyses they support will be a critical part of any real-world, high-cost application of multi-agent systems. In terms of NASA missions, the formal analyses could be performed, rapidly, outside of DSS, resulting in tested and improved teamwork prescriptions that would then be tested inside of DSS. Alternatively, a hybrid approach might be feasible where some of the probabilistic functions of the MTDP framework are realized by software modules that are part of the DSS.

Note, as discussed earlier, we envision that the main role for MTDP to be in the analysis of algorithms or informing the design of new algorithms, as opposed to synthesis of MTDP policies as a replacement for existing algorithms.

As a first step towards applying this MTDP framework to the problem of designing better satellite teams, we would propose to cast an example NASA satellite constellation problem, specifically MMS, into the MTDP framework. This will allow us to evaluate alternative approaches to role replacement and adjustable autonomy eventually and contrast them with optimal policies. We also envision that an ISAAC-like tool that incorporates the MTDP framework could be readily incorporated into the DSS environment. To fully exploit the potential of the MTDP work, research is needed to develop efficient algorithms for finding approximately optimal policies.

As NASA embarks on developing multi-satellite missions, we believe it is important to explore general approaches to teamwork reasoning and analysis from the start. We believe this is true even in early multi-satellite missions that may seemingly require minimal teamwork coordination. For example, it may seem that a mission like MMS is simple enough that it does not require general architectures for teamwork or extensive analysis of alternative coordination schemes.. However, ad hoc coordination schemes that address specific coordination tasks as special cases are too brittle. This conclusion has come to the multi-agent community through hard-earned experience. Quite simply, human designers cannot think of every way coordination can break down, so there is always another special case rule to add. Further, it ends up being more time consuming and costly to come up with the host of ad hoc rules. Finally, by incorporating general teamwork reasoning and analysis early on, these initial missions could lay critical groundwork that could be exploited in later more ambitious missions.

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Summary of the Report:
Teamwork Reasoning
and
Multi-Satellite Missions

NASA Agreement
Investigating Teamwork Among Spacecraft
Number
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NASA is rapidly moving towards the use of spatially distributed multiple satellites operating in near Earth orbit and Deep Space. The satellites will be required to cooperate with each other as a *team* that must achieve common objectives with a high degree of autonomy from ground based operations. Such satellite teams will be able to perform spatially separated, synchronized observations that are currently not feasible in single satellite missions. Autonomous operations will reduce the need for ground-based support that would otherwise be prohibitively expensive in such missions. However, the underlying control systems necessary to enable such missions will raise many new challenges in autonomous, multi-platform operations.

In particular, a critical requirement for these satellite constellations is that they must act coherently as a coordinated, at times autonomous team, even in the face of unanticipated events such as observation opportunities or equipment failures. Further, the satellites will need to take actions that will not only impact the constellation's current tasks but may also impact subsequent tasks, an issue that is particularly relevant given the often long duration of some missions and the limited power and fuel resources available to each satellite. Overall, the ability to operate as a team will need to be satisfied in many of the multi-satellite missions being planned. Therefore, it is important to understand this requirement, elucidate the research challenges it presents and consider approaches to satisfying it.

The multi-agent research community has made considerable progress in investigating the challenges of realizing such teamwork. In the full report, we discuss some of the teamwork issues that will be faced by multi-satellite operations. In particular, we discuss the Magnetospheric Multiscale mission (MMS) to explore Earth's magnetosphere. We describe this mission and then consider how multi-agent technologies might be applied to improve the design and operation of such missions.

Specifically, the report illuminates several basic issues. It discusses the need to develop robust and effective coordination techniques for multi-satellite teamwork. Rather than mission-by-mission ad hoc approaches to coordination, we focus on a general approach to teamwork that will be both more robust in a particular mission while also building across mission, teamwork-technology infrastructure. We also stress the need for analysis and suggest a formal approach to assessing the quality of alternative coordination techniques, based on the MTDP (*Multi-agent Team Decision Problem*) framework that allows both formal and empirical evaluation. We illustrate how this approach could be applied to MMS's science operations and discuss how it could be extended to provide a faithful rendering of difficult resource limits that such missions will operate under. In addition, we discuss alternatives to realizing the teamwork reasoning and how teamwork and autonomy is integrated into a craft's overall software architecture.

MTDP provides a tool to address a range of analyses critical to fielding teams in real world applications. Using the MTDP framework, the complexity of deriving optimal teamwork policies across various classes of problem domains can be determined. The framework also provides a means of contrasting the optimality of alternative approaches to key teamwork issues like role replacement and communication. Finally, the framework allows us to empirically analyze a specific problem domain or application of interest. To that end, a suite of domain independent algorithms has been developed in prior work that allows a problem domain to be cast into the MTDP framework. This allows the empirical comparison of alternative teamwork approaches in that domain. Derivation of the optimal policy for the problem domain serves not only as the basis of comparison but also can inform the design of more practical policies. Most recently, progress is being made in addressing how real world operating constraints like power consumption can be modeled in this framework.

But of course, teamwork and autonomy reasoning are just one part of the multi-satellite team's operation, which must include various flying, observation, communication and maintenance tasks over the duration of the mission. So, the report also discusses the supervisory control software that manages and schedules these tasks. In particular, we discuss one approach to the design of this supervisory software and the integration of teamwork reasoning within this supervisory control software.

The report makes several recommendations for the future of the research and also potential collaborations with NASA. In particular, it is suggests that the formal MTDP work could play a key role in analyzing designs for distributed satellite missions. MTDP formalisms could be used in the analysis of algorithms or informing the design of new algorithms. For example, the best-case, worst-case and average case analyses that the MTDP models support could be of critical assistance in the design and development of any real-world, high-cost application of multi-agent systems. In terms of NASA missions, the formal analyses could be performed entirely within the MTDP framework, resulting in tested and improved teamwork prescriptions. Alternatively, the MTDP framework could be realized by software modules that are incorporated into ongoing NASA Goddard work in distributed satellite simulation.

As a first step towards applying this MTDP framework to the problem of designing better satellite teams, we propose to cast an example NASA satellite constellation problem, specifically MMS, into the MTDP framework. This will allow us to evaluate alternative approaches to teamwork and adjustable autonomy as well as contrast them with optimal policies.

As NASA embarks on developing multi-satellite missions, we believe it is important to explore general approaches to teamwork reasoning and analysis from the start. We believe this is true even in early multi-satellite missions that may seemingly require minimal teamwork coordination. For example, it may seem that early missions will be simple enough that they will not require general architectures for teamwork or extensive analysis of alternative coordination schemes. However, ad hoc coordination schemes that address specific coordination tasks as special cases are too brittle. This conclusion has come to the multi-agent community through hard-earned experience. Quite simply, human designers cannot think of every way coordination can break down, so there is always another special case rule to add. Further, it ends up being more time consuming and costly to come up with the host of ad hoc rules. Finally, by incorporating general teamwork reasoning and analysis early on, these early multi-satellite missions could lay critical groundwork that could be exploited in later even more ambitious missions.