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BASIC AVIONICS MODULE DESIGN FOR GENERAL AVIATION AIRCRAFT

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ABSTRACT: This report describes the design of an Advanced Digital Avionics System (Basic Avionics Module) for General Aviation aircraft operated with a single pilot under IFR conditions. The microprocessor based system provides all avionic functions including flight management, navigation, and lateral flight control. The mode selection is interactive with the pilot. The system uses a navigation map data base to provide operation in the current and planned Air Traffic Control environment. The system design includes software design listings for some of the required modules. The distributed microcomputer uses the IEEE 488 bus for interconnecting the microcomputer and sensors. (Author)

DESCRIPTORS: Digital avionics, distributed microcomputers, digital data busses, navigation, digital flight control, avionics data control center, interactive mode selection, navigation map, flight management, single pilot IFR, General Aviation, modular software, higher order language for avionics, microprocessor, distributed processing.

IDENTIFIERS: Digital avionics for General Aviation, navigation, digital flight control.

Foreword

This final report is prepared in compliance with part IV E of Contract No. NAS1-15284 covering the preliminary design of a Basic Avionics Module (BAM) for general aviation aircraft.

The authors acknowledge the interactions and helpful discussions with the NASA Langley personnel particularly Mr. Charles T. Woolley, Technical Representative and Dr. John D. Shaughnessy, Alternate Technical Representative.

The authors also wish to acknowledge discussions with Mssrs. Henry J. E. Reid, Jr. and H. Douglas Gardner of NASA Langley regarding low cost sensors which influenced the final selection of the dead reckoning sensors.

Customary units were used for the principal measurements in this report.

SI units are presented in the report except in those cases in which handbook data is presented which is in customary units. /handbook data is presented which is in customary units. The authors wish to acknowledge the module schematics prepared by Mr. Robert Simmons and the system schematics prepared by Mr. Robert Allen.

Mr. David Micek provided support to the software development.

Mrs. Emilie Smyth and Ms. Dawn Smyth were responsible for the word processor preparation of the report on the COMPUTRM 32/63Ø computer. Mrs. Emilie Smyth prepared the figures used in the report.

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BAM NOMENCLATURE

AC	alternating current
ADC	analog to digital converter
ADCC	avionics data control center
ADF	automatic direction finder
APU	arithmetic processor unit
ASCII	American standard code for alphanumeric characters
ATC	air traffic control
BAM	basic avionics module
BAMME	BAM microcomputer equipment
BCD	binary coded decimal
BCS	broadcast station
BHP	brake horsepower
CG	center of gravity
CPU	central processor unit
CRT	cathode ray tube
DAC	digital to analog converter
DC	direct current
DIP	dual in line package (I.C. chip)
DMA	direct memory access
DMC	distributed microcomputer complex
DME	distance measuring equipment
DOS	disk operating system
ETA	estimated time of arrival
FPM	feet per minute
GAA	general aviation aircraft
GLIDE SLOPE	radio aids on ILS approach course
GMT	Greenwich mean time
GPH	gallons per hour

BAM NOMENCLATURE (CONT.)

IAS	indicated air speed
IFR	instrument flight rules
ILS	instrument landing system
I/O	input/output
JEPPESEN	well known supplier of flight maps
LAT	latitude
LNG	longitude
LORAN C	long range navigation system
MAG HDG	magnetic heading
MARKER, OUTER & MIDDLE	radio aids on ILS approach course
MEA	minimum enroute altitude
NAVSTAR/GPS	satellite navigation aids, Global Positioning System
NDB	non directional beacon
OAT	outside air temperature
PA	pressure altitude
PC	printed circuit (connectors)
RAM	random access memory
RNAV	area navigation
ROC	rate of climb
SID	standard instrument departure
STAR	standard arrival route
TAS	true air speed
T.O. DIST	take off distance
VNAV	vertical navigation
VOR	visual omni range
W&B	weight and balance

1.Ø INTRODUCTION

The BAM design is intended to provide a low cost research and development system for use by NASA Langley in investigating methods of reducing pilot workload and improving safety during sigle pilot IFR operations. The NASA Langley investigations will utilize the LaRC simulation facilities and general aviation test aircraft. The BAM design has been oriented towards a Cessna 172 class of general aviation aircraft.

The Basic Avionics Module (BAM) for General Aviation Aircraft (GAA) is intended to provide the functions required to relieve the work load on a single pilot operating in today's air traffic control (ATC) environment. The BAM utilizes interactive display techniques devised to simplify the procedures of selecting the many modes provided by BAM. The BAM interactive display techniques are specifically aimed at providing assistance to the single IFR pilot during conditions which would otherwise cause work load saturation such as changes in flight plan route by the ATC controller, operations in high density ATC areas, or during emergencies when it is important to have available the emergency check list.

One problem that is universal for single pilot IFR operation is the management of paper (flight plans, charts, operation handbook, etc.) that a copilot would otherwise assist with. The BAM is specifically directed towards managing this cockpit paper.

Another problem confronting the single pilot in IFR conditions in high density ATC areas is the possibility of geographical disorientation which can occur when the ATC controller issues numerous radar vectors without reference to location or Navigation aids. The BAM provides a navigation map display which maintains geographical orientation relative to the destination waypoint and the associated navigation aids (VOR's, NDB's, and ILS localizers).

A key design objective for the BAM is to utilize a modular architecture so that additional functions can be added to BAM to provide additional capabilities such as DME based RNAV and VNAV and vertical guidance. The use of a common data bus plus a common data base, which can be accessed by any of the avionics functions, provides the desired data base.

A parallel data bus (the IEEE 488) was selected over a serial data bus (e.s. the MIL-STD-1553A) in order to provide adequate data rates for the avionic functions using existing available components. The lower speed parallel bus is easier to implement than the 1 Mbit/sec 1553 bus.

The BAM design utilizes a third generation microprocessor to implement the distributed microcomputer complex (DMC). The continuing decrease in the cost of microprocessors and their associated memory promise a low cost system with the BAM functional features in the near future.

2.0 FUNCTIONAL DESCRIPTION

The BAM functions are presented in figure 2.0-1 which includes Flight Management, Navigation & Position Fixing, Lateral Flight Control, and the Navigation Map which is displayed on the Avionics Data Control Center (ADCC). The computations to support the BAM functions are performed by the Distributed Microcomputer (DMC) which provides for functional communications via the common data bus. The ADCC provides the means for the single pilot to communicate interactively with the BAM functions. The BAM acts as a surrogate copilot to the single pilot in IFR operations and helps prevent work load saturation by

- o Aiding the pilot in making enroute ATC changes
- o Assisting in Navigation Orientation in High Traffic Density areas
- o Providing rapid access to emergency procedures in emergency situations

The "broken arrow" in figure 2.0-1 implies that the BAM system acting as a surrogate copilot prevents the single pilot in an IFR environment from becomming saturated by ATC route changes, high density operations and emerging situations which may arise.

2.1 FUNCTION/MODE SELECTION

The BAM functions and modes are selected by means of interactive ADCC. The menus are hierarchical begining with the top level functions as shown in figure 2.1-1. When a function is selected from the master menu, then the next functional level menu is selected as shown in the figure 2.1-1. The functional menus contain the mode selections for the selected function. The next level below the functional menus are the submenus for selection of submodes, or in some cases an interactive display appears which may have one or two options to select.

At each level in the hierachy of menus there is a selection which permits returning to the higher level menus. As an added 'sign post', the various level menus are given a decimal 'outline' number to indicate the level in the hierarchy for orientation purposes. If at any time the pilot becomes confused as to where he is in the 'maze' of modes, he can readily 'home' to a familiar high level menu to get re orientated.

The function/mode selection is interactive with the BAM giving prompts to the pilot so he does not have to remember complex syntaxes of switching procedures.

Care has been taken in the design of the interactive operating system that any mistake in data entry or mode selection can be easily recovered from in an unambiguous fashion.

A key benefit of the interactive hierarchical menu concept is the elimination of complex mode switching panels. The ADCC data entry .eyboard is very simple compared with the myriad of mode selection panels scattered about the cockpit for the various functions of conventional avionics.

FIGURE 2.0-1

BAM FUNCTIONS

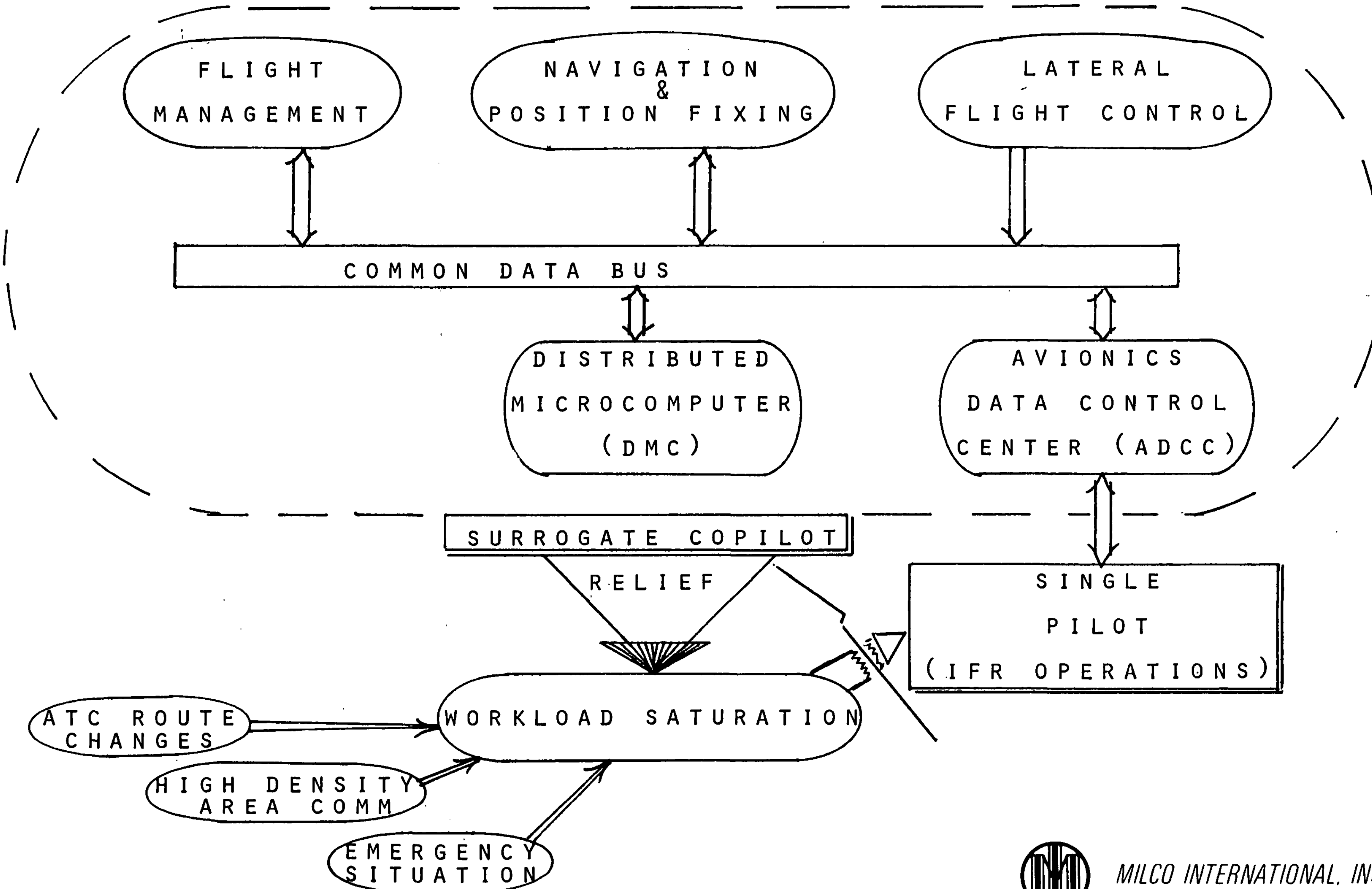

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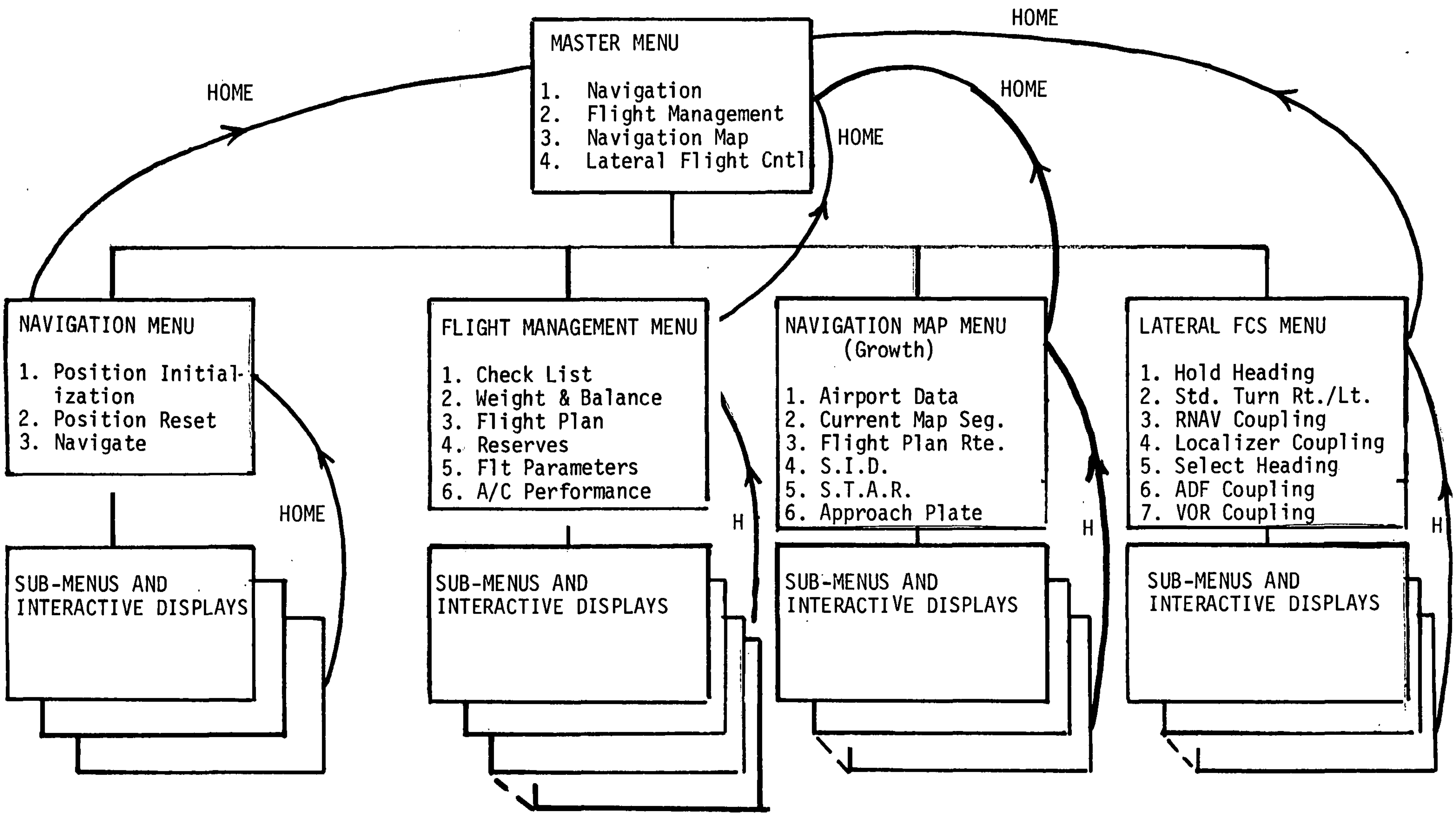
Figure 2.1-1 MODE & FUNCTION MENU HIERARCHY CONCEPT



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2.2 FLIGHT MANAGEMENT FUNCTION

The Flight Management Function Menu shown in figure 2.2-1 is selected from the master menu. The flight management function includes the following modes and subfunctions:

2.2.1 CHECKLISTS

Each checklist in the operations manual is stored and can be selected by the checklist menu. The Cessna 172 checklists have been programmed, however, any aircraft checklists can be programmed. For example, the Rockwell 112TC checklists were programmed initially. The checklists are permanently stored on a mass memory device on the Avionics Data Control Center (ADCC) display.

The checklists are listed on the menu in the normal sequence they would be used during a typical flight. For a given checklist a cursor appears next to each item on the checklist when displayed on the ADCC. As the enter key is depressed on the ADCC keyboard, the cursor steps to the next checklist item in the sequence. When each item has been sequenced the checklist menu is again displayed. Figure 2.2.1-1 shows additional checklist selections as examples.

Emergency checklists are automatically displayed based upon an emergency word which examines sensors and switches which indicate the emergency condition. This feature has not been programmed in the BAM demonstration software.

2.2.2 WEIGHT AND BALANCE

The weight and balance computation mode is also selected from the Flight Management Menu as shown in figure 2.2.2-1. The pilot enters the pilot and passenger weights, the baggage weight, and the fuel on board in gallons. The W&B mode then computes the moment arm and gross weight and displays the CG on the ADCC display and issues a warning message if the weight or CG limits are exceded.

2.2.3 FLIGHT PLAN

The flight plan mode is selected from the flight management menu as shown in figure 2.2.3-1. The first option is for entering an original flight plan or revising an existing flight plan. The selection of option 1 with the resulting entry of the flight plan data is shown in figure 2.2.3-1. The first step in the flight plan entry is to enter the initial data such as initial fuel, intended cruise % BHP (Brake Horse Power), etc.

The next step is to enter the initial Map# as a four digit code. Then the waypoints are entered in sequence using the waypoint coding scheme shown in figure 2.2.3-2 A modified telephone keyboard is used for entering the waypoint using coded numbers which are echoed back on the display in alphanumeric symbols. As each waypoint is entered the desired altitude at the waypoint is designated in thousands of feet. The program checks the minimum enroute altitude, (MEA) associated with each waypoint and flashes an error message if an altitude below the MEA is selected.

FIGURE 2.2-1

FUNCTION SELECTION MENU

MASTER MENU

```
NAVIGATION.................... 1
FLIGHT MANAGEMENT............ 2
NAVIGATION MAP............... 3
LATERAL FLIGHT CONTROL....... 4

WHICH FUNCTION ?2
```

FLIGHT MANAGEMENT MENU

```
CHECKLIST.................... 1
WEIGHT AND BALANCE........... 2
FLIGHT PLAN.................. 3
RESERVES..................... 4
FLIGHT PARAMETERS............ 5
AIRCRAFT PERFORMANCE......... 6
WHICH FUNCTION ? 1
```

CHECKLIST MENU

```
EXTERIOR INSPECTION................ 1
BEFORE STARTING ENGINE............. 2
STARTING ENGINE.................... 3
BEFORE TAKEOFF..................... 4
NORMAL TAKEOFF..................... 5
MAXIMUM PERFORMANCE TAKEOFF........ 6
CLIMB.............................. 7
CRUISING........................... 8
WHICH FUNCTON ? 1
  REMOVE CONTROL WHEEL LOCK
  CHECK IGNITION SWITCH OFF
  TURN ON MASTER SWITCH, CHECK FUEL, TURN OFF MASTER SWITCH
  FUEL SELECT VALVE ON BOTH
  CHECK BAGGAGE DOOR
  REMOVE RUDDER GUST LOCK
  UNTIE TAIL
  CHECK RUDDER AND ELEVATOR
  CHECK AILERON
  UNTIE WINGS
  CHECK TIRE INFLATION
  VISUALLY CHECK FUEL, FILLER CAP
  CHECK OIL LEVEL, 6 QTS MINIMUM
  PULL FUEL STRAINER-DRAIN
```

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FIGURE 2.2.1-1

CHECKLIST MENU

CHECK LIST SELECTION

```
EXTERIOR INSPECTION................. 1
BEFORE STARTING ENGINE.............. 2
STARTING ENGINE..................... 3
BEFORE TAKEOFF...................... 4
NORMAL TAKEOFF...................... 5
MAXIMUM PERFORMANCE TAKEOFF......... 6
CLIMB............................... 7
CRUISING............................ 8
WHICH FUNCTON ? 2
```

(1)

(2)

SEATS, SEAT BELTS--ADJUST AND SECURE
FUEL SLECTOR--BOTH
BRAKES--TEST AND SET
RADIOS AND ELECTRICAL EQUIPMENT--OFF

(3)

MIXTURE--RICH
CARB HEAT--COLD
PRIMER--2 TO 6 STROKES, NONE IF WARM. CLOSE AND LOCK PRIMER
THROTTLE--OPEN 1/8 INCH
MASTER SWITCH--ON
PROPELLER AREA--CLEAR
IGNITION SWITCH--START (RELEASE WHEN ENGINE STARTS)
OIL PRESSURE--CHECK

(4)

PARKING BRAKE--SET
FLIGHT CONTROLS--CHECK FOR FREE AND CORRECT MOVEMENT
FUEL SELECTOR--BOTH
ELEVATOR TRIM--TAKEOFF SETTING
THROTTLE--1700 RPM
ENGINE INST AND AMMETER--CHECK
SUCTION GAUGE--4.6 TO 5.4
MAGNETOS--CHECK EACH, RPM LOSS LESS THAN 125 RPM
CARB HEAT--CHECK OPERATION
FLIGHT INSTRUMENTS AND RADIOS--SET
AUTOPILOT--OFF
CABIN DOORS AND WINDOW--LOCKED

(5)

WING FLAPS-- 0'
CARB HEAT--COLD
POWER--FULL THROTTLE
ELEVATOR--LIFT NOSE WHEEL AT 60 MPH
CLIMB SPEED--75 TO 85 MPH

(6)

WING FLAPS- 0'
CARB HEAT--COLD
BRAKES--APPLY
POWER--FULL THROTTLE
BRAKES--RELEASE
AIRPLANE ATTITUDE--SLIGHTLY TAIL LOW

(7)

(8)

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FIGURE 2.2.2-1

W E I G H T & B A L A N C E

```
                               MASTER MENU

NAVIGATION................... 1
FLIGHT MANAGEMENT............ 2
NAVIGATION MAP............... 3
LATERAL FLIGHT CONTROL....... 4

WHICH FUNCTION ?2

                               FLIGHT MANAGEMENT MENU

CHECKLIST.................... 1
WEIGHT AND BALANCE........... 2
FLIGHT PLAN.................. 3
RESERVES..................... 4
FLIGHT PARAMETERS............ 5
AIRCRAFT PERFORMANCE......... 6
WHICH FUNCTION ? 2
```

```
WEIGHT AND BALANCE

WEIGHT OF PILOT: 180       COPILOT: 125

REAR SEAT PASSENGER: 200   PASSENGER: 100

FUEL:  50                  BAGGAGE: 55
WEIGHT AND BALANCE WITHIN LIMITS
 MOMENT ARM= 106.1
MAX ALLOWED= 111.5
MIN ALLOWED= 92.7
WEIGHT LBS = 2369
GROSS WT   = 2300
```

FIGURE 2.2.3-1

FLIGHT PLAN SELECTION

FLIGHT MANAGEMENT MENU

```
CHECKLIST . . . . . . . . .1
WEIGHT AND BALANCE . . . 2
FLIGHT PLAN. . . . . . . 3
RESERVES . . . . . . . . 4
FLIGHT PARAMETERS . . . .5
AIRCRAFT PERFORMANCE. . .6
WHICH FUNCTION ? 3
        Original Flight Plan...1  OR  Revise Flight Plan......2 ?  1
   INIT FUEL: 50 gal                  TEMP 'C AT AIRPORT: 20'
   WIND: 250'  25kts                  CRUISE % BHP: 75%
   ETD: 14.30 hrs
```

DATA ENTRY

WAYPOINT ENTRY

INITIAL MAP #: 0422

MAP #	WAYPT#	WAYPT	ALT.X 1000 ft
0422	0	MEAD01	CLB
0422	1	BFL	3000
0422	2	KWSO	4000
0422	3	POND	5000
0422	4	PIXLEO	5000
0422	5	DELAN	5000
0422	6	KWSO	4000
0422	7	BFL	3000
0422	8	MEAD01	LND

AUTOMATIC COMPUTATION

DEPART FROM	ETD	INITIAL FUEL/GAL
MEAD01	14.30	50.0

FROM	TO	COURSE DDD	DIST NN.N	HDG DDD	ETER H.MM	EGS KTS	ALT FT.	RES/GAL GAL	RES/HRS HRS
MEAD01	BFL	323	3.8	323	.02	100	CLB	49.4	3.32
BFL	KWSO	282	11.6	282	.05	139	3000	48.3	3.27
KWSO	POND	353	15.2	353	.08	111	4000	46.4	3.19
POND	PIXLEO	331	8.7	331	.04	121	5000	45.4	3.15
PIXLEO	DELAN	147	15.3	146	.07	125	5000	43.7	3.08
DELAN	KWSO	193	10.1	192	.04	143	5000	42.7	3.03
KWSO	BFL	102	11.6	101	.07	106	4000	41.2	2.57
BFL	MEAD01	143	3.8	142	.02	121	3000	40.7	2.55

DESTINATION	TDIST	ETA	FINAL RES/GAL	RES/HRS
MEAD01	80.1	15.09	40.7	2.55

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FIGURE 2.2.3-2

WAYPOINT CODING SCHEME

USE A MODIFIED TELEPHONE STYLE KEYBOARD

PRS 7	TUV 8	WXY 9
GHI 4	JKL 5	MNO 6
QZ 1	ABC 2	DEF 3
/	Ø	.

→

LOOK-UP TABLE

TYPE OF WAYPOINT	
VOR	3 CHARACTERS
INTERSECTIONS	5 CHARACTERS
AIRPORTS	5 CHARACTERS + 1 or Ø *
ILS	I + 3 CHARACTERS
NDB/CBS	4 CHARACTERS

→

- FILE SEARCH AIDED BY NUMBER OF CHARACTERS
- ECHOES BACK ALPHANUMERIC DESIGNATOR
- AMBIGUITY RESOLUTION
  e.g.
  1 SMO ← 766
  2 POM ← 766

  KEY IN 1 or 2

ADVANTAGE: OBTAIN ALPHANUMERIC READOUT USING NUMERIC KEYBOARD

* 1 ≡ IFR APPROACH
0 ≡ VISUAL ONLY

In many cases a way point has more than one airway emanating from the waypoint with the MEA depending on the direction of flight from the waypoint. The waypoint stored in the map data base will include an asterisk when the MEA is flight dependent. The multiple MEA's for 'asterisked' wayoints will be coded in the map data base as shown below in table 2.2.3-1 by example.

TABLE 2.2.3-1 EXAMPLE OF WAYPOINTS WITH DIRECTION DEPENDENT MEAs

WAYPOINT	DIRECTION OF FLT	MEA
* BFL	32,35,19	3Ø
	26,12	4Ø
	14	6Ø
* SHAFT	26	4Ø
	Ø8	25
* ARVIN	12	78
	29	4Ø
* TAFTO	19	9Ø
	11	1ØØ
	29	45
	Ø1	6Ø
PONDO		3Ø

The waypoint BFL is a VOR which has six airway segments emanating from it. BFL is located near the southern end of the San Joaquin Valley with mountainous terrain to the east and south, consequently the MEA is highly dependent upon the direction of flight as indicated. BFL is coded with an asterisk which means the MEA is direction dependent. The direction of flight of the airway is coded with the first two digits of the magnetic bearing, the MEA is coded in hundreds of feet (3Ø.53's of meters). When two or more directions of flight have the same MEA, then the directions are separated by commas in the data base file.

The waypoints SHAFT and ARVIN have only two airway segments with differnt MEA's for each segment.

The waypoint PONDO which is not denoted by an asterisk has a single MEA independent of direction of flight.

For the final destination waypoint the altitude entered is LND (land) which signals the program the flight plan computations should be performed.

The flight plan computations are displayed on the ADCC. After printig out the computed flight plan data, the pilot is given the option of selecting an alternate routing.

The flight plan mode provides for revised routing after the original flight plan is entered. The revision could take place, for example if the clearance delivery controller issues a different routing than that which was originally filed on the flight plan by telephone, or if the enroute ATC controller issues a revised routing.

After entering the revised routing a new flight plan computation is performed.

During the flight the pliot can select the flight plan display to obtain the current flight plan estimates based upon ground speed made good and actual fuel rates.

2.2.4 RESERVES

During flight the pilot may select the reserves mode which permits the pilot to enter any waypoint (which is stored in the data base) and BAM will compute and display the reserves based upon the currently encountered winds and the current fuel rates. The system issues warnings if the selected waypoint is beyond the current range with IFR reserves (45 minutes). The reserve computations include range, fuel and endurance.

The reserves mode is selected from the Flight Management Menu (selection 4) shown in figure 2.1-1. After selection of the reserves mode (4) the pilot is offered the following selection menu on the CRT display:

```
            RESERVES MENU
Reserve to Current Destination...............1
Reserves at Other Waypoint...................2
Return to Flight Management Menu.............3

Which Function ?
```

The pilot enters his selection by depressing the appropriate number on the "telephone" keyboard. If the pilot selects "1," then the information is displayed on the CRT screen as shown in figure 2.2.4-1.

In the event the pilot selects a new power setting the alternate reserves will be presented in the same format as figure 2.2.4-1 but with the revised power setting, fuel rate and ground speed displayed. This option permits the pilot to assess changes in power settings in the current reserves.

If the waypoint used in the reserves mode is in the current flight plan, the program assumes the flight plan route is followed. If the waypoint is not in the current flight plan, then the program assumes a ruhmbline course from the current position to the waypoint. The rhumbline course and distance are displayed for this mode.

FIGURE 2.2.4-1

RESERVES STATUS

Fuel Remaining at Destination	FF gal
Endurance at Destination	TT.MM hours & min.
Range at Destination	DD.d N. Miles
Distance to Destination	DD.d N. Miles
Bearing to Destination	BBB degrees

Your reserves are based on current power setting, fuel consumption rate and winds which are:

Power Setting	RRRR RPM = HHH.h BHP
Fuel Rate	G.g GPM
Winds Aloft	WW Kts from DDD degrees
Ground Speed	SSS Kts

Enter Alternate RPM if you desire reserves for new power setting: RRRR

2.2.5 FLIGHT PARAMETERS

This mode displays the current relevent flight parameters upon selection of this mode including IAS, TAS, pressure altitude, fuel flow rate, OAT, MEA of the current flight plan segment (if on airways or RNAV airways), and Brake Horsepower. The flight parameters are based on a combination of sensed data and computed data.

The flight parameters mode is selected by depression selection 5 from the flight management menu shown in figure 2.2.2-1. The information as illustrated in figure 2.2.5-1 is displayed to the CRT screen.

FIGURE 2.2.5-1 FLIGHT PARAMETERS DISPLAY

CURRENT FLIGHT PARAMETERS

Pressure Altitude	HHHHH feet
Minimum Enroute Altitude	HHHHH feet
Ground speed	SSS knots
True Air Speed	SSS knots
Indicated Air Speed	SSS knots
Brake Horse Power	PP.p Horsepower
Fuel Flow Rate	GG.g gallons/hour
Outside Air Temperature	TT.t degrees Celsius
Winds Aloft	WW.w knots from DDD degrees
Drift Angle	DD.d degrees Right or Left
Heading	DDD degrees magnetic
Bearing/Distance to next Waypt.	BBB/DDD degrees magnetic
ETA to next waypoint	HHMM.m
Magnetic Variation	DD.d degrees East or West

* In the event the aircraft is not following a stored flight plan route the MEA is shown as "OFF AIRWAYS"

2.2.6 AIRCRAFT PERFORMANCE

The Aircraft Performance Modes are selected by selecting function 6 from the flight management menu shown in figure 2.2-1 which the yields the following menu:

AIRCRAFT PERFORMANCE MENU

TAKE OFF PERFORMANCE 1

CLIMB PERFORMANCE 2

CRUISE PERFORMANCE 3

LANDING PERFORMANCE 4

The aircraft performance algorithms are illustrated in figure 2.2.6-1. The performance algorithms are based on the Cessna 172 handbook. The aircraft performance modes can be called prior to take off or during flight, since they are essentially providing handbook data.

2.2.6.1 Take off Performance

Take off performance is mode '1' from the performance menu. The input data is formatted as shown below:

TAKE OFF PERFORMANCE

HARD SURFACE RUNWAY -- WITH FLAPS UP

OUTSIDE AIR TEMP,DEG C

AIRPORT ALTITUDE, FEET

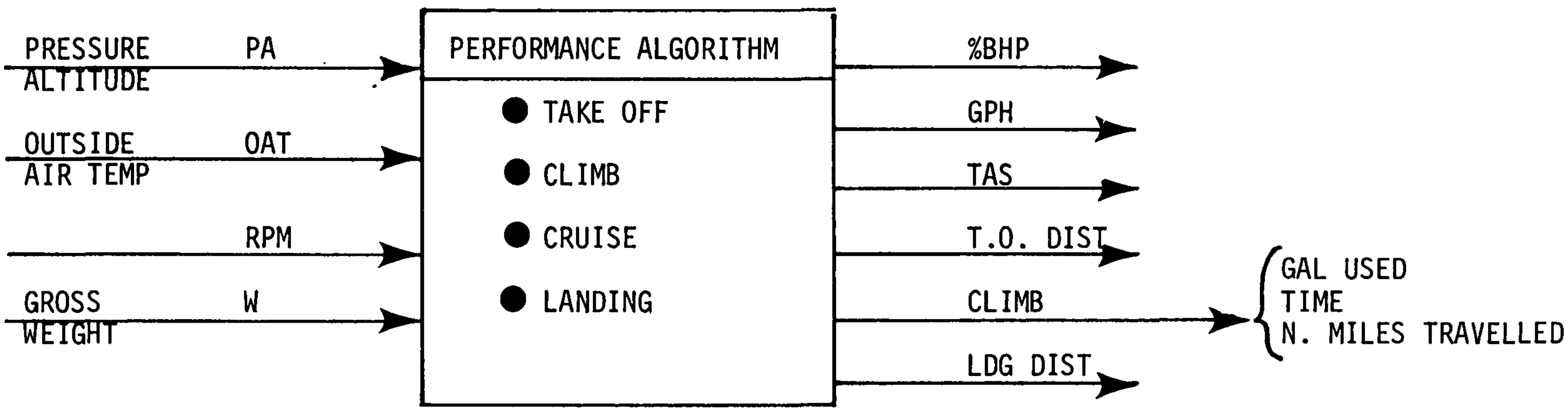
TAKE OFF WEIGHT, POUNDS

HEAD WIND, KNOTS

The take off performance algorithm is presented in figure 2.2.6-2. The output format of the computation is as follows:

TAKE OFF DISTANCE TO CLEAR 50 FT. OBSTACLE = ----- FT.

FIGURE 2.2.6-1 AIRCRAFT PERFORMANCE ALGORITHMS



APPLICATIONS

- FLIGHT PLAN
- POWER SETTING
- PERFORMANCE EVALUATION

FIGURE 2.2.6-2 TAKE OFF PERFORMANCE

$$TD = K_w \left[1 + \left(\frac{OAT - 15 - .002PA}{14.9}\right) \times 0.1\right] \left[-1184 + 1.14w\right] e^{\left[-.0000620 + .000000079w\right] PA}$$

$K_w = 1.0 - .0215V_w$

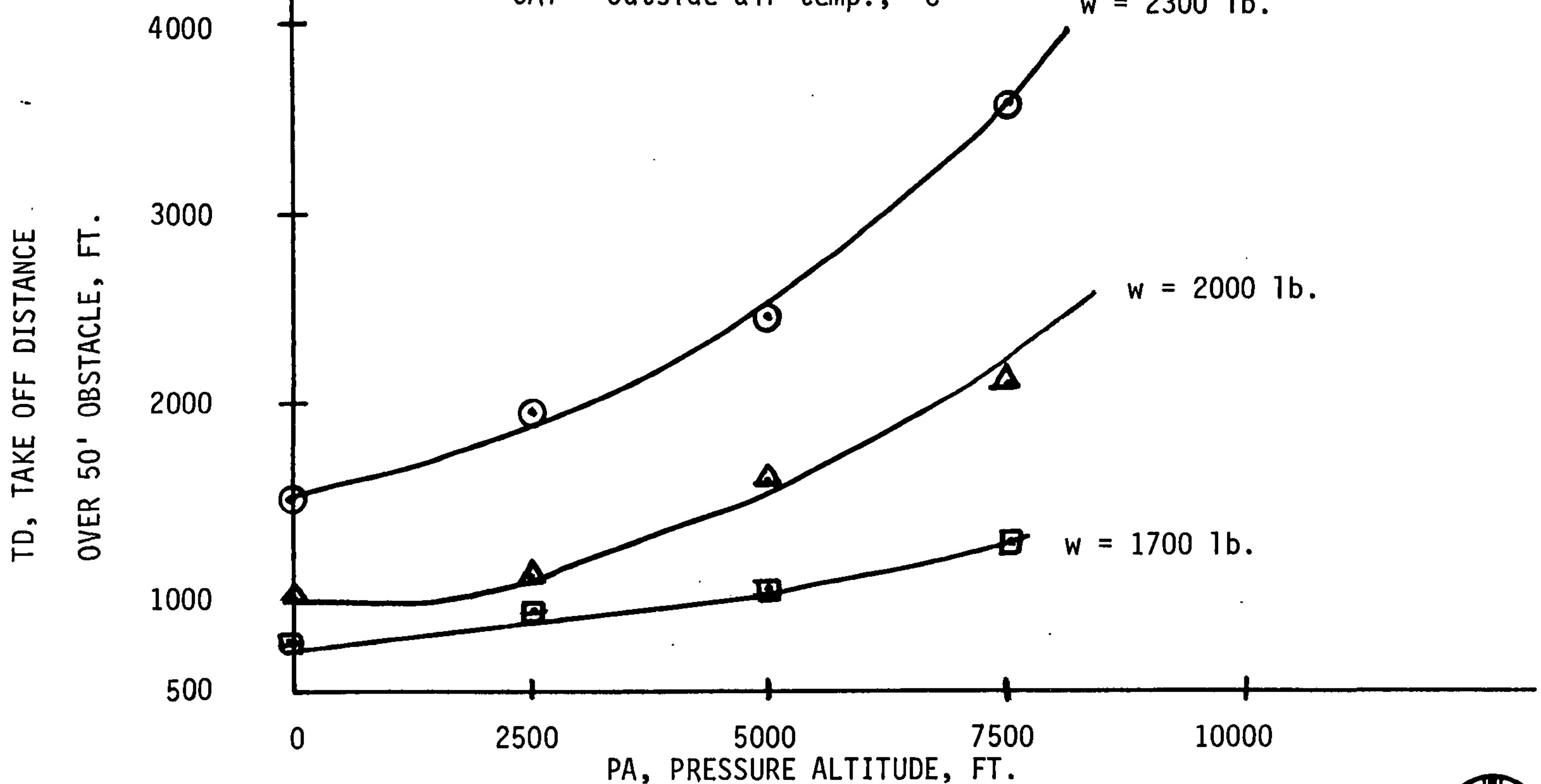
V_w = wind in Knots

PA = pressure altitude, ft.

W = weight, lb.

OAT = outside air temp., ^oC

HARD SURFACE RUNWAY
FLAPS UP
ZERO WIND
NOTE: EMPTY WEIGHT = 1285 lb.



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After completing the computation the pilot is offered the following options:

```
CHOOSE FUNCTION:                              ENTER:
----------------
RETURN TO AIRCRAFT PERFORMANCE MENU .......1
RETURN TO MASTER MENU .....................2
RETURN TO TAKE OFF PERFORMANCE ............3
```

2.2.6.2 Climb Performance

The climb performance is mode '2'. The climb performance algorithms are shown in figure 2.2.6-3. Following is the selection menu for climb performance:

```
CLIMB PERFORMANCE MENU
----------------------
RATE OF CLIMB AT SELECTED ALTITUDE .......1
TIME/DISTANCE TO CLIMB ...................2
FUEL TO CLIMB ............................3
```

The rate of climb mode is '1' and the input data required is as follows:

```
RATE OF CLIMB AT SELECTED ALTITUDES
-----------------------------------
ASSUME: FULL THROTTLE, FLAPS UP, MIX LEANED AT 3000 FT
ENTER DATA:
ALTITUDE, FEET
OAT @ ALTITUDE, DEGREES C
AIRCRAFT WEIGHT, POUNDS
```

The Rate of Climb performance algorithm is also shown in figure 2.2.6-3. The output format is as follows:

```
RATE OF CLIMB AT ----- FT = ----- FT PER MIN
```

After displaying the output the following options are offered:

```
CHOOSE FUNCTION:                         ENTER:
----------------
RETURN TO CLIMB PERFORMANCE MENU ........1
RETURN TO AIRCRAFT PERFORMANCE MENU .....2
COMPUTE ANOTHER ROC CASE ................3
RETURN TO MASTER MENU ...................4
```

The time/distance to climb to altitude mode is '2' and the input data required is as follows:

```
TIME/DISTANCE TO CLIMB TO ALTITUDE
----------------------------------.
INPUT DATA:
INITIAL ALTITUDE, FEET
FINAL ALTITUDE, FEET
OAT, DEGREES C
AIRCRAFT WEIGHT, POUNDS
```

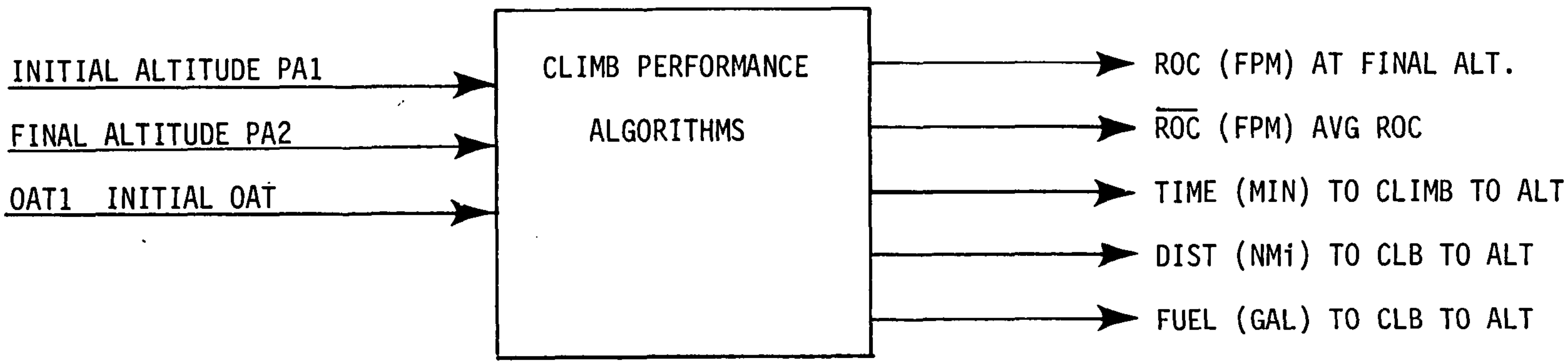
The algorithms for the time/distance to climb to altitude are presented in figure 2.2.6-4. These algorithms are also used for the flight plan computation to determine the time and distance for altitude changes. The expression for TAS in the figure is derived from the handbook which relates TAS to the aircraft weight in lbs.

The input data format is as follows:

```
TIME TO CLIMB FROM ----- FT TO ----- FT = -----MIN
```

FIGURE 2.2.6-3

CLIMB PERFORMANCE ALGORITHMS



CONDITIONS: FULL THROTTLE, FLAPS UP, MIXTURE LEANED ABOVE PA = 3000 ft.

RATE OF CLIMB (ROC) ALGORITHM AT FINAL ALT.

$$ROC(FPM) = (2319 - 0.731667w) + (-.078533 + .00001617w)PA - (OAT - 15^{o} + .002PA)1.80$$

where w = weight, lb.

PA = final pressure altitude, ft.

OAT = outside air temp at PA, ^{o}C

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FIGURE 2.2.6-4

CLIMB PERFORMANCE ALGORITHMS CONT.

AVERAGE RATE OF CLIMB ($\overline{ROC}$)

$$\overline{ROC}\ (FPM) = \frac{ROC1 + ROC2}{2}$$

$$OAT2\ (^{o}C) = OAT1 - .002\ (PA2 - PA1)$$

TIME TO CLIMB

$$T\ (MIN) = \frac{PA2 - PA1}{\overline{ROC}}$$

DISTANCE TO CLIMB

$$DIST\ (NMi) = \frac{T\ (MIN)}{\overline{60}} \times TAS$$

$$TAS\ (Kts) = 47.417 + .01375w$$

$$w = \text{AIRCRAFT WEIGHT}$$

DISTANCE TO CLIMB = -----N.MI.

After displaying the results the pilot is offered the following options:

```
CHOOSE FUNCTION:                          ENTER:
RETURN TO AIRCRAFT PERFORMANCE MENU .....1
RETURN TO CLIMB PERFORMANCE MENU ........2
RETURN TO MASTER MENU ...................3
```

Mode '3' of climb performance is the fuel to climb. The algorithms used for this mode are illustrated in figure 2.2.6-5. The input data required by this mode is as follows:

```
FUEL TO CLIMB
------------
INPUT DATA:
INITIAL ALTITUDE, FEET
FINAL ALTITUDE, FEET
AIRCRAFT WEIGHT, POUNDS
ENTER:    1 = FROM TAKEOFF    2 = ENROUTE CHANGE
```

The output format for the computation is as follows:

FUEL TO CLIMB FROM ----- FT TO ----- FT = ----- GALS

After completing the computations the pilot is offered the following options:

```
CHOOSE FUNCTION:                        ENTER:
---------------
RETURN TO AIRCRAFT PERFORMANCE MENU ....1
RETURN TO CLIMB PERFORMANCE MENU .......2
RETURN TO MASTER MENU ..................3
```

2.2.6.3 Cruise Performance

The cruise performance is mode '3' of the aircraft performance menu. The cruise performance mode requires the following inputs:

```
CRUISE PERFORMANCE
-----------------
ASSUME :   GROSS WEIGHT = 2300
           STANDARD TEMPERATURE
           LEAN MIXTURE
INPUT DATA:
CRUISE ALTITUDE, FT ---------
ENGINE RPM ----------
```

The cruise performance algorithms are given in figure 2.2.6-6. These algorithms are also used by the flight plan mode.

The cruise performance data output is as follows:

```
% BRAKE HORSEPOWER = ---------- %
TRUE AIR SPEED  = ----- KNOTS
GALLONS PER HOUR = ------
```

After displaying the performance then the pilot is offered the following options:

```
CHOOSE  FUNCTION:                             ENTER:
----------------
TO RETURN TO AIRCRAFT PERFORMANCE MENU ........1
TO RETURN TO CLIMB PERFORMANCE MENU ...........2
```

FIGURE 2.2.6-5 CLIMB PERFORMANCE ALGORITHMS (CONT.)

FUEL TO CLIMB FROM SEA LEVEL TO SELECTED PRESSURE ALT.

$$F(GAL) = 1.06\, e^{(-.00007936 + .000000102W)PA}$$

WHERE w = AIRCRAFT WEIGHT IN LBS.

PA = ALTITUDE TO CLIMB

FUEL TO CLIMB FROM INITIAL ALTITUDE TO FINAL ALTITUDE

$$F = F2 - F1$$

WHERE F2 = FUEL TO CLIMB FROM SEA LEVEL TO PA1

F1 = FUEL TO CLIMB FROM SEA LEVEL TO PA2

FIGURE 2.2.6-6

CRUISE PERFORMANCE ALGORITHMS

% BRAKE HORSEPOWER

$$\%BHP = (-104.60 + .07225\ RPM)\ e^{-.000021680 PA}$$

WHERE RPM = ENGINE RPM

PA = PRESSURE ALTITUDE

TRUE AIRSPEED, KNOTS

$$TAS = -25.92 + .0525\ RPM$$

GALLONS PER HOUR

$$GPH = \left[0.7085\ e^{+.00098621 RPM}\right] \times e^{-A_o}$$

$$A_o = .000000435\ e^{.000150114 RPM}$$

TO CALCULATE ANOTHER CRUISE PERFORMANCE 3
TO RETURN TO MASTER MENU 4

2.2.6.4 Landing Performance

The landing performance is mode '4' from the aircraft performance menu. The landing performance input data is as follows:

```
LANDING PERFORMANCE
-------------------
ASSUMES:     40 DEGREE FLAPS
             POWER OFF
             GROSS WEIGHT = 2300 POUNDS
             APPROACH = 60 KNOTS IAS
INPUT DATA:
AIRPORT ELEVATION, FEET ------
HEAD WIND, KNOTS --------
```

The landing performance utilizes the algorithms of figure 2.2.6-7. The output format is as follows:

```
LANDING DISTANCE OVER 50 FT OBSTACLE = ----- FT
```

After printing the output the pilot is offered the following options:

```
CHOOSE FUNCTION:                          ENTER:
---------------
TO RETURN TO AIRCRAFT PERFORMANCE MENU ......1
TO RETURN TO CLIMB PERFORMANCE MENU .........2
TO CALCULATE ANOTHER LANDING PERFORMANCE ....3
TO RETURN TO MASTER MENU ....................4
```

FIGURE 2.2.6-7 **LANDING PERFORMANCE**

ASSUMES: NO WIND, 40 FLAPS, POWER OFF
GROSS WEIGHT = 2300 LB, IAS = 60 KTS

$$\text{LDG DIST} = (1 - .02\,V_W) \times 1248.3\,e^{+.00002045\,PA}$$

V_W = HEAD WIND IN KNOTS

PA = PRESSURE ALTITUDE OF AIRPORT IN FEET

2.3 NAVIGATION

The navigation function is an important aspect of BAM in relieving the pilot workload. Normally enroute navigation is not a difficult or stressful task in a well equipped general aviation aircraft, but in conditions of heavy precipitation, moderate turbulence, the threat of rime ice, and ATC revised routings, the single pilot in IFR can begin to make mistakes. The mental strain enhances the feeling of overload even though the same navigation workload in VFR conditions or smooth on top flying may not be excessive.

The BAM navigation relies on dual VOR to provide RNAV position and is the basis for lateral guidance as described in section 2.5 on flight control.

The navigation features are summarized in figure 2.3-1. The navigation function programmed for the BAM demonstration utilizes two VOR bearings to update the dead reckoning estimated position. The update computation utilizes a deterministic, least squares algorithm to compute the current latitude/longitude. It is recommended that when the navigation algorithms are revised that a statistical Kalman filter be employed for the navigation state update. There was not sufficient time in the BAM design effort to complete the Kalman filter algorithms.

The Navigation Menu is presented below:

FIGURE 2.3-1

NAVIGATION & POSITION FIXING

- NAVIGATION BASED ON AIR DATA/DIR GYRO DEAD RECKONING
  - UP DATE BY MULTIPLE VOR BEARING MEASUREMENTS
  - PROVISION FOR PILOT "FLY OVER" UP DATE
  - 4 STATE KALMAN FILTER POSITION ESTIMATE ALGORITHM
- NAVIGATION UTILIZES LAT/LONG COORDINATES
  - PILOT ENTERS WAYPOINT CODE
  - DATA BASE STORES LAT/LONG FOR EACH WAYPOINT
  - PRESENT POSITION DISPLAYED ON NAV MAP
- NAVIGATION FUNCTION
  - TUNES VOR/LOC RECEIVERS TO PROPER FREQUENCIES
  - COMPUTES LATERAL GUIDANCE COMMANDS
  - PROVIDES DISTANCE/COURSE TO SELECTED WAYPOINTS
  - COMPUTES WINDS AT FLIGHT ALTITUDE

NAVIGATION MENU

The navigation system utilizes a number of dedicated registers in the microcomputer complex random access memory to maintain the current value of the navigation parameters as indicated in table 2.3-1.

TABLE 2.3-1 STORAGE REGISTERS FOR NAVIGATION PARAMETERS

NAVIGATION PARAMETER	REGISTER #	DATA FORMAT	SOURCE
Current Latitude	R1	LL11.11	computed
Current Longitude	R2	LLL11.11	computed
Navigate Mode	R3	M	pilot select
True Airspeed	R4	SSS	sensed
Ground Speed	R5	SSS.ss	computed
Winds Aloft Speed	R6	SS.s	computed
Winds Aloft Direction	R7	DDD.d	computed
True Course Made Good	R8	DDD.d	computed
VOR1 Latitude	R9	LL11.1	Nav data base
VOR1 Longitude	R1Ø	LLL11.1	Nav data base
VOR1 Bearing From/Name	R11	DDD.d/VVV	Sensed/data base
VOR2 Latitude	R12	LL11.1	Nav data base
VOR2 Longitude	R13	LLL11.1	Nav data base
VOR2 Bearing From/Name	R14	DDD.d/VVV	sensed/data base
VOR3 Latitude	R15	LL11.1	Nav data base
VOR3 Longitude	R16	LLL11.1	Nav data base
VOR3 Bearing From/Name	R17	DDD.d/VVV	sensed/data base
Magnetic Variation	R18	+/-DD.d	Nav data base
ADF Latitude	R19	LL11.1	Nav data base
ADF Longitude	R2Ø	LLL11.1	Nav data base
ADF Bearing	R21	+/-DDD	sensed
NX Waypoint latitude	R22	LL11.1	Nav data base
NX Waypoint Longitude	R23	LLL11.1	Nav data base
NX Waypoint Bearing	R24	DDD.d	computed
NX Waypoint Distance	R25	DDD.d	computed
NX Waypoint ETA	R26	HHMM.m	computed
MEA between Lst Wp&Nx Wp	R27	HHH	data base
Name of Next Waypoint	R28	WWWWW	data base
Reset Point Latitude	R29	LL11.1	pilot entry
Reser Point Longitude	R3Ø	LLL11.1	pilot entry
ILS Latitude	R31	LL11.1	data base
ILS Longitude	R32	LLL11.1	data base
ILS Course (Loclizr)/Name	R33	DDD/NNNN	data base
ILS Outer Marker Latitude	R34	LL11.1	data base
ILS Outer Marker Long.	R35	LLL11.1	data base
ILS Middle Marker Lat.	R36	LL11.1	data base
ILS Middle Marker Long.	R37	LLL11.1	data base
Offset Distance From RNAV Course Line	R38	+/-DDD.dd	computed
Required Heading For Nav Mode	R39	DDD.d	computed

Table 2.3-1 STORAGE REGISTERS FOR NAVIGATION PARAMETERS (cont.)

NAVIGATION PARAMETER	REGISTER#	DATA FORMAT	SOURCE
Current Airway Segment	R40	VNNN	data base
Current magnetic Heading	R41	DDD.d	sensed
Current Time (GMT)	R42	HHMM.m	computed

When the pilot selects position initialization, selection "1" from the menu the CRT display requests the pilot to enter the latitude and longitude of the point used for intialization or the waypoint designation if the point has been previously stored in the data base. Registers R29 and R30 defined in Table 2.3-1 are used for this purpose. When the pilot depresses the "return" key on the "telephone" keyboard, the contents of registers R29 & R30 are moved to Registers R1 and R2 to become the current position.

When the pilot selects position reset by selecting "2" from the menu, the CRT display requests the pilot to enter the latitude and longitude of the fix to be used for the position reset. Registers R29 and R30 are used for the reset position. During this mode the pilot must "fly over" the known position stored in R29 and R30 and depress the return key to reset the present position to the reset position in R29 and R30. The new current position is moved to R1 and R2 from R29 and R30 at the instant the return key is depressed.

The navigation options are presented to the pilot when he depresses the navigate selection "3" on the navigation menu as shown below:

NAVIGATE OPTIONS:
DISPLAY NAVIGATION DATA 1
VOR RNAV 2
ILS APPROACH 3
RETURN TO MASTER MENU 4
For Default depress the Return Key

Note: The default situation is the VOR RNAV mode in which two or more VORs are used to update the DR position using the VORFIX routine described in section 5.0 and to display the navigation data shown on the data display shown later in this section which is always on the upper right hand corner of the CRT display

Selection of option "1" provides additional navigation data display as indicated in table 2.3-2 below:

TABLE 2.3-2 NAVIGATION DATA DISPLAY, OPTION 1

PARAMETER	VALUE	REGISTER#
Next Waypoint Name	WWWWW	R28
Range/Mag. Bearing to Nx Wp	DDD.d/DDD.d	R25/R24
ETA to Next Waypoint	HHMM.m	R26
Present position Latitude	LL11.1	R1
Present Position Longitude	LLL11.1	R2
Current MEA	HHHHH	R27
Ground Speed	SSS.s	R5
Magnetic Course	DDD.d	R8+R18

Selection of option "2" provides additional information relative to the RNAV course as shown in table 2.3-3 below:

TABLE 2.3-3 NAVIGATION DATA DISPLAY, RNAV

PARAMETER	VALUE	REGISTER#
Next Waypoint Name	WWWWW	R28
Range/Mag. Bearing to NX WP	DDD.d/DDD.d	R25/R24
ETA to Next Waypoint	HHMM.m	R26
Lateral Offset Distance	+/-DDD.d	R28
Required Magnetic Heading	DDD	R39
Actual Magnetic Heading	DDD	R41
Ground Speed	SSS.s	R5

Selection of option "3" provides the information relevant to an ILS approach to a selected ILS equipped airport. An ILS approach requires entering the name or LAT/LNG of the fix used to intercept the localizer course (usually a few miles outside the outer marker) and the four letter designator of the assigned ILS to be used in the approach. For those ILS approaches which include an outer marker (OM) and middle marker (MM) the pilot uses the reset mode to indicate that the aircraft has arrived at the OM and MM in order to correct the navigation postion at the these two points.

The information displayed for the ILS aproach (option "3") is shown in Table 2.3-4 below:

TABLE 2.3-4 NAVIGATION DISPLAY, ILS APPROACH

PARAMETER	VALUE	REGISTER#
ILS Name/course	NNNN/DDD	R33
Next Waypoint	WWWWW	R28
Altitude at Next Waypoint	HHHH	R27
Distance to Touchdown	DD.d	R25
Required Magnetic Heading	DDD	R39
Actual Magnetic Heading	DDD	R41
Lateral Offset Distance	DD.d	R28
Ground Speed	SSS.s	R5

The next waypoint during the ILS is sequenced as follows:

- o Assigned Intercept Waypoint
- o Outer Marker
- o Middle Marker
- o Approach Minimum

The altitude at the next waypoint is either the MEA or the ILS Glide Slope altitude at the waypoint.

The software developed during the BAM program is described in section 5.Ø which includes flow diagrams and listings for that software completed. Some of the key navigation equations are presented in Table 2.3-5 below. The nomenclature used in these equations utilize the register definitions of Table 2.3-1. For example sin R1 means sin of the contents of register 1 interpreted in degrees or radians as may be appropriate for the particular equation.

TABLE 2.3-5 KEY NAVIGATION EQUATIONS

Compute Incremental LAT/LNG from dead reckoning:

$$\Delta R1 = \Delta T\ R5\ COS\ R8$$

$$\Delta R2 = \Delta T\ R5\ \ SIN\ R8/COSR1$$

Where ΔT = time increment for dead reckoning update

Compute LAT/LNG from dead reckoning

$$R1 = R1 + \Delta R1$$
$$R2 = R2 + \Delta R2$$

Compute Range, bearing, and ETA from present position to next waypoint

$$R25 = 6\emptyset(R22-R1/COSR24),\ \text{providing COS R24} \neq \emptyset$$
$$R25 = 6\emptyset(R23-R2)COS\ R1,\ \text{if COS R24} = \emptyset$$
$$R24 = INV\ TAN\{Pi(R2-R23)\}/\{18\emptyset[\ln TAN(45+R22/2)-\ln TAN(45+R1/2)]\}$$
$$R26 = R42 + R25/R5$$

Compute Ground Speed for one observtion at time T"

$$R5(T2) = \{R25(T2)-R25(T1)\} / \{R42(T2)-R42(T1)\}$$

Where T1,T2 are at different times separated by 5 to 1Ø minutes.

Average computed ground speed over several observations

$$R5 = \{R5(T1)+R5(T2)+...+R5(TN)\} / \{R42(TN)-R42(T1)\}$$

Compute wind

$$A = R8 - (R18 + R41)$$
$$h = R4\ SIN\ A$$
$$G1 = R5 - R4(COS\ A)$$
$$R6 = \sqrt{N^2 + G1^2}$$
$$R7 = R8 + 9\emptyset - INV\ TAN\ (G1/h)$$

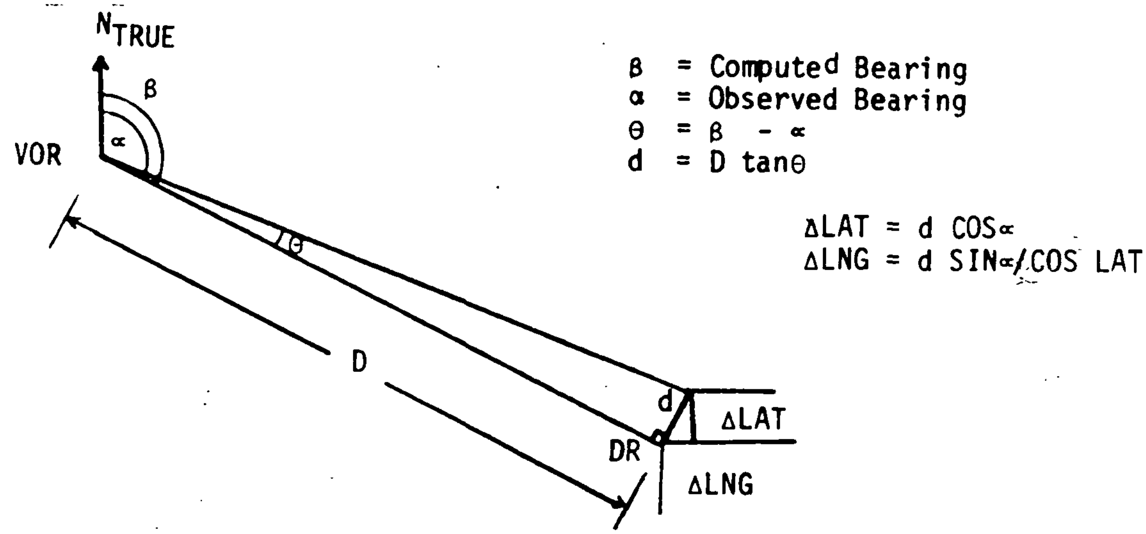
Compute Offset Distance from Course Line

$$R38 = R25\ SIN(R24-R43)$$

The dead reckoning position R1/R2 is periodically updated by means of measuring the bearings to two or mor VORs within receiving range of the aircraft position. The flow diagram and listings used for the VOR fix are described in section 5.Ø under the VORFIX software module description

The VORFIX method and equations will be described here. The geometry for the bearing measurement to one of the multiple VORs is shown in Figure 2.3-2.

FIGURE 2.3-2 VOR FIX GEOMETRY



VORFIX uses the latitudes, longitudes, and frequencies from the Nav data base of all the nearby VORTACs as well as the aircraft DR position. The bearings from the VOR stations will be obtained by tuning the navigation radiow, which will return the magnetic bearing over a parallel bus to the computer for the computations.

VORs used are within 1 degree in latitude and longitude of the current aircraft DR position. The available VORs are designated by the quadrants they are located in relative to the DR position as shown below:

```
              N
              |
        2     |     1
              |
  W-------------------E
              |
        3     |     4
              |
              S
```

VORs from each quadrant are relocated if possible in order to reduce the GDOP (Geometrical Dilution of Precision) errors. The quadrant designations are used to insure proper sign conventions and angular results during the computation.

The compiled bearing from each chosen VOR is found by:

$$\beta = \tan^{-1} \frac{(LNG_{VOR} - LNG_{DR}) \cos LAT_{VOR}}{(LAT_{VOR} - LAT_{DR})}$$

and the distance by:

$$D = \sqrt{\{(LNG_{VOR} - LNG_{DR}) \cos LAT_{VOR}\}^2 + (LAT_{VOR} - LAT_{DR})^2}$$

The observed bearing is obtained from the VOR Nav radio. The most probable position is found by dropping a perpendicular ffom the DR position to the observed bearing as shown in figure 2.4-2.

The position fix is found by averaging the ΔLAT and ΔLNG components found for each VOR.

$$LAT = LAT_{DR} + \frac{\Delta LAT_1 + \Delta LAT_2 + \ldots \Delta LAT_n}{n}$$

and:

$$LNG = LNG_{DR} + \frac{\Delta LNG_1 + \Delta LNG_2 + \ldots \Delta LNG_n}{n}$$

The navigation modes recognize the fact that for most IFR flights the initial flight phase after take-off is under vector steers from the departure controller and the final flight phase is under radar vector steers from the approach controller. *During radar vectors* the navigation mode is keeping track of the position by dead reconing and performing dual VOR updates from the VOR stations which are within reception range of the present position. When the pilot receives the ATC instructions "resume normal navigation" after the departure radar steers, or receives the ATC instruction "intercept the localizer and contact the tower at the outer marker," then he is ready to fly to the next waypoint on his flight plan and always knows where he is relative to the next waypoint. Often a flight plan waypoint will be bypassed during the radar steers.

The ADCC always displays the following navigation data when any of the navigation modes are selected regardless of the other display modes which may be selected at the same time. This data is formatted as follows and is displayed in the upper right hand corner of the display:

```
********* NAVIGATION DATA ************
*                                    *
*  NEXT WAYPOINT:   BFL              *
*  RANGE/MAG BRG:   14.7 NMi/Ø23 DEG *
*  ETA:             1Ø47 Z           *
*  PRESENT POSITION: LAT 34 15.6     *
*                    LNG 118 47.2    *
**************************************
```

The dead reconing algorithm uses true airspeed, estimated wind, and magnetic heading to extrapolate the aircraft present position between updates. It is not necessary for the pilot to selsct the VORs or ADFs being used for position update. The pilot must make sure the VORs and ADF are turned on and functioning. The navigation microcomputer issues frequency tuning commands to the VOR receivers to tune in VORs within +/- 1 degree of latitude and longitude of the present aircraft position. The crossing angle of the VOR bearings must be greater than 3Ø degrees before the two LOP (line of position) crossings are considered a valid position update. However, the BAM demonstration software does not yet include this feature. The position correction for ADFs will be weighted lower than VOR position corrections in the eventual Kalman filter.

2.4 NAVIGATION MAP

The navigation map display is a growth feature, but the navigation map data base is utilized for the navigation modes. The BAM navigation map coding scheme is illustrated in figure 2.4-1 for the Jeppesen US Low Altitude Enroute Avigation Map number3 and 4. Each BAM navigation map is a 2 deg. LAT by 2 deg. LNG segment of the complete map. The BAM design and demonstration software has utilized map #Ø422 as an example. This map segment contains a number of VORs, NDBs, airways, airports, ILSs and waypoints (intersections) which are reasonable representative of the US airway structure. It is estimated that this map #Ø422 would require about 1528 bytes of data storage. Any 2 deg. by 2 deg. map segment can be expanded into four 1 deg. by 1 deg. segments for showing more detail as shown in figure 2.4-1.

BAM utilizes a MILCO Navigation Map data base defined in figure 2.4-2. This unique NAV MAP data base greatly simplifies the pilot's data entry requirements. Even though the BAM navigation is conducted in LAT/LNG coordinates, it is never necessary for the pilot to enter the waypoint LAT/LNG coordinates; he only has to enter the waypoint designation using a modified telephone key pad. He enters the telephone code numbers and the alphanumeric designation for the waypoint is "echoed" back.

The navigation map data base is stored in mass memory and the various BAM functions such as FLIGHT PLAN, NAVIGATION, & NAVIGATION MAP access this data base which is transparent to the pilot. For example, if the navigation update method used LORAN C or NAVSTAR/GPS instead of dual VOR, the pilot's operational procedure would not vary. This feature of making the navigation procedures independent of the navigation aid is an important contribution of BAM which has significant implication to future FAA navigation system updates.

The navigation map display is a growth feature of BAM and is not a part of the present design. The navigation map menu is presented below.

NAV MAP MENU

AIRPORT DATA 1
CURRENT MAP SEGMENT....................2
FLIGHT PLAN ROUTE......................3
STANDARD INSTRUMENT DEPARTURE (SID)...4
STANDARD ARRIVAL ROUTE (STAR).........5
APPROACH PLATE.........................6
RETURN TO MASTER MENU.................7

The NAV MAP is displayed "north up" to avoid the complexity of a "heading up" oriented display.

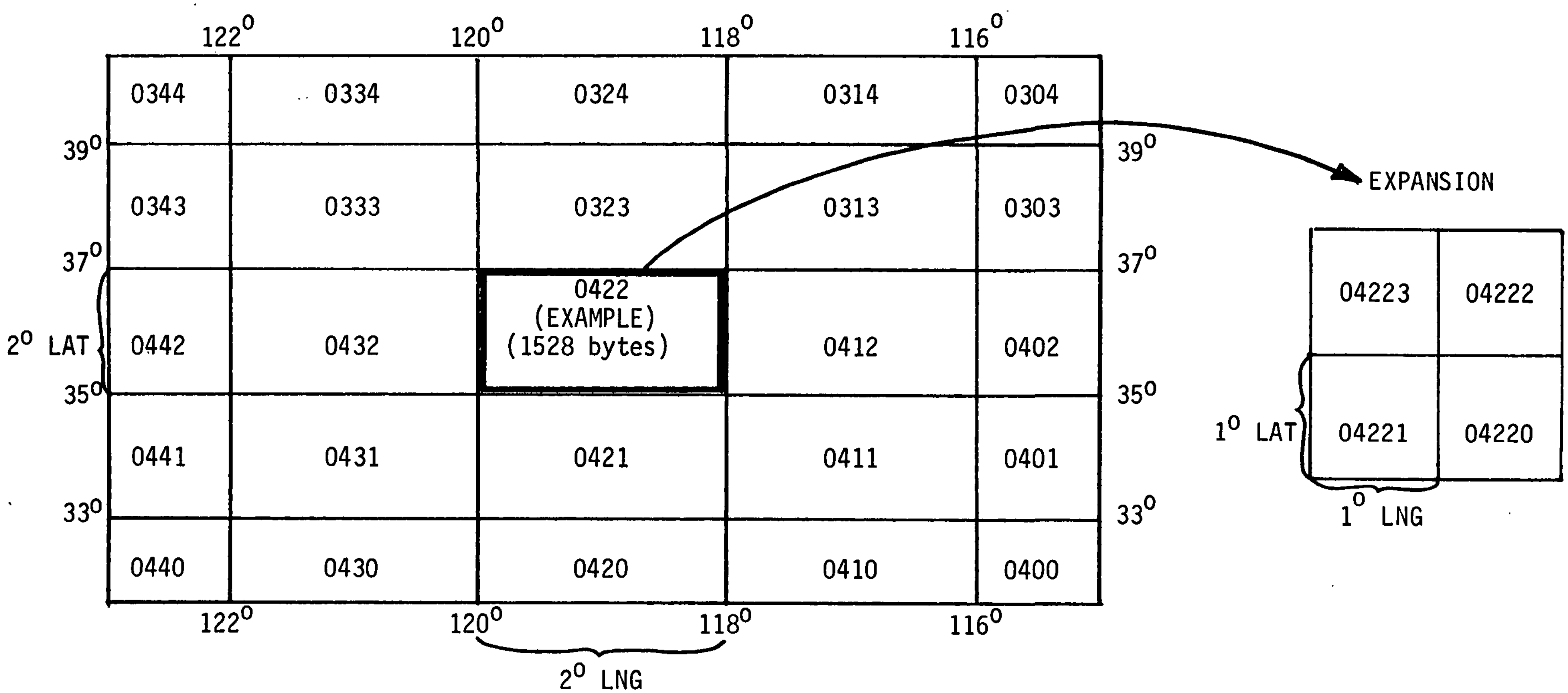
The navigation data base for BAM is stored on a sual floppy disk mass memory. A typical 2 deg. LAT by 2 deg. LNG map is estimated to contain approximately 1528 bytes of information for the VORs intersections, NDBs (including AM broadcase stations), airports, ILSs, and airways.

It is estimated that there are 213 2 deg. by 2 deg. maps in the continental US. Assuming 1528 bytes per 2 deg. by 2 deg. map would

FIGURE 2.4-1

NAVIGATION MAP CODING SCHEME

COVERS THE SAME AREAS AS JEPCO NAVIGATION MAPS   EXAMPLE US(LO) 3/4



EACH MAP IS 2° LAT x 2° LNG.

FIGURE 2.4-2

NAVIGATION MAP DIGITAL DATA BASE

- CATEGORY OF WAYPOINTS IN DATA BASE

WAYPOINT TYPE	"TEL" CODE	CALL LTRS.	FREQ.	LAT.	LONG.	MEA	SPECIAL
VOR	3 NO'S	3 LTRS.	5 NO'S	5 NO'S	6 NO'S	3 NO'S	AIRWAY (3)
INTERSECTION	5 NO'S	5 LTRS.	-	5 NO'S	6 NO'S	3 NO'S	AIRWAY (3)
ILS	4 NO'S	4 LTRS.	5 NO'S	5 NO'S	6 NO'S	3 NO'S	DIRECTION
AIRPORT	6 NO'S	6 LTRS.	5 NO'S	5 NO'S	6 NO'S	5 NO'S (ELEV.)	IFR CODE
NDB/BCS	4 NO'S	4 LTRS.	4 NO'S	5 NO'S	6 NO'S	3 NO'S	

- EACH MAP SEGMENT HAS VICTOR AIRWAYS TABULATED WITH WAYPOINTS.
- EACH MAP SEGMENT HAS STORED THE AVERAGE MAGNETIC VARIATION.
- THE MAP DATA BASE IS RECALLED FROM MASS MEMORY BY ENTERING A 4 DIGIT CODE.
- ALL DATA ENTERED FROM TELEPHONE TYPE KEYPAD.
- ALPHANUMERIC DESIGNATORS ARE "ECHOED" BACK.

yield 325,464 bytes. An alternate approach to estimating the amount of NAV MAP data storage requirements is covered in table 2.4-1. This approach yields an estimate of 278,952 bytes.

If we assume a packing density of 50% on the floppy diskettes due to inefficiencies of the file system, the total storage requirements for the US NAV MAP data base is about 605,000 bytes. A single quad density 5 1/4" diskette planned for BAM contains 315,000 bytes. Consequently, it would require two floppy diskettes to contain the NAV MAP data for the US.

The current BAM demonstration NAV MAP does not store the airways. However, the final BAM system will store the airways with the associated waypoint names. This feature will permit the entering of a clearance such as "Bonanza 72D you are cleared from the Orange County Airport radar vectors Seal Beach, Victor 65 Blyth, Victor 16 Buckeye, Victor 461 Gila Bend, Victor 66 Tuscon,..." The pilot enters the following sequence on his keyboard: RV SLI, V64 BLH, V16 BXH, V461 GBN, V66 TUS. The airway files are accessed on the NAV MAP data base and the flight plan route is displayed on the NAV MAP (mode 2).

The BAM demonstration sytem has utilized a 128 x 128 resolution display for the NAV MAP which is considered too granular to be satisfactory. It is recommended that the final NAV MAP display have a 512 x 512 resolution display with superimposed 5 x 9 dot matrix alphanumeric symbols. Such high resolution display cards are now available for the type of microcomputer used in the BAM design.

TABLE 2.4-1

ESTIMATE OF MEMORY REQUIREMENTS FOR US NAV MAP DATA BASE

TYPE OF WAYPOINT	ESTIMATE NO.	NO. BYTES EACH	TOTAL MEMORY
VOR	924	28	25,872
INTERSECTIONS	5000	27	135,000
ILS	500	30	15,000
AIRPORTS	2000	34	68,000
NDB/BCS	580	26	15,080
AIRWAYS	200	100	20,000
		TOTAL	278,952

2.5 LATERAL FLIGHT CONTROL

The BAM lateral flight control system is shown in figure 2.5-1. The BAM closes the outer loop flight control in the distributed microcomputer (DMC). The DMC issues an aileron command to the analog autopilot which is assumed to include a yaw damper loop which provides turn coordination. The control equations for the lateral flight control modes will be discussed later. These control equations define how the heading command ψC and bank angle command ϕC are generated by the lateral flight control computations.

The output of the navigation geometry computation is the heading command. The dead reckoning is based upon ground speed and ground track which in turn are derived from the wind estimate and from the aircraft true airspeed.

The basic navigation geometry provides a heading command which results in maintaining the sum of the lateral deviation from the desired navigation ground track plus the lateral deviation rate equal zero, that is the following lateral guidance equation is imposed:

$$Y + K\dot{Y} = 0$$

This lateral guidance equation results in a smooth convergence to the desired ground track along an exponential trajectory whose shape is controlled by the constant K. The ground track in the navigation segment between waypoints.

The dead reckoning position is updated periodically from VOR, NDB, or ILS position measurements. The current BAM demonstration system includes only the VOR update equations.

the lateral flight control menu is as follows:

LATERAL FLIGHT CONTROL MENU

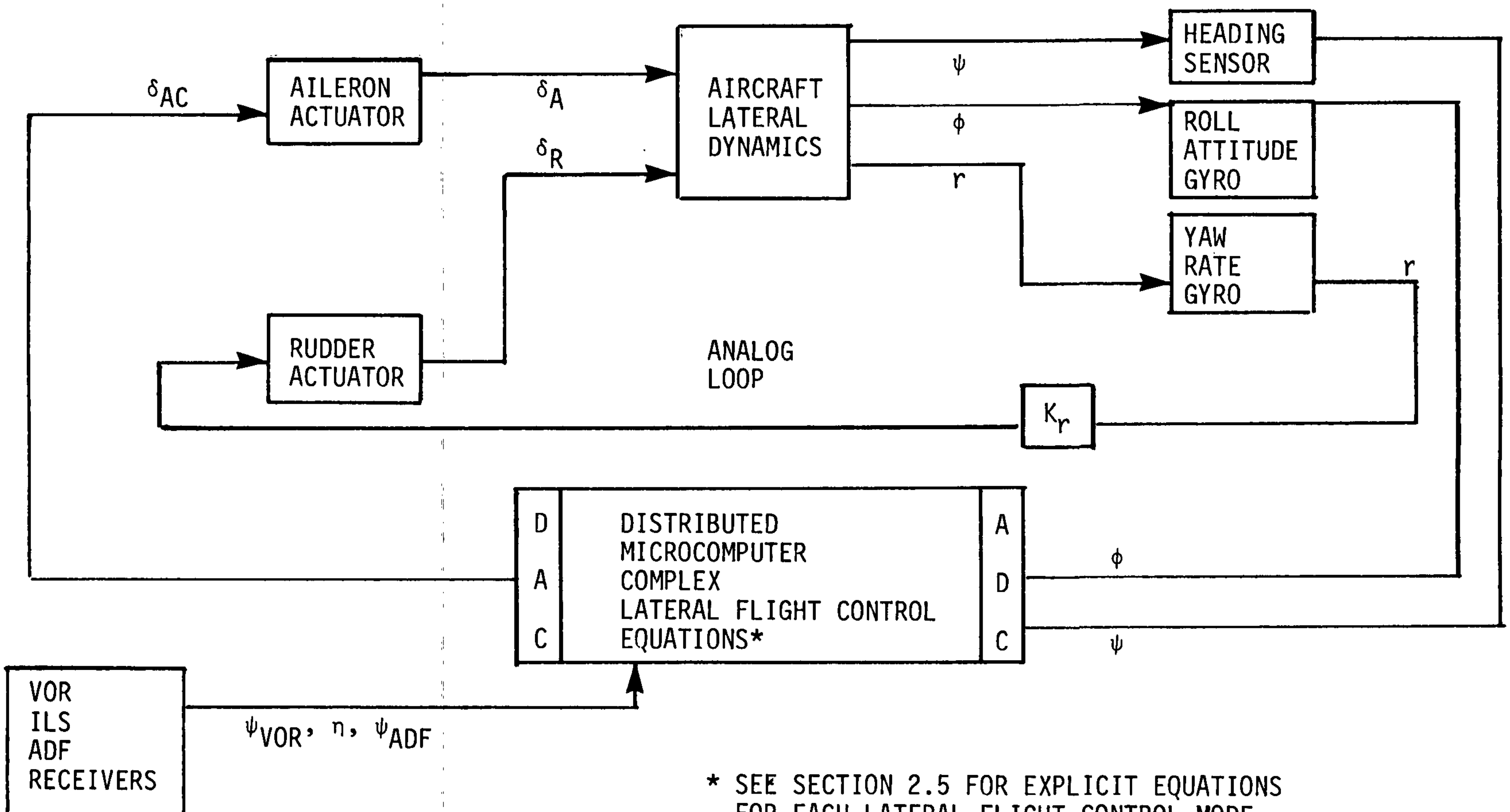
HOLD HEADING............................1
TURN RIGHT OF LEFT (3 DEG/SEC).........2
RNAV COUPLING...........................3
LOCALIZER COUPLING......................4
TURN TO SELECTED HEADING................5
ADF COUPLING............................6
VOR COUPLING............................7
DISENGAGE AUTOPILOT.....................8
RETURN TO MASTER MENU...................9

2.5.1 HOLD HEADING MODE

The lateral control system implements the hold heading mode which is selected from the lateral flight control menu by selecting the "1" key on the "telephone" keyboard. The control equations for the hold heading mode are given by:

$$\delta AC = K_\phi \, \phi_{LIM} + K_\psi(\psi - \psi_0) \qquad \text{EQN 2.5-1}$$

FIGURE 2.5-1 BAM LATERAL FLIGHT CONTROL SYSTEM



* SEE SECTION 2.5 FOR EXPLICIT EQUATIONS FOR EACH LATERAL FLIGHT CONTROL MODE.

where δ_{AC} = aileron command

ϕ_{LIM} = ϕ , for $|\phi|<30^o$
30^o, for $|\phi|>30^o$

ψ = magnetic heading angle

ψ_o = heading existing at time the selection "1" is made

K_ϕ, K_ψ = flight control system gains

At the time the hold heading mode is selected, the heading existing at that time is placed in memory as a reference. The measured heading is compared with the reference to generate an error signal. The error is multiplied by the gain K_ψ. The resulting error is then added with the limited bank angle signal to generate the aileron command.

These equations are implemented in the flight control microcomputer, consequently a sampled data stability analysis must be performed to select the gains K_ϕ and K_ψ.

2.5.2 STANDARD TURN RATE COMMAND, RIGHT OR LEFT

The standard rate turn mode is selected by depressing the "2" key from the lateral flight control menu. the control equations for the standard rate turn are given by:

$$\delta_{AC} = K_\phi(\phi \pm \phi_{REF}) \quad \text{EQN 2.5-2}$$

$$\phi_{REF} = \tan^{-1}\frac{V}{g}\frac{3}{57.3}$$

where v = true air speed in ft/sec
g = 32.2 ft/sec^2 (the acceleration due to gravity)

ϕREF is the bank angle which will yield a standard time rate of 3 deg/sec during a coordinated turn maueuver (zero side slip). The sign of ϕ REF will determine whether a right or left turn is executed. The gain $K\phi$ is selecyed to give smooth roll into the turn within the limits of sampled data stability.

2.5.3 R-NAV COUPLING

The RNAV coupling mode is selected by entering "3" on the lateral flight control menu. The control equations are given by:

$$\delta_{AC} = K_\phi \phi_{LIM} + K_\psi(\psi-\psi_{CMD}) \quad \text{EQN 2.5-3}$$

$$\psi_{CMD} = \psi_{CRS} - \Delta\psi$$

$$\Delta\psi = \sin^{-1} \dot{Y}/R5$$

ψ_{CRS} = RNAV magnetic course

$\dot{Y}$ = R38/K1

ϕ_{LIM} = ϕ when $\phi<\phi_{REF}$

ϕ_{LIM} = ϕ_{REF} when $\phi \geq \phi_{REF}$

ϕ_{REF} defined in EQN 2.5-2

Where the register contents are defined in Table 2.3-1, K1 is the RNAV gain constant, K_ϕ and K_ψ are flight control gain constants.

The RNAV coupling control equation results in an exponential correction back to the selected RNAV course line.

2.5.4 LOCALIZER COUPLING

The localizer coupling mode is selected by entering "4" on the lateral flight control menu. The control equations are given by:

$$\delta_{AC} = K_\phi \, \phi_{LIM} + K_\psi(\psi - \psi_{CMD}) \qquad \text{EQN 2.5-4}$$

$$\psi_{CMD} = R33 - \Delta\psi$$

$$\Delta\psi = \sin^{-1} \dot{Y}/R5$$

$$\dot{Y} = Y/K2$$

$$Y = R \tan \eta$$

where
- η = the localizer error in degrees
- R5 = distance from present position to the localizer transmitter
  = R25 (when the localizer is the next waypoint)
- K2 = the displacement gain for the localizer mode which control the shape of the capture exponential
- R33 = the localizer CRS
- ϕ_{LIM} = same as for equation 2.5-3

The localizer coupling control equation linearizes the localizer mode by converting the angular deviation η into the lateral off set distance. This form for the localizer coupler allows the localizer gain K2 to remain constant as the runway is approached. Conventional localizer couplers which operate only on the regular data must reduce the coupler gain K2 as the runway is approached to maintain stability.

2.5.5 TURN TO SELECTED HEADING The turn to selected heading mode is selected by entering "5" on the keyboard and entering the desired heading. The control equation for this mode is as follows:

$$\delta_{AC} = K_\phi \, \phi_{LIM} + K_\psi(\psi - \psi_{REF}) \qquad \text{EQN 2.5-5}$$

ϕ_{LIM} is the same as equation 2.5-3
ψ_{REF} is the desired or "set" heading value

If the reference heading ψREF is considerably different from the existing heading ψ, then the aircraft will be commanded to a bank angle equal to ϕREF which causes the aircraft to turn towards the desired heading at a standard turn rate (3 deg/sec).

When the aircraft reaches the desired heading it rolls out and maintains the reference heading ϕREF.

2.5.6 ADF COUPLING

The ADF coupling mode is selected by entering a "6" on the keyboard from the lateral flight control menu. The control equation for the ADF coupling mode is as follows:

$$\delta_{AC} = K_{\phi}\,\phi_{LIM} + K\psi(\psi - \psi_{CMD}) \qquad \text{EQN 2.5-6}$$

$\psi_{CMD} = \psi + \Delta\psi_{ADF}$ Tracking inbound

OR $= \psi + 180 - \Delta\psi_{ADF}$ Tracking outbound

Where $\Delta\psi_{ADF}$ is the bearing to the ADF station relative to the forward reference line (FRL)

The ADF coupling mode as implemented will result in a curved path to the ADF station when there is a cross wind.

2.5.7 VOR COUPLING

The VOR coupling mode is selected by entering "7" on the keyboard from the lateral flight control menu. The VOR coupling mode will be implemented the same as the RNAV mode except that it is assumed no flight plan has been entered, consequently it will be necessary for the pilot to enter the name of the VOR, the radial desired to track, and whether the track is inbound or outbound. The control equations are given by:

$$\delta_{AC} = K_{\phi}\,\phi_{REF} + K_{\psi}(\psi - \psi_{CMD}) \qquad \text{EQN 2.5-7}$$

$\psi_{CMD} = \psi_{CRS} \pm \Delta\psi$

Where ψ_{CRS} is the selected course (radial),

the + sign is used if the track is outbound
the - sign is used if the track is inbound

$\Delta\psi = \sin^{-1} \dot{Y}/R5$

$\dot{Y} = R38/K1$

This coupling control equation will provide an exponential convergence to the selected radial. The stability of this mode is independent of the distance from the VOR since the control law utilizes the lateral offset distances from the radial rather than the angular deviation from the selected radial.

It is assumed during this mode that the aircraft is navigating and consequently the LAT/LNG position of the aircraft is known. A default VOR mode may be selected automatically when the aircraft is not navigating in LAT/LNG coordinates. In this case the following control equation is utilized:

$$\delta_{AC} = K_\phi \, \phi + K\psi(\psi - \psi_{CMD}) \qquad \text{EQN 2.5-7.1}$$

$$\psi_{CMD} = \psi_{CRS} \pm \Delta\psi$$

$$\Delta\psi = \psi_{SEL\ RADIAL} - \psi_{VOR\ BRG} \qquad \text{Inbound track}$$

$$= \psi_{SEL\ RADIAL} - \psi_{VOR\ BRG} + 180^\circ \qquad \text{Outbound track}$$

When this default mode is engaged the stability degrades as the aircraft approaches the VOR station since angular, rather than linear data is used to define the error between the desired radial and the received bearing.

The lateral directional airplane transfer functions are presented in Appendix A which is taken from General Aviation Feedback Control Technology Outline which was prepared by Professor Jan Roskam and Gerald Jerks of the University of Kansas (reference 1).

3.Ø BAM SYSTEM DESIGN

The Basic Avionics Module (BAM) is intended as a research tool for NASA Langley to study the problems of single pilot IFR in a single engine General Aviation aircraft, such as the Cessna 172, Grumman American Traveller, Beech Musketeer, and Piper Cherokee. The BAM will be used in the NASA Langley research light aircraft such as the Cessna 172.

The BAM microcomputer equipment (BAMME) will be capable of being flown in a light aircraft with the computer elements mounted in the baggage compartment strapped down with the baggage elements. The display and control elements can be located in the cockpit area.

The BAMME design is similar to the BAM hardware design described in the MILCO briefing to NASA Langley, BR-78Ø6-BAM-199, presented in June 1978.

A number of simplifications have been made to that design by virtue of the decision to use the low cost NASA Langley electro-fluidic sensors for the magnetic heading and to use all S-1ØØ bus modules for the microcomputer complex rather than to use a mixture of S-1ØØ modules and SBC-8Ø cards.

A DC power supply will be furnished which will convert the aircraft 12 volt DC battery into the power supply voltages required by the microcomputer complex.

3.1 BAMME CONFIGURATION

The BAM microcomputer equipment (BAMME) will include the following elements:

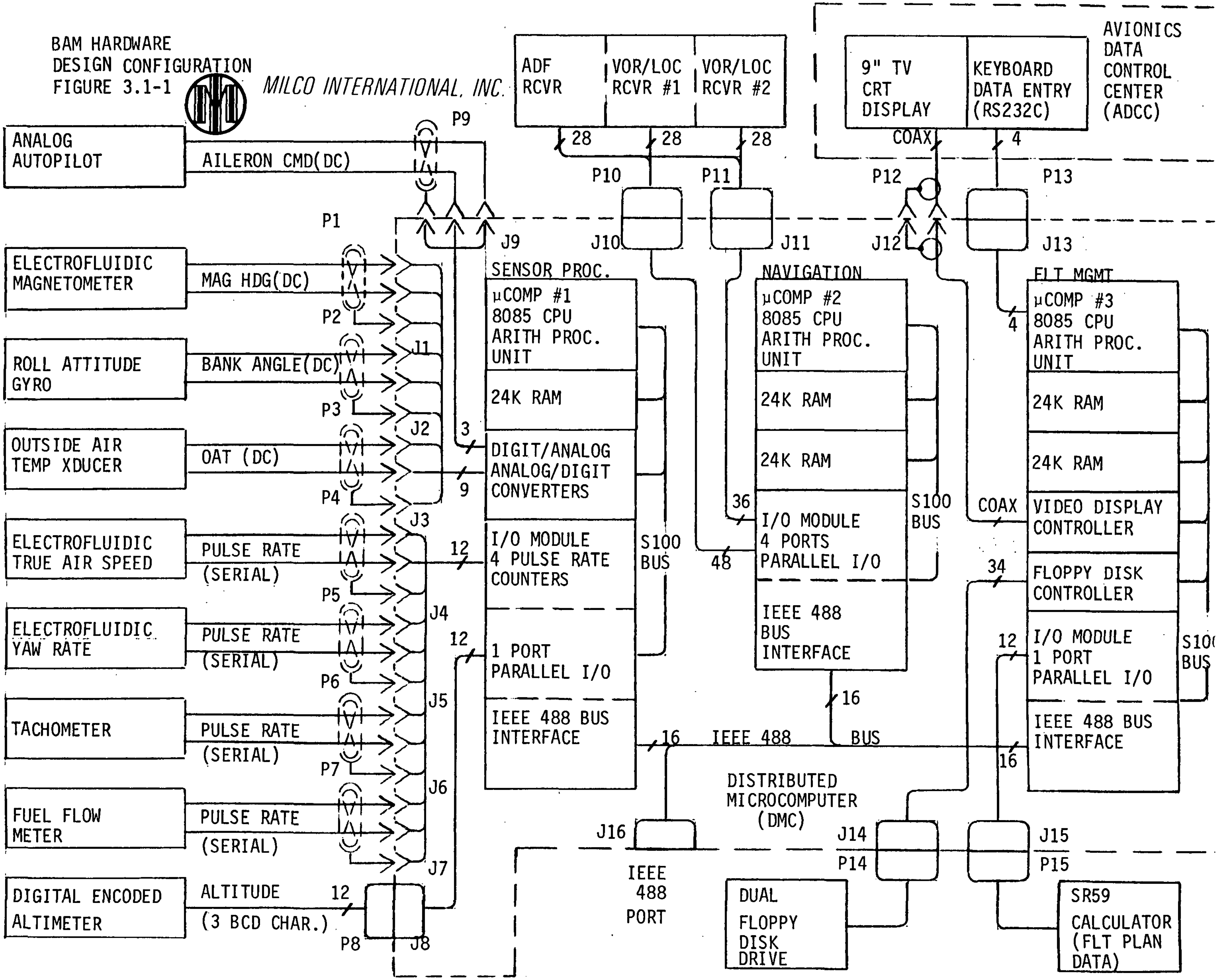
- o Distributed microcomputer unit with three microcomputer sections The microcomputer unit includes six separate module types described below with a total of 15 modules
- o Dual Micro-Floppy disk drive
- o 9" TV emulator for cockpit display
- o Data entry keyboard
- o SR-59 calculator

The BAMME will interface with the following equipment:

- o Dual VOR receivers with BCD (Binary Coded Decimal) interface for frequency command and VOR bearing output such as the Collins VIR-351 which has digital readout and responds to the BCD frequency commands.
- o ADF receiver with BCD interface for frequency command and ADF bearing output such as the Collins ADF 650.
- o Electro-fluidic magnetometer with DC output proportional to magnetic heading
- o Electro-fluidic true airspeed sensor with digital output with pulse rate proportional to TAS
- o Electro-fluidic yaw rate sensor which produces a pulse rate proportional to turn rate
- o outside air temperature sensor with DC output proportional to OAT
- o Pressure alitmeter with BCD (Binary Coded Decimal) output
- o Tachometer with digital output with pulse rate proportional to RPM
- o Fuel flow meter with pulse rate proportional to gallons per hour
- o Roll Attitude Gyro with DC output
- o Analog autopilot with yaw rate loop closed in the analog circuitry and an aileron actuator
- o Analog aileron commands generated by the distributed microcomputer complex

The BAM hardware design configuration is shown in figure 3.1-1. The BAM system is divided into the BAM system hardware groups and the BAM

BAM HARDWARE
DESIGN CONFIGURATION
FIGURE 3.1-1



microcomputer equipment groups. The microcomputer equipment groups include:

- o DISTRIBUTED MICROCOMPUTER COMPLEX (DMC)
  - o Microcomputer #1 for sensors includes:
    - o 8085 CPU module with 8253 timer, serial RS232C I/O, and a 9511 arithmetic processor unit with 32 bit floating point math and transcendental functions
    - o One 24K byte RAM module
    - o An analog interface module (wire wrap) which includes a 16 channel analog to digital acquisition module with 12 bit resolution (only 6 channels are used), a 12 bit digital to analog converter, and a 24 bit 8255 programmable parallel interface unit.
    - o Digital I/O Module #1 (wire wrap) which includes a MC 68488 IEEE 488 bus chip plus bidirection bus support chips, one 24 bit 8255 parallel I/O chip, and two 8253 timer chips which provide six (6) timer registers for the four serial pulse rate sensors
  - o Microcomputer #2 for navigation includes:
    - o 8085 CPU module with timer (8253), RS232C port, and a 9511 arithmetic processor with 32 bit floating point math and transcendental function.
    - o Two 24K byte RAM modules
    - o Digital I/O Module #2 (wire wrap) which includes a MC 68488 IEEE 488 bus chip plus bidirectional bus support chips, and four (4) 8255 parallel I/O (with 96 parallel I/O lines)
    - o Bus terminator module provided to terminate the S-100 bus on the mother board associated with Microcomputer #2
  - o Microcomputer #3 for Flight Management includes:
    - o 8085 CPU module with 8253 timer, RS 232C port, and a 9511 Arithmetic Processor with 32 bit floating point math and transcendental functions
    - o Two 24K byte RAM modules
    - o Video display controller module
    - o Floppy disk drive controller modules
    - o Digital I/O module #3 (wire wrap) which includes a MC 68488 IEEE 488 bus chip plus bidirectional bus support chips, and one 8255 parallel I/O lines

The schematics for the 8085 CPU module which includes the AMD 9511 arithmetic processor chip and other digital I/O is shown in figure 3.1-2. This is a standard S-100 module which MILCO has modified to integrate the CPU and APU functions on a single module. This design which has been validated and tested uses the APU in one of the available sockets on the board plus necessary jumpers to provide the interconnects. This configuration permits operating the 9511 on an interrupt basis but not on a DMA basis.

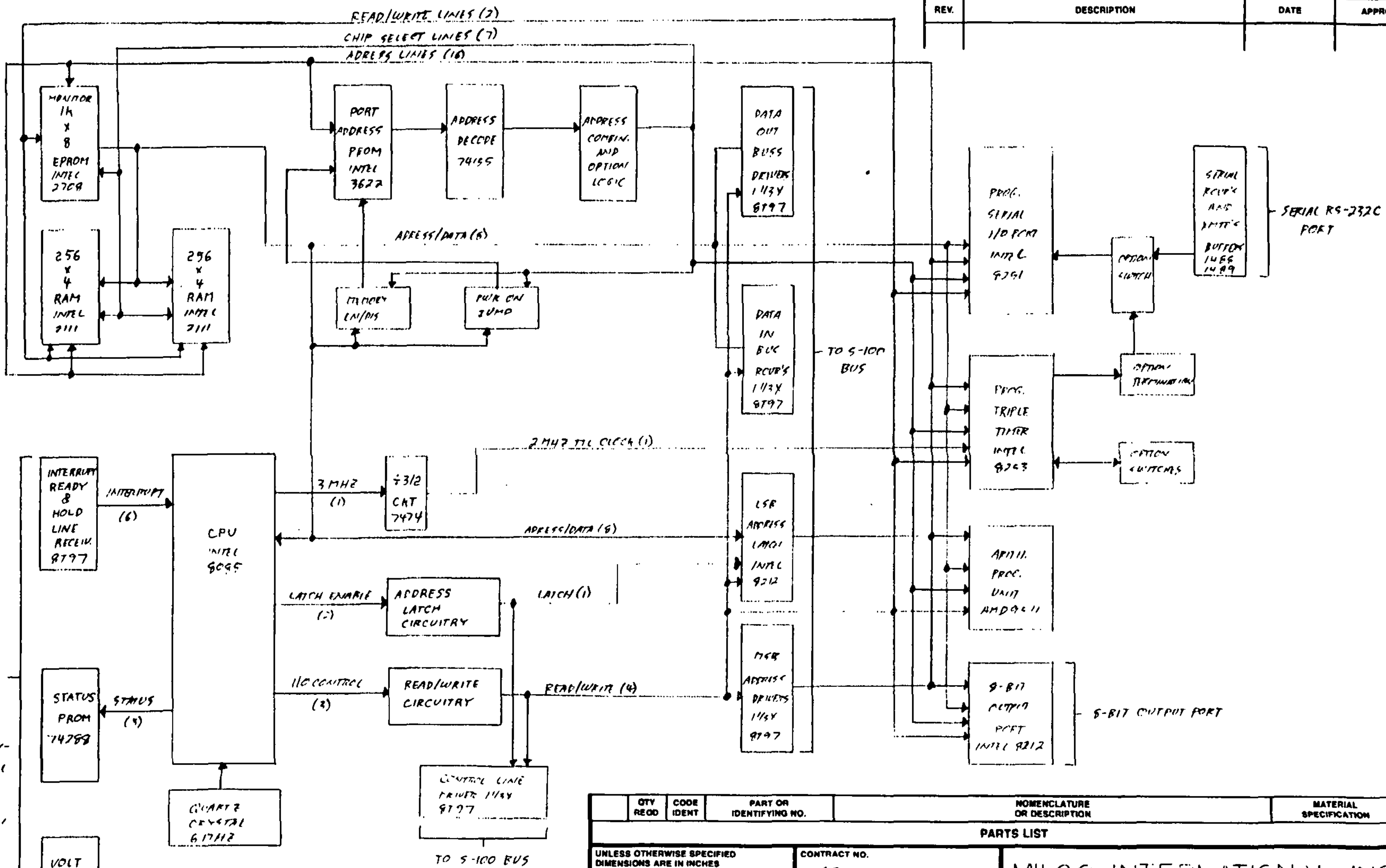
The schematic for the digital I/O module is shown in figure 3.1-3. The digital I/O module is a wire wrap design which provides for the three (3) digital I/O modules used by each of the three microcomputers by populating the board with the required number of 8253 timer chips (maximum of 2) and 8255 programmable parallel I/O chips (maximum of 4).

All three versions of the digital I/O module contain the MC 68488 IEEE

DWG. NO.	SH	REV.

REVISIONS

REV.	DESCRIPTION	DATE	APPROVED



TO S-100 BUS

NOTES:

1. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
2. DIAGRAM HAS BEEN GREATLY SIMPLIFIED TO FACILITATE SIGNAL FLOW
3. CARDS ARE PREFABRICATED, STOCK ITEMS
4. ONE CARD REQUIRED FOR EACH COMPUTER

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION	N/A

PARTS LIST

3003	BAM
NEXT ASSY	USED ON
APPLICATION	

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MATERIAL

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DRAWN	RFS	11/10/78
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ISSUED		

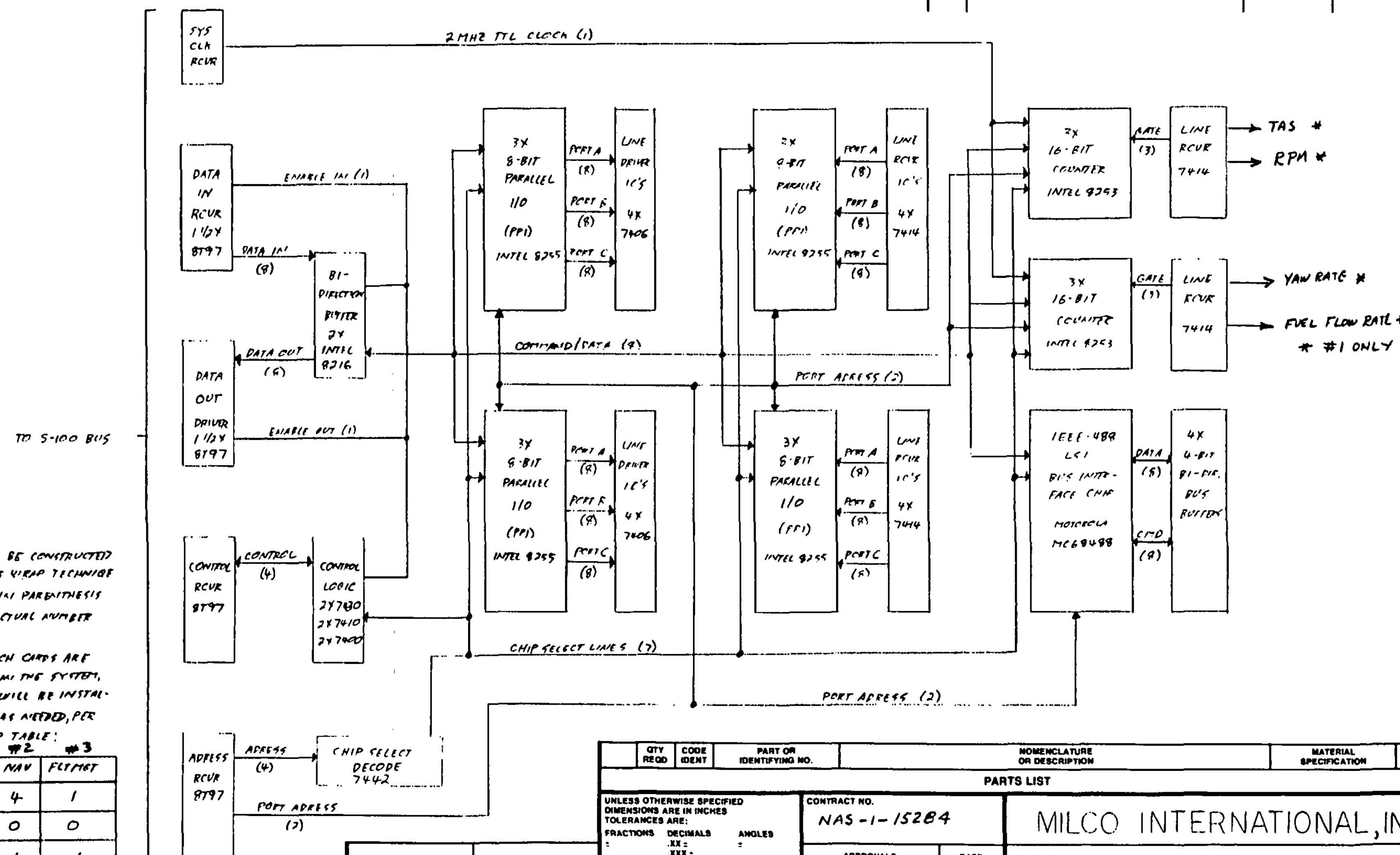
MILCO INTERNATIONAL, INC.

8085 CPU/APU MODULE
MICROPROCESSOR UNIT

SIZE	FSCM NO.	DWG. NO.	REV.
B	4301	FIG 3.1-2	ϕ
SCALE N/A		SHEET 1 OF 1	

DWG. NO.	SH	REV.

REVISIONS			
REV.	DESCRIPTION	DATE	APPROVED



NOTES:

1. CARD SHALL BE CONSTRUCTED USING WIRE WRAP TECHNIQE
2. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
3. THREE SUCH CARDS ARE RESIDENT IN THE SYSTEM, BUT IC'S WILL BE INSTALLED ONLY AS NEEDED, PER FOLLOWING TABLE:

	#1 SENSOR	#2 NAV	#3 FLTMGT
8255	1	4	1
8253	2	0	0
68488	1	1	1

4. CONNECTIONS TO REAR PANEL CONNECTORS NOT SHOWN, CONNECTIONS WILL BE MADE VIA SCOTCH-FLEX RIBBON CABLE CONNECTORS

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

NEXT ASSY	USED ON
3003	BAM

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL N/A

FINISH N/A

DO NOT SCALE DRAWING

CONTRACT NO. NAS-1-15284

APPROVALS		DATE
DRAWN	RRS	11/10/78
CHECKED	RFS	11/12/78
ISSUED		

MILCO INTERNATIONAL, INC.

DIGITAL I/O UNIT

SIZE	FSCM NO.	DWG. NO.	REV.
B	4304	FIG 3.1-3	Ø

SCALE N/A SHEET 1 OF 1

BISHOP GRAPHICS, INC. REORDER NO. 20510

bus chip and the 3 bidirectional bus support chips to provide the IEEE 488 bus function. The bus controller function will be provided by microcomputer #3. The chip population on the three versions of the I/O module are shown in the Table of figure 3.1-3.

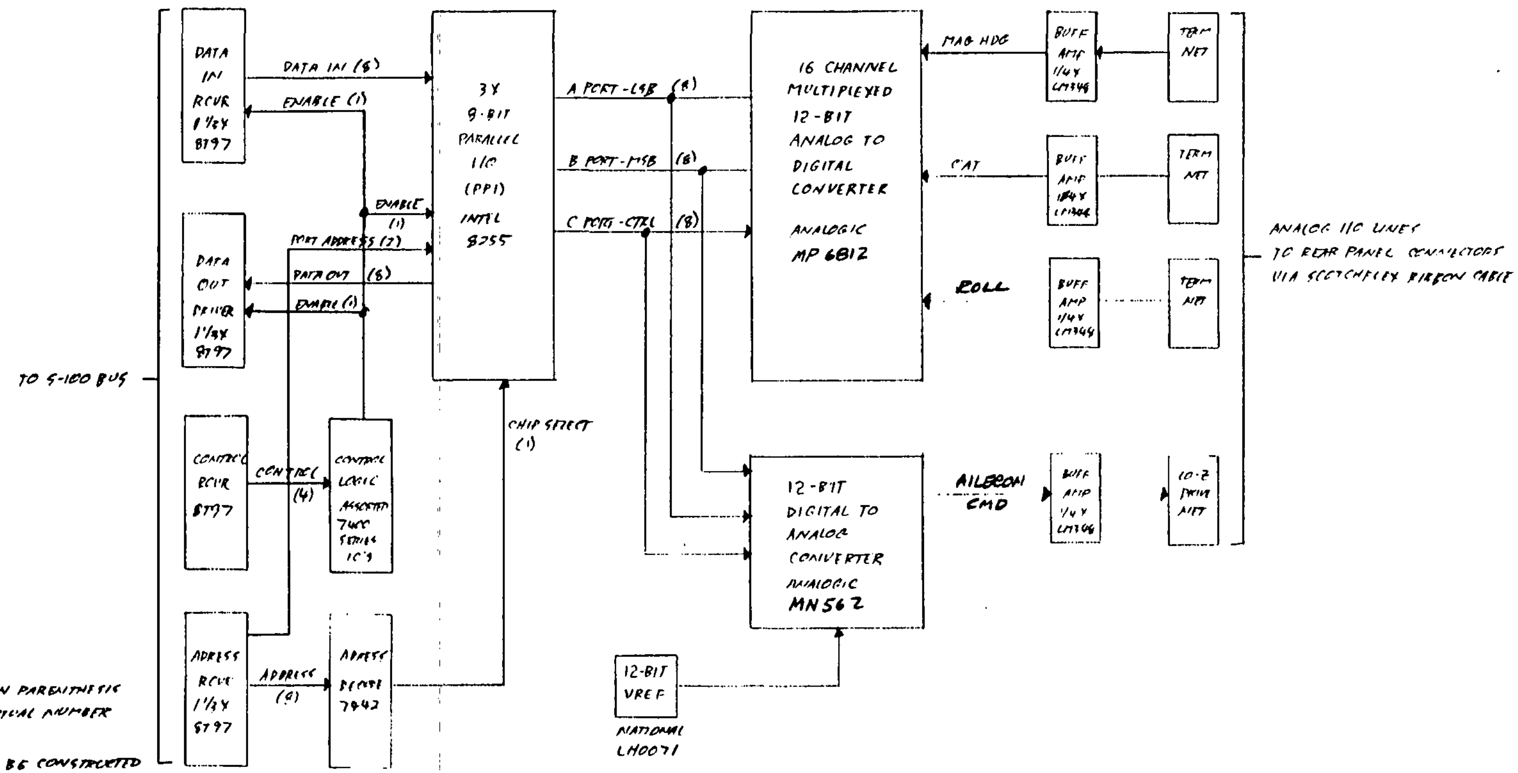
The schematic for the analog module is displayed in figure 3.1-4. The 16 channel 12 bit analog to digital conversion is provided by the analogic MP6812 which has a conversion time of 35 microsec, the digital to analog conversion is provided by the MN562 which has a conversion time of 1.5 microsec. Also included on the module is an 8255 programmable parallel I/O chip which provides 24 parallel I/O lines.

The schematic for the 24K RAM modules used is shown in figure 3.1-5. This RAM card is compatible with the 8Ø85 CPU/APU module. The memory has 45Ø ns access time.

The floppy disk drive controller schematic is shown in figure 3.1-6. This controller can provide the interface for two dual disk drives for a total of 126ØK bytes on line mass memory. The BAM includes a single disk drive with 63ØK memory.

The video modulator module shown in figure 3.1-7 provides the video interface with a CRT monitor to the video amplifier. This module provides a 24 line x 8Ø character alpha numeric display as well as limited dot matrix graphics. The video can be positive or reverse.

- o AVIONICS DATA CONTROL CENTER
  - o 9" TV driven by the video module in the microcomputer #3 for alphanumerics and graphics
    - o Displays 256 characters
    - o 7 x 1Ø dot matrix for each character
    - o 24 lines x 8Ø characters
    - o characters are x-z addressable
  - o Keyboard Data Entry Module
    - o Serial RS-232C I/O
    - o 55 key keyboard
    - o Upper case/lower case alphanumerics
    - o ASCII coded
    - o Uncoded mode
    - o Operates at 24ØØ BAUD (or slower)
  - o "Telephone" Keyboard (utilized as an alternate during flight test to the 55 key keyboard used during simulation and software development)
    - o Sixteen Keys
    - o ASCII coded
    - o Contained in a 1.67 x 1Ø exp 7 nanometer by 1.67 x 1Ø exp 7 nm by 7.87 x 1Ø exp 6 nm (4-1/4" x 4-1/4" x 2" expressed in customary units) enclosure
    - o RS 232C serial I/O
  - o DUAL MICRO FLOPPY DISK DRIVE
    - o 77 tracks
    - o 16 records/track



NOTES:

1. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
2. CARD SHALL BE CONSTRUCTED USING WIRE WRAP TECHNIQUE
3. ONE CARD ONLY REQUIRED IN SENSOR COMPUTER

DWG. NO.	SH	REV.

REVISIONS

REV.	DESCRIPTION	DATE	APPROVED

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL N/A

FINISH N/A

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
3003	BAM

APPLICATION

CONTRACT NO. NAS-1-15284

APPROVALS		DATE
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ISSUED		

MILCO INTERNATIONAL, INC.

ANALOG I/O UNIT

SIZE	FSCM NO.	DWG. NO.	REV.
B	4303	FIGURE 3.1-4	¢

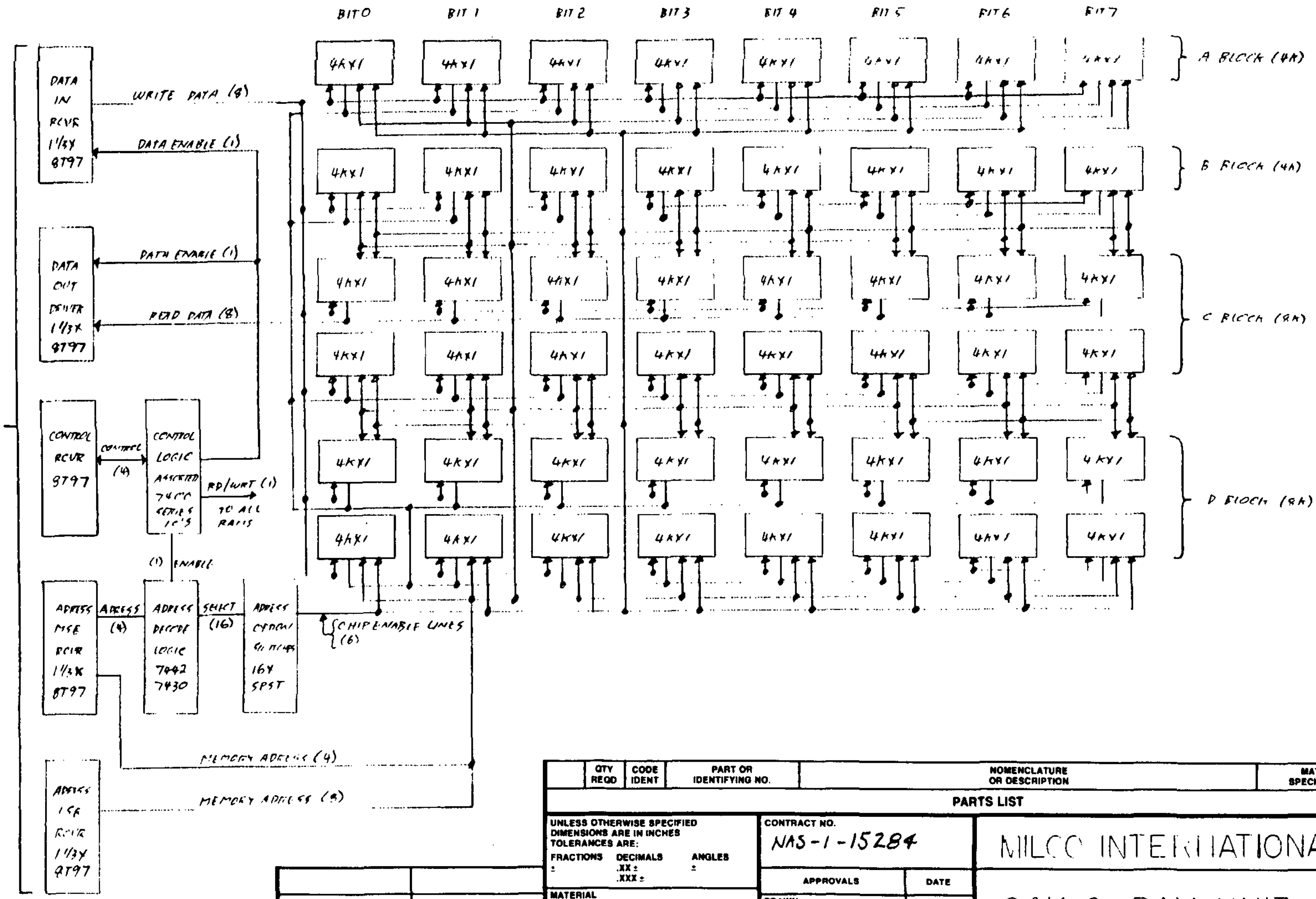
SCALE N/A SHEET 1 OF 1

BISHOP GRAPHICS, INC. REORDER NO. 20510

DWG. NO.	SH	REV.

REVISIONS

REV.	DESCRIPTION	DATE	APPROVED



NOTES:

1. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
2. CARDS ARE PRE FAB-RICATED, STOCK ITEMS
3. TWO SUCH CARDS REQUIRED IN NAV. & FLT MGT COMPUTER, ONE IN SENSOR COMPUTER

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

3003	BAM
NEXT ASSY	USED ON
APPLICATION	

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FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL N/A

FINISH N/A

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APPROVALS		DATE
DRAWN	RFS	11/12/78
CHECKED	RFS	11/12/78
ISSUED		

MILCO INTERNATIONAL, INC.

24K×8 RAM UNIT

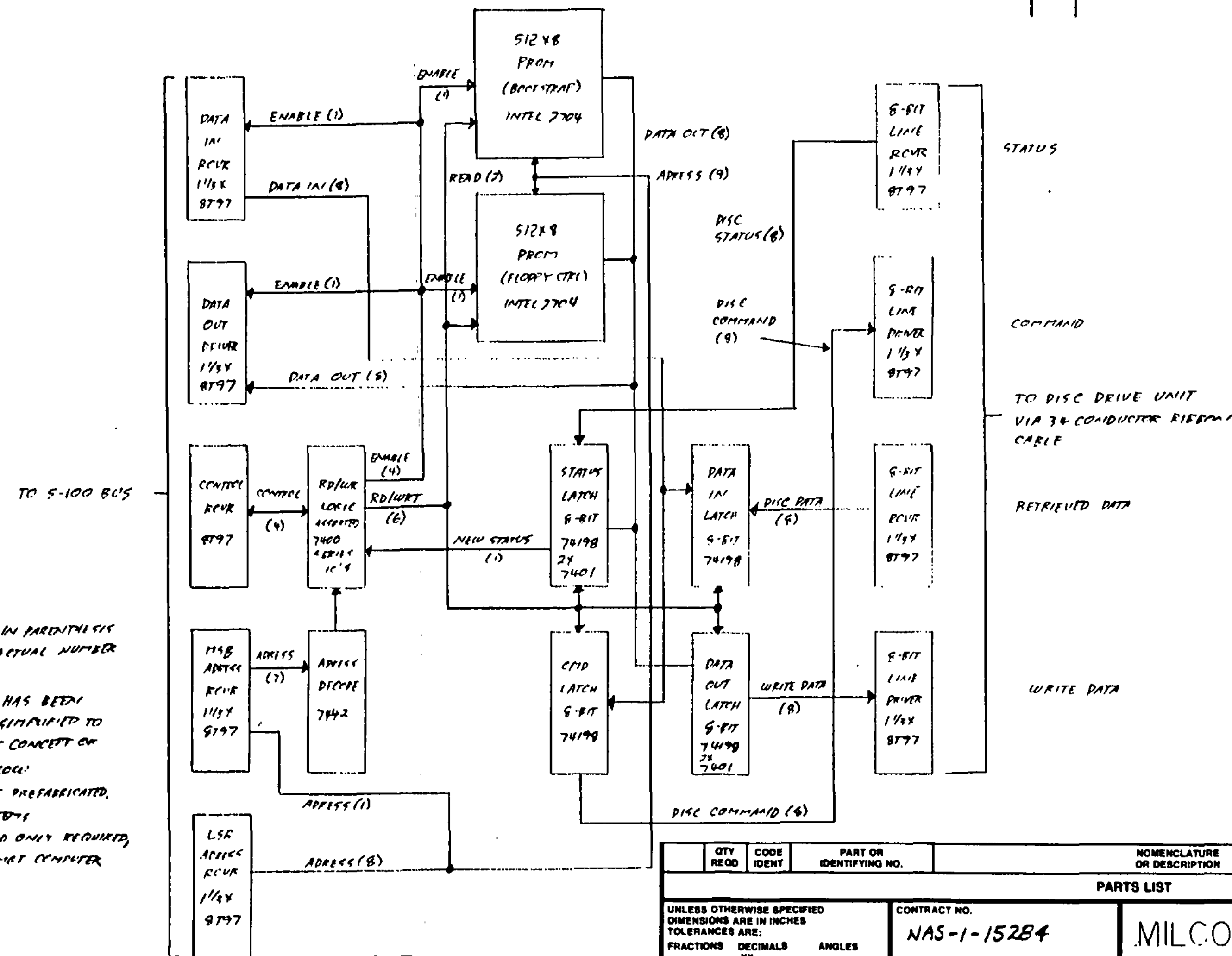
SIZE	FSCM NO.	DWG. NO.	REV.
B	4302	FIG 3.1-5	∅

SCALE N/A SHEET 1 OF 1

DWG. NO.	SH	REV.

REVISIONS

REV.	DESCRIPTION	DATE	APPROVED



NOTES:

1. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
2. DIAGRAM HAS BEEN GREATLY SIMPLIFIED TO FACILITATE CONCEPT OF SIGNAL FLOW
3. CARDS ARE PREFABRICATED, STOCK ITEMS
4. ONE CARD ONLY REQUIRED IN FLT MGT COMPUTER

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

NEXT ASSY	USED ON
3003	BAM

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL N/A

FINISH N/A

DO NOT SCALE DRAWING

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APPROVALS		DATE
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CHECKED	RFS	11/12/78
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MILCO INTERNATIONAL, INC.

DISC DRIVE CONTROL UNIT

SIZE B | FSCM NO. 4306 | DWG. NO. FIG 3.1-6 | REV. ф

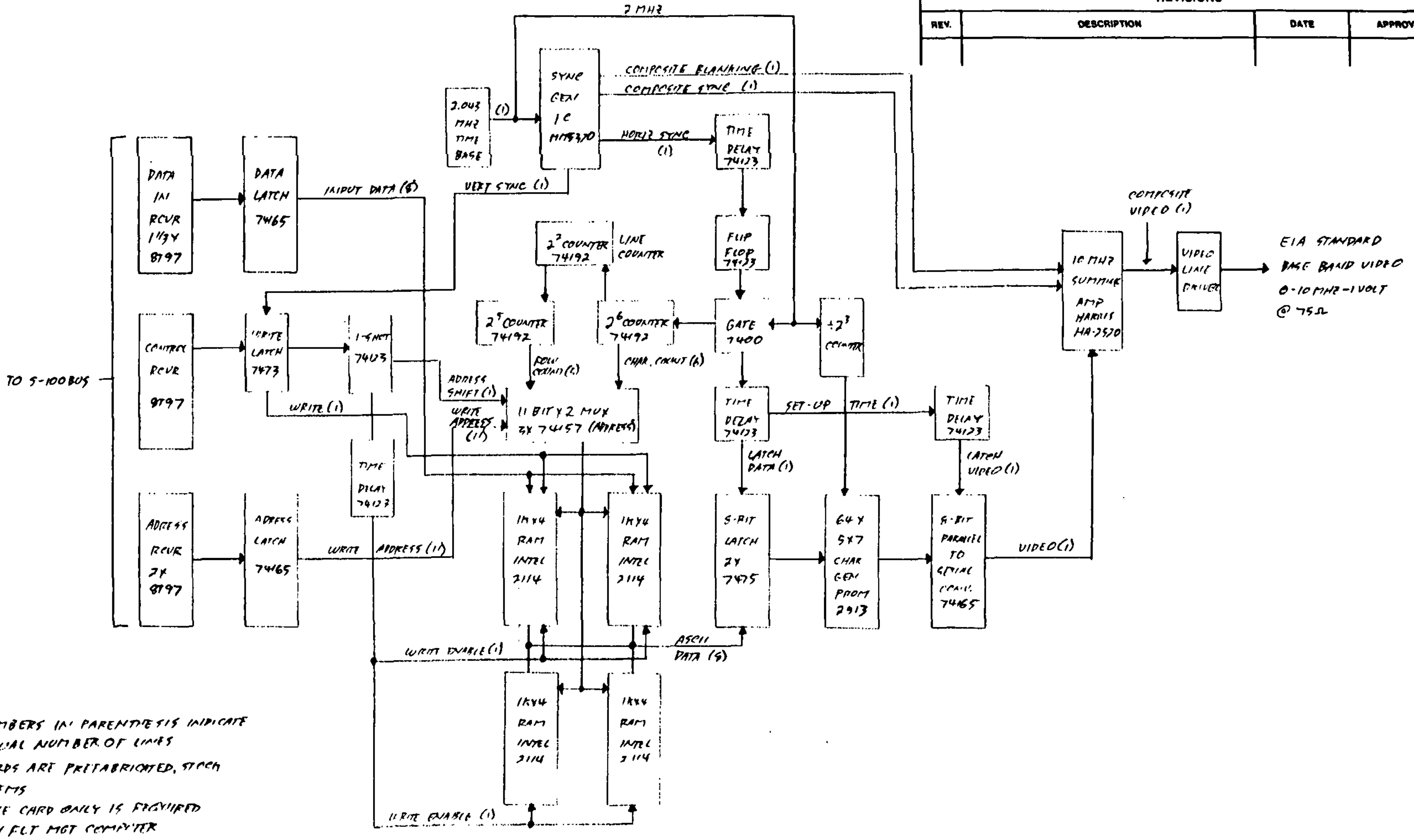
SCALE N/A | SHEET 1 OF 1

BISHOP GRAPHICS, INC. REORDER NO. 20510

DWG. NO.	SH	REV.

REVISIONS

REV.	DESCRIPTION	DATE	APPROVED



NOTES:

1. NUMBERS IN PARENTHESIS INDICATE ACTUAL NUMBER OF LINES
2. CARDS ARE PREFABRICATED, STOCK ITEMS
3. ONE CARD ONLY IS REQUIRED IN FLT MGT COMPUTER

QTY REQD	CODE IDENT	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION

PARTS LIST

NEXT ASSY	USED ON
3003	8AM

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE:
FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±

MATERIAL N/A

FINISH N/A

DO NOT SCALE DRAWING

CONTRACT NO. NAS-1-15284

APPROVALS		DATE
DRAWN	RRS	11/10/78
CHECKED	RFS	11/12/78
ISSUED		

MILCO INTERNATIONAL, INC.

VIDEO DISPLAY UNIT

SIZE	FSCM NO.	DWG. NO.	REV.
B	4307	FIG 3.1-7	ϕ

SCALE N/A SHEET 1 OF 1

    - 25Ø bytes/record
    - 315,ØØØ bytes/diskette
    - 25Ø,ØØØ bits/sec data transfer
    - 3Ø MS track to track access
    - 63Ø,ØØØ bytes total storage on two drives
    - Modified to accept AC or DC power

  - SR-59 PROGRAMMABLE CALCULATOR FOR FLIGHT PLAN DATA
    - Connects to DMC thru 11 bit cable/connector
    - Dumps previously stored flight plan data into microcomputer #3 RAM memory

The BAM system hardware groups include:

- NAVIGATION RADIO GROUPS
  - Two VOR/DME receivers
    - Must accept parallel binary coded decimal (BCD) frequency tuning commands (4 digits)
    - Must output parallel BCD VOR bearing signal (3 digits)
    - Must output parallel BCD ILS localizer error signal (phase sensitive) to three digits plus a sign bit
  - ADF receiver
    - Must accept parallel BCD frequency commands (4 digits) (4 digits)
    - Must output parallel BCD ADF bearing signal (3 digits)

- SENSOR GROUPS
  - magnetometer Sensor
    - DC output voltage Ø to 5 volts with zero volts corresponding to Ø deg/36Ø deg magnetic heading
    - Input bias current 2 microamps
    - Input impedance 2Ø M ohms at sample period of 1MS, .ØØ1 micro F input capacitance

  - Outside Air Temperature Transducer
    - DC output voltage Ø to 5v with Øv corresponding to Ø degrees C
    - Range +/- 6Ø deg C
    - Same input characteristics as for magnetometer

  - True Airspeed Sensor
    - Pulse rate proportional to true airspeed
    - Pulse amplitude limited to +2.5v with pulse excursions from Øv.

  - Yaw Rate Sensor
    - Same characteristics as true airspeed sensor

  - Altimeter, Pressure Altitude
    - Parallel binary coded decimal output (3 digits)
    - Range - 1ØØØ' to + 2Ø,ØØØ', 1ØØ' resolution

  - Tachometer
    - Same characteristics as true airspeed sensor

  - Fuel Flow Meter

- Same characteristics as true airspeed sensor

- AUTOPILOT GROUP

The autopilot shall consist of a two axis lateral autopilot which provides adequate yaw damping augmentation (if required) turn coordination, and will accept a DC voltage command scaled such that +/- 5v DC corresponds to a full scale aileron deflection. The output impedance of the driver is Ø.25 ohms with the maximum load current available of 1.5ma.

The microcomputer #1 will provide the necessary outer loop flight control computations necessary to provide for a stable lateral flight control as described in section 2.5. The autopilot will provide the necessary surface actuators. Also a mode switch shall be provided to allow autopilot mode control to be exercised by the DMC.

The software of the BAMME will be designed to provide the functions set forth in MILCO spec 78Ø4-BAM-19Ø.

3.2 EQUIPMENT LIST

The work breakdown structure for the BAM hardware design configuration is shown in figure 3.2-1. All of the distributed microcomputer modules are the S-1ØØ bus modules. All are standard off the shelf modules, with the exception of the three I/O mo modules. The BAM microcomputer equipment (BAMME) list is given in table 3.2.1 The BAM system hardware list is given in table 3.2-2.

The system schematic for BAM is shown in figure 3.1-1, the connector list is given in table 3.2-3. The distributed microcomputer is mounted in a single enclosure which has three separate mother boards. Two of the mother boards are obtained by taking a 1Ø slot mother board and separating it into two. The terminator circuitry on the mother board is used for microcomputer #1 and a separate bus board used by microcomputer #2 to prevent bus ringing etc. A third 6 module mother board is installed in the chassis for microcomputer #3 which also has the bus terminator circuitry on the board.

The sensors interface with microcomputer #1. The sensors are connected to the distributed microcomputer (DMC) chassis by means of shielded cable terminated in Bendix connectors. The three DC output sensors (the magnetic heading, the outside air temperature and the roll attitude gyro utilize shielded twisted wire pairs carrying the ground wire and the voltage wire. The internal wiring inside the chassis utilizes twisted shielded cable with connectors which terminate on the analog module.

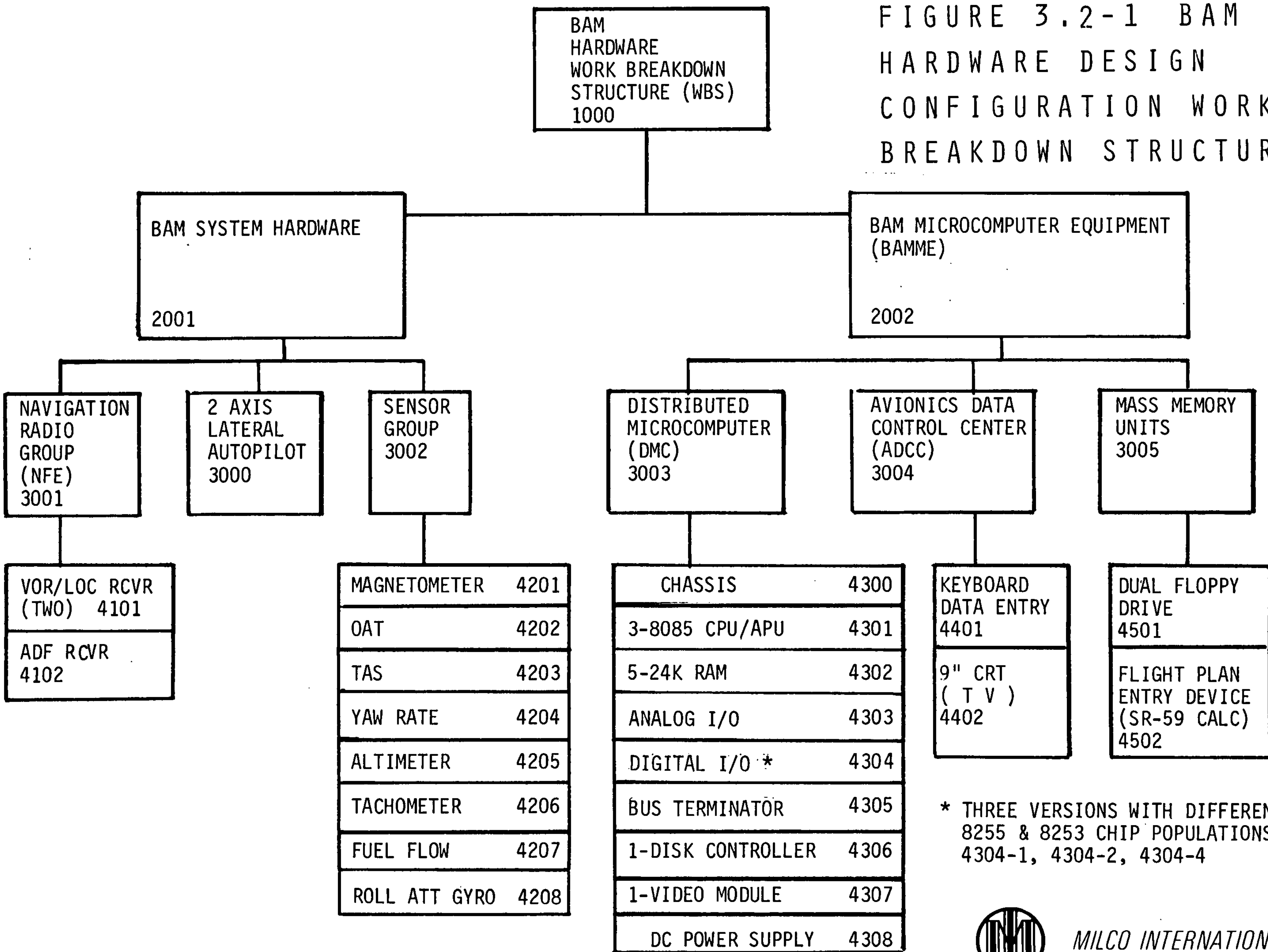
The MAG HDG signal is Ø to +5v with Øv corresponding to Ø deg and +5v corresponding to 359.9 deg. The OAT signal is +/- 5v with Øv corresponding to Ø deg C and +/-5v corresponding to +/- 6Ø deg C. The bank angle signal is +/-5v with Øv corresponding to Ø deg bank angle and +/-5v corresponding to +/-5Ø deg bank angle.

These three DC signals utilize three channels of the MP 6812 data acquisition system located on the analog module of microcomputer #1. The 6812 has sixteen single ended or eight double ended ADC channels each with 12 bit resolution, three of the double ended channels are used leaving ten spare single ended channels. The ADC utilizes a multiplexer for the inputs with a single sample and hold and 12 bit ADC. The multichannel throughput is 27.5 KHz or a conversion time of 36 microsec per channel or 27,778 samples per sec throughput.

The four pulse rate signals are connected to the chassis using a shielded twisted pair terminated with a Bendix connector. The internal wiring uses shielded twisted pair cable with connectors terminated in the digital I/O module #1, which provides connections to four of the timer/counter registers in the two 8253 timer chips.

The 12 bit BCD encoded altitude signal utilizes a 12 conductor ribbon cable terminated with a ribbon connector. The internal wiring is on a ribbon cable terminated with a printed circuit connector on the digital I/O module #1.

FIGURE 3.2-1 BAM HARDWARE DESIGN CONFIGURATION WORK BREAKDOWN STRUCTURE



* THREE VERSIONS WITH DIFFERENT 8255 & 8253 CHIP POPULATIONS 4304-1, 4304-2, 4304-4

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TABLE 3.2-1 BAM MICROCOMPUTER EQUIPMENT LIST

SYSTEM	WBS#	MILCO#	VENDOR	VENDOR#	QTY	EXTENDED WT(Kg)	EXTENDED VOL(litres)	EXTENDED PWR(W)	APPROX COST
DMC Chassis with AC Power Supply	4300	630-001	IMSAI	8015	1	9.53	39.00	3220(CAP)[1]	$1088
8085 CPU Module	4301	630-1000	MILCO	CPU/APU	3	0.95	incl	27W	1500
24K RAM Module	4302	630-1001	Godbout	ECONORAM IV	5	1.59	incl	55W	3025
Analog I/O Module	4303	630-1008	MILCO	-	1	0.32	incl	39	650
Digital I/O Module	4304	630-1005	MILCO	-	3	0.95	incl	27	1350
Bus Terminator	4305	630-1004	IMSAI	P106-6	1	0.32	incl	5	100
Disk Controller	4306	630-1014	Micropolis	-	1	0.32	incl	10	incl
Video Module	4307	630-1017	IMSAI	VIO-C	1	0.36	incl	11	465
DC Power Supply	4308-1	630-1013-1	ABBOTT	BN100D-5A	2	3.99incl	incl	200[2]	950
DC Power Supply	4308-2	630-1013-2	ABBOTT	BN100D-12V	2	3.99incl	incl	200[2]	950
6 Slot Motherboard	4300-1	630-1002	Godbout	6 SMB	1	0.49	incl	5	90
Cables	4300-2	630-1015	COMPUTERM	1015	1 lot	8.85	incl	-0-	150
Misc. Hardware					1 lot	incl	incl	-0-	1000
DMC SUBTOTAL	3003					31.66Kg	39.00 litre	400W[3]	$11,318

1. AC Power Supply has capacity of 30 amps at 110V
2. DC Power Supplies have capacity of 200W
3. Cards require 200W DC power.

TABLE 3.2-1 (Cont.) Page two of two

						EXTENDED			APPROX
SYSTEM	WBS#	MILCO#	VENDOR	VENDOR#	QTY	WT(Kg)	VOL(litres)	PWR(W)	COST
Telephone Keyboard	440101	630-1006-1	MILCO	-	1	0.45	.45	1W	$ 120
Keyboard Data Entry	4401	630-1006	IMSAI	IKB-1	1	4.08	5.05	10W	275
9" TV CRT	4402	630-1016	Panosonic	AC/DC	1	3.99	4.92	25	160
ADCC SUBTOTAL	3004					8.52	10.51	36	555
Dual Floppy Disk Drive	4501	630-003	Micropolis	1053MODII	1	8.16	15.68	78	1895
DC Power Supply	4501	630-1017	COMPUTERM	1017	1	0.91	incl	78(incl)	300
Flight Plan Entry	4502	630-1018	TI	SR 59	1	0.23	.34	0.1	175
MASS MEMORY SUBTOTAL	3005					9.66	16.03	78.1	$2370
GRAND TOTAL						59.50Kg	65.53 litre	514W[4]	$14,243.

4. (43A @ 12V DC)

SYSTEM ELEMENT	WBS#	VENDOR, VENDOR #	QTY	EXTENDED WT Kg	EXTENDED VOL litre	EXTENDED PWR Watts	APPROX COST
NAVIGATION RADIO GROUP	3001						
VOR/LOC RCVR	4101	COLLINS,VIR-351	2	3.36	3.31	24	$3,370.
ADF RCVR	4102	COLLINS, ADF-650	1	2.40	1.61	24	1,595.
SENSOR GROUP	3002						
MAGNETOMETER	4201	NASA LaRC, TBD	1	0.91	1.64	15	500.
OAT TRANSDUCER	4202	TBD,TBD	1	0.14	.02	0.5	100.
TAS SENSOR	4203	NASA LaRC, TBD	1	.23	.10	10	500.
YAW RATE SENSOR	4204	NASA LaRC, TBD	1	.68	.82	15	500.
ENCODING ALTIMETER	4205	Aircrft Instru & Dev, 371005	1	.91	1.23	10	650.
TACHOMETER	4206	STD,STD	1	.91	1.64	-0-	100
FUEL FLOW TRANSDUCER	4207	TBD,TBD	1	.91	1.64	-0-	100
AUTOPILOT GROUP	3000	ASTRONAUTICS, P2A	1	6.89	16.39	30	3,008.
		TOTAL		17.33	28.42	128.5	$10,423.
	BAMME (FROM TABLE 3.2-1)			59.50	65.53	514	14,243.
		BAM GRAND TOTAL		76.83 Kg	93.95 litres	642.5 Watts	$24,666.

TABLE 3.2-2 BAM SYSTEM HARDWARE

TABLE 3.2-3 BAM CONNECTOR LIST

	PART NO.
P1-P7, P9	MS 3106A-10SL-3S
J1-J7, J9	MS 3101A-10SL-3P
J10, J11	50 PIN RIBBON CROSSOVER RECEPTACLE
P10, P11	50 PIN RIBBON CONNECTOR
J12	UG492A BULKHEAD ADAPTER
P12	UG88B/U COAX PLUG
J13	DB-25S RS232C CONNECTOR
P13	DB-25P RS232C PLUG
J14	34 PIN RIBBON CROSSOVER RECEPTACLE
P14	34 PIN RIBBON CONNECTOR
J15	20 PIN RIBBON CROSSOVER RECEPTACLE
P15	20 PIN RIBBON CONNECTOR
J16	IEEE 488 INTERFACE CONNECTOR

The autopilot actuator interfaces with the DMC using a cable consisting of a shielded twisted pair terminated in a Bendix connector. The internal wiring is via a shielded twisted pair cable connected to the Analog module with PC connectors which interfaces to the MN562 digital to analog converter (which is a 24 pin DIP) on the module. The MN562 has 12 bits resolution, converts in 1.5 microsec with an accuracy of .012% of full scale. If the full scale aileron deflection is 20 deg this corresponds to an accuracy of .0024 deg of aileron.

The three microcomputers are interconnected via the IEEE 488 parallel bus using the three digital I/O modules. The bus is implemented using a smart 488 bus chip (the MC 69488) which includes all the bus protocol and provides for defining the bus interface as a controller, talker, and listener. The controller function is assigned to microcomputer #3 (digital I/O module #3). The IEEE 488 bus interface for each microcomputer can be assigned as either a talker of listener with the assignment changeable. Microcomputer #2 is mainly a listener, and #3 is both a talker and listener as well as being the controller. An IEEE 488 bus connector is brought to the back of the DMC chassis so that other IEEE 488 devices can access the bus during simultaion. Internally the IEEE 488 bus connections are made to the three digital I/O modules using ribbon cable and PC connectors on the modules.

A pair of ribbon cables containing 50 conductors each terminated by two ribbon chassis connectors are used for each of the three nvaigation radios (two VOR/LOC receivers and one ADF receiver). Internally the connections are made to the digital I/O #3 module via two ribbon connectors. It would be highly desirable to put each of the navigation radios on the IEEE 488 bus which would reduce the amount of aircraft cabling from 96 wires to 16 wires, however, this would mean a special IEEE 488 bus interface at the radios.

The dual microfloppy diskette drive is connected to the DMC via a ribbon cable to the PL connector on the disk driver module located in microcomputer #3.

The 55 key keyboard as well as the 16 key telephone keyboard are connected to the DMC via an RS232C cable terminated in an RS232C connector. The internal connections is via a ribbon cable to a connector on the CPU/APU module. Each CPU/APU module has a RS232C interface, however the only one utilized is that on microcomputer #3.

The video for the 9" TV CRT display uses a shielded video cable connected to a BNC connector.

The SR-59 calculator is connected to the DMC from an 11 wire shielded cable from the cockpit to a Bendix connector on the DMC. The internal connection is via a ribbon connecter. A special ribbon cable from the SR-59 to a PC connector on the control panel is used to connect from the SR-59 printer interface to the calculator. The SR-59 is used to enter flight plan data into the DMC using a magnetic card entered into the SR-59.

4.0 SOFTWARE MODULES

The work breakdown structure of BAM software is shown in figure 4.0-1. The software is broken down into those modules which are operational and those modules which are I/O orientated.

The preliminary BAM software is summarized in figure 4.0-2. The application software addressed during the BAM design used NORTHSTAR BASIC. A floating point board with floating point BASIC was acquired but not used for the BAM preliminary software. The BAM operational software will be updated to MICROPOLIS extended BASIC. Also a FORTRANIV and PASCAL compiler are available to generate compiled code executable by the 8085 microprocessor.

The support software is available software compatible with the Micropolis disk drive and provides for both higher order language and assembly language programming.

The common software modules are used by all three microcomputers of the DMC and include:

o APU Floating Point MAth Routines

This module includes a number of assembly language subroutines callable by BASIC which execute the AM 9511 arithmetic processor 32 bit floating commands including add, subtract, multiply, and the transcendental functions (log, exponentiation, sin, cos, etc.). The floating point math utilizes the direct interface between the 8085 CPU and the 9511 APU with the results available on an interrupt basis. A growth feature can provide DMA control of the floating point APU to enhance the computational throughput should this prove to be desorable. This feature can be added by another wire wrap module with a DMA controller chip.

o IEEE 488 Bus Control and Access

This module includes a number of I/O subroutines callable by BASIC which provide for:

- o Accessing data fron the bus
- o Sending data to the bus

The 488 bus protocol is implemented on an MC 68488 chip which is programmed to provide the controller function for microcomputer #3 and provides the talker listener functions as required by the DMC.

o Microcomputer Self Test

This module includes subroutines callable by BASIC which provide for testing all memory cells, I/O ports, and performing checks of other microcomputer elements.

The MILCO software development system is shown in figure 4.0-3. MILCO has recently acquired a FORTRAN IV Compiler which compiles into machine code. However, the compiler was not used on BAM.

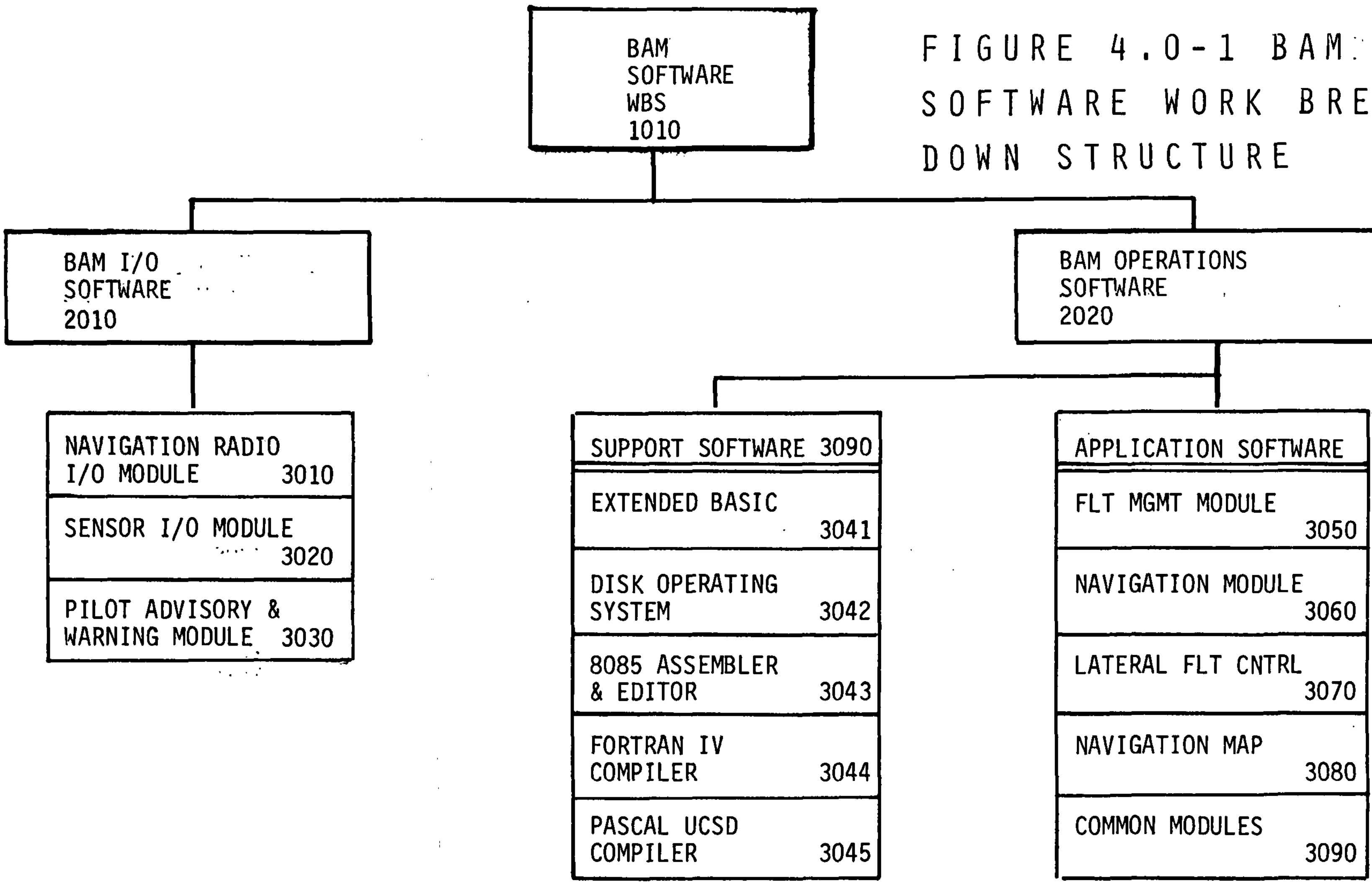


FIGURE 4.0-1 BAM SOFTWARE WORK BREAK-DOWN STRUCTURE

FIGURE 4.0-2

BAM PRELIMINARY SOFTWARE

COMPLETED

		MEMORY ALLOCATED (BYTES)
MASTER MENU	MASTER	2560
● FLIGHT MANAGEMENT MENU	MENU	2560
● FLIGHT PLAN MODULE	FLTPLN	15,360
● CHECK LISTS MODULE	CHECKLST	5120
● ENGINE MANAGEMENT MODULE	ENGMGT	3072
● WEIGHT & BALANCE	WT&BAL	2560
● CLIMB PERFORMANCE	CLBPRF	5120
● TAKE OFF PERFORMANCE	TOPRF	2560
● CRUISE PERFORMANCE	CRSPRF	1280
● LANDING PERFORMANCE	LNDPRF	1280
● NAVIGATION MAP	NAVMAP	10,240**
● VOR UPDATE ***	VOR FIX	8,960
● LATERAL FLIGHT CONTROL	FLT CNTRL	11,520
● FLIGHT PLAN UPDATE	FLTPLNUP	12,800
	TOTAL	84,992 BYTES*

THE PROGRAMS DO NOT UTILIZE THIS MUCH SPACE AND CAN BE CONSIDERABLY COMPACTED

* DISKETTE CAPACITY 89,600

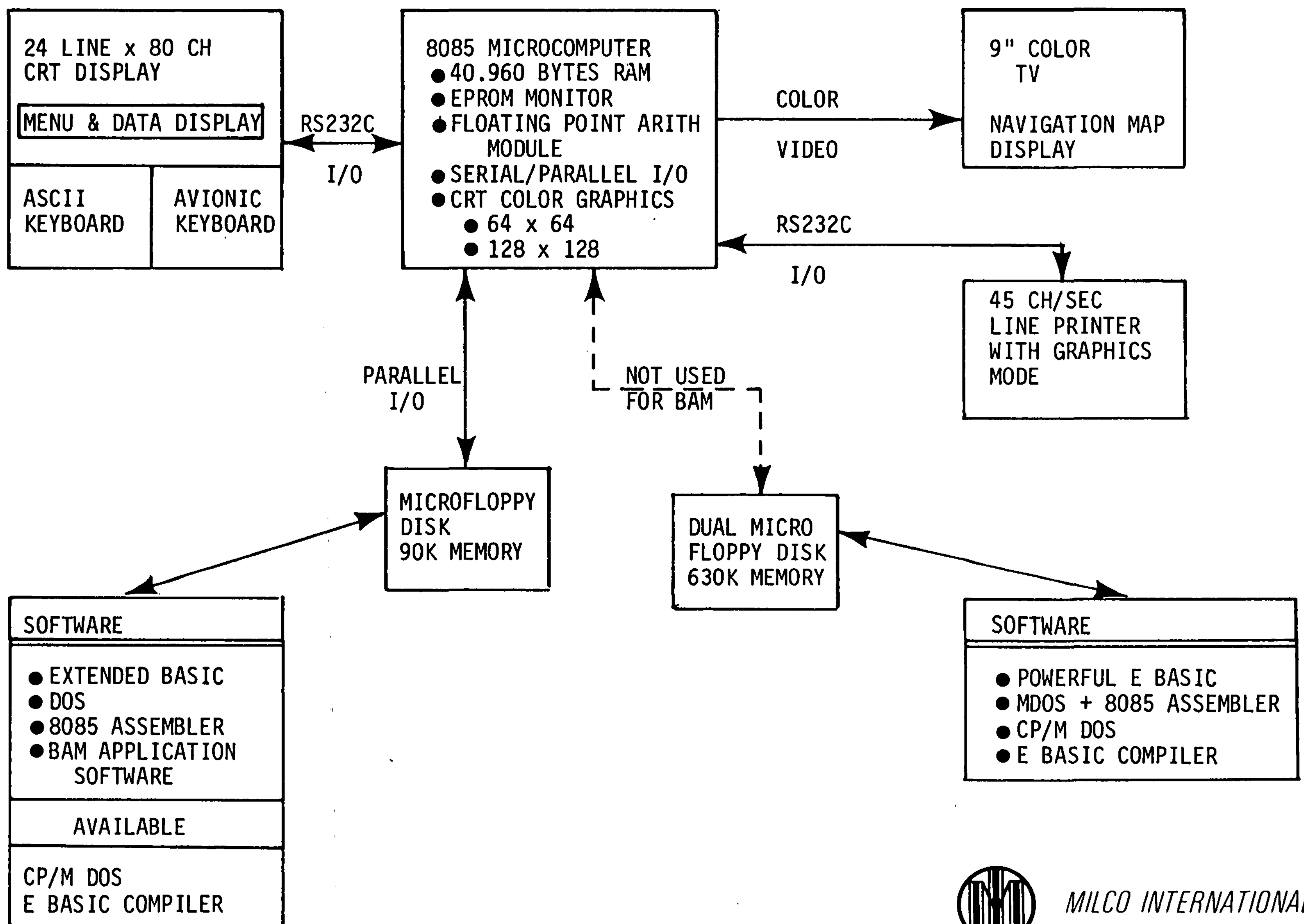
** CONTAINS MAP DATA BASE, PARTIAL

*** PARTIAL

FIGURE 4.0-3

MILCO DEVELOPMENT SYSTEM

USED FOR BAM



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MILCO recommends that a compiler be user during the BAM inplementation to reduce memory requirements and to increase the throughput.

A detailed breakdown of the BAM software modules is presented in table 4.Ø-1 which summarizes the status on the preliminary BAM software relative to the workbreakdown structure defined in figure 4.Ø-1. It should be noted that 1ØØ% complete means coded and validated using North Star BASIC. A modest conversion effort is required to convert to the more powerful Micropolis extended BASIC.

TABLE 4.Ø-1 BAM SOFTWARE STATUS RELATIVE TO WORK BREAKDOWN STRUCTURE

WBS#	NAME	PROGRAM MNEMONIC	% COMPLETE
1Ø1Ø	BAM SOFTWARE WORK BREAKDOWN STRUCTURE		
2Ø1Ø	BAM I/O SOFTWARE		
3Ø1Ø	NAVIGATION RADIO I/O MODULE		
3Ø11	VOR/LOC TUNING MODULE		Ø%
3Ø12	VOR/LOC BEARING MODULE		Ø%
3Ø13	ADF TUNING MODULE		Ø%
3Ø14	ADF BEARING MODULE		Ø%
3Ø2Ø	SENSOR I/O MODULE		
3Ø21	ANALOG INPUT MODULE		Ø%
3Ø22	PULSE RATE INPUT MODULE		Ø%
3Ø23	PARALLEL DIGITAL INPUT MODULE		Ø%
3Ø3Ø	PILOT ADVISORY & WARINING MODULE		
2Ø2Ø	BAM OPERATIONS SOFTWARE		
3Ø4Ø	SUPPORT SOFTWARE		
3Ø41	EXTENDED BASIC VERSION 4.Ø	BASIC	1ØØ%
3Ø42.1	MICROPOLIS DISK OPERATING SYSTEM	MDOS	1ØØ%
3Ø43	8Ø85 ASSEMBLER & LINE EDITOR		1ØØ%
3Ø42.2	CP/M DISK OPERATING SYSTEM	CP/M	1ØØ%
3Ø44	FORTRAN IV COMPILER	F8Ø	1ØØ%
3Ø45	UCSD PASCAL COMPILER		AVAILABLE
	APPLICATION SOFTWARE MODULES		
3Ø5Ø	FLIGHT MANAGEMENT MODULES		
3Ø51.1	CHECKLIST	CHCKLST	1ØØ%
3Ø51.2	IFR CHECKLIST	IFRCHKL	1ØØ%
3Ø52	WEIGHT AND BALANCE	WT&BAL	1ØØ%
3Ø53.1	FLIGHT PLAN	FLTPLN2	1ØØ%
3Ø53.2	FLIGHT PLAN UPDATE	FLTPLNUP	8Ø%
3Ø54	RESERVES	RESERVES	Ø%
3Ø55	FLIGHT PARAMETERS	FLTPAR	Ø%
3Ø56.1	AIRCRAFT PERFORMANCE (TAKE OFF)	TOPRF	1ØØ%

TABLE 4.0-1 BAM SOFTWARE STATUS RELATIVE TO WORK BREAKDOWN STRUCTURE (CONT)

3056.2	AIRCRAFT PERFORMANCE (CLIMB)	CLBPRF	100%
3056.3	AIRCRAFT PERFORMANCE (LAND)	LNDPRF	100%
3060	NAVIGATION MODULES		
3061	POSITION INITIALIZATION		0%
3062	POSITION RESET		0%
3063	DISPLAY NAVIGATION DATA		0%
3064.1	VOR RNAV	VORFIX	95%
3064.2	VOR RNAV	VORRNAV	0%
3065	ILS APPROACH		0%
3070	LATERAL FLIGHT CONTROL MODULES		
3071	HOLD HEADING		0%
3072	TURN LEFT OR RIGHT		0%
3073	RNAV COUPLING	FLTCTRL	100%
3074	LOCALIZER COUPLING		0%
3075	TURN TO SELECTED HEADING		0%
3076	ADF COUPLING		0%
3077	VOR COUPLING		0%
3078	AUTOPILOT OUTPUT		0%
3080	NAVIGATION MAP MODULES		PARTIAL
3081	ENTER NAV MAP DATA BASE		
3082	UPDATE NAV MAP DATA BASE		0%
3083	ACCESS NAV MAP DATA BASE (USED IN FLTPLN)		90%
3084	DISPLAY NAV MAP FORMATS (GROWTH FUNCTION)		
3090	COMMON MODULES		
3091	APU FLOATING POINT ROUTINES (NO LISTINGS AVAILABLE)		10%
3092	IEEE 488 I/O		0%
3093	MICROCOMPUTER SELF TEST (NO LISTINGS AVAIL.)	MEMTEST	10%

5.Ø BAM SOFTWARE LISTINGS

The source listings for preliminary BAM software sdhown completed in table 4.Ø-1 are included in this section. The source listings are well documented with REM (remark) statements to explain their operation. The listings are in the same order as table 4.Ø-1 with the WBS# shown on the listing for cross reference.

An additional listing of the BAM operational software including data files is shown in table 5.Ø-1.

TABLE 5.0-1
BAM OPERATIONAL SOFTWARE

NAME	ADDR	LEN	TYP	DESCRIPTION
MASTER	4	4	2	MASTER MENU PROGRAM
VORFIX	8	18	2	POSITION UPDATE BY MULTI. VOR PROGRAM
POSITION	26	18	2	DATA FILE FOR POSITION IN LAT/LNG
MENU	27	4	3	FLIGHT MANAGEMENT MENU PROGRAM
CHECKLST	31	17	2	VFR CHECK LIST PROGRAM
IFRCHKL	48	40	2	IFR CHECK LIST PROGRAM
WT&BAL	88	10	2	WEIGHT AND BALANCE PROGRAM
FLTPLN2	98	41	2	FLIGHT PLANNING PROGRAM
0422	139	15	3	MAP DATA BASE FOR MAP SEGMENT 0422
FPDATA	154	4	3	DATA COMPUTED BY FLTPLN2 PROGRAM
TOPRF	158	6	2	TAKE OFF PERFORMANCE PROGRAM
CLBPRF	154	12	2	CLIMB PERFORMANCE PROGRAM
LNDPRF	176	4	2	LANDING PERFORMANCE PROGRAM
RESERVES	180	3	2	RESERVES CALCULATING PROGRAM
FLTPAR	183	3	2	FLIGHT PARAMETER DISPLAY PROGRAM
FLTCTRL	190	29	2	LATERAL FLIGHT CONTROL PROGRAM
0				

ADDR = Sector number of program beginning on disk. Disk has 350 sectors, 219 have been used so far.

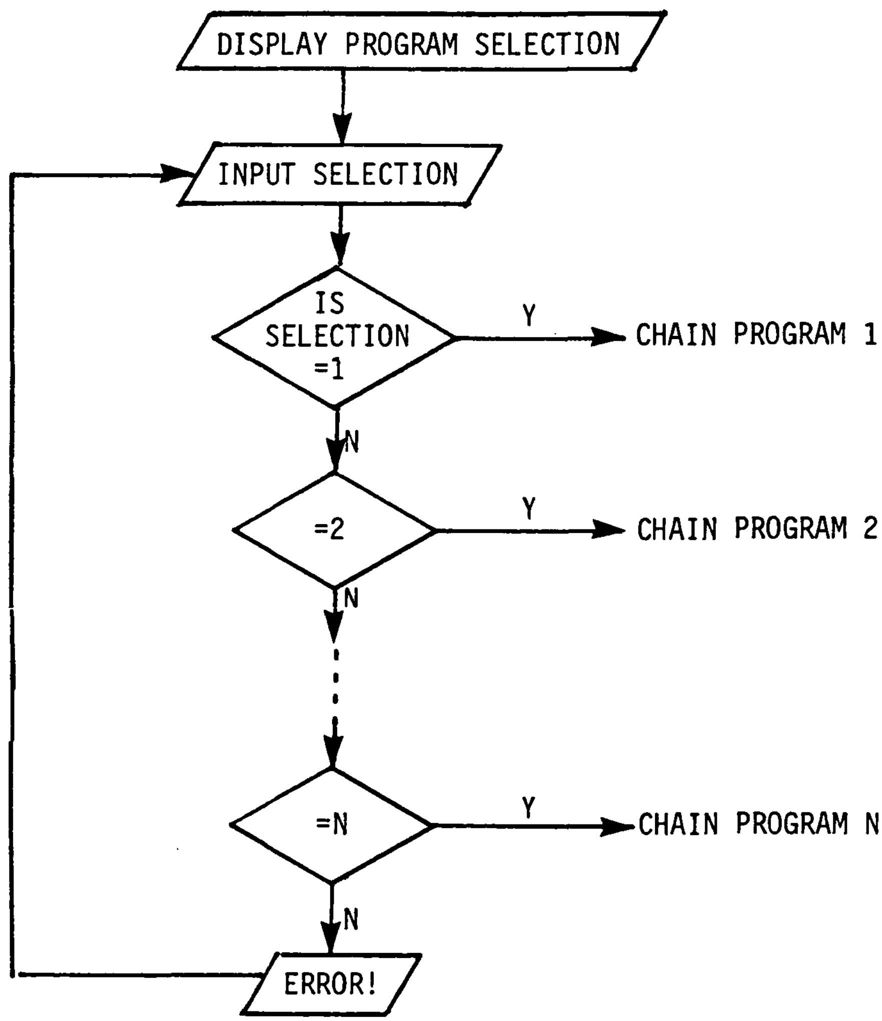
LEN = Program length in 256 byte blocks

TYP = Type of file: 2 = program
3 = data

5.1 MASTER MENU PROGRAM

FIGURE 5.1-1 BAM FLOW CHART FOR MASTER MENU

MASTER and MENU are program select routines which merely allow the operator to choose from a displayed selection of programs. The logic for both programs is simple:



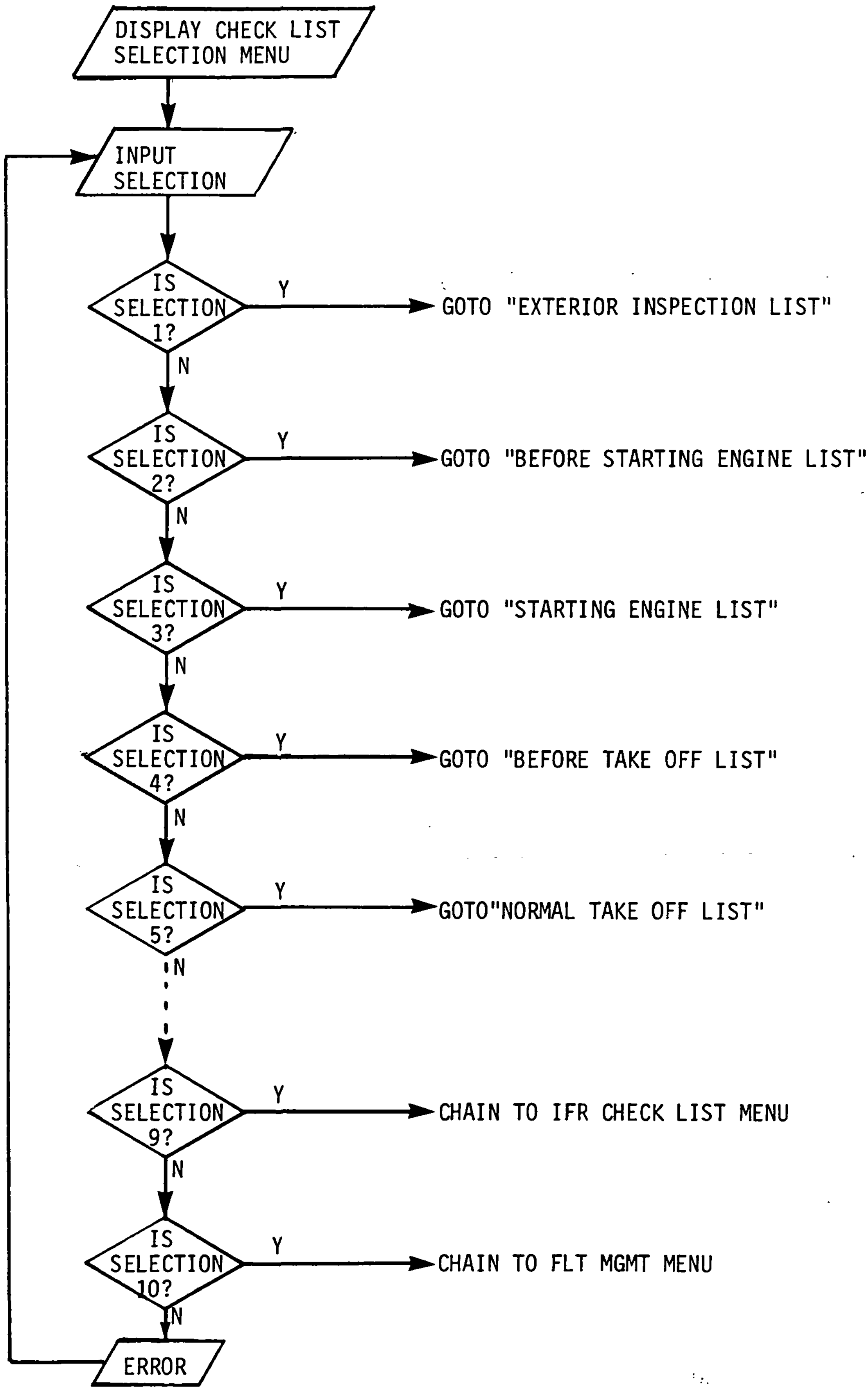
The display format is similar for both menu programs, which consists of a selection description, followed by a number, and, if the selection is not yet operational, a lower case 'n'.

WBS# 3050.1

```
10 REM***** MASTER PROGRAM 5/31/78
20 A=CALL(10608,25)\A=CALL(10608,11)
30 REM MASTER MENU PROGRAM   5/26/78
40 !TAB(10),"MASTER MENU"
50 !
60 !"FUNCTION:                    ENTER:"
70 !"NAVIGATION.................... 1 n"
80 !"FLIGHT MANAGEMENT............ 2"
90 !"NAVIGATION MAP............... 3 n"
100 !"LATERAL FLIGHT CONTROL....... 4 n"
110 !
120 !"WHICH FUNCTION ?",\B=CALL(10608,29)
130 INPUT "",A$
140 B=CALL(10608,29)
150 IF A$>"9" THEN 220
160 A=VAL(A$)
170 IF A<>2 THEN 220
180 IF A=1 THEN CHAIN "NAVMENU"
190 IF A=2 THEN CHAIN "MENU"
200 IF A=3 THEN CHAIN "MAPMENU"
210 IF A=4 THEN CHAIN "CTLMENU"
220 !"RE-ENTER FUNCTION"
230 B=CALL(10608,31)\A=CALL(10608,31)
240 GOTO 120
```

```
10 A=CALL(10608,25)\A=CALL(10608,11)
20 REM FLIGHT MANAGMENT MENU  5/26/78
30 !TAB(10),"FLIGHT MANAGEMENT MENU"
40 !
50 !"FUNCTION:                    ENTER:"
60 !"CHECKLIST.................... 1"
70 !"WEIGHT AND BALANCE........... 2"
80 !"FLIGHT PLAN.................. 3"
90 !"RESERVES..................... 4   n"
100 !"FLIGHT PARAMETERS............ 5   n"
110 !"AIRCRAFT PERFORMANCE......... 6"
120 !"WHICH FUNCTION ? ",\A=CALL(10608,29)
130 INPUT "",A$\IF A$="/" THEN CHAIN "MASTER"
140 IF A$="M" THEN CHAIN "MASTER"
150 A=VAL(A$)
160 B=CALL(10608,29)
170 IF A=1 THEN CHAIN "CHECKLST"
180 IF A=2 THEN CHAIN "WT&BAL"
190 IF A=3 THEN CHAIN "FLTPLN2"
200 IF A=4 THEN CHAIN "RESERVES"
210 IF A=5 THEN CHAIN "FLTPAR"
220 IF A=6 THEN CHAIN "TOPRF"
230 !"RE-ENTER FUNCTION"
240 A=CALL(10608,31)\A=CALL(10608,31)
250 GOTO 120
```

5.2 CHECKLIST PROGRAMS
FIGURE 5.2-1
CHECK LIST FLOW DIAGRAM WBS# 3051.1



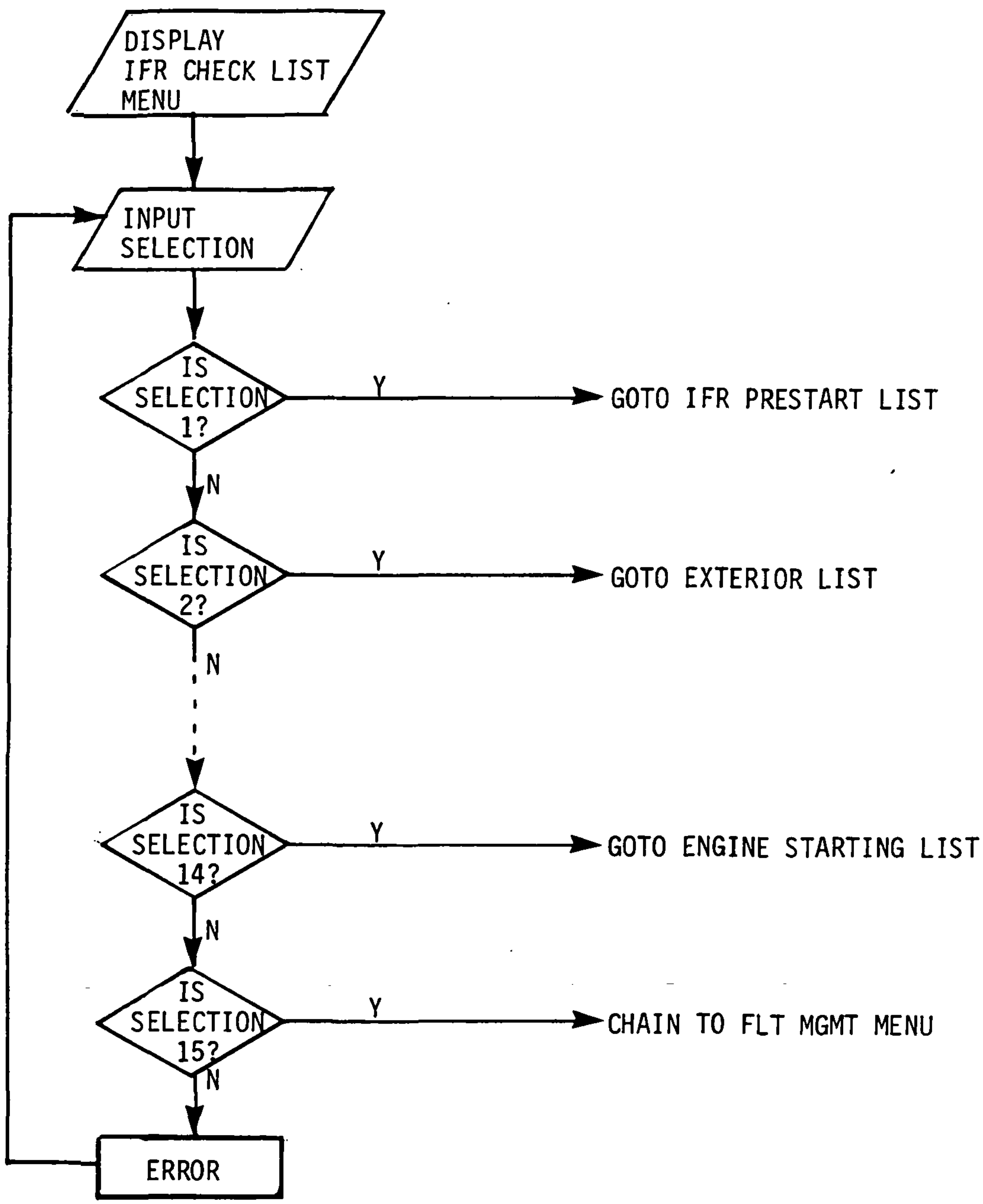
```
10  DIM A1$(1),A2$(1),A3$(1),A4$(1),A5$(1),A6$(1),A7$(1),A8$(1),A9$(1)
20 REM CHECKLST PROGRAM 5/31/78
30 A=CALL(10608,25)\A=CALL(10608,11)
40 !"CHECKLIST MENU"
50 !
60 !"FUNCTION:                             ENTER:"
70 !A1$,TAB(3),"EXTERIOR INSPECTION................ 1"
80 !A2$,TAB(3),"BEFORE STARTING ENGINE............. 2"
90 !A3$,TAB(3),"STARTING ENGINE.................... 3"
100 !A4$,TAB(3),"BEFORE TAKEOFF..................... 4"
110 !A5$,TAB(3),"NORMAL TAKEOFF..................... 5"
120 !A6$,TAB(3),"MAXIMUM PERFORMANCE TAKEOFF........ 6"
130!A7$,TAB(3),"CLIMB.............................. 7"
140!A8$,TAB(3),"CRUISING........................... 8"
150!A9$,TAB(3),"IFR CHECKLIST...................... 9"
160!A9$,TAB(3),"CHECK LIST COMPLETE................ 10"
170 !"WHICH FUNCTON ? ",
180 INPUT "",Q$
190 IF Q$="/"THEN CHAIN "MENU"
200 IF Q$="" THEN GOTO 330
210 Q=VAL(Q$)
220 IF Q =1 THEN 370
230 IF Q =2 THEN 690
240 IF Q =3 THEN 790
250 IF Q =4THEN 930
260 IF Q =5 THEN 1110
270 IF Q =6 THEN 1220
280 IF Q =7 THEN 1340
290 IF Q =8 THEN 1430
300 IF Q =9 THEN INPUT"INSERT DISK #302 THEN HIT RETURN",C
310 IF Q =9 THEN CHAIN "IFRCHKL"
320 IF Q =10 THEN CHAIN "MENU"
330 !"RE-ENTER FUNCTION"
340 A=CALL(10608,31)
350 A=CALL(10608,31)
360 GOTO 170
370 A=CALL(10608,25)\A=CALL(10608,11)
380 !"EXTERIOR INSPECTION CHECKLIST"
390 !"   REMOVE CONTROL WHEEL LOCK"
400 !"   CHECK IGNITION SWITCH OFF"
410 !"   TURN ON MASTER SWITCH, CHECK FUEL, TURN OFF MASTER SWITCH"
420 !"   FUEL SELECT VALVE ON BOTH"
430 !"   CHECK BAGGAGE DOOR"
440 !"   REMOVE RUDDER GUST LOCK"
450 !"   UNTIE TAIL"
460 !"   CHECK RUDDER AND ELEVATOR"
470 !"   CHECK AILERON"
480 !"   UNTIE WINGS"
490 !"   CHECK TIRE INFLATION"
500 !"   VISUALLY CHECK FUEL, FILLER CAP"
```

```
510 !"  CHECK OIL LEVEL, 6 QTS MINIMUM"
520 !"  PULL FUEL STRAINER-DRAIN"
530 !"  CHECK PROP AND SPINNER"
540 !"  CHECK LANDING LIGHT"
550 !"  CHECK NOSE GEAR STRUT"
560 !"  CHECK STATIC SOURCE FOR STOPPAGE"
570 !"  REMOVE COVER AND INSPECT PITOT TUBE"
580 !"  CHECK FUEL TANK VENT FOR STOPPAGE"
590 !"  CHECK STALL WARNING VENT FOR STOPPAGE"
600 !"  CHECK AILERON"
610 Z=22
620 A1$="*"
630 FOR R=1 TO Z  \A=CALL(10608,31)\NEXT R
640 FOR R=1 TO Z
650 INPUT "*",A$
660 NEXT R
670 A=CALL(10608,25)\A=CALL(10608,11)
680 GOTO 20
690 A=CALL(10608,25)\A=CALL(10608,11)
700 !"BEFORE STARTING ENGINE"
710 !
720 !"  SEATS, SEAT BELTS--ADJUST AND SECURE"
730 !"  FUEL SLECTOR--BOTH"
740 !"  BRAKES--TEST AND SET"
750 !"  RADIOS AND ELECTRICAL EQUIPMENT--OFF"
760 Z=4
770 A2$="*"
780 GOTO 630
790 A=CALL(10608,25)\A=CALL(10608,11)
800 !"STARTING ENGINE"
810 !
820 !"  MIXTURE--RICH"
830 !"  CARB HEAT--COLD"
840 !"  PRIMER--2 TO 6 STROKES, NONE IF WARM. CLOSE AND LOCK PRIMER"
850 !"  THROTTLE--OPEN 1/8 INCH"
860 !"  MASTER SWITCH--ON"
870 !"  PROPELLER AREA--CLEAR"
880 !"  IGNITION SWITCH--START (RELEASE WHEN ENGINE STARTS)"
890 !"  OIL PRESSURE--CHECK"
900 A3$="*"
910 Z=8
920 GOTO 630
930 A=CALL(10608,25)\A=CALL(10608,11)
940 !"BEFORE TAKE-OFF"
950 !
960 !"  PARKING BRAKE--SET"
970 !"  FLIGHT CONTROLS--CHECK FOR FREE AND CORRECT MOVEMENT"
980 !"  FUEL SELECTOR--BOTH"
990 !"  ELEVATOR TRIM--TAKEOFF SETTING"
1000 !"  THROTTLE--1700 RPM"
```

```
1010 !"  ENGINE INST AND AMMETER--CHECK"
1020 !"  SUCTION GAUGE--4.6 TO 5.4"
1030 !"  MAGNETOS--CHECK EACH, RPM LOSS LESS THAN 125 RPM"
1040 !"  CARB HEAT--CHECK OPERATION"
1050 !"  FLIGHT INSTRUMENTS AND RADIOS--SET"
1060 !"  AUTOPILOT--OFF"
1070 !"  CABIN DOORS AND WINDOW--LOCKED"
1080 A4$="*"
1090 Z=12
1100 GOTO 630
1110 A=CALL(10608,25)\A=CALL(10608,11)
1120 !"NORMAL TAKE-OFF"
1130 !
1140 !"  WING FLAPS-- 0´"
1150 !"  CARB HEAT--COLD"
1160 !"  POWER--FULL THROTTLE"
1170 !"  ELEVATOR--LIFT NOSE WHEEL AT 60 MPH"
1180 !"  CLIMB SPEED--75 TO 85 MPH"
1190 Z=5
1200 A5$="*"
1210 GOTO 630
1220 A=CALL(10608,25)\A=CALL(10608,11)
1230 !"MAXIMUM PERFORMANCE TAKEOFF"
1240 !
1250 !"  WING FLAPS- 0´"
1260 !"  CARB HEAT--COLD"
1270 !"  BRAKES--APPLY"
1280 !"  POWER--FULL THROTTLE"
1290 !"  BRAKES--RELEASE"
1300 !"  AIRPLANE ATTITUDE--SLIGHTLY TAIL LOW"
1310 Z=6
1320 A6$="*"
1330 GOTO 630
1340 A=CALL(10608,25)\A=CALL(10608,11)
1350 !"  CLIMB"
1360 !
1370 !"  AIRSPEED--80 TO 90 MPH"
1380 !"  POWER--FULL THROTTLE"
1390 !"  MIXTURE--FULL RICH (MAY BE LEANED ABOVE 3000 FEET)"
1400 Z=3
1410 A7$="*"
1420 GOTO 630
1430 A=CALL(10608,25)\A=CALL(10608,11)
1440 !"  CRUISING"
1450 !
1460 !"  POWER--2200 TO 2700 RPM"
1470 !"  ELEVATOR TRIM--ADJUST"
1480 !"  MIXTURELEAN FOR MAXIMUM RPM"
1490 Z=3
1500 A8$="*"

1510 GOTO 630
```

FIGURE 5.2-2 IFR CHECK LIST WBS# 3051.2



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WBS# 3051.2

```
10 REM ***** THIS IS THE IFR CHECKLIST SUBROUTINE CALLED FROM CHECKLST
20 REM  IFRCHKL
30 DIM A$(14)
40 !CHR$(12)
50 PRINT"                    IFR CHECKLIST MENU          1.2.9"
60 PRINT"                 -----------------------"\PRINT\PRINT
70 PRINT"FUNCTION:                              ENTER:"
80 PRINT
90 !A$(1,1),TAB(3),"IFR PRESTART................. 1"
100 !A$(2,2),TAB(3),"EXTERIOR..................... 2"
110 !A$(3,3),TAB(3),"TAXI & SHUT DOWN............. 3"
120 !A$(4,4),TAB(3),"MISSED APPCH SEGMENT......... 4"
130 !A$(5,5),TAB(3),"FINAL APPCH SEGMENT.......... 5"
140 !A$(6,6),TAB(3),"INTERMEDIATE SEGMENT......... 6"
150 !A$(7,7),TAB(3),"INITIAL APPCH SEGMENT........ 7"
160 !A$(8,8),TAB(3),"TRANSITION................... 8"
170 !A$(9,9),TAB(3),"LANDING ENROUTE.............. 9"
180 !A$(10,10),TAB(3),"ENROUTE..................... 10"
190 !A$(11,11),TAB(3),"TAKE OFF / CLIMB OUT........ 11"
200 !A$(12,12),TAB(3),"RUN UP...................... 12"
210 !A$(13,13),TAB(3),"PRETAXI AND TAXI............ 13"
220 !A$(14,14),TAB(3),"ENGINE STARTING............. 14"
230 !"    RETURN TO FLIGHT MGMT MENU.. 15"
240 INPUT "WHICH FUNCTION ? ",F
250 IF F=1 THEN GOTO 490
260 IF F=2 THEN GOTO 730
270 IF F=3 THEN GOTO 950
280 IF F=4 THEN GOTO 1200
290 IF F=5 THEN GOTO 1350
300 IF F=6 THEN GOTO 1530
310 IF F=7 THEN GOTO 1680
320 IF F=8 THEN GOTO 1880
330 IF F=9 THEN GOTO 2070
340 IF F=10 THEN GOTO 2330
350 IF F=11 THEN GOTO 2590
360 IF F=12 THEN GOTO 2760
370 IF F=13 THEN GOTO 3130
380 IF F=14 THEN GOTO 3400
390 IF F=15 THEN INPUT"INSERT DISK #203......THEN HIT RETURN",S$
400 IF F=15 THEN CHAIN "MENU"
410 FOR R=1 TO Z
420 !CHR$(31),
430 NEXT R
440 FOR R=1 TO Z
450 INPUT "*",B$
460 NEXT R
470 !CHR$(12)
480 GOTO 40
490 !CHR$(12)
```

```
500 PRINT
510 PRINT"                    IFR PRESTART CHECKLIST"
520 PRINT"                   -----------------------"
530 !
540 !"   AIRCRAFT DOCUMENTS ON BOARD"
550 !"   CHARTS,PLATES,LOG,WX,ORGANIZED"
560 !"   AIRSPEED INDICATOR ZERO"
570 !"   ALTIMETER (SET TO FIELD ELEVATION)"
580 !"   CLOCK (WIND & SET TO GMT)"
590 !"   ENGINE INSTRUMENTS (ON ZERO)"
600 !"   DG UNCAGED"
610 !"   MAG COMPASS FULL OF FLUID"
620 !"   VOR ACCURACY LOGGED"
630 !"   A/C LOG BOOK CHECKED"
640 !"   SUCTION GAUGE ZERO"
650 !"   TURN & BANK CENTERED & FULL OF FLUID"
660 !"   VERTICAL SPEED INDICATOR ON ZERO"
670 !"   SET COMM FREQS."
680 !"   NAV #2 (ILS) SET DEP. ARPT. APPCH"
690 !"   NAV #1  SET ENROUTE VOR"
700 Z=16
710 A$(1)="*"
720 GOTO 410
730 !CHR$(12)
740 PRINT "                 EXTERIOR CHECKLIST"
750 PRINT "                -------------------"
760 !
770 !"    INSIDE -- MAG OFF, MASTER OFF, FLAPS DOWN, BRAKE ON"
780 !"    INSIDE -- CONTROLS FREE, PRIME"
790 !"     RWING -- FLAP, AILERON, TIP, LIGHTS, LEADING EDGE, FUEL"
800 !"     RWING -- VENTS, GEAR 2 2/4, DRAIN, TIEDOWN, DRAIN FUEL"
810 !"    ENGINE -- SECURE R COWLING, GEN BELT, PULL PROP,AIR FLOW"
820 !"    ENGINE -- OIL 9, BRAKE FLUID,SECURE L COWLING"
830 !"     LWING -- FUEL, GEAR, VENT, DRAIN,TIEDOWN, STALL WARNING"
840 !"     LWING -- PITOT TUBE, LEADING EDGE, TIP, LIGHTS"
850 !"     LWING -- AILERON, FLAP"
860 !" FUS/TAIL -- STATIC PORT, ANTENNAS, STABILATOR, RUDDER, LIGHT"
870 !" FUS/TAIL -- TIEDOWN, UNDERSIDE, STATIC PORT, STOW TOW BAR"
880 !" FUS/TAIL -- BAGGAGE DOOR"
890 !"    INSIDE -- SWITCH TANKS, MASTER ON, PITOT HEAT ON, FLAPS UP"
900 !"    INSIDE -- MASTER OFF, PITOT HEAT OFF"
910 !"   OUTSIDE -- DRAIN FUEL, PITOT HEAT, CLOSE FUEL DRAIN DOOR"
920 Z=15
930 A$(2)="*"
940 GOTO 410
950 !CHR$(12)
960 PRINT"                    TAXI & SHUT DOWN"
970 PRINT"                   ----------------------"\PRINT
980 !"    FLAPS UP"
990 !"    MK 7 ON (OFF)"
1000 !"    MK 5 OFF (ON)"
```

```
1010 !"   ADF OFF"
1020 !"   NAV 122 OFF"
1030 !"   XPDR OFF"
1040 !"   FUEL PUMP OFF"
1050 !"   STROBE OFF"
1060 !"   REMOTE COMPASS OFF"
1070 !"   LANDING LIGHTS  (AS NEEDED)"
1080 !"   PITOT HEAT OFF"
1090 !"   CARB HEAT OFF"
1100 !"   TURN & BANK OFF"
1110 !"   CLOSE FLIGHT PLAN  (NO TOWER)"
1120 !"   RADIOS OFF, IDLE MAG CHECK"
1130 !"   RPM 1000 12000, MIXTURE IDLE CUT OFF"
1140 !"   BEACON OFF, MAGS OFF, MASTER OFF"
1150 !"   LOG TIME, SECURE CONTROL SURFACES"
1160 !"   TIE DOWN AIRCRAFT, LOCK DOOR"
1170 Z=19
1180 A$(3)="*"
1190 GOTO 410
1200 REM
1210 !CHR$(12)
1220 !"                    MISSED APPCH SEGMENT"
1230 !"                  -------------------------"
1240 !
1250 !"     TURN TIME TWIST THROTTLE TALK TRACK"
1260 !"     GUMP"
1270 !"     NO TURN BEFORE MAP"
1280 !"     CHECK MISSED APPCH ALT & HDG"
1290 !"     REPORT TO TWR"
1300 !"     LANDING LIGHTS OFF"
1310 !"     CONTACT APPROACH CONTROL"
1320 Z=7
1330 A$(4)="*"
1340 GOTO 410
1350 REM
1360 !CHR$(12)
1370 PRINT"                 IFR FINAL APPCH SEGMENT"
1380 PRINT"               -------------------------"
1390 !
1400 !"     TURN-TIME-TWIST-THROTTLE-TALK-TRACK"
1410 !"     START CLOCKS AT FAF"
1420 !"     REPORT FAF"
1430 !"     GUMP"
1440 !"     SCAN ALT/MDA"
1450 !"     SCAN TIME/MAT"
1460 !"     DESCEND TO MDA/DH"
1470 !"     SMALL CORRECTIONS"
1480 !"     FIELD IN SIGHT"
1490 !"     FLAPS AS NEEDED"
1500 Z=10
```

```
1510 A$(5)="*"
1520 GOTO 410
1530 REM
1540 !CHR$(12)
1550 PRINT"                    IFR INTERMEDIATE SEGMENT"
1560 PRINT"                  ----------------------------"
1570 !
1580 !"      TURN-TIME-TWIST-THROTTLE-TALK-TRACK"
1590 !"      DESCEND TO IFR ALT."
1600 !"      GUMP"
1610 !"      LANDING LIGHTS ON"
1620 !"      SCAN APPCH PLATE"
1630 !"      MAINTAIN APPCH SPEED"
1640 !"      CONTACT TOWER"
1650 Z=7
1660 A$(6)="*"
1670 GOTO 410
1680 REM
1690 !CHR$(12)
1700 PRINT"                   IFR INITIAL APPCH SEGMENT"
1710 PRINT"                  ----------------------------"
1720 !
1730 !"    TURN-TIME-TWIST-THROTTLE-TALK-TRACK"
1740 !"    SLOW TO APPCH SPEED"
1750 !"    DESCEND TO IFR ALT."
1760 !"    SCAN APPCH PLATE"
1770 !"    TIME LEGS"
1780 !"    SET ADI"
1790 !"    SET DG BY COMPASS"
1800 !"    LOAD HP25 MDA & TIME TO MAP"
1810 !"    SET REMOTE COMPASS POINTER"
1820 !"    SET ILS OBS CRS"
1830 !"    SET ALTIMETER"
1840 !"    CHECK OAT"
1850 Z=12
1860 A$(7)="*"
1870 GOTO 410
1880 REM
1890 !CHR$(12)
1900 PRINT"                   IFR TRANSITION SEGMENT"
1910 PRINT"                  -------------------------"
1920 !
1930 !"    TURN-TIME-TWIST-THROTTLE-TALK-TRACK"
1940 !"    DESCEND TO IFR ALT"
1950 !"    SCAN APPCH PLATE"
1960 !"    STUDY FINAL APPCH CRS"
1970 !"    STUDY TIME TO MAP "
1980 !"    STUDY MDA OR DH"
1990 !"    STUDY AIRPORT DIAGRAM"
2000 !"    STUDY MISSED APPCH"
```

```
2010 !"    PITOT HEAT AS NEEDED"
2020 !"    COPY APPCH CLEARANCE"
2030 !"    CARB HEAT AS NEEDED"
2040 Z=11
2050 A$(8)="*"
2060 GOTO 410
2070 REM
2080 !CHR$(12),
2090 PRINT"              IFR LANDING ENROUTE CHECKLIST"
2100 PRINT"            ---------------------------------"
2110 !
2120 !"    WX (ATIS) OBTAIN"
2130 !"    SCAN APPCH. PLATE"
2140 !"    GROUNDSPEED ON FINAL DETERMINED"
2150 !"    TIME FAF TO MAP DETERMINED"
2160 !"    TIME TO START DESCENT"
2170 !"    SET DG BY COMPASS"
2180 !"    CHECK OAT"
2190 !"    SEAT BELTS FASTENED"
2200 !"    SELECT FULLEST TANK"
2210 !"    DEFROSTER AS NEEDED"
2220 !"    RESET CLOCK SECOND HAND"
2230 !"    MKR BCN SPKR ON (TEST)"
2240 !"    TUNE VOR & IDENT"
2250 !"    TUNE ILS & IDENT"
2260 !"    TUNE ADF & IDENT"
2270 !"    TUNE TWR  #2 RADIO"
2280 !"    PITOT HEAT AS NEEDED"
2290 !"    SET ALTIMETER"
2300 Z=18
2310 A$(9)="*"
2320 GOTO 410
2330 REM
2340 !CHR$(12)
2350 PRINT"             IFR ENROUTE CHECKLIST"
2360 PRINT"           -------------------------"\PRINT
2370 !"    CRUISE POWER SET"
2380 !"    MIXTURE / EGT SET"
2390 !"    CARB HEAT AS NEEDED"
2400 !"    OAT CHECKED"
2410 !"    FUEL MGMT"
2420 !"    PITOT HEAT AS NEEDED"
2430 !"    SET DG BY COMPASS"
2440 !"    OIL PRESSURE / TEMP NORMAL"
2450 !"    FUEL PRESSURE NORMAL"
2460 !"    FUEL PUMP OFF"
2470 !"    GENERATOR CHARGING"
2480 !"    SUCTION 4-5 IN."
2490 !"    SET ALTIMETER"
2500 !"    RUDDER TRIM BALL CENTERED"
```

```
2510 !"    INDENT VORS"
2520 !"    FCST / CURRENT WX REPORTS"
2530 !"    REPORTS TO ATC"
2540 !"    MAINTAIN MEA / MOCA"
2550 !"    COM FAILURE SEE FAR 91.127"
2560 Z=19
2570 A$(10)="*"
2580 GOTO 410
2590 REM
2600 !CHR$(12)
2610 PRINT"            TAKE OFF / CLIMB OUT CHECKLIST"
2620 PRINT"            ---------------------------------"\PRINT\PRINT
2630 !"    DG SET TO RUNWAY HEADING"
2640 !"    ADI WINGS LEVEL"
2650 !"    ROTATE AT SG KTS"
2660 !"    RETRACT GEAR"
2670 !"    NORMAL CLIMB 90 KTS"
2680 !"    Vx = 70 KTS,  Vy = 80 KTS"
2690 !"    REDUCE POWER 24''  2400 RPM"
2700 !"    XPDR ON"
2710 !"    CONTACT DEPARTURE"
2720 !"    RETURN TO TOWER (NEGATIVE CONTACT)"
2730 Z=10
2740 A$(11)="*"
2750 GOTO 410
2760 REM
2770 !CHR$(12),
2780 PRINT"            RUN UP CHECKLIST"
2790 PRINT"          -------------------"
2800 !"    BRAKE ON "
2810 !"    SWITCH TANKS"
2820 !"    SET 1700 RPM"
2830 !"    CHECK MIXTURE CONTROL"
2840 !"    CHECK CARB HEAT"
2850 !"    SET 2000 RPM"
2860 !"    CHECK MAG DROP"
2870 !"    FULL IDLE-THEN 1000-15000 RPM"
2880 !"    SET TRIM TAB"
2890 !"    AUTO PILOT OFF"
2900 !"    CHECK CONTROL SURFACES (FLAPS UP)"
2910 !"    DOOR CLOSED & LOCKED"
2920 !"    SEAT BELTS"
2930 !"    FUEL PUMP ON"
2940 !"    EMERGENCY GEAR HANDLE CLEAR"
2950 !"    RECEIVE CLEARANCE"
2960 !"    XPNDR SET- ON"
2970 !"    COM FREQ SET "
2980 !"    TWR FOR TAKE OFF CLEARANCE"
2990 !"    RECORD TIME"
3000 !"    STROBE ON"
```

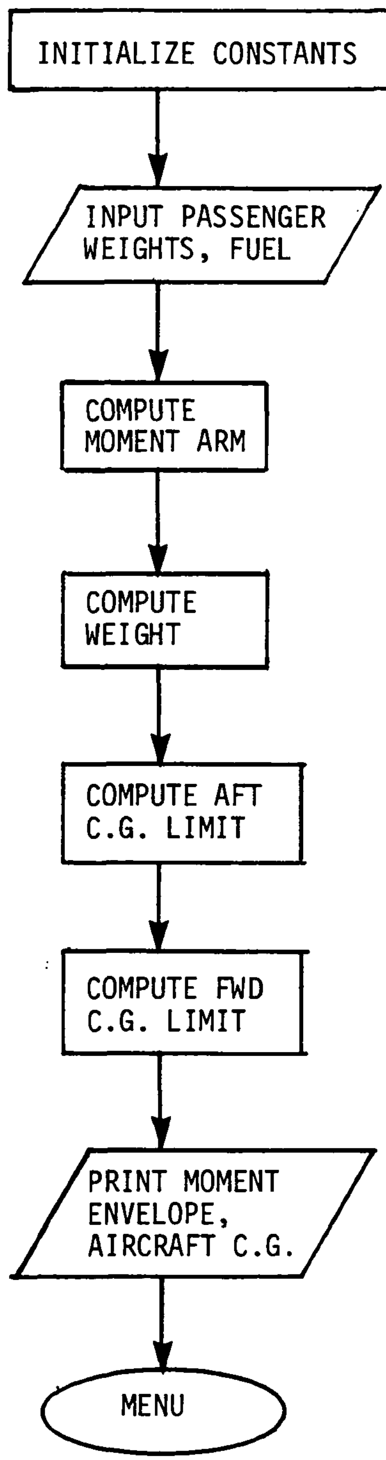
```
3010 !"    BRAKE OFF",
3020 Z=22
3030 A$(12)="*"
3040 FOR R=1 TO Z
3050 !CHR$(31),
3060 NEXT R
3070 !
3080 FOR R=1 TO Z
3090 INPUT "*",B$
3100 NEXT R
3110 !CHR$(12)
3120 GOTO 40
3130 REM
3140 !CHR$(12)
3150 PRINT"              PRETAXI AND TAXI CHECKLIST"
3160 PRINT"             -------------------------------"
3170 PRINT
3180 !"    RADIOS ON,  XPDR STBY"
3190 !"    ROTATING BEACON ON"
3200 !"    TURN & BANK ON"
3210 !"    GENERATOR CHARGING"
3220 !"    XMTRS CHECKED"
3230 !"    OBTAIN ATIS INFORMATION"
3240 !"    OBTAIN TAXI CLEARANCE"
3250 !"    SET DG / WET"
3260 !"    SET ADI LEVEL"
3270 !"    SET ALTIMETER (ERROR < 75FT)"
3280 !"    ADF POINTS TO LOCAL NDB"
3290 !"    NAV SET FOR IFR APPCH"
3300 !"    TEST AUTO PILOT OPERATION"
3310 !"    BRAKE OFF"
3320 !"    CHECK TURN & BANK"
3330 !"    CHECK DG"
3340 !"    CHECK ADI"
3350 !"    CHECK ADF"
3360 !"    VOR ACCURACY CHECK"
3370 Z=19
3380 A$(13)="*"
3390 GOTO 410
3400 REM
3410 !CHR$(12),
3420 PRINT"             ENGINE STARTING CHECKLIST"
3430 PRINT"            ------------------------------"
3440 !
3450 !"    BRAKE ON,  RADIOS OFF"
3460 !"    RADIOS OFF"
3470 !"    CIRCUIT BREAKERS IN"
3480 !"    GEAR SWITHC DOWN"
3490 !"    EMPTIEST TANK"
3500 !"    CARB HEAT OFF"
```

```
3510 !"    PROP IN"
3520 !"    MIXTURE RICH"
3530 !"    MASTER SWITCH ON "
3540 !"    FUEL PUMP ON "
3550 !"    CHECK FUEL PRESSURE"
3560 !"    PRIME,  FUEL PUMP OFF"
3570 !"    THROTTLE (1/4'')"
3580 !"    MAGS ON,  CLEAR PROP"
3590 !"    START ENGINE (LOG TIME)"
3600 !"    MAGS BOTH,  1000 RPM"
3610 !"    OIL PRESSURE CHECKED"
3620 !"    VACUUM 4-5 IN"
3630 !"    FUEL GAUGES CHECKED"
3640 !"    GEN CHARGING AT 1500 RPM"
3650 !"    SEATS BELTS ON",
3660 Z=21
3670 A$(14)="*"
3680 GOTO 3040
```

5.3 WEIGHT AND BALANCE PROGRAM

TABLE 5.3-1 is a list of symbols for weight and balance.

FIGURE 5.3-1 WEIGHT AND BALANCE FLOW DIAGRAM



SYMBOLS FOR W&B FLOW CHARTS, TABLE 5.3-1

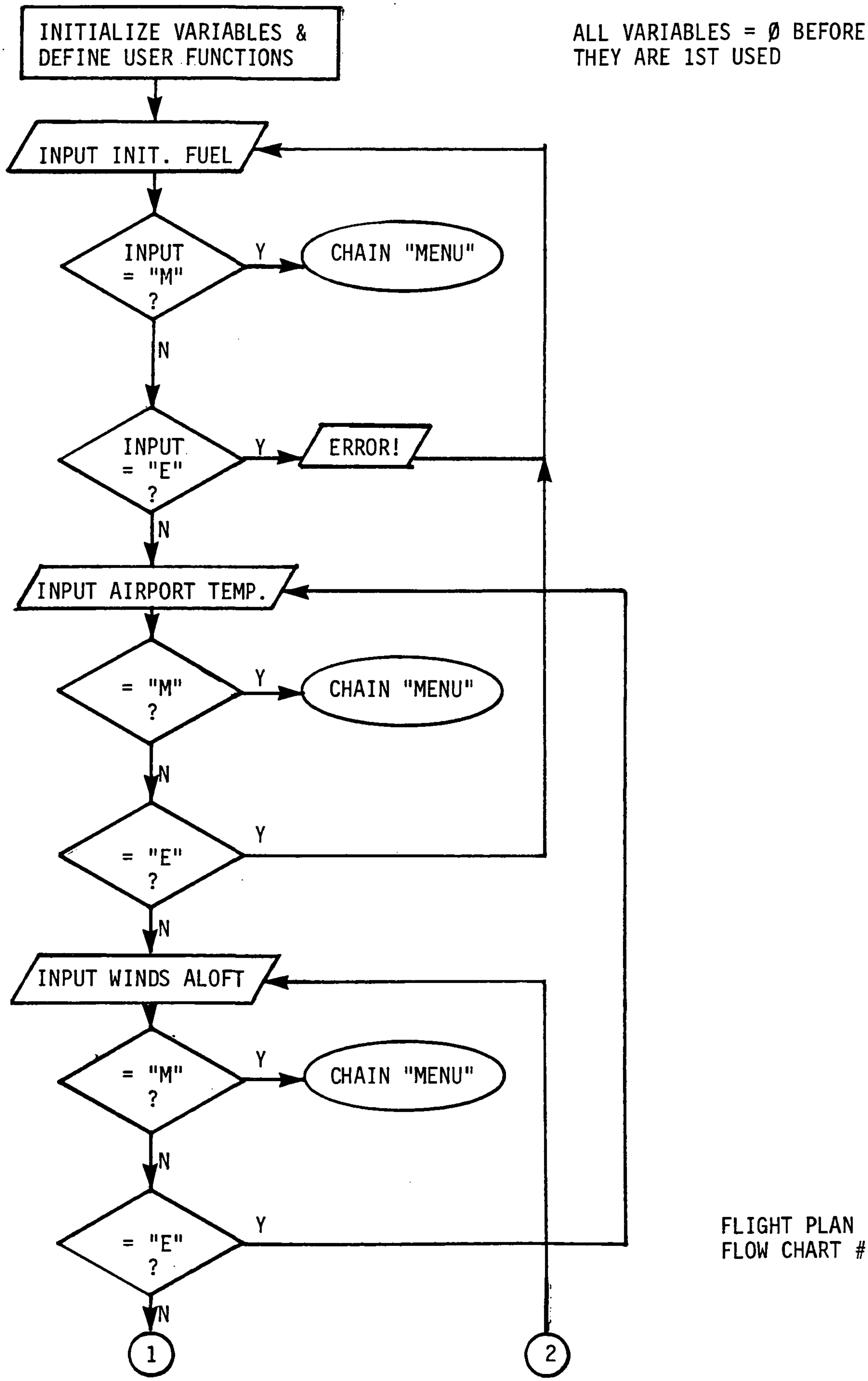
A	Dummy for cursor control
B	Baggage lever arm
C1	Pilot weight, pounds
C2	Copilot weight, pounds
C3	Passenger weight, pounds
C4	Passenger weight, pounds
C5	Fuel weight, pounds
C6	Baggage, pounds
E	Empty weight of airplane
F	Fuel lever arm
G1	Fuel, gallons
M2	Moment of loaded plane
M	Moment used for plotting
M1	Moment of empty plane
P	Passenger (rear) lever arm
P1	Pilot (front seat) lever arm
R	Loop variable
W	Weight of loaded plane
W1	Weight used for plotting
W9	Weight (plotting) loop
Y	Aft C. G. limit
Y1	Forward C. G. limit

```
10 A=CALL(10608,25)\A=CALL(10608,11)
20 REM ** WEIGHT AND BALANCE, DATA FOR CESSNA 172
30 E=1364 \REM EMPTY WT OF AIRPLANE
40 F=48.25\REM FUEL LEVER ARM
50 P1=37.5 \REM PILOT LEVER ARM
60 P=73.00 \REM REAR SEAT LEVER ARM
70 B =95.0 \REM BAGGAGE LEVER ARM
80 M1=51.7 \REM MOMENT OF EMPTY PLANE/1000
90 !"WEIGHT AND BALANCE"
100 !
110 !"WEIGHT OF PILOT: LBS ",
120 GOSUB 450
130 C1=VAL(A$)
140 OUT 2,29
150 !TAB(30),"COPILOT: LBS ",
160 GOSUB 450
170 C2=VAL(A$)
180 OUT 2,29
190 !
200 !"REAR SEAT PASSENGER: LBS ",
210 GOSUB 450
220 C3=VAL(A$)
230 OUT 2,29
240 !TAB(30),"PASSENGER: LBS ",
250 GOSUB 450
260 C4=VAL(A$)
270 OUT 2,29
280 !
290 !
300 !"FUEL: GAL ",
310 GOSUB 450
320 G1=VAL(A$)
330 OUT 2,29
340 !TAB(30),"BAGGAGE: LBS ",
350 GOSUB 450
360 C6=VAL(A$)
370 OUT 2,29
380 !
390 C5=G1*6 \REM FUEL WT IN LBS
400 M=((C1+C2)*P1+(C3+C4)*P+C5*F+C6*B)/1000+M1
410 W=C1+C2+C3+C4+C5+C6-136
420 Y=.0475*W+71
430 IF W>450 THEN Y1=.059375*W+42 ELSE Y1=3.444444E-02*W+52.5
440 GOTO 490
450 FOR R=1 TO 4\A=CALL(10608,8)\NEXT R
460 INPUT1"",A$
470 IF A$="M" THEN CHAIN "MENU"
480 RETURN
490 W1=W+E+151
500 M=M/1.6
510 A=CALL(10608,25)\A=CALL(10608,11)
520 !"              C.G. FORWARD      /  C.G. OK /     C.G. AFT"
530 FOR W9=2500 TO 2350 STEP -50
540 IF W1<W9 AND W1>W9-50 THEN !"ERROR  OVER GROSS",TAB(M/1.5),"*"ELSE!
550 NEXT W9
560 !TAB(56),"------------"
570 FOR W9=2300 TO 1950 STEP -50
580 Y1=.059375*(W9-1515)+42
590 Y1=Y1/1.6
600 Y=.0475*(W9-1515)+71
```

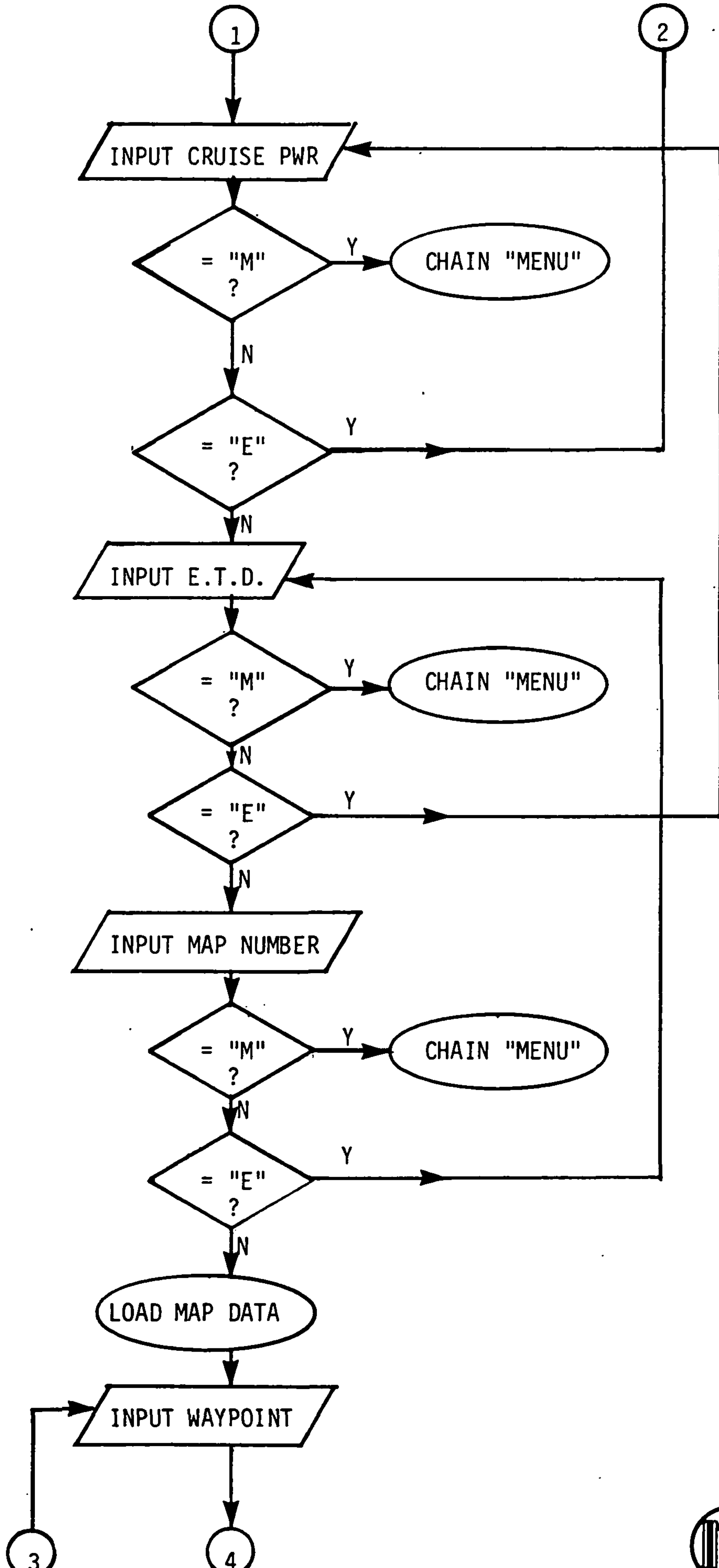
```
610 Y=Y/1.6
620 IF Y>79 THEN Y=79
630 IF W1<=W9-50 OR W1> W9 THEN 680
640 IF Y1<M AND M<Y THEN 720
650 IF Y1>M THEN 700
660 !"ERROR  AFT CG",TAB(Y1),"/",TAB(Y1),"/",TAB(M),"*"
670 GOTO 730
680 !W9,TAB(Y1),"/",TAB(Y),"/"
690 GOTO 730
700 !"CALL FAT-SO'S ANONYMOUS! ",TAB(M),"*",TAB(Y1),"/",TAB(Y),"/"
710 GOTO 730
720 !"WT & BAL O.K",TAB(Y1),"/",TAB(M),"*",TAB(Y),"/"
730 NEXT W9
740 FOR W9=1900 TO 1400 STEP -50
750 Y1=3.44444E-2*(W9-1515)+52.5
760 Y1=Y1/1.6
770 Y=.0475*(W9-1515)+71
780 Y=Y/1.6
790 IF W9<1951 AND W9>1849 THEN Y1=Y1-1
800 IF W9=1950 THEN Y=Y-1
810 IF W1<W9-50 OR W1>W9 THEN 860
820 IF Y1<M AND M<Y THEN 900
830 IF Y1>M THEN 880
840 !"ERROR  AFT CG",TAB(Y1),"/",TAB(Y),"/",TAB(M),"*"
850 GOTO 910
860 !W9,TAB(Y1),"/",TAB(Y),"/"
870 GOTO 910
880 !"ERROR  HELIUM IN BAGGAGE",TAB(M),"*",TAB(Y1),"/",TAB(Y),"/"
890 GOTO 910
900 !"WT & BAL O.K",TAB(Y1),"/",TAB(M),"*",TAB(Y),"/"
910 NEXT W9
920 !TAB(30),"----------"
930 !"1 ........ ANOTHER WEIGHT & BALANCE"
940 !"2 ........ RETURN TO MENU"
950 INPUT "WHICH FUNCTION ? ",A
960 IF A=2 THEN CHAIN "MENU"
970 GOTO 10
```

5.4 FLIGHT PLAN PROGRAM

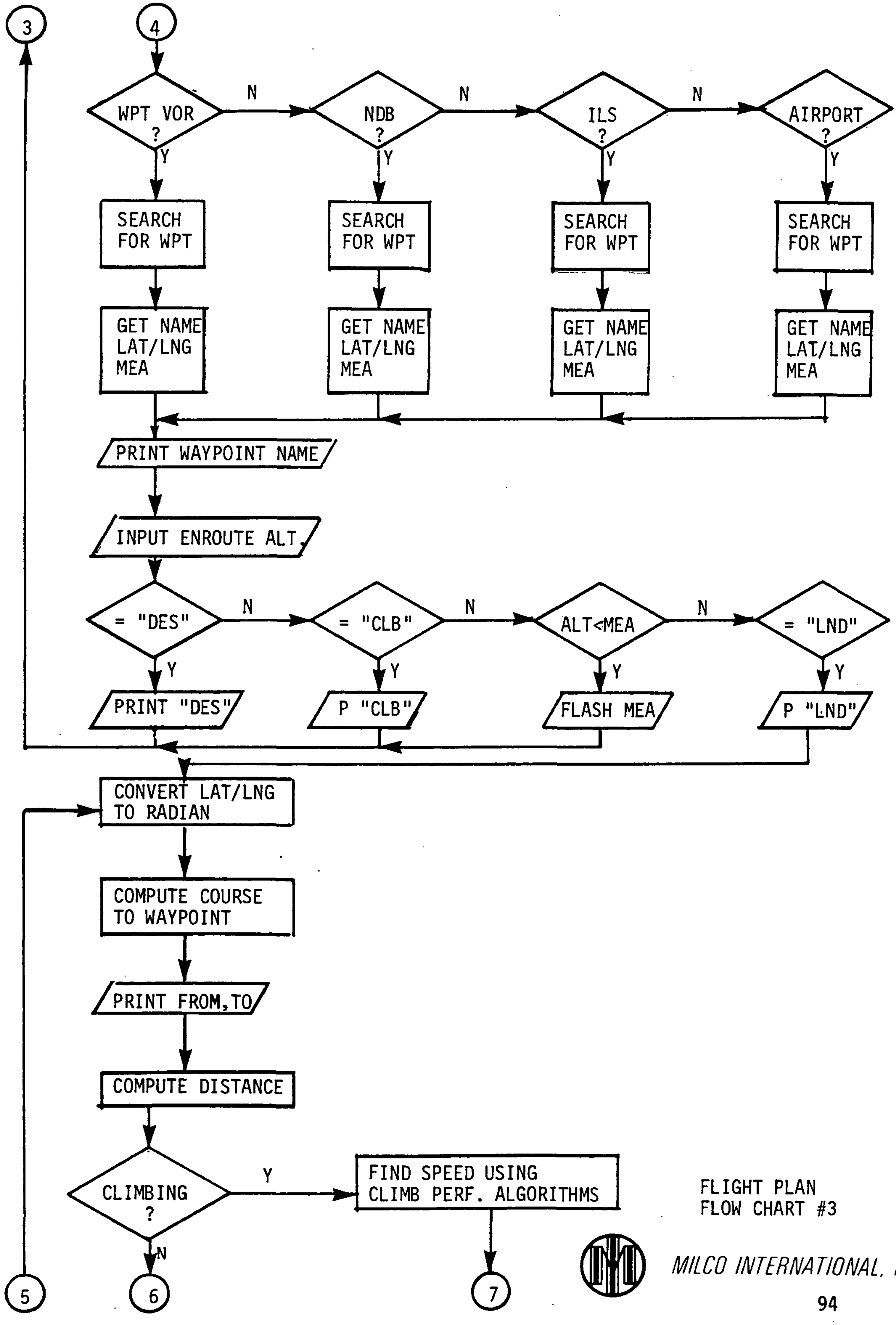
FIGURE 5.4-1 FLTPLN FLOWCHART . . .FLIGHT PLAN FLOW CHART



FLIGHT PLAN
FLOW CHART #1



FLIGHT PLAN
FLOW CHART #2



FLIGHT PLAN
FLOW CHART #3

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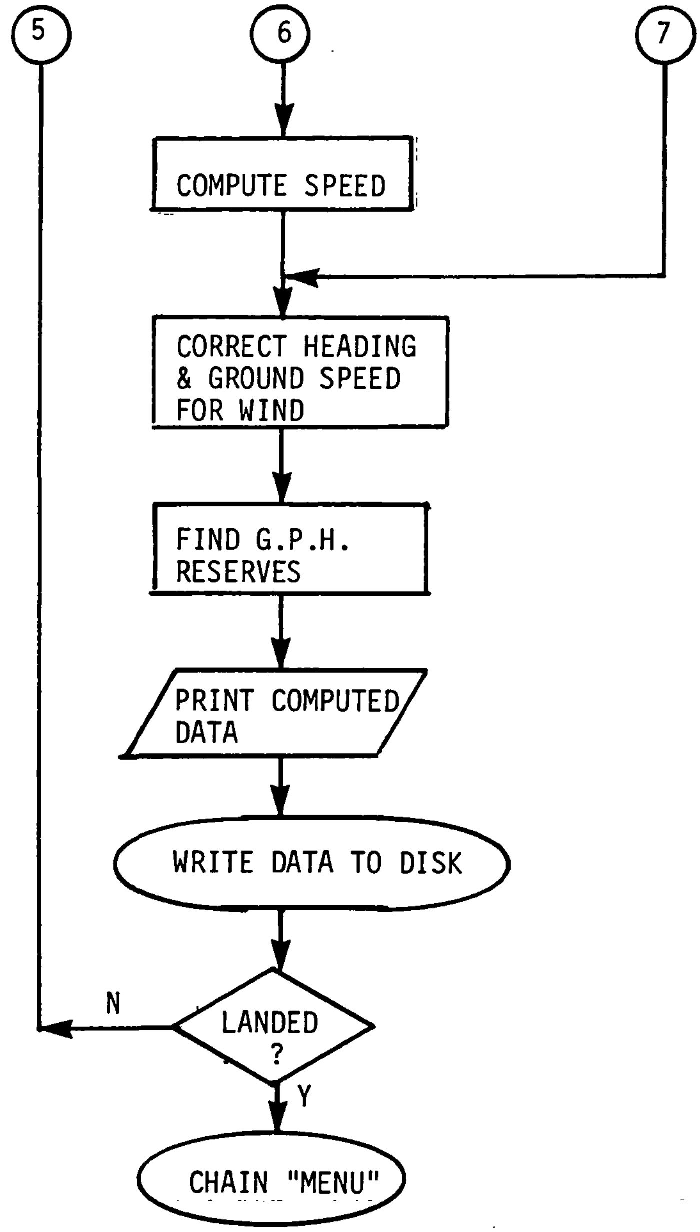


FLIGHT PLAN
FLOW CHART #4

FLIGHT PLAN SYMBOL TABLE 5.4-1

A	DUMMY FOR CURSOR CONTROL
A$	AIRPORT NAME FROM DISK
A8	NUMBER OF LAST WAYPOINT
A9	WAYPOINT POINTER
A@	AIRPORT PARAMETER ARRAY
B$	NDB NAME FROM DISK
B1	INPUT FORMAT TAB VARIABLE
B2	INPUT FORMAT TAB VARIABLE
B3	INPUT FORMAT TAB VARIABLE
B@	NDB PARAMETER ARRAY
C$	ALTITUDE MNEMONIC
C2	MEA INDICATOR
C@	ALTITUDE INPUT
D1	WINDS ALOFT DIRECTION
D@	WAYPOINT NUMBER INPUT
E	ALT < MEA ERROR FLAG
E$	INPUT VARIABLE
E2	ESTIMATED TIME ENROUTE
E3	ESTIMATED TOTAL TIME
F1	NUMBER OF VOR ON MAP
F2	NUMBER OF INTERSECTIONS ON MAP
F3	NUMBER OF AIRPORTS ON MAP
F4	NUMBER OF ILS ON MAP
F5	NUMBER OF N.D.B. ON MAP
G$	WAYPOINT MNEMONIC
G1	INITIAL FUEL
G2	GPH
H1	TEMP AT AIRPORT
H3	DIST FROM WPT(A9) TO (A9+1)
H9	TOTAL DISTANCE OF FLIGHT
I$	ILS NAME FROM DISK
I@	ILS PARAMETER ARRAY
J2	USED IN COURSE COMPUTATION
J3	SAME
J4	SAME
J5	SAME
J6	SAME
J7	SAME
J7	MAGNETIC HEADING
J8	SAME
J9	TRUE COURSE
K2	RADIAN LAT ARRAY
K@	WAYPOINT LATITUDE ARRAY
L2	RADIAN LNG ARRAY
L@	WAYPOINT LONGITUDE ARRAY
M@	MAGNETIC VARIATION FOR MAP SEC
N$	INTERSECTION NAME FROM DISK
N@	INTERSECTION PARAMETER ARRAY
O$	CURRENT MAP SECTOR NUMBER

FLIGHT PLAN SYMBOL TABLE 5.4-1 (CONT.)

P	PI OR 3.14159...
P$	INITIAL MAP SECTOR NUMBER
P1	NUMBER OF VOR ON MAP
P2	NUMBER OF INTERSECTION PARAMET
P3	NUMBER OF AIRPORT PARAMETERS
P4	NUMBER OF ILS PARAMETERS
P5	NUMBER OF N.D.B. PARAMETERS
R	LOOP VARIABLE
R$	STRING OF ALL INTER. NAMES
R1	REMAINING FUEL
R2	TIME RESERVES
S$	STRING OF ALL AIRPORT NAMES
T$	STRING OF ALL ILS NAMES
T1	CRUISE POWER SETTING (%)
T2	ESTIMATED TIME OF DEPARTURE
T4	AIRSPEED
U$	STRING OF ALL NDB NAMES
V$	VOR NAME AS READ FROM DISK
V@	VOR PARAMETER ARRAY
W	LOOP VARIABLE
W1	WINDS ALOFT WINDSPEED
X	LOOP VARIABLE
X	DUMMY FOR DEG TO RAD CONVERSIO
Y	DECIMAL LAT
Y	DUMMY FOR ARCSIN FUNCTION
Y1	DECIMAL LAT OF NEXT WAYPOINT
Z$	STRING OF ALL VOR NAMES

```
10 REM  FLTPLN  8/31/78
20 !CHR$(12)
30 OPEN #2,"FPDATA"
40 REM FNS(X) RETURNS ARCSIN(X)
50 DEF FNS(X)
60 Y=1.5707288-.2121144*X+.074261*X^2-.0187293*X^3
70 Y=3.141592654/2-SQRT(1-X)*Y
80 RETURN Y
90 FNEND
100 DEF FNR(X)=X*3.141592654/180
110 DIM D(20),C(20),K(20),L(20)
120 REM *********** INPUT INITIAL FUEL ********************
130 !"INIT FUEL: GG",
140 !CHR$(29),
150  FOR R=1 TO 2\A=CALL(10608,8)\NEXT R
160 INPUT1 "",E$
170 !CHR$(29),
180 IF E$="M" THEN CHAIN "MENU"
190 IF E$<>"E" THEN 210
200 !\!CHR$(31),\GOTO 130
210 G1=VAL(E$)
220 !" gal",TAB(30),
230 REM ************** INPUT AIRPORT OAT *******************
240 !"TEMP 'C AT AIRPORT: CC",
250 FOR R=1 TO 2\!CHR$(8),\NEXT R
260 INPUT1"",E$
270 !CHR$(29),
280 IF E$="M" THEN CHAIN "MENU"
290 IF E$<>"E" THEN 310
300 !\!CHR$(31),\GOTO 130
310 H1=VAL(E$)
320 !"'"
330 REM *************** INPUT FORCAST WINDS ALOFT **************
340 !"WIND: DEG   KTS",
350 FOR R=1 TO 9\!CHR$(8),\NEXT R
360 INPUT1"",E$
370 IF E$="M"THEN CHAIN "MENU"
380 IF E$<>"E" THEN 420
390 !\!CHR$(31),\!CHR$(29),\!CHR$(31),
400 FOR R=1 TO 28\!CHR$(28),\NEXT
410 GOTO 240
420 D1=VAL(E$)-180
430 IF D1<0 THEN D1=VAL(E$)+180
440 !"'",
450 FOR R=(5-LEN(E$)) TO 1 STEP -1
460 !" ",
470 NEXT R
480 INPUT1 "",E$
490 !CHR$(29),
500 IF E$="M" THEN CHAIN "MENU"
510 IF E$<>"E"THEN 540
520 !\!CHR$(31),
530 GOTO 340
540 W1=VAL(E$)
550 !" kts",
560 FOR R=1 TO 12-LEN(E$)\!" ",\NEXT R
570 REN ****************** INPUT CRUISE POWER SETTING *****************
580 !"CRUISE % BHP: PP ",
590 !CHR$(8),
600 !CHR$(8),
```

```
610 !CHR$(8),
620 INPUT1"",E$
630 !CHR$(29),
640 IF E$="M" THEN CHAIN "MENU"
650 IF E$<>"E" THEN 710
660 !\!CHR$(31),
670 FOR R=1 TO 12\!CHR$(28),\NEXT
680 !"KTS",\!CHR$(29),
690 FOR R=1 TO 3\!CHR$(8),\NEXT
700 GOTO 480
710 T1=VAL(E$)
720 !"%"
730 REM ************** INPUT ETD ***********************
740 !"ETD: HH.MM",
750 FOR R=1 TO 5\!CHR$(8),\NEXT
760 INPUT1"",E$
770 IF E$="M"THEN CHAIN "MENU"
780 IF E$<>"E" THEN 820
790 !\!CHR$(31),\!CHR$(29),\!CHR$(31),
800 FOR R=1 TO 28\!CHR$(28),\NEXT
810 GOTO 580
820 T2=VAL(E$)
830 !" hrs"
840 !
850 A9=0
860 B1=10\B2=20\B3=30
870 REM ************* INPUT INITIAL MAP # ********************
880 !"INITIAL MAP #: NNNN",\FOR R=1 TO 4\A=CALL(10608,8)\NEXT R
890 INPUT"",P$
900 A=CALL(10608,11)
910 IF P$="M" THEN CHAIN "MENU"
920 IF P$=O$ THEN 1010
930 IF P$<>"E" THEN 960
940 A=CALL(10608,31)\A=CALL(10608,29)\A=CALL(10608,31)\A=CALL(10608,31)
950 A=CALL(10608,29)\GOTO 740
960 IF P$>"3500"THEN 2820
970 IF P$<"0099"THEN 2820
980 IF P$<>"0422"THEN 2820   \REM REMOVE WHEN MORE MAPS ARE ON FILE
990 GOTO 1440                \REM ****** LOAD MAP DATA BASE
1000 REM *************** INPUT WAYPT, ALT *****************
1010 !"MAP#", TAB(B1),"WAYPT#    ",TAB(B2),"WAYPT   ",TAB(B3),"ALT.X 1000 ft"
1020 !P$,TAB(B1),A9,TAB(B2),\A=CALL(10608,29)\INPUT1 E$
1030 IF E$="M" THEN CHAIN "MENU"
1040 IF E$<>"E"THEN 1070
1050 !\FOR R=1 TO 3\A=CALL(10608,31)\A=CALL(10608,29)\NEXT R
1060 GOTO 880
1070 D(0)=VAL(E$)
1080  FOR R=0 TO LEN(E$)\A=CALL(10608,8)\NEXT R\A=CALL(10608,11)
1090 GOSUB 1940
1100 IF A<>999 THEN 1130
1110 A=0
1120 GOTO 1020
1130 !G$,\FOR R=1 TO 10-LEN(G$)\!" ",\NEXT R
1140 REM ************* INPUT ALTITUDE IN 1000 ' *******************
1150 INPUT1 E$
1160 IF E$="M" THEN CHAIN "MENU"
1170 IF E$<>"E" THEN 1190
1180 !\A=CALL(10608,31)\GOTO 1020
1190 C(A9)=VAL(E$)*1000
1200 GOSUB 2430
```

```
1210 A9=A9+1
1220 !P$,TAB(B1),A9,TAB(B2),\A=CALL(10608,29)\INPUT1 E$
1230 IF E$="M" THEN CHAIN "MENU"
1240 IF E$<>"E" THEN 1290
1250 !\A=CALL(10608,31)\A=CALL(10608,29)\A=CALL(10608,31)
1260 FOR R=1 TO B3\A=CALL(10608,28)\NEXT R\A=CALL(10608,29)
1270 A9=A9-1
1280 IF A9=0 THEN 1150 ELSE 1350
1290 D(A9)=VAL(E$)
1300 GOSUB 1940
1310 IF A<>999 THEN 1330
1320 GOTO 1220
1330 FOR R=0 TO LEN(E$)\A=CALL(10608,8)\NEXT R\A=CALL(10608,11)
1340 !G$,\FOR R=1 TO 10-LEN(G$)\!" ",\NEXT R
1350 INPUT1 E$
1360 IF E$="M" THEN CHAIN "MENU"
1370 IF E$<>"E" THEN 1400
1380 !\A=CALL(10608,31)\A=CALL(10608,29)
1390 GOTO 1220
1400 C(A9)=VAL(E$)*1000
1410 IF C(A9)<C2 THEN E=1
1420 GOTO 1200
1430 REM *************** LOAD MAP DATA BASE **********************
1440 OPEN #0,P$
1450 WRITE #2,G1,H1,D1,W1,T1,T2,P$
1460 O$=P$
1470 READ #0,M(A9),P1,F1    \ REM          LOAD VOR DATA,MAGVAR
1480 DIM V(P1-1,F1),V$(3),Z$(F1*3)
1490 FOR W=1 TO F1
1500 READ #0,V$
1510 Z$=V$+Z$
1520 FOR X=1 TO P1-1
1530 READ #0,V(X,W)
1540 NEXT X
1550 NEXT W
1560 READ #0,P2,F2    \ REM          LOAD INTERSECTION DATA
1570 DIM N(P2-1,F2),N$(5),R$(F2*5)
1580 FOR W=1 TO F2
1590 READ #0,N$
1600 R$=N$+R$
1610 FOR X=1 TO P2-1
1620 READ #0,N(X,W)
1630 NEXT X
1640 NEXT W
1650 READ #0,P3,F3    \ REM          LOAD AIRPORT DATA
1660 DIM A(P3-1,F3),A$(6),S$(F3*6)
1670 FOR W=1 TO F3
1680 READ #0,A$
1690 S$=A$+S$
1700 FOR X=1 TO P3-1
1710 READ #0,A(X,W)
1720 NEXT X
1730 NEXT W
1740 READ #0,P4,F4    \ REM          LOAD ILS DATA
1750 DIM I(P4,F4),I$(4),T$(F4*4)
1760 FOR W=1 TO F4
1770 READ #0,I$
1780 T$=I$+T$
1790 FOR X=1 TO P4-1
1800 READ #0,I(X,W)
```

```
1810 NEXT X
1820 NEXT W
1830 READ #0,P5,F5       \ REM         LOAD NDB DATA
1840 DIM B(P5-1,F5),B$(4),U$(F5*4)
1850 FOR W=1 TO F5
1860 READ #0,B$
1870 U$=B$+U$
1880 FOR X=1 TO P5-1
1890 READ  #0,B(X,W)
1900 NEXT X
1910 NEXT W
1920 CLOSE #0\GOTO 1010
1930 REM ************** GET WAYPT MNEMONIC, LAT/LNG, MEA *************
1940 IF D(A9)<1000 THEN 2340     \REM    WAYPT IS A VOR
1950 IF D(A9)<10000 THEN 2050    \REM    WAYPT IS NDB OR ILS
1960 IF D(A9)<100000 THEN 2250   \REM    WAYPT IS AN INTRSECTION
1970 FOR W=0 TO F3-1        \REM   WAYPT IS AN AIRPORT
1980 IF A(1,W+1)=D(A9) THEN 2010
1990 NEXT W
2000 GOTO 2750
2010 G$=S$(6*(F3-W)-5,6*(F3-W))
2020 K(A9)=A(3,W+1)       \REM  ASSIGN LAT
2030 L(A9)=A(4,W+1)         \REM  ASSIGN LONG
2040 RETURN
2050 IF D(A9)<5000 THEN 2140
2060 FOR W=0 TO F5-1          \ REM WYPT IS NDB
2070 IF B(1,W+1)=D(A9)THEN 2100
2080 NEXT W
2090 GOTO 2750
2100 G$=U$(4*(F5-W)-3,4*(F5-W))
2110 K(A9)=B(3,W+1)       \REM  ASSIGN LAT
2120 L(A9)=B(4,W+1)         \REM  ASSIGN LONG
2130 RETURN
2140 IF D(A9)>4000 THEN 2170
2150 REM B IS A NDB
2160 GOTO 2060
2170 FOR W=0 TO F4-1       \REM    WAYPT IS AN ILS
2180 IF I(1,W+1)=D(A9) THEN 2210
2190 NEXT W
2200 GOTO 2750
2210 G$=T$(4*(F4-W)-3,4*(F4-W))
2220 K(A9)=I(3,W+1)       \REM  ASSIGN LAT
2230 L(A9)=I(4,W+1)         \REM  ASSIGN LONG
2240 RETURN
2250 FOR W=0 TO F2-1        \REM    WAUPT IS AN INTERSECTION
2260 IF N(1,W+1)=D(A9) THEN 2290
2270 NEXT W
2280 GOTO 2750
2290 G$=R$(5*(F2-W)-4,5*(F2-W))
2300 L(A9)=N(4,W+1)      \REM ASSIGN LNG
2310 K(A9)=N(3,W+1)      \REM ASSIGN LAT
2320 C2=N(2,W+1)*100
2330 RETURN
2340 FOR W=0 TO F1-1          \ REM WYPT IS VOR
2350 IF V(1,W+1)=D(A9) THEN 2380
2360 NEXT W
2370 GOTO 2750
2380 G$=Z$(3*(F1-W)-2,3*(F1-W))
2390 K(A9)=V(3,W+1)      \REM ASSIGN LAT
2400 L(A9)=V(4,W+1)         \REM  ASSIGN LONG
```

```
2410 RETURN
2420 REM *********** ALT MNEMONICS, ERROR MSGS ****************
2430 IF E=1 THEN 2590
2440 !                \REM  AND ALT
2450 A=CALL(10608,29)
2460 A=CALL(10608,31)
2470 IF C(A9)=252000 THEN C$="CLB  " ELSE 2490
2480 GOTO 2550
2490 IF C(A9)=337000 THEN C$="DES  " ELSE 2510
2500 GOTO 2550
2510 IF C(A9)=563000 THEN C$="LND  " ELSE 2530
2520 GOTO 2850
2530 !P$,TAB(B1),A9,TAB(B2),G$,TAB(B3),C(A9),
2540 GOTO 2560
2550 !P$,TAB(B1),A9,TAB(B2),G$,TAB(B3+1),C$,
2560 A=CALL(10608,29)
2570 !
2580 RETURN
2590 REM      THIS CAUSES FLASHING OF THE CORRECT
2600 REM      MINIMUM ENROUTE ALTITUDE FOR 10 SECONDS
2610 C(A9)=C2
2620 FOR R=0 TO LEN (E$)\A=CALL(10608,8)\NEXT R
2630 A=CALL(10608,29)
2640 C$=STR$(C2)
2650 FOR R6=1 TO 5
2660 FOR R=1 TO 500\NEXT R
2670 A=CALL(10608,11)
2680 FOR R=1 TO  50\NEXT R
2690 !C$,
2700 FOR R=1 TO LEN(C$)\A=CALL(10608,8)\NEXT R
2710 NEXT R6
2720 E=0
2730 !
2740 RETURN
2750 !
2760 !"*******ERROR WAYPT NOT ON FILE*******"
2770 A=CALL(10608,31)\A=CALL(10608,31)
2780 A=CALL(10608,29)
2790 A=999
2800 RETURN
2810 GOTO 1090
2820 !"****** ERROR ILLEGAL MAP# *****"
2830 A=CALL(10608,31)\A=CALL(10608,31)\A=CALL(10608,2)
2840 GOTO 880
2850!P$,TAB(B1),A9,TAB(B2),G$,TAB(B3+1),C$,
2860 OUT 2,29
2870 !
2880 !"DESTINATION ",
2890 OUT 2,31
2900 !"99"
2910 A8=A9
2920 FOR R=1 TO 1200
2930 NEXT
2940 A=CALL(10608,25)
2950 A=CALL(10608,11)
2960 REM ************** BEGINNING OF CALCULATION ***********************
2970 !"DEPART FROM                   ETD                INITIAL FUEL/GAL"
2980 A9=0
2990 GOSUB 1940
3000 !G$,TAB(28),%#5F2,T2,TAB(47),%#4F1,G1
```

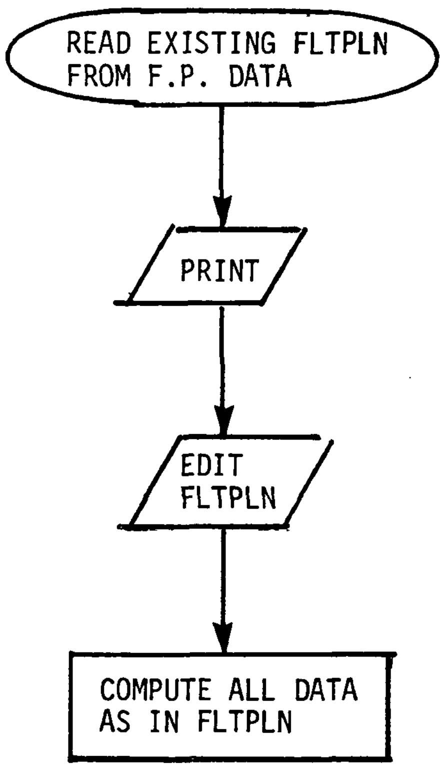
```
3010 !
3020 !"FROM      TO     COURSE DIST    HDG     ETER  EGS    ALT    RESERVES"
3030 !"                   DDD  NN.N    DDD     H.MM  KTS    FT.    GAL     HRS"
3040 P=3.14159265                               \REM P= PI
3050 DIM K2(19),L2(19)
3060 REM **************** CHANGE LAT & LNG TO RADIANS & DECIMAL **********
3070 FOR A9=0 TO A8
3080 IF K(A9)=0 THEN 4130
3090 K2(A9)=INT(K(A9))+(K(A9)-INT(K(A9)))/.6   \REM RADIAN LAT
3100 K2(A9)=K2(A9)*P/180
3110 L2(A9)=INT(L(A9))+(L(A9)-INT(L(A9)))/.6   \REM DECIMAL LNG
3120 NEXT A9
3130 A9=-1
3140 A9=A9+1
3150 IF A9=A8 THEN 4130
3160 REM ************ FIND COURSE FROM WAYPOINT A9 TO A9+1 ************
3170 J2=L2(A9)-L2(A9+1)
3180 J3=P/4+K2(A9+1)/2
3190 J4=P/4+K2(A9)/2
3200 J5=LOG(SIN(J3)/COS(J3))-LOG(SIN(J4)/COS(J4))
3210 J6=ABS((P*J2)/(180*J5))
3220 J8=ATN(J6)
3230 J7=180*J8/P                           \REM GIVES TRUE HDG IN DEG
3240 J9=J7                                 \REM J9=TRUE COURSE
3250 J7=J7+M(0)                             \REM J7=MAG HDG
3260 REM ************ CORRECT COURSE ANGLE FOR EACH QUADRANT ***********
3270 IF K(A9)<K(A9+1) AND L(A9)>L(A9+1) THEN 3370
3280 IF K(A9)>K(A9+1) AND L(A9)<L(A9+1) THEN 3330
3290 IF K(A9)>K(A9+1) AND L(A9)>L(A9+1) THEN 3420
3300 REM ***** HDG NE
3310 IF J7<0 THEN J7=360+J7
3320 GOTO 3450
3330 REM ***** HDG SE
3340 J7=180-J7+2*M(0)
3350 J9=180-J9
3360 GOTO 3450
3370 REM ***** HDG NW
3380 J7=360-J7+2*M(0)
3390 IF J7>360 THEN J7=J7-360
3400 J9=360-J9
3410 GOTO 3450
3420 REM ***** HDG SW
3430 J7=J7+180
3440 J9=J9+180
3450 J7=INT(J7+.5)
3460 REM *********** PRINT FROM & TO WAYPTS, MAG COURSE ************
3470 !G$,TAB(8 ),                     \REM OUTPUT "FROM" WAYPT
3480 A9=A9+1
3490 D=D(A9)
3500 GOSUB 1940                         \REM OUTPUT "TO" WAYPT AND
3510 A9=A9-1
3520 !G$,TAB(17),%#3I,J7,TAB(20),
3530 REM *********** FIND DIST FROM WAYPT A9 TO A9+1 ***************
3540 IF J9=270 OR J9=90 THEN 3410             \REM  IS TRUE COURSE E OR W?
3550 Y=K2(A9)*180/P              \REM  Y=DECIMAL LAT
3560 Y1=K2(A9+1)*180/P
3570 H3=60*(Y1-Y)/COS(FNR(J8)) \REM  DIST = H3 IF COS(J8)<>0
3580 GOTO 3600
3590 H3=60*(L2(A9+1)-L2(A9))*COS (K2(A9))  \REM DIST=H3 IF COS(J8)=0
3600 H3=ABS(H3)
```

```
3610 H3=INT(10*H3)/10               \REM ROUND DIST TO 1/10
3620 H9=H9+H3          \REM  SUM DIST
3630 IF H9>1000 THEN 4340
3640 !%#6F1,H3,TAB(29),
3650 REM ********** SELECT CLB, CRUISE OR DESCEND ROUTINES *********
3660 IF C(A9)<>252000 THEN 3770
3670 REM ********* INSERT CLIMB PERFORMANCE ALGORITHMS HERE ********
3680 C$="CLB"
3690 T4=80
3700 GOSUB 3930
3710 G2=22
3720 GOSUB 4050
3730!%#3I,J8,TAB(36),%#4F2,E2,TAB(42),%#3I ,T3,TAB(48),C$,TAB(54),%#4F1,R1,
3740 ! TAB(60),%#5F2,R2
3750 WRITE #2,D(A9),D(A9+1),J7,H3,J8,E2,T3,C(A9),R1,R2,T4
3760 GOTO 3140
3770 IF C(A9)<>337000 AND C(A9+1)<>563000 THEN 3840
3780 REM ********* INSERT DESCENT PERFORMANCE ALGRITHMS HERE **********
3790 C$="DES"
3800 IF C(A9+1)=563000 THEN T4=100 ELSE T4=120
3810 GOSUB 3930
3820 GOSUB 4020
3830 GOTO 3730
3840 REM ****************** LEVEL FLIGHT ****************************
3850 GOSUB 3900
3860 GOSUB 4010
3870 !%#3I,J8,TAB(36),%#4F2,E2,TAB(42),%#3I ,T3,TAB(47),%#5I,C(A9),TAB(54),
3880 !%#4F1,R1,TAB(60),%#5F2,R2
3890 WRITE #2,D(A9),D(A9+1),J7,H3,J8,E2,T3,C(A9),R1,R2,T4
3900 REM ********* CRUISE PERFORMANCE ROUTINE **********************
3910 T4=128+.00111*C(A9)+(T1-64.4)*1.1 \REM T3=TAS AT 2400RPM,30"MAP
3920 REM ********** CORRECT HDG & GS FOR WIND ***********************
3930 J8=J7+FNS(W1/T4)*180/P*SIN(FNR(D1-J7))
3940 T3=T4*COS(FNR(J8-J7))-W1*COS(FNR(D1-J7))
3950 J8=INT(J8+.5)
3960 E2=H3/T3                      \REM E2 = ETER
3970 E3=E3+E2                      \REM E3=ETT FOR TRIP
3980 E2=INT(E2)+(E2-INT(E2))*.6   \REM E2=HRS.MIN
3990 E2=INT(E2*100+.5)/100
4000 RETURN
4010 REM ************** FIND GPH, RESERVES *****************************
4020 IF T1<68 THEN K=.1545        \REM T1=CRUISE %BHP
4030 IF T1>=68 THEN K=.1545+(.0045*(T1-68))
4040 G2=K*T1                      \REM G2=GPH
4050 R1=G1-(G2*E3)                \REM R1=GAL REMAINING
4060 IF R1<=0 THEN 4260           \REM CHECK FOR NO FUEL
4070 R2=R1/G2
4080 R2=INT(R2)+(R2-INT(R2))*0.6  \REM HRS,MIN RESERVE
4090 R2=INT(100*R2)/100
4100 R1=INT(R1*10)/10
4110 T3=INT(T3)
4120 RETURN
4130 !
4140 CLOSE #2
4150 !"DESTINATION           TDIST   ETA           FINAL RES/GAL  RES/HRS"
4160 T2=INT(T2)+(T2-INT(T2))/.6
4170 H9=INT(10*H9)/10             \REM H9=TOTAL DIST IN MM.m
4180 E3=E3+T2                     \REM E3=ETA, OR ETT+ETD
4190 E3=INT(E3)+(E3-INT(E3))*.6  \REM E3=HRS.MIN
4200 E3=INT(E3*100)/100         \REM CORRECTION FOR E3 IN MIN ONLY
```

```
4210 !G$,TAB(21),%#5F1,H9,TAB(28),%#5F2,E3,TAB(48),%#4F1,R1,
4220 !TAB(56),%#5F2,R2
4230 !\!\!"DO YOU WISH TO TRY ANOTHER ROUTE?(1=YES,0=NO): ",
4240 INPUT "",Z9\IF Z9=0 THEN CHAIN "MENU"
4250 CHAIN "FLTPLNUP"
4260 !
4270 !
4280 !"********** ERROR INSUFFICIENT FUEL*********** "
4290 !"RE-INPUT INIT.FUEL: ",
4300 INPUT "",G9
4310 IF G9>G1 THEN 2940
4320 !"ILLEGAL ENTRY"
4330 GOTO 4290
4340 !
4350 !
4360 !"********** ERROR DIST EXCEEDS MAX RANGE **********"
4370 !"TRY AGAIN!!"
4380 CHAIN "FLTPLN"
```

5.5 FLIGHT PLAN UPDATE PROGRAM

FIGURE 5.5-1 FLT PLN UP . . . FLIGHT PLAN UPDATE FLOW CHART



```
10 REM FLTPLNUP PROGRAM
20 REM PROGRAM FOR UPDATING FLIGHTPLAN
30 A=CALL(10608,25)\A=CALL(10608,11)
40 A9=0
50 B1=15\B2=33\B3=50
60 OPEN #2,"FPDATA"
70 DIM D( 20),C( 20),K( 20),L( 20),Y(19),Y1(19),H3(20)
80 DIM F(20,11)
90 READ #2,G1,H1,D1,W1,T1,T2,P$
100 FOR R=0 TO 20          \REM LOAD ORIGINAL FLIGHT PLAN
110  FOR R1=1 TO 11
120   READ #2,F(R,R1)
130  NEXT R1
140  IF TYP(2)=0 THEN 160
150 NEXT R
160 GOTO 2070              \REM *** GO LOAD MAP DATA BASE ***
170 REM************* THIS SECTION MAY NOT BE USED ****************
180 !"INIT FUEL: GG",
190  A=CALL(10608,29)
200  FOR R=1 TO 2\A=CALL(10608,8)\NEXT R
210 INPUT1 "",E$
220 IF E$="M" THEN CHAIN "MENU"
230 IF E$<>"E" THEN 250
240 !\A=CALL(10608,31)\GOTO 180
250 G1=VAL(E$)
260 !" gal",TAB(30),
270 !"TEMP 'C AT AIRPORT: CC",
280 FOR R=1 TO 2\A=CALL(10608,8)\NEXT R
290 INPUT1"",E$
300 A=CALL(10608,29)
310 IF E$="M" THEN CHAIN "MENU"
320 IF E$<>"E" THEN 340
330 !\A=CALL(10608,31)\GOTO 180
340 H1=VAL(E$)
350 !"'"
360 !"WIND: DEG   KTS",
370 FOR R=1 TO 9\A=CALL(10608,8)\NEXT R
380 INPUT1"",E$
390 IF E$="M"THEN CHAIN "MENU"
400 IF E$<>"E" THEN 440
410 !\A=CALL(10608,31)\A=CALL(10608,29)\A=CALL(10608,31)
420 FOR R=1 TO 28\A=CALL(10608,28)\NEXT R
430 GOTO 270
440 D1=VAL(E$)-180
450 IF D1<0 THEN D1=VAL(E$)+180
460 !"'",
470 FOR R=(5-LEN(E$)) TO 1 STEP -1
480 !" ",
490 NEXT R
500 INPUT1 "",E$
510 A=CALL(10608,29)
520 IF E$="M" THEN CHAIN "MENU"
530 IF E$<>"E"THEN 560
540 !\A=CALL(10608,31)
550 GOTO 360
560 W1=VAL(E$)
570 !" kts",
580 FOR R=1 TO 12-LEN(E$)\!" ",\NEXT R
590 !"CRUISE % BHP: PP ",
600 A=CALL(10608,8)
```

```
610 A=CALL(10608,8)
620 A=CALL(10608,8)
630 INPUT1"",E$
640 A=CALL(10608,29)
650 IF E$="M" THEN CHAIN "MENU"
660 IF E$<>"E" THEN 720
670 ! \ A=CALL(10608,31)
680 FOR R=1 TO 12\A=CALL(10608,28)\NEXT R
690 !"KTS",\A=CALL(10608,29)
700 FOR R=1 TO 3\A=CALL(10608,8)\NEXT R
710 GOTO 500
720 T1=VAL(E$)
730 !"%"
740 !"ETD: HH.MM",
750 FOR R=1 TO 5\A=CALL(10608,8)\NEXT R
760 INPUT1"",E$
770 IF E$="M"THEN CHAIN "MENU"
780 IF E$<>"E" THEN 820
790 !\A=CALL(10608,31)\A=CALL(10608,29)\A=CALL(10608,31)
800 FOR R=1 TO 28\A=CALL(10608,28)\NEXT R
810 GOTO 590
820 T2=VAL(E$)
830 !" hrs"
840 !
850 A9=0
860 B1=10\B2=20\B3=30
870 !"INITIAL MAP #: NNNN",\FOR R=1 TO 4\A=CALL(10608,8)\NEXT R
880 INPUT"",P$
890 A=CALL(10608,11)
900 IF P$="M" THEN CHAIN "MENU"
910 IF P$=O$ THEN 1000
920 IF P$<>"E" THEN 950
930 A=CALL(10608,31)\A=CALL(10608,29)\A=CALL(10608,31)\A=CALL(10608,31)
940 A=CALL(10608,29)\GOTO 740
950 IF P$>"3500"THEN 3430
960 IF P$<"0099"THEN 3430
970 IF P$<>"0422"THEN 3430   \REM REMOVE WHEN MORE MAPS ARE ON FILE
980 GOTO 2070
990 REM ****************** END OF MAY NOT BE USED SECTION ***********
1000 PRINT "EXISTING FLIGHT PLAN                  UPDATED FLIGHT PLAN"
1010 PRINT "WAYPOINT            ALT.               WAYPOINT          ALT."
1020 PRINT
1030 REM ****************** PRINT OUT OLD WAYPOINTS ******************
1040 FOR R1=0 TO R
1050  D(A9)=F(R1,1)        \REM GET MNEMONIC
1060  GOSUB 2560
1070  IF R1=0 THEN G1$=G$ \REM SAVE WAYPOINT 0 MNEMONIC
1080  !G$,TAB(B1),
1090  IF F(R1,8)<>252000 THEN 1120
1100  !" CLB"
1110  GOTO 1190
1120  IF F(R1,8)<>337000 THEN 1150
1130  !" DES"
1140  GOTO 1190
1150  IF F(R1,8)<>563000 THEN 1180
1160  !" LND"
1170  GOTO 1190
1180  !F(R1,8)
1190 NEXT R1
1200 FOR R1=0 TO R
```

```
1210  A=CALL(10608,31)   \REM REPOSITION CURSOR UP
1220 NEXT R1
1230 FOR R1=1 TO B2
1240  A=CALL(10608,28)   \REM MOVE CURSOR OUT
1250 NEXT R1
1260 REM***************** INPUT NEW WAYPOINTS **********************
1270 !G1$,               \REM PRINT AIRPORT NAME, WILL NOT CHANGE
1280 FOR R1=LEN(G1$) TO 17
1290  A=CALL(10608,28)   \REM MOVE CURSOR OUT
1300 NEXT R1
1310 !" CLB"             \REM WILL ALWAYS CLB OUT FROM AIRPORT!
1320 FOR R1=1 TO B2
1330  A=CALL(10608,28)   \REM MOVE CURSOR OUT
1340 NEXT R1
1350 R=1
1360 A9=1
1370 A=CALL(10608,8)       \REM BS
1380 REM ***** INPUT WAYPOINT ******
1390 INPUT1 E$
1400 IF E$="M" THEN CHAIN "MENU"
1410 IF E$<>"E" THEN 1590
1420 IF A9<>0 THEN 1480
1430 A=CALL(10608,7)       \REM BUZZ
1440 A=CALL(10608,8)       \REM BS
1450 A=CALL(10608,8)       \REM BS
1460 A=CALL(10608,29)      \REM ERASE
1470 GOTO 1380
1480 REM ***** RE-POSITION CURSOR TO RE-INPUT LAST ALT *****
1490 A=CALL(10608,8)       \REM BS
1500 A=CALL(10608,8)       \REM BS
1510 A=CALL(10608,29)      \REM ERASE
1520 FOR R1=1 TO 17
1530  A=CALL(10608,28)     \REM SPACE OUT
1540 NEXT R1
1550 A=CALL(10608,31)      \REM UPSPACE
1560 A=CALL(10608,29)      \REM ERASE OLD ALT
1570 A9=A9-1
1580 GOTO 1850           \REM RE-INPUT OLD ALT
1590 IF E$<>"" THEN 1700
1600 D(A9)=F(R,1)          \REM NO WAYPOINT CHANGE
1610 A=CALL(10608,8)
1620 GOSUB 2560          \REM GET WAYPOINT MNEMONIC
1630 !" ",G$,
1640 FOR R1=LEN(G$) TO 17
1650  A=CALL(10608,28)     \REM SPACE OUT
1660 NEXT R1
1670 !F(R,8)
1680 R=R+1
1690 GOTO 2010           \REM REPOSITION CURSOR
1700 IF E$(1,1)= "/" THEN 1730
1710 R=R+1
1720 GOTO 1750
1730 E$=E$(2,LEN(E$))
1740 A=CALL(10608,8)
1750 D(A9)=VAL(E$)
1760 GOSUB 2560          \REM GET WAYPOINT MNEMONIC
1770 FOR R1=LEN(E$) TO 0 STEP -1
1780  A=CALL(10608,8)
1790 NEXT R1
1800 A=CALL(10608,29)
```

```
1810 !" ",G$,
1820 FOR R1 =LEN(G$) TO 17
1830  A=CALL(10608,28)
1840 NEXT R1
1850 REM ***** INPUT ALTITUDE *****
1860 INPUT1 E$
1870 IF E$="M" THEN CHAIN "MENU"
1880 IF E$<>"E" THEN 1940
1890 FOR R1=17 TO 1 STEP -1
1900 A=CALL(10608,8)
1910 NEXT R1
1920 A=CALL(10608,29)
1930 GOTO 1380            \REM CHANGE LAST WAYPOINT
1940 C(A9)=VAL(E$)*1000
1950 IF C(A9)<C2 THEN ERROR  \REM CHECK FOR ALT<MEA
1960 IF C(A9)=563000 THEN COMPUTE FLIGHTPLAN
1970 FOR R1=LEN(E$) TO 0 STEP -1
1980  A=CALL(10608,8)    \REM BS
1990 NEXT R1
2000 !C(A9)
2010 REM ***** REPOSITION CURSOR, GET READY FOR NEXT WP *************
2020 A9=A9+1
2030 FOR R1=1 TO B2
2040 A=CALL(10608,28)
2050 NEXT R1
2060 GOTO 1370           \REM GO GET NEXT WAYPOINT
2070 REM ****************** LOAD MAP DATA BASE ******************
2080 OPEN #0,P$
2090 O$=P$
2100 READ #0,M(A9),P1,F1    \ REM          LOAD VOR DATA,MAGVAR
2110 DIM V(P1-1,F1),V$(3),Z$(F1*3)
2120 FOR W=1 TO F1
2130 READ #0,V$
2140 Z$=V$+Z$
2150 FOR X=1 TO P1-1
2160 READ #0,V(X,W)
2170 NEXT X
2180 NEXT W
2190 READ #0,P2,F2    \ REM          LOAD INTERSECTION DATA
2200 DIM N(P2-1,F2),N$(5),R$(F2*5)
2210 FOR W=1 TO F2
2220 READ #0,N$
2230 R$=N$+R$
2240 FOR X=1 TO P2-1
2250 READ #0,N(X,W)
2260 NEXT X
2270 NEXT W
2280 READ #0,P3,F3    \ REM          LOAD AIRPORT DATA
2290 DIM A(P3-1,F3),A$(6),S$(F3*6)
2300 FOR W=1 TO F3
2310 READ #0,A$
2320 S$=A$+S$
2330 FOR X=1 TO P3-1
2340 READ #0,A(X,W)
2350 NEXT X
2360 NEXT W
2370 READ #0,P4,F4    \ REM          LOAD ILS DATA
2380 DIM I(P4,F4),I$(4),T$(F4*4)
2390 FOR W=1 TO F4
2400 READ #0,I$
```

```
2410 T$=I$+T$
2420 FOR X=1 TO P4-1
2430 READ #0,I(X,W)
2440 NEXT X
2450 NEXT W
2460 READ #0,P5,F5      \ REM          LOAD NDB DATA
2470 DIM B(P5-1,F5),B$(4),U$(F5*4)
2480 FOR W=1 TO F5
2490 READ #0,B$
2500 U$=B$+U$
2510 FOR X=1 TO P5-1
2520 READ  #0,B(X,W)
2530 NEXT X
2540 NEXT W
2550 CLOSE #0\GOTO 1000
2560 IF D(A9)<1000 THEN 2960    \REM    WAYPT IS A VOR
2570 IF D(A9)<10000 THEN 2670   \REM    WAYPT IS NDB OR ILS
2580 IF D(A9)<100000 THEN 2870  \REM    WAYPT IS AN INTRSECTION
2590 FOR W=0 TO F3-1       \REM   WAYPT IS AN AIRPORT
2600 IF A(1,W+1)=D(A9) THEN 2630
2610 NEXT W
2620 GOTO 3360
2630 G$=S$(6*(F3-W)-5,6*(F3-W))
2640 K(A9)=A(3,W+1)       \REM  ASSIGN LAT
2650 L(A9)=A(4,W+1)         \REM  ASSIGN LONG
2660 RETURN
2670 IF D(A9)<5000 THEN 2760
2680 FOR W=0 TO F5-1         \ REM WYPT IS NDB
2690 IF B(1,W+1)=D(A9)THEN 2720
2700 NEXT W
2710 GOTO 3360
2720 G$=U$(4*(F5-W)-3,4*(F5-W))
2730 K(A9)=B(3,W+1)       \REM  ASSIGN LAT
2740 L(A9)=B(4,W+1)         \REM  ASSIGN LONG
2750 RETURN
2760 IF D(A9)>4000 THEN 2790
2770 REM B IS A NDB
2780 GOTO 2680
2790 FOR W=0 TO F4-1       \REM    WAYPT IS AN ILS
2800 IF I(1,W+1)=D(A9) THEN 2830
2810 NEXT W
2820 GOTO 3360
2830 G$=T$(4*(F4-W)-3,4*(F4-W))
2840 K(A9)=I(3,W+1)       \REM  ASSIGN LAT
2850 L(A9)=I(4,W+1)         \REM  ASSIGN LONG
2860 RETURN
2870 FOR W=0 TO F2-1         \REM    WAUPT IS AN INTERSECTION
2880 IF N(1,W+1)=D(A9) THEN 2910
2890 NEXT W
2900 GOTO 3360
2910 G$=R$(5*(F2-W)-4,5*(F2-W))
2920 L(A9)=N(4,W+1)      \REM ASSIGN LNG
2930 K(A9)=N(3,W+1)      \REM ASSIGN LAT
2940 C2=N(2,W+1)*100
2950 RETURN
2960 FOR W=0 TO F1-1         \ REM WYPT IS VOR
2970 IF V(1,W+1)=D(A9) THEN 3000
2980 NEXT W
2990 GOTO 3360
3000 G$=Z$(3*(F1-W)-2,3*(F1-W))
```

```
3010 K(A9)=V(3,W+1)      \REM ASSIGN LAT
3020 L(A9)=V(4,W+1)         \REM  ASSIGN LONG
3030 RETURN
3040 IF E=1 THEN 3200
3050 !                 \REM  AND ALT
3060 A=CALL(10608,29)
3070 A=CALL(10608,31)
3080 IF C(A9)=252000 THEN C$="CLB  " ELSE 3100
3090 GOTO 3160
3100 IF C(A9)=337000 THEN C$="DES  " ELSE 3120
3110 GOTO 3160
3120 IF C(A9)=563000 THEN C$="LND  " ELSE 3140
3130 GOTO 3460
3140 !P$,TAB(B1),A9,TAB(B2),G$,TAB(B3),C(A9),
3150 GOTO 3170
3160 !P$,TAB(B1),A9,TAB(B2),G$,TAB(B3+1),C$,
3170 A=CALL(10608,29)
3180 !
3190 RETURN
3200 REM     THIS CAUSES FLASHING OF THE CORRECT
3210 REM     MINIMUM ENROUTE ALTITUDE FOR 10 SECONDS
3220 C(A9)=C2
3230 FOR R=0 TO LEN (E$)\A=CALL(10608,8)\NEXT R
3240 A=CALL(10608,29)
3250 C$=STR$(C2)
3260 FOR R6=1 TO 5
3270 FOR R=1 TO 500\NEXT R
3280 A=CALL(10608,11)
3290 FOR R=1 TO  50\NEXT R
3300 !C$,
3310 FOR R=1 TO LEN(C$)\A=CALL(10608,8)\NEXT R
3320 NEXT R6
3330 E=0
3340 !
3350 RETURN
3360 !
3370 !"*******ERROR WAYPT NOT ON FILE*******"
3380 A=CALL(10608,31)\A=CALL(10608,31)
3390 A=CALL(10608,29)
3400 A=999
3410 RETURN
3420 GOTO 1150
3430 !"****** ERROR ILLEGAL MAP# *****"
3440 A=CALL(10608,31)\A=CALL(10608,31)\A=CALL(10608,2)
3450 GOTO 870
3460!P$,TAB(B1),A9,TAB(B2),G$,TAB(B3+1),C$,
3470 OUT 2,29
3480 !
3490 !"DESTINATION ",
3500 OUT 2,31
3510 !"99"
3520 A8=A9-1
3530 OUT 2,13
3540 GOTO 4180
3550 END
3560 !"DEPART FROM                   ETD                  INITIAL FUEL/GAL"
3570 A9=0
3580 GOSUB 2560
3590 !G$,TAB(28),%#5F2,T2,TAB(47),%#4F1,G1
3600 !
```

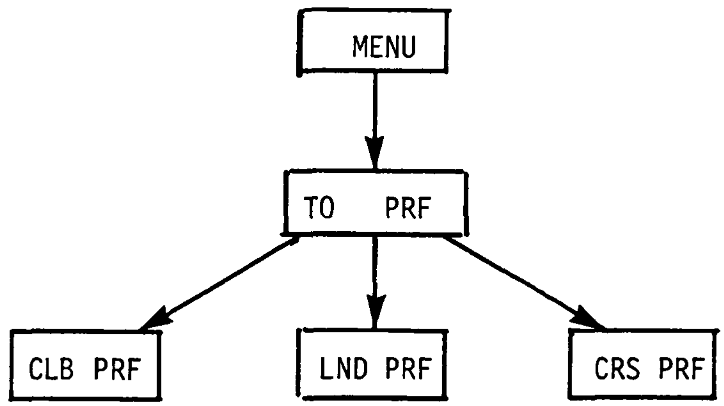
```
3610 !"FROM      TO    COURSE DIST   HDG    ETER  EGS   ALT   RESERVES"
3620 !"                  DDD  NN.N   DDD    H.MM  KTS   FT.   GAL    HRS"
3630 P=3.14159265                                \REM P= PI
3640 DIM K2(19),L2(19)
3650 A9=-1
3660 FOR R=1 TO 2
3670 A9=A9+1
3680 IF K(A9)=0 THEN 4690
3690 K2(A9)=INT(K(A9))+(K(A9)-INT(K(A9)))/.6   \REM RADIAN LAT
3700 K2(A9)=K2(A9)*P/180
3710 L2(A9)=INT(L(A9))+(L(A9)-INT(L(A9)))/.6   \REM RADIAN LNG
3720 NEXT R
3730 A9=A9-1              \REM THIS IS THE HP-65 RHUMBF
3740 J2=L2(A9)-L2(A9+1)   \REM ROUTINE MODIFIED FOR RADIAN TRIG
3750 J3=P/4+K2(A9+1)/2
3760 J4=P/4+K2(A9)/2
3770 J5=LOG(SIN(J3)/COS(J3))-LOG(SIN(J4)/COS(J4))
3780 J6=ABS((P*J2)/(180*J5))
3790 J9=(J6-1)/(J6+1)
3800 J8=ATN(J6)
3810 J7=180*J8/P                          \REM GIVES TRUE HDG IN DEG
3820 IF K(A9)>K(A9+1) THEN 3840
3830 IF L(A9)>L(A9+1) THEN 3870 ELSE 3900  \REM COURSE<90
3840 IF L(A9)>L(A9+1) THEN 3890
3850 J7=180-J7                            \REM 180>COURSE>90
3860 GOTO 3900
3870 J7=360-J7                            \REM 360>COURSE>270
3880 GOTO 3900
3890 J7=J7+180
3900 REM              MAG COURSE=J7+MAG VAR
3910 J9=J7         \REM J9=TRUE COURSE
3920 J7=J7+M(0)
3930 IF H2>.5 THEN 3960                 \REM ROUND OFF MAG HDG
3940 J7=INT(J7)
3950 GOTO 3970
3960 J7=1+INT(J7)
3970 !G$,TAB(8 ),                     \REM OUTPUT "FROM" WAYPT
3980 A9=A9+1
3990 D=D(A9)
4000 GOSUB 2560                         \REM OUTPUT "TO" WAYPT AND
4010 !G$,TAB(17),%#3I,J7,TAB(20),
4020 IF J7-M(0)=270 THEN 4070         \REM  IS TRUE COURSE E OR W?
4030 Y(A9)=K2(A9)*180/P              \REM  Y(A9)=DECIMAL LAT
4040 Y(A9-1)=K2(A9-1)*180/P
4050 H3=60*(Y(A9)-Y(A9-1))/COS(J8)  \REM  DIST = H3 IF COS(J8)<>0
4060 GOTO 4100
4070 Y1(A9)=L2(A9)*180/P               \REM  Y1(A9)=DECIMAL LNG
4080 Y1(A9-1)=L2(A9-1)*180/P
4090 H3=60*(Y1(A9)-Y1(A9-1))*COS (K2(A9))  \REM DIST=H3 IF COS(J8)=0
4100 H3(A9-1)=H3
4110 H3=ABS(H3)
4120 H3=INT(10*H3)/10                 \REM ROUND DIST TO 1/10
4130 H9=H9+H3           \REM  SUM DIST
4140 IF H9>1000 THEN 4960
4150 !%#6F1,H3,TAB(29),
4160 GOTO 4230
4170 !"ARRRGH! I QUIT!!!"
4180 FOR R=1 TO 900
4190 NEXT R
4200 OUT 2,25
```

```
4210 OUT 2,11
4220 GOTO 3560
4230 A9=A9-1
4240 IF C(A9)=252000 THEN C$="CLB  " ELSE 4310
4250 T3=100
4260 GOSUB 4460
4270!%#3I,J7,TAB(36),%#4F2,E2,TAB(42),%#3I ,T3,TAB(48),C$,TAB(54),%#4F1,R1,
4280 ! TAB(60),%#5F2,R2
4290 WRITE #2,D(A9),D(A9+1),J7,H3,J7,E2,T3,C(A9),R1,R2
4300 GOTO 4680
4310 IF C(A9)=337000 THEN C$="DES  " ELSE 4370
4320 IF C(A9+1)=563000 THEN T3=100 ELSE 4350
4330 GOSUB 4410
4340 GOTO 4270
4350 GOSUB 4410
4360 GOTO4270
4370 IF C(A9+1)=563000 THEN T3=100
4380 GOSUB 4400
4390 GOTO 4640
4400 T3=128+.00111*C(A9)+(T1-64.4)*1.1 \REM T3=TAS AT 2400RPM,30"MAP
4410 R6=W1/T3
4420 R6=1.5707288-.2121144*R6+.074261*R6^2-.0187293*R6^3
4430 J7=J7+(P/2-SQRT(1-W1/T3)*R6)*SIN((D1-J9)/180*P)
4440 T3=T3*COS((J9-J7-M(0))/180*P)-W1*COS((D1-J9)/180*P)
4450 J7=INT (J7)
4460 E2=H3/T3                        \REM E2 = ETER
4470 E3=E3+E2                        \REM E3=ETT FOR TRIP
4480 E2=INT(E2)+(E2-INT(E2))*.6   \REM E2=HRS.MIN
4490 IF E2-INT(E2*100)/100>=.005 THEN 4520
4500 E2=INT (E2*100)/100
4510 GOTO 4530
4520 E2=INT(E2*100)/100+.01
4530 IF T1<68 THEN K=.1545
4540 IF T1>=68 THEN K=.1545+(.0045*(T1-68))
4550 G2=K*T1                        \REM G2=GPH
4560 R1=G1-(G2*E3)                  \REM R1=GAL REMAINING
4570 IF R1<=0 THEN 4840      \REM CHECK FOR NO FUEL
4580 R2=R1/G2
4590 R2=INT(R2)+(R2-INT(R2))*0.6  \REM HRS,MIN RESERVE
4600 R2=INT(100*R2)/100
4610 R1=INT(R1*10)/10
4620 T3=INT(T3)
4630 RETURN
4640!%#3I,J7,TAB(36),%#4F2,E2,TAB(42),%#3I ,T3,TAB(47),%#5I,C(A9),TAB(54),
4650 !%#4F1,R1,
4660 ! TAB(60),%#5F2,R2
4670 WRITE #2,D(A9),D(A9+1),J7,H3,J7,E2,T3,C(A9),R1,R2
4680 GOTO 3660
4690 !
4700 CLOSE #2
4710 !"DESTINATION              TDIST   ETA            FINAL RES/GAL  RES/HRS"
4720 T2=INT(T2)+(T2-INT(T2))/.6
4730 H9=INT(10*H9)/10              \REM H9=TOTAL DIST IN MM.m
4740 E3=E3+T2                      \REM E3=ETA, OR ETT+ETD
4750 E3=INT(E3)+(E3-INT(E3))*.6  \REM E3=HRS.MIN
4760 E3=INT(E3*100)/100          \REM CORRECTION FOR E3 IN MIN ONLY
4770 !G$,TAB(21),%#5F1,H9,TAB(28),%#5F2,E3,TAB(48),%#4F1,R1,
4780 !TAB(56),%#5F2,R2
4790 WRITE #2,0,0,0,0,0,0,0,0,0,0
4800 CLOSE #2
```

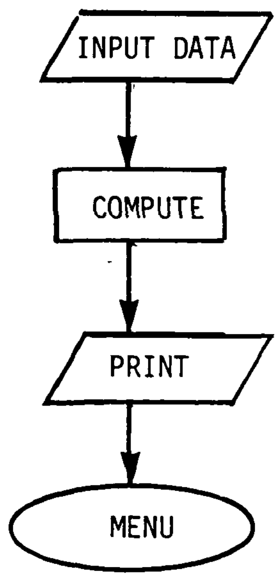
```
4810 !\!\!"DO YOU WISH TO TRY ANOTHER ROUTE?(1=YES,0=NO): ",
4820 INPUT "",Z9\IF Z9=0 THEN CHAIN "MENU"
4830 A=CALL(10608,25)\A=CALL(10608,11)\GOTO 180
4840 !
4850 !
4860 !"********* ERROR INSUFFICIENT FUEL*********** "
4870 !"RE-INPUT INIT.FUEL: ",
4880 INPUT "",G9
4890 IF G9>G1 THEN 4180
4900 !"ILLEGAL ENTRY"
4910 OUT 2,31
4920 OUT 2,31
4930 OUT 2,31
4940 OUT 2,29
4950 GOTO 4870
4960 !
4970 !
4980 !"********* ERROR DIST EXCEEDS MAX RANGE **********"
4990 FOR R=1 TO 600
5000 NEXT R
5010 OUT 2,25
5020 OUT 2,11
5030 GOTO 760
5040 END
5050!TAB(29), E2,TAB (35),T3,TAB(41),C(A9)*100,TAB(47),R1,TAB(56),R2
5060!%#4F2,E2,TAB(35),%#6F2,T3,TAB(42),%#5I,C(A9)*100,TAB(50),%#4F1,R1
```

5.6 AIRCRAFT PERFORMANCE PROGRAMS

FIGURE 5.6-1 AIRCRAFT PERFORMANCE PROGRAM HIERARCHY FLOW DIAGRAM



EACH MODULE IS FULLY SELF DOCUMENTED, EXHIBITING STRAIGHT THRU PROGRAMMING. FLOW CHARTS FOR ALL ARE SIMILAR:



```
10 REM  CLBPRF  6/1/78
20 A=CALL(10608,25)\A=CALL(10608,11)
30 PRINT "CLIMB PERFORMANCE MENU"
40 PRINT "----------------------"
50 PRINT
60 PRINT"RATE OF CLIMB AT SELECTED ALT ....... 1"
70 PRINT"TIME/DISTANCE TO CLIMB .............. 2"
80 PRINT"FUEL TO CLIMB ....................... 3"
90 INPUT X$\IF X$="M" THEN CHAIN "MENU" ELSE X=VAL(X$)
100 IF X=1 THEN GOTO 130
110 IF X=2 THEN GOTO 450
120 IF X=3 THEN GOTO 870
130 A=CALL(10608,25)\A=CALL(10608,11)
140 PRINT "RATE OF CLIMB AT SELECTED ALT"
150 PRINT "-----------------------------"
160 PRINT"ASSUME: FULL THROTTLE,FLAPS UP,MIX LEANED AT 3000 FT"
170 PRINT\PRINT
180 PRINT "ENTER DATA:"
190 PRINT
200 INPUT"ALTITUDE, FT     ",A1
210 PRINT
220 INPUT"OAT AT ALT, DEG C      ",O
230 PRINT
240 INPUT "AIRCRAFT WEIGHT, LBS       ",W
250 PRINT
260 V1=2319-.731667*W
270 V2=-.078533+.00001617*W
280 V3=O-15+.002*A1
290 R=V1+V2*A1+V3*1.8
300 R=INT(R)
310 PRINT "RATE OF CLIMB AT ",A1," FT  = ",R," FT PER MIN"
320 PRINT\PRINT\PRINT
330 PRINT "CHOOSE FUNCTION:                      ENTER:"
340 PRINT
350 PRINT"RETURN TO CLIMB PERFORMANCE MENU ...... 1"
360 PRINT "RETURN TO AIRCRAFT PERFORMANCE MENU.... 2"
370 PRINT"COMPUTE ANOTHER  ROC CASE .............. 3"
380 PRINT"RETURN TO MASTER MENU .................. 4"
390 INPUT X\PRINT\PRINT
400 IF X=1 THEN GOTO 20
410 IF X=2 THEN CHAIN "TOPRF"
420 IF X=3 THEN GOTO 130
430 IF X=4 THEN CHAIN "MASTER"
440 GOTO 330
450 PRINT
460 PRINT"TIME/DISTANCE TO CLIMB TO ALTITUDE"
470 PRINT "----------------------------------"
480 PRINT
490 PRINT "INPUT DATA:"\!\!
500 INPUT "INITIAL ALT, FT         ",A1
510 PRINT
520 INPUT "FINAL ALT, FT           ",A2
530 PRINT
540 INPUT "OAT, DEG C              ",O1
550 PRINT
560 INPUT "AIRCRAFT WEIGHT, LBS    ",W
570 V1=2319-.731667*W
580 V2=-.078533+.00001617*W
590 V3=O1-15+.002*A1
600 O2=O1-.002*A2+.002*A1
```

```
610 V4=02-15+.002*A2
620 R1=V1+V2*A1-V3*1.8
630 R2=V1+V2*A2-V4*1.8
640 R3=R1+R2
650 R4=R3/2
660 T1=A2-A1
670 T=T1/R4
680 T2=T/60
690 V5=47.417+.01375*W
700 D=T2*V5
710 T=INT(T)\D=INT(D)
720 PRINT
730 PRINT "TIME TO CLIMB FROM ",A1," FT TO ",A2,"FT = ",T," MIN"
740 PRINT
750 PRINT"DISTANCE TO CLIMB = ",D," N. MI."
760 PRINT\PRINT
770 PRINT "CHOOSE FUNCTION:                         ENTER:"
780 PRINT
790 PRINT"RETURN TO AIRCRAFT PERFORMANCE MENU ........ 1"
800 PRINT"RETURN TO CLIMB PERFORMANCE MENU ........... 2"
810 PRINT"RETURN TO MASTER MENU ...................... 3"
820 INPUT X\PRINT\PRINT
830 IF X=1 THEN CHAIN "TOPRF"
840 IF X=2 THEN GOTO 20
850 IF X=3 THEN CHAIN "MASTER"
860 GOTO 770
870 PRINT
880 PRINT "FUEL TO CLIMB"
890 PRINT "-------------"
900 PRINT\PRINT
910 PRINT "INPUT DATA:"
920 PRINT
930 INPUT "INITIAL ALT, FT      ",A1
940 PRINT
950 INPUT "FINAL ALT, FT        ",A2
960 PRINT
970 INPUT "AIRCRAFT WEIGHT, LBS ",W
980 PRINT
990 PRINT "ENTER:   1 = FROM TAKEOFF     2 = ENROUTE CHANGE"
1000 INPUT C1
1010 PRINT
1020 V1=-.00007936+.000000102*W
1030 V2=V1*A1
1040 V3=V1*A2
1050 F1=1.06*2.71828^V2
1060 F2=1.06*2.71828^V3
1070 F=F2-F1
1080 F3=F*100
1090 F3=INT(F3)
1100 F4=F3/10
1110 F4=INT(F4)
1120 F=F4/10
1130 IF C1=1 THEN F=F+1
1140 PRINT
1150 PRINT "FUEL TO CLIMB FROM ",A1," FT TO ",A2," FT = ",F," GALS"
1160 PRINT\PRINT
1170 PRINT "CHOOSE FUNCTION:                         ENTER:"
1180 PRINT
1190 PRINT "RETURN TO AIRCRAFT PERFORMANCE MENU ..... 1"
1200 PRINT "RETURN TO CLIMB PERFORMANCE MENU ........ 2"
```

```
1210 PRINT "RETURN TO MASTER MENU .................... 3"
1220 INPUT X\PRINT\PRINT
1230 IF X=1 THEN CHAIN "TOPRF"
1240 IF X=2 THEN GOTO 20
1250 IF X=3 THEN CHAIN "MASTER"
1260 GOTO 1170
```

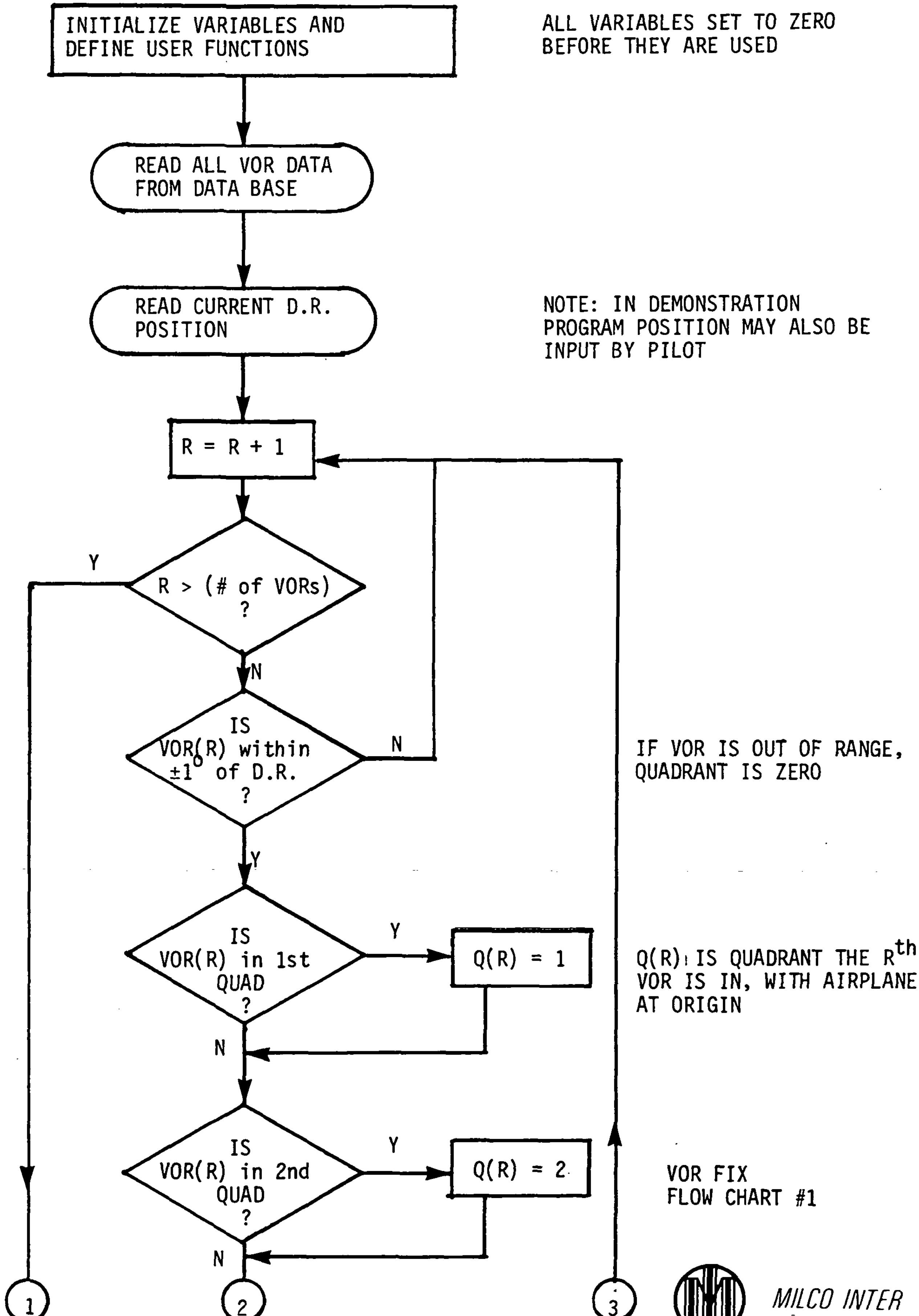
```
10 REM***** TOPRF PROGRAM 5/31/78
20 A=CALL(10608,25)\A=CALL(10608,11)
30 PRINT "AIRCRAFT PERFORMANCE MENU"
40 PRINT"--------------------------"
50 PRINT
60 PRINT "TAKE OFF PERFORMANCE ....... 1"
70 PRINT "CLIMB PERFORMANCE .......... 2"
80 PRINT "CRUISE PERFORMANCE ......... 3"
90 PRINT "LANDING PERFORMANCE ........ 4"
100 PRINT
110 INPUT X$\PRINT\PRINT
120 IF X$="M"THEN CHAIN "MENU"ELSE X=VAL(X$)
130 IF X=2 THEN CHAIN "CLBPRF"
140 IF X=3 THEN CHAIN "CRSPRF"
150 IF X=4 THEN CHAIN "LNDPRF"
160 A=CALL(10608,25)\A=CALL(10608,11)
170 PRINT "          TAKE OFF PERFORMANCE"
180 PRINT "         ---------------------"
190 PRINT
200 PRINT "HARD SURFACE RUNWAY -- WITH FLAPS UP"
210 PRINT
220 INPUT "OUTSIDE AIR TEMP, DEG C       ",O
230 PRINT
240 INPUT "AIRPORT ALT, FT.          ",P
250 PRINT
260 INPUT "TAKE OFF WEIGHT, LBS        ",W
270 PRINT
280 INPUT "HEAD WIND, KNOTS          ",W2
290 K=1.0-.0215*W2
300 A1=(O-15)+.002*P
310 A2=A1/14.9
320 A3=A2*.1+1
330 A4=K*A3
340 B1=-1184+1.14*W
350 A5=A4*B1
360 V1=-.0000620+.000000079*W
370 V2=V1*P
380 B2=2.718282^V2
390 A6=A5*B2
400 A6=INT(A6)
410 PRINT
420 PRINT
430 PRINT "TAKE OFF DISTANCE TO CLEAR 50 FT. OBSTACLE = ",A6," FT."
440 PRINT
450 PRINT\PRINT
460 PRINT " CHOOSE FUNCTION:                    ENTER:"
470 PRINT
480 PRINT "RETURN TO AIRCRAFT PERFORMANCE MENU ........ 1"
490 PRINT "RETURN TO MASTER MENU ...................... 2"
500 PRINT "RETURN TO TAKE OFF PERFORMANCE ............. 3"
510 INPUT X\PRINT\PRINT
520 IF X=1 THEN GOTO 20
530 IF X=2 THEN CHAIN "MASTER"
540 IF X=3 THEN GOTO 160
550 GOTO 460
```

```
10 A=CALL(10608,25)\A=CALL(10608,11)
20 PRINT
30 PRINT" CRUISE PERFORMANCE"
40 PRINT "------------------"
50 PRINT\PRINT
60 PRINT"ASSUME:   GROSS WEIGHT = 2300"
70 PRINT"          STANDARD TEMP."
80 PRINT"          LEAN MIXTURE"
90 PRINT
100 PRINT "INPUT DATA:"\PRINT
110 INPUT "CRUISE ALTITUDE, FT       ",A1
120 PRINT
130 INPUT "ENGINE RPM                ",R
140 PRINT
150 V1=-104.60+.07225*R
160 V3=-.00002168*A1
170 V2=2.17828^V3
180 B=V1*V2
190 B=INT(B)
200 T1=-25.92+.0525*R
210 E=2.71828
220 T1=INT(T1)
230 U1=.0009862*R
240 U2=.000150*R
250 U3=E^U1
260 U4=E^U2
270 U5=.000000435*U4
280 U6=E^-U5
290 G=.7085*U3*U6
300 G1=G*100
310 G1=INT(G1)
320 G2=G1/10
330 G2=INT(G2)
340 G3=G2/10
350 PRINT "% BRAKE HORSEPOWER = ",B," %"
360 PRINT
370 PRINT"TRUE AIR SPEED = ",T1," KNOTS"
380 PRINT
390 PRINT "GALLONS PER HOUR = ",G3
400 PRINT\PRINT
410 PRINT "CHOOSE FUNCTION:                        ENTER:"
420 PRINT
430 PRINT "TO RETURN TO AIRCRAFT PERFORMANCE MENU ...... 1"
440 PRINT "TO RETURN TO CLIMB PERFORMANCE MENU ......... 2"
450 PRINT "TO CALCULATE ANOTHER CRUISE PERFORMANCE...... 3"
460 PRINT "TO RETURN TO MASTER MENU .................... 4"
470 INPUT X\PRINT\PRINT
480 IF X=1 THEN CHAIN "TOPRF"
490 IF X=2 THEN CHAIN "CLBPRF"
500 IF X=3 THEN GOTO 20
510 IF X=4 THEN CHAIN "MASTER"
520 GOTO 400
```

```
10 PRINT
20 PRINT "LANDING PERFORMANCE"
30 PRINT "-------------------"
40 PRINT\PRINT
50 PRINT "ASSUMES:   40 DEG FLAPS"
60 PRINT "           POWER OFF"
70 PRINT "           GROSS WEIGHT = 2300 LBS"
80 PRINT "           APPROACH = 60 KNOTS IAS"
90 PRINT
100 PRINT "INPUT DATA:"
110 PRINT
120 INPUT "AIRPORT ELEVATION, FT    ",E
130 PRINT
140 INPUT "HEAD WIND, KNOTS         ",H
150 E1=2.17828
160 V1=1-.02*H
170 V2=.00002045*E
180 V3=V1*1248.3
190 V4=E1^V2
200 F=V3*V4
210 F=INT(F)
220 PRINT
230 PRINT"LANDING DISTANCE OVER 50 FT OBSTACLE = ",F," FT"
240 PRINT\PRINT
250 PRINT"CHOOSE FUNCTION:                          ENTER:"
260 PRINT
270 PRINT"TO RETURN TO AIRCRAFT PERFORMANCE MENU .... 1"
280 PRINT"TO RETURN TO CLIMB PERFORMANCE MENU ....... 2"
290 PRINT"TO CALCULATE ANOTHER LANDING PERFORMANCE .. 3"
300 PRINT"TO RETURN TO MASTER MENU .................. 4"
310 INPUT X\PRINT\PRINT
320 IF X=1 THEN CHAIN "TOPRF"
330 IF X=2 THEN CHAIN "CLBPRF"
340 IF X=3 THEN GOTO 10
350 IF X=4 THEN CHAIN "MASTER"
360 GOTO 240
```

5.7 VORFIX PROGRAM

FIGURE 5.7-1 FLOW CHART FOR VORFIX



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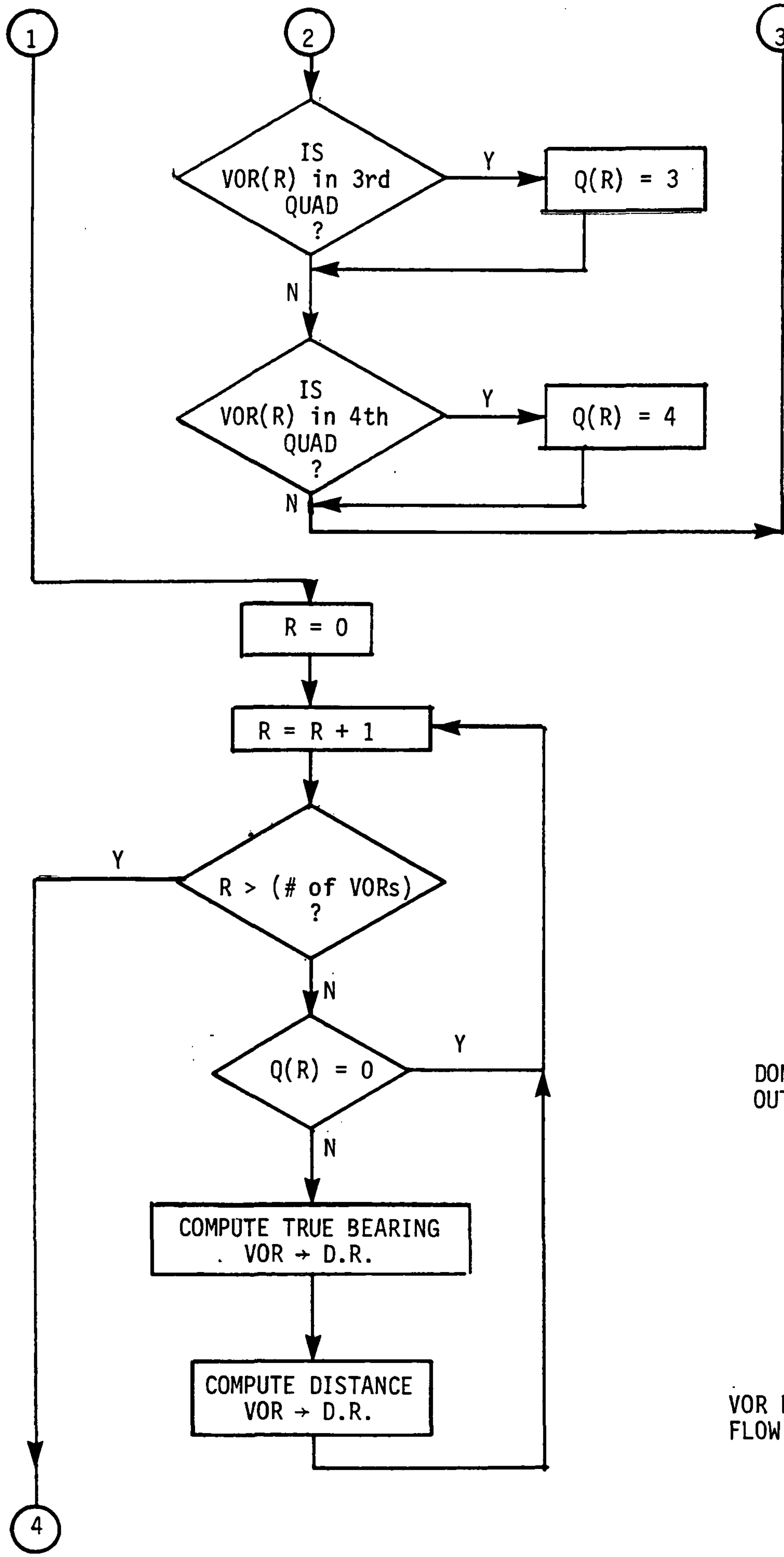
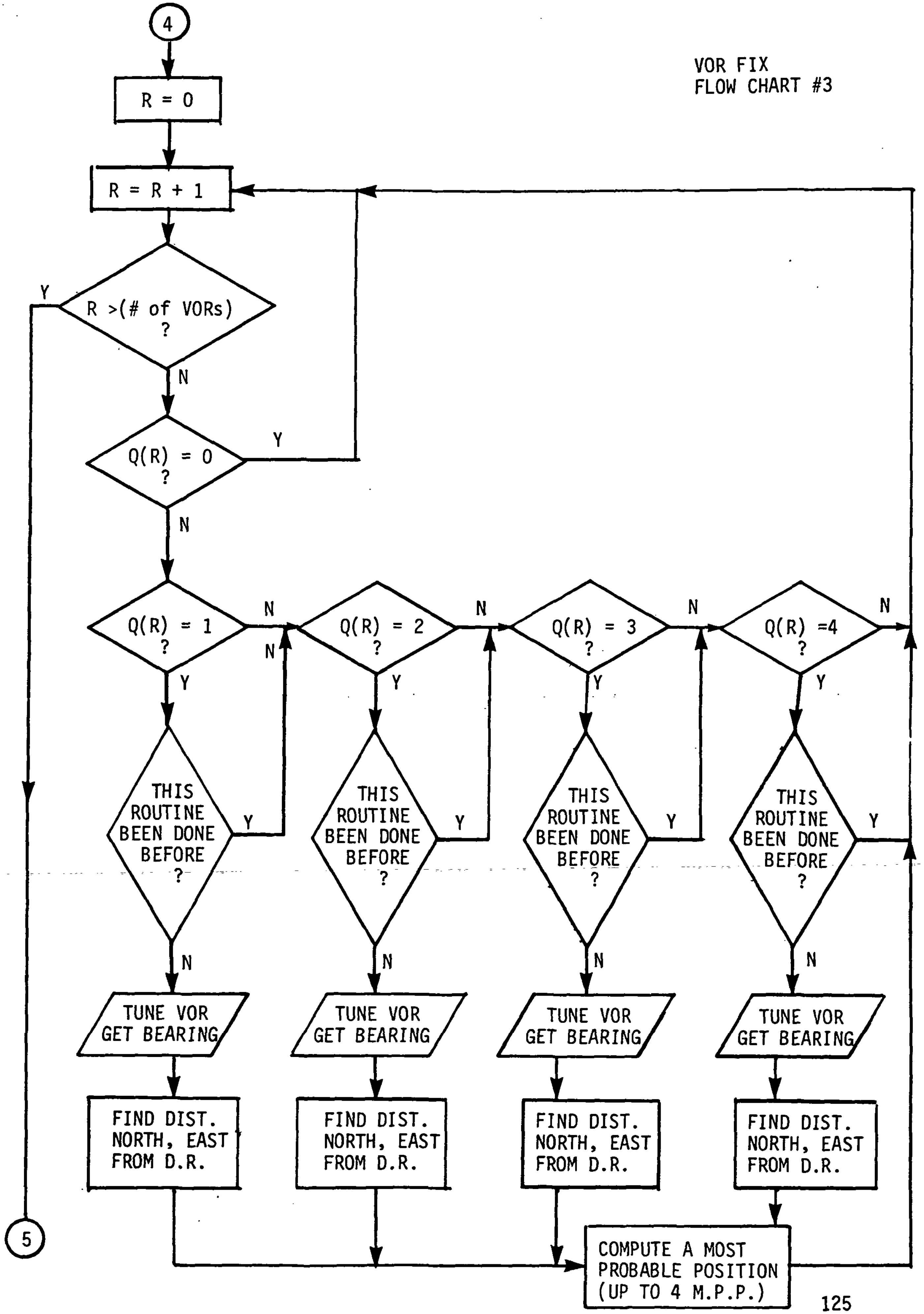
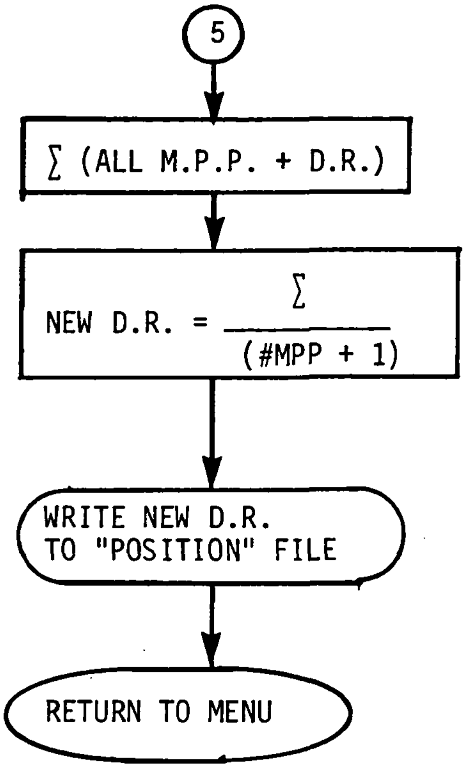


DON'T DO IF VOR IS
OUT OF RANGE

VOR FIX
FLOW CHART #2

VOR FIX
FLOW CHART #3





AVERAGE ALL POSITIONS
FOR UPDATE

VOR FIX
FLOW CHART #4

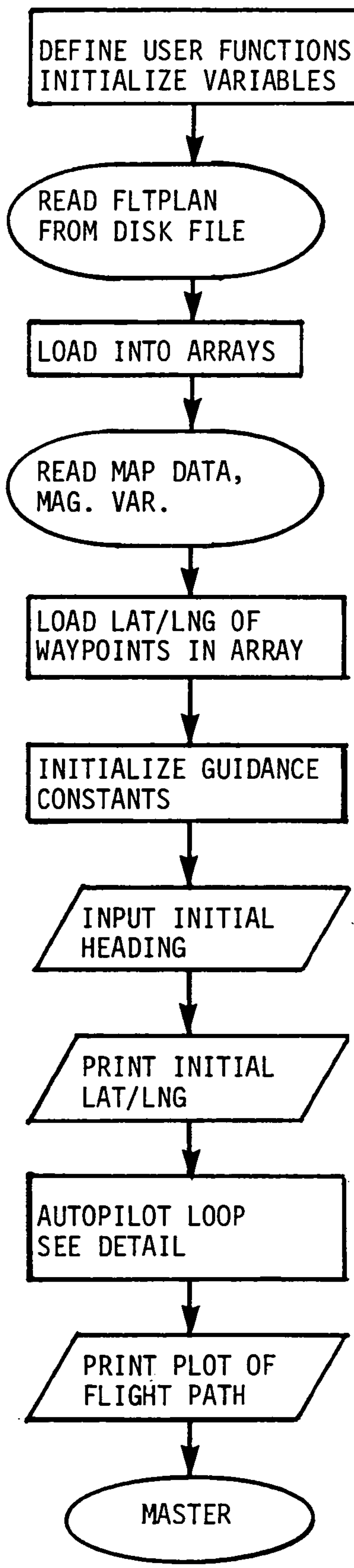
```
10 REM  VORFIX
20 REM  UPDATE POSITION BY 2 VOR BEARINGS
30 REM
40 REM    PLAN
50 REM 1. LOAD ALL VORS FROM MAP DATA BASE.
60 REM 2. SELECT ALL VORS WHICH ARE WITHIN 1'LAT & 1'LNG OF
70 REM    BELEIVED POSITION.
80 REM 3. COMPUTE BEARING FROM VOR TO DR POSITION.
90 REM 4. CORRECT BEARING FOR WHICH QUADRANT THE VOR IS IN
100 REM    WITH RESPECT TO THE DR POSITION.
110 REM 5. COMPUTE DIST FROM VOR TO DR POSITION.
120 REM 6. SELECT VOR FOR EACH QUADRANT, ONLY ONE PER QUADRANT.
130 REM 7. TUNE RADIOS, GET ACTUAL BEARING FROM VOR.
140 REM 8. COMPUTE DISTANCE OFF COURSE, DIST NORTH, DIST EAST.
150 REM 9. AVERAGE LAT & LNG UPDATES FOR NEW DR POSITION, WRITE
160 REM    TO DISK, CHAIN TO A MENU OR FLTCTRL
170 DEF FNR(X)=X*3.141592654/180
180 DEF FND(X)=X*180/3.141592654
190 DEF FNT(X)=SIN(X)/COS(X)
200 REM ********** LOAD VORS FROM MAP DATA BASE ***************
210 OPEN #0,"0422"
220 READ #0,M,P,N    \REM  MAG VAR, # OF VOR PARAMETERS, # OF VORS
230 DIM V(P-1,N),V$(N*3)
240 FOR W=1 TO N
250  READ #0,X$      \REM  GET VOR NAME
260  V$=V$+X$
270  FOR X=1 TO P-1
280   READ #0,V(X,L) \REM  GET VOR PARAMETERS
290  NEXT X
300 NEXT W
310 N1=N
320 CLOSE #0
330 REM  VOR PARAMETERS ARE,
340 REM  #CODE,FREQ,LAT,LNG
350 REM ********* SELECT VORS WITHIN 1'LAT AND 1'LNG ***********
360 OPEN #0 POSITION
370 READ #0, L,N
380 FOR R=1 TO N1
390  IF V(3,R)<L-1 OR V(3,R)>L+1 THEN 470
400  IF V(4,R)<N-1 OR V(4,R)>N+1 THEN 470
410  S=S+1
420 REM ******** Q(R) IS QUADRANT VOR IS IN W/RESPECT TO DR *******
430  IF V(3,R)>L AND V(4,R)>N THEN Q(R)=1
440  IF V(3,R)<L AND V(4,R)>N THEN Q(R)=2
450  IF V(3,R)<L AND V(4,R)<N THEN Q(R)=3
460  IF V(3,R)>L AND V(4,R)<N THEN Q(R)=4
470 NEXT
480 FOR R=1 TO N1
490  IF Q(R)=0 THEN 670
500 REM ******** B(R) IS BEARING FROM VOR TO DR ************
```

```
510  J2=V(4,R)-N
520  J3=P/4+FNR(L)/2
530  J4=P/4+FNR(V(3,R))/2
540  J5=LOG(FNT(J3))-LOG(FNT(J4))
550  J6=ATN(ABS(FNR(J2/J5)))
560  J7=FND(J6)
570  IF Q(R)=1 THEN B(R)=J7+180
580  IF Q(R)=2 THEN B(R)=360-J7
590  IF Q(R)=3 THEN B(R)=J7
600  IF Q(R)=4 THEN B(R)=180-J7
610 REM ******** D(R) IS DIST FOR VOR TO DR ****************
620  IF B(R)=270 OR B(R)=90 THEN 650
630  D(R)=60*(L-V(3,R))/COS(FNR(J6))
640  GOTO 660
650  D(R)=60*(N-V(4,R))*COS(FNR(L))
660  D(R)=ABS(D(R))
670 NEXT R
680 FOR R=1 TO N1
690  IF Q(R)=0 THEN 710
700  ON Q(R) GOSUB 730,830,930,1030
710 NEXT R
720 GOTO 1190
730 REM ********** VOR IN 1ST QUAD ************
740 IF Q1<>0 THEN RETURN
750 Q1=1                          \REM ONLY 1 VOR / QUAD
760 U=U+1
770 GOSUB 1150
780 T=A-B(R)
790 D1=D(R)*SIN(FNR(T))
800 D2= D1*SIN(FNR(A-180))     \REM DIST NORTH
810 D3=-D1*COS(FNR(A-180))     \REM DIST EAST
820 GOTO 1120
830 REM ********** VOR IN 2ND QUAD ************
840 IF Q2<>0 THEN RETURN
850 Q2=1                          \REM ONLY 1 VOR / QUAD
860 U=U+1
870 GOSUB 1150
880 T=A-B(R)
890 D1=D(R)*SIN(FNR(T))
900 D2= D1*SIN(FNR(A-180))     \REM DIST NORTH
910 D3= D1*COS(FNR(A-180))     \REM DIST EAST
920 GOTO 1120
930 REM ********** VOR IN 3RD QUAD ************
940 IF Q3<>0 THEN RETURN
950 Q3=1                          \REM ONLY 1 VOR / QUAD
960 U=U+1
970 GOSUB 1150
980 T=A-B(R)
990 D1=D(R)*SIN(FNR(T))
1000 D2=-D1*SIN(FNR(A-180))     \REM DIST NORTH
```

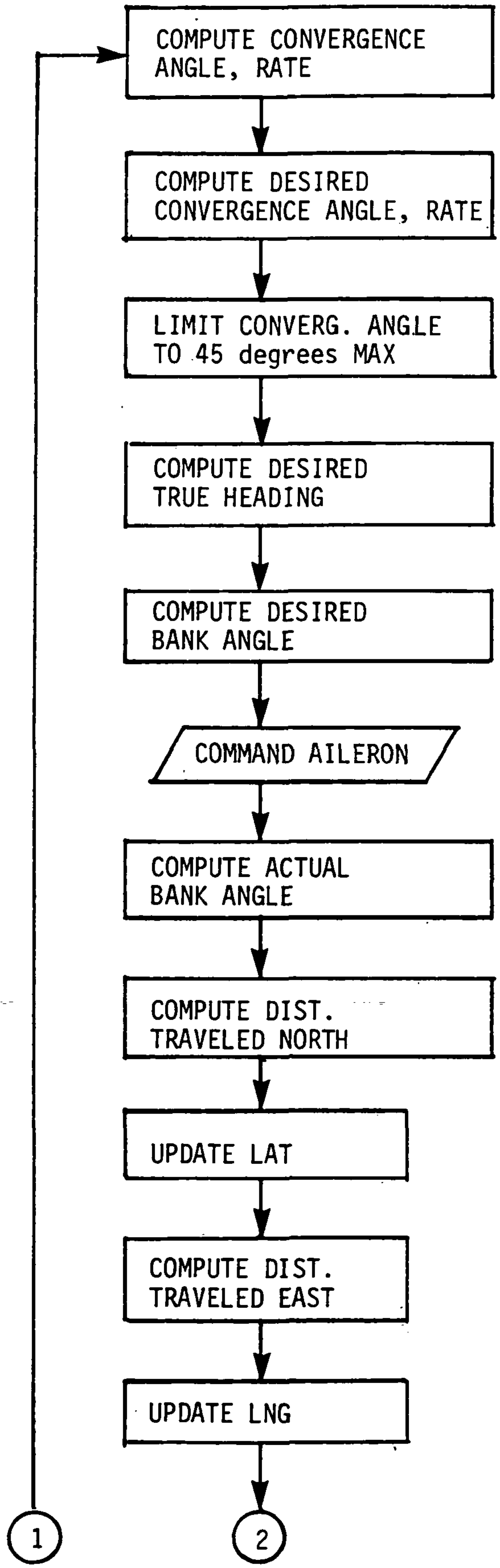
```
1010 D3= D1*COS(FNR(A-180))     \REM DIST EAST
1020 GOTO 1120
1030 REM ********** VOR IN 4TH QUAD ************
1040 IF Q4<>0 THEN RETURN
1050 Q4=1                        \REM ONLY 1 VOR / QUAD
1060 U=U+1
1070 GOSUB 1150
1080 T=A-B(R)
1090 D1=D(R)*SIN(FNR(T))
1100 D2=-D1*SIN(FNR(A-180))     \REM DIST NORTH
1110 D3=-D1*COS(FNR(A-180))     \REM DIST EAST
1120 L(U)=L+D2/60
1130 N(U)=N+(D3/60)*COS(FNR(L))
1140 RETURN
1150 !"COMPUTED BEARING FRM VOR IS ",B(R)
1160 !"COMPUTED DISTANCE TO VOR IS ",D(R)
1170 INPUT "ACTUAL BEARING FROM VOR ? ",A
1180 RETURN
1190 FOR R=1 TO U
1200  L1=L1+L(U)
1210  N1=N1+N(U)
1220 NEXT
1230 L1=L1/U                    \REM  UPDATE LAT
1240 N1=N1/U                    \REM  UPDATE LNG
1250 OPEN #0, POSITION
1260 WRITE #0, L1,N1
1270 !"UPDATED LAT             UPDATED LNG"
1280 !INT(L1)+(L1-INT(L1))*.6,"          ",INT(N1)+(N1-INT(N1))*.6
1290 REM *** PUT A CHAIN HERE
```

5.8 LATERAL FLIGHT CONTROL

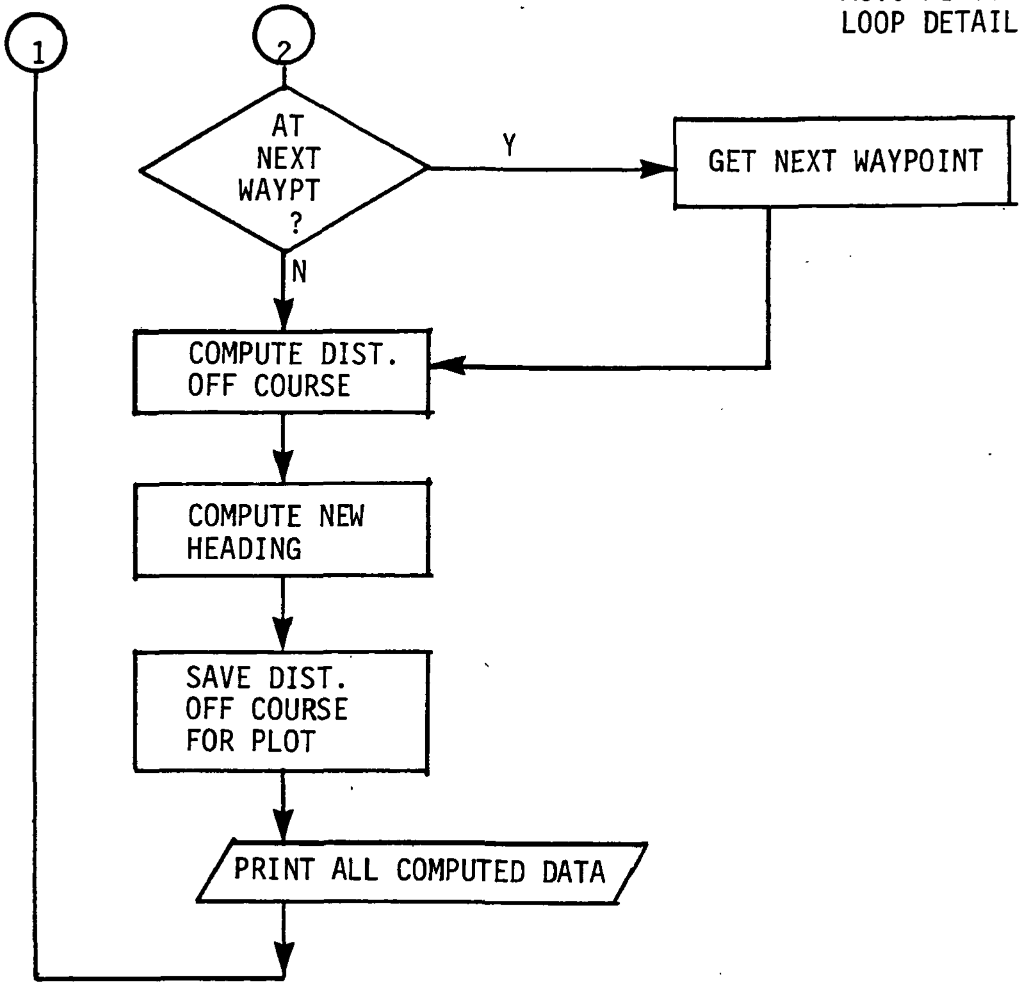
FIGURE 5.8-1 FLTCTRL FLOW CHART . . . . FLIGHT CONTROL FLOW CHART



AUTO PILOT LOOP DETAIL



AUTO PILOT
LOOP DETAIL (CONT.)



```
10 REM FLTCTRL
20 REM LATERAL GUIDANCE FOR BAM
30 LINE 80
40 A=CALL(10608,25)\A=CALL(10608,11)
50 K1=.02
60 K2=2                 \REM  2'BANK/DEG HDG ERROR
70 K4=1                 \REM  AILERON GAIN
80 K5=3600              \REM  DEG/HR AILERON RESPONSE
90 P1=3.141592654
100  REM CONVERT DEG.MIN -> DECIML DEG
110 DEF FND(X)=INT(X)+(X-INT(X))/.6
120  REM ARCSIN FUNCTION
130 DEF FNS(S)
140 X=1.5707288-.2121144*S+.0742610*S^2-.0187293*S^3
150 X=P1/2-SQRT(1-S)*X
160 RETURN X
170 FNEND
180  REM  CONVERT DEGREES -> RADIANS
190 DEF FNR(X)=X*P1/180
200  REM TANGENT
210 DEF FNT(X)=SIN(X)/COS(X)
220  REM ROUND TO 3 DECIMAL PLACES
230 DEF FNF(X)=INT(X*1000+.5)/1000
240 B1=15\B2=33\B3=50
250 OPEN #2,"FPDATA"
260 DIM L(20),N(20),Y(50)
270 DIM F(20,11)
280 REM ******************** LOAD FLT PLN AS ENTERED ******************
290 REM  G1=INIT FUEL\H1=OAT AT AIRPORT\D1=WIND DIRECTON\W1=WINDSPEED
300 REM  T1=CRUISE %BHP\T2=ETD\P$=INIT MAP #
310  READ #2,G1,H1,D1,W1,T1,T2,P$
320 REM  F(R,R1) IS FLIGHT PLAN AS ENTERED IN FLTPLN & FLTPLNUP
330 REM  R(R,1)= FROM WAYPOINT CODE
340 REM  F(R,2)= TO WAYPOINT CODE
350 REM  F(R,3)= MAG COURSE
360 REM  F(R,4)= DIST  NT. MI
370 REM  F(R,5)= MAG HEADING (WIND CORRECTED COURSE)
380 REM  F(R,6)= ETER  HOURS
390 REM  F(R,7)= EGS KNOTS (WIND CORRECTED TAS)
400 REM  F(R,8)= ALT  FEET
410 REM  F(R,9)= RESERVES  GAL
420 REM  F(R,10)= RESERVES  HRS
430 REM  F(R,11)= TAS  KNOTS
440 FOR R=0 TO 20          \REM LOAD ORIGINAL FLIGHT PLAN
450  FOR R1=1 TO 11
460   READ #2,F(R,R1)
470  NEXT R1
480  IF TYP(2)=0 THEN 500
490 NEXT R                 \REM  NOTE R IS THE NUMBER OF WAYPOINTS
500 REM ******************** LOAD MAP DATA BASE *******************
510 OPEN #0,P$
520 O$=P$
530 READ #0,M,M1,F1    \ REM          LOAD VOR DATA,MAGVAR
540 DIM V(M1-1,F1),V$(3),Z$(F1*3)
550 FOR W=1 TO F1
560  READ #0,V$
570  Z$=V$+Z$
580  FOR X=1 TO M1-1
590   READ #0,V(X,W)
600  NEXT X
```

```
610 NEXT W
620 READ #0,P2,F2    \ REM          LOAD INTERSECTION DATA
630 DIM T(P2-1,F2),N$(5),R$(F2*5)
640 FOR W=1 TO F2
650  READ #0,N$
660  R$=N$+R$
670  FOR X=1 TO P2-1
680   READ #0,T(X,W)
690  NEXT X
700 NEXT W
710 READ #0,P3,F3    \ REM          LOAD AIRPORT DATA
720 DIM A(P3-1,F3),A$(6),S$(F3*6)
730 FOR W=1 TO F3
740  READ #0,A$
750  S$=A$+S$
760  FOR X=1 TO P3-1
770   READ #0,A(X,W)
780  NEXT X
790 NEXT W
800 READ #0,P4,F4    \ REM          LOAD ILS DATA
810 DIM I(P4,F4),I$(4),T$(F4*4)
820 FOR W=1 TO F4
830  READ #0,I$
840  T$=I$+T$
850  FOR X=1 TO P4-1
860   READ #0,I(X,W)
870  NEXT X
880 NEXT W
890 READ #0,P5,F5     \ REM          LOAD NDB DATA
900 DIM B(P5-1,F5),B$(4),U$(F5*4)
910 FOR W=1 TO F5
920  READ #0,B$
930  U$=B$+U$
940  FOR X=1 TO P5-1
950   READ  #0,B(X,W)
960  NEXT X
970 NEXT W
980 CLOSE #0
990 REM *************** END OF MAP LOAD ***********************
1000 REM ****GET FLIGHT PATH FROM WAYPOINT N TO WAYPOINT N+1****
1010 FOR N=0 TO R
1020  GOSUB 1050      \REM  LOAD LAT & LNG ARRAYS
1030 NEXT N
1040 GOTO 1590
1050 REM ************** SELECT WHAT WAYPOINT IS *******************
1060 IF F(N,1)<1000 THEN 1460     \REM    WAYPT IS A VOR
1070 IF F(N,1)<10000 THEN 1170    \REM    WAYPT IS NDB OR ILS
1080 IF F(N,1)<100000 THEN 1370   \REM    WAYPT IS AN INTRSECTION
1090 FOR W=0 TO F3-1       \REM   WAYPT IS AN AIRPORT
1100  IF A(1,W+1)=F(N,1)THEN 1130
1110 NEXT W
1120 GOTO 1540
1130 G$=S$(6*(F3-W)-5,6*(F3-W))
1140 L(N)=A(3,W+1)       \REM  ASSIGN LAT
1150 N(N)=A(4,W+1)         \REM  ASSIGN LONG
1160 RETURN
1170 IF F(N,1)<5000 THEN 1260
1180 FOR W=0 TO F5-1         \ REM WYPT IS NDB
1190  IF B(1,W+1)=F(N,1)THEN 1220
1200 NEXT W
```

```
1210 GOTO 1540
1220 G$=U$(4*(F5-W)-3,4*(F5-W))
1230 L(N)=B(3,W+1)      \REM  ASSIGN LAT
1240 N(N)=B(4,W+1)        \REM  ASSIGN LONG
1250 RETURN
1260 IF F(N,1)>4000 THEN 1290
1270 REM B IS A NDB
1280 GOTO 1180
1290 FOR W=0 TO F4-1       \REM    WAYPT IS AN ILS
1300  IF I(1,W+1)=F(N,1)THEN 1330
1310 NEXT W
1320 GOTO 1540
1330 G$=T$(4*(F4-W)-3,4*(F4-W))
1340 L(N)=I(3,W+1)      \REM  ASSIGN LAT
1350 N(N)=I(4,W+1)        \REM  ASSIGN LONG
1360 RETURN
1370 FOR W=0 TO F2-1        \REM    WAUPT IS AN INTERSECTION
1380  IF T(1,W+1)=F(N,1)THEN 1410
1390 NEXT W
1400 GOTO 1540
1410 G$=R$(5*(F2-W)-4,5*(F2-W))
1420 L(N)=T(3,W+1)     \REM ASSIGN LAT
1430 N(N)=T(4,W+1)     \REM ASSIGN LNG
1440 C2=T(2,W+1)*100
1450 RETURN
1460 FOR W=0 TO F1-1         \ REM WYPT IS VOR
1470  IF V(1,W+1)=F(N,1)THEN 1500
1480 NEXT W
1490 GOTO 1540
1500 G$=Z$(3*(F1-W)-2,3*(F1-W))
1510 L(N)=V(3,W+1)     \REM ASSIGN LAT
1520 N(N)=V(4,W+1)        \REM  ASSIGN LONG
1530 RETURN
1540 !
1550 !"*******ERROR WAYPT NOT ON FILE*******"
1560 !
1570 !"BOMBING OUT! CHECK WAYPOINT CODE!!"
1580 END
1590 REM ************* BEGIN GUIDANCE AT WAYPOINT #0 *************
1600 B3=0                \REM  BANK ANGLE INITIALLY 0
1610 G=69552             \REM  ACELLERATION OF GRAVITY, MI/HR^2
1620 T=1/3600            \REM  1 SEC IN HOURS
1630 W=0                 \REM  W=FROM WAYPOINT NUMBER
1640 L=FND(L(W))         \REM  INIT DECIML LAT
1650 N=FND(N(W))         \REM  INIT DECIML LNG
1660 L1=FND(L(W+1))      \REM  NEXT DECIML LAT
1670 N1=FND(N(W+1))      \REM  NEXT DECIML LNG
1680 C1=F(W,3)           \REM  MAG COURSE
1690 C=C1-M              \REM  TRUE COURSE
1700 D=F(W,4)            \REM  DIST FROM W(W) TO W(W+1)
1710 S=F(W,11)           \REM  TAS
1720 B1=ATN(3*S/19.2)    \REM  MAX BANK ANGLE
1730 B1=B1*180/P1        \REM      IN DEGREES
1740 IF B1>45 THEN B1=45
1750 INPUT "INIT HDG:",H
1760 !   "INIT LAT   INIT LNG    FINAL LAT    FINAL LNG"
1770 !   L,"    ",N,"    ",L1,"    ",N1,"    "
1780 IF W>0 THEN 1810
1790 Y=0                 \REM  AT AIRPORT, Y=0
1800 GOTO 1840
```

```
1810 GOSUB 2410         \REM  GET COURSE (C3) AND DIST (D)
1820 C2=C3-C            \REM  ANGLE OFF COURSE
1830 Y=D*SIN(FNR(C2))   \REM  Y=DIST OFF COURSE
1840 !"INIT DIST OFF COURSE =",Y
1850 !"MAX BANK ANGL=",B1
1860 !"HDG",TAB(10),"A CONV A",TAB(20),"A CONV R",TAB(30),"D CONV A",
1870 !TAB(40),"Y"       ,TAB(50),"D BANK",TAB(60),"BANK C",TAB(70),
1880 !"BANK"
1890 FOR Q=1 TO 50      \REM ******* BEGIN MINOR LOOP *******
1900 H9=H-C             \REM ACTUAL CONVERGENCE ANGLE
1910 Y1=-S*SIN(FNR(H9))\REM ACTUAL CONVERGENCE RATE
1920 Y2=-Y/K1           \REM DESIRED CONVERGENCE RATE
1930 H8=FNS(-Y2/S)      \REM DESIRED CONVERGENCE ANGLE
1940 H8=H8*180/P1       \REM DESIRED CONV ANGLE IN DEGREES
1950 IF H8>45 THEN H8=45
1960 H1=H8+C            \REM DESIRED TRUE HEADING
1970 B=K2*(H8-H9)       \REM DESIRED BANK ANGLE
1980 IF B>B1 THEN B=B1
1990 B9=K4*(B-B3)       \REM AILERON DEFLECTION COMMAND
2000 IF B9>15 THEN B9=15
2010 B3=B3+K5*B9*T      \REM ACTUAL BANK ANGLE
2020 D1=S*COS(FNR(H))*T
2030 L=L+D1/60          \REM UPDATE LAT
2040 D2=S*SIN(FNR(H))*T
2050 N=N-D1/(60*COS(FNR(L)))
2060 IF ABS(L-L1)<.001 AND ABS(N-N1)<.001 THEN EXIT 2330
2070 Y=Y+Y1*T           \REM NEW DIST OFF COURSE
2080                     REM NEW HDG
2090 H=H+(G/S)*FNT(FNR(B3))*T*180/P1
2100 Y(Q)=Y             \REM SAVE DIST OFF COURSE FOR PLOT
2110 D=D-S*T
2120 !INT(H),TAB(10),INT(H9*100)/100,TAB(20),FNF(Y1),TAB(30),FNF(H8),
2130 !TAB(40),FNF(Y),TAB(50),INT(B*10)/10,TAB(60),INT(B9*10)/10,
2140 !TAB(70),INT(B3*10)/10
2150 NEXT Q             \REM ******* END MINOR LOOP *******
2160 !"END MINOR LOOPS"
2170 LINE 80
2180 X=Y(1)             \REM  FIND MAX DIST OFF COURSE
2190 FOR Q=2 TO 50
2200 IF ABS(X)<ABS(Y(Q)) THEN X=Y(Q)
2210 NEXT Q
2220 IF X=0 THEN 2240
2230 E=79/(X*2)         \REM  TAB FACTOR TO XPAND PLOT FULL SCREEN
2240 FOR Q=1 TO 50      \REM  PLOT DIST OFF COURSE
2250 IF Y(Q)*E>-1AND Y(Q)*E<0 THEN Y(Q)=Y(Q)-1/E
2260 IF Y(Q)>0 THEN PRINT TAB(40),":",TAB(Y(Q)*E+40),"*"
2270 IF Y(Q)<0 THEN PRINT TAB(40-Y(Q)*E),"*",TAB(40),":"
2280 IF Y(Q)=0 THEN PRINT TAB(40),"*"
2290 NEXT Q
2300 !"LAT=",L
2310 !"LNG=",N
2320 GOTO 1890
2330 W=W+1
2340 GOSUB 1050
2350 PRINT "FROM ",G$,"    TO ",
2360 W=W+1
2370 GOSUB 1050
2380 !G$
2390 W=W-1
2400 GOTO 1660
```

```
2410 REM  FIND COURSE BETWEEN TWO LAT/LNG COORDINATES
2420 J2=P1/4+FNR(L1)/2
2430 J3=P1/4+FNR(L)/2
2440 J4=FNR(N)-FNR(N1)
2450 J5=LOG(FNT(J2))-LOG(FNT(J3))
2460 J6=ABS(J4/J5)
2470 J8=ATN(J6)
2480 C=J8*180/P1        \REM  RETURN TRUE COURSE
2490 IF L>L1 AND N>N1 THEN C=180-C
2500 IF L>L1 AND N<N1 THEN C=180+C
2510 IF L<L1 AND N<N1 THEN C=360-C
2520 REM  FIND DIST BETWEEN TWO LAT/LNG COORDINATES
2530 REM  NOTE THIS ROUTINE MUST BE DONE AFTER THE 40000 ROUTINE
2540 D=60*(L-L1)/COS(J8)
2550 RETURN
```

6.0 CONCLUSIONS AND RECOMMENDATIONS

The BAM design for General Aviation Aircraft has verified that a low cost, microprocessor based avionics system can be defined to aid the single pilot during IFR conditions in the low end of the General Aviation Aircraft spectrum.

The design study has validated the concept of a navigation system utilizing waypoints stored in a navigation map data base. The concept of an area navigation system using dead reckoning updated by a navigation aid such as dual VOR has been shown to be sound. Such a concept for which the update method is transparent to the pilot provides a sound basis for future upgrades of the US navigation facilities such as the introduction of NAVSTAR/GPS.

Considerable work remains to integrate all of the BAM software into an operationally usable system. This BAM study has been a start in that direction with some of the critical software modules addressed.

A number of the software modules require a dynamic simulation environment to validate, which was beyond the scope of the BAM study. For example the VOR update requires a dynamic simulation to complete the VOR RNAV module. A critical module used for VOR RNAV is the VORFIX module which was completed during the BAM study.

The navigation map display used a graphics module with 128 x 128 resolution display format without high resolution alphanumerics superimposed. The study showed this format to be unsatisfactory. A 512 x 512 resolution graphics mode with superimposed alphanumerics is necessary for an acceptable NAV MAP display.

The programming in BASIC using an interpreter loaded into RAM proved to be an effective way to develop the BAM demonstration software rapidly. Making changes is very easy. The disadvantage is the excessive memory used and the relatively slow execution time caused by the interpreter compared to a compiled program for example.

Implementing the RNAV outer loop guidance in the distributed microcomputer (DMC) appears to be a reasonable approach. The short period dutch roll dynamics were not included in the closed loop demonstrations, however, it is not believed that including these dynamics would change the results since the natural frequency of the outer loop guidance mode is considerable lower frequency than the dutch roll. The DMC commands an aileron deflector to satisfy the lateral flight control equations. An analog yaw rate loop is closed in the off the shelf autopilot to provide turn coordination.

Both the handbook checklists and IFR checklists were included in the BAM preliminary software. It appears that having the additional IFR checklists would be helpful to the single pilot during IFR to prompt him on procedures that a copilot would otherwise help him to remember. The BAM acts as a surrogate copilot.

The following recommendations are offered as a result of the BAM design study:

1. The hardware for the NASA Langley simulation and flight test R&D can use the type of microcomputer hardware utilized by MILCO for software development provided: a. A suitable DC power supply is incorporated in the DMC b. Provision is made to constrain the cards in the DMC card cage with some appropriate mechanical means.

2. The mounting of a 9 inch TV in the cockpit poses a difficult installation problem which could be costly. It is recommended that the TV be mounted on a slanted bracket located near the center of the control panel console. The TV longitudinal axis would be about 60 deg relative to the horizontal with the TV display pointing up towards the pilot. The ADCC "telephone" keyboard data entry panel can be mounted near by.

3. A dual floppy disk should be used for storing the NAV MAP data base and application programs during the NASA Langley R&D program The data base and programs can be stored on EPROMs to eliminate the need to fly the floppy disks during the mature stages of the R&D program. However, there should be no problems in flying the floppy disks. The advantage of using floppy disks is the ease of making software changes during the R&D. The use of EPROMs makes changes much more difficult.

4. The operational software should be written in a higher order language such as FORTRAN IV which has an efficient microcomputer oriented compiler. The compiler should be resident in the 8085 microcomputer rather than use a cross compiler. MILCO has acquired a true FORTRAN IV compiler from MICROSOFT which will operate on the MILCO 8085 microcomputer, however the compiler was not used during the BAM design program. The translation of BASIC into FORTRAN IV is a fairly straight forward process.

5. The low cost electropneumatic sensors developed by NASA Langley are recommended for the BAM dead reckoning sensors. The availability of a good low cost true airspeed sensor significantly simplifies the sensor computations. MILCO presented and alternate method based on absolute and differential pressure transducers and OAT transducer to compute TAS in the midterm briefing.

6. A parallel data bus is recommended rather than a serial bus in order to have a moderate byte data rate without using very high serial bit rates. MILCO has found that components to implement the IEEE 488 bus are currently more available and considerably cheaper than the components to implement the 1553 bus.

7. It is recommended that the three navigation radios be placed on the IEEE 488 bus to redice the number of wires from the navigation radios from 96 to 16 wires. This would require building a IEEE 488 bus interface unit located adjacent to the radios.

8. It is recommended that the BAM be implemented for simulation and flight test by NASA Langley as a cost effective avionics research tool.

APPENDIX A LATERAL DIRECTIONAL TRANSFER FUNCTIONS FOR AIRPLANE "A"

The lateal directional transfer functions for airplane "A" presented in this section can be used for point stability analyses of the flight control equations presented in section 2.5. The level of effort on the BAM design did not permit a detailed stability design of the BAM lateral flight control system.

Figure A-1 and A-2 presents the lateral transfer functions in terms of the aircraft stability.

The numerical values for aircraft A stability derivatives at two flight conditions: cruise at 5000 feet and approach are taken from reference 1 and attached for reference as tables A-10, A-12, and A-14.

FIGURE A-2 LATERAL DIRECTIONAL TRANSFER FUNCTION IN TERMS OF STABILITY DERIVATIVES

$$\frac{\phi(s)}{\delta(s)} = \frac{\begin{vmatrix} (sU_1 - Y_\beta) & Y_\delta & s(U_1 - Y_r) \\ -L_\beta & L_\delta & -(s^2A_1 + sL_r) \\ -N_\beta - N_{T_\beta} & N_\delta & (s^2 - sN_r) \end{vmatrix}}{\Delta_2} = \frac{N_\phi}{D_2}$$

$$\boxed{N_\phi = s(A_\phi s^2 + B_\phi s + C_\phi)}$$

$$A_\phi = U_1(L_\delta + N_\delta A_1)$$

$$B_\phi = U_1(N_\delta L_r - L_\delta N_r) - Y_\beta(L_\delta + N_\delta A_1) + Y_\delta(L_\beta + N_\beta A_1 + N_{T_\beta} A_1)$$

$$C_\phi = -Y_\beta(N_\delta L_r - L_\delta N_r) + Y_\delta(L_r N_\beta + L_r N_{T_\beta} - N_r L_\beta) + (U_1 - Y_r)(N_\beta L_\delta + N_{T_\beta} L_\delta - L_\beta N_\delta)$$

$$\boxed{D_2 = s(As^4 + Bs^3 + Cs^2 + Ds + E)}$$

$$A = U_1(1 - A_1B_1)$$

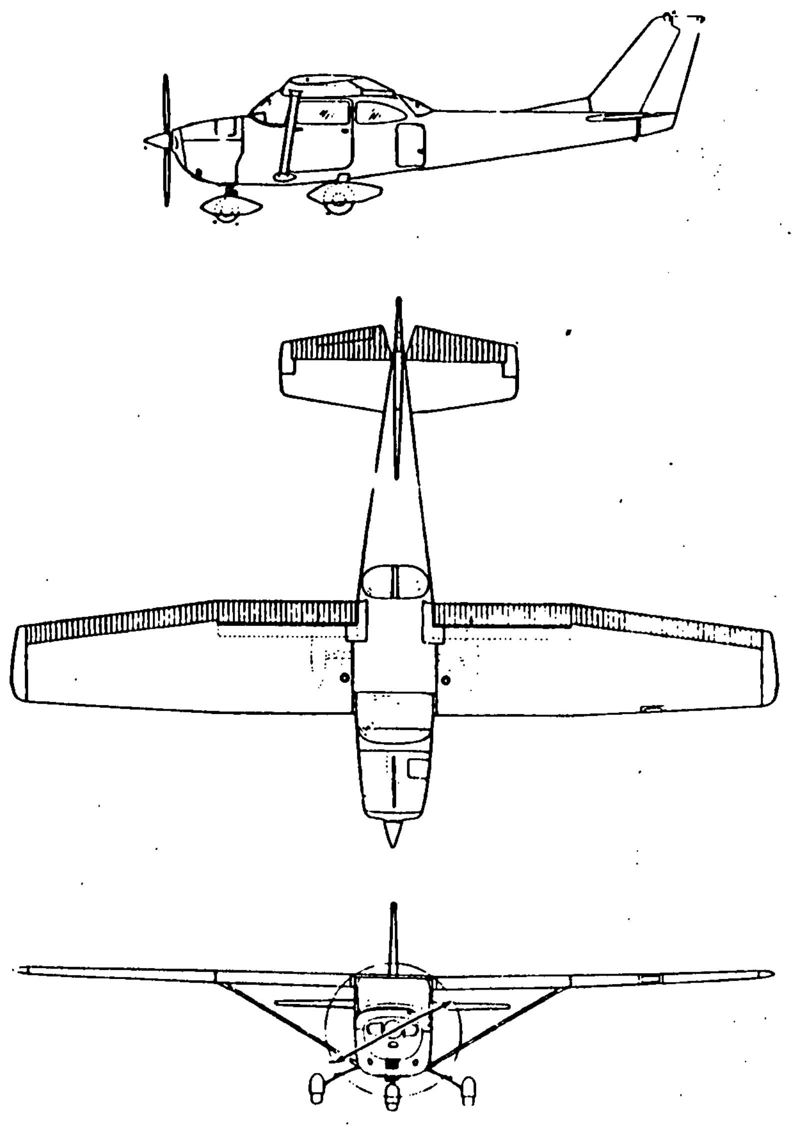
$$B = -Y_\beta(1 - A_1B_1) - U_1(L_p + N_r + A_1N_p + B_1L_r)$$

$$C = U_1(L_pN_r - L_rN_p) + Y_\beta(N_r + L_p + A_1N_p + B_1L_r) - Y_p(L_\beta + N_\beta A_1 + N_{T_\beta} A_1) + U_1(L_\beta B_1 + N_\beta + N_{T_\beta}) - Y_r(L_\beta B_1 + N_\beta + N_{T_\beta})$$

$$D = -Y_\beta(L_pN_r - L_rN_p) + Y_p(L_\beta N_r - N_\beta L_r - N_{T_\beta} L_r) - g\cos\theta_1(L_\beta + N_\beta A_1 + N_{T_\beta} A_1) + U_1(L_\beta N_p - N_\beta L_p - N_{T_\beta} L_p) - Y_r(L_\beta N_p - N_\beta L_p - N_{T_\beta} L_p)$$

$$E = g\cos\Theta_1(L_\beta N_r - N_\beta L_r - N_{T_\beta} L_r)$$

FIGURE A-1 LATERAL DIRECTIONAL AIRPLANE TRANSFER FUNCTIONS



$$\frac{\phi(s)}{\delta_A(s)} = K_{\phi_{\delta_A}} \frac{\left(\frac{s^2}{\omega_{n_{\phi_A}}^2} + \frac{2\zeta_{\phi_A}}{\omega_{n_{\phi_A}}} s + 1\right)}{(T_S s + 1)(T_R s + 1)\left(\frac{s^2}{\omega_{n_D}^2} + \frac{2\zeta_D}{\omega_{n_D}} s + 1\right)} = \frac{N\phi}{D_2}$$

AIRPLANE "A"

Table A10 Aerodynamic, Geometric and Inertial Characteristics of Airplane A. Flight Condition: 5,000 ft, 219 ft/sec

INPUT

WING AREA,SQ.FT.		174.00
WEIGHT,LBS.		2645.00
WING SPAN,FT.		35.8000
MEAN AERODYNAMIC CHORD,FT.		4.9000
AIRSPEED,FT./SEC.		219.00
DENSITY,SLUGS/CU.FT.		0.00205000
INITIAL THETA,RAD.		0.
IYY,SLUG-SQ.FT.		1346.
IXX,SLUG-SQ.FT.		948.
IZZ,SLUG-SQ.FT.		1967.
IXZ,SLUG-SQ.FT.		0.
CL1,-----	0.3100	
CD1,-----	0.0310	
CTX1,----	0.0310	
CM1,-----	0.	
CMT1,----	0.	

NONDIMENSIONAL DERIVATIVES		DIMENSIONAL DERIVATIVES	
LONGITUDINAL DERIVATIVES			
CMU,-----	0.	MU ,RAD/FT /SEC	0.
CMA,-----	-0.8900	MA ,RAD/SEC/SEC	-27.7142
CMAD,----	-5.2000	MAD,RAD/SEC/	-1.8115
CMQ,-----	-12.4000	MQ ,RAD/SEC/	-4.3197
CMTU,----	0.	MTU,RAD/FT /SEC	0.
CMTA,----	0.	MTA,RAD/SEC/SEC	0.
CLU,-----	0.	ZU ,RAD/SEC/	-0.2946
CLA,-----	4.6000	ZA ,FT /SEC/SEC	-481.8540
CLAD,----	1.7000	ZAD,FT /SEC/	-1.9788
CLQ,-----	3.9000	ZQ ,FT /SEC/	-4.5397
CDA,-----	0.1300	XA ,FT /SEC/SEC	18.7289
CDU,-----	0.	XU ,RAD/SEC/	-0.0295
CTXU,----	-0.0930	XTU,RAD/SEC/	-0.0147
CLDE,----	0.4300	ZDE,FT /SEC/SEC	-44.7414
CDDE,----	0.0600	XDE,FT /SEC/SEC	-6.2430
CMDE,----	-1.2800	MDE,RAD/SEC/SEC	-39.8586
LATERAL-DIRECTIONAL DERIVATIVES			
CLB,/RAD	-0.0890	LB,RAD/SEC/SEC	-28.7492
CLP,/RAD	-0.4700	LP,RAD/SEC/SEC	-12.4092
CLR,/RAD	0.0960	LR,RAD/SEC/SEC	2.5346
CLD,/RAD	0.1780	LD,RAD/SEC/SEC	57.4984
CNB,/RAD	0.0650	NB,RAD/SEC/SEC	10.1194
CNP,/RAD	-0.0300	NP,RAD/SEC/SEC	-0.3817
CNR,/RAD	-0.0990	NR,RAD/SEC/SEC	-1.2597
CND,/RAD	-0.0530	ND,RAD/SEC/SEC	-8.2512
CYB,/RAD	-0.3100	YB, FT/SEC/SEC	-32.2554
CYP,/RAD	-0.0370	YP, FT/SEC/SEC	-0.3147
CYR,/RAD	0.2100	YR, FT/SEC/SEC	1.7859
CYD,/RAD	0.	YD, FT/SEC/SEC	0.

Table A.12 Dynamic Stability Characteristics of Airplane A. (Approach)

LONGITUDINAL

ROOT NO.	REAL PART	IMAG.PART
ONE	-0.2092E-01	0.1797E 00
TWO	-0.4130E 01	0.4390E 01
THREE	-0.2092E-01	-0.1797E 00
FOUR	-0.4130E 01	-0.4390E 01

UNDAMPED NATURAL FREQUENCY(FN)CYCLES/SEC	0.029
UNDAMPED NATURAL FREQUENCY,OMEGA(N),RAD/SEC	0.181
TIME TO HALF AMPLITUDE,OSC MODE,SEC	32.98
DAMPING RATIO	0.116
UNDAMPED NATURAL FREQUENCY(FN)CYCLES/SEC	0.960
UNDAMPED NATURAL FREQUENCY,OMEGA(N),RAD/SEC	6.027
TIME TO HALF AMPLITUDE,OSC MODE,SEC	0.17
DAMPING RATIO	0.685

THE CHARACTERISTIC EQUATION IN FACTORED FORM

(S*S+ 0.41839E-01S+ 0.32720E-01)(S*S+ 0.82607E 01S+ 0.36328E 02)=0

TWO PAIRS OF COMPLEX CONJUGATES

SECOND MODE ABOVE IS SHORT PERIOD WITH THESE FEATURES

LOAD FACTOR/ANGLE OF ATTACK, G-UNITS/RAD	14.5
OMEGA SQUARED /N/ ALPHA	2.508

LATERAL-DIRECTIONAL

ROOT NO.	REAL PART	IMAG.PART
ONE	-0.1095E-01	0.
TWO	-0.6858E 00	0.3306E 01
THREE	-0.1243E 02	-0.3213E-11
FOUR	-0.6858E 00	-0.3306E 01

TIME CONSTANT,SEC	91.318
UNDAMPED NATURAL FREQUENCY,OMEGA(N),RAD/SEC	3.377
UNDAMPED NATURAL FREQUENCY,FN,CYCLES/SEC	0.538
DAMPING RATIO	0.203
ZTD*OMND=	0.6858
OSCILLATORY PHI/BETA RATIO	0.69
OMEGA(N)SQUARED X PHI/BETA,1/SEC/SEC	7.91
TIME CONSTANT,SEC	0.080

THE FIRST TIME CONSTANT IS THE SPIRAL WHILE THE SECOND IS THE ROLL TIME CONSTANT

TIME TO DOUBLE THE AMPLITUDE IN THE SPIRAL MODE,SEC, 63.009

THE CHARACTERISTIC EQUATION IN FACTORED FORM

(S+ 0.10951E-01)(S+ 0.12434E 02)(S*S+ 0.13717E 01S+ 0.11403E 02)=0

TWO ROOTS ARE REAL AND TWO ROOTS ARE COMPLEX CONJUGATES

Table A.14 Transfer Functions for Airplane A.
Flight Condition: Cruise, 5,000 ft, 219 ft/sec

TRANSFER FUNCTION POLYNOMIAL COEFFICIENTS

THE COEFFICIENTS OF THE LONGITUDINAL CHARACTERISTIC EQUATION=

A= 0.22098E 03 B= 0.18347E 04 C= 0.81112E 04

D= 0.39559E 03 E= 0.26266E 03

THE COEFFICIENTS FOR THE NUMERATOR U(S) ARE.

AU=-0.13796E 04 BU=-0.12231E 05 CU= 0.66961E 05 DU= 0.57804E 06

THE COEFFICIENTS FOR THE NUMERATOR ALPHA(S) ARE.

AA=-0.44741E 02 BA=-0.87415E 04 CA=-0.37830E 03 DA=-0.37776E 03

THE COEFFICIENTS FOR THE NUMERATOR THETA(S) ARE.

AT=-0.87269E 04 BT=-0.18355E 05 CT=-0.10647E 04

STANDARD FORMAT FOR LONGITUDINAL TRANSFER FUNCTIONS

U(S)/DELTA-E(S) COEFFICIENTS ARE .

KUDE = 2200.708
TU1 = 1/ 6.59873
TU2 = 1/ 9.18224
OMN = 0.18089
OMN = 6.02723
ZT = 0.11565
ZT = 0.68528

ALPHA(S)/DELTA-E(S) COEFFICIENTS ARE .

KALPHADE = -1.438
TALPHA = 1/195.33547
OMN ALPHA = 0.20790
ZETA ALPHA = 0.10357
OMN = 0.18089
OMN = 6.02723
ZETA = 0.11565
ZETA = 0.68528

THETA(S)/DELTA-E(S) COEFFICIENTS ARE .

KTHETADE = -4.054
TTHETA1 = 1/ 2.04357
TTHETA2 = 1/ 0.05970
OMN = 0.18089
OMN = 6.02723
ZETA = 0.11565
ZETA = 0.685281

Table A.14 (cont'd) Transfer Functions for Airplane A.
Flight Condition: Cruise, 5,000 ft, 219 ft/sec

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THE COEFFICIENTS OF THE LATERAL-DIRECTIONAL CHARACTERISTIC EQUATION=

A= 0.21900E 03     B= 0.30257E 04     C= 0.62653E 04

D= 0.31117E 05     E= 0.34001E 03

THE COEFFICIENTS FOR THE BETA(S) -DUE TO AILERONS- POLYNOMIAL ARE.

AB= 0.             BB= 0.17742E 04  CB= 0.28842E 05  DB= 0.16576E 04

THE COEFFICIENTS FOR THE PHI(S) -DUE TO AILERONS- POLYNOMIAL ARE.

AF= 0.12592E 05      BF= 0.13137E 05      CF= 0.76521E 05

THE COEFFICIENTS FOR THE PSI(S) -DUE TO AILERONS- POLYNOMIAL ARE.

AS=-0.18070E 04  BS=-0.27497E 05  CS=-0.41191E 04  DS= 0.11088E 05


STANDARD FORMAT FOR LATERAL DIRECTIONAL TRANSFER FUNCTIONS
                    (DUE TO AILERONS)


BETA(S)/DELTA-A(S) COEFFICIENTS ARE .

K BETA DELTA-A =       4.875
T BETA A1 = 1/ 16.19892
T BETA A2 = 1/  0.05768
TS = 1/  0.01095
TR = 1/ 12.43357
OMND =    3.37678
ZETAD =    0.20311

PHI(S)/DELTA-A(S) COEFFICIENTS ARE .

K PHI DELTA-A =    225.055
OMN PHI A =    2.46513
ZETA PHI A =    0.21161
TS = 1/  0.01095
TR = 1/ 12.43357
OMND =    3.37678
ZETAD =    0.20311

PSI(S)/DELTA-A(S) COEFFICIENTS ARE .

K PSI DELTA-A =     32.611
T PSI A = 1/  0.73437
OMN PSI A =    0.
ZETA PSI A =    0.
TS = 1/  0.01095
TR = 1/ 12.43357
OMND =    3.37678
ZETAD=    0.20311
```