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HP-41CV FLIGHT PERFORMANCE ADVISORY SYSTEM (FPAS)
FOR THE E-2C, E-2B, AND C-2A AIRCRAFT

LCDR Dennis R. Ferrell, USN

June 1982

Final Report for Period April 1982 - June 1982

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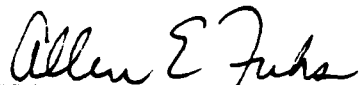
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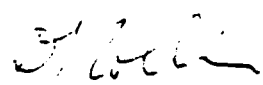
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(NADC). NADC desired to obtain the input of several fleet experienced aviators in order to design program code for the HP-41CV handheld, programmable calculator that would benefit pilots by providing them with fuel efficiency parameters in flight. Calculators were made available to the participants with the proviso that a completed and operable code for each aircraft be submitted by the end of the academic quarter, September 1981.

Upon completion of the E-2C program, attempts were made to use the calculator in flight. One test was conducted informally in an E-2C at RVAW-110, NAS Miramar. Unfortunately, the voltage field induced in the cockpit by the main lobe of the radar passing over the cockpit caused the calculator to cease functioning.

The need to devise shielding for the calculator, plus the desire to simplify and improve the existing code lead to this effort. Concurrently, a decision was made to modify a program designed for the E-2B by another officer and to create a program for the C-2A. Since all three aircraft are similar in performance characteristics, an attempt has been made to standardize code format. All programming efforts were sponsored by NADC.

Upon special request from NADC, a kneeboard was also designed to incorporate the HP-41CV in a compact arrangement to enhance its utility and prevent additional loose items in the cockpit. Photographs and construction details are included.

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Chapter I

FLIGHT PERFORMANCE ADVISORY SYSTEMS

For many years, NADC has been concerned with developing technologies to enhance the performance of Naval aircraft in all phases of flight by improving hardware and capabilities. One of their most current and urgent efforts is the improvement of fuel consumption characteristics for Naval aircraft. Specifically, there are six aircraft that represent the greatest percentage of fuel consumed. They are the F-4, P-3, A-6, A-7, A-4 and the F-14. Some of the methods considered to improve the fuel consumption characteristics of these aircraft include engine modifications, changing operational characteristics, and the design of computer software that assists the pilot in determining the most efficient fuel consumption profile to fly at any given moment during a flight.

The design of fuel efficiency software falls within a classification called Flight Performance Advisory Systems (FPAS). Since the hardware/software on-board capabilities of most military aircraft are committed to operational considerations, handheld programmable calculators have been pressed into service in the cockpit to provide easily accessible flight performance parameters.

1.1 BACKGROUND

NADC has set a goal to reduce fuel consumption in Naval aircraft by five percent through the application of advanced technologies. The motivation for such a goal is obvious: the 1973 oil embargo by Arab nations and subsequent incidents sent the cost of fuel skyrocketing and has reduced supplies on more than one occasion. Methods must be found to minimize reliance on foreign sources by reducing fuel consumption rates without affecting training and operational capability.

Opportunities exist in the operational profile of any aircraft to reduce fuel consumption rates by providing the pilot with a method of determining optimal configurations for maximum range and maximum endurance. Currently, the only information available to pilots exists in the NATOPS Manuals. This information, however, is very limited in utility because of the bulk of material and its complexity. The use of information in NATOPS is generally limited to ready-room research, a practice hardly conducive to enhancement of real-time performance.

1.1.1 Handheld Programmable Calculators

Inexpensive calculators have been available in the US market now for 10 to 15 years. The most recent additions to this market are programmable calculators, those capable of taking a set of input parameters and computing a numerical response with an infinite variety and complexity of equations.

By manipulating the data in the NATOPS Manual, equations can be programmed to return answers to such questions as what is the correct airspeed to fly max range corrected for temperature, altitude and winds.

NADC used the most current ideas in the design of such programs by formulating a code for the A-7¹ to be used with the HP-41CV, an advanced technology calculator manufactured by Hewlett-Packard. This program served as a prototype for the efforts which were sponsored by NADC at the Naval Post-graduate School.

1.1.2 EPAS Program Designs

AE3001, Aircraft Energy Conservation, is a course offered by the Aeronautical Engineering Department at the Naval Post-graduate School at least once each year to interested students. When offered in the Summer Quarter, 1981, NADC sponsored the use of the HP-41CV calculator to participating students who agreed to design programs for their aircraft. Primary emphasis was placed on programs for the six major fuel consuming aircraft previously mentioned, but program designs for other aircraft were given consideration as well.

Few restrictions were placed on the design of these programs. The A-7 code designed by NADC was made available as a reference, and lecture material provided background on the

¹ The work which lead to the development of this program was originally performed by officers/engineers attached to A-7 squadrons at NAS Lemoore. Their intent was to use regression analysis on NATOPS data to devise simple equations that could be used in a programmable calculator to provide pilots with mission planning data.

need for programs. NADC hoped to learn what fleet experienced aviators really wanted to see in the cockpit, thereby avoiding needless duplication of effort and the presentation of parameters of limited utility.

Aircraft for which final code were submitted include the F-14, S-3, SH-3, A-6, EA-6B, E-2B, E-2C, A-4, and the F-4. This author designed the program for the E-2C.

1.2 THE E-2C/HP-41CV FPAS

The calculator code developed for the E-2C was designed primarily using information available in Chapter 11 of the E-2C NATOPS Manual. There are at least two reasons for this.

1. Information available from the manufacturer is generally not available in a convenient format or is closely held as proprietary.
2. The NATOPS Manual is, very simply, supposed to be the final word for aviators needing to know information about their aircraft. Other sources cannot be relied upon unless officially sanctioned. Most of that material is generally not available in a squadron.

The original E-2C program was designed to provide the pilot with max range and max endurance airspeeds to fly for any given set of input parameters read from cockpit instruments during flight. Equations were devised by using regression analysis on specific range charts for the clean and 10 degrees flaps configurations. Corrections applied for altitude, temperature and winds at altitude adjusted the calibrated airspeed to an appropriate indicated airspeed.

Cruise ceiling, the optimal altitude for max range flight, was also computed.

Parameters needed by the program are requested in an interactive manner by the calculator, which is capable of displaying words as well as numbers. Elapsed time from input of the last of five requested input parameters to output of the indicated airspeed to fly is less than 30 seconds. Fuel flow and indicated shaft horsepower to fly the indicated airspeed are also computed and presented at the end of the program. Additionally, a data algorithm allowed the user to compute fuel, time and distance to go for a given amount of fuel on board. Climb and descent information is not computed by the program.

The program and report for the E-2C code were submitted to the instructor and NADC at the end of the quarter with a short presentation by each student. Two engineers from NADC listened to each presentation and pressed for additional information. One conclusion reached by virtually all students and conveyed to NADC, however, was that the opportunities for ship based aircraft to use a calculator that computes max range and max endurance parameters is probably limited. An F-14 looks like an E-2 looks like an S-3 in that each aircraft generally flies mission profiles that do not allow use of fuel efficiency codes. Only those short periods of time during transits to or from station, or during holding

in marshall, will any of these aircraft need max range or max endurance information. A concern was also expressed regarding the use of a device in a single seat aircraft that requires the pilot to divert attention away from outside the aircraft.²

1.2.1 Continuation of the E-2C PPAS

Early in October, 1981, the E-2C PPAS calculator was taken on a flight by an instructor at RVAW-110, the E-2B/E-2C Fleet Replacement Training Squadron for the West Coast at NAS Miramar. The original intent of the flight was to determine if selected output parameters matched the performance of the aircraft. Before such a determination could be made, however, the energy field³ created by passage of the main beam of the radar over the cockpit rendered the calculator unusable. It was later determined that all program flags were set by the energy field. One of those flags turns the calculator off. Operation was restored after the flight by reseating the batteries. No damage occurred to the calculator or memory, and loaded programs remained intact. ROM chips installed in the calculator were not affected, either.

² Additionally, the calculator could not be of any benefit during low level navigation or formation flying because of the external concentration required. Calculators for fighter and attack aircraft will probably gain greatest acceptance as a ready room mission planning aid.

³ Grumman engineers have assured E-2 flight crew that the microwave energy field that sweeps through the cockpit is not a health hazard. The transitory nature of the beam results in radiation levels less than specified by standards.

During these tests, several aviators in the squadron became interested in the effort and suggested several other ways a calculator could be used. Many of those ideas centered around safety of flight information such as determination of BINGO fuel required data, cross wind landing limitations, and calculation of refusal speed for takeoff.

1.2.2 Directed Studies

During subsequent months, several ideas were generated to cope with informally defined problems with the E-2C FPAS. But no effort could be made without a formal work structure. Professor A.E. Fuhs, who conducted the AE3001 course during the Summer 1981 Quarter, consented to sponsor further work regarding the E-2C program. NADC also provided sponsorship and assistance. Drawing upon several ideas generated between September 1981 and the beginning of the Spring 1982 Quarter, the following research items were agreed upon as a format for a one-time AE4900, Directed Studies in Aeronautical Engineering.

1.2.2.1 E-2C/HP-41CV FPAS Continuation

Work was to be resumed on the E-2C program to redefine program objectives. Primarily, the code was to be simplified by eliminating the 10 degrees of flaps information, adding a descent profile, and possibly eliminating unneeded or unreliable parameters such as fuel flow and horsepower readouts.

1.2.2.2 EMI Effects on the HP-41CV

Electromagnetic interference effects required several simple methods of protecting the HP-41CV from the energy field in cockpit. Possible methods include foil shielding, a metal keyboard mask, and metal-laminated transparent bags.

1.2.2.3 E-2B and C-2A FPAS Programs

Since the flight characteristics of each of the three aircraft are similar, efforts to design standardized programs for each aircraft would be relatively simple. The E-2B program could rely on equations already developed by another student. The C-2A program would have to rely on development of equations patterned after the work on the E-2C.

1.2.2.4 Safety of Flight Programs

The one program most E-2 aviators considered most useful is quick and reliable access to BINGO fuel required. Again, design of a program for the E-2C would provide a guideline for programs for the other two aircraft.

1.2.2.5 Examination of Other Calculators

Since it appeared the HP-41CV might have difficulties coping with the E-2 environment, the possibility of using other types of advanced technology calculators or pocket sized computers was considered. This idea did not work out, however, due to lack of funding.

Chapter II

TECHNICAL DISCUSSION

Prior to discussing the programs, an understanding of the hardware and methodologies is necessary. As mentioned previously, handheld programmable calculators are available that will perform a variety of computations in an interactive manner. Since many types of calculators can be used for any given situation, a full explanation of why the HP-41CV is used for the FPAS program is in order.

A short discussion of regression analysis is also included to familiarize the reader with the methodology used to obtain equations for use in the FPAS programs.

2.1 THE HP-41CV

Handheld programmable calculators go far beyond the realm of "four-bangers", those calculators that perform simple addition, subtraction, multiplication and division. One step beyond that capability includes calculators with at least one memory for temporary, volatile* storage of numbers used in a hand-fed computation sequence.

Programmable calculators include those with more than one memory location, each of which can be accessed by a sequencing operation that "reads" an instruction and performs a desired operation, then moves on to the next instruction. Ob-

* Volatile generally means that any data stored in memory will be lost when power to the calculator is turned off.

viously, these calculators are more complicated to learn to use, but certainly not impossible. Various predefined mathematical operations are also included such as sine, cosine, tangent, log, etc.

Prior to the HP-41, programmable calculators were strictly "number crunchers". The user had to know where the calculator's program was operating in order to interpret a numerical output. Peripheral printers aided the effort, however, by providing a limited interactive, word presentation capability. The TI-59 is probably the best example of this type of calculator. Some TI-59's have been used for FPAS programs, notably one for the AV-8 Harrier. A special mask is used to identify redefined key functions. A special ROM chip, designed especially for the Harrier, makes the program non-volatile.

2.1.1 Basic Features

The HP-41 improves programmable capability considerably. Hewlett-Packard originally issued this calculator as the HP-41C, but later responded to market pressure with the HP-41CV. The two calculators are identical except for the smaller initial memory size of the "C" model. The "CV" has approximately 2.2K of RAM,⁵ or 319 registers. Each key

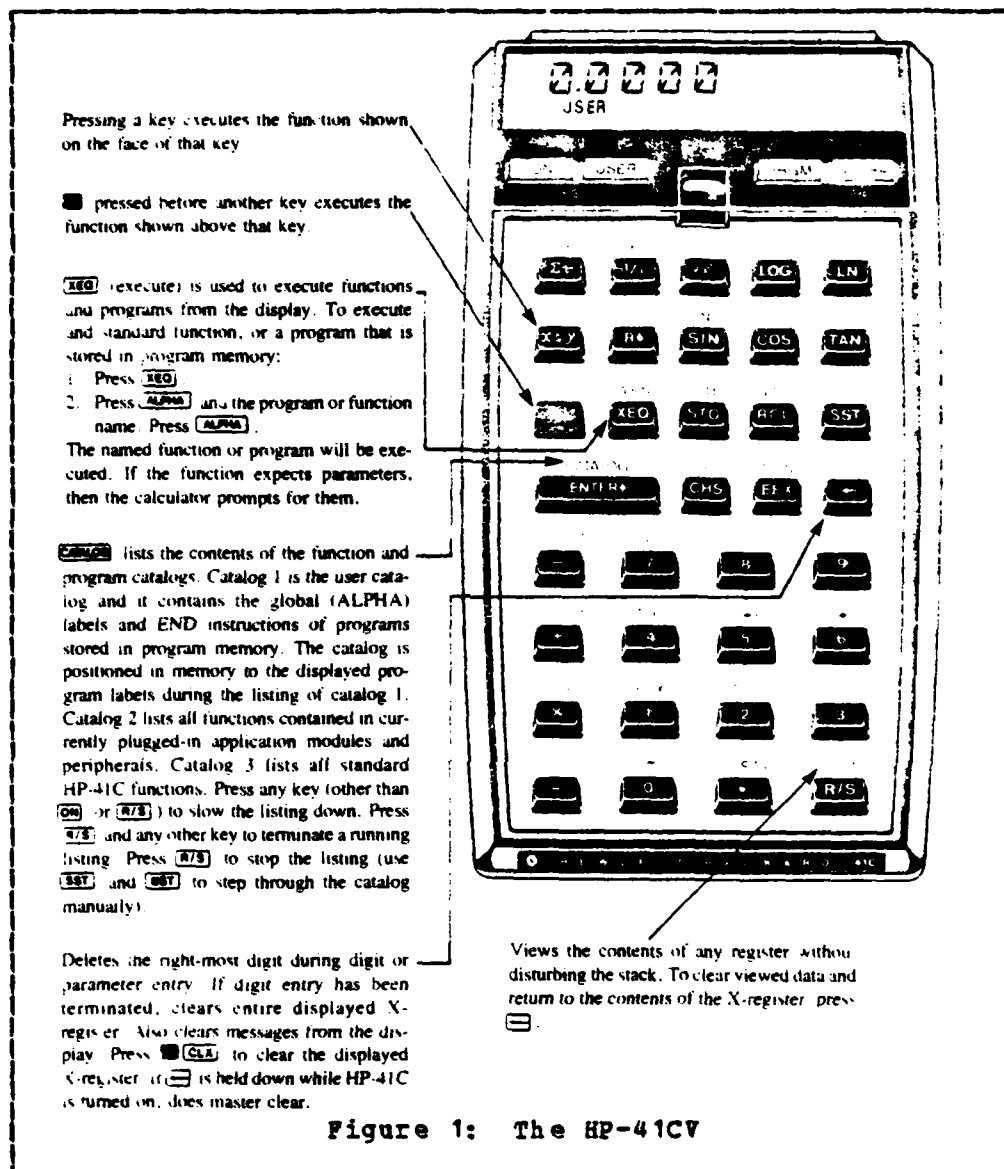
⁵ Random Access Memory (RAM) refers to memory in a computer that is used to perform transitory operations and store instructions and data temporarily. Read Only Memory (ROM) is not accessible to the user. ROM generally contains machine dedicated code for use by the processing unit. ROM may also be used to permanently store program code in non-volatile memory.

represents three or four functions, depending on the mode selected. Variables are stored in registers and are either stored or recalled by program code. The ALPHA mode is used to define alpha-numeric titles or labels that access certain information or spell out interactive wording to which the user responds. The program mode, PRGM on the calculator, allows the user to enter code for later execution. Keys can be assigned program accessing functions so that execution can be initiated easily when in the USER mode.

The calculator's arithmetic operations are conducted in Reverse Polish Notation. RPN eliminates the need for complicated, parenthetically nested equations. Although different from the method of operating a standard calculator, its use can be learned in a few short steps.

Documentation for the calculator is better than average and contains few ambiguities. An interested user can learn enough about the calculator to perform relatively sophisticated programming in about one day. Usage of the FPAS programs requires no special knowledge about the calculator and can be briefed in less than 15 minutes.

Figure 1, reproduced by permission from Hewlett-Packard, shows the calculator keyboard layout and major functions.



Courtesy of Hewlett-Packard Co.

2.1.2 Extended Functions/Memory

Hewlett-Packard recently introduced ROM modules which can be plugged into HP-41CV I/O ports to expand the memory storage capability. The calculator used in this research was supplied with one Extended Functions module and two Extended

Memory modules. The Extended Functions module increases the number of commands that can be accessed directly by the user or by program code. Executable sizing functions can be used to repartition register allocations for different programs.

The Extended Memory modules are used to store program code not currently in use in main memory. Only programs in the main memory of the calculator can be operated. The Extended Memory modules can be considered similar to disk drives on a microcomputer for mass storage of programs and data. The programs are accessed and loaded into main memory when called.

Early on in the design of the FPAS programs at NPS, most program designers realized that the main memory (2.2KB RAM) was not sufficient to handle programs without the use of either two calculators to perform different sections or compromise of the accuracy. For the E-2 and C-2 programs designed for this project, a control program is resident in main memory that calls the desired program from Extended Memory, repartitions the register space as required, and places the program into main memory for operation by the user. When a different program is needed, the current main memory program is erased, and the new one loaded. The Extended Memory modules function essentially like ROM chips; loaded programs remain intact, even when accessed by the main memory program. Fortunately, however, the programs can be modi-

fied when required by altering the main memory program and writing over the program stored in Extended Memory.

The Extended Memory programs loaded for each of the three programs written for this project include the FPAS, a BINGO program, and a CROSSWIND LIMITATIONS program. The code for each program has been "tightened" sufficiently to allow the addition of two or three small programs in the future.*

2.2 REGRESSION ANALYSIS

Regression analysis allows researchers to take a given set of data with an apparent functional relationship and devise an equation that will describe that relationship. The equation approximates the data for any given independent variable by determining coefficients for a selected equation form. For instance, one might assume a first order relationship for data of a form such as $y = a + bx$; x is the independent variable and a and b are the coefficients determined by the regression analysis. y is the dependent variable which approximates the desired value. With regression analysis, a set of x and y value pairs are known and the a and b coefficients are determined. Differences between the approximated values of y and the actual value is the residual. Any regression routine will seek to minimize the residual.

* The Extended Functions module and two Extended Memory modules add about 4KB of memory to the HP-41CV for a total of 6.2KB. The current setup of programs for the E-2C leaves 109 registers available in Extended Memory for future programs.

Regression analysis often requires the consideration of two or more independent variables, a process called multiple linear regression. The equations devised for the E-2/C-2 FPAS programs required use of multiple variables. For instance, the calibrated airspeed to define no-wind, max range values is a function of aircraft gross weight (GW) and pressure altitude (PA). The Minitab program, resident on the IBM370/3033 at the Naval Postgraduate School, was used to formulate appropriate equations.

Simpler relationships involving one variable or easily recognized functional relationship patterns were regressed using a curve fitting program on the HP-41CV.

Chapter III

THE E-2C/HP-41CV PROGRAMS

Since the E-2C program was used as the control program to devise codes for the other two aircraft, a more complete description of these codes will be presented here. Flowcharts and a listing of program code are presented after each description rather than in separate appendices to avoid confusion.

3.1 THE E-2C FPAS PROGRAM

The E-2C Flight Performance Advisory Program is called by the main memory accessing program from Extended Memory and loaded into main memory in about 30 seconds. The flow chart should be referenced to understand the theory of operation.

3.1.1 Program Initiation

Program operation is initiated by pressing the START key at the upper left corner of the keyboard.⁷ The program will display "***E-2C FPAS**" for about one second, then proceed to request needed information with the following displays:

1. "BASIC WT = ?", then
2. "CARGO WT = ?", then
3. "NO. CREW = ?".

⁷ Subsequently, keys will be referred to by a coded position based on a row/column numbering system. The START key is on row 1, column 1; hence, key 11. There are 8 rows with 5 columns in the first three rows, and 4 columns each in lower rows.

Each label will stop program operation until the user responds by keying in the appropriate number. Program operation proceeds to the next label when Run/Stop (R/S: key 84) is pressed after each numerical entry.

Finally, "PROFILE?" is displayed, asking the user to select one of three modes of operation: RANGE, ENDURANCE, or DESCENT.

3.1.2 RANGE

Pressing the RANGE key (12) initiates the calculation of maximum range indicated airspeed to fly corrected for altitude, temperature and winds at altitude. Upon pressing the key, "***MAX RANGE*" displays as an echo check verification of the selection, followed by:

1. "ALT = FT?", enter current altitude from the altimeter;
2. "OAT = C", outside air temperature in degrees centigrade (the CHS (change sign) key (42) places a negative sign in front of a number);
3. "IAS = KTS?", current indicated airspeed in knots (this number is used to correct OAT for heating effects on the temperature probe);
4. "FUEL = LBS?", total fuel weight read from the quantity gages.

Each of these parameters are loaded into appropriate registers for later access by the program. Temperature deviation (TDEV), a function of OAT and altitude (PA), is then calculated for use in a Cruise Ceiling (CC) calculation, a function of TDEV and Gross Weight (GW). Max Range Calibrated

Airspeed (MRCAS), from the NATOPS charts, is then computed as a function of PA and GW.

The inverse of SQRT sigma (SSI) is calculated and stored for use in later true airspeed (TAS) computations. A compressibility correction based on PA and CAS is also computed.

Winds are accounted for by asking the user if the ground speed is available (from CAINS or TACAN calculations). Response is with the YES or NO keys, (15) or (25). The label will read "GS,AVAIL? Y/N". If yes, the program will ask "GS = KTS?"; enter the value and press R/S. If no, the program will respond, "INPUT WINDS.."; the dots indicate a temporary label with a query to follow.

- 1.. "WIND DIR = ?", enter forecast or computed winds in degrees, 001 to 360;
2. "WIND VEL = ?", enter forecast or computed winds in knots;
3. "A/C HDG = ?", enter aircraft heading in degrees, 001 to 360.

Headwind calculations are a function of TAS based indicated airspeed (TASi). After determining if the headwind is positive or negative (tailwind), corrections are applied to the CAS to adjust for winds. This value is then corrected for compressibility and stored for later display. The calculator then displays, "**DATA READY**".

3.1.3 ENDURANCE

The ENDURANCE profile functions much the same way as the RANGE profile. Subroutine AIOFG again asks for altitude, airspeed, OAT, and fuel weight, then calculates gross weight. Max endurance is easily calculated as a function of gross weight only. Headwind corrections, obviously, are not performed.

Equivalent (indicated)* airspeed and true airspeed are then calculated and stored for later display.

3.1.4 DESCENT

The DESCENT profile calculates an indicated airspeed to fly a max range descent such as might be used during a BINGO to a shore based field. Headwind corrections have been incorporated into this algorithm; the assumption is made, however, that the RANGE profile has been run at least once prior to DESCENT so that an approximate headwind correction can be applied.

When selected, the DESCENT profile initially asks for present altitude, then fuel weight, then the desired level off altitude. Gross weight is calculated and stored.

Since the charts in the NATOPS manual show a weight only dependency above 10000 feet and a weight and altitude dependency below 10000 feet, the program determines whether present altitude is above or below 10000 and uses the correct

* Position error corrections for each of the three aircraft are negligible and not computed. Hence, EAS is approximately equal to IAS.

set of equations to determine the CAS. Headwind corrections are then applied, and indicated airspeed is calculated. Descent distance, the distance from the field to start the descent, is calculated as a function of present altitude and level-off altitude.

Stored values are then displayed in a short routine that also warns the user to increase IAS 1 knot per 1000 feet below 10000 feet. A label also warns the pilot to use 500 SHP for the descent. Readers will note that the NATOPS manual specifies flight idle. The 500 SHP value was chosen because of the common knowledge ability to simulate feathered flight by using 500 SHP.⁹

3.1.5 DATA

The DATA algorithm can be called at any time to display the values calculated for the latest run of the RANGE or ENDURANCE profiles. The DESCENT profile displays its own values separately.

If the RANGE profile was the most recently run selection, the DATA algorithm will display a recommended IAS to fly max range,¹⁰ followed by several other parameters of interest.

⁹ The exact value of SHP to use can be determined in flight in the following manner. At a given altitude with one engine feathered, trim the aircraft for straight and level flight at the IAS specified for max range descent at that weight and altitude. Without retrimming, restart the feathered engine and adjust its power setting to that required to duplicate the flight conditions previously set for feathered flight. Note the SHP on the restarted engine and use this value. Several aircraft should be tested in this manner to arrive at a nominal value.

¹⁰ There exists an AOA to fly max range at any weight (no wind conditions). Informal tests indicate this AOA to be about 16 units.

Each value may be observed by pressing R/S to proceed to the next. After all values have been seen, the program will cycle back to the MRIAS value again.

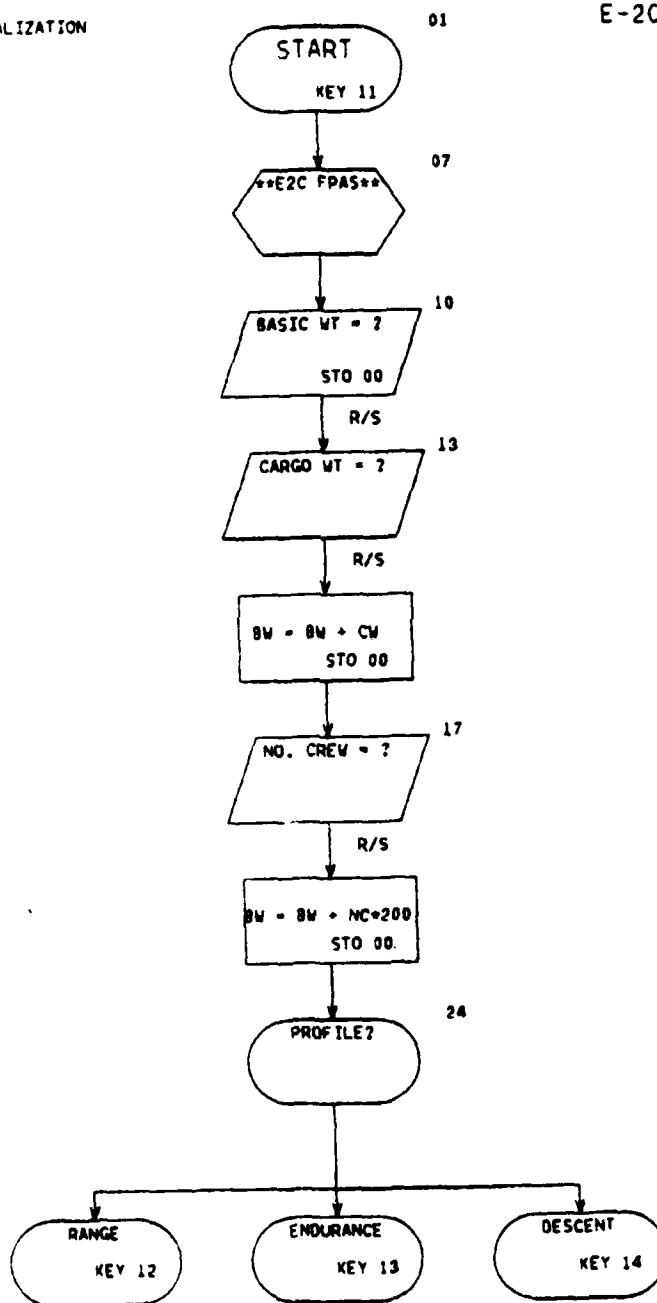
3.1.6 E-2C FPAS Flowcharts

The following nine pages present the E-2C FPAS algorithm in flowchart format for a conceptual understanding of program operation. Numbers adjacent to function blocks refer to line numbers in the FPAS code that follows.

PROGRAM INITIALIZATION

XEQ SIZE 022

E-2C FPAS

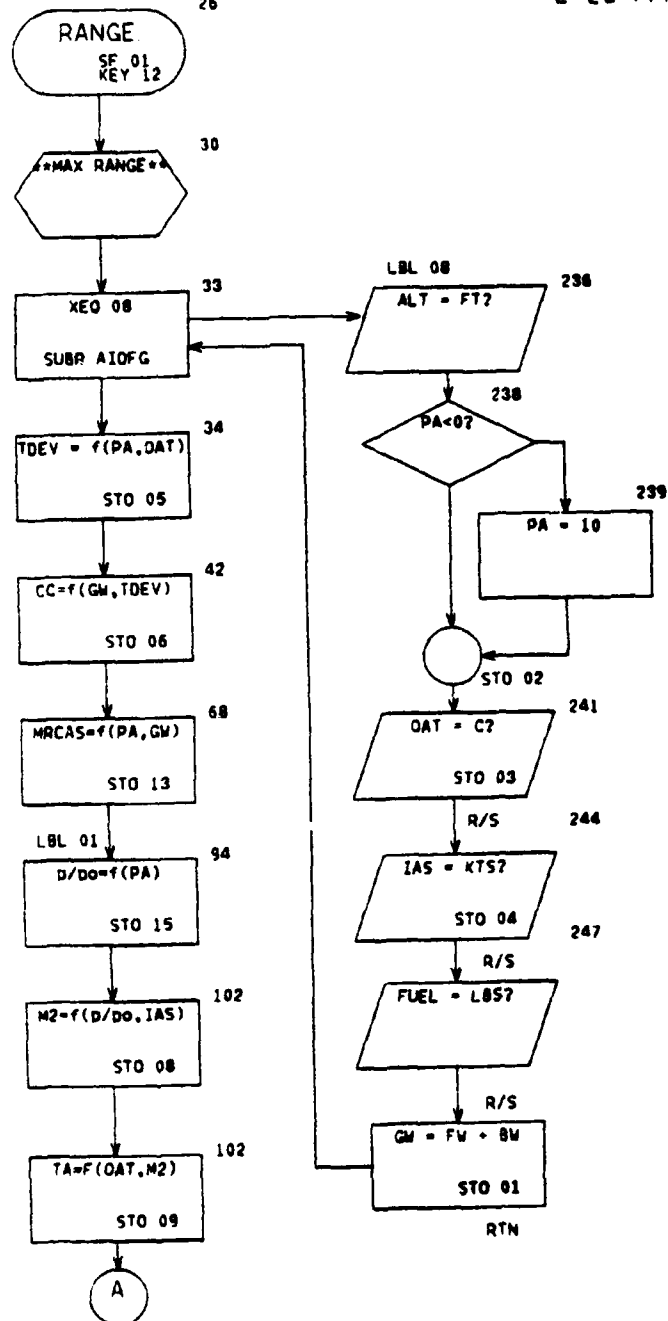


RANGE ALGORITHM

LBL 8

26

E-2C FPAS

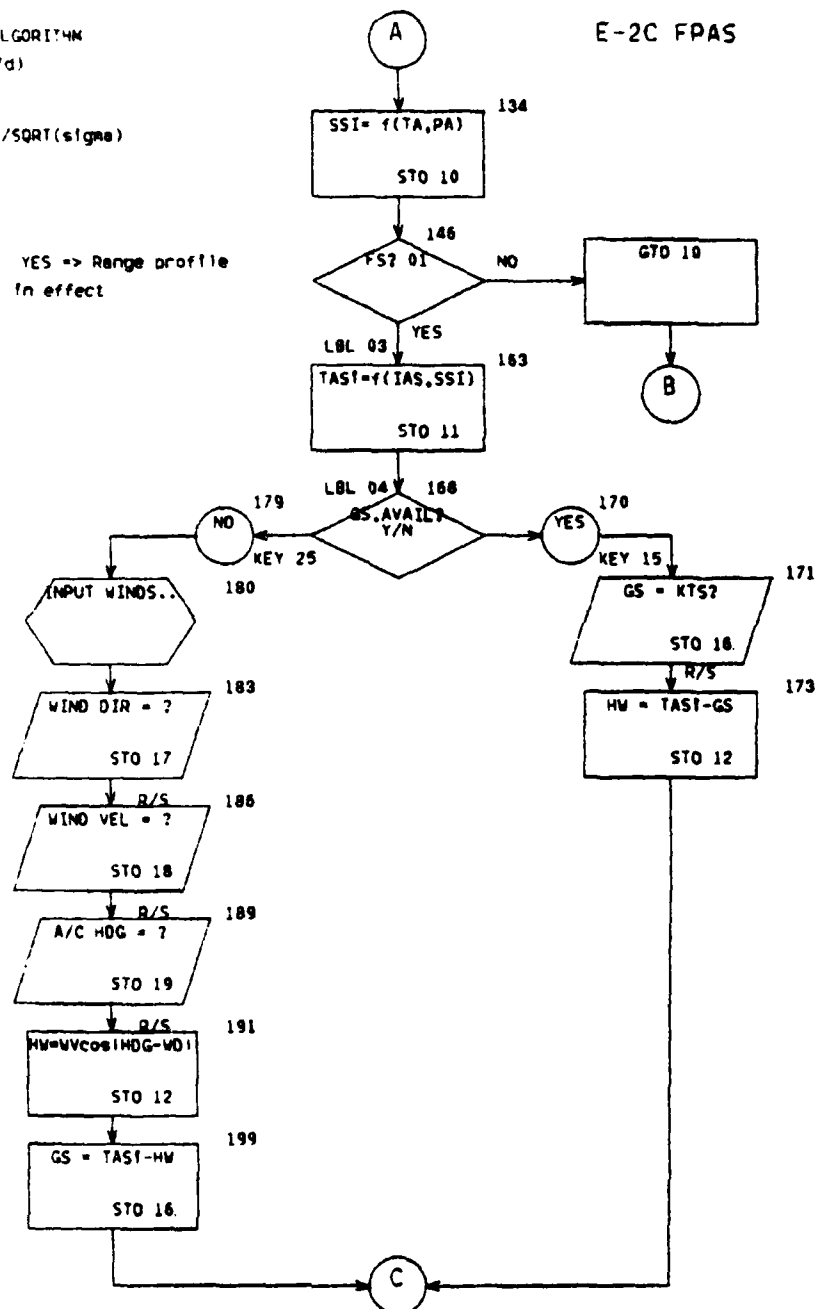


RANGE ALGORITHM
(cont'd)

$SSI = 1/\sqrt{SIGMA}$

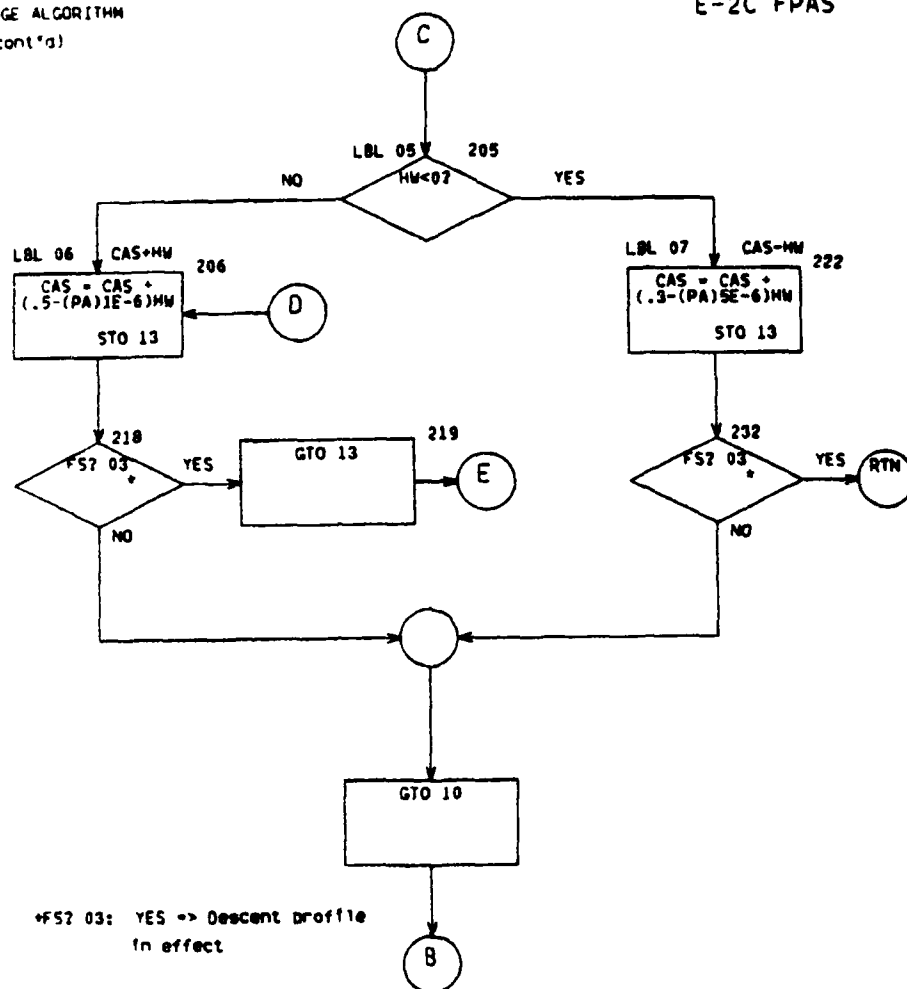
FS? 01: YES => Range profile
in effect

E-2C FPAS



RANGE ALGORITHM
(cont'd)

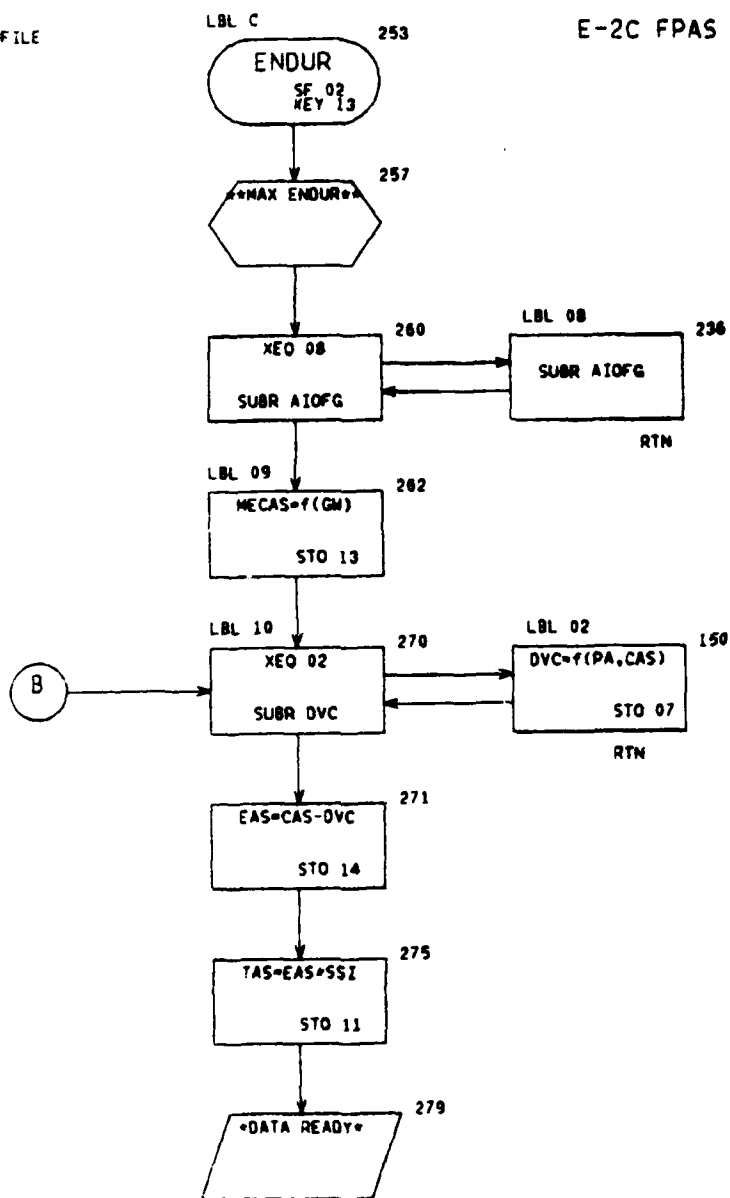
E-2C FPAS



ENDURANCE PROFILE

LBL C

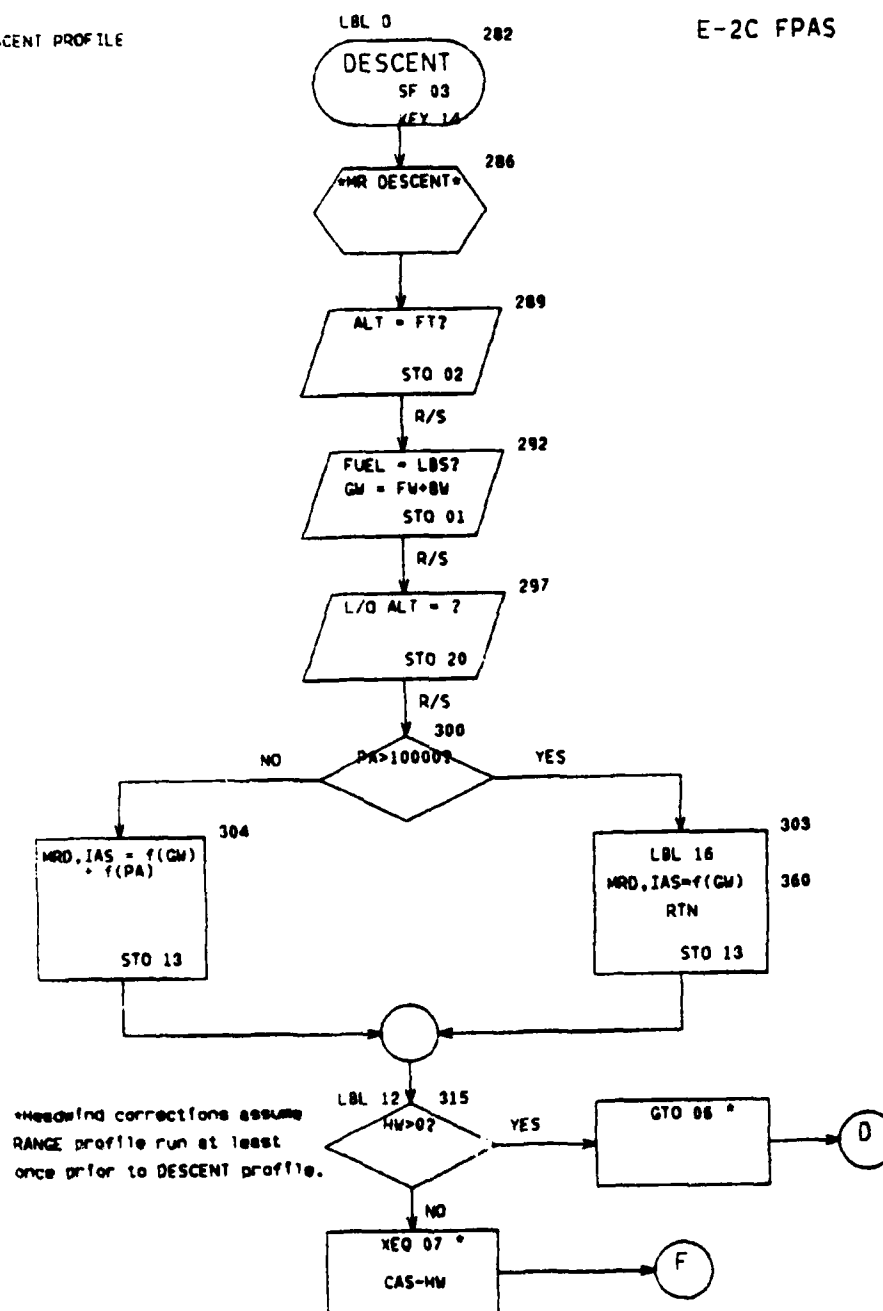
E-2C FPAS



PRESS DATA KEY (21) OR R/S
TO CONTINUE

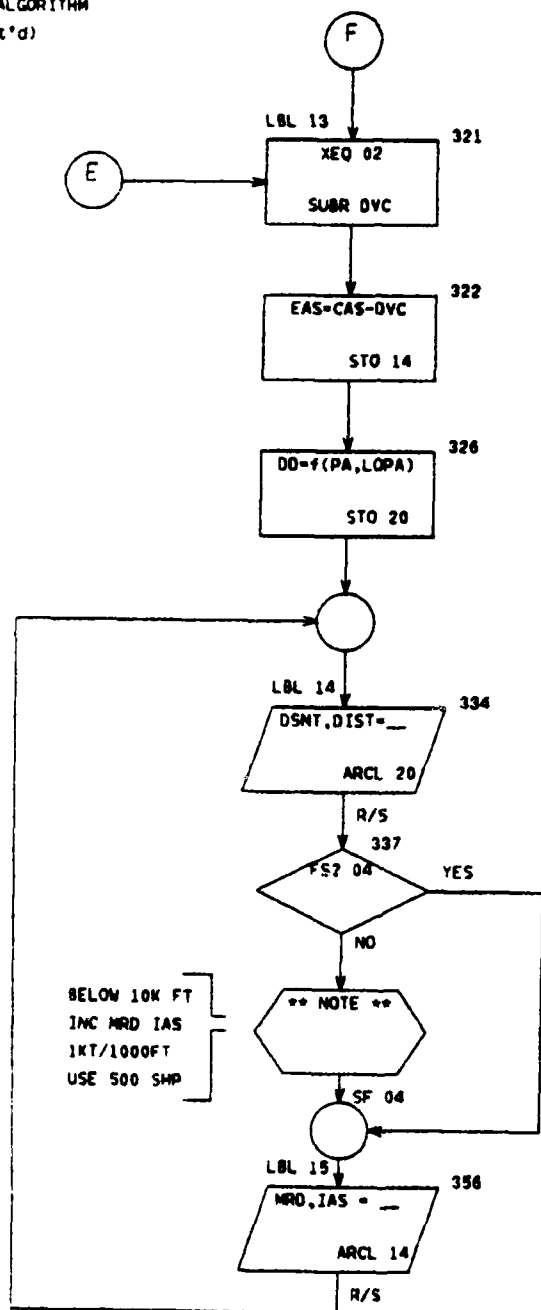
DESCENT PROFILE

E-2C FPAS



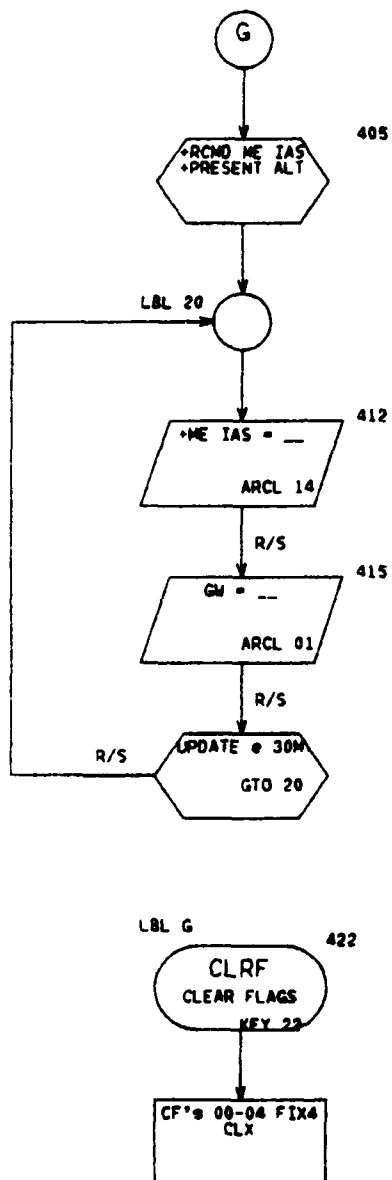
DESCENT ALGORITHM
(cont'd)

E-2C FPAS



DATA ALGORITHM
(cont'd)

E-2C FPAS



E-2C FPAS/HP-41CV Code (June 1982; 1/3)

01*LBL "STF"	51 *	101 STO 15
02 CF 01	52 *	102 RCL 04
03 CF 02	53 CHS	103 661.7
04 CF 03	54 30	104 /
05 CF 04	55 RCL 05	105 X+2
06 CLRG	56 -	106 .2
07 **E2C FPAS**	57 78.67	107 *
08 AVIEW	58 *	108 1
09 PSE	59 +	109 +
10 "BASIC MT = ?"	60 58480	110 3.5
11 PROMPT	61 +	111 Y+X
12 STO 00	62 100	112 1
13 "CARGO MT = ?"	63 /	113 -
14 PROMPT	64 INT	114 RCL 15
15 +	65 100	115 1/X
16 STO 00	66 *	116 *
17 "NO. CREW = ?"	67 STO 06	117 1
18 PROMPT	68 179.67	118 +
19 200	69 RCL 02	119 .286
20 *	70 173 E-5	120 Y+X
21 RCL 00	71 *	121 1
22 +	72 -	122 -
23 STO 00	73 RCL 01	123 5
24 "PROFILE?"	74 816 E-6	124 *
25 PROMPT	75 *	125 STO 08
26*LBL 8	76 +	126 .2
27 SF 01	77 RCL 01	127 *
28 CF 02	78 X+2	128 1
29 CF 03	79 RCL 02	129 +
30 **MAX RANGE**	80 X+2	130 1/X
31 AVIEW	81 516 E-20	131 RCL 03
32 PSE	82 *	132 *
33 XEQ 00	83 *	133 STO 09
34 RCL 03	84 +	134 1936 E-6
35 15	85 RCL 02	135 *
36 -	86 1 E-3	136 RCL 02
37 RCL 02	87 *	137 1500
38 198 E-5	88 LN	138 -
39 *	89 3.074	139 2112 E-8
40 +	90 *	140 *
41 STO 05	91 -	141 +
42 30	92 STO 13	142 E+X
43 RCL 05	93*LBL 01	143 .982
44	94 RCL 02	144 *
45 -.0031	95 -6875 E-9	145 STO 10
46 *	96 *	146 FS? 01
47 1	97 1	147 GTO 03
48 +	98 +	148 GTO 10
49 .705	99 5.2563	149*LBL 02
50 RCL 01	100 Y+X	150 RCL 02

E-2C/FPAS HP-41CV Code (June 1982; 2/3)

151 91 E-6	201 -	251 STO 01
152 *	202 STO 16	252 RTN
153 E+X	203 RCL 12	253*LBL C
154 1 E-7	204*LBL 05	254 SF 02
155 *	205 X<0?	255 CF 01
156 RCL 13	206 GTO 07	256 CF 03
157 2.852	207*LBL 06	257 **MAX ENDUR**
158 Y+X	208 .5	258 AVIEW
159 *	209 RCL 02	259 PSE
160 STO 07	210 1 E-5	260 XEQ 08
161 RTN	211 *	261*LBL 09
162*LBL 03	212 -	262 65
163 RCL 04	213 RCL 12	263 RCL 01
164 RCL 10	214 *	264 125 E-5
165 *	215 RCL 13	265 *
166 STO 11	216 +	266 +
167*LBL 04	217 STO 13	267 STO 13
168 *GS,AVAIL? Y/N-	218 FS? 03	268 GTO 01
169 PROMPT	219 GTO 13	269*LBL 10
170*LBL E	220 GTO 10	270 XEQ 02
171 *GS = KTS?*	221*LBL 07	271 RCL 13
172 PROMPT	222 .3	272 RCL 07
173 STO 16	223 RCL 02	273 -
174 RCL 11	224 5 E-6	274 STO 14
175 RCL 16	225 *	275 RCL 10
176 -	226 -	276 *
177 STO 12	227 RCL 12	277 STO 11
178 GTO 05	228 *	278 BEEP
179*LBL J	229 RCL 13	279 **DATA READY**
180 *INPUT WINDS..*	230 +	280 PROMPT
181 AVIEW	231 STO 13	281 GTO F
182 PSE	232 FS? 03	282*LBL D
183 *WIND DIR = ?*	233 RTN	283 SF 03
184 PROMPT	234 GTO 10	284 CF 01
185 STO 17	235*LBL 08	285 CF 02
186 *WIND VEL = ?*	236 *ALT = FT?*	286 **MR DESCENT**
187 PROMPT	237 PROMPT	287 AVIEW
188 STO 18	238 X<0?	288 PSE
189 *A/C HDG = ?*	239 10	289 *ALT = FT?*
190 PROMPT	240 STO 02	290 PROMPT
191 STO 19	241 *OAT = C?*	291 STO 02
192 RCL 17	242 PROMPT	292 *FUEL = LBS?*
193 -	243 STO 03	293 PROMPT
194 ABS	244 *IAS = KTS?*	294 RCL 00
195 COS	245 PROMPT	295 +
196 RCL 18	246 STO 04	296 STO 01
197 *	247 *FUEL = LBS?*	297 *L/O ALT = ?*
198 STO 12	248 PROMPT	298 PROMPT
199 RCL 11	249 RCL 00	299 STO 20
200 RCL 12	250 +	300 10000

E-2C/FPAS HP-41CV Code (June 1982; 3/3)

301 RCL 02	351 SF 04	401 AVIEW
302 X>Y?	352 "USE 500 SHP"	402 PSE
303 GTO 11	353 AVIEW	403 GTO 18
304 XEQ 16	354 PSE	404*LBL 19
305 RCL 02	355*LBL 15	405 "+RCMD ME IAS"
306 .001	356 "MRD IAS="	406 AVIEW
307 *	357 ARCL 14	407 PSE
308 -	358 PROMPT	408 "+PRESENT ALT"
309 10	359 GTO 14	409 AVIEW
310 +	360*LBL 16	410 PSE
311 GTO 12	361 RCL 01	411*LBL 20
312*LBL 11	362 32687 E-10	412 "+ME IAS="
313 XEQ 16	363 *	413 ARCL 14
314*LBL 12	364 E1X	414 PROMPT
315 STO 13	365 130.4677	415 "CW = "
316 RCL 12	366 *	416 ARCL 01
317 X>0?	367 RTN	417 PROMPT
318 GTO 06	368*LBL F	418 "UPDATE e 30M"
319 XEQ 07	369 FIX 0	419 AVIEW
320*LBL 13	370 FS? 01	420 PSE
321 XEQ 02	371 GTO 17	421 GTO 20
322 RCL 13	372 FC? 01	422*LBL G
323 RCL 07	373 GTO 19	423 CF 00
324 -	374*LBL 17	424 CF 01
325 STO 14	375 "+RCMD MR IAS"	425 CF 02
326 .00233	376 AVIEW	426 CF 03
327 RCL 02	377 PSE	427 CF 04
328 RCL 20	378 "+PRESENT ALT"	428 FIX 4
329 -	379 AVIEW	429 CLX
330 *	380 PSE	430 .END.
331 STO 20	381*LBL 18	
332*LBL 14	382 "+MR IAS="	
333 FIX 0	383 ARCL 14	
334 "BSNT,DIST="	384 PROMPT	
335 ARCL 20	385 "+MR TAS="	
336 PROMPT	386 ARCL 11	
337 FS? 04	387 PROMPT	
338 GTO 15	388 "+HM = "	
339 " ** NOTE **"	389 ARCL 12	
340 AVIEW	390 PROMPT	
341 PSE	391 "RCMD CRS CLG"	
342 "BELOW 10K FT"	392 AVIEW	
343 AVIEW	393 PSE	
344 PSE	394 "CC = "	
345 "INC MRD IAS"	395 ARCL 06	
346 AVIEW	396 PROMPT	
347 PSE	397 "CW = "	
348 "1 KT/1000FT"	398 ARCL 01	
349 AVIEW	399 PROMPT	
350 PSE	400 "UPDATE e 30M"	

3.1.8 Variable Locations and Governing Equations

3.1.8.1 Variable Register Locations

The following variables are applicable to all three FPAS programs.

BW - R00 (Basic Weight)
 GW - R01 (Gross Weight)
 PA - R02 (Pressure Altitude)
 OAT - R03 (Outside Air Temp)
 IAS - R04 (Indicated Airspeed)
 TDEV - R05 (Temp Deviation)
 CC - R06 (Cruise Ceiling)
 DVC - R07 (Delta Vc; Compressibility Correction)
 M2 - R08 (Mach Number Squared)
 TA - R09 (Ambient Temperature)
 SSI - R10 (SQRT Sigma Inverse)
 TAS - R11 (True Airspeed)
 HW - R12 (Headwind)
 CAS - R13 (Calibrated Airspeed)
 EAS - R14 (Equivalent Airspeed)
 GS - R16 (Groundspeed)
 WD - R17 (Wind Direction)
 WV - R18 (Wind Velocity)
 HDG - R19 (Aircraft Heading)
 LOPA - R20 (Level off altitude)

3.1.8.2 Governing Equations

Single asterisks "*" imply multiplication, double "**" imply exponent.

Temperature Deviation: $TDEV = f(OAT, PA)$

$$TDEV = OAT - 15 + (198E-5) (PA)$$

Cruise Ceiling: $CC = f(TDEV, GW)$

$$\begin{aligned}
 CC = & 58480 + 78.67 (30 - TDEV) - \\
 & - (1 - 0.0031 (30 - TDEV)) (0.705) (GW)
 \end{aligned}$$

Max Range Calibrated Airspeed: $MRCAS = f(PA, GW)$

$$MRCAS = 179.67 - (173E-5) (PA) + (816E-6) (GW) \\ + (516E-20) (PA)**2 (GW)**2 - \\ - 3.074LN(PA E-3)$$

Max Endurance Calibrated Airspeed: $MECAS = f(GW)$

$$MECAS = 65 + (125E-5) (GW)$$

Delta, Atmospheric Pressure Ratio: $p/po = f(PA)$

$$p/po = (1 - (6875E-9) (PA))**5.2563$$

Mach Number Squared: $M2 = f(p/po, IAS)$

$$M2 = 5 ((po/p ((1 + .2 (IAS/661.7)**2)**3.5 - 1) + 1)**-.286 - 1)$$

Ambient Temperature: $TA = f(OAT, M2)$

$$TA = OAT / (1 - .2 * M2)$$

SQRT Sigma Inverse: $SSI = f(TA, PA)$

$$SSI = .982 \exp((1936E-6) (TA) + (2112E-8) (PA - 1500))$$

Delta Vc (Comp Corr): $DVC = f(PA, CAS)$

$$DVC = ((1E-7) \exp(91E-6) (PA)) CAS**2.852)$$

IAS Dependent TAS: $TASi$

$$TASi = IAS * SSI$$

Headwind: HW

$$HW = TASi - GS$$

CAS Corrected for Headwind: $CAS+HW$

$$CAS+HW = CAS + (.5 - (PA)E-5) (HW)$$

CAS Corrected for Tailwind: CAS-HW

$$\text{CAS-HW} = \text{CAS} + (.3 - (\text{PA})5\text{E-6}) (\text{HW})$$

Equivalent Airspeed: EAS

$$\text{EAS} = \text{CAS} - \text{DVC}$$

True Airspeed: TAS

$$\text{TAS} = \text{EAS} * \text{SSI}$$

Max Range Descent CAS (>10000): MRDCAS = f(GW)

$$\text{MRDCAS} = 130.4677 \exp((\text{GW}) (32687\text{E-10}))$$

Max Range Descent CAS (<10000): MRDCAS = f(GW) + f(PA)

$$\text{MRDCAS} = 130.4677 \exp((\text{GW}) (32687\text{E-10}))$$

$$+ 10 - .001 (\text{PA})$$

3.2 THE E-2C BINGO PROGRAM

First efforts to design a BINGO program for the E-2C included use of regression analysis to approximate the values listed in the BINGO charts. This effort was abandoned early on as being impractical and inaccurate. The charts are already rounded off the nearest five pound increment and the exact method used to compute the original values is unknown.

The method used in this report is to load all the values of fuel required and time required into a data set, then use a calculator program to access the correct value. There are seven configurations; only the boldface fuel required values are used. All other values are disregarded. Sorting algorithms are used to determine the correct recommended altitude to fly and similar methods are used to calculate the appropriate address for indirect addressing of the correct fuel-required:time-required value.

Interpolation calculates fuel and time required for values not explicitly shown in the charts. No corrections are made for headwinds or tailwinds. Since fuel required and time required are stored in the data set as a decimal number, integer functions and appropriate calculations are used to separate the indirectly accessed value for storage and display.

3.2.1 Theory of Operation

The EINGO program can be easily selected by the user by pressing the shift key, then key 21. The program loads and is ready for use in about 30 seconds. Once loaded, START is pressed. An echo check is displayed, "***E2C BINGO*", followed by a request for "DIST TO GO?". Then, "SELECT.., ENGS, GR, FLPS".

At this point, the pilot determines the probable configuration for any BINGO situation that might arise. Generally, two engines, gear up and flaps up can be assumed. If, however, the aircraft was experiencing a stuck flaps or gear down situation, those configurations could also be selected. Time permitting, fuel and time required for all seven configurations could be requested and written down in a short amount of time.

The 2E key is now pressed, followed by GU, then FU. Program operation will proceed to display "VFR, IFR?" so that 1000 pounds can be added to the fuel required if IFR is selected. After the VFR or IFR key is pressed, program operation proceeds automatically without user assistance. The correct value of fuel and time required are selected by the program and stored for display. Flowchart operation is pictured in the following pages. Fuel required, time required, recommended altitude to fly, initial sea level IAS to fly, a climb schedule airspeed correction, and initial power setting are all displayed to the user.

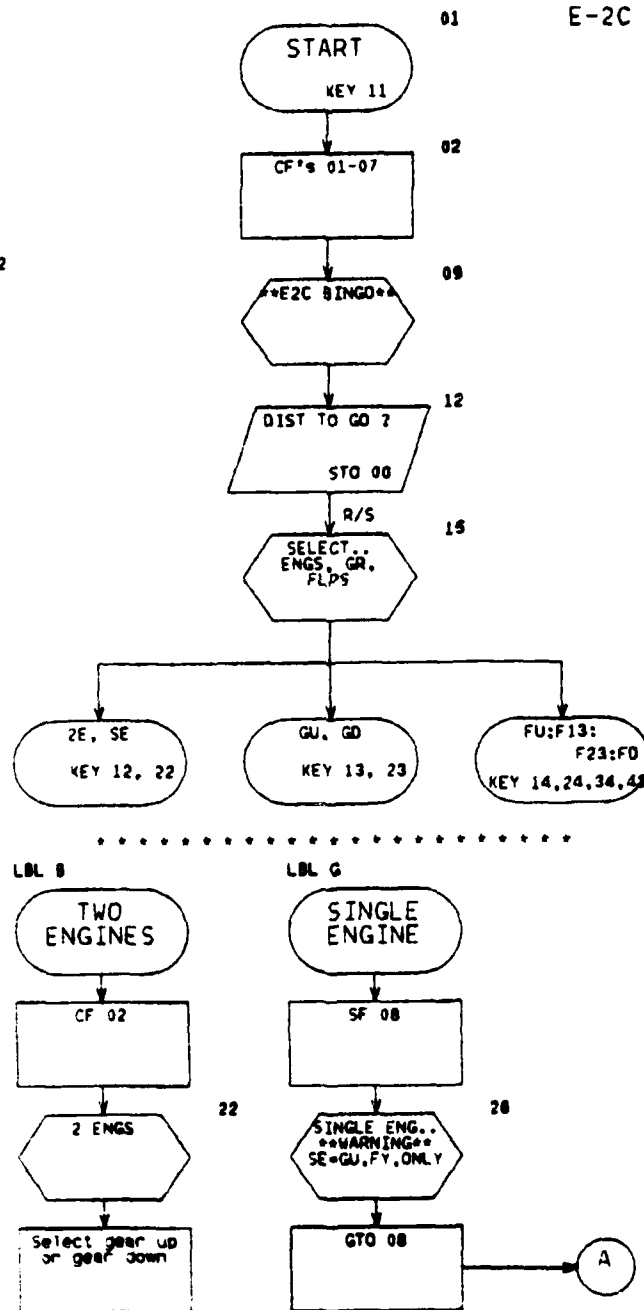
3.2.2 Future Corrections

The current program configuration performs exactly what the pilot would find if the pocket checklist was used. The advantage to using the calculator is the ability to chose new configurations without sorting through several pages of configurations scattered in the checklist booklet. The checklist booklet has always been somewhat difficult to use; hopefully, the calculator will ease that problem somewhat.

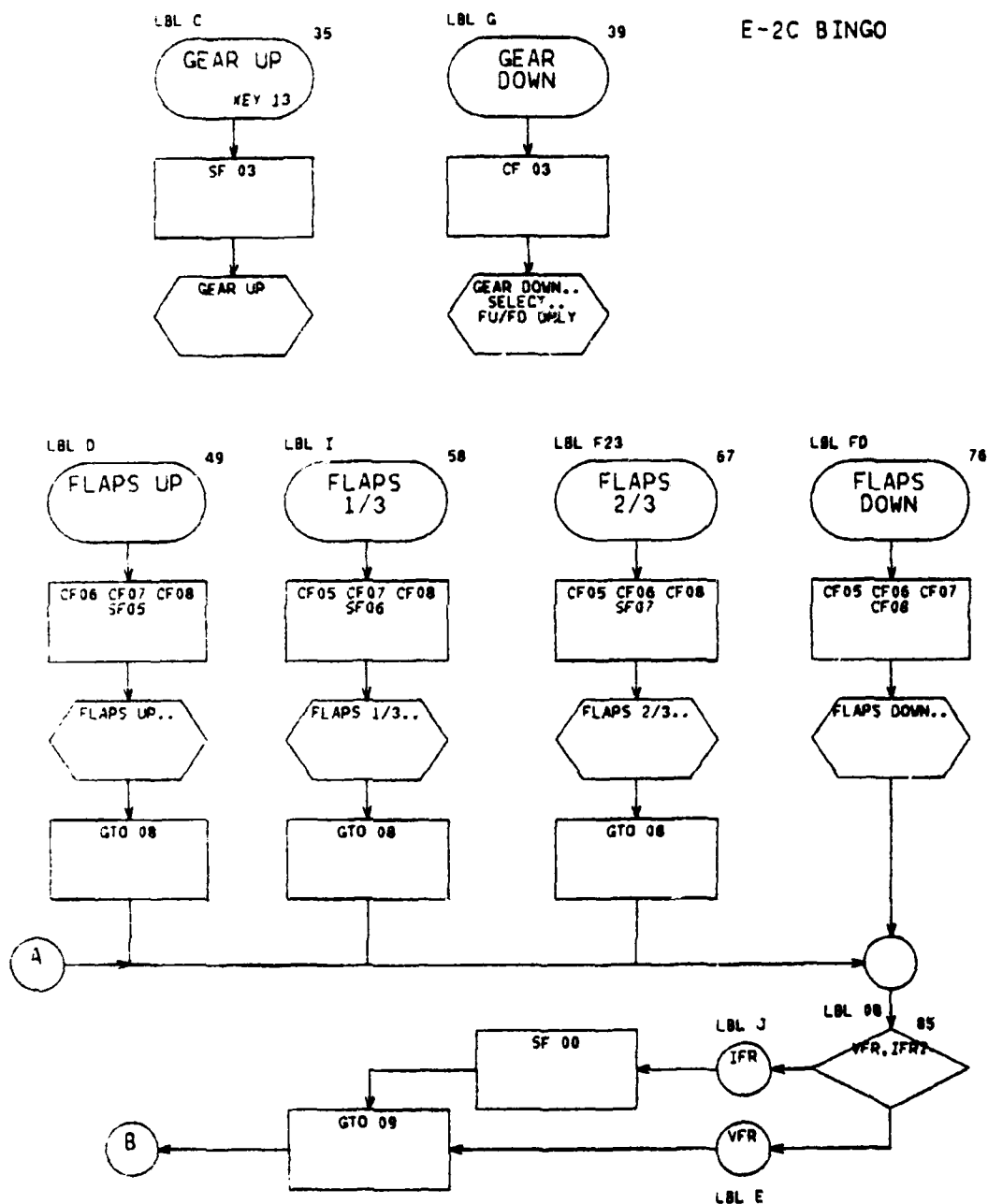
The next modification to this program, a subject of future research, will be to incorporate headwind and tailwind corrections to fuel and time required values.

XEO SIZE 142

E-2C BINGO



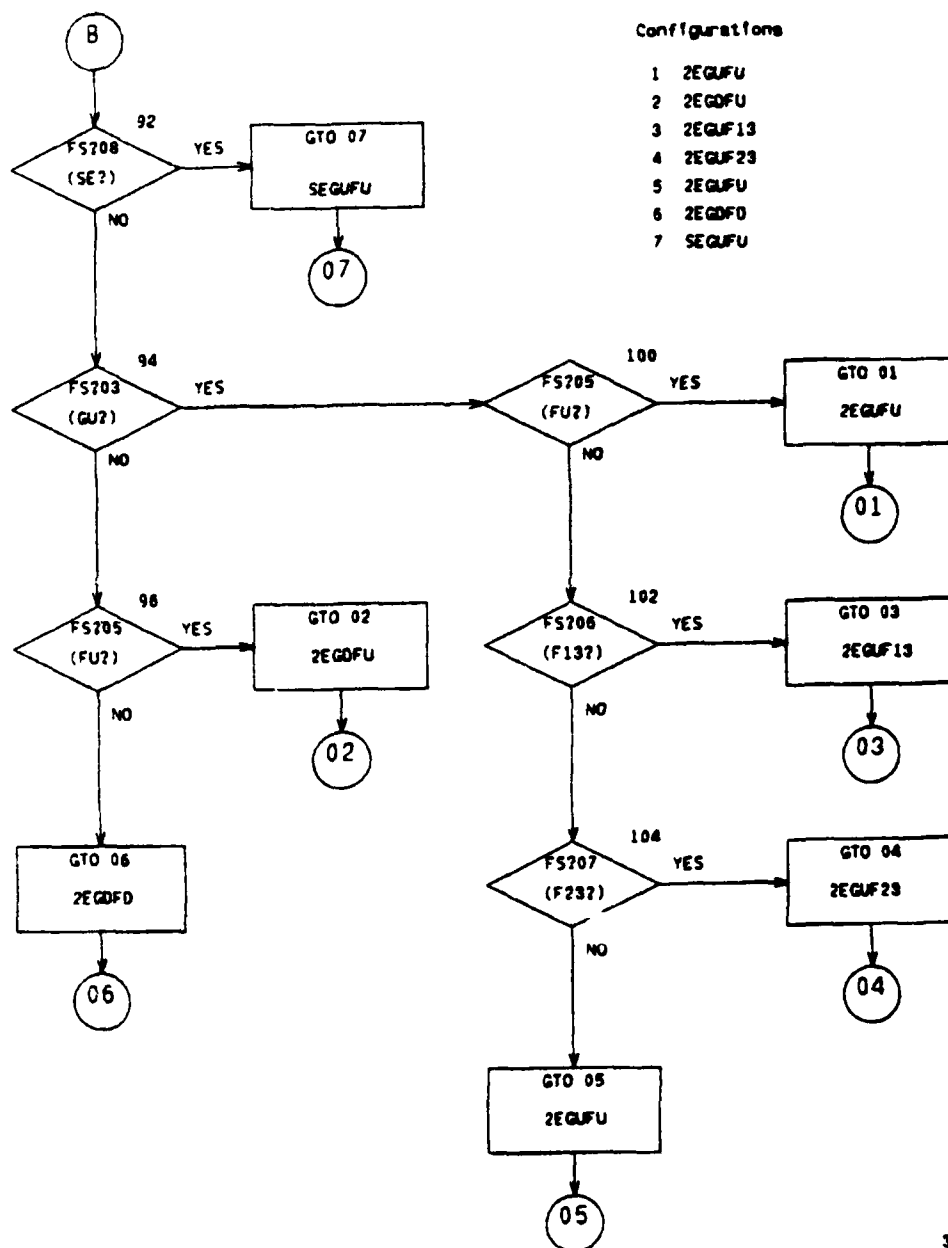
E-2C BINGO



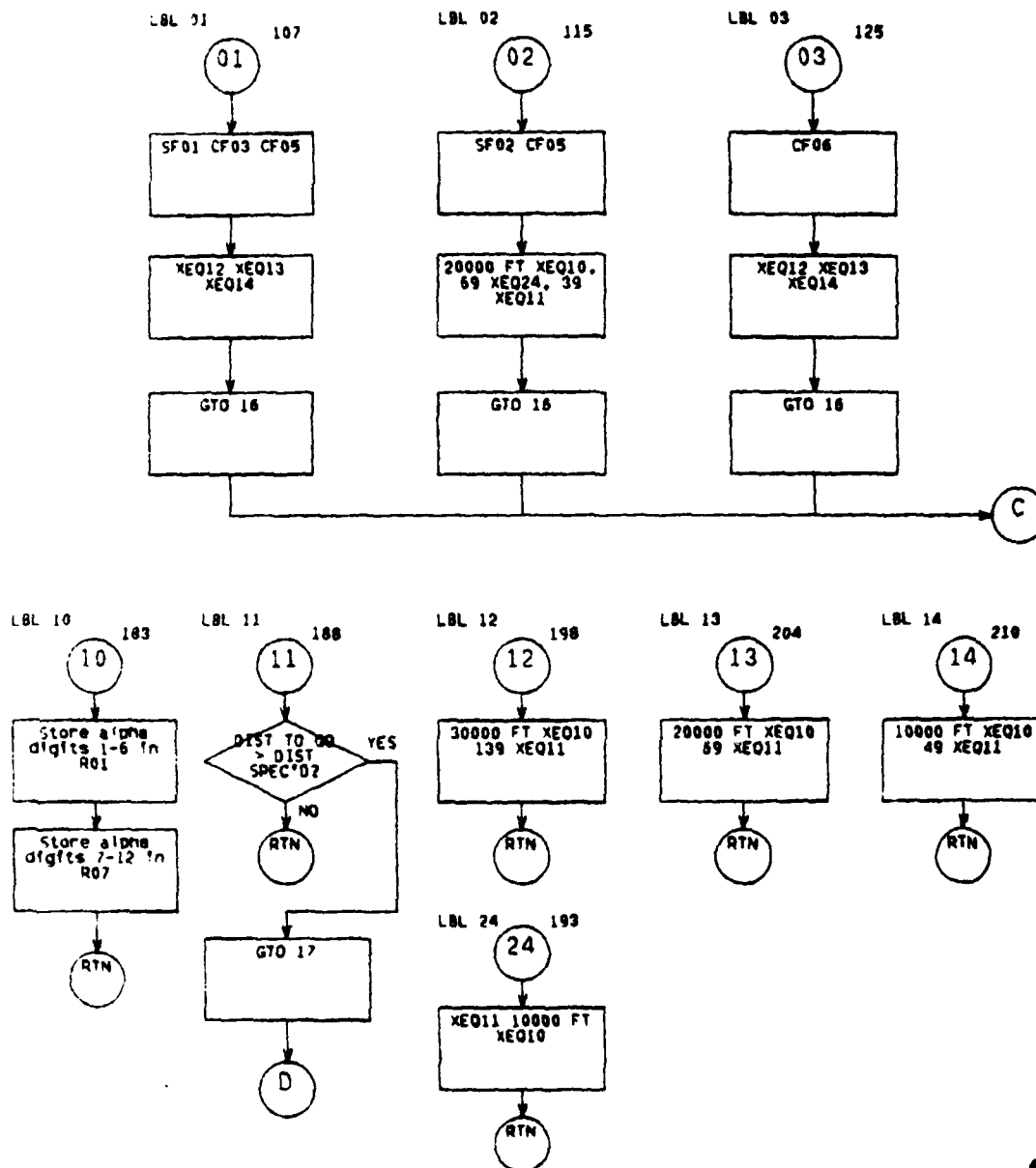
E-2C BINGO

Configurations

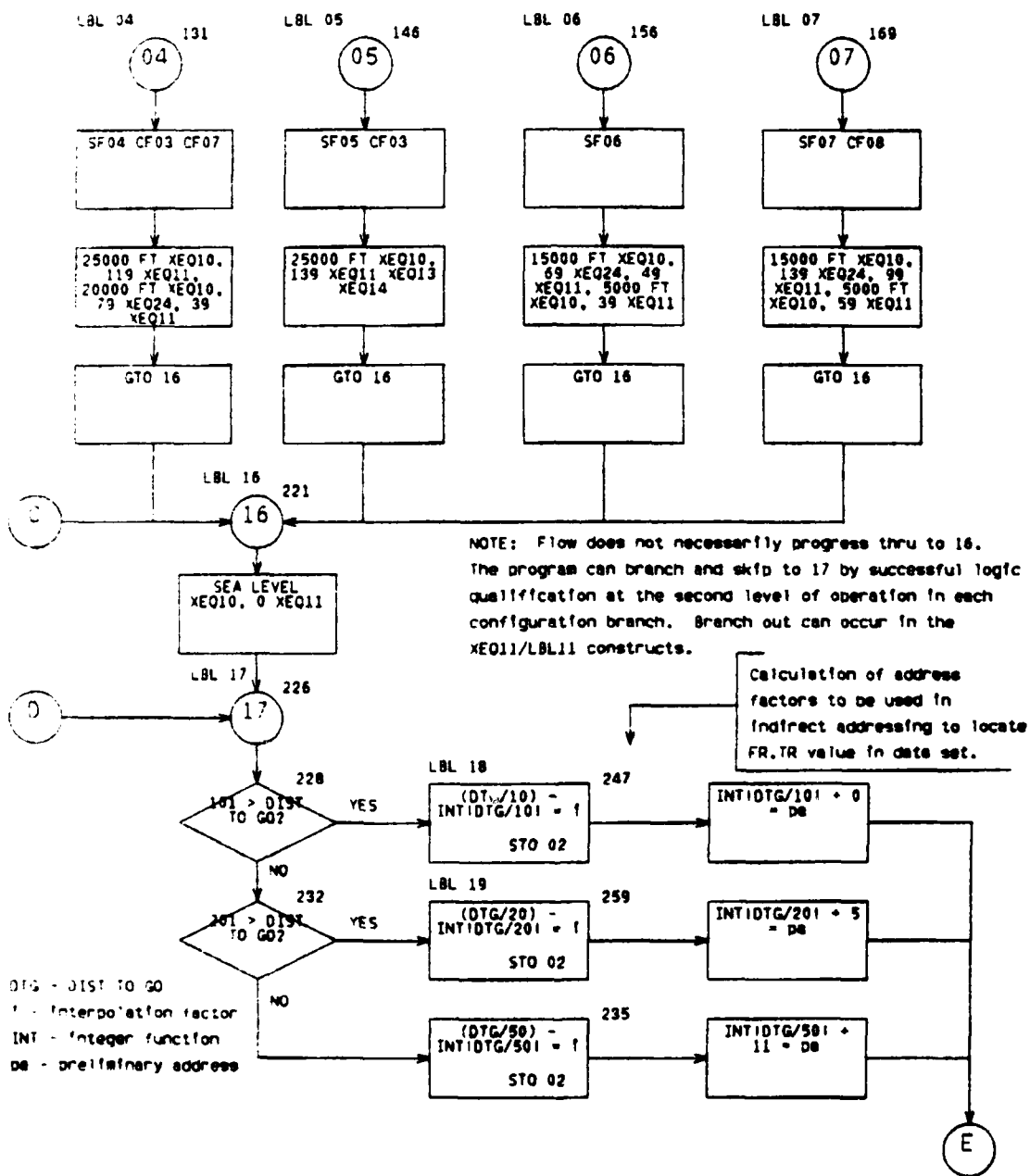
- 1 2EGUFU
- 2 2EGDFU
- 3 2EGUF13
- 4 2EGUF23
- 5 2EGUFU
- 6 2EGDFD
- 7 SEGUFU



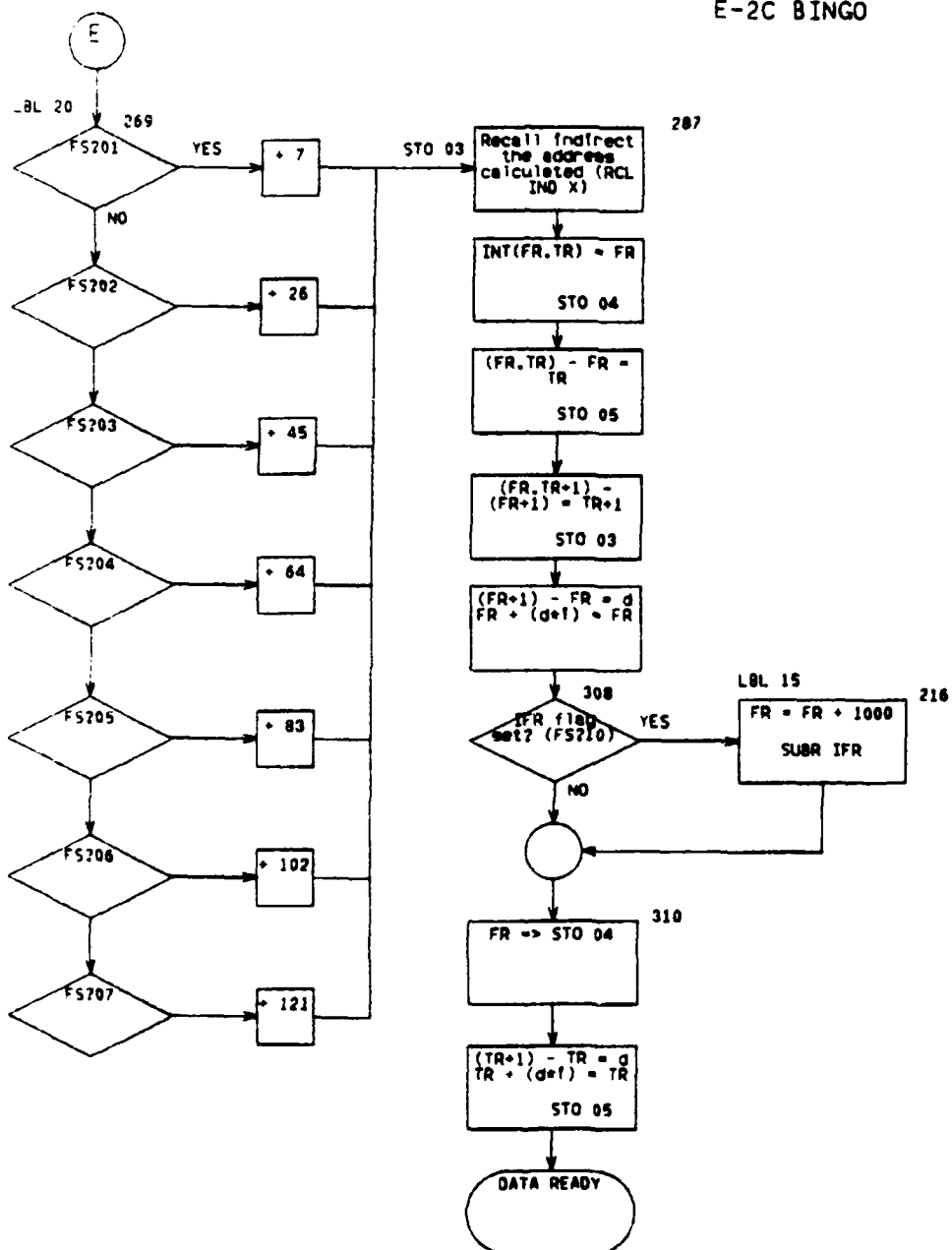
E-2C BINGO



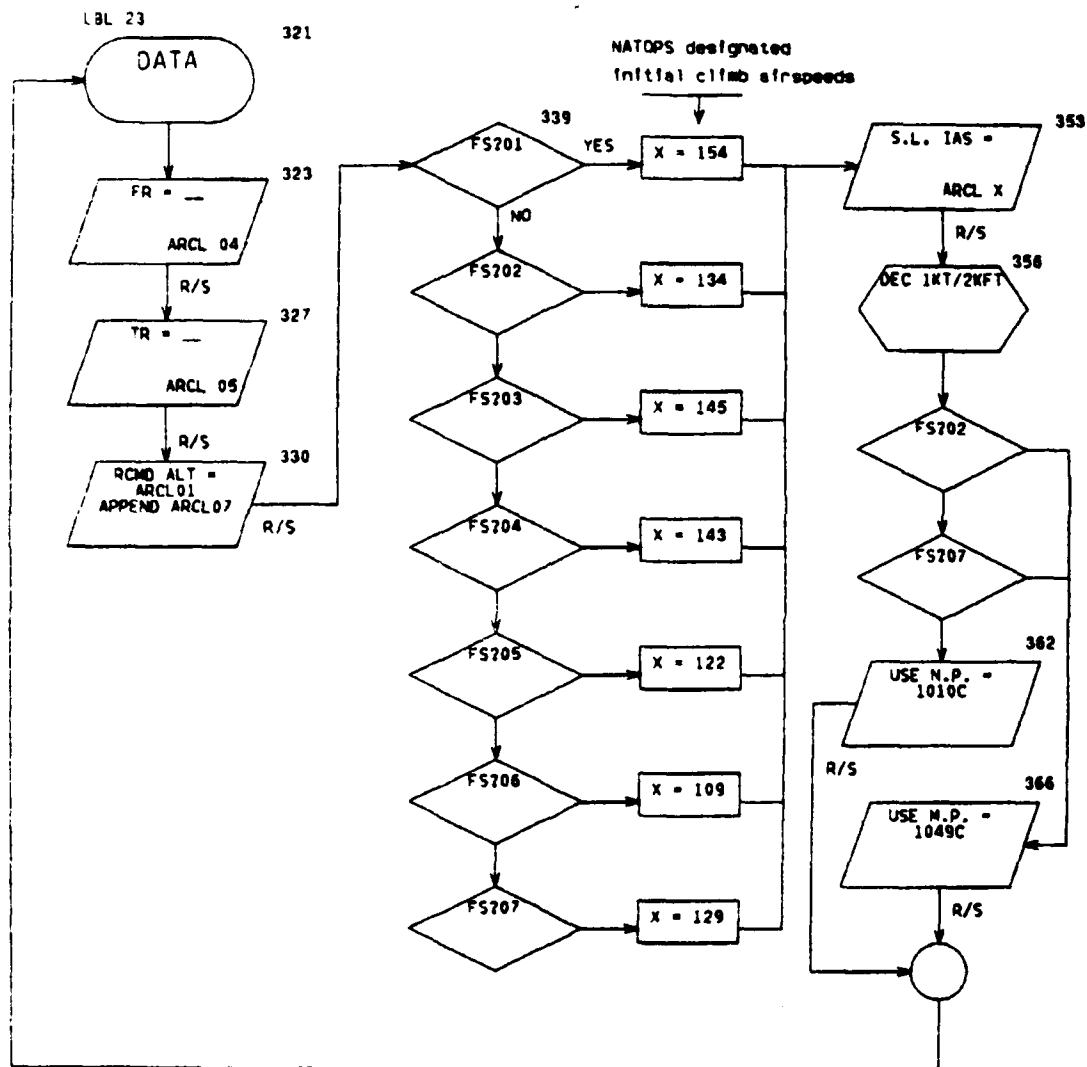
E-2C BINGO



E-2C BINGO



E-2C BINGO



E-2C BINGO/HP-41CV Code (June 1982, 1/4)

01*LBL "STB"	51 CF 07	101 GTO 01
02 CF 01	52 CF 08	102 FS? 06
03 CF 02	53 SF 05	103 GTO 03
04 CF 03	54 "FLAPS UP..."	104 FS? 07
05 CF 04	55 AVIEW	105 GTO 04
06 CF 05	56 PSE	106 GTO 05
07 CF 06	57 GTO 08	107*LBL 01
08 CF 07	58*LBL I	108 SF 01
09 **E2C BINGO**	59 CF 05	109 CF 03
10 AVIEW	60 CF 07	110 CF 05
11 PSE	61 CF 08	111 XEQ 12
12 "DIST TO GO ?"	62 SF 06	112 XEQ 13
13 PROMPT	63 "FLAPS 1/3..."	113 XEQ 14
14 STO 00	64 AVIEW	114 GTO 16
15 "SELECT..."	65 PSE	115*LBL 02
16 AVIEW	66 GTO 08	116 CF 05
17 PSE	67*LBL "F23"	117 SF 02
18 "ENGS, GR, FLPS"	68 CF 05	118 "20000 FT"
19 PROMPT	69 CF 06	119 XEQ 10
20*LBL B	70 CF 08	120 69
21 CF 02	71 SF 07	121 XEQ 24
22 "2 ENGS"	72 "FLAPS 2/3..."	122 39
23 PROMPT	73 AVIEW	123 XEQ 11
24*LBL G	74 PSE	124 GTO 16
25 SF 08	75 GTO 08	125*LBL 03
26 "SINGLE ENG..."	76*LBL "FD"	126 CF 06
27 AVIEW	77 CF 05	127 XEQ 12
28 PSE	78 CF 06	128 XEQ 13
29 **WARNING**	79 CF 07	129 XEQ 14
30 AVIEW	80 CF 08	130 GTO 16
31 "SE=GU,FU,ONLY..."	81 "FLAPS DOWN..."	131*LBL 04
32 AVIEW	82 AVIEW	132 CF 07
33 PSE	83 PSE	133 CF 03
34 GTO 08	84*LBL 08	134 SF 04
35*LBL C	85 "VFR, IFR ?"	135 "25000 FT"
36 SF 03	86 PROMPT	136 XEQ 10
37 "GEAR UP"	87*LBL E	137 119
38 PROMPT	88 GTO 09	138 XEQ 11
39*LBL H	89*LBL J	139 "20000 FT"
40 CF 03	90 SF 10	140 XEQ 10
41 "GEAR DOWN..."	91*LBL 09	141 79
42 AVIEW	92 FS? 08	142 XEQ 24
43 PSE	93 GTO 07	143 39
44 "SELECT..."	94 FS? 03	144 XEQ 11
45 AVIEW	95 GTO 22	145 GTO 16
46 PSE	96 FS? 05	146*LBL 05
47 "FU/FD ONLY"	97 GTO 02	147 CF 03
48 PROMPT	98 GTO 06	148 SF 05
49*LBL D	99*LBL 22	149 "25000 FT"
50 CF 06	100 FS? 05	150 XEQ 10

E-2C BINGO/HP-41CV Code (June 1982, 2/4)

151 139	201 139	251 INT
152 XEQ 11	202 XEQ 11	252 STO 03
153 XEQ 13	203 RTN	253 -
154 XEQ 14	204*LBL 13	254 STO 02
155 GTO 16	205 *20000 FT*	255 RCL 03
156*LBL 06	206 XEQ 10	256 0
157 SF 06	207 69	257 GTO 20
158 *15000 FT*	208 XEQ 11	258*LBL 19
159 XEQ 10	209 RTN	259 RCL 00
160 69	210*LBL 14	260 20
161 XEQ 24	211 *10000 FT*	261 /
162 49	212 XEQ 10	262 ENTER↑
163 XEQ 11	213 49	263 INT
164 * 5000 FT*	214 XEQ 11	264 STO 03
165 XEQ 10	215 RTN	265 -
166 39	216*LBL 15	266 STO 02
167 XEQ 11	217 CF 10	267 RCL 03
168 GTO 16	218 1000	268 5
169*LBL 07	219 +	269*LBL 20
170 CF 00	220 RTN	270 +
171 SF 07	221*LBL 16	271 FS? 01
172 *15000 FT*	222 * SEA LEVEL*	272 7
173 XEQ 10	223 XEQ 10	273 FS? 02
174 139	224 0	274 26
175 XEQ 24	225 XEQ 11	275 FS? 03
176 99	226*LBL 17	276 45
177 XEQ 11	227 RCL 00	277 FS? 04
178 * 5000 FT*	228 101	278 64
179 XEQ 10	229 X>Y?	279 FS? 05
180 59	230 GTO 18	280 83
181 XEQ 11	231 X<>Y	281 FS? 06
182 GTO 16	232 201	282 102
183*LBL 10	233 X>Y?	283 FS? 07
184 ASTO 01	234 GTO 19	284 121
185 ASHF	235 RCL 00	285 +
186 ASTO 07	236 50	286 STO 03
187 RTN	237 /	287 RCL IND X
188*LBL 11	238 ENTER↑	288 ENTER↑
189 RCL 00	239 INT	289 INT
190 X>Y?	240 STO 03	290 STO 04
191 GTO 17	241 -	291 -
192 RTN	242 STO 02	292 STO 05
193*LBL 24	243 RCL 03	293 1
194 XEQ 11	244 11	294 ST+ 03
195 *10000 FT*	245 GTO 20	295 RCL IND 03
196 XEQ 10	246*LBL 18	296 ENTER↑
197 RTN	247 RCL 00	297 INT
198*LBL 12	248 10	298 STO 06
199 *30000 FT*	249 /	299 -
200 XEQ 10	250 ENTER↑	300 STO 03

E-2C BINGO/HP-41CV Code (June 1982, 3/4)

301 RCL 06	351 109	R26= 4,375.138
302 RCL 04	352 FS? 07	R27= 1,275.004
303 -	353 129	R28= 1,460.007
304 RCL 02	354 "S.L. IAS = "	R29= 1,640.010
305 *	355 ARCL X	R30= 1,800.014
306 RCL 04	356 PROMPT	R31= 1,940.017
307 +	357 "DEC 1KT/2KFT"	R32= 2,000.020
308 FS? 10	358 PROMPT	R33= 2,210.024
309 XEQ 15	359 FS? 02	R34= 2,325.027
310 STO 04	360 GTO 38	R35= 2,435.030
311 RCL 03	361 FS? 07	R36= 2,545.033
312 RCL 05	362 GTO 38	R37= 2,775.039
313 -	363 "USE M.P.=1010C"	R38= 3,000.045
314 RCL 02	364 PROMPT	R39= 3,225.051
315 *	365 GTO 23	R40= 3,465.057
316 RCL 05	366*LBL 38	R41= 3,695.103
317 +	367 "USE M.P.=1049C"	R42= 4,265.118
318 10	368 PROMPT	R43= 4,845.133
319 *	369 GTO 23	R44= 5,430.148
320 STO 05	370 .END.	R45= 6,020.204
321*LBL 21		R46= 1,250.003
322*LBL 23		R47= 1,400.006
323 FIX 0		R48= 1,545.009
324 - FR = "		R49= 1,685.012
325 ARCL 04	R00= 0.000	R50= 1,795.015
326 FIX 2	R01= 1.000	R51= 1,905.018
327 PROMPT	R02= 2.000	R52= 2,015.021
328 - TR = "	R03= 3.000	R53= 2,105.024
329 ARCL 05	R04= 4.000	R54= 2,195.027
330 PROMPT	R05= 5.000	R55= 2,280.030
331 "RCMD ALT ="	R06= 6.000	R56= 2,460.036
332 AVIEW	R07= 7.000	R57= 2,620.040
333 PSE	R08= 1,240.003	R58= 2,775.045
334 CLA	R09= 1,380.006	R59= 2,925.050
335 ARCL 01	R10= 1,515.009	R60= 3,080.055
336 "-"	R11= 1,655.012	R61= 3,465.107
337 ARCL 07	R12= 1,760.015	R62= 3,860.120
338 PROMPT	R13= 1,865.018	R63= 4,245.133
339 FIX 0	R14= 1,950.020	R64= 4,630.145
340 FS? 01	R15= 2,040.023	R65= 1,250.003
341 154	R16= 2,120.025	R66= 1,400.007
342 FS? 02	R17= 2,200.028	R67= 1,550.010
343 134	R18= 2,365.033	R68= 1,685.013
344 FS? 03	R19= 2,525.038	R69= 1,800.016
345 145	R20= 2,665.042	R70= 1,915.019
346 FS? 04	R21= 2,810.047	R71= 2,035.022
347 143	R22= 2,945.052	R72= 2,130.025
348 FS? 05	R23= 3,300.103	R73= 2,220.028
349 122	R24= 3,655.115	R74= 2,310.031
350 FS? 06	R25= 4,015.126	R75= 2,490.036

E-2C BINGO/HP-41CV Code (June 1982, 4/4)

R76=	2,660.041	R126=	1,650.019
R77=	2,835.047	R127=	1,750.023
R78=	3,010.052	R128=	1,850.026
R79=	3,185.058	R129=	1,950.029
R80=	3,625.112	R130=	2,050.033
R81=	4,060.126	R131=	2,145.037
R82=	4,495.139	R132=	2,330.043
R83=	4,945.153	R133=	2,495.050
R84=	1,280.004	R134=	2,670.056
R85=	1,465.008	R135=	2,845.103
R86=	1,650.012	R136=	3,025.109
R87=	1,810.015	R137=	3,475.125
R88=	1,960.019	R138=	3,920.142
R89=	2,100.023	R139=	4,360.157
R90=	2,250.026	R140=	4,810.214
R91=	2,365.029		
R92=	2,485.033		
R93=	2,605.036		
R94=	2,840.042		
R95=	3,075.048		
R96=	3,300.054		
R97=	3,530.101		
R98=	3,760.107		
R99=	4,340.123		
R100=	4,910.139		
R101=	5,510.155		
R102=	6,120.211		
R103=	1,310.004		
R104=	1,530.008		
R105=	1,750.013		
R106=	1,950.017		
R107=	2,130.021		
R108=	2,310.025		
R109=	2,470.029		
R110=	2,625.032		
R111=	2,780.036		
R112=	2,945.040		
R113=	3,270.048		
R114=	3,590.055		
R115=	3,915.103		
R116=	4,235.110		
R117=	4,555.117		
R118=	5,365.136		
R119=	6,210.155		
R120=	9,999.999		
R121=	9,999.999		
R122=	1,210.004		
R123=	1,320.008		
R124=	1,430.011		
R125=	1,540.015		

3.3 THE E-2C CROSSWIND LANDING LIMITATIONS PROGRAM

The Crosswind Landing Limitations program is a straight forward interpretation of the Takeoff and Landing Crosswind Limits chart on page 11-26 of the E-2C NATOPS manual. Subsequently, it was determined that the same chart is used for the E-2B and C-2A; hence, the code for those aircraft is exactly the same except for the label that appears in the calculator readout when the program is initially selected. A separate section for the E-2B and C-2A programs is not included.

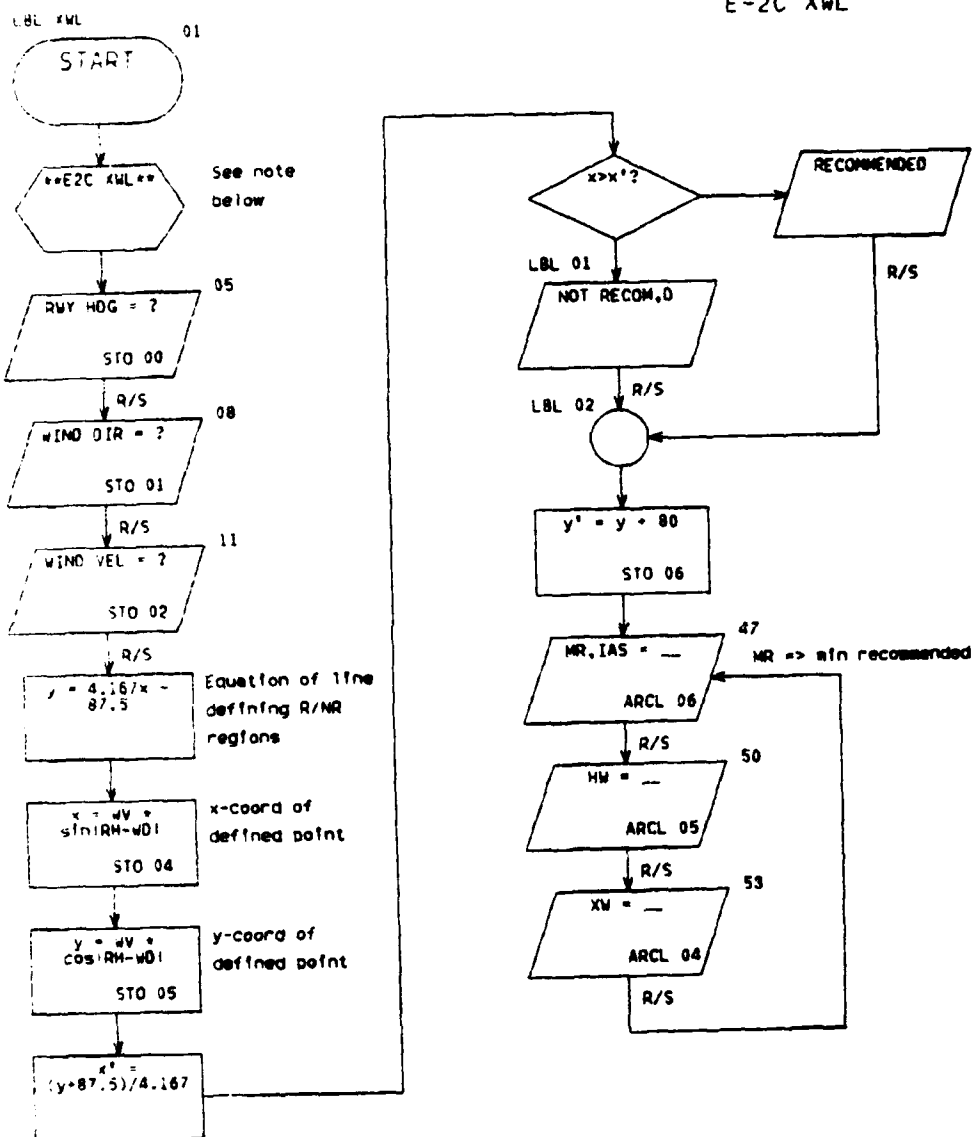
3.3.1 Theory of Operation

The IWL program loads from extended memory in less than 10 seconds. The press key 33 and observe "***E-2C IWL**" appear momentarily in the display.¹¹ Assuming the program is being used during the setup to landing from an approach or during a VFR touch and go pattern, the user is then asked for "RWY HDG = ?" (runway heading). Enter the correct number (010 to 360) followed by R/S. In the same manner, the program asks for "WIND DIR = ?" and "WIND VEL = ?". The program computes x and y positions based on the input parameters then compares these against an equation for the line defining the boundary between recommended and not recommended. Depending on the outcome of the logic, the program will then, obviously, display "RECOMMENDED" or "NOT RECOMMENDED". The program then computes minimum recommended IAS for touch-

¹¹ Or "***E-2B IWL**" or "***C-2A IWL**" as previously noted.

down (MR,IAS), headwind (HW) and crosswind (XW) and displays each. The flowchart and code for the program are listed on the following pages.

E-2C XWL



Note: Program for E-2B and C-2A is the same in all respects except for the viewer label.

E-2C IWL/HP-41CV Code (June 1982, 1/1)

01*LBL "XWL"	30 4.167
02 ***E-2C XWL**	31 /
03 AVIEW	32 RCL 04
04 PSE	33 X>Y?
05 "RWY HDG = ?"	34 GTO 01
06 PROMPT	35 "RECOMMENDED"
07 STO 00	36 PROMPT
08 "WIND DIR = ?"	37 GTO 02
09 PROMPT	38*LBL 01
10 STO 01	39 "NOT RECON,D"
11 "WIND VEL = ?"	40 PROMPT
12 PROMPT	41*LBL 02
13 STO 02	42 RCL 05
14 RCL 00	43 00
15 RCL 01	44 +
16 -	45 STO 06
17 ABS	46 FIX 0
18 STO 03	47 "MR,IAS = "
19 SIN	48 ARCL 06
20 RCL 02	49 PROMPT
21 *	50 " HW = "
22 STO 04	51 ARCL 05
23 RCL 03	52 PROMPT
24 COS	53 " XW = "
25 RCL 02	54 ARCL 04
26 *	55 PROMPT
27 STO 05	56 GTO 02
28 87.5	57 .END.
29 +	

3.4 SAMPLE PROGRAM OPERATION

The best way to understand operation of the calculator is to create a scenario in which the calculator might be used. The following scene is typical of what might be expected.

3.4.1 Using the FPAS Program

Assume the mission is complete, marshall instructions have been received, and the aircraft is proceeding to the assigned holding fix with an expected push time. Approximate distance from present position to the holding fix is sufficient to justify calculating a max range profile. The copilot, most probable operator of the calculator, turns the HP-41 on and ensures that USER mode appears in the window. The FPAS program is selected by SHIFT/KEY¹²11. The program operation symbol (a flying "duck") appears in the window while the FPAS program loads from extended memory to main memory. Upon completion of the load sequence, the window again displays whatever numbers were in the window to begin with.

KEY 11 is now pushed again to start the program. "***E2C FPAS***" appears momentarily in the window as an echo check verification, followed by "BASIC WT = ?". Enter 39600, then R/S. The other prompts occur as follows.

<u>PROMPT</u>	<u>Response</u>
CARGO WT = ?	50 R/S
NO. CREW = ?	5 R/S

¹² The yellow SHIFT key doubles the USER functions of each of the program selecting keys. KEY 11 is also the START key for programs in the unshifted mode.

PROFILE?	RANGE KEY 12
MAX RANGE	(momentary echo check)
ALT = FT?	25000 R/S
OAT = C?	-15 R/S (key CHS for +/-)
IAS = KTS?	155 R/S (current IAS)
FUEL = LBS?	6500 R/S (read from gages)
GS/AVAIL? Y/N	YES KEY 15 (assuming CAINS up)
GS = KTS?	250 R/S
DATA READY	Press R/S or KEY 21 to continue
*RCMD MR IAS	
*PRESENT ALT	
*MR IAS = 169	R/S
*MR TAS = 265	R/S
*HW = -7	R/S (a tail wind)
RCMD CRS CLG	
CC = 27100	R/S
GW = 47150	
UPDATE e 30M	R/S to repeat data

The pilot now establishes IAS = 169 knots to fly max range fuel consumption to the marshall holding point. Enroute, the copilot accesses the max endurance program to plan a holding airspeed.¹³ KEY 13 is pressed and the following sequence of commands and responses occur.

<u>Prompt</u>	<u>Response</u>
**MAX ENDUR*	
ALT = FT?	25000 R/S
OAT = C?	-15 R/S

¹³ The traditional method of flying max endurance is to set 21 to 22 units angle of attack. The AOA probe, however, is a pressure differential device that measures pressure at two positions on the surface of a small cylinder. It is least accurate at slower airspeeds because of lower static pressures and stiction in the mechanism. There is also a caution in the NATOPS regarding reverse power effects (ie, back side of power curve) at 22uAOA. Since the airspeed indicators are more accurate in a steady state condition, it is recommended that an output of NEI-AS-to-fly be used in preference to an AOA setting.

IAS = KTS?	169	R/S
FUEL = LBS?	9000	R/S
DATA READY		R/S or KEY 21
+RCND ME IAS		
+PRESENT ALT		
+ME IAS= 126		R/S
GW = 49650		R/S
UPDATE @ 30M		R/S to repeat data

The pilot enters holding and establishes 126 knots IAS and cross checks with the AOA. (This airspeed is based on a 9000 pound fuel load and should be updated periodically if a long period in holding occurs. ME IAS is strictly a function of gross weight).

3.4.2 Using the BINGO Program

In holding, the copilot now accesses the BINGO program by pressing SHIFT/KEY 21. When loaded, the START key (11) is pressed.^{1*}

<u>Prompt</u>	<u>Response</u>
**B2C BINGO*	
DIST TO GO ?	90 R/S
SELECT..	
ENGS, GR, FLAPS	2E KEY 12
2 ENGS	GU KEY 13
GEAR UP	FU KEY 14
FLAPS UP..	
VFR, IFR ?	IFR KEY 25
"Traveling duck"	
FR = 3120	R/S (3120 lbs fuel req'd)
TR = 0.25	R/S (25 min enroute)

^{1*} Assume a BINGO distance of 90 miles has been assigned by Marshall. The ship and BINGO field are IFR. The anticipated aircraft configuration is two engines, gear up, and flaps up.

RCMD ALT =	
20000 FT	R/S
S.L. IAS = 154	R/S (initial IAS to start climb)
DEC 1KT/2KFT	R/S (decrease IAS 1 knot/2000ft climb)
USE N.P.=1010C	R/S to repeat data

This data is duly recorded for possible use later in the recovery. Commencing the approach, fuel is dumped down to appropriate landing weight. Enroute, the E-2 is vectored in the usual manner to allow preceeding aircraft to clear the bolter pattern. Shortly after setting the approach configuration, the aircraft just prior to the E-2 manages to foul the deck indefinitely. A bolter is anticipated for the E-2. Upon cleaning up, the pilot experiences a jammed landing gear handle that precludes raising the gear. The flaps come up satisfactorily. Again, the BINGO program is accessed.

<u>Prompt</u>	<u>Response</u>
**E2C BINGO*	
DIST TO GO ?	90 R/S
SELECT..	
ENGS, GR, FLPS	2E
2 ENGS	GD
GEAR DOWN..	
SELECT..	
FU/PD ONLY	FU
FLAPS UP..	
VFR, IFR ?	IFR
"Traveling Duck"	
FR = 3435	R/S
TR = 0.30	R/S
RCMD ALT =	

20000 FT	R/S
S.L. IAS = 134	R/S
DEC 1KT/2KFT	R/S
USE M.P.=1049C	R/S to repeat data

Clearance to BINGO is received, and during the climb, one of the crew produces a screw driver that frees the landing gear handle. The gear come up and the pilot reestablishes a clean configuration.

3.4.3 The FPAS Program Again

Leveling off at 20000 feet, the FPAS program is accessed once more. The following max range data is obtained.

<u>Prompt</u>	<u>Response</u>
	START KEY 11
E2C FPAS	
BASIC WT = ?	39600 R/S
CARGO WT = ?	50 R/S
NO.CREW/PAX=?	5 R/S
PROFILE?	RANGE KEY 12
MAX RANGE	
ALT = FT?	20000 R/S
OAT = C?	-10 R/S
IAS = KTS?	165 R/S
FUEL = LBS?	4500 R/S
GS,AVAIL? Y/N	NO (CAINS is down)
INPUT WINDS..	
WIND DIR = ?	025 R/S (forecast or last known)
WIND VEL = ?	50 R/S
A/C HDG = ?	090 R/S
DATA READY	
*RCHD HR IAS	
*PRESENT ALT	
*HR IAS= 181	R/S
*HR TAS= 259	R/S
*HW = 21	R/S

RCMD CRS CLG	
CC = 29300	R/S
GW = 45150	R/S
UPDATE e 30M	R/S to repeat data

The pilot elects to remain at 20000 feet, anticipating higher winds at higher altitude, and calls for the max range descent program. The following responses are obtained.

<u>Prompt</u>	<u>Response</u>
	DESCENT KEY 14
HR DESCENT	
ALT = FT?	20000 R/S (altitude to descend from)
FUEL = LBS?	4000 R/S (anticipated)
L/O ALT = ?	2000 R/S (approach mda)
"Traveling Duck"	
DSNT, DIST=42	R/S
** NOTE **	
BELOW 10K FT	
INC HRD IAS	
1 KT/1000FT	
USE 500 SHP	
HRD IAS=156	R/S to repeat data

3.4.4 The Crosswind Landing Limitations Program

Checking in with approach the pilot receives the following pertinent weather data: winds 240 at 30, gusting to 35, runway 200 in use. The XWL program is called.

<u>Prompt</u>	<u>Response</u>
	XWL KEY 33
E-2C XWL	
RWY HDG = ?	200 R/S
WIND DIR = ?	240 R/S
WIND VEL = ?	35 R/S

RECOMMENDED
MR, IAS = 107

HW = 27
XW = 22

R/S
R/S (min rcmd touch
down speed)
R/S
R/S to repeat data

Chapter IV

THE E-2B/HP-41CV PROGRAMS

The E-2C program is the standardization format used to design programs for the E-2B and C-2A. Hence, a detailed explanation for programs for each of the other two aircraft is not included. The reader is urged to study the E-2C programs for details on theory of operation.

It is appropriate to mention at this point, however, that no significant changes have been made in the E-2B NATOPS manual, Chapter 11, since 1964. Engine modifications and a major propeller change have occurred since then. Only experience will determine whether computed parameters in this program are valid.

4.1 THE E-2B FPAS PROGRAM

The major differences between the E-2B and E-2C programs are specific equations, listed at the end of this chapter, and the theory of operation of the descent profile for the E-2B.

4.1.1 DESCENT

The max range descent IAS profile for the E-2C is dependent only on gross weight above 10000 feet, and on gross weight and altitude below 10000 feet. Program operation is dependent on selecting the correct starting altitude.

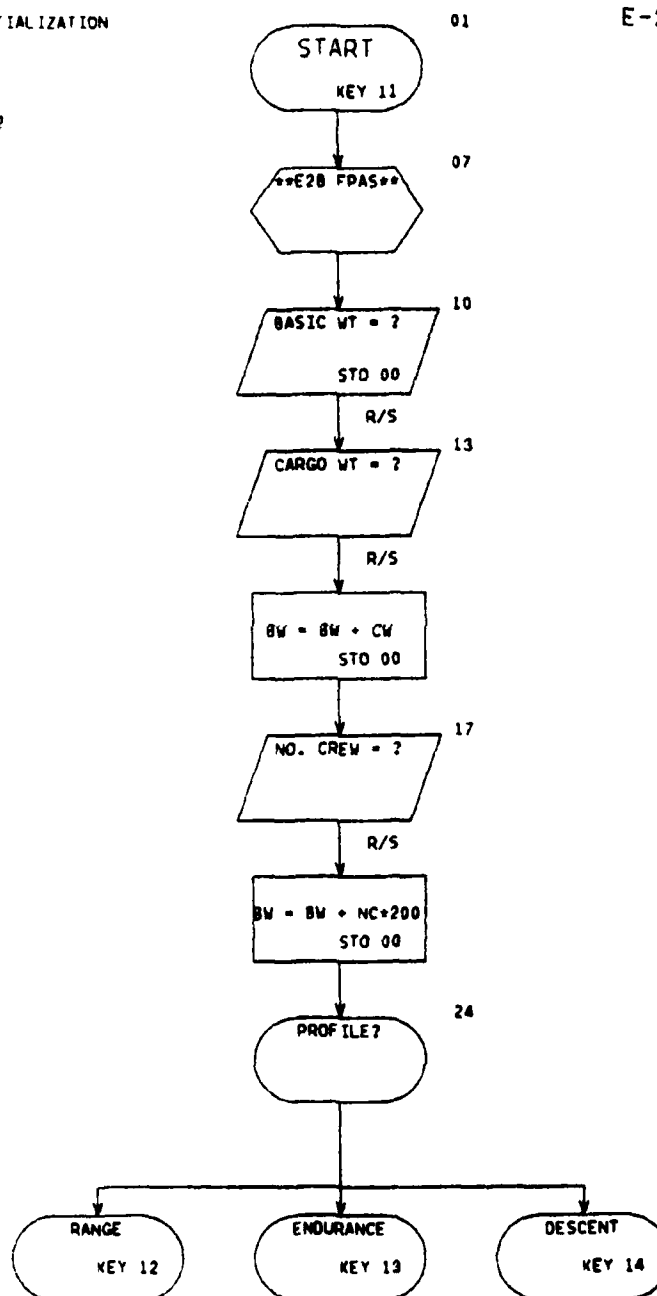
The E-2B (and C-2A) max range descent IAS profiles are exponential functions dependent on gross weight and altitude. Regression analysis yielded two sets of equations that split at 10000 feet to maintain accuracy. Program operation is transparent to the user, but the user is required to update the IAS at least once every 2000 feet during a descent.

The following pages document the flowchart and code for the E-2B FPAS.

PROGRAM INITIALIZATION

REQ SIZE 022

E-2B FPAS

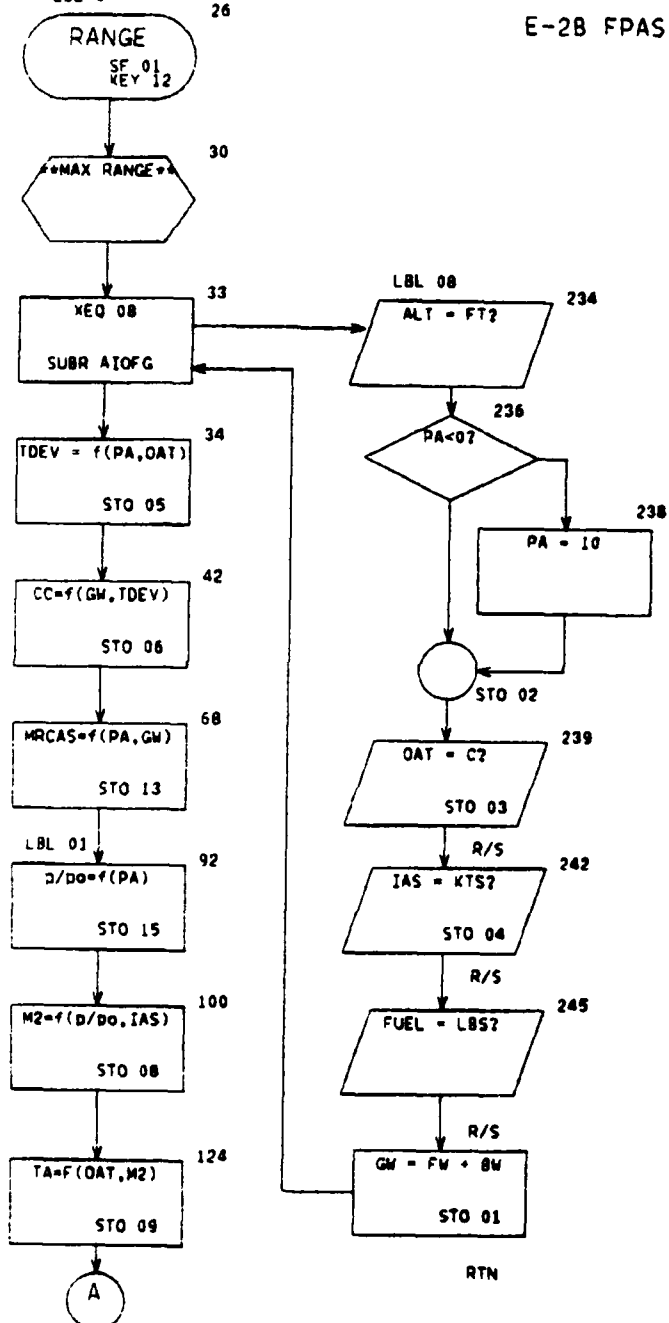


RANGE ALGORITHM

LBL 8

26

E-2B FPAS

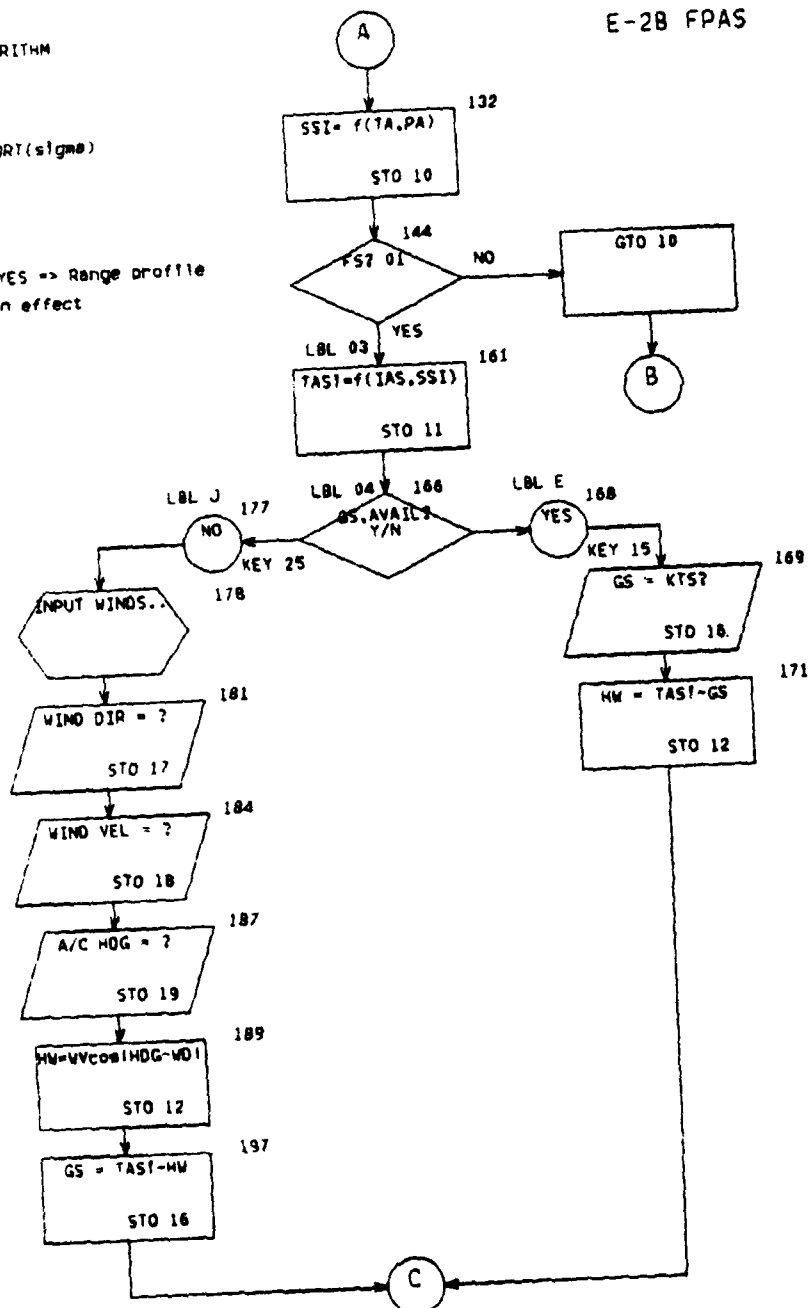


RANGE ALGORITHM
(cont'd)

$SSI = 1/\sqrt{\text{SIGMA}}$

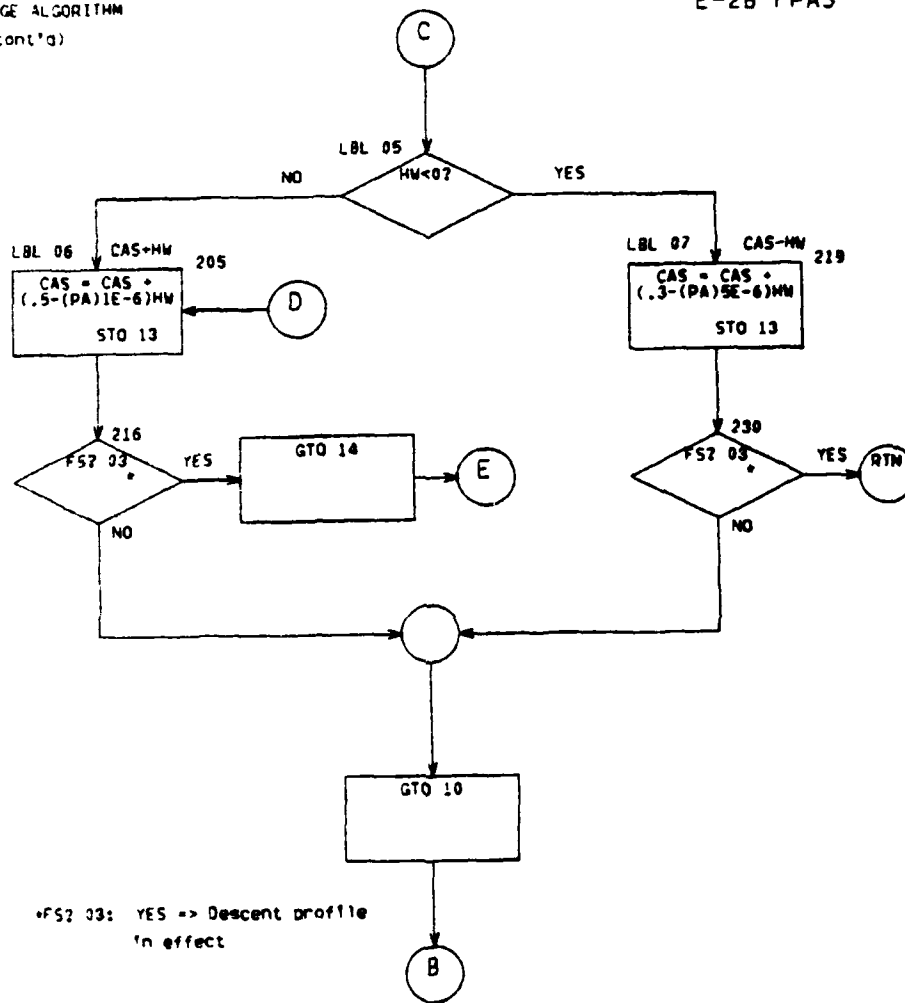
FS? 01: YES => Range profile
in effect

E-2B FPAS



RANGE ALGORITHM
(cont'd)

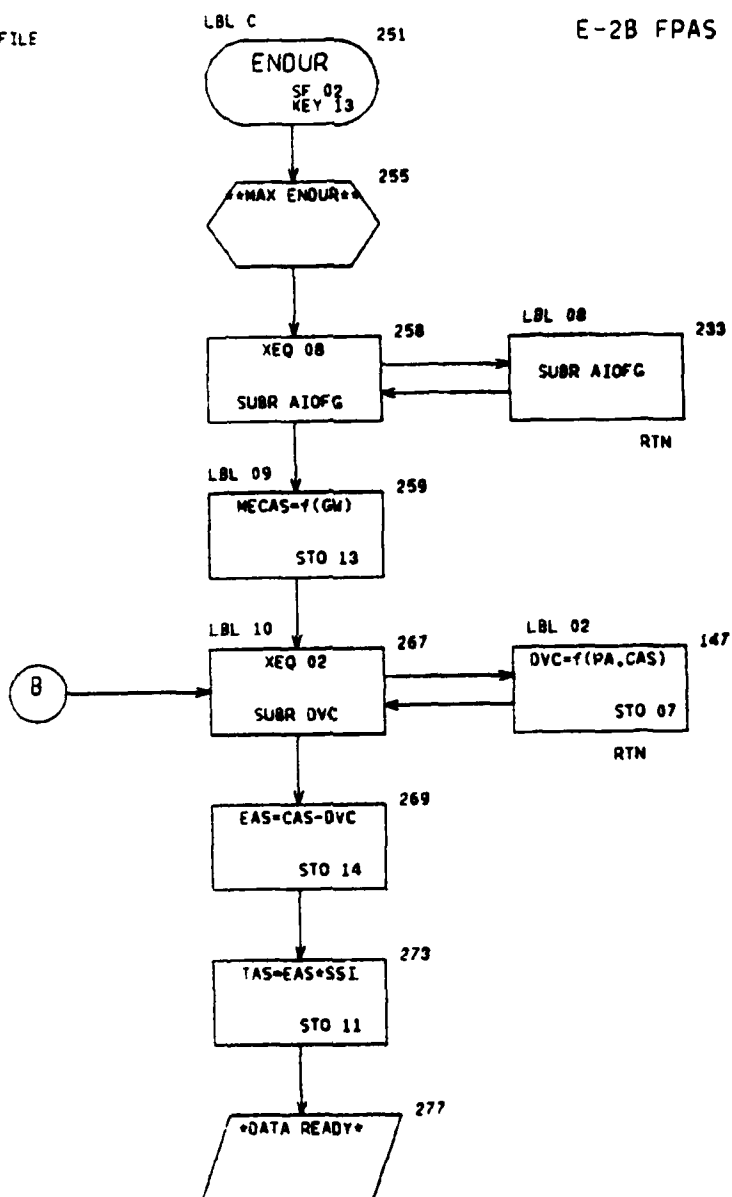
E-2B FPAS



ENDURANCE PROFILE

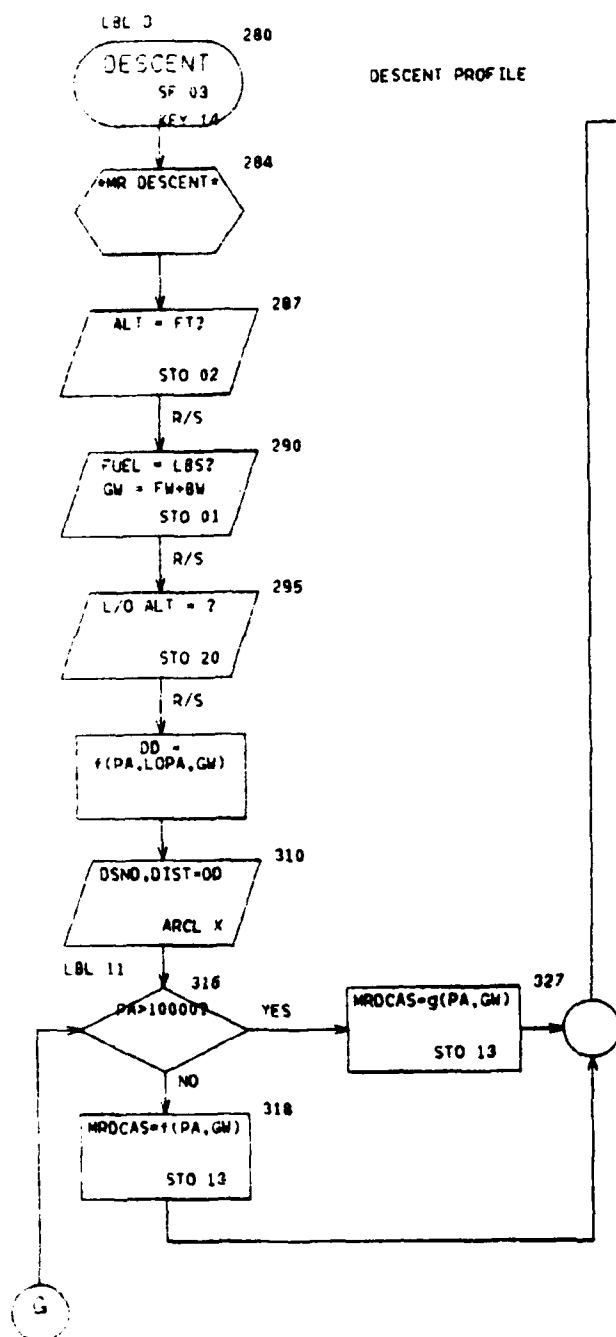
LBL C

E-2B FPAS

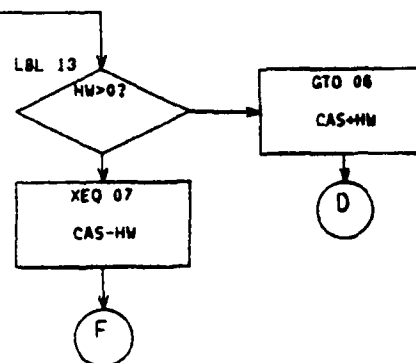


PRESS DATA KEY (21) OR R/S
TO CONTINUE

5/9



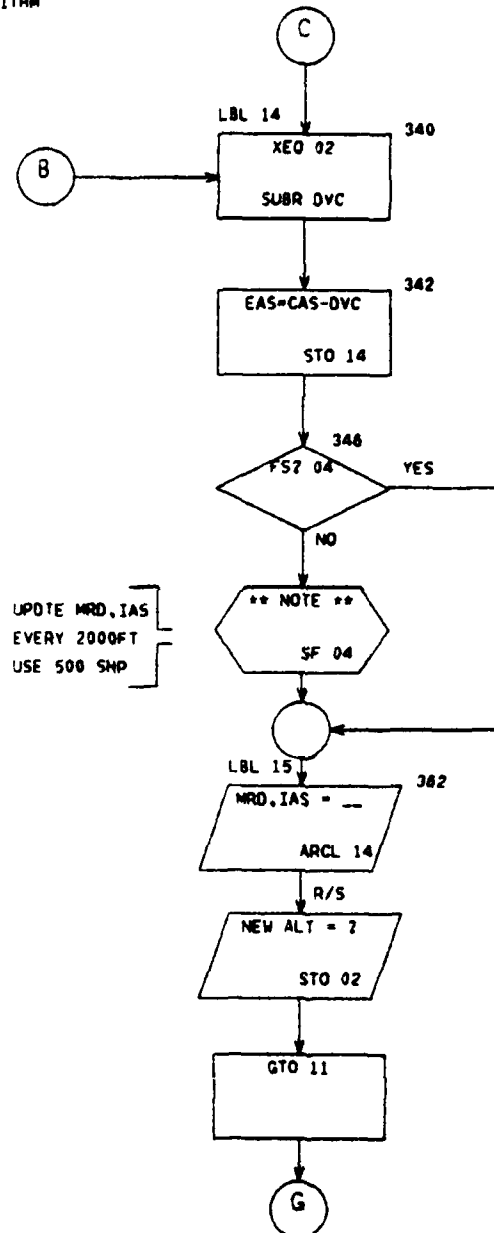
E-2B FPAS



LBL's 06 and 07 are headwind corrections which assume RANGE corrections run at least once prior to DESCENT profile.

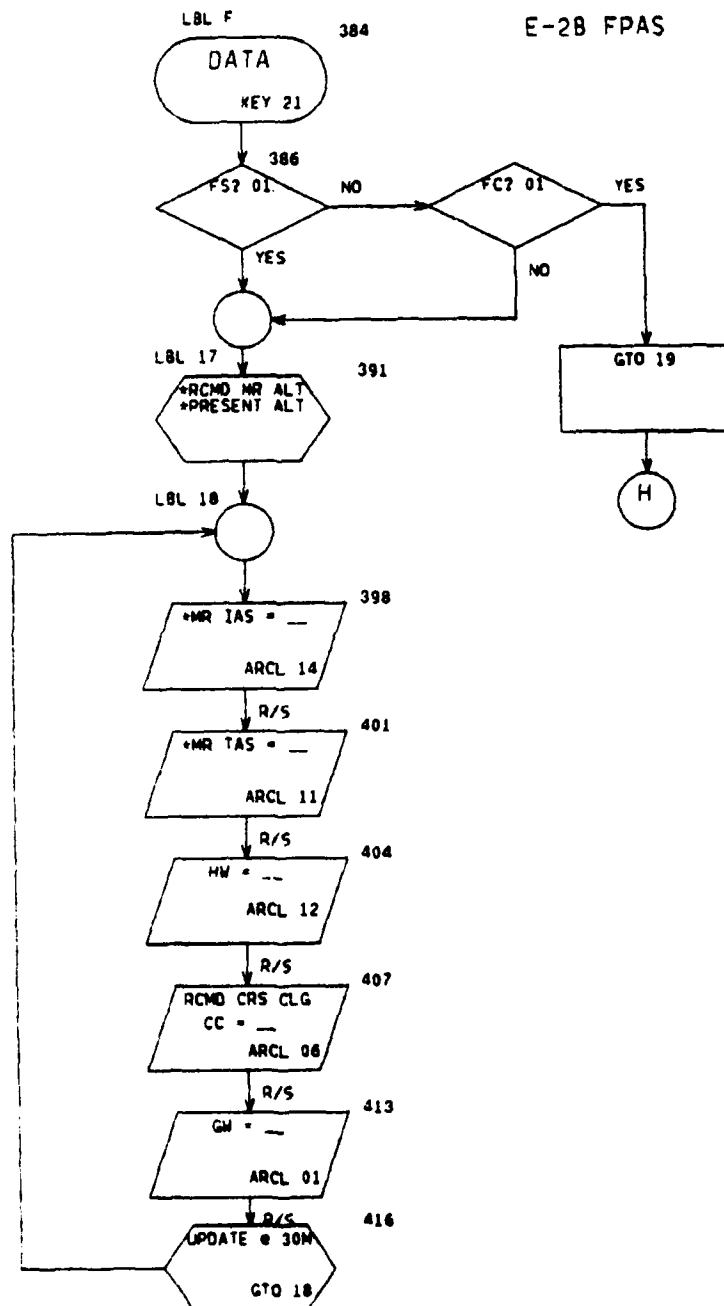
DESCENT ALGORITHM
(cont'd)

E-2B FPAS



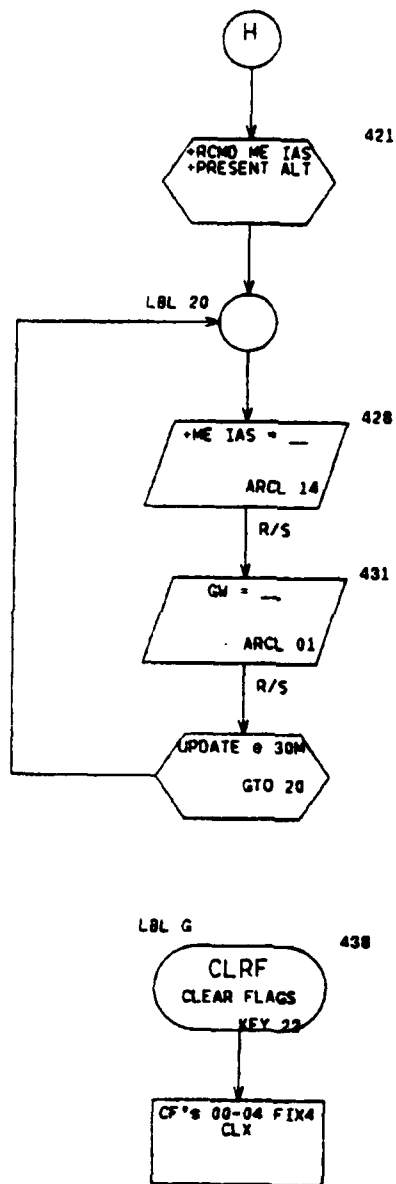
DATA ALGORITHM

E-2B FPAS



DATA ALGORITHM
(cont'd)

E-2B FPAS



E-2B FPAS/HP-41CV Code (June 1982; 1/3)

01+LBL "STF"	51 *	101 661.7
02 CF 01	52 *	102 /
03 CF 02	53 CHS	103 X12
04 CF 03	54 30	104 .2
05 CF 04	55 RCL 05	105 *
06 CLRG	56 -	106 1
07 ***E2B FPAS**	57 78.67	107 +
08 AVIEW	58 *	108 3.5
09 PSE	59 +	109 Y1X
10 "BASIC WT = ?"	60 58550	110 1
11 PROMPT	61 +	111 -
12 STO 00	62 100	112 RCL 15
13 "CARGO WT = ?"	63 /	113 1/X
14 PROMPT	64 INT	114 *
15 +	65 100	115 1
16 STO 00	66 *	116 +
17 "NO. CREW = ?"	67 STO 06	117 .286
18 PROMPT	68 174.838	118 Y1X
19 200	69 RCL 01	119 1
20 *	70 75 E-5	120 -
21 RCL 00	71 *	121 5
22 +	72 +	122 *
23 STO 00	73 RCL 02	123 STO 08
24 "PROFILE?"	74 2522 E-6	124 .2
25 PROMPT	75 *	125 *
26+LBL 8	76 -	126 1
27 SF 01	77 RCL 01	127 +
28 CF 02	78 RCL 02	128 1/X
29 CF 03	79 5580656 E-15	129 RCL 03
30 ***MAX RANGE**	80 *	130 *
31 AVIEW	81 *	131 STO 09
32 PSE	82 +	132 1936 E-6
33 XEQ 08	83 RCL 02	133 *
34 RCL 03	84 X12	134 RCL 02
35 15	85 RCL 01	135 1500
36 -	86 671 E-15	136 -
37 RCL 02	87 *	137 2112 E-8
38 198 E-5	88 *	138 *
39 *	89 +	139 +
40 +	90 STO 13	140 E1X
41 STO 05	91+LBL 01	141 .982
42 30	92 RCL 02	142 *
43 RCL 05	93 -6875 E-9	143 STO 10
44 -	94 *	144 FS? 01
45 -.0031	95 1	145 GTO 03
46 *	96 +	146 GTO 10
47 1	97 5.2563	147+LBL 02
48 +	98 Y1X	148 RCL 02
49 .705	99 STO 15	149 91 E-6
50 RCL 01	100 RCL 04	150 *

E-2B FPAS/HP-41CV Code (June 1982; 2/3)

151 E+X	201 RCL 12	251*LBL C
152 1 E-7	202*LBL 05	252 SF 02
153 *	203 X<0?	253 CF 01
154 RCL 13	204 GTO 07	254 CF 03
155 2.852	205*LBL 06	255 ***MAX ENBUR**
156 Y+X	206 .5	256 AVIEW
157 *	207 RCL 02	257 PSE
158 STO 07	208 1 E-5	258 XEQ 08
159 RTN	209 *	259*LBL 09
160*LBL 03	210 -	260 54.75
161 RCL 04	211 RCL 12	261 RCL 01
162 RCL 10	212 *	262 155 E-5
163 *	213 RCL 13	263 *
164 STO 11	214 +	264 +
165*LBL 04	215 STO 13	265 STO 13
166 "GS,AVAIL? Y/N"	216 FS? 03	266 GTO 01
167 PROMPT	217 GTO 14	267*LBL 10
168*LBL E	218 GTO 10	268 XEQ 02
169 "GS = KTS?"	219*LBL 07	269 RCL 13
170 PROMPT	220 .3	270 RCL 07
171 STO 16	221 RCL 02	271 -
172 RCL 11	222 5 E-6	272 STO 14
173 RCL 16	223 *	273 RCL 10
174 -	224 -	274 *
175 STO 12	225 RCL 12	275 STO 11
176 GTO 05	226 *	276 BEEP
177*LBL J	227 RCL 13	277 **DATA READY**
178 "INPUT WINDS..."	228 +	278 PROMPT
179 AVIEW	229 STO 13	279 GTO F
180 PSE	230 FS? 03	280*LBL D
181 "WIND DIR = ?"	231 RTN	281 SF 03
182 PROMPT	232 GTO 10	282 CF 01
183 STO 17	233*LBL 08	283 CF 02
184 "WIND VEL = ?"	234 "ALT = FT?"	284 **MR DESCENT**
185 PROMPT	235 PROMPT	285 AVIEW
186 STO 18	236 X<0?	286 PSE
187 "A/C HDG = ?"	237 10	287 "ALT = FT?"
188 PROMPT	238 STO 02	288 PROMPT
189 STO 19	239 "OAT = C?"	289 STO 02
190 RCL 17	240 PROMPT	290 "FUEL = LBS?"
191 -	241 STO 03	291 PROMPT
192 ABS	242 "IAS = KTS?"	292 RCL 00
193 COS	243 PROMPT	293 +
194 RCL 18	244 STO 04	294 STO 01
195 *	245 "FUEL = LBS?"	295 "L/O ALT = ?"
196 STO 12	246 PROMPT	296 PROMPT
197 RCL 11	247 RCL 00	297 STO 20
198 RCL 12	248 +	298 RCL 02
199 -	249 STO 01	299 -
200 STO 16	250 RTN	300 CHS

E-2B FPAS/HP-41CV Code (June 1982; 3/3)

301 RCL 01	351 *UPDTE MRD, IAS*	401 *MR TAS=
302 40000	352 AVIEW	402 ARCL 11
303 -	353 PSE	403 PROMPT
304 134367 E-13	354 *EVERY 2000FT*	404 *HW = "
305 *	355 AVIEW	405 ARCL 12
306 1676 E-6	356 PSE	406 PROMPT
307 +	357 *USE 500 SHP*	407 *RCMD CRS CLG*
308 *	358 AVIEW	408 AVIEW
309 FIX 0	359 PSE	409 PSE
310 *DSND, DIST=*	360 SF 04	410 *CC = "
311 ARCL X	361*LBL 15	411 ARCL 06
312 PROMPT	362 *MRD IAS=*	412 PROMPT
313*LBL 11	363 ARCL 14	413 *CW = "
314 10000	364 PROMPT	414 ARCL 01
315 RCL 02	365 *NEW ALT = ?*	415 PROMPT
316 XYY?	366 PROMPT	416 *UPDATE e 30M*
317 GTO 12	367 STO 02	417 AVIEW
318 RCL 02	368 GTO 11	418 PSE
319 -77 E-7	369*LBL 16	419 GTO 18
320 *	370 RCL 02	420*LBL 19
321 E+X	371 .9	421 *RCMD ME IAS*
322 162.4	372 *	422 AVIEW
323 *	373 LN	423 PSE
324 XEQ 16	374 4.57	424 *PRESENT ALT*
325 GTO 13	375 +	425 AVIEW
326*LBL 12	376 RCL 01	426 PSE
327 RCL 02	377 40000	427*LBL 20
328 -239 E-8	378 -	428 *ME IAS=*
329 *	379 *	429 ARCL 14
330 E+X	380 10000	430 PROMPT
331 153.1	381 /	431 *CW = "
332 *	382 +	432 ARCL 01
333 XEQ 16	383 RTN	433 PROMPT
334*LBL 13	384*LBL F	434 *UPDATE e 30M*
335 STO 13	385 FIX 0	435 AVIEW
336 RCL 12	386 FS? 01	436 PSE
337 X)0?	387 GTO 17	437 GTO 20
338 GTO 06	388 FC? 01	438*LBL G
339 XEQ 07	389 GTO 19	439 CF 00
340*LBL 14	390*LBL 17	440 CF 01
341 XEQ 02	391 *RCMD MR IAS*	441 CF 02
342 RCL 13	392 AVIEW	442 CF 03
343 RCL 07	393 PSE	443 CF 04
344 -	394 *PRESENT ALT*	444 FIX 4
345 STO 14	395 AVIEW	445 CLX
346 FS? 04	396 PSE	446 .END.
347 GTO 15	397*LBL 18	
348 * ** NOTE **	398 *MR IAS=*	
349 AVIEW	399 ARCL 14	
350 PSE	400 PROMPT	

4.1.4 Governing Equations

Register locations for the E-2B FPAS are the same as for the E-2C and will not be repeated. Governing equations, obviously, will be different and are listed here for the record. The headwind corrections used in this program are the same as those in the E-2C program. Equations common to both programs are not listed.

Cruise Ceiling: $CC = f(TDEV, GW)$

$$CC = 58550 + 78.67(30 - TDEV) - (1 - 0.0031(30 - TDEV))(0.705)(GW)$$

Max Range Calibrated Airspeed: $MRCAS = f(PA, GW)$

$$MRCAS = 174.838 + 75E-5(GW) - 2522E-6(PA) + 5580656E-15(GW)(PA) + 671E-15(GW)(PA)**2$$

Max Endurance Calibrated Airspeed: $MECAS = f(GW)$

$$MECAS = 54.75 + 155E-5(GW)$$

Descent Distance: $DD = f(PA, LOPA, GW)$

$$DD = (PA - LOPA)((GW - 40000)(13436E-13) + (1676E-6))$$

Max Range Descent CAS (>10000): $MRDCAS = f(PA, GW)$

$$MRDCAS = 153.1 \exp((PA)(-239E-8)) + ((4.57 + \ln(.9PA))(GW - 40000)/10000)$$

Max Range Descent CAS (<10000): $MRDCAS = f(PA, GW)$

$$MRDCAS = 162.4 \exp((PA)(-77E-7)) + ((4.57 + \ln(.9PA))(GW - 40000)/10000)$$

4.2 THE E-2B BINGO PROGRAM

The seven BINGO flight configurations used for the E-2C are used also for the E-2B. Program operation is essentially the same in all respects.

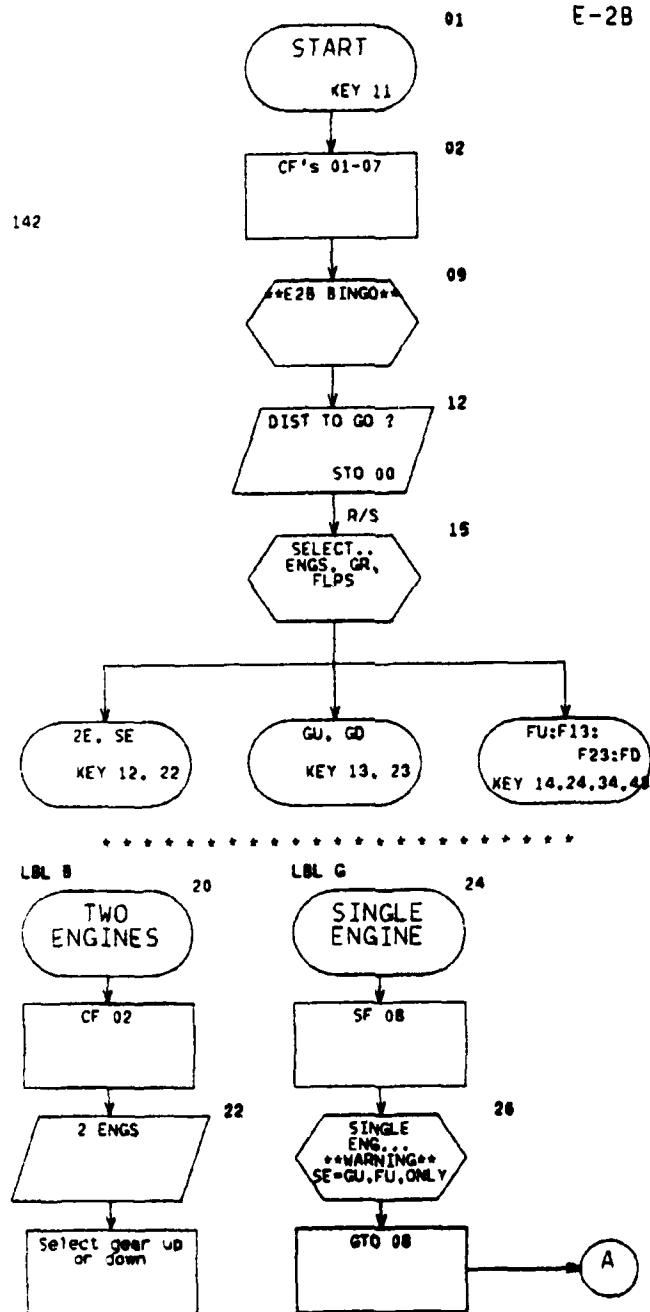
The fuel and time required values used in the data set were chosen by taking the smallest value of fuel required per horizontal line in the chart (primary) and/or the smallest time required (secondary). 900 pounds of fuel is used to add for IPR fuel required.

As in the case of the E-2B FPAS, no significant changes have been made in the E-2B BINGO charts in spite of engine modifications and a propeller system change. It is requested that any "gouge" figures used by E-2B squadrons to modify these numbers be brought to the attention of the author so that appropriate software changes can be made.

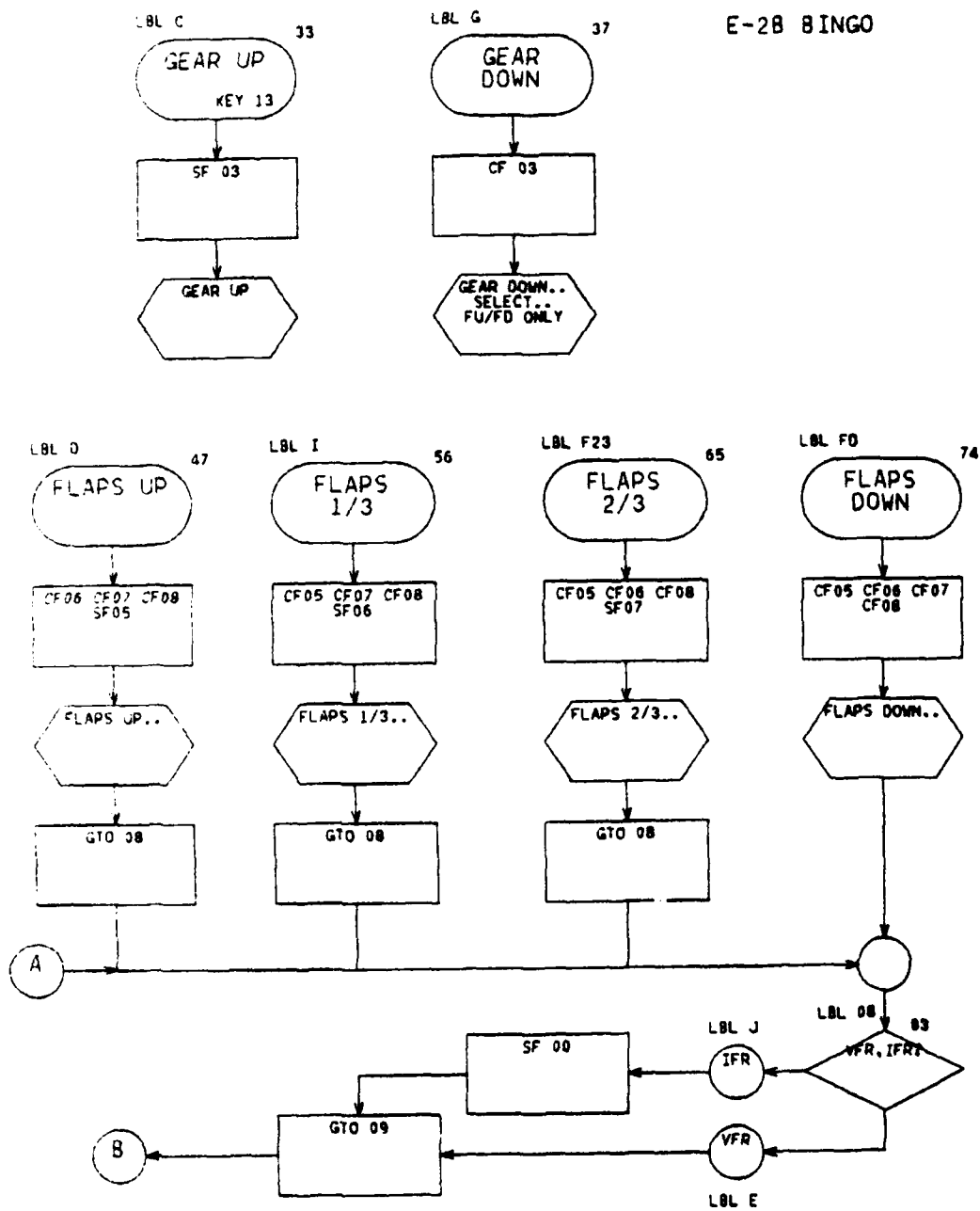
The following pages show flowcharts and program code for the E-2B BINGO program.

XEQ SIZE 142

E-2B BINGO



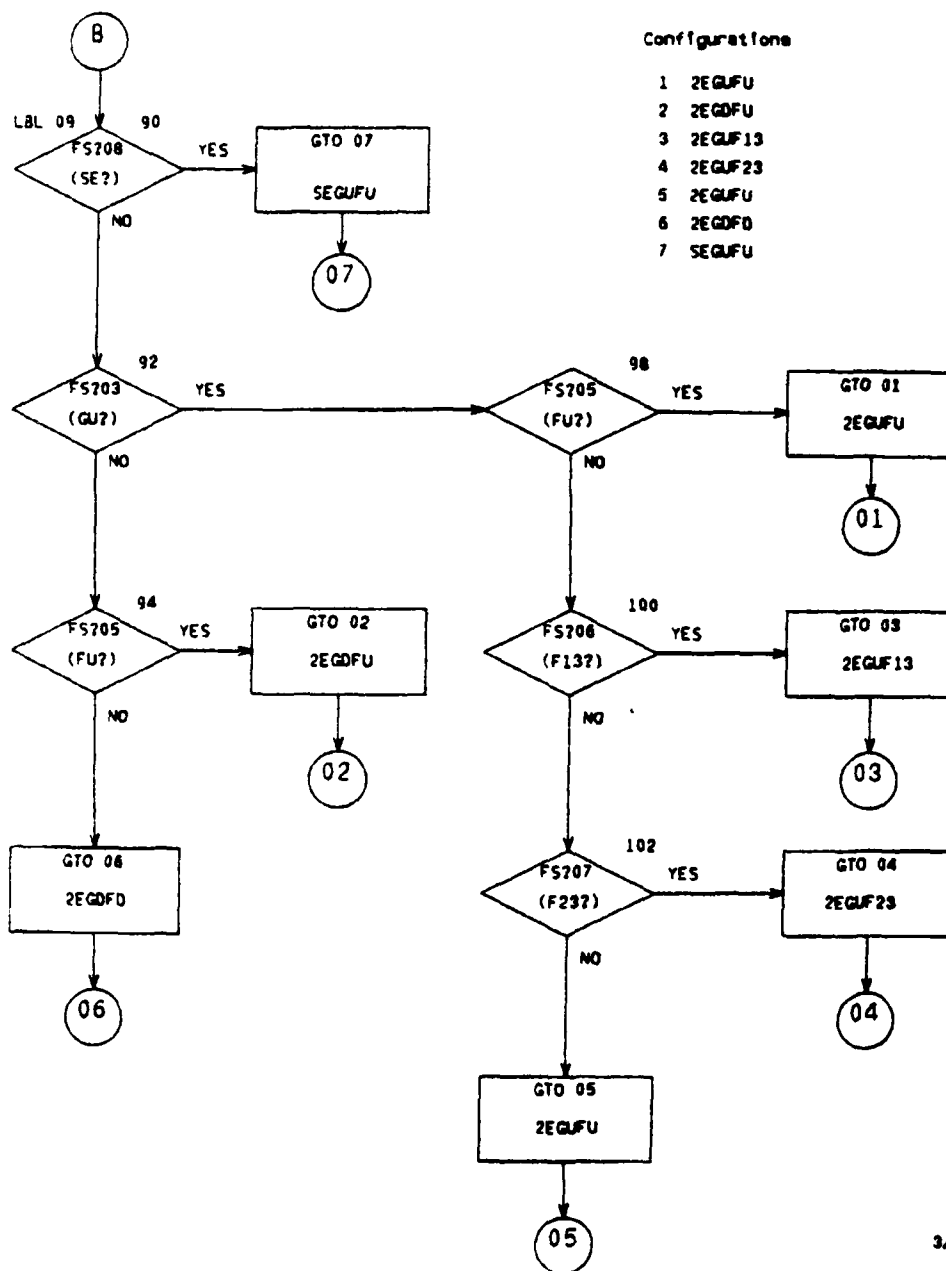
E-2B BINGO



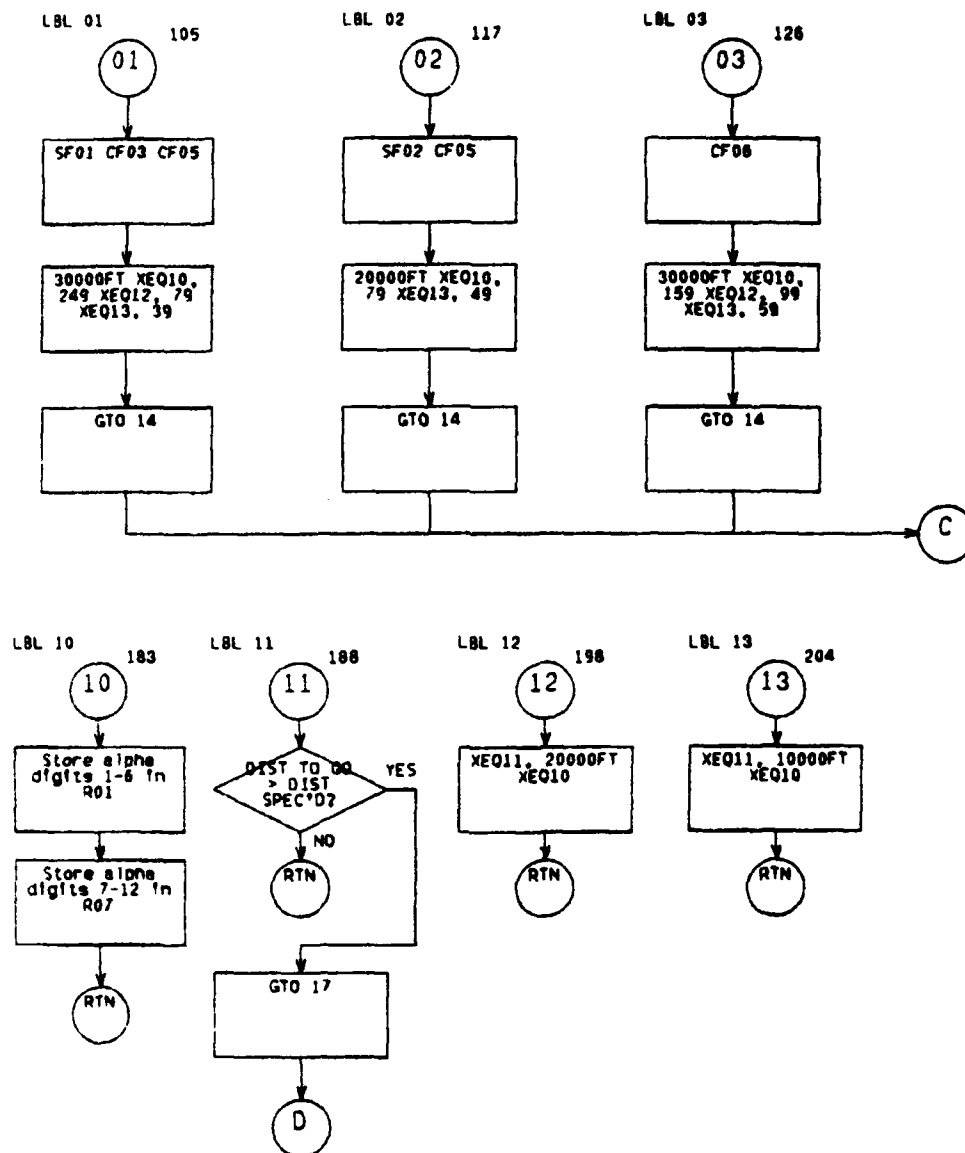
E-2B BINGO

Configurations

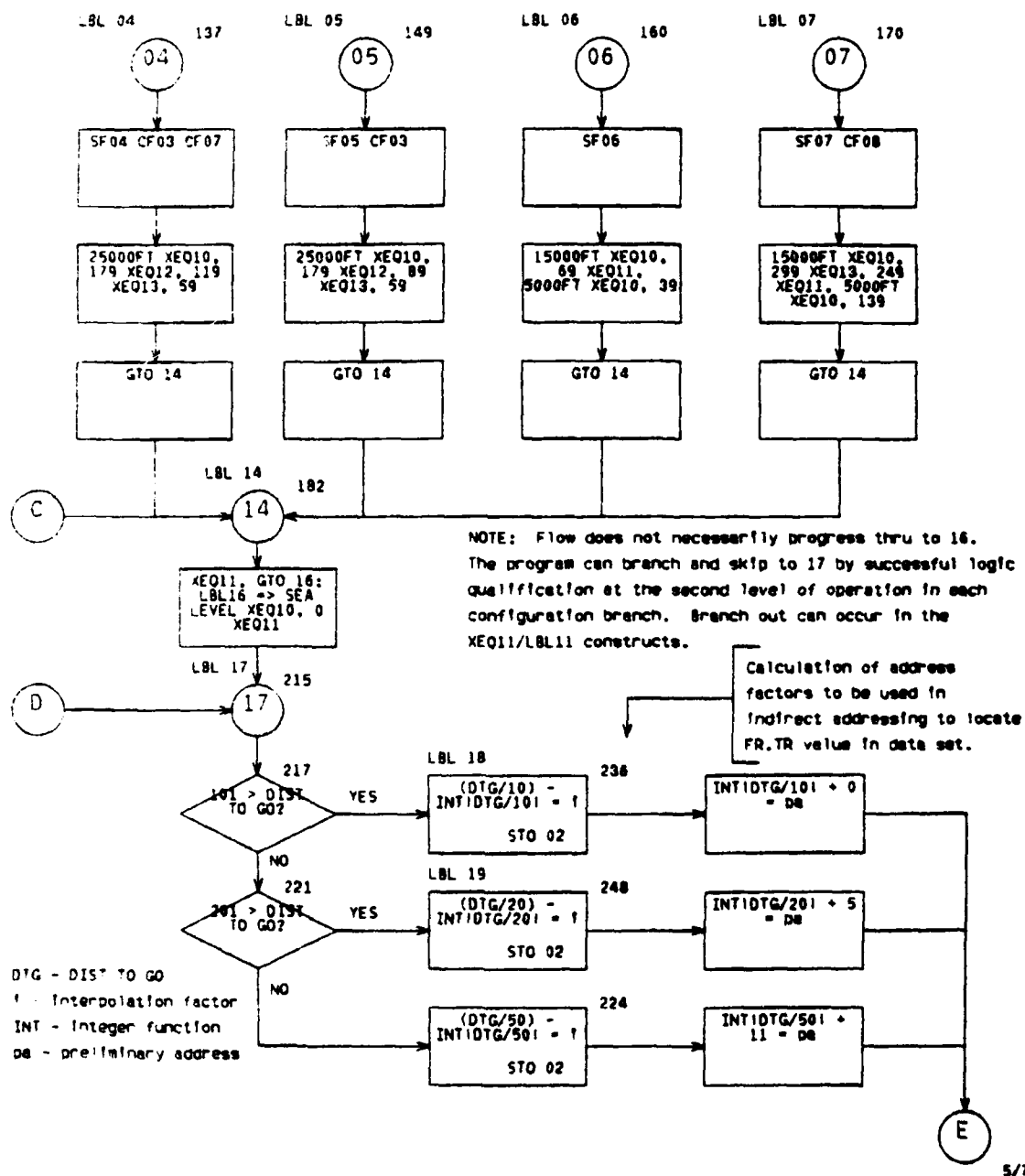
- 1 2EGUFU
- 2 2EGDFU
- 3 2EGUF13
- 4 2EGUF23
- 5 2EGUFU
- 6 2EGDFD
- 7 SEQUFU



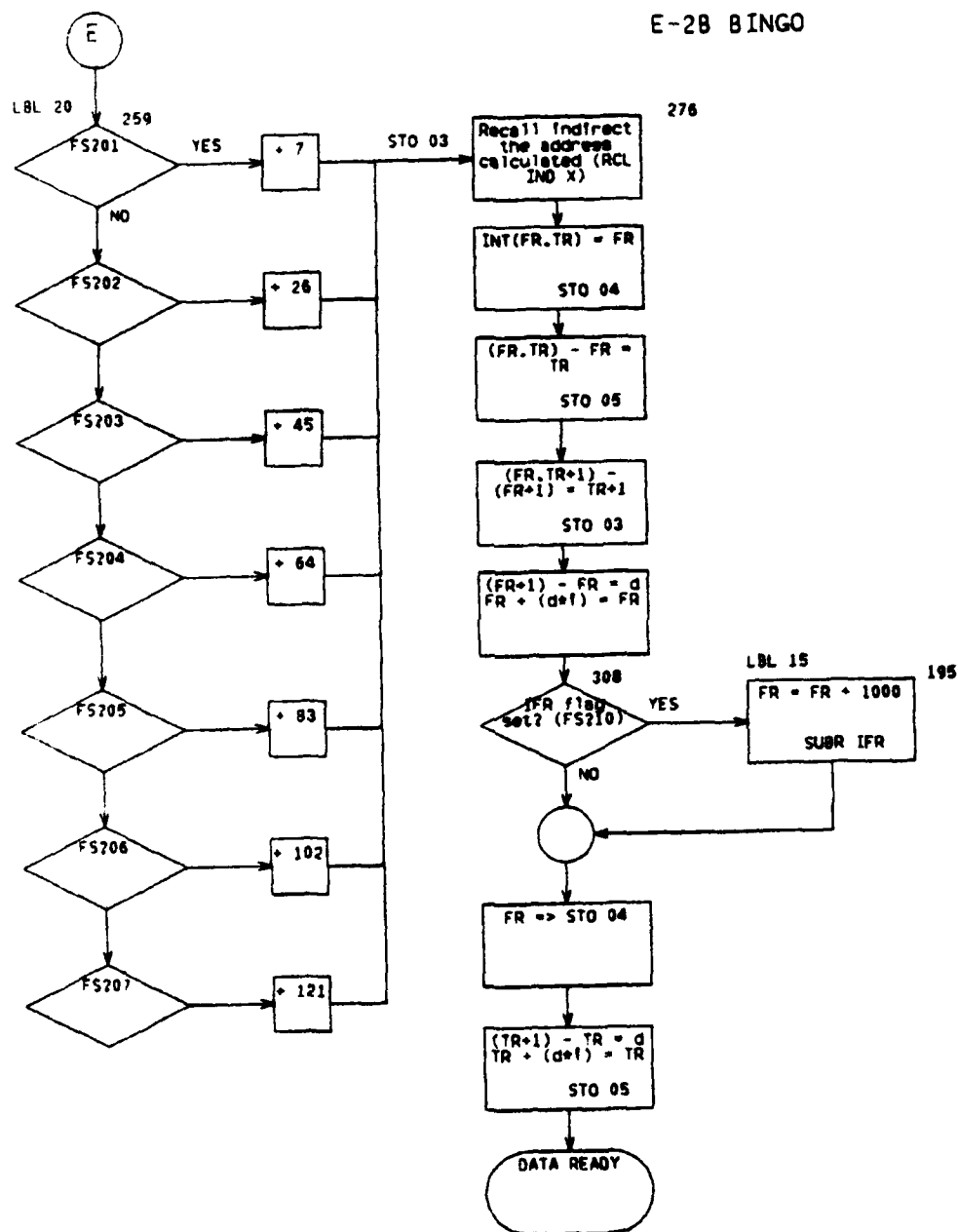
E-2B BINGO



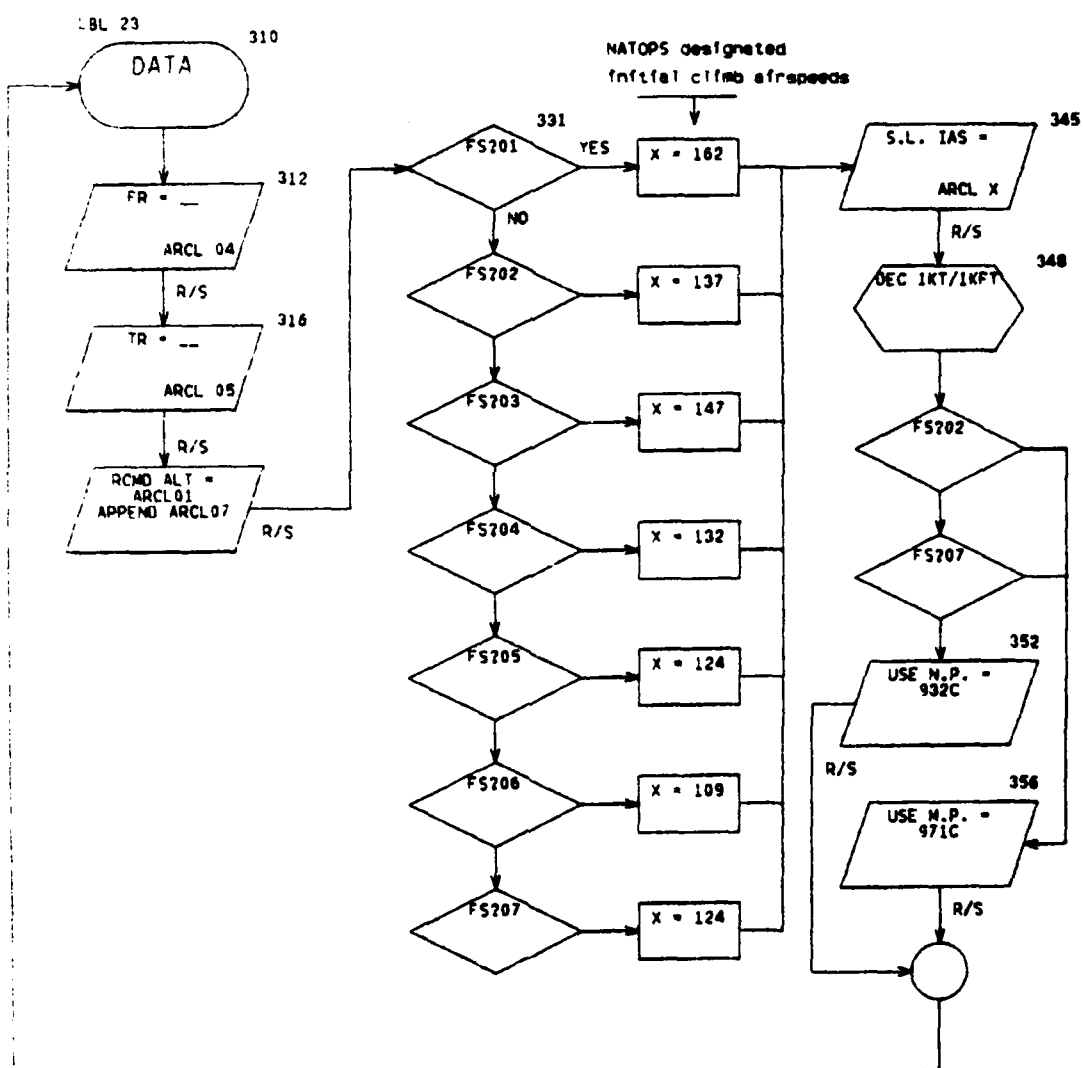
E-2B BINGO



E-2B BINGO



E-2B BINGO



B-2B BINGO/HP-41CV Code (June 1982; 1/4)

01+LBL "STB"	51 SF 05	101 GTO 03
02 CF 01	52 "FLAPS UP..."	102 FS? 07
03 CF 02	53 AVIEW	103 GTO 04
04 CF 03	54 PSE	104 GTO 05
05 CF 04	55 GTO 08	105+LBL 01
06 CF 05	56+LBL I	106 SF 01
07 CF 06	57 CF 05	107 CF 03
08 CF 07	58 CF 07	108 CF 05
09 "E2B BINGO"	59 CF 08	109 "30000 FT"
10 AVIEW	60 SF 06	110 XEQ 10
11 PSE	61 "FLAPS 1/3..."	111 249
12 "DIST TO GO?"	62 AVIEW	112 XEQ 12
13 PROMPT	63 PSE	113 79
14 STO 00	64 GTO 08	114 XEQ 13
15 "SELECT..."	65+LBL "F23"	115 39
16 AVIEW	66 CF 05	116 GTO 14
17 PSE	67 CF 06	117+LBL 02
18 "ENGS, GR, FLPS"	68 CF 08	118 CF 05
19 PROMPT	69 SF 07	119 SF 02
20+LBL B	70 "FLAPS 2/3..."	120 "20000 FT"
21 CF 02	71 AVIEW	121 XEQ 10
22 "2 ENGS"	72 PSE	122 79
23 PROMPT	73 GTO 08	123 XEQ 13
24+LBL G	74+LBL "FD"	124 49
25 SF 08	75 CF 05	125 GTO 14
26 "SINGLE ENG..."	76 CF 06	126+LBL 03
27 AVIEW	77 CF 07	127 SF 03
28 PSE	78 CF 08	128 CF 06
29 "SE=GU,FU,ONLY..."	79 "FLAPS DOWN..."	129 "30000 FT"
30 AVIEW	80 AVIEW	130 XEQ 10
31 PSE	81 PSE	131 159
32 GTO 08	82+LBL 08	132 XEQ 12
33+LBL C	83 "VFR, IFR?"	133 99
34 SF 03	84 PROMPT	134 XEQ 13
35 "GEAR UP"	85+LBL E	135 59
36 PROMPT	86 GTO 09	136 GTO 14
37+LBL H	87+LBL J	137+LBL 24
38 CF 03	88 SF 10	138 CF 07
39 "GEAR DOWN..."	89+LBL 09	139 CF 03
40 AVIEW	90 FS? 08	140 SF 04
41 PSE	91 GTO 07	141 "25000 FT"
42 "SELECT..."	92 FS? 03	142 XEQ 10
43 AVIEW	93 GTO 22	143 179
44 PSE	94 FS? 05	144 XEQ 12
45 "FU/FD ONLY"	95 GTO 02	145 119
46 PROMPT	96 GTO 06	146 XEQ 13
47+LBL D	97+LBL 22	147 59
48 CF 06	98 FS? 05	148 GTO 14
49 CF 07	99 GTO 01	149+LBL 05
50 CF 08	100 FS? 06	150 CF 03

E-2B BINGO/HP-41CV Code (June 1982; 2/4)

151 SF 05	201 XEQ 11	251 ENTER†
152 *25000 FT*	202 *20000 FT*	252 INT
153 XEQ 10	203 XEQ 10	253 STO 03
154 179	204 RTN	254 -
155 XEQ 12	205+LBL 13	255 STO 02
156 09	206 XEQ 11	256 RCL 03
157 XEQ 13	207 *10000 FT*	257 5
158 59	208 XEQ 10	258+LBL 20
159 GTO 14	209 RTN	259 +
160+LBL 06	210+LBL 16	260 FS? 01
161 SF 06	211 * SEA LEVEL*	261 7
162 *15000 FT*	212 XEQ 10	262 FS? 02
163 XEQ 10	213 0	263 26
164 69	214 XEQ 11	264 FS? 03
165 XEQ 11	215+LBL 17	265 45
166 * 5000 FT*	216 RCL 00	266 FS? 04
167 XEQ 10	217 101	267 64
168 39	218 X>Y?	268 FS? 05
169 GTO 14	219 GTO 18	269 83
170+LBL 07	220 X<Y	270 FS? 06
171 CF 00	221 201	271 102
172 SF 07	222 X>Y?	272 FS? 07
173 *15000 FT*	223 GTO 19	273 121
174 XEQ 10	224 RCL 00	274 +
175 299	225 50	275 STO 03
176 XEQ 13	226 /	276 RCL IND X
177 249	227 ENTER†	277 ENTER†
178 XEQ 11	228 INT	278 INT
179 * 5000 FT*	229 STO 03	279 STO 04
180 XEQ 10	230 -	280 -
181 139	231 STO 02	281 STO 05
182+LBL 14	232 RCL 03	282 1
183 XEQ 11	233 11	283 ST+ 03
184 GTO 16	234 GTO 20	284 RCL IND 03
185+LBL 10	235+LBL 18	285 ENTER†
186 ASTO 01	236 RCL 00	286 INT
187 ASHF	237 10	287 STO 06
188 ASTO 07	238 /	288 -
189 RTN	239 ENTER†	289 STO 03
190+LBL 11	240 INT	290 RCL 06
191 RCL 00	241 STO 03	291 RCL 04
192 X>Y?	242 -	292 -
193 GTO 17	243 STO 02	293 RCL 02
194 RTN	244 RCL 03	294 *
195+LBL 15	245 0	295 RCL 04
196 CF 10	246 GTO 20	296 +
197 900	247+LBL 19	297 FS? 10
198 +	248 RCL 00	298 XEQ 15
199 RTN	249 20	299 STO 04
200+LBL 12	250 /	300 RCL 03

E-2B BINGO/HP-41CV Code (June 1982; 3/4)

301 RCL 05
 302 -
 303 RCL 02
 304 *
 305 RCL 05
 306 +
 307 10
 308 *
 309 STO 05
 310+LBL 21
 311+LBL 23
 312 FIX 0
 313 * FR = "
 314 ARCL 04
 315 FIX 2
 316 PROMPT
 317 * TR = "
 318 ARCL 05
 319 PROMPT
 320 "RCMMB ALT = "
 321 AVIEW
 322 PSE
 323 CLA
 324 ARCL 01
 325 "+"
 326 ARCL 07
 327 PROMPT
 328 FIX 0
 329 * DIST = "
 330 ARCL 00
 331 PROMPT
 332 FS? 01
 333 162
 334 FS? 02
 335 137
 336 FS? 03
 337 147
 338 FS? 04
 339 132
 340 FS? 05
 341 124
 342 FS? 06
 343 109
 344 FS? 07
 345 124
 346 "S.L. IAS = "
 347 ARCL X
 348 PROMPT
 349 "DEC 1KT/1KFT"
 350 PROMPT

351 FS? 07
 352 GTO 38
 353 "USE N.P. = 932C"
 354 PROMPT
 355 GTO 23
 356+LBL 38
 357 "USE N.P. = 971C"
 358 PROMPT
 359 GTO 23
 360 .END.

R00= 0.000
 R01= 1.000
 R02= 2.000
 R03= 3.000
 R04= 4.000
 R05= 5.000
 R06= 6.000
 R07= 7.000
 R08= 1,220.003
 R09= 1,320.006
 R10= 1,440.009
 R11= 1,520.012
 R12= 1,610.014
 R13= 1,700.017
 R14= 1,790.020
 R15= 1,850.022
 R16= 1,930.025
 R17= 2,000.028
 R18= 2,150.033
 R19= 2,290.038
 R20= 2,440.043
 R21= 2,530.048
 R22= 2,730.053
 R23= 3,090.101
 R24= 3,390.112
 R25= 3,700.123
 R26= 4,000.135
 R27= 1,240.004
 R28= 1,390.007
 R29= 1,530.011
 R30= 1,680.014
 R31= 1,800.018
 R32= 1,920.021
 R33= 2,040.024
 R34= 2,160.026
 R35= 2,250.029

R36= 2,350.032
 R37= 2,540.038
 R38= 2,740.044
 R39= 2,930.050
 R40= 3,130.056
 R41= 3,320.102
 R42= 3,810.117
 R43= 4,290.132
 R44= 4,780.147
 R45= 5,270.202
 R46= 1,220.003
 R47= 1,340.006
 R48= 1,470.009
 R49= 1,590.012
 R50= 1,710.015
 R51= 1,800.019
 R52= 1,900.022
 R53= 2,000.024
 R54= 2,090.027
 R55= 2,170.030
 R56= 2,330.035
 R57= 2,490.040
 R58= 2,630.044
 R59= 2,770.049
 R60= 2,900.054
 R61= 3,240.105
 R62= 3,580.117
 R63= 3,920.129
 R64= 4,260.141
 R65= 1,240.003
 R66= 1,380.007
 R67= 1,520.011
 R68= 1,660.014
 R69= 1,800.018
 R70= 1,910.022
 R71= 2,020.025
 R72= 2,130.028
 R73= 2,240.032
 R74= 2,350.035
 R75= 2,520.041
 R76= 2,700.048
 R77= 2,880.054
 R78= 3,050.100
 R79= 3,210.106
 R80= 3,620.120
 R81= 4,020.135
 R82= 4,430.150
 R83= 4,830.205
 R84= 1,260.004
 R85= 1,430.008

E-2B BINGO/HP-41CV Code (June 1982; 4/4)

R86= 1,600.011	R136= 2,780.107
R87= 1,750.015	R137= 3,150.123
R88= 1,920.019	R138= 3,520.137
R89= 2,060.023	R139= 3,870.152
R90= 2,200.026	R140= 4,270.207
R91= 2,330.030	
R92= 2,460.032	
R93= 2,570.035	
R94= 3,000.042	
R95= 3,030.048	
R96= 3,260.055	
R97= 3,190.101	
R98= 3,700.107	
R99= 4,250.122	
R100= 4,780.137	
R101= 5,330.152	
R102= 9,999.999	
R103= 1,290.004	
R104= 1,470.008	
R105= 1,650.013	
R106= 1,840.017	
R107= 2,010.021	
R108= 2,170.025	
R109= 2,320.029	
R110= 2,460.032	
R111= 2,630.036	
R112= 2,740.040	
R113= 3,020.047	
R114= 3,290.055	
R115= 3,570.103	
R116= 3,840.110	
R117= 4,120.117	
R118= 4,810.136	
R119= 5,500.155	
R120= 9,999.999	
R121= 9,999.999	
R122= 1,190.004	
R123= 1,200.007	
R124= 1,360.010	
R125= 1,450.014	
R126= 1,540.017	
R127= 1,620.021	
R128= 1,710.024	
R129= 1,800.027	
R130= 1,800.031	
R131= 1,970.034	
R132= 2,140.041	
R133= 2,300.047	
R134= 2,460.054	
R135= 2,620.101	

4.3 THE E-2B CROSSWIND LANDING LIMITATIONS PROGRAM

See the explanation, flowchart and code for the E-2C program.

4.4 SAMPLE PROGRAM OPERATION

Rather than repeat the scenario improvised for the E-2C, a set of program runs are listed here that the user may use to verify program operation.

4.4.1 FPAS

<u>Prompt</u>	<u>Response</u>
	START KEY 11
E2B FPAS	
BASIC WT = ?	360 00 R/S
CARGO WT = ?	50 R/S
NO. CREW = ?	5 R/S
PROFILE?	RANGE
**MAX RANGE*	
ALT = FT?	250 00 R/S
OAT = C?	- 15 R/S
IAS = KTS?	165 R/S
FUEL = LBS?	95 00 R/S
GS, AVAIL? Y/N	YES
GS = KTS?	250 R/S
DATA READY	R/S or KEY 21
*RCND NR IAS	
*PRESENT ALT	
*NR IAS= 172	R/S
*NR TAS= 271	R/S
*HW = 9	R/S
RCND CRS CLG	
CC = 27600	R/S
GW = 46550	R/S
UPDATE = 30H	R/S to repeat data

ENDUR KEY 13

**MAX ENDUR*

ALT = FT?	250 00	R/S
OAT = C?	- 15	R/S
IAS = KTS?	150	R/S
FUEL = LBS?	60 00	R/S
DATA READY		R/S or KEY 21
+RCHD ME IAS		
+PRESENT ALT		
+ME IAS = 121		R/S
GW = 43050		R/S
UPDATE @ 30M		R/S to repeat data

DESCENT KEY 14

MR DESCENT

ALT = FT?	250 00	R/S
FUEL = LBS?	40 00	R/S
L/O ALT = ?	20 00	R/S
DSND, DIST=39		R/S
** NOTE **		
UPDTE MRD, IAS		
EVERY 2000FT		
USE 500 SHP		
MRD IAS = 146		R/S
NEW ALT = ?	230 00	R/S
MRD IAS = 148		R/S etc.

4.4.2 BINGOPromptResponse

START KEY 11

**E2B BINGO*

DIST TO GO ?	95	R/S
SELECT..		
ENGS, GR, FLPS	2E	
2 ENGS	GU	
GEAR UP	F 13	
FLAPS 1/3..		

VFR, IFR?	VFR KEY 15
FR = 3030	R/S
TR = 0.29	R/S
RCMND ALT =	
10000 FT	R/S
DIST = 95	R/S
S.L. IAS = 147	R/S
DEC 1KT/1KFT	R/S
USE N.P. = 932C	R/S to repeat data

4.4.3 Crosswind Landing

Refer to section describing program operation for the E-2C.

Chapter V
THE C-2A/HP-41CV PROGRAMS

As in the case of the E-2B, programs for the C-2A were modeled after the E-2C.

5.1 THE C-2A FPAS PROGRAM

Program initiation and "button-ology" are similar to that for the other two aircraft. The DESCENT profile for the C-2A is similar to that for the E-2B. An equation for cruise ceiling¹⁵ could not be devised from information available in the NATOPS.¹⁶ The Sample Program Operation section gives an example of typical responses.

The following pages are the flowcharts for the C-2A FPAS and are notated to correspond to the HP-41CV code that follows.

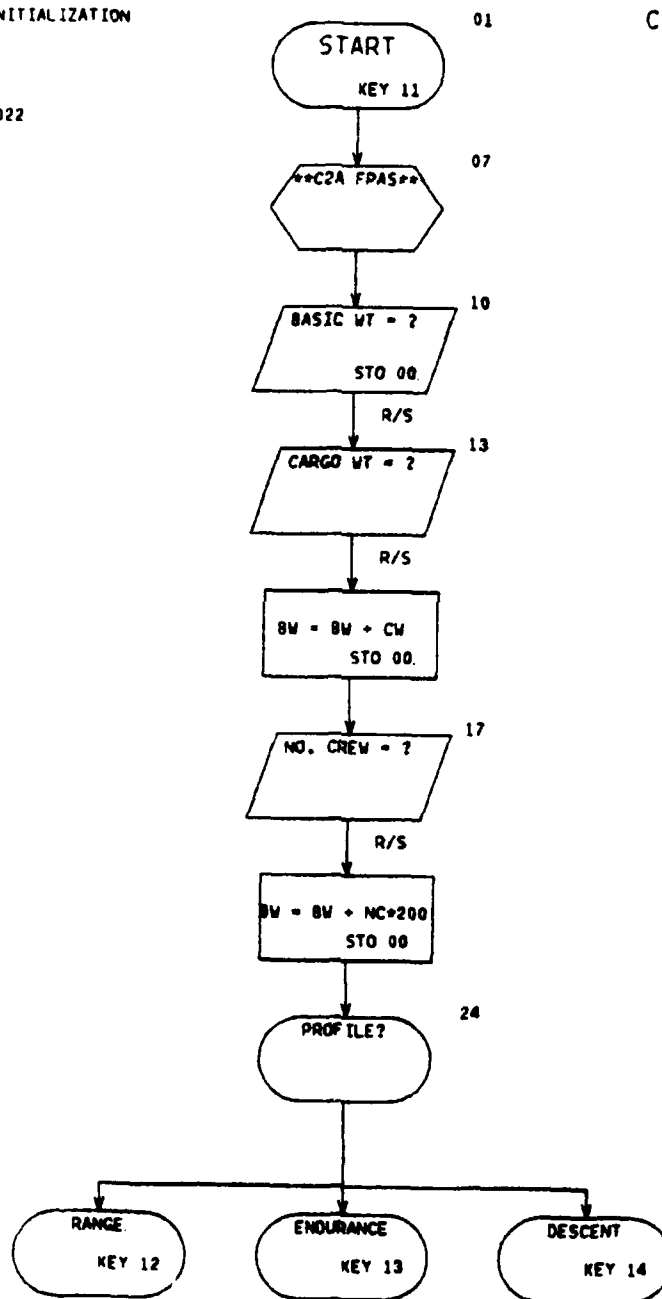
¹⁵ Interestingly enough, one may obtain the service ceiling for the C-2A although this parameter has little utility to fleet operators. A method of obtaining cruise ceiling, the optimal altitude to fly max range, would seem to be more important for an aircraft that can regularly use max range profiles.

¹⁶ Users of this program are advised that, like the E-2B NATOPS, few corrections have been made to Chapter 11 in spite of major changes to the aircraft. If these programs do not conform to actual performance, the program methodology should at least provide a format for future modifications.

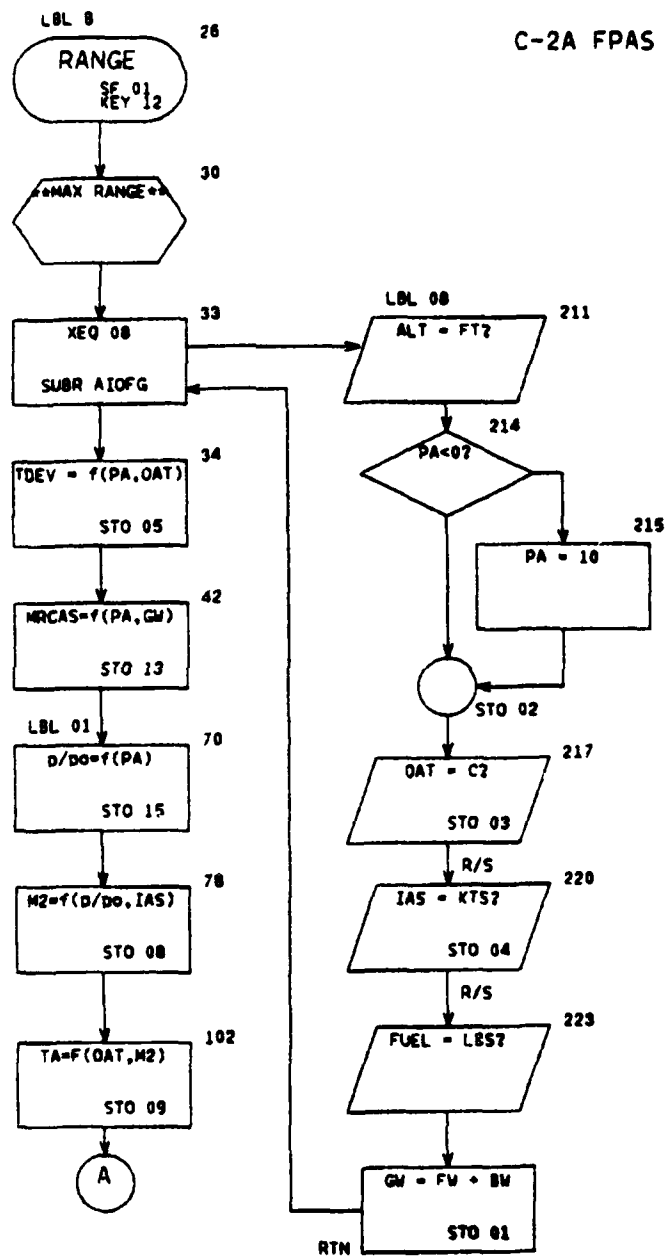
PROGRAM INITIALIZATION

REQ SIZE 022

C-2A FPAS



RANGE ALGORITHM

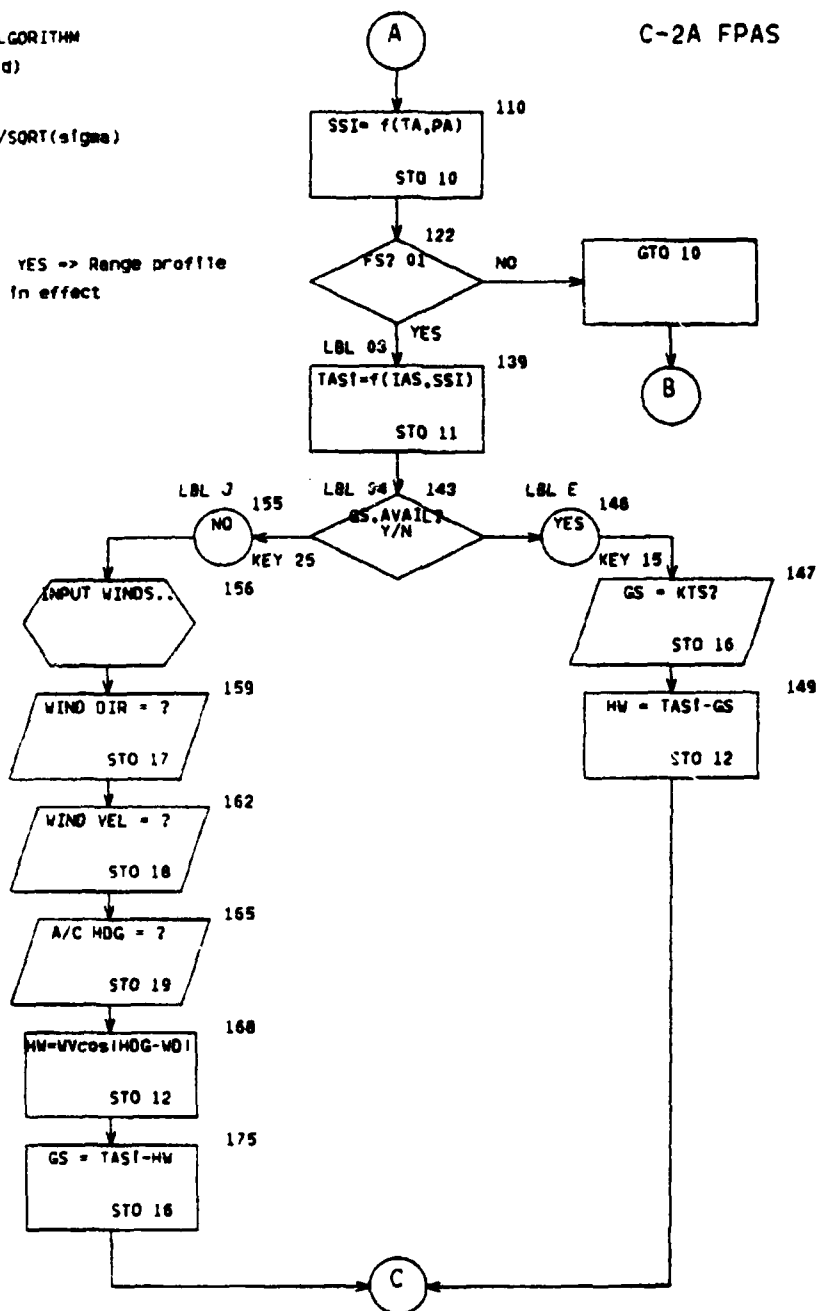


RANGE ALGORITHM
(cont'd)

$$SSI = 1/\sqrt{\sigma_{\text{sigas}}}$$

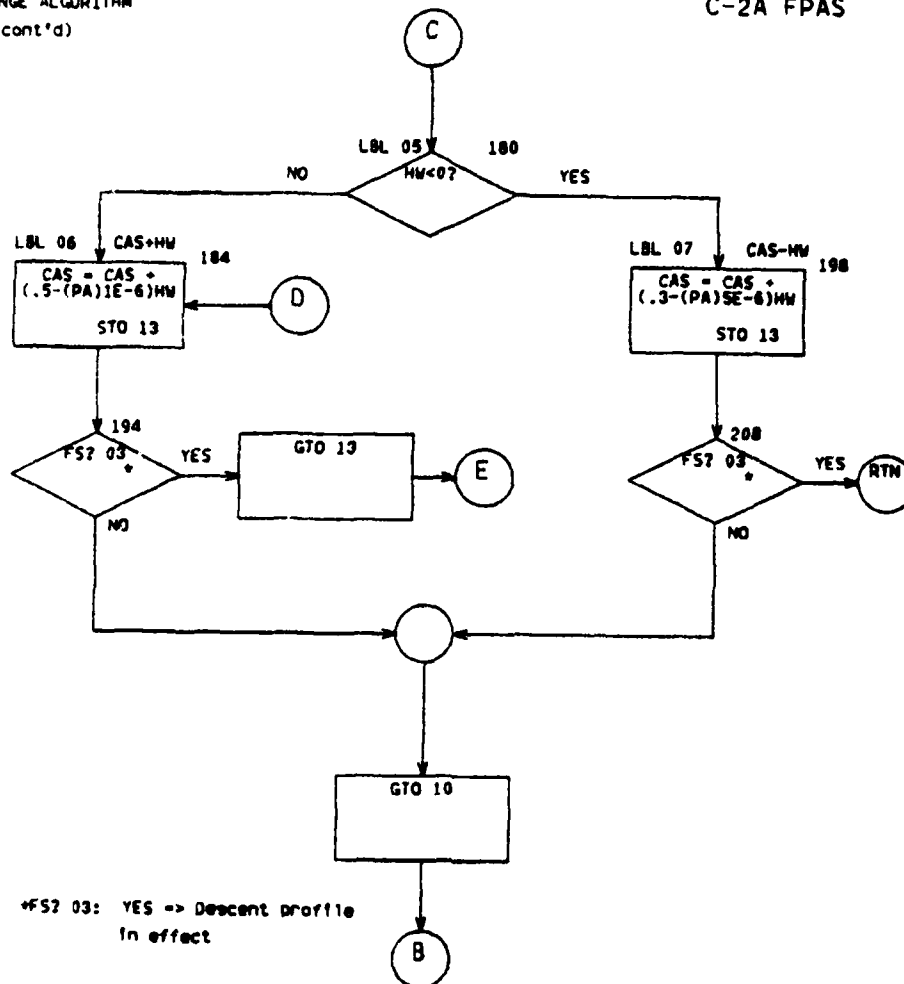
FS2 01: YES => Range profile
in effect

C-2A FPAS



RANGE ALGORITHM
(cont'd)

C-2A FPAS

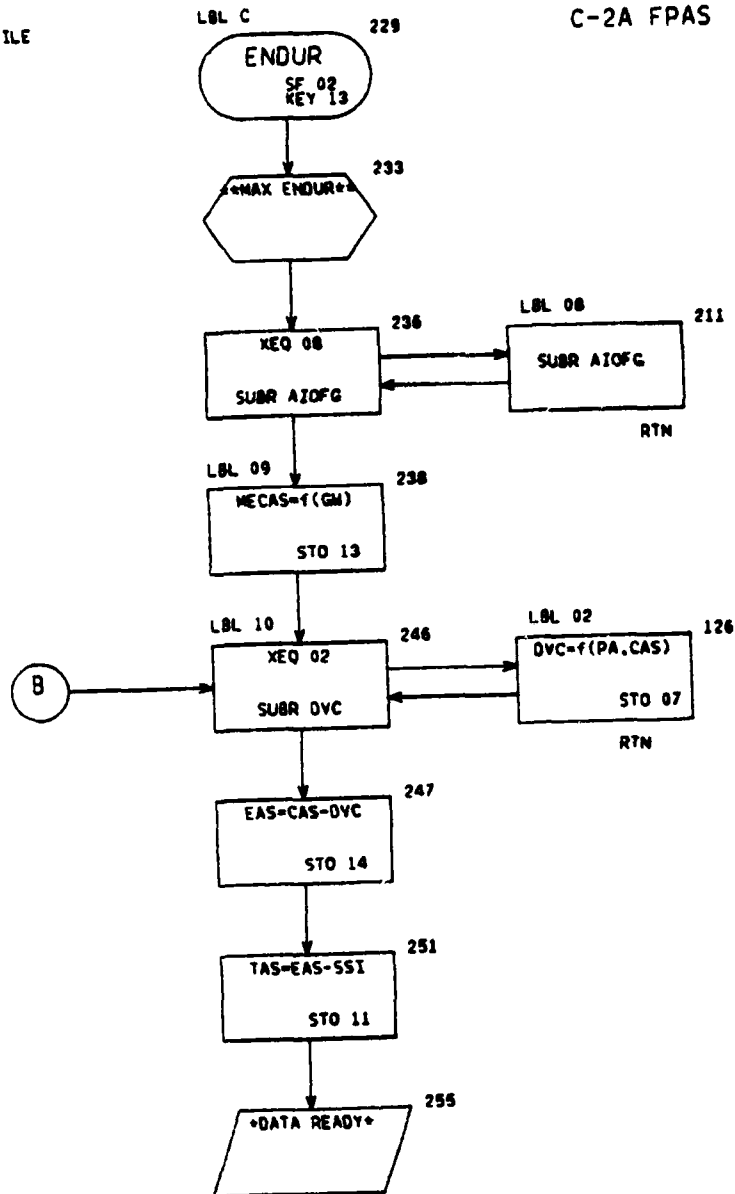


ENDURANCE PROFILE

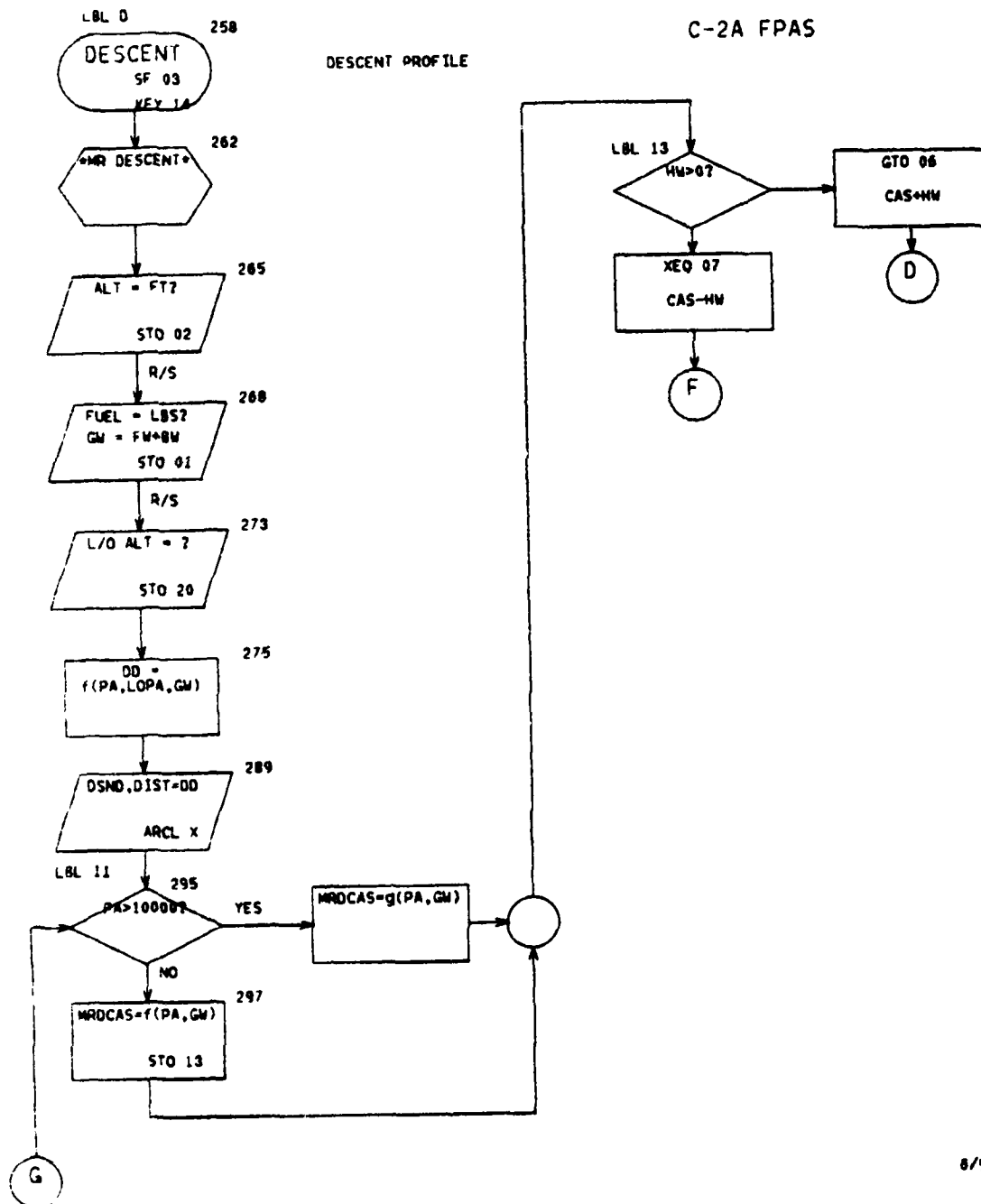
LBL C

229

C-2A FPAS

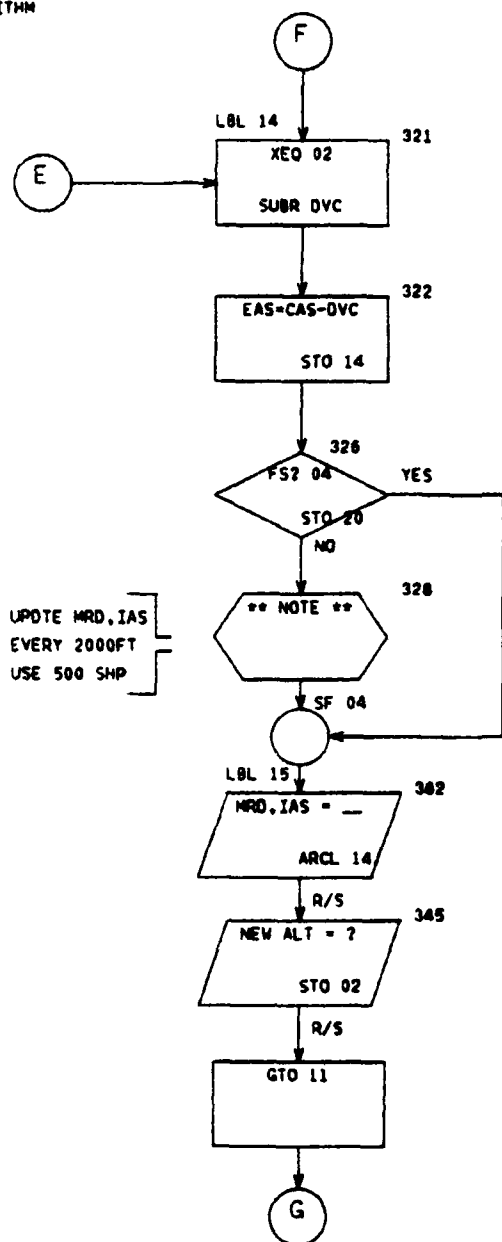


PRESS DATA KEY (21) OR R/S
TO CONTINUE



DESCENT ALGORITHM
(cont'd)

C-2A FPAS

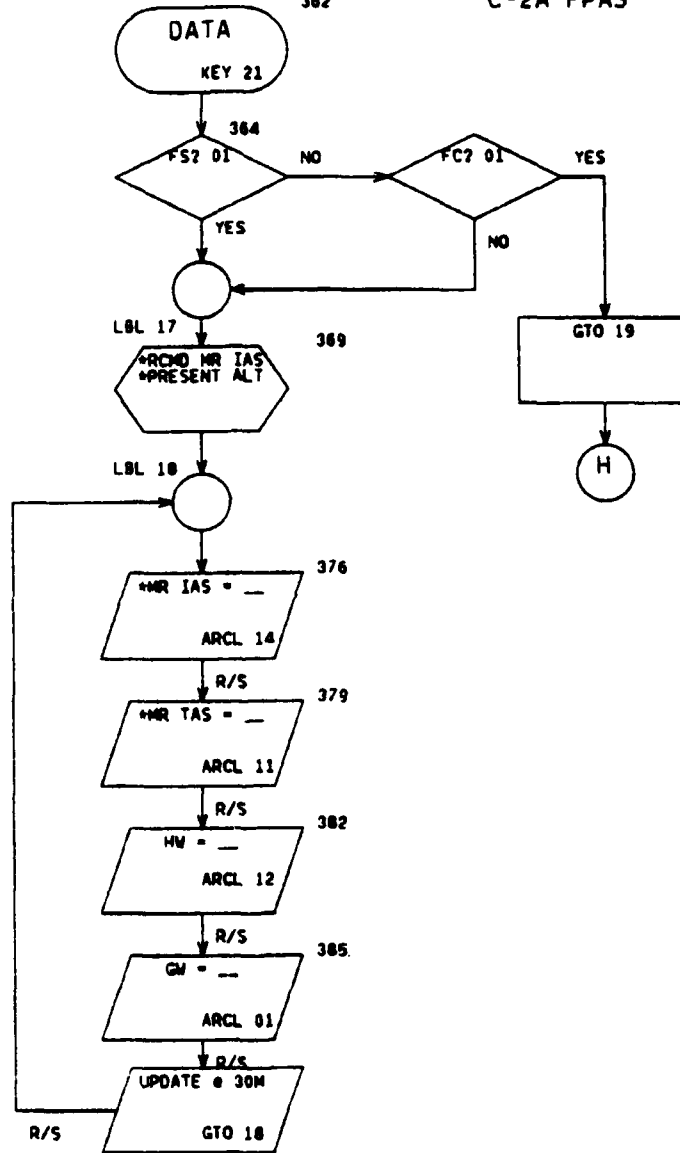


DATA ALGORITHM

LBL F

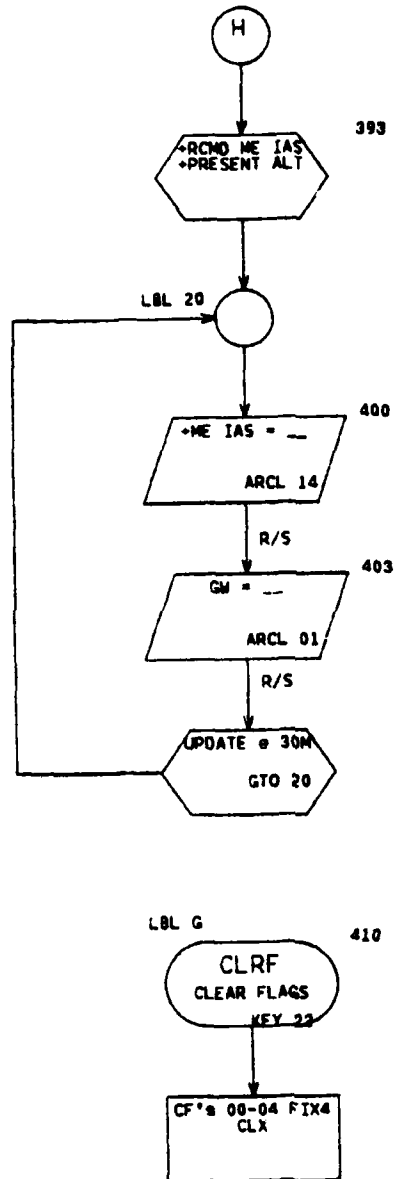
362

C-2A FPAS



DATA ALGORITHM
(cont'd)

C-2A FPAS



01*LBL "STF"	51 RCL 02	101 STO 08
02 CF 01	52 *	102 .2
03 CF 02	53 146.95	103 *
04 CF 03	54 +	104 1
05 CF 04	55 .001235	105 +
06 CLRG	56 1546 E-12	106 1/X
07 ***C2A FPAS**	57 RCL 01	107 RCL 03
08 AVIEW	58 *	108 *
09 PSE	59 -	109 STO 09
10 "BASIC WT = ?"	60 RCL 01	110 1936 E-6
11 PROMPT	61 *	111 *
12 STO 00	62 +	112 RCL 02
13 "CARGO WT = ?"	63 RCL 02	113 1500
14 PROMPT	64 LN	114 -
15 +	65 .1518	115 2112 E-8
16 STO 00	66 *	116 *
17 "NO.CREW/PAX=?"	67 +	117 +
18 PROMPT	68 STO 13	118 E+X
19 200	69*LBL 01	119 .982
20 *	70 RCL 02	120 *
21 RCL 00	71 -6875 E-9	121 STO 10
22 +	72 *	122 FS? 01
23 STO 00	73 1	123 GT0 03
24 "PROFILE?"	74 +	124 GT0 10
25 PROMPT	75 5.2563	125*LBL 02
26*LBL 8	76 Y+X	126 RCL 02
27 SF 01	77 STO 15	127 91 E-6
28 CF 02	78 RCL 04	128 *
29 CF 03	79 661.7	129 E+X
30 ***MAX RANGE**	80 /	130 1 E-7
31 AVIEW	81 X+2	131 *
32 PSE	82 .2	132 RCL 13
33 XEQ 08	83 *	133 2.852
34 RCL 03	84 1	134 Y+X
35 15	85 +	135 *
36 -	86 3.5	136 STO 07
37 RCL 02	87 Y+X	137 RTN
38 198 E-5	88 1	138*LBL 03
39 *	89 -	139 RCL 04
40 +	90 RCL 15	140 RCL 10
41 STO 05	91 1/X	141 *
42 342 E-10	92 *	142 STO 11
43 397 E-15	93 1	143*LBL 04
44 RCL 02	94 +	144 "GS,AVAIL? Y/N"
45 *	95 .286	145 PROMPT
46 -	96 Y+X	146*LBL E
47 RCL 02	97 1	147 "GS = KTS?"
48 *	98 -	148 PROMPT
49 .0019574	99 5	149 STO 16
50 -	100 *	150 RCL 11

C-2A FPAS/HP-41CV Code (June 1982; 2/3)

151 RCL 16	201 *	251 RCL 10
152 -	202 -	252 *
153 STO 12	203 RCL 12	253 STO 11
154 GTO 05	204 *	254 BEEP
155*LBL J	205 RCL 13	255 **DATA READY**
156 "INPUT WINDS..."	206 +	256 PROMPT
157 AVIEW	207 STO 13	257 GTO F
158 PSE	208 FS? 03	258*LBL D
159 "WIND DIR = ?"	209 RTN	259 SF 03
160 PROMPT	210 GTO 10	260 CF 01
161 STO 17	211*LBL 00	261 CF 02
162 "WIND VEL = ?"	212 "ALT = FT?"	262 **NR DESCENT**
163 PROMPT	213 PROMPT	263 AVIEW
164 STO 18	214 X<0?	264 PSE
165 "A/C HDG = ?"	215 10	265 "ALT = FT?"
166 PROMPT	216 STO 02	266 PROMPT
167 STO 19	217 "OAT = C?"	267 STO 02
168 RCL 17	218 PROMPT	268 "FUEL = LBS?"
169 -	219 STO 03	269 PROMPT
170 ABS	220 "IAS = KTS?"	270 RCL 00
171 COS	221 PROMPT	271 +
172 RCL 18	222 STO 04	272 STO 01
173 *	223 "FUEL = LBS?"	273 "L/O ALT = ?"
174 STO 12	224 PROMPT	274 PROMPT
175 RCL 11	225 RCL 00	275 STO 20
176 RCL 12	226 +	276 RCL 02
177 -	227 STO 01	277 -
178 STO 16	228 RTN	278 CHS
179 RCL 12	229*LBL C	279 RCL 01
180*LBL 05	230 SF 02	280 35000
181 X<0?	231 CF 01	281 -
182 GTO 07	232 CF 03	282 134367 E-13
183*LBL 06	233 **MAX ENDUR**	283 *
184 .5	234 AVIEW	284 1676 E-6
185 RCL 02	235 PSE	285 +
186 1 E-5	236 XEQ 00	286 *
187 *	237*LBL 09	287 FIX 0
188 -	238 RCL 01	288 "DSNT, DIST="
189 RCL 12	239 .0016	289 ARCL X
190 *	240 *	290 PROMPT
191 RCL 13	241 46	291*LBL 11
192 +	242 +	292 10000
193 STO 13	243 STO 13	293 RCL 02
194 FS? 03	244 GTO 01	294 X>Y?
195 GTO 14	245*LBL 10	295 GTO 12
196 GTO 10	246 XEQ 02	296 RCL 02
197*LBL 07	247 RCL 13	297 -1413 E-8
198 .3	248 RCL 07	298 *
199 RCL 02	249 -	299 E+X
200 5 E-6	250 STO 14	300 166.783

C-2A/FPAS/HP-41CV Code (June 1982; 3/3)

301 *	351 *	401 PROMPT
302 XEQ 16	352 E+X	402 "GW = "
303 GTO 13	353 9014 E-7	403 ARCL 01
304+LBL 12	354 *	404 PROMPT
305 RCL 02	355 RCL 01	405 "UPDATE e 30M"
306 CHS	356 35000	406 AVIEW
307 5077 E-9	357 -	407 PSE
308 *	358 *	408 GTO 20
309 E+X	359 +	409+LBL G
310 151.503	360 RTN	410 CF 00
311 *	361+LBL F	411 CF 01
312 XEQ 16	362 FIX 0	412 CF 02
313+LBL 13	363 FS? 01	413 CF 03
314 STO 13	364 GTO 17	414 CF 04
315 RCL 12	365 FC? 01	415 FIX 4
316 X)0?	366 GTO 19	416 CLX
317 GTO 06	367+LBL 17	417 END
318 XEQ 07	368 "+RCND MR IAS"	
319+LBL 14	369 AVIEW	
320 XEQ 02	370 PSE	
321 RCL 13	371 "+PRESENT ALT"	
322 RCL 07	372 AVIEW	
323 -	373 PSE	
324 STO 14	374+LBL 18	
325 FS? 04	375 "+MR IAS="	
326 GTO 15	376 ARCL 14	
327 " ** NOTE **"	377 PROMPT	
328 AVIEW	378 "+MR TAS="	
329 PSE	379 ARCL 11	
330 "UPDTE MRD, IAS"	380 PROMPT	
331 AVIEW	381 "+HW = "	
332 PSE	382 ARCL 12	
333 "EVERY 2000FT"	383 PROMPT	
334 AVIEW	384 "GW = "	
335 PSE	385 ARCL 01	
336 "USE 500 SHP"	386 PROMPT	
337 AVIEW	387 "UPDATE e 30M"	
338 PSE	388 AVIEW	
339 SF 04	389 PSE	
340+LBL 15	390 GTO 18	
341 "MRD IAS="	391+LBL 19	
342 ARCL 14	392 "+RCND ME IAS"	
343 PROMPT	393 AVIEW	
344 "NEW ALT = ?"	394 PSE	
345 PROMPT	395 "+PRESENT ALT"	
346 STO 02	396 AVIEW	
347 GTO 11	397 PSE	
348+LBL 16	398+LBL 20	
349 RCL 02	399 "+ME IAS="	
350 2389 E-8	400 ARCL 14	

5.1.3 Governing Equations

As in the case for the E-2B, equations common to the E-2C program will not be listed. Headwind corrections are the same for the C-2A as the E-2C.

Max Range Calibrated Airspeed: $MR_{CAS} = f(PA, GW)$

$$\begin{aligned} MR_{CAS} = & 146.95 - .0019574(PA) + .001235(GW) \\ & + 342E-10(PA)^2 - 397E-15(PA)^3 - \\ & - 1546E-12(GW)^2 + .1518LN(PA) \end{aligned}$$

Max Endurance Calibrated Airspeed: $ME_{CAS} = f(GW)$

$$ME_{CAS} = 46 + .0016(GW)$$

Descent Distance: $DD = f(PA, LOPA, GW)$

$$DD = (PA - LOPA) ((GW - 35000) (134367E-13) + 1676E-6)$$

Max Range Descent CAS (>10000): $MR_{DCAS} = f(PA, GW)$

$$\begin{aligned} MR_{DCAS} = & 151.503 \exp((-5077E-9)(PA)) \\ & + (GW - 35000) * 9014E-7 \exp((2389E-8)(PA)) \end{aligned}$$

Max Range Descent CAS (<10000): $MR_{DCAS} = f(PA, GW)$

$$\begin{aligned} MR_{DCAS} = & 166.783 \exp((-1413E-8)(PA)) \\ & + (GW - 35000) * 9014E-7 \exp((2389E-8)(PA)) \end{aligned}$$

5.2 THE C-2A BINGO PROGRAM

There are only three configurations to choose from when setting up a BINGO profile for the C-2A. No choices are allowed for possible stuck flap situations. The three configurations allowed are: 2EGUFU, 2EGDFU, and SEGUFU.

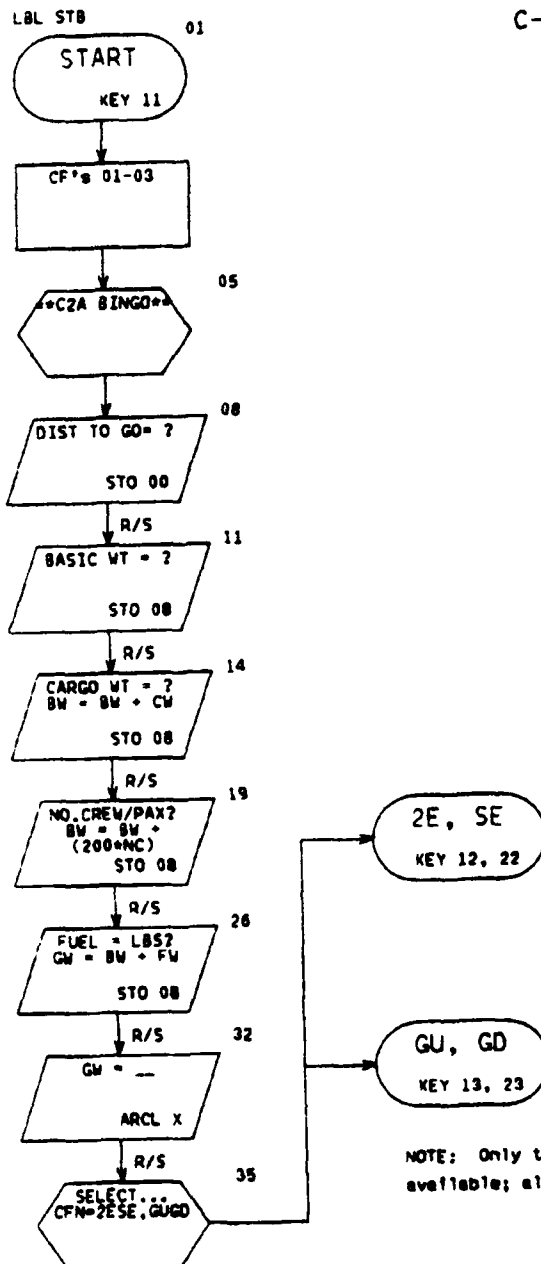
It is interesting to note, also, that the fuel required values for the C-2A are not rounded off to the nearest five pound increment, and instructions are included on how to adjust the fuel required for variations in weight above or below 45000 pounds gross weight. The C-2A BINGO program reflects all of these differences while still retaining the basic operating principles of the E-2C and E-2B programs.

Program initiation is somewhat more extensive than the other two programs since the C-2A program requires gross weight. The Sample Program Operation section presents a detailed example of how the program works.

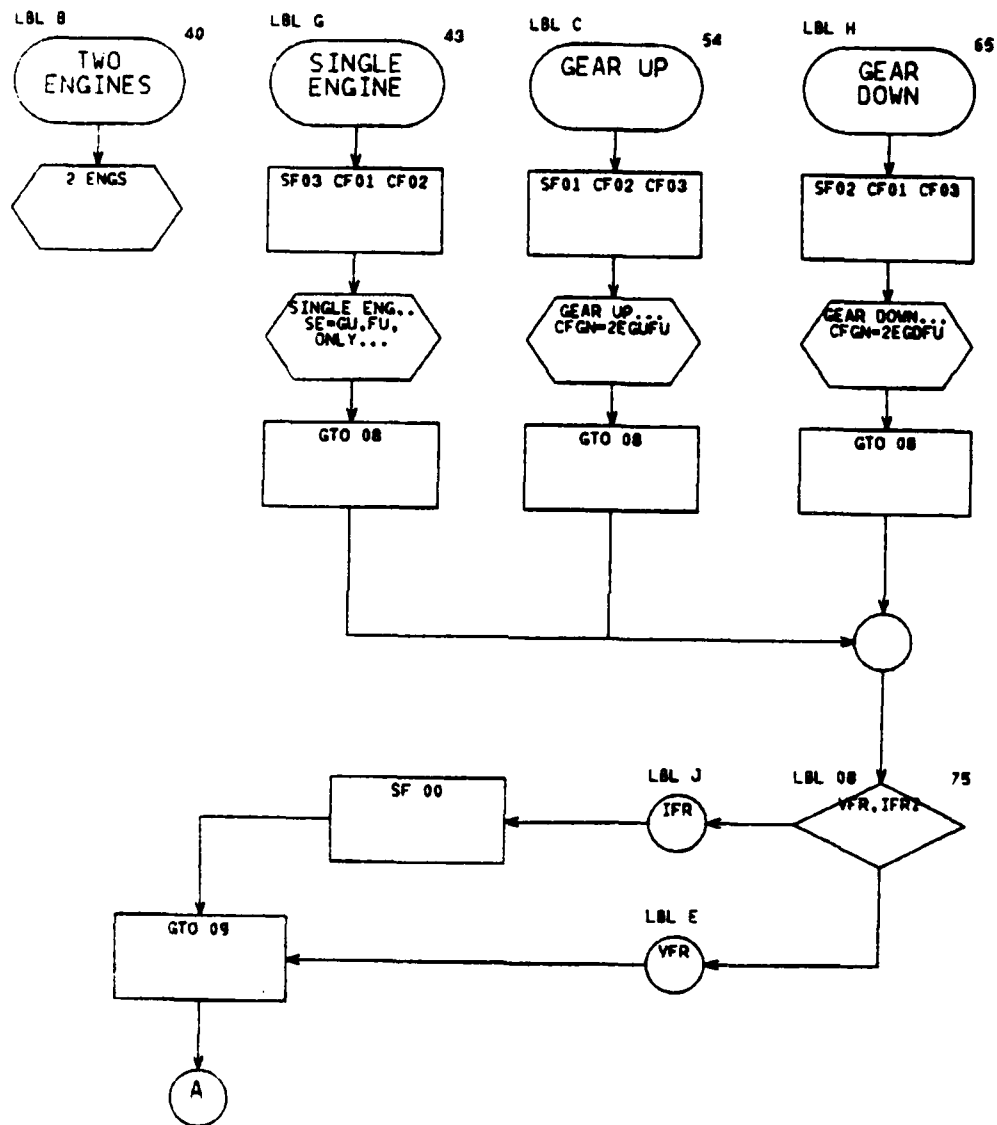
The following flowcharts record the algorithm for the C-2A BINGO program. Line numbers next to function blocks reference line numbers in the code listing that follows the flowcharts.

C-2A BINGO

REQ SIZE 065



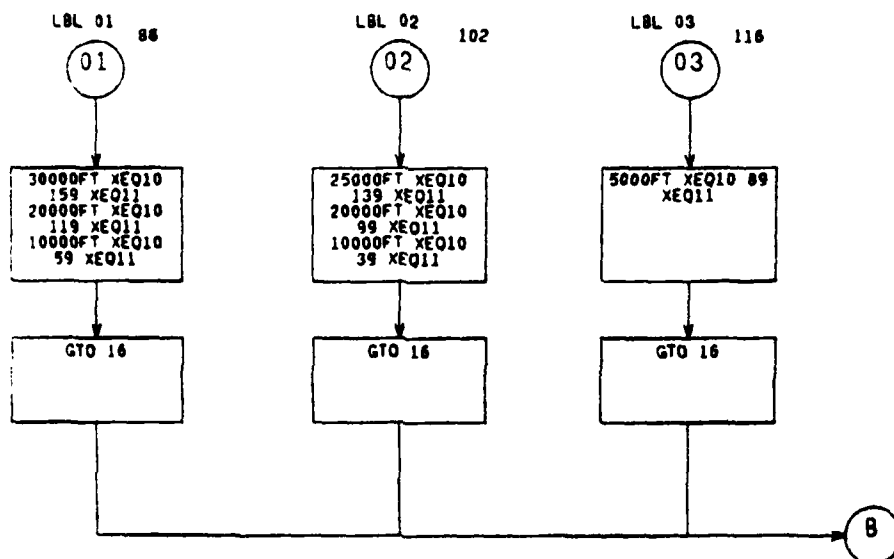
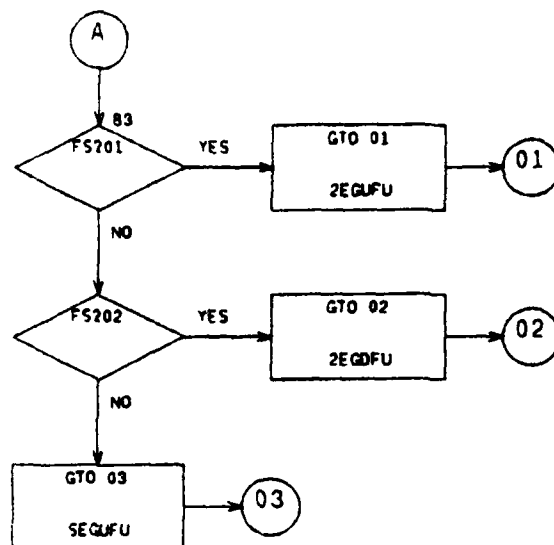
C-2A BINGO



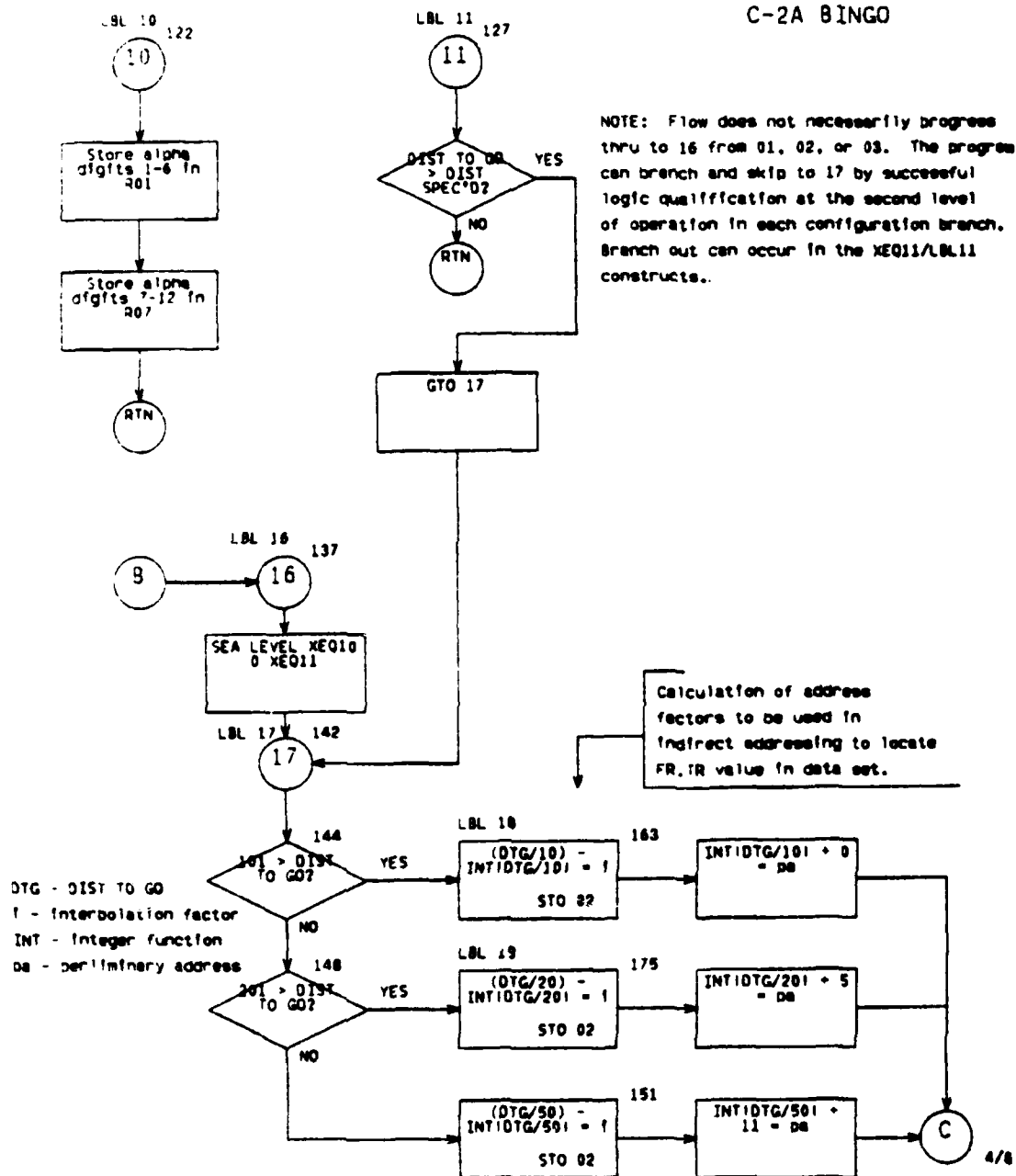
C-2A BINGO

Configurations

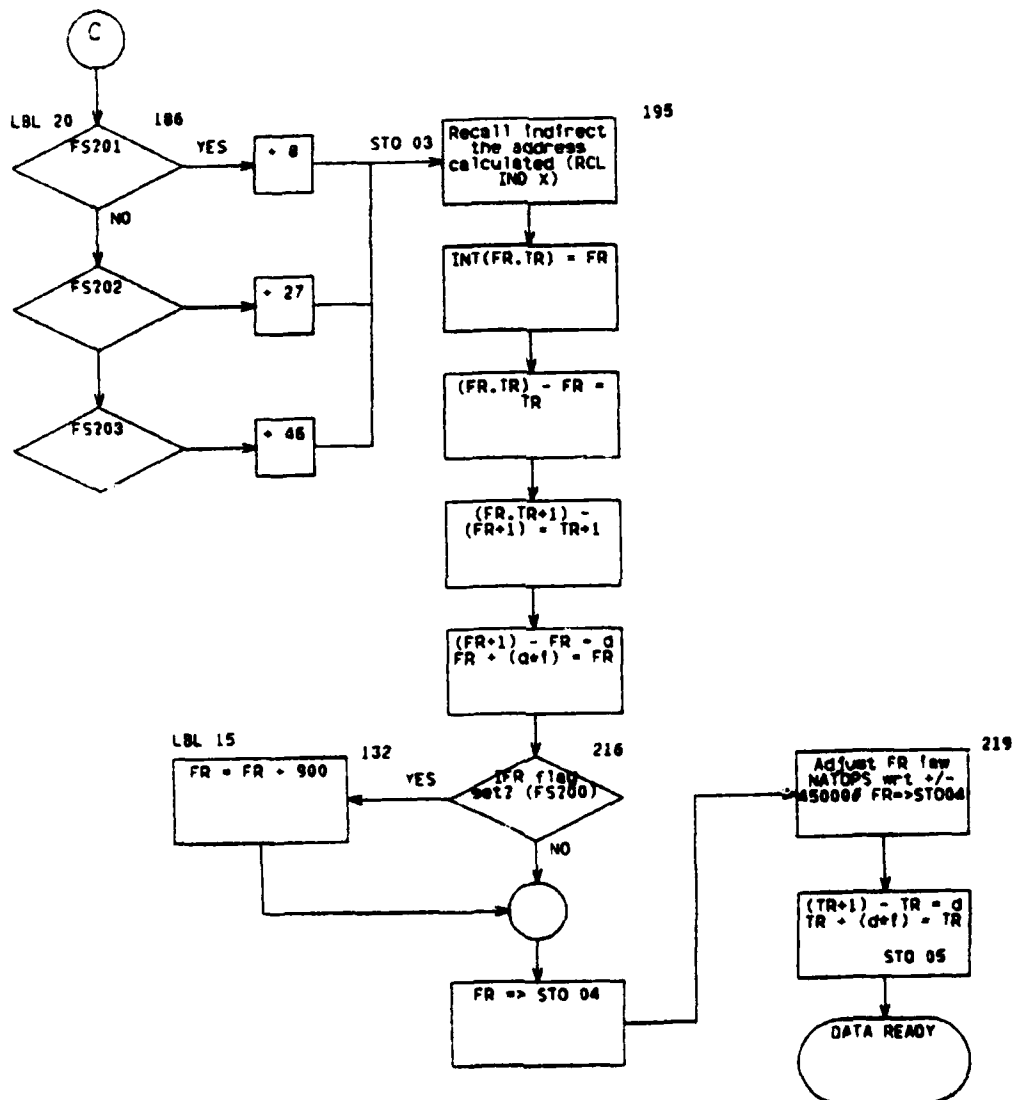
- 1 2EGUFU
- 2 2EGDFU
- 3 SEGUFU



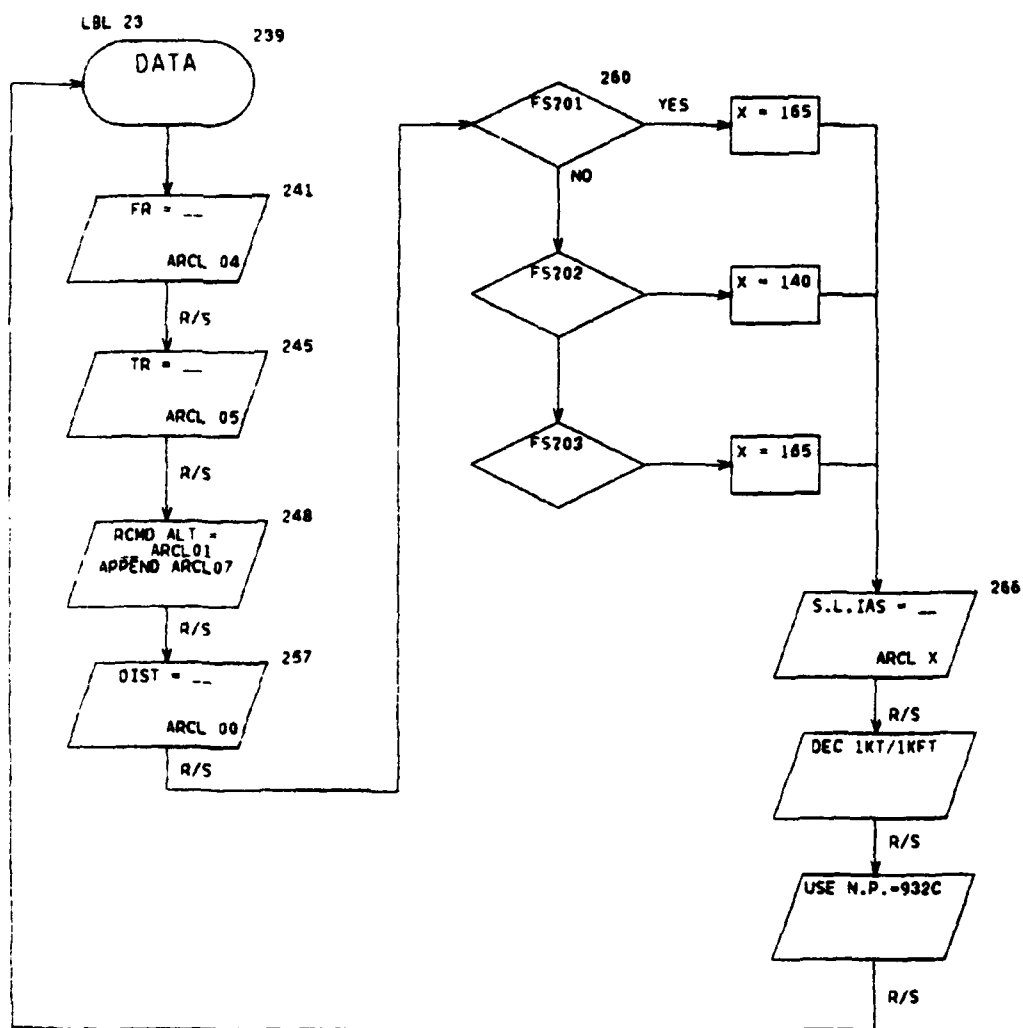
C-2A BINGO



C-2A BINGO



C-2A BINGO



C-2A BINGO/HP-41CV Code (June 1982; 1/3)

01*LBL *STB*	51 AVIEW	101 GTO 16
02 CF 01	52 PSE	102*LBL 02
03 CF 02	53 GTO 08	103 *25000 FT*
04 CF 03	54*LBL C	104 XEQ 10
05 **C2A BINGO*	55 SF 01	105 139
06 AVIEW	56 CF 02	106 XEQ 11
07 PSE	57 CF 03	107 *20000 FT*
08 *DIST TO GO ?*	58 *GEAR UP..*	108 XEQ 10
09 PROMPT	59 AVIEW	109 99
10 STO 00	60 PSE	110 XEQ 11
11 *BASIC WT = ?*	61 *CFGN=2EGUFU..*	111 *10000 FT*
12 PROMPT	62 AVIEW	112 XEQ 10
13 STO 00	63 PSE	113 39
14 *CARGO WT = ?*	64 GTO 08	114 XEQ 11
15 PROMPT	65*LBL H	115 GTO 16
16 RCL 00	66 SF 02	116*LBL 03
17 +	67 CF 01	117 * 5000 FT*
18 STO 00	68 CF 03	118 XEQ 10
19 *NO.CREW/PAX=?*	69 *GEAR DOWN..*	119 89
20 PROMPT	70 AVIEW	120 XEQ 11
21 200	71 PSE	121 GTO 16
22 *	72 *CFGN=2EGDFU..*	122*LBL 10
23 RCL 00	73 AVIEW	123 ASTO 01
24 +	74 PSE	124 ASHF
25 STO 00	75*LBL 08	125 ASTO 07
26 *FUEL = LBS?*	76 * VFR, IFR ?*	126 RTN
27 PROMPT	77 PROMPT	127*LBL 11
28 RCL 00	78*LBL E	128 RCL 00
29 +	79 GTO 09	129 X>Y?
30 STO 00	80*LBL J	130 GTO 17
31 FIX 0	81 SF 00	131 RTN
32 *GN = *	82*LBL 09	132*LBL 15
33 ARCL X	83 FS? 01	133 CF 00
34 PROMPT	84 GTO 01	134 900
35 *SELECT..*	85 FS? 02	135 +
36 AVIEW	86 GTO 02	136 RTN
37 PSE	87 GTO 03	137*LBL 16
38 *CFGN=2E:SE, GU:D*	88*LBL 01	138 * SEA LEVEL*
39 PROMPT	89 *30000 FT*	139 XEQ 10
40*LBL 8	90 XEQ 10	140 0
41 *2 ENGS*	91 159	141 XEQ 11
42 PROMPT	92 XEQ 11	142*LBL 17
43*LBL G	93 *20000 FT*	143 RCL 00
44 SF 03	94 XEQ 10	144 101
45 CF 01	95 119	145 X>Y?
46 CF 02	96 XEQ 11	146 GTO 18
47 *SINGLE ENG...*	97 *10000 FT*	147 X<>Y
48 AVIEW	98 XEQ 10	148 201
49 PSE	99 59	149 X>Y?
50 *SE=GU,FU,ONLY..*	100 XEQ 11	150 GTO 19

151 RCL 00	201 1	251 CLA
152 50	202 ST+ 03	252 ARCL 01
153 /	203 RCL IND 03	253 "+"
154 ENTER↑	204 ENTER↑	254 ARCL 07
155 INT	205 INT	255 PROMPT
156 STO 03	206 STO 06	256 FIX 0
157 -	207 -	257 "DIST = "
158 STO 02	208 STO 03	258 ARCL 00
159 RCL 03	209 RCL 06	259 PROMPT
160 11	210 RCL 04	260 FS? 01
161 GTO 20	211 -	261 165
162+LBL 18	212 RCL 02	262 FS? 02
163 RCL 00	213 *	263 140
164 10	214 RCL 04	264 FS? 03
165 /	215 +	265 165
166 ENTER↑	216 FS? 00	266 "S.L. IAS = "
167 INT	217 XEQ 15	267 ARCL X
168 STO 03	218 STO 04	268 PROMPT
169 -	219 RCL 08	269 "DEC 1KT/1KFT"
170 STO 02	220 45000	270 PROMPT
171 RCL 03	221 -	271 "USE N.P. = 932C"
172 0	222 90000	272 PROMPT
173 GTO 20	223 /	273 GTO 23
174+LBL 19	224 RCL 04	274 .END.
175 RCL 00	225 *	
176 20	226 RCL 04	
177 /	227 +	
178 ENTER↑	228 STO 04	R00= 0.000
179 INT	229 RCL 03	R01= 1.000
180 STO 03	230 RCL 05	R02= 2.000
181 -	231 -	R03= 3.000
182 STO 02	232 RCL 02	R04= 4.000
183 RCL 03	233 *	R05= 5.000
184 5	234 RCL 05	R06= 6.000
185+LBL 20	235 +	R07= 7.000
186 +	236 10	R08= 8.000
187 FS? 01	237 *	R09= 921.003
188 8	238 STO 05	R10= 1.044.006
189 FS? 02	239+LBL 23	R11= 1.166.009
190 27	240 FIX 0	R12= 1.288.012
191 FS? 03	241 "FR = "	R13= 1.410.015
192 46	242 ARCL 04	R14= 1.506.021
193 +	243 FIX 2	R15= 1.602.024
194 STO 03	244 PROMPT	R16= 1.699.027
195 RCL IND X	245 "TR = "	R17= 1.795.030
196 ENTER↑	246 ARCL 05	R18= 1.891.032
197 INT	247 PROMPT	R19= 2.053.041
198 STO 04	248 "RCIND ALT = "	R20= 2.207.046
199 -	249 AVIEN	R21= 2.356.102
200 STO 05	250 PSE	R22= 2.485.107

C-2A BINGO/HP-41CV Code (June 1982; 3/3)

R23= 2,621.111
R24= 2,945.123
R25= 3,265.135
R26= 3,592.146
R27= 3,906.158
R28= 961.004
R29= 1,123.007
R30= 1,284.011
R31= 1,436.015
R32= 1,559.018
R33= 1,683.022
R34= 1,806.025
R35= 1,930.028
R36= 2,053.032
R37= 2,171.034
R38= 2,371.040
R39= 2,570.046
R40= 2,763.051
R41= 2,955.057
R42= 3,141.103
R43= 3,596.117
R44= 4,063.132
R45= 4,505.146
R46= 4,939.200
R47= 897.004
R48= 994.007
R49= 1,091.010
R50= 1,188.014
R51= 1,284.018
R52= 1,382.021
R53= 1,478.025
R54= 1,575.029
R55= 1,662.041
R56= 1,751.044
R57= 1,926.051
R58= 2,101.058
R59= 2,276.105
R60= 2,450.111
R61= 2,626.118
R62= 3,062.135
R63= 3,496.152
R64= 3,927.209
R65= 4,355.226

5.3 SAMPLE PROGRAM OPERATION (C-2A)5.3.1 FPAS

<u>Prompt</u>	<u>Response</u>	
	START	R/S
C2A FPAS		
BASIC WT = ?	31000	R/S
CARGO WT = ?	2500	R/S
NO.CREW/PAX=?	8	R/S
PROFILE?	RANGE	R/S
**MAX RANGE*		
ALT = FT?	25000	R/S
OAT = C?	-15	R/S
IAS = KTS?	165	R/S
FUEL = LBS?	8000	R/S
GS,AVAIL? Y/N	NO	KEY 25
INPUT WINDS..		
WIND DIR = ?	300	R/S
WIND VEL = ?	45	R/S
A/C HDG = ?	275	R/S
DATA READY	R/S or KEY 21	
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS = 173	R/S	
*MR TAS = 271	R/S	
*HW = 41	R/S	
GW = 43100	R/S	
UPDATE @ 30M	R/S to repeat data	
ENDUR KEY 13		
**MAX ENDUR*		
ALT = FT?	20000	R/S
OAT = C?	-10	R/S
IAS = KTS?	150	R/S
FUEL = LBS?	5000	R/S
DATA READY	R/S or KEY 21	
*RCMD MR IAS		
*PRESENT ALT		
*MR IAS = 110	R/S	

GW = 40100
UPDATE e 30M

R/S
R/S to repeat data

DESCENT KEY 14

NR DESCENT

ALT = FT?	26 000	R/S
FUEL = LBS?	7 000	R/S
L/O ALT = ?	1 000	R/S
DSND, DIST=44		R/S

** NOTE **

UPDTE NRD, IAS
EVERY 2000FT
USE 500 SHP
NRD IAS = 153
NEW ALT = ?
NRD IAS = 154

R/S
24 000 R/S
R/S etc.

5.3.2 BINGOPromptResponse

START R/S

**C2A BINGO*

DIST TO GO ?	85	R/S
BASIC WT = ?	310 00	R/S
CARGO WT = ?	70 00	R/S
NO, CREW/PAX=?	10	R/S
FUEL = LBS?	45 00	R/S
GW = 44500		R/S

SELECT..

CFGW=2E:SE, GU:D 2E

2 ENGS GU

GEAR UP..

CFGW=2EGUFU..

VFR, IFR ? IFR

FR = 2632 R/S

TR = 0.29 R/S

RCHND ALT =

10000 FT R/S

DIST = 85	R/S
S.L. IAS = 165	R/S
DEC 1KT/1KFT	R/S
USE N.P. = 932C	R/S to repeat data

5.3.3 Crosswind Landing

Refer to section describing program operation for the E-2C.

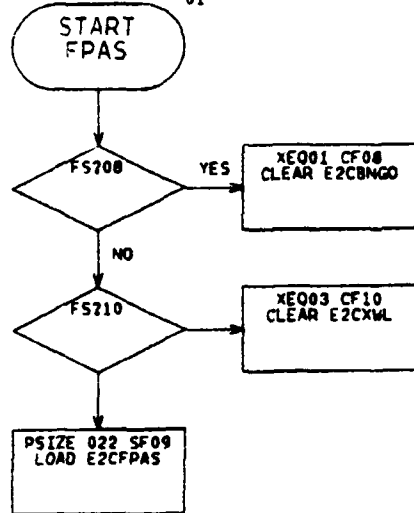
Chapter VI
MAIN MEMORY ACCESSING PROGRAM

Theory of operation is simple and straight forward. One of three programs loaded in main memory should have set one of flags 8, 9, or 10 when loaded. When a new program is requested, a program check for the flag already set calls a subrcutine that clears the loaded program. The new program is then called and loaded.

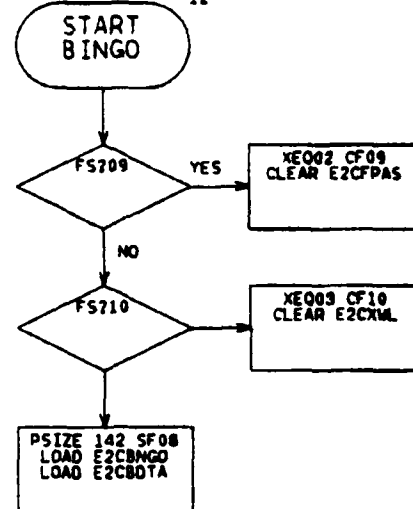
The next page is a flowchart for this algorithm, and the next page a code listing.

MAIN MEMORY ACCESSING PROGRAM

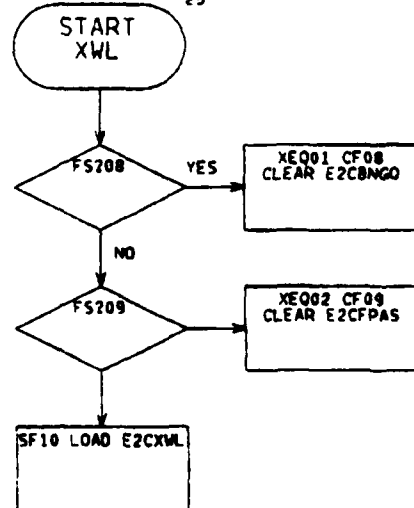
LBL FP 01



LBL BG 12



LBL XM 25



NNAP/HP-41CV Code (June 1982; 1/1)

01*LBL "FP"
 02 FS? 08
 03 XEQ 01
 04 FS? 10
 05 XEQ 03
 06 022
 07 PSIZE
 08 SF 09
 09 "E2CFPAS"
 10 GETP
 11 STOP
 12*LBL "BG"
 13 FS? 09
 14 XEQ 02
 15 FS? 10
 16 XEQ 03
 17 142
 18 PSIZE
 19 SF 08
 20 "E2CBNGO"
 21 GETP
 22 "E2CBDDTA"
 23 GETR
 24 STOP
 25*LBL "XM"
 26 FS? 08
 27 XEQ 01
 28 FS? 09
 29 XEQ 02
 30 SF 10
 31 "E2CXML"
 32 GETP
 33 STOP
 34*LBL 01
 35 CF 08
 36 "STB"
 37 PCLPS
 38 RTN
 39*LBL 02
 40 CF 09
 41 "STF"
 42 PCLPS
 43 RTN
 44*LBL 03
 45 CF 10
 46 "XML"
 47 PCLPS
 48 RTN
 49 END

01*LBL "FP"
 02 FS? 08
 03 XEQ 01
 04 FS? 10
 05 XEQ 03
 06 022
 07 PSIZE
 08 SF 09
 09 "E2BFPAS"
 10 GETP
 11 STOP
 12*LBL "BG"
 13 FS? 09
 14 XEQ 02
 15 FS? 10
 16 XEQ 03
 17 142
 18 PSIZE
 19 SF 08
 20 "E2BBNGO"
 21 GETP
 22 "E2BBDDTA"
 23 GETR
 24 STOP
 25*LBL "XM"
 26 FS? 08
 27 XEQ 01
 28 FS? 09
 29 XEQ 02
 30 SF 10
 31 "E2BXML"
 32 GETP
 33 STOP
 34*LBL 01
 35 CF 08
 36 "STB"
 37 PCLPS
 38 RTN
 39*LBL 02
 40 CF 09
 41 "STF"
 42 PCLPS
 43 RTN
 44*LBL 03
 45 CF 10
 46 "XML"
 47 PCLPS
 48 RTN
 49 END

01*LBL "FP"
 02 FS? 08
 03 XEQ 01
 04 FS? 10
 05 XEQ 03
 06 022
 07 PSIZE
 08 SF 09
 09 "C2AFPAS"
 10 GETP
 11 STOP
 12*LBL "BG"
 13 FS? 09
 14 XEQ 02
 15 FS? 10
 16 XEQ 03
 17 65
 18 PSIZE
 19 SF 08
 20 "C2ABNGO"
 21 GETP
 22 "C2ABDDTA"
 23 GETR
 24 STOP
 25*LBL "XM"
 26 FS? 08
 27 XEQ 01
 28 FS? 09
 29 XEQ 02
 30 SF 10
 31 "C2AXML"
 32 GETP
 33 STOP
 34*LBL 01
 35 CF 08
 36 "STB"
 37 PCLPS
 38 RTN
 39*LBL 02
 40 CF 09
 41 "STF"
 42 PCLPS
 43 RTN
 44*LBL 03
 45 CF 10
 46 "XML"
 47 PCLPS
 48 RTN
 49 END

Chapter VII

CALCULATOR SHIELDING

During the course of this project, an opportunity arose in early May 1982 to travel to RFAW-110 at NAS Miramar to try several methods of protecting the HP-41CV from electromagnetic interference (EMI) in the E-2. The EMI was discovered to adversely affect the HP-41 during an informal test flight in September 1981. In the intervening period, discussions were initiated with customer support engineers at Hewlett-Packard to seek a solution to the problem.

Most of their suggestions centered around providing shielding for the calculator. The HP-41 uses a type of circuitry technology referred to as CMOS. CMOS is sensitive to external EMI. Program flags in the HP-41 are apparently set by the electric field incident in the cockpit¹⁷ whenever the main beam of the radar passes. Based on a knowledge of the calculator, it is reasonable to assume that one of those flags turns the calculator off. No damage occurs when this happens, either physically or to memory and circuitry. But the calculator can only be restored to operation by reseating the batteries.

¹⁷ Grumman engineers estimate the potential of this field at 30 to 50 volts per meter in certain areas of the cockpit, most notably near windows and mirrors.

The Hewlett-Packard engineers suggested that consideration be given to conformal coatings for the calculator's circuits. Conformal coating is an epoxy like resin formed around circuit parts. The resin can then be coated with various shielding materials. While this method is feasible, it would also be impractical. Any warranties would be invalidated and repair becomes virtually impossible.

The only other way to protect the HP-41 is with some form of external shielding. There are two areas of the calculator that are suspected of causing the most problems: a logic board directly behind the key pad, and a display driver hybrid behind the LCD.

The HP engineers sent two types of special purpose plastic bags to try in a shielding experiment. The first was an anti-static bag, the type used to enclose various electrical parts for shipment. The second was a nickel laminated plastic bag.

Other shielding ideas consisted of aluminum foil wraps with appropriate cutouts and a metal mask similar in design to the overlay masks used on the calculator to label special use keys.

During the flight in early may, the calculator was unwrapped from a full aluminum foil shield and found to be in operating order. A second wrap, below the first, exposed only those areas of the calculator needed to view output and

operate the keys. The stainless steel mask, manufactured by shop personnel at NPS, covered the keyboard area. The calculator was held in the vicinity of the kneeboard while the foil was removed in sections from the bottom up. The calculator continued to work the entire time; the steel mask remained in place. It appeared at this point that previous apprehensions concerning failure of the calculator in the E-2's EMI environment were unfounded. However, by placing the calculator against the overhead hatch (an obvious extreme), the phenomena previously explained was duplicated. The batteries were reseated and operation restored.

At this point, the anti-static bags were used and found to be totally unacceptable for shielding the calculator. The nickel laminated bags, however, worked quite well. Only one was required. These bags will be used again in future efforts if new shielding problems arise. Their main disadvantage, however, is the dark, translucent coloring that makes them somewhat difficult to see through. Lighting experiments would have to be conducted to determine the amount of night lighting required to use them. Day light use appears to be no problem.

None of the above experimentation could be examined under the light of strict compliance with scientific principles. No formal or rigorous treatment of electromagnetic propagation theory has been delved into. The work performed, how-

ever, is sufficient to warrant continued work with the HP-41CV in the E-2 cockpit. Original fears that the calculator would not work at all were unfounded. Currently, it appears that the only shielding actually required is the stainless steel mask. This arrangement probably serves to protect the logic board behind the key pad. It is also important to point out that the Extended Functions module and two Extended Memory modules were installed. The presence of these modules may have had a net shielding effect for the display driver hybrid behind the LCD.

Chapter VIII

PROGRAM LOADING INSTRUCTIONS

Basic to understanding the instructions listed here is a familiarity with the HP-41CV. Chapter I gives a brief overview, but users are encouraged to read documentation provided with the calculator by Hewlett-Packard and become familiar with programming and basic functions. The HP-41CV is easier to learn than most programmable calculators and the RPN logic should not be a deterrent. Once learned, RPN is easier than standard operating procedures on other calculators.

It is assumed that all programs for one particular aircraft are loaded on magnetic storage cards (magcards). The total number of magcards varies for each aircraft, but the operating principles are the same. In those cases where there is an aircraft or program dependent label or instruction, that instruction will be written in an E-2C/E-2B/C-2A format.

It is also assumed that one Extended Functions/Memory module and two Extended Memory modules are mounted in the calculator. Read the HP instructions carefully so that modules are located in the proper position. The following figure is an end view of the calculator with a suggested mounting order. Attention to proper mounting order is important.

X FUNCTIONS	X MEMORY
X MEMORY	

Figure 2: Suggested Module Mounting Order

Without the modules, the calculator will accomodate only the FPAS or the BINGO program, not both. XWL could possible loaded with either one. More than one calculator would be required to have all programs without the modules. (Using modules is less expensive).

If the program is not already loaded on magcards, manual entry will be required.¹⁸ The FPAS and BINGO programs each involve several hundred separate entries.¹⁹ Once loaded, appropriate user labels will have to be assigned; refer to program code.

In the following instructions, an underlined label refers to a function/mode key, boldface refers to alpha/numeric entries.

¹⁸ See appendix A for data loading instructions for BINGO data.

¹⁹ Users desiring a set of magcards are encouraged to send about 20 blank cards for loading from the master program. Addresses are listed in Appendix B.

1. Calculator on, set USER mode. USER mode should be on during the entire procedure.
2. XEQ SIZE 022 (ie. XEQ ALPHA SIZE 022)
3. Insert each magcard in order, side one, then side two.
4. After the last card is loaded, the window displays "WORKING" to indicate that program entry is complete and the code is being packed.
5. ALPHA STF,E2CFPAS/STF,E2BFPAS/STF,C2AFPAS ALPHA; XEQ SAVEP (This instruction loads FPAS into Extended Memory).
6. XEQ ENDIR The display should respond with "E2CFPAS/E2BFPAS/C2AFPAS nnn", indicating successful loading of the program into Extended Memory).
7. XEQ CLP STF (Clear FPAS from main memory).
8. XEQ SIZE 141
9. Load program cards for the BINGO program.
10. ALPHA CLR STB,E2CBNGO/STB,E2BBNGO/STB,C2ABNGO ALPHA
11. XEQ SAVEP
12. XEQ CLP STB
13. 0.140/0.140/0.065 ENTER
14. XEQ RDTAX (After ALPHA pressed, display prompts for BINGO data cards).
15. ALPHA CLR E2CBDTA/E2BBDTA/C2ABDTA ALPHA
16. 141/141/66 ENTER
17. XEQ CRFLD
18. XEQ SAVER
19. XEQ CLRG
20. Load IWL program card.
21. ALPHA CLR IWL,E2CXWL/IWL,E2BXWL/IWL,C2AXWL ALPHA
22. XEQ SAVEP
23. XEQ CLP IWL
24. Load control program card.
25. SHIFT GTO.. (This procedure is very important. The calculator will pack the control program and place an END statement at the end of the code. Failure to do this will result in some very strange responses from the calculator)

The calculator is now fully loaded and ready to run. Refer to the section in each chapter regarding how to access certain programs for correct operation.

Chapter IX

KNEEBOARD DESIGN

When this project was first proposed to the NADC engineer²⁰ in charge of sponsoring FPAS efforts, a request was made to look into a design for incorporating the HP-41CV in a convenient kneeboard format. Based on ideas and conversations with pilots from various aircraft communities, the design on the following pages is being submitted for consideration.

The design seeks to minimize size and weight, yet retain room to write on standard 5X8 cards issued by the ship for card-of-the-day purposes. The current design uses the standard issue kneeboard. The top was removed and raised by a spacer to accommodate the thickness dimension of the HP-41. A cutout in the top, left of center and aft, allows the calculator to be dropped into a sleeve. Velcro on the bottom of the calculator and on the sleeve holds the calculator in place. The sleeve is shaped to let the calculator face lie flush with the top face of the kneeboard.

The light assembly and lower clip have been removed. A separate clip board, purchased from a civilian source and slightly larger than 5X8, is attached with a hinge to the upper clip. A 5X8 paper pad will fit on the clip board, and a 3X5 paper pad, adjacent to the calculator, fits into the

²⁰ Mr. Michael Herskovitz

upper clip. A small area immediately to the right of the calculator face could be used to tape a small reference card to enhance use of the calculator.

The next page shows construction details for the kneeboard. The following pages are photographs of the kneeboard constructed by Aeronautical Engineering shop personnel at NPS. No provisions have been made for an integrated light. The lights that come with a kneeboard seldom work for an extended period; cockpit auxiliary lights should be sufficient for illumination.

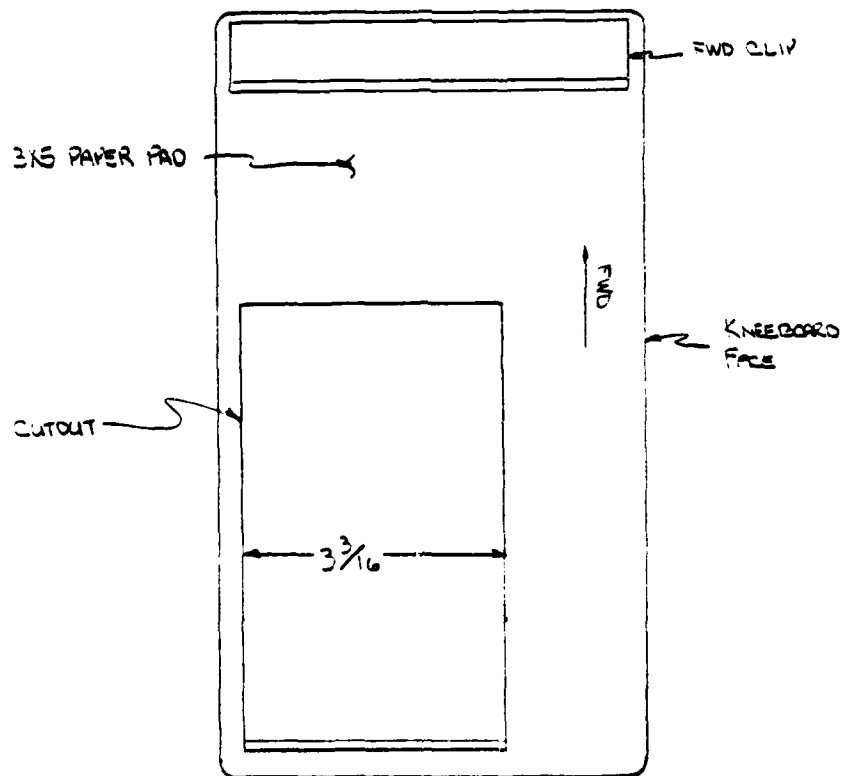
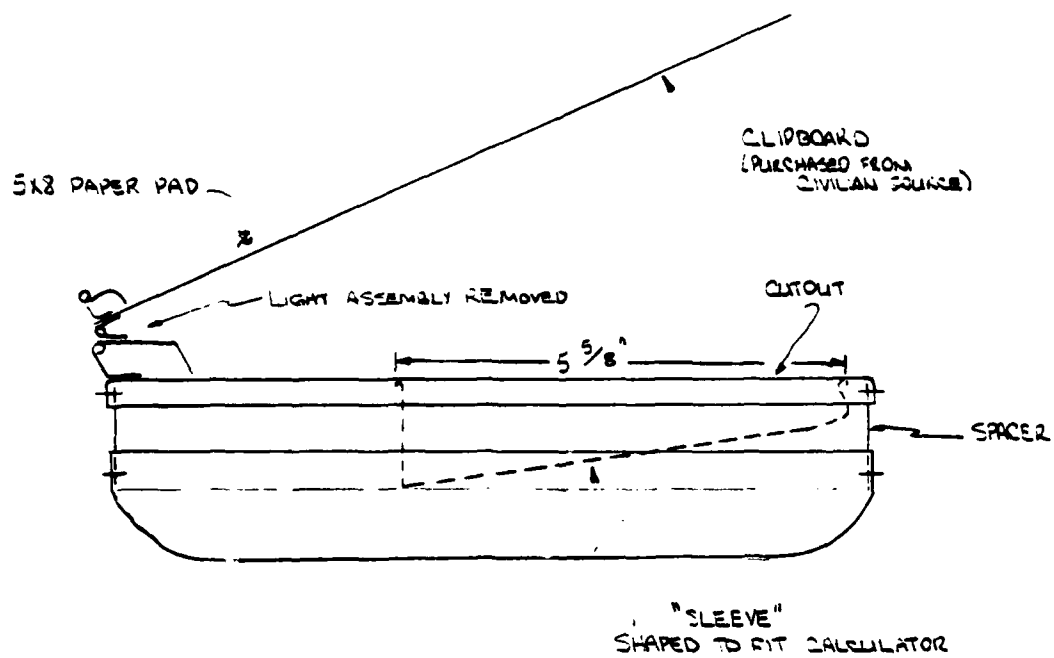


Figure 3: Kneeboard/HP-41CV Construction Details



Figure 4: Kneeboard/HP-41CV, Closed



Figure 5: Kneeboard/HP-41CV, Open

Chapter X

CONCLUSIONS AND RECOMMENDATIONS

A number of auxiliary topics were generated in the course of preparing this report. Many are outside the scope of this work but are included here for future reference.

10.1 CONCLUSIONS

1. The HP-41CV is currently one of the most advanced handheld programmable calculators available. There are, however, pocket sized computers that use microprocessor technology that should be examined for potential. Many are faster when accessing specific data, but they may be more difficult to learn and and to maintain in a squadron environment. Compliance with FCC regulations must also be confirmed for operation in aircraft.
2. The kneeboard/HP-41CV combination should alleviate problems and concerns generated with regards to additional loose items in the cockpit. Other communities interested in using the HP-41CV are encouraged to consider this or a similar kneeboard design.
3. The kneeboard may provide additional EMI protection for the HP-41CV in the E-2. Other agencies would have to conduct appropriate testing to confirm this, however.

4. The HP-41CV can be used by aircrew not familiar with the HP-41CV or handheld programmable calculators. However, at least one person per squadron should be thoroughly familiar with how the calculator works in order to maintain software and program status.
5. The potential to reduce fuel consumption in fleet aircraft is probably limited. The true benefit to having the capabilities represented by FPAS program is the ability to stretch out a critical situation, such as a low fuel state BINGO. The use of FPAS in conjunction with safety of flight programs such as BINGO will gain greater acceptance than as a fuel conservation aid.
6. During the EMI effects test flight, the original version of the E-2C FPAS contained readouts for fuel flow and horsepower to fly IAS. These values were found to be radically inaccurate, however, and the equations to generate those values have been eliminated from all three FPAS programs. The original purpose in including such calculations was to enable the pilot to calculate fuel, time and distance to go parameters. With a calculator handy, however, such parameters can easily be computed assuming the linear fuel consumption nature of the E-2 and C-2.

10.2 RECOMMENDATIONS

1. It is recommended that a validation of the programs in this report be undertaken. In that regard, research funds have been requested through NPS in order to purchase at least one more calculator and appropriate peripherals to support software and continuing research. Validation efforts will be conducted in cooperation with NADC.
2. If there is interest in the C-2 community in a validation effort, request they contact NADC or myself for assistance.
3. Consideration should be given to incorporating a validated suite of programs into a ROM chip obtained under contractual agreement with Hewlett-Packard.
4. Pending approval, or failing to approve, a ROM chip, consideration should be given to having program code converted to printed bar code for non-volatile storage. The ship environment may be too precarious for magcards to retain microcode accurately over an extended period of time on-board.
5. Upon incorporation of the HP-41CV into daily flight operations, at least one officer per squadron, preferably from the NATOPS Department, should be appointed to be in charge of coordinating the squadron's use of the calculator. Responsibilities would include loading and check-

ing of hardware, coordination of warranties/maintenance, and instruction of squadron aircrew in the use of the calculator.

6. Minimum E-2/C-2 squadron inventory of HP-41CV calculators and peripherals should include the following: four (4) HP-41CV calculators with one (1) Extended Functions/Memory module and two (2) Extended Memory modules per calculator; two (2) magnetic card readers; one (1) printer/plotter; and one (1) optical wand (assuming bar code is available).
7. Development of other programs to enhance safety of flight and fuel efficient operation should be researched and incorporated. The limitation on this effort, however, is the amount of memory space available in the calculator. This limitation is relieved if more than one calculator at a time can be used.
8. Request information be forwarded concerning the validity of using the current issue of the E-2B and C-2A NATOPS Manuals for FPAS and BINGO programs. If SOP or more current information is available, it should be incorporated.
9. Incorporate wind at altitude corrections into the E-2 and C-2 BINGO programs.
10. Research into designing the BINGO programs demonstrated that a microcomputer based BINGO program could be de-

signed for use by the ship to quickly plan the fuel required values for all airwing aircraft for each recovery. Such a program could, most importantly, incorporate adjustments to fuel required for forecast winds aloft. Quick access could also be obtained for various aircraft configurations determined by emergencies such as hydraulic failures.

Appendix A
DATA LOADING PROGRAM

The following is a code listing of a short program designed to load data in the HP-41CV registers. Indirect addressing is used so that registers beyond R99 can be loaded.

The program starts with R00 and loads sequentially in an interactive manner. Assignment of user labels is at the discretion of the user. The second half of the program can be used to read the contents of designated registers. The program can enter data starting with any register by carefully loading an address into the X register. Caution is urged to prevent overwriting old data or entry of data into the wrong location.

```
01+LBL "STO"  
02 0  
03 STO 00  
04+LBL 01  
05 "R="   
06 ARCL 00  
07 PROMPT  
08 STO IND 00  
09 1  
10 ST+ 00  
11 GTO 01  
12+LBL "RCL"  
13 0  
14 STO 00  
15+LBL 02  
16 FIX 0  
17 "R="   
18 ARCL 00  
19 PROMPT  
20 FIX 3  
21 RCL IND 00  
22 STOP  
23 1  
24 ST+ 00  
25 GTO 02  
26 END
```

Appendix B

ADDRESSES

Perscns interested in obtaining clarification of details in this report or who desire to pass on corrections can use the following addresses in the time frames indicated.

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October 1982 to March/April 1983

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Appendix C
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Suggested Mask Label Scheme for User Labels

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