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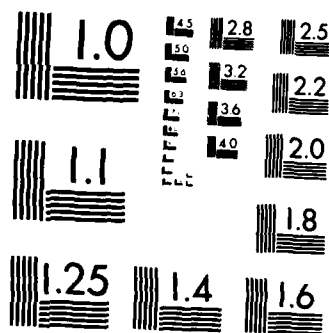
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AD-A156 089

NAVAL POSTGRADUATE SCHOOL

Monterey, California



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THESIS

DEVELOPMENT OF NATOPS
PERFORMANCE SOFTWARE
FOR THE H-46D HELICOPTER

by

John Michael Caram

March 1985

Thesis Advisor:

D. M. Layton

Approved for public release: distribution unlimited.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Development of NATOPS Performance Software for the H-46D Helicopter		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis March 1985
7. AUTHOR(s) John Michael Caram		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE March 1985
		13. NUMBER OF PAGES 73
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES <i>Development of Training and Operating Procedures Standardization (NATOPS)</i>		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) NATOPS Computerization H-46D Helicopter Performance Planning Numerical Regression Flight Planning Curve Fitting HP-41 Programs NATOPS Software		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This thesis generates closed-form equations for significant and frequently used NATOPS performance charts for the H-46D and H-46A (with T58-GE-10 engines) helicopters. These equations are developed into interactive software for the Hewlett-Packard HP-41CV hand-held programmable calculator. With this software installed in the calculator the user is able to calculate numerous NATOPS performance parameters (expeditiously, with reduced risk of error) both prior to and in flight.		

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Development of NATOPS Performance Software
for the H-46D Helicopter

by

John M. Caram
Lieutenant, United States Navy
B.S., University of Florida, 1977

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

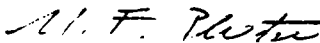
NAVAL POSTGRADUATE SCHOOL
March 1985

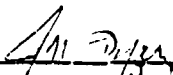
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ABSTRACT

This thesis generates closed-form equations for significant and frequently used NATOPS performance charts for the H-46D and H-46A (with T58-GE-10 engines) helicopters. These equations are developed into interactive software for the Hewlett-Packard HP-41CV hand-held programmable calculator. With this software installed in the calculator the user is able to calculate numerous NATOPS performance parameters (expeditiously, with reduced risk of error) both prior to and in flight.

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ACKNOWLEDGEMENTS

The support of my wife, Joette, was instrumental in the completion of this thesis.

I. INTRODUCTION

A. COORDINATION OF EFFORT

A similar software development for the H-3D and H-3H helicopters was conducted at the same time as this development by Curtis [Ref. 1]. Because of the nature and complexity of the problem, the initial stages of these investigations were a joint effort. As a result, the Approach to the Problem (Chapter II) and the basic method of the Solution (Chapter III) of this work and of Reference 1 are very similar.

B. BACKGROUND

Performance planning is an essential task to ensure the safe conduct of any aircraft and crew during their flight. Naval aircrew use the Naval Air Training and Operating Procedure Standardization (NATOPS) manual to acquire all necessary performance data. For the most part, NATOPS performance information is presented in a graphical format often requiring the user to transit several subcharts, which may be located on different pages, to obtain the desired performance parameter. This procedure is time consuming, prone to error, and impractical in-flight.

The purpose of this thesis is to propose a correction to these NATOPS deficiencies by transforming selected performance charts into interactive, user-friendly, computer software for a hand-held programmable calculator. This solution would enable aircrew to obtain performance data with increased accuracy, reduced time and effort, and permit in-flight use.

Previously there have been several successful efforts in NATOPS computerization. The most recent study [Ref. 2] developed software for the A-6 aircraft utilizing the Hewlett-Packard HP-41CV hand-held programmable calculator. This research demonstrated the feasibility of NATOPS computerization and was a prime motivator for this thesis.

C. GOALS

The first goal of this study was to generate a closed-form equation for each selected NATOPS chart or subchart. The equations were required to be of a form such that independent variables were the specific chart input parameters and the dependent variable, the output parameter. The equations used to "fit" each NATOPS chart had to allow an explicit calculation of the dependent variable. Furthermore, they had to consist of standard functions (no differentials/integral equations) which could be programmed on a calculator or computer.

Once the equations representing the performance charts had been derived, it was necessary to select the hardware which would be used for software design. The HP-41CV programmable calculator was selected due to its small size, relatively large memory capability (6.4 Kbytes), and successful use in the past.

Upon completion of the software development the ultimate goal of this research was the testing and implementation of the end product into the fleet.

II. APPROACH TO THE PROBLEM

The first and foremost problem encountered was the generation of the closed-form equation in a manner which accurately represented each performance chart with a minimum number of terms. For the majority of charts considered there were two independent input variables that yielded a single dependent output variable. This was visualized as a three dimensional surface in space.

To accomplish fitting an equation to a surface of irregular nature required the utilization of a numerical regression routine. These routines are numerous and have been developed into several software packages for main frame computers. The software chosen for this study was the Biomedical Computer Program (BMDP) statistical package [Ref. 3], installed on an IBM 3033 main frame computer located at the Naval Postgraduate School in Monterey, California. A regression is linear in nature no matter how many independent variables are involved. However, nonlinear functions may be used in a regression if they are first "linearized". For example, if the nonlinear functions x^2 , x^3 , and $\ln(x)$ are transformed into independent variables (transforms) U , Y , and Z , respectively, then a regression can be performed to yield an equation of the form:

$$S = aU + bY + cZ + d \quad (\text{eqn 2.1})$$

where a , b , and c , are the regression coefficients, d is the intercept, and S is the dependent variable. The specific BMDP routine used for the majority of charts analyzed was the "all possible subset" multiple regression routine (P9R) which allows the user to input a large selection of

and the NATOPS software program cards; several steps must be taken before the calculator can be used as described earlier.

1. Become familiar with the HP-41CV owner's manual and all peripherals operating instructions. While the basic user can avoid an in depth knowledge of the system, the initial set up requires someone who is familiar with the hardware and procedures listed in [Refs. 5,6,7].
2. With the extended memory and extended functions modules in their proper ports, and the card reader attached, loading the programs into main and extended memory can begin.
 - Load the following programs into extended memory: HIGW, VTOGW, HITQ, HOTQ, SE/EV, VNE, RNG, ENDA, and ENDB.
 - Load the following programs into main memory (in the order listed): MAIN, QD, DA, and IQAV.
3. Ensure the only programs in main memory are the ones listed above and erase any other programs.
4. Pack the programs in main memory.
5. Execute the program MAIN.

The calculator is now loaded and positioned to the main program. By pressing the user key the performance programs are assigned to their respective key locations and the calculator is ready for program execution.

are shown in the display. Some charts yield more than one performance parameter, so it is necessary to note each parameter displayed and then push the R/S key to continue execution.

6. Once all performance parameters have been calculated pushing R/S will display "NEXT" which tells the user he has been given all available output and the calculator is ready to execute the next program.
7. Before executing the PRE FLT program ensure the calculator is turned off. With the printer also turned off plug the printer input chord into the only remaining extension port. Turn the calculator and printer on, select the normal mode on the printer, and push the PRE FLT key. All other instructions remain the same.

B. GENERAL USER INFORMATION

The NATOPS software should generate accurate answers within the range of a selected performance chart. If data is entered erroneously, or in excess of a particular chart's range, the output will be in error.

In the cases where a chart has limitations such as density altitude [Ref. 4: p. 11-9], these have been taken into account within the program and the output will tell the user if they exceed that limitation. If the user is ever in doubt as to the validity of the calculator generated performance data, the NATOPS should be consulted.

C. INITIAL CALCULATOR PREPARATION

The basic use instructions assume the user has a calculator that has all the performance software installed. If the user merely has the calculator (with two extended memory modules, and an extended functions module), a card reader,

The programs listed in Table I are assigned to the corresponding keys shown in Figure A.1. The key marked "PRE FLT" performs all 10 programs and produces a hard copy of the output. This program requires that a printer is attached. To execute a program follow the steps presented below.

1. Turn the calculator on.
2. Ensure the calculator is in the user mode, if the word user is not visible in the display push the user key.
3. Find the key with the particular performance chart desired and push it. As the program is initiated the calculator will prompt the user for any needed information. The exact prompt meanings are defined below:
 - PA? FT - pressure altitude in ft.
 - OAT? C - outside air temperature in °C.
 - GW? LBS - gross weight in lbs.
 - WIND? KTS - head wind in kts.
 - CLIMB? FPM - climb rate in ft. per min.
 - FUEL? LBS - fuel on board in lbs.
4. Answer the prompt by pushing the corresponding numbered keys until the desired value is seen in the display. If a mistake is made, simply push the key with the horizontal arrow (far right column four keys from the top) and re-enter the number. If the number to be entered is negative (negative OAT), push the key marked CHS after the number has been entered in the display. When the desired number is displayed in the window push the key marked R/S (run/stop, bottom right key).
5. After all the prompts required have been answered the calculator will execute the program. While the calculator is working "PRGM" will be visible in the display. As the calculator generates answers they

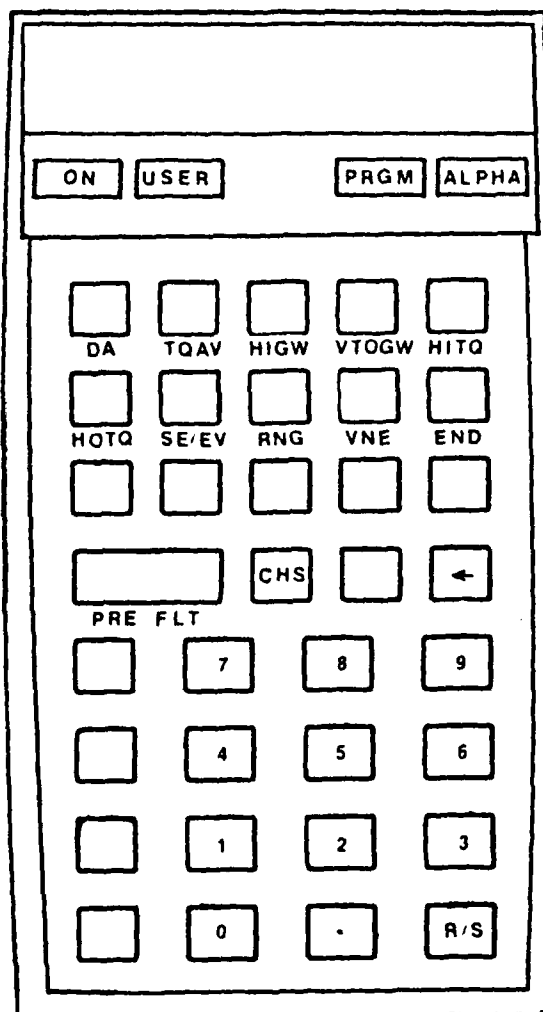


Figure A.1 Hewlett-Packard HP-41CV Calculator

APPENDIX A
NATOPS PERFORMANCE SOFTWARE USER'S GUIDE

A. BASIC USE

The NATOPS performance software designed for the HP-41CV calculator is simple and expeditious to use. The calculator keyboard configuration is depicted in Figure A.1. As you can see the first top two rows have abbreviated program names under the keys. The exact meaning of each performance chart abbreviation and its NATOPS [Ref. 4] page reference are contained in Table I below.

TABLE I
NATOPS Performance Chart Reference

HP-41CV ABBREVIATION	NATOPS CHART TITLE	NATOPS PAGE NUMBER
DA	Density Altitude Chart	11-3
TQAV	Engine Performance Chart (Military Power 100% Nr)	11-5
HIGW	Max Gross Weight for Hovering in Ground Effect	11-9
VTOW	Max Gross Weight for Vertical Takeoff	11-11
HITQ	Torque Required to Hover in Ground Effect	11-12
HOTQ	Torque Required to Hover Out of Ground Effect	11-13
SE/EV	Ability to Maintain Flight One Engine Operating (100% Nr)	11-37
RNG	Max Range (100% Nr)	11-22/3
VNE	Indicated Never Exceed Speed	1-173
END	Max Level Flight Endurance	11-32/3

V. CONCLUSIONS AND RECOMMENDATIONS

From the results of this thesis it can be concluded that graphical NATOPS performance data can be computerized. To effectively accomplish this, computer oriented numerical regression routines must be utilized to generate closed-form equations.

Once the equations have been derived, computer software can be developed that executes the programs in an expeditious, accurate, and portable fashion. Furthermore, this software can be designed for virtually any type of computer from hand-held programmable calculators to personal computers.

It is recommended that the NATOPS performance software developed in this study be submitted to a fleet squadron or Fleet Replacement Squadron (FRS) for test and evaluation. Since the software can be utilized as is, with off the shelf Hewlett-Packard components, the cost of testing would be minimized. If this software proved to be fleet applicable, Hewlett-Packard should be contracted to develop plug-in application modules which would increase reliability and decrease execution time.

code. It should be noted that the regression equations can be programmed for use with any capable system. The results presented here are for the H-46D and modified H-46A (with T58-GE-10 engines) NATOPS performance charts referenced in Appendix A. Future modification of these charts would invalidate the performance software for those particular charts.

IV. RESULTS

At the onset of this study 10 different NATOPS performance charts were selected for computerization based on their significance and frequency of use. It was anticipated that the final performance chart programs would be too voluminous to be collectively stored within the HP-41CV memory. This would necessitate using an external mass storage device or executing individual programs piecemeal. Both of these alternatives would have had serious degrading effects, forcing the only other alternative of contracting Hewlett-Packard to hardwire one or more plug-in read-only-memory (ROM) modules containing the NATOPS software.

Fortunately, the majority of programs were reasonable in length. With efficient programming techniques employed, and two external memory modules in series with an extended functions module (total memory of 6.4 Kbytes), it became evident that all programs could be simultaneously stored within the calculator. With this in mind a master program was written which functioned as a software manager which assigned performance charts to key locations (Appendix A), called programs from inexecutable extended memory to the executable work space in main memory, and interactively communicated with the user. In general the master program functioned as a communications system and manager between the user and performance chart software in an interactive and user-friendly mode.

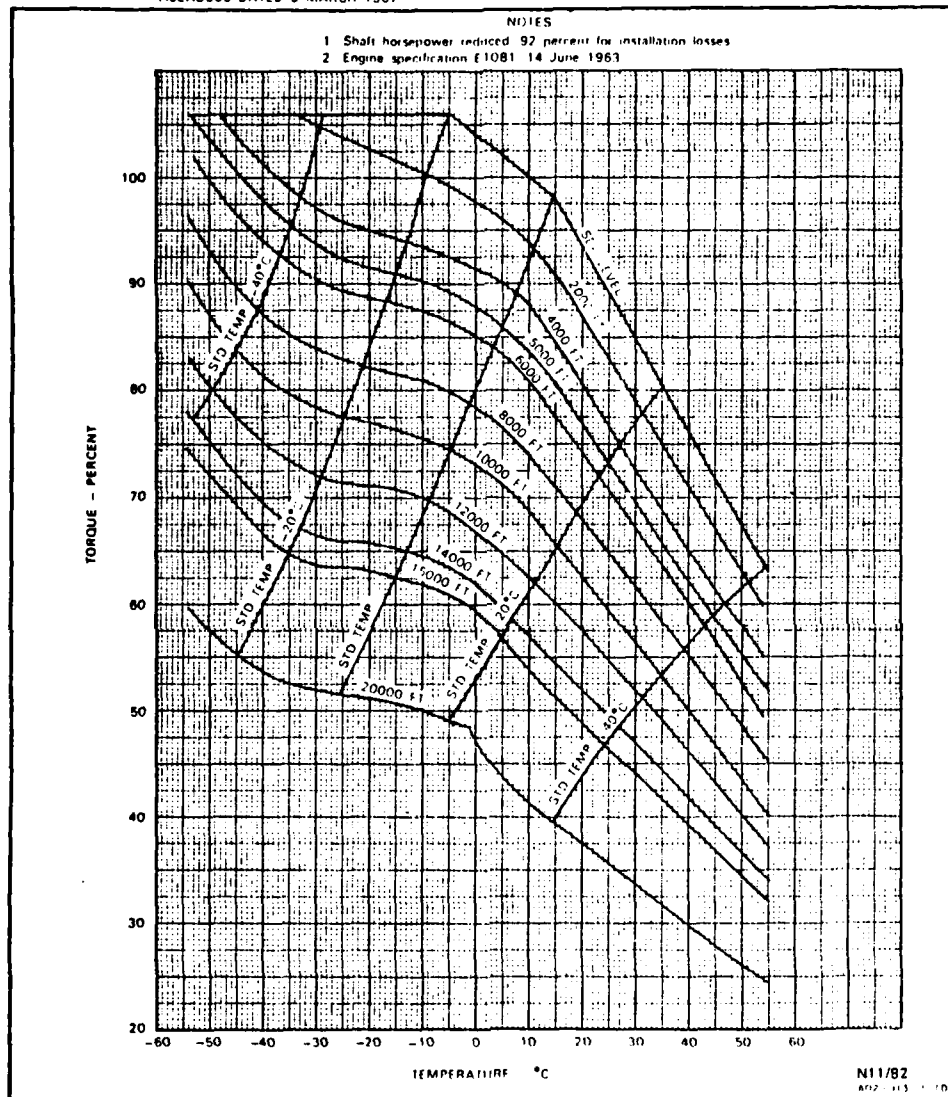
Appendix A contains the simple user instructions to execute any of the 10 listed NATOPS charts desired. With a printer attached a complete performance profile can be executed and printed for any mission plan. Appendix B lists all surface regression equations, flow charts, and program

MODEL: H 48D

ROTOR RPM 100 PERCENT

ENGINES: (1) T58 GE 10

FUEL GRADE JP 4 JP 5

DATA BASIS: FLIGHT TEST VERTOL REPORT
A02AD005 DATED 3 MARCH 1967Figure 11-1A. Engine Performance (Military Power - 100 Percent N_r)

11-5

Figure 3.1 Engine Performance (Military Power - 100% N_r)

Next a numerical regression was performed with the "method is none" option selected utilizing the standard fourth order polonomial (22 transforms) discussed earlier. The resulting output listed the terms excluded from the regression analysis due to exceeding tolerance limits (4), the regression R^2 (.99942), and other fit statistics. The high R^2 value indicated that the selected polonomial transforms were representative of the surface.

The next step was to determine if some of the retained transforms could be eliminated without significantly effecting the fit. The four out-of-tolerance terms were deleted from the transform selection and the program was executed with the "method is CP" option in effect. This resulted in an elimination of eight transforms while only degrading the R^2 value to .99936 (Appendix B: p. 36).

The equation for the surface was tested by writing a program stub and checked to ensure accuracy. Since the surface fit did not consider altitudes below the 2000 foot line, an interpolation routine was required in the final program to calculate torque when pressure altitude was between 2000 feet and sea level.

III. THE SOLUTION

The polonomial transform program yielded acceptable regression results in the majority of cases. For the performance charts that had difficult surfaces to fit, requiring as many as 38 transformed terms (Appendix B: p. 58), it was found to be advantageous to take the penalty of a large regression equation rather than fitting influence lines and interpolating between them. Of all the surfaces considered (23), only the single engine envelope (Appendix B: p. 64) required nonlinear transformed terms, specifically exponential and high order fractions.

A. EXAMPLE SURFACE REGRESSION ANALYSIS

The engine performance chart Figure 3.1 was chosen to illustrate the regression technique since it demonstrated the capability of numerical regression to generate an accurate closed form equation of a fairly irregular surface.

The first step in the solution of this performance chart was to create the data file for the regression program. Data sets were taken along each pressure altitude influence line at increments of 10° centigrade (C) with additional points added for the 4000 to 6000 foot altitude lines, due to their close proximity to each other. Each of the 155 data sets consisted of two independent variables (temperature and altitude) and the resulting dependent variable (torque). The sea level altitude line was omitted since it could be calculated directly (linear equation) and due to its discontinuities at -5 and 15 °C causing difficulties in fitting the surface.

transforms. If this algebra created numbers outside the tolerance range specified in the program (default tolerance = .0001), the "method is none" option would eliminate the offending variable, or transform, and continue execution. The resulting output contained the R^2 value along with other fit statistics and listed all terms eliminated for low tolerance. Performing a second iteration with the out-of-tolerance transforms eliminated, and with "method is CP" selected, allowed the BMDP software to analyze subsets of the remaining transforms. Performing this two step process yielded the best fit with fewest terms for each surface.

a performance chart were as accurate as possible and that the data file clearly defined the surface. Obviously, those surfaces that were irregular in nature required significantly more data sets than smoother or more "well behaved" surfaces. If a surface contained a sharp point or discontinuity, this portion of the surface was eliminated from the regression analysis due to the inability of the software to accurately fit aberrations.

The transformed variable selection was the key to successful regression analysis. Through experience one gained an intuitive feel for what type of transformed variables would yield a close fit to a surface. Fortunately, most of the surfaces responded well to regression analysis utilizing combinations of the independent variables raised to powers between one and four (polynomial regression). A standard polynomial regression program was developed containing all the possible polynomial terms up to the fourth order, for three and four dimensional surfaces.

For a few surfaces, obtaining a close fit by regression analysis incurred the penalty of retaining a large number of transformed terms. An alternative to this was to fit each of the depicted influence curves and develop the final computer software to interpolate between curves. The trade off with an interpolation scheme was increased accuracy at the expense of inordinate program size and complexity, causing the result to be unacceptable. In a few cases it became necessary to use nonlinear transforms of the independent variables such as exponentials, and high order fractional combinations of terms (Appendix B: pp. 64-65).

On the first execution of each regression analysis "method is none" was selected in the P9R program. This keyed the BMDP software to use all the offered transforms for the regression analysis. During execution, matrix algebra was performed with the independent variables and

transformed independent variables to be examined during the regression analysis. The P9R could be selected to either use all transformed variables offered (method is none), or perform the regression selecting subsets of the offered transforms and output the subset with the best fit statistics (method is CP).

The dominating criteria used to determine the best fit statistics was the squared multiple regression correlation (R^2). Accuracy was gauged by how close R^2 was to the ideal value of 1.0. The required R^2 for an acceptable fit was found to vary between performance charts, and was a function of what dependent output variable was being generated, the irregularity of the surface, and the number of independent input variables. For each chart multiple regression analyses were performed varying the offered transforms in number and/or type, until a closed form equation was generated that yielded output that was within the accuracy of manual chart interpolation.

The accuracy with which NATOPS chart could be read was subject to the individual chart's characteristics, but in general the following tolerances for dependent variables were established (for the regression analysis).

- airspeed: within 2 knots
- altitude: within 100 feet
- weight: within 150 pounds
- torque: within 1 %
- distance: within 1 mile
- time: within .1 hour

Prior to the execution of the regression program, a data file for each surface was created. The file consisted of data sets which were merely the independent variable values and the corresponding dependent variable value. For a three dimensional surface each data set consisted of three values. It was critical to ensure that the data sets extracted from

APPENDIX B

REGRESSION EQUATIONS AND SOFTWARE DOCUMENTATIONS

This appendix contains all of the regression equations generated for each NATOPS chart, associated flow charts, and resulting computer code. For the most part, the regression equations are listed in a tabular form due to their size. The actual equations are of the form shown in equation 2.1. The R^2 and standard error of estimate for each regression is also listed. The standard error of estimate is the average error expected over one standard deviation of the surface's area. The flow charts use standard symbology and depict the general programming logic but are not detailed in nature. The computer code listings are in the Reverse Polish Notation (RPN) language developed by Hewlett-Packard.

Table II lists all the variables used in the regression equations throughout the programs. Table III lists the programming flags used and their definitions. The following is a listing of memory storage registers and their contents.

REGISTER VARIABLE/TRANSFORM

00	A
01	A ²
02	A ³
03	A ⁴
04	B
05	B ²
06	B ³
07	B ⁴
08	C
09	C ²
10	C ³
11	C ⁴
12	D
13	D ²
14	D ³
15	D ⁴
16	E
17	E ²
18	E ³
19	E ⁴
20	F
21	G
22	scratch

<u>REGISTER</u>	<u>VARIABLE/TRANSFORM</u>
23	scratch
24	scratch
25	scratch
26	scratch
27	scratch
28	scratch
29	scratch
30	scratch
31	scratch

TABLE II
Variable Definitions

<u>VARIABLE</u>	<u>DEFINITION</u>
A	(Pressure Altitude)/1000
B	(Outside Air Temperature)/1000
C	(Gross Weight)/1000
D	(Density Altitude)/1000
E	Wind
F	(Fuel)/100
G	(Vertical Climb)/10
H	(Torque Available)/100
I	Standard temperature (END)
J	Base Line Gross Weight No Wind (HIGW)
K	Base Line Gross Weight No Wind (VTOGW)
L	Base Line Gross Weight No Climb (VTOGW)
M	Base Line Average Torque (HITQ)
N	Base Line Average Torque (HOTQ)
P	Base Line Unit Range (RNG)
Q	Unit Range (RNG)
R	Base Line Indicated Airspeed (RNG)
T	Base Line Time (END)
U	Base Line Torque (SE/EV)

TABLE III
Flag Definitions

FLAG	DEFINITIONS
01	Pre Flt program in execution
02	Do not display register contents
03	Recalculate endurance for new weight (END)
21	Print a hard copy of results

A. MASTER PROGRAM (MAIN)

1. Equations- This program serves as the software manager and does not contain equations in itself.
2. Flowchart- See Figure B.1.
3. Program listing- See pages 31-32.

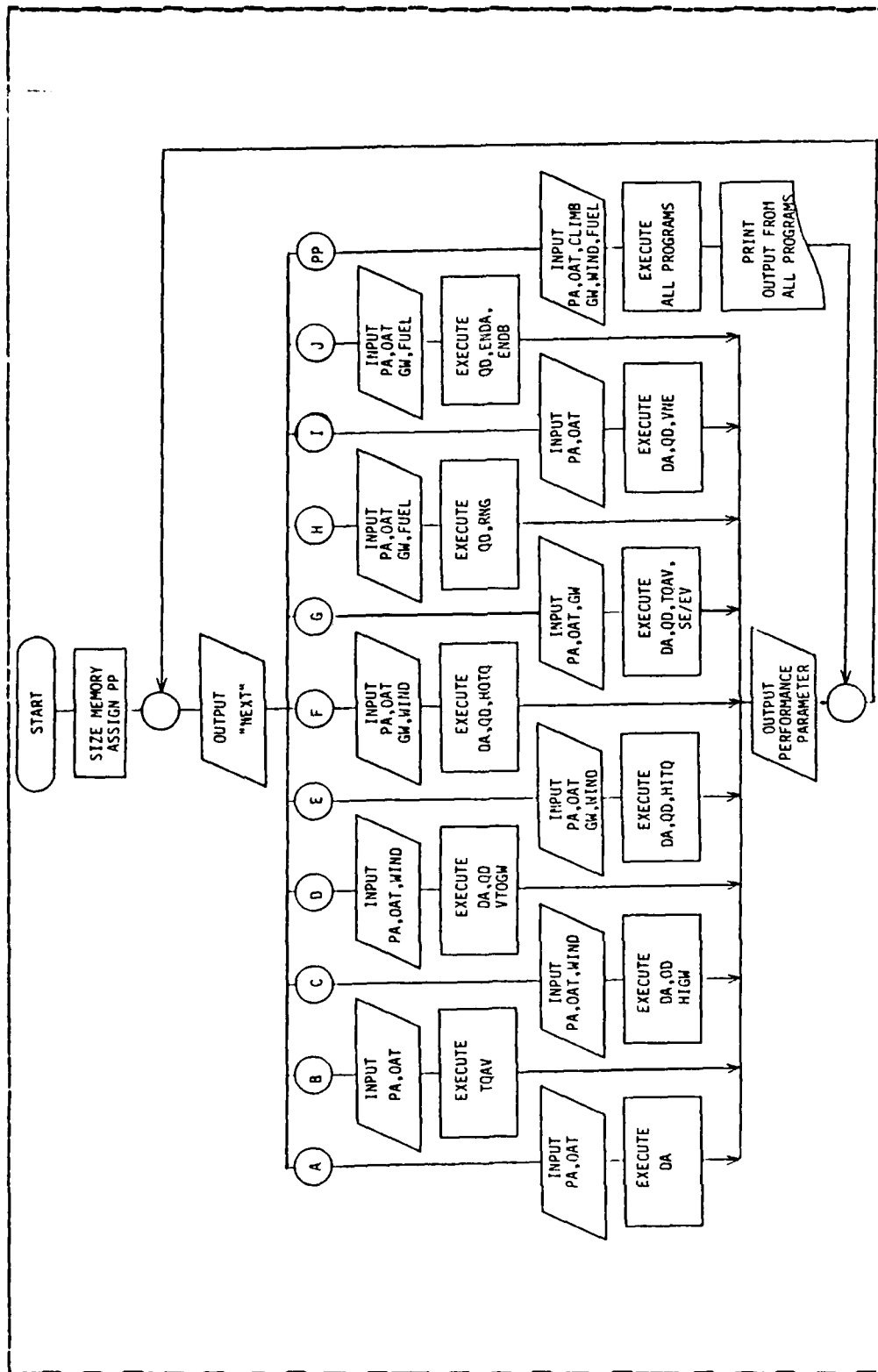


Figure B.1 MAIN Flowchart

01*LBL "MAIN"
 02 32
 03 PSIZE
 04 41
 05 "PP"
 06 PASN
 07*LBL 13
 08 ADV
 09 ADV
 10 FIX 0
 11 "NEXT"
 12 PROMPT
 13*LBL A
 14 XEQ 06
 15 XEQ "DA"
 16 ADV
 17 PROMPT
 18 GTO 13
 19*LBL B
 20 XEQ 06
 21 XEQ "TOAV"
 22 PROMPT
 23 GTO 13
 24*LBL C
 25 XEQ 08
 26 "HIGH"
 27 GETP
 28 XEQ "HIGH"
 29 PROMPT
 30 GTO 13
 31*LBL D
 32 XEQ 08
 33 "VTOGW"
 34 GETP
 35 XEQ "VTOGW"
 36 PROMPT
 37 GTO 13
 38*LBL E
 39 XEQ 10
 40 "HITQ"
 41 GETP
 42 XEQ "HITQ"
 43 PROMPT
 44 GTO 13
 45*LBL F
 46 XEQ 10
 47 "HOTO"
 48 GETP
 49 XEQ "HOTO"
 50 PROMPT

51 GTO 13
 52*LBL G
 53 XEQ 09
 54 XEQ "TOAV"
 55 "SE/EV"
 56 GETP
 57 XEQ "SE/EV"
 58 PROMPT
 59 GTO 13
 60*LBL H
 61 XEQ 07
 62 XEQ 11
 63 "PNG"
 64 GETP
 65 XEQ "RNG"
 66 PROMPT
 67 GTO 13
 68*LBL I
 69 XEQ 09
 70 "VNE"
 71 GETP
 72 XEQ "VNE"
 73 PROMPT
 74 GTO 13
 75*LBL J
 76 XEQ 07
 77 XEQ 11
 78 "ENDA"
 79 GETP
 80 XEQ "ENDA"
 81 PROMPT
 82 "ENDB"
 83 GETP
 84 XEQ "ENDB"
 85 PROMPT
 86 GTO 13
 87*LBL PP
 88 FS 21
 89 GTO 14
 90 "FTR REQ"
 91 PROMPT
 92 GTO 13
 93*LBL 14
 94 SF 01
 95 XEQ 10
 96 "CLINE" FRM
 97 PROMPT
 98 10
 99 /
 100 GTO 21

101 XEQ 11
 102 RCL 12
 103 1000
 104 *
 105 "DA=" "
 106 ARCL X
 107 ADV
 108 PPA
 109 XEQ "TOAV"
 110 PPA
 111 "HIGH"
 112 GETP
 113 XEQ "HIGH"
 114 PPA
 115 "VTOGW"
 116 GETP
 117 XEQ "VTOGW"
 118 PPA
 119 "HITO"
 120 GETP
 121 XEQ "HITO"
 122 PPA
 123 "HOTO"
 124 GETP
 125 XEQ "HOTO"
 126 PPA
 127 "SE/EV"
 128 GETP
 129 XEQ "SE/EV"
 130 PPA
 131 "PNG"
 132 GETP
 133 XEQ "RNG"
 134 PPA
 135 "VNE"
 136 GETP
 137 XEQ "VNE"
 138 PPA
 139 "ENDA"
 140 GETP
 141 XEQ "ENDA"
 142 PPA
 143 "ENDB"
 144 GETP
 145 XEQ "ENDB"
 146 PPA
 147 CF 01
 148 GTO 13
 149*LBL 06
 150 XEQ 01

151 XEQ 02
 152 RTN
 153*LBL 07
 154 XEQ 06
 155 XEQ 03
 156 RTN
 157*LBL 08
 158 SF 02
 159 XEQ 06
 160 XEQ 05
 161 XEQ "DA"
 162 CF 02
 163 RTN
 164*LBL 09
 165 SF 02
 166 FS? 01
 167 CF 02
 168 XEQ 07
 169 XEQ "DA"
 170 XEQ 04
 171 CF 02
 172 RTN
 173*LBL 10
 174 XEQ 09
 175 XEQ 05
 176 RTN
 177*LBL 01
 178 "PA? FT"
 179 PROMPT
 180 1000
 181 /
 182 STO 00
 183 01.003
 184 XEQ "QD"
 185 RTN
 186*LBL 02
 187 "OAT? C"
 188 PROMPT
 189 STO 04
 190 05.007
 191 XEQ "QD"
 192 RTN
 193*LBL 03
 194 "GW? LBS"
 195 PROMPT
 196 1000
 197 /
 198 STO 08
 199 09.011
 200 XEQ "QD"

201 RTN
 202*LBL 04
 203 RCL 12
 204 13.015
 205 XEQ "QD"
 206 RTN
 207*LBL 05
 208 "WIND? KTS"
 209 PROMPT
 210 STO 16
 211 17.019
 212 XEQ "QD"
 213 RTN
 214*LBL 11
 215 "FUEL? LBS"
 216 PROMPT
 217 100
 218 /
 219 STO 20
 220 END

01*LBL "QD"
 02 STO T
 03 XQV
 04 ENTER↑
 05 ENTER↑
 06 X12
 07*LBL 12
 08 STO IND T
 09 *
 10 ISG T
 11 GTQ 12
 12 END

B. DENSITY ALTITUDE (DA)

1. Equations- $DA = (1 - a \cdot 234711) / 6.863 \times 10^{-3}$
where $a = b/c$
and $b = [1 - 6.863 \times 10^{-3} (A)]^{5.260559}$
and $c = (273.15 + B) / 288.15$

2. Flowchart- See Figure B.2.

3. Program listing- See page 35.

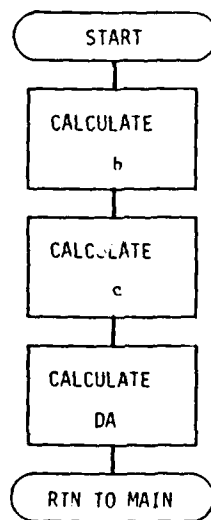


Figure B.2 DA Flowchart

```

01 *LBL "D9"
02 RCL 00
03 6.863 E-7
04 *
05 CHS
06 1
07 +
08 5.280559
09 Y↑X
10 RCL 04
11 273.15
12 +
13 288.15
14 /
15 /
16 .234711
17 Y↑X
18 CHS
19 1
20 +
21 6.863 E-7
22 /
23 STD 12
24 FST 02
25 RTN
26 1000
27 *
28 "D9="
29 ACCL X
30 END

```

C. ENGINE PERFORMANCE (TQAV)

1. Equation/Fit statistics-

Regression equation- For Figure 11-1A
chart [Ref. 4 p. 11-5].

$R^2 = .99936$

Standard error of estimate = .539449 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	104.758
A	-3.56893
B	-.394746
A ⁴ B ²	-.171715X10 ⁻⁷
A ²	.0324431
A ² B	-.000340744
A ² B ²	.0000147638
A ² B ³	.144471X10 ⁻⁶
AB	.0107422
AB ⁴	-.346277X10 ⁻⁷
B ²	-.00809738
B ³	-.0000582075
B ⁴	.189613X10 ⁻⁵

2. Flowchart- See Figure B.3.

3. Program listing- See page 38.

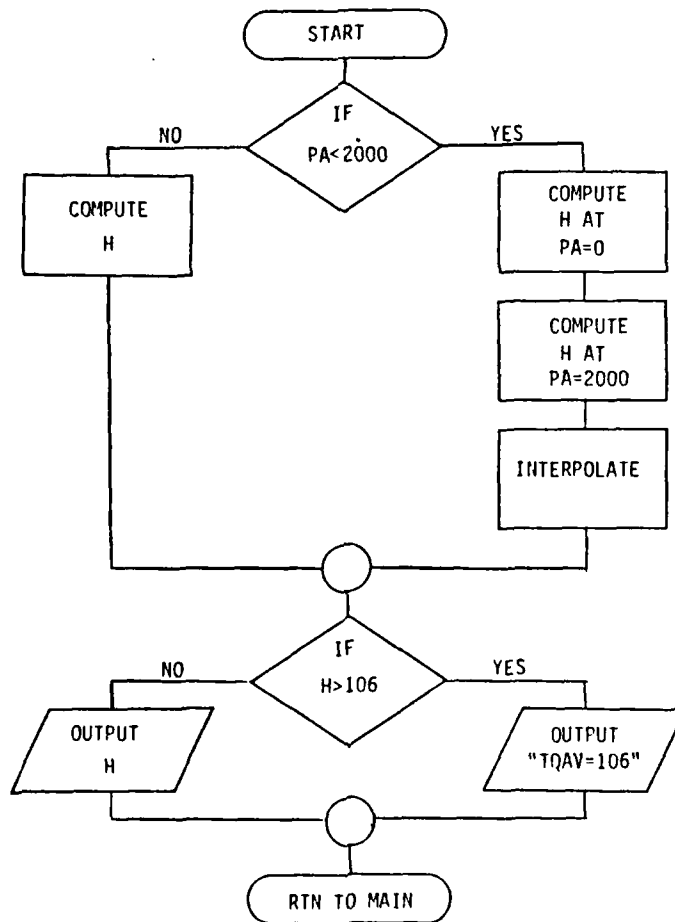


Figure B.3 TQAV Flowchart

01*LBL "TQAV"
 02 RCL 00
 03 STO 05
 04 2.0
 05 X²
 06 GT0 05
 07 XEQ 01
 08 GT0 10
 09*LBL 05
 10 -5.0
 11 RCL 04
 12 X=Y?
 13 GT0 02
 14 15.0
 15 RCL 04
 16 X=Y?
 17 GT0 03
 18 60
 19 +
 20 -.0625
 21 *
 22 162.6875
 23 +
 24 STO 23
 25 GT0 07
 26*LBL 03
 27 60
 28 +
 29 -.4
 30 *
 31 128
 32 +
 33 STO 23
 34 GT0 07
 35*LBL 02
 36 106.0
 37 STO 23
 38*LBL 07
 39 2.0
 40 STO 00
 41 X12
 42 STO 01
 43 X12
 44 STO 03
 45 XEQ 01
 46 STO 24
 47 CHS
 48 RCL 23
 49 +
 50 RCL 25

51 2.0
 52 /
 53 CHS
 54 *
 55 RCL 23
 56 +
 57*LBL 10
 58 106.0
 59 X12Y
 60 X12Y
 61 GT0 11
 62 10
 63 /
 64 STO 22
 65 FST 02
 66 RTN
 67 10
 68 *
 69 "TQAV="
 70 ARCL X
 71 ADV
 72 RTN
 73*LBL 11
 74 10.6
 75 STO 22
 76 FST 02
 77 RTN
 78 "TQAV=106"
 79 ADV
 80 RTN
 81*LBL 01
 82 104.753
 83 RCL 00
 84 -3.56893
 85 *
 86 +
 87 RCL 04
 88 -.394746
 89 *
 90 +
 91 RCL 03
 92 RCL 05
 93 *
 94 -.171715 E-7
 95 *
 96 +
 97 RCL 01
 98 .0324431
 99 *
 100 +

101 RCL 01
 102 RCL 04
 103 *
 104 -.00034074
 105 *
 106 +
 107 RCL 01
 108 RCL 05
 109 *
 110 .147638 E-4
 111 *
 112 +
 113 RCL 01
 114 RCL 06
 115 *
 116 .144471 E-6
 117 *
 118 +
 119 RCL 00
 120 RCL 04
 121 *
 122 .0107422
 123 *
 124 +
 125 RCL 00
 126 RCL 07
 127 *
 128 -.346277 E-7
 129 *
 130 +
 131 RCL 05
 132 -.00009738
 133 *
 134 +
 135 RCL 06
 136 -.583075 E-4
 137 *
 138 +
 139 RCL 07
 140 .189613 E-5
 141 *
 142 +
 143 END

D. MAX GROSS WEIGHT FOR HOVERING (HIGH)

1. Equation/Fit statistics-

Regression equation- For Figure 11-4
top chart [Ref. 4 p. 11-9].

$R^2 = .99888$

Standard error of estimate = 128.142 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	28.8369
B	-.104947
A	-.957611
B ⁴	.236917X10 ⁻⁶
AB ⁴	.738596X10 ⁻⁷
A ² B ⁴	-.108756X10 ⁻⁷
A ³ B ⁴	.547916X10 ⁻⁹
AB ³	-.231012X10 ⁻⁵
A ² B ³	.167621X10 ⁻⁶
B ²	-.00209967
A ² B ²	.000015347
A ³ B ²	-.108395X10 ⁻⁵
A ² B	.000201287
A ⁴ B	-.852947X10 ⁻⁶
A ²	.00815863

Regression equation- For Figure 11-4
bottom chart [Ref. 4 p. 11-9].

$R^2 = .99993$

Standard error of estimate = 19.776 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	.128617
J	.990746
E ² J	.000043718
EJ	.00283739
J ⁴	.3069X10 ⁻⁶

2. Flowchart- See Figure B.4.

3. Program listing- See page 41.

H. MAXIMUM RANGE (RNG)

1. Equations/Fit statistics-

Regression equation- For Figure 11-13
bottom right [Ref. 4 p. 11-22].

$$R^2 = .99773$$

Standard error of estimate = .000884 nm/lb fuel.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	.1383
A	.00187702
C	-.00218126
A ³	-.000027957
AC ³	-.62102X10 ⁻⁷
A ⁴ C ⁶	.930331X10 ⁻¹⁴
A ⁶ C ²	-.300259X10 ⁻¹⁰
A ⁵ C	.106168X10 ⁻⁷
A ³ C ⁶	-.279396X10 ⁻¹²
A ²	.000307637

Regression equation- For Figure 11-13
bottom left [Ref. 4 p. 11-22].

$$R^2 = .99995$$

Standard error of estimate = .000166 nm/lb fuel.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-.423343X10 ⁻⁴
P	1.00044
B	-.403071X10 ⁻⁴
P ⁴ B	.277347
P ⁴ B ⁴	-.49131X10 ⁻⁵
P ³ B	-.0402217
P ³ B ⁴	.80486X10 ⁻⁶
B ⁴	-.421314X10 ⁻⁹

Regression equation- For Figure 11-14
chart [Ref. 4 p. 11-23].

$$R^2 = .99991$$

Standard error of estimate = 1.045573 nm.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	.459586
F	.227375
FQ	99.6167

01*LBL "HOTO"	51 STO 23
02 23	52 X12
03 RCL 08	53 STO 24
04 X<=Y?	54 -.0523486
05 GT0 03	55 RCL 16
06 "GM>23.000"	56 -.30622
07 ADV	57 *
08 RTN	58 +
09*LBL 03	59 RCL 23
10 15.0892	60 1.00117
11 RCL 12	61 *
12 .100012	62 +
13 *	63 RCL 19
14 +	64 RCL 24
15 RCL 11	65 *
16 RCL 12	66 -.43441 E-9
17 *	67 *
18 .18747 E-5	68 +
19 *	69 RCL 16
20 +	70 RCL 24
21 RCL 11	71 *
22 RCL 15	72 -.266181 E-4
23 *	73 *
24 -.520378 E-8	74 +
25 *	75 "H0GE T0="
26 +	76 APCL X
27 RCL 10	77 ADV
28 -.0035362	78 .END.
29 *	
30 +	
31 RCL 10	
32 RCL 15	
33 *	
34 .123336 E-6	
35 *	
36 +	
37 RCL 03	
38 .226524	
39 *	
40 +	
41 RCL 08	
42 RCL 13	
43 *	
44 .00162427	
45 *	
46 +	
47 RCL 14	
48 -.00265822	
49 *	
50 +	

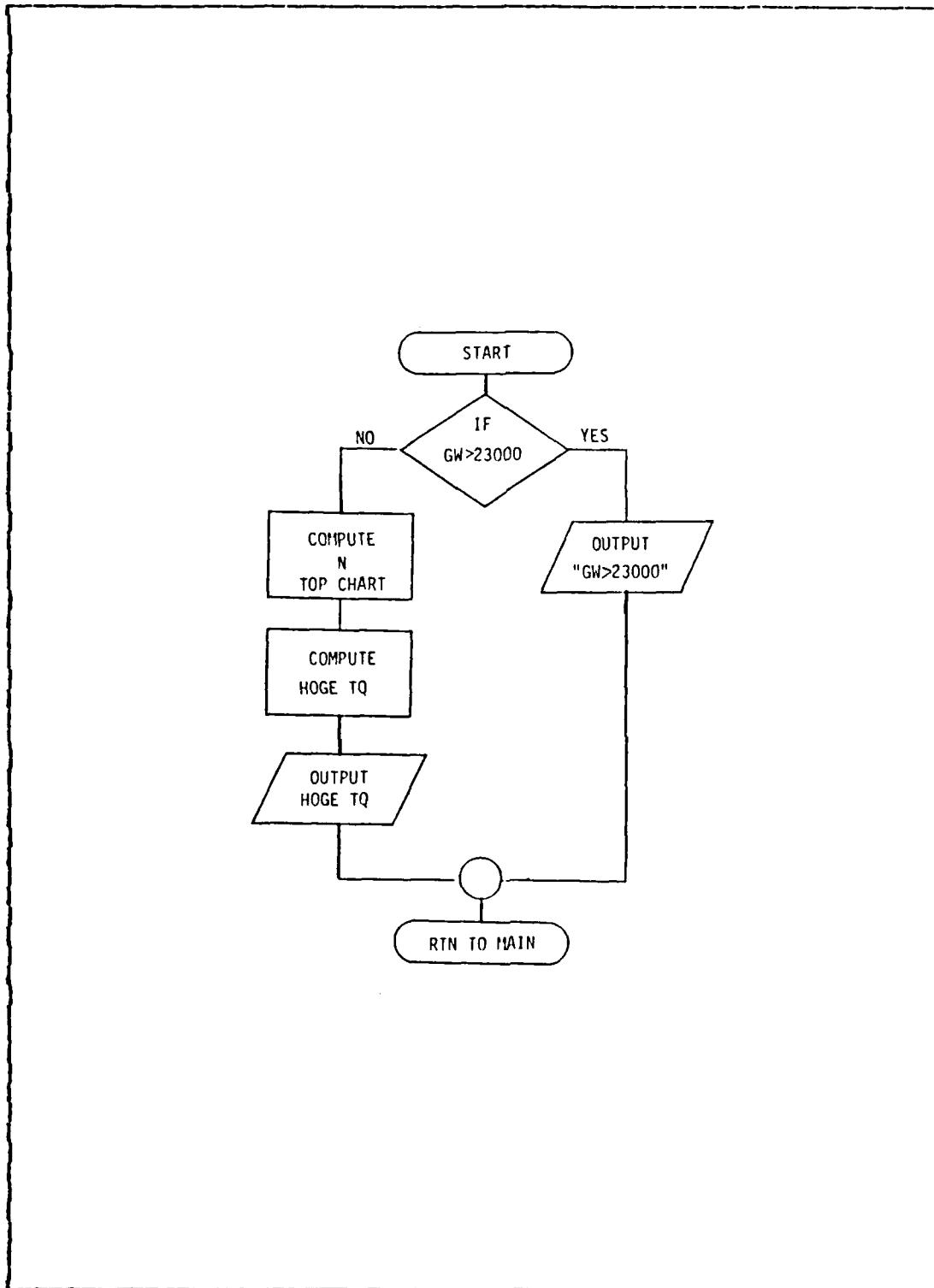


Figure B.7 HOTQ Flowchart

G. TORQUE REQUIRED TO HOVER OUT OF GROUND EFFECT (HOTQ)

1. Equations/Fit statistics-

Regression equation- For Figure 11-7
top chart [Ref. 4 p. 11-13].

$$R^2 = .99987$$

Standard error of estimate = .215589 % tq.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	15.0892
D	.108012
C ⁴ D	.18747X10 ⁻⁵
C ⁴ D ⁴	-.520378X10 ⁻⁸
C ³	-.00353622
C ³ D ⁴	.123336X10 ⁻⁶
C ²	.226524
CD ²	.00162427
D ³	-.00265822

Regression equation- For Figure 11-7
bottom chart [Ref. 4 p. 11-13].

$$R^2 = .99978$$

Standard error of estimate = .292877 % tq.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-.0523486
E	-.30622
N	1.00117
E ⁴ N ²	-.434411X10 ⁻⁹
EN ²	-.266181X10 ⁻⁴

2. Flowchart- See Figure B.7.

3. Program listing- See page 52.

01*LBL "HIT0"	51 *
02 23	52 +
03 RCL 08	53 RCL 19
04 X<=Y?	54 RCL 24
05 GT0 03	55 *
06 *GM>23.000*	56 .100327 E-9
07 ADV	57 *
08 RTN	58 +
09*LBL 03	59 RCL 17
10 -1.4252	60 -.00292623
11 RCL 08	61 *
12 3.17576	62 +
13 *	63 RCL 16
14 +	64 RCL 23
15 RCL 11	65 *
16 .2945 E-4	66 -.0296401
17 *	67 *
18 +	68 +
19 RCL 11	69 RCL 16
20 RCL 17	70 RCL 24
21 *	71 *
22 .862219 E-7	72 .000268967
23 *	73 *
24 +	74 +
25 RCL 10	75 RCL 16
26 RCL 12	76 RCL 25
27 *	77 *
28 .431755 E-4	78 -.647012 E-2
29 *	79 *
30 +	80 +
31 RCL 14	81 "HIGE T0="
32 .000620298	82 APCL X
33 *	83 ADV
34 +	84 .END.
35 ST0 23	
36 X+2	
37 ST0 24	
38 X+2	
39 ST0 25	
40 -.037637	
41 RCL 16	
42 .694891	
43 *	
44 +	
45 RCL 23	
46 1.00055	
47 *	
48 +	
49 RCL 19	
50 -.163135 E-5	

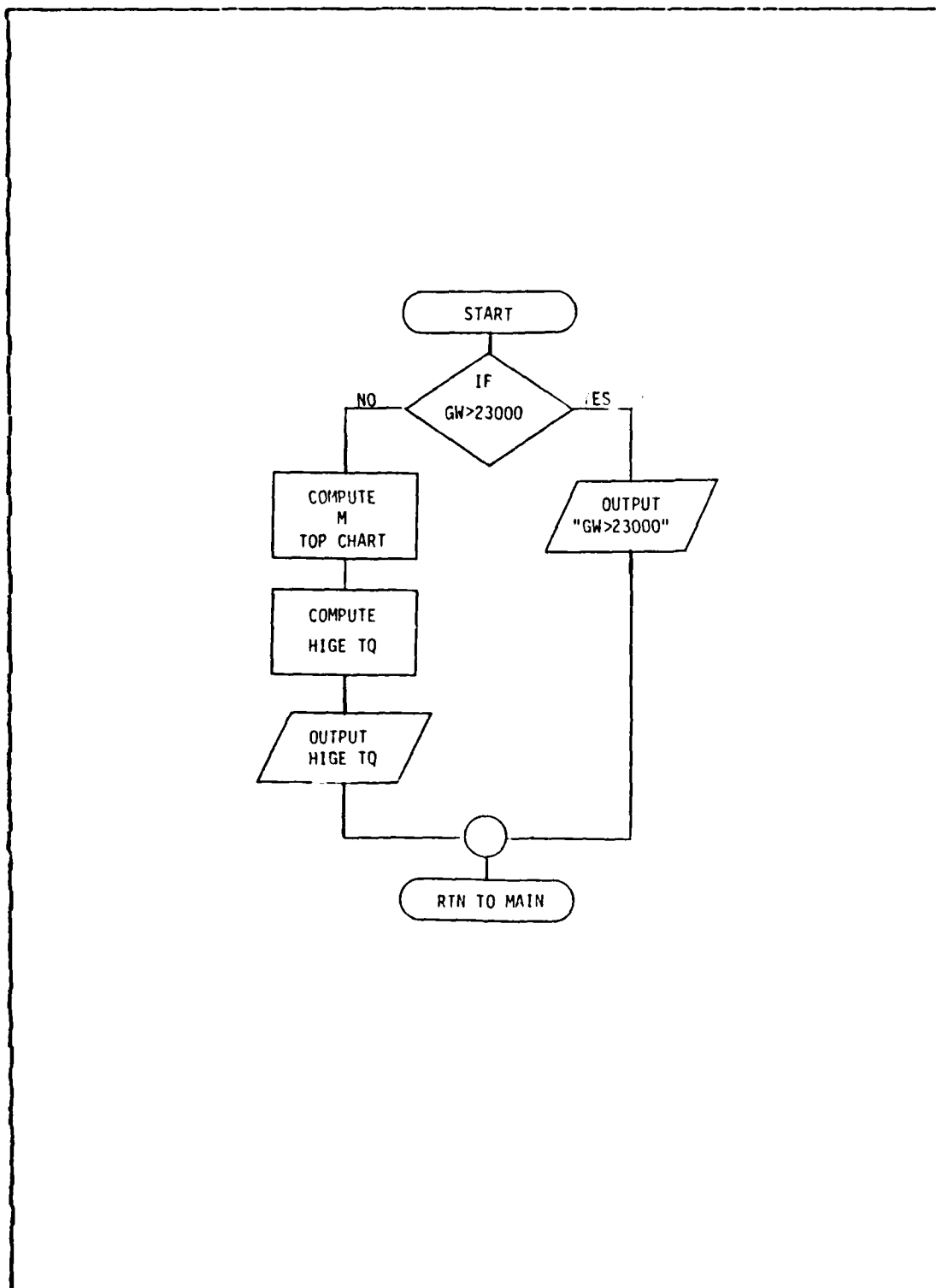


Figure B.6 HITQ Flowchart

F. TORQUE REQUIRED TO HOVER IN GROUND EFFECT (HITQ)

1. Equations/Fit statistics-

Regression equation- For Figure 11-6
top chart [Ref. 4 p. 11-12].

$$R^2 = .99941$$

Standard error of estimate = .445612 % tq.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-1.4252
C	3.17576
C ⁴	.29445X10 ⁻⁴
C ⁴ D ²	.862219X10 ⁻⁷
C ³ D	.431755X10 ⁻⁴
D ³	.000628288

Regression equation- For Figure 11-6
bottom chart [Ref. 4 p. 11-12].

$$R^2 = .99997$$

Standard error of estimate = .123506 % tq.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-.0376377
E	.694891
M	1.00055
E ⁴	-.163135X10 ⁻⁵
E ⁴ M ²	.100327X10 ⁻⁹
E ²	-.00298623
EM	-.0296401
EM ²	.000268863
EM ⁴	-.647012X10 ⁻⁸

2. Flowchart- See Figure B.6.

3. Program listing- See page 49.

151 +	201 *
152 RCL 18	202 -.0018941
153 -.164715 E-4	203 *
154 *	204 +
155 +	205 RCL 21
156 RCL 17	206 RCL 25
157 RCL 24	207 *
158 *	208 .425897 E-5
159 .00038988	209 *
160 *	210 +
161 +	211 RCL 21
162 RCL 17	212 RCL 26
163 RCL 25	213 *
164 *	214 -.146897 E-6
165 -.250156 E-4	215 *
166 *	216 +
167 +	217 23.0
168 RCL 17	218 X<=Y?
169 RCL 26	219 GT0 04
170 *	220 X<>Y
171 .234975 E-7	221 1000
172 *	222 *
173 +	223 "VTO GW="
174 RCL 16	224 ARCL X
175 RCL 24	225 ADV
176 *	226 RTN
177 .0103111	227 *LBL 04
178 *	228 "VTO GW=23.000"
179 +	229 ADV
180 RCL 16	230 .END.
181 RCL 26	
182 *	
183 -.220855 E-6	
184 *	
185 +	
186 STO 24	
187 ENTER↑	
188 ENTER↑	
189 X↑2	
190 *	
191 STO 25	
192 *	
193 STO 26	
194 .0278529	
195 RCL 24	
196 .993241	
197 *	
198 +	
199 RCL 21	
200 RCL 24	

01*LBL "VTQGW"
 02 FSP 01
 03 GTO 09
 04 "CLIMB? FPM"
 05 PROMPT
 06 10
 07 /
 08 STO 21
 09*LBL 09
 10 RCL 12
 11 14
 12 X>Y?
 13 GTO 01
 14 "NO VTO OGE"
 15 ADV
 16 PTN
 17*LBL 01
 18 3.72796
 19 RCL 04
 20 -.0954314
 21 *
 22 +
 23 RCL 05
 24 -.00188251
 25 *
 26 +
 27 RCL 06
 28 -.596998 E-4
 29 *
 30 +
 31 RCL 07
 32 -.609172 E-6
 33 *
 34 +
 35 STO 23
 36 RCL 00
 37 X<=Y?
 38 GTO 03
 39 26.1925
 40 RCL 04
 41 -.117656
 42 *
 43 +
 44 RCL 00
 45 -1.04142
 46 *
 47 +
 48 RCL 07
 49 .311223 E-6
 50 *

51 +
 52 RCL 07
 53 RCL 03
 54 *
 55 .876216 E-11
 56 *
 57 +
 58 RCL 06
 59 -.734593 E-5
 60 *
 61 +
 62 RCL 06
 63 RCL 03
 64 *
 65 .358246 E-9
 66 *
 67 +
 68 RCL 05
 69 -.00147462
 70 *
 71 +
 72 RCL 05
 73 RCL 00
 74 *
 75 .495106 E-4
 76 *
 77 +
 78 RCL 05
 79 RCL 01
 80 *
 81 -.451883 E-5
 82 *
 83 +
 84 RCL 04
 85 RCL 00
 86 *
 87 .0060469
 88 *
 89 +
 90 RCL 04
 91 RCL 01
 92 *
 93 -.000202418
 94 *
 95 +
 96 RCL 01
 97 .0268048
 98 *
 99 +
 100 RCL 02

101 -.00063067
 102 *
 103 +
 104 GTO 05
 105*LBL 02
 106 23.346
 107 RCL 04
 108 -.0155989
 109 *
 110 +
 111 RCL 00
 112 -.1987
 113 *
 114 +
 115 RCL 07
 116 -.219767 E-6
 117 *
 118 +
 119 RCL 07
 120 RCL 00
 121 *
 122 .389472 E-8
 123 *
 124 +
 125 RCL 06
 126 -.769256 E-5
 127 *
 128 +
 129 RCL 05
 130 .000147492
 131 *
 132 +
 133 RCL 01
 134 -.00129983
 135 *
 136 +
 137*LBL 05
 138 STO 24
 139 X12
 140 STO 25
 141 X+2
 142 STO 26
 143 .00553456
 144 RCL 16
 145 -.0756063
 146 *
 147 +
 148 RCL 24
 149 .999707
 150 *

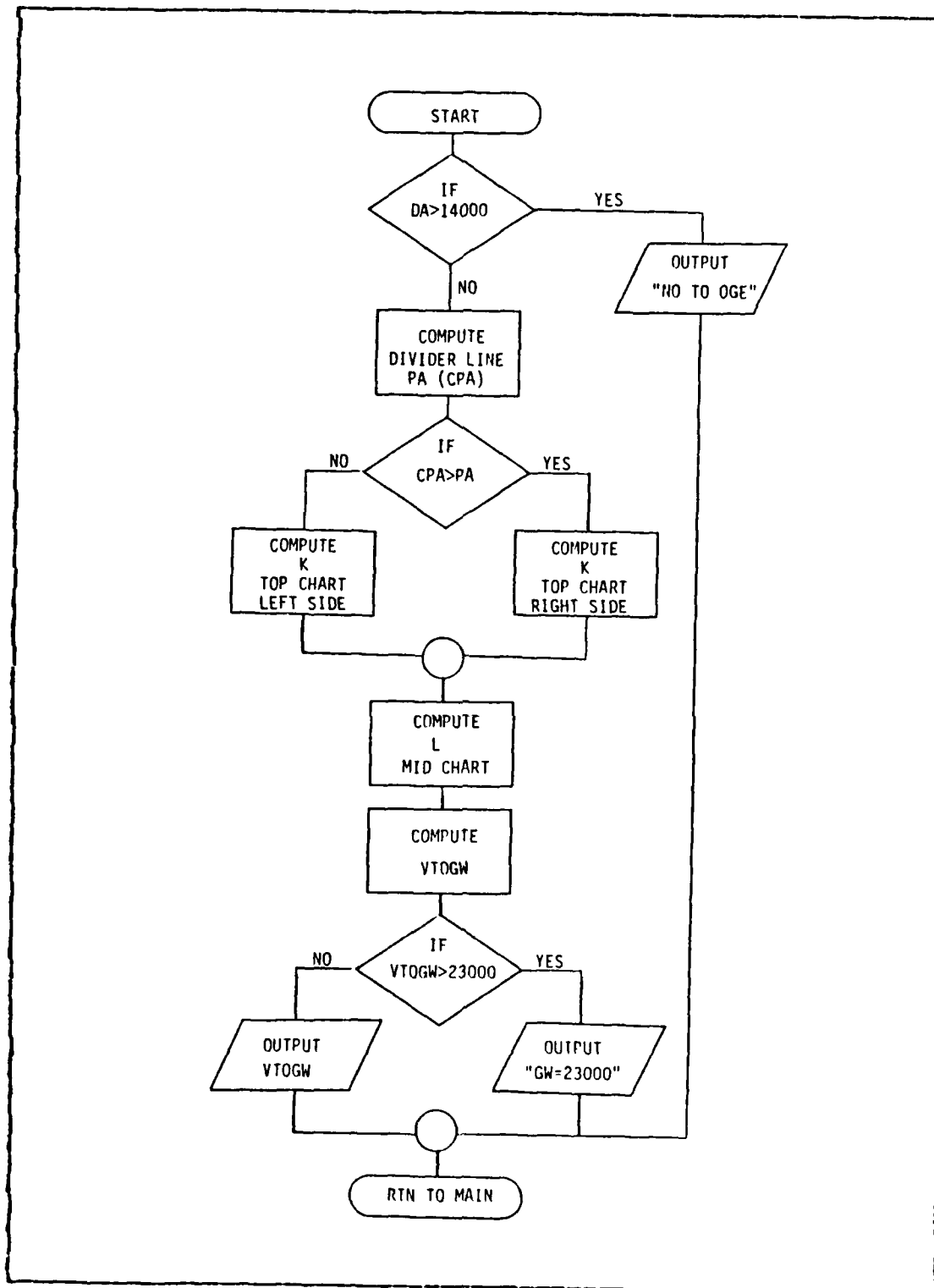


Figure B.5 VTOGW Flowchart

Regression equation- For Figure 11-5
middle chart [Ref. 4 p. 11-11].

$R^2 = .99996$

Standard error of estimate = 32.545 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	.00559456
E	-.0756063
K	.999707
E ³	-.164715X10 ⁻⁴
E ² K	.00038988
E ² K ²	-.250156X10 ⁻⁴
E ² K ⁴	.234975X10 ⁻⁷
EK	.0103111
EK ⁴	-.220855X10 ⁻⁶

Regression equation- For Figure 11-5
bottom chart [Ref. 4 p. 11-11].

$R^2 = .99996$

Standard error of estimate = 24.736 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	.0278589
L	.998241
GL	-.00189451
GL ³	.425897X10 ⁻⁵
GL ⁴	-.140897X10 ⁻⁶

2. Flowchart- See Figure B.5.

3. Program listing- See page 45-46.

E. MAX GROSS WEIGHT FOR VERTICAL TAKEOFF (VTOGW)

1. Equation/Fit statistics-

Regression equation- For Figure 11-5
top chart discontinuity
curve (CPA) [Ref. 4 p. 11-11].

$R^2 = .99923$

Standard error of estimate = 81.257 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	3.72796
B	-.0954314
B ²	-.00188251
B ³	-.0000596998
B ⁴	-.608172X10 ⁻⁶

Regression equation- For Figure 11-5
top chart left of
discontinuity [Ref. 4 p. 11-11].

$R^2 = .99919$

Standard error of estimate = 96.041 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	26.1925
B	-.117656
A	-1.04142
B ⁴	.311223X10 ⁻⁶
A ⁴ B ⁴	.876216X10 ⁻¹¹
B ³	-.734593X10 ⁻⁵
A ⁴ B ³	.358246X10 ⁻⁹
B ²	-.00147462
AB ²	.0000495106
A ² B ²	-.451883X10 ⁻⁵
AB	.0060469
A ² B	-.000282418
A ²	.0268048
A ³	-.000633067

Regression equation- For Figure 11-5
top chart right of
discontinuity [Ref. 4 p. 11-11].

$R^2 = .99944$

Standard error of estimate = 12.521 lbs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	23.346
B	-.0155989
A	-.1907
B ⁴	-.219767X10 ⁻⁶
AB ⁴	.389472X10 ⁻⁸
B ³	-.769256X10 ⁻⁵
B ²	.000147492
A ²	-.00128983

01*LBL "HIGH"
 02 RCL 12
 03 14
 04 X*Y?
 05 GT0 01
 06 "NO HIGH"
 07 ADV
 08 RTN
 09*LBL 01
 10 28.8369
 11 RCL 04
 12 -.164947
 13 *
 14 +
 15 RCL 00
 16 -.957611
 17 *
 18 +
 19 RCL 07
 20 .236917 E-6
 21 *
 22 +
 23 RCL 07
 24 RCL 00
 25 *
 26 .738596 E-7
 27 *
 28 +
 29 RCL 07
 30 RCL 01
 31 *
 32 -.100756 E-7
 33 *
 34 +
 35 RCL 07
 36 RCL 02
 37 *
 38 .547916 E-9
 39 *
 40 +
 41 RCL 06
 42 RCL 00
 43 *
 44 -.231012 E-5
 45 *
 46 +
 47 RCL 06
 48 RCL 01
 49 *
 50 .167621 E-6

51 *
 52 +
 53 RCL 05
 54 -.00209967
 55 *
 56 +
 57 RCL 05
 58 RCL 01
 59 *
 60 .15347 E-4
 61 *
 62 +
 63 RCL 05
 64 RCL 02
 65 *
 66 -.100395 E-5
 67 *
 68 +
 69 RCL 04
 70 RCL 01
 71 *
 72 .000201287
 73 *
 74 +
 75 RCL 04
 76 RCL 03
 77 *
 78 -.852947 E-6
 79 *
 80 +
 81 RCL 01
 82 .00015863
 83 *
 84 +
 85 STO 23
 86 .990746
 87 *
 88 .128617
 89 +
 90 RCL 17
 91 RCL 23
 92 *
 93 .43718 E-4
 94 *
 95 +
 96 RCL 16
 97 RCL 23
 98 *
 99 .00283739
 100 *

101 +
 102 RCL 23
 103 4
 104 V*W
 105 .3069 E-6
 106 *
 107 +
 108 23.0
 109 X*Y?
 110 GT0 03
 111 X*Y?
 112 1000
 113 *
 114 "HIGH"
 115 RCL X
 116 ADV
 117 RTN
 118*LBL 03
 119 "HIGH=23.000"
 120 ADV
 121 .END.

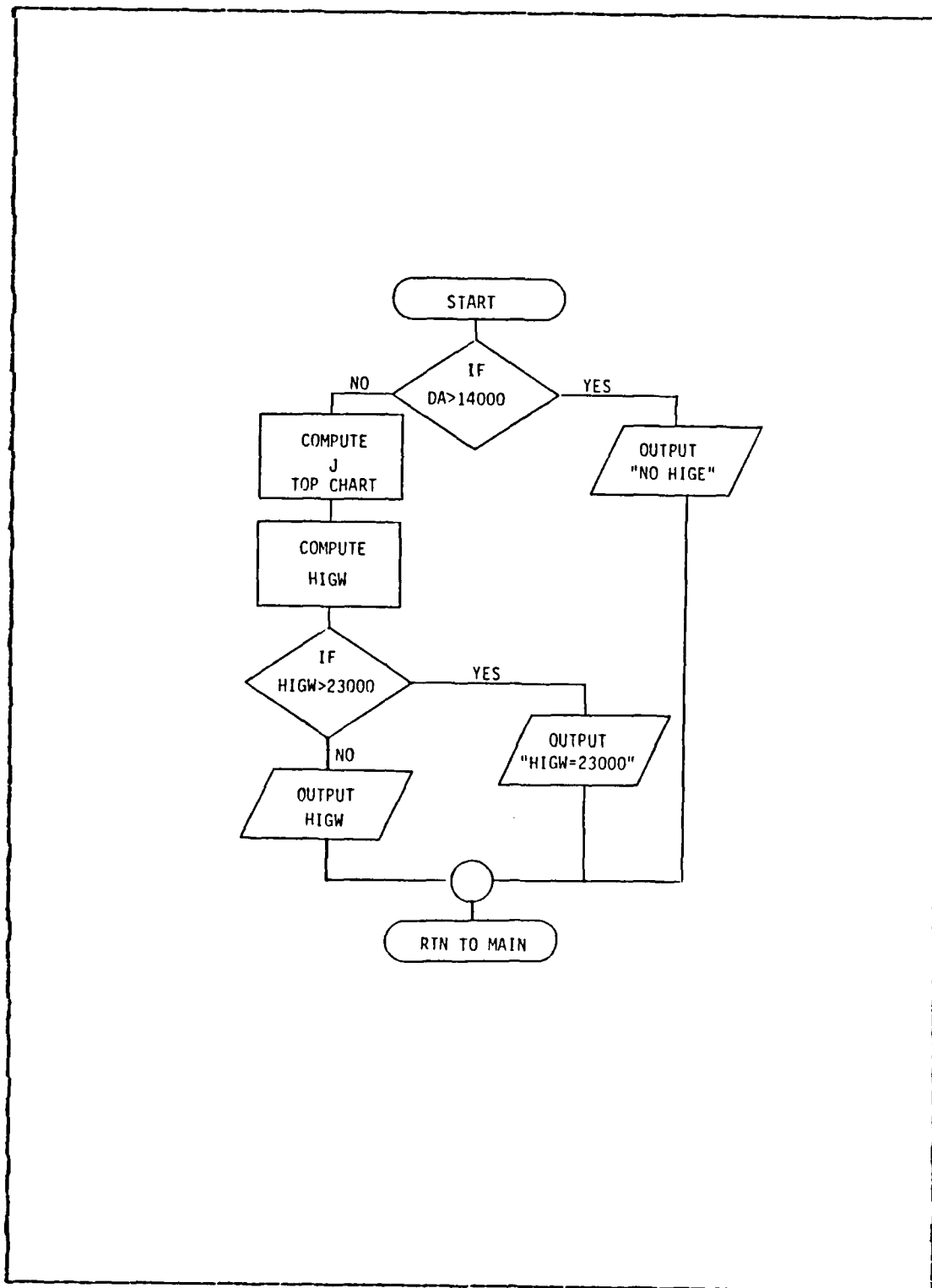


Figure B.4 HIGW Flowchart

Regression equation- For Figure 11-13
middle right [Ref. 4 p. 11-22].

$R^2 = .99676$

Standard error of estimate = .703488 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	116.811
A	-2.20562
A ³ C ²	.0000960635
A ³ C ⁴	-.128465X10 ⁻⁶
A ² C ³	-.0000375032
C ²	.0333256
A ⁶ C ⁵	-.121685X10 ⁻¹⁰
A ⁶ C ⁶	.491492X10 ⁻¹²
AC ⁵	.404972X10 ⁻⁵
AC ⁶	-.174029X10 ⁻⁶

Regression equation- For Figure 11-13
middle left [Ref. 4 p. 11-22].

$R^2 = .99839$

Standard error of estimate = .870905 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	51.8923
B	-3.6787
R ⁴	-.403206X10 ⁻⁶
R ⁴ B	-.261757X10 ⁻⁸
R ⁴ B ³	-.286464X10 ⁻¹²
R ³	.0000882727
R ² B ²	-.165604X10 ⁻⁵
RB	.0330258
RB ²	.00045386
B ²	-.0356287

2. Flowchart- See Figure B.8.

3. Program listing- See pages 56-57.

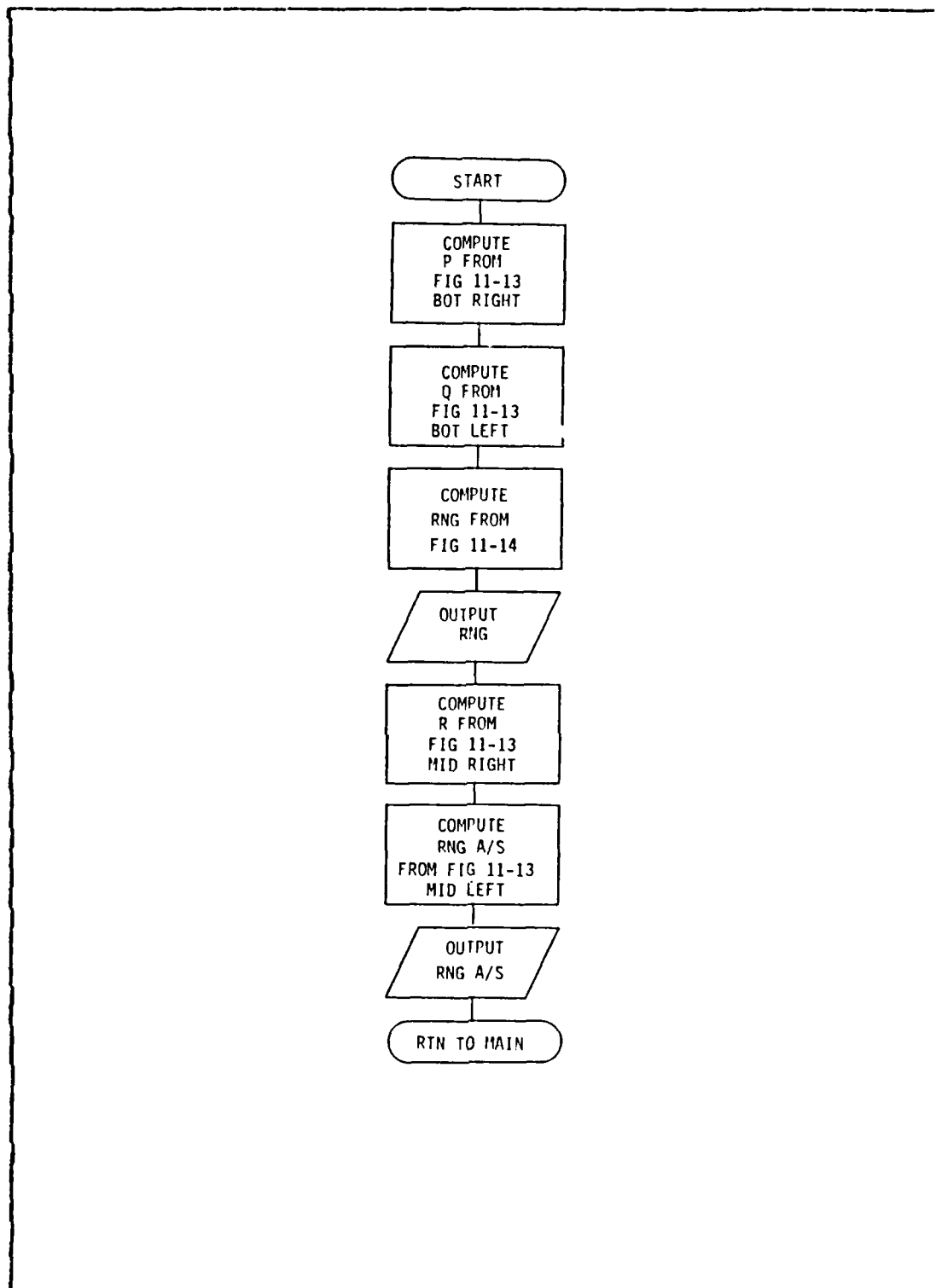


Figure B.8 RNG Flowchart

01*LBL "RNG"
 02*LBL 01
 03 RCL 02
 04 X+2
 05 STO 23
 06 RCL 10
 07 X+2
 08 STO 24
 09 .1383
 10 RCL 00
 11 .00187702
 12 *
 13 +
 14 RCL 08
 15 -.00218126
 16 *
 17 +
 18 RCL 02
 19 -.27957 E-4
 20 *
 21 +
 22 RCL 06
 23 RCL 10
 24 *
 25 -.62102 E-7
 26 *
 27 +
 28 RCL 03
 29 RCL 24
 30 *
 31 .930331 E-14
 32 *
 33 +
 34 RCL 23
 35 RCL 09
 36 *
 37 -.300259 E-10
 38 *
 39 +
 40 RCL 00
 41 5
 42 Y+X
 43 RCL 08
 44 *
 45 .106168 E-7
 46 *
 47 +
 48 RCL 02
 49 RCL 24
 50 *

51 -.279396 E-12
 52 *
 53 +
 54 RCL 01
 55 .000307673
 56 *
 57 +
 58 STO 25
 59 26.028
 60 XEQ "RD"
 61 -.423343 E-4
 62 RCL 25
 63 1.00044
 64 *
 65 +
 66 RCL 04
 67 -.403071 E-4
 68 *
 69 +
 70 RCL 28
 71 RCL 04
 72 *
 73 .277347
 74 *
 75 +
 76 RCL 28
 77 RCL 07
 78 *
 79 -.49131 E-5
 80 *
 81 +
 82 RCL 27
 83 RCL 04
 84 *
 85 -.0402217
 86 *
 87 +
 88 RCL 27
 89 RCL 07
 90 *
 91 .00486 E-6
 92 *
 93 +
 94 RCL 07
 95 -.421314 E-9
 96 *
 97 +
 98 RCL 20
 99 *
 100 99.6167

101 *
 102 .459506
 103 +
 104 RCL 20
 105 .227375
 106 *
 107 +
 108 "MAX RNG="

109 APRCL X
 110 FS? 01
 111 GTO 03
 112 ADV
 113 PROMPT
 114 GTO 04
 115*LBL 03
 116 ADV
 117 PRP
 118*LBL 04
 119 116.011
 120 RCL 00
 121 -2.20562
 122 *
 123 +
 124 RCL 02
 125 RCL 09
 126 *
 127 .950635 E-4
 128 *
 129 +
 130 RCL 02
 131 RCL 11
 132 *
 133 -.128465 E-6
 134 *
 135 +
 136 RCL 01
 137 RCL 10
 138 *
 139 -.375032 E-4
 140 *
 141 +
 142 RCL 09
 143 .0333256
 144 *
 145 +
 146 RCL 23
 147 RCL 08
 148 5
 149 Y+X
 150 *

151 -.121695 E-10	201 +
152 *	202 RCL 26
153 +	203 RCL 05
154 RCL 23	204 *
155 RCL 24	205 -.165604 E-5
156 *	206 *
157 .491492 E-12	207 +
158 *	208 RCL 04
159 +	209 RCL 25
160 RCL 00	210 *
161 RCL 08	211 .0330258
162 5	212 *
163 Y1X	213 +
164 *	214 RCL 25
165 .404972 E-5	215 RCL 05
166 *	216 *
167 +	217 .00045386
168 RCL 00	218 *
169 RCL 24	219 +
170 *	220 RCL 05
171 -.174029 E-6	221 -.0356207
172 *	222 *
173 +	223 +
174 STO 25	224 "RNG A/S="
175 26.028	225 ARCL X
176 XEQ "00"	226 ADV
177 51.8923	227 .END.
178 RCL 04	
179 -3.6787	
180 *	
181 +	
182 RCL 28	
183 -.403206 E-6	
184 *	
185 +	
186 RCL 28	
187 RCL 04	
188 *	
189 -.261757 E-8	
190 *	
191 +	
192 RCL 28	
193 RCL 06	
194 *	
195 -.286464 E-12	
196 *	
197 +	
198 RCL 27	
199 .882727 E-4	
200 *	

I. MAXIMUM LEVEL FLIGHT ENDURANCE (END)

1. Equations/Fit statistics-

Regression equation- For Figure 11-21
bottom chart [Ref. 4 p. 11-32].

$R^2 = .97211$

Standard error of estimate = .988268 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-563.098
I	2.74663
C	94.3518
A	48.7049
C ²	-4.6753
A ²	-.6005
C ³	.077392
AC	-4.49562
A ² C ²	.00153818
C ³ A	.00927324
C ³ A ³	.769943X10 ⁻⁵
I ³ A	.0000905311
IA ²	.0262874
A ² I ³	-.0000161533
A ³ I ³	.191249X10 ⁻⁵
IC	-.188195
ICA ³	.0000604516
ICA ²	-.00373104
C ³ IA ²	.0000123564
IC ² A	-.00230188
C ³ IA	.000205707
I ⁴ C ³ A ³	.101077X10 ⁻¹⁰
I ⁴ CA	-.102061X10 ⁻⁶
C ⁴ A ³ I ³	-.233492X10 ⁻¹⁰
C ⁴ AI	-.476391X10 ⁻⁵
I ⁴ C	.440832X10 ⁻⁶
C ⁴ I	.550886X10 ⁻⁵
C ⁴ A	-.000212041
AC ² I ⁴	.144642X10 ⁻⁸
A ² C ⁴ I ³	.45315X10 ⁻¹⁰
A ² C ⁴ I	-.285156X10 ⁻⁶
A ⁴ I ² C ³	.81415X10 ⁻¹⁰
A ⁴ I ² C ⁴	-.204801X10 ⁻¹⁰
I ⁴	-.782574X10 ⁻⁵
I ⁴ C ⁴	-.487904X10 ⁻¹¹
I ³ A ⁴	-.107731X10 ⁻⁶
C ⁴ A ⁴	.290421X10 ⁻⁹
C ⁴ A ³	-.364546X10 ⁻⁶
C ⁴ A ²	-.532767X10 ⁻⁷

Regression equation- For Figure 11-21
top chart [Ref. 4 p. 11-33].

$R^2 = .99959$

Standard error of estimate = .095246 hrs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-14.1228
A	-.540052
C	1.18957
A ² C ⁴	-.294347X10 ⁻⁷
AC	.0570829
AC ²	-.000939808
C ⁴	-.70554X10 ⁻⁵

Regression equation- For Figure 11-21
bottom chart [Ref. 4 p. 11-33].

$R^2 = .99998$

Standard error of estimate = .016675 hrs.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	-.00553605
T	1.00062
T ⁴ I ⁴	-.349348X10 ⁻¹¹
T ² I ²	.158075X10 ⁻⁵
TI	-.00117903
TI ²	-.216546X10 ⁻⁴
TI ⁴	.847453X10 ⁻⁸

2. Flowchart- See Figure B.9.

3. Program listing- See pages 61-63.

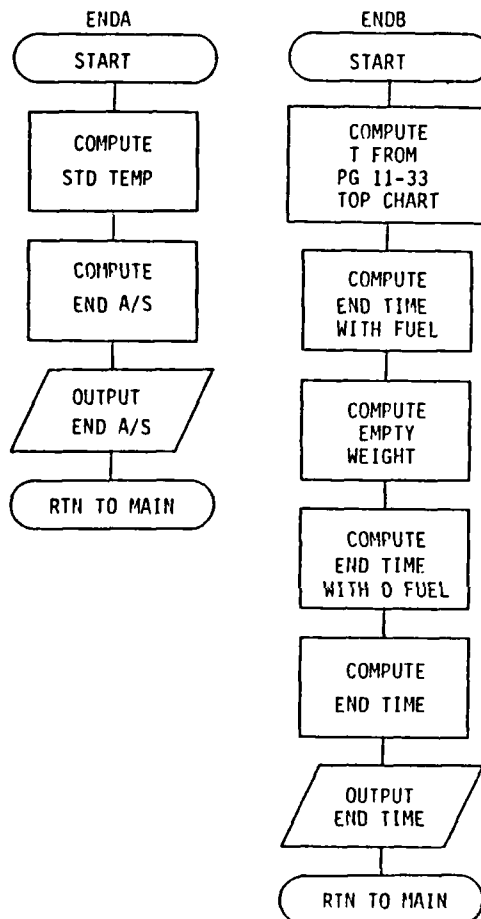


Figure B.9 END Flowcharts

01*LBL "ENDR"
 02 RCL 04
 03 15
 04 -
 05 RCL 06
 06 2
 07 *
 08 +
 09 STO 23
 10 STO 29
 11 24.026
 12 XEQ "0D"
 13 20
 14 RCL 23
 15 X<=Y?
 16 GTO 05
 17 4
 18 RCL 00
 19 X<=Y?
 20 GTO 05
 21 8.001
 22 X>Y?
 23 GTO 01
 24 GTO 02
 25*LBL 01
 26 20
 27 RCL 08
 28 X<=Y?
 29 GTO 05
 30*LBL 02
 31 "OFF CHART"
 32 ADV
 33 RTN
 34*LBL 05
 35 -563.098
 36 RCL 23
 37 2.74663
 38 *
 39 +
 40 RCL 08
 41 94.3518
 42 *
 43 +
 44 RCL 00
 45 48.7049
 46 *
 47 +
 48 RCL 09
 49 -4.6753
 50 *

51 +
 52 RCL 01
 53 -.6005
 54 *
 55 +
 56 RCL 10
 57 .077392
 58 *
 59 +
 60 RCL 00
 61 RCL 08
 62 *
 63 -4.49562
 64 *
 65 +
 66 RCL 01
 67 RCL 09
 68 *
 69 .00153818
 70 *
 71 +
 72 RCL 10
 73 RCL 00
 74 *
 75 .00927324
 76 *
 77 +
 78 RCL 10
 79 RCL 02
 80 *
 81 .769943 E-5
 82 *
 83 +
 84 RCL 25
 85 RCL 00
 86 *
 87 .905311 E-4
 88 *
 89 +
 90 RCL 23
 91 RCL 01
 92 *
 93 .0262874
 94 *
 95 +
 96 RCL 01
 97 RCL 25
 98 *
 99 -.161533 E-4
 100 *

101 +
 102 RCL 02
 103 RCL 25
 104 *
 105 .191249 E-5
 106 *
 107 +
 108 RCL 23
 109 RCL 08
 110 *
 111 -.108195
 112 *
 113 +
 114 RCL 23
 115 RCL 00
 116 *
 117 RCL 02
 118 *
 119 .604516 E-4
 120 *
 121 +
 122 RCL 23
 123 RCL 08
 124 *
 125 RCL 01
 126 *
 127 -.00373104
 128 +
 129 +
 130 RCL 10
 131 RCL 23
 132 *
 133 RCL 01
 134 *
 135 .123564 E-4
 136 *
 137 +
 138 RCL 23
 139 RCL 09
 140 *
 141 RCL 00
 142 *
 143 -.00230188
 144 *
 145 +
 146 RCL 10
 147 RCL 23
 148 *
 149 RCL 00
 150 *

151 .000205707
152 *
153 +
154 RCL 26
155 RCL 10
156 *
157 RCL 02
158 *
159 .101077 E-10
160 *
161 +
162 RCL 26
163 RCL 08
164 *
165 RCL 00
166 *
167 -.102061 E-6
168 *
169 +
170 RCL 11
171 RCL 02
172 *
173 RCL 25
174 *
175 -.233492 E-10
176 *
177 +
178 RCL 11
179 RCL 00
180 *
181 RCL 23
182 *
183 -.476391 E-5
184 *
185 +
186 RCL 26
187 RCL 08
188 *
189 .440832 E-6
190 *
191 +
192 RCL 11
193 RCL 23
194 *
195 .550886 E-5
196 *
197 +
198 RCL 11
199 RCL 00
200 *

201 -.000212041
202 *
203 +
204 RCL 00
205 RCL 09
206 *
207 RCL 26
208 *
209 .144642 E-8
210 *
211 +
212 RCL 01
213 RCL 11
214 *
215 RCL 25
216 *
217 .45315 E-10
218 *
219 +
220 RCL 01
221 RCL 11
222 *
223 RCL 23
224 *
225 -.205156 E-6
226 *
227 +
228 RCL 03
229 RCL 24
230 *
231 RCL 10
232 *
233 .81415 E-10
234 *
235 +
236 RCL 03
237 RCL 24
238 *
239 RCL 11
240 *
241 -.204801 E-10
242 *
243 +
244 RCL 26
245 -.782574 E-5
246 *
247 +
248 RCL 26
249 RCL 11
250 *

251 -.487904 E-11
252 *
253 +
254 RCL 25
255 RCL 03
256 *
257 -.107731 E-6
258 *
259 +
260 RCL 11
261 RCL 03
262 *
263 .290421 E-9
264 *
265 +
266 RCL 11
267 RCL 02
268 *
269 -.364546 E-6
270 *
271 +
272 RCL 11
273 RCL 01
274 *
275 -.532767 E-7
276 *
277 +
278 "END A/S"
279 ARCL X
280 ADV
281 .END.

```

01*LBL "END"
02 RCL 29
03 STO 04
04 5.007
05 XEQ "QD"
06*LBL 01
07 -14.12328
08 RCL 00
09 -.540052
10 *
11 +
12 RCL 08
13 1.18957
14 *
15 +
16 RCL 01
17 RCL 11
18 *
19 -.294347 E-7
20 *
21 +
22 RCL 00
23 RCL 00
24 *
25 .0570829
26 *
27 +
28 RCL 00
29 RCL 09
30 *
31 -.000939808
32 *
33 +
34 RCL 11
35 -.70554 E-5
36 *
37 +
38 STO 23
39 24.026
40 XEQ "QD"
41 -.00553605
42 RCL 23
43 1.00062
44 *
45 +
46 RCL 26
47 RCL 07
48 *
49 -.349348 E-11
50 *

```

```

51 +
52 RCL 24
53 RCL 05
54 *
55 .150075 E-5
56 *
57 +
58 RCL 23
59 RCL 04
60 *
61 -.00117903
62 *
63 +
64 RCL 23
65 RCL 05
66 *
67 -.216546 E-4
68 *
69 +
70 RCL 23
71 RCL 07
72 *
73 .847453 E-8
74 *
75 +
76 FC?C 03
77 GTQ 02
78 CHS
79 RCL 27
80 +
81 STO 28
82 INT
83 "END TIME="
84 ARCL X
85 "HHR"
86 FS? 01
87 GTQ 04
88 ADV
89 PROMPT
90 GTQ 05
91*LBL 04
92 ADV
93 PRA
94*LBL 05
95 RCL 28
96 FRC
97 60
98 *
99 " "
100 ARCL X

```

```

101 "HMM"
102 PTM
103*LBL 02
104 STO 27
105 RCL 08
106 RCL 20
107 10
108 /
109 -
110 STO 00
111 9.011
112 XEQ "QD"
113 SF 03
114 GTQ 01
115 .END.

```

J. ABILITY TO MAINTAIN FLIGHT WITH ONE ENGINE (SE/EV)

1. Equations/Fit statistics-

Regression equation- For Figure 11-23
top chart [Ref. 4 p. 11-37].

$R^2 = .99926$

Standard error of estimate = .50233 % tq.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	69.3394
D	3.29399
C ⁴	.000125967
C ⁴ D	-.577415X10 ⁻⁴
C ⁴ D ²	-.192526X10 ⁻⁵
C ³ D	.00245945
C ³ D ²	.424577X10 ⁻⁴
C ² D ⁴	.462872X10 ⁻⁶
CD	-.662361

Regression equation- For Figure 11-23
bottom chart above
base line [Ref. 4 p. 11-37].

$R^2 = .996$

Standard error of estimate = 1.225218 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	449.498
U ⁻¹ H ⁴	-.0344426
H ⁻²	-31869.1
H ⁶	-.295226X10 ⁻⁴
U ⁷ H ⁸	.264768X10 ⁻¹³
U ⁸ H ⁸	-.196344X10 ⁻¹⁴
U ⁻⁷	46749423
U ⁻⁸	-.349828X10 ⁹
U ⁻⁵ H ⁵	-29.0417
U ⁻⁵ H ⁸	.0176142
U ⁻⁶ H	1120118
H ⁻⁵ U ⁴	-2663.33
H ⁻⁶ U ³	381481
H ⁻⁸ U ⁴	-1179202

Regression equation- For Figure 11-23
bottom chart below
base line [Ref. 4 p. 11-37].

$R^2 = .99245$

Standard error of estimate = 1.47515 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	8824.72
$\exp(U^{-4}H^3)$	61.1876
$\exp(U^{-4}H^4)$	22.1052
$\exp(U^{-3}H^2)$	5.78698
$\exp(U^{-3}H^4)$	$.835267 \times 10^{-12}$
$\exp(U^{-2}H^2)$	-2388.27
$\exp(U^{-2}H^3)$	$-.44832 \times 10^{-8}$
$\exp(U^{-1}H)$	-6109.32
$\exp(U^{-1}H^2)$	$.601748 \times 10^{-6}$
$\exp(H^{-1})$	-210.325
$\exp(2U^{-1}H)$	1954.4

2. Flowchart- See Figure B.10.

3. Program listing- See pages 67-68.

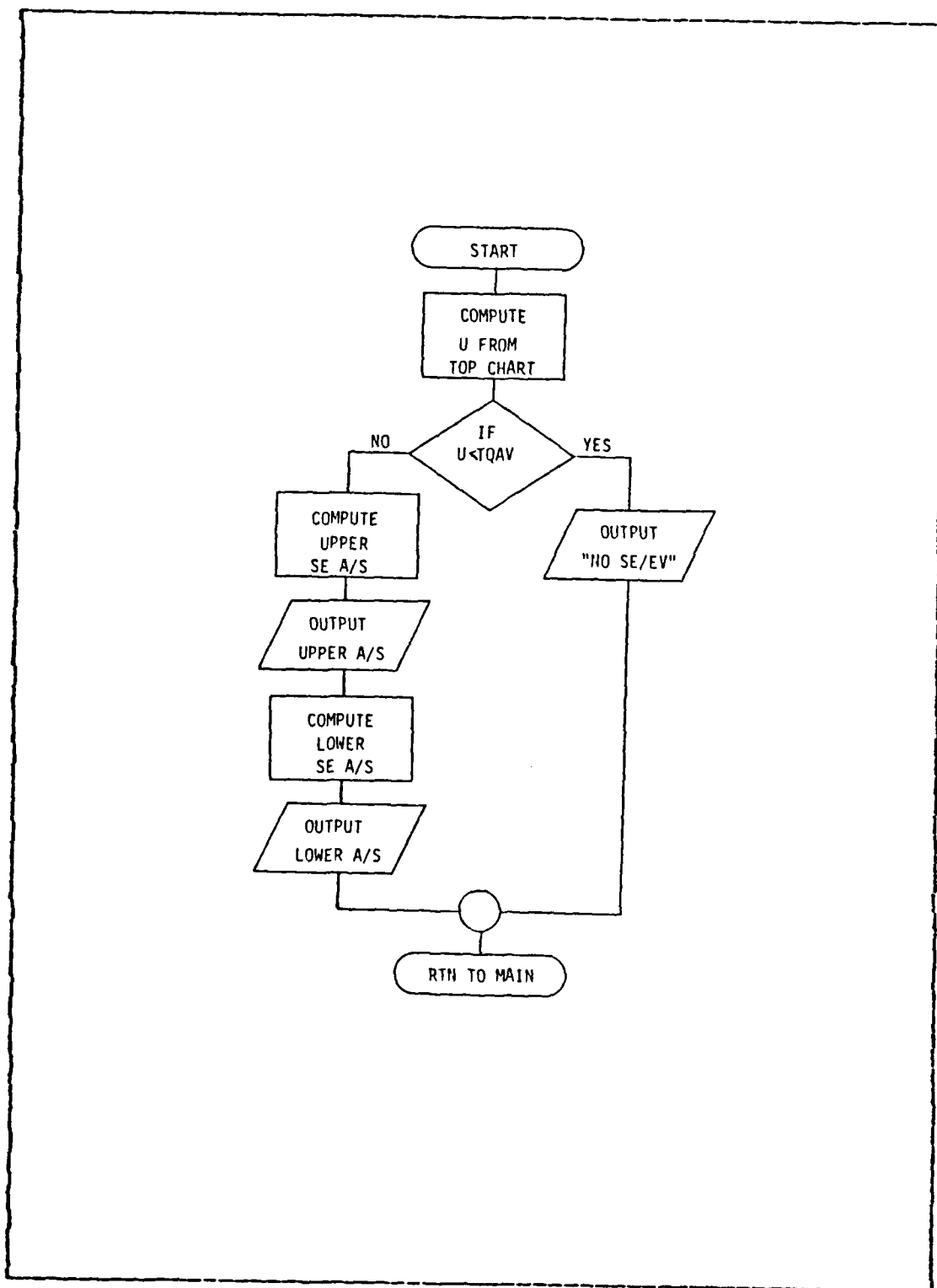


Figure B.10 SE/EV Flowchart

01*LBL "SE/EV"
 02 69.3394
 03 RCL 12
 04 3.29399
 05 *
 06 +
 07 RCL 11
 08 .000125967
 09 *
 10 +
 11 RCL 11
 12 RCL 12
 13 *
 14 -.577415 E-4
 15 *
 16 +
 17 RCL 11
 18 RCL 13
 19 *
 20 -.192526 E-5
 21 *
 22 +
 23 RCL 10
 24 RCL 12
 25 *
 26 .00245945
 27 *
 28 +
 29 RCL 10
 30 RCL 13
 31 *
 32 .424577 E-4
 33 *
 34 +
 35 RCL 09
 36 RCL 15
 37 *
 38 .462972 E-6
 39 *
 40 +
 41 RCL 08
 42 RCL 12
 43 *
 44 -.662361
 45 *
 46 +
 47 10
 48 /
 49 STO 27
 50 RCL 22

51 XYY?
 52 GTO 01
 53 *NO SE/EV"
 54 ADV
 55 RTN
 56*LBL 01
 57 23.025
 58 XEQ "OD"
 59 RCL 25
 60 X12
 61 STO 26
 62 RCL 27
 63 1/X
 64 STO 27
 65 28.030
 66 XEQ "OD"
 67 RCL 30
 68 RCL 27
 69 *
 70 STO 31
 71 449.490
 72 RCL 27
 73 RCL 25
 74 *
 75 -.034426
 76 *
 77 +
 78 RCL 23
 79 1/X
 80 -31869.1
 81 *
 82 +
 83 RCL 22
 84 6
 85 Y1X
 86 -.295226 E-4
 87 *
 88 +
 89 RCL 27
 90 -7
 91 Y1X
 92 RCL 26
 93 *
 94 .264760 E-13
 95 *
 96 +
 97 RCL 27
 98 -8
 99 Y1X
 100 RCL 26

101 *
 102 -.196344 E-14
 103 *
 104 +
 105 RCL 27
 106 7
 107 Y1X
 108 46749423
 109 *
 110 +
 111 RCL 27
 112 8
 113 Y1X
 114 -.349620 E9
 115 *
 116 +
 117 RCL 31
 118 RCL 22
 119 5
 120 Y1X
 121 *
 122 -29.0417
 123 *
 124 +
 125 RCL 31
 126 RCL 26
 127 *
 128 .0176140
 129 *
 130 +
 131 RCL 27
 132 6
 133 Y1X
 134 RCL 22
 135 *
 136 1120110
 137 *
 138 +
 139 RCL 22
 140 -5
 141 Y1X
 142 RCL 30
 143 1/X
 144 *
 145 -2663.33
 146 *
 147 +
 148 RCL 22
 149 -6
 150 Y1X

151 RCL 29
 152 1/X
 153 *
 154 381481
 155 *
 156 +
 157 RCL 26
 158 1/X
 159 RCL 30
 160 1/X
 161 *
 162 -1179202
 163 *
 164 +
 165 "SE A/S="
 166 ARCL X
 167 FS? 01
 168 GTO 04
 169 ADV
 170 PROMPT
 171 GTO 05
 172*LBL 04
 173 ADV
 174 PRA
 175*LBL 05
 176 8824.72
 177 RCL 30
 178 RCL 24
 179 *
 180 E+X
 181 61.1876
 182 *
 183 +
 184 RCL 30
 185 RCL 25
 186 *
 187 E+X
 188 22.1052
 189 *
 190 +
 191 RCL 29
 192 RCL 23
 193 *
 194 E+X
 195 5.78698
 196 *
 197 +
 198 RCL 29
 199 RCL 25
 200 *

201 E+X
 202 .835267 E-12
 203 *
 204 +
 205 RCL 28
 206 RCL 23
 207 *
 208 E+X
 209 -2388.27
 210 *
 211 +
 212 RCL 28
 213 RCL 24
 214 *
 215 E+X
 216 -.44832 E-8
 217 *
 218 +
 219 RCL 27
 220 RCL 22
 221 *
 222 E+X
 223 -6109.32
 224 *
 225 +
 226 RCL 27
 227 RCL 23
 228 *
 229 E+X
 230 .601748 E-6
 231 *
 232 +
 233 RCL 22
 234 1/X
 235 E+X
 236 -210.325
 237 *
 238 +
 239 RCL 27
 240 RCL 22
 241 *
 242 2
 243 *
 244 E+X
 245 1954.4
 246 *
 247 +
 248 " TO "
 249 ARCL X
 250 .END.

K. INDICATED NEVER EXCEED SPEED (VNE)

1. Equations/Fit statistics-

Regression equation- For Figure 1-138
chart [Ref. 4 p. 1-173].

$$R^2 = .99959$$

Standard error of estimate = .483568 kts.

<u>VARIABLE/ TRANSFORM</u>	<u>REGRESSION COEFFICIENT</u>
INTERCEPT	93.7068
D	7.64496
D ⁴	-.000541484
C ³ D ³	.106803X10 ⁻⁵
D ²	-.168473
C ² D	-.0383634
C ⁴ D	.251008X10 ⁻⁴
C ²	.321101
C ⁴	-.000420052

2. Flowchart- See Figure B.11.

3. Program listing- See page 71.

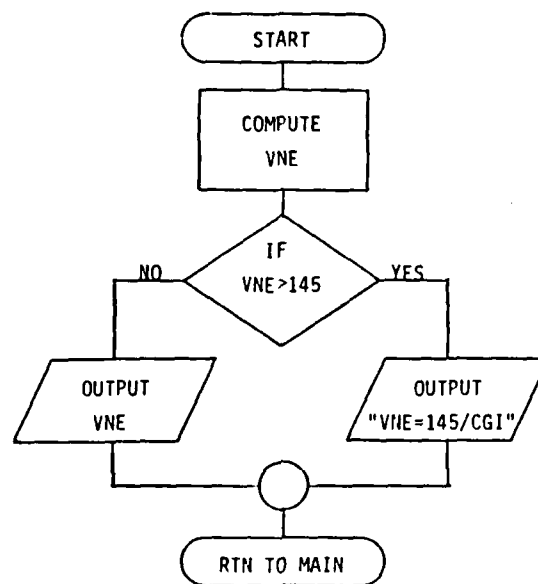


Figure B.11 VNE Flowchart

01*LBL "VNE"
02 93.7068
03 RCL 12
04 7.64496
05 *
06 +
07 RCL 15
08 -.000541484
09 *
10 +
11 RCL 10
12 RCL 14
13 *
14 .106803 E-5
15 *
16 +
17 RCL 13
18 -.168473
19 *
20 +
21 RCL 09
22 RCL 12
23 *
24 -.0383634
25 *
26 +
27 RCL 11
28 RCL 12
29 *
30 .251000 E-4
31 *
32 +
33 RCL 09
34 .321101
35 *
36 +
37 RCL 11
38 -.000420052
39 *
40 +
41 145
42 X<=Y?
43 GTO 01
44 "VNE="
45 ARCL Y
46 ADV
47 RTH
48*LBL 01
49 "VNE=145/CGI"
50 ADV
51 .END.

LIST OF REFERENCES

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