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THESIS

COMPUTER PROGRAM
FOR
CONCEPTUAL TANDEM ROTOR HELICOPTER DESIGN

by

Bruce A. Vandenbos

September 1987

Thesis Advisor:

D. M. Layton

Approved for public release: distribution is unlimited

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Computer Program for Conceptual
Tandem Rotor Helicopter Design

by

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Submitted in partial fulfillment of the
requirements for the degree of

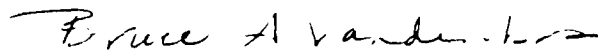
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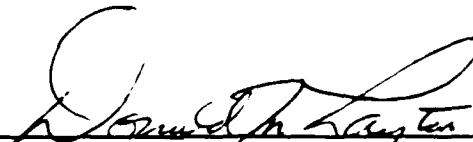
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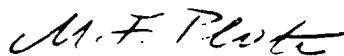


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ABSTRACT

The conceptual phase of a helicopter design includes comparison of configurations which will meet the specified performance requirements. To perform this comparison, the designer must have the proper tools at hand. This thesis presents an interactive computer program for the conceptual design of tandem rotor helicopters. It is intended to complement the existing single rotor helicopter design program written for the Helicopter Design course, AE-4306, taught at the Naval Postgraduate School, Monterey, California.

This program manages the myriad of interrelated parameters by prompting for input, providing the opportunity for changes, and displaying the results. This relieves the (student) designer of the tedious calculations and bookkeeping, thus allowing time for a more thorough analysis of the design.



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TABLE OF CONTENTS

I. INTRODUCTION 6
A. BACKGROUND 6
B. OBJECTIVES 8

II. APPROACH AND SOLUTION 10

III. RESULTS 13

IV. CONCLUSIONS AND RECOMMENDATIONS 14

APPENDIX A: TANDEM ROTOR HELICOPTER DESIGN
USER'S GUIDE 15

APPENDIX B: PROGRAM RESULTS 20

APPENDIX C: VARIABLE DEFINITIONS AND PROGRAM
LISTING 30

LIST OF REFERENCES 59

INITIAL DISTRIBUTION LIST 60

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I. INTRODUCTION

A. BACKGROUND

Helicopter Design, AE-4306, as taught at the Naval Postgraduate School requires the "Conceptual Design" of a specific mission-capable helicopter as one of the course requirements.

Conceptual Design is the first of five phases where configurations are compared; cost, weight and size are estimated; feasibility is studied; and then follow-on recommendations are made [Ref. 1]. It is the first of these, comparison of configurations, which prompted this thesis.

Tandem rotor helicopters have been successfully employed since March of 1945 when the PV-3 Dogship was developed for the U.S. Navy. As with all else in aviation, humble beginnings give way to technology and ingenuity, so that by the mid 1960's, Boeing Vertol had developed the H-46 Sea Knight and H-47 Chinook. Both are still currently in use, flying today in all four U.S. armed services, various commercial operations (logging, oil production, etc.) as well as servicing in other countries such as Japan, Canada, Great Britain and Sweden.

To the casual observer the appeal of the tandem rotor scheme is obvious--both rotors provide thrust in the correct direction (up) and therefore a fraction of the power isn't wasted pushing the helicopter sideways, as in the tail rotor configuration. Although somewhat true, this observation does require clarification. Tail rotors typically absorb 10 to 20 percent of the engine power required to hover [Ref. 2]. This decreases in forward flight because of translational lift effects which produce a decrease in main rotor

torque. This provides a slight reduction in tail rotor power. Tandems also have a power penalty due to interference effects found where the two rotor disks overlap. Analytically, this is accounted for by correcting induced power with a "rotor interference factor", K , which has been determined empirically to be a function of the rotor shaft spacing ratio [Ref. 3 and Ref. 4]. For forward flight, another factor must be included, K_u , the "induced power correction factor". A combination of these factors results in losses comparable to those of the tail rotor configuration, depending on the regime of flight. It is noticeable that tandems appear better in hover and low forward velocities with the single rotor having advantages at medium to high forward velocity. However, these apparent respective advantages are not clearly defined, nor are they easily quantified.

Reference [5] is an interactive program for conceptual helicopter design, but is restricted to the single rotor configuration. This thesis project sought to complete the designer's "tool box" with the development of a Tandem Rotor Helicopter Design program. Configuration selection could then be based upon design superiority and mission requirement rather than philosophical whim.

Aside from the nebulous factors discussed above, there are distinct advantages and disadvantages to a tandem rotor system. Some advantages of the tandem rotor design are:

- Anti-torque is encumbent in the counter-rotating rotor system.
- No tail rotor losses or side force that require compensation.
- Lighter drive system due to smaller diameter, higher rpm rotors (therefore less speed reduction).

- Much larger range in center of gravity locations.
- Relatively small effect of wind direction on hover capability. [Ref. 2]

As important as the advantages of a given system are, its limitations must be considered also. Disadvantages, relative to single rotor systems, are:

- Greater directional instability, due to decreased distance from center of gravity position to tail surface.
- High moment of inertia about the vertical axis due to transmission mass located at each end.
- Higher induced power required on aft rotor due to the forward rotor downwash.
- Vibration--twice as many rotors tend to produce greater vibration problems than a single rotor configuration. [Ref. 2]

Although some of these are significant problems, none are insurmountable. Furthermore, the technological developments of the past 20 years are updating the previous solutions to these design problems with current computer and material technology. For example, the Army is currently updating its H-47 fleet to the "D" model Chinook and the Navy and Marine Corps are upgrading their H-46's through the Survivability, Reliability and Maintainability (S R & M) program. Both programs are intended to extend service life well into the next century.

B. OBJECTIVES

The primary objective of this thesis project was to write a computer program for the conceptual design of tandem rotor helicopters. Secondary goals included: interactivity for design flexibility; user friendliness so people will use it; compactness, for microcomputer application; and accuracy so the results are meaningful. All of this required the development of a substantial amount of program software.

The program will be available to students taking the Helicopter Design course, AE-4306. This will provide the option to easily design a helicopter of either rotor system scheme depending on the specific mission that it will be required to perform.

II. APPROACH AND SOLUTION

The initial intent of this project was to integrate a tandem rotor design section into the existing Helicopter Design program written by LT Bob Drake [Ref. 5]. This, however, proved hopeless as the differences in design, equations, input and output became apparent. The problem then became to develop the program in a format compatible with reference 5, but be totally independent.

"User friendliness" is a key phrase commonly heard these days in the computer business, and with good reason. People want to use the computer as a tool to accomplish a given task without themselves becoming a slave to the green screen and microchip. To this end, Tandem Rotor Helicopter Design was written as a menu driven, interactive program that would, to the maximum extent possible, trap errors and return to a menu or input field without terminating the program.

Microsoft GWBASIC was chosen as the language, not only to be consistent with Reference 5 but also because of its compatibility with IBM, and all true compatibles. Furthermore, since there was only a small amount of serious number crunching to be done, vast speed was not required; hence, GWBASIC was the logical choice.

The program is formatted into a sequence of chapters that roughly correspond to the Helicopter Design Manual [Ref. 1]. Although tandems are different in some respects, they share many similarities with their single rotor cousins. Therefore, the program references the design manual frequently, and also provides additional, tandem rotor specific, information when appropriate. This provides the student designer

hard copy reference material to complement the "information" and "help windows" that are built into the program.

Each chapter is designed to run as a follow-on to the previous, with provisions to make changes if desired. New data is then entered, when prompted, into specific input fields. When data entry is complete the computer will calculate the results and display them on an output field, usually on the same screen, so that input and output can be viewed simultaneously. The "ANY CHANGES?" prompt will then appear allowing the adjustment of parameters to meet design specification. Once a design is refined, a print-screen command gives a hard copy of the results, then the appropriate menu selection proceeds to the next section or returns to the main menu. All chapters are linked via the "chain" command which not only passes control and executes the next program, but also passes all variables.

One important feature of this program is the use of FLASHUP WINDOWS^R [Ref. 6] to display menus, information and help to the user. This outstanding application software allows addition of useful documentation that can be easily accessed by the user. By simply pressing ALT-F1, with the cursor on the appropriate line, a "help window" will be displayed for each major input parameter, pressing "Enter" clears the window and returns to the input line. Information windows will display automatically when a particular chapter or section is selected and will remain as long as desired. Again, "Enter" clears the window and proceeds with the program. Menus function in much the same fashion, except that they remain until the user makes a selection, either by pressing the first character (letter or number) in the menu line or by using the

"up"- "down" arrow keys to highlight the item then pressing "Enter" to execute the selection.

For this project the Helicopter Design Manual [Ref. 1] and Helicopter Performance [Ref. 3] were the primary source of equations. In addition, several other resources were tapped in the development of the analytical routines of the program. Power requirements for tandems are computed using equations developed from a combination of momentum theory and test data. This set of semi-empirical equations was found to be the most accurate when compared to actual H-46 and H-47 test data [Ref. 4]. Weight estimation used parametric equations, specially developed for tandem rotor helicopters in [Ref. 7].

III. RESULTS

Conceptual helicopter design is based on a myriad of interrelated parameters which constantly require changes and iteration to meet the design specification. This program handles the tedious calculations and bookkeeping allowing the designer to delve deeper into the intricacies of the design. Thus the engineer will spend his time evaluating options, optimizing parameters or conducting trade-off studies, instead of performing mindless hand calculations. Furthermore, this program is designed to teach, as well as being a tool. The optional "help windows" and information screens all serve to help the novice helicopter designer learn the process. Once the process is learned, the designer can quickly refresh his memory without interrupting the continuity of the program. In short, the Tandem Rotor Helicopter Design program complements existing software, is easy to use, and gives excellent results for Conceptual Design.

Appendix A contains the "user's guide" to the program. It is intended to help students get started and use the program regardless of their experience level with personal computers.

Appendix B shows results for a conceptual design of a helicopter with design parameters similar to those of the H-46.

Appendix C is the program listing.

IV. CONCLUSIONS AND RECOMMENDATIONS

Computer assisted design is a rapidly expanding aspect of the engineering world--and with good reason. Virtually all aspects of design are easier, faster and more accurate with the advent of the modern digital computer. Furthermore, microcomputers have become so common that the power of the computer is available to virtually everyone.

Tandem Rotor Helicopter Design is a small addition to the vast amount of software that is being developed. With it, the student can work through the conceptual design of several helicopters in a fraction of the time that it previously took for just a single design.

It is recommended as a follow-on to this thesis that graphics routines be integrated into the program that will plot directly the important relationships between parameters. For example, the Power -vs- Velocity graph which shows induced, profile, parasitic, as well as total power and high speed effects could be plotted directly from the results produced in chapter 5. This would provide an immediate visual presentation of how the design should perform.

Another recommendation would be the addition of a "blade optimization" routine similar to the one in the Single Rotor Helicopter Design program [Ref. 5]. This program however, should run separately from the remainder of the program since blade optimization is more "detailed" than "conceptual" design.

Finally it is recommended that microcomputers receive more emphasis in the Aeronautical Engineering curriculum. A course that includes an introduction to personal computers as well as basic operation procedures would be of great value to the students.

APPENDIX A
TANDEM ROTOR HELICOPTER DESIGN
USER'S GUIDE

1. INTRODUCTION

This program is designed as a menu driven, interactive design tool that will perform the bookkeeping and iterative calculations required in a conceptual design. Since no tandem rotor design manual is available, information screens are displayed automatically when amplifying information was deemed appropriate. These will remain until the "Enter" key is pressed to continue. Also available, in most chapters, are "help windows" which are not normally displayed but are there if required. A notice (ALT-F1 for help) will appear to the right of the title if "help" is available. These "help windows" can be accessed by first locating the cursor on the corresponding input line, then press the "Alt" and "F1" keys (ALT-F1). Pressing "Enter" clears the window and restores program execution. Finally the Helicopter Design Manual [Ref. 1] is referenced extensively throughout the program. Though not totally compatible with tandem design, the program does follow this design manual where possible. Thus, the Tandem Rotor Helicopter Design program complements the Helicopter Design Manual [Ref. 1] with additional tandem rotor specific information.

2. BASICS

a. HARDWARE

COMPUTER: IBM PC or compatible with 128K of RAM.

MONITOR: Color if possible, but monochrome will work.

PRINTER: Any that will respond to the "Shift-PrtSc" option.

b. GETTING STARTED

Place the program disk into drive A and turn on the computer. The "system" as well as all other support software are on the disk for user convenience. The program will be loaded and run automatically, so relax and let the system work. If the computer is on, just insert the disk and press the CTRL-ALT-DELETE keys simultaneously to reboot the system.

c. USING THE PROGRAM

The main menu is the first display seen and will serve as a road map for progressing through the program. At the end of each chapter, control will be transferred back to the main menu to select the next option or quit if so desired. Selections can be made in one of two ways. First, use the up-down arrow keys to move the cursor to highlight the desired item, then press "Enter". The second option is to simply press the first letter or number key of the desired menu item; program execution will begin immediately.

Once established within a chapter, follow the prompts and input the data as requested. If a mistake is made -DON'T WORRY- the opportunity will be provided to change any item once all data is entered. Note that some variables require a positive, non-zero value. If zero or a negative number is entered a window will appear to advise you of the error. Press "Enter" to clear the window and then enter the correct number. A similar window appears if an error is made when

selecting an item to change. Again, press "Enter" and continue.

Each chapter is organized into a series of spread sheet type screens that show input and output together (if possible). When the input parameters have met the requirements, press the Shift-PrtSc keys simultaneously for a hard copy.

d. SPECIAL INSTRUCTIONS

This section provides a brief synopsis of each chapter in the program. Each chapter correlates, by number, directly to a corresponding chapter in the Helicopter Design Manual [Ref. 1], with one notable exception; Chapter 4 is reserved for a future blade optimization program since tail rotors don't really fit into the tandem rotor design scheme.

(1) CHAPTER ONE

This contains a brief introduction and is included for those who do not have access to this user's guide.

(2) CHAPTER TWO

Chapter Two performs the preliminary rotor design for the helicopter. This follows the Helicopter Design Manual [Ref. 1] in determining the major parameters that will effect the eventual performance of the helicopter. Note that one rotor is designed to carry half the gross weight and the two rotor system is assembled in Chapter Three.

(3) CHAPTER THREE

This is the Tandem Rotor System Design segment of the program where two identical counter-rotating rotors are put together as a system. Any of the 13 input variables can be adjusted to observe its effect on power, figure of merit, disk loading, etc. When

these are acceptable, proceed to the weight estimation portion of the program.

Weight estimation is based primarily on power required, but power is a function of weight, hence an iterative process. As with previous sections, input the requisite information at the prompts and the computer does the rest.

(4) CHAPTER FOUR

Blade optimization is to be included at a later date.

(5) CHAPTER FIVE

This chapter incorporates the effects of retreating blade stall, advancing blade shock losses, high altitude hover, and various survivability/safety additions to the total power required. Total power required will be needed to select the engines in the next chapter.

(6) CHAPTER SIX

Engine and transmission selection are the topic of this chapter. To complete the analysis, specific engine data is required. Table VI-1 in the Helicopter Design Manual [Ref. 1] provides a summary of six generic engines that are representative of currently available, power plants. If a specific manufacturer's data is available it too can be used.

(7) CHAPTER SEVEN

This section computes the range and endurance for the helicopter being designed. Chapter 7 should be reviewed before beginning. Once the data is entered it will take a few minutes to solve the equations, so be patient; the computer will beep when it is done.

(8) CHAPTER EIGHT

This chapter is reserved to calculate all of those requirements that don't fit elsewhere. Due to

the differences between tandem and single rotor design some of these are completed in earlier chapters. Check the design gross and empty weight as determined back in Chapter 3.

Maximum hover altitude was specified back in Chapter 5 and used in determining engine power required. However, the maximum power is often in forward flight, thus a higher than specification hover ceiling will be available.

(9) CHAPTER NINE

This provides a final summary of the helicopter's designed performance and geometric parameters.

(10) CHAPTER TEN

Chapter 10 computes an estimate of cost based on a set of parametric equations that incorporate component weights (Chapter 3), the inflation rate and expected production quantity.

APPENDIX B
PROGRAM RESULTS

* PRELIMINARY ROTOR DESIGN *

1. DESIGN MAX GROSS WEIGHT [lbs] (2.1)MGW = 23000
2. ESTIMATE OF EMPTY WEIGHT [lbs] (2.2)MTW = 12000
3. ROTOR TIP VELOCITY (2.3; 700 fps recommended) VT = 700
4. DISC LOADING [lbs/ft²] (2.4 ; FIG. 2-2)DL = 5.7
ROTOR RADIUS [ft] (2.4).....R = 25.3418
ROTATIONAL VELOCITY [rpm]RPM = 263.7940
THRUST COEFFICIENT (2.6).....CT = 0.0049
5. SPECIFICATION MAX AIRSPEED [knots] (2.7) ..TASMX = 150
ADVANCE RATIO (2.7)MU = 0.3619
6. MAX BLADE LOADING (2.7; FIG.2-3; CT/S)MBL = .09
ROTOR SOLIDITY (2.7)S = 0.0544
7. NUMBER OF ROTOR BLADES PER HEAD (2.8).....B = 3
BLADE CHORD [ft] (2.9)C = 1.4431
ASPECT RATIO (2.9)AR = 17.5609
AVG LIFT COEFF (2.10)CL = 0.5400
8. RETURN TO MAIN MENU.

WHICH PARAMETER DO YOU WISH TO CHANGE / SELECT ? 8

*** FOR HARD COPY PRESS <Shift-PrtSc> BEFORE RETURNING TO MAIN MENU ***

* TANDEM ROTOR SYSTEM DESIGN * (Alt-F1 for help)

1. DESIGN MAX GROSS WEIGHT [lbs].....MGW = 23000.0
2. ROTOR RADIUS [ft].....R = 25.3
3. BLADE CHORD [ft]C = 1.4
4. BLADE PROFILE DRAG COEFFICIENTCDO = 0.0090
5. NUMBER OF ROTOR BLADES PER HEADB = 3
6. OPERATING RPM [rpm]RPM = 263.8
7. ROTOR SHAFT SPACING [ft]S1 = 33.8
8. ROTOR HEAD VERTICAL SPACING [ft]GAP = 4.0
9. HEIGHT OF FORWARD HEAD ABOVE WHEELS [ft]FHH = 12.0
10. PRESSURE ALTITUDE [ft MSL]PA = 0
11. HOVER ALTITUDE [ft AGL]AGL = 10
12. TRUE AIRSPEED [knots] (0 FOR HOVER)TAS = 0
13. EQUIVALENT FRONTAL AREA [ft^2]FF = 44.0
14. COMPONENT WEIGHT ESTIMATES 15. RETURN TO MAIN MENU

-- RESULTS --

PI = 1209.82 FM = 0.77 (.75 to .85) *HOVER
PO = 365.92 DL = 4.20 (5 to 15) ONLY
PP = 0.00 CL = 0.42 (CLmax; 1.55)
PT = 1575.75 HP AR = 17.56 (15 to 20)
BL = 0.070 (BLmax; 0.12)
WHICH PARAMETER DO YOU WISH TO SELECT / CHANGE ? 15

* COMPONENT WEIGHT APPROXIMATIONS * (Alt-F1 for help)

1. TYPE LNDG GEAR (TRICYCLE STYLE)			
1=FIXED	2=RETRACTABLE	1
2. NUMBER OF ENGINES (2 or more)	...	2	
3. ESTIMATED FUEL CAPACITY (lbs)	...	2600	
4. NUMBER OF CREW AND PASSENGERS	...	25	
5. WT OF SPECIAL AVIONICS (lbs)	...	120	
6. SPECIFICATION USEFUL LOAD (lbs)	...	1800	
7. RETURN TO TANDEM ROTOR SYSTEM DESIGN			
SELECTION ? (1 thru 6 for changes)			
=====			
SPEC MAX GROSS WT (MGW)	=	23000.0	lbs
NEW A/C EMPTY WT	=	12093.4	
FUEL WT	=	2600.0	
PERSONNEL WT	=	6250.0	
USEFUL LOAD	=	1800.0	

NEW GROSS WT ESTIMATE	=	22743.4	lbs
TOTAL POWER FOR HOVER	=	2023.9	SHP

		TOTAL COMPONENT WEIGHT	= 12093.4

* press <Shift-PrtSc> for hard copy *

* HIGH SPEED EFFECTS AND POWER SUMMARY * (Alt-F1 for HELP)

1. GROSS WEIGHT [lbs]GW = 23000.0
 2. ROTOR RADIUS [ft].....R = 25.3
 3. BLADE DATA: CHORD [ft]C = 1.4
 4. PROFILE DRAG COEFFICIENTCDO = 0.0090
 5. LIFT CURVE SLOPE [per RAD]CLALFA = 5.73
 6. STALL ANGLE OF ATTACK [deg]AOAST = 12
 7. GEOMETRIC TWIST [deg with sign]TWIST = -8
 8. CRITICAL MACH NUMBERMCRT = .73
 9. NUMBER OF ROTOR BLADES PER HEADB = 3
 10. OPERATING RPM [rpm]RPM = 263.8
 11. ROTOR SHAFT SPACING [ft]S1 = 33.8
 12. ROTOR HEAD VERTICAL SPACING [ft]GAP = 4.0
 13. HEIGHT OF FORWARD HEAD ABOVE WHEELS [ft]FHH = 12.0
 14. SPEC PRESSURE ALT [normally 4000 ft MSL]..PASPEC = 4000
 15. HOVER ALTITUDE [ft AGL]AGL = 10
 16. SPEC CRUISE AIRSPEED [knots]TASCR = 130
 17. SPEC MAX AIRSPEED [knots]TASMX = 150
 18. EQUIVALENT FRONTAL AREA [ft^2]FF = 44.0
 19. SPEC MAX HOVER ALTITUDE (IGE) [ft]MXHVR = 10000
 20. COMPUTE NEW POWER REQUIREMENTS 21. RETURN TO MAIN MENU
 press <Shift-PrtSc> for hard copy, ENTER to continue

* TOTAL POWER (SHP) REQUIRED WITH HIGH SPEED EFFECTS *

TAS(kts)	PI	PO	PP	PS	PM	PT
0	1398	366	0	0	0	1763
20	1332	370	4	0	0	1705
40	1170	381	29	0	0	1580
60	966	399	99	0	0	1464
70	870	411	157	0	11	1449
80	784	425	235	0	75	1519
100	646	458	458	0	207	1769
120	545	498	792	0	349	2183
130	504	521	1006	168	425	2624
140	469	545	1257	400	505	3177
150	439	572	1546	692	591	3839
160	412	600	1876	1058	683	4629
180	367	663	2671	2077	887	6664

MINIMUM POWER = 1,449 SHP AT 70 knots
 MAXIMUM POWER = 3,839 SHP AT 150 knots
 POWER AT HOVER CEILING = 1,926 SHP AT 10000 ft MSL
 press <Shift-PrtSc> for hard copy, ENTER to continue

* POWER REFINEMENTS -- INSTALLATION LOSSES *

I. - INLETS AND INLET DUCTING -

1. -S- TYPE (5%)		
2. ICE SHIELD (10%)		
3. STRAIGHT-IN (2%)	INLET LOSSES =	77 SHP 2.0 %

II. - ENGINE AIR PARTICLE SEPARATORS - EAPS

4. FOAM TYPE BARRIER FILTERS (10%)		
5. POWER (HYDRAULIC) SEPARATORS (2 - 6%)		
6. NONE INSTALLED	EAPS LOSSES =	154 SHP 4.0 %

III. - ENGINE EXHAUST DEVICES - EEDS

7. SIMPLE HEAT DIFFUSER (3%)		
8. INFRA-RED SUPPRESSOR (5%)		
9. NONE INSTALLED	EEDS LOSSES =	0 SHP 0.0 %

ENGINE, XMSN and MISC INSTALLATION LOSSES = 509 SHP 13.3 %
 TOTAL LOSSES (percent of ESHP) = 740 SHP 16.1 %
 MAXIMUM POWER REQUIRED [RSHP] = 3,839 SHP
 ENGINE SHAFT HORSEPOWER REQUIRED [ESHP] = 4,579 SHP

press <Shift-PrtSc> for hard copy, ENTER to continue

* NUMBER OF ENGINES * (SECTION 6.1)
 1. NUMBER OF ENGINES = 2 (specified in Chapter 3)
 * TYPE OF ENGINES * (SECTION 6.2)
 2. NUMBER OF ENGINES COMPETING FOR SELECTION ? 2

=====

* ENGINE SELECTION PARAMETERS *

ENGINE:	
A	B
3. DRY WEIGHT (lbs).....	709 580
4. SHP (ssl) military....	1800 2500
5. SFC (ssl) military....	.595 .615
6. INITIAL COST..... \$K	360 640
7. OP COST/HR/ENG..... \$	35 40
8. PREV MAINT/HR/ENG.. \$	125 160
9. MTBMA (hrs).....	3 4
10. MDT (hrs).....	1.3 2
11. MTBF (hrs).....	285 280
12. MTBR (hrs).....	800 1000

13. SPECIFICATION AVERAGE FLIGHT HOURS PER YEAR ? 120
 14. SPECIFICATION AVERAGE AIRFRAME SERVICE LIFE IN YEARS ? 9
 15. AVERAGE FLIGHT HOURS PER FLIGHT ? .7

press <Shift-PrtSc> for hard copy, ENTER to continue

* ENGINE SELECTION CRITERIA * (6.3 & 6.4)

	ENGINE				
	A	B	C	D	E
POWERPLANT WEIGHT(installed)....	879	737			
LIFE-CYCLE COSTK\$	1066	1712			
ENGINE LIFE (hrs).....	800	1000			
NO. OF REPLACEMENTS.....	0	0			
R/D COSTS.....K\$	0	0			
INITIAL COSTS.....K\$	360	640			
ANNUAL MAINT. COST.....K\$	15	19			
ANNUAL OPERATING COST.....K\$	4	5			
REPLACEMENT COST.....K\$	486	864			
SALVAGE VALUE.....K\$	288	512			
AVAILABILITY (per engine).....	0.698	0.667			
RELIABILITY (per engine).....	0.998	0.998			
MAINTAINABILITY (per engine)....	0.212	0.233			
PERFORMANCE (military SHP).....	1800	2500			

ENTER THE LETTER OF THE SELECTED ENGINE (i.e. A,B,C) a

press <Shift-PrtSc> for hard copy, ENTER to continue

* TRANSMISSION SELECTION * (6.5)

ENGINES: TOTAL SHAFT HP = 4579.0 SHP
 NUMBER INSTALLED = 2
 INSTALLED WEIGHT = 879.2 lbs
 TRANSMISSION: POWER RATING = 1900.0 SHP
 WEIGHT = 1100.0 lbs

=====

REVISED WEIGHT ESTIMATES

A/C EMPTY WT = 11561.7
 FUEL WT = 2600.0
 PERSONNEL WT = 6250.0
 USEFUL LOAD = 1800.0

GROSS WT ESTIMATE = 22211.7 lbs
 TOTAL POWER FOR HOGE = 1948.1 SHP
 DISK LOADING = 5.5046 psf
 FIGURE OF MERIT = 0.8142

* REVISED COMPONENT WT (6.6)

- 1. MAIN ROTORS 2554.9
- 2. FUSELAGE 2485.5
- 3. LANDING GEAR 501.7
- 4. ENGINE NACELLES 158.6
- 5. ENGINES 772.5
- 6. DRIVE TRAIN/XMSN 1163.7
- 7. FUEL TANKS 323.9
- 8. FLIGHT CONTROLS 554.5
- 9. AUX POWER (APU) 139.0
- 10. INSTRUMENTS 114.7
- 11. HYDRAULIC SYSTEM 58.5
- 12. ELECTRICAL SYSTEM ... 448.1
- 13. AVIONICS 445.0
- 14. FURNISHINGS 644.7
- 15. AC / DE-ICE EQUIP ... 125.1
- 16. LOAD HANDLING EQUIP.. 149.2

REVISED COMPONENT WEIGHT = 11561.7

press <Shift-PrtSc> for hard copy, ENTER returns to MENU

* RANGE and ENDURANCE * (Chap 7)

1. SFC (lb/hr/shp)	2. SHP	FUEL FLOW (lb/hr)
MILITARY: .595	1800	2142.00
NORMAL: .606	1530	1854.36
CRUISE: .661	1148	1517.66

3. SPECIFICATION CONDITIONS: ALTITUDE = 4000 TEMP = 95
 ZERO HP INTERCEPT = +418.35 (ssl) +373.64 (spec)
 PHANTOM HORSEPOWER = +873.76 (ssl) +780.39 (spec)

* MAX RANGE *	* MAX ENDURANCE *
AIRSPEED = 120 kts	AIRSPEED = 70 kts
POWER = 2,183 SHP	POWER = 1,449 SHP
FUEL FLOW = 1,463 lb/hr	FUEL FLOW = 1,112 lb/hr

* CRUISE PWR & FUEL FLOW: 130 kts * (ssl)	* TOTAL FUEL REQUIREMENTS *
2,624 SHP (spec)	4. SPEC MAX RANGE (NM) = 200
1,675 lb/hr	TOTAL FUEL REQUIRED = 2,954 lbs
	DESIGN FUEL CAPACITY = 2,600 lbs
	FUEL DEFICIENCY = 354 lbs

ANY CHANGES ? (0=NO,1=YES) 0

APPENDIX C

VARIABLE DEFINITIONS AND PROGRAM LISTING

1. Units and Constants

weight = pounds
airspeed = knots
velocity = feet per second
length = feet
angles = degrees
power = horsepower
fuelflow = pounds per hour
temperature = degrees Fahrenheit

PIE = 3.1415927
RHO = sea level density
MACH = mach number at sea level

2. Chapter Two Variables

MGW - specification maximum gross weight
GW - rough estimate gross weight
MTW - estimate of manufacturer's empty weight
VTIPMAX - maximum tip velocity
R - rotor radius
RPM - revolutions per minute
RV - rotational velocity in radians per second
CT - thrust coefficient
S - blade solidity
B - number of blades
C - main rotor blade chord
AR - main rotor blade aspect ratio
CL - average lift coefficient
CDO - blade drag coefficient
DL - disk loading
MU - advance ratio
MBL - maximum blade loading
VMAX - maximum forward velocity in feet per second
TASMX - maximum true airspeed in knots

3. Chapter Three Variables

TIPLOSS - main rotor blade tiploss
PI - induced power
PO - profile power
PP - parasite power
PT - total power
FM - figure of merit
PDW - percent difference in weight
FF - equivalent flat plate area
PEOPLE - number of people, including crew
PAX - weight of passengers and crew
SPECIAL - weight of special equipment
AV - vertical area presented by 2 rotors as seen from the front
AE - total main rotor blade area
W(N,N) - component weight
UL - useful load
FUEL - fuel weight in pounds
GEAR - type of landing gear
FHH - forward rotor height above the ground
VF - airspeed in feet per second
PI(I) - induced power in forward flight
PO(I) - profile power in forward flight

PP(I) = parasite power in forward flight
PT(I) = total power in forward flight
I = airspeed counter in knots
ENGN = number of engines installed

4. Chapter Four Variables

Blade optimization program to be added at a later date.

5. Chapter Five Variables

CLALFA = blade lift curve slope
TWIST = main rotor twist angle in degrees
T7 = main rotor twist angle in radians
AOAST = stall angle of attack for rotor blades
in degrees
PASPEC = specification altitude
AE = effective disk area
VT = main rotor tip velocity
TAS(I) = airspeed in knots
MU = advance ratio
AOA90 = blade angle of attack at 90 degree position
AOA270 = blade angle of attack at 270 degree
position
MACHVEL = local mach number as a function of
altitude
MTIP = main rotor blade tip mach number
M90 = mach number advancing at 90 degree
position
MCRT = main rotor blade critical mach number
DMD = difference between M90 and MCRT
MD = main rotor blade critical mach number for drag
divergence
MTIPHVR = local tip mach number in hover
MTIPFLT = local tip mach number in forward
flight
MXHVR = specification hover ceiling
CTHC = thrust coefficient at hover ceiling
TIPHC = tiploss at hover ceiling
PIHC = main rotor induced power at hover ceiling
B1 = tiploss
COLANGLE = collective angle in degrees
H8 = collective angle in radians
CYCLIC = cyclic angle in degrees
H2 = cyclic angle in radians
TASCR = cruise airspeed in knots, specification
TASMX = maximum airspeed in knots,
specification
TASMAXP = airspeed for maximum power required
TASMINP = airspeed for minimum power required
PSPECHVR = total power to HIGE at hover ceiling
DELTA = pressure ratio
THETA = temperature ratio
RSHP = maximum rotor shaft horsepower required
INLET = inlet losses
PINLET = percent loss due to inlets
RSHPINLT = added horsepower for inlets
EAPS = losses due to engine air partical separators
PEAPS = percent loss due to EAPS
RSHPEAPS = added horsepower for EAPS
EEDS = losses due to engine exhaust diffusers
PEEDS = percent loss due to EEDS
RSHPEEDS = added horsepower with EEDS
ENGNLOST = horsepower required to operate engine
devices
PCTENGN = percent power required for engine devices

MICSLOST - horsepower absorbed by engine,
 transmissions and accessories
 PCTMISC - percent power required for engines,
 transmissions and accessories
 RSHPLOST - total power lost between engines and
 rotors
 PCTLOST - percent power lost between engines and
 rotors
 ESHP - engine shaft horsepower required to provide
 rotor power

6. Chapter Six Variables

NENGSEL - number of engines competing for selection
 MDT - maintenance down time
 MTBF - mean time between failure
 MTBR - mean time between replacement
 DW(X) - engine dry weight
 SHP(X) - engine shaft horsepower at military
 SFC(X) - specific fuel consumption at military
 ENG - number of engines
 IC(X) - initial cost
 OC(X) - operating cost per hour
 PMA(X) - preventative maintenance per engine per
 hour
 MTBMA(X) - mean time between maintenance action
 AFL - average flight hours per year
 SL - aircraft service life
 TAV - average flight hour per flight
 YM(X) - engine yearly maintenance cost
 YO(X) - engine yearly operating cost
 NRPL(x) - number of engine replacements
 LC(X) - engine life-cycle cost
 RD(X) - engine research and development costs
 AVAIL(x) - engine availability
 MAINT(x) - engine maintainability
 RELY(x) - engine reliability
 RC(X) - replacement costs
 SV(X) - salvage costs
 EWT(x) - installation engines weight
 XMSNW - transmission weight
 XMSNP - transmission power rating

7. Chapter Seven Variables

SFC(X) - specific fuel consumption
 SHP - shaft horsepower
 WDOTF(x) - fuel flow in pounds per hour
 BETAH - slope of the fuel flow versus horsepower
 curve
 ALPHAH - zero horsepower intercept
 DELTA - pressure ratio
 THETA - temperature ratio
 ALT - specification altitude
 TEMP - specification temperature
 PF - phantom horsepower
 TASMXR - maximum range velocity in knots
 FFMXR - maximum range fuel flow
 RHPMXR - maximum range referred horsepower
 PTMXR - maximum range horsepower
 TASMNP - maximum endurance velocity in knots
 PTMIN - SHP for maximum endurance
 RHPMXE - maximum endurance referred horsepower
 FFMXE - maximum endurance fuel flow

TASCR = cruise velocity
PTCR = cruise power in horsepower
FFCR = cruise fuel flow
MXR = specification maximum range
TFUEL = total fuel required

8. Chapter Eight Variables

See program listing for variable definition.

9. Chapter Nine Variables

All variables are the same as above.

10. Chapter Ten Variables

C(X) = component cost
CE(X) = total cost
IFR = inflation rate
Q = quantity to be produced

```

1  'PROGRAM "TR1.BAS"
2  KEY OFF : FLG2=0
11
14  '*****
15  '*** TANDEM ROTOR HELICOPTER DESIGN ***
16  '*****
18  '
19  '*** ADMIN / CONTROL ***
20  '
21  PRINT "~L=TANDEM1/"
25  COLOR 1,1,1:PRINT "~C=ALL/":CLS: LOCATE 1,1,0
30  PRINT "~W=T_R_MENU/": INPUT " ",XX : PRINT "~C=ALL/" :
CLS
35  ON XX GOSUB
50,100,3000,4000,5000,6000,7000,8000,9000,9500,95
40  GOTO 25
50  LOCATE 1,1,0: PRINT "~W=INTRO/": INPUT " ",X1
55  PRINT "~C=ALL/" : RETURN 25
90
95  COLOR 1,1,1:LOCATE 1,1,0:PRINT "~W=R U SURE/"
96  INPUT " ",ANS: IF ANS = 1 THEN 25 ELSE SYSTEM
97
98  '
100  '*** PRELIMINARY ROTOR DESIGN ***
110  '
120  COLOR 1,1,1:LOCATE 1,1,0: PRINT "~C=ALL/":
PRINT "~W=PRELIM/": INPUT X2
125  COLOR 15,1 : PRINT "~C=ALL/"
130  CNT = 0
140  CLS: LOCATE 1,27 : PRINT "* PRELIMINARY ROTOR
DESIGN *"
150  PRINT
160  PRINT " 1. DESIGN MAX GROSS WEIGHT [lbs] (2.1)
170  PRINT " MGW = "
180  PRINT " 2. ESTIMATE OF EMPTY WEIGHT [lbs]
(2.2) MTW = "
190  PRINT " 3. ROTOR TIP VELOCITY (2.3; 700 fps
recommended) VT = "
200  PRINT " 4. DISC LOADING [lbs/ft^2] (2.4 ; FIG.
2-2) DL = "
210  PRINT " ROTOR RADIUS [ft]
(2.4) R = "
220  PRINT " ROTATIONAL VELOCITY [rpm]
RPM = "
230  PRINT " THRUST COEFFICIENT
(2.6) CT = "
240  PRINT " 5. SPECIFICATION MAX AIRSPEED [knots]
(2.7) TASMx = "
250  PRINT " ADVANCE RATIO (2.7)
CT/S) MU = "
260  PRINT " 6. MAX BLADE LOADING (2.7; FIG.2-3;
270  PRINT " ROTOR SOLIDITY (2.7)
(2.8) MBL = "
280  PRINT " 7. NUMBER OF ROTOR BLADES PER HEAD
S = "
290  PRINT " BLADE CHORD [ft] (2.9)
B = "
300  PRINT " ASPECT RATIO (2.9)
C = "
310  PRINT " AVG LIFT COEFF (2.10)
AR = "
320  PRINT " CL = "
330  PRINT " COLOR 14,1
340  LOCATE 23,6: PRINT "*** FOR HARD COPY PRESS
<Shift-PrtsC> BEFORE RETURNING TO MAIN MENU ***": COLOR
15,1

```

```

345 '
350 CNT = CNT + 1: J = 0
360 IF CNT = 1 THEN 370 ELSE LOCATE 21,1: PRINT
SPC(77): GOTO 410
370 FOR J = 1 TO 7
380 LOCATE 21,20 : PRINT "ENTER YOUR VALUE FOR ITEM
NUMBER " ; J
390 X = J : GOTO 430
410 LOCATE 21,11: INPUT "WHICH PARAMETER DO YOU WISH TO
CHANGE / SELECT ? " , X
430 IF X < 1 OR X > 8 THEN GOSUB 1500 : IF J = 0
THEN 410 ELSE 380
440 ON X GOSUB 510,520,530,540,550,560,570,25
450 IF CNT = 1 THEN NEXT J ELSE GOSUB 800
455 FLG1 = 1 : GOTO 350
460 '
480 ' *** PRELIM ROTOR DESIGN INPUT
SUBROUTINES ***
500 '
510 LOCATE 3,61 : PRINT SPC(7) : LOCATE 3,60 : INPUT "
" MGW
515 IF MGW <= 0 THEN PRINT "~W=DVN0/" : GOTO 510 ELSE
RETURN
520 LOCATE 4,61 : PRINT SPC(7) : LOCATE 4,60 : INPUT "
" MTW
525 IF MTW <= 0 THEN PRINT "~W=DVN0/" : GOTO 520 ELSE
RETURN
530 LOCATE 5,61 : PRINT SPC(7) : LOCATE 5,60 : INPUT "
" VT
535 IF VT <= 0 THEN PRINT "~W=DVN0/" : GOTO 530 ELSE
RETURN
540 LOCATE 6,61 : PRINT SPC(7) : LOCATE 6,60 : INPUT "
" DL
545 IF DL <= 0 THEN PRINT "~W=DVN0/" : GOTO 540 ELSE
GOSUB 630 : RETURN
550 LOCATE 10,61: PRINT SPC(7) : LOCATE 10,60: INPUT "
" TASMX
555 IF TASMX <= 0 THEN PRINT "~W=DVN0/": GOTO 550 ELSE
GOSUB 690 : RETURN
560 LOCATE 12,61: PRINT SPC(7) : LOCATE 12,60: INPUT "
" MBL
565 IF MBL <= 0 THEN PRINT "~W=DVN0/" : GOTO 560 ELSE
GOSUB 710 : RETURN
570 LOCATE 14,61: PRINT SPC(7) : LOCATE 14,60: INPUT "
" B
575 IF B <= 0 THEN PRINT "~W=DVN0/" : GOTO 570 ELSE
GOSUB 730 : RETURN
590 '
600 ' *** PRELIMINARY ROTOR DESIGN EQUATIONS AND
OUTPUT ***
610 '
630 PIE = 3.141592 : RHO0 = .0023769 : RHO = .0023769
636 R = SQR(ABS (.5 * MGW / (DL * PIE)))
640 RPM = VT * 9.55 / R
650 CT = MGW / (2 * RHO * PIE * R * R * VT * VT)
660 LOCATE 7,52 : PRINT USING "####.####" : R
670 LOCATE 8,52 : PRINT USING "####.####" : RPM
680 LOCATE 9,52 : PRINT USING "####.####" : CT :
RETURN
690 MU = TASMX * 1.68893 / VT
700 LOCATE 11,52 : PRINT USING "####.####" : MU :
RETURN
710 ' *** solidity calcn ***
715 S = CT / MBL
720 LOCATE 13,52 : PRINT USING "####.####" : S :
RETURN
730 ' *** chord, aspect ratio, and lift coeff ***
735 C = S * PIE * R / B

```

```

740     AR = R/C
750     CL= CT * 6 / S
770 LOCATE 15, 52 : PRINT USING "####.####" : C
780 LOCATE 16, 52 : PRINT USING "####.####" : AR
790 LOCATE 17, 52 : PRINT USING "####.####" :
CL: RETURN
800
820     *** PRELIMINARY ROTOR DESIGN SUBROUTINE ***
840
850     R = SQR(ABS (.5 * MGW/(DL * PIE)))
860     RPM = VT * 9.55 / R
870     CT = .5 * MGW / ((RHO * PIE * R * R * VT * VT))
880 LOCATE 7, 52 : PRINT USING "####.####" : R
890 LOCATE 8, 52 : PRINT USING "####.####" : RPM
900 LOCATE 9, 52 : PRINT USING "####.####" : CT
910     MU = TASM * 1.688 / VT
920 LOCATE 11, 52 : PRINT USING "####.####" : MU
935     S = CT/MBL
940 LOCATE 13, 52 : PRINT USING "####.####" : S
950     C = S * PIE * R / B
960     AR = R/C
970     CL= CT * 6 / S
980 LOCATE 15, 52 : PRINT USING "####.####" : C
990 LOCATE 16, 52 : PRINT USING "####.####" : AR
1000 LOCATE 17, 52 : PRINT USING "####.####" : CL: RETURN
1500 LOCATE 1, 10 : PRINT "~W=TRYAGAIN/": LOCATE 23, 1:
PRINT, SPC(77): RETURN
2000
3000     LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : FLG2=1:
CHAIN "TR3", ALL
4000 LOCATE 1, 1, 0 : PRINT "~W=BLDOPT/" : INPUT "", X4: GOTO 25
5000 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR5", ALL
6000 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR6", ALL
7000 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR7", ALL
8000 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR8", ALL
9000 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR9", ALL
9500 LOCATE 1, 1, 0 : PRINT "~W=LOADNOTE/" : CHAIN "TR10", ALL
9999 END
1020 ' PROGRAM "TR3.BAS"...17 SEPT 87
1021
*****
1022 ' * *** TANDEM ROTOR SYSTEM DESIGN & WEIGHT
ESTIMATION *** *
1023
*****
1024 ' PLEASE NOTE: USING BASICA TO RUN THIS PROGRAM
WILL CAUSE THE INPUT LINE TO BE DELETED IF THE FLASHUP
HELPWINDOW IS DISPLAYED !
1025
DIM
W(20, 20), GW(20), WE(20), W6(10), W6A(10), W6B(10), W6C(10), -
PDW(9)
1030 PIE = 3.141592 : RHO0 = .002377
1035 'MGW = 23000: R=25.5: C=1.5: CDO=.0089999: B = 3:
RPM = 267.4
1040 'S1= 34: GAP= 4: FHH= 16: PA=1: TAS=1: FF=44:
AGL=10:
1045 AS="#####.#" : BS="#####" : CS="###.####"
1050 PRINT "~L=TANDEM3/" : 'FLG2 = 1: FLG3 = 0
: 'FLG2: flag fm TR1 rbf, FLG3
1060 KEY OFF : COLOR 15, 1 : CLS: PRINT "~C=ALL/"
1090
1100 ' ***** POWER VARIABLES INPUT
*****
1150
1170 CNT = 1 : CLS: LOCATE 1, 22

```

```

1180 PRINT  "* TANDEM  ROTOR SYSTEM  DESIGN  *"
(Alt-F1 for help)"
1190 PRINT
1200 PRINT  "          1.  DESIGN  MAX  GROSS  WEIGHT
[lbs]  ..PRINT  .."
1210 PRINT  "          2.  ROTOR  RADIUS
[ft]  ..PRINT  .."
1220 PRINT  "          3.  BLADE  CHORD  [ft]
C = "
1230 PRINT  "          4.  BLADE  PROFILE  DRAG  COEFFICIENT
CDO = "
1240 PRINT  "          5.  NUMBER  OF  ROTOR  BLADES  PER  HEAD
B = "
1250 PRINT  "          6.  OPERATING  RPM  [rpm]
RPM = "
1260 PRINT  "          7.  ROTOR  SHAFT  SPACING  [ft]
S1 = "
1270 PRINT  "          8.  ROTOR  HEAD  VERTICAL  SPACING  [ft]
GAP = "
1280 PRINT  "          9.  HEIGHT  OF  FORWARD  HEAD  ABOVE
WHEELS [ft] ..FHH = "
1290 PRINT  "         10.  PRESSURE  ALTITUDE  [ft  MSL]
PA = "
1300 PRINT  "         11.  HOVER  ALTITUDE  [ft  AGL]
AGL = "
1310 PRINT  "         12.  TRUE  AIRSPEED  [knots]  (0  FOR
HOVER) ..TAS = "
1320 PRINT  "         13.  EQUIVALENT  FRONTAL  AREA  [ft^2]
FF = "
1325 COLOR 14,1
1330 PRINT  "         14.  COMPONENT  WEIGHT  ESTIMATES  15.
RETURN  TO  MAIN  MENU"
1331 COLOR 15,1
1332 IF  FLG2 = 1 THEN 1335 ELSE 1375
1335 'load data from previous chapter, if applicable;
or allows input!
1336
1338 IF  MGW <>0 THEN LOCATE 3,61: PRINT USING A$; MGW
ELSE GOSUB 1500
1340 IF  R <>0 THEN LOCATE 4,61: PRINT USING A$; R
ELSE GOSUB 1520
1342 IF  C <>0 THEN LOCATE 5,61: PRINT USING A$; C
ELSE GOSUB 1540
1344 IF  CDO <>0 THEN LOCATE 6,61: PRINT USING C$; CDO
ELSE GOSUB 1560
1346 IF  B <>0 THEN LOCATE 7,61: PRINT USING B$; B
ELSE GOSUB 1580
1348 IF  RPM <>0 THEN LOCATE 8,61: PRINT USING A$; RPM
ELSE GOSUB 1600
1350 IF  S1 <>0 THEN LOCATE 9,61: PRINT USING A$; S1
ELSE GOSUB 1620
1352 IF  GAP <>0 THEN LOCATE 10,61: PRINT USING A$; GAP
ELSE GOSUB 1640
1354 IF  FHH <>0 THEN LOCATE 11,61: PRINT USING A$; FHH
ELSE GOSUB 1660
1356 IF  PA =>0 THEN LOCATE 12,61: PRINT USING B$; PA
ELSE GOSUB 1680
1358 IF  AGL <>0 THEN LOCATE 13,61: PRINT USING B$; AGL
ELSE GOSUB 1700
1360 IF  TAS =>0 THEN LOCATE 14,61: PRINT USING B$; TAS
ELSE GOSUB 1720
1362 IF  FF <>0 THEN LOCATE 15,61: PRINT USING A$; FF
ELSE GOSUB 1740
1364 GOSUB 1770 : GOSUB 2140
1366
1370 CNT = CNT + 1: J = 0
1375 IF  CNT = 1 THEN 1380 ELSE LOCATE 23,1: PRINT
SPC(77): GOTO 1420

```

```

1380   FOR J = 1 TO 13
1390   LOCATE 23,20:PRINT "ENTER YOUR VALUE FOR ITEM
NUMBER " ; J
1400   X = J : GOTO 1440
1420   LOCATE 23,11:INPUT"WHICH PARAMETER DO YOU WISH
TO SELECT / CHANGE " ; X
1440   IF X < 1 OR X > 15 THEN GOSUB 4500: IF J = 0
THEN 1420 ELSE 1390
1450   ON X GOSUB 1500,1520,1540,1560,1580,1600,1620,
1640,1660,1680,1700,1720,1740,2250,9000
1460   IF CNT = 1 THEN NEXT J
1470   FLG2 = 1 : GOTO 1370
1480   '***** DATA ENTRY SUBROUTINES
*****
1490   '
1500   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW1/"
1505   LOCATE 3,61:PRINT SPC(8):LOCATE 3,60:INPUT" ",MGW:
PRINT"~K={ALT-F1}/"
1510   IF MGW <= 0 THEN PRINT"~W=DVN0/": GOTO 1500
1515   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1520   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW2/"
1522   LOCATE 4,61:PRINT SPC(8): LOCATE 4,60:INPUT" ",R
: PRINT"~K={ALT-F1}/"
1524   IF R <= 0 THEN PRINT"~W=DVN0/": GOTO 1520 ELSE
1526   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1540   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW3/"
1542   LOCATE 5,61:PRINT SPC(8):LOCATE 5,60:INPUT" ",C :
PRINT"~K={ALT-F1}/"
1544   IF C <= 0 THEN PRINT"~W=DVN0/": GOTO 1540 ELSE
1546   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1560   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW4/"
1565   LOCATE 6,61:PRINT SPC(8):LOCATE 6,60: INPUT"
",CDO:PRINT"~K={ALT-F1}/"
1570   IF CDO <= 0 THEN PRINT"~W=DVN0/": GOTO 1560 ELSE
1575   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1580   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW5/"
1585   LOCATE 7,61:PRINT SPC(8):LOCATE 7,60: INPUT" ",B:
PRINT"~K={ALT-F1}/"
1590   IF B <= 0 THEN PRINT"~W=DVN0/": GOTO 1580 ELSE
1595   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1600   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW6/"
1610   LOCATE 8,61:PRINT SPC(8):LOCATE 8,60: INPUT" ",RPM
:PRINT"~K={ALT-F1}/"
1615   IF RPM <= 0 THEN PRINT"~W=DVN0/": GOTO 1600 ELSE
1618   IF CNT>1 THEN GOSUB 1770:GOSUB 2140: RETURN ELSE
RETURN
1620   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW7/"
1630   LOCATE 9,61:PRINT SPC(8):LOCATE 9,60: INPUT" ",S1
1635   PRINT"~K={ALT-F1}/" : IF CNT>1 THEN GOSUB 1770:GOSUB
2140: RETURN ELSE RETURN
1640   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW8/"
1650   LOCATE 10,61: PRINT SPC(8):LOCATE 10,60:INPUT"
",GAP
1655   PRINT"~K={ALT-F1}/" : IF CNT>1 THEN GOSUB
1770:GOSUB 2140: RETURN ELSE RETURN
1660   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW9/"
1665   LOCATE 11,61:PRINT SPC(8):LOCATE 11,60:INPUT"
",FHH:PRINT"~K={ALT-F1}/"
1670   IF FHH <= 0 THEN PRINT"~W=DVN0/": GOTO 1660 ELSE
1675   IF CNT>1 THEN GOSUB 1770:GOSUB 2140 : RETURN ELSE
RETURN
1680   LOCATE 1,1,0: PRINT"~K={ALT-F1},HW10/"

```

```

1685 LOCATE 12,61:PRINT SPC(8):LOCATE 12,60: INPUT"
1690 PA
1700 PRINT "~K=(ALT-F1)/" : IF CNT>1 THEN GOSUB
1710 GOSUB 2140: RETURN ELSE RETURN
1720 LOCATE 1,1,0: PRINT "~K=(ALT-F1),HW11/"
1730 ACCL LOCATE 13,61:PRINT SPC(8):LOCATE 13,60: INPUT"
1740 PA
1750 PRINT "~K=(ALT-F1)/" : IF CNT>1 THEN GOSUB
1760 GOSUB 2140: RETURN ELSE RETURN
1770 LOCATE 1,1,0: PRINT "~K=(ALT-F1),HW12/"
1780 AS LOCATE 14,61:PRINT SPC(8):LOCATE 14,60: INPUT"
1790 PA
1800 PRINT "~K=(ALT-F1)/" : IF CNT>1 THEN GOSUB
1810 GOSUB 2140: RETURN ELSE RETURN
1820 LOCATE 1,1,0: PRINT "~K=(ALT-F1),HW13/"
1830 AS LOCATE 15,61:PRINT SPC(8):LOCATE 15,60: INPUT"
1840 PA
1850 PRINT "~K=(ALT-F1)/"
1860 IF FF <= 0 THEN PRINT "~W=DVN0/":GOTO 1740 ELSE
GOSUB 1770
1870 GOSUB 2140: RETURN : '1460
1880
1890 ***** POWER COMPUTATION SUBR
1900 *****
1910 N = 1 :GW(1) = MGW : 'subr access from line 1755
1920
1930 'N = 1 thru 5 as sent from weight comp admin subr.
1940 GW(1) = .8 * MGW
1950 CNT = CNT + 1
1960 RHT = FHH + 5 * GAP
1970 GE = (AQL+RTRHT) / (2*R)
1980 GE^4 = .5147 + 1.3432*GE - 1.457*GE^2 + .708*GE^3 -
1990 RV^4 = RPM/9.55 : VT = RV * R : VF = TAS *
2000
2010 SIGMA = (1 - 6.87535E-06 * PA)^4.2561
2020 IF PA=0 THEN RHO=RHO0 ELSE IF PA=4000 THEN
RHO = .001918 ELSE RHO = SIGMA * RHO0 : 'lb-sec^2/ft^4
2030 MU = VF / VT
2040 S1 = 1.055 * GW(N)
2050 PLOSS = C / ((PI * R) / (SQR(2 * CT) / B))
2060 S1 = S1 * TIPLOSS
2070 RE^2 = (PI - (PI/180)*ACOS(S1/(2*RE))) +
2080 CT / (S1 * RHO * AE * VT^2)
2090 AV = 1.46 * R^2.53 * SR
2100 VI = SQR(T / (2 * RHO * AE))
2110 KU = SQR(SQR(1 + .25 * ((AV/AE) * (VF/VI))^4) -
2120 (AV/AE) * (VF/VI))
2130 DL = GW(N) / AE
2140 CT = CT / S
2150 IF B * CT / S1 > 3.75 THEN COLOR 1,1,1:LOCATE 1,1,0:
PRINT "~W=BLDSTRK/":INPUT X4:PRINT "~C=ALL/": COLOR 15,i
2160
2170 ***** POWER CALCULATION *****
2180
2190 IF GE <= 2 THEN PI = PGE * T * VI * K * KU / 550
2200
2210 PI = T * VI * K * KU / 550
2220 PO = (CDO * B * C * R * VT^3 * RHO / 2200) * (1 + 4.3
2230 MU^2)
2240 PP = VF^3 * FF * RHO / 1100
2250 PC = (T * VV + RHO * FF * VV^3) / 1100
2260 FM = PI / (PI + PO)

```

```

2110 PT = PI + PO + PP + PC
2120 RETURN
2130 '
2140 ' ***** POWER RESULTS OUTPUT SUBR
*****
2150 '
2170 LOCATE 17,34:PRINT "-- RESULTS --"
2180 LOCATE 18,14:PRINT USING"PI = ####.##": PI
2190 LOCATE 19,14:PRINT USING"PO = ####.##": PO
2200 LOCATE 20,14:PRINT USING"PP = ####.##": PP
2210 LOCATE 21,14:PRINT USING"PC = ####.##": PC
2220 LOCATE 22,14:PRINT USING"PT = ####.##": PT:LOCATE
22,29:PRINT "HP"
2230 LOCATE 18,46:PRINT USING"FM = ###.##": FM:LOCATE
18,59:PRINT"(.75 to .85) *HOVER
2232 LOCATE 19,46:PRINT USING"DL = ###.##": DL:LOCATE
19,59:PRINT"( 5 to 15 ) ONLY
2234 LOCATE 20,46:PRINT USING"CL = ###.##": CL:LOCATE
20,59:PRINT"(CLmax; 1.55)
2236 LOCATE 21,46:PRINT USING"AR = ###.##": AR:LOCATE
21,59:PRINT"( 15 to 20 )
2238 LOCATE 22,46:PRINT USING"BL = ##.###": BL:LOCATE
22,59:PRINT"(BLmax; 0.12)
2239 '
2240 RETURN :returns to 1366 or 1460
2249 '
2250 ' ***** COMPONENT WEIGHT APROX INPUT SUBR
*****
2251 '
2252 'FLG3=1: GEAR=1: ENGN=1: FUEL=2500: PEOPLE=25:
SPECIAL=100: UL=1000:'remove before flight
2253 CLS:PRINT"~C=ALL/":LOCATE 1,1,0:PRINT"~w=WT_EST/":
INPUT" X3:PRINT"~C=ALL/":CLS
2255 LOCATE 1,22:PRINT" * COMPONENT WEIGHT
APPROXIMATIONS * (Alt-F1 for help)"
2260 PRINT"~K={ALT-F1},WTAPRXHW/"
2265 IF FLG3 = 1 THEN 2360 ELSE
2270 ' ***** SUPPLEMENTARY DATA INPUT
*****
2271 '
2272 LOCATE 3,2: PRINT"1. TYPE LNDG GEAR (TRICYCLE
STYLE)"
2276 LOCATE 4,2: INPUT" 1=FIXED 2=RETRACTABLE
" GEAR
2280 LOCATE 5,2: INPUT"2. NUMBER OF ENGINES (2 or more)
" ENGN
2285 LOCATE 6,2: INPUT"3. ESTIMATED FUEL CAPACITY
(lbs) " FUEL
2290 LOCATE 7,2: INPUT"4. NUMBER OF CREW AND PASSENGERS
" PEOPLE
2292 LOCATE 8,2: INPUT"5. WT OF SPECIAL AVIONICS (lbs)
" SPECIAL
2294 LOCATE 9,2: INPUT"6. SPECIFICATION USEFUL LOAD
(lbs) " UL
2295 GOSUB 3000
2296 COLOR 14,1:LOCATE 10,2: PRINT"7. RETURN TO TANDEM
ROTOR SYSTEM DESIGN"
2298 LOCATE 12,2: PRINT SPC(40) : FLG3 = 1
2300 LOCATE 12,2: INPUT" SELECTION ? (1 thru 6 for
changes) " X:COLOR 15,1
2307 IF X = 7 THEN PRINT"~K={ALT-F1}/"
2310 IF X < 1 OR X > 7 THEN BEEP:GOTO 2296 ELSE
2315 ON X GOSUB 2320,2325,2330,2335,2340,2345,1100:
GOSUB 3000:GOTO 2296
2320 LOCATE 4,39: PRINT SPC(6): LOCATE 4,38:INPUT"
" GEAR:RETURN
2325 LOCATE 5,39: PRINT SPC(6): LOCATE 5,38:INPUT"
" ENGN:RETURN

```



```

2560 LOCATE 13,2:
PRINT "====="
2565 LOCATE 14,5: PRINT USING"SPEC MAX GROSS WT (MGW)
= #####.## lbs":MGW
2570 LOCATE 15,5: PRINT USING" NEW A/C EMPTY WT
= #####.##":WE(NN)
2574 LOCATE 16,5: PRINT USING" FUEL WT
= #####.##":FUEL
2580 LOCATE 17,5: PRINT USING" PERSONNEL WT
= #####.##":PAX
2582 LOCATE 18,5: PRINT USING" USEFUL LOAD
= #####.##":UL
LOCATE 19,2:
PRINT "-----"
2587 LOCATE 20,5: PRINT USING" NEW GROSS WT ESTIMATE
= #####.## lbs":NGWE(NN)
2590 LOCATE 21,5: PRINT USING" TOTAL POWER FOR HOVER
= #####.## SHP":PT
2600 LOCATE 23,22: PRINT " * press <Shift-PrtSc> for
hard copy "
2620 FLG3=1 : RETURN
3000 ***** WEIGHT COMPUTATION SUBR
3001 *****
3005 N = 0 : PRINT"~W=COMP/"
3010 FOR N = 1 TO 5
3020 IF MTW<>0 THEN WE(1)=MTW ELSE
WE(1) = .7407*MGW-2500
3040 GOSUB 1800 : 'computes PT,PI and PO based on
GW(N)
3050 HP = PT
3060 GOSUB 4000 : ' computes new GW est based on
previous GW and HP
3070 NEXT N
3100 NN = 0 : PDW(0) = 10
3110 N = 0 : FOR N = 1 TO 5
3120 IF PDW(N) < 10 THEN 3130 ELSE 3140
3130 IF PDW(N) < PDW(N-1) THEN NN = N ELSE
3140 NEXT N
3150 IF NN = 0 THEN LOCATE 1,1,0: PRINT"~W=NOTCONVG/":
INPUT ".X3: NN = 1
3160
3200 PRINT"~C=ALL/" : GOSUB 2465 : RETURN : 'output
results
3990 ***** HELO COMPONENT WT EQN'S SUBR
4000 *****
4010
4020 PAX = PEOPLE * 250
4030 SB = 567.688 * EXP(.000041 * GW(N))
4050 W(1,N) = 1414.348 * EXP(.00539*B*C*R) : W(2,N) =
0
4060 W(3,N) = 3467.29 * LOG(SB) - 22118.3
4070 W(4,N) = .4013 * GW(N)^.6662 * GEAR * 3^.536
4080 W(5,N) = .014 * (.2014 * GW(N))^1.136
4090 W6A(N) = 565.507 * EXP(.000198 * HP)
4100 W6B(N) = .999 * (HP)^.959
4110 W6C(N) = 454.619*(FUEL /6.5)^-.0566 : W(6,N) =
W6A(N)+W6B(N)+W6C(N)
4120 W(7,N) = .00334 * (GW(N))^1.224
4130 W(8,N) = 139
4140 W(9,N) = 68.226 * LOG(HP) - 387.598
4150 W(10,N) = 6.63E-07 * (GW(N))^1.863
4160 W(11,N) = 9.78 * (SB)^.539
4170 W(12,N) = 325 + SPECIAL
4175 W(13,N) = .159 * SB +18.11 * PEOPLE
4180 W(14,N) = 117.771 * LOG(SB) -710.594

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```

4190 W(15,N) = .111 * SB + 3.49 * PEOPLE - 72
4200 I=0:WE(N)=0:FOR I=1 TO 15:WE(N)=W(I,N)+WE(N):NEXT
I:weight summation
4210 GW(N+1) = WE(N) + UL + PAX + FUEL
4215 NGWE(N) = WE(N) + UL + PAX + FUEL
4220 PDW(N) = 100*ABS(1 - (GW(N+1)/GW(N)))
4300 RETURN
4500 LOCATE 1,1,0: PRINT "~W=TRYAGAIN/": LOCATE 23,1:
PRINT SPC(77): RETURN
9000 CLS: GW=MGW: FLG2=1:PRINT "~C=ALL/":
PRINT "~W=LOADNOTE/": CHAIN"TR1",,ALL
9999 END
10 PROGRAM "TR5.BAS"...17 SEPT 87
20
'*****
30 '*** POWER REFINEMENTS PROGRAM w/HIGH SPEED EFFECTS
***
40
'*****
44 DIM
TAS(300),PI(300),PO(300),PP(300),PT(300),PS(300), PM(3-
00)
50 KEY OFF : A$="#####.#" : B$="#####":
C$="###.###"
51 IF ENGN=0 THEN ENGN=2
52 GW = 23000 : R = 25.5 : C = 1.5 : CDO = 8.999999E-03
: B = 3 : RPM = 267.4 : S1 = 34 : GAP = 4 : FHH = 12 :
PASPEC = 4000 : FF = 44 : AGL = 10 : FLG3 = 1 : MXHVR = 10000
: CLALFA = 5.73 : AOAST = 14 : TWIST = -9.5 : MCRT = .8
58 TASC = 130 : TASM = 150
70 COLOR 15,1 : PRINT "~L=TANDEM3/" : PRINT "~C=ALL/"
90 '*** INPUT VARIABLES ***
100 CLS: CNT = 0
120 LOCATE 1,12: PRINT "* HIGH SPEED EFFECTS AND POWER
SUMMARY * {Alt-F1 for HELP}"
130 PRINT
140 PRINT " 1. GROSS WEIGHT [lbs]
150 PRINT ".....GW = "
160 PRINT " 2. ROTOR RADIUS
[ft].....R = "
160 PRINT " 3. BLADE DATA: CHORD [ft]
.....C = "
170 PRINT " 4. PROFILE DRAG COEFFICIENT
.....CDO = "
180 PRINT " 5. LIFT CURVE SLOPE [per RAD]
.....CLALFA = "
190 PRINT " 6. STALL ANGLE OF ATTACK [deg]
.....AOAST = "
200 PRINT " 7. GEOMETRIC TWIST [deg with
sign].....TWIST = "
210 PRINT " 8. CRITICAL MACH NUMBER
.....MCRT = "
220 PRINT " 9. NUMBER OF ROTOR BLADES PER HEAD
.....B = "
230 PRINT " 10. OPERATING RPM [rpm]
.....RPM = "
240 PRINT " 11. ROTOR SHAFT SPACING [ft]
.....S1 = "
250 PRINT " 12. ROTOR HEAD VERTICAL SPACING [ft]
.....GAP = "
260 PRINT " 13. HEIGHT OF FORWARD HEAD ABOVE WHEELS
[ft].....FHH = "
270 PRINT " 14. SPEC PRESSURE ALT [normally 4000 ft
MSL].....PASPEC = "
280 PRINT " 15. HOVER ALTITUDE [ft AGL]
.....AGL = "
290 PRINT " 16. SPEC CRUISE AIRSPEED [knots]
.....TASC = "

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300 PRINT "          17. SPEC MAX AIRSPEED [knots]
310 PRINT "          18. EQUIVALENT FRONTAL AREA [ft^2]
320 PRINT "          19. SPEC MAX HOVER ALTITUDE (IGE) [ft]
325 COLOR 14,1
330 PRINT "          20. COMPUTE NEW POWER REQUIREMENTS
21. RETURN TO MAIN MENU"
335 COLOR 15,1
340 IF FLG3 = 1 THEN 350 ELSE 560
350 'load data from previous chapter, if applicable; or
allows input!
370 IF GW <> 0 THEN LOCATE 3,61: PRINT USING A$; GW
ELSE GOSUB 710
380 IF R <> 0 THEN LOCATE 4,61: PRINT USING A$; R
ELSE GOSUB 750
390 IF C <> 0 THEN LOCATE 5,61: PRINT USING A$; C
ELSE GOSUB 790
400 IF CDO <> 0 THEN LOCATE 6,61: PRINT USING C$; CDO
ELSE GOSUB 830
410 IF CLALFA <> 0 THEN LOCATE 7,61: PRINT USING
A$:CLALFA ELSE GOSUB 870
420 IF AOAST <> 0 THEN LOCATE 8,61: PRINT USING
A$:AOAST ELSE GOSUB 910
430 IF TWIST <> 0 THEN LOCATE 9,61: PRINT USING
A$:TWIST ELSE GOSUB 950
440 IF MCRT <> 0 THEN LOCATE 10,61: PRINT USING A$;MCRT
ELSE GOSUB 980
450 IF B <> 0 THEN LOCATE 11,61: PRINT USING B$;B
ELSE GOSUB 1010
460 IF RPM <> 0 THEN LOCATE 12,61: PRINT USING A$;RPM
ELSE GOSUB 1180
470 IF S1 <> 0 THEN LOCATE 13,61: PRINT USING A$;S1
ELSE GOSUB 1080
480 IF GAP <> 0 THEN LOCATE 14,61: PRINT USING A$;GAP
ELSE GOSUB 1110
490 IF FHH <> 0 THEN LOCATE 15,61: PRINT USING A$;FHH
ELSE GOSUB 1140
500 IF PASPEC <> 0 THEN LOCATE 16,61: PRINT USING
B$:PASPEC ELSE GOSUB 1180
510 IF AGL <> 0 THEN LOCATE 17,61: PRINT USING B$;AGL
ELSE GOSUB 1190
520 IF TASCRC <> 0 THEN LOCATE 18,61: PRINT USING
B$:TASCRC ELSE GOSUB 1200
530 IF TASMXX <> 0 THEN LOCATE 19,61: PRINT USING
B$:TASMXX ELSE GOSUB 1210
540 IF FF <> 0 THEN LOCATE 20,61: PRINT USING A$;FF
ELSE GOSUB 1220
545 IF MXHVR <> 0 THEN LOCATE 21,61: PRINT USING
B$:MXHVR ELSE GOSUB 1225
550 CNT = 1: J = 0
560 IF CNT = 0 THEN 570 ELSE LOCATE 23,1:PRINT SPC(77):
GOTO 610
570 FOR J = 1 TO 19
580 LOCATE 23,20:PRINT "ENTER YOUR VALUE FOR ITEM
NUMBER " ;J
590 X = J : GOTO 630
610 LOCATE 23,18:INPUT"WHICH DO YOU WISH TO CHANGE /
SELECT " ;X
630 IF X < 1 OR X > 21 THEN GOSUB 4500: IF J = 0
THEN 610 ELSE 580
640 ON X GOSUB 710,750,790,830,870,910,950,980,
1010,1050,1080,1110,1140,1180,1190,1200,1210,1220,1225,
1230,9000
650 IF CNT = 0 THEN NEXT J ELSE 550
660 GOTO 550
670

```

```

680 ,
710 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW1/": LOCATE 3,61:
PRINT SPC(8): LOCATE 3,60: INPUT " ",GW
PRINT "~K={ALT-F1}/" : IF GW <= 0 THEN PRINT "~W=DVN0/" :
GOTO 710 ELSE RETURN
750 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW2/": LOCATE 4,61:
PRINT SPC(8): LOCATE 4,60: INPUT " ",R
PRINT "~K={ALT-F1}/" : IF R <= 0 THEN PRINT "~W=DVN0/" :
GOTO 750 ELSE RETURN
790 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW3/": LOCATE 5,61:
PRINT SPC(8): LOCATE 5,60: INPUT " ",C
PRINT "~K={ALT-F1}/" : IF C <= 0 THEN PRINT "~W=DVN0/" :
GOTO 790 ELSE RETURN
830 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW4/": LOCATE 6,61:
PRINT SPC(8): LOCATE 6,60: INPUT "
" CDO: PRINT "~K={ALT-F1}/"
850 IF CDO <= 0 THEN PRINT "~W=DVN0/" : GOTO 830 ELSE
RETURN
870 LOCATE 1,1,0: PRINT "~K={ALT-F1},CLALPHA/": LOCATE
7,61: PRINT SPC(8)
880 LOCATE 7,60: INPUT " ",CLALFA: PRINT "~K={ALT-F1}/"
890 IF CLALFA <= 0 THEN PRINT "~W=DVN0/" : GOTO 870
ELSE RETURN
910 LOCATE 1,1,0: PRINT "~K={ALT-F1},STALLAOA/": LOCATE
8,61: PRINT SPC(8)
920 LOCATE 8,60: INPUT " ",AOAST : PRINT "~K={ALT-F1}/"
930 IF AOAST <= 0 THEN PRINT "~W=DVN0/" : GOTO 910 ELSE
RETURN
950 LOCATE 1,1,0: PRINT "~K={ALT-F1},BLDTWIST/": LOCATE
9,61: PRINT SPC(8)
960 LOCATE 9,60: INPUT " ",TWIST : PRINT "~K={ALT-F1}/"
: RETURN
980 LOCATE 1,1,0: PRINT "~K={ALT-F1},MCRIT/": LOCATE
10,61: PRINT SPC(8)
990 LOCATE 10,60: INPUT " ",MCRT : PRINT "~K={ALT-F1}/"
1000 IF MCRT <= 0 THEN PRINT "~W=DVN0/" : GOTO 980 ELSE
RETURN
1010 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW5/": LOCATE
11,61: PRINT SPC(8)
1020 LOCATE 11,60: INPUT " ",B : PRINT "~K={ALT-F1}/"
1030 IF B <= 0 THEN PRINT "~W=DVN0/" : GOTO 1010
ELSE RETURN
1050 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW6/": LOCATE
12,61: PRINT SPC(8)
1060 LOCATE 12,60: INPUT " ",RPM : PRINT "~K={ALT-F1}/"
1070 IF RPM <= 0 THEN PRINT "~W=DVN0/" : GOTO 1050 ELSE
RETURN
1080 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW7/": LOCATE
13,61: PRINT SPC(8)
1090 LOCATE 13,60: INPUT " ",S1 : PRINT "~K={ALT-F1}/"
: RETURN
1110 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW8/": LOCATE
14,61: PRINT SPC(8)
1120 LOCATE 14,60: INPUT " ",GAP : PRINT "~K={ALT-F1}/"
: RETURN
1140 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW9/": LOCATE
15,61: PRINT SPC(8)
1150 LOCATE 15,60: INPUT " ",FHH : PRINT "~K={ALT-F1}/"
1160 IF FHH <= 0 THEN PRINT "~W=DVN0/" : GOTO 1140 ELSE
RETURN
1180 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW10/": LOCATE
16,61: PRINT SPC(8)
1185 LOCATE 16,60: INPUT " ",PASPEC :
PRINT "~K={ALT-F1}/" : RETURN
1190 LOCATE 1,1,0: PRINT "~K={ALT-F1},HW11/": LOCATE
17,61: PRINT SPC(8)
1192 LOCATE 17,60: INPUT " ",AGL : PRINT "~K={ALT-F1}/"
: RETURN

```

```

200 LOCATE 1,1,0: PRINT "~K=(ALT-F1),TASCRUZ/": LOCATE
2061:PRINT SPC(8)
205 LOCATE 18,60:INPUT " ",TASCR: PRINT "~K=(ALT-F1)/"
RETURN
210 LOCATE 1,1,0: PRINT "~K=(ALT-F1),HW12/": LOCATE
2161:PRINT SPC(8)
212 LOCATE 19,60:INPUT " ",TASMX: PRINT "~K=(ALT-F1)/"
RETURN
220 LOCATE 1,1,0: PRINT "~K=(ALT-F1),HW13/": LOCATE
2261:PRINT SPC(8)
222 LOCATE 20,60:INPUT " ",FF : PRINT "~K=(ALT-F1)/"
223 IF FF <= 0 THEN PRINT "~W=DVN0/": GOTO 1220 ELSE
RETURN
1225 LOCATE 1,1,0: PRINT "~K=(ALT-F1),MXHVRALT/": LOCATE
2161:PRINT SPC(8)
1227 LOCATE 21,60:INPUT " ",MXHVR: PRINT "~K=(ALT-F1)/"
1228 IF MXHVR <= 0 THEN PRINT "~W=DVN0/": GOTO 1225
ELSE RETURN
1230 ***** ADMIN/CONTROL SUBR
*****
123 LOCATE 23,1: PRINT SPC(77)
123 LOCATE 23,13:INPUT "press <Shift-PrtSc> for hard
copy ENTER to continue",X5
1235 CLS: LOCATE 1,1,0: PRINT "~W=COMP/"
1237 I=299:TAS(I) = 0:PA = MXHVR:TEMP=59: GOSUB 1300:
PSPEC: HVR = PT(I)
1240 I=298:TAS(I)=TASCR: PA=PASPEC: TEMP=95: GOSUB
1300:GOSUB 1800: PTCRSP=PT(I)
1250 I=0:PA=0: TEMP=59
1260 FOR I=0 TO TASM X + 30 STEP 10
1270 TAS(I) = I : GOSUB 1300 : GOSUB 1800 :
compute power and hse
1280 NEXT I : PRINT "~C=ALL/": BEEP: CLS: GOSUB 3000 :
print out results
1290 LOCATE 23,1: PRINT SPC(77)
1292 LOCATE 23,13:INPUT "press <Shift-PrtSc> for hard
copy ENTER to continue",X5
1294 GOTO 4000 : calc losses due to inlets,EAPS and
EEDS
1300 ***** POWER COMPUTATION SUBR
*****
1301 PIE = 3.141592: RHO0 = 2.37691E-03 : RAD = 57.296
: VV = FPM/60 = 0
1302 CNT = CNT + 1 : RTRHT = FHH + .5 * GAP : GE =
(AG - RTRHT) / (2 * R)
1303 GE = .5147 + 1.3432 * GE - 1.457 * GE^2 + .708 * GE^3 -
.12 * GE^4
1304 VT = RPM/9.55 : VT = RV * R : VF = TAS(I) *
DELTA=(1-6.87535E-06*PA)^5.256 : THETA =
(9.69)/518.69
1305 MA = DELTA / THETA : RHO =
00
1306 = VF / VT : T = GW : S = B * C / (PIE
* R
1307 LOSS=1-( SQR(2 * CT) / B) : RE = R *
: SR = S1 / R
1308 = 2 * RE^2 * (PIE - (PIE/180) * ACOS(S1 / (2 * RE))) +
S1^2 - S1^2 / 4
1309 GW / ( RHO * AE * VT^2 ) : VI =
SQR( RHO * AE )
1310 1.46 - .253 * SR : AV = PIE * R^2 - 2 * R * GAP
1311 = SQR( SQR( (.25 * (AV/AE)^4 * (VF/VI)^4 + 1) -
E)^2 * (VF/VI)^2 )
1312 L = 6 * CT / S : AR = R / C : BL=CT/S : DL =
GW
1313 IE = R^2
1314 I) = T * VI * K * KU / 550
1315 GE <= 2 THEN PI(I) = PGE * T * VI * K * KU / 550

```

```

1630 PO(I) = (CDO * B * C * R * VT^3 * RHO / 2200)*(1+
4.3 * MU^2)
1640 PP(I) = VF^3 * FF * RHO / 1100
1660 PT(I) = PI(I) + PO(I) + PP(I) : FM = PI(I) /
(PI(I) + PO(I))
1680 RETURN
1800 ***** HIGH SPEED EFFECTS ROUTINE w/ CONTROL
ANGLES *****
1805 IF TAS(I)=0 THEN
PTMIN=PT(I):PTMAX=PT(I):TASMINP=TAS(I):TASMAXP=TAS(I):
RETURN
1810 IF TAS(I) < 59 THEN RETURN
1820 B1 = TIPLOSS : T7 = TWIST/RAD : VIFF = (T/(2 *
RHO * AE * VF))
1890 LAMDA = -(PP(I)*550/GW + VIFF)/VT
1900 T1 = .5*(B1^2+.5*MU^2) : T2 = B1^3 /3 +
.5*MU^2*B1
1920 T3 = .25* B1^2 *(B1^2 + MU^2) : T4 = .5* MU*
(B1^2 + MU^2/4)
1940 J2 = 2 * CT / (CLALFA *S) : J3 = LAMDA *T1 : J4
= J2 - J3 - (T7 * T3)
1960 A11 = (4*((MU*(B1^2)/2)-(MU^3/8)))/(B1^2*(B1^2-.5*
MU^2))
1970 A12 = 8*MU*B1/(3*(B1^2-.5*MU^2))
1980 A13 = (2*B1^2 * MU)/(B1^2 - .5 * MU^2)
1985 A14=(B1^2+1.5*MU^2)/(B1^2-.5*MU^2)
1990 J5 = -LAMDA * A11 - (T7*A13)
2000 H8=(J4*A14-J5*T4)/(T2*A14-T4*A12) : COLANGLE =
H8*RAD
2010 H2=(J5*T2-J4*A12)/(T2*A14-T4*A12) : CYCLIC =
H2*RAD
2030 K0= LAMDA/(1+MU) : F = H8-H2+K0+T7 : AOA270 =
F*RAD
2040 IF AOA270 < AOAST THEN PS(I)=0: GOTO 2060
2050 PS(I) = PO(I)*((AOA270 - AOAST)/4)
2060 GG = H8+H2+K0+T7 : AOA90 = GG*RAD
2070 MACHVEL
49.042*(518.67*(1-.0000068755856#*PA))^.5
2080 MTIPHVR = (RV*R)/MACHVEL : MTIPFLT =(
RV*R+VF)/MACHVEL
2090 M90 = MTIPHVR*(1+MU): IF MTIPFLT < MCRT THEN
PM(I)=0: GOTO 2120
2100 DMD = M90-MCRT : CPM=S*(.012*DMD+.1*(DMD^3)) :
PM(I)=(CPM*AE*RHO*VT^3)/550
2120 PT(I) = PI(I) + PO(I) + PP(I) + PS(I) + PM(I)
2140 IF PT(I) < PTMIN THEN PTMIN = PT(I) : TASMINP = I
2143 IF TAS(I) = TASCRT THEN PTCR = PT(I)
2145 IF TAS(I) > TASMXX THEN 2180
2150 IF PT(I) > PTMAX THEN PTMAX = PT(I) : TASMAXP = I
2180 RETURN
3000 ***** HIGH SPEED EFFECTS/POWER RESULTS
OUTPUT SUBR *****
3003 IF PSPECHVR >PTMAX THEN PTMAX = PSPECHVR: TASMAXP
= 0
3004 RSHP = PTMAX
3005 FOR I = 0 TO TASMXX + 30 STEP 10
3010 IF TAS(I) = 0 THEN 3020
3011 IF TAS(I) = TASMINP THEN 3050
3012 IF TAS(I) = TASCRT THEN 3050
3014 IF TAS(I) = TASMXX THEN 3050
3018 I2 = (I+20)/20 : IF I2 - FIX(I2) = 0 THEN 3050
ELSE 3080
3020 PRINT" * TOTAL POWER (SHP) REQUIRED WITH
HIGH SPEED EFFECTS *"
3025 PRINT
3030 PRINT" PM TAS(kts) PI PO PP
PS PT"

```

```

-----"
3050 PRINT USING"
#####:TAS(I),PI(I),PO(I),PP(I),PS(I),PM(I),PT(I)
3080 NEXT I
3090 LOCATE 20,12: PRINT USING"MINIMUM POWER = ###,###
SHP AT #### knots";PTMIN,TASMINP
3100 LOCATE 21,12: PRINT USING"MAXIMUM POWER = ###,###
SHP AT #### knots";PTMAX,TASMAXP
3110 LOCATE 22,12: PRINT USING"POWER AT HOVER CEILING =
###,### SHP AT #### ft MSL";PSPECHVR,MXHVR
3190 RETURN : 'returns' to ADMIN/CONTROL SUBR at
line 1250
3900
4000 CLS: '***** ENGINE INSTALLATION LOSSES SUBR &
OUTPUT *****'
4005 PRINT" * POWER REFINEMENTS --
INSTALLATION LOSSES *"
4010 PRINT
4015 PRINT" I. - INLETS AND INLET DUCTING --"
4020 PRINT" 1. -S- TYPE { 5% }"
4025 PRINT" 2. ICE SHIELD { 10% }"
4030 PRINT" 3. STRAIGHT-IN { 2% }"
4034 PRINT
4040 PRINT" II. - ENGINE AIR PARTICLE SEPARATORS
- EAPS"
4045 PRINT" 4. FOAM TYPE BARRIER FILTERS (
10% )"
4050 PRINT" 5. POWER ( HYDRAULIC )
SEPARATORS ( 2 - 6% )"
4055 PRINT" 6. NONE INSTALLED"
4060 PRINT
4070 PRINT" III. - ENGINE EXHAUST DEVICES -
EEDS"
4075 PRINT" 7. SIMPLE HEAT DIFFUSER { 3% }"
4080 PRINT" 8. INFRA-RED SUPPRESSOR { 5% }"
4085 PRINT" 9. NONE INSTALLED"
4100 GOSUB 4200: GOSUB 4230: GOSUB 4260: GOSUB 4280:
GOTO 4300
4200 LOCATE 23,1: PRINT SPC(77)
4202 LOCATE 23,10: INPUT"SELECT THE DESIRED INLET
SYSTEM ",Y1
4204 IF Y1 < 1 OR Y1 > 3 THEN GOSUB 4500: GOTO 4200
4208 ON Y1 GOSUB 4220,4224,4228
4212 PINLET = INLET * 100 : RSHPINLT = RSHP * INLET
4216 LOCATE 6,42: PRINT USING "INLET LOSSES = ####
SHP ###.# %";RSHPINLT,PINLET
4218 RETURN
4220 INLET =.05:LOCATE 4,9 : PRINT"***":LOCATE
5,9:PRINT" :LOCATE 6,9:PRINT" :RETURN
4224 INLET =.1 :LOCATE 5,9 : PRINT"***":LOCATE
4,9:PRINT" :LOCATE 6,9:PRINT" :RETURN
4228 INLET =.02:LOCATE 6,9 : PRINT"***":LOCATE
4,9:PRINT" :LOCATE 5,9:PRINT" :RETURN
4229
4230 LOCATE 23,1: PRINT SPC(77)
4232 LOCATE 23,10: INPUT"SELECT THE DESIRED EAPS
SYSTEM ",Y1: Y1=Y1-3
4234 IF Y1 < 1 OR Y1 > 3 THEN GOSUB 4500: GOTO 4230
4238 ON Y1 GOSUB 4248,4250,4252
4242 PEAPS = EAPS * 100 : RSHPPEAPS = RSHP * EAPS
4246 LOCATE 11,42: PRINT USING "EAPS LOSSES = ####
SHP ###.# %";RSHPPEAPS,PEAPS
4247 RETURN
4248 EAPS =.1: LOCATE 9,9: PRINT"***":LOCATE
10,9:PRINT" :LOCATE 11,9:PRINT" :RETURN

```

```

4250 EAPS =.04: LOCATE 10,9: PRINT"***":LOCATE
9,9:PRINT" ":LOCATE 11,9:PRINT" ":RETURN
4252 EAPS = 0 : LOCATE 11,9: PRINT"***":LOCATE
9,9:PRINT" ":LOCATE 10,9:PRINT" ":RETURN
4259
4260 LOCATE 23,1: PRINT SPC(77)
4261 LOCATE 23,10: INPUT"SELECT THE DESIRED EEDS
SYSTEM " Y1: Y1=Y1-6
4262 IF Y1 < 1 OR Y1 > 3 THEN GOSUB 4500: GOTO 4260
4264 ON Y1 GOSUB 4277,4278,4279
4272 PEEDS = EEDS * 100 : RSHPEEDS = RSHP * EEDS
4274 LOCATE 16,42: PRINT USING "EEDS LOSSES = ####
SHP ###.# %";RSHPEEDS,PEEDS
4276 RETURN
4277 EEDS =.03: LOCATE 14,9: PRINT"***":LOCATE
15,9:PRINT" ":LOCATE 16,9:PRINT" ":RETURN
4278 EEDS =.05: LOCATE 15,9: PRINT"***":LOCATE
14,9:PRINT" ":LOCATE 16,9:PRINT" ":RETURN
4279 EEDS = 0 : LOCATE 16,9: PRINT"***":LOCATE
15,9:PRINT" ":LOCATE 14,9:PRINT" ":RETURN
4280 '*** total losses computation subr
*****
4281 ENGNLOST = RSHP*(INLET+EAPS+EEDS) : MISCLOST =
RSHP*(.05*ENGN+.03)+10
4282 PCTENGN = ENGNLOST*100/RSHP : PCTMISC =
MISCLOST*100/RSHP
4284 RSHPLOST = ENGNLOST + MISCLOST
4286 ESHP = RSHP + RSHPLOST : PCTLOST =
RSHPLOST*100/ESHP
4288 LOCATE 18,12: PRINT USING"ENGINE, XMSN and MISC
INSTALLATION LOSSES = #### SHP ###.#
%":MISCLOST,PCTMISC
4290 LOCATE 19,12: PRINT USING" TOTAL LOSSES
(percent of ESHP) = #### SHP ###.#
%":RSHPLOST,PCTLOST
4292 LOCATE 20,12: PRINT USING" MAXIMUM POWER
REQUIRED [RSHP] = ###,### SHP";RSHP
4294 LOCATE 21,10: PRINT USING"* ENGINE SHAFT
HORSEPOWER REQUIRED [ESHP] = ###,### SHP";ESHP
4296 FLG3 = 1 : RETURN
4300 LOCATE 23,1: PRINT SPC(77)
4305 LOCATE 23,13: INPUT"ANY CHANGES ? (0=N0, 1=YES)
"ANS
4310 IF ANS=0 THEN 4370 ELSE IF ANS=1 THEN 4340 ELSE
GOSUB 4500: GOTO 4300
4340 LOCATE 23,45: INPUT" WHICH ITEM ? (1,2 or 3)
"X5
4344 IF X5 < 1 OR X5 > 3 THEN GOSUB 4500: GOTO 4340
4350 ON X5 GOSUB 4200,4230,4260
4360 GOSUB 4280 : GOTO 4300
4370 LOCATE 23,1: PRINT SPC(77)
4375 LOCATE 23,13:INPUT"press <Shift-PrtSc> for hard
copy, ENTER to continue",X5
4380 GOTO 100
4500 LOCATE 1,1,0: PRINT"~W=TRYAGAIN/" : LOCATE 23,1:
PRINT SPC(77): RETURN
9000 CLS: PRINT"~C=ALL/" : PRINT"~W=LOADNOTE/" :
CHAIN"TR1",,ALL
9999 END
10 'PROGRAM"TR6.BAS" 17 SEPT 87
20 KEY OFF : BS="####" : CS="#.###"
30
'*****
*****
40 ' * *** ENGINE & XMSN SELECTION ***
50

```

```

' *****
*****
70 '          *** CHAPTER SIX MAIN PROGRAM
***
80 '
100 PRINT "~C=ALL/":PRINT "~L=TANDEM6/"
120          COLOR          1,1,1:CLS:LOCATE
23,1,0:PRINT "~W=ENGMENU/":INPUT "",X
130 COLOR 15,1 : ON X GOSUB 200,300,400 : GOTO 120
160 '
200          COLOR          1,1,1:CLS:LOCATE
23,1,0:PRINT "~W=ENGNSELN/":INPUT "",X6 :RETURN
210 '
300 'temporary data for weight summation, power etc.
310 'ENGN = 2 : W(1,1)=2625 : W(3,1)=3333 : W(4,1)=600
: W(5,1)=2100
320 'W(6,1)=2800 : W(7,1)=780 : W(8,1)=130 : W(9,1)=140
: W(10,1)=100
330 'W(11,1)=500 : W(12,1)=400 : W(13,1)=700:
W(14,1)=150: W(15,1)=190
340 'W6A(1)=900:W6B(1)=1600:W6C(1)=300:
MGW=23000:R=25.5:C=1.5:CDO=.009
342 'B=3:RPM=267.4:
S1=34:GAP=4:FHH=12:PA=0:TAS=0:AGL=10:NENG=2:ESH=2600
344 'PAX=6250:FUEL=2500:UL=1000:RHO=.002377:PIE=3.14159:
RHO0=.002377
350 GOTO 500
360 '
400 '
23,1,0:CLS:PRINT "~W=LOADNOTE/":CHAIN"TR1",,ALL LOCATE
460 '
500 ' ***** SECTION 6.1 & 6.2
*****
510 CLS
512 LOCATE 1,28: PRINT "* NUMBER OF ENGINES *
(SECTION 6.1)"
516 LOCATE 2,10: PRINT "1. NUMBER OF ENGINES = ";ENGN
520 LOCATE 2,44: PRINT "(specified in Chapter 3)"
530 LOCATE 3,28: PRINT "* TYPE OF ENGINES *
(SECTION 6.2)"
540 LOCATE 4,10: INPUT "2. NUMBER OF ENGINES COMPETING
FOR SELECTION ":NENGSEL
550 LOCATE 23,33: PRINT " ":LOCATE 23,5: INPUT "ANY
CHANGES ? (0=NO, 1=YES) ",ANS
560 IF ANS=0 THEN 605 ELSE IF ANS=1 THEN 570 ELSE
BEEP: GOTO 550
570 LOCATE 23,38: INPUT "WHICH ITEM ? (1 or 2) ",X6
580 ON X6 GOSUB 590,595 : LOCATE 23,1: PRINT SPC(75)
:GOTO 550
585 '
590 LOCATE 2,33: PRINT SPC(3): LOCATE 2,34:
INPUT "" ENGN : RETURN
595 LOCATE 4,55: PRINT SPC(3): LOCATE 4,56:
INPUT "" :NENGSEL: RETURN
600 '
605 LOCATE 5,2:
PRINT "====="
606 LOCATE 23,1: PRINT SPC(75)
610 LOCATE 6,25: PRINT "* ENGINE SELECTION PARAMETERS *"
611 PRINT " ENGINE:"
613 PRINT " 3. DRY WEIGHT (lbs)....."
614 PRINT " 4. SHP (ssl) military...."
615 PRINT " 5. SFC (ssl) military...."
616 PRINT " 6. INITIAL COST..... $K"
620 PRINT " 7. OP COST/HR/ENG..... $"
622 PRINT " 8. PREV MAINT/HR/ENG.. $"

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631 PRINT" 9. MTBMA (hrs)....."
632 PRINT" 10. MDT (hrs)....."
633 PRINT" 11. MTBF (hrs)....."
634 PRINT" 12. MTBR (hrs)....."
640 K=32:KK=30:FOR I=1 TO NENGSEL:IF I=1 THEN AS="A"
ELSE IF I=2 THEN AS="B":ELSE IF I=3 THEN AS="C" ELSE IF
I=4 THEN AS="D" ELSE IF I=5 THEN AS="E"
650 LOCATE 7,K:PRINT AS
651 LOCATE 8,KK:INPUT:" ",DW(I)
652 LOCATE 9,KK:INPUT:" ",SHP(I)
653 LOCATE 10,KK:INPUT:" ",SFC(I)
654 LOCATE 11,KK:INPUT:" ",IC(I)
655 LOCATE 12,KK:INPUT:" ",OC(I)
656 LOCATE 13,KK:INPUT:" ",PMA(I)
657 LOCATE 14,KK:INPUT:" ",MTBMA(I)
660 LOCATE 15,KK:INPUT:" ",MDT(I)
661 LOCATE 16,KK:INPUT:" ",MTBF(I)
662 LOCATE 17,KK:INPUT:" ",MTBR(I)
670 LOCATE 23,5:INPUT"ANY CHANGES ? (0=NO,1=YES) ",ANS
680 IF ANS=0 THEN 720 ELSE IF ANS=1 THEN 690 ELSE
BEEP:GOTO 710
690 LOCATE 23,38:INPUT"WHICH ITEM ? (3 thru 12) ",X6
: X6=X6-2
700 ON X6 GOSUB
780,784,788,792,794,796,798,800,802,804
710 LOCATE 23,1:PRINT SPC(75):GOTO 670
720 K=K+10:KK=KK+10:LOCATE 23,1:PRINT SPC(75):NEXT
I
725
730 FOR I=1 TO 3:LOCATE 18+I,67:PRINT SPC(9):NEXT
I:LOCATE 23,1:PRINT SPC(75)
731 LOCATE 19,10
732 INPUT"13. SPECIFICATION AVERAGE FLIGHT HOURS PER
YEAR " ;AFL
734 LOCATE 20,10
735 INPUT"14. SPECIFICATION AVERAGE AIRFRAME SERVICE
LIFE IN YEARS " ;SL
737 LOCATE 21,10
738 INPUT"15. AVERAGE FLIGHT HOURS PER FLIGHT
..... " ;TAV
740
745 LOCATE 23,5:INPUT"ANY CHANGES ? (0=NO,1=YES) ",ANS
747 IF ANS=0 THEN 750 ELSE IF ANS=1 THEN 730 ELSE
BEEP:LOCATE 23,1:PRINT SPC(38):GOTO 745
750 LOCATE 23,1:PRINT SPC(75)
752 LOCATE 23,13:INPUT"press <Shift-PrtSc> for hard
copy, ENTER to continue",X6
755
760 FOR I=1 TO NENGSEL:RD(I)=0: 'R & D costs
included in the IC
764 YM(I)=PMA(I)*AFL/1000:YO(I)=OC(I)*AFL/1000:
NRPL1=AFL*SL/MTBR(I)
766 NRPL(I)=NENG*(CINT(NRPL1))
767
LC(I)=ENGN*(RD(I)+IC(I)+(SL*(YO(I)+YM(I)))+(NRPL(I)
*((1.35*IC(I))-.8*IC(I))))
768 AVAIL(I)=(MTBMA(I))/(MTBMA(I)+MDT(I))
770 MAINT(I)=(MDT(I))/(MTBMA(I)+MDT(I))*TAV:
RELY(I)=EXP(-TAV/MTBF(I))
771 RC(I)=1.35*IC(I):SV(I)=.8*IC(I)
772 NEXT I:GOTO 840
774
775 ***** ENGINE SELECTION PARAMETER INPUT
CHANGE SUBR *****
776
780 LOCATE 8,KK:PRINT SPC(7):LOCATE
8,KK:INPUT:" ",DW(I):RETURN

```

```

784 LOCATE 9, KK: PRINT SPC(7):LOCATE
9, KK: INPUT; "", SHP(I): RETURN
788 LOCATE 10, KK: PRINT SPC(7):LOCATE
10, KK: INPUT; "", SFC(I): RETURN
792 LOCATE 11, KK: PRINT SPC(7):LOCATE
11, KK: INPUT; "", IC(I) : RETURN
794 LOCATE 12, KK: PRINT SPC(7):LOCATE
12, KK: INPUT; "", OC(I) : RETURN
796 LOCATE 13, KK: PRINT SPC(7):LOCATE
13, KK: INPUT; "", PMA(I): RETURN
798 LOCATE 14, KK: PRINT SPC(7):LOCATE
14, KK: INPUT; "", MTBMA(I): RETURN
800 LOCATE 15, KK: PRINT SPC(7):LOCATE
15, KK: INPUT; "", MDT(I) : RETURN
802 LOCATE 16, KK: PRINT SPC(7):LOCATE
16, KK: INPUT; "", MTBF(I) : RETURN
804 LOCATE 17, KK: PRINT SPC(7):LOCATE
17, KK: INPUT; "", MTBR(I) : RETURN
810 ,
820 ,
840 FOR I=1 TO NENGSEL
841 IF DW(I)<=300 THEN GOTO 850 ELSE
842 IF DW(I)>300 AND DW(I)<=700 GOTO 860 ELSE
844 IF DW(I)>700 AND DW(I)<=1100 GOTO 870 ELSE IF
DW(I)>1100 GOTO 880
850 EWT(I)=DW(I)*1.29: GOTO 890
860 EWT(I)=DW(I)*1.27: GOTO 890
870 EWT(I)=DW(I)*1.24: GOTO 890
880 EWT(I)=DW(I)*1.2: GOTO 890
890 NEXT I
940 ,
950 ,
960 ,
970 ,
980 ,
990 CLS:LOCATE 1,25:PRINT"* ENGINE SELECTION CRITERIA *
( 6.3 & 6.4 )"
991 LOCATE 3,38:PRINT"----- ENGINE
-----"
992 LOCATE 4,39:PRINT"A B C D
E"
993 PRINT
994 PRINT" POWERPLANT WEIGHT(installed)... "
995 PRINT" LIFE-CYCLE COST...K$ "
1000 PRINT" ENGINE LIFE (hrs)... "
1001 PRINT" No. OF REPLACEMENTS... "
1002 PRINT" R/D COSTS...K$ "
1003 PRINT" INITIAL COSTS...K$ "
1004 PRINT" ANNUAL MAINT. COST...K$ "
1005 PRINT" ANNUAL OPERATING COST...K$ "
1006 PRINT" REPLACEMENT COST...K$ "
1010 PRINT" SALVAGE VALUE...K$ "
1011 PRINT" AVAILABILITY (per engine)... "
1012 PRINT" RELIABILITY (per engine)... "
1013 PRINT" MAINTAINABILITY (per engine)... "
1014 PRINT" PERFORMANCE (military SHP)... "
1020 K1=37: FOR I=1 TO NENGSEL
1021 LOCATE 6,K1:PRINT USING B$:EWT(I)
1022 LOCATE 7,K1:PRINT USING B$:LC(I)
1023 LOCATE 8,K1:PRINT USING B$:MTBR(I)
1024 LOCATE 9,K1:PRINT USING B$:NRPL(I)
1025 LOCATE 10,K1:PRINT USING B$:RD(I)
1026 LOCATE 11,K1:PRINT USING B$:IC(I)
1030 LOCATE 12,K1:PRINT USING B$:YM(I)
1031 LOCATE 13,K1:PRINT USING B$:YO(I)
1032 LOCATE 14,K1:PRINT USING B$:RC(I)
1033 LOCATE 15,K1:PRINT USING B$:SV(I)
1034 LOCATE 16,K1:PRINT USING C$:AVAIL(I)

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1035 LOCATE 17,K1:PRINT USING C$:RELY(I)
1040 LOCATE 18,K1:PRINT USING C$:MAINT(I)
1041 LOCATE 19,K1:PRINT USING B$:SHP(I):K1=K1+9
1050 NEXT I
1060 IF NENGSEL=1 THEN EN=1:GOTO 1080 ELSE
1061 LOCATE 21,1:PRINT SPC(77):LOCATE 21,12
1065 INPUT"ENTER THE LETTER OF THE SELECTED ENGINE
(i.e. A,B,C)" D$
1070 IF D$="A" THEN EN=1: GOTO 1080 ELSE IF D$="a"
THEN EN=1: GOTO 1080
1072 IF D$="B" THEN EN=2: GOTO 1080 ELSE IF D$="b"
THEN EN=2: GOTO 1080
1074 IF D$="C" THEN EN=3: GOTO 1080 ELSE IF D$="c"
THEN EN=3: GOTO 1080
1076 IF D$="D" THEN EN=4: GOTO 1080 ELSE IF D$="d"
THEN EN=4: GOTO 1080
1078 IF D$="E" THEN EN=5: GOTO 1080 ELSE IF D$="e"
THEN EN=5: GOTO 1080 ELSE 1060
1080 LOCATE 22,1: PRINT SPC(75)
1085 LOCATE 23,5:INPUT"ANY CHANGES ? (0=NO, 1=YES)
" ANS
1090 IF ANS=0 THEN 1095 ELSE IF ANS=1 THEN 1061 ELSE
BEOP: GOTO 1080
1095 LOCATE 23,1: PRINT SPC(77)
1100 LOCATE 23,13:INPUT"press <Shift-PrtSc> for hard
copy, ENTER to continue",X6
1110 ,
1130 ,
1150 CLS
1155 LOCATE 2,5: PRINT"* TRANSMISSION SELECTION *
(6.5)"
1160 LOCATE 4,3: PRINT USING"ENGINES: TOTAL SHAFT HP
= ####.# SHP": ESHP
1165 LOCATE 5,3: PRINT USING" NUMBER INSTALLED
= ####.#": ENGN
1170 LOCATE 6,3: PRINT USING" INSTALLED WEIGHT
= ####.# lbs": EWT(EN)
1171 LOCATE 1,1:COLOR 1,1,1
1172 PRINT"~W=XMSNMENU/":INPUT"",XM:ON XM GOSUB
1210,1212,1214,1216,1218,1220
1173 COLOR 15,1: PRINT"~C=ALL/"
1174 LOCATE 7,3: PRINT USING"TRANSMISSION: POWER RATING
= ####.# SHP": XMSNP
1176 LOCATE 8,3: PRINT USING" WEIGHT
= ####.# lbs": XMSNW
1178 LOCATE 9,2:
PRINT"====="
1180 GOSUB 1250: GOSUB 1800:LOCATE
1,1,0:PRINT"~C=ALL/": GOSUB 2465
1182 LOCATE 10,2: PRINT" REVISED WEIGHT
ESTIMATES "
1184 LOCATE 12,3: PRINT USING" A/C EMPTY WT
= ####.#":WE2
1186 LOCATE 13,3: PRINT USING" FUEL WT
= ####.#":FUEL
1188 LOCATE 14,3: PRINT USING" PERSONNEL WT
= ####.#":PAX
1190 LOCATE 15,3: PRINT USING" USEFUL LOAD
= ####.#":UL
1192 LOCATE 16,2:
PRINT"-----"
1194 LOCATE 17,3: PRINT USING" GROSS WT ESTIMATE
= ####.# lbs":GW(NN)
1196 LOCATE 18,3: PRINT USING" TOTAL POWER FOR HOGE
= ####.# SHP":PT
1197 LOCATE 19,3: PRINT USING" DISK LOADING
= ##.#### psf":DL

```

```

1198 LOCATE 20,3: PRINT USING"          FIGURE OF MERIT
= ##.###";FM
1200
1203 LOCATE 23,13:INPUT"press <Shift-PrtSc> for hard
COD.V, ENTER returns to MENU",X6
1204 GOTO 120
1205
1210 XMSNP = 1150 : XMSNW = 700 : RETURN
1212 XMSNP = 1900 : XMSNW = 1100 : RETURN
1214 XMSNP = 3100 : XMSNW = 1700 : RETURN
1216 XMSNP = 4400 : XMSNW = 3000 : RETURN
1218 XMSNP = 5700 : XMSNW = 4000 : RETURN
1220 XMSNP = 8500 : XMSNW = 6500 : RETURN
1225
1230
1235
1250
1255
1260
1270
1271
1272
1273
1275
1280
1290
1800
1820
1830
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2008
2009
2020
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2040
2060
2070
2080
2090
2100

```

*** SECTION 6.6 ***

```

***** NEW WEIGHT SUMMATION SUBR *****
LOCATE 1,1,0: PRINT"~W=COMP/"
NN=1: W(6,NN)=W6C(NN)+XMSNW+(ENGN*EWT(EN)): WE2=0
FOR I=1 TO 15
WE2=WE2+W(I,NN)
NEXT I
NGW=WE2+FUEL+UL+PAX
N = NN : GW(N) = NGW : RETURN
***** POWER COMPUTATION SUBR *****
CNT = CNT + 1
RTRHT = FHH + .5 * GAP
GE = (AGL+RTRHT) / (2*R)
PGE = .5147 + 1.3432*GE - 1.457*GE^2 + .708*GE^3 -
.1276*GE^4
RV = RPM/9.55 : VT = RV * R : VF = TAS *
.68893
SIGMA = (1 - 6.87535E-06 * PA)^4.2561
IF PA=0 THEN RHO=RHO0 ELSE IF PA=4000 THEN
RHO=.001918 ELSE RHO=SIGMA*RHO0 : 'lb-sec^2/ft^4
MU = VF / VT
T = 1.055 * GW(N)
S = B * C / (PIE * R)
TIPLOSS = 1 - (SQR(2 * CT) / B)
RE = R * TIPLOSS
SR = S1 / R
AE = 2*RE^2*(PIE-(PIE/180)*ACOS(S1/(2*RE))) +
S1*SQR(RE^2-(S1^2)/4)
CT = T / (RHO * AE * VT^2)
K = 1.46 - .253 * SR
AV = PIE * R^2 - 2 * R * GAP
VI = SQR(T/(2*RHO*AE))
KU = SQR(SQR(1+.25*((AV/AE)*(VF/VI))^4) -
.5*((AV/AE)*(VF/VI))^2)
DL = GW(N) / (2 * PIE * R^2)
CL = 6 * CT/S
AR = R/C
BL = CT / S
IF B*C*R/S1 > 3.75 THEN COLOR 1,1,1:LOCATE 1,1,0:
PRINT"~W=BLDSTRK/":INPUT X4 :PRINT"~C=ALL/": COLOR 15,1
***** POWER CALCULATION *****
IF GE <= 2 THEN PI = PGE * T * VI * K * KU /550
ELSE
PI = T * VI * K * KU / 550
PO = (CDO * B * C * R * VT^3 * RHO / 2200)*(1+ 4.3
* MU^2)
PP = VF^3 * FF * RHO / 1100
PC = (T * VV + RHO * FF * VV^3) / 1100

```

```

2105 FM = PI / (PI + PO)
2110 PT = PI + PO + PP + PC
2120 RETURN
2130 '
2465 ' ***** COMP WT RESULTS OUTPUT SUBR
*****
2468 '
2469 LOCATE 2,47 : PRINT" * REVISED COMPONENT WT
(6.6)"
2470 LOCATE 4,47 : PRINT USING" 1. MAIN ROTORS
#####.#": W(1,NN)
2475 LOCATE 5,47 : PRINT USING" 2. FUSELAGE
#####.#": W(3,NN)
2480 LOCATE 6,47 : PRINT USING" 3. LANDING GEAR
#####.#": W(4,NN)
2485 LOCATE 7,47 : PRINT USING" 4. ENGINE NACELLES
#####.#": W(5,NN)
2490 LOCATE 8,47 : PRINT USING" 5. ENGINES
#####.#": W6A(NN)
2495 LOCATE 9,47 : PRINT USING" 6. DRIVE TRAIN/XMSN
#####.#": W6B(NN)
2500 LOCATE 10,47 : PRINT USING" 7. FUEL TANKS
#####.#": W6C(NN)
2505 LOCATE 11,47 : PRINT USING" 8. FLIGHT CONTROLS
#####.#": W(7,NN)
2510 LOCATE 12,47 : PRINT USING" 9. AUX POWER (APU)
#####.#": W(8,NN)
2515 LOCATE 13,47 : PRINT USING"10. INSTRUMENTS
#####.#": W(9,NN)
2520 LOCATE 14,47 : PRINT USING"11. HYDRAULIC SYSTEM
#####.#": W(10,NN)
2525 LOCATE 15,47 : PRINT USING"12. ELECTRICAL SYSTEM
#####.#": W(11,NN)
2530 LOCATE 16,47 : PRINT USING"13. AVIONICS
#####.#": W(12,NN)
2535 LOCATE 17,47 : PRINT USING"14. FURNISHINGS
#####.#": W(13,NN)
2540 LOCATE 18,47 : PRINT USING"15. AC / DE-ICE EQUIP
#####.#": W(14,NN)
2545 LOCATE 19,47 : PRINT USING"16. LOAD HANDLING
EQUIP..#####.#": W(15,NN)
2550 LOCATE 20,47:
PRINT"-----"
2555 LOCATE 21,46: PRINT USING"REVISED COMPONENT WEIGHT
=#####.#": WE2
2560 RETURN
9999 END
10 PROGRAM TR7.BAS.....19 SEPT 1987
20
*****
30 ' * *** RANGE AND ENDURANCE ***
*
40
*****
50 KEY OFF: PRINT "~L=TANDEM7/" : PRINT "~C=ALL/"
60 COLOR 15,1
70 DIM ANG(200):IF ENGN=0 THEN ENGN=2 'FUEL=2400:
PTCR=1800:PTCRSP=1890:PTMIN=1400
80 'TASMINP=70: TASCRA=130: TASMXX=150:
PT(70)=1400:PT(80)= 1500:PT(90)= 1610:PT(100)=
1730:PT(110)= 1860:PT(120)= 2050:PT(130)= 2300:PT(140)=
2600:PT(150)= 3000
90
100 CLS
110 LOCATE 1,27: PRINT" * RANGE and ENDURANCE *
{Chap 7}"
120 PRINT"

```

```

130 PRINT" FUEL FLOW (lb/hr)" 1. SFC (lb/hr/shp) 2. SHP
140 PRINT" MILITARY:"
150 PRINT" NORMAL:"
160 PRINT" CRUISE:"
170 PRINT"
180 PRINT" 3. SPECIFICATION CONDITIONS: ALTITUDE
= TEMP = "
190 PRINT" ZERO HORSEPOWER INTERCEPT = "
200 PRINT" PHANTOM HORSEPOWER = "
210 PRINT" =====
220 PRINT" * MAX RANGE * ;
* MAX ENDURANCE * " ;
230 PRINT" ;
240 PRINT" ;
250 PRINT" ;
260 PRINT" ;
270 PRINT" =====
280 PRINT" * CRUISE PWR & FUEL FLOW: * ;
* TOTAL FUEL REQUIREMENTS * " ;
290 PRINT" (ssl) (spec) ;
300 PRINT" ;
310 PRINT" ;
320 PRINT" ;
350 GOSUB 400: GOSUB 450: GOSUB 500: GOSUB 600: GOSUB
630
360 GOSUB 800: GOSUB 1000: GOSUB 1100: GOSUB 1120: GOTO
1200
390 '
400 ' ***** SFC INPUT SUBR
*****
401 '
403 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
405 LOCATE 23,10: PRINT" 1. ENTER SPECIFIC FUEL
CONSUMPTION FOR EACH POWER SETTING.": COLOR 15,1
410 LOCATE 4,21: PRINT" ": LOCATE 4,21: INPUT" ",
SFC(1): IF SFC(1)=0 THEN PRINT"~W=DVN0/":GOTO 410
420 LOCATE 5,21: PRINT" ": LOCATE 5,21: INPUT" ",
SFC(2): IF SFC(2)=0 THEN PRINT"~W=DVN0/":GOTO 420
430 LOCATE 6,21: PRINT" ": LOCATE 6,21: INPUT" ",
SFC(3): IF SFC(3)=0 THEN PRINT"~W=DVN0/":GOTO 430
445 RETURN
449 '
450 ' *** SHP RATING INPUT SUBR
*****
451 '
453 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
455 LOCATE 23,10: PRINT" 2. ENTER RATED SHP FOR EACH
POWER SETTING.": COLOR 15,1
460 LOCATE 4,37: PRINT" ": LOCATE 4,37: INPUT" ",
SHP(1): IF SHP(1)=0 THEN PRINT"~W=DVN0/":GOTO 460
470 LOCATE 5,37: PRINT" ": LOCATE 5,37: INPUT" ",
SHP(2): IF SHP(2)=0 THEN PRINT"~W=DVN0/":GOTO 470
480 LOCATE 6,37: PRINT" ": LOCATE 6,37: INPUT" ",
SHP(3): IF SHP(3)=0 THEN PRINT"~W=DVN0/":GOTO 480
490 LOCATE 23,1: PRINT SPC(77)
495 RETURN
499 '
500 ' *** COMPUTE & OUTPUT FUEL FLOW
*****
501 '
505 FOR I = 1 TO 3
510 WDOTF(I) = SFC(I) * SHP(I) * ENGN
520 NEXT I
530 LOCATE 4,53: PRINT USING" #####.##";WDOTF(1)
540 LOCATE 5,53: PRINT USING" #####.##";WDOTF(2)

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```

550 LOCATE 6,53: PRINT USING" #####.##";WDOTF(3)
595 RETURN
599
600 '***          spec          condition          input          subr
*****
601
603 LOCATE 23,1: PRINT SPC(77) : COLOR 14,1
605 LOCATE 23,6: PRINT" 3. ENTER SPECIFICATION
CONDITIONS -- NORMALLY 4000 ft MSL 95 deg F": COLOR
15,1
610 LOCATE 8,49: PRINT" " : LOCATE 8,49: INPUT" ",
ALT
620 LOCATE 8,65: PRINT" " : LOCATE 8,65: INPUT" ",
TEMP
625 RETURN
629
630 '*** compute & output 0 HP interceptand phantom HP
*****
631
640 BETAH=(WDOTF(1)-WDOTF(3))/(ENGN*(SHP(1)-SHP(3)))
650 ALPHAH=WDOTF(1)-(ENGN*BETAH*SHP(1))
660 DELTA(1)=1: DELTA(2)=(1-6.87535E-06*ALT)^5.2561
670 THETA(1)=1: THETA(2)=(459.688+TEMP)/518.688
680 FOR I=1 TO 2:
ALPHAH(I)=ALPHAH*DELTA(I)*SQR(THETA(I)): NEXT I
690 FOR I=1 TO 2: PF(I)=ALPHAH(I)/BETAH: NEXT I
750 LOCATE 9,10: PRINT USING" ZERO HP INTERCEPT =
+####.## (ssl) +####.## (spec)";ALPHAH(1),ALPHAH(2)
760 LOCATE 10,10: PRINT USING" PHANTOM HORSEPOWER =
+####.## (ssl) +####.## (spec)";PF(1),PF(2)
770 RETURN
780 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
782 LOCATE 23,5: INPUT"ANY CHANGES ? (0=NO,1=YES)
" ANS
785 IF ANS=0 THEN 800 ELSE IF ANS=1 THEN 790 ELSE
BEEP: GOTO 798
790 LOCATE 23,38: INPUT"WHICH ITEM (1 thru 3) ",X7
794 ON X7 GOSUB 400,450,600
798 GOTO 780
799
800 '*** COMPUTE Range airspeed and power then output
*****
801
805 PRINT"~W=COMP/"
809 ANG(TASMIMP-10) = 999
810 FOR I = TASMIMP TO TASMIX STEP 10 : ' change to step
1 ANG(I-10) too!!
820 PWR = PF(1) + PT(I) : TAS(I) = I
830 ANG(I) = PWR/TAS(I)
840 IF ANG(I) < ANG(I-10) THEN
RHPMXR=PWR:PTMXR=PWR-PF(1):TASMXR=TAS(I)
850 NEXT I
860 FFMXR = RHPMXR * BETAH : PRINT"~C=ALL/"
870 LOCATE 13,8 : PRINT USING" AIRSPEED = ###
kts":TASMXR
880 LOCATE 14,8 : PRINT USING" POWER = ###,###
SHP":PTMXR
890 LOCATE 15,8 : PRINT USING"FUEL FLOW = ###,###
lb/hr":FFMXR
900 '*** COMPUTE MAX Endurance fuel flow, A/S and P
from HSE program ****
910 RHPMXE = PF(1) + PTMIN : FFMXE = RHPMXE * BETAH
920 LOCATE 13,48 : PRINT USING" AIRSPEED = ###
kts":TASMXP
930 LOCATE 14,48 : PRINT USING" POWER = ###,###
SHP":PTMIN
940 LOCATE 15,48 : PRINT USING"FUEL FLOW = ###,###
lb/hr":FFMXE

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950 '
1000 '*** COMPUTE SPEC cruise pwr and fuel flow
*****
1001 '
1010 RHPCR(1) = PF(1) + PTCR : FFCR = RHPCR(1) * BETAH
1020 RHPCR(2) = PF(2) + PTCRSP : FFCRSP = RHPCR(2) *
BETAH
1030 LOCATE 18,29: PRINT USING"### kts":TASCR
1040 LOCATE 20,3: PRINT USING"###,### SHP      ###,###
SHP": PTCR,PTCRSP
1050 LOCATE 21,3: PRINT USING"###,### lb/hr    ###,###
lb/hr":FFCR,FFCRSP
1060 RETURN
1090 '
1100 '*** input      max range for total fuel reqmnt
*****
1101 '
1103 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
1105 LOCATE 23,10: PRINT"4. ENTER SPECIFICATION MAX
RANGE IN NAUTICAL MILES !": COLOR 15,1
1108 LOCATE 19,42: PRINT SPC(36)
1110 LOCATE 19,43: INPUT"4. SPEC MAX RANGE (NM) = ",MXR
1115 RETURN
1119 '
1120 '***      compute      total      fuel      required
*****
1121 '
1125 TIME = MXR/TASCR
1130      TFUEL=(.1*BETAH*(SHP(2)+PF(1)))+
(.25*RHPMXE*BETAH)+(TIME*FFCRSP)
1140 LOCATE 20,43: PRINT USING" TOTAL FUEL REQUIRED =
###,### lbs":TFUEL
1150 LOCATE 21,43: PRINT USING"DESIGN FUEL CAPACITY =
###,### lbs":FUEL
1155 FUELDIF = ABS(TFUEL - FUEL)
1160 IF TFUEL < FUEL THEN 1165 ELSE 1170
1165 LOCATE 22,48: PRINT USING"          EXCESS FUEL =
###,### lbs":FUELDIF : GOTO 1180
1170 LOCATE 22,48: PRINT USING"FUEL DEFICIENCY =
###,### lbs":FUELDIF
1175 LCCATE 1,1,0: PRINT"~W=FUELQUAN/"
1180 RETURN
1190 '
1200 '***      input      changes
*****
1201 '
1205 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
1210 LOCATE 23,5: INPUT"ANY CHANGES ? (0=NO,1=YES)
"ANS
1220 IF ANS=0 THEN 1300 ELSE IF ANS=1 THEN 1230 ELSE
BEEP: GOTO 1200
1230 LOCATE 23,38: INPUT"WHICH ITEM (1 thru 4) ",X7
1235 IF X7 < 1 OR X7 > 4 THEN GOSUB 8000 :GOTO 1230
1240 COLOR :5,1: ON X7 GOSUB 400,450,600,1100
1250 GOSUB 500:GOSUB 630: GOSUB 800: GOSUB 1000:
GOSUB 1120
1280 GOTO 1200
1290 '
1300 LOCATE 23,1: PRINT SPC(77): COLOR 14,1
1305 LOCATE 23,13:INPUT"press <Shift-PrtSc> for hard
copy, ENTER to continue",X5
1310 COLOR 15,1 : GOTO 9000
8000 LOCATE 1,1,0: PRINT"~W=TRYAGAIN/" : LOCATE 23,1:
PRINT SPC(77): RETURN
9000 CLS: PRINT"~W=LOADNOTE/": CHAIN"TR1",,ALL
9999 END

```

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