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COMPREHENSIVE MISSION ANALYSIS COMPUTER PROGRAM (COMAP) FOR VTOL AIRCRAFT

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SUMMARY

COMAP is a Comprehensive Mission Analysis Program developed by the Sikorsky Aircraft Division of United Aircraft Corporation through the sponsorship of the Naval Air Systems Command under Contract NOw 66-0694-c. Its purpose is to facilitate the calculation of mission performance and to establish required engine size for rotary-wing aircraft.

The program is available for use on the IBM 7090 and UNIVAC 1108 electronic data processing systems. Among the important calculable factors are (1) performance of any pure rotary wing, compound or semi-compound aircraft for any logical tactical mission sortie with either a known or "rubber" engine; (2) mission performance trends as a function of mission variables, rotor geometry or rotor rpm; and (3) general aircraft performance information independent of a specific mission. Aircraft performance data may be input directly or calculated by the program using generalized rotor performance tables generated by the Sikorsky Generalized Rotor Performance Method.

Tolerances on internal program iterations and curve fit techniques are all less than one percent of the iterative parameter. Overall accuracy of the program can be manipulated by the user through input variation of the incremental fuel weight as discussed in the main body of this report.

The capabilities, equations, calculation procedures and usage instructions for COMAP are presented herein. It is strongly recommended that any person intending to use COMAP read this report and be familiar with its contents.

INTRODUCTION

The performance of an aircraft is meaningful only when expressed as mission capability. Payload based on a specified hover ceiling, for example, is meaningless without an associated range and speed. Mission analysis is therefore a necessary and important part of any evaluation of relative aircraft usefulness.

Because of the infinite variety of missions, generalization of mission capability (payload-range for example) for a given aircraft is difficult, and past practice has been to hand-calculate each specified mission as required. Complicating this procedure has been the frequent necessity to evaluate aircraft-engine combinations for which basic performance is not established (for example, evaluation of next generation engines in a proposed aircraft) thus making detailed performance calculations a mandatory and time-consuming prerequisite to mission analysis.

During the preliminary design stages of an aircraft and the initial establishment of mission ground rules, an awareness of the impact of variations in individual configuration parameters or performance requirements on overall mission effectiveness is desirable. For example, the difference between a required 150 or 160 knot dash speed might significantly change the installed power, rotor geometry, and weight of the configuration without contributing substantially to mission effectiveness.

The Comprehensive Mission Analysis Program (COMAP) was developed by the Sikorsky Aircraft Division of United Aircraft Corporation, under Naval Air Systems Command Contract NOw 66-0694-c, to improve the speed and accuracy with which mission performance and its relationship to engine and airframe configuration can be established.

When known performance capability exists for a given configuration, this can be input directly to COMAP to establish mission capability. When flight test derived or analytically calculated power required information is unavailable or inadequate, the program utilizes stored non-dimensional rotor performance tables to calculate power required. To supplement the power required data, individual inputs for engine performance and weight fractions provide complete flexibility without sacrificing input simplicity.

In addition to the capability to calculate performance for a specified mission, it is frequently desirable to establish the optimum mission profile to maximize, for example, range or endurance. This is often an iterative process which requires either excessive time or gross oversimplification to compute by hand. COMAP greatly speeds up this process without sacrificing accuracy.

In addition, COMAP provides, as an option, performance trend information to provide rational guidance for configuration redesign or mission redefinition.

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TECHNICAL APPROACH

COMAP, a Comprehensive Mission Analysis Computer Program, is designed primarily for rapid accurate mission analysis of any rotary wing aircraft/powerplant combination. Figure (1) is a general flow chart designed to explain the output and input combinations available to the user. The major capabilities of this program are:

(1) Mission Performance - to calculate mission parameters such as payload, endurance, range, required take-off gross weight, fuel, etc. for any specified mission profile;

(2) Mission Parameter Trending-to obtain trending information on mission parameters. For example, one may wish to determine the effect of cruise speed on productivity, payload, range, endurance, take-off gross weight, engine power required or weight empty;

(3) Rotor Parameter Trending - to examine the effect of changes in main rotor geometry (radius, chord, number of blades) and tip speed on mission parameters;

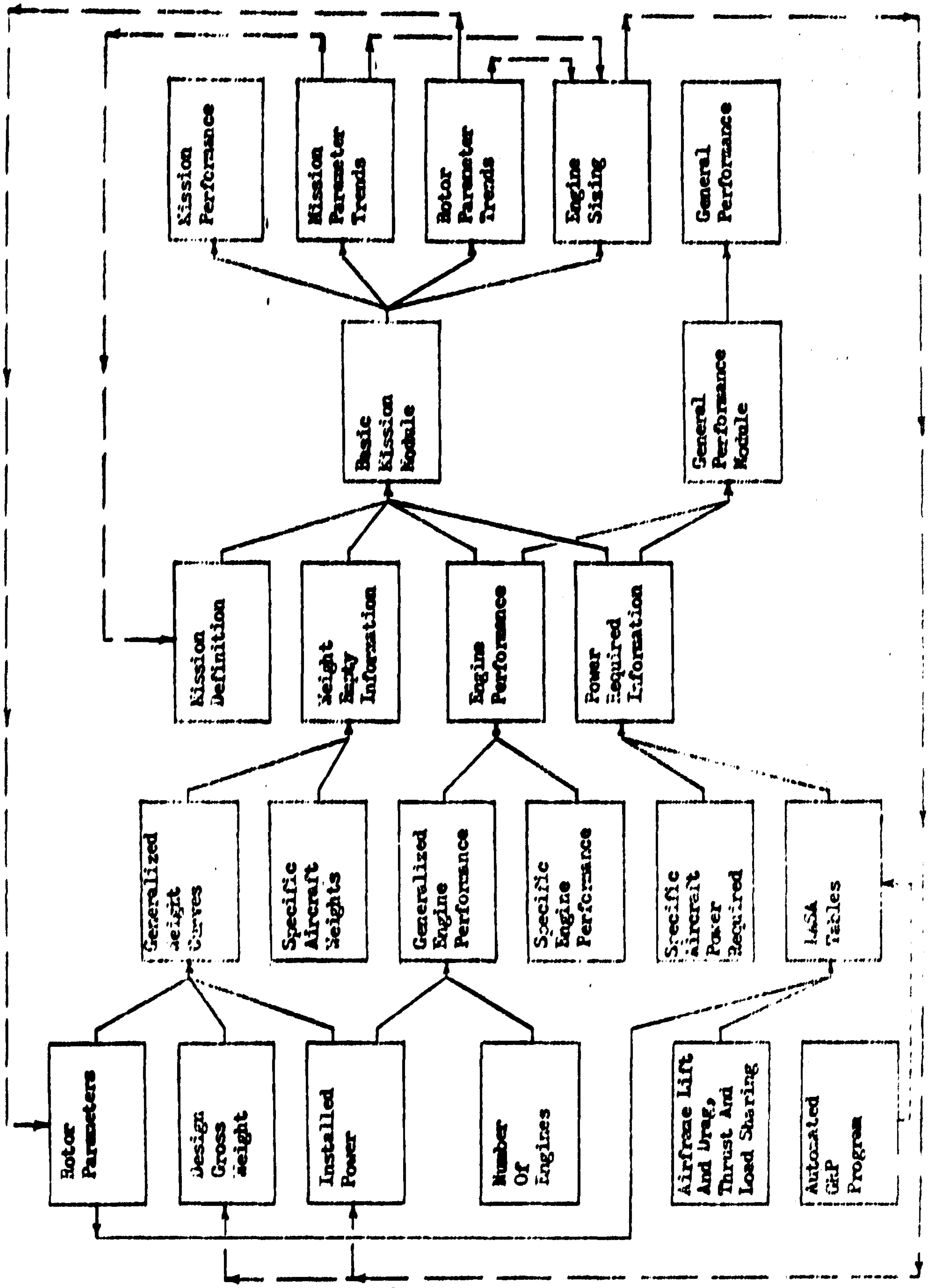
(4) Engine Sizing - used in conjunction with any of the major capabilities listed above to determine the engine power rating required to accomplish a mission and to calculate the corresponding engine and powertrain weights from stored parametric weight trending data;

(5) General Performance - to generate general performance data for a specified aircraft for an input range of gross weights, altitudes and temperatures. Included are subroutines for calculating the following:

a. Power required to hover
b. Hover ceiling
c. Rate of climb
d. Service ceiling
e. Specific range vs. velocity including the higher velocity for 99 percent of the maximum specific range.

To accommodate the many input and output options while maintaining a versatile expandable program with a single input format for all running options, a modular design approach was taken.

INPUT - OUTPUT RELATIONSHIPS



The Basic Mission Module is utilized in calculating information for all but the General Performance output option. Most input information required by the program can either be input directly or calculated utilizing preloaded information. These loading options are graphically displayed on the left in Figure (1).

A Mission Definition is a required input for all options involving mission calculations. The mission definition consists of identifying the type of mission, specifying appropriate initial conditions and arranging the mission element cards in the proper order. Each mission element has been programmed as a separate, independent subroutine to maximize the flexibility of the program and to simplify the changes required to add capabilities to COMAP at a later date. The mission elements available are presented below. The abbreviations correspond to the symbols used in the computer program.

(1) WUPTO (warm-up and take off) - calculates fuel based on a specified duration at any power rating or at an input percent of maximum engine power. A fuel weight for warm-up and take-off can also be input directly.

(2) PAYLD (delta payload) - allows an incremental increase or decrease of payload at any point in the mission. This change can be input as a fixed-weight increment or as a percent of the payload present when the subroutine is called.

(3) DELDR (delta drag) - allows an incremental increase or decrease of equivalent parasite drag area (f) at any point in the mission.

(4) HOVER - calculates the fuel required to hover OGE or IGE for an input time or calculates hover time to satisfy other mission requirements.

(5) CLIMB - calculates fuel required to climb at an input forward velocity or at the speed for best rate of climb. Rate of climb can be input or calculated based on any power rating (NRP, MIL, MAX) or any input percent of maximum power. The final altitude may be input or calculated as the altitude for best range or endurance at the speed for best range or endurance.

(6) DISCR and TIMCR - (distance cruise and time cruise) - calculates fuel required to cruise for a given distance (or time), or calculates the distance (or time) based on other mission criteria. Cruise speed may be input directly or calculated based on normal, military or maximum rated engine power, a percent of maximum power, rotor stall speed, speed for best range or best endurance

at a specified altitude, or speed for best range or endurance at the optimum altitude. A provision is included wherein if two cruise criteria are input, the criterion which gives the lower speed is used. If the aircraft input "red line" velocity is exceeded, the program will automatically downgrade the speed to the red line velocity and print an appropriate diagnostic.

(7) FULCR (fuel cruise) - calculate a cruise distance and time based on an input quantity of fuel to be burned. Any of the speed criteria discussed above may be used.

(8) AIRFL (aerial refueling) - provides the capability of filling the aircraft's tanks to capacity or replacing the fuel burned in the mission to this point. The time to refuel is based on an input refueling rate (lb/hr) and the amount of fuel transferred. Aircraft speed is determined by any of the speed criteria used in the TIMCR subroutine. Fuel burned during the refueling operation is accounted for and replaced.

(9) RESFL (reserve fuel) - is calculated either as a percent of total mission fuel or as the fuel required to cruise for an input time at any cruise speed condition available in the TIMCR subroutine.

(10) TOGWT or TOGIN - allows the calculation of aircraft gross weight at the initiation of the mission (TOGIN) or at any point during the mission (TOGWT). The gross weight can be calculated to satisfy mission requirements (range, payload, etc.) or to meet the aircraft's ability to: hover OGE or IGE, cruise at a specified velocity, climb at an input rate of climb at an input velocity or climb at the speed for best rate of climb at any specified power rating.

Details concerning the use of these mission element subroutines are presented in the main body of this report. In general, they can be arranged in any order to define any logical mission for the purpose of calculating any of the following:

Take-off gross weight

Endurance

Range

Fuel required

Payload

Temperature, altitude, and number of operative engines can be changed between any two mission elements. Information such as productivity, optimum flight profile, etc. fall out as by-products of the major solution.

As Figure (1) indicates, the Weight Empty information may be input directly as a single weight or a weight breakdown, or may be calculated based on generalized weight curves for the aircraft structure, power train and engines. If the general weight curves are used, rotor geometry must be input while design gross weight may be input or determined from program output. Installed power can either be input or calculated to satisfy mission requirements. The latter method is usually used in conjunction with a "rubber engine" analysis as indicated in Figure (1) by the dashed line connecting the Engine Sizing output option with the Installed Power input. This dashed line indicates an iterative loop.

Engine Performance information is a required input for all basic mission performance and general performance options. Like the empty weight information, specific engine performance data may be loaded directly, or generalized engine performance data, based on a particular state-of-the-art technology, can be pre-loaded and utilized. Use of the generalized engine performance data necessitates the input of the number of engines in the aircraft and the installed power. If it is desired to size an engine, COMAP will calculate the installed power.

Aircraft Power Required curves may either be input directly for the specific aircraft being analyzed or calculated within the program using the nondimensional rotor performance tables (commonly called "NASA Tables") which are stored in the program. Provision has been made to calculate performance data for any rotor-airframe-wing-auxiliary propulsion combination. The nondimensional rotor performance tables stored in COMAP as of this date are those of Reference (2) for a 0012 airfoil section and -8^{o} linear blade twist. These tables were derived under contract for the National Aeronautics and Space Administration using the Sikorsky Generalized Rotor Performance Method (Reference (4)).

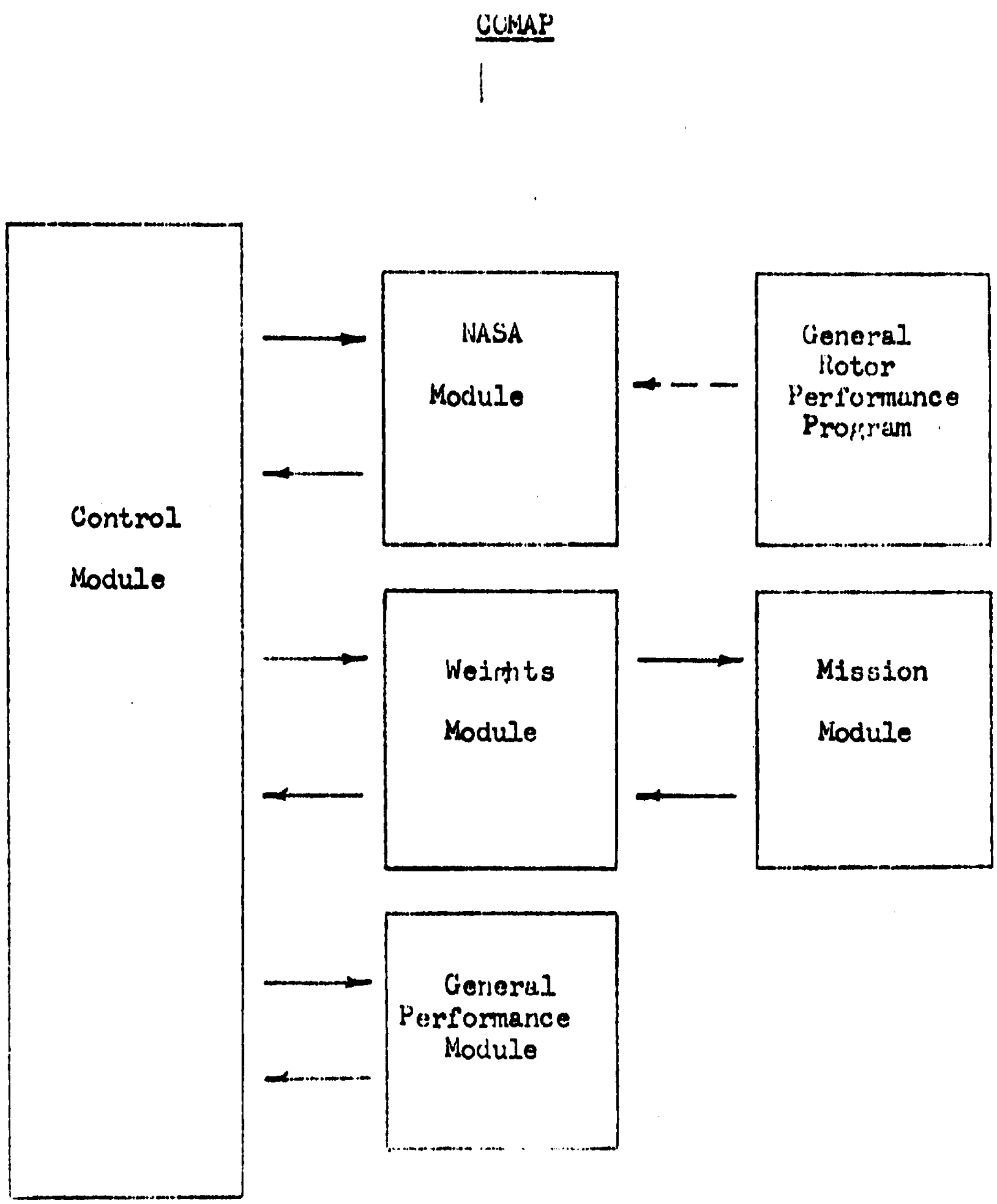
If similar tables are required for a rotor having a different twist or airfoil section, the Automated Generalized Rotor Performance Program supplied separately under this contract can be used to generate them for any desired range of rotor advance ratio and advancing blade tip Mach Number. In addition to the normal printed output, this program supplies the requested tabular data in punched card form for direct input to the COMAP deck.

The interrelationships among the various modules of the computer program are illustrated in Figure (2).

The Control Module reads the input data, sets the major operating switches for the type of calculation requested, stores data calculated by all modules of the program and arranges the requested printout format.

FUNCTIONAL FLOW CHART

MAJOR MODULES OF COMAP



The NASA Module calculates power required data if this calculation is requested in the input.

The Weights Module controls the computation of the aircraft weight empty based on either an input weight breakdown or on the general weight curves for the airframe, engines, and powertrain.

The General Performance Module performs all calculations for the General Performance option discussed previously. Since no mission analysis is involved in the use of this running option, the General Performance Module operates in conjunction with the Control Module only.

The Mission Module is responsible for all mission element calculations and contains all of the mission element subroutines.

The Automated Generalized Rotor Performance Program is a physically separate computer deck designed to calculate data for use in the NASA Module and to produce this data on punched cards for direct input to COMAP.

Comparison of the usage options as illustrated in Figure (1) with the functional flow chart of Figure (2) will help to point out how the Control Module manages the operation of the many iterative processes required by the various running options and types of mission calculations that may be requested.

After reading the input data, if aircraft power required curves are to be calculated by COMAP, the NASA Module is called upon to perform the calculations and the data is stored by the Control Module. Next, the Weights Module is interrogated for an empty weight determined from an input breakdown or from stored generalized weights curves. Using this empty weight, the Mission Module is then activated to perform the mission element calculations as requested on the input mission element cards. The Control Module sets the appropriate switches to control the type of iteration required to determine the unknown mission parameter. If an engine sizing analysis has been requested, a loop is established between the Weights and Mission Modules to define the engine and powertrain weights for the critical power ratings required during the mission.

Upon completion of a mission solution, if the Mission Parameter Trend option has been requested, the Control Module alters the independent mission parameter variable as requested by the input data and recalculates the dependent variables until the requested number of trending points are obtained.

If the Rotor Parameter Trend option has been requested, the Control Module, upon completion of the first mission calculation, alters the independent rotor parameter as requested, calls on the NASA Module for another set of power required curves for the modified rotor geometry, and recalculates the dependent mission parameters.

The General Performance Module is called directly by the Control Module to calculate the data required for the General Performance running option. In the operation of this option, the NASA Module may be called to generate power required data, but the Weights and Mission Modules are not used.

MODULES

Control Module

The Control Module is an internal module within the overall program. Its primary function is to read the input data and set the appropriate major program routing switches to solve the input problem. If the input data is not consistent such that a solution is impossible or unreasonable, the Control Module will stop the operation or obtain a solution with appropriate diagnostics to pinpoint the inconsistency. The module also scans the curve input to determine whether forward flight power required and stall speed data and hover power required data has been input, and calls on the NASA Module to supply the missing data blocks as shown in Figure (3).

This module also updates input information when trending and will cycle the major option, OPTION A, through as many runs as required, updating the input data for each run. The printing of data and results is also controlled from this module.

Since this module does not directly calculate the solution to the input problem, the engineer need only be aware of its existence and major functions as outlined above.

Weights Module

The primary function of the Weights Module is to supply the Mission Module with an empty weight from information contained in the WTGRP (weights group) section of the input.

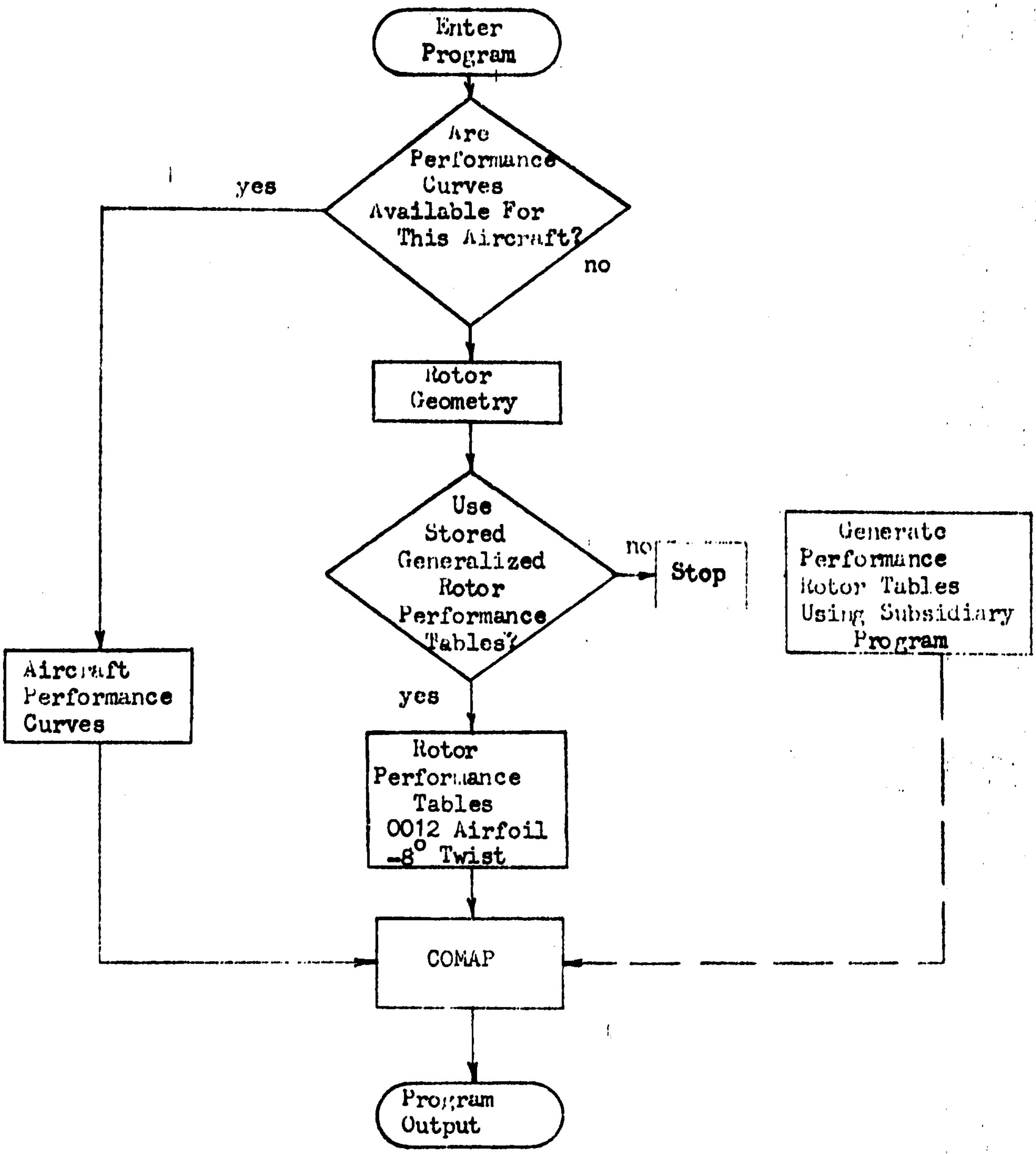
The empty weight may be defined as a single input value or in terms of the following breakdown:

1. Fixed Weight Group - Fixed equipment weight fraction, input in pounds or percent of design gross weight. Fixed equipment consists of instruments, navigational, hydraulic, pneumatic, electrical and electronic equipment, furnishings, air conditioning, anti-icing and photographic equipment, auxiliary gear, and miscellaneous.

2. Military Weight Group - Fixed military load weight fraction, input in pounds or percent of design gross weight. Fixed military load consists of guns, armament, and crew.

3. Disposable Weight Group - Disposable military load weight fraction, input in pounds or percent of design gross weight. Disposable military load consists of torpedoes, pyrotechnics, and ammunition.

SELECTION OF PERFORMANCE INPUT DATA



4. Fluid Weight Group - Tankage and fluid system weight fraction, input in pounds or percent of design gross weight. The tankage and fluid system consists of lubricating system, fuel system, tankage, unusable fuel, trapped oil, engine oil, clutch oil, reduction gear box oil, transmission oil, and cooling system.

5. Structural Weight Group - Structural weight fraction, input in pounds or percent of design gross weight. The structure consists of rotor, tail, body, alighting gear, engine section, nacelle, and flight controls.

6. Engine Weight Group - Installed propulsion system weight fraction, input in pounds or percent of design gross weight. The installed propulsion system consists of engine, installation, air induction system, exhaust system, engine controls, starting system, rotor drive system, cooling system, transmission and clutch, accessories.

The module interprets all inputs greater than one (1) as pounds and inputs less than one (1) as decimal equivalents of percentages of take-off gross weight. Pound inputs are summed and designated WE. Percentage inputs are likewise added, the sum represented by C. The Mission Module uses these terms as shown in the following equation:

FUEL (START) = (1 - C) TOGW - UL - PAYLD - WE

As an example, if the empty weight is defined as a single input, C = 0 and WE will represent the total empty weight. Otherwise, the value of C will be between zero and one and WE term will represent only that part of the empty weight input in pounds.

The aircraft structural weight includes the weight of the rotors and may be defined with one weight input (FIX), by a curve input as a function of blade radius (RAD) or by curve input as a function of number of blades (BLD). When the structural weight is to be calculated as a function of either rotor radius or number of blades, the module will calculate the weight based on the curve inputs, STRCV or BLDCV, respectively. These curves present the structural weight as functions of blade radius and number of blades respectively.

The powerplant group weight can be fixed or rubberized depending on the particular problem. The module will expect to read the weight in pounds in the appropriate input columns if the engine weight is fixed. If a rubber engine is being analyzed, the powerplant group weight can either be specified or be obtained from curve input data consisting of total engine weight, transmission and clutch weight and a miscellaneous installation weight, all as functions of total shaft horsepower. Table I summarizes the various rubberized engine possibilities that have been programmed.

TABLE I

ENGWT	FULIN	PLDIN	TOGIN
PCT	MIN	LBS	PAR
PCT	LBS	MAX	PAR
LBS	MIN	LBS	PAR
LBS	LBS	MAX	PAR
-	MIN	MAX	LBS
-	MIN	LBS	LBS
-	LBS	MAX	LBS
-	MIN	LBS	PAR
-	LBS	MAX	PAR
-	LBS	LBS	PAR

ENGWT - engine group weight. This weight may be expressed as:

1. LBS - pounds
2. PCT - percentage of initial take off gross weight
3. - - no input. Program will automatically determine weight based on power to satisfy mission requirements.

FULIN - fuel at start of mission. Mission fuel may be expressed as:

1. LBS - pounds
2. MIN - to be minimized

PLDIN - PAYLOAD AT START OF MISSION. Payload may be expressed as:

1. LBS - pounds
2. MAX - to be maximized

TOGIN - initial mission take off criteria. This subroutine is discussed in detail in the Mission Module description.

NOTE: Any other combination of ENGWT, FULIN, PLDIN, and TOGIN will cause the Control Module to stop the operation.

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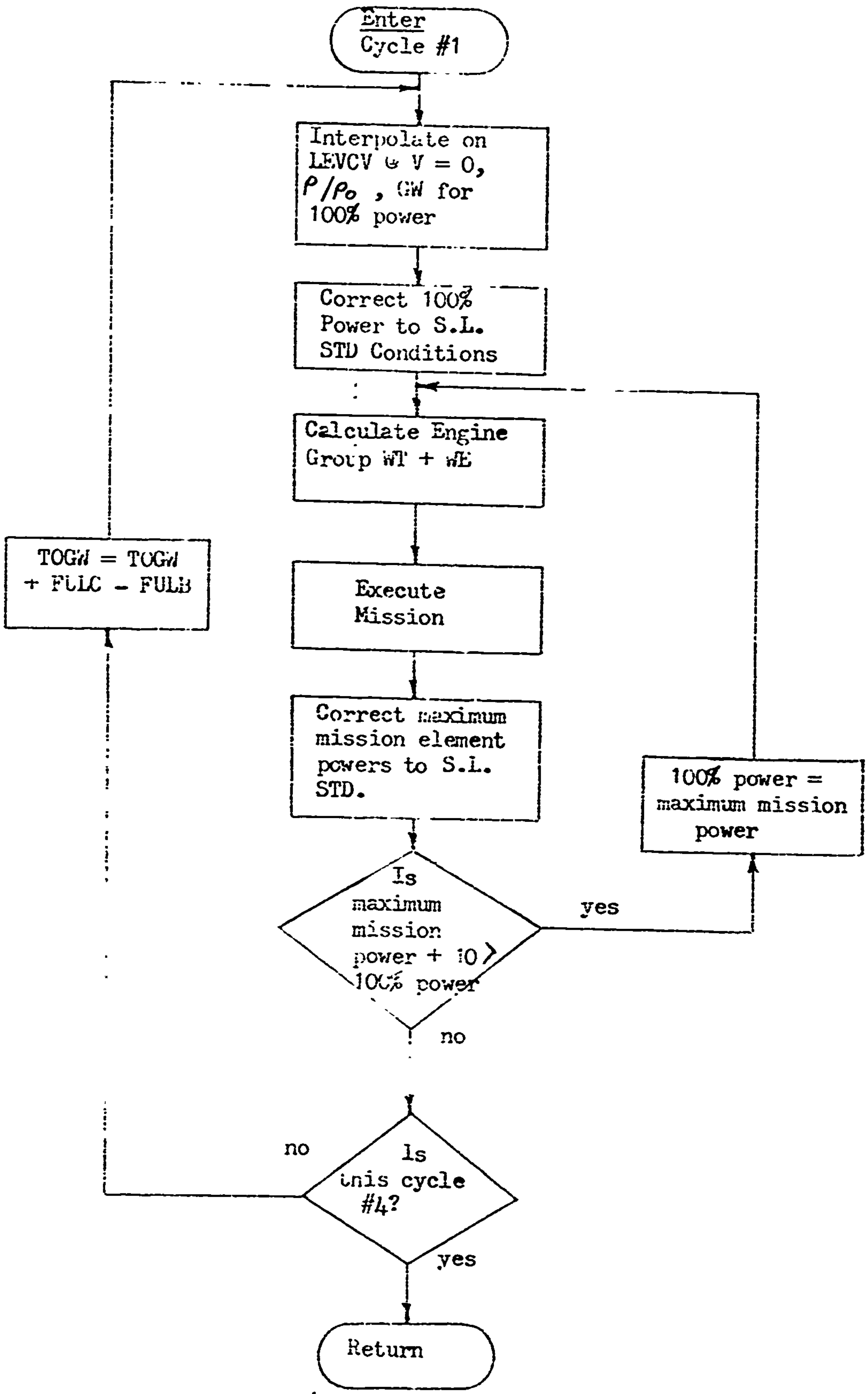
An iteration loop is provided between the Weights and Mission Modules in relation to rubberized engines only. It is within this loop that 100% power is calculated and, in turn, checked against maximum required mission power generated in the Mission Module. Prior to the execution of the mission, 100% power is calculated by interpolating on the LEVCV or level flight power required data at zero velocity, P/P_0 value (calculated from altitude and temperature inputs) and a gross weight input. This power is immediately corrected to sea level standard using the RUBCV curve input. Engine group weight is based on the corrected horsepower. The Mission Module executes the input mission using fuel flow data based on the above calculated and corrected 100% power. The maximum power utilized in each mission element is returned to the Weights Module where each is corrected to sea level standard and checked against the 100% power value. If this 100% power is not exceeded in the mission, the initial mission gross weight is adjusted by FULC - FULB, the difference between estimated and actual fuel burned, a corresponding 100% power is calculated with an empty weight adjustment and the mission rerun. A total of four complete cycles, or four passes through the mission are accomplished.

Should the 100% power be exceeded in the mission, an additional loop within any one cycle will allow the 100% power to be adjusted for a fixed take off gross weight. The power and empty weight are adjusted until two consecutive passes through the mission yield maximum power values within 10 horsepower of each other. At this point, the operation returns to the large loop where an adjustment on the take off weight is accomplished. Here again, four cycles are completed, each cycle containing the adjustment on 100% power at constant gross weight. Should the initial take off weight be fixed in pounds, adjustments are made to the engine group weight and, in turn, empty weight.

A simplified flow chart of this operation is presented in Figure (4).

FUNCTIONAL FLOW CHART
RUBBER ENGINE



Mission Module

The only function of the Mission Module is mission analysis. This module can be divided descriptively into three parts:

1. the logic by which a solution is obtained;
2. a group of subroutines representing mission element segments such as warm-up and take-off, hover, climb, etc;
3. a group of speed subroutines which calculate specific range data at specified velocity criterion for cruise, such as speed for best range, a specified velocity, speed at normal rated power, for use in cruise mission elements.

The logic of the module is flow charted in Figure (5) and provides a solution through iteration to determine one of the following:

1. Payload (maximum payload with a percent payload change in the mission definition, if required).
2. Distance (maximum).
3. Time (maximum cruise and/or hover time).
4. Mission Take-off Gross Weight (initial mission take-off gross weight is considered known if it is input or can be calculated by the initial Take off Gross Weight subroutine, TOGIN.)

Those missions not falling in the above categories which can be solved by this module are non-iterative type missions where gross weight is known throughout the mission profile and maximum payload, fuel burned or both are to be calculated. When payload is unknown, the program will automatically start with an initial guess of five thousand (5000) pounds. When mission take-off gross weight, mission element distance, or time are unknown, the module iterates, starting with an initial guess input by the user.

Having established the unknown parameter, if any, an estimate of mission fuel is calculated using the equation:

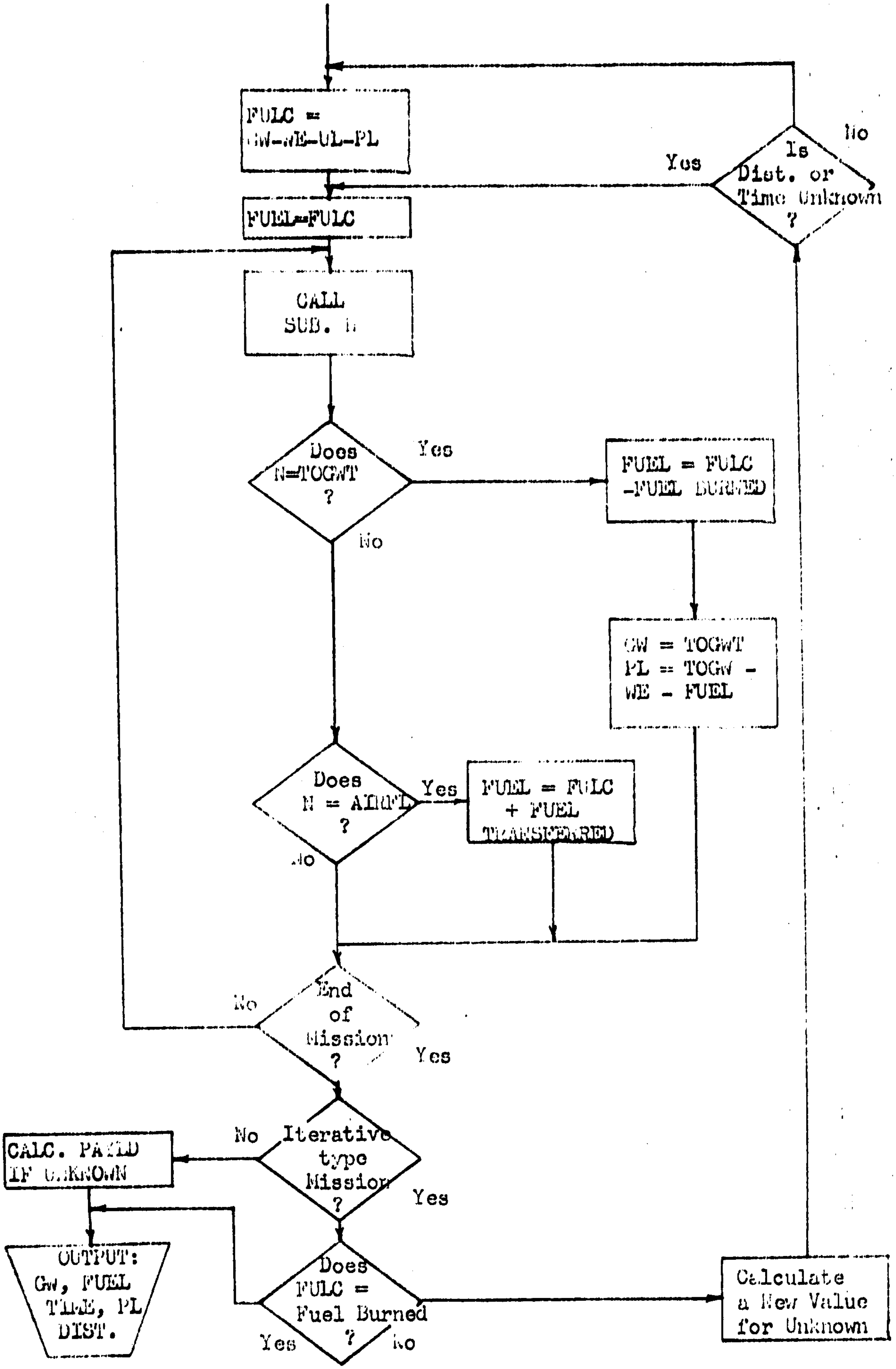
$$FULC = \frac{(1 - c)\ TOGIN - ULOAD - PLDIN - WTEMP + (ax - 1)\ FULCP}{ax}$$

where:

FULC - estimated fuel at start of mission

c - portion of total aircraft empty weight input as decimal equivalent of percent of initial take off gross weight

MISSION MODULE LOGIC



TOGIN - initial take-off gross weight
ULOAD - fixed useful load
PLDIN - initial mission payload
WTEMP - portion of total aircraft empty weight input as pounds
FULCP - internal fuel capacity
ax - auxiliary fuel tankage constant as described below

The mission elements are then executed in the input sequence, the main output from each element being gross weight, payload and fuel burned. Total fuel burned (FULB) for the mission is compared with the estimated mission fuel (FULC) for iterative type missions only (non-iterative types require no comparison). The module will iterate using adjusted values of the unknown parameter until the following equation is satisfied:

$$\frac{FULC - FULB}{FULC + FULB} \leq 0.001$$

Only those values calculated on the final pass through the mission are printed out by the Control Module. Productivity and average speed for the mission are additional outputs.

Should the TOGWT subroutine be listed in the mission definition, this implies that payload is to be optimized from that point in the mission. As such, the equation

$$PAYLD = (1 - c)TOGIN - WE - UL - \left[\text{total fuel (FULC)} - \text{fuel burned (FULB)}\right]$$

is calculated before the next mission element is executed. Total mission fuel is automatically increased when aerial refueling is listed in the mission definition.

When the module is used to determine cruise distance or time, or take-off gross weight for the mission, "PAR" is input for appropriate elements as explained in the individual subroutine descriptions to identify those subroutines containing an initial guess of an unknown parameter. The module allows a maximum of two mission elements containing "PAR" inputs with the restriction that the unknown parameters be the same dimension, i.e., time or distance but not time and distance in any one mission. If the mission definition does contain two subroutines with "PAR" inputs, the program will ratio the input guess of the first subroutine containing "PAR" to the initial guess of the second element containing "PAR" to determine the desired ratio of the correct value. For instance, a radius type mission of unknown range having equal outbound and inbound legs requires a "guess" ratio of one (1.00) or equal estimated distance inputs for both subroutines. For a typical ASW mission where it might be desired to hover 75% and cruise 25% of the time on station, the HOVER subroutine requires an initial guess of time three (3) times greater than the TIMCR (time-cruise) subroutine.

This module is also capable of determining the size and weight of required auxiliary fuel tanks. This is accomplished utilizing the "ax" term in the estimated mission fuel (FULC) equation. The module keys on the input "AUX" and "JP4" or "JP5" input in the Initial Conditions Group (INCND). When this capability is not desired, as is normally the case, ax automatically equals one (1). This reduces the FULC equation to one more familiar to the mission analyst. However, if this capability is desired, ax assumes values of 1.077 and 1.035, depending on whether "JP4" or "JP5" are input. The total equation is derived as follows:

$$FULC_1 = (1 - c)TOGIN - ULOAD - PLDIN - WTEMP$$

If $FULC_1 > FULCP$

$$(FULC_1 - FULCP)/ax = AUX.\ FUEL \quad \text{where}$$

$$ax = \frac{AUX\ FUEL + AUX\ TANK\ WT}{AUX\ FUEL} \sim 1.077 \text{ or } 1.035 \text{ for JP-4 or JP-5, respectively.}$$

since

$$FULC = FULCP + AUXFUEL$$

$$FULC = FULCP + \frac{FULC_1 - FULCP}{ax}$$

$$FULC = FULCP + \frac{(1 - c)TOGIN - ULOAD - PLDIN - WTEMP - FULCP}{ax}$$

$$FULC = \frac{(1 - c)TOGIN - ULOAD - PLDIN - WTEMP + (ax - 1)FULCP}{ax}$$

Initial Take-off Gross Weight Subroutine (TOGIN)

The initial take-off gross weight for a mission is determined by this subroutine. Gross weight values are calculated based on the particular take-off criterion specified on the input data card. This gross weight value is transferred to the first mission element listed in the mission definition.

The capabilities of this subroutine are listed below:

1. accepts an input value for gross weight at take-off;
2. accepts an estimated value for the take-off weight which the Mission Module will use as a starting point to establish the correct value through iteration;
3. calculates a maximum gross weight for hovering, in or out of ground effect, at a specified power rating and Z/R ratio;

4. calculates a maximum gross weight based on the aircraft's ability to climb at a specified forward speed, power rating, and rate of climb.

Maximum gross weights for hover are calculated by interpolating on the specified power curve for horsepower, calculating a corresponding power coefficient based on total power and interpolating on the Cw-Cp hover input curve for Cw. If Cw is based on ground effect hover data and more than one Z/R ratio curve is input, a Z/R value must be specified.

Calculation of gross weights based on a rate of climb capability requires an iteration starting with an initial input value. Powers for level flight at the specified forward speed and the input rate of climb are summed and compared to the power available determined from input information. The gross weight is varied until the calculated power required and the power available are within 1% of each other.

If in ground effect hover data is not available for input, the subroutine will automatically calculate appropriate Cw values using Cheeseman's equation:

$$Cw_{IGE} = Cw_{OGE} + \left[\frac{\sigma (5.73)}{(64)\sqrt{2}\ (Z/R)^2} \right] \cdot (Cw_{OGE})^{1/2}$$

Literal inputs are used to define each capability for this subroutine and the mission element subroutines contained in the Mission Module. The inputs are read from left to right on any one line as shown in Figure (6). As an example, "TOGIN OGE MIL" defines this subroutine's capability of calculating the maximum gross weight to hover out of ground effect using military power.

Any gross weight value calculated within this subroutine is checked against the maximum gross weight listed in the Initial Conditions Group, INCND, and downgraded if the maximum gross weight has been exceeded. The corresponding power required, in turn, can never exceed the transmission rating listed in the input. Any downgrading will be noted on the printout.

This subroutine cannot be used in the mission definition as such and its use is restricted to defining a take-off criterion listed in the INCND or Initial Conditions Group.

Mission Element Subroutines

The mission elements contained herein represent mission segments available to the program user to define a mission. They are:

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

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TOGIN SUBROUTINE INPUT

Figure 6

TØGIN	PAR	NRP	(GWTØ)	(Z/R)	(RØC)	(VEL)
	IGE	MIL				
	ØGE	MAX				
	VEL					
	BRC					

SAMPLE INPUTS

TØGIN			(GWTØ)			
TØGIN	PAR		(GWTØ)			
TØGIN	IGE	NRP		(Z/R,		
TØGIN	ØGE	MIL				
TØGIN	VEL	MIL	(GWTØ)		(RØC)	(VEL)
TØGIN	BRC	MAX	(GWTØ)		(RØC)	

1. WUPTO warm-up and take-off
2. HOVER hover
3. CLIMB climb
4. PAYLD payload
5. DELDR delta drag
6. DISCR distance cruise
   TIMCR time cruise
   FULCR fuel cruise
7. AIRFL aerial refueling
8. TOGWT take-off gross weight at mis-mission point
9. RESFL reserve fuel

These mission element subroutines can be listed in any number and sequence to define a mission since they are completely independent packages. Elemental and cumulative values for distance, time, and fuel burned, and values for gross weight and payload at the end of each element as well as the maximum element-power used are returned to the Control Module to be printed out.

The HOVER, CLIMB, DISCR, TIMCR, FULCR, AIRFL, and RESFL (based on time to cruise) subroutines require a fuel increment input, DELW. The subroutine varies the gross weight in DELW increments and generates specific range data for the average gross weight for each DELW increment until the input requirements for the mission element are satisfied.

Linear corrections are applied to distance, time and fuel when the aircraft overshoots the input requirement. For instance, to cruise 100 miles, the cruise subroutine will calculate distance, time and fuel burned for each DELW fuel increment. The last DELW increment will probably take the aircraft past the 100 mile mark. At this point, linear interpolations for distance, time, and fuel during the last DELW increment will determine the exact delta distance, delta time, and delta fuel burned required to fulfill the 100 mile input.

The DELW input increment also provides the user with some control of the program's accuracy. Specific range and velocity data are generated for the average gross weight for the DELW increments. Increasing the number of increments needed to fulfill the requirements for the mission element will increase the accuracy of the output parameters at some expense in running time. Reasonable values for DELW can be determined from program usage.

Altitude, temperature and number of engines are specified at the beginning of the mission. Values for these items are carried forward from one subroutine to the next. Altitude and temperature are automatically updated should new values be calculated within a subroutine, such as the Climb and Optimum Cruise elements. Provisions are made for the user to change the "running" value of altitude, temperature and number of engines by inputting the new value between two subroutines. An example of a discontinuous mission is:

1. Hover at 6000' 95°F

2. Cruise at SEA LEVEL STD

3. Fuel reserve (10%)

Since the input defines the capabilities of the mission elements, inputs for each are included in the description of each element. Those in parenthesis are numerical inputs that require a decimal point and are listed in Table II. Table III presents the literal inputs defining the capabilities of the elements.

Warm-up and Take-off Subroutine (WUPTO)

This subroutine calculates the fuel burned as specified on the input data card and decrements the existing gross weight an equal amount.

The subroutine accepts a fixed amount of fuel in pounds or will calculate the fuel at normal, military or maximum rated power for a specified time. In addition, warm-up at a percentage of maximum power can be calculated with maximum power defined as follows:

1. fixed or specified engine - maximum rated power

2. rubberized engine - maximum mission power

The program expects a time input for all capabilities of this subroutine. All powers are downgraded to the transmission rating if calculated to be greater.

The input format defining the capabilities is presented in Figure (7).

Hover Subroutine (HOVER)

The HOVER subroutine is used to represent a hovering point in the mission. The fuel burned during the hover is calculated for a specified hover time, or for a time to be calculated by COMAP. The element will

TABLE II

Mission Element Numerical Input Symbols

ALT	altitude in feet
DELFF	external aircraft drag increment in ft^2
DELW	fuel increment in pounds
DIST	distance in nautical miles
END ALT	final altitude in feet
FTR	fuel transfer rate in lbs. per hour
FUEL	fuel in pounds
GWTO	gross weight at take-off in pounds
PCT	percentage in decimal form
ROC	rate of climb in feet per minute
TEMP	temperature in Fahrenheit degrees
TIME	time in hours
VEL	true velocity in knots
Z/R	ratio of rotor height above ground to rotor radius

TABLE III

Literal Inputs for Mission Elements	
BRC	best rate of climb speed
FIL	fill to capacity
IGE	in ground effect
JP4	type of fuel
JP5	type of fuel
LBS	pounds
MAX	maximum (PLDIN subroutine only) or maximum rated power
NRP	normal rated power
MIL	military rated power
OGE	out of ground effect
OPE	optimum flight path for best endurance
OPR	optimum flight path for best range
PAR	parameter
PCT	percentage
ROC	rate of climb
RPL	replace
TIM	time
VBE	speed for best endurance
VBR	speed for best range
VEL	velocity
VST	stall speed

WUPTO SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ____ EXT ____ TITLE ____
MAIL ADDRESS ____
ANALYST ____
JOB NO. ____
SHEET ____ OF ____
ACCOUNT NO. ____
W.O. NO. ____

WUPTØ	NRP	(TIME)	(LBS)
	MIL		(PCT)
	MAX		
	PCT		
	LBS		

SAMPLE INPUTS

WUPTØ	LBS	(TIME)	(LBS)
WUPTØ	NRP	(TIME)	
	MIL		
	MAX		
WUPTØ	PCT	(TIME)	(PCT)

expect an initial guess input for time if "PAR" is input, signifying that hover time is to be optimized.

The subroutine relies on the OGECV and IGECV curve inputs (Cw-Cp plots) to calculate power required. If in ground effect hover data is not available, the subroutine calculates the required powers using the out of ground effect data and Cheeseman's equation at a specified Z/R, rotor height to rotor radius, ratio. This equation is:

$$Cw_{OGE} = \left[\frac{(-5.73)\sigma + \left[(5.73)^2 \sigma^2 + (8)^5 (Z/R)^4 (Cw_{IGE})\right]^{1/2}}{(128)\ (2)^{1/2}\ (Z/R)^2} \right]^2$$

where:

σ = main rotor solidity

Z/R = rotor height ratio

Cw_{IGE} = weight coefficient in ground effect = $GW/\pi R^2 \rho (\Omega R)^2$

CwOGE represents the equivalent weight coefficient for OGE using the same power. The corresponding Cp is obtained from the OGECV.

The initial value for gross weight in this subroutine is that value carried forward from the previous mission element. Specific fuel consumption data is based on the power corresponding to the average gross weight for the fuel increment, DELW. If the horsepower calculated is larger than the transmission rating listed in the INCND group, an appropriate diagnostic will be printed out.

Input for this subroutine is presented in Figure (8).

Climb Subroutine (CLIMB)

The Climb subroutine calculates the fuel burned during the climb from an initial altitude to a specified final altitude or to the altitude for optimum cruise.

Climbs may be executed at any specified forward speed including the best rate of climb speed for any power rating, a percentage of maximum power, or a specified rate of climb. Maximum power is defined as the maximum rated power if the engine is fixed, or the maximum mission power when the engine is rubberized.

When the final altitude is to be the altitude for optimum cruise, this subroutine calculates that altitude by generating specific range versus velocity curves for each altitude resulting from a DELW fuel increment burn-off until Δ SR/SR $<$ 0.01 (ROC) DELW/(1.05)SFC(HP). When the gross weight is low and the optimum flight altitude lies above the input level flight power required data, the climb subroutine will use the last altitude calculated within the element.

HOVER SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

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ANALYST ______ SHEET ______ OF ______

ACCOUNT NO. ______

W.O. NO. ______

```
HØVER  IGE  PAR    (TIME)  (Z/R)  (DELW)
       ØGE
```

SAMPLE INPUTS

```
HØVER  IGE         (TIME)  (Z/R)  (DELW)

HØVER  ØGE         (TIME)         (DELW)

HØVER  ØGE  PAR    (TIME)         (DELW)
```

The subroutine calculates the specific range data using data extrapolated from the input curve data. The climb is terminated at this altitude so as to limit the number of extrapolations on the input power required curve data to one (1).

A rate of climb is determined by the power difference between the power available and level flight power required as follows:

$$ROC = \frac{(SHP_{Avail} - HP_{LF})\ (33000)\ \eta\ (K)}{GW}$$

where:

η is the mechanical efficiency and K is a correction factor, obtained from the ROCCV input data, used to account for vertical drag and body lift in a climb which cannot be obtained from the input curve data. A rate of climb is initially calculated using an assumed K value of one (1.00). Corrected K values are obtained from the ROCCV curve input at the calculated rates of climb until two successive values of K are within 0.1% of each other. Power available is checked against the transmission rating (GBXHP) and downgraded if necessary.

Input for this subroutine is presented in Figure (9). VEL and BRC are used to define the forward speed while columns 11 - 13 designate the type of climb,,such as NRP, etc. Columns 15 - 17 define the altitude which the climb is to be executed to.

Payload Subroutine (PAYLD)

The Payload subroutine is used to add or subtract either a percent or a fixed weight from the existing payload aboard the aircraft.

The input format is presented in Figure (10). Percentages are expressed in decimal equivalents. An appropriate diagnostic is printed out if the gross weight resulting from a payload change exceeds the maximum gross weight allowable as listed in the INCND group of the program input.

Delta Drag Subroutine (DELDR)

The Delta Drag subroutine is used to change the external drag of the aircraft from the initial drag input listed in the Initial Conditions Group to account, for example, for pickup of an external load or dropping of auxiliary tanks.

All mission elements following this subroutine correct the power required for level flight by means of (DELFF)$\rho V^3/1100$. An additional correction is applied on stall velocities in the Stall Speed subroutine since stall velocities calculated from the input VSTCV, Stall speed vs.

CLIMB SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______
MAIL ADDRESS ______ JOB NO ______
ANALYST ______ SHEET ______ OF ______
ACCOUNT NO ______
W.O. NO. ______

CLIMB	VEL	NRP	FIX	(END ALT)	(VEL)	(DELW)	(RØC)
	BRC	MIL	ØPR				(PCT)
		MAX	ØPE				
		PCT					
		RØC					

SAMPLE INPUTS

CLIMB	VEL	NRP	FIX	(END ALT)	(VEL)	(DELW)	
CLIMB	BRC	NRP	FIX	(END ALT)		(DELW)	
CLIMB	BRC	RØC	FIX	(END ALT)		(DELW)	(RØC)
CLIMB	BRC	MIL	ØPR			(DELW)	
CLIMB	VEL	PCT	ØPE		(VEL)	(DELW)	(PCT)

PAYLD SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ________ EXT. ________ TITLE ________

MAIL ADDRESS ________ JOB NO ________

ANALYST ________ SHEET ____ OF ____

LOG NO. ________ ACCOUNT NO ________

W.O. NO. ________

PAYLD	PCT	(PCT)
	LBS	(LBS)

SAMPLE INPUTS

PAYLD	PCT	(PCT)
PAYLD	LBS	(LBS)

Gross weight curve data, are valid only for the initial parasite area (AREAF) listed in the INCND group.

Input for this subroutine is in units of square feet and is presented in Figure (11).

Cruise Subroutine (DISCR, TIMCR, FULCR)

The cruise subroutines simulate the cruise portions of a mission. The DISCR and TIMCR elements are used for cruising specified distances and time, respectively, while the FULCR element is utilized for burning off specified amounts of fuel.

These subroutines call upon a bank of speed subroutines which generate specific range and velocity data for the average gross weight for each DELW fuel increment required to satisfy input requirements. If two speed elements are listed on the cruise input card, both elements calculate corresponding specific range and velocity values but the cruise subroutine uses the element which calculates the lesser velocity.

Climb distance or time becomes part of the cruise distance or time when the climb is listed immediately preceding a cruise. Distance and time for each DELW increment are calculated by DELW·SR and DELW·SR/V, respectively. There will be one DELW increment that will put the aircraft past the input requirement of distance or time. The aircraft is "backed up" to the proper distance or time by linearly interpolating on delta distance, delta time and delta fuel using the specific range and velocity values for that particular DELW fuel increment.

Distance or time may easily be optimized by listing "PAR" in the appropriate locations of the input card with a starting value of distance or time for the cruise subroutine to use. The Mission Module will establish the correct value through mission iteration. No "PAR" input is allowed for the fuel cruise (FULCR) subroutine.

A general input format illustrating the capabilities is shown in Figure (12).

Aerial Refueling Subroutine (AIRFL)

The Aerial Refueling subroutine will replace the fuel burned through that point in the mission where this subroutine is listed or, will fill the fuel tanks to the fuel capacity value specified in the Initial Conditions Group. Fuel is transferred from the tanker aircraft at a specified flow rate and speed criterion. This element includes the fuel burned during the refueling operation when calculating fuel to be transferred.

Figure 11

DELDR SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ____ EXT. ____ TITLE ____

MAIL ADDRESS ____

ANALYST ____

LOG NO. ____

JOB NO. ____

SHEET ____ OF ____

ACCOUNT NO. ____

* O. NO. ____

DELDR (DELFF)

CRUISE SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO ______

W.O. NO. ______

DISCR	PAR	ØPR	ØPR	(DIST)	(VEL)	(DELW)
TIMCR		ØPE	ØPE	(TIME)	(PCT)	
FULCR		VBR	VBR	(FUEL)		
		VBE	VBE			
		VST	VST			
		NRP	NRP			
		MIL	MIL			
		MAX	MAX			
		PCT	PCT			
		VEL	VEL			

SAMPLE INPUTS

DISCR		VST		(DIST)		(DELW)
DISCR		NRP	VST	(DIST)		(DELW)
DISCR	PAR	VEL		(DIST)	(VEL)	(DELW)
TIMCR		VEL		(TIME)	(VEL)	(DELW)
TIMCR		PCT		(TIME)	(PCT)	(DELW)
FULCR		VBR		(FUEL)		(DELW)

Inputs for this subroutine are shown in Figure (13). Any of the speed subroutines may be utilized to supply specific range and velocity data for the AIRFL subroutine.

Take-off Gross Weight Subroutine (TOGWT)

The TOGWT subroutine calculates a gross weight based on the particular take-off criterion specified on the input data card. This value for gross weight is transferred to the next mission element subroutine prior to the execution of the remaining mission elements. Mission logic also calls for a payload calculation based on existing values for gross weight, useful load, weight empty, etc., immediately following the execution of this subroutine.

The capabilities of this subroutine are:

1. accept a fixed value for gross weight

2. calculate a maximum gross weight for hovering, in or out of ground effect, at a specified power rating and Z/R ratio

3. calculate a maximum gross weight based on the aircraft's ability to climb at a specified forward speed, power rating, and rate of climb.

Maximum gross weights for hovering are calculated by interpolating on the specified power available curve for horsepower, calculating a corresponding Cp based on total power and interpolating on the Cw - Cp hover input curve for Cw. If Cw is based on ground effect hover data, a Z/R value must be specified on the input card.

Calculation of gross weight based on a rate of climb capability requires an iteration starting with an initial weight value input. Power for the input rate of climb is checked against the power available determined from input information. The gross weight is varied systematically until the calculated power required and the power available are within 1%. Gross weights and corresponding powers are checked against maximum transmission horsepower and maximum allowable gross weight. Weights and powers exceeding these input limits are downgraded.

Figure (14) presents the general input required for the various capabilities of the subroutine.

If no ground effect hover data is available for input, the subroutine will automatically calculate appropriate Cw values using Cheeseman's equation.

AIRFL SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______
MAIL ADDRESS ______ JOB NO. ______
ANALYST ______ SHEET ______ OF ______
ACCOUNT NO ______
A/C NO ______

SAMPLE INPUTS

AIRFL	FIL	ØPR	(FTR)	(VEL)	(DELW)
	RPL	ØPE			
		VBR			
		VBE			
		VST			
		NRP			
		MIL			
		MAX			
		PCT			
		VEL			

AIRFL	FIL	VEL	(FTR)	(VEL)	(DELW)
AIRFL	RPL	VBE	(FTR)		(DELW)

TOGWT SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER EXT TITLE
MAIL ADDRESS JOB NO
SHEET

TØGWT	IGE / ØGE / VEL / BRC	NRP / MIL / MAX	(GWTØ)	(Z/R)	(RØC)	(VEL)

SAMPLE INPUTS

TØGWT			(GWTØ)			
TØGWT	IGE	MIL		(Z/R)		
TØGWT	ØGE	MAX				
TØGWT	VEL	MAX	(GWTØ)		(RØC)	(VEL)
TØGWT	BRC	MIL	(GWTØ)		(RØC)	

This subroutine cannot be used to define the mission take-off gross weight and is only used when the mission requires payload optimization at a mid-mission point.

Reserve Fuel Subroutine (RESFL)

This subroutine calculates fuel reserve based on:

1. an input percentage of total mission fuel

2. a specified cruise criterion and time

Percentage of total mission fuel is calculated using the equation:

$$\text{reserve fuel} = \frac{\text{FULB} \cdot \text{PCT}}{1 - \text{PCT}}$$

where:

FULB = fuel burned up to this point in the mission

PCT = input percentage

A PCT value of .10 is automatically assumed by the program if the user neglects to input a percentage in columns 21 - 30.

When reserve fuel is based on cruise, any of the speed subroutines may be listed, and must be accompanied by a time input. The subroutine will call upon the speed subroutine listed to furnish the specific range and velocity data necessary to fulfill the input requirements.

Inputs defining the capabilities of this element are shown in Figure (15).

Speed Subroutines

The main function of the speed subroutines is to generate specific range information for the mission element subroutines. Specific range data is generated using the power required and fuel flow curve input data for as many DELW fuel increments as are needed to fulfill the cruise or hover requirements. A list of the speed subroutines follows:

OPR	speed and altitude for best range
OPE	speed and altitude for best endurance
VBR	speed for best range at a specified altitude
VBE	speed for best endurance at a specified altitude
VST	speed for rotor stall at a specified altitude

RESFL SUBROUTINE INPUT

SIKORSKY ... ING ... M

ENG ... EXT ... TITLE ...
MA. ... JOB NO ...
AN. ...

RESFL	PCT	ØPR	(PCT)	(VEL)	(DELW)
	TIM	ØPE	(TIME)	(PCT)	
		VBR			
		VBE			
		VST			
		NRP			
		MIL			
		MAX			
		PCT			
		VEL			

SAMPLE INPUTS

RESFL	PCT		(PCT)		
RESFL	TIM	VBE	(TIME)		(DELW)
RESFL	TIM	PCT	(TIME)	(PCT)	(DELW)
RESFL	TIM	VEL	(TIME)	(VEL)	(DELW)

NRP	speed at normal rated power
MIL	speed at military rated power
MAX	speed at maximum rated power
PCT	speed at a specified percentage of maximum power
VEL	specified speed

Temperatures for the optimum flight path subroutines are calculated using the standard lapse rate equation to modify the initial input temperature. Since the program can accept two speed subroutines, a minimum of downgrading is necessary. Listed below are the speed elements that have diagnostic and downgrading incorporated in them. The diagnostic statement is advisory while the downgrade statement is an announcement that the input flight profile has not been adhered to due to the aircraft's inability to maintain the requested speed.

	Speed Element	Diagnostic	Downgrade
NRP	Speed at normal rated power		V=RLVEL
MIL	Speed at military rated power	V > VST	HP=GBXHP
MAX	Speed at maximum rated power		
PCT	Speed at percentage of max. power		
VEL	specified speed	V > VST V > NRP,MIL	V=RLVEL HP=GBXHP HP=MAX POWER
VST	stall speed	V > NRP,MIL	V=RLVEL HP=GBXHP HP=MAX POWER
VBR	speed for best range (99% SR max)	V > RLVEL	
VBE	speed for best endurance	V > VST	
OPR	speed/altitude for best range (99% SR max)	V > RLVEL	
OPE	speed/altitude for best endurance	V > VST	

Specific fuel consumption (SFC) is obtained from the input SFCCV (specific fuel consumption) curves. Specific range is calculated using the equation:

$$SR = \frac{VEL}{(1.05)SFC \cdot (HP/E)\,(E)}$$

where

E is the number of engines.

Speeds for best range (VBR) require the generation of an SR vs. VEL curve. Specific range values are initially calculated using 20 knot velocity increments until a calculated SR value is less than the one preceding it. From the maximum value, specific range values are again calculated in

5 knot increments and, in turn, one (1) knot increments. The maximum point on the specific range curve has now been determined. From this point, in 5 knot increments, SR values are calculated to obtain the 99% SR max value and the corresponding velocity.

The optimum range (OPR) subroutine calculates the above described specific range curve in 2000 foot increments until the following tolerance is met:

$$\Delta SR/SR < 0.01 \left(\frac{ALT}{1000}\right)$$

The VBE or speed for best endurance subroutine calculates specific endurance using the equation:

$$SE = \frac{1}{(1.05)SFC\ HP/E.E}$$

The maximum point is determined similar to the best range analysis. The OPE (speed and altitude for best endurance) subroutine operates the same as the optimum range subroutine.

NASA MODULE

The NASA Module provides the level flight power required, hover and stall speed information required by the Mission Module when this data is unavailable for direct punched card input to the program.

This module employs a bank of non-dimensionalized rotor performance tables for a particular airfoil/twist combination. Tables for a NASA 0012 airfoil and -8° linear theoretical blade twist have been provided for use in the module and are described in detail in References (2) and (3) which were prepared under NASA Contract NASw-745, dated 10 August 1964. Should a different airfoil/twist combination be required, the Automated Generalized Rotor Performance Program will provide the tables in punched card form for direct input into the NASA Module.

The NASA Charts are carpet plots of rotor C_D/σ, C_L/σ, and C_Q/σ at various advancing tip Mach numbers for the values of rotor $V/\Omega R$ from .25 to .5. In hover, C_T/σ - C_Q/σ plots for various solidities are presented for tip Mach numbers of .5, .6, and .7. For the speed range between hover and the speed corresponding to ten (10) knots less than the lowest μ available in the NASA Tables, an approximate method is utilized to calculate horsepower.

The module calculates powers for the complete speed range in the following manner:

HOVER

The hover curves in the NASA Module are in the form C_T/σ vs. C_Q/σ at various solidities for blade tip Mach numbers of .5, .6, and .7. Solidity is calculated from input data using the equation $\sigma = bc/\pi R$. At this solidity, values for C_Q/σ at the three Mach numbers are obtained for values of C_T/σ from 0 to 0.10 in increments of .02 and from .11 to .17 in increments of .01. Temperatures for the three Mach numbers are calculated using the equation:

$$Temp = \left[(\Omega R)^2/2402.96\ M_T{}^2\right] - 460$$

The out of ground effect CW - CP values calculated take into account the input vertical drag, DRAGF. The overall mechanical efficiency curve, EFFCV, is used to obtain engine power from main rotor power.

Output consists of three out of ground effect CW-CP curves, each at a different temperature.

FORWARD FLIGHT

The power required for level flight is calculated for an input range of gross weights, density ratios and temperatures for the μ range of the NASA Tables.

The thrust and power factors, $\rho \pi R^2(\Omega R)^2$ and $\rho \pi R^2(\Omega R)^3/550$, respectively, are calculated to non-dimensionalize the gross weight and power. C_L/σ and C_D/σ values are calculated and used to determine corresponding C_Q/σ values from the Tables. This operation occurs for each μ in the Tables. The hover point is calculated directly from the hover curve generated in the hover section described above. Output thus far consists of SHP - VEL pts. for input gross weights for hover and over the velocity range corresponding to the μ range of the NASA Tables.

To calculate power between hover and the speed corresponding to the lowest μ value, powers are calculated using the equation:

$$SHP_{VEL} = \frac{\left[(SHP)\,(\eta)\right]_{(V = 0)} - \frac{GW}{550}(\Omega R)\left(\frac{C_W}{2}\right)^{1/2}(1 - u/u_0)}{K \cdot \eta_{VEL}} + (4.475)(10)^{-7}(F)V^3 \cdot \rho/\rho_0$$

Feingold's relationship of v/u_0 and u/u_0 for $\alpha = 0^\circ$ are incorporated in the module. Shaft horsepowers are calculated in 20 knot increments from V = 20 knots to a point at least 10 knots less than the speed corresponding to the lowest μ value available in the NASA Tables.

Thus, the complete set of data is obtained from hover to the velocity corresponding to the highest $V/\Omega R$ in the NASA Tables. The data plotted is in the form SHP versus VEL for the gross weights and density ratios listed in the input.

Figure (16) presents the input for this module. "PLO" is input only when a plot of the data generated is desired.

Tandem rotor calculations are handled by dividing the total thrust requirement equally between the two rotors and including the interference effects for hover and level flight in the rotor power required calculation. These terms are INTHV and INTLF, respectively, and are equal to unity for single rotor helicopters.

When a wing is to be added, the module will use input wing lift and drag curves to adjust the rotor lift and propulsive force prior to the determination of the rotor lift and drag coefficients. Wing lift and drag data are input in the form LIFT/q vs. VEL and DRAG/q vs. VEL, respectively. The module expects both curves to be input for a winged configuration and will key on "WNG" on the NASAP control card.

The module will also key on "AUX" if auxiliary thrust is to be considered and decrease the rotor's required propulsive force component by an amount obtained from an input auxiliary thrust versus velocity curve. A DELTA SHP vs. VEL curve must be input if the auxiliary thrust device draws its power from the engines powering the rotor as with a pusher propeller.

Horsepower derived from this DELTA SHP curve will be added to the main rotor power requirements. If the auxiliary thrust is derived from an independent power source such as a turbofan, the DELTA SHP curve should reflect (0) horsepower throughout the speed range. A rapid hand calculation is necessary to determine the fuel burned by the independent power source.

The required input is presented in Figure (16). AREA F and DRAG F represent the parasite and vertical drags, respectively. Level flight curve data is generated for the input density ratio (ρ/ρ_o) range, RRRNG, and corresponding temperature range, TPRNG, and gross weight range, GWRNG, at the various MU's contained in the MU range, MURNG. The NASA tables used to generate the above level flight data are numbered 1 through 10 and 11 - 20 which represent the $\frac{C_L}{\sigma}$ vs $\frac{C_Q}{\sigma}$ and $\frac{BC_QD}{\sigma}$ vs $\frac{C_Q}{\sigma}$ curves, respectively. Curves 1 and 11, 2 and 12, etc. are curve data at equal Mach numbers.

Curve No. 21 represents the C_T vs. C_Q data for hover at various Mach numbers. Figure (17) presents the input of the NASA tables behind the NDATA control card and a card containing the airfoil and twist. Only the curve number for each set of data is shown. An END card signifies the end of the NASA data input. If required, the wing lift and drag curves, WLICV and WDRCV, and the auxiliary power curves, THRCV and SHPCV, are input following Curve No. 21. These univariant type curves are coded as shown in Figure (48) with the "X" parameter corresponding to velocity.

SER-50528
Figure 16

NASA MODULE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO. ______

W.O. NO. ______

NASAP	PLØ / PCH	WNG	AUX			
INTLF				( )		
INTHV				( )		
AREAF				( )		
DRAGF				( )		
RRRNG				( )	( )	( )
TPRNG				( )	( )	( )
GWRNG				( )	( )	( )
HVRNG				( )	( )	( )

NASA MODULE INPUT (CONT)

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO. ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO ______

* O. NO. ______

NDATA DUMP

AFØIL= (   )   TWIST= (   )

1
↕
10
11
↕
20
21

END

GENERAL PERFORMANCE MODULE

The Performance Module is designed to generate general performance data applicable to a specific airframe-rotor-powerplant combination.

This module consists of a small control program and a group of independent subroutines which may be called in any number and sequence. The subroutines are:

SUBROUTINE	DEFINITION
1. HOVPR	Power required to hover
2. HOVCE	Hover ceiling
3. RCLMB	Rate of climb
4. SRVCE	Service ceiling
5. SPRNG	Specific range

These subroutines use the same level flight, hover, power available and fuel flow curve input data that the Mission Module utilizes. As such, no additional curve data is necessary to run this module. Additional capabilities may be added to this module by adding subroutines to those already incorporated. Each subroutine calculates its data over the range of gross weights, altitudes, and temperatures requested in the input. The input temperatures represent the temperatures at the initial altitude and are held constant or allowed to vary with altitude in accordance with the standard lapse rate equation if "CTP or "LTP" is input, respectively.

Power Required to Hover Subroutine (HOVPR)

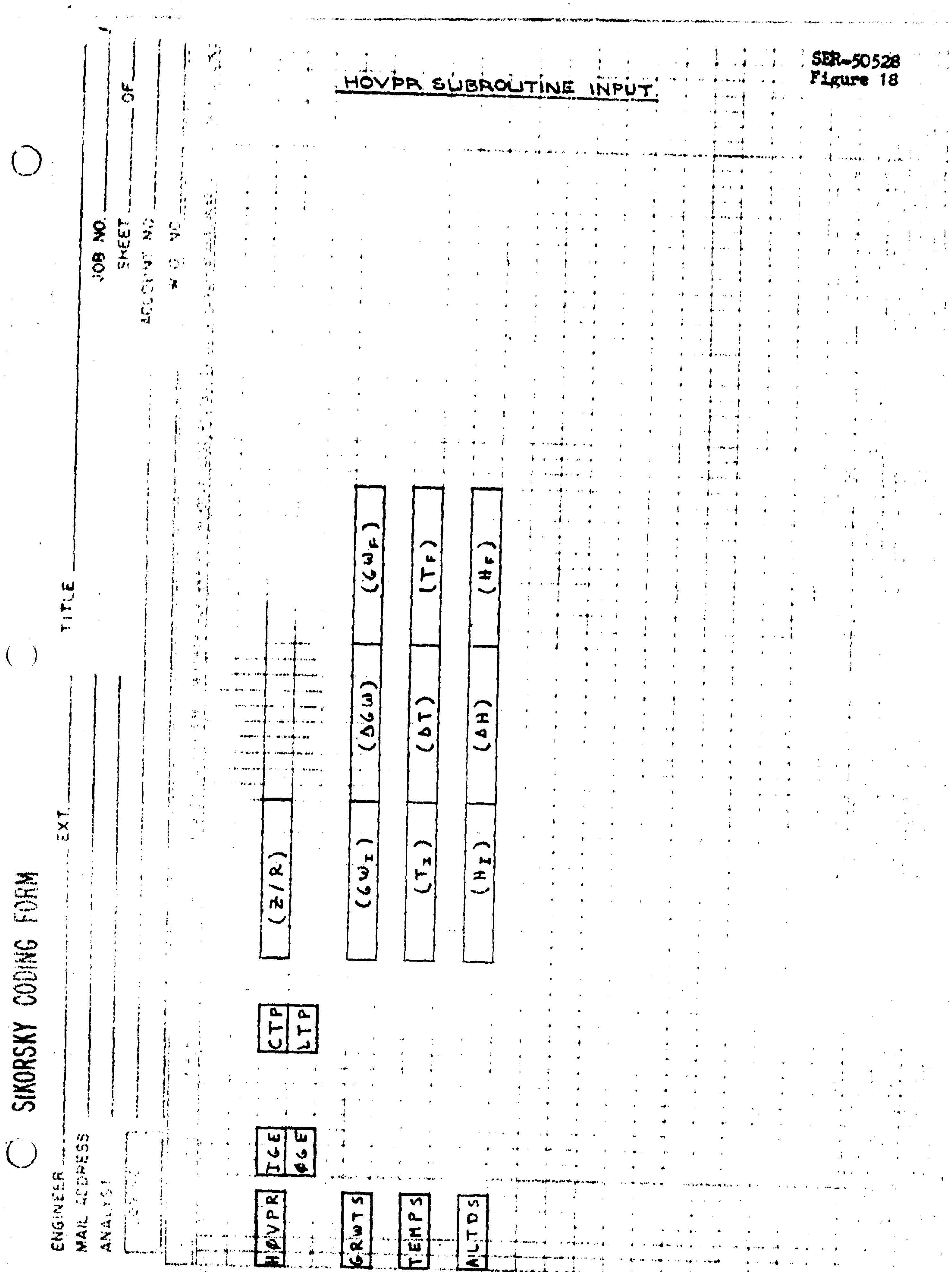
The HOVPR subroutine calculates power required data for a range of input pressure altitudes, temperatures, and gross weights, in or out of ground effect.

Weight coefficients are calculated using the equation: $CW = \frac{GW}{\rho \pi R^2 (\Omega R)^2}$. Corresponding power coefficients are obtained from the input hover data, OGECV and IGECV for existing CW and temp values. Total engine shaft horsepower is calculated by the equation $SHP = C_P \left[\frac{\rho \pi R^2 (\Omega R)^3}{550}\right]$.

Temperature may be varied or held constant with altitude by inputting either LTP or CTP respectively.

Input for this subroutine consists of four (4) cards as shown in Figure (18). A Z/R input is not required for an out of ground effect condition. If only one value of gross weight, temperature or altitude is desired, it is necessary to input this value in the locations for both the initial and final values.

HOVPR SUBROUTINE INPUT



Hover Ceiling Subroutine (HOVCE)

This subroutine calculates hover ceilings for a range of gross weights and temperatures, in or out of ground effect.

Power required to hover is calculated and compared to the power available for the same altitude/temperature condition using altitude increments specified on the input card. Power and weight coefficients are calculated using the equations outlined in the HOVPR subroutine. Power available, derived from the input engine curve data, is downgraded to GBXHP (transmission rating) when calculated to be greater. The final altitude is used only as a cut-off point. Calculations will cease for that particular gross weight-temperature condition if the hover ceiling is not attained.

Input for this subroutine consists of four (4) cards as shown in Figure (19). This input is identical to the HOVPR subroutine input with the added required input of E, number of engines.

Rate of Climb Subroutine (RCLMB)

The RCLMB subroutine calculates rates of climb for an input range of gross weights, altitudes, and temperatures at a specified power setting. Either a specified velocity or the velocity for best rate of climb may be used.

Level flight power requirements are determined from the LEVCV or forward flight curves. Available power is determined from the input engine curves and the number of engines specified on the input subroutine card and checked against the input transmission rating. Rates of climb are calculated using the equation

$$ROC = \frac{(HPA - HPR)\ 33000}{GW} \times \eta \times K \qquad \text{where:}$$

HPA = total power available
HPR = level flight power required
η = mechanical efficiency
K = correction factor for fuselage download

Mechanical efficiency, η, is obtained at the calculated MU, μ, using the EFFCV curve input. The program assumes a K value of one, calculates a rate of climb, interpolates on the ROCCV for a K and iterates until two consecutive K values are within 1%. Rates of climb are calculated for all altitudes and for each gross weight at constant or standard lapse rate temperatures.

HOVCE SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

MAIL ADDRESS ______ JOB NO. ______

ANALYST ______ SHEET ______ OF ______

LOG NO. ______ ACCOUNT NO. ______

W.O. NO. ______

HØVCE	IGE / ØGE	NRP / MIL / MAX	CTP / LTP	(Z/R)	(E)	
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)

Input for this subroutine is shown in Figure (20). The first card essentially defines the capability of the subroutine and precedes the three cards containing the gross weight, temperature, and altitude ranges.

Service Ceiling Subroutine (SRVCE)

This subroutine calculates service ceilings based on a 100 ft/min climb capability for a range of gross weights and temperatures at a specified forward speed criterion.

Rates of climb are calculated for an input gross weight and temperature starting at the specified initial altitude and proceding in input increments of altitude until a climb rate less than 100 ft/min is obtained. A linear interpolation between the altitude where the rate of climb is less than 100 ft/min and the previous altitude produces the service ceiling. Temperatures may be held constant or be allowed to vary with altitude, depending on whether "CTP" or "LTP" is specified.

Power available is obtained from the input engine data at the specified power rating and power required for level flight is obtained from the input forward flight data at a specified velocity or the minimum power speed.

If the input final altitude is reached prior to a calculated 100 ft/min rate of climb, the calculations for that particular gross weight-temperature condition will cease.

Input for this subroutine is presented in Figure (21).

Specific Range Subroutine (SPRNG)

This subroutine calculates specific range (nautical miles per pound of fuel) for a range of gross weights, altitude and temperature conditions. The velocity range for each gross weight , altitude and temperature condition is from 50 - 150 knots in ten knot increments. If a maximum value for specific range is not obtained from the above data, the velocity range is extended from 150 - 250 knots. Specific range values are calculated and a maximum value determined with its corresponding velocity. Additional SR values are calculated in one knot increments from a speed ten knots less than the velocity corresponding to the maximum value. A new maximum point and velocity are determined from the second set of data. The 99% maximum specific range is calculated and its corresponding velocity determined from the one knot increment data.

Input for this subroutine is shown in Figure (22).

SER-50528
Figure 20

RCLMB SUBROUTINE INPUT

SIKORSKY CODING FORM

ENG ...
MA ...RESS ...
AN ...

EXT

TITLE

JOB NO
SHEET ... OF
ACCOUNT NO

RCLMB	VEL / BKD	NRP / MIL / MAX	CTP / LTP	(E_I)	(E)	
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)

SER-50528
Figure 21

SRVCE SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

AN ______ SHEET ______ OF ______

ACCOUNT NO ______

SRVCE	VEL / BIRC	NRP / MIL / MAX	CTP / LTP	(VEL)	(E)
GRWTS				(GW_I)	(ΔGW)
					(GW_F)
TEMPS				(T_I)	(ΔT)
					(T_F)
ALTDS				(H_I)	(ΔH)
					(H_F)

SPRNG SUBROUTINE INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO ______

W.O. NO ______

SPRNG	CTP / LTP		(E)	
GRWTS		(GW_I)	(ΔGW)	(GW_F)
TEMPS		(T_I)	(ΔT)	(T_F)
ALTDS		(H_I)	(ΔH)	(H_F)

AUTOMATED GENERALIZED ROTOR PERFORMANCE PROGRAM

The GRP Program generates non-dimensionalized rotor performance tables for any specified blade airfoil/twist combination. This program is an automated and modified version of that already documented in References (4) and (5) which contain detailed descriptions of equations and required input.

A strip analysis of the blade is made using two-dimensional blade section lift and drag characteristics as a function of local Mach and Reynolds' numbers. Rotor flapping is initially assumed. Blade forces are calculated along with the resultant flapping assuming constant rotor inflow and the process repeated until initial and final flapping are equal. Total rotor lift, drag and power are then determined from a summation of blade forces.

The particular blade spanwise subdivision provided in this program is presented on page 62, card count 109 - 112. The blade is divided into fifteen increments, the first increment being .10R, representing a typical blade cuff offset. Lift and drag equal zero for this increment since there is negligible lift derived from this portion of the blade and blade cuff drag is accounted for in the parasite drag of the aircraft. The second increment, .15R, represents a typical blade spar extending to the innermost blade pocket. Increments 3 - 14 represent equal segments of .06R. Tip losses are accounted for by assuming zero lift on the outermost 3% of the blade, or fifteenth increment. The calculations account for retreating blade stall and compressibility through use of a appropriate airfoil data. The spar data supplied is shown from card count 124 - 138 and 140 - 155, which are representative $\alpha - C_L$ and $\alpha - C_D$ characteristics derived from two-dimensional wind tunnel tests.

The program generates C_L/σ , C_D/σ , C_Q/σ, and BC_QD/σ assuming various inflows, λ , at θ 75 values of -4° to +20° in 4° increments. Using this information, a cross plot subroutine calculates C_D/σ , C_Q/σ , and BC_QD/σ for various θ 75's at constant C_L/σ . The output from this cross plot subroutine is printed in tabular form in addition to the punched card output. This output consists of C_D/σ vs. C_Q/σ and C_D/σ vs. BC_QD/σ at constant C_L/σ for various input Mach numbers and MU's, in that order. The program currently allows a maximum of ten (10) MU's, the C_D/σ vs. C_Q/σ curves being numbered from 1 - 10 and the C_D/σ vs. BC_QD/σ curves numbered from 11 - 20. The C_T vs. C_Q curve for hover is curve number 21. These curves must be loaded into the NASA module in ascending order.

The input format for this program is presented in general form in Figure (23), followed by a complete listing of the input supplied with the computer deck. The first three cards signify the curves to be generated.

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______

JOB NO ______

SHEET ______ OF ______

ACCOUNT NO ______

GRP INPUT

SER-50526
Figure 23

CQ/CD

BCQD/CD

CT/CQ

CARD

II

JJ	(ITEMS)	(M_{T1})	(α_1)	(C_{L1})	(α_2)	(C_{L2})	(α_3)	(C_{L3})	(α_n)	(C_{Ln})
KK	(ITEMS)	(M_{T2})	(α_1)	(C_{L1})	(α_2)	(C_{L2})	(α_3)	(C_{L3})	(α_n)	(C_{Ln})
LL	(ITEMS)	(M_{TII})	(α_1)	(C_{L1})	(α_2)	(C_{L2})	(α_3)	(C_{L3})	(α_n)	(C_{Ln})

II

JJ	(ITEMS)	(M_{T1})	(α_1)	(C_{D1})	(α_2)	(C_{D2})	(α_3)	(C_{D3})	(α_n)	(C_{Dn})
KK	(ITEMS)	(M_{T2})	[illegible]	(C_{D1})	(α_2)	(C_{D2})	(α_3)	(C_{D3})	(α_n)	(C_{Dn})
LL	(ITEMS)	(M_{TII})	[illegible]	(C_{D1})	(α_2)	(C_{D2})	(α_3)	(C_{D3})	(α_n)	(C_{Dn})

GRP INPUT (Cont'd)

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______
MAIL ADDRESS ______ JOB NO. ______
ANALYST ______ SHEET ______ OF ______
ACCOUNT NO ______
W. O. NO ______

5	1		(RADIUS)	(TIPSD)	(RHØ)	(BLADES)
2	6		(E/R)			
5	8	(DX_1)	(DX_2)	(DX_3)	(DX_4)	(DX_5)
5	13	(DX_6)	(DX_7)	(DX_8)	(DX_9)	(DX_{10})
5	18	(DX_{11})	(DX_{12})	(DX_{13})	(DX_{14})	(DX_{15})
5	53	(CH_1)	(CH_2)	(CH_3)	(CH_4)	(CH_5)
5	58	(CH_6)	(CH_7)	(CH_8)	(CH_9)	(CH_{10})
5	63	(CH_{11})	(CH_{12})	(CH_{13})	(CH_{14})	(CH_{15})
5	68		(# FLAP TRIALS)	(β_0)	(β_0')	(β_0'')
5	78	(1ST MOMENT)	(2ND MOMENT)	(GRAV. ANGLE A)	(GRAV. ANGLE B)	(GRAV. ANGLE C)
5	83	(Δ DRAG)	(TAN δ_3)	(A_1S)	(B_1S)	

GAF INPUT (CONT'D)

[redacted]

SIKORSKY CODING FORM

ENGINEER ____ EXT ____ TITLE ____
MAIL ADDRESS ____ JOB NO ____
ANALYST ____ SHEET ____
ACCOUNT NO ____
W O NO ____

5	88					(TWIST)
2	93	(# SEG.)	(6)			
5	101	(β TOL.)	(β' TOL)	(# SPAR SEG.)	(A_2S)	(B_2S)
4	106	(SIGMA)	(≠0. → NON-SYM. AIRFOIL)	(SPRING AT FLAP HINGE)	(FLAP DAMPER)	
5	150	# DATA ITEMS IN SPAR CL TABLE	(α_1)	(SPAR C_{L1})	(α_2)	(SPAR C_{L2})
5	155	(α_3)	(SPAR C_{L3})	(α_4)	(SPAR C_{L4})	(ETC)
5	250	# DATA ITEMS IN SPAR CD TABLE	(α_1)	(SPAR C_{D1})	(α_2)	(SPAR C_{D2})
5	255	(α_3)	(SPAR C_{D3})	(α_4)	(SPAR C_{D4})	(ETC)
-1	99					

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

MAIL ADDRESS ______ JOB NO. ______

ANALYST ______ SHEET ______ OF ______

LOG NO. ______ ACCOUNT NO. ______

W. O. NO. ______

GRP INPUT (CONT'D)

XX								
	(μ_1)	(μ_2)	(μ_3)	(μ_4)	(μ_5)	(μ_6)	(μ_{n-1})	(μ_n)
YY								
	(M_{T_1})	(M_{T_2})	(M_{T_3})					
ZZ								
	(M_{T_1})	(M_{T_2})	(M_{T_3})					

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Figure 23 (Cont'd)

The fourth card must appear with the word "CARD" in the location shown. Airfoil data consists of C_L and C_D curves at various input Mach numbers. II is the number of input Mach numbers and cannot be greater than thirteen (13). JJ, KK, ...LL represent the number of data items for each input Mach number and cannot exceed 74. The number of points for each Mach number, therefore, cannot exceed 36.

GRP data is identical to the input data for current versions of the Sikorsky Generalized Rotor Performance program. However, a few items such as velocity have been omitted. The total GRP input listing is presented in Figure (24).

The number of MU's, XX, and advancing blade tip Mach numbers, YY, for level flight follow the GRP data, followed by the number of Mach numbers, ZZ, for hover. XX, YY, and ZZ cannot be greater than 10, 3 and 3 respectively.

LISTING OF SAMPLE INPUT DATA FOR CRP

```
         1         2         3         4         5         6         7         8
.........0.........0.........0.........0.........0.........0.........0.........0   CD COUNT
                                                                                    001
C9/C9                                                                               002
bC[illegible]/C[illegible]                                                          003
CARD                                                                                004
13   [illegible] DATA (CL[illegible] WITH .95 [illegible])
50   24.0 0.600  60.0   [illegible] 10.0   1.000  13.2   1.200  15.0   1.000CLR12.0  005
     15.2 [illegible] 25.0 [illegible] 33.0 1.160  43.0   1.151  55.0   1.110CLR12.0  006
     62.0 [illegible] 76.0 [illegible] 90.0 0.000 105.0  -0.393 125.0  -0.750CLR12.0  007
     130.0-0.570 135.0  -1.020 140.0 -1.050 145.0  -1.022 150.0  -0.930CLR12.0        008
     150.0-0.700 150.0  -1.260 160.0 -0.540 172.0  -0.732 180.0   0.000CLR12.0        009
50   24.0 0.100  60.0   [illegible] 10.0   1.000  13.5   1.200  15.0   1.500CLR12.1  010
     12.0 [illegible] 25.0 [illegible] 33.0 1.100  43.0   1.160  50.0   1.100CLR12.1  011
     62.0 [illegible] 75.0 [illegible] 90.0 0.000 135.0  -0.395 121.0  -0.750CLR12.1  012
     130.0-0.970 135.0  -1.120 140.0 -1.050 145.0  -1.022 150.0  -0.900CLR12.1        013
     150.0-0.710 150.0  -1.260 160.0 -0.540 172.0  -0.733 180.0   0.000CLR12.1        014
42   [illegible] 0.200 60.0  [illegible] 11.0  1.168  12.0   1.250  13.0   1.335CLR12.2 015
     14.5 1.336  14.0    1.336 14.5   1.290  15.0   1.200  15.5   1.180CLR12.2        016
     16.0 1.050  17.0    0.970 16.0   0.392  19.0   0.843  20.0   0.510CLR12.2        017
     21.0 0.600  22.0    0.805 24.0   0.555  26.0   0.833  28.0   0.932CLR12.2        018
     30.0 0.990                                                  CLR12.2              019
34   [illegible] 0.500 35.0 1.000  10.0  1.180  11.0   1.193  12.0   1.250CLR12.3     020
     12.0 1.222  13.0    1.260 13.5   1.260  14.0   1.223  15.0   1.090CLR12.3        021
     [illegible] 0.910 17.0 0.910 13.0 0.355 19.0   0.825  26.0   0.610CLR12.3        022
     22.0 0.520  30.0    1.015                                   CLR12.3              023
30   [illegible]  [illegible] 0.000 8.0 0.915  9.0  1.010 [illegible] 1.030CLR12.4    024
     [illegible] 1.120 12.0 1.133 15.0 1.120  16.0   1.035  17.0   0.932CLR12.4       025
     16.0 0.876  19.0    0.840 23.0   0.828  22.0   0.831  30.0   1.040CLR12.4        026
35   17.5 0.500  [illegible] 0.000 0.0 0.740  7.0   0.850   8.0   0.923 CLR12.5       027
     9.8  0.567  10.0    0.985 11.0   0.996  12.0   1.000  13.0   1.090 CLR12.5       028
     16.0 0.920  17.0    0.970 16.0   0.945  19.0   0.900  20.0   0.863 CLR12.5       029
     21.0 0.646  22.0    0.647 30.0   1.630                         CLR12.5           030
34   16.0 [illegible] [illegible] 0.000 5.0 0.675 6.0 0.770  8.0   0.873 CLR12.6      031
     10.0 0.950  12.0    0.959 14.0   0.970  15.0   0.950  17.0   0.973 CLR12.6       032
     16.0 [illegible] 19.0 0.960 20.0 0.550  21.0   0.850  22.0   0.875 CLR12.6       033
     27.0 [illegible] [illegible] 1.173                             CLR12.6           034
18   [illegible] 0.700 60.0 0.000   2.5   0.390   4.0   0.565   5.0   0.675 CLR12.7   035
     7.0  [illegible] 10.0 0.909 12.0   0.940  30.0   0.940             CLR12.7       036
26   12.0 0.750  [illegible] 0.000 1.0 0.175  2.0   0.345   2.5   0.430 CLR12.75      037
     3.0  0.516   3.5    0.520  4.0   0.635   4.5   0.620   5.0   0.717 CLR12.75      038
     5.5  0.765  [illegible] 0.765 30.0 0.765                        CLR12.75         039
16   [illegible] [illegible] [illegible] 0.000 2.0 0.395 3.0 0.520 4.0 0.600 CLR12.8  040
     5.0  0.675   6.0    0.729 30.0   0.720                         CLR12.8           041
16   7.0  0.900  20.0    0.000  1.0   0.150   2.0   0.200   3.0   0.300 CLR12.9       042
     4.0  0.400   5.0    0.500 30.0   0.500                         CLR12.9           043
8    5.   .95     0.0    0.0    5.    .375   30.    .375                .95           044
8    5.   2.      0.0    0.0    5.    .375   30.    .375                2.0           045
13                                                                                    046
62   30.0 0.000  00.0    0.000 10.0   0.010  12.0   0.020  15.0   0.190 CORR12.0      047
     2[illegible] 0.310 25.0 0.500 31.0 0.690 35.0  0.800  40.0   1.000 CORR12.0      048
     60.0 1.640  65.0    1.760 70.0   1.859  80.0   1.960  95.0   2.000 CORR12.0      049
     95.0 2.020  [illegible] [illegible] 100.0 1.950 155.0 1.940 110.0 1.850 CORR12.0 050
     125.0 1.500 140.0   1.000 155.0  0.455 157.0   0.415 160.0   0.300 CORR12.0      051
     165.0 0.250 167.0   0.200 172.0  0.110 175.0   0.070 179.0   0.030 CORR12.0      052
     180.0 0.020                                                    CORR12.0          053
62   30.0 0.100  90.0    0.000 10.0   0.010  12.0   0.020  15.0   0.190 CORR12.1      054
```

LISTING OF SAMPLE INPUT DATA FOR ORP

	1		2		3		4		5		6		7	8	CD COUNT
	20.0	0.310	28.0	0.555	31.0	0.606	35.0	0.800	40.0	1.000				CORN12.1	055
	60.0	[illegible]	65.0	1.759	70.0	1.350	30.6	1.960	55.9	2.000				CORN12.1	056
	90.0	2.022	95.0	2.010	100.0	1.950	105.0	1.940	110.0	1.850				CORN12.1	057
	125.0	1.500	140.0	1.000	155.0	0.435	157.0	0.415	160.0	0.300				CORN12.1	058
	150.0	0.250	167.0	0.200	172.0	0.110	175.0	0.070	179.0	0.030				CORN12.1	059
	180.0	0.020												CORN12.1	060
52	25.0	0.205	60.0	[illegible]	4.0	0.0084	5.0	0.0088	8.9	0.010				CORN12.2	061
	10.2	0.012	11.0	0.013	11.8	0.0145	12.3	0.016	12.9	0.020				CORN12.2	062
	13.4	0.0245	13.8	0.033	14.1	0.040	14.47	0.050	14.5	0.070				CORN12.2	063
	14.57	0.090	15.0	0.100	15.3	0.120	15.6	0.140	16.0	0.155				CORN12.2	064
	17.0	[illegible]	19.0	0.243	21.0	0.300	24.0	0.399	25.0	0.520				CORN12.2	065
	30.0	[illegible]												CORN12.2	066
52	25.0	0.300	30.0	0.005	4.0	0.0068	6.0	0.0092	8.0	0.0107				CORN12.3	067
	9.0	0.0117	10.0	0.013	10.4	0.014	10.3	0.0153	11.2	0.0175				CORN12.3	068
	11.7	0.0220	12.2	0.025	12.6	0.037	13.23	0.0600	13.65	0.080				CORN12.3	069
	14.0	0.130	15.0	0.150	15.6	0.170	17.0	0.210	18.0	0.240				CORN12.3	070
	20.0	0.300	22.0	0.350	24.0	0.420	25.0	0.485	22.0	0.550				CORN12.3	071
	30.0	0.620												CORN12.3	072
52	25.0	[illegible]	60.0	0.005	3.0	0.0082	4.0	0.0084	4.6	0.0087				CORN12.4	073
	5.2	0.0092	5.0	0.010	7.0	0.0117	8.0	0.0140	8.6	0.016				CORN12.4	074
	9.4	0.019	10.0	0.025	10.2	0.0300	11.4	0.0380	11.8	0.046				CORN12.4	075
	12.2	0.062	12.6	0.080	13.05	0.1000	13.7	0.1300	14.1	0.150				CORN12.4	076
	14.6	0.170	15.1	0.185	16.0	0.2100	19.0	0.2650	23.0	0.410				CORN12.4	077
	14.5	0.170	15.1	0.185	16.0	0.2100	19.0	0.2850	23.0	0.410				CORN12.4	078
52	25.0	0.500	[illegible]	0.308	3.0	0.0082	4.0	0.0084	4.6	0.0086				CORN12.5	079
	5.5	0.0092	5.8	0.010	6.4	0.0117	7.0	0.0137	7.6	0.0165				CORN12.5	080
	9.2	0.0235	9.8	0.027	10.0	0.0500	10.8	0.0700	11.4	0.090				CORN12.5	081
	12.0	0.110	12.5	0.130	13.2	0.150	14.0	0.180	15.0	0.210				CORN12.5	082
	18.0	0.235	17.0	0.260	19.0	0.315	21.0	0.370	24.0	0.470				CORN12.5	083
	30.0	0.740												CORN12.5	084
44	21.0	0.650	60.0	0.008	2.0	0.0082	3.0	0.0085	4.0	0.009				CORN12.6	085
	[illegible]	0.0097	[illegible]	0.0109	5.2	0.0125	5.0	0.0130	6.9	0.030				CORN12.6	086
	7.8	0.027	8.0	0.050	8.9	0.068	10.6	0.120	11.4	0.150				CORN12.6	087
	12.0	0.170	14.0	0.210	17.0	0.250	20.0	0.370	22.0	0.450				CORN12.6	088
	25.0	0.250	30.0	0.750										CORN12.6	089
44	21.0	0.700	60.0	0.005	0.7	0.0081	1.2	0.0035	1.6	0.009				CORN12.7	090
	2.0	0.010	2.3	0.011	2.6	0.013	3.0	0.017	3.4	0.022				CORN12.7	091
	3.8	0.027	4.4	0.035	5.0	0.044	5.9	0.060	6.2	0.066				CORN12.7	092
	6.9	[illegible]	7.6	0.094	9.0	0.123	10.0	0.146	11.0	0.170				CORN12.7	093
	12.0	0.197	30.0	0.197										CORN12.7	094
34	16.0	0.750	60.0	0.0102	0.6	0.0115	1.0	0.013	2.0	0.020				COR12.75	095
	2.6	0.026	3.0	0.0322	3.4	0.040	3.8	0.050	4.0	0.055				COR12.75	096
	4.4	0.064	4.8	0.073	5.0	0.0775	5.2	0.082	5.6	0.091				COR12.75	097
	6.0	0.090	30.0	0.098										COR12.75	098
30	14.0	0.600	60.0	0.0187	0.4	0.0195	0.5	0.0215	1.0	0.023				CORN12.8	099
	1.6	0.039	2.2	0.040	2.8	0.053	3.4	0.066	4.0	0.080				CORN12.8	100
	4.5	0.094	5.2	0.106	5.6	0.113	6.0	0.120	30.0	0.120				CORN12.8	101
16	7.0	[illegible]	[illegible]	0.070	1.0	0.076	2.0	0.090	3.0	0.103				CORN12.9	102
	4.0	0.125	5.0	0.140	30.0	0.140								CORN12.9	103
15	7.	.95	0.0	.125	1.	.155	2.	.2	3.	.27				.95	104
	4.	.332	5.	.48	30.	.48									105
16	7.	2.0	0.0	.125	1.	.155	2.	.2	3.	.27				2.0	106
	4.	.382	5.	.46	30.	.48									107
5	1		31.547		1117.		.002378	6.							108

LISTING OF SAMPLE INPUT DATA FOR GRP

```
          1         2         3         4         5         6         7         8
 .........0.........0.........0.........0.........0.........0.........0.........0   CD COUNT
 5   6             0.          .10        .15           .06                             109
 5  11 .06       .05        .06        .06        .06                                   110
 5  16 .06       .06        .06        .06        .06                                   111
 2  21     .06             .03                                                          112
 5  53 .0        .065       1.667      1.667      1.667                                 113
 5     1.667     1.667      1.667      1.667      1.667                                 114
 5     1.667     1.667      1.667      1.667      1.667                                 115
 2  60     30.             15.                                                          116
 3  70 .0000001  .0000001   .0000001                                                    117
 2  75 100.      2932.                                                                  118
 2  80     0.              0.                                                           119
 5  90     -0.             15.         32.2       15.                                   120
 2 101 .001      .001                                                                   121
 1 102     2.                                                                           122
 1 150    96.                                                                           123
   151    0.0            0.0        15.            1.775                4     CL1       124
          19.            .95        20.            .83       21.        5       2       125
             .703   22.              .781     23.            .790       5       3       126
          25.            .86        27.            .967      30.        5       4       127
             1.30   35.              1.2      38.            1.255      5       5       128
          40.            1.275      43.            1.29      45.        5       6       129
             1.292  47.              1.29     50.            1.262      5       7       130
          53.            1.125      115.           -.82      118.       5       8       131
             -.86   120.             -.879    123.           -.897      5       9       132
          127.           -.903      130.           -.9       135.       5      10       133
             -.879  140.             -.84     145.           -.782      5      11       134
          150.           -.675      152.           -.595     164.       5      12       135
             .03    165.             .075     167.           .16        5      13       136
          173.           .142       175.           .16       176.5      5      14       137
             .15    180.             0.0                                3      15       138
 1 250 96.                                                                              139
   251    0.0            .151       6.                                  3     CD1       140
             .150   11.              .165     16.            .192       5       2       141
          17.            .221       36.            1.109     41.        5       3       142
             1.563  46.              1.48     48.            1.541      5       4       143
          51.            1.605      56.            1.675     58.        5       5       144
             1.70   60.              1.708    61.            1.711      5       6       145
          64.            1.721      66.            1.732     69.        5       7       146
             1.716  71.              1.712    76.            1.679      5       8       147
          81.            1.645      91.            1.598     96.        5       9       148
             1.560  101.             1.555    106.           1.523      5      10       149
          116.           1.45       121.           1.402     126.       5      11       150
             1.36   131.             1.292    136.           1.21       5      12       151
          141.           1.095      151.           .795      156.       5      13       152
             .625   161.             .465     166.           .343       5      14       153
          171.           .251       176.           .190      180.       5      15       154
             .163                                                       1      16       155
-1   99                                                                                 156
 2                                                                                      157
.3       .4                                                                             158
 2                                                                                      159
.7       .8                                                                             160
```

OPTIONS

The first step in using COMAP is the selection of one of the four major running Options which determines the general type of analysis to be run. Insertion of the proper "Option" control card in the computer deck sets major switches among the various modules to produce the general types of calculation and output format desired.

Option A is used for the analysis of any mission.

Option D is used to determine mission performance trends with mission requirements.

Option E is used to determine the trends of mission performance with rotor parameters.

Option F is used to calculate general aircraft performance characteristics independent of any mission.

Since Options A, D, and E all deal with mission analysis, their input formats are essentially identical.

Options B and C which were discussed in References (5) and (6) have been incorporated into Option A to improve the flexibility, simplify the use and expand the capabilities of the program.

OPTION A

Option A employs the following modules for mission analysis as shown in Figure (25).

1. Control
2. Weights
3. Mission
4. NASA

The above modules have been discussed in detail in the preceding sections. Therefore, this section will discuss only the integration of these modules to develop the overall capabilities and operation of Option A.

The Control Module reads the input data and checks for a complete, consistent set of information. It determines if fuel and payload are properly defined for the start of the mission. If the NASA Module is to generate power required information, NASA is called to supply this curve data prior to the running of the Mission Module.

The Weights Module will then determine the empty weight from the input data. If the empty weight is a single input, this WTEMP value is stored and the operation immediately switches to the Mission Module. If the input consists of a weight breakdown, the input component weights are summed. If the structural weight in this breakdown is to be computed as a function of blade radius or number of blades, this data is immediately obtained from curves STRCV and BLDCV, respectively. A fixed engine weight is added to the previous weights summed. In the case of a rubberized engine, the power system weight is obtained from the Power, Transmission and Clutch, and Miscellaneous Weight versus Horsepower curves based on a power derived from the level flight curves at zero velocity using the initial take-off gross weight as the entering parameter.

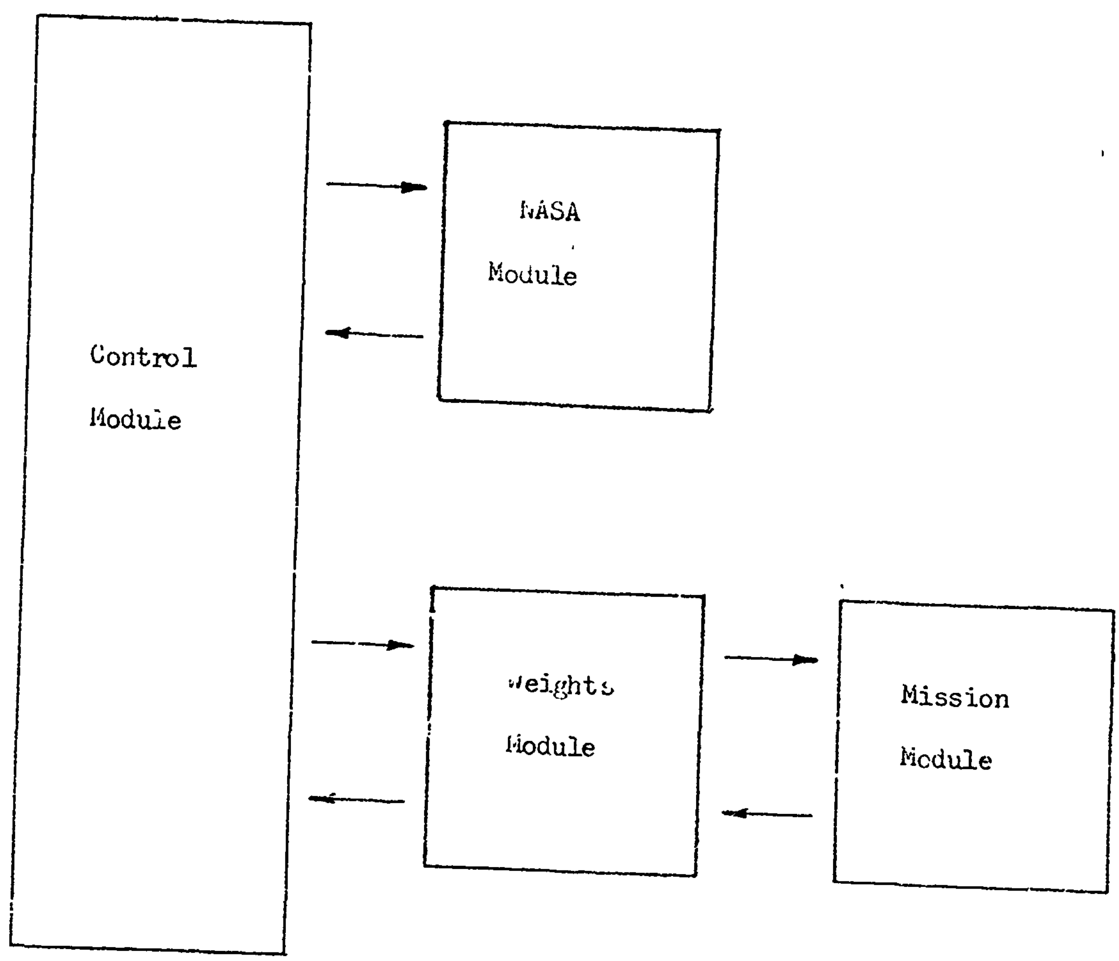
The empty weight is now completely defined, but its value may be incorrect for a rubber engine analysis which uses maximum mission power required to size the engine. This problem is eliminated by an iteration loop between the Weights and Mission Modules.

At this point, the operation switches to the Mission Module.

The logic of the Mission Module allows a solution when payload is to be optimized at the start of the mission or at some mid-mission point. Distance and time may be optimized for the mission over a maximum of two mission elements per mission.

INTERRELATIONSHIPS OF MODULES

Option A



Missions can be categorized according to the mission parameter to be solved for. To illustrate this, the main mission parameters are listed with some sample missions. It must be remembered that the take-off gross weight is known (defined) either if it is input directly or if it can be calculated within the TOGIN subroutine itself.

1. Payload (*indicates where optimization of payload begins)

Mission A

* a. Initial mission take off gross weight defined
b. Warm-up and take off
c. Cruise a specified distance or time
d. Reserve fuel

Mission B

* a. Initial mission take off gross weight defined
b. Warm-up and take off
c. Cruise a specified distance or time
d. Payload drop in percent
e. Cruise a specified distance or time
f. Reserve fuel

Mission C

a. Initial mission take off gross weight unknown
b. Warm-up and take off
c. Cruise a specified distance or time
d. Hover
* e. Mid-mission take off gross weight defined
f. Cruise a specified distance or time
g. Reserve fuel

Mission A is non-iterative since the gross weight is defined throughout the mission and maximum payload is only dependent on the mission fuel. B and C are iterative missions. Mission B requires iteration on payload while Mission C iterates on the initial take off gross weight. Optimization of payload is automatically begun in Mission C prior to the execution of the mission element following the take off gross weight subroutine since the TOGWT element will normally calculate a gross weight different from the gross weight at the end of the previous mission element and the difference must be accounted for in payload.

2. Distance (* indicates segments to be optimized)

Mission A

a. Initial mission take off gross weight defined
b. Warm-up and take off
* c. Cruise (distance)

d. Hover
* e. Cruise (distance)
f. Reserve fuel

Mission C

a. Initial mission take off gross weight defined
b. Warm-up and take off
c. Cruise a specified distance
d. Payload change
* e. Cruise (distance)
f. Reserve fuel

3. Time (* indicates segments to be optimized)

Mission A

a. Initial take off gross weight defined
b. Warm-up and take off
* c. Cruise (endurance)
d. Reserve fuel

Mission B

a. Initial take off gross weight defined
b. Warm-up and take off
* c. Cruise (endurance)
d. Payload change
* e. Cruise (endurance)
f. Reserve fuel

Mission C

a. Initial take off gross weight defined
b. Warm-up and take off
c. Cruise a specified distance
* d. Hover (endurance)
* e. Cruise (endurance)
f. Cruise a specified distance
g. Reserve fuel

Mission D

a. Initial take off gross weight defined
b. Warm-up and take off
c. Cruise a specified distance or time
* d. Hover (endurance)
e. Cruise a specified distance or time
f. Reserve fuel

In addition to the mission types outlined above where maximum payload, distance, and time are to be calculated, certain missions can be grouped where the initial take off gross weight is to be determined. This gross weight is calculated for a known payload and the fuel required to complete the mission.

4. Initial mission take off gross weight unknown

Mission A

a. Initial take off gross weight unknown
b. Warm-up and take off
c. Cruise a specified distance or time
d. Reserve fuel

Mission B

a. Initial take off gross weight unknown
b. Warm-up and take off
c. Cruise a specified distance or time
d. Payload change
e. Cruise a specified distance or time
f. Reserve fuel

The four categories discussed above represent the major capabilities of Option A. The capability of calculating the size and weight of auxiliary fuel tanks is also incorporated in the program. This capability is used by inputting "AUX" and "JP-4" or "JP-5" in the appropriate spaces of the FULCP card in the INCND (Initial Conditions) Group. If the actual fuel burned during the mission exceeds the useable fuel capacity listed on the FULCP card and "AUX" is not input, the following diagnostic is printed:

WARNING: FUEL BURNED EXCEEDS FUEL CAPACITY

Option A represents the major portion of the complete COMAP Program. Its design will permit the user to analyze a high percentage of all missions encountered. Missions which do not fall within the capabilities of this option will probably require the determination of more than one of the four major parameters discussed above. When this is the case, Option D (Mission Parameter Trending) should be utilized as discussed in the TRENDING section.

Since curve input is identical for all Options, instructions for loading curve input data follow the description of the Options.

Option A Input

The input for Option A is divided into small groups of data, each of which is identified by the first or "control" card. Asterisks in Columns 7 - 9 enable the reader to locate the various groups of input data on the print-out and are recommended but not necessary for the operation of the computer program. The various groups are:

Group	Control Card
1. Rotor Group	OPT -A
2. Weights Group	WTGRP
3. Initial Conditions Group	INCND
4. Mission Data Group	MDATA
5. General Curve Data Group	GDATA
6a. Performance Curve Data Group	PDATA
6b. NASA Module	NASAP

Descriptions of each group including the input are contained below. A" COMAP" input card precedes all input cards and is used to indicate the beginning of a case. Numerical inputs, indicated by parenthesis, require a decimal point.

Rotor Group

The Rotor Group lists the seven (7) major rotor characteristics. "COMAP" and "OPT-A" control cards precede inputs for airfoil, twist (degrees), number of rotors, main rotor tip speed (ft/sec), number of blades, blade chord (ft) and rotor radius (ft.). Inputs are as shown in Figure (26).

The inputs listed above must agree with the first two cards in the "PDATA" Group which contain these same seven inputs. An inconsistency between the two will cause the Control Program to call the NASA subroutine to generate the power required and stall speed information based on the parameters listed in the Rotor Group.

The user can request intermediate information consisting of values for gross weight, distance, time and fuel burned for each mission element for each iteration in the mission by printing "DUMP" in locations 7 - 10 of the COMAP control card.

Weights Group

Aircraft empty weight information is presented in the Weights Group (WTGRP).

Following the initial WTGRP control card, the empty weight may be specified as one input on the WTEMP input card or may be input as a breakdown, as follows:

FIXWT	fixed equipment weight
MILWT	fixed military weight
DISWT	disposable weight
FLDWT	fluid weight
STRWT	structural weight
ENGWT	engine group weight

ROTOR GROUP INPUT

SIKORSKY CODING FORM

ENGINEER ________ EXT ________ TITLE ________

MAIL ADDRESS ________ JOB NO

ANALYST ________ SHEET

ACCOUNT NO

COMAP DUMP

ØPT-A ***

AFØIL ( )

TWIST ( )

NURØT ( )

TIPSD ( )

BLDES ( )

CHØRD ( )

RØRAD ( )

The above weights may be input in pounds or expressed as the decimal equivalent of a percentage of the initial take off gross weight in the locations shown in Figure (27).

The structural weight input card, STRWT, must contain FIX, RAD, or BLD in locations 7 - 9. Locations 21 - 30 are available for a fixed weight represented by FIX. When RAD or BLD are entered, the locations 21 - 30 are left blank.

The engine weight card, ENGWT, must contain the key FIX or RUB. If the engine is defined, FIX is input with a numerical value of the engine weight and the Mission Module will use the normal, military and maximum power rating curve inputs in the "GDATA" group. When RUB is entered, the program will expect to use the Engine Weight, Transmission and Clutch Weight, and Miscellaneous Weight versus Shaft Horsepower curve inputs in the GDATA Group.

The general input format is presented in Figure (27).

Initial Conditions Group INCND

This group of data lists the necessary aircraft characteristics plus some initial conditions for the mission.

The first card is the "INCND" control card and is followed by:

1. GBXHP transmission rating (hp)
2. RLVEL red line speed (kn)
3. FULCP internal fuel capacity (lbs.). AUX and either JP-4 or JP-5 are input in locations 7 - 9 and 11 - 13 ONLY when the size and weight of auxiliary tanks is to be calculated if the fuel burned in a mission exceeds the internal fuel capacity.
4. ULOAD fixed useful load (lbs.)
5. GWMAX maximum allowable gross weight (lbs.)
6. AREAF total parasite drag (ft^2)
7. ALTDE mission initial altitude (ft)
8. TMPRE mission initial temperature (°F)
9. NUENG number of engines at mission start
10. FULIN initial mission fuel (lbs), if known. MIN is input in locations 7 - 9 when fuel is to be calculated.
11. PLDIN mission initial payload (lbs), if known. When maximum payload is to be calculated, MAX is input in locations 7 - 9.
12. TOGIN mission initial take off gross weight criterion. Capabilities of this subroutine were discussed previously.

Figures (28) and (29) present the input for this group of data.

SIKORSKY CODING FORM

ENGINEER ________ EXT ________ TITLE ________
MAIL ADDRESS ________ JOB NO ________
ANALYST ________ SHEET ________ OF ________
ACCOUNT NO ________
W.O. NO ________

WEIGHTS GROUP INPUT

WTGRP	***	
FIXWT		( )
MILWT		( )
DISWT		( )
FLDWT		( )
STRWT	FIX / RAD / BLD	( )
ENGWT	FIX / RUB	( )
(OR)		
WTEMP		( )

INCND GROUP INPUT

SIKORSKY CODING FORM

ENGINEER ________ EXT ________ TITLE ________

MAIL ADDRESS ________ JOB NO ________

AN ________ SHEET ____ OF ____

ACCOUNT NO ________

INCND	***		
GBXHP			( )
RLVEL			( )
FULCP	AUX	JP4 / JP5	( )
ULØAD			( )
GWMAX			( )
AREAF			( )
ALTDE			( )
TMPRE			( )
NUENG			( )
FULIN	MIN		( )
PLDIN	MAX		( )

INCND GROUP INPUT (CONT)

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______
MAIL ADDRESS ______
ANALYST ______
JOB NO ______
SHEET ______
ACCOUNT NO ______
W O NO ______

TØGIN

IGE
ØGE
VEL
BRC
PAR

NRP
MIL
MAX

(GWTØ)	(Z/R)	(RØC)	(VEL)

Mission Data Group

Following the "MDATA" control card, the mission element segments are input according to the mission definition. The program is designed to accommodate all information pertaining to a mission element on a single input card. An "END" card follows all data in this group and signifies the end of the mission. Only one mission can be loaded at this position in the deck. When two or more missions are to be analyzed, the remaining missions are stacked at the end of the input deck as noted under "Stacking Cases".

Figures 30 - 32 present the general input formats for all of the mission elements which may be listed in any order and number (not to exceed 20). Time, distance, speed and rate of climb are input in hours, nautical miles, knots and feet per minute respectively. Since the literal inputs define the capability of the elements, they are used to key the program to the appropriate solution and therefore, must be input.

Curve input is identical for all Options and is presented following the descriptions of all the Options.

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Figure 30

MDATA GROUP INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO. ______

ANALYST ______ SHEET ______

ACCOUNT NO. ______

MDATA	***						
WUPTØ		NRP / MIL / MAX / PCT / LBS		(TIME)	(LBS) / (PCT)		
PAYLD		LBS / PCT		(LBS) / (PCT)			
HØVER	IGE / ØGE	PAR		(TIME)	(Z/R)	(DELW)	
CLIMB	VEL / BRC	NRP / MIL / MAX / PCT / RØC	FIX / ØPR / ØPE	(END ALT)	(VEL)	(DELW)	(RØC) / (PCT)
DELDR				(DELFF)			

MDATA GROUP INPUT (CONT)

SIKORSKY CODING FORM

ENG — EXT — TITLE —
MAIL —
AN — JOB NO —
SHEET — OF —
ACCOUNT NO —

TØGWT	IGE	NRP		(GWTØ)	(Z/R)	(RØC)	(VEL)
	ØGE	MIL					
	VEL	MAX					
	BRC						

DISCR	PAR	ØPR	ØPR	(DIST)	(VEL)	(DELW)
TIMCR		ØPE	ØPE	(TIME)	(PCT)	
		VBR	VBR			
		VBE	VBE			
		VST	VST			
		NRP	NRP			
		MIL	MIL			
		MAX	MAX			
		PCT	PCT			
		VEL	VEL			

FULCR	DITTØ	DITTØ	(FUEL)	(VEL)	(DELW)
				(PCT)	

SIKORSKY CODING FORM

ENGINEER ____ EXT ____ TITLE ____
MAIL ADDRESS ____
ANALYST ____ JOB NO ____
SHEET ____ OF ____

MDATA GROUP INPUT (CONT)

AIRFL	FIL	DITTØ	(FTR)	(VEL)	(DELW)
	RPL			(PCT)	
RESFL	PCT	DITTØ	(PCT)	(VEL)	(DELW)
	TIM		(TIME)	(PCT)	
END					

TRENDING

The effects of mission or rotor parameter changes on mission performance can be evaluated quickly and easily through the use of Options D and E which allow the variance of one mission and rotor parameter, respectively.

The operation of these Options is much the same as stacking cases but provides the advantage of a simplified and centralized input format. The Control Module will cycle Option A through as many runs as there are input values for the trending parameter. Input for Option A is updated for each cycle and will provide results based on the revised input.

Since Option E requires new curve input data to be generated by the NASA Module as a rotor parameter is allowed to vary through an input range of values, the two Options are presented separately for clarity.

OPTION D

This Option allows the variance of one of the following mission parameters for either a fixed engine or rubberized engine analysis:

Mission Parameter	Identification	Definition
Speed	SPEED	mission segment speed
Range	RANGE	mission segment distance
Endurance	ENDUR	mission segment time
Payload	PLDIN	payload at start of mission
Take off gross weight	TOGIN	gross weight at start of mission
Altitude	ALTDE	altitude at start of mission
Temperature	TMPRE	ambient temperature at start of mission
Z/R	WHLHT	ratio of rotor height above ground plane to rotor radius at start of mission

Any of the above parameters can be varied through a range of input values not to exceed six with the limitation that the last value entered on the input card cannot be zero (0.0). Since this Option functions by cycling Option A, its capabilities are identical to those of Option A. A complete set of data is output for each Option A run followed by a summary of mission totals. When speed, range, or endurance are to be varied, this varying parameter can apply to a maximum of two mission elements.

A typical mission performance relationship that can be generated with the Mission Trending Option is the familiar Payload - Range curve. Holding the mission definition constant except for the variation of range, one Option D case will yield the data to plot a Payload - Range curve for one gross weight criterion. By stacking cases at various take off gross weights, an entire family of Payload - Range curves at various take off gross weights can be calculated in one machine run, as shown in Figure 33.

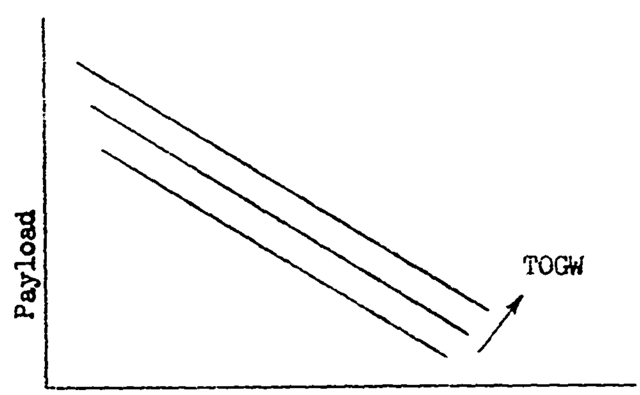


Figure 33

Figure (34) presents Payload-Wheel Height curves, each curve at constant power. In addition, a Take-Off Gross Weight - Pressure Altitude (hover ceiling) family can be generated (Figure (34)) each curve at constant temperature as shown.

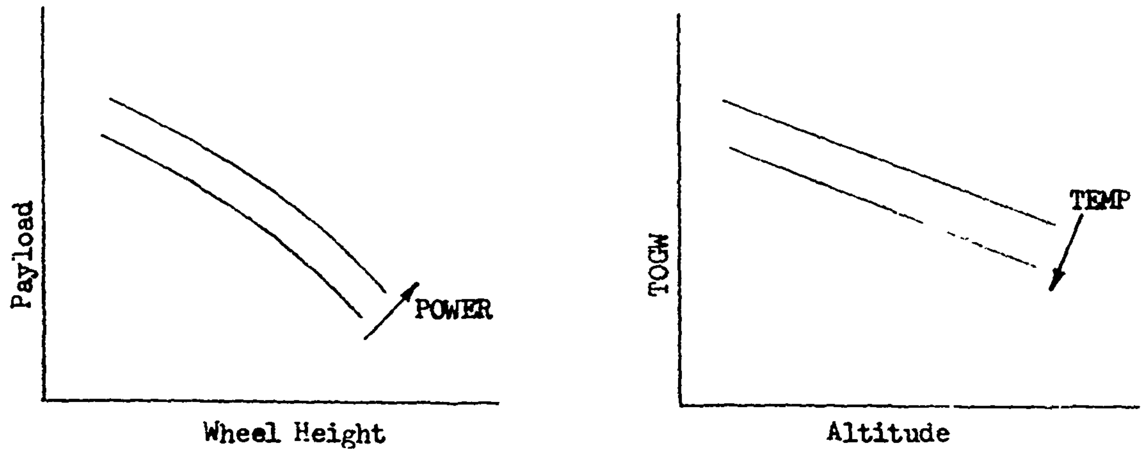


Figure 34

The effect of cruise speed on mission payload for constant range is shown in Figure (35). Here again, allowing the range to vary for each stacked case, a family of curves can be plotted from a single output.

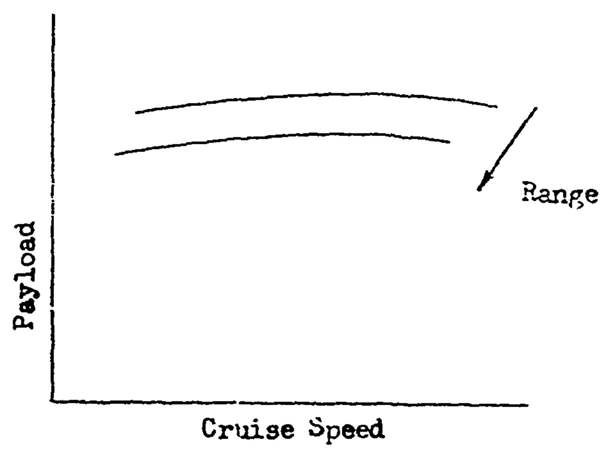


Figure 35

One can also determine the cruise speed for a specified mission that will result in maximum productivity. By allowing the cruise speed to vary, corresponding values of productivity can be plotted as in Figure (36).

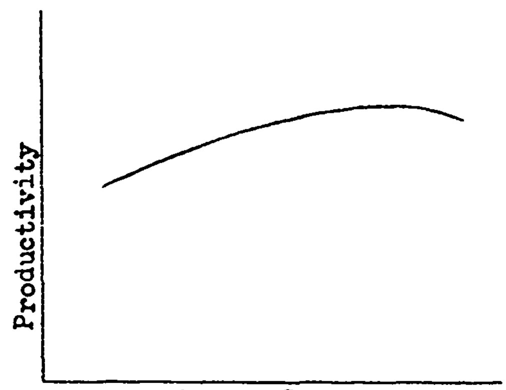


Figure 36

A useful plot for rubberized engine analyses is the Maximum Mission Power versus Range curve at constant payload. Lines of constant Take off Gross Weight, superimposed on a family of Power-Range curves, produces a plot similar to Figure (37).

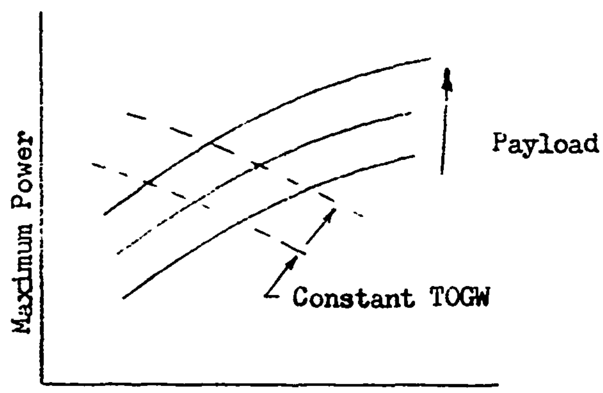


Figure 37

The effects of engine uprating on mission performance can be obtained for use in a cost-effectiveness analysis to facilitate rapid evaluation of proposed powerplant modifications.

Some missions will fall beyond the capability of the basic program, Option A. If the reason should be a capability of a mission element subroutine, that capability must be added to the mission element. However, for those missions requiring the determination of two of the four major parameters (Payload, Distance, Time, Take off Gross Weight), Option D should be utilized. For instance, if it is desired to calculate mission radius with a fixed take off gross weight and a possible power limited hover at a mid-mission point, a solution can be obtained by trending on mission radius using the initial take off gross weight as a parameter. Mission radius can be plotted as a function of the mid-point hover gross weight. Entering the plot with the maximum gross weight to hover at the mid-mission point, the maximum mission radius is determined.

Input for Option-D is identical to that of Option-A with the following substitutions and additions.

1. An "OPT-D" control card is substituted for the "OPT-A" card.

2. An additional card is added to the Rotor Group to identify the mission parameter to be varied. This card is placed after the "RORAD" card as shown in Figures (38) and (39). Locations 1 - 12 are used to identify the run. The varying parameter must be input in locations 15 - 19 using the literal identification as illustrated in Figure (39). Locations 21 - 80 are available in fields of ten for up to six corresponding numerical values of the varying parameter. The last input value CANNOT be zero (0.0).

3. Since SPEED, RANGE, and ENDURANCE are mission element parameters, the mission elements affected must be identified. This is done by imputting "TREND" in locations 61 - 65 on the appropriate mission element input cards as shown in Figure (39).

4. When the initial payload (PLDIN) or initial take off gross weight (TOGIN) is to be varied, the program will expect to read the PLDIN or TOGIN cards in the INCND group but will obtain the numerical values for them from the appropriate card in the Rotor Group as explained in Item 2 above.

5. If ALTD, TMPRE, or WHLHT is to be varied, the locations of values for each on the ALTDE, TMPRE, and TOGIN cards are left blank. Here again, the program will obtain values as in Item 4 above.

Figures (38) and (39) present the required input format for each parameter.

ROTOR GROUP INPUT

SIKORSKY CODING FORM

ENGINEER ________ EXT ________ TITLE ________

MAIL ADDRESS ________ JOB NO ________

ANALYST ________ SHEET ________

ACCOUNT NO ________

W. O. NO ________

CØMAP	DUMP	
ØPT-D	***	
AFØIL		( )
TWIST		( )
NURØT		( )
TIPSD		( )
BLDES		( )
CHØRD		( )
RØRAD		( )

OPTION D INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

JOB NO. ______

SHEET ______ OF ______

ACCOUNT NO. ______

(GEN INFØ)

SPEED	( )	( )	( )	( )	( )	( )
PLDIN						
RANGE						
ENDUR						
TØGIN						
ALTDE						
TMPRE						
WHLHT						

DISCR
TIMCR

TREND

OPTION E

The effect (on mission performance) of small changes in certain rotor parameters is determined by Option E. Any one of the following four (4) main rotor parameters can be varied at one time:

Parameter	Definition
TIPSD	tip speed
BLDES	number of blades
CHORD	rotor blade chord
RORAD	rotor radius

The Control Module cycles Option A through one run for each input value of the rotor parameter, calculating new power required and stall speed information for each cycle of Option A. The NASA Module generates complete sets of power required data which can be returned in plotted form, if requested.

The operation of Option E is very similar to that of Option D. The structural weight can be listed as a function of rotor radius or number of blades. However, when tip speed and chord are allowed to vary, no change in the structural weight will take place. As in Option D, output will consist of complete Option A output plus a summary of mission totals.

Input for this Option consists of "COMAP" and "OPT-E" control cards followed by the seven (7) rotor parameters (similar to Option A). However, since one of the seven parameters is allowed to vary, the card containing that particular parameter will contain not just one but up to six input values as shown in Figure (40). A breakdown of the empty weight must be used if the structural weight is a function of rotor radius or number of blades or if the engine size is rubberized. For all other cases, one weight empty input may be used.

The remaining input is identical to the Option A input.

Two useful plots which can be readily generated are shown in Figure (41). They are Power versus Payload for varying number of blades and Power versus Rotor Radius for varying payloads. Here again, stacked cases will produce all the necessary data to generate the plots with a single machine run.

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO ______

W.O. NO ______

OPTION E INPUT

ØMAP

ØPT-E

AFØIL ( )

TWIST ( )

NURØT ( )

TIPSD ( )

BLDES ( )

CHØRD ( )

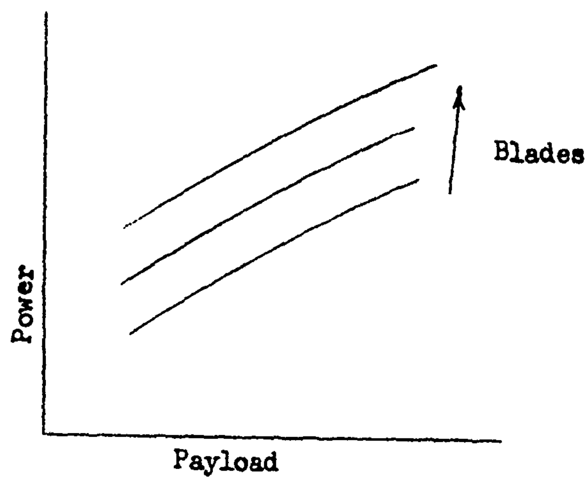
RØRAD ( )

(GEN INFA) TIPSD ( ) ( ) ( ) ( ) ( ) ( )

BLDES

CHØRD

RØRAD



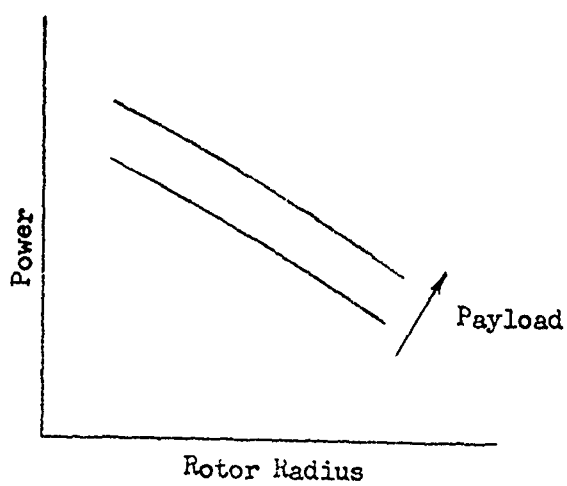


Figure 41

OPTION F

Option F, the General Performance Option, is discussed in detail in the Performance Module section. Its operation utilizes the Control, NASA, and Performance Modules as shown in Figure (42). The integration of these modules allows the user to obtain general performance data for a specified rotor/airframe/powerplant system.

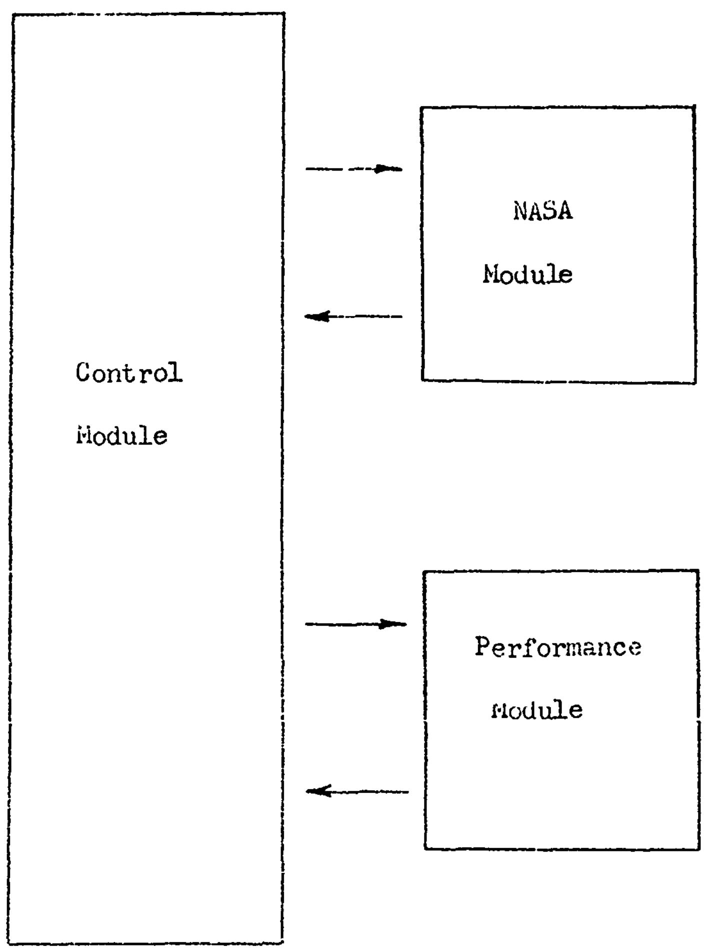
Performance data consists of rate of climb, service ceiling, power required to hover, hover ceiling and specific range information as described previously. The Control Module will call upon the NASA Module to supply the power required information if necessary.

Input for this Option consists of COMAP and OPT-F control cards followed by the seven rotor parameter cards and an FDATA card as shown in Figure (43). Subroutine input, Figures (44 - 46), follows the FDATA card, followed by a FINIS card to signify the end of the input data. Each subroutine has its own input format as illustrated in Figures (44-46) . These subroutines may be stacked in any order and number not to exceed 20.

Curve data input is identical to Option A and is described separately.

This Option cannot run without being stacked behind an Option A, D, or E case.

Option F



SIKORSKY CODING FORM

ENGINEER ____ EXT ____ TITLE ____

MAIL ADDRESS ____ JOB NO ____

ANALYST ____ SHEET ____ OF ____

ACCOUNT NO ____

A D NO ____

OPTION F INPUT

CØMAP

ØPT-F

AFØIL ( )

TWIST ( )

NURØT ( )

TIPSD ( )

BLDES ( )

CHØRD ( )

RØRAD ( )

FDATA

OPTION F INPUT (CONT)

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______

ANALYST ______ JOB NO ______

SHEET ______

ACCOUNT NO ______

W O NO ______

HØVPR	IGE / ØGE		CTP / LTP	(Z/R)		
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)
HØNCE	IGE / ØGE	NRP / MIL / MAX	CTP / LTP	(Z/R)	(E)	
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)

SIKORSKY CODING FORM

ENGINEER ________ EXT. ________ TITLE ________

MAIL ADDRESS ________ JOB NO ________

SHEET ____ OF ____

ACCOUNT NO ________

W.O. NO ________

OPTION F INPUT (CONT)

RCLMB	VEL / RRC	NRP / MIL / MAX	CTP / LTP	(VEL)	(E)	
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)
SRVCE	VEL / BRC	NRP / MIL / MAX	CTP / LTP	(VEL)	(E)	
GRWTS				(GW_I)	(ΔGW)	(GW_F)
TEMPS				(T_I)	(ΔT)	(T_F)
ALTDS				(H_I)	(ΔH)	(H_F)

OPTION F INPUT (CONT)

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

MAIL ADDRESS ______ JOB NO ______

ANALYST ______ SHEET ______ OF ______

ACCOUNT NO ______

W. O. NO ______

SPRNG	CTP / LTP		(E)	
GRWTS		(GW_I)	(ΔGW)	(GW_F)
TEMPS		(T_I)	(ΔT)	(T_F)
ALTDS		(H_I)	(ΔH)	(H_F)
FINIS				

CURVE DATA

Curve data for input is divided into groups to allow rapid substitution as better data becomes available (for example, flight test data).

Figure (47) presents the general format of all curve inputs for this program. The interpolation subroutine will accommodate up to a quadrivariant curve coded as shown in Figure (48). The first card identifies the curve while the second card contains any descriptive information that might be helpful to the user. These two cards are part of the output format. Literal inputs identifying the X and Y axis are contained on the third card followed by the fourth card containing the number of points plus the ALPHA, BETA, and GAMMA parameters. The remaining cards contain the X and Y coordinates of the points. ALPHA must be varied before BETA and BETA before GAMMA. Literal inputs identifying curve data must be among those presented in this report.

Altitude and temperature are input in feet and degrees Fahrenheit, respectively. A partial listing of curve input data is presented in Figures (49) and (50) to clarify the coding of data.

GDATA Group

The GDATA group contains engine power and fuel flow information, a mechanical efficiency curve for converting main rotor power to total engine shaft horsepower, structural weight data and an airframe download correction factor curve used in rate of climb calculations. These curves are listed below:

Fixed Engine

NRPCV - normal rated power	
MILCV - military rated power	Altitude vs. Shaft Horsepower at various
MAXCV - maximum rated power	speeds and temperatures
SFCCV - specific fuel consumption -	SFC vs. Shaft Horsepower at various speeds, altitudes, and temperatures

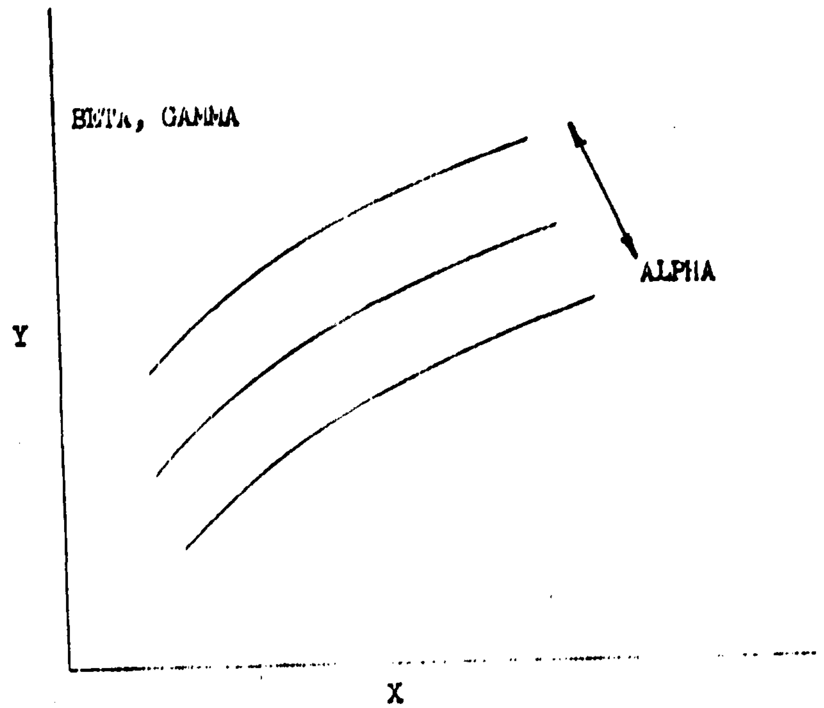
Rubber Engine

POWCV - total engine weight - Weight vs. Shaft Horsepower

TRACV - transmission and clutch weight - Weight vs. Shaft Horsepower

MISCV - miscellaneous installation weight - Weight vs. Shaft Horsepower

Curve Input



SIKORSKY CODING FORM

ENGINEER ________ EXT ________ TITLE ________

JOB NO ________
SHEET ________
ACCOUNT NO ________
W O NO ________

CURVE CODING FORMAT

IDENT

TITLE CARD

X-AXIS Y-AXIS

NPTS = ( ) ALPHA = ( ) BETA = ( ) GAMMA = ( )

(X_1)	(Y_1)	(X_2)	(Y_2)	(X_3)	(Y_3)	(X_n)	(Y_n)

PARTIAL LISTING OF INPUT DATA FOR GDATA GROUP

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Figure 49

```
         1                2         3         4         5         6         7         8
.......  ..........0.........0.........0.........0.........0...  ...0.........0    CD COUNT
SFCCV
T56-[illegible] - [illegible] 29500 RPM                                                  703
SHAFT HP          [illegible]                                                        704
NPTS    7.        V 0.        ALT       0.                  T 20.                    705
300.       [illegible]    [illegible]    .[illegible]      700.      .746      900.      .676         706
1100.      [illegible]    [illegible]    .[illegible]      1500.     .601                             707
NPTS    7.        [illegible]     ALT       0.                  T 20.                    708
300.       [illegible]    [illegible]    .[illegible]      700.      .737      [illegible]     .668         709
1100.      [illegible]    [illegible]    .[illegible]      1500.     .592                             710
NPTS    7.        [illegible]     ALT       0.                  T 20.                    711
300.       [illegible]    [illegible]    .317      700.      .72       900.      .654         712
1100.      [illegible]    [illegible]    .[illegible]      1500.     .582                             713
NPTS    10.       V 0.        ALT       5000.               T 20.                    714
300.       [illegible]    [illegible]    [illegible]       500.      .725      500.      .73          715
700.       [illegible]    [illegible]    .[illegible]      900.      .64       1000.     .622         716
1100.      [illegible]    1200.     .[illegible]01                                              717
NPTS    10.       V 100.      ALT       5000.               T 20.                    718
300.       .[illegible]       400.      .851      500.      .773      600.      .725         719
700.       [illegible]    800.      .555      900.      .635      1000.     .618         720
1100.      [illegible]    1200.     .[illegible]                                                721
NPTS    10.       V 200.      ALT       5000.               T 20.                    722
300.       .9[illegible]      400.      .627      500.      .759      600.      .708         723
700.       .571      800.      .[illegible]      900.      .625      1000.     .608         724
1100.      .595      1200.     .585                                                725
NPTS    10.       V 0.        ALT       10000.              T 20.                    726
200.       1.0[illegible]7    300.      .[illegible]7      400.      .788      500.      .739         727
600.       .711      700.      .[illegible]9      800.      .672      900.      .66          728
1000.      [illegible]    1100.     .543                                                729
NPTS    10.       V 100.      ALT       10000.              T 20.                    730
200.       1.097     300.      .357      400.      .788      500.      .722         731
600.       .[illegible]77     700.      .646      800.      .623      900.      .606         732
1000.      .59[illegible]     1100.     .5[illegible]7                                                733
NPTS    10.       V 200.      ALT       10000.              T 20.                    734
200.       1.0[illegible]7    300.      .88       400.      .775      500.      .709         735
600.       .[illegible]       700.      .631      800.      .61       900.      .594         736
1000.      .5[illegible]      1100.     .575                                                737
NPTS    7.        V 0.        ALT       0.                  T 60.                    738
300.       1.05      500.      .36[illegible]      700.      .75       900.      .685         739
1100.      .646      1300.     .622      1500.     .609                             740
NPTS    7.        V 100.      ALT       0.                  T 60.                    741
300.       1.031     [illegible]    .85       700.      .742      900.      .679         742
1100.      .64       1300.     .516      1500.     .603                             743
NPTS    7.        V 200.      ALT       0.                  T 60.                    744
300.       1.022     500.      .33       700.      .728      900.      .669         745
1100.      .63       1300.     .605      1500.     .59                              746
NPTS    10.       V 0.        ALT       5000.               T 60.                    747
300.       .96       400.      .857      500.      .778      600.      .727         748
700.       .692      800.      .666      900.      .646      1000.     .63          749
1100.      .516      1200.     .61                                                 750
NPTS    10.       V 100.      ALT       5000.               T 60.                    751
300.       .963      400.      .846      500.      .773      600.      .721         752
700.       .[illegible]57     [illegible]    .631      900.      .641      1000.     .626         753
1100.      .61[illegible]     1200.     .605                                                754
NPTS    10.       V 200.      ALT       5000.               T 60.                    755
                                                                                     756
```

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Figure 50

PARTIAL LISTING OF INPUT DATA FOR GDATA GROUP

```
1         1         2         3         4         5         6         7         8
..........0.........0.........0.........0.........0.........0.........0.........0    CD COUNT
300.      .95       400.      .838      500.      .76       600.      .71                 757
700.      .877      800.      .850      900.      .334      1000.     .619                758
1100.     .807      1200.     .598                                                        759
NPTS   3.          V 0.          ALT    10000.              T 60.                         760
200.      1.07      300.      .912      400.      .321      500.      .76                 761
600.      .721      700.      .695      800.      .677      900.      .665                762
1000.     .65                                                                             763
NPTS   9.          V 100.        ALT    10000.              T 60.                         764
200.      1.07      300.      .9        400.      .303      500.      .735                765
600.      .69       700.      .66       800.      .337      900.      .62                 766
1000.     .607                                                                            767
NPTS   5.          V 200.        ALT    10000.              T 60.                         768
200.      1.07      300.      .384      400.      .765      500.      .721                769
600.      .677      700.      .546      900.      .626      900.      .609                770
1000.     .591                                                                            771
NPTS   6.          V 0.          ALT    0.                  T 100.                        772
300.      1.031     500.      .391      700.      .78       900.      .705                773
1100.     .66       1300.     .54                                                         774
NPTS   6.          V 100.        ALT    0.                  T 100.                        775
300.      1.039     500.      .362      700.      .752      900.      .687                776
1100.     .544      1300.     .522                                                        777
NPTS   6.          V 200.        ALT    0.                  T 100.                        778
300.      .95       500.      .345      700.      .745      900.      .676                779
1100.     .635      1300.     .616                                                        780
NPTS   6.          V 0.          ALT    5000.               T 100.                        781
300.      .904      400.      .875      500.      .795      600.      .742                782
700.      .706      800.      .682      900.      .663      1000.     .65                 783
NPTS   6.          V 100.        ALT    5000.               T 100.                        784
300.      .97       400.      .855      500.      .732      600.      .731                785
700.      .697      800.      .675      900.      .655      1000.     .643                786
NPTS   6.          V 200.        ALT    5000.               T 100.                        787
300.      .902      400.      .855      500.      .755      600.      .72                 788
700.      .653      800.      .665      900.      .649      1000.     .636                789
NPTS   7.          V 0.          ALT    10000.              T 100.                        790
200.      1.037     300.      .93       400.      .348      500.      .795                791
600.      .76       700.      .737      800.      .727                                    792
NPTS   7.          V 100.        ALT    10000.              T 100.                        793
200.      1.06      300.      .9        400.      .311      500.      .753                794
600.      .714      700.      .677      800.      .672                                    795
NPTS   7.          V 200.        ALT    10000.              T 100.                        796
200.      1.053     300.      .89       400.      .799      500.      .739                797
600.      .697      700.      .672      800.      .656                                    798
EFFCV                                                                                     799
MECH. EFF.                                                                                800
MU                 EFF                                                                    801
NPTS   6.                                                                                 802
0.0       .35       .143      .885      .167      .387      .238      .895                803
.286      .900      .476      .900                                                        804
ROCCV                                                                                     805
CLIMB CORR.                                                                               806
ROC                K                                                                      807
NPTS   2.                                                                                 808
0.0       1.        6000.     1.                                                          809
END                                                                                       810
```

PCTCV - specific fuel consumption - SFC vs. Percent Sea Level Standard Military Shaft Horsepower at various speeds, altitudes, and temperatures.

RUBCV - altitude and temperature correction - Shaft Horsepower (S.L. STD) vs. Shaft Horsepower (Altitude, Temperature) at various altitudes and temperatures.

Miscellaneous Curves

EFFCV - mechanical efficiency - Efficiency vs. MU

ROCCV - fuselage download correction factor - K vs. rate of climb

RADCV - rotor radius - Structural Weight vs. Rotor Radius

BLDCV - number of blades - Structural Weight vs. Number of Blades

Figures (51 - 54) illustrate the format of the above inputs acceptable to the program. Since the program searches a group of input for the particular curve required, it is not necessary to input only those curves required for any one computer run. The EFFCV and ROCCV curves are necessary input when climb data is calculated and also when the NASAP Module is employed to generate power required data.

Input for the GDATA Group consists of CURVE and GDATA control cards followed by the individual curve data inputs as shown in Figures (55 - 56). Only the IDENT or identification card for each curve input is shown. If a plot of the input curve data or the printout is desired, the word PLOT is punched on the CURVE control card as shown.

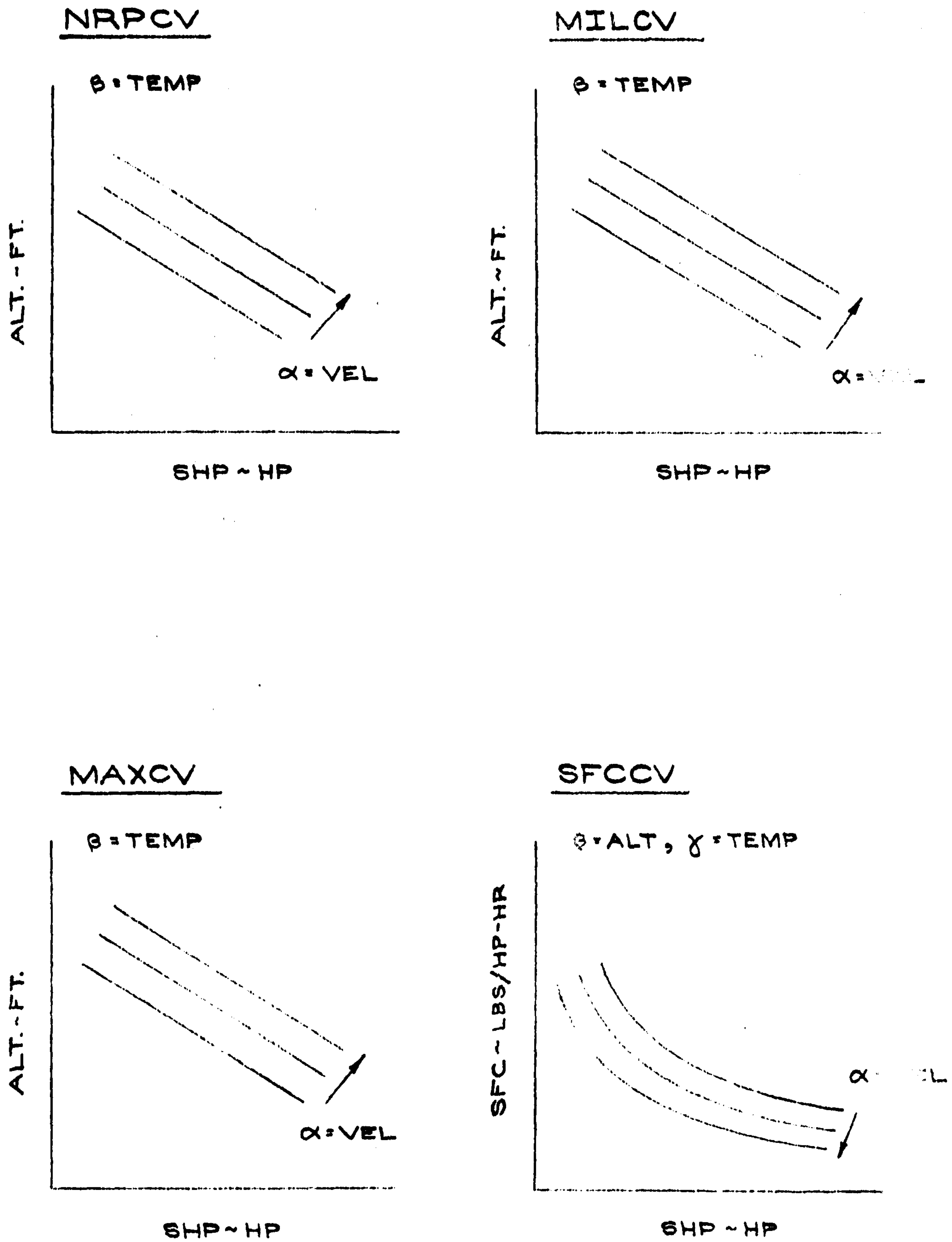
PDATA

Figure (57) presents the curve inputs for the PDATA group. Level flight power required, hover power and stall speed information represent a complete set of data in punched card form.

Level flight data is presented at various gross weights and density ratios. The out of ground effect hover Cw-Cp data is shown at various temperatures to account for compressibility effects. In ground effect data has the additional Z/R parameter and it is recommended that the highest Z/R value input be an OGE condition to eliminate extrapolations on this data. Stall speed data is input in the form VST versus Gross Weight at various density ratios. This data must correspond to the parasite drag (DRAGF) input listed for Option A.

Figure (58) presents the input format for the PDATA Group. Only the identification or IDENT card is shown for each curve. The two cards

GDATA


NRPCV
β = TEMP
ALT. - FT.
α = VEL
SHP ~ HP
MILCV
β = TEMP
ALT. ~ FT.
α =
SHP ~ HP
MAXCV
β = TEMP
ALT. - FT.
α = VEL
SHP ~ HP
SFCCV
β = ALT, γ = TEMP
SFC ~ LBS/HP-HR
α
SHP ~ HP

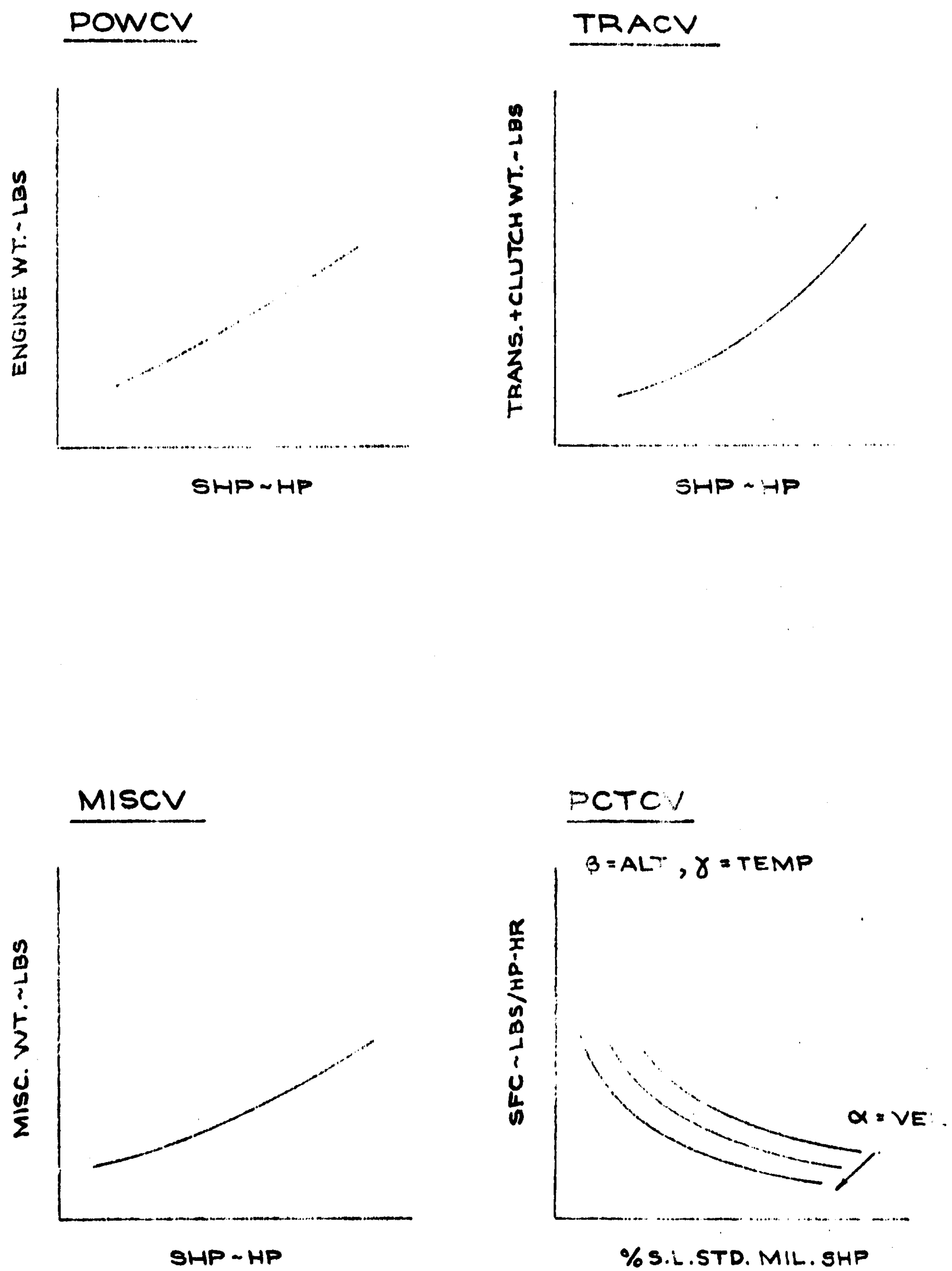
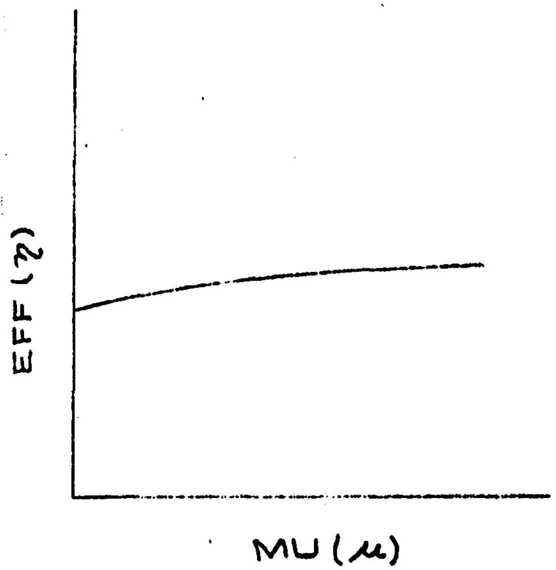
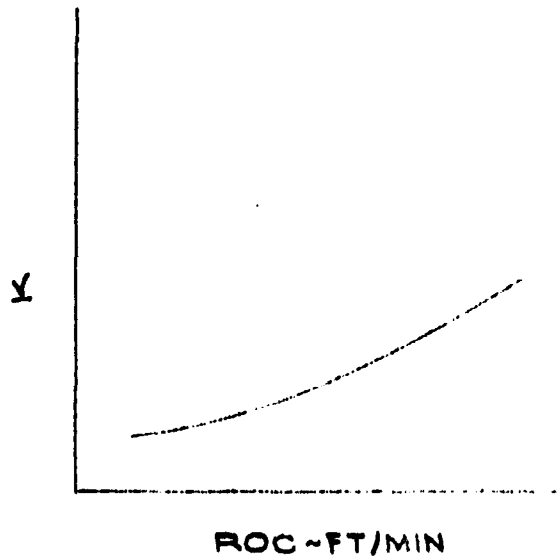

POWCV
ENGINE WT.-LBS
SHP~HP
TRACV
TRANS.+CLUTCH WT.-LBS
SHP~HP
MISCV
MISC. WT.~LBS
SHP-HP
PCTCV
β = ALT , γ = TEMP
SFC~LBS/HP-HR
α = VE
% S.L. STD. MIL. SHP

Figure 53

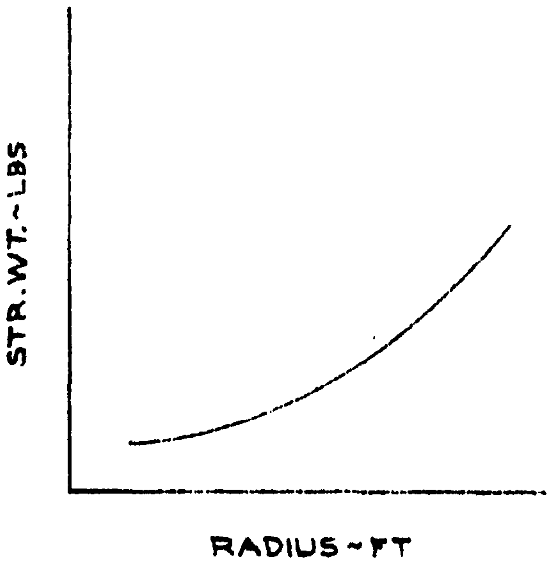
EFFCV



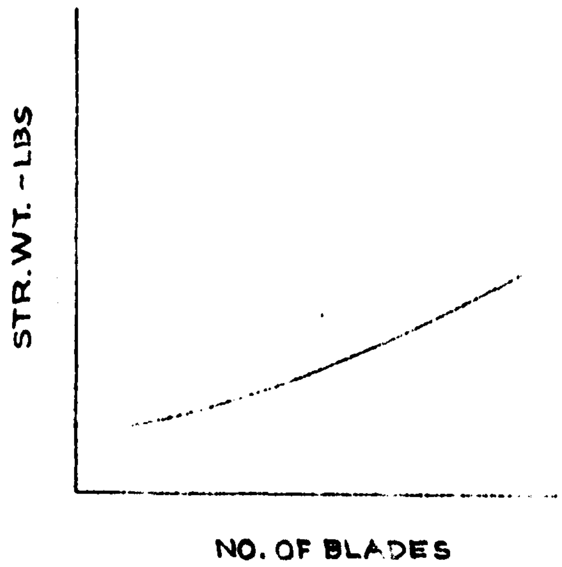
ROCCV

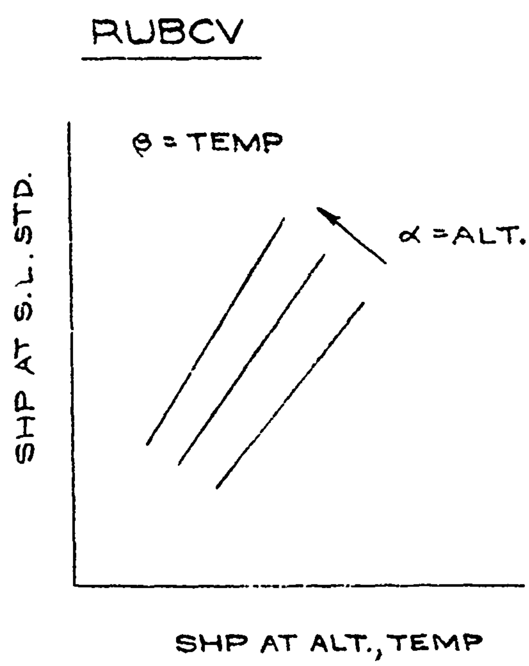


RADCV



BLDCV




RUBCV
β = TEMP
α = ALT.
SHP AT S.L. STD.
SHP AT ALT., TEMP

SEL-50528
Figure 55

GDATA GROUP INPUT

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______ JOB NO. ______

MA[illegible]ESS ______ SHEET ______

ANA[illegible] ______ ACCOUNT NO. ______

PLØT

CURVE

GDATA

NRPCV

MINCV

MAXCV

SFCCV

EFFCV

PØWCV

TRACV

MISCV

SER-50528
Figure 56

GDATA GROUP INPUT (CONT)

SIKORSKY CODING FORM

ENGINEER ______ EXT ______ TITLE ______

MAIL ADDRESS ______

ANALYST ______

JOB NO ______

SHEET ______ OF ______

ACCOUNT NO ______

W.O. NO ______

RUBCY

PCTCY

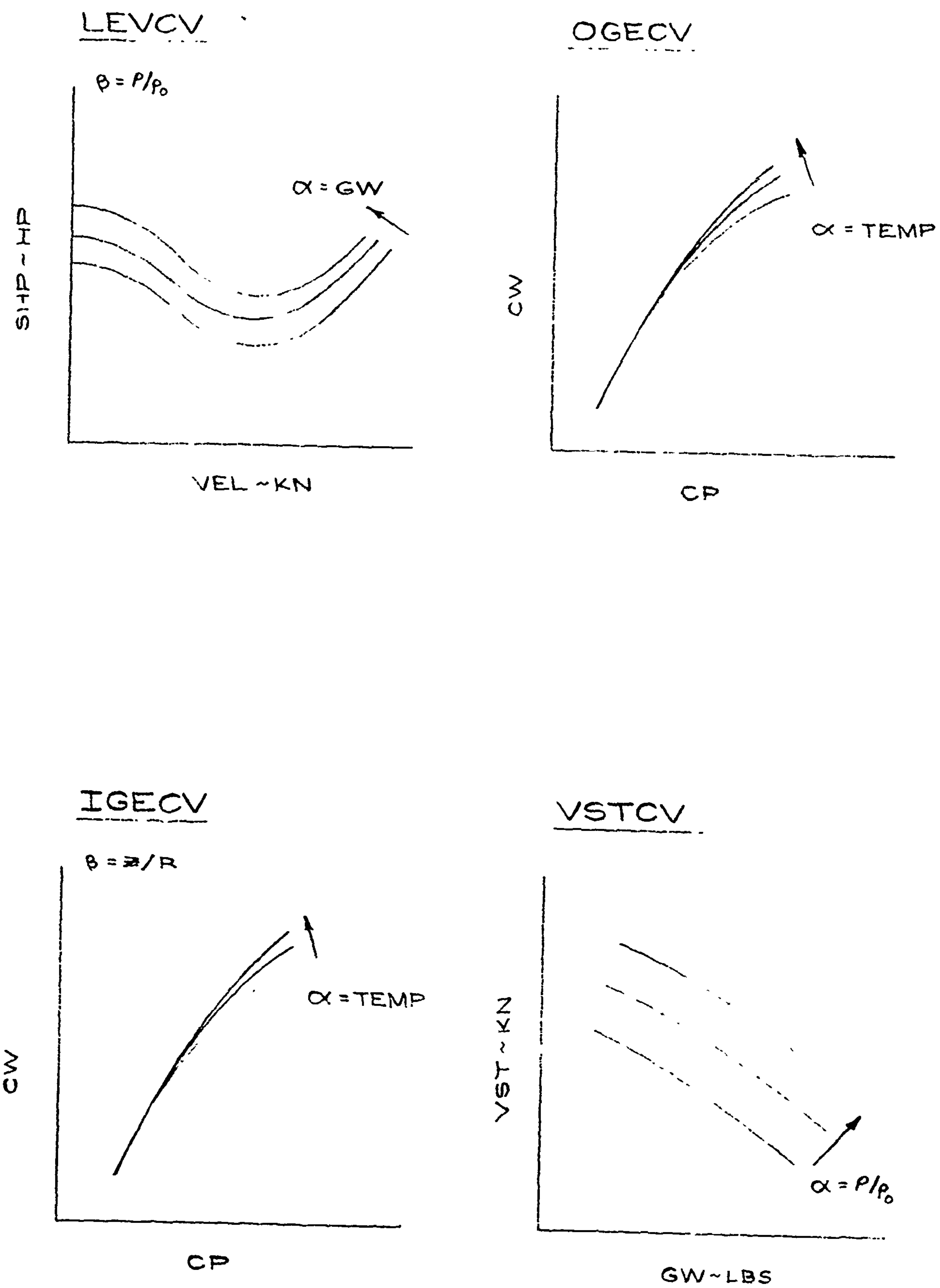
RADCV

BLDCY

RØCCY

END

PDATA


LEVCV
β = ρ/ρ0
α = GW
SHP ~ HP
VEL ~ KN
OGECV
α = TEMP
CW
CP
IGECV
α = TEMP
CW
CP
VSTCV
VST ~ KN
α = ρ/ρ0
GW ~ LBS

containing the seven rotor parameters are part of the output format for reference putposes only and should correspond to the values input in the Rotor Group.

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______
MAIL ADDRESS ______
ANALYST ______
JOB NO ______
SHEET ______
ACCOUNT NO. ______
W. O. NO. ______

PDATA GROUP INPUT

PDATA

AFØIL ( ) TWIST ( ) NURØT ( )

TIPSD ( ) BLDES ( ) CHØRD ( ) RØRAD ( )

LEVCV

ØIGECV

IGECV

VISTCV

END

FINIS

SER-50526
Figure 58

OUTPUT FORMAT

Some sample missions have been compiled to better illustrate the output from a computer run. For every case, the input is printed out for reference purposes.

CASE I

Case No. I, Figure (59), is a typical fixed engine Option A case where the empty weight has been input as one value. From the INCND or Initial Conditions Group, this aircraft is to take off with a 1000 pound payload at sea level standard conditions and mission fuel is to be calculated. The initial take-off weight is unknown and depends on the fuel burned. The mission definition is:

1. Warm-up at NRP for .08 hour (5 minutes)
2. Climb at 60 knots forward speed to a fixed altitude of 4000 feet using normal rated power and 100 pound fuel increments.
3. Cruise (at normal rated power) for 50 miles using 500 pound fuel increments.
4. Hover, out of ground effect, at 6000 feet and 95°F, for .10 hours (6 minutes) using 1000 pound fuel increments.
5. Pick up 1000 pounds of payload.
6. Cruise, sea level standard, at speed for normal rated power or stall, whichever is less, for 50 miles using 500 pound fuel increments.
7. Reserve fuel based on .5 hours cruise at best endurance speed.

The curve data loaded in the program is referenced in the GDATA and PDATA Groups.

The first part of the output, Figure (60), summarizes conditions at the start of the mission. Gross weight, payload and fuel are included. The actual mission element outputs follow with values for gross weight at the end of the elements, maximum power utilized in the elements, and distance, time and fuel burned, both delta and accumalative values. Appropriate diagnostics and any downgrading occurring in the elements are listed.

A summary of mission totals include:

Distance	total mission distance
Time	total mission time
Speed	average overall mission speed (total distance over total time)

Max. Power maximum power utilized during the mission.
Productivity sum of products of payload-distance for the elements divided by total mission time
Wt. Empty empty weight of aircraft

The Mission Variable Profile contains values for fuel, distance, time, speed, power, altitude, temperature and any diagnostics for every DELW fuel increment used in the CLIMB, DISCR, TIMCR, FULCR, AIRFL, and RESFL subroutines. This profile is used primarily to trace the aircraft's flight path during an optimum cruise and, as such, is actually a more detailed breakdown of the above mentioned mission elements.

This format is standard for Options A, D, and E for fixed engine cases.

CASE 2

This case is an Option A run with a rubberized engine. The empty weight breakdown includes the weights for all the groups except the engine group weight, as shown in Figure (61). This weight, based on the installed power to satisfy mission requirements, is printed out following the Mission Totals as shown in Figure (62). This engine group weight is part of the output format only for rubberized engine cases. The remaining format is identical to the previous case.

CASE 3

The Option D output format consists of "n" complete Option A formats plus a summary of mission parameters for "n" runs of Option A.

In this case, Figure (63), mission element range was to be varied. The appropriate mission element input card has been properly identified with "TREND" in locations 61 - 65. The parameter to be varied has been input with its corresponding values following the Rotor Group cards. Each Option A output follows, including the final summary of mission parameters. Figures (64 - 67) present the output.

CASE 4

This Option E case was run varying the chord of the main rotor blade. The values for the chord have been input on the "CHORD" card of the Rotor Group as shown in Figure (68). The output again consists of an Option A run for each value of the chord plus a summary of mission totals along with the varying rotor parameter, as presented in Figures (69 - 71).

CASE 1

SER-50528
Figure 59

```
MISSION INPUT  1

COMAP DUMP

OPT-A ***
AFOIL                  .0012
TWIST                 -5.00
NUROT                  1.00
TIPSD                660.00
BLDES                  5.00
CHORD                  1.52
RORAD                 31.00

WTGRF ***
ATEMP -            12400.00

INCND ***
GBXHP               2500.00
RLVEL                142.00
FULCP               4700.00
ULOAD                600.00
GWMAX              20500.00
AREAF                 30.00
ALTDE                   .00
TMPRE                 59.00
NOENG                  2.00
FULIN MIN
PLDIN               1300.00
TOGIN PAR          20000.00

MDATA ***
WUPTO       NRP          .08
CLIMB VEL   NRP FIX   4000.        60.        100.
DISCR       NRP         50.                   500.
ALTDE                 6000.
TMPRE                   95.
HOVER OGE                .10                  1000.
PAYLD       LBS       1000.
ALTDE
TMPRE                   59.
DISCR       NRP VST     50.                   500.
RESFL TIM   VBE          .50                  300.
END

CURVE

GDATA
NRPCV     T58-GE-10 ENGINE DATA 19500 RPM NRP
MILCV     T58-GE-10 ENGINE DATA 19500 RPM MIL
MAXCV     T58-GE-10 ENGINE DATA 19500 RPM MAX
SFCCV     T58-GE-10 ENGINE DATA 19500 RPM
EFFCV     MECH. EFFICIENCY
END

PDATA ***
AFOIL     .0012     TWIST   -6.00      NUROT    1.
TIPSD  660.         BLDES    5.        CHORD    1.52      RORAD   31.00
LEVCV     SH-3D FORWARD FLIGHT PERFORMANCE 203 RPM
OGECV     SH-3D HOVER PERFORMANCE ALL TEMPERATURES
VSTCV     SH-3D VSTALL 203 RPM
END
```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CASE 1 (CONT'D)

SER-50528
Figure 60

MISSION OUTPUT 1

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
15573.	1000.	1573.	600.	30.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	PAR	0.	0.	.000	.000	0.	0.	0.	15573.		
WUPTO	NRP	-0.	0.	.080	.080	132.	132.	2498.	15442.		
CLIMB	VEL NRP FIX	1.	1.	.022	.102	36.	168.	2527.	15405.		
DISCR	NRP	49.	50.	.343	.445	410.	578.	1762.	14995.		V=RLVEL
ALTDE	= 6000.										
TMPRE	= 95.										
HOVER	OGE	-0.	50.	.100	.545	122.	700.	1716.	14873.		
PAYLD	= 2000.										
ALTDE	= 0.										
TMPRE	= 59.										
DISCR	NRP VST	50.	100.	.352	.897	450.	1151.	1808.	15423.		V=RLVEL
RESFL	TIM VBE	30.	100.	.500	.897	423.	1573.	895.	15000.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
100.	.90	111.	2527.	84.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
CLIMB	168.	1.3	.10	60.	2527.	4000.	45.		
DISCR	578.	50.0	.44	142.	1762.	4000.	45.		V=RLVEL
DISCR	1151.	100.0	.90	142.	1808.	0.	59.		V=RLVEL
RESFL	1451.	121.2	1.25	60.	895.	0.	59.		
RESFL	1573.	130.0	1.40	60.	879.	0.	59.		

CASE 2

SER-50528
Figure 61

```
MISSION INPUT 1

COMAP DUMP

OPT-A
AFOIL                      .0012
TWIST                     -8.00
NUROT                      1.00
TIPSD                    696.00
BLDES                      6.00
CHORD                      2.17
RORAD                     36.00

WTGRP ***
FIXWT                   3358.00
MILWT                     19.00
DISWT                      .00
FLDWT                    616.00
STRWT                  12904.00
ENGWT RUB                 -.00

INCND ***
GBXHP                   6400.00
RLVEL                    696.00
FULCP                   4340.00
ULOAD                    866.00
GWMAX                  42000.00
AREAF                     46.00
ALTDE                      .00
TMPRE                     59.00
NUENG                      2.00
FULIN MIN
PLDIN                   8949.00
TOGIN PAR              40000.00

MDATA ***
WUPTO     LBS              .08      100.
DIS(R     VST          200.                  1000.
PAYL)     PCT             -.50
DISCR     VEL           50.         140.     1000.
RESFL PCT                  .10
END

CURVE

GDATA
POWCV     POWCV  ENGINE WEIGHT VS SHAFT HORSEPOWER ADV. TECH. ENGINE TWO ENG TOTAL
TRACV     TRACV  TRANS. AND CLUTCH WT. VS SHAFT HORSEPOWER  TYPE S-65  2 ENG. TOT.
MISCV     MISCV  MISC. ENG. INST. WT. VS SHP  TYPE S-65  TWO ENGINE TOTAL
PCTCV     TEST DATA, SFC VS PCT STD MIL SHP (60 DEG DAY- SEA LEVEL)
EFFCV     MECH. EFFICIENCY
END

PDATA
AFOIL     .0012      TWIST    -8.00      NUROT     1.
TIPSD   696.         BLDES     6.        CHORD     2.17       RORAD    36.00
LEVCV     LEVCV LEVEL FLIGHT PERFORMANCE CH-53A NF=13600 RPM
OGECV     HOVER PERFORMANCE OGE NO TEMP. CH-53A T64-GE-6A ENGINES 100 PCT.
VSTCV     STALL SPEEDS   CH-53A   NF=13600 RPM
END

FINIS
```

CASE 2 (CONT'D)

MISSION OUTPUT 1

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
35599.	8949.	3882.	866.	46.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	PAR	0.	0.	.000	.000	0.	0.	0.	35645.		
WUPTO	LBS	-0.	0.	.080	.080	100.	100.	0.	35545.		
DISCR	VST	200.	200.	1.279	1.359	2801.	2901.	5100.	32744.		
PAYLD	= 4474.										
DISCR	VEL	50.	250.	.357	1.716	593.	3494.	3619.	27677.		
RESFL	PCT	-0.	250.	-.000	1.716	388.	3882.	0.	27289.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
250.	1.72	146.	5100.	587.	21902.

RUBBER ENGINE WEIGHT BASED ON HP = 5336.

ENGINE = 1064.

MISCELLANEOUS = 265.

TRANSMISSION = 3676.

***TOTAL WT = 5005.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
DISCR	1100.	72.1	.55	154.	4782.	0.	59.		
DISCR	2100.	143.4	1.00	157.	4956.	0.	59.		
DISCR	2901.	200.0	1.36	160.	5100.	0.	59.		
DISCR	3494.	250.0	1.72	140.	3619.	0.	59.		

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Figure 62

CASE 3

```
MISSION INPUT  1

COMAP DUMP

OPT-D ***
AFOIL                       .0012
TWIST                      -8.00
NUROT                       1.00
TIPSD                     660.00
BLDES                       5.00
CHORD                       1.52
RORAD                      31.00
TREND          RANGE       50.00     100.00     150.00

WTGRP ***
WTEMP                   12400.00

INCND ***
GBXHP                    2500.00
RLVEL                     142.00
FULCP                    4700.00
ULOAD                     600.00
GWMAX                   20500.00
AREAF                      30.00
ALTDE                        .00
TMPRE                      59.00
NUENG                       2.00
FULIN MIN
FLDIN MAX
TOGIN OGE MIL

MDATA ***
WUPTO     NRP               .08
DISCR     VEL                        135.       500.          TREND
HOVER OGE                   .10                1000.
PAYLD     PCT              -.50
DISCR     NRP                                   500.          TREND
RESFL PCT                   .10
END

CURVE

GDATA
NRPCV     T58-GE-10 ENGINE DATA 19500 RPM NRP
MILCV     T58-GE-10 ENGINE DATA 19500 RPM MIL
MAXCV     T58-GE-10 ENGINE DATA 19500 RPM MAX
SFCCV     T58-GE-10 ENGINE DATA 19500 RPM
EFFCV     MECH. EFFICIENCY
END

FDATA ***
AFOIL     .0012     TWIST   -8.00       NUROT    1.
TIPSD  660.         BLDES    5.         CHORD    1.52      RORAD   31.00
LEVCV     SH-3D FORWARD FLIGHT PERFORMANCE 203 RPM
OGECV     SH-3D HOVER PERFORMANCE ALL TEMPERATURES
VSTCV     SH-3D VSTALL 203 RPM
END

FINIS
```

SER-50528
Figure 63

CASE 3 (CONT'D)

SER-50528
Figure 64

MISSION OUTPUT 1

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
20483.	6057.	1427.	600.	30.0	0.	59.	2.

ELEMENT		DISTANCE		TIME		FUEL BURN		MAX POWER	GROSS WT	DIAGNOSTIC DOWN-GRADE
		DELTA	TOTAL	DELTA	TOTAL	DELTA	TOTAL			
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	20483.	GW=F(GBXHP)
WUPTO	NRP	-0.	0.	.080	.080	132.	132.	2498.	20352.	
DISCR	VEL	50.	50.	.370	.450	537.	669.	2161.	19815.	
HOVER	OGE	-0.	50.	.100	.550	154.	822.	2285.	19661.	
PAYLD	= 3029.									
DISCR	NRP	50.	100.	.352	.902	462.	1285.	1874.	16170.	V=RLVEL
RESFL	PCT	-0.	100.	-.000	.902	143.	1427.	0.	16028.	

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
100.	.90	111.	2500.	252.	12400.

23145

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC DOWN-GRADE
DISCR	532.	46.5	.42	135.	2161.	0.	59.	
DISCR	669.	50.0	.45	135.	2077.	0.	59.	
DISCR	1285.	100.0	.90	142.	1874.	0.	59.	V=RLVEL

CASE 3 (CONT'D)

MISSION OUTPUT 3

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
20483.	4977.	2506.	600.	30.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	20483.		GW=F(GBXHP)
WUPTO	NRP	-0.	0.	.080	.080	132.	132.	2498.	20352.		
DISCR	VEL	100.	100.	.741	.821	1059.	1191.	2161.	19293.		
HOVER	OGE	-0.	100.	.100	.921	149.	1339.	2189.	19144.		
PAYLD	= 2489.										
DISCR	NRP	100.	200.	.704	1.625	916.	2255.	1877.	15739.		V=RLVEL
RESFL	PCT	-0.	200.	-.000	1.625	251.	2506.	0.	15489.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
200.	1.62	123.	2500.	230.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
DISCR	632.	46.5	.42	135.	2161.	0.	59.		
DISCR	1132.	94.2	.78	135.	2077.	0.	59.		
DISCR	1191.	100.0	.82	135.	1999.	0.	59.		
DISCR	1609.	154.0	1.30	142.	1877.	0.	59.		V=RLVEL
DISCR	2255.	200.0	1.62	142.	1820.	0.	59.		V=RLVEL

SER-50528
Figure 65

CASE 3 (CONT'D).

SER-50528
Figure 66

SSION OUTPUT 2

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
20483.	3917.	3566.	600.	30.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	20483.		GW=F(GBXHP)
YUPTO	NRP	-0.	0.	.080	.080	132.	132.	2498.	20352.		
DISCP	VEL	150.	150.	1.111	1.191	1567.	1698.	2161.	18785.		
HOVER	OGE	-0.	150.	.100	1.291	145.	1843.	2101.	18641.		
PAYLD	= 1959.										
DISCP	NRP	150.	300.	1.056	2.347	1367.	3209.	1881.	15315.		V=RLVEL
RESFL	FCT	-0.	300.	-.000	2.347	357.	3566.	0.	14959.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
300.	2.3[illegible]	126.	2500.	188.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
DISCR	652.	46.5	.42	135.	2161.	0.	59.		
DISCR	1132.	94.2	.78	135.	2077.	0.	59.		
DISCR	1552.	143.3	1.14	135.	1999.	0.	59.		
DISCR	1698.	156.0	1.19	135.	1920.	0.	59.		
DISCR	2543.	203.9	1.67	142.	1861.	0.	59.	V=RLVEL	
DISCR	2843.	239.2	2.06	142.	1821.	0.	59.	V=RLVEL	
DISCR	3269.	300.0	2.35	142.	1799.	0.	59.	V=RLVEL	

TRENDING

RANGE	DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	GROSS WT	PAYLOAD
50.	100.	.90	111.	2500.	252.	20483.	6057.
100.	200.	1.62	123.	2500.	230.	20483.	4977.
150.	300.	2.35	128.	2500.	168.	20463.	3917.

CASE 3 (CONT'D)

SER-50528
Figure 67

MISSION INPUT 1 **CASE 4**

SER-50528
FIG. NO. 68

```
COMAP
OPTPL
AFOIL
TWIST                         .0012
NOROT                        -8.00
TIPSD                         1.00
BLDCS                       660.00
NORAD                         5.00
TREND                        31.00
             CHORD            1.60       1.80       2.00
WTGRP ***
WTEMP
                          12400.00
ENGRD ***
BCKHP
HOVEL                      2500.00
FULCP                       170.00
ULOAD                      4700.00
WMAX                        600.00
AREAF                     25000.00
ALTDE                        25.00
TMPRE                          .00
NOENG                        59.00
FULIN MIL                     2.00
PLUIN MAX
TOGIN OGE MIL

MDATA ***
WOPTO       LBS
DISCR       HRP                .08      100.
RESFL PCT              200.                          500.
END                            .10

CURVE

SDATA ***
MRPCV       T58-GE-10 ENGINE DATA 19500 RPM MRP
MILCV       T58-GE-10 ENGINE DATA 19500 RPM MIL
MAXCV       T58-GE-10 ENGINE DATA 19500 RPM MAX
SFCCV       T58-GE-10 ENGINE DATA 19500 RPM
EFFCV       MECH. EFF.
ACCCV       CLIMB CORR.
END
```

MISSION INPUT 1

CASE 4 (CONT'D)

SER-50528
FIG. NO. 68(CONT)

```
NASAP PLC
NOTCP           1.00
INTHV           1.00
AREAP          25.00
CPASF           1.04
KKRNG           1.00      -.05       .70
TPRNC          59.00     -7.13     16.20
GWRNG       12000.00   2000.00  22000.00
MURNG            .25       .05       .50

UDATA
AFOIL     .0012    TWIST   -8.00
      1    GRP FORWARD FLIGHT CURVES. THIS CURVE FOR MU=.25
      2    GRP FORWARD FLIGHT  CURVES. THIS CURVE  FOR MU=.30
      3    GRP FORWARD FLIGHT  CURVES. THIS CURVE FOR MU=.35
      4    GRP FORWARD FLIGHT CURVES. THIS CURVE FOR MU=.40
      5    GRP FORWARD  FLIGHT  CURVES.  THIS CURVE FOR MU=.45
      6    GRP  FORWARD  FLIGHT CURVES.THIS CURVE FOR MU=.50
     11    GRP FORWARD FLIGHT  CURVES.THIS CURVE FOR MU=.25
     12    GRP FORWARD FLIGHT  CURVES.THIS CURVE FOR MU=.30
     13    GRP FORWARD FLIGHT  CURVES.THIS CURVE FOR MU=.35
     14    GRP FORWARD FLIGHT  CURVE.THIS CURVE FOR MU=.40
     15    GRP FORWARD FLIGHT  CURVE.THIS CURVE FOR MU=.45
     16    GRP FORWARD FLIGHT  CURVE THIS CURVE FOR MU=.50
     21           THETA1 -8 DEG MACH NUMBERS .5,.6,.7   TYPE 3 (HOVER)

FINIS
```

CASE 4 (CONT'D)

MISSION OUTPUT 1

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
21017.	5599.	2417.	600.	25.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	21017.		GW=F(GBXHP)
WUPTO	LBS	-0.	0.	.080	.080	100.	100.	0.	20917.		
DISCP	NRP	200.	200.	1.286	1.366	2070.	2176.	2498.	18841.	V>VSTALL	
RESFL	PCT	-0.	200.	-.000	1.366	242.	2417.	0.	18599.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
200.	1.37	146.	2500.	410.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
[illegible]	[illegible]	47.4	.39	153.	2498.	0.	59.	V>VSTALL	
[illegible]	1100.	95.4	.79	155.	2498.	0.	59.	V>VSTALL	
[illegible]	[illegible]	145.9	1.03	156.	2490.	0.	59.	V>VSTALL	
[illegible]	[illegible]	192.6	1.42	157.	2498.	0.	59.	V>VSTALL	
[illegible]	2175.	200.0	1.37	158.	2498.	0.	59.	V>VSTALL	

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Figure 69

MISSION OUTPUT 2

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
20488.	5135.	2352.	600.	25.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	20488.		GW=F(GBXHP)
AUPTO	LBS	-0.	0.	.080	.080	100.	100.	0.	20388.		
DISCR	HRP	200.	200.	1.250	1.330	2017.	2117.	2498.	18370.	V>VSTALL	
RESFL	PCT	-0.	200.	-.000	1.330	235.	2352.	0.	18135.		

CASE 4 (CONT'D)

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
200.	1.33	150.	2500.	386.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
DISCR	[illegible]	49.2	.39	159.	2498.	0.	59.	V>VSTALL	
DISCR	1100.	96.7	.70	160.	2498.	0.	59.	V>VSTALL	
DISCR	1600.	148.4	1.01	159.	2498.	0.	59.	V>VSTALL	
DISCR	2100.	198.3	1.32	161.	2498.	0.	59.	V>VSTALL	
DISCR	2117.	200.0	1.33	162.	2498.	0.	59.	V>VSTALL	

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Figure 70

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Figure 71

CASE 4 (CONT'D)

MISSION OUTPUT

INITIAL CONDITIONS AT START OF MISSION

GROSS WT	PAYLOAD	FUEL	USEFUL LOAD	AREAF	ALTITUDE	TEMP	ENGINES
20008.	4672.	2336.	600.	25.0	0.	59.	2.

ELEMENT		DISTANCE DELTA	DISTANCE TOTAL	TIME DELTA	TIME TOTAL	FUEL BURN DELTA	FUEL BURN TOTAL	MAX POWER	GROSS WT	DIAGNOSTIC	DOWN-GRADE
TOGIN	OGE MIL	0.	0.	.000	.000	0.	0.	2500.	20008.		GW=F(GBXHP)
AUPTO	LBS	-0.	0.	.080	.080	100.	100.	0.	19908.		
DISCR	HRP	200.	200.	1.241	1.321	2003.	2103.	2498.	17905.		
RESFL	PCT	-0.	200.	-.000	1.321	234.	2336.	0.	17672.		

MISSION TOTALS

DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	WT EMPTY
200.	1.32	151.	2500.	354.	12400.

MISSION VARIABLE PROFILE

ELEMENT	FUEL	DISTANCE	TIME	SPEED	MAX POWER	ALTITUDE	TEMP	DIAGNOSTIC	DOWN-GRADE
[illegible]	[illegible]	49.7	.39	160.	2498.	0.	59.		
[illegible]	[illegible]	99.5	.70	161.	2498.	0.	59.		
[illegible]	[illegible]	149.5	1.01	161.	2498.	0.	59.		
[illegible]	[illegible]	199.7	1.32	162.	2498.	0.	59.		
[illegible]	[illegible]	200.6	1.32	162.	2498.	0.	59.		

[illegible]

[illegible]	DISTANCE	TIME	SPEED	MAX POWER	PRODUCTIVITY	GROSS WT	PAYLOAD
1.6	[illegible]	1.37	146.	2500.	410.	21017.	5599.
1.8	[illegible]	1.35	150.	2500.	386.	20483.	5135.
2.0	[illegible]	1.32	151.	2500.	354.	20008.	4672.

CASE 5

Figure (72) presents the format of input information for a typical Option F case.

In this case, the Power Required to Hover subroutine, HOVPR, is to generate data for an out of ground effect condition for gross weights of 26000 to 42000 pounds in 8000 pound increments and altitudes from sea level to 16000 feet in 2000 foot increments. The temperature at sea level is 59°F and is to vary with altitude.

The Hover Ceiling subroutine will calculate out of ground effect hover ceilings using military rated power, two engines. Similarly, the remaining subroutines have been listed.

Figure (73) presents the calculated power required to hover. Figure (74) displays the hover ceiling data. Ceilings are underlined for clarity. Figures (75) and (76) show the output from the SRVCE and RCLMB subroutine respectively. Columns of data are clearly identified. As in the HOVCE subroutine, SRVCE underlines the service ceiling.

The Specific Range subroutine, SPRNG, outputs the specific range data in ten knot increments from 50 - 150 knots and the one knot increment data along with the 99% maximum specific range and corresponding velocity, as shown in Figure (77).

MISSION INPUT 2

CASE 5

SER-50528
Figure 72

```
COMAP

OPT-F

FDATA
HOVPR OGE     LTP
GRWTS                      26000.00      8000.00     42000.00
TEMPS                         59.00          .00        59.00
ALTDS                           .00      2000.00     16000.00
HOVCE OGE MIL LTP                            2.
GRWTS                      26000.00      8000.00     42000.00
TEMPS                         59.00          .00        59.00
ALTDS                           .00      2000.00     16000.00
SRVCE BRC NRP LTP                            2.
GRWTS                      26000.00      8000.00     42000.00
TEMPS                         59.00          .00        59.00
ALTDS                           .00      2000.00     16000.00
RCLMB BRC NRP LTP                            2.
GRWTS                      26000.00      8000.00     42000.00
TEMPS                         59.00          .00        59.00
ALTDS                           .00      2000.00     16000.00
SPRNG                                        2.
GRWTS                      26000.00      8000.00     42000.00
TEMPS                         59.00          .00        59.00
ALTDS                           .00      2000.00     16000.00

FINIS
```

CASE 5 (CONT'D)

SER-50528
Figure 73

SUBROUTINE REQUESTED -- HOVPR
GROUND EFFECT OPTION -- OGE
POWER SETTING --
TEMPERATURE OPTION -- LTP
NO. OF ENGINES -- -0.
POWER REQUIRED TO HOVER

TEMP (FRNHT)	GR WT (LBS)	ALT (FT)	HP REQUIRED
59.	26000.	0.	3490.
52.	26000.	2000.	3545.
45.	26000.	4000.	3602.
38.	26000.	6000.	3669.
30.	26000.	8000.	3753.
23.	26000.	10000.	3852.
16.	26000.	12000.	3992.
9.	26000.	14000.	4192.
2.	26000.	16000.	4400.
59.	34000.	0.	4957.
52.	34000.	2000.	5102.
45.	34000.	4000.	5290.
38.	34000.	6000.	5554.
30.	34000.	8000.	5806.
23.	34000.	10000.	6046.
16.	34000.	12000.	6275.
9.	34000.	14000.	6493.
2.	34000.	16000.	6701.
59.	42000.	0.	7025.
52.	42000.	2000.	7314.
45.	42000.	4000.	7590.
38.	42000.	6000.	7854.
30.	42000.	8000.	8106.
23.	42000.	10000.	8347.
16.	42000.	12000.	8576.
9.	42000.	14000.	8794.
2.	42000.	16000.	9001.

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Figure 74

CASE 5 (CONT'D)

SUBROUTINE REQUESTED -- HOVCE
GROUND EFFECT OPTION -- OGE
POWER SETTING -- MIL
TEMPERATURE OPTION -- LTP
NO. OF ENGINES -- 2.
HOVER CEILING

TEMP (FRNHT)	GR WT (LBS)	ALT (FT)	HP REQUIRED	HP AVAILABLE
59.	26000.	0.	3490.	5370.
52.	26000.	2000.	3545.	5231.
45.	26000.	4000.	3602.	5060.
38.	26000.	6000.	3669.	4857.
30.	26000.	8000.	3753.	4681.
23.	26000.	10000.	3852.	4486.
16.	26000.	12000.	3992.	4272.
11.	26000.	13488.	4141.	4141.
59.	34000.	0.	4957.	5370.
52.	34000.	2000.	5102.	5231.
49.	34000.	2716.	5169.	5169.
59.	42000.	0.	7025.	5370.

CASE 5 (CONT'D)

SUBROUTINE REQUESTED -- SRVCE
VELOCITY OPTION -- BRC
POWER SETTING -- NRP
TEMPERATURE OPTION -- LTP
NO. OF ENGINES -- 2.
SERVICE CEILING

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Figure 75

TEMP (FRNHT)	GR WT (LBS)	ALT (FT)	ROC (FT/MIN)
59.	26000.	0.	2864.
52.	26000.	2000.	2624.
45.	26000.	4000.	2383.
38.	26000.	6000.	2125.
30.	26000.	8000.	1883.
23.	26000.	10000.	1650.
16.	26000.	12000.	1407.
9.	26000.	14000.	1201.
2.	26000.	16000.	1006.
59.	34000.	0.	1748.
52.	34000.	2000.	1579.
45.	34000.	4000.	1400.
38.	34000.	6000.	1234.
30.	34000.	8000.	1060.
23.	34000.	10000.	876.
16.	34000.	12000.	651.
9.	34000.	14000.	463.
2.	34000.	16000.	289.
59.	42000.	0.	990.
52.	42000.	2000.	864.
45.	42000.	4000.	710.
38.	42000.	6000.	525.
30.	42000.	8000.	340.
23.	42000.	10000.	162.
21.	42000.	10685.	100.

CASE 5 (CONT'D)

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Figure 76

SUBROUTINE REQUESTED -- RCLMB
VELOCITY OPTION -- BRC
POWER SETTING -- NRP
TEMPERATURE OPTION -- LTP
NO. OF ENGINES -- 2.
RATE OF CLIMB

TEMP (FRNHT)	GR WT (LBS)	ALT (FT)	ROC (FT/MIN)
59.	26000.	0.	2864.
52.	26000.	2000.	2624.
45.	26000.	4000.	2383.
38.	26000.	6000.	2125.
30.	26000.	8000.	1883.
23.	26000.	10000.	1650.
16.	26000.	12000.	1407.
9.	26000.	14000.	1201.
2.	26000.	16000.	1006.
59.	34000.	0.	1748.
52.	34000.	2000.	1579.
45.	34000.	4000.	1400.
38.	34000.	6000.	1234.
30.	34000.	8000.	1060.
23.	34000.	10000.	876.
16.	34000.	12000.	651.
9.	34000.	14000.	463.
2.	34000.	16000.	289.
59.	42000.	0.	990.
52.	42000.	2000.	864.
45.	42000.	4000.	710.
38.	42000.	6000.	525.
30.	42000.	8000.	340.
23.	42000.	10000.	162.
16.	42000.	12000.	-18.
9.	42000.	14000.	-165.
2.	42000.	16000.	-298.

CASE 5 (CONT'D)

SUBROUTINE REQUESTED -- SPRNG
VELOCITY OPTION --
POWER SETTING --
TEMPERATURE OPTION --
NO. OF ENGINES -- 2.

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Figure 77

SPECIFIC RANGE

TEMP.	ALT.	RRO	GW
59.	0.	1.00000	42000.

VEL	SPRNG	HP	SFC
50.	.02363	1812.	.5560
60.	.03011	1655.	.5733
70.	.03617	1580.	.5833
80.	.04193	1545.	.5880
90.	.04719	1545.	.5878
100.	.05182	1575.	.5835
110.	.05570	1640.	.5734
120.	.05833	1755.	.5582
130.	.05901	1950.	.5380
140.	.05809	2220.	.5170
150.	.05637	2547.	.4974
120.	.05833	1755.	.5582
121.	.05839	1774.	.5561
122.	.05846	1794.	.5539
123.	.05853	1814.	.5518
124.	.05861	1833.	.5496
125.	.05869	1852.	.5475
126.	.05877	1872.	.5453
127.	.05886	1891.	.5432
128.	.05892	1911.	.5413
129.	.05896	1930.	.5397
130.	.05901	1950.	.5380
131.	.05890	1977.	.5357
132.	.05879	2004.	.5335
133.	.05870	2031.	.5312
134.	.05862	2058.	.5290
135.	.05854	2085.	.5267
136.	.05845	2112.	.5246
137.	.05835	2139.	.5227
138.	.05826	2166.	.5208
139.	.05817	2193.	.5189
140.	.05809	2220.	.5170

99% SR = .05842 AT VEL. = 136.34

STACKING CASES

When two or more cases are desired for any one computer run, it becomes necessary only to input the changes occuring in each group with the appropriate control card for each stacked case from the previous set of input data. If no change occurs in a particular data group, no new input for that group is necessary. For each stacked case, "COMAP" and "FINIS" cards are necessary to indicate the beginning and end of a case. Any number of changes are allowed for any one case since the computer merely replaces the input for the previous case with new data.

Figure (78) is presented to illustrate the stacking of two cases behind an initial case. A complete set of input data is put together for the first case. The second case differs from the first only in the MDATA block. Therefore, it is necessary only to input the initial "COMAP" and "OPT-A" cards and, the "MDATA" control card and a complete mission, an "END" card to signify end of mission and a "FINIS" card to complete the case. The third case to be run differs from the second case only in the Initial Conditions Group. Therefore, following the "COMAP" and "OPT-A" control cards is the "INCND" card followed by the changes from the second case and a "FINIS" card.

SIKORSKY CODING FORM

ENGINEER ______ EXT. ______ TITLE ______

MAIL ADDRESS ______ JOB NO. ______

ANALYST ______ SHEET ______ OF ______

JOB NO ______ ACCOUNT NO ______

W O NO ______

SAMPLE INPUT FOR STACKED CASES

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Figure 78

```
CØMAP
  ↓
FINIS

CØMAP
ØPT-A
MDATA
  ↓
END
FINIS

CØMAP
ØPT-A
INCND
PLDIN
FINIS
```

PROGRAM ACCURACY

An absolute error cannot be established for COMAP since the validity of results obtained from this computer program depends largely on curve input data. For instance, level flight and hover curve data, generated from a performance program or flight test data, represent the fairing of points to illustrate performance representative of a particular helicopter model. In turn, this curve data is loaded into the COMAP Program where the number of curves and number of points defining each curve greatly affect the output results. A high degree of accuracy can be attained, however, by being thoroughly familiar with the program design and operation.

All interpolations on curve input data are linear. As such, the user should use discretion when inputting curve data by defining the high curvature portion of the curves more closely than the more linear segments.

The tolerances incorporated in the Weights and Mission Module are summarized below. These tolerances are judged to be well within the accuracy of the input curve data, but if necessary can be increased or decreased by any programmer.

Weights Module (rubber engine)

1. Maximum mission power is determined when two consecutive passes through the mission calculate maximum mission powers within 10 hp of each other for any one cycle (as explained previously).

2. When maximum power for a rubberized engine is utilized at the start of a mission, the engine is sized to the initial take off gross weight necessary to satisfy mission requirements. Four passes or cycles through the mission are accomplished with adjusted value for initial gross weight and corresponding engine power. If a fifth pass were allowed, the resultant gross weight change would be within approximately .1%. The corresponding power change would therefore be totally insignificant.

Mission Module

1. The estimate of mission fuel and that actually burned must be within 0.2%.

2. The initial take off gross weight calculation, when based on a specified rate of climb, compares power required and power available. Maximum tolerance on power is 1%.
3. The iteration on rate of climb using the ROCCV curve input stops when $\Delta K/K < 0.1\%$.

4. The optimum altitude is determined in the CLIMB Subroutine when Δ SR/SR $<$ 0.01 (ROC) DELW/(1.05) SFC (HP).

5. The optimum altitude in the cruise subroutines is determined when Δ SR/SR $<$ 0.01 $\cdot$ [Δ ALT/1000].

6. The iteration on power available ceases when the difference between power required and power available is less than 10 HP.

Since the total cumulative error for any mission is a function of the type of mission and the number and type of subroutines used, it is not possible to assign a single confidence level to COMAP. The accuracy of the program is generally within 1.0% and can be controlled by selecting reasonable DELW values and exercising care in the loading of curve data.

SUGGESTIONS FOR PROGRAM USAGE

Listed below are some suggestions pointed toward efficient program utilization:

1. Since continued usage of the program will yield a considerable amount of input data, this data should be systematically stored to expedite the operation of setting up the computer deck.

2. Because of its size, the program should be stored on tape to eliminate the handling of a large number of cards.

3. The program does not print out the resultant payload aboard the aircraft immediately following the execution of the TOGWT Subroutine in the mission definition. However, by listing the PAYLD Subroutine with zero payload change immediately following the TOGWT Subroutine, payload is automatically listed on the output format.

4. The NASA Module calculates hover, level flight and stall speed data. If it is desired to use part NASA and part test data as input for any one case, the mission must be initially run using power required data from NASA. The same mission is then rerun as a stacked case with the desired flight test curves input to partially replace the NASA generated curves.

5. The DELW fuel increment affects program accuracy and computer running time. The trade off between accuracy and running time can readily be determined by calculating mission performance using various values of DELW, such as 300, 500, 700, etc., and comparing the changes in mission parameters with the increase in machine time.

6. The NRPCV, MILCV, and MAXCV curves must be input for a fixed or known engine. If a maximum power rating is non-existent, the military rating can be duplicated, the copy then identified as the MAXCV input.

7. Increased computer time is required for those missions containing cruise at speed for best range or endurance. Computer time can be decreased, if necessary, by increasing the fuel increment values in the appropriate subroutines.

8. Total familiarization with the Generalized Rotor Performance Method is necessary by the engineer to obtain reasonable correlation between calculated and actual rotor performance. The input data supplied with the program and listed in this report will result in performance data which agrees with the charts of Reference (2).

CONCLUSION

COMAP provides the engineer with the capability of rapid, accurate mission analysis. Its operational and reliability status has been demonstrated during a recent Sikorsky study of growth versions of the present Sikorsky S-61 model. For this study, approximately 150 missions were run at a cost of 30 minutes machine time on the UNIVAC 1108 computer. As many as 44 missions were output from one machine run.

The development of COMAP will enable both contractor and manufacturer to evaluate helicopter mission performance in an expeditious manner at a minimum total cost to both.

RECOMMENDATIONS FOR FUTURE MODIFICATIONS

The capabilities of COMAP have been described in detail and in its present form the program has few limitations. Several modifications are recommended below which would further increase the capabilities of the program and simplify its use. As experience in the use of COMAP increases, this list will undoubtedly expand.

1. The program currently does not account for the fuel burned by an auxiliary engine. Incorporation of this capability requires minor modification of appropriate subroutines.

2. When calculating mission performance of compound configurations, COMAP will accept only total aircraft power required data or will generate this data using the NASA Module. The capability of inputting pure helicopter power required information with wing and/or auxiliary power characteristics is desirable. This can be accomplished by modifying the mission element subroutines to utilize the revised input or adding a module which would accept the revised input and convert it to the form presently required. The latter appears to be most favorable.

3. A minor modification of the NASA Module will allow the user to input a portion of the power required data, the remaining input to be generated by NASA.

4. A new approach to rotor performance has been developed and is being substantiated. A high degree of accuracy exists in the prediction of performance of rotor configurations of 2 - 6 blades and 0 - (-14^{o}) linear twist throughout the speed range, including hover, in and out of ground effect. The incorporation of this method as a module into COMAP could conceivably reduce the computer time presently required by the NASA Module by a factor of ten.

5. To expedite the usage of COMAP and to minimize total elapsed time, it is strongly recommended that a supporting program be made available to generate engine power available information in punched card form for direct input into COMAP.

6. Option F should be expanded to produce the data necessary to plot the Standard Aircraft Characteristics Charts and also to output the input data required by the Transport Payload Constraint Model recently developed by Sikorsky Aircraft. This program is a performance simulation model developed for transport helicopters to measure and compare the cargo capabilities of various helicopters performing under a battery of randomly selected operating conditions.

7. COMAP is currently being coupled with the IBM 2250 Display Unit by Sikorsky Aircraft. Incorporated within this company funded version of COMAP is an improved input format which could readily be adapted to both the UNIVAC 1108 and IBM 7090 versions. Mission element subroutine input has been standardized and simplified and the aircraft definition has been improved to increase the flexibility of the program.

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13. ABSTRACT

COMAP is a Comprehensive Mission Analysis Program. Its purpose is to facilitate the calculation of mission performance and to establish required engine size for rotary wing aircraft.

The program is available for use on the IBM 7090 and UNIVAC 1108 electronic data processing systems. Among the important calculable factors are (1) performance of any pure rotary wing, compound or semi-compound aircraft for any logical tactical mission sortie with either a known or "rubber" engine; (2) mission performance trends as a function of mission variables, rotor geometry or rotor rpm; and (3) general aircraft performance information independent of a specific mission. Aircraft performance data may be input directly or calculated by the program using generalized rotor performance tables generated by the Sikorsky Generalized Rotor Performance Method.

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Security Classification

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	ROLE	WT	ROLE	WT	ROLE	WT
Aircraft Mission Performance						
Mission Parameter Trending						
Rotor Parameter Trending						

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Unclassified
Security Classification