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THESIS

COMPUTER PROGRAM ANALYSIS OF
 HELICOPTER WEIGHT ESTIMATE RELATIONSHIPS
 UTILIZING PARAMETRIC EQUATIONS

by
 Rudolph T. Schwab

June 1983

Thesis Advisor: Donald M. Layton

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Three categories of military helicopters can be designed; observation, utility, and cargo. Detailed knowledge of helicopters is not required.

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Computer Program Analysis of
Helicopter Weight Estimate Relationships
Utilizing Parametric Equations

by

Rudolph T. Schwab
Captain, United States Army
B.S., United States Military Academy, 1973

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

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June 1983

Author:

Rudolph T. Schwab

Approved by:

Donald M. Layton

Thesis Advisor

Donald M. Layton

Chairman, Department of Aeronautics

G. M. Dyer

Dean of Science and Engineering

ABSTRACT

This thesis gives the user of an HP-41CV handheld programmable calculator or the IBM 3033 computer, acceptable results of helicopter system weight estimations during the preliminary design phase.

The computer program consists of several subroutines and will compute system weight estimates according to Military Standard 1374A. Three categories of military helicopters can be designed; observation, utility, and cargo. Detailed knowledge of helicopters is not required.

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I. INTRODUCTION

A. BACKGROUND

The estimation of the weight of a helicopter is an essential preliminary step in design procedure. The aerospace industry uses large complex computer programs with hundreds of inputs in order to obtain the predicted weight of the various helicopter systems. This, of course, is the most accurate method in determining precise weights needed in actual design and construction. However, these programs require a detail knowledge of the components and materials to be used, which are not normally available outside the industry. Therefore, another method using the HP41-CV hand held calculator or the IBM 3033 was undertaken that would give acceptable results while providing instantaneous solutions. To date, no known programs of this type have been designed for the HP41-CV or IBM 3033.

B. GOALS

The objective of this study is to provide a self-prompting, alpha-numeric computer program for helicopter weight estimates. In addition it is to be used by Aeronautical Engineering students at the Naval Postgraduate School enrolled in the Helicopter Design and Advanced Helicopter Design courses.

II. APPROACH TO THE PROBLEM

The basic approach was to write a computer program on the IBM 3033 using Fortran IV and converting this program to HP41-CV usage. The program consists of the following subroutines:

- A. Input
- B. Output
- C. Observation
- D. Utility
- E. Cargo

This method greatly reduces the amount of computer memory required. Subroutines Observation, Utility, and Cargo are independent of each other and dependent only on the Input and Output subroutines.

These subroutines use parametric equations derived from the best curve fit of the various system weights. Detailed knowledge of helicopter weights is not required, however, a basic knowledge of helicopter characteristics and aerodynamics, along with proficiency in either the IBM 3033 or HP41-CV is required.

III. THE SOLUTION

Weight data was collected for 14 military helicopters. These helicopters were separated into three categories; observation, utility, and cargo. This provided a more accurate weight estimate relationship (WER) for the 18 systems as provided by Military Standard 1374A (Table I). Due to the selection of helicopters, a WER for the wing was not required. The air conditioning and anti-icing weights were combined into one WER. The data was obtained from actual military records located at Fritsche Army Airfield, Ft. Ord, California, [Ref. 1] and Edwards Air Force Base, Ca. [Ref. 2]. In addition Jane's All The Worlds Aircraft [Ref. 3], Jane's Pocketbook of Helicopters [Ref. 4], and NASA CR152315 [Ref. 5] were used. The data are summarized in Table II.

In analyzing the data design gross weight was the major correlating factor in determining the individual system weights. There are eight factors that affect gross weight: empty weight, blade planform area, number of personnel, personnel weight, fuel, horsepower, cargo weight, and number of engines.

Utilizing these factors and an HP41-CV curve fit program, parametric equations were obtained for each of the helicopter systems, providing acceptable results for establishing preliminary design weights. The equations for each type helicopter are found in Table III. Example problems for the HP-41CV and IBM 3033 are contained in Appendix A and Appendix B.

TABLE I
Helicopter Systems

1. Rotor
2. Tail
 - A. Tail Rotor
 - B. Tail Structure
3. Body
4. Landing Gear
5. Nacelle
6. Propulsion
 - A. Engine
 - B. Drive
 - C. Fuel Tanks
7. Flight Controls
8. Auxiliary Power
9. Instruments
10. Hydraulics
11. Electrical
12. Avionics
13. Furnishings and Equipment
14. Air Conditioning and anti-icing
15. Load and Handling

These systems correspond to the 18 standard weight groups defined in Military Standard 1374A, except pneumatics, wing, and armament have been deleted while air conditioning and anti-ice were combined.

TABLE II
Helicopter System Weight Summary

MODEL	Empty Weight W1	Gross Weight Wg	Main Rotor W1	Rotor Platform S (sq ft)
OH-6A	1202	2400	174	26.0
TH-57A	1535	2900	277	31.99
OH-58A	1545	3000	281	33.99
OH-13S	1926	2850	284	32.55
OH-4A	-	-	250	28.88
UH-1H	5235	9500	742	76.69
H-52A	5585	8310	785	92.55
UH-19D	5831	7100	786	92.55
UH-60A	10222	20250	1705	160.00
CH-34A	7803	14000	1313	129.1
CH-46F	13313	23000	2424	136.5
CH-47A	17752	33000	2996	315.7
CH-53A	23097	40000	4489	348.7
CH-37A	21238	30342	3251	272.6

MODEL	Tail W2	Tail Rotor W2A	Tail Structure W2B	Surface Area S2 (sq ft)
OH-6A	23	7	16	12.3
TH-57A	34	8	26	19.9
OH-58A	132	10	22	18.6
OH-13S	17	8	9	8.7
OH-4A	118	11	7	7.9
UH-1H	384	30	54	31.3
H-52A	106	53	53	37.0
UH-19D	101	60	41	*23.8
UH-60A	346	105	241	106.4
CH-34A	260	74	186	75.3
CH-46F	0	0	0	0.0
CH-47A	0	0	0	0.0
CH-53A	673	367	306	93.4
CH-37A	570	345	225	112.0

MODEL	Body W3	Body Surface Sb (sq ft)	Landing Gear W4	Type Gear
OH-6A	242	205	70	skid
TH-57A	335	244	45	skid
OH-58A	332	247	35	skid
OH-13S	221	121	54	skid
OH-4A	359	243	43	skid
UH-1H	1035	626	121	skid
H-52A	1263	849	485	coll
UH-19D	985	640	287	coll
UH-60A	1729	805	659	coll
CH-34A	1044	817	475	coll
CH-46F	3126	1452	591	coll
CH-47A	4487	2150	1086	coll
CH-53A	5260	2587	1019	coll
CH-37A	3247	1553	983	coll

* Not used in developing WER

Table II (cont)
Helicopter System Weight Summary

MODEL	Nacelle W5	Engine Type #	Number of Engines	Propulsion System W6
OH-6A	*8	2	1	341
TH-57A	32	2	1	416
OH-58A	36	2	1	419
OH-13S	37	1	1	*845
OH-4A	*25	2	1	390
UH-1H	114	2	1	1632
H-52A	63	2	1	1115
UH-19D	147	1	1	2525
UH-60A	155	2	2	2730
CH-34A	150	1	1	3189
CH-46F	71	2	2	3235
CH-47A	176	2	2	5151
CH-53A	394	2	2	6057
CH-37A	*1098	1	2	8419

MODEL	Eng W6a	Drive W6b	Fuel Tanks W6c	Horse- power HP
OH-6A	192	113	36	250
TH-57A	194	176	36	317
OH-58A	*165	215	39	317
OH-13S	*588	*155	*102	260
OH-4A	1998	159	*32	250
UH-1H	683	658	291	1103
H-52A	360	621	*134	1050
UH-19D	1244	*1064	217	800
UH-60A	362	1405	463	3036
CH-34A	1737	1091	361	1525
CH-46F	951	2010	274	2600
CH-47A	1342	3531	278	4400
CH-53A	1762	3913	376	*5700
CH-37A	*5516	2567	336	4200

MODEL	Fuel Quantity G (gals)	Flight Controls W7	Aux W8	Instru- ments W9
CH-6A	62	65	0	30
TH-57A	76	133	0	29
OH-58A	73	125	0	27
OH-13S	--	--	0	24
OH-4A	--	--	0	--
UH-1H	211	357	0	59
H-52A	325	353	0	124
UH-19D	175	*164	0	70
UH-60A	343	594	164	152
CH-34A	263	378	0	108
CH-46F	380	828	106	158
CH-47A	620	1212	99	172
CH-53A	638	1168	211	*395
CH-37A	410	965	0	191

* Not used in developing WER
Engine types: 1- reciprocating; 2 - turboshaft

Table II (cont)

Helicopter System Weight Summary

MODEL	Hydraulic W10	Electrical W11	Avionics W12	Furnish & Equip W13
OH-6A	0	68	113	58
TH-57A	0	110	--	64
OH-58A	0	85	106	42
OH-13S	0	130	91	30
UH-1H	33	360	246	408
H-52A	43	419	427	216
UH-19D	47	327	*110	205
UH-60A	87	464	466	675
CH-34A	26	327	269	189
CH-46F	168	654	645	854
CH-47A	212	555	303	866
CH-53A	132	601	559	1299
CH-37A	129	497	*269	810

MODEL	Air & Ice W14	Load & Handling W15	Number Crew	Number Passengers
OH-6A	10	0	1	2
TH-57A	27	0	3	0
OH-58A	25	0	2	0
OH-13S	40	0	--	--
OH-4A	--	0	1	1
UH-1H	44	0	2	11
H-52A	97	89	3	--
UH-19D	77	0	2	10
UH-60A	86	80	3	11
CH-34A	72	3	2	14
CH-46F	*257	196	3	22
CH-47A	179	258	3	32
CH-53A	*311	439	3	37
CH-37A	176	*12	--	--

* Not used in developing WER

TABLE III
Observation Helicopter Weight Estimating Relationships

1. Rotor	$W1 = 408.562 * \ln(S) - 1142.917$
2. Tail	
Rotor	$W2A = 2.219 * \exp(.0005 * Wt)$
Structure	$W2B = 19.131 * \ln(Stt) - 32.414$
3. Body	$W3 = .00901 * Sb^{**1.917}$
4. Landing Gear	$W4 = -.0539 * Wg + 200.912$
5. Nacelle	$W5 = 34.0$
6. Propulsion	
Engine	$W6A = -.0896 * Hp + 221.388$
Drive	$W6B = 17.190 * \exp(.0008 * Wg)$
Fuel Tanks	$W6C = .384 * (Fuel/6.5)^{**1.0710}$
7. Flight Controls	$W7 = .000000000128 * Wg^{**3.469}$
8. Aux Power	$W8 = 0.0$
9. Instruments	$W9 = 24.571 * \exp(.0004 * Hp)$
10. Hydraulics	$W10 = 0.0$
11. Electrical	$W11 = -51.0661 * \ln(Sb) + 367.947$
12. Avionics	$W12 = 1062.00451 - 122.282 * \ln(1120.354 * \exp(.003 * Hp))$
13. Furnishings	$W13 = 19.800 * (\exp(.372 * People) + \exp(-.033 * Sb))$
14. Air & ice	$W14 = -22.371 * \ln(Sb) + 143.396$
15. Load & Handling	$W15 = 0.0$

Symbols Used In WER

People	Number of crew and personnel
Sb	Body surface area (sq ft)
Wg	Gross Weight (lbs)
We	Manufacturers Empty Weight (lbs)
S	Main rotor platform area (lbs)
Hp	Shaft Horse Power (lbs)
Fuel	Amount of fuel (lbs)
Stt	Total tail surface area (sq ft)

APPROXIMATIONS

Gross Weight	$Wg = 173.701 * We^{**0.378}$
Tail Surface Area	$Stt = .264 * \exp(.0135 * Hp)$
Body Surface Area	$Sb = 194.274 * \ln(Wg) - 1306.779$

Table III (con't)
Utility Helicopter Weight Estimating Relationships

1. Rotor	$W1 = 11.0702 * S - 168.888$
2. Tail	
Rotor	$W2A = .00438 * Wg + 12.470$
Structure	$W2B = 2.411 * Stt - 19.531$
3. Body	$W3 = .282 * Sb^{**1.272}$
4. Landing Gear	
	$W4 = .025 * \exp(.000062 * Wg + 8.020)$
	$*W4 = 301.577 * \ln(Wg) - 2319.890$
5. Nacelle	$W5 = .02 * \exp(.000062 * Wg + 8.02)$
6. Propulsion	
Engine	$W6A = 130.0 + .451 * Hp$
	$*W6A = 295.0 + .188 * Hp$
Drive	$W6B = 741.460 * \ln(Hp) - 4542.0420$
Fuel Tanks	$W6C = 363.240 * \ln(Fuel/6.5)$ -1656.521
7. Flight Controls	$W7 = 210.858 * \exp(.000059 * Wg)$
8. Aux Power	
	$W8 = 0.0$
	$*W8 = 190.0$
9. Instruments	$W9 = 56.0975 * \ln(Hp) - 312.237$
10. Hydraulics	$W10 = .00362 * Wg + 11.553$
11. Electrical	$W11 = 481.735 * \ln(Sb) - 2794.530$
12. Avionics	$W12 = .139 * Hp + 77.823$
13. Furnishings	$W13 = .175 * Sb + 22.0 * People - 10.0$
14. Air & ice	$W14 = 122.458 * \ln(Sb) - 730.252$
15. Load & handling	$W15 = 84.5$

Approximations

Gross Weight
 $Wg = 16239.430 * \ln(We) - 130252.760$
Tail Surface Area
 $Stt = .0376 * Hp - 8.106$
Body Surface
 $Sb = 636.081 * \exp(.000011 * Wg)$
*Helicopters with two engines
*Gross weight greater than 6000 lbs.

Table III (con't)

Cargo Helicopter Weight Estimating Relationships

1. Rotor	$W1 = 707.174 * \exp(.00539 * S)$
	$**W1 = 1414.348 * \exp(.00539 * S)$
2. Tail	
Rotor	$W2A = 324.550 * \ln(Wg) - 3021.510$
Structure	$W2B = -18.0 + 2.830 * Stt$
3. Body	
	$W3 = 2.9818 * Sb - 1321.921$
	$**W3 = 3467.291 * \ln(Sb) - 22118.298$
4. Landing Gear	$W4 = 258.358 * \exp(.000041 * Wg)$
5. Nacelle	$W5 = .014 * (.2041 * Wg) ** 1.136$
6. Propulsion	
Engine	$W6A = 348.0 + .910 * Hp$
	$**W6A = 565.507 * \exp(.000198 * HP)$
Drive	$W6B = .999 * Hp ** .959$
Fuel Tanks	$W6C = 454.619 * (Fuel/6.5) ** (-.0566)$
7. Flight Controls	$W7 = .00334 * WG ** 1.224$
8. Aux Power	$W8 = 139.0$
9. Instruments	$W9 = 68.266 * \ln(Hp) - 387.598$
10. Hydraulics	$W10 = .000000563 * Wg ** 1.863$
11. Electrical	$W11 = 9.780 * Sb ** .539$
12. Avionics	$W12 = (16744.967 * \ln(Hp) - 108666.0) / (.536 * 1.90)$
13. Furnishings	$W13 = .159 * Sb + 18.11 * People$
14. Air & Ice	$W14 = 117.771 * \ln(Sb) - 710.594$
15. Load & Handling	$W15 = -72.0 + .111 * Sb + 3.490 * People$

Approximations

Gross Weight	$Wg = 4.975 * We ** .887$
Tail Surface Area	$Stt = 60.127 * \exp(.000145 * Hp)$
Body Surface Area	$Sb = 426.378 * \exp(.000045 * Wg)$
**Tandem Helicopter	$Stt = 0.0$
	$Sb = 567.688 * \exp(.000041 * WG)$

IV. SYSTEM DESCRIPTION

This section provides a detailed discussion of each system as described by Feltramo [Ref. 5] and summarized in Table II.

A. ROTOR

The rotor system consists of the blade assembly and the hub and hinge assembly. The blade assembly includes the interspace structure, leading and trailing edges, tips (if not integral), balance weights, and mounting hardware and blade foldings. The hub and hinge assembly includes the yoke, universal joints, shafting between the rotor system and the drive box, spacers and bushings, lubrication system, fittings, pins, drag brace, retention strap assembly, and fasteners and miscellaneous hardware.

B. TAIL

The tail system includes all the aerodynamic surfaces and the mounts for the tail rotor. Tandem helicopters are not considered to have a tail.

C. BODY

The body consists of the fuselage shell structure, door and window frames, floors, bulkheads, cockpit windshield, and radome. Door actuation mechanisms, airstairs (when installed) and loading ramps are also included.

D. LANDING GEAR

The system includes landing gear structure, which is made up of struts, side and drag braces, trunnions and attachment fittings. The landing gear controls include components for braking, steering and retraction (if available). For wheel type landing gear this also includes wheels, brakes and tires.

E. NACELLE

This includes the engine mount, firewall and cowl structure, engine air inlet, oil cooler scoop and miscellaneous installation hardware.

F. PROPULSION

The propulsion system includes three main subsystems: the engine, drive, and the fuel system. The engine includes the dry engine, residual fluids and installation hardware as well as related components: starter, air inductor, exhaust and cooling items, lubrication systems and the engine controls. The drive subsystem includes the gear speed reducers, transmission drive, rotor brake and shaft, and lube system. The fuel subsystem includes the fuel fill and drain system, fuel distribution system, fuel vent plumbing and fuel tanks.

G. FLIGHT CONTROLS

This system includes: cabin controls (cyclic control column, collective pitch levers and rudder or tail rotor pedal); mechanical operating mechanism (swash plate, stabilizing bar, linkages, bearings, and levers, bellcranks); hydraulic controls; fluid; and miscellaneous hardware.

H. AUXILIARY POWER

The auxiliary power system supplies all power for ground operations in lieu of ground support equipment. These operations include: cabin ground air conditioning, engine starting, and driving a generator for electric power.

I. INSTRUMENTS

Instruments perform basic monitoring and warning functions associated with the flight of the helicopter: electrical, hydraulic and pneumatic systems operation, engine operation and fuel quantity. The instrument system includes cockpit indicators and warning lights, transducers, signal inputs, circuitry, and the monitoring devices.

J. HYDRAULICS

The hydraulic system consists of the pumps, reservoirs, filters, accumulators, regulators, valves, manifolds, plumbing, fluid, and supports, and mounting hardware.

K. ELECTRICAL

The electrical system supplies power to a variety of helicopter operating components, including, among others: lights, avionics, instruments, passenger and cargo doors, cargo hoist, and environmental control system.

The electrical system consists of the AC power system, the DC power system and lighting system. The AC system includes power generating equipment, while the DC power system includes converters and batteries, and both include the necessary controls, wiring, cables fittings, and supports to distribute the electrical power from the power source to the electrical power center.

The lighting system includes all interior and exterior lights, together with the switches, associated circuitry from the electric power center, and support hardware.

The wiring and circuitry leading from the electric power center to the various components which use electricity are included with the respective systems.

L. AVIONICS

The avionics system consists of the integrated flight guidance and control subsystem, communication subsystem, navigation subsystem and miscellaneous equipment subsystem.

The integrated flight guidance and controls subsystem includes the auto pilot unit, the flight director unit, the gyrocompass unit, the attitude and heading reference unit, and the inertial navigation unit. These units are interdependent and may be either separate, interconnected units or one, integrated functional unit. All indicators, servomechanisms, and associated circuitry, supports, and attachments related to the integrated flight guidance and controls subsystem are also included. Although usually colocated with this subsystem, the auto-throttle/thrust management unit is part of the propulsion system because it functions to control the engine.

The communication subsystem is separated into internal and external units. The internal communication unit includes the interphone system, the public address system, and the multiplex (MUX) system. The external communication unit includes the transceiver equipment which is used for aircraft-to-aircraft or aircraft-to-ground communications.

The navigation subsystem includes all radar equipment, the automatic direction finding (ADF) unit, the distance measuring equipment (DME) unit, the doppler unit, the navigation computer units, the station-keeping unit, the

tactical air navigation (TACAN) unit, the variable omnirange (VOR) unit, the marker beacon, the instrument landing system (ILS), the collision avoidance unit (CAS), the airport traffic control (ATC) unit, the radio altimeter, the glide slope indicator, and the radar beacon unit. All the navigation units, indicators, antennae, associated circuitry and antenna coaxial cable, and the units' supports and attachments related to the navigation subsystem are included.

M. FURNISHINGS AND EQUIPMENT

Furnishings and equipment include a variety of items in the cockpit and the passenger and/or cargo compartment. In the cockpit, this category includes all instrument and console panels, seats, insulation, lining, crew oxygen system, and cockpit door and partitions.

N. AIR CONDITIONING AND ANTI-ICING

The air conditioning system, in addition to supplying conditioned air to the cabin, heats the cargo compartment and supplies conditioned air for avionic and electrical load center cooling.

Anti-icing functions can be performed either by hot bleed air or by electrical heat. Bleed air systems include all ducting from the main pneumatic source and inner skins, which form the hot air cavities. Electrical systems include the electrical blankets fastened to the outer surfaces of critical items, plus all wiring and controls.

In the passenger and/or cargo compartment, this category includes seats, floor covering, insulation, side panels, ceiling structure, and passenger comfort items such as galley or lavatory installations.

Miscellaneous items include the engine and cabin fire extinguisher systems, fire warning system, exterior finish, and emergency equipment (i. e., first aid kit and fire extinguisher). Cargo loading equipment is also a part of this system.

O. LOAD AND HANDLING

This system consists of loading and handling gear, including provisions for jacking, hoisting and mooring, and ballast.

V. RESULTS AND CONCLUSIONS

As stated earlier, the primary objective of this study was to develop a rapid and easy means for estimating system weights during the preliminary design phase. The computer programs that were developed result in acceptable estimates. The validity of the output is excellent for the intended purpose of preliminary helicopter design weight estimations. However, individual systems sometimes experience large errors in estimated system weight, as compared to actual, but when combined with the other systems that make up the helicopter the error is small. These limitations resulted from:

A. Data missing or unreliable. For example, smaller nacelles usually had no defined surface area, or an individual system was divergent from the overall system norm. Therefore, these were not included in the WER.

B. There is no definite factor that delineates between the use of skids or wheels. Empty weight of 6000 lbs was arbitrarily used as the change over between skid and roll.

C. The various armed forces utilize different avionics systems. In order to obtain a precise estimate, a WER for each service would be required, resulting in additional computer inputs. Instead, the avionics WER's were averaged to produce but one input.

D. There was no factor which dictated when auxiliary power was required, therefore average aux weight was used for the cargo category WER. However, in the utility category it appeared that only helicopters with two engines had auxiliary power, therefore this was the criterion for the utility WER.

The user should utilize the enclosed example problems as initial input when working with the computer. This will insure the user that he has implemented the programs correctly or assist in debugging if incorrect. The user should insure that the HP-41CV is sized for 32 before executing any program.

APPENDIX A
HP41-CV COMPUTER LISTING

Replace PLUS with "+" and set SIZE 32

A. OBS SUBROUTINE LISTING

01 LBL "OBS"	26 408.562	52 -.0539
02 XEQ "IN"	27 *	53 *
	28 1142.917	54 200.912
03 LBL "p"	29 -	55 PLUS
04 RCL 01	30 STO 12	56 STO 15
05 .378	31 RCL 09	57 34
06 Y1X	32 .0005	58 STO 16
07 173.701	33 *	59 RCL 07
08 *	34 E1X	60 -.0896
09 STO 09	35 2.219	61 *
10 RCL 07	36 *	62 221.388
11 .0135	37 32.414	63 PLUS
12 *	38 -	64 STO 17
13 E1X	39 RCL 10	65 RCL 09
14 .264	40 LN	66 .0008
15 *	41 19.131	67 *
16 STO 10	42 *	68 E1X
17 RCL 09	43 +	69 17.198
18 LN	44 STO 13	70 *
19 194.274	45 RCL 11	71 STO 18
20 *	46 1.917	72 RCL 06
21 1306.779	47 Y1X	73 6.5
22 -	48 .00901	74 /
23 STO 11	49 *	75 1.071
24 RCL 02	50 STO 14	76 Y1X
25 LN	51 RCL 09	77 .384

78 *	112 *
79 STO 19	113 1062.004
80 RCL 09	114 PLUS
81 3.469	115 STO 25
82 Y1X	116 RCL 03
83 1.281E-10	117 .372
84 *	118 *
85 STO 20	119 E1X
86 0	120 19.8
87 STO 21	121 *
88 RCL 07	122 RCL 11
89 .0004	123 -.033
90 *	124 *
91 E1X	125 E1X
92 24.571	126 PLUS
93 *	127 STO 26
94 STO 22	128 RCL 11
95 0	129 Ln
96 STO 23	130 -22.371
97 RCL 11	131 *
98 LN	132 143.396
99 -51.0661	133 PLUS
100 *	134 STO 27
101 367.947	135 0
102 +	136 STO 28
103 STO 24	137 XEQ "OUT"
104 RCL 07	138 RCL 30
105 .003	139 X<=0?
106 *	140 GTO 03
107 E1X	141 "WE?"
108 1120.354	142 PROMPT
109 *	143 STO 01
110 LN	144 XEQ "P"
111 -122.282	145 LBL 03

146 END

B. UTIL SUBROUTINE LISTING

01 LBL "UTIL"	33 7.061	66 PLUS
02 XEQ "IN"	34 -	67 STO 17
	35 RCL 10	68 RCL 07
03 LBL "P"	36 2.411	69 LN
04 RCL 01	37 *	70 741.460
05 LN	38 +	71 *
06 16239.43	39 STO 13	72 4542.042
07 *	40 RCL 11	73 -
08 130252.76	41 1.272	74 STO 18
09 -	42 Y 1X	75 RCL 06
10 STO 09	43 .282	76 6.5
11 RCL 07	44 *	77 /
12 .0376	45 STO 14	78 LN
13 *	46 RCL 09	79 363.24
14 8.106	47 LN	80 *
15 -	48 301.577	81 1656.521
16 STO 10	49 *	82 -
17 RCL 09	50 2319.89	83 SIO 19
18 .000011	51 -	84 RCL 09
19 *	52 STO 15	85 .000059
20 E 1X	53 RCL 09	86 *
21 636.081	54 .000062	87 E 1X
22 *	55 *	88 210.858
23 STO 11	56 8.02	89 *
24 RCL 02	57 +	90 STO 20
25 11.0702	58 E 1X	91 0
26 *	59 .02	92 STO 21
27 168.888	60 *	93 RCL 07
28 -	61 STO 16	94 LN
29 STO 12	62 RCL 07	95 56.0975
30 RCL 09	63 .451	96 *
31 .00438	64 *	97 312.237
32 *	65 130	98 -

99 STO 22	131 122.458	162 PLUS
100 RCL 09	132 *	163 STO 17
101 .00362	133 730.252	164 190
102 *	134 -	165 STO 21
103 11.553	135 STO 27	
104 +	136 84.5	166 LBL 02
105 STO 23	137 STO 28	167 XEQ "OUT"
106 RCL 11	138 RCL 01	168 RCL 30
107 LN	139 6000	169 X<=0?
108 481.735	140 -	170 GTO 03
109 *	141 X>0?	171 "WE?"
110 2794.53	142 GTO 01	172 PROMPT
111 -	143 RCL 09	173 STO 01
112 STO 24	144 .000062	174 XEQ "P"
113 RCL 07	145 *	
114 .139	146 8.02	175 LBL 03
115 *	147 +	176 END
116 77.823	148 E 1X	
117 +	149 .025	
118 STO 25	150 *	
119 RCL 03	151 STO 15	
120 22		
121 *	152 LBL 01	
122 10	153 RCL 08	
123 -	154 2	
124 RCL 11	155 -	
125 .175	156 X=/0?	
126 *	157 GTO 02	
127 +	158 RCL 07	
128 STO 26	159 .188	
129 RCL 11	160 *	
130 LN	161 295	

C. CGO SUBROUTINE LISTING

01 LBL "CGO"	33 STO 12	66 E1X
02 XEQ "IN"	34 RCL 07	67 567.688
03 "TANDEM?"	35 .91	68 *
04 PROMPT	36 *	69 STO 11
05 STO 31	37 348	70 RCL 12
	38 +	71 2
06 LBL "P"	39 STO 17	72 *
07 RCL 01	40 RCL 09	73 STO 12
08 .887	41 LN	74 RCL 07
09 Y1X	42 324.55	75 .000198
10 4.975	43 *	76 *
11 *	44 -3039.51	77 E1X
12 STO 09	45 +	78 565.507
13 RCL 07	46 RCL 10	79 *
14 .000145	47 2.83	80 STO 17
15 *	48 *	81 RCL 11
16 E1x	49 +	82 LN
17 60.127	50 STO 13	83 3467.291
18 *	51 RCL 11	84 *
19 STO 10	52 2.918	85 22118.298
20 RCL 09	53 *	86 -
21.000045	54 1321.921	87 STO 14
22 *	55 -	
23 E1X	56 STO 14	88 LBL 01
24 426.378	57 RCL 31	89 RCL 09
25 *	58 X<=0?	90 .000041
26 STO 11	59 STO 01	91 *
27 RCL 02	60 0	92 E1X
28 .00539	61 STO 10	93 258.358
29 *	62 STO 13	94 *
30 E1X	63 RCL 09	95 STO 15
31 707.174	64 .000041	96 RCL 09
32 *	65 *	97 .204

98 *	129 *	160 18.11
99 1.136	130 387.598	161 *
100 Y1X	131 -	162 PLUS
101 .014	132 STO 22	163 STO 26
102 *	133 RCL 09	164 RCL 11
103 STO 16	134 1.863	165 LN
104 RCL 07	135 Y1X	166 117.771
105 .959	136 .000000663	167 *
106 Y1X	137 *	168 710.594
107 .999	138 STO 23	169 -
108 *	139 RCL 11	170 STO 27
109 STO 18	140 .539	171 RCL 03
110 RCL 06	141 Y1X	172 3.49
111 6.5	142 9.78	173 *
112 /	143 *	174 72
113 -.0566	144 STO 24	175 -
114 Y1X	145 RCL 07	176 RCL 11
115 454.619	146 LN	177 .111
116 *	147 16744.967	178 *
117 STO 19	148 *	179 PLUS
118 RCL 09	149 108666	180 STO 28
119 1.224	150 -	181 XEQ "OUT"
120 Y1X	151 .536	182 RCL 30
121 .00334	152 Y1X	183 X<=0?
122 *	153 1.9	184 GTO 03
123 STO 20	154 *	185 "WE?"
124 139.0	155 STO 25	186 PROMPT
125 STO 21	156 RCL 11	187 STO 01
126 RCL 07	157 .159	188 XEQ "P"
127 LN	158 *	189 LBL 03
128 68.266	159 RCL 03	190 END

D. OUTPUT SUBROUTINE LISTING

01 LBL "OUT"	34 RCL 28	67 AVIEW
02 FIX 1	35 +	68 PROMPT
03 RCL 12	36 STO 29	69 "F TKS="
04 RCL 13	37 "WG EST="	70 ARCL 19
05 +	38 ARCL 09	71 AVIEW
06 RCL 14	39 AVIEW	72 PROMPT
07 +	40 PROMPT	73 "CNTR="
08 RCL 15	41 "ROTOR="	74 ARCL 20
09 +	42 ARCL 12	75 AVIEW
10 RCL 16	43 AVIEW	76 PROMPT
11 +	44 PROMPT	77 "AUX="
12 RCL 17	45 "TAIL="	78 ARCL 21
13 +	46 ARCL 13	79 AVIEW
14 RCL 18	47 AVIEW	80 PROMPT
15 +	48 PROMPT	81 "INST="
16 RCL 19	49 "BODY="	82 ARCL 22
17 +	50 ARCL 14	83 AVIEW
18 RCL 20	51 AVIEW	84 PROMPT
19 +	52 PROMPT	85 "HYD="
20 RCL 21	53 "GEAR="	86 ARCL 23
21 +	54 ARCL 15	87 AVIEW
22 RCL 22	55 AVIEW	88 PROMPT
23 +	56 PROMPT	89 "ELEC="
24 RCL 23	57 "NACE="	90 ARCL 24
25 +	58 ARCL 16	91 AVIEW
26 RCL 24	59 AVIEW	92 PROMPT
27 +	60 PROMPT	93 "AVIN="
28 RCL 25	61 "ENG="	94 ARCL 25
29 +	62 ARCL 17	95 AVIEW
30 RCL 26	63 AVIEW	96 PROMPT
31 +	64 PROMPT	97 "FRN="
32 RCL 27	65 "DRIVE="	98 ARCL 26
33 +	66 APCL 18	99 AVIEW

100 PROMPT	112 PROMPT	124 PROMPT
101 "AIAC="	113 RCL 29	125 FIX 3
102 ARCL 27	114 RCL 06	126 "AGAIN?"
103 AVIEW	115 PLUS	127 PROMPT
104 PROMPT	116 RCL 04	128 STO 30
105 "IH="	117 PLUS	129 END
106 ARCL 28	118 RCL 05	
107 AVIEW	119 PLUS	
108 PROMPT	120 STO 31	
109 "REV WE="	121 "REV WG="	
110 ARCL 29	122 ARCL 31	
111 AVIEW	123 AVIEW	

E. INPUT SUBROUTINE LISTING

01 IEL "IN"	19 STO 06
02 "WE?"	20 "SHP?"
03 FROMPT	21 PROMPT
04 STO 01	22 STO 07
05 "S?"	23 "NENG?"
06 FROMPT	24 PROMPT
07 STO 02	25 STO 08
08 "F?"	26 END
09 FROMPT	
10 STO 03	
11 "EWT?"	
12 FROMPT	
13 STO 04	
14 "CGC?"	
15 FROMPT	
16 STO 05	
17 "F?"	
18 FROMPT	

F. LISTING OF CALCULATOR DISPLAYS

DISPLAY	EXPLANATION	WER NOTATION
WE?	Prompt: initial empty weight (lbs)	We
S?	Prompt: main rotor planform area (sq ft)	S
P?	Prompt: total number of personnel	People
PWT?	Prompt: weight of personnel (lbs)	Weight
CGO?	Prompt: weight of baggage and cargo (lbs)	Cargo
F?	Prompt: total weight of fuel (LBS)	Fuel
SHP?	Prompt: shaft horsepower (lbs)	HP
NENG?	Prompt: number of engines	Neng
TANDEM?	Prompt: helicopter tandem?; 1-Yes, 0-No	Tandem
AGAIN?	Prompt: another run desired?; 1-Yes, 0-No	--
WG EST=	Answer: gross weight estimate (lbs)	Wg
ROTOR=	Answer: main rotor blade weight (lbs)	W1
TAIL=	Answer: tail rotor/structure weight (lbs)	W2
BODY=	Answer: body structure weight (lbs)	W3
GEAR=	Answer: landing gear weight (lbs)	W4
NACE=	Answer: nacelle weight (lbs)	W5
ENG=	Answer: engine weight (lbs)	W6A
DRIVE=	Answer: drive train weight (lbs)	W6B
F TKS=	Answer: weight of fuel cells (lbs)	W6C
CNTR=	Answer: flight control weight (lbs)	W7
AUX=	Answer: auxiliary power system (Lbs)	W8
INST=	Answer: instruments	W9
HYD=	Answer: hydraulic system (lbs)	W10
ELEC=	Answer: electrical system	W11
AVIN=	Answer: avionics system (lbs)	W12
FRN=	Answer: furnishings and equipment (lbs)	W13
AIAC=	Answer: anti-ice and air cond. (lbs)	W14
LH=	Answer: load and handling (lbs)	W15
REV WE=	Answer: WE using above computed values	--
REV WG=	Answer: Sum of P, PWT, CGO, and REV WE	--

G. STORAGE ALLOCATIONS

Storage Register Number	Contents
01	WE
02	S
03	P
04	PWT
05	CGO
06	F
07	SHP
08	NENG
09	Wg
10	Stt
11	Sb
12	W1
13	W2
14	W3
15	W4
16	W5
17	W6A
18	W6B
19	W6C
20	W7
21	W8
22	W9
23	W10
24	W11
25	W12
26	W13
27	W14
28	W15
29	RWE
30	K
31	Tanden/RWG

APPENDIX B
IBM 3033 COMPUTER LISTING

A. MAIN PROGRAM

```
C          VARIABLES AND CONSTANTS
C          *****
C
C      RWE      REVISED EMPTY WEIGHT
C      WE       INITIAL EMPTY WEIGHT
C      WG       ESTIMATED GROSS WEIGHT
C      WG1      YOUR GROSS WEIGHT
C      W1       MAIN ROTOR BLADE
C      W2       TOTAL TAIL SECTION
C      W2A      TAIL ROTOR BLADE
C      W2B      TAIL STRUCTURE
C      W3       BOIY
C      W4       LANDING GEAR
C      W5       NACELLE
C      W6       TOTAL PROPULSION SYSTEM
C      W6A      ENGINE
C      W6B      DRIVE
C      W6C      FUEL CELLS
C      W7       FLIGHT CONTROLS
C      W8       AUXILIARY POWER
C      W9       INSTRUMENTS
C      W10      HYDRAULICS
C      W11      ELECTRICAL
C      W12      AVIONICS
C      W13      FURNISHING AND EQUIPMENT
C      W14      ANTI-ICE AND AIR-CONDITIONING
C      W15      LOADING AND HANDLING
C      CARGO    TOTAL WEIGHT OF CARGO AND BAGGAGE
```


C WEIGHT TOTAL WEIGHT OF PERSONNEL
 C PEOPLE TOTAL NUMBER OF PERSONNEL
 C S MAIN ROTOR BLADE PLANFORM AREA (SQ FT)
 C NENG NUMBER OF ENGINES
 C HP SHAFT HORSEPOWER
 C FUEL TOTAL ON BOARD FUEL CAPACITY (LBS)
 C CREWWT ACTUAL WEIGHT OF CREW PERSONNEL ONLY
 C RERUN INTEGER INPJT FOR RERUNNING PROGRAM
 C COUNT COUNTER FOR PAGE OUTPUT
 C TANDEM IF 1 THEN HELICOPTER IS TANDEM
 C K CONSTANT (INITIAL EMPTY WEIGHT minus
 C REVISED EMPTY WEIGHT)

MAIN PROGRAM

C INTEGER RERUN
 10 CALL FRTCMS ('CLRSCRN ')
 WRITE (6,20)
 READ (5,*) TYPE
 IF (TYPE.EQ.1) CALL OBS
 IF (TYPE.EQ.2) CALL UTILITY
 IF (TYPE.EQ.3) CALL CARGO
 C CALL FRTCMS ('CLRSCRN ')
 WRITE (6,30)
 READ (5,*) RERUN
 IF (RERUN.EQ.1) GO TO 10
 STOP
 20 FORMAT('WHAT TYPE OF HELICOPTER ARE YOU DESIGNING ?
 */4X,15H 1 OBSERVATION /,4X,11H 2 UTILITY
 */4X,9H 3 CARGO /18H ENTER 1, 2, OR 3)
 30 FORMAT(30H DO YOU WANT ANOTHER RUN ?
 11H 1 - YES /39H 0 - no)
 END

B. OBSERVATION SUBROUTINE

SUBROUTINE OBS
REAL K, NENG
INTEGER COUNT
COUNT=0

C

CALL INPUT (WE, S, PEOPLE, WEIGHT, CARGO, FUEL, HP, NENG)

C

10 WG=173.701*WE**.378
STT=.264*EXP(.0135*HP)
SB=194.274*ALOG(WG)-1306.779
W1=408.5622*ALOG(S)-1142.917
W2A=2.219*EXP(.0005 * WG)
W2B=19.131*ALOG(STT)-32.414
W2=W2A+W2B
W3=.0090*S E**1.917
W4=-.0539*WG+200.912
W5=34.0
W6A=-.0896*HP+221.388
W6B=17.190*EXP(.0008 * WG)
W6C=.384*(FUEL/6.5)**1.0710
W6=W6A+W6B+W6C
W7=.000000000128*WG**3.469
W8=0.0
W9=24.571*EXP(.00040* HP)
W10=0.0
W11=-51.066*ALOG(SB)+367.947
W12=-122.282*ALOG(1120.354 * EXP(.003 * HP))
* +1062.00451
W13=19.80*(EXP(.372*PEOPLE) + EXP(-.033*SB))
W14=-22.371*ALOG(SB)+143.396
W15=0.0

```

        CALL OUTPUT(RWE,WE,W1,W2,W3,W4,W5,W6,W6A,W6B,W6C,
        *W7,W8,W9,W10,W11,W12,W13,W14,W15,WG,WG1,N,
        *CREWWT,FUEL,CARGO,WEIGHT,COUNT)
        IF (ABS(K) .LE. .02*WE) GO TO 20
        IF (N.EQ.1) GO TO 10
20     RETURN
        END

```

C. UTILITY SUBROUTINE

```

        SUBROUTINE UTILTY
        REAL K,NENG
        INTEGER COUNT
        COUNT=0
C
        CALL INPUT (WE,S,PEOPLE,WEIGHT,CARGO,FUEL,HP,NENG)
C
10     WG=16239.430*ALOG(WE) -130252.750
        STT=.0376*HP-8.106
        SB=636.081*EXP(.000011 * WG)
        W1=11.0702*S-168.888
        W2A=.00438*WG+12.470
        W2B=2.411*STT-19.531
        W2=W2A+W2B
        W3=.282*SB**1.272
        W4 = 301.577 * ALOG(WG) -2319.890
        IF (WE.LE.6000) W4=.025*EXP(.000062*WG +8.02)
        W5=.02*EXP(.000062 * WG +8.02)
        W6A=130.0+.451*HP
        IF (NENG.EQ.2) W6A=295.0+.188*HP
        W6B=741.460*ALOG(HP) -4542.0420
        W6C=363.240*ALOG(FUEL/6.5) -1656.521
        W6=W6A+W6B+W6C
        W7=210.858*EXP(.000059 * WG)

```

```
W8=0.0
IF (NENG.EQ.2) W8 = 190.0
W9=56.0975*ALOG(HP) - 312.237
W10=.00362*WG+11.553
W11=481.735*ALOG(SB) - 2794.530
W12=.139*HF+77.823
W13=.175*SE+22.0*PEOPLE-10.
W14=122.45E*ALOG(SB) - 730.252
W15=84.50
```

C

```
CALL OUTPUT(RWE,WE,W1,W2,W3,W4,W5,W6,W6A,W6B,W6C,
*W7,W8,W9,W10,W11,W12,W13,W14,W15,WG,WG',N,
*CREWWT,FUEL,CARGO,WEIGHT,COUNT)
IF (ABS(K) .LE. .02*WE) GO TO 20
IF (N.EQ.1) GO TO 10
```

20

```
RETURN
```

C

```
END
```

D. CARGO SUBROUTINE

```
SUBROUTINE CARGO
REAL K,NENG
INTEGER COUNT
CCOUNT=0
```

C

```
CALL INPUT(WE,S,PEOPLE,WEIGHT,CARGO,FUEL,HP,NENG)
WRITE(6,71)
READ(5,*) TANDEM
IF (TANDEM.EQ.1.) WRITE(8,72)
IF (TANDEM.EQ.0.) WRITE(8,73)
```

C

10

```
WG=4.975*WF**.887
STT=60.127*EXP(.000145*HP)
```

```
SB=426.378*EXP(.000045 * WG)
W1=707.174*EXP(.00539 *S)
W6A = 348.C + .910*HP
W2A=324.55(*ALOG(WG) - 3021.510
W2B=- 18.0+2.83*STT
W3=2.918*SE-1321.921
IF (TANDEM.NE.1.)GO TO 45
STT=0.0
SB = 567.688*EXP(.000041*WG)
W1 =2*W1
W2A=0.0
W2B=0.0
W3=3467.291*ALOG(SB) - 22118.298
W6A=565.507*EXP(.000198*HP)
```

C

45

```
W2=W2A+W2B
W4=258.358*EXP(.000041*WG)
W5=.014*(.204 * WG)**1.136
W6B=.999*HP**.959
W6C=454.619*(FUEL/6.5)**(-.0566)
W6=W6A+W6B+W6C
W7=.00334 *WG**1.224
W8=139.0
W9=68.266*ALOG(HP) -387.598
W10=.000000663*WG**1.863
W11=9.780*SB**.539
W12=1.90*(16744.967*ALOG(HP) -108666.0)**.536
W13=.159*SE+18.11*PEOPLE
W14=117.771*ALOG(SB) - 710.594
W15=-72.0+.111*SB+3.490*PEOPLE
```

```
CALL OUTPUT(RWE,WE,W1,W2,W3,W4,W5,W6,W6A,W6B,W6C,
*W7,W8,W9,W10,W11,W12,W13,W14,W15,WG,WG1,N,
*CREWWT,FUEL,CARGO,WEIGHT,COUNT)
```

```
IF (ABS(K) .LE. .02*WE) GO TO 20
IF (N.EQ.1) GO TO 10
```

```
71  FORMAT(' ARE YOU DESIGNING A TANDEM HELICOPTER ?
      *1 - YES/'                                0 - NO')
72  FORMAT(T16,'A TANDEM HELICOPTER IS BEING
      *DESIGNED//)
73  FORMAT(T15,'A TANDEM HELICOPTER IS NOT BEING
      *designed//)

C
20  RETURN
    END
```

E. OUTPUT SUBROUTINE

```
      SUBROUTINE OUTPUT(RWE,WE,W1,W2,W3,W4,W5,W6,W6A,W6B,
      *W6C,W7,W8,W9,W10,W11,W12,W13,W14,W15,WG,WG1,N,
      *CREWWT,FUEL,CARGO,WEIGHT,COUNT)
      REAL R
      INTEGER COUNT
      RWE=W1+W2+W3+W4+W5+W6+W7+W8+W9+W10+W11+W12+W13
      *W14+W15
      CREWWT=WEIGHT+CARGO
      WG1=RWE+FUEL+CREWWT
      K=WE-RWE
      CALL FRTCMS ('CLRSCRN ')
      WRITE (6,210) WE
      WRITE (8,210) WE
      WRITE (6,220) WG
      WRITE (8,220) WG
      WRITE (6,230) W1,W2
      WRITE (8,230) W1,W2
      WRITE (6,240) W3,W4
      WRITE (8,240) W3,W4
      WRITE (6,250) W5,W6A
```

```

WRITE (8,250) W5,W6A
WRITE (6,260) W6B,W6C
WRITE (8,260) W6B,W6C
WRITE (6,270) W7,W8
WRITE (8,270) W7,W8
WRITE (6,280) W9,W10
WRITE (8,280) W9,W10
WRITE (6,290) W11,W12
WRITE (8,290) W11,W12
WRITE (6,300) W13,W14
WRITE (8,300) W13,W14
WRITE (6,310) W15
WRITE (8,310) W15
WRITE (6,320) RWE
WRITE (8,320) RWE
WRITE (6,330) CREWWT, FUEL
WRITE (8,330) CREWWT, FUEL
WRITE (6,340) WG1
WRITE (8,340) WG1
IF (ABS(K) .LE. .02 * WE) GO TO 20
WRITE (6,350)
WRITE (8,350)
WRITE (6,360)
READ (5,*) N
WRITE (8,370)
COUNT=COUNT+1
IF (COUNT.EQ.3) WRITE (8,380)
IF (N.EQ.1) WE=RWE

```

C

20 RETURN

C

210 FORMAT(T15,'EMPTY WEIGHT ESTIMATE (LBS) = ,F11.3)

220 FORMAT(T15,'GROSS WEIGHT ESTIMATE (LBS) = ,F11.3/)

230 FORMAT('ROTOR =,T21,F8.3,T35,'TAIL=,T50,F8.3)

```

240  FORMAT('BODY = ,T21,F8.3,T35,'LANDING GEAR=,T50,
      *F8.3)
250  FORMAT('NACELLE = ,T21,F8.3,T35,'ENGINE = ,T50,
      *F8.3)
260  FORMAT('DRIVE = ,T21,F8.3,T35,'FUEL TANKS = ,T50,
      *F8.3)
270  FORMAT('FLIGHT CONTROLS = ,T21,F8.3,T35,
      *'AUX POWER = ,T50,F8.3)

280  FORMAT('INSTRUMENTS = ,T21,F8.3,T35,'HYDRAULICS = ,
      *T50,F8.3)
290  FORMAT('ELECTRICAL = ,T21,F8.3,T35,'AVIONICS = ,
      *T50,F8.3)
300  FORMAT('FURNISHINGS = ,T21,F8.3,T35,'ICE AND AIR=,
      *T50,F8.3)
310  FORMAT(21H LOAD AND HANDLING = ,T21,F8.3,/)
320  FORMAT(T10,24H REVISED EMPTY WEIGHT = ,F11.3)
330  FORMAT('PERSONNEL & CARGO = ,T22,F8.3,T35,'FUEL =,
      *F8.3/)
340  FORMAT(T10,21H YOUR GROSS WEIGHT = ,F11.3/)
350  FORMAT (T5,53HINITIAL AND REVISED EMPTY WEIGHT VARY
      *BY MORE THAN 2%)
360  FORMAT (' FOR RECYCLE, ENTER 1 -- OTHERWISE 0')
370  FORMAT (////)
380  FORMAT (1H 1)
      END

```

F. INPUT SUBROUTINE

```

SUBROUTINE INPUT(WE,S,PEOPLE,WEIGHT,CARGO,FUEL,
*HP,ENG)
REAL NENG
CALL FRTCMS ('CLRSCRN ')
WRITE (8,380)
WRITE (8,30)

```



```

WRITE (6,40)
READ (5,*) WE
WRITE (8,50) WE
WRITE (6,60)
READ (5,*) S
WRITE (8,70) S
WRITE (6,80)
READ (5,*) PEOPLE
WRITE (8,90) PEOPLE
WRITE (6,100)
READ (5,*) WEIGHT
WRITE (8,110) WEIGHT
WRITE (6,120)
READ (5,*) CARGO
WRITE (8,130) CARGO
WRITE (6,140)
READ (5,*) FUEL
WRITE (8,150) FUEL
WRITE (6,160)
READ (5,*) HP
WRITE (8,170) HP
CALL FRTCMS ('CLRSCRN ')
WRITE (6,190)
READ (5,*) NENG
WRITE (8,200) NENG
WRITE (8,180)
RETURN
30  FORMAT (T10,46H *** INITIAL INPUT *****,//)
40  FORMAT('ENTER INITIAL EMPTY WEIGHT ESTIMATE (LBS)')
50  FORMAT('INITIAL EMPTY WEIGHT ESTIMATE (LBS)=,F11.3')
60  FORMAT (34F ENTER BLADE PLANFORM AREA(SQ FT) )
70  FORMAT (31H BLADE PLANFORM AREA (SQ FT) = ,F8.3)
80  FORMAT (32H ENTER NUMBER CREW + PASSENGERS )
90  FORMAT (28F NUMBER CREW + PASSENGERS = ,F3.0)
100 FORMAT (39F ENTER TOTAL WEIGHT OF PERSONNEL (LBS))

```

```
110  FORMAT (29H TOTAL WEIGHT OF PERSONNEL = ,F8.3)
120  FORMAT('ENTER TOTAL WEIGHT OF BAGGAGE/CARGO (LBS) ')
130  FORMAT (' TOTAL WEIGHT OF BAGGAGE/CARGO = ',F8.3)
140  FORMAT (27H ENTER FUEL CAPACITY (LBS) )
150  FORMAT (21H FUEL CAPACITY (LBS) ,F8.3)
160  FORMAT (24H ENTER SHAFT POWER (HP) )
170  FORMAT (18H SHAFT POWER (HP) ,F11.3)
180  FORMAT (T10,'***** WEIGHT ESTIMATE *****',//)
190  FORMAT (34H ENTER NUMBER OF ENGINES (1 OR 2 ))
200  FORMAT (21H NUMBER OF ENGINES = ,F2.0//)
380  FORMAT (1H1)
      END
```

G. WT EXEC

WT

```
THIS FILE COMPILES AND EXECUTES THE PROGRAM WEIGHT
GIVE THE COMMAND "WT <FILENAME> <DEVICE>"
GLOBAL TXTLIB CMSLIB FORTMOD2 MOD2EEH NCNIMSL
GLOBAL IMSLSP IMSLDP
FORTGI &1
FILEDEF C5 TERM
FILEDEF O6 TERM
FILEDEF O8 DISK AIR LISTING
LOAD &1 (START)
&END
```

APPENDIX C
HP41-CV EXAMPLE PROGRAMS

This section contains example programs for three helicopter categories.

A. OBS SUBROUTINE PROGRAM

This subroutine is for designing light observation helicopters.

1. Read the following cards into your calculator:
 - a. Input
 - b. Output
 - c. Obs
2. Execute the following instructions in order.

"XEQ OBS"

PROMPT	ENTER	PRESS
WE?	1502	R/S
S?	31.3	R/S
P?	3	R/S
PWT?	600	R/S
CGO?	20	R/S
F?	499	R/S
SHP?	317	R/S
NENG?	1	R/S

After approximately twenty seconds the following output will be displayed.

	DISPLAY	PRESS
WG EST=	2757.9	R/S
RCTOR=	264.0	R/S
TAIL=	32.8	R/S
BODY=	309.8	R/S
GEAR=	52.3	R/S
NACE=	34.0	R/S
ENG=	193.0	R/S
DRIVE=	156.1	R/S
F TKS=	40.1	R/S
CNTR=	110.4	R/S
AUX=	0.0	R/S
INST=	27.9	R/S
HYD=	0.0	R/S
ELECT=	89.7	R/S
AVIN=	87.1	R/S
FRN=	60.4	R/S
AIAC=	21.5	R/S
LH=	0.0	R/S
REV WE=	1478.8	R/S
REV WG=	2597.8	R/S
AGAIN?	For another run enter 1 If not enter 0	R/S

B. UTIL SUBROUTINE PROGRAM

This subroutine is for designing military utility helicopters.

1. Read the following cards into your calculator:
 - a. Input
 - b. Output
 - c. UTIL
2. Execute the following instructions in order.

"XEQ UTIL"

PROMPT	ENTER	PRESS
WE?	5200	R/S
S?	77.8	R/S
P?	13	R/S
PWT?	2600	R/S
CGO?	0	R/S
F?	1388	R/S
SHP?	1150	R/S
NENG?	1	R/S

After approximately twenty seconds the following output will be displayed.

	DISPLAY	PRESS
WG EST=	8698.5	R/S
ROTOR=	692.4	R/S
TAIL=	115.7	R/S
BCDY=	1172.7	R/S
GEAR=	130.4	R/S
NACE=	104.3	R/S
ENG=	648.7	R/S
DRIVE=	683.4	R/S
F TKS=	291.8	R/S
CNTR=	352.3	R/S
AUX=	0.0	R/S
INST=	83.1	R/S
HYD=	43.0	R/S
ELECT=	361.3	R/S
AVIN=	237.7	R/S
FRN=	398.5	R/S
AIAC=	72.0	R/S
LH=	84.5	R/S
REV WE=	5471.7	R/S
REV WG=	9459.7	R/S
AGAIN?	For another run enter 1 If not enter 0	R/S

C. CGO SUBROUTINE PROGRAM

This subroutine is for designing military cargo helicopters.

1. Read in the following cards into your calculator:
 - a. Input
 - b. Output
 - c. CGO
2. Execute the following instructions in order.

"XEQ CGO"

PROMPT	ENTER	PRESS
WE?	7700	R/S
S?	127.3	R/S
P?	18	R/S
PWT?	3600	R/S
CGO?	200	R/S
F?	1750	R/S
SHP?	1535	R/S
NENG?	1	R/S
TANDEM?	0 No	R/S

After approximately twenty seconds the following output will be displayed.

	DISPLAY	PRESS
WG EST=	13935.1	R/S
ROTOR=	1404.5	R/S
TAIL=	270.0	R/S
BODY=	1007.3	R/S
GEAR=	457.5	R/S
NACE=	117.4	R/S
ENG=	1744.9	R/S
DRIVE=	1135.1	R/S
F TKS=	331.2	R/S
CNTR=	394.6	R/S
AUX=	139.0	R/S
INST=	113.2	R/S
HYD=	34.8	R/S
ELECT=	358.6	R/S
AVIN=	319.2	R/S
FRN=	452.9	R/S
AIAC=	76.4	R/S
LH=	79.4	R/S
REV WE=	8435.9	R/S
REV WG=	13985.9	R/S
AGAIN?	For another run enter 1 If not enter 0	R/S

APPENDIX D
IBM 3033 EXAMPLE PROGRAMS

This section contains example programs for all three helicopter categories. This program contains all subroutines in one interactive file named "Weight". The program must be compiled, then loaded before it will execute. To assist in this procedure an exec "WT" has been provided. Simply go to your flist and write, "wt" next to the program "Weight". Upon completion, just answer the questions with desired input. The following is a listing of "Weight" input and output for all three type helicopters.

A. OBSERVATION HELICOPTER

1. Input

SCREEN DISPLAY	ENTER
WHAT TYPE OF HELICOPTER ARE YOU DESIGNING?	
1 OBSERVATION	
2 UTILITY	
3 CARGO	
ENTER 1,2 or 3.?	1
ENTER INITIAL EMPTY WEIGHT ESTIMATE (LBS)?	1502
ENTER BLADE PLANFORM AREA(SQ FT)?	31.3
ENTER NUMBER CREW + PASSENGERS?	3
ENTER TOTAL WEIGHT OF PERSONNEL (LBS)?	600
ENTER TOTAL WEIGHT OF BAGGAGE/CARGO (LBS)?	20
ENTER FUEL CAPACITY (LBS)?	499
ENTER SHAFT POWER (HP)?	317
ENTER NUMBER OF ENGINES (1 OR 2)?	1

2. Output

The output will be located on your "A disk" under file name "Air Listing".

***** INITIAL INPUT *****

INITIAL EMPTY WEIGHT ESTIMATE (LBS) = 1502.000
BLADE PLANFORM AREA (SQ FT) = 31.300
NUMBER CREW + PASSENGERS = 3.
TOTAL WEIGHT OF PERSONNEL = 600.000
TOTAL WEIGHT OF BAGGAGE/CARGO = 20.000
FUEL CAPACITY (LBS) 499.000
SHAFT POWER (HP) 317.000
NUMBER OF ENGINES = 1.

***** WEIGHT ESTIMATE *****

EMPTY WEIGHT ESTIMATE (LBS) = 1502.000
GRCSS WEIGHT ESTIMATE (LBS) = 2757.933

ROTOR =	264.015	TAIL =	32.789
BODY =	309.014	LANDING GEAR =	52.259
NACELLE =	34.000	ENGINE =	192.985
DRIVE =	156.128	FUEL TANKS =	40.121
FLIGHT CONTROLS =	110.303	AUX POWER =	0.0
INSTRUMENTS =	27.893	HYDAULICS =	0.0
ELECTRICAL =	89.737	AVIONICS =	87.124
FURNISHINGS =	60.451	ICE AND AIR =	21.518
LOAD AND HANDLING =	0.0		

REVISED EMPTY WEIGHT = 1478.335
PERSONNEL & CARGO = 620.000 FUEL = 499.000
YOUR GROSS WEIGHT = 2597.335

B. UTILITY HELICOPTER

1. Input

SCREEN DISPLAY	ENTER
WHAT TYPE OF HELICOPTER ARE YOU DESIGNING?	
1 OBSERVATION	
2 UTILITY	
3 CARGO	
ENTER 1,2 or 3.?	2
ENTER INITIAL EMPTY WEIGHT ESTIMATE (LBS)?	5200
ENTER BLADE PLANFORM AREA(SQ FT)?	77.8
ENTER NUMBER CREW + PASSENGERS?	13
ENTER TOTAL WEIGHT OF PERSONNEL (LBS)?	2600
ENTER TOTAL WEIGHT OF BAGGAGE/CARGO (LBS)?	0
ENTER FUEL CAPACITY (LBS)?	1388
ENTER SHAFT POWER (HP)?	1150
ENTER NUMBER OF ENGINES (1 OR 2)?	1

2. Output

The output will be located on your "A disk" under file name "Air Listing".

***** INITIAL INPUT *****

INITIAL EMPTY WEIGHT ESTIMATE (LBS) = 5200.000
BLADE PLANFORM AREA (SQ FT) = 77.800
NUMBER CREW + PASSENGERS = 13.
TOTAL WEIGHT OF PERSONNEL = 2600.000
TOTAL WEIGHT OF BAGGAGE/CARGO = 0.0
FUEL CAPACITY (LBS) 1388.000
SHAFT POWER (HP) 1150.000
NUMBER OF ENGINES = 1.

***** WEIGHT ESTIMATE *****

EMPTY WEIGHT ESTIMATE (LBS) = 5200.000

GROSS WEIGHT ESTIMATE (LBS) = 8698.500

ROTOR =	692.373	TAIL =	115.746
BODY =	1172.667	LANDING GEAR =	130.377
NACELLE =	104.301	ENGINE =	648.650
DRIVE =	683.406	FUEL TANKS =	291.832
FLIGHT CONTROLS =	352.269	AUX POWER =	0.0
INSTRUMENTS =	83.111	HYDRAULICS =	43.042
ELECTRICAL =	361.321	AVIONICS =	237.673
FURNISHINGS =	398.491	ICE AND AIR =	71.971
LOAD AND HANDLING =	84.500		

REVISED EMPTY WEIGHT = 5471.719

PERSONNEL & CARGO = 2600.000 FUEL = 1388.000

YOUR GROSS WEIGHT = 9459.719

INITIAL AND REVISED EMPTY WEIGHT VARY BY MORE THAN 2%

C. CARGO HELICOPTER

1. Input

SCREEN DISPLAY	ENTER
WHAT TYPE OF HELICOPTER ARE YOU DESIGNING?	
1 OBSERVATION	
2 UTILITY	
3 CARGO	
ENTER 1,2 or 3.?	3
ENTER INITIAL EMFTY WEIGHT ESTIMATE (LBS)?	7700
ENTER BLADE PLANFORM AREA(SQ FT)?	127.3
ENTER NUMBER CREW + PASSENGERS?	18
ENTER TOTAL WEIGHT OF PERSONNEL (LBS)?	3600
ENTER TOTAL WEIGHT OF BAGGAGE/CARGO (LBS)?	200
ENTER FUEL CAPACITY (LBS)?	1750
ENTER SHAFT POWER (HP)?	1535
ENTER NUMBER OF ENGINES (1 OR 2)?	1
ARE YOU DESIGNING A TANDEM HELICOPTER? 1 YES, 0 NO	0

2. Output

The output will be located on your "A disk" under file name "Air Listing".

***** INITIAL INPUT *****

INITIAL EMPTY WEIGHT ESTIMATE (LBS) = 7700.000
BLADE PLANFORM AREA (SQ FT) = 127.300
NUMBER CREW + PASSENGERS = 18.
TOTAL WEIGHT OF PERSONNEL = 3600.000
TOTAL WEIGHT OF BAGGAGE/CARGO = 200.000
FUEL CAPACITY (LBS) 1750.000
SHAFT POWER (HP) 1535.000
NUMBER OF ENGINES = 1.

***** WEIGHT ESTIMATE *****

A TANDEN HELICOPTER IS NOT BEING DESIGNED

EMPTY WEIGHT ESTIMATE (LBS) = 7700.000

GRCSS WEIGHT ESTIMATE (LBS) = 13935.105

ROTOR =	1404.482	TAIL =	269.979
BODY =	1007.335	LANDING GEAR =	457.458
NACELLE =	117.375	ENGINE =	1744.850
DRIVE =	1135.124	FUEL TANKS =	331.09
FLIGHT CONTROLS =	394.582	AUX POWER =	139.000
INSTRUMENTS =	113.221	HYDAULICS =	34.833
ELECTRICAL =	358.581	AVIONICS =	319.190
FURNISHINGS =	452.899	ICE AND AIR =	76.399
LOAD AND HANDLING =	79.424		

REVISED EMPTY WEIGHT = 8435.922

PERSONNEL & CARGO = 3800.000 FUEL = 1750.000

YOUR GROSS WEIGHT = 13985.922

INITIAL AND FEVISED EMPTY WEIGHT VARY BY MORE THAN 2%

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