Project RAND

(U) COST ESTIMATE OF AN EXPERIMENTAL SATELLITE PROGRAM

RA-15030

February 1, 1947

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PROJECT RAND

(AAF PROJECT MX-791)

COST ESTIMATE OF AN EXPERIMENTAL SATELLITE PROGRAM

J. H. GUNNING

RA-15030

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February 1, 1947

DOUGLAS AIRCRAFT COMPANY, INC.

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*This initial external distribution list includes the distribution of all related technical reports on the satellite vehicle.

COST ESTIMATE OF AN EXPERIMENTAL SATELLITE PROGRAM

SUMMARY

This report outlines in maximum detail consistent with available information, the method and results of a study involving the cost of an experimental satellite program.

The final study configuration as developed in references 1 and 2, is a three-stage, hydrazine-oxygen rocket which will place a 500 pound payload on an orbit 350 miles above the earth's surface. The cost of such a rocket, including development, construction, and preliminary flight tests is $82,000,000. The contractor's fee and the cost of overseas expeditions are not included in the above figure.

The estimated costs of the two and the three-stage satellite rocket programs, plotted against various gross weights, are shown in Fig. 1.

A curve, Fig. 2, determined by methods similar to those used in reference 2, is also presented of gross weight versus payload with other features remaining constant. The combined use of Figs. 1 and 2 permits the estimation of costs for payloads other than 500 pounds. For example, the three-stage, hydrazine-oxygen arrangement with 1000 pounds of payload would weigh about 127,500 pounds, Fig. 2, and therefore cost approximately $117,000,000, Fig. 1.

INTRODUCTION

In view of the complexity of this project and the increase of its magnitude with the transition to larger launching stages, it will be better to progress during the test program from the smaller to the larger stages in sequence in order to reap full benefit of the experience, rather than to attempt all stages at once. This testing program will dictate that more smaller stage units will be built than the larger ones; and the stages will be tested individually and in combination. Flight testing of any torso part of the three-stage aggregate will require provision for fairing or dummy heads, otherwise the high air resistance in the lower atmosphere is likely to seriously impair the behavior of the vehicle.

The number of flight tests for the various rocket combinations in the three-stage vehicle program is as follows:

Combinations	III_ℓ	$II_\ell+III_d$	$II_\ell+III_\ell$	$I_\ell+II_d+III_d$	$I_\ell+II_\ell+III_d$	$I_\ell+II_\ell+III_\ell$
No. of Flight Tests	12	8	4	4	4	4

For references see page 10.

where: I_ℓ is live units of first stage
II_ℓ is live units of second stage
III_ℓ is live units of third stage
I_d is dummy units of first stage
II_d is dummy units of second stage
III_d is dummy units of third stage

The above quantities plus three static test units for the three-stage vehicle program are summarized as follows:

	No. of Live Units (ℓ)	No. of Dummy Units (d)
Stage III	12 + 4 + 4 = 20	8 + 4 + 4 + 1* = 17
Stage II	8 + 4 + 4 + 4 = 20	4 + 1* = 5
Stage I	4 + 4 + 4 = 12	1*

*For static tests, one unit of III_d, II_d, and I_d will be constructed.

In the two-stage vehicle program, the number of flight tests for the various rocket combinations is as follows:

Combinations	II_ℓ	$I_\ell + II_d$	$I_\ell + II_\ell$
No. of Flight Tests	12	8	4

The above quantities plus two static test units for the two-stage vehicle program, are summarized as follows:

	No. of Live Units (ℓ)	No. of Dummy Units (d)
Stage II	16	8 + 1** = 9
Stage I	12	1**

**For static test, one unit of II_d and I_d will be constructed.

CALCULATIONS AND RESULTS

The typical rocket vehicles chosen to determine points 'A' and 'B' on the cost curves, use hydrazine-fluorine fuel to carry 500 pounds of payload to an orbit altitude of 300 miles with a motor chamber pressure of 300 psi. The three-stage vehicle, point 'A', has an estimated gross weight of 48,742 lbs (Table I), and its program is estimated to cost $48,246,772 less the contractor's fixed fee (Table IV). The two-stage vehicle, point 'B', has an estimated gross weight of 92,271 lbs (Table II), and its program is estimated to cost $56,177,435 less fixed fee (Table IV).

As described in the 'Discussion', the three-stage vehicle using hydrazine-oxygen instead of hydrazine-fluorine, and increasing its orbit altitude from 300 miles to 350 miles, has an estimated gross weight of 96,000 lbs, and an estimated program cost less fixed fee of $90,000,000. The two-stage vehicle when subjected to the same changes is estimated to weigh 228,000 lbs and will cost about $130,000,000, less fixed fee. In order to reduce these weights and costs, the motor chamber pressure was varied from 300 psi for all stages to the best pressure for each stage. The estimated gross weight of the three-stage vehicle reduced to 86,400 lbs, and the estimated cost of its program became $82,000,000, less fixed fee. The estimated gross weight of the two-stage vehicle reduced to 205,000 lbs, and the estimated cost of its program reduced to $116,000,000 less fixed fee.

From past experience the cost of aircraft design, development, and construction has been found to be directly related to the weight of the product. This relationship was utilized in plotting the cost curves shown in Fig. 1. The cost trend slope versus gross weight was determined from graphs which contained the actual cost of development and construction of many varieties of experimental aircraft plotted against their gross weights. These lines of known slope were located on the graph by passing them through points determined by cost estimates of two typical cases. The basis for these typical cost estimates are the weights listed in Tables I and II. These weights were estimated for a two-stage vehicle and a three-stage vehicle by means of methods developed in Appendix I of Report No. RA-15026, entitled, 'Structural and Weight Studies of a Satellite Rocket', and are representative of typical satellite rockets employing the given configuration.

The cost weights from these tables are used in Table III to determine the weights which when multiplied by the pertinent factor of manufacturing labor gives the manufacturing labor man-hours (direct) required for each type vehicle. The number of manufacturing labor hours form the principal basis of the cost tabulation as shown in Table IV. The factors for obtaining manufacturing labor hours vary in value because the quantity of units to be produced varies in each case. When large production quantities are involved, cost has been found to decrease noticeably per pound as the production of units increase. In experimental work, however, the quantity required is small and the changes numerous so that the cost decrease per pound is slight.

The results of Tables I, II, and IV give the quantities required to plot the two points 'A' and 'B' which locate the lines of known slope in Fig. 1.

DISCUSSION

In order to show the estimated cost trend compared to gross weights of the satellite rocket programs, two points were plotted on log graph, Fig. 1. To determine point 'A' for the three-stage vehicle program, the estimated gross weight of 48,742 lbs (abscissa) was obtained from Table I, and the estimated cost of $48,246,772 (ordinate) from Table IV. The two-stage vehicle program estimated to weigh 92,271 lbs in Table II and cost $56,177,435 in Table IV, located point 'B'. Through these points were drawn parallel straight lines with a slope of slightly less than 45 degrees or abscissa/ordinate is proportional to 1/0.925. Since this slope was found consistent for the costs versus gross weights of many experimental models developed and constructured in the past for gross weights under 150,000 lbs, it was felt that a straight line extrapolated to 250,000 lbs was reasonable. The slope of the line shows that as the gross weight increases, the cost per pound decreases slightly.

As mentioned previously in the 'Introduction', the weights listed in Tables I and II were estimated by methods developed in reference 2. The costs mentioned above, however, largely depend upon these weights for their derivation. For example, the cost weights listed in Table III are taken from Tables I and II. The total cost weight of 128,893 lbs, when multiplied by the factor of 18.65 equals 2,403,900 direct manufacturing man-hours of labor for the three-stage vehicle program. Likewise, the direct manufacturing man-hours of labor for the two-stage vehicle program are obtained by multiplying the factor 19.65 by the pertinent total cost weight in Table III as follows: $19.65 \times 166{,}615 = 3{,}273{,}500$ hours. These values for direct labor of manufacturing become the main basis in estimating the costs listed in Table IV. As noted, the labor factor of 18.65 for the three-stage vehicle program is less than 19.65 for the two-stage vehicle program. This difference is caused by the greater quantity of units required in the three-stage vehicle program. Cost versus quantity curves resulting from past experience involving experimental projects, were used as the basis in selecting these factors.

Direct tooling labor was found by past practice to be approximately 20% of direct manufacturing labor.

The estimated direct engineering time should not be greater than the most complex of experimental airplanes developed by this company. On the basis of past experience, therefore, the direct engineering time should equal about 1,000,000 hours.

Labor and burden rates used in Table IV were those currently approved by Management for use in normal bidding on projected future work. These rates can be expected to vary depending on the calendar period during which the work will be accomplished.

The 'Direct Charges' including such items as travel expenses, insurance, etc., are estimated in normal proportion to direct manufacturing labor.

Past experience has shown that in producing experimental aircraft, the 'Material Cost' is about 50% of the direct manufacturing labor cost.

The cost of the motors was estimated on a basis of dollars per thrust horsepower derived from quotations received from manufacturers of rocket motors.

The 'Instrumentation' which includes payload, automatic pilot, ground radio, and observing equipment is the most indeterminate item included in the cost proposal. Considerable design, research, development and testing will be necessary before these items will be acceptable. As some background for an estimating assumption, it has been observed that the Bell Laboratories have spent about $750,000 on the instrumentation for a rocket project during 1946, while Douglas Aircraft Company has spent $600,000 developing and constructing the remainder of the project, less the motors, during the same period. With this ratio in mind and because of the present vague knowledge concerning the payload, automatic pilot, ground radio and observing equipment, the 'Instrumentation' cost for either program has been assumed to equal approximately the total cost of the three-stage vehicle program less motors and flight tests.

The flight test costs are based on our past expenditures at White Sands, New Mexico while testing rockets there.

From Fig. 2 in Report RA-15026, 'Structural and Weight Studies of a Satellite Rocket', the estimated gross weight for a three-stage vehicle program using hydrazine-oxygen instead of hydrazine-fluorine, and increasing its orbit altitude from 300 miles to 350 miles, is 96,000 lbs. The revised weight of the two-stage vehicle program when subjected to the same changes, is 228,000 lbs.

If the 300 psi motor chamber pressure in all rocket stages is varied so that the best pressure is utilized for each stage, the weight of the three-stage vehicle used for the design study given in reference 2, is 86,400 lbs.

In order to estimate the change in weight of the 228,000 lb two-stage vehicle when the motor chamber pressure is varied from 300 psi to the best pressure for each stage, its gross weight is assumed to reduce in proportion to the weight reduction of the three-stage vehicle program when subjected to these motor pressure changes. Then the gross weight of the two-stage vehicle becomes $228,000 \times \frac{86,400}{96,000}$ or 205,000 lbs.

CONCLUSION

The final study configuration is a three-stage, hydrazine-oxygen rocket which will place a 500 pound payload on an orbit 350 miles above the earth's surface. The cost of such a rocket, including development, construction, and preliminary flight tests is $82,000,000.

The two trend curves of Fig. 1 show the estimated program costs of either the two or three-stage vehicle for various gross weights provided the quantities of units required for each type of program remains respectively the same as used in plotting points 'A' and 'B'. The quantities of live and dummy vehicles to be constructed are:

	Three-Stage Vehicle		Two-Stage Vehicle	
	No. of Live Units	No. of Dummy Units	No. of Live Units	No. of Dummy Units
Stage I	12	1	12	1
Stage II	20	5	16	9
Stage III	20	17	-	-

Likewise, the configuration proportions of the vehicle to be estimated must be approximately the same as the typical case used to locate the pertinent curve. This rule especially applies to the proportion of fuel weight to initial gross weight.

In addition, this preliminary cost estimate has been based on assumptions and conditions which are as follows:

1. The series of flight tests will be conducted at White Sands, New Mexico, or some equivalent location in this country with the exception of the final 'equatorial' stage.

2. No additional flight test facilities to those now available will be required for the tests in this country.

3. No costs have been included for the final 'all-live' flights at the equator, or for any transportation or expedition cost involved therein.

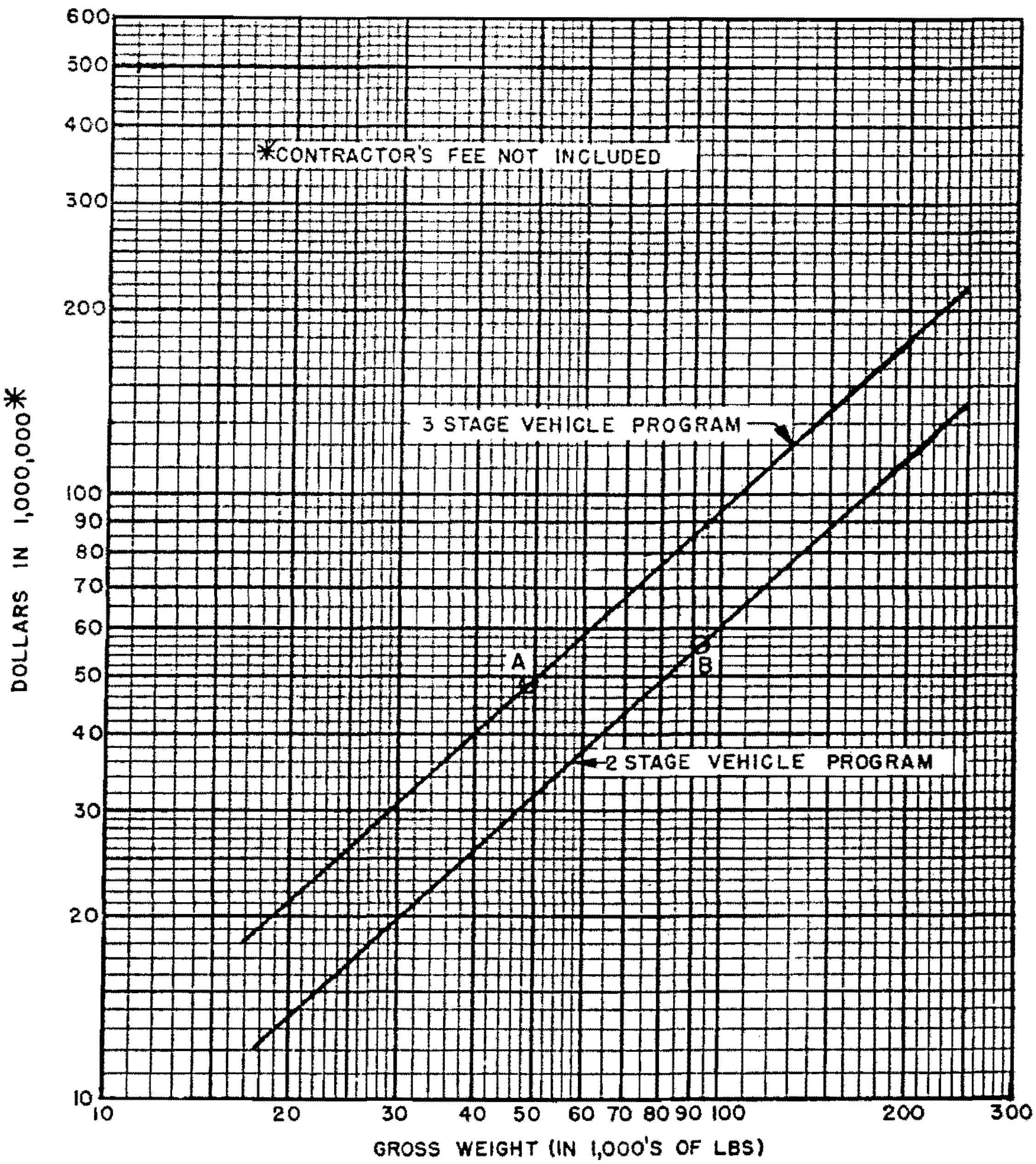
4. No contractor's fixed fee has been included in the estimated costs.

Because this preliminary estimate is based on extremely limited data, it shall be considered as a study for information only.

References

[1] 'Flight Mechanics of a Satellite Rocket', RA-15021, Project RAND, Douglas Aircraft Company, Inc., Feb. 1, 1947.

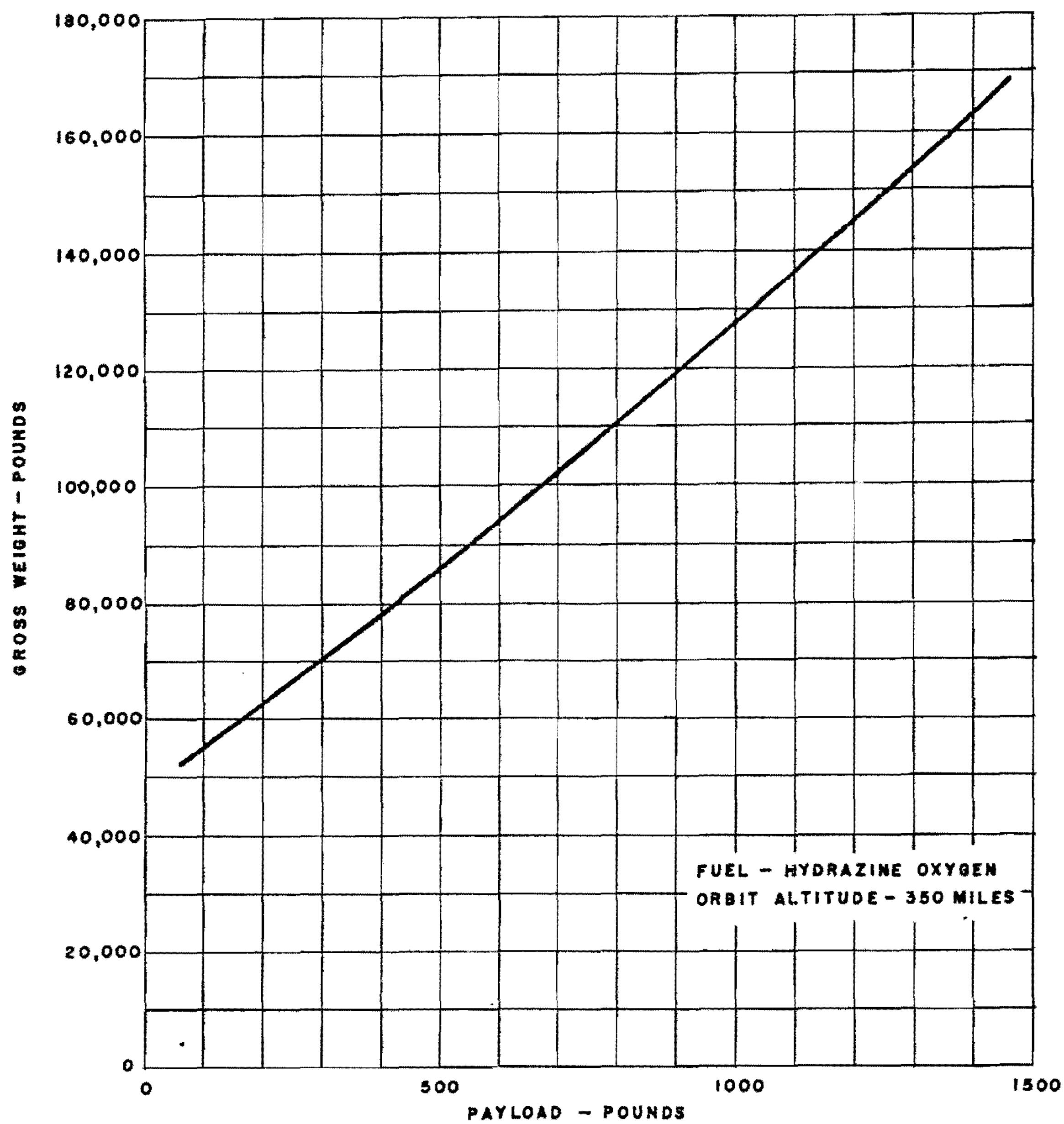
[2] 'Structural and Weight Studies of a Satellite Rocket', RA-15026, Project RAND, Douglas Aircraft Company, Inc., Feb. 1, 1947.



ESTIMATED COSTS VS GROSS WEIGHTS

FOR TWO AND THREE-STAGE SATELLITE ROCKET PROGRAMS

FIG. 1



GROSS WEIGHT VS PAYLOAD
THREE-STAGE SATELLITE ROCKET
FIG. 2

Table No. I

WEIGHT ESTIMATE OF TYPICAL THREE-STAGE VEHICLE

Fuel	Hydrazine-Fluorine	Payload	500 pounds
Orbit Altitude	300 miles	Motor Chamber Pres.	300 psi

	Stage III	Stage II	Stage I	Total
LIVE WEIGHT				
Tanks & Structure	282	384	1,540	2,206
Motor and Fuel System	182	516	2,205	2,903
Control Devices	44	201	2,205	2,450
Miscellaneous Weight	42	239	732	1,013
Total Cost Weight	550	1,340	6,682	8,572 lbs
Fuel	2,020	7,350	30,100	39,470
Payload and Auto Pilot	700	- -	- -	700
Total Gross Weight	3,270	8,690	36,782	48,742 lbs
DUMMY WEIGHT				
Tanks & Structure	282	384	1,540	
Miscellaneous Weight	42	239	732	
Total Dummy Weight	324	623	2,272 lbs	

Table No. II

WEIGHT ESTIMATE OF TYPICAL TWO-STAGE VEHICLE

Fuel . . . . . Hydrazine-Fluorine   Payload . . . . . . 500 pounds
Orbit Altitude 300 miles   Motor Chamber Pres. 300 psi

	Stage II	Stage I	Total
LIVE WEIGHT			
Tanks & Structure	396	3,912	4,308
Motor & Fuel System	183	1,947	2,130
Control Devices	110	4,800	4,910
Miscellaneous Weight	58	1,443	1,501
Total Cost Weight	747	12,102	12,849
Fuel	5,771	72,951	78,722
Payload & Auto Pilot	700	- -	700
Total Gross Weight	7,218	85,053	92,271 lbs
DUMMY WEIGHT			
Tanks & Structure	396	3,912	
Miscellaneous Weight	58	1,443	
Total Dummy Weight	454	5,355 lbs	

Table No. III

ESTIMATED COST WEIGHTS FOR DETERMINING
HOURS OF DIRECT MANUFACTURING LABOR

TYPICAL THREE-STAGE VEHICLE PROGRAM			
Stage	Quantity	Cost Wt ea.	Total Cost Weight
III	20 live units	550 lb	11,000 lb
II	20 live units	1,340	26,800
I	12 live units	6,682	80,200
III	13 dummy units	324	4,210
II & III combined	4 dummy units	947	3,788
II	1 dummy unit	623	623
I	1 dummy unit	2,272	2,272
Total	70 units		128,893 lbs

TYPICAL TWO-STAGE VEHICLE PROGRAM			
Stage	Quantity	Cost Wt ea.	Total Cost Weight
II	16 live units	747 lb	11,950 lb
I	12 live units	12,102	145,220
II	9 dummy units	454	4,090
I	1 dummy unit	5,355	5,355
Total	38 units		166,615 lbs

Table No. IV

COST ESTIMATES OF TWO SATELLITE ROCKETS

	Unit Rate	Typical Three-Stage Vehicle Program	Typical Two-Stage Vehicle Program
Direct Labor (hours)			
Engineering		1,000,000 hr.	1,000,000 hr.
Tooling	20% mfg.	480,800	654,700
Manufacturing		2,403,900	3,273,500
Direct Labor Cost			
Engineering	$2.57/hr	$2,570,000	$2,570,000
Tooling	2.01/hr	966,408	1,315,947
Manufacturing	1.86/hr	4,471,254	6,088,710
TOTAL LABOR COST		$8,007,662	$9,974,657
Burden Cost			
Engineering	115% direct	$2,955,500	$2,955,500
Tooling	115% direct	1,111,369	1,513,339
Manufacturing	130% direct	5,812,630	7,915,323
TOTAL BURDEN COST		$9,879,499	$12,384,162
Administrative Burden 13% total direct		$1,040,996	$1,296,705
Material 50% direct mfg. labor		2,235,627	3,044,355
Direct Charges		223,563	304,436
Motors		5,352,000	7,676,760
*Instrumentation		21,000,000	21,000,000
Flight Tests (Incl. Fuel)		507,425	496,360
TOTAL COST less fixed fee		$48,246,772	$56,177,435

*Note: Instrumentation includes payload, auto pilot, ground radio, and observing equipment.

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University of Southern California Naval Research Project, College of Engineering Los Angeles, California Attn: Dr. R. T. DeVault	Bureau of Aeronautics Rep. 15 South Raymond Street Pasadena, California	BUAER
University of Texas Defense Research Lab. Austin, Texas Attn: Dr. C. P. Boner	Development Contract Officer 500 East 24th Street Austin 12, Texas	BUORD
Willys-Overland Motors, Inc. Maywood, California Attn: Mr. Joe Talley	Representative-in-Charge, BUAER Consolidated-Vultee Aircraft Corp. Downey, California	BUAER

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D. COMPONENT CONTRACTORS

(1) AERODYNAMICS & BALLISTICS

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
New Mexico School of Mines Research & Development Div. Albuquerque, New Mexico	Development Contract Officer New Mexico School of Mines Albuquerque, New Mexico	BUORD
New Mexico School of Agri- culture & Mechanic Arts State College, New Mexico Attn: Dr. George Gardner	Development Contract Officer New Mexico School of Mines Albuquerque, New Mexico	BUORD
New York University Applied Mathematics Center New York, New York Attn: Mr. Richard Courant	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Office of the Chief of Ordnance Ordnance Research & Development Division Research & Materials Branch Ballistics Section Pentagon Washington 25, D.C.		ORD DEPT
Polytechnic Institute of Brooklyn Brooklyn, New York Attn: Mr. R.P. Harrington	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
University of Minnesota Minneapolis, Minnesota Attn: Dr. Akerman	Inspector of Naval Material Federal Bldg. Milwaukee 2, Wis.	BUORD
Aerojet Engineering Corp. Azusa, California Attn: K.F. Mundt	Bureau of Aeronautics Rep. 15 South Raymond Street Pasadena, California	BUAER
Marquardt Aircraft Co. Venice, California Attn: Dr. R. E. Marquardt	Bureau of Aeronautics Rep. 15 South Raymond Street Pasadena, California	BUAER

(2) GUIDANCE & CONTROL

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Belmont Radio Corporation 5921 West Dickens Avenue Chicago 29, Illinois Attn: Mr. Harold C. Mattes		AAF
Bendix Aviation Corp. Eclipse-Pioneer Division Teterboro, New Jersey Attn: Mr. R. C. Sylvander	Bureau of Aeronautics Resident Representative Bendix Aviation Corp. Teterboro, New Jersey	BUAER
Bendix Aviation Corp. Pacific Division, SPD West North Hollywood, Calif.	Development Contract Officer Bendix Aviation Corp. 11600 Sherman Way North Hollywood, California	BUORD
Bendix Aviation Radio Division East Joppa Road Baltimore 4, Maryland Attn: Mr. J. W. Hammond		AAF
Buehler and Company 1607 Howard Street Chicago 26, Illinois Attn: Mr. Jack M. Roehn		AAF
Commanding General Army Air Forces Pentagon Washington 25, D.C. Attn: AC/AS-4, DRE-2F		AAF

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D. COMPONENT CONTRACTORS (Cont'd)

(2) GUIDANCE & CONTROL

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Consolidated-Vultee Aircraft Corporation San Diego, California Attn: Mr. C. J. Breitwieser	Bureau of Aeronautics Representative, Consolidated-Vultee Aircraft Corp. San Diego, California	BUAER
Cornell University Ithaca, New York Attn: Mr. William C. Ballard, Jr.		AAF
Director, U.S. Navy Electronics Laboratory, San Diego, California		NAVY
Electro-Mechanical Research Ridge Field, Connecticut Attn: Mr. Charles B. Aiken		AAF
Farnsworth Television and Radio Co. Fort Wayne, Indiana Attn: Mr. J. D. Schantz	DCO, Applied Physics Laboratory Johns Hopkins University 8621 Georgia Avenue, Silver Spring, Maryland	BUORD
Federal Telephone and Radio Corp. 200 Mt. Pleasant Avenue Newark 4, New Jersey Attn: Mr. E. N. Wendell		AAF
Galvin Manufacturing Corp. 4545 Augusta Blvd. Chicago 5, Illinois Attn: Mr. G. R. MacDonald		AAF
G. M. Giannini and Co., Inc. 285 West Colorado St. Pasadena, California	Bureau of Aeronautics Rep. 15 South Raymond St. Pasadena, California	BUAER
Gilfillan Corp. 1815-1849 Venice Blvd. Los Angeles 6, California Attn: Mr. G. H. Miles		AAF
Hillyer Engineering Co. New York, New York Attn: Mr. Curtiss Hillyer	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Kearfott Engineering Co. New York, New York Attn: Mr. W. A. Reichel	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Lear Incorporated 110 Iona Avenue, N.W. Grand Rapids 2, Michigan Attn: Mr. R.M. Mock		AAF
Manufacturers Machine & Tool Co. 320 Washington Street Mt. Vernon, N.Y. Attn: Mr. L. Kenneth Mayer, Comptroller		AAF
Minneapolis-Honeywell Mfgr. Co. 2753 Fourth Avenue Minneapolis 8, Minnesota Attn: Mr. W. J. McGoldrick, Vice-President		AAF
Ohio State University Research Foundation Columbus, Ohio Attn: Mr. Thomas E. Davis, Staff Assistant		AAF

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D. COMPONENT CONTRACTORS (Cont'd)

(2) GUIDANCE & CONTROL

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Haller, Raymond & Brown P.O. Box 342 State College, Pennsylvania Attn: Dr. R. C. Raymond, Pres.		AAF
Office of Chief Signal Officer Engineering & Technical Services, Engineering Division Pentagon Washington 25, D.C.		ORD DEPT
Raytron, Inc. 209 E. Washington Avenue Jackson, Michigan Attn: Mr. John R. Gelzer, Vice-Pres.		AAF
L. N. Schwein Engineering Co. 5736 Washington Blvd. Los Angeles 16, California Attn: L.N. Schwein, General Partner		AAF
Senior Naval Liaison Officer U.S. Naval Electronic Liaison Office Signal Corps, Engineering Laboratory Fort Monmouth, New Jersey		NAVY
Servo Corporation of America Huntington, L.I., New York	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Square D Co. Kollsman Instrument Division Elmhurst, New York Attn: Mr. V. E. Carbonara	Bureau of Aeronautics Rep. 90 Church Street New York 7, New York	BUAER
Stromberg-Carlson Company Rochester, New York Attn: Mr. L.L. Spencer, Vice-Pres.		AAF
Submarine Signal Company Boston, Massachusetts Attn: Mr. Edgar Horton	Development Contract Officer Massachusetts Institute of Technology Cambridge 39, Massachusetts	BUORD
Summers Gyroscope Co. 1100 Colorado Avenue Santa Monica, California Attn: Mr. Tom Summers, Jr.		AAF
Sylvania Electric Products Inc. Flushing, Long Island, N.Y. Attn: Dr. Robert Bowie	Inspector of Naval Material 90 Church Street New York 7, New York	BUORD
University of Illinois Urbana, Illinois Attn: Mr. H. E. Cunningham, Sec.		AAF
University of Pennsylvania Moore School of Electrical Engr. Philadelphia, Pa.	Commanding Officer Naval Aircraft Modification Unit Johnsville, Pa.	BUAER
University of Pittsburgh Pittsburgh, Pennsylvania Attn: Mr. E. A. Holbrook, Dean		AAF
University of Virginia Physics Department Charlottesville, Virginia Attn: Dr. J. W. Beams	Development Contract Officer University of Virginia Charlottesville, Virginia	BUORD

D. COMPONENT CONTRACTORS (Cont'd)

(2) GUIDANCE & CONTROL

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Washington University Research Foundation 8135 Forsythe Blvd., Clayton 5, Missouri Attn: Dr. R. G. Spencer		AAF
Westinghouse Electric Corp. Springfield, Massachusetts Attn: J.K.B. Hare, Vice-Pres. (Dayton Office)		AAF
Director of Specialty Products Development Whippany Radio Laboratory Whippany, N.J. Attn: Mr. M.H. Cook		ORD DEPT
Zenith Radio Corporation Chicago, Illinois Attn: Hugh Robertson, Executive Vice-Pres.		AAF

(3) PROPULSION

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Aerojet Engineering Corp. Azusa, California Attn: K.F. Mundt	Bureau of Aeronautics Rep. 15 South Raymond Street Pasadena, California	BUAER
Armour Research Foundation Technical Center, Chicago 16, Illinois Attn: Mr. W. A. Casler		ORD DEPT
Arthur D. Little, Inc. 30 Memorial Drive, Cambridge, Mass. Attn: Mr. Helge Holst		ORD DEPT
Battelle Memorial Institute 505 King Avenue Columbus 1, Ohio Attn: Dr. B. D. Thomas		AAF & BUAER
Bendix Aviation Corp. Pacific Division, SPD West N. Hollywood, Calif.	Development Contract Officer Bendix Aviation Corp. 11600 Sherman Way N. Hollywood, Calif.	BUORD
Bendix Products Division Bendix Aviation Corporation 401 Bendix Drive South Bend 20, Indiana Attn: Mr. Frank C. Mock		AAF BUORD
Commanding General Army Air Forces Pentagon Washington 25, D.C. Attn: AC/AS-4 DRE-2E		AAF
Commanding General Air Materiel Command Wright Field Dayton, Ohio Attn: TSEPP-4B(2) TSEPP-4A(1) TSEPP-5A(1) TSEPP-5C(1) TSORE-(1)		
Commanding Officer Picatinny Arsenal Dover, New Jersey Attn: Technical Division		ORD DEPT

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D. COMPONENT CONTRACTORS (Cont'd)

(3) PROPULSION

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Commanding Officer Watertown Arsenal Watertown 72, Massachusetts. Attn: Laboratory.		ORD DEPT
Continental Aviation and Engr. Corp. Detroit, Michigan	Bureau of Aeronautics Rep. 11111 French Road Detroit 5, Michigan	BUAER & AAF
Curtiss-Wright Corporation Propeller Division Caldwell, New Jersey Attn: Mr. C. W. Chillson		AAF
Experiment, Incorporated Richmond, Virginia Attn: Dr. J. W. Mullen, II	Development Contract Officer P.O. Box 1-T Richmond 2, Virginia	BUORD
Fairchild Airplane & Engine Co. Ranger Aircraft Engines-Div. Farmingdale, L.I., New York	Bureau of Aeronautics Rep. Bethpage, L.I., N.Y.	BUAER
General Motors Corporation Allison Division Indianapolis, Indiana Attn: Mr. Ronald Hazen	Bureau of Aeronautics Rep. General Motors Corporation Allison Division Indianapolis, Indiana	BUAER
G. M. Giannini & Co., Inc. 285 W. Colorado St. Pasadena, California		AAF
Hercules Powder Co. Port Ewen, N.Y.	Inspector of Naval Material 90 Church Street New York 7, New York	BUORD
Marquardt Aircraft Company Venice, California Attn: Dr. R. E. Marquardt	Bureau of Aeronautics Rep. 15 South Raymond Street Pasadena, California	AAF BUAER
Menasco Manufacturing Co. 805 E. San Fernando Blvd. Burbank, California Attn: Robert R. Miller Exec. Vice-Pres.		AAF
New York University Applied Mathematics Center New York, New York Attn: Dr. Richard Courant	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Office of Chief of Ordnance Ordnance Research & Development Div. Rocket Branch Pentagon, Washington 25, D.C.		ORD DEPT
Polytechnic Institute of Brooklyn Brooklyn, New York Attn: Mr. R.P. Harrington	Inspector of Naval Material 90 Church Street New York 7, New York	BUAER
Purdue University Lafayette, Indiana Attn: Mr. G. S. Meikel	Inspector of Naval Material 141 W. Jackson Blvd. Chicago 4, Illinois	
Reaction Motors, Inc. Lake Denmark Dover, New Jersey	Bureau of Aeronautics Resident Representative Reaction Motors, Inc. Naval Ammunition Depot Lake Denmark, Dover, N.J.	BUAER

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D. COMPONENT CONTRACTORS (Cont'd)

(3) PROPULSION

CONTRACTOR	TRANSMITTED VIA	COGNIZANT AGENCY
Rensselaer Polytechnic Institute Troy, New York Attn: Instructor of Naval Science		BUORD
Solar Aircraft Company San Diego 12, California Attn: Dr. M.A. Williamson		ORD DEPT
Standard Oil Company Esso Laboratories Elizabeth, New Jersey	Development Contract Officer Standard Oil Company Esso Laboratories, Box 243 Elizabeth, New Jersey	BUORD
University of Virginia Physics Department Charlottesville, Virginia Attn: Dr. J. W. Beams	Development Contract Officer University of Virginia Charlottesville, Virginia	BUORD
University of Wisconsin Madison, Wisconsin Attn: Dr. J.O. Hirschfelder	Inspector of Naval Material, 141 W. Jackson Blvd. Chicago 4, Illinois	BUORD
Westinghouse Electric Co. Essington, Pennsylvania	Bureau of Aeronautics Resident Representative Westinghouse Electric Corp. Essington, Pennsylvania	BUAER
Wright Aeronautical Corp. Woodridge, New Jersey	Bureau of Aeronautics Rep. Wright Aeronautical Corp. Woodridge, New Jersey	BUAER
Bethlehem Steel Corp. Shipbuilding Division Quincy 69, Mass. Attn: Mr. B. Fox	Supervisor of Shipbuilding, USN Quincy, Mass.	BUAER

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