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WS 117L ADVANCED RECONNAISSANCE SYSTEM

DEVELOPMENT PLAN

VOLUME II SUBSYSTEM PLANS

B. Propulsion

3-6806-15
00920385

DOWNGRADED AT 12 YEAR INTERVALS, NOT AUTOMATICALLY DECLASSIFIED. DOD DIR 5200.10

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MISSILE SYSTEMS DIVISION
PALO ALTO, CALIFORNIA

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WS 117L ADVANCED RECONNAISSANCE SYSTEM

DEVELOPMENT PLAN

VOLUME II SUBSYSTEM PLANS

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LOCKHEED AIRCRAFT CORPORATION

MISSILE SYSTEMS DIVISION

FOREWORD TO VOLUME II

The Advanced Reconnaissance System (Weapon System 117L) consists of a satellite vehicle which can perform visual, electronic, and infrared reconnaissance, together with the necessary system of ground stations, data processing centers, and training facilities.

In accordance with the instructions of CCN No. 1 to Contract AF 33(616)-3105, the Missile Systems Division, Lockheed Aircraft Corporation, has revised its Subsystem Development Plan (MSD 1536, Volume II) to be consonant with the WDD Development Plan, dated 2 April 1956, as modified and published in Volume I of this report.

It should be noted the outline of subsystems as given in MSD 1536 has been changed to agree with the WDD Plan. Subsystems H and J of MSD 1536 have been combined to give a new Subsystem H - Ground-Space Communications.

In accordance with oral instructions from WDD, the Flight Test Subsystem I of MSD 1536 has not been documented at this time. The information pertaining to flight testing is presented in the other subsystem volumes as appropriate. The titles of old Subsystems K and L (now I and J, respectively) have been changed.

OUTLINE

OF

WS 117L DEVELOPMENT PLAN

CONTENTS

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MSD 2011

RDB PROJECT CARD

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Subsystem B

PROPULSION

ERRATUM

In this subsystem the word "swivelled" should be "hinged" throughout.

MSD-2011

RDB PROJECT CARD

TYPE OF REPORT

REPORTS CONTROL SYMBOL DD-RDB(A)48

1. PROJECT TITLE
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED)
WEAPON SYSTEM 117 L

2. SECURITY ~~S~~

3. PROJECT NUMBER WS 117 L

4. INDEX NUMBER

5. REPORT DATE 1 November 1956

6. BASIC FIELD OR SUBJECT Strategic Air Warfare

7. SUBFIELD OR SUBJECT SUBGROUP

7A. TECH. OBJ.

8. COGNIZANT AGENCY Air Research and Development Command

9. DIRECTING AGENCY Hq ARDC Western Development Command

OFFICE SYMBOL

TELEPHONE NO.

10. REQUESTING AGENCY Hq USAF

11. PARTICIPATION, COORDINATION, INTEREST

12. CONTRACTOR AND/OR LABORATORY Lockheed Aircraft Corp., Missile Systems Division

CONTRACT/W.O. NO.

13. RELATED PROJECTS

14. DATE APPROVED

15. PRIORITY

16.

17. EST. COMPL. DATES

RES.	
DEV.	
TEST	
OP. EVAL.	

18. FY	FISCAL ESTS. (M $)

19.

20. REQUIREMENT AND/OR JUSTIFICATION

a. Equipment is required for propulsion and control forces of the satellite stage vehicle of the Advanced Reconnaissance System.

b. Propulsion units will provide the velocity increment required after booster separation and the control forces required to orient the vehicle into orbit during this acceleration.

22. RDB	SN	CN	IC & P	X.	I.	C.

R&D PROJECT CARD
CONTINUATION SHEET

1. PROJECT TITLE	SECURITY CLASSIFICATION		MSD-2011
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L		2. SECURITY OF PROJECT ~~S~~	3. PROJECT NUMBER WS 117 L
		4.	5. REPORT DATE 1 November 1956

21 a. Brief and Operational Characteristics

This subsystem will provide the satellite with the following: (1) lateral and roll control forces to maintain the required attitude and to avoid excessive roll during the coasting period; (2) thrust to obtain the desired orbit; (3) lateral and roll control to effect the transition maneuver into orbit and proper orientation of the vehicle with respect to its line of flight. The subsystem consists of the following subassemblies:

1. Coast control engines
2. Orbital booster engine
3. Orbital boost control engines
4. Propellant feed system, including a system for ensuring reliable starts and operation in vacuum under zero-gravity conditions
5. Propellant flow and utilization control
6. Electrical system
7. Hydraulic system
8. Additional equipment for loading and servicing the propulsion system.

21 b. Approach

The design of this subsystem will provide sufficient margin to ensure attainment of the required orbit even with significant variations in booster performance and with substantial growth in vehicle weight and payload requirements. Wherever possible, state-of-the-art components and subsystems will be used and improved systems will be obtained by an evolution of the systems used for the earlier phases rather than by the development of new types. Alternative components and subsystems are considered whenever the attainment of the objectives of the ARS Development Program does not appear fully assured within schedules for the proposed components and subsystems.

Major target of the Development Program will be availability, compatibility with schedules, reliability, minimum complexity and weight, and high performance (specific impulse).

21 c. Subsystem Tasks

1 a. OTV Control Force Generators for Coasting Period

b. Contractor: Not yet determined

c. Use of gas jets obtained from either stored high-pressure

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

21 c. Subsystem Tasks (cont'd)

gas or from a chemical reaction to provide the required lateral and roll control forces is being considered. The subsystem will be determined after final specifications which, in turn, depend upon the selection of the operational mode and of guidance and control subsystems for this flight segment.

2 a. <u>Advanced Control Force Generators for Coasting Period</u>

b. Contractor: Not yet determined.

c. A refined version of the system developed in Task 1 will be used for the Advanced and Surveillance systems. A substantial saving in weight will result from the appropriate combination with the orbital booster control system (Tasks 6 and 7) and from the use of high-energy gas generators.

3 a. <u>OTV Orbital Thrust Engine</u>

b. Contractor: Bell Aircraft Corporation.

c. The present Bell XLR-81-Hustler pump-fed engine will be used. Using inhibited red fuming nitric acid-JP4 propellant, this engine delivers a thrust of 15,150 pounds in vacuum with an over-all specific impulse of 263 seconds. The engine assembly, which will have a fixed thrust mount, includes the thrust chamber, the gas generator-turbo pump subassembly, and the propellant flow control and regulating, start, and shutdown subassemblies. It will weigh approximately 225 pounds. Certain additional testing and minor alterations over and above that performed for the Convair Hustler Program are contemplated to increase the operational time from 65 seconds to approximately 100 seconds.

4 a. <u>Pioneer and Early Advanced Orbital Thrust Engine</u>

b. Contractor: Bell Aircraft Corporation.

c. A modified Bell XLR-81-Hustler engine will be used for the Pioneer and Early Advanced Systems. The modifications will consist of replacing the JP4 fuel by unsymmetrical dimethyl hydrazine, increasing the nozzle expansion ratio from 14.8:1 to 20:1, and improving the fuel control system. These

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	~~S~~	WS 117 L
	4.	5. REPORT DATE 1 November 1956

changes can be accomplished within the development schedules for the ARS. They will increase the vacuum specific impulse to 277 seconds, and will probably reduce the tolerance in propellant mixture ratio to such an extent that sufficient vehicle performance will be obtained without incorporation of an additional system for propellant utilization.

5 a. <u>Late Advanced Orbital Thrust Engine</u>

b. Contractor: Rocketdyne Division, North American Aviation, Inc., or
Bell Aircraft Corporation, (fluorine-ammonia)
Aerojet General Corporation, (LOX-JP-4).

c. For the Advanced vehicles it is proposed to conduct a study to determine the usefulness of and potential necessity for an engine with considerably improved performance. For potential high-energy propellants, this study will also evaluate the boil-off loss prior to orbital boost against the gain in specific impulse. Potential engines will be limited to types which are in such state of development that reliable operation and availability can be predicted within schedules compatible with the ARS Development Plan. Providing the above study indicates that such development is required, it is intended to initiate a program for an ammonia-fluorine type engine. Because of the four-year development time required for an engine of this type, an early start on any required development is mandatory.

It is proposed to base this program on a thrust value of 20,000 to 30,000 pounds with the goal of attaining a specific impulse of 342 seconds in the final state of development with a pump-fed engine. The engine system may include a separate propellant with its feeding system for the operation of the turbopump gas generator. An alternate program may be initiated to produce an engine of at least 20,000 pounds thrust with liquid oxygen-JP4 propellant at an over-all specific impulse of at least 304 seconds, if the pursuance of such a reduced program appears justified from the results of the aforementioned study.

6 a. <u>OTV Orbital Boost Control and Vernier Engines</u>

b. Contractor: Bell Aircraft Corporation, or
Reaction Motors, Inc.

R&D PROJECT CARD
CONTINUATION SHEET

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	~~S~~	WS 117 L
	4.	5. REPORT DATE: 1 November 1956

MSD-2011

c. Four hinged, uncooled control and vernier engines having 300 pounds thrust each will be provided. They will consist of an integral decomposition-thrust chamber, swivel-type thrust mounts, and propellant control valves and actuators. A monopropellant, 90 per cent hydrogen peroxide, will be used and will be fed to the engines by a gas pressurization system. This will provide a specific impulse of at least 160 seconds in vacuum. Provisions will be made to ensure operation prior to and after the main engine operation. This system will be completely separate from the orbital thrust engine system and therefore will not affect the development and delivery schedules of the latter.

7 a. <u>Pioneer and Early Advanced Orbital Boost Control and Vernier Engines</u>

b. Contractor: Bell Aircraft Corporation, or
Reaction Motors, Inc., or
Aerojet General Corporation.

c. The lateral and roll control system will be improved for the Pioneer and Early Advanced vehicles by using a higher energy propellant. With the propellant combination IRFNA-UDMH, about the same specific impulse may be obtained as in the main engine. A gas-fed propellant system with separate tanks is contemplated in order to avoid any interference between the controls of the two engine systems. The control engines will be either of the uncooled type and protected by heavy ceramic liners, or cooled, probably by an excessive flow of propellant bypassed from the main engine propellant system.

8 a. <u>Late Advanced Orbital Boost Control and Vernier Engines</u>

b. Contractor: North American Aviation, Inc., or
Aerojet General Corporation, or
Bell Aircraft Corporation.

c. A study will be conducted to determine the gain in weight and in simplicity which results from the use of the turbine exhaust (with afterburning, if feasible) for the generation of the required control forces. If justified, a development of such a system compatible with the orbital boost engine selected for this phase will be initiated. In case the turbine exhaust can not provide sufficient control

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	~~S~~	WS 117 L
	4.	5. REPORT DATE 1 November 1956

forces, gimballed or hinged control engines will be used, and an attempt will be made to improve this system by integrating its propellant supply with that of the main engine.

9 a. Propellant Feed System

b. Contractor: Lockheed Aircraft Corporation, Missile Systems Division.

c. The feed system for the propellants of the pump-fed oribital boost engines will consist of: (1) a pressure system to maintain the appropriate pump inlet pressure and to provide sufficient propellant to the turbopump gas generator for starting purposes and (2) the required propellant lines connecting the tanks with the engines. This system will be designed and altered according to the specific requirements of the engine system used during the different phases of the ARS Development Program. For the Late Advanced vehicles it might include a complete gas pressure or pump feeding subsystem for separate propellants used in the turbopump gas generator as well as in the turbine exhaust afterburner.

For the control engines, the pressure gas feeding system consists of separate propellant tanks, pressure regulators, valves and plumbing. Pressure gas will be unheated helium stored within a separate tank or together with the helium required for the pressurization of the main propellant tanks.

Both systems will include means of ensuring proper propellant level location as well as positive displacement propellant expulsion under the gravity-free or near gravity-free conditions prevailing prior to main engine operation. This may involve the incorporation of bladders in the propellant tanks through which the pressurization gas is fed. These bladders will rupture after sufficient gravity field has been established by the starting of the main engine.

R&D PROJECT CARD
CONTINUATION SHEET

MSD-2011

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

10 a. Pioneer Propellant Flow and Utilization Control

b. Contractor: Bell Aircraft Corporation

c. An analysis will be conducted to determine whether an improved governor-type propellant flow control system, incorporated in the modified XLR-81-Hustler engine (Task 4), will reduce sufficiently the changes in propellant mixture ratio so that a residual propellant weight of less than two per cent of the initial propellant weight is obtained. If this goal can not be reached with the present control system, a crude propellant utilization system consisting of capacitance-type propellant level sensing elements actuating one propellant valve via a servomotor, will be developed.

11 a. Advanced Propellant Flow and Utilization Control

b. Contractor: North American Aviation, Inc.

c. A refined propellant utilization system will be used for the Advanced System. With this system, the amount of residual propellant in the tanks will be kept below 0.5 per cent of the total propellant weight.

12 a. Electrical System

b. Contractor: Lockheed Aircraft Corporation,
Missile Systems Division.

c. The electric subsystem consists of the master control and distribution panel, pressurization system relays, engine relays, hydraulic power supply, and associated wiring and fittings. The required electrical power will be furnished by the battery of the Auxiliary Power Subsystem of the satellite vehicle. This system will be designed and altered according to the specific requirements of other propulsion subsystem components used during the different phases of the ARS Development Program.

13 a. Hydraulic System

b. Contractor: Lockheed Aircraft Corporation,
Missile Systems Division.

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	S	WS 117 L
	4.	5. REPORT DATE 1 November 1956

MSD-2011

c. The hydraulic system consists of a positive displacement pump, reservoir accumulator, pressure regulator, valves, servovalves, and associated hardware. This system will be designed and altered according to the specific requirements of the other components of the propulsion subsystem used during the different phases of the ARS Development Program.

14 a. OTV Propellant Loading and Servicing Equipment

b. Contractor: Not yet determined.

c. A conventional closed-circuit tank filling system, using commercially available components, will be used. Vent lines will be arranged in such a way that no-ullage filling of tanks can be obtained. Ullage space will be provided after filling by expelling an appropriate amount of propellant, e. g., by blowing up a properly located bladder inside of the tank with pressurizing gas.

15 a. Pioneer and Advanced Systems Propellant Loading and Servicing Equipment

b. Contractor: Not yet determined

c. For the latter phase of the ARS Development Program the loading and servicing system will be improved by incorporating refined components which permit accelerated loading operations and provide the means for adjusting the amount of loaded propellants to compensate for changes in temperature and propellant density. This system, together with the propellant utilization control system Tasks 10 and 11, will reduce considerably the amount of unutilized propellant.

21 d. Other Information

1. The performance characteristics of the subsystem are predicted on a specified performance of the ICBM booster. Allowance has been made for some degradation in booster performance and also for booster guidance and control limitations which result in less than optimum trajectory.

2. No existing equipment is available which possesses the performance characteristics required of the entire subsystem. Standardized or off-shelf items are used (valves, plumbing, etc.)

R&D PROJECT CARD
CONTINUATION SHEET

MSD-2011

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) WEAPON SYSTEM 117 L	~~S~~	WS 117 L
	4.	5. REPORT DATE 1 November 1956

21 d. Other Information (cont'd)

wherever their characteristics are demonstrated to be of required performance and reliability.

3. The selected Bell XLR-81-Hustler engine is the only engine within the range of required total impulse and thrust which is available with a turbopump feed system and which can be altered, modified, and procured on a non-interference basis with the WS-107 program. It has the additional unique advantage that the control system is probably accurate enough to provide adequate propellant utilization without incorporation of an additional system.

4. This subsystem has been designed to operate in the absence of gravity and atmosphere. Its characteristics are generally not applicable to other weapon systems or manned aircraft.

5. This subsystem would be maintained by the contractor, and operators would be contractor-trained.

21 e. <u>Background Data</u>

Not applicable.

21 f. <u>Future Plans</u>

The development of this subsystem is contingent on the initiation of the program at a date compatible with the ARS Development Plan. The development of the Advanced propulsion systems is contingent upon the initiation of the development program presented in the General Design Specification.

21 g. <u>References</u>

Not applicable.

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MSD 2011

TABS

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION

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Subsystem B - PROPULSION

Tab 1 - General Design Specification

I. GENERAL

A. Statement of Problem

The orbital stage propulsion system must provide the acceleration required to place the payload on orbit after separation from the booster and to control the orbital vehicle during the coast and acceleration period. The orbital boost rocket engine must deliver an additional impulse of at least 1,500,000 pound-seconds, and the characteristics of current guidance system components indicate that the orbital boost period should not exceed approximately 100 seconds. Control engines are required for thrust directional control during orbital boost and for elimination of attitude and roll disturbances resulting from the shut-off of the booster engine as well as from the operation of the orbital thrust engine. These control engines may also be used as vernier engines for final impulse correction.

B. Approach

The proposed propulsion subsystems will provide sufficient range of performance to ensure placing a reduced payload on orbit with the OTV vehicles and the operational payload on orbit with the later vehicles. The orbital condition will be achieved even with significant variation in the Atlas booster performance. Wherever possible, state-of-the art components and subsystems will be used and improved subsystems will be obtained by an evolution of the systems used for the earlier phases rather than by the development of new types. Alternative components and subsystems are considered whenever the attainment of the objectives of the ARS Development Program does not appear fully assured within the schedules.

The major objectives of the Development Program will be availability, compatibility with schedules, reliability, minimum complexity and weight, and high-performance (specific impulse).

The propulsion system progresses through three different phases of refinement in order to fulfill the requirements of the OTV phase, the Pioneer through Early Advanced phase, and the Late Advanced phase of the ARS Development Program, respectively. The operational requirements for these three phases are listed below in Table I. In addition, both the sustainer and control engines must be capable of starting in a vacuum with a zero-gravity field. The orbital boost control forces must be available over a sufficient period prior to and after the orbital thrust engine operation to align correctly the longitudinal axis of the orbital vehicle with respect to the desired trajectory and to correct missile attitude during the thrust decay and turbopump shutdown period. The control engines will also be able, if required, to fulfill the function of vernier engines for accurate impulse cutoff. In addition, the propulsion system will be capable of withstanding the environment existing during the boost period (accelerations up to 15 g's, vibrations, and aerothermodynamic heating of propellants and components) and during the coast period between booster

TABLE I OPERATIONAL REQUIREMENTS

Orbital Boost Engine

Phase	OTV	Pioneer Through Early Advanced	Late Advanced
Thrust, lb	15,000	15,000	above 20,000
Total Impulse, lb-sec	1.5×10^6	1.5×10^6	above 2×10^6
Duration, sec	100	100	
Specific Impulse, sec	above 260	275 - 285	300 (preferably substantially higher

Orbital Boost Control

Engine			
Number of Engines	4	4	2 or 4
Arrangement	swivelled	swivelled	gimballed or swivelled
Thrust (per engine), lb	300	300	
Total Impulse, lb-sec	120,000	120,000	
Duration, sec	100 + 4	100 + 4	
Specific Impulse, sec	above 150	above 250	
Maximum Deflection, degree	± 45	± 45	
Average Deflection Rate, cps	~1	~1	

stage burnout and the start of orbital stage propulsion (gravity-free condition). Operation will be ensured within a temperature range of 32 degrees F to 120 degrees F for the propellants and a temperature environment of 32 degrees F to 500 degrees F within the engine compartment.

Combining the various subsystems and subassemblies of the propulsion system with the development phases, the following Tasks are obtained:

1. OTV and Pioneer control force generators for coasting period.
2. Advanced control force generators for coasting period.
3. OTV orbital thrust engine.
4. Pioneer and Early Advanced thrust engine.
5. Late Advanced orbital thrust engine.
6. OTV orbital boost control and vernier engines.
7. Pioneer and Early Advanced orbital boost control and vernier engines.
8. Late Advanced orbital boost control and vernier engines.
9. Propellant feed system.
10. Pioneer propellant flow and utilization control.
11. Advanced propellant flow and utilization control.
12. Electrical system.
13. Hydraulic system.
14. OTV propellant loading and servicing equipment.
15. Pioneer and Advanced propellant loading and servicing equipment.

In the OTV vehicle program, emphasis has been placed on a propulsion system with the greatest promise of operational status within the established time period. State-of-the-art components will be used if they have adequate performance to place a reduced payload on orbit.

For the Pioneer and Early Advanced Vehicle Systems, propulsion systems and components which require a moderate development to meet the schedules are contemplated. The propulsion systems proposed for the Late Advanced vehicles may require a major development effort to obtain the considerably improved performance which will permit a substantial growth in vehicle gross weight and useful payload. Potential engines will, however, still be limited to types which are in such state of development that reliable operation and availability within ARS schedules can be predicted. For this phase, an alternative propulsion system may be considered.

C. Solution

Since availability is the paramount consideration for the OTV vehicles, the XLR-81 engine has been chosen for this application. This is the only available turbopump feed system within the range of required thrust and total impulse which can be altered and procured on a non-interference basis with the WS 107 program. Also, its control system appears capable of reducing the amount of residual propellants to a small value without incorporation of an additional propellant utilization system. It is being developed by the Bell Aircraft Corporation for the Convair Hustler program and is now undergoing flight rating tests. The only required alteration is to provide a gear lubrication system in order to increase the duration from 65 seconds to approximately 100 seconds and to reinforce some structural components in order to withstand the increased acceleration loads.

For the Pioneer and Early Advanced vehicle programs, a modification of the Hustler engine is being considered. In this way, its performance will be increased to such an extent that the requirements of the ARS program during these phases can be met.

For the Late Advanced phases of the ARS development program, it is planned to conduct a study to determine the necessity for and usefulness of improved performance such as that obtainable from a fluorine-type oxidizer engine. If an affirmative result is obtained from this study, a propulsion system based on a fluorine-type oxidizer will be developed with the goal of a specific impulse higher than 340 seconds. It is predicted that such propulsion system can be made available within a four-year development program. As an alternative solution, the development of a suitable propulsion system using the conventional propellant combination of LOX-JP4 fuel is proposed; this can be achieved within a shorter period.

The major characteristics and the performance obtainable with the selected and proposed systems, including control engines, are presented in Table II.

TABLE II

OPERATIONAL CHARACTERISTICS AND PERFORMANCE OF PROPULSION SUBSYSTEM

A. Orbital Thrust System

Phase	OTV	Pioneer-Early Advanced	Late Advanced	
			Primary	Alternate
Engine	XLR-81, altered (1)	XLR-81, modified (2)		
Potential Contractor	Bell Aircraft Corp.	Bell Aircraft Corp.	Rocketdyne or Bell Aircraft Corp.	Aerojet General Corp.
Propellant	IRFNA-JP4	IRFNA-UDMH	Fe-NH_3, or F_2+O_2-hydro-carbon	LOX-JP fuel
Propellant Feed System	Turbopump	Turbopump	Turbopump (5)	Turbopump
Vacuum Thrust, lb	15,150	15,400	20,000-30,000	20,000-30,000
Vacuum Engine Specific Impulse, sec	263	277	326 (3)-342 (4)	300 - 305
Operation Duration, sec	100	100	Approx. 100	Approx. 100
Nozzle Exp. Ratio	14.85:1	20:1	25:1	25:1
Combustion Chamber Pressure, psia	500	500	500	
Propellant Mixture Ratio				
Combustion Chamber	4.55:1	2.8:1	2.7:1 (6)-3.0:1 (7)	2.33:1
Gas Generator	0.76:1	0.14:1		
Engine	4.25:1	2.57:1	2.7:1 (6)-3.0:1 (7)	
Coolant	Oxidizer	Oxidizer	Fuel	Fuel
Engine Weight, lb	225	Approx. 235		

(1) Altered from 65 to 100 seconds duration.
(2) Modified to UDMH fuel, 20:1 nozzle exp. ratio, 100-second duration, governor type mixture ratio control.
(3) Initial development engines.
(4) Prototype and Production engines.
(5) Probably separate propellant (H_2O_2) for gas generator.
(6) Fluorine+ammonia, Advanced design.
(7) F_2-O_2 + hydrocarbon, present design.

TABLE II
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OPERATIONAL CHARACTERISTICS AND PERFORMANCE OF PROPULSION SYSTEM

B. Orbital Boost Lateral Force and Roll Control System

Phase	System	No. Units	Type of Mount	Thrust Per Unit, lb.	Propellant	Vacuum Spec. Impulse, sec	Press. System
OTV	Rocket motors, self[1] sustained	4	Swivel	300	90% H_2O_2 Monopropellant	At Least 160	Gas Fed
Pioneer & Early Advanced	Rocket motors, self[2] sustained	4	Swivel	300	Bipropellant, probably IRFNA-UDMH	250[3]-280[4]	Gas Fed
Late Advanced	Rocket motors, or turbine exhaust with afterburning	4 or 2	Swivel or Gimballed		Bipropellant, same as, or different from main propellant		Gas Fed or Pump Fed

(1) Pressurized gas may be derived from main system.

(2) Coolant may be bypassed main propellant.

(3) Uncooled ceramic chamber or regeneratively cooled chamber.

(4) Chamber cooled by flow of main propellant.

II. DESCRIPTION

A. Tasks

1. OTV and Pioneer Control Force Generators for Coasting Period

Use of gas jets obtained from either stored high-pressure gas or from a chemical reaction is being considered to provide the required lateral and roll control forces. The details will be determined from the final specifications which, in turn, depend upon the selection of the operational mode and guidance and control subsystems for this flight segment.

2. Advanced Control Force Generators for Coasting Period

A refined version of the system developed in Task 1 will be used for the Advanced and Surveillance systems. A substantial saving in weight will result from the appropriate combination with the orbital booster control system (Tasks 6 and 7) and from the use of higher energy gas generants.

3. OTV Orbital Thrust Engine

The XLR-81 engine now being developed by Bell Aircraft Corporation for the Hustler project will be used. It consists of a single thrust chamber, gas generator including starting solid propellant charge, turbine-driven pumps, propellant control valves, and auxiliary equipment to start, operate, and shut down. These components are assembled within the engine thrust mount which is a welded, tubular structure constructed of 8630 steel. This mount lends itself well to the addition of other structures or brackets for other equipment or components, and it can easily accommodate the swivel mounts for the four control engines.

The propellants are inhibited red fuming nitric acid (IRFNA) and JP-4. The aluminum thrust chamber is of drilled-wall construction, completely machined, and regeneratively oxidizer-cooled. It is rated at 15,150 pounds thrust in vacuum for a duration of 65 seconds at 500 psia chamber pressure. With a nozzle expansion ratio of 14.85:1 and an engine propellant mixture ratio of 4.25, a specific impulse of 263 seconds will be obtained in vacuum. The combustion in the engine is started by a preflow of unsymmetrical-dimethyl-hydrazine in the propellant line; this will probably obviate the necessity for using a nozzle closure diaphragm for starts. At shutdown the impulse-decay tolerance will not exceed ± 300 pound-seconds. The mixture ratio in the turbine gas generator is 0.76:1. The engine will be furnished orificed to a mixture ratio which is + 2.5 percent of the nominal value; the actual value will be determined for each engine within ± 1 percent.

The control system of the engine maintains the mixture ratio during operation close to the design value. Use of pumps of special design (combination of spoke-type impellers with a diffuser-type exit orifice) results in a characteristic similar to that of a positive displacement pump in which the flow rate is independent of the pressure head. This alleviates the control problem considerably and makes this design especially suited for use without a separate propellant utilization system. The engine propellant control valves are hydraulically operated by propellant pressure. The weights of various components of the rocket engine assembly are as follows:

Thrust Chamber Assembly (includes Combustion Chamber, Main Propellant Valves, Tubing & Fittings)	100 lb
Turbine Pump Assembly, Starter and Igniter, Gas Generator, Engine Mount, Propellant Valves	100 lb
Engine Accessories (includes Exhaust Duct, Control System Tubing and Fittings)	25 lb
Total	225 lb

For the ARS application, the XLR-81 engine must be altered so that it can operate for 100 seconds. Tests have shown that, with the existing gear train, permanent damage occurs between 85 and 120 seconds. With the addition of oil splash or a gear-dip type of lubrication, however, tests have been run from 3 to 8 minutes with no damage. Thus, it is proposed that this lubrication system be provided as an alteration kit to the existing unit. The oiler will consist of a small cylinder and piston assembly filled with oil. Fuel pressure from the pump discharge will be applied to the piston which forces oil to the gears. The development of this unit constitutes no problem and will not delay delivery of a complete engine.

With regard to the thrust chamber assembly, no difficulty is anticipated in extending its life to 100 seconds. Various tests have demonstrated the durability of the existing chamber and accumulated durations of over one hour have been reached on a single thrust chamber.

Therefore, it is believed that a complete XLR-81 engine assembly can be delivered within ten months from date of order.

4. Pioneer and Early Advanced Orbital Thrust Engine

For the Pioneer and Early Advanced vehicles, a modified Bell XLR-81 engine will be used. The modifications consist of increasing the nozzle area ratio from 14.85:1 to 20:1, the substitution of unsymmetrical-dimethyl-hydrazine (UDMH) for JP-4 fuel, and the incorporation of a speed governor to the control system. These changes will increase the vacuum thrust from 15, 150 pounds to 15,400 pounds, increase the specific impulse from 263 to 277 seconds, and improve mixture ratio control. The latter improvement will probably reduce the amount of residual propellants in the tanks to such a low value that no additional system for propellant utilization control will be required in the Pioneer and Early Advanced Vehicles.

A number of changes are required in the engine before it can operate satisfactorily with UDMH fuel for a duration of 100 seconds. The injector must accommodate the new mixture ratio of 2.57. However, this is considered a minor modification since injectors have been fabricated and fired successfully using this propellant combination in the XLR-81 thrust chamber. Preliminary tests indicate that sufficient cooling is available for the combustion chamber regardless of the reduced mixture ratio, but this will be verified by extensive testing under the new condition. A new gas generator with a mixture ratio of 0.14 is necessary; however, based on the performance of preliminary tests, changes for a production unit will be minor. The pump outlet ports must also be rebored to accommodate the mixture ratio change; this may require a new fuel pump casting. Other changes are necessary to the turbine pump assembly to ensure adequate strength of the fuel pump gear to handle the increased load. The addition of the speed governor to the control system requires only a minor change in the gear box assembly and will not affect the over-all development time. Based on information available at this time it appears that the pump impellers, oxidizer pump casing and other components are satisfactory without change. It is estimated that these changes will require a development time of 18 months; this includes the Preliminary Flight Rating Tests.

5. <u>Late Advanced Orbital Boost Engine</u>

For the Advanced vehicles it is proposed to conduct a study to determine the usefulness of and potential necessity for the use of an engine with considerably improved performance. This study will also evaluate the boil-off loss versus the gain in specific impulse for promising high-energy propellants. Potential engines will be limited to types which are in such state of development that reliable operation and availability can be predicted within schedules compatible with the ARS Development Plan. Providing the above study indicates sufficient improvement, it is proposed to initiate and conduct the development of such an improved propulsion system. Because of the four-year development time required for an engine of this type, an early start on any required development is mandatory.

Both primary and alternative programs are proposed. The primary program is based on a fluorine-ammonia type of propellant system. It will be conducted by the Rocketdyne Division of North American Aviation or by Bell Aircraft Corporation. The feasibility and basic design criteria for such engines have been established by over three years of experimental investigation of fluorine-oxidized rocket propellant systems. A thrust level of 20,000 to 30,000 pounds has been tentatively selected with the goal of attaining an engine specific impulse of 342 seconds in the final development stage.

The following description is based on a proposal made by the Rocketdyne Division of North American Aviation; Inc., and is believed to be typical for such a development. The engine is envisaged as being basically similar to existing large Rocketdyne engines. It will consist of a fixed-mount, single-unit engine with integral missile-attitude and roll control provided by the turbine exhaust. The propellants are fed to the thrust chamber by a direct-drive turbo-pump. The turbine is powered by the decomposition products of hydrogen peroxide delivered to the gas generator by a separate pump driven by the missile auxiliary power unit.

The selection of the system was based on the requirement of simplicity in design and operation, reliability, and minimum development through maximum use of available experience and design information. The choice of a thrust level of 20,000 pounds was made somewhat arbitrarily for the present discussion; the design considerations are applicable to a wide range of thrust levels and operating conditions. In general, however, the development of larger units would involve fewer difficulties than the development of smaller units. This results primarily from heat transfer considerations. For high-energy propellants, heat transfer rates are high and chamber cooling is particularly difficult because both the combustion temperature and the propellant mixture ratio are high. Estimates made by Rocketdyne indicate that the initial development engines will attain a specific impulse of 326 seconds and that the specific impulse of 342 seconds will be attained with a nozzle expansion ratio of 25:1 at the end of the four-year development.

The alternative program is based on the liquid oxygen-JP-4 fuel propellant combination with Aerojet-General Corporation as a potential subcontractor. Based on information obtained from the Aerojet-General Corporation, an engine of the following type is envisaged. It will consist of a single rocket thrust chamber assembly (including mount), a gas generator driven turbo-pump assembly, propellant control valves, and the necessary plumbing and auxiliary controls to start, operate, and shut down. The rocket engine will use a regeneratively fuel cooled thrust chamber rated at 20,000 pounds thrust in a vacuum. The thrust chamber will be capable of operating for a minimum of 120 seconds. The propellants will be LOX and JP-4 injected at a nominal mixture ratio of 2.33:1 by weight of oxidizer to fuel. The specific impulse for complete engine performance will be between 300 and 305 seconds in a vacuum. The ability of the engine to start, operate, and shut down will be unlimited relative to altitude. A propellant control system will be supplied and the tolerance in the total impulse under the thrust decay curve will be limited not to exceed 200 pound-seconds. The engine will start in any attitude so long as the propellant lines leading to the propellant control valve are maintained full of propellant under a positive pressure head. The rocket engine will attain 90 percent of rated thrust within 0.8 second after signaling the thrust chamber valve to open. The transient starting pressure will not be greater than 125 percent of maximum rated chamber pressure. Thrust chamber pressure oscillations will not exceed ± 5 percent of normal operating chamber pressure during the period of effective steady-state operation. This program will require approximately three years for completion.

6. OTV Orbital Boost Control and Vernier Engines

For the earlier phases of the development, the proposed lateral force, roll control, and vernier engines were selected on the basis of minimum operational interference with the orbital boost propulsion system. Since no available system meets the requirements of the ARS vehicles, every phase will require development. Consequently, for the OTV system phase, the simplest possible solution using only state-of-the-art components was selected. It consists of a self-sustained, gas-fed system using 90 percent hydrogen peroxide monopropellant. Four integral decomposition-thrust chambers are used; they are designed to deliver 300 pounds of thrust each at a chamber pressure of 100 to 150 psia and with a nozzle expansion ratio of between 10:1 and 20:1. A vacuum specific impulse of at least 160 seconds is obtained. The engines are assembled in individual swivel mounts permitting a deflection of at least ± 45 degrees. Other components are the propellant control valves and the hydraulic actuators. These engines are scheduled to be available 10 months after placement of the orders.

7. <u>Pioneer and Early Advanced Orbital Boost Control and Vernier Engines</u>

The development of an improved control system will be initiated simultaneously with Task 6. Major goal of the improvement will be the reduction in over-all system weight attained by the application of a higher energy bi-propellant system. Since cooling of these small size combustion chambers becomes a problem with higher energy propellant combinations, different approaches will be taken. A gas-fed propellant system with separate tanks will, however, be considered in each case.

Possible solutions, based on the use of the IRFNA-UDMH propellant combination, are:

1. Use of uncooled, ceramic inserted thrust chambers giving a specific impulse of approximately 250 seconds.

2. Use of regeneratively cooled chambers giving a specific impulse of approximately 250 seconds. This requires a complete new development since the presently developed types of combustion chambers are not adaptable to very small dimensions.

3. Use of cooled chambers with the coolant provided by a by-pass flow of main propellant. This will give a specific impulse of approximately 280 seconds.

It is proposed to determine experimentally the best solution compatible with complete development within the required schedules.

8. Late Advanced Orbital Boost Control and Vernier Engines

A study will be conducted to determine the improvement with respect to weight and simplicity which can be obtained by the use of turbine exhaust (with after-burning if feasible) for the generation of the required control forces. If justified, a development will be initiated of such a system compatible with the orbital boost engine selected for this phase.

9. Propellant Feed System

The feed system for the propellants of the pump-fed orbital boost engines will consist of: (1) a pressure system to maintain the appropriate pump inlet pressures and to provide sufficient propellant to the turbo-pump gas generator for starting; (2) means of ensuring proper propellant level orientation in the tanks under the zero-gravity condition prior to engine start; and (3) the required lines for connecting the tanks with the engine. This system will be designed and altered according to the specific requirements of the engine system used during the different phases of the ARS Development Program. For the Late Advanced phase it might include a complete gas pressure or pump feeding sybsystem for separate propellants used in the turbo-pump gas generator as well as in the turbine exhaust afterburner.

The propellant feed system used in the OTV, Pioneer, and Early Advanced vehicles in connection with the altered or modified Bell XLR-81 engines consists of a dual-stage pressure regulating assembly, relief valves and associated lines, hardware and fittings. The system is designed to maintain under flight conditions the required pump inlet pressures of 40 and 35 psia for the oxidizer and 27 and 35 psia for the modified engines, respectively. Proper orientation of the ullage space in the tanks and provision of propellants for starting under a zero-gravity condition is obtained by incorporating in each tank an expandable and contractable container, such as a bladder, a cylinder-piston combination, or a bellows. Proper function of this device is contingent upon adequate design of the tanks and propellant loading system in order to prevent air from being trapped during the filling operation.

The propellant feed system for the Late Advanced vehicles will be altered according to the specific requirements of the propellants used. An additional positive-displacement-type propellant feed system will be provided for engine starting under zero-gravity condition. Since liquid oxygen, fluorine, and ammonia are all liquified gases, boiloff must be considered. Tank insulation might be used or the tanks will be designed to withstand the pressure buildup during flight.

The pressure gas feeding system used for the control engine propellant system will consist of separate propellant tanks, pressure regulators, valves, and plumbing. Pressure gas will be unheated helium, stored within a separate tank or together with the helium required for the pressurization of the main propellant tanks. Initial operation of the control engines prior to main engine operation in a gravity-free field will be made possible by assuring positive displacement, e.g., by incorporating bladders in the propellant tanks through which the pressurization gas is fed. These bladders may rupture after the starting of the main engine has established a sufficient gravity field.

10. Pioneer System Propellant Flow and Utilization Control

An analysis will be conducted in order to determine whether an improved governor-type propellant flow control system, incorporated in the modified XLR-81-Hustler engine (Task No. 4), will suffice to reduce the changes in propellant mixture ratio so that the residual propellant weight is less than two per cent of the initial propellant weight. If this goal cannot be reached with the present control system, then a crude propellant utilization system will be developed; it will consist of capacitance-type propellant level sensing elements actuating one propellant valve by means of a servomotor.

11. Advanced Systems Propellant Flow and Utilization Control

This system corrects the fuel-to-oxidizer ratio and thus ensures simultaneous exhaustion of both propellant tanks with a high accuracy. The residual propellant is less than one half per cent of the total amount. Through sensing elements, it will continuously compare the tank levels during propellant expulsion and will generate signals proportional to the deviation from the proper ratio of levels corresponding to tank geometry and to the design ratio of fuel to oxidizer. This signal is amplified and used to actuate servomotors and valves in the propellant supply lines.

12. Electrical System

The electrical subsystem consists of the master control and distribution panel, pressurization system relays, engine relays, hydraulic system power supply, and associated wiring and fittings. The required electrical power will be furnished by the battery of the auxiliary power system of the orbital vehicle.

13. Hydraulic System

The hydraulic system consists of a positive displacement pump, reservoir, accumulator, pressure regulator, valves, servovalves and associated hardware. The pump will be driven either by an electric motor or by a separate auxiliary power unit. The electric power is obtained from the auxiliary power system, Subsystem C. If the capacity of this system is not sufficient, an additional battery will be provided.

This system will be designed and altered according to the specific requirements of the other components of the propulsion subsystem used during the different phases of the ARS Development Program.

14. OTV Propellant Loading and Servicing Equipment

A conventional closed-circuit tank filling system, employing commercially available components, will be used. Vent lines are arranged in such a way that no-ullage filling of tanks can be obtained. Ullage space will be provided after filling by expelling an appropriate amount of propellant. This will be accomplished by blowing up a bladder properly located inside of the tank with pressurizing gas.

15. Pioneer, and Advanced Propellant Loading and Servicing Equipment

For the latter phase of the ARS Development Program, the loading and servicing system will be improved by incorporating refined components which permit accelerated loading operations and provide means for adjusting the amount of loaded propellants to compensate for changes in temperature and propellant density. This system, in combination with the propellant utilization control system (Tasks Nos. 10 and 11) will permit a considerable reduction in the amount of unutilized propellant.

B. <u>Development Status Availability</u>

The Bell XLR-81 engine developed for the Convair Hustler program under Air Force Contract No. AF 33(0381-21250) is now undergoing preliminary flight rating tests. The engine proposed for the ARS Orbital Test Vehicles is the same engine except for a small alteration required to increase the operation time from 65 to 100 seconds. For this engine, Bell has proposed a delivery date of 10 months after contract date.

The engine proposed for the Pioneer and Early Advanced vehicles is a modified Hustler engine (changes in fuel, nozzle expansion ratio and control system). These modifications can be considered minor ones, and Bell has proposed a delivery date of 18 months after contract date.

For the Later Advanced vehicles, the proposed engines must be developed, but there is sufficient background for them to ensure completion within the required time.

Under the sponsorship of the Air Force contract AF 33(616)-2134, the Rocketdyne Division of North American Aviation, Inc., has been engaged continuously since July 1952 in an experimental evaluation of rocket-engine oxidizers containing fluorine. This program is being conducted to advance the state of the art and to demonstrate the engineering feasibility of such highly reactive materials for use in rocket-powered missiles.

Rocket experimentation has been conducted with excellent results at up to 5,000 pounds thrust with fluorine and ammonia and with fluorine-oxygen mixtures and jet fuels. Bipropellant gas generation with a fluorine oxidizer has been explored, and various physical properties of the oxidizers have been measured.

Under a supplemental agreement to the above contract, experimental studies of the problems involved in operating a high-speed, light-weight centrifugal pump for use with liquid fluorine or liquid-oxygen solution have been intensified. In addition, corrosion studies of construction materials have been conducted and physical data of fluorine-oxygen mixtures were determined.

Recently, North American Aviation, Inc., and Bell Aircraft Corporation have received Air Force contracts to investigate the possibilities of using fluorine propellant for the second and third stages of missiles, including experimental work on small vernier units, pumps, and alternative pressure systems.

This background is deemed adequate by Rocketdyne personnel to permit the prediction of performance of fluorine engines and to begin prototype design and development in the areas of injector design, performance, operational techniques and fluorine supply and storage. In all other areas, preliminary design and development can be initiated except in the particular fields of thrust cylinder, gas generator, pump and shaft seals, turbine and hot gas seals, and valves. In these latter instances, some research is still required.

For the alternate development of the LOX JP fuel engine sufficient background is available with different potential contractors to ensure completion of a development program within three years.

C. <u>Development and Test Program</u>

The primary development effort for the OTV, Pioneer, and Early Advanced engines will be system integration rather than component development since nearly all components are already developed or in advanced stage of development. Extensive testing will be conducted to determine the interactions of the various subsystems constituting the propulsion system as well as the entire vehicle system (see Tabs 2 and 3).

Development of engines for the Late Advanced Vehicles will require approximately four years to complete and represents the major development program for the propulsion system (See Tab 2). This program will be conducted either by the Rocketdyne Division of North American Aviation, Inc., or by Bell Aircraft Corporation. If by July 1957 investigation proves this program is not feasible, then a LOX-JP-4 program may be initiated which will result in an engine after three years of development.

The development of a propulsion feed system for the fluorine-ammonia propellant system will require approximately two and one-half years of research and development. This program will mainly consist of research in the fields of materials, especially for seals and gaskets. In addition, investigations will be made to establish the design requirements for propellant systems using fluorine oxidizer.

The control engines require development since no engines of suitable size and performance are available. However, the performance of this subsystem is not critical with respect to the overall performance of the ARS vehicles. Consequently, state-of-the-art designs can be used for the first phases and thus leave sufficient time for the development of more refined engines and subsystems and subsystem components for the later high-performance vehicles.

The unusually high costs of flight testing inherent to the ARS program require that special emphasis must be placed on a vigorous ground test program. This is reflected in an unusually large number of components and subsystem units required for ground testing.

D. <u>Flight Test Program</u>

The propulsion system for the Orbital Test Vehicles (Altered Hustler engine) will be flight tested primarily on OTV flight number 2. As required, additional information data will be obtained on subsequent flights.

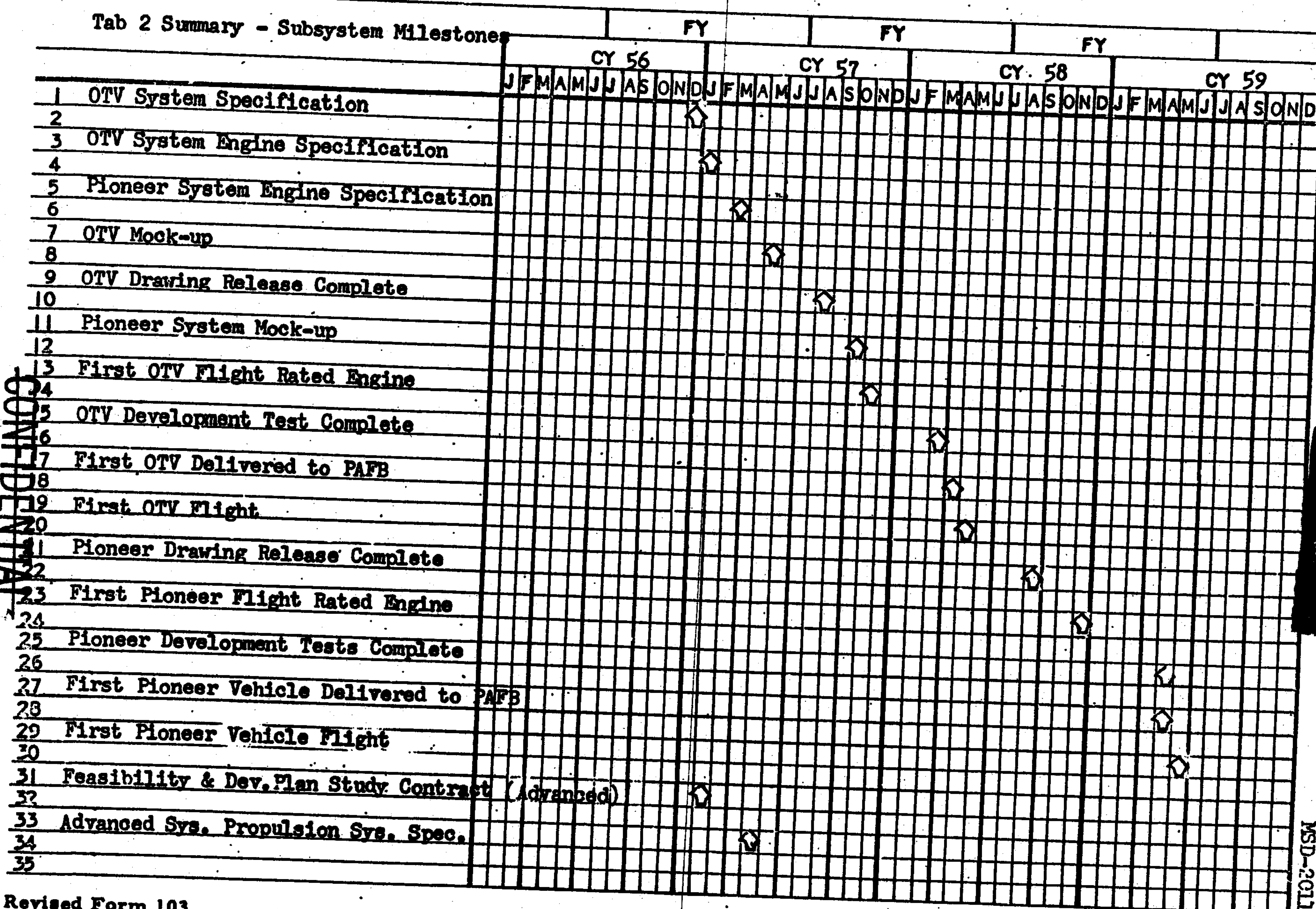
The sixth OTV flight will be used to obtain flight and suitability data for the Pioneer propulsion system (Modified Hustler engine).

E. <u>Special Test and Development Facilities</u>

To develop the propulsion sybsystem, the Missile Systems Division of Lockheed Aircraft Corporation will establish a Systems Test Facility which is described in Subsystem J, Ground Support and Training.

The Late Advanced Engine Program will require new facilities for the potential contractor. This program will also require that the Missile Systems Division erect a facility in some area remote from inhabited areas for propulsion systems development testing.

The LOX-JP-4 back-up program for the Late Advanced Systems will require no new facilities for the potential contractor. A LOX handling facility will, however, have to be added to the contractor's System Test Facility.



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OTV = ORBITAL TEST VEHICLE

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Subsystem B - Propulsion

Tab 2 Summary - Subsystem Milestones cont'd

		FY / CY 56 (J F M A M J J A S O N D)	FY / CY 57 (J F M A M J J A S O N D)	FY / CY 58 (J F M A M J J A S O N D)	CY 59 (J F M A M J J A S O N D)
1	Advanced Engine Contract		◇ F		
2					
3	Material & Component Research Complete (MSD)				◇ F
4					
5	Advanced Sys. Eng. Spec.		◇ D		
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Subsystem B - Propulsion

Tab 2 Summary - Subsystem Milestone

													FY												FY												FY												
		CY 60												CY 61												CY 62												CY 63											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Advanced Vehicle PFRT Complete													◇																																			
2																																																	
3	Advanced Vehicle First Flight																		◇																														
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Tab 2 Summary - Hardware Delivery

FY | FY | FY

CY 56

		J	F	M	A	M	J	J	A	S	O	N	D
1	Orbital Test Vehicle System												
2													
3	Ground Test Engines												
4	Flight Development Engines												
5	Flight Rated Engines												
6	Ground Test Control Engine												
7	Flight Development Control Engine												
8	Flight Rated Control Engine												
9	Propellant Feed Sys Components (Subcontract)												
10	Electrical System Components (Subcontract)												
11	Hydraulic System Components (Subcontract)												
12	Propellant Feed System (MSD)												
13	Electrical System Components (MSD)												
14	Hydraulic System Components, (MSD)												
15	Complete Propulsion Systems (Flight)												
16	Complete Propulsion System (Test)												
17													
18	Pioneer Vehicle System												
19													
20	Ground Test Engines												
21	Flight Development Engines												
22	Flight Rated Engines												
23	Ground Test Control Engines												
24	Flight Development Control Engines												
25	Flight Rated Control Engines												
26	Propellant Feed System Components (Subcontract)												
27	Electrical System Components (Subcontract)												
28	Hydraulic System Components (Subcontract)												
29	Propellant Feed System Components (MSD)												
30	Hydraulic System Components (MSD)												
31	Complete Propulsion System (Flight)												
32	Complete Propulsion System (Test)												
33													
34													
35													

CY 57

		J	F	M	A	M	J	J	A	S	O	N	D
1	Orbital Test Vehicle System												
2													
3	Ground Test Engines												
4	Flight Development Engines								1	2	1		
5	Flight Rated Engines											1	1
6	Ground Test Control Engine											1	2
7	Flight Development Control Engine								4	8	4		
8	Flight Rated Control Engine											4	4
9	Propellant Feed Sys Components (Subcontract)											4	8
10	Electrical System Components (Subcontract)					[redacted]							
11	Hydraulic System Components (Subcontract)					[redacted]							
12	Propellant Feed System (MSD)					[redacted]							
13	Electrical System Components (MSD)					[redacted]							
14	Hydraulic System Components, (MSD)					[redacted]							
15	Complete Propulsion Systems (Flight)					[redacted]							
16	Complete Propulsion System (Test)												
17												1	1
18	Pioneer Vehicle System												
19													
20	Ground Test Engines												
21	Flight Development Engines												
22	Flight Rated Engines												
23	Ground Test Control Engines												
24	Flight Development Control Engines												
25	Flight Rated Control Engines												
26	Propellant Feed System Components (Subcontract)												
27	Electrical System Components (Subcontract)												
28	Hydraulic System Components (Subcontract)												
29	Propellant Feed System Components (MSD)												
30	Hydraulic System Components (MSD)												
31	Complete Propulsion System (Flight)												
32	Complete Propulsion System (Test)												
33													
34													
35													

CY 58

		J	F	M	A	M	J	J	A	S	O	N	D
1	Orbital Test Vehicle System												
2													
3	Ground Test Engines												
4	Flight Development Engines												
5	Flight Rated Engines												
6	Ground Test Control Engine	1	1	1	1	1	1	1	1	1	1	1	
7	Flight Development Control Engine												
8	Flight Rated Control Engine												
9	Propellant Feed Sys Components (Subcontract)	4	4	4	4	4	4	4	4	4	4	4	
10	Electrical System Components (Subcontract)	[redacted]											
11	Hydraulic System Components (Subcontract)	[redacted]											
12	Propellant Feed System (MSD)	[redacted]											
13	Electrical System Components (MSD)	[redacted]											
14	Hydraulic System Components, (MSD)	[redacted]											
15	Complete Propulsion Systems (Flight)	[redacted]											
16	Complete Propulsion System (Test)	2	1	1	1	1	1	1	1	1	1	1	
17													
18	Pioneer Vehicle System												
19													
20	Ground Test Engines												
21	Flight Development Engines						1	2	1				
22	Flight Rated Engines									1	1		
23	Ground Test Control Engines												1
24	Flight Development Control Engines								4	8	4		
25	Flight Rated Control Engines									4	4		
26	Propellant Feed System Components (Subcontract)												4
27	Electrical System Components (Subcontract)	[redacted]											
28	Hydraulic System Components (Subcontract)	[redacted]											
29	Propellant Feed System Components (MSD)	[redacted]											
30	Hydraulic System Components (MSD)	[redacted]											
31	Complete Propulsion System (Flight)	[redacted]											
32	Complete Propulsion System (Test)												
33													1
34													
35													

CY 59

		J	F	M	A	M	J	J	A	S	O	N	D
1	Orbital Test Vehicle System												
2													
3	Ground Test Engines												
4	Flight Development Engines												
5	Flight Rated Engines												
6	Ground Test Control Engine												
7	Flight Development Control Engine												
8	Flight Rated Control Engine												
9	Propellant Feed Sys Components (Subcontract)												
10	Electrical System Components (Subcontract)												
11	Hydraulic System Components (Subcontract)												
12	Propellant Feed System (MSD)												
13	Electrical System Components (MSD)												
14	Hydraulic System Components, (MSD)												
15	Complete Propulsion Systems (Flight)												
16	Complete Propulsion System (Test)												
17													
18	Pioneer Vehicle System												
19													
20	Ground Test Engines												
21	Flight Development Engines												
22	Flight Rated Engines												
23	Ground Test Control Engines	2	2	1	1	1	1	1	1	1	1		
24	Flight Development Control Engines												
25	Flight Rated Control Engines												
26	Propellant Feed System Components (Subcontract)	8	8	4	4	4	4	4	4	4	4	4	4
27	Electrical System Components (Subcontract)	[redacted]											
28	Hydraulic System Components (Subcontract)	[redacted]											
29	Propellant Feed System Components (MSD)	[redacted]											
30	Hydraulic System Components (MSD)	[redacted]											
31	Complete Propulsion System (Flight)	[redacted]											
32	Complete Propulsion System (Test)		2	1	1	1	1	1	1	1	1	1	1
33		1											
34													
35													

Revised Form 103

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[redacted]

Subsystem B - Propulsion

Tab 2 Summary - Hardware Delivery cont'd

FY FY FY

	CY												CY 60												CY 61												CY 62											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1 Orbital Test Vehicle System																																																
2																																																
3 Ground Test Engines																																																
4 Flight Development Engines																																																
5 Flight Rated Engines																																																
6 Ground Test Control Engine																																																
7 Flight Development Control Engine																																																
8 Flight Rated Control Engine																																																
9 Propellant Feed Sys Components (Subcontract)																																																
10 Electrical System Components(Subcontract																																																
11 Hydraulic System Components(Subcontract)																																																
12 Propellant Feed System(MSD)																																																
13 Electrical System Components(MSD)																																																
14 Hydraulic System Components,(MSD)																																																
15 Complete Propulsion Systems (Flight)																																																
16 Complete Propulsion System (Test																																																
17																																																
18 Pioneer Vehicle System																																																
19																																																
20 Ground Test Engines																																																
21 Flight Development Engine																																																
22 Flight Rated Engines																																																
23 Ground Test Control Engines												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
24 Flight Rated Control Engines																																																
25 Propellant Feed System Components(Subcontract)												4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4																		
26 Electrical System Components (Subcontract)												[redacted]																																				
27 Hydraulic System Components(Subcontract)																																																
28 Propellant Feed System Components (MSD)																																																
29 Electrical System Components (MSD)																																																
30 Hydraulic System Components (MSD)																																																
31 Complete Propulsion System (Flight)												1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																		
32 Complete Propulsion System (Test)																																																
33																																																
34																																																
35																																																

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Tab 2 Summary - Hardware Delivery cont'd

											FY												FY												FY														
		CY												CY 60												CY 61												CY 62											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Advanced Vehicle System																																																
2																																																	
3	Ground Test Engines																																																
4	Flight Development Engines																										1	2	2	2	1	1	1																
5	Flight Rated Engines																														1	1																	
6	Propellant Feed System Components (Subcontract)																													1	1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	2	2	1
7	Electrical System Components (Subcontract)																													[redacted]																			
8	Hydraulic System Components (Subcontract)																													[redacted]																			
9	Propellant Feed System Components (MSD)																													[redacted]																			
10	Electrical System Components (MSD)																													[redacted]																			
11	Hydraulic System Components (MSD)																													[redacted]																			
12	Complete Propulsion System (Flight)																													[redacted]																			
13	Complete Propulsion System (Test)																																1	2	1	1	1	1	1	1	1	2	2	1	1	2	2	2	2
14																															1	1																	
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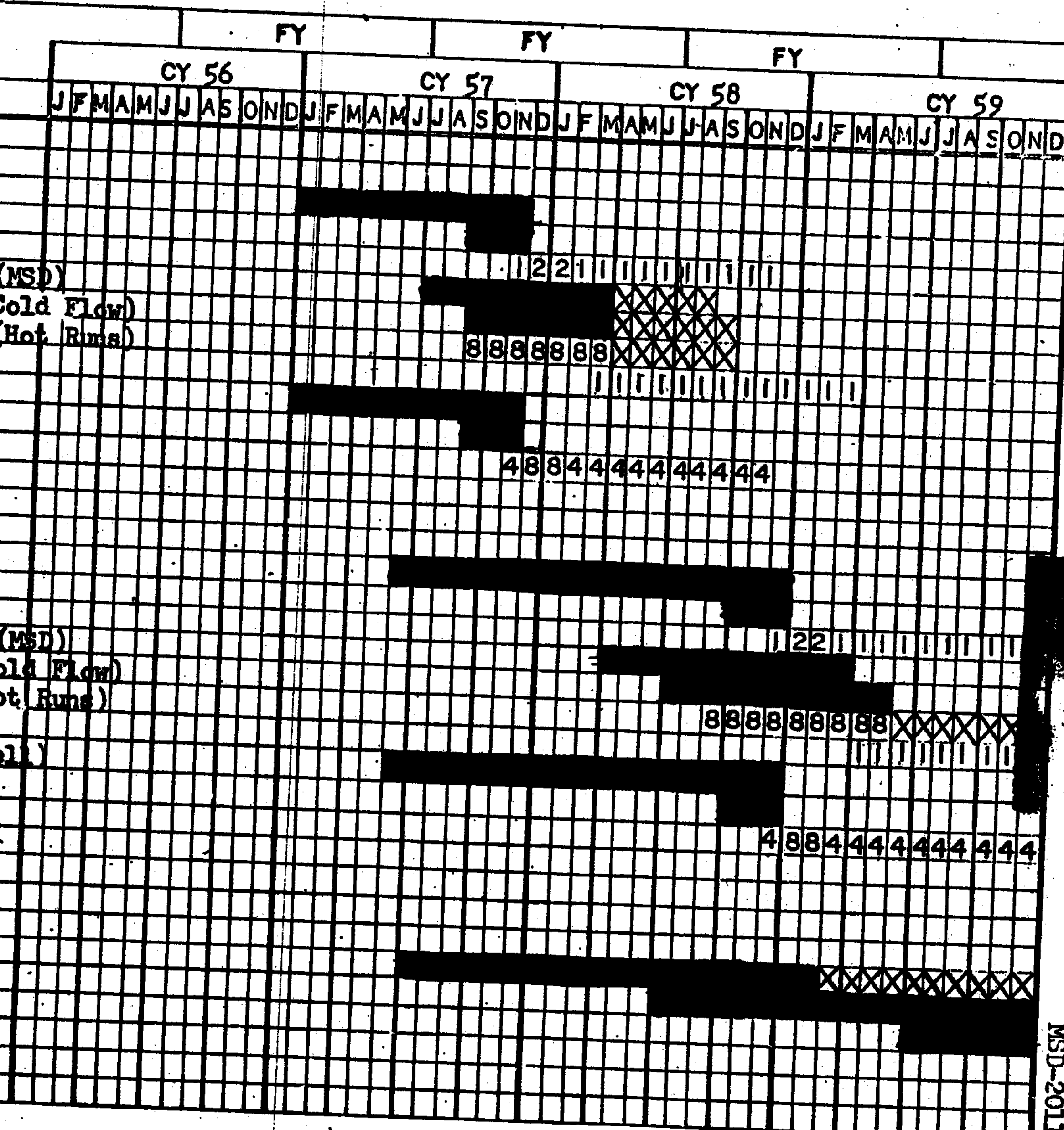
Subsystem B - Propulsion

Tab 2 Summary - Subsystem Test Schedule

1 Orbital Test Vehicle System
2
3 Engine Development Tests (Bell)
4 Engine PFRT Tests (Bell)
5 Engine Acceptance Tests (Bell)
6 Propulsion System Component Tests (MSD)
7 Complete Propulsion System Test (Cold Flow)
8 Complete Propulsion System Tests (Hot Runs)
9 Preflight Tests (Hot Runs)
10 Control Engine Development (Bell)
11 Engine PFRT
12 Control Engine Acceptance (Bell)
13
14 Pioneer Vehicle System
15
16 Engine Development Tests, (Bell)
17 Engine PFRT Tests (Bell)
18 Engine Acceptance Tests (Bell)
19 Propulsion System Component Tests (MSD)
20 Complete Propulsion System Tests (Cold Flow)
21 Complete Propulsion System Tests (Hot Runs)
22 Preflight Tests (Hot Runs)
23 Control Engine Development Tests (Bell)
24 Control Engine PFRT (Bell)
25 Control Acceptance Test (Bell) Engine
26
27
28 Advanced Vehicle System
29
30 Research Testing
31 Component Development Tests
32 Complete Engine Development Tests
33
34
35



Revised Form 103

MSD-2011

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Subsystem B - Propulsion

1 Orbital Test Vehicle
2
3
4
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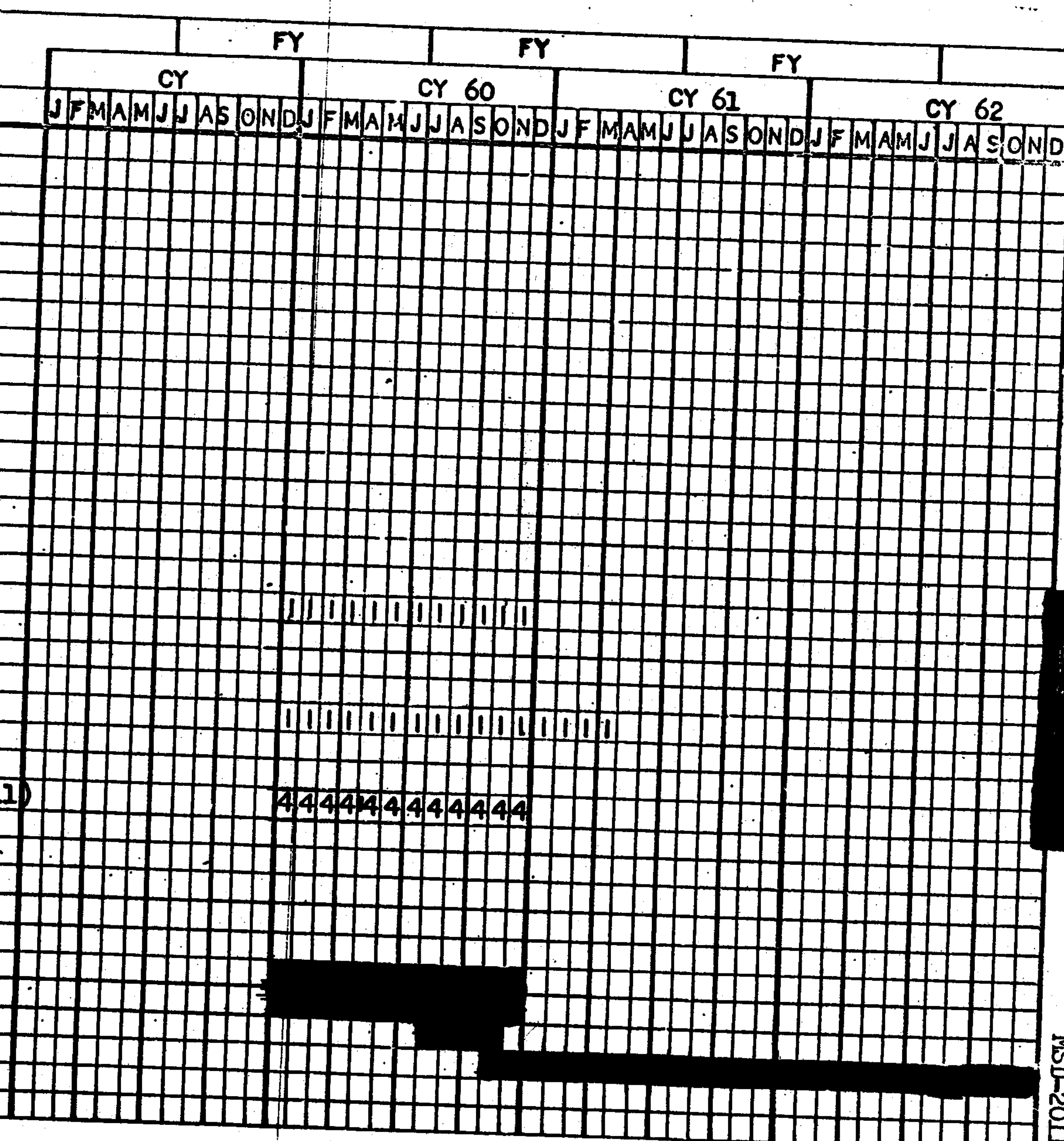
7
8
9
10
11
12
13 Pioneer Vehicle
14
15 Engine Development Test (Bell)
16 Engine PFRT Tests (Bell)
17 Engine Acceptance Test (Bell)
18
19
20
21 Preflight Test (Hot Runs)
22
23
24 Control Engine Acceptance Test (Bell)
25
26
27 Advanced Vehicle
28
29 Research Tests
30 Component Development Tests
31 Complete Engine Development Tests
32 PFRT Tests
33 Acceptance Tests
34
35



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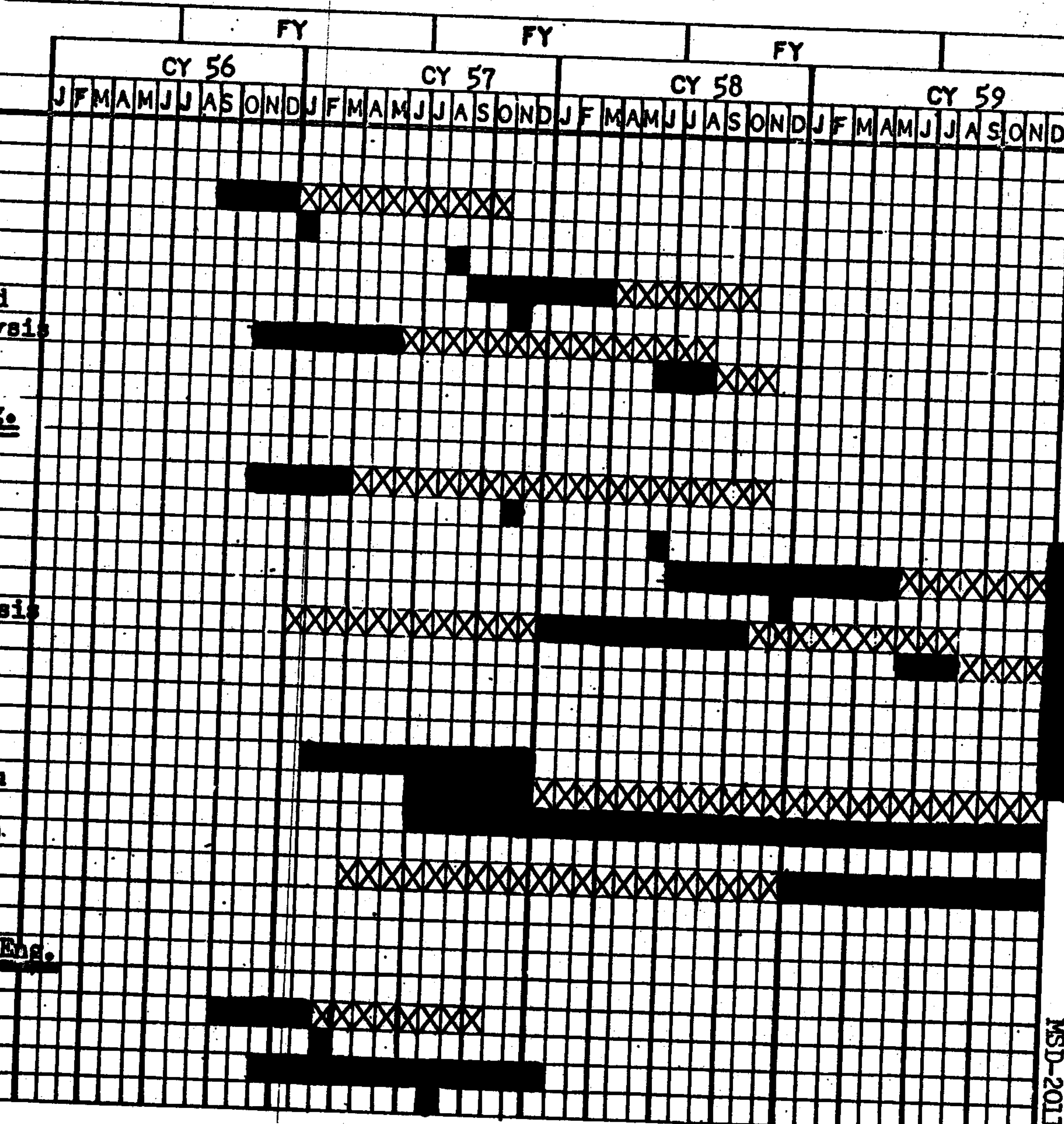
Subsystem B - Propulsion

Tab 2 Summary - R & D Schedule

1 Task #3 OTV Eng.
2
3 Specification & R & D Program
4 Engine Mockup Delivered
5 Ground Test Engine Delivered
6 Engine Ground Test (MSD)
7 1st Flight Approved Eng. Delivered
8 Engine Installation Design & Analysis
9 Flight Test
10
11 Task #4 Pioneer Vehicle System Eng.
12
13 Specification & R & D Program
14 Engine Mockup Delivered
15 Ground Test Eng. Delivered
16 Engine Ground Test (MSD)
17 1st Flight Approved Eng. Delivered
18 Engine Installation Design & Analysis
19 Flight Test
20
21 Task #5 Advanced Vehicle Eng.
22
23 Preliminary Requirements
24 Specification & Development Program
25 Engine Design (Subcontractor)
26 Development Testing (Subcontractor)
27 Installation Design & R & D
28 1st Flight Engine Delivered
29
30 Task #6 Eng. OTV Test Sys. Control Eng.
31
32 Specification & R & D Program
33 Engine Mockup Delivered
34 Engine Design & Development Testing
35 Ground Test Eng. Delivered



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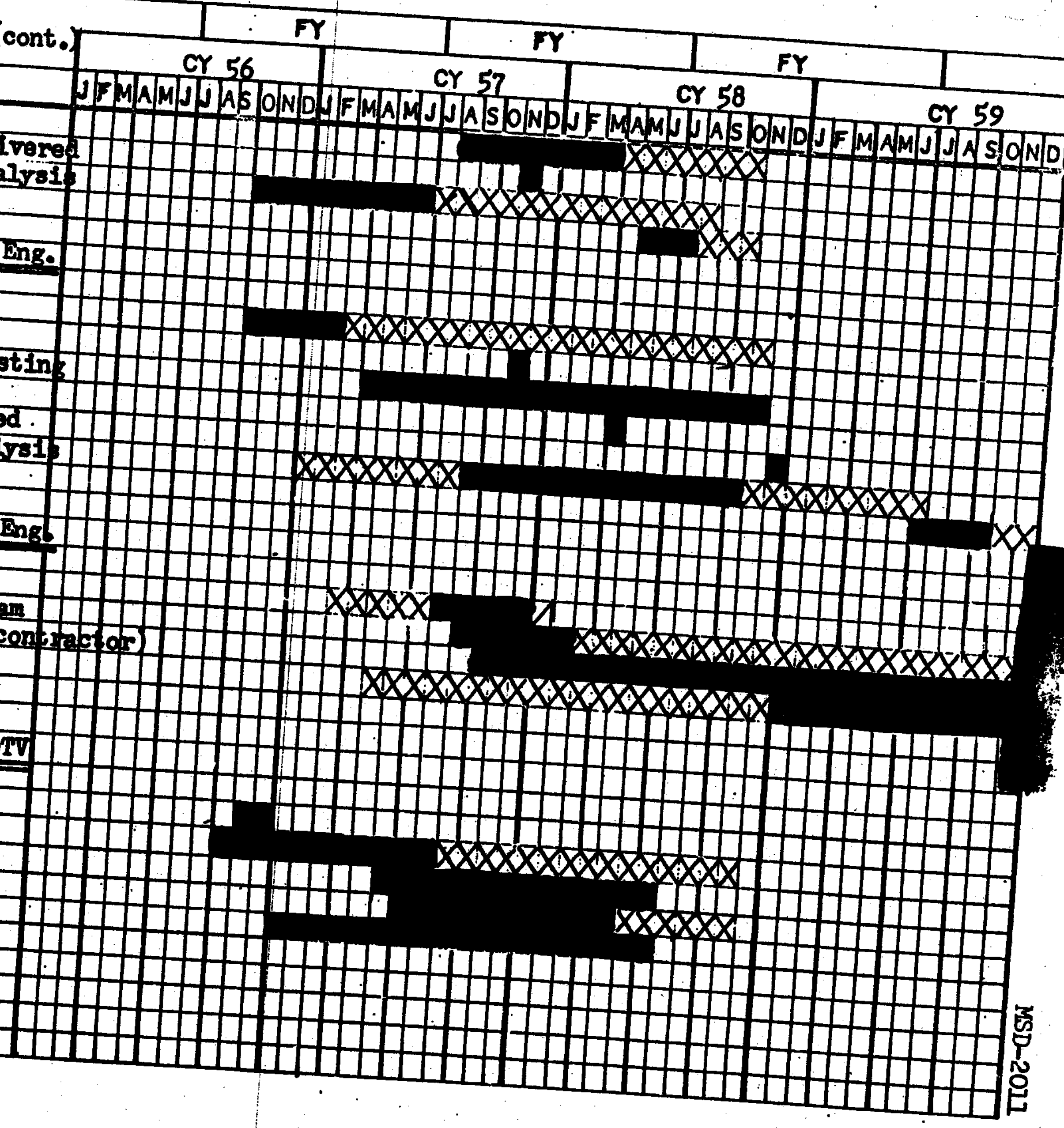
Subsystem B - Propulsion

Tab 2 Summary - R & D Schedule (cont.)

1 Engine Ground Test (MSD)
2 1st Flight Approval Engines Delivered
3 Engine Installation Design & Analysis
4 Flight Test
5
6 Task #7 Pioneer Vehicle Control Eng.
7
8 Specification & R & D Program
9 Engine Mockup Delivered
10 Engine Design and Development Testing
11 Ground Test Eng. Delivered
12 1st Flight Approval Eng. Delivered
13 Engine Installation Design & Analysis
14 Flight Test
15
16 Task #8 Advanced Vehicle Control Eng.
17
18 Prelim. Requirements & Spec.
19 Specification & Development Program
20 Design & Development Testing (Subcontractor)
21 Installation Design & R & D
22 1st Flight Engines Delivered
23
24 Task #9 Propellant Feed System - OTV
25
26 System Specification
27 Design Analysis
28 Fabrication
29 Development Testing
30 Component Procurement
31
32
33
34
35



MSD-2011

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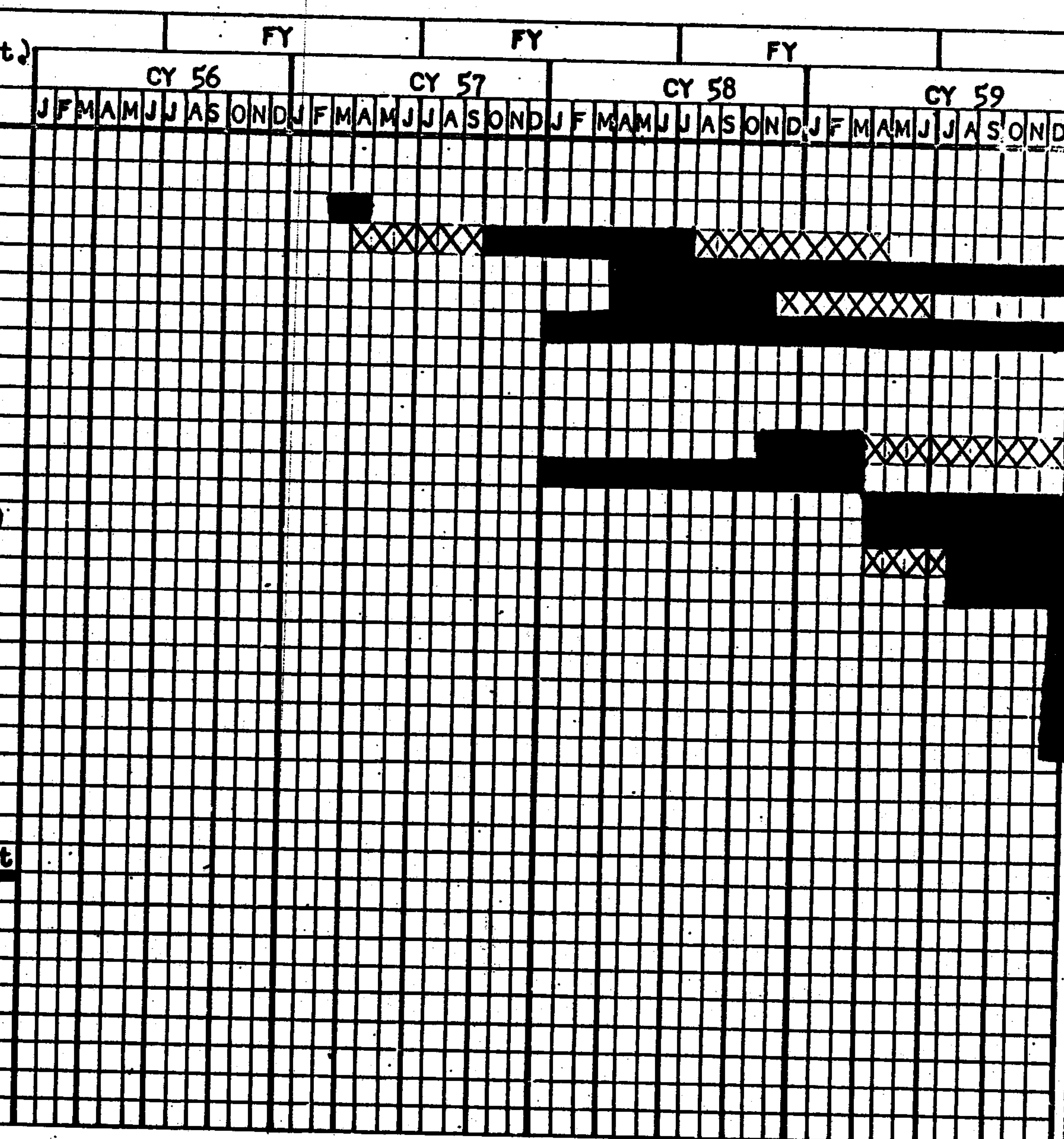
Subsystem B - Propulsion

Tab 2 Summary - R & D Schedule (cont.)



1 Task #9 (cont.) Pioneer Vehicle
2
3 System Specification
4 Design and Analysis
5 Fabrication
6 Development Test
7 Component Procurement
8
9 Task #9 (cont.) Advanced Vehicle
10
11 System Specification
12 Research & Analysis
13 System Design & Analysis
14 Component Development (Subcontract)
15 Component Testing & Research
16 Fabrication (Test Components)
17 Fabrication Flight Article
18 Test of Subsystem
19
20 Task #10 Pioneer System Propellant Flow & Utilization Control
21
22
23
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26 Task #11 Advanced Vehicle Propellant Flow & Utilization Control
27
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Revised Form 103

MSD-2011

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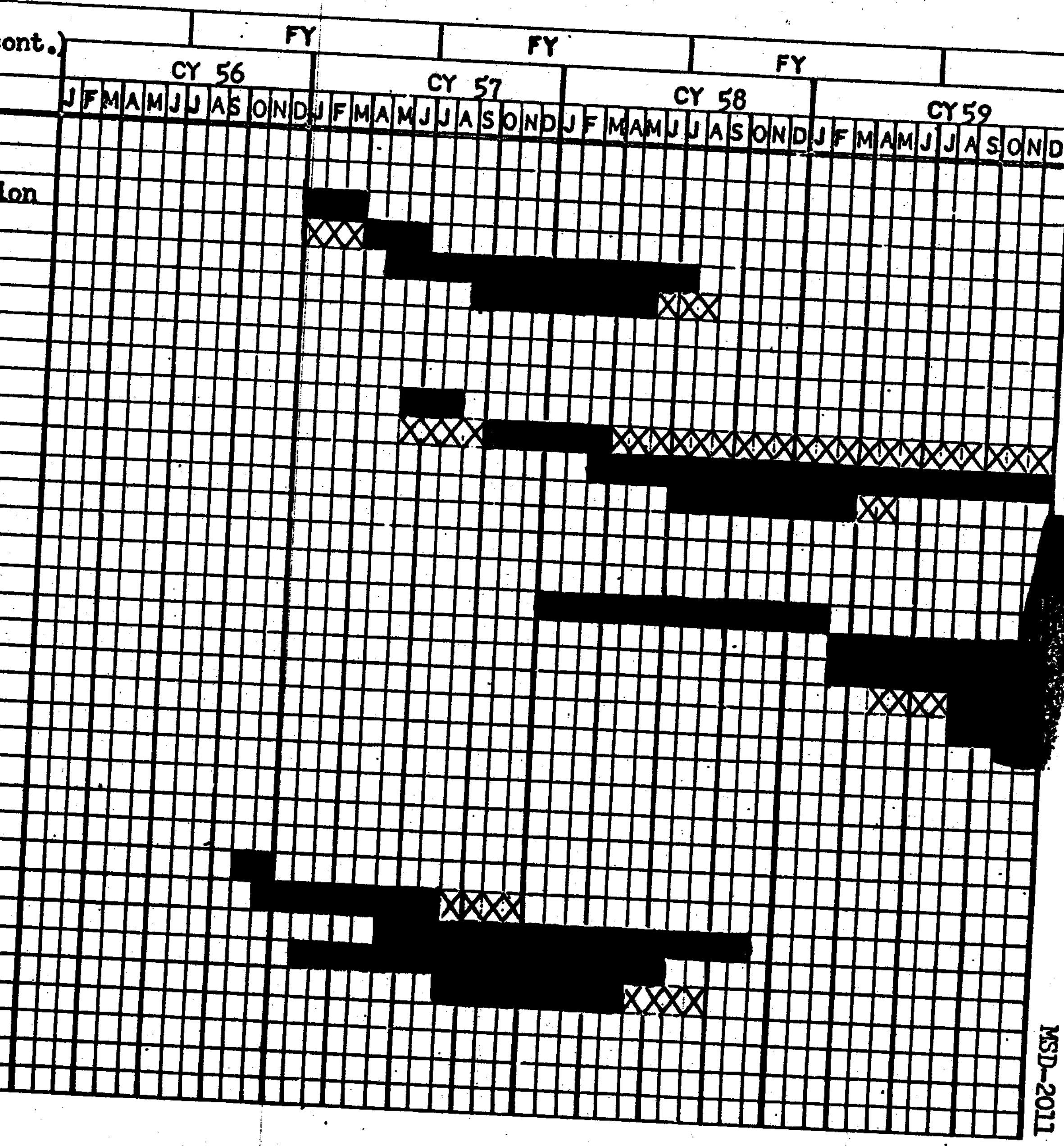
Subsystem B - Propulsion

Tab 2 Summary - R & D Schedule (cont.)



1 Task #12 Electrical System - OTV
2
3 System Requirements & Configuration
4 Design & Analysis
5 Component Procurement
6 Development Tests
7
8 Task #12 (cont.) Pioneer Vehicle
9
10 System Requirements
11 Design & Analysis
12 Component Procurement
13 Development Tests
14
15 Task #12 (cont.) Advanced Vehicle
16
17 Research
18 System Design & Analysis
19 Component Development
20 Component Testing & Research
21 Fabrication Test Components
22 Fabrication Flight Articles
23 Subsystem Tests
24
25 Task #13 Hydraulic System - OTV
26
27 System Specification
28 Design & Analysis
29 Fabrication
30 Component Procurement
31 Development Testing
32
33
34
35

Revised Form 103

CONFIDENTIAL

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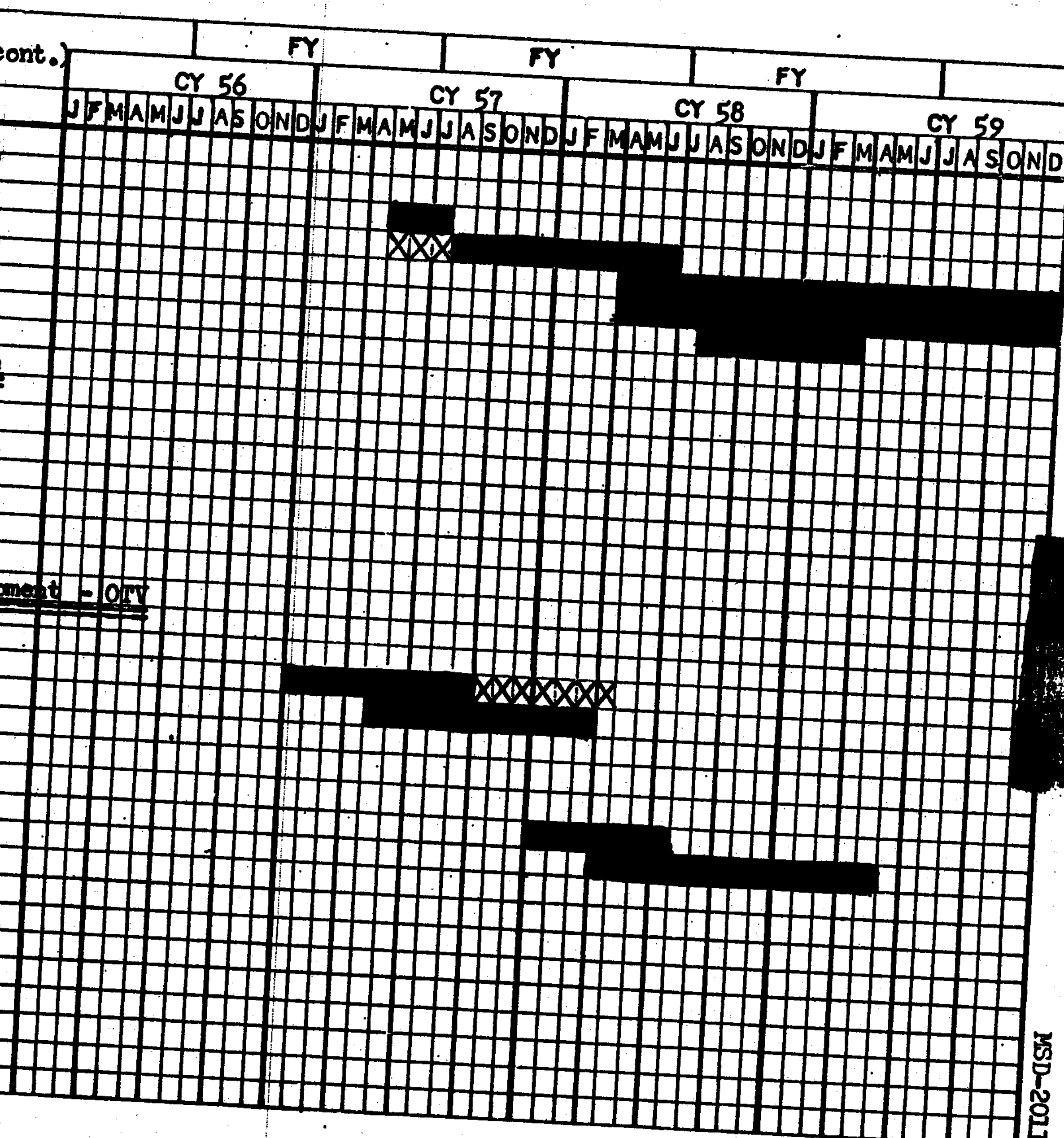
Subsystem B - Propulsion

Tab 2 Summary - R & D Schedule (cont.)

1 Task #13 (cont.) Pioneer Vehicle
2
3 System Specification
4 Design & Analysis
5 Fabrication
6 Component Procurement
7 Development Testing
8
9 Task #13 (cont.) Advanced Vehicle
10
11 System Specification
12 Design & Analysis
13 Fabrication
14 Component Procurement
15 Development Testing
16
17 Task #15 Loading & Servicing Equipment - OTV
18
19 Prototype Test System
20 Design Analysis & Requirements
21 Component Procurement
22
23 Task #15 (cont.) Pioneer Vehicle
24
25 Design Analysis & Requirements
26 Component Procurement
27
28 Task #15 (cont.) Advanced Vehicle
29
30 Design Analysis & Requirements
31 Component Procurement
32
33
34
35



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MSD-2011

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

1.	
2. REPORTS CONTROL SYMBOL	
PAGE 1 OF 5 PAGES	
3. DATE	
4. TITLE	SUBSYSTEM B - PROPULSION
5. INITIAL ☐ CHANGE	
6. NUMBER	WS 117L
7. RESP CENTER	
8. PROJECT OFFICER	
9. SUPPORTS (Sys or Proj)	
10. CONTRACTOR	
11. CONTR NR	
12. PRIORITY AND PREC	
13. SECURITY	~~S~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
1.	Orbital Test Vehicle Engine	Development Testing of Modified Turbopump for Duration-Checkout of thrust Chamber for Duration. PFRT Tests Complete Engine.	Bell Aircraft Corp., Buffalo, N.Y.		Nov. 1957
2.	Orbital Test Vehicle Control Engine	Development Testing to Prove Design and Performance.	"		
		Development Testing of Complete Engine.	"		
		PFRT Tests Complete Engine.	"		Nov. 195[redacted]
3.	Orbital Test Vehicle Propulsion Systems		Lockheed Aircraft Corp.		
	a. Propellant Feed System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	July 1957	May 1958

TEST CENTER APPROVAL		
20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE
		DATE
RESPONSIBLE CENTER APPROVAL		
22. NAME	ORGANIZATION	DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 2 OF 5 PAGES

3. DATE

4. TITLE: SUBSYSTEM B - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER: WS 117L

7. RESP CENTER:

8. PROJECT OFFICER:

9. SUPPORTS (Sys or Proj):

10. CONTRACTOR:

11. CONTR NR:

12. PRIORITY AND PREC:

13. SECURITY: ~~S~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
	b. Hydraulic System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	Sept. 1957	May 1958
	c. Electrical System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	Sept. 1957	May 1958
	d. Complete Propulsion System (Engines, Propellant Feed, Press, Hydraulic, and Electrical)	Development and System Integration Testing	Systems Test Facility	Oct. 1957	May 1958
4.	Orbital Test Vehicle Propulsion System	Preflight Checkout Tests	Lockheed Aircraft Corp., Systems Test Facility	Jan. 1958	*

* As required for flights - See Flight Schedule - Sec. Tab. 2

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE
		DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 3 OF 5 PAGES

3. DATE

4. TITLE: SUBSYSTEM B - PROPULSION

5. INITIAL ☐ CHANGE

6. NUMBER: WS 117L

7. RESP CENTER

8. PROJECT OFFICER

9. SUPPORTS (Sys or Proj)

10. CONTRACTOR

11. CONTR NR

12. PRIORITY AND PREC

13. SECURITY: ~~S~~

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
5.	Pioneer Vehicle Engine	Development Testing of Redesigned Turbopump. Development Testing of Injector. Investigation of Thrust Chamber Cooling. Development Testing of Gas Generator. PFRT Tests Complete Engine.	Bell Aircraft Corp., Buffalo, N.Y.		Dec. 1958
6.	Pioneer Vehicle Control Engines	Development Testing of Injector and Thrust Chamber. Investigation of Thrust Chamber Heating. Selection of Correct Mixture Ratio. PFRT Tests Complete Engine.	Bell Aircraft Corp., Buffalo, N.Y.		Dec. 1958

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	DATE
21. NAME	ORGANIZATION	DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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1.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL	PAGE 4 OF 5 PAGES
3. DATE	
4. TITLE: SUBSYSTEM B - PROPULSION	5. INITIAL ☐ CHANGE
6. NUMBER	WS 117L

7. RESP CENTER	8. PROJECT OFFICER	9. SUPPORTS (Sys or Proj)	10. CONTRACTOR	11. CONTR NR	12. PRIORITY AND PREC	13. SECURITY
						S

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
7.	Pioneer Vehicle Propulsion Systems		Lockheed Aircraft Corp.		
	a. Propellant Feed System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	April 1958	Nov. 1958
	b. Hydraulic System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	Aug. 1958	Mar. 1959
	c. Electrical System Components	Performance, Operational Suitability and Reliability Tests	Component Test Laboratory	July 1958	Mar. 1959
	d. Complete Propulsion System (Engines, Propellant Feed System Pressurization, Hydraulic, Electrical)	Development and System Integration Testing	Systems Test Facility	July 1958	May 1959

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE
		DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

ARDC FORM 1 JUL 55 105 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.

R & D TEST ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

1.	2. REPORTS CONTROL SYMBOL
	PAGE 5 OF 5 PAGES
4. TITLE: SUBSYSTEM B - PROPULSION	3. DATE
5. INITIAL ☐ CHANGE	6. NUMBER: WS 117L
7. RESP CENTER	
8. PROJECT OFFICER	
9. SUPPORTS (Sys or Proj)	
10. CONTRACTOR	
11. CONTR NR	
12. PRIORITY AND PREC	
13. SECURITY	

14. ITEM NUMBER	15. TEST ITEM	16. TEST DESCRIPTION	17. TEST AGENCY AND SITE	18. TEST ITEM AVAILABLE	19. RQD TEST COMPL DATE
8.	Pioneer Vehicle Propulsion System	Preflight Checkout Tests	Lockheed Aircraft Corp., Systems Test Facility	(#1) April 1959	*
9.	Advanced Vehicle Systems Engine	Component Development Tests Engine Component Integration and Development Tests PFRT Tests	Subcontractor		
10.	Advanced Vehicle Propulsion System	Materials Research Testing Preflight Tests	Lockheed Aircraft Corp.	(#1) Mar. 1961	Jan. 1961 Feb. 1959

* As required for flights - See Flight Schedule Sec. Tab. 2

TEST CENTER APPROVAL

20. NAME	ORGANIZATION	
21. NAME	ORGANIZATION	DATE
		DATE

RESPONSIBLE CENTER APPROVAL

22. NAME	ORGANIZATION	DATE

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1.

R & D TEST AND TEST SUPPORT AIRCRAFT ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

4. TITLE: Subsystem B-PROPULSION

5. INITIAL ☒ CHANGE

3. DATE: 1 November 1956

6. NUMBER: WS 117L

7. ITEM NUMBER	8. AIRCRAFT REQUIRED: QTY	TYPE, MODEL AND SERIES	SERIAL NUMBER	9. ASG CODE	10. MOD REQD	11. DATE REQD AND LOCATION	12. ESTIMATED RELEASE DATE	13. RECOMMENDED DISPOSITION	14. F HRS F CST	15. EST COST

AIRCRAFT WILL NOT BE REQUIRED FOR TESTS OF THE PROPULSION SUBSYSTEM.

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B-Tab 4

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LOCKHEED AIRCRAFT CORPORATION MISSILE SYSTEMS DIVISION

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1.

R & D MATERIEL ANNEX

☐ SYSTEM ☒ PROJECT ☐ TASK ☐ OTHER

2. REPORTS CONTROL SYMBOL

PAGE 1 OF 1 PAGES

3. DATE 1 November 1956

4. TITLE Subsystem B-PROPULSION (PROPELLANT QUANTITIES in 1000 lbs)

5. INITIAL ☒ CHANGE

6. NUMBER WS 117L

7. MATERIEL REQUIREMENTS (Indicate Items in Columnar Form using Columns as cited in Examples)

	1956	1957	1958	1959	1960	1961	1962	1963
System Test Facility								
IRFNA		29	50	55	105			
JP-4		7	10	2				
UDMH			8	18	40			
Ammonia								
Fluorine								
Hydrogen Peroxide		2	5	1				
AFMTC								
IRFNA			40	25				
JP-4			10	3.5				
UDMH				7.5				
Ammonia								
Fluorine								
Hydrogen Peroxide			6.2	2				
Operational Base								
IRFNA				25	515			
JP-4				3.5				
UDMH				7.5	200			
Ammonia								
Fluorine								
Hydrogen Peroxide				2				

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SUBSYSTEM B - PROPULSION

DATE 1 November 1956

ITEM: MSD - IN PLANT TEST FACILITY*
SYSTEM TEST FACILITY*

USING AGENCY: LOCKHEED MSD

LOCATION:

BUDGET CONTROL ESTIMATE:

NEED DATE:

SCHEDULE:	1956						1957												1958												1959											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D

DESCRIPTION AND UTILIZATION:

*Descriptions of these facilities are given in Tab 6 of Subsystem J - Ground Support & Training

REMARKS:

Revised Form 108

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Subsystem B - Propulsion
Tab 7 - Contract Funds
(in thousands of dollars)

	FY-57					FY-58			FY-59				FY-60			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LAC																
(1) Research & Engineering	95	263	263	263	263	263	263	263	263	263	263	263	224	224	187	182
(a) Sub Contracts	1300	1300	1301	1824	1824	1824	1825	1765	1765	1765	1765	1670	1670	1670	1670	415
(2) Fabrication*																
(a) Purchased Components	300	300	301	447	447	447	447	388	388	388	388	798	798	798	798	940
Sub Total	1695	1863	1865	2534	2534	2534	2535	2416	2416	2416	2416	2731	2692	2692	2655	1537
Fee	170	186	186	253	253	253	254	242	242	242	242	273	269	269	266	154
TOTAL	1865	2049	2051	2787	2787	2787	2789	2658	2658	2658	2658	3004	2961	2961	2921	1691
Total Fiscal Year		5965				11,150				10,632				11,847		

*Engine Installation included in Airframe Costs.

Subsystem B - Propulsion
Tab 7 - Contract Funds (cont'd)
(in thousands of dollars)

	FY-61			FY-62				FY-63							
	17	18	19	20	21	22	23	24	25	26	27	28	29	30	TOTALS
LAC															
(1) Research & Engineering	162	147	149	149	74	74	65	60	60	55	35				4,835
(a) Sub Contracts	415	415	415	264	264	264	264	214	214	214	214				28,510
(2) Fabrication*															
(a) Purchased Components	940	940	940	746	746	746	746	746	746	746	746				17,161
Sub Total	1517	1502	1504	1159	1084	1084	1075	1020	1020	1015	995				50,506
Fee	152	150	150	116	108	108	108	102	102	102	100				5,052
TOTAL	1691	1652	1654	1275	1192	1192	1183	1122	1122	1117	1095				55,558
Total Fiscal Year		6666				4842				4456					
*Engine Installation included in Airframe Costs.															

MSD-2011

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Subsystem B - Propulsion
Tab 8 - R & D Manpower Annex

WORK ITEM	Type of Manpower	FY 57				FY 58				Quarters FY 59				FY 60			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
LAC																	
Research & Engineering	1-2-3*	17	48	48	48	48	48	48	48	48	48	48	48	45	45	38	37

*Average:
40% Type 1 Scientific & Technical
50% Type 2 Engineering Support
10% Type 3 Management & Administration

Subsystem B - Propulsion
Tab 8 - R & D Manpower Annex (cont'd)

WORK ITEM / Type of Manpower	FY 61 17	18	19	20	21	FY 62 22	23	Quarters 24	25	26	FY 63 27	28	29	30	** TOTALS
LAC															
Research & Engineering 1-2-3*	33	30	30	30	15	15	13	12	12	11	7				918
*Average:															
40% Type 1 Scientific & Technical															
50% Type 2 Engineering Support															
10% Type 3 Management & Administration															
** Totals in Man Quarters															