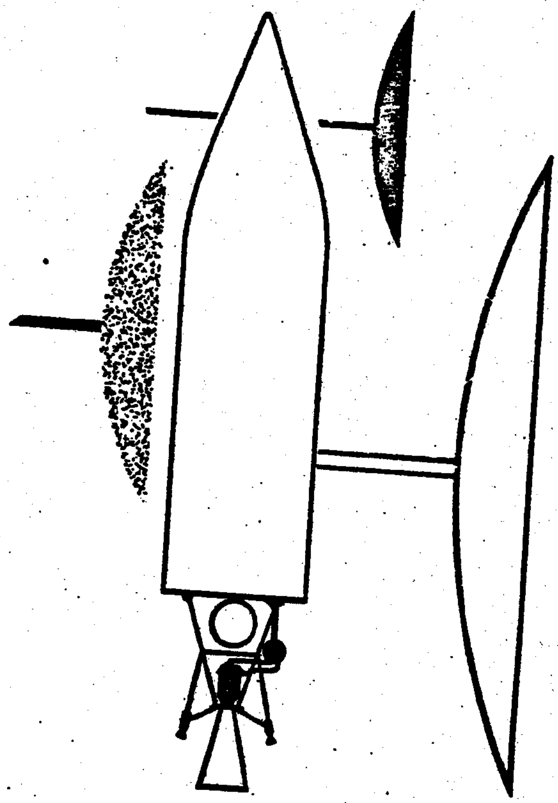
LMSD
1536
Vol. II
Part B
C?P (..E-62)

[redacted]

370270

CONFIDENTIAL

MSD 1536



Pied Piper DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

B. Propulsion

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

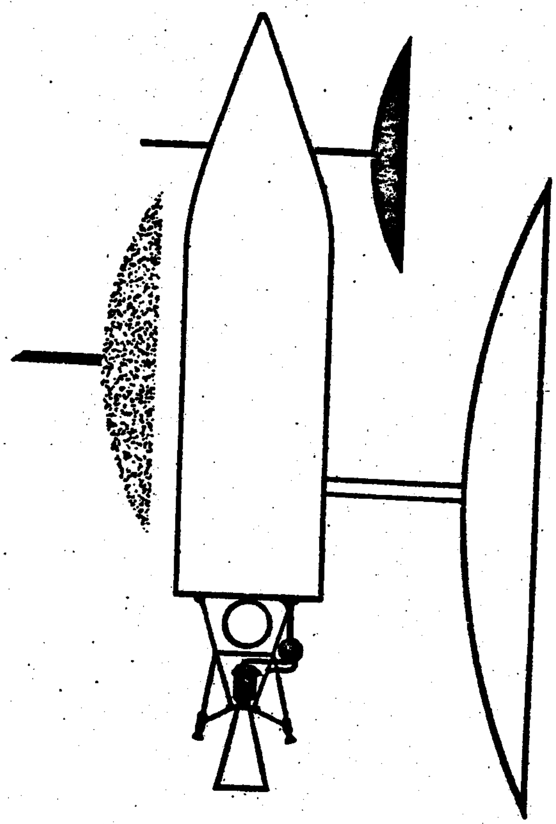
SECRET
DDC CONTROL
NO. C1218

CONFIDENTIAL

CONFIDENTIAL

MSD 1536
1 MARCH 1956

COPY NO. E-62
35 SHEETS



Pied Piper DEVELOPMENT PLAN

VOL. II SUB-SYSTEM PLAN

B. Propulsion

DOWNGRADED AT 12 YEAR INTERVALS;
NOT AUTOMATICALLY DECLASSIFIED
DOD DIR 5200.10

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of AFSSD Code SSSD.

LOCKHEED AIRCRAFT CORPORATION
MISSILE SYSTEMS DIVISION
VAN NUYS, CALIFORNIA

CONFIDENTIAL

FOREWORD

The Advanced Reconnaissance System (ARS) consists of a satellite vehicle containing equipment to perform visual, ferret, and infrared reconnaissance, together with the necessary system of ground stations and data processing centers.

This Development Plan for the accomplishment of the ARS was prepared by the Missile Systems Division, Lockheed Aircraft Corporation and its subcontractors, CBS Laboratories and Eastman Kodak Company. The specifications for the system were determined in the course of a one-year study now being conducted for the United States Air Force under contract AF 33(616)-3105. The plan is presented in two parts; Volume I, System Plan, and Volume II, Subsystem Plan. The subsystems are described in separate books, Volume II-A through II-L.

CONTENTS

Subsystem B-Propulsion

SECURITY CLASSIFICATION SECRET

MSD 1536
1 Mar 56

RDB PROJECT CARD

TYPE OF REPORT: New System - Development Plan

REPORTS CONTROL SYMBOL DD-RDB(A)148

1. PROJECT TITLE: PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCL.) (PIED PIPER)

2. SECURITY: SECRET

3. PROJECT NUMBER: 1115

4. INDEX NUMBER:

5. REPORT DATE: 1 March 1956

6. BASIC FIELD OR SUBJECT:

7. SUBFIELD OR SUBJECT SUBGROUP:

7A. TECH. OBJ.

8. COGNIZANT AGENCY:

9. DIRECTING AGENCY:

OFFICE SYMBOL: | TELEPHONE NO.:

10. REQUESTING AGENCY:

11. PARTICIPATION, COORDINATION, INTEREST:

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

CONTRACT/W.O. NO.: AF 33(616)-3105

13. RELATED PROJECTS:

14. DATE APPROVED:

15. PRIORITY: Maximum

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 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 | SH | CN | IC & P | X. | L. | C.

DD FORM 1 JAN 52 613

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	SECRET	1115
	4.	5. REPORT DATE 1 March 1956

of approximately 60 to 100 seconds. The engine assembly will have a fixed thrust mount, and will weigh approximately 135 pounds.

The engine starting system will accomplish ignition and cutoff of the sustainer and control engines on command from the Guidance and Control Subsystem. The sustainer engine is started 2 seconds after ignition of the control engines. The cutoff command from the Guidance and Control Subsystem activates the engine cutoff sequencer. Propellant to the sustainer engine is shut off, and the control engines operate alone for 2 additional seconds to correct attitude disturbances induced by sustainer engine cutoff.

2a. Pioneer Control Engines

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. Two control engines provide lateral and roll control of the vehicle. They will orient the vehicle and its thrust vector as directed by the Guidance and Control Subsystem and will position the vehicle in orbit. For the Pioneer vehicles the thrust of each engine will be approximately 150 pounds for a duration of about 60 to 100 seconds. The engine assemblies will include a gimballed thrust mount capable of deflection through ± 30 degrees in a square pattern.

3a. Pioneer Propellant Feed System

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. A gas-pressurized propellant feed system is used in the Pioneer vehicles and will consist of fuel and oxidizer tanks, a tank pressurization gas supply, valves, and plumbing. The tanks will be insulated and will operate at approximately 330 psi. Pressurization gas will be heated helium. Initial operation of control engines and starting of sustainer engine in a gravity-free field is accomplished by use of a bladder inside the tank and attached to the pressurizing gas inlet. The bladder ruptures after sufficient acceleration is attained to ensure proper orientation of the liquid in the tanks. The subsystem dry weight will be approximately 530 pounds.

4a. Pioneer Control Engine Actuator System

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. The control engine actuators will be package units consisting of an electrically driven hydraulic pump, servo-valve, actuator, and position feed-back potentiometer. Electrical power will be supplied by the auxiliary power subsystem.

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED) (PIED PIPER)	~~SECRET~~	1115
	4.	5. REPORT DATE 1 March 1956

21 a. Brief and Operational Characteristics

This subsystem will provide the satellite with the following: (1) thrust to attain the desired orbit; (2) lateral and roll control to effect the transition maneuver into orbit, and proper orientation of the vehicle with respect to its line of flight; (3) a propellant feed system; (4) a propellant flow and utilization control; and (5) means of effecting ignition and cutoff of the vehicle propulsion units in a safe and reliable manner.

It will be capable of starting in the absence of gravity and external pressure.

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.

Components will be selected for:

Pioneer Vehicles: These are within the current state of the art and will be available in schedules compatible with Phase I of the Advanced Reconnaissance System, and as an alternative,

Advanced Vehicles: Those will provide an increase in specific impulse of at least 10 percent over presently available values and are within such state of development that reliable operation and availability within schedules compatible with that of the Advanced Reconnaissance System can be predicted.

For both phases, backup alternate developments are considered.

Major targets of the development program will be availability, compatibility with the schedules, reliability, a propellant supply system of minimum complexity and weight, and high performance (specific impulse).

21 c. Subsystem Tasks

1a. Pioneer Sustainer Engine

b. Contractor: Aerojet-General or Reaction Motors, Inc.

c. The sustainer engine will provide the required acceleration to the vehicle as the orbit is approached. The specific impulse at altitude is 278 seconds. Thrust will be approximately 7500 pounds for a duration

R&D PROJECT CARD
CONTINUATION SHEET

SECRET
SECURITY CLASSIFICATION

MSD 1536
1 Mar 56

1. PROJECT TITLE	2. SECURITY OF PROJECT	3. PROJECT NUMBER
PROPULSION SUBSYSTEM FOR ADVANCED RECONNAISSANCE SYSTEM (UNCLASSIFIED)	~~SECRET~~	1115
(PIED PIPER)	4.	5. REPORT DATE 1 March 1956

5a. Advanced Sustainer Engine with Integral Control System

b. Contractor: North American Aviation or Aerojet-General

c. For the Advanced vehicles the proposed engine is in process of contractor-sponsored development by North American Aviation, Inc. Propellants of this engine are fluorine and ammonia. In the Advanced engine, four control engines, hinged for deflection in one plane, may be used. This system may be replaced by utilizing turbo-pump exhaust in a similar manner.

6a. Advanced Propellant Utilization Control

b. Contractor: North American Aviation or Aerojet-General

c. The propellant utilization control will accomplish simultaneous exhaustion of fuel and oxidizer by a continuous comparison of tank levels. A departure from the proper ratio of levels, corresponding to the ratio of fuel to oxidizer, will be sensed. This signal is amplified and used to actuate servomotors and valves in the propellant supply lines. Thus, the control satisfies engine demand fuel-oxidizer ratio and ensures simultaneous exhaustion of both propellant tanks.

7a. Advanced Propellant Feed System

b. Contractor: North American Aviation or Aerojet-General

c. In the Advanced vehicle a conventional turbopump propellant feed system is used. An additional pressure-fed system will provide sufficient propellant for the control engines for operating 2 seconds before and 2 seconds after main engine operation in gravitational-free field. This system also provides propellant to the turbopump gas generator of the sustainer engine for starting purposes.

21 d. Other Information

1. The performance characteristics of the subsystem are predicated on specified performance of the XSM-65 as a booster unit. 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.) whenever their characteristics are demonstrated to be of required performance and reliability.

In addition to these requirements both the sustainer engine and the control engine will be capable of starting in a zero gravity field and in vacuum. The control forces must be available for two seconds prior to the sustainer engine ignition to correctly align the longitudinal axis of the orbital stage with respect to the desired trajectory, and for more than one second after sustainer engine shutdown to correct missile attitude during the thrust decay phase when sustainer engine thrust misalignments may occur. In addition, the propulsion system will be capable of withstanding the environment existing during boost (accelerations up to 10g, vibrations aerothermodynamic heating of propellants and components) and the coast period between booster stage burnout and orbital stage propulsion initiation (gravity-free conditions).

C. Solution

Because of the high degree of availability, the Project Vanguard engine being developed by the Aerojet General Corp. is proposed for the pioneer sustainer engine. It will be installed in a fixed thrust mount. Attitude control engines will be supplied. This method was selected because it corresponds to the present design approach to the operational vehicle.

As an alternative, the sustainer engine could be gimbal mounted without major modification to the present Vanguard engine design. The final selection of the type of thrust mount will be made after a further study to be conducted during the next four months.

A summary table of the operational characteristics of these propulsion systems is given in Table I.

SECRET

Table I

OPERATIONAL CHARACTERISTICS OF PROPOSED PROPULSION SUBSYSTEMS

	PIONEER VEHICLE		ADVANCED VEHICLE	
	PRIMARY	ALTERNATE	PRIMARY	ALTERNATE
Contractor	Aerojet General	Reaction Motors	Rockodyne	Aerojet General
Propellant Feed System	Pressure (1)	Pump	Pump	Pump
Thrust (Vacuum)	7,500 lbs	9,600 lbs	20,000	15,000 - 20,000
Specific Impulse (Vacuum)	273 - 278	286	$326^{(4)}$ $342^{(5)}$	303
Propellant System	WFNA - UDMH	90% H_2O_2-JP-5	F_2 - NH_3	LOX - JP-4
Mixture Ratio	2.80	7.0	$2.1^{(4)}$ $2.7^{(5)}$	2.33
Bulk Density	1.20	1.39	$1.09^{(4)}$ $1.14^{(5)}$	1.00
Nozzle Area Ratio	20:1	30:1	15:1	25:1
Weight	163	200	375	

Notes:
1. Hot gas pressurization system
2. No film cooling
3. Including gas generator propellant
4. Initial development engines
5. Prototype and production engines

II. DESCRIPTION

A. Tasks

(1) Pioneer Sustainer Engine

The project Vanguard rocket engine now being developed by the Aerojet General Corp. will have a single thrust chamber and a fixed thrust mount. The thrust chamber will be capable of operating for a minimum of 100 seconds, be regeneratively cooled and have a nozzle area ratio of 20 to 1. The propellant combination will be white fuming nitric acid and unsymmetrical-dimethylhydrazine injected at a normal mixture ratio of 2.8. Because the propellants are hypergolic no separate ignition system will be required. However, a nozzle closure diaphram will be provided to assist in obtaining reliable starts. The engine propellant control valves are hydraulically operated by fuel pressure.

An engine which is being currently developed as a super-performance rocket engine for manned aircraft by Reaction Motors, Inc. is proposed as a back-up. This engine will be an integral unit consisting of a decomposition chamber, turbo-pump, thrust chamber, propellant control valves and necessary lines and fittings. It will use the propellant combination 90% hydrogen peroxide JP-5. The thrust chamber for use in the pioneer vehicle must be modified to have a substantially increased nozzle expansion ratio. The existing design is scheduled for flight early in 1957.

(2) Pioneer Control Engines

Two control engines having 150 pounds of thrust each will be provided. The control engine will consist of a thrust chamber, gimbal-type thrust mount, and propellant control valves and will be capable of operating for 100 seconds. The control engines will operate on propellants supplied from the main propellant feed system. Gimballing will be ± 30°.

These engines may be either liquid cooled or uncooled as determined by development testing. With a regeneratively cooled design, it may be necessary to feed propellant in excess of requirements through the cooling passages and then return this excess to the main propellant feed line.

In the event that the sustainer engine is gimballed, then the control engines may be replaced by small helium gas jets to provide roll control forces. This system will require only the development of a flow control valve.

(3) Pioneer Propellant and Feed and Starting System

The pioneer propellant feed system will be a pressure feed type propellant system. It will incorporate a helium pressurization system. Pressurization helium will be stored in a spherical tank at an initial pressure of 3,000 psi. The pressure feed system is designed to provide propellants to the engine inlets at a pressure of 300 psi.

Since the engines must be started in a gravity-free field, the ullage space in each of the propellant tanks must be remote from the tank outlet. To accomplish this, small bladders will be installed in each propellant tank at the helium inlet fittings located in the upper part of each propellant tank. These bladders will have sufficient expansion to permit the starting of the sustainer engine, provide for two seconds of control engine thrust prior to main system operation. After completion of sustainer engine starting, the bladder cells will rupture permitting a normal pressurization program to proceed. After sustainer shutdown, the control engine thrust will provide sufficient acceleration to properly orientate the remaining propellants in the tanks for the additional control engine operation.

Loading of the propellants will be accomplished with a closed cycle propellant loading system, which is described in the appendix. For accurate loading of the propellants, a propellant loading control system which will sense the correct level for the desired weight of propellant will be developed. After loading the propellant, the bladder cell will be pressurized to fill the ullage space in each tank. The pressurization system to be used with the Reaction Motors engine will be identical to the pressure feed system used with the Aerojet engine except for the tank pressure.

(4) <u>Pioneer Actuator System</u>

The control engine actuators will be complete package units consisting of an electric driven hydraulic pump, servo valve, actuator, and a position feed back potentiometer. Electrical power will be supplied by the auxiliary power system.

15,000 lbs. of thrust and using the propellant combination LOX-JP-4. This program will require approximately three years.

The development of a propulsion feed system for the flourine ammonia propellant system will require approximately two and one-half years of research and development. The program will 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 flourine oxidizer.

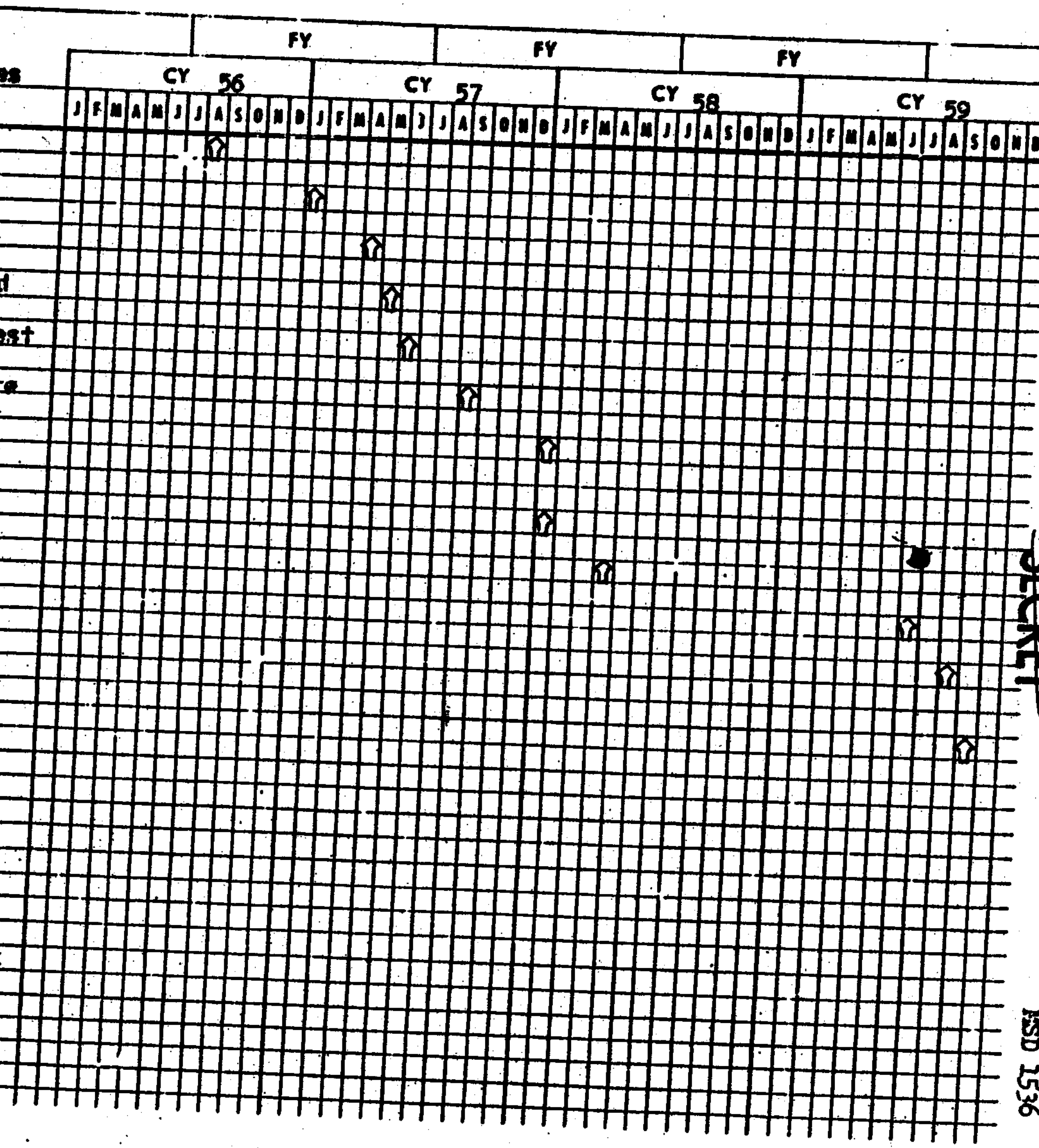
b. Flight Test Program

The propulsion system for the pioneer vehicle will be flight tested primarily on the STV. Flights 10, 11 and 12 of the STV will be used to collect propulsion system performance data, and, as required, data will be taken on subsequent flights. These data will demonstrate the suitability of the design. The early OTV's will also be instrumentated to record propulsion system performance data. To support the pioneer engine development program, flights will be made prior to STV flight #10 to investigate the ignition characteristics of the engine in a vacuum. The flight test program for the advanced engines will require extensive instrumentation to obtain performance data on turbo-pump, gas generator and thrust chamber performance. Because of the advanced engine propellant combination and the lack of background information on those propellants, this testing will be required. The advanced engine flight test program will require at least six flights on the STV.

Subsystem B - PROPULSION

Tab 2 Summary - Subsystem Milestones

1 Advanced Engine Spec. ✲
2
3 WFNA/UDMH Pioneer Engine Mock-up
4
5 STV Engine Dev. Test Complete
6
7 WFNA/UDMH Pioneer Engine Delivered
8
9 WFNA/UDMH Engine System Captive Test
10
11 STV Propulsion System Test Complete
12
13 WFNA/UDMH Pioneer Propulsion Test
14 Complete
15
16 Advanced Engine Mock-up
17
18 WFNA/UDMH Engine NOTV Flight Test
19
20 Advanced Engine Delivery
21
22 Engine First Flight (STV)
23
24 Advanced Engine Tests (Acc)
25
26 Engine First Flight (PTV)
27
28
29
30
31
32
33 ✲ F_2-NH_3 Engine proposed may be
34
35 replaced by alternate LOX - JP-4
36
37 engine.
38
39
40



Revised Form 103

Subsystem B - PROPULSION

Tab 2 Summary - Hardware Delivery

	CY 56												CY 57												CY 58												CY 59											
	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
WFNA/UDMH Engines for STV																																																
Ground test engines																																																
Flight Development Engines															2	2	1	1	1	1																												
Flight Prototype Engines																	1	1	1																													
																					1	1	1	1	1	1	1	1	1	1	1	1	1			1		1				1							1
WFNS/UDMH Engines of OTV																																																
Ground test engines																																																
Flight Development Engines																		2	1	2	1	2	2																									
Flight Prototype Engines																										2	1	1		1																		
																																1	1	1		1		1	1	1	1	1	1	1	1	1	1	1
Advanced Engines for OPN*																																																
Ground test engines																																																
Flight Development Engines																																																
Flight Prototype Engines (First)																																					2		2	1		1						
																																											2		1	2	1	
																																								1	Jan 60							
T-64 Solid Propellant Rocket Engine																																																
								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1														
																								(Continue at rate of 6/year to 1962)																								

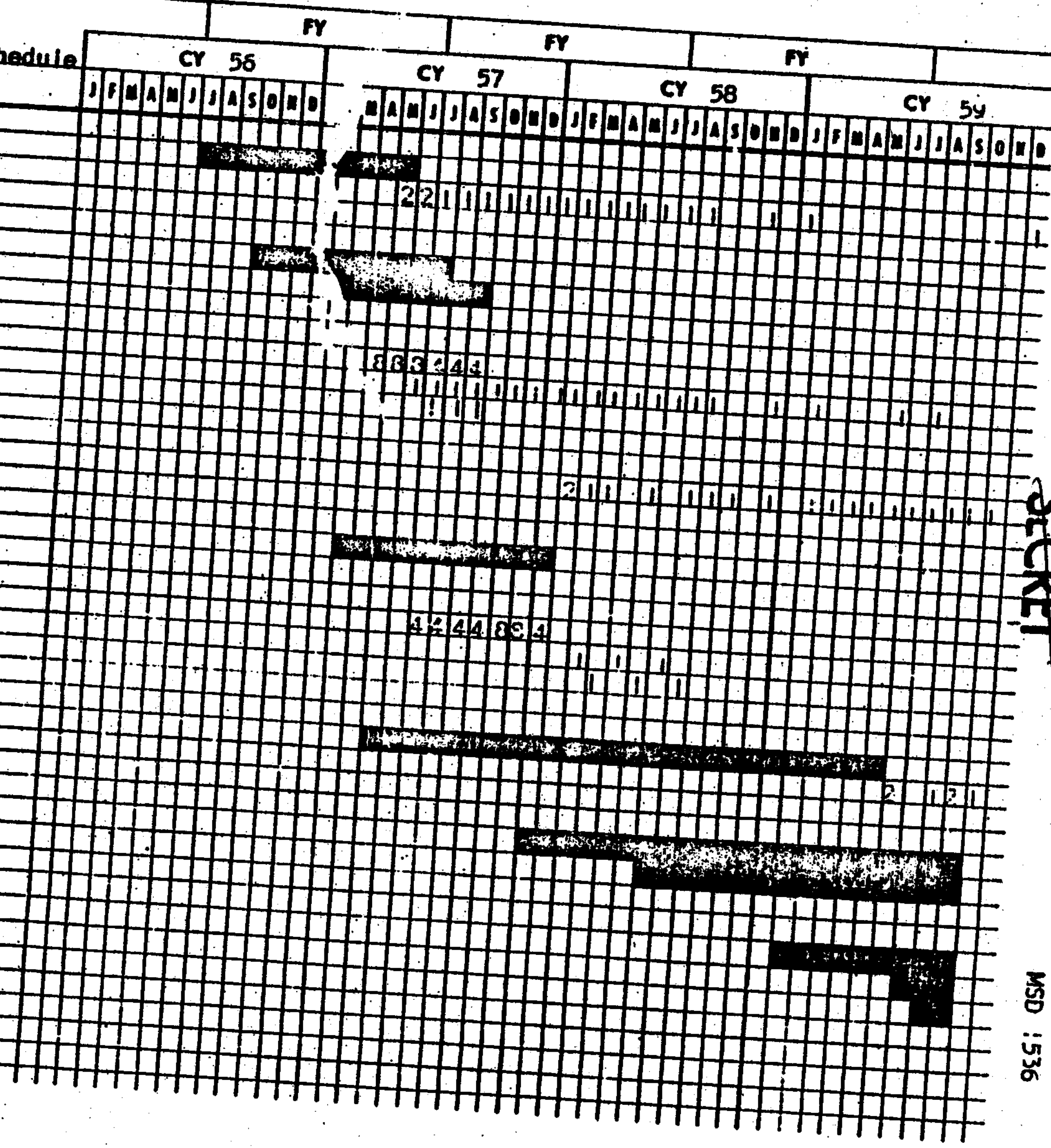
*F_2-NH_3 Engine proposed may be replaced by alternate LOX - JP-4 engine.

Revised Form 103

Subsystem B - PROPULSION

Tab 2 Summary - Subsystem Test Schedule

1 Engines WFNA/UDMH for STV
2 Engine Development Tests
3 Engine Acceptance Tests
4
5 Propellant Feed System for STV
6 Component Development Tests
7 System Development Tests
8
9 Propulsion System for STV
10 Development Tests (Hot Firing)
11 Preflight Tests
12 Flight Tests
13
14 Engines WFNA/UDMH for OTV
15 Engine Acceptance Tests
16
17 Propellant Feed System for OTV
18 System Development Tests
19
20 Propulsion System for OTV
21 Development Tests (Hot Firing)
22 Preflight Tests
23 Flight Tests
24
25 Advanced Engines (1) for OPN
26 Engine Development Tests
27 Engine Acceptance Tests
28
29 Propellant Feed System for OPN
30 Component Development Tests
31 System Development Tests
32
33 Propulsion System for OPN
34 Development Tests (Hot Firing)
35 Preflight Tests
36 Flight Tests
37
38 * F_2-NH_3 Engine proposed may be
39 replaced by alternate LOX - JP-4
40 engine



Revised Form 103