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WS 117L ADVANCED RECONNAISSANCE SYSTEM

DEVELOPMENT PLAN

VOLUME II SUBSYSTEM PLANS

B. Propulsion

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

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MISSILE SYSTEMS DIVISION
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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

Volume	I	SYSTEM PLAN
		Supplement (Top Secret)
Volume	II	SUBSYSTEM PLANS
	A	Vehicle
	B	Propulsion
	C	Auxiliary Power
	D	Guidance and Control
	E	Visual Reconnaissance
	F	Electronic Reconnaissance
	G	Infrared Reconnaissance
	H	Ground-Space Communications
	I	Data Processing and Intelligence Dissemination
	J	Ground Support and Training

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RDB PROJECT CARD

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Subsystem B

PROPULSION

ERRATUM

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

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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.

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LOCKHEED AIRCRAFT CORPORATION

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21 a. <u>Brief and Operational Characteristics</u>

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. <u>Approach</u>

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. <u>Subsystem Tasks</u>

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

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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

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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.

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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

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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 consistsof 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.

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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.

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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.)

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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. Background Data

Not applicable.

21 f. Future Plans

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. References

Not applicable.

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TABS

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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	$\pm$ 45	$\pm$ 45	
Average Deflection Rate, cps	~1	~1	