NASA - Lewis 29 S - NARA

High energy pst vehicle

May 12, 1959

MEMORANDUM For Associate Director

Subject: Proposal for Expanded and Intensified Research on High Energy Upper Stage Propulsion Systems

Reference: Lewis ltr. to NASA Hdqtrs. Attn: Director of Space Flight Development, BTL:bhc, April 16, 1959

1. The potential performance advantages of high-energy propulsion systems have, of course, been recognized for many year; the recent establishment of a National Vehicle Program has also provided a more definite and realistic framework within which to evaluate their worth from a performance standpoint. Whether such performance gains are ~~reliable~~ realizable and practicable depends, however, on the accumulation of further knowledge and experience. It is the objective of this proposal to expand and intensify current research on various critical problem areas as required to provide this necessary knowledge and experience at an early date.

2. The present National Vehicle Program is established, for the most part, on the basis of conventional propellants in the large basement stages and "storable" liquid or solid propellants in the top stages. High energy propellants - specifically, hydrogen and oxygen - are to be first used in the intermediate stages. As pointed out in the reference letter, however, this early use of hydrogen and oxygen in the Centaur stage does not fully capitalize the potential of high energy propellants; second-generation stages of more advanced design seem highly desirable at some future date. Whether such second-generation stages should be hydrogen-oxygen or hydrogen-fluorine cannot be established with certainty at the present time. It is, therefore, the objective of part of this proposal to determine if the performance advantages of fluorine over oxygen are realizable in practice and to establish the design features and operational procedures necessary to its practical application.

3. Looking to the top stages, which must operate in deep space and sometimes execute soft landing maneuvers, large performance advantages may be possible by the use of high-energy systems instead of storables or solids. High energy systems may

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also have additional operational advantages for such stages in terms of starting and re-start capability, throttle-ability over wide thrust ranges and stability at low chamber pressures. As a specific example of the performance advantages of a high-energy top stage, consider the mission of a lunar soft landing with the following system:

Stage 1 - ABMA Cluster	(RPI-O_2)
Stage 2 - Titan I	(RPI-O_2)
Stage 3 - Titan II	(RPI-O_2)
Stage 4 - Centaur 30K	(H_2 - O_2)
Stage 5 - 6K Storable	

It will be recognized that this vehicle is essentially the Juno V-a with the substitution of the Centaur for the presently contemplated 20K storable 4th stage. It should be operational sometime in 1963, about the time a high-energy top stage should be possible. The payload capacity of this system for a soft lunar landing is computed at 2550 pounds. (This compares with 1700 pounds for the standard Juno V-a)

4. It is not presently known whether a high-energy 5th stage should be hydrogen-oxygen or hydrogen-fluorine; both have many relative and conflicting advantages and disadvantages. The use of both propellant combinations were therefore studied, with the following stage specifications as a general guide:

Propellants	H_2 - F_2	H_2 - O_2
Thrust, lb. (variable)	3 - 6K	3 - 6K
Specific Impulse, sec	456	437
Chamber Pressure, psi	30 - 60	300 - 600
Propellant Delivery	pressurized	pumped
Tank pressure, psi	150	40
Stage Gross Weight, lb.	15,000	15,000
Propellant Weight, lb.	8,665	9,635
Hardware Weight, lb.	1,100	1,038
Payload & Guidance, lb.	5,200	4,300

Both stages are restartable, have variable thrust and thrust vector control. An allowance of 300 pounds was made for orientation control, extra propellant for orientation and propellant shielding.

5. As apparent from the above, the substitution of the top storable stage of this system by a 6K high-energy stage may approximately double the payload for a lunar mission. This vehicle system is, furthermore, our first real capability for lunar explorations until Nova becomes available - some 7 or 8 years from now. To thus enhance the capability of this important vehicle, to have a 5,000 instead of a 2,500 pound payload capability in the period of 1963 onward, seems highly desirable and a goal worthy of a fairly intensive research effort.

6. During the past year or so, this Center has had between 60 and 70 research professionals working on the HETU project. Cancellation of this project thus releases these personnel for other tasks. As indicated in the reference letter and in the preceeding, it is proposed to direct this research capability into the following three areas:

(a) Continue ~~and modify~~ those parts of HETU project that provide assistance or assurance for Centaur.

(b) Investigate critical problem areas and components of a 20-30K hydrogen-fluorine booster stage.

(c) Initiate research on hydrogen-fluorine and hydrogen-oxygen systems for top stage applications.

7. Part A - Centaur Assistance

(a) Thrust-chamber development.

An evaluation of the present flight-weight chamber for starting, performance and cooling. Would be conducted in South 40 by Kinney's section and in PSL-1 under altitude conditions by Shillito's section. Tests of prototype engines currently in progress and tests of flight-weight engines scheduled to begin July 1.

Research Personnel Required - 10

Estimated equipment and propellant cost - $300,000

(b) Ground handling and loading tests.

To study and gain experience on loading, hold-times, unloading, topping, disconnect systems and need for strippable insulation of actual flight-type tank at a Plum Brook site. Flight tanks due in three weeks and can be insulated in another three to four weeks. Should be able to start to erect setup in two to three months. Not yet completely established whether this work should be done by Simpkinson's Space Task Group, who were handling this ground launch of the HETV, or by Fluid Systems Division. Seems highly desirable to the writer, however, to have Simpkinson's group make major contribution, both because of heavy work load in Fluid Systems Division in other areas and to make this knowledge and experience available to Space Task Group. After a year's experience on these problems at Plum Brook, the Space Group should be in a good position to contribute importantly to handling and launching of Centaur; they will be the only group with any real experience.

Research Personnel Required - 9 (6 from Space Group, 3 from FSD)

Estimated Cost - $200,000

(c) Flow-System Components

Tests of lines, valves, regulators, controllers for liquid hydrogen. Preliminary phases in progress in Cell 23, Rocket Lab, and scheduled to start at Plum Brook in three months. Ordin's Branch.

Research Personnel Required - 4

Estimated Cost - $150,000

8. <u>Part B - Hydrogen-Fluorine Booster Stage Research</u>

It is visualized that work during the next year would concentrate on those problem areas and components particularly critical to the use of fluorine. This would include some work

on thrust chambers and concentrate most heavily on pumps, bearings and seals, tank materials, gas generators and certain fluid system components. Pending successful developments in the critical areas, work during the second year would proceed into such system integration problems as system stability, turbopumps, tankage, insulation and launching problems.

(a) Thrust Chamber.

Previous research at Lewis indicates that high performance can be obtained and that the chamber and nozzle can be regeneratively cooled. Future work would therefore be directed primarily to determine how closely equilibrium expansion can be approached over a range of chamber pressures, mixture ratios, and nozzle expansion ratios. Much of the work will be done with regeneratively cooled chambers. Work on 5K engines in progress in Cell 22 and scheduled to start on 26K engines at Plum Brook by Saari's section in August.

Required Research Personnel - 8

Estimated equipment and propellant cost - $320,000

(b) Turbopumps and Related Components.

Research on turbopumps would be carried out initially through individual research on the components: fluorine pump, turbine, bearings, seals, and gas generator. Research on fluorine pumps would progress in the direction already taken. Initially, tests would be conducted on pumps of three different existing designs. The results of these tests would lead to a design which would be used in building up a complete turbopump unit of a size compatible with the flight-type thrust chambers mentioned under "Thrust Chamber Research" (approximately 26K).

Turbine research would involve primary emphasis on a 3-stage reentry turbine with a 3-stage axial turbine as a backup. Of special interest would be the corrosion problems associated with HF at high temperature. From this work a turbine design would be evolved for the turbopump unit already mentioned.

Research on bearings and seals would be a necessary part of the research on pumps. This research would involve studies and tests of materials compatibility (friction, etc.), various seal designs, and various bearing types (both hydrodynamic and hydrostatic). Design of the final pumps for the turbopump unit would have to await the results of this research.

Gas generator research would involve designs and tests of several combustion chambers for burning hydrogen and fluorine, along with the necessary controls. Some of these gas generators would be used to supply hot gas to experimental turbines, and a final design would be employed for use with the proposed turbopump unit.

Practically all of this work will be done in the Plum Brook Fluid Systems facility; operation of the pump rig is currently scheduled to start in December, 1959, and other rigs should be available during the next two or three months; much depends on the money situation.

Research Personnel Required

Pumps	- 4
Turbine	- 3
Bearings and Seals	- 4
Gas Generator	- 2
Total	13

Estimated Cost

Pumps	$225,000
Turbines	125,000
Bearings and Seals	275,000
Gas Generator	100,000
Propellants	80,000
Instrumentation	100,000
Total	$905,000

(c) Controls.

The use of fluorine imposes some req ments on controls that are much more seve than for other propellants. Such factors materials compatibility, seals, and adequa purge capability, require research devoted directly to the problems of handling fluorine.

This research would involve flow controls, pressure controls, gas generator controls, turbopump controls, pressurization system controls, and propellant utilization controls. A certain amount of the research would be conducted independently, and the remainder in conjunction with research on thrust chambers, pumps, turbines, gas generators, and complete turbopump systems.

Research Personnel Required - 4

Estimated Cost - $185,000

(d) Materials and Structures.

Research would concentrate on the behavior of materials in fluorine under conditions of storage, high stress, and dynamic loading, and on the problems of notch sensitivity and biaxial stress in liquid hydrogen. This would continue and expand the present program to put more emphasis on the fluorine environment, include types of joining for fluorine service, and determining the effects melting methods, heat treatments, and mechanical working of materials on low temperature notch sensitivity and susceptibility to fluorine attack. Study of joints other than continuous welds are included in this program, but would not be started until the latter part of fiscal 1960.

Materials would include aluminum alloys, austenitic stainless steels, precipitation hardening stainless steels, nickel base alloys, and titanium alloys.

Research Personnel Required - 10

Estimated Cost -

Chemical reaction effects	$100,000
Development of optimum material properties	325,000
Joining studies	10,000
Total	$435,000

9. Part C - Research for High-Energy Top Stage Applications.

While past research at this center, as well as many aspects of the above program of work, provides a considerable background of experience and facilities to build upon, the satisfactory application of high energy propellants to top stages will require the accumulation of new knowledge in many areas and the development of several new concepts. For the pressurized hydrogen-fluorine system, new exploratory research is required on performance and cooling at low chamber pressures, on low-pressure injector performance and on starting, restarting and throttling characteristics over wide thrust ranges. Important, new problem areas relating to a hydrogen-oxygen system are starting and re-start methods, the stability and performance over wide thrust ranges, and on the performance levels obtainable with these small pumps and turbines. Principal problem areas for either propellant combination are orientation controls, small control motors, landing control systems, landing gear systems, hydrogen tankage and insulation and on the heat dynamics of the complete vehicle. A four-year program of work on these, and other, aspects of high-energy top stages has been laid out, the salient features of which are the following:

In Fiscal Year 1960.

1. Experimental studies of performance and cooling at low chamber pressures (10 to 60 psia), low injection pressure differentials (2 to 6 psi) and high area ratios (75:1). Use ~~The~~ existing and modified H-F thrust chambers. 5 Research people, Douglass' section.

2. Experimental testing of flight-type thrust chamber. To include starting, restarting, throttling, endurance, performance and cooling. 4 research people for H-F from Douglass' section; 3 people for H-O from Kinney's section.

3. Analysis and experimental investigation of radiation heat transfer, particularly as a means of cooling part or all of the engine. 4 people, Saari's section.

4. Design tanks, test materials, develop fabrication techniques, prescribe handling methods, evaluate finished tanks and insulation. 8 people, 4 from Esgar's branch and 4 from Ritter's group.

5. Design and investigate performance characteristics of small hydrogen pumps and turbine drives. 6 research people, Ginsburg's branch.

To start in Fiscal Year 1963.

1. Static fire complete system at altitude conditions.

11. The overall cost estimate for equipment and propellants for the above program of work is as follows:

(a) Centaur Support.

1.	Thrust Chamber development	- $300,000	
2.	Ground handling and loading	- 200,000	
3.	Flow system components	- 150,000	
	Subtotal, Centaur		$ 650,000

(b) Hydrogen-Fluorine Booster Stage Research.

1.	Thrust Chamber	- $320,000	
2.	Turbopumps and related components	- 905,000	
3.	Controls	- 185,000	
4.	Materials and Structures	- 435,000	
	Subtotal, H-F Booster		$1,845,000

(c) High-Energy Top Stage Research

1.	Performance and cooling at low P_c	- $200,000	
2.	Tests of flight thrust chambers	- 450,000	
3.	Radiative heat transfer tests	- 60,000	
4.	Tanks and test materials	- 180,000	
5.	Pumps and turbines	- 240,000	
6.	Ground handling equipment	- 150,000	
7.	Analysis of heat dynamics	- 3,000	
8.	Orientation and landing controls	- 80,000	

9.	Landing gear	- $120,000	
10.	Mission analysis and vehicle design	- 2,000	
	Subtotal, high-energy top stage		$1,485,000
	Total, complete program		$3,980,000

12. A summary of the estimated personnel required is as follows:

		PSD	FSD	M&S	Space Group
(1)	Centaur Support	10	7		6
(2)	H-F Booster Stage	12	13	6	
(3)	High-Energy Top Stage	28	11	4	6
	Total	50	31	10	12

Because not all phases of this program of work reach full manpower requirements simultaneously, these estimates may be a little on the high side. It is also worth noting that approximately this number of people have been, or are currently, working on both the HETV project and certain other phases of this program. It is therefore our considered opinion that the research personnel requirements of this total program could be readily met by the pertinent research divisions of the Lewis staff.

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BTL:bhc