OAST SPACE THEME WORKSHOP

VOLUME III

WORKING GROUP SUMMARY

V. PROPULSION (P-1)
   A. Summary Statement
   B. Technology Needs (Form I)
   C. Priority Assessments (Form II)

HELD AT THE
LANGLEY RESEARCH CENTER

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Foreword

The attached material represents the working papers from the OAST Space Theme Workshop held at the Langley Research Center, April 26-30, 1976, and contains a quick-look analysis of the proceedings. The material is unedited and intended for further use by the participants of the workshop and the planning elements of NASA concerned with space mission research and technology. It should be understood that the data do not represent official plans or positions but are part of the process of evolving such plans and positions.

Nearly 100 of the Agency's top technologists and scientists joined with another 35 theme specialists to produce this working document - a document that provides a technical foundation, including research and technology base candidates, for each of the six space themes.

The material in this report is considered essential to the development of Center initiatives in support of these themes. Copies of the report will be made available to the Center Management Board and the individuals at the Centers responsible for the FY'78 program planning cycle. The timing of this planning activity has caused us to distribute this document in this unedited form. Thus, it possibly contains errors, hopefully, more of a typographical rather than a technological nature. Nonetheless, the information contained is of a high professional level, reflecting the efforts of the workshop participants and will be invaluable to the planning and successful execution of the Agency's near- and far-term advanced technology program.

Stanley R. Sadin
OAST Space Theme Workshop
Chairman
NASA Headquarters
Study, Analysis, & Planning Office
Office of Aeronautics and Space Technology
PROPULSION (WG P-1)

Impact of Theme on Discipline Planning.- All theme requirement documents were reviewed and assessed against ongoing and projected propulsion technology programs. Discussions were held with individual theme teams to review overall theme philosophy and clarify specific theme thrusts. Unique propulsion technology requirements to satisfy theme needs were identified and preliminary program planning was attempted.

It became readily apparent that satisfying theme needs, in many cases, will require augmentation of present available resources.

Propulsion programs were generated reflecting these inputs and the technology planned to meet the schedule goals.
Summary of Theme Needs. - All themes require some form of advanced propulsion capability to achieve their stated objectives. Requirements cover a broad spectrum ranging from a new generation of heavy lift launch vehicles to low thrust, long lift system for on-orbit operations.

The first effort of the group was to establish the commonality extant between propulsive technologies and an attempt to group technologies into vehicle classes by functional capability. The Space Transportation Theme (#12) had identified 5 classes of launch vehicles and a time frame for their availability. These classes were augmented by the working group with a sixth class, encompassing planetary and on-orbit operations. Propulsion technologies in each class were then ranked, and assigned priority numbers.

Finally, prioritized technologies were matched to theme requirements and final discussions held with the Theme Teams.
During this process, it became apparent that some Theme needs could not be satisfied without the generation of New Initiative proposals to initiate new efforts or to augment existing programs. These were identified for later submittal.

The views of the Working Group are summarized on the following figures.
PROPULSION TECHNOLOGY WORKING GROUP FINDINGS

OAST SPACE TECHNOLOGY WORKSHOP

APRIL 30, 1976

LANGLEY RESEARCH CENTER

HAMPTON, VIRGINIA
PROPULSION TECHNOLOGY WORKING GROUP

APPROACH

(1) EXAMINED VEHICLE MATRIX FROM THEME 12
(2) DETERMINE TRANSPORTATION NEEDS OF OTHER SPACE THEMES AGAINST THEME 12 REQUIREMENTS
(3) IDENTIFIED TWO ADDITIONAL PROPULSION FUNCTIONS
(4) IDENTIFIED TOTAL PROPULSION NEEDS AGAINST REVISED MATRIX
(5) PRIORITIZED & EVALUATED ALL PROPULSION "NEEDS" FOR EACH VEHICLE
(6) PROVIDED DOCUMENTATION (Rx FORMS)
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PROPULSION TECHNOLOGY WORKING GROUP

PROPULSION NEED RATING CRITERIA

- USE DATE
- CRITICALITY
  - ENABLING
  - ENHANCING
    - HIGH
    - MEDIUM
    - LOW
- PROBABILITY OF MEETING TECHNOLOGY GOAL
PROPULSION WORKING GROUP SUMMARY

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LARGE SPACE STRUCTURES

PTV
FAR TERM

P-1-7
PROPULSION TECHNOLOGY WORKING GROUP

CONCLUSIONS

- THEME 12 UNDERLYING TO ALL OTHERS

- ENABLING PROPULSION TECHNOLOGY AREA KEY TO REDUCED TRANSPORTATION COSTS AND INCREASED SPACE CAPABILITY

- FURTHER OAST EVALUATION OF ALL PROPULSION NEEDS NECESSARY TO ESTABLISH RESOURCE REQUIREMENTS
1. **TITLE**

H₂-O₂ High Performance, Reusable Main Propulsion Systems for Orbit Transfer Vehicles

**NO.1,7,8,12/P-1/1**

**THEME / W.G. / TASK**

**DATE** 4/27/76

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2. **OBJECTIVE**

Develop technology for high performance, reusable H₂-O₂ space propulsion systems, including staged combustion bell nozzle, expander cycle bell nozzle, aerospike, and plug cluster.

---

3. **NEED ANALYSIS**

a) **LEVEL NOW**: [ ]

b) **REQUIRED ADVANCEMENT** - SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY DATE: 1986

c) **RISK IN ACHIEVING ADVANCEMENT**: HIGH [ ] MEDIUM [X] LOW [ ]

d) **CRITICALITY TO THE ACCOMPLISHMENTS**: ENABLING [ ] OR ENHANCING: HIGH [X] MEDIUM [ ] LOW [ ]

e) **TASKS NEEDED**: STUDY [X] ANALYSIS [X] RESEARCH [X] GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]

f) **R&T BASE CANDIDATE**

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4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

---

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

(a) Staged combustion, bell nozzle engine (ASE) - Continue LeRC component technology program on thrust chamber, main fuel and oxidizer turbopumps, preburner, main injector, low cycle thermal fatigue chamber life, turbo-pump bearings and seals, and boost pump multiroller drive system. Expand program with FY78 now initiative, entitled "Reusable Engine Systems Test (RECEST)" (FY78 new start #119) to obtain data on operation of the power-head breadboard assembly of the staged combustion cycle engine and the aerospike engine breadboard. (Cont'd on page 3.)
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

High performance reusable engines are needed to provide maximum payload and low cost through multiple reuses up to 100 missions. High pressure is desirable to provide maximum specific impulse in a small compact package and minimize engine weight. Slush cryogens are needed to reduce tankage volume.

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

506-21-11, 506-21-12, 910-03-01

FY78 New Start #119 - RECEST
FY79 New Start #305 - Plug Cluster Nozzle

9. TECHNOLOGY SCHEDULES

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<td>b) Aerospike Eng. RECEST(FY78#119)</td>
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| MANPOWER (M-Y) |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| INHOUSE CONTRACT |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

| FUNDING (10^6 $) |       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| INHOUSE CONTRACT |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
(b) Aerospike expander cycle engine - Complete planned LeRC program on testing of 25K thrust aerospike chamber. Work also needed on thermal fatigue life of segments of chamber and breadboard system test using
Mark 48 fuel and oxidizer pumps as part of FY78 new start #119 (RECEST).

(c) Plug cluster nozzle program - Complete present program on studies of plug cluster feasibility and performance. Determine operational constraints and system constraints. Conduct flight test of full scale system as part of FY79 new start #305.

(d) Slush cryogens - Evaluate methods of manufacture, storage, handling, pumping, and cost of applying to a flight system. Demonstrate these technology areas at moderate scale.

(e) Reusable cryogenic insulation systems - Continue LeRC program to provide technology on two approaches: (1) evacuated load bearing insulation system, and (2) purged multilayer insulation system.
1. **TITLE**

   Dual Fuel Engine Technology for Mixed Mode Orbit Transfer Vehicle

   **DATE**: 4/27/76

   **THEME/W.G./-task**: NO. 1, 7, 8, 12/P-1/2

2. **OBJECTIVE**

   Develop technology for dual fuel engines burning hydrocarbon or amine fuel and LH₂/LOX in the same engine.

3. **NEED ANALYSIS**

   a) LEVEL NOW [X], WILL BE LEVEL [X] UNDER EXISTING PLANS.

   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL [X] FOR OPERATIONAL SYSTEM USE BY **DATE**: 1986

   c) RISK IN ACHIEVING ADVANCEMENT:

      HIGH [X] MEDIUM [X] LOW [ ]

   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLENIG [X] OR ENHANCING: HIGH [X] MEDIUM [X] LOW [ ]

   e) TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [X]

      GRD TEST [X] AIR CRAFT TEST [X] SPACE FLIGHT TEST [ ]

      (Check one or more)

   f) R&T BASE CANDIDATE [ ]

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

   Perform studies to evaluate use of mixed mode propulsion using dual fuel engine(s) for orbit transfer vehicles. Perform engine system trade-off and parametric studies to determine fuel/oxidizer combinations, engine turbopump drive cycle, cooling method, and component preliminary designs for selected thrust level in the range from 20,000 to 40,000 pounds. Perform component technology programs based on selection of critical components for the engine configuration and propellant combination selected.
Mixed mode propulsion is attractive for OTV's because it provides payload capability equivalent to H₂-O₂ in a smaller volume stage. Where compact size is important, e.g., to fit in the shuttle cargo bay, mixed mode pays off. A dual fuel engine capable of operating on hydrocarbon fuel/LOX/LH₂ or MMH/LOX/LH₂ is required.

9. TECHNOLOGY SCHEDULES

| SCHEDULE ITEM | FY 76 | FY 77 | FY 78 | FY 79 | FY 80 | FY 81 | FY 82 | FY 83 | FY 84 | FY 85 | FY 86 | FY 87 | FY 88 | FY 89 | FY 90 | FY 91 | FY 92 | FY 93 | FY 94 | FY 95 |
|---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| TASK ITEM     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Vehicle Studies |     |     |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Engine Studies |     |     |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Engine Component Technology |     |     |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Engine System Demo |     |     |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

MANPOWER (M-Y)
INHOUSE
CONTRACT

FUNDING (10^6 $)
INHOUSE
CONTRACT
**1. Title**  
LIQUID/SOLID HYBRID PROPULSION FOR OTV  
NO. 7-8-12 P-1 3  
THEME / W.G. / TASK  
DATE 4 / 27 / 76

**2. Objective**  
A HIGHER PERFORMANCE, HIGHER DENSITY PROPULSION SYSTEM WITH  
RESTART CAPABILITY WHICH RESULTS IN LOW WEIGHT FOR ABORT LAUNCH VEHICLE  
LANDINGS WITHOUT ATTENDANT HAZARDS DURING PROPELLANT DUMP OPERATION

**3. Need Analysis**

- **a) Level Now**: 1, will be level 2 under existing plans.
- **b) Required Advancement**: Should be technology ready at level 5 for operational system use by Date: 1987
- **c) Risk in Achieving Advancement**:  
  - HIGH □  
  - MEDIUM X  
  - LOW □
- **d) Criticality to the accomplishments**:  
  - ENABLING □  
  - ENHANCING: HIGH □  
  - MEDIUM X  
  - LOW □
- **e) Tasks Needed**: Study □  
  Analysis X  
  Research X  
  Grd Test X  
  Air Craft Test □  
  Space Flight Test □  
  OTHER (Specify) □
  (Check one or more)

**4. Complementary Technology Advancements Required for Use of This Technology**:  
DEVELOPMENT OF ENERGETIC SOLID FUEL

**5. Specify Technology Advancement Required to Accomplish Need**  
ANALYSIS AND TEST OF A PROPULSION SYSTEM EMPLOYING A LIQUID OXIDIZER  
(E.G. LOX) AND A SOLID FUEL. SYSTEM WOULD PROVIDE A HIGH DENSITY  
MEDIUM ISP COMBINATION, WHICH WOULD HAVE RESTART CAPABILITY. IN CASE  
OF VEHICLE ABORT THE LANDING WEIGHT CAN BE REDUCED WITHOUT THE HAZARDS  
ASSOCIATED WITH THE DUMPING OF TWO IGNITABLE PROPELLANTS (ONLY LOX  
WOULD BE DUMPED).
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

APPLICATION STUDY TO DETERMINE PAY-OFF AND ESTABLISH DESIGN CRITERIA.

REVIEW OF PAST TECHNOLOGY RELATED TO LIQUID/SOLID HYBRIDS. DETERMINE

THE PROPELLANT COMBINATIONS TO BE EVALUATED. INVESTIGATE BURNING

PROPERTIES IN SMALL MOTORS. FABRICATE AND TEST A PROTOTYPE MOTOR.

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

NONE

9. TECHNOLOGY SCHEDULES

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MANPOWER (M-Y)

INHOUSE       | 1.0 | 1.0 | 1.0 |

CONTRACT      |     |     |     |

FUNDING ($10^6$)

INHOUSE       | 1.1 | 1.1 | 1.1 |

CONTRACT      | 1.1 | 2.2 | 3.3 |
TITLE: Liquid/Solid Hybrid Propulsion for OTV

OBJECTIVE: A higher performance, higher density propulsion system with restart capability.

JUSTIFICATION: A liquid/solid hybrid system will provide higher lsp than a solid and higher density than a liquid. In case of abort landings, it is lighter than a solid and less hazardous than a liquid.

TECHNICAL APPROACH/PLAN:
Application study to determine pay-off and establish design criteria. Review past technology related to liquid/solid hybrids. Determine the propellant combinations to be evaluated. Investigate burning and ballistic properties in small motors. Fabricate & test a prototype.

SCHEDULE:

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MANPOWER (M-Y)

| IN-HOUSE | 1.0 | 1.0 | 2.0 | 2.0 | 2.0 |
| CONTRACT |     |     |     |     |     |

FUNDING ($10^6)

| IN-HOUSE | 1.0 | 2.0 | 2.2 | 2.2 | 2.2 |
| CONTRACT |     |     |     |     |     |

NOTE: FY78 Funding in R&T Base

PROPOSED LEAD CENTER: MSFC with JPL support.

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
# SPACE TECHNOLOGY NEED

## 1. TITLE
Solid Propulsion Advanced Technology

### NO7-8-10-12/P-1

#### THEME / W.G. / TASK
Motor

#### DATE 4 / 27 / 76

## 2. OBJECTIVE
Improve performance, operational flexibility and decrease cost of solid propellant motors used in the advanced space transportation system (launch vehicles and orbital transfer vehicles).

## 3. NEED ANALYSIS

<table>
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<th>Will Be Level</th>
<th>Under Existing Plans</th>
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### b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL 5 FOR OPERATIONAL SYSTEM USE BY DATE: 1985

### c) RISK IN ACHIEVING ADVANCEMENT: Not approved Level 5 by 1980

### d) CRITICALITY TO THE ACCOMPLISHMENTS:
- ENABLING |
- MEDIUM |
- LOW

### e) TASKS NEEDED:
- STUDY |
- ANALYSIS |
- RESEARCH
- GRD TEST |
- AIR CRAFT TEST |
- SPACE FLIGHT TEST |
- OTHER (Specify)

### f) R&T BASE CANDIDATE
Yes

## 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY
- Materials suitable for hot gas valve and duct, high strength composites, carbon ablative propellant formulations providing high performance.

## 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
- Hot gas manifold and valve for hot gas bleed TVC system, materials and fabrication techniques for low cost nozzles; stop-restart; low cost, light-weight case designs; improved propellant and insulation formulations; low pollution (mixed oxidizer) propellants; extendable nozzles.
**TITLE:** Solid Propulsion Advanced Technology Motor

**NO:** 7-8-10/1976-1/4

**THEME/W.G./TASK:**

**DATE:** 4/27/76

### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Conduct feasibility design studies and component tests leading to prototype motor demonstration tests including the technology items described above. The plan will be accomplished using appropriately scaled motors depending on whether the application is OTV or launch vehicles.

### 7. ALTERNATIVE APPROACHES/OPTIONS

- Liquids and liquid/solid hybrid propulsion systems.

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

- RTOP 506-21-32 (Advanced solid propulsion concepts)
- New initiative has been proposed from JPL-No. 302
- New initiative has been proposed from MSFC-No. TBD

### 9. TECHNOLOGY SCHEDULES

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# SPACE TECHNOLOGY NEED

**FORM NO. 1**

**PAGE 1 OF 2**

## 1. TITLE

<table>
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<th>ATOMIC/METALLIC HYDROGEN PROPULSION TECHNOLOGY</th>
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**NO.1\_7-9-10-11-12/P-1/6**

**THEME / W.G. / TASK**

**DATE 4/27/76**

## 2. OBJECTIVE

Develop basic technology to show the feasibility of manufacturing and storing atomic or metallic H₂ in quantities needed for propulsion applications.

## 3. NEED ANALYSIS

a) **LEVEL NOW** [ ] **WILL BE LEVEL** [ ] **UNDER EXISTING PLANS.**

b) **REQUIRED ADVANCEMENT** – SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY **DATE: 2000**

c) **RISK IN ACHIEVING ADVANCEMENT:**

| HIGH [x] | MEDIUM [ ] | LOW [ ] |

d) **CRITICALITY TO THE ACCOMPLISHMENTS:**

| ENABLING [x] | HIGH [x] | MEDIUM [ ] | LOW [ ] |

e) **TASKS NEEDED:**

| STUDY [x] | ANALYSIS [x] | RESEARCH [x] | GRD TEST [x] | AIR CRAFT TEST [ ] | SPACE FLIGHT TEST [ ] |

**OTHER (Specify) [ ]**

(f) **R&T BASE CANDIDATE**

| YES (FY 78 - 350K) |

## 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

________________________________________________________________________

________________________________________________________________________

## 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

THEORETICAL STUDIES HAVE SHOWN THAT SIGNIFICANT INCREASES IN PERFORMANCE (1700 ISP) CAN BE ACHIEVED IN PROPULSION SYSTEMS UTILIZING ATOMIC OR METALLIC FORMS OF HYDROGEN. TECHNOLOGY MUST BE DEVELOPED TO PERMIT THE MANUFACTURE AND STORAGE OF THESE PROPELLANTS IN THE QUANTITIES NEEDED IN PROPULSION APPLICATIONS, TO DETERMINE THEIR PHYSICAL PROPERTIES AND ASSESS THEIR APPLICATION TO PROPULSION SYSTEMS.

________________________________________________________________________

________________________________________________________________________
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED
   - Produce & measure properties of metallic hydrogen
   - Assess feasibility of metallic hydrogen as a rocket propellant
   - Produce & measure properties of atomic hydrogen
   - Assess feasibility of producing large quantities & rocket application
   - Develop storage capability to store atomic & metallic forms

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
   Research on production of atomic & metallic hydrogen in progress.

9. TECHNOLOGY SCHEDULES

   | SCHEDULE ITEM | FY 76 | FY 77 | FY 78 | FY 79 | FY 80 | FY 81 | FY 82 | FY 83 | FY 84 | FY 85 | FY 86 | FY 87 | FY 88 | FY 89 | FY 90 | FY 91 | FY 92 | FY 93 | FY 94 | FY 95 |
   |---------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
   | TASK ITEM     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
   | PRODUCE METAL-LIC H |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
   | ASSESS FEASIBILITY |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
   | PRODUCE ATOMIC H |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
   | QUANTITY ASSESS |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
   | DEVELOP STORAGE |     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

   MANPOWER (M-Y)
   INHOUSE: 8, 8, 8, 8, 8, 8
   CONTRACT: 8, 8, 8, 8, 8, 8

   FUNDING (10^6 $)
   INHOUSE: 8, 8, 8, 8, 8, 8
   CONTRACT: 8, 8, 8, 8, 8, 8
1. TITLE  
**STORAGE, SUPPLY AND TRANSFER OF CRYOGENIC FLUIDS IN SPACE**  
NO. 7, 8, 12/P-17  
THEME / W.G. / TASK  
DATE 4/27/76

2. OBJECTIVE  
Provide a subcritical storage and supply system for cryogenic fluids to minimize system weight and provide the means to replenish fluids on-orbit.

3. NEED ANALYSIS

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| Other (Specify) | |
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4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

- Demonstrate reusability of insulation system
- Determine behavior in reduced gravity of LH₂, LO₂ and LHe
- Demonstrate thermal control system performance
- Demonstrate fluid acquisition and control in reduced gravity for cryogens
- Demonstrate outflow and inflow fluid dynamics
5. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED
   * Continue current technology program
   * Flight verification of storage and acquisition system
   * Flight verification of complete transfer system

6. ALTERNATIVE APPROACHES/OPTIONS

7. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
   Technology program on reduce gravity fluid systems,
   thermal control systems and reusable insulation systems

8. TECHNOLOGY SCHEDULES

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<p>| MANPOWER (M-Y) |</p>
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**SPACE TECHNOLOGY NEED**

**FORM NO. 1**

**PAGE 1 OF 3**

**1. TITLE** Liquid Hydrogen/Liquid Oxygen Attitude Control Systems for OTV Application

**NO.** 1,7,8,12/P-1/8

**THEME / W.G. / TASK**

**DATE** 4/27/76

**2. OBJECTIVE**

Develop technology for components of a LH$_2$/LOX APS, such as thrusters, pumps, zero g reservoirs, and accumulators, and perform systems testing.

**3. NEED ANALYSIS**

a) LEVEL NOW [3], WILL BE LEVEL [4] UNDER EXISTING PLANS.


c) RISK IN ACHIEVING ADVANCEMENT:

HIGH [ ] MEDIUM [x] LOW [ ]

d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [ ] OR ENHANCING: HIGH [ ] MEDIUM [x] LOW [ ]

e) TASKS NEEDED: STUDY [ ] ANALYSIS [ ] RESEARCH [x]

GRD TEST [x] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [x]

OTHER (Specify) [ ]

(Check one or more)

f) R&T BASE CANDIDATE [ ] Yes

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**


**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

Development of technology for LH$_2$/LOX system for OTV's, including small thrusters (25 to 100 lbs. thrust), small cryogenic positive displacement pumps, accumulators, controls, refillable zero g reservoir, and propellant systems. After component technology is completed, systems testing will be performed to evaluate control requirements and measure heat input effects to thrusters and feed lines. Flight test demonstration as shuttle payload package needed to fully show flight readiness of all aspects of this system technology.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Cryogenic APS offers advantages of high performance, light total system weight, clean non-toxic exhaust, and commonality of propellants with main propulsion system. Thruster technology has been demonstrated at 1250 lbs. thrust but not at smaller sizes where thermal control problems are more difficult. Small thrust cryogenic engines must be specially designed for accurate thermal control so that rapid start-up is achieved with cryogenic (See page 3.)

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

FY80 New Start (#317) - "Functional and Performance Verification of an Integrated LH₂/LOX APS"

9. TECHNOLOGY SCHEDULES

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FUNDING (10^6 $)
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<td>propellants entering a warm engine. Long life and small impulse bits are required to meet OTV requirements. For small pumps, rapid start-up and long life are needed which are difficult requirements for small cryogenic positive displacement pumps.</td>
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**SPACE TECHNOLOGY NEED**

**FORM NO. 1**

**PAGE 1 OF 2**

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<th>1. TITLE</th>
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2. **OBJECTIVE**

Improve lifetime capability and performance level of earth-storable bipropellants.

3. **NEED ANALYSIS**

   a) **LEVEL NOW** | 4 |
   
   b) **REQUIRED ADVANCEMENT** - SHOULD BE TECHNOLOGY READY AT LEVEL | 4 |
   
   c) **RISK IN ACHIEVING ADVANCEMENT:**
      - HIGH | X |
      - MEDIUM | |
      - LOW | |
   
   d) **CRITICALITY TO THE ACCOMPLISHMENTS:**
      - ENABLING | X |
      - MEDIUM | |
      - LOW | |
   
   e) **TASKS NEEDED:**
      - STUDY | |
      - ANALYSIS | X |
      - RESEARCH | |
      - GRD TEST | X |
      - AIR CRAFT TEST | |
      - SPACE FLIGHT TEST | |
      - OTHER (Specify) | |
   
   f) **R&T BASE CANDIDATE** | Yes |

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

None

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

Improve the lifetime capability of earth storable liquid bipropellants by the development of new materials for thrusters and hard seats for valves. Increase the performance level by the test and evaluation of the bimodal engine technology.
**SPACE TECHNOLOGY NEED**

**TITLE** Earth Storable Propulsion for Planetary Spacecraft

**NO.** 10/P-1/9  
**THEME / W.G. / TASK**  
**DATE** 4/28/76

**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

Conduct systems studies to identify life-limiting components.
Evaluate components and assemble a system for verification testing.
Determine interactions and technology readiness. Test and evaluate bimodal engine system operation.

**7. ALTERNATIVE APPROACHES/OPTIONS**

Monopropellant system, which has lower performance; or live with life-limiting components and replace as necessary.

**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

None

**9. TECHNOLOGY SCHEDULES**

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</table>
**Title:** Resistojet for (c) OTV Main Propulsion, No. 7-12 P-1 11
**Auxiliary Propulsion SEP-NEP**

**Objective:** Develop a long life, high performance Resistojet capable of using monopropellant Hydrazine or low freezing point monopropellants utilizing electrical heater power from either NEP or SEP sources.

**Need Analysis:**
- a) Level now [3], will be level [4] under existing plans.
- c) Risk in achieving advancement: High [ ], Medium [x], Low [x].
- d) Criticality to the accomplishments: Enabling [ ], or Enhancing: High [ ], Medium [x], Low [ ].
- e) Tasks needed: Study [ ], Analysis [x], Research [x], Grd test [x], Air craft test [ ], Space flight test [ ].
- f) R&T base candidate $250K for FY 78.

**Complementary Technology Advancements Required for Use of This Technology:**
- Resistojet requires electrical heater power from the NEP or SEP.

**Specify Technology Advancement Required to Accomplish Need:**
1. Thrust levels must be scaled up from present low levels.
2. Resistojet utilizing low freezing point propellant (e.g. MMH) must be developed.
3. Improved long life heaters must be developed for HIPET - LFP propellant application.
4. Materials improvement program must be initiated.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

(1) Complete hydrazine electrothermal thruster development at 22N thrust level.

(2) Develop a 22N HIPETH

(3) Develop low freezing point full electrothermal thruster to eliminate thermal problem.

(4) Develop HIPET type heaters for use with carbon based low freezing point fuels.

7. ALTERNATIVE APPROACHES/OPTIONS

None

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

Auxiliary Electric Propulsion Systems

RTOP 506-22-10

9. TECHNOLOGY SCHEDULES

| SCHEDULE ITEM       | FY 76 | FY 77 | FY 78 | FY 79 | FY 80 | FY 81 | FY 82 | FY 83 | FY 84 | FY 85 | FY 86 | FY 87 | FY 88 | FY 89 | FY 90 | FY 91 | FY 92 | FY 93 | FY 94 | FY 95 |
|---------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| TASK ITEM           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (1) 22N EHT         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (2) 22N HIPETH      |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (3) LFP ET          |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (4) LFP HIPET       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (5) Materials       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| (6) Life Test       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

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| INHOUSE             | 55    | 25    | 15    | 10    | 10    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| CONTRACT            | 55    | 25    | 15    | 10    | 10    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |</p>
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<td>(5)</td>
<td>Conduct a materials improvement program to prevent nitriding of thruster.</td>
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<td>(6)</td>
<td>Conduct long life testing of developed hardware in both the pulse and steady state mode of operation.</td>
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**SPACE TECHNOLOGY ADDITIONAL INITIATIVE**

**FORM IV**

**TITLE** Hydrogen Resistojet C(OTV)

**DATE** 4/29/76

**TT NO.** 7-12  **OR WORKING GROUP NO.** P-1

**OBJECTIVE**
Develop High ISP moderate thrust resistojet

**JUSTIFICATION**
Present resistojets utilize hydrazine which provides moderate ISP

**TECHNICAL APPROACH/PLAN**
1. Design, fabricate, and conduct tests on high temperature H₂ resistojet
2. Conduct development on high temperature heaters
3. Conduct life test program
4. System development and test

**SCHEDULE**

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**PROPOSED LEAD CENTER** JSC

**RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT**
1. TITLE  MPD Thruster System Technology  NO.7,8,9,10,11,12/P-1/12
       Readiness (SEP and NEP)

2. OBJECTIVE
   The MPD thruster propulsion system, now seen as essential for economical large cargo earth orbit operations, will be brought to technology readiness.

3. NEED ANALYSIS
   a) LEVEL NOW  [2], WILL BE LEVEL  [5] UNDER EXISTING PLANS (includes new initiative)
   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY
      AT LEVEL  [7] FOR OPERATIONAL SYSTEM USE BY  [DATE: 1990]
   c) RISK IN ACHIEVING ADVANCEMENT:
      HIGH [ ] MEDIUM [x] LOW [ ]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [x] OR ENHANCING: HIGH [x] MEDIUM [ ] LOW [ ]
   e) TASKS NEEDED: STUDY [x] ANALYSIS [x] RESEARCH [x]
      GRD TEST [x] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [x]
      OTHER (Specify) [ ]
      (Check one or more)
   f) R&T BASE CANDIDATE  yes

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY
   Nuclear-thermonic power system development
   or high power lightweight solar arrays.

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
   Incorporate recent research results on pulsed mode operating research devices into a high power level thruster capable of operating at steady state. Determine performance levels & identify promising avenues of thruster improvement. Define an MPD Thruster System and initiate development of critical components.
### SPACE TECHNOLOGY NEED

**TITLE:** MPD Thruster System Technology Readiness (SEP & NEP)

**NO:** 7, 8, 9, 10, 11, 12/P-1/12

**THEME / W.G. / TASK:**

**DATE:** 4/27/76

---

6. **RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

1. Design, fabricate, and conduct tests on a high power MPD thruster.
2. Conduct research into ways of increasing MPD thruster efficiency and lifetime.
3. Develop thrust subsystem concepts.
4. Design, fabricate & test critical system components.

---

7. **ALTERNATIVE APPROACHES/OPTIONS**

- Large size Ion thrusters (~100 cm dia)

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8. **CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

- JPL FY78 new initiative on MPD thruster system technology readiness.

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9. **TECHNOLOGY SCHEDULES**

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**PAGE 2 OF 2**
1. **TITLE**  
High Specific Impulse Electric Propulsion for Orbital Transfer Vehicle (OTV)

**NO.7,8,9,11,12/P1/13**  
**THEME/W.G./TASK**  
**DATE 4/28/76**

2. **OBJECTIVE**  
Provide the Technology for an Efficient High Specific Impulse Ion Thruster System for Orbit Raising from Low Earth Orbit to a Higher Orbit using Low Cost Inert Fuels

3. **NEED ANALYSIS**

   a) **LEVEL NOW**: 8, **WILL BE LEVEL**: 5 **UNDER EXISTING PLANS**.
   
b) **REQUIRED ADVANCEMENT** – **SHOULD BE TECHNOLOGY READY AT LEVEL**: 7 **FOR OPERATIONAL SYSTEM USE BY DATE: 1990**
   
c) **RISK IN ACHIEVING ADVANCEMENT**:  
   HIGH [ ]  MEDIUM [ ]  LOW [x]
   
d) **CRITICALITY TO THE ACCOMPLISHMENTS**:  
   ENABLING [x] OR ENHANCING:  
   HIGH [ ]  MEDIUM [ ]  LOW [ ]
   
e) **TASKS NEEDED**:  
   STUDY [x]  ANALYSIS [ ]  RESEARCH [x]  
   GRD TEST [x]  AIR CRAFT TEST [ ]  SPACE FLIGHT TEST [x]
   
   (Check one or more)
   
f) **R&T BASE CANDIDATE**

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**  
High power, lightweight solar arrays, N.E.P. Power Source

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

   (1) Scaling of present thruster systems to required sizes
   
   (2) Efficient operation demonstrated on inert gases
   
   (3) Demonstration of adequate total impulse per thruster module

   (Check one or more)
**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

1. Define System Requirements
2. Design Thruster System
3. Incorporate into Existing Technology Program
4. Perform Directed R&T
5. Demonstrate Critical Performance Parameters

**7. ALTERNATIVE APPROACHES/OPTIONS**

---

**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

- RTOP 506-22-30, 506-22-40
- Propulsion Pallet Experiment, SPHINX B/C
- LeRC '78 New Initiative to develop thrust subsystem technology

**9. TECHNOLOGY SCHEDULES**

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**MANPOWER (M-Y)**

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**FUNDING ($10^6)**

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### SPACE TECHNOLOGY NEED

**FORM NO. 1**

**PAGE 1 OF 3**

<table>
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<th>1. TITLE</th>
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#### 2. OBJECTIVE

To provide high specific impulse in a low thrust propulsion system suitable for spacecraft. The use of (Cont)

#### 3. NEED ANALYSIS

- **a) LEVEL NOW** [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
- **b) REQUIRED ADVANCEMENT** – SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY [ ] DATE: 1990 [ ]
- **c) RISK IN ACHIEVING ADVANCEMENT:** HIGH [ ] MEDIUM [ ] LOW [ ]
- **d) CRITICALITY TO THE ACCOMPLISHMENTS:** ENABLING [ ] OR ENHANCING: HIGH [ ] MEDIUM [ ] LOW [ ]
- **e) TASKS NEEDED:** STUDY [X] ANALYSIS [X] RESEARCH [X]
  - GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [X]
  - OTHER (Specify) [ ]
  - (Check one or more)
- **f) R&T BASE CANDIDATE** [ ] Yes

#### 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

Long term storage of cryogens in space.

#### 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

The system is visualized as consisting of a solar energy collector, a form of a solar furnace, a heat exchanger, and a nozzle. The concept is to heat hydrogen (stored as a liquid) and expand it to a high exhaust velocity through a suitable nozzle. Technology is required to provide a lightweight form of a solar furnace suitable for a spacecraft.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Conduct total system studies to determine design criteria and interface requirements. Prepare conceptual design. Execute technology demonstration of subsystem elements. Fabricate and test total system. Conduct flight tests in space environment.

7. ALTERNATIVE APPROACHES/OPTIONS

- Hydrogen/oxygen system
- Oxygen/hydrocarbon system
- SEP, N₂H₄ monopropellant

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

9. TECHNOLOGY SCHEDULES

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MANPOWER (M-Y)

| INHOUSE       | .2 | .4 | .4 | 1.0 | 1.5 | TBD |
| CONTRACT      |    |    |    |    |    |     |

FUNDING (10^6 $)

| INHOUSE       | .1 | .4 | .8 | 1.6 | 1.8 | TBD |
| CONTRACT      |    |    |    |    |    |     |
1. TITLE  Solar Heated Hydrogen Thruster

(continuation)

Solar energy to heat hydrogen eliminates the need to carry an oxidizer, and provides the potential for Isp values greater than 1000 sec. In addition, the exhaust products are benign and avoid potential contamination of sensors and optical devices.
# SPACE TECHNOLOGY NEED

## 1. TITLE
- Laser Propulsion System for Orbit Transfer Vehicle

## 2. OBJECTIVE
- Provide high Isp (1000 to 2000 sec) laser-heated rocket engine for orbit to orbit transfer of unmanned payloads and to provide attitude control capability.

## 3. NEED ANALYSIS
- **a)** Level now **3**, will be level **4** under existing plans.
- **b)** Required advancement - should be technology ready at level **7** for operational system use by **1990**
- **c)** Risk in achieving advancement:
  - High [ ]
  - Medium [ ]
  - Low [ ]
- **d)** Criticality to the accomplishments:
  - Enabling [ ]
  - Enhancing [ ]
- **e)** Tasks needed:
  - Study [x]
  - Analysis [x]
  - Research [x]
  - Grd Test [x]
  - Air Craft Test [ ]
  - Space Flight Test [ ]
  - Other (Specify) [ ]

- **f)** R&T Base Candidate: Yes (FY '76 $200k; FY '78 $1000k)

## 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY
- Laser power transmitter, large power systems (greater than 1 Mw) in geosync orbit.

## 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
- **a)** Demonstrate absorption of laser radiation in gases to produce Isp between 1000 and 2000 sec
- **b)** Devise practical lightweight laser-tube collector to focus beam into rocket propellants.
**SPACE TECHNOLOGY NEED**

**TITLE** Laser Propulsion System for Orbit Transfer Vehicle.

**DATE** 4/27/76

6. **RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**
   - Continue current research on laser propulsion
   - Conduct ground demonstration of a laser propulsion system
   - Conduct flight test of a scale model of a laser propulsion system
   - Conduct flight test of lightweight collector and optics system.

7. **ALTERNATIVE APPROACHES/OPTIONS**

8. **CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**
   - Research on laser-heated rocket propulsion systems

9. **TECHNOLOGY SCHEDULES**

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**MANPOWER (M-Y)**
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  - FY 78: 4
  - FY 80: 5
  - FY 82: 5
  - FY 83: 7
  - FY 86: 6

**CONTRACT**
- **INHOUSE**
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**FUNDING ($10^6)**
- **INHOUSE**
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- **CONTRACT**
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## Space Technology Need

### 1. Title
- **H/O Bell Nozzle Engine (Advanced SSME)**
- **No. 8-10-12 P-1 17**
- **Theme / W.G. / Task**
- **Date 4/27/76**

### 2. Objective
- Provide an advanced SSME for HLLV, HLLV<sub>2</sub>, and advanced vehicle. Improvements with increase I<sub>s</sub>p, expand operational capability, and decrease ullage & vehicle weight. (Cont'd)

### 3. Need Analysis

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<td>a) Level now 3, will be level 3 under existing plans.</td>
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<td>b) Required advancement - should be technology ready at level 3 for operational system use by [Date: 1985]</td>
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<td>f) R&amp;T Base Candidate</td>
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### 4. Complementary Technology Advancements Required for Use of This Technology
- Zero NPSH for LOX pumps, extendible nozzles, materials for high temperature turbine blades

### 5. Specify Technology Advancement Required to Accomplish Need
- Component testing for zero NPSH in LOX pumps (LH<sub>2</sub> zero NPSH already established); cooling techniques and material advancements necessary for increased chamber pressure; engine system tests to examine transient and steady state parameters (similar to J25 testing); idle more analyses and demonstration.
### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Study engine system to quantify potential improvements; acquire component technology; redesign, fabricate and test subsystems; assemble and test experimental engine.

### 7. ALTERNATIVE APPROACHES/OPTIONS

Standard SSME

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

RTOP in planning stage

### 9. TECHNOLOGY SCHEDULES

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**MANPOWER (M-Y)**

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**FUNDING (10^6 $)**

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### SPACE TECHNOLOGY NEED

**1. TITLE**  
H/0 BELL NOZZLE ENGINE  
(ADVANCED SSME)

**NO.** B-10-12  
**P-1 17**  
**THEME/W.G./TASK**  
**DATE** 4/27/76

---

**ADVANCED VEHICLE STUDIES HAVE INDICATED A PRIME NEED FOR EXTENDIBLE NOZZLES.**  
THE SSME EXPERIMENTAL ENGINE IS IDEAL FOR PROVIDING THIS TECHNOLOGY WHICH IS READILY TRANSFERABLE TO OTHER ENGINE CONFIGURATIONS.  

BY PROVIDING IDLE MODE CAPABILITY IN THE SSME, IT MAY BE POSSIBLE TO ELIMINATE THE NEED FOR AN ORBIT MANEUVERING SYSTEM IN THE ORBITER OR THE 2ND STAGE OF AN HLLV, OR HLLV_2. IDLE MODE AND ZERO NPSH ARE ATTRACTIVE METHODS FOR UTILIZING PROPELLANT RESIDUALS. ZERO NPSH ALSO DECREASES THE REQUIRED PROPELLANT ULLAGE PRESSURES, AND CONSEQUENTLY DECREASES VEHICLE WEIGHT. INCREASED Isp CAN BE PROVIDED BY INCREASING EXPANSION RATIO MADE POSSIBLE BY INCREASED CHAMBER PRESSURE. PRELIMINARY STUDIES INDICATE THAT INCREASED PC WILL PROBABLY REQUIRE INCREASED TURBINE INLET TEMPERATURES, WHICH IN TURN REQUIRES ADVANCED MATERIALS FOR TURBINE BLADES.

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**CONTINUATION (If Needed)**

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**SPACE TECHNOLOGY NEED**

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<th>AIR AUGMENTATION OF EARTH TO ORBIT SOLID ROCKET ENGINES</th>
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<td>NO. 8-12 P-1 19 THEME/W.G.7 TASK</td>
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| 2. OBJECTIVE | To provide a 5 to 7 percent increase in booster engine Isp through air augmentation |

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<td>c) RISK IN ACHIEVING ADVANCEMENT: HIGH [X] MEDIUM [ ] LOW [X]</td>
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<td>d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING: HIGH [X] MEDIUM [ ] LOW [ ]</td>
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<td>e) TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [ ] GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [X] OTHER (Specify) [ ]</td>
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<tr>
<td>f) R&amp;T BASE CANDIDATE</td>
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| 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY |

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<th>5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED</th>
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<tr>
<td>Air augmentation is currently used in cruise missile applications where essentially steady state operation is achieved. Launch vehicle benefit will be determined where altitude variation results in transient operating conditions. Analysis and preliminary data indicate a 5 to 7 percent increase in Isp may be realized.</td>
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</table>
AIR AUGMENTATION OF EARTH TO ORBIT
SOLID ROCKET ENGINES

DATE 4/27/76

6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED
- Conduct R & T studies to develop concept and verify overall benefit
- Conduct ground based tests and subscale flight test to verify experimentally the performance gains
- Conduct full scale flight verification test

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

9. TECHNOLOGY SCHEDULES

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MANPOWER (M-Y)
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FUNDING (10^6 $)
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CONTRACT 0.0 1.5 1.0 1.0 1.0
1. **TITLE** Liquid Hydrogen/Liquid Oxygen
   Attitude Control Systems for
   Launch Vehicles (HLLV)

2. **OBJECTIVE**
   Develop technology for components of a LH2/LOX APS, such as
   thrusters, pumps, zero "g" reservoir, and accumulators, and
   perform systems testing.

3. **NEED ANALYSIS**
   a) **LEVEL NOW** [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
   b) **REQUIRED ADVANCEMENT** - SHOULD BE TECHNOLOGY READY
      AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY [DATE: 1985]
   c) **RISK IN ACHIEVING ADVANCEMENT:**
      HIGH [ ] MEDIUM [X] LOW [ ]
   d) **CRITICALITY TO THE ACCOMPLISHMENTS:**
      ENABLING [ ] OR
      ENHANCING: HIGH [ ] MEDIUM [X] LOW [ ]
   e) **TASKS NEEDED:**
      STUDY [ ] ANALYSIS [ ] RESEARCH [X]
      AIR CRAFT TEST [ ] SPACE FLIGHT TEST [X]
      OTHER (Specify) [ ]
   f) **R&T BASE CANDIDATE** Yes

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR
   USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO
   ACCOMPLISH NEED**
   Development of technology for LH2/LOX system for advanced
   launch vehicles, including thrusters (800 to 1,500 lbs. thrust),
   small cryogenic positive displacement pumps, accumulators,
   controls, refillable zero "g" reservoirs, and propellant
   systems. After component technology is completed, systems
   testing will be performed to evaluate control requirements
   and measure heat input effects to thrusters and feed lines.
   Flight test demonstration of a subscale system as Shuttle
   payload package needed to fully show flight readiness of all
   aspects of this system technology.
**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

Cryogenic APS offers advantages of high performance, low total system weight, clean non-toxic exhaust, and commonality of propellants with main propulsion system. Thruster technology has been pursued at 1,250 lbs. thrust which showed that liquid cryogens could be successfully used in a pulsing attitude control thruster. The expected problems of thermal (continued)

**7. ALTERNATIVE APPROACHES/OPTIONS**


**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

506-21-11

FY 80 New Start (#317) - "Functional and Performance Verification of an Integrated LH₂/LOX APS."

**9. TECHNOLOGY SCHEDULES**

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<p>|      | MANPOWER (M-Y)                    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|      | INHOUSE                           |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|      | CONTRACT                          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|      | FUNDING (10^6 $)                  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|      | INHOUSE                           |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|      | CONTRACT                          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |</p>
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<td>control, performance, ignition, and combustion stability were solved. However, additional work is needed on performance, cooling, and thruster life. Additional component work is needed on small cryogenic positive displacement pumps, accumulators, zero &quot;g&quot; refillable tanks, propellant feed lines and manifolds, and system controls.</td>
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## SPACE TECHNOLOGY NEED

### 1. TITLE
Auxiliary Propulsion, Low Cost Space Propellants for QTV, HLLV, HLLV₂, and Advanced Vehicle

### 2. OBJECTIVE
To evaluate the ignition, combustion, and cooling characteristics of low cost, high density impulse propellants (such as LOX-Propane) under space start, restart, and steady state conditions. This technology is

### 3. NEED ANALYSIS

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<th>f) R&amp;T BASE CANDIDATE</th>
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### 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

### 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
The following is required: ignition characteristics, performance, cooling capability, and combustion stability.
**SPACE TECHNOLOGY NEED**

**TITLE**  
Auxiliary Propulsion: Low Cost Space Propellants  
for OTV, HLLV₁, HLLV₂, and Advanced Vehicle

**NO.** 12/P-1/21  
**THEME / W.G. / TASK**

**DATE** 4/27/76

---

### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Conduct limited survey of low cost and high density fuels and oxidizers for both pressure-fed and pump-fed systems. Conduct single element and subscale firings over a range of propellant temperatures, pressures, and mixture ratios. Photographic coverage shall be conducted to obtain qualitative understanding of the measured data (Cₚ, Q/P, etc.). Full scale injector firings of a limited number of the most promising propellants shall be conducted. (Continued on page 3.)

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### 7. ALTERNATIVE APPROACHES/OPTIONS

Use less dense O-H system with its inherent complexity and packaging problems or pay increased costs of amine fuel, if available.

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### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

None.

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### 9. TECHNOLOGY SCHEDULES

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**MANPOWER (M-Y)**

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**FUNDING \(10^6 \$\)**

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This technology is required so that the amine fuel presently being used in the shuttle OMS and RCS can be replaced with a more easily available and cheaper fuel. The cost of amine type fuels has risen from the beginning of the shuttle program from approximately $4/lb. to $8/lb. Hydrocarbon fuels can be obtained for less than 50¢/lb. In addition, amine fuels are becoming more difficult to process due to environmental problems, so it is necessary to have a replacement available in event that production is sharply cut back and/or costs increase excessively.

Recommended Approach/Program Plan to Accomplish Need (Cont'd) -

ducted. Vacuum ignition, heat flux, performance and combustion stability shall be investigated.
TITLE: Low Cost Propellant Auxiliary Propulsion

OBJECTIVE:
To develop technology for low cost hydrocarbon fuels for RCS and OMS propulsion for Shuttle improvements and advanced launch vehicles.

JUSTIFICATION:
Low cost (and higher performance) propellant combinations, such as LOX-propane, are needed to replace the earth storables now used on Shuttle.

TECHNICAL APPROACH/PLAN:
Work will be initiated on both attitude control thrusters of about 1000 lbs. thrust and a pump-fed OMS engine of about 6000 lbs. thrust. Various hydrocarbon fuel/LOX propellant combinations will be evaluated and one selected for experimental work on injectors, thrust chambers, engine cycle studies, and pumps.

SCHEDULE:

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PROPOSED LEAD CENTER: LeRC in consultation with JSC

RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT
1. **TITLE**: Advanced Hydrogen/Oxygen Propulsion System for Launch Vehicles  
   **THEME**: W.G. / TASK  
   **DATE**: 1/28/76

2. **OBJECTIVE**: Provide the technology base for large hydrogen/oxygen engines operating at chamber pressures greater than 3000 psi, and employing unconventional configurations.

3. **NEED ANALYSIS**
   a) **LEVEL NOW**: 2, WILL BE LEVEL 3 UNDER EXISTING PLANS.
   b) **REQUIRED ADVANCEMENT** — SHOULD BE TECHNOLOGY READY AT LEVEL ___ FOR OPERATIONAL SYSTEM USE BY [DATE: 1990]
   c) **RISK IN ACHIEVING ADVANCEMENT**: HIGH X MEDIUM LOW
   d) **CRITICALITY TO THE ACCOMPLISHMENTS**: ENABLING X OR ENHANCING: HIGH MEDIUM LOW
   e) **TASKS NEEDED**: STUDY [ ] ANALYSIS X RESEARCH X GRD TEST X AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ] OTHER (Specify) [ ]
   (Check one or more)
   f) **R&T BASE CANDIDATE**: Yes

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**: None

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**
   Material research to enable higher turbine inlet temperatures and extended low cycle fatigue life for combustor components, improved long-life bearings and seals. Conceptual design studies and subsequent system demonstration programs are required for the geometric configurations being considered. They are: Bell nozzles; linear/aerospike; and plug cluster. The thrust level being considered is 350K to 1000K lbf.
## Title
Advanced Hydrogen/Oxygen Propulsion System for Launch Vehicles

### 6. Recommended Approach/Program Plan to Accomplish Need

Material investigations should be initiated immediately. For the unconventional configurations, system studies are required to determine design criteria and component operating levels (temp., pressure, etc.). Establishment of component technology base is followed by fabrication & test of breadboard systems.

### 7. Alternative Approaches/Options
None

### 8. Current/Planned Related Activities (RTOP, Other)

RTOP's 506-21-11 and 790-40-12.

### 9. Technology Schedules

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| FUNDING (10^6 $)    | 1.7| 1.5| 1.5| 3  | 3  | 2.5|    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| INHOUSE             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| CONTRACT            |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
### SPACE TECHNOLOGY NEED

1. **TITLE**  
   High Performance LOX/Hydrocarbon Propulsion Systems for Booster Applications  
   (HLLV2)

2. **OBJECTIVE**  
   Develop technology for high performance LOX/hydrocarbon propulsion systems including bell nozzle types, aerospike/linear engines, and plug cluster arrangements for booster applications.

3. **NEED ANALYSIS**
   a) LEVEL NOW [2], WILL BE LEVEL [3] UNDER EXISTING PLANS.
   c) RISK IN ACHIEVING ADVANCEMENT:  
      - HIGH [ ]  
      - MEDIUM [X]  
      - LOW [ ]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING [ ]
   e) TASKS NEEDED:  
      - STUDY [X]  
      - ANALYSIS [X]  
      - RESEARCH [X]  
      - GRD TEST [X]  
      - AIR CRAFT TEST [ ]  
      - SPACE FLIGHT TEST [ ]
      - OTHER (Specify) [ ]
   f) R&T BASE CANDIDATE [Yes]

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**
   High performance LOX/hydrocarbon propulsion systems are needed for future booster applications that provide high specific impulse, compact size, high thrust/weight ratio, reusability, and use high bulk density propellants. A variety of engine cycles and configurations are applicable including high pressure bell nozzle engines, plug cluster, or linear/aerospike (plug nozzle) types that provide high specific impulse at sea level and throughout the flight by the use of altitude compensating nozzles.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED
Technology program should include: engine and vehicle studies; determination of relative advantages of various engine types; thrust chamber cooling studies with fuel, oxidizer, or auxiliary coolant; studies of various candidate hydrocarbon fuels, such as methane, propane, RP-1, RJ-5, and other intermediate density or heavy hydrocarbon fuels to evaluate their performance, cooling capability, and operational problems; engine component tech-
(See page 3.)

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
790-40-12, 506-21-11, 506-21-10
FY79 New Start #305, "Plug Cluster Engine Demonstration"
FY80 New Start #307, "Comp. Tech. for High Press. LOX/Hydrocarbon Booster Engine."

9. TECHNOLOGY SCHEDULES
1. TITLE  High Performance LOX/Hydrocarbon
       Propulsion Systems for Booster Applications

( ) CONTINUATION (If Needed)

Block No.

Technology program, including design, fabrication, and testing of selected
critical components, such as fuel and oxidizer rich preburners, main
injector, thrust chamber and main fuel turbopump; pressure-fed breadboard
testing of preburners, main injector, and thrust chamber.

Supporting work is needed on low cycle thermal fatigue life of thrust
chambers, turbopump bearings and seals, high temperature turbine materials,
and cold and hot flow evaluation of plug cluster arrangements to determine
nozzle performance losses.
**1. TITLE**  
High Performance Dual Fuel Engines for Booster Applications (HLLV2)

**2. OBJECTIVE**  
Develop technology for advanced dual fuel engines for hydrocarbon/LOX/hydrogen propellants for use on advanced boosters using mixed mode propulsion.

**3. NEED ANALYSIS**  

- a) LEVEL NOW [2], WILL BE LEVEL [3] UNDER EXISTING PLANS.
- c) RISK IN ACHIEVING ADVANCEMENT: HIGH [X] MEDIUM [ ] LOW [ ]
- d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [ ] OR ENHANCING: HIGH [X] MEDIUM [ ] LOW [ ]
- e) TASKS NEEDED: STUDY [ ] ANALYSIS [X] RESEARCH [X]  
GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]  
OTHER (Specify) [ ]

- f) R&T BASE CANDIDATE Yes

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

Dual fuel engines are applicable to advanced boosters using mixed mode propulsion. The dual fuel engine burns high density propellants, such as LOX/hydrocarbon early in the flight and switches to LOX/HLx later in the flight. Various engine configurations are applicable, including: high pressure staged combustion engines, LOX cooled; high pressure tripropellant engine, Hx cooled; dual throat engine; split combustor aerospike, etc.
### Title
High Performance Dual Fuel Engines for Booster Applications

#### Date
4/28/76

### 6. Recommended Approach/Program Plan to Accomplish Need
Perform studies to evaluate use of mixed mode propulsion using dual fuel engines for advanced boosters. Perform engine system trade-off and parametric studies to determine fuel and oxidizer combinations, engine turbo-pump drive cycle, cooling method, and component preliminary design for selected thrust levels in the range from 500,000 to 1,500,000 pounds. Perform (continued)

### 7. Alternative Approaches/Options

### 8. Current/Planned Related Activities (RTOP, OTHER)

### 9. Technology Schedules

| FY | Schedule Item | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|----|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Task Item | Engine Vehicle Studies | △ | △ | | | | | | △ | △ | △ | | | | | | | | | |
| Basic Subscale Component Research | | △ | △ | | | | | | | | | | | | | | | | | |
| #307-Comp. Tech. Dual Fuel Engine | △ | △ | △ | | | | | | | | | | | | | | | | | |
| #117-System Breadboard Engine System Demo. | △ | △ | △ | | | | | | | | | | | | | | | | | |

### Power (M-Y) House Tract
- 10^6 $
component technology programs based on selection of critical components for the engine configuration and propellant combination selected.

The technology in this area is supported by work on high pressure H2-O2 booster engines and high performance LOX/hydrocarbon engines and also requires additional work on specific problem areas related to the use of two propellant combinations in the same engine.
1. **TITLE** Liquid Hydrogen/Liquid Oxygen Attitude Control Systems for Launch Vehicles (Adv. Vehicle)  
   **NO.** 1,8,10,12/P-1 / 25  
   **THEME/W.G.** TASK  
   **DATE** 4/28/76

2. **OBJECTIVE**
   Develop technology for components of a LH2/LOX APS, such as thrusters, pumps, zero "g" reservoir, and accumulators, and perform systems testing.

3. **NEED ANALYSIS**
   a) **LEVEL NOW** [3], WILL BE LEVEL [5] UNDER EXISTING PLANS.  
   b) **REQUIRED ADVANCEMENT** — SHOULD BE TECHNOLOGY READY AT LEVEL [7] FOR OPERATIONAL SYSTEM USE BY **DATE: 1990**  
   c) **RISK IN ACHIEVING ADVANCEMENT:**  
      HIGH [ ] MEDIUM [X] LOW [ ]  
   d) **CRITICALITY TO THE ACCOMPLISHMENTS:**  
      ENABLING [ ] OR ENHANCING: HIGH [ ] MEDIUM [X] LOW [ ]  
   e) **TASKS NEEDED:**  
      STUDY [ ] ANALYSIS [ ] RESEARCH [X]  
      GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [X]  
      OTHER (Specify) [ ] (Check one or more)  
   f) **R&T BASE CANDIDATE** Yes

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**
   Development of technology for LH2/LOX system for advanced launch vehicles, including thrusters (800 to 1,500 lbs. thrust), small cryogenic positive displacement pumps, accumulators, controls, refillable zero "g" reservoirs, and propellant systems. After component technology is completed, systems testing will be performed to evaluate control requirements and measure heat input effects to thrusters and feed lines. Flight test demonstration of a subscale system as Shuttle payload package needed to fully show flight readiness of all aspects of this system technology.
Cryogenic APS offers advantages of high performance, low total system weight, clean non-toxic exhaust, and commonality of propellants with main propulsion system. Thruster technology has been pursued at 1,250 lbs. thrust which showed that liquid cryogens could be successfully used in a pulsing attitude control thruster. The expected problems of thermal (continued)

7. ALTERNATIVE APPROACHES/OPTIONS


8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

506-21-11

FY 80 New Start (#317) - "Functional and Performance Verification of an Integrated LH2/LOX APS."

9. TECHNOLOGY SCHEDULES

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| MANPOWER (M-Y)                |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | |
| INHOUSE CONTRACT              |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | |
| FUNDING (10^6 $)              |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | |
| INHOUSE CONTRACT              |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       | |
**SPACE TECHNOLOGY NEED**

**FORM NO. 1**

**PAGE 1 OF 3**

**1. TITLE** High Performance H₂-Ο₂ Reusable Propulsion Systems for Orbit Maneuvering System (OMS) Applications

**THEME / W.G. / TASK** NO. 1, 7, 8, 9, 11, 12/P-1/26

**DATE** 4/28/76

**2. OBJECTIVE**
Develop technology for high performance, reusable H₂-Ο₂ space propulsion systems including staged combustion bell nozzle, expander cycle bell nozzle, and aerospike engines.

**3. NEED ANALYSIS**

a) **LEVEL NOW** [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.

b) **REQUIRED ADVANCEMENT** - SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY **DATE: 1990**

c) **RISK IN ACHIEVING ADVANCEMENT:**

   HIGH [ ] MEDIUM [x] LOW [ ]

d) **CRITICALITY TO THE ACCOMPLISHMENTS:**

   ENABLING [ ] OR ENHANCING: HIGH [ ] MEDIUM [x] LOW [ ]

e) **TASKS NEEDED:** STUDY [ ] ANALYSIS [X] RESEARCH [X]

   GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]

   OTHER (Specify) [ ]

   (Check one or more)

f) **R&T BASE CANDIDATE** YES

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

a) **Staged combustion bell nozzle engine (ASE)** - Continue LeRC component technology program on thrust chamber, main fuel and oxidizer turbopumps, preburner, main injector, low cycle thermal fatigue chamber life, turbopump bearings and seals, and boost pump multiroller drive system. Expand program with FY '78 new initiative #119, "Reusable Engine Systems Test (RECEST)," to obtain data on operation of the powerhead breadboard assembly of staged combustion cycle engine and aerospike engine breadboard.

b) **Aerospike expander cycle engine** - Complete planned LeRC program on testing of 25K thrust aerospike chamber. Work also needed on thermal fatigue life of segments of chamber and breadboard system test using...

(Continued on page 3)
**SPACE TECHNOLOGY NEED**

**TITLE**
High Performance $\text{H}_2-\text{O}_2$ Reusable Propulsion Systems for Orbit Maneuvering System (OMS) Applications

**FORM NO. 1**

**PAGE 2 OF 3**

**THEME** / W.G. / TASK

**DATE** 4/28/76

**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

High performance reusable engines are needed for OMS applications using hydrogen-oxygen propellants to reduce system weight, provide commonality with main propulsion, APS, and fuel cells, thereby reducing cost. $\text{H}_2-\text{O}_2$ systems are inherently clean, have non-toxic exhaust, and good reusability aspects. High pressure engines are desirable to provide maximum specific impulse in a small compact package and minimize engine weight. Slush

(Continued on page 3)

**7. ALTERNATIVE APPROACHES/OPTIONS**

**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

506-21-11, 506-21-12, 910-03-01

FY '78 New Start #119, "RECEST - Reusable Cryogenic Engine Systems Test."

**9. TECHNOLOGY SCHEDULES**

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<tr>
<th>FY</th>
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<td>TASK ITEM</td>
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<td>Tech. Program</td>
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<td>RECEST (#119)</td>
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<td>Slush Cryogens</td>
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<td>Reusable Cryogen Insulation Systems</td>
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<td>ASE with Boose Pumps</td>
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<td>MANPOWER (M-Y)</td>
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<td>INHOUSE CONTRACT</td>
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</table>
1. TITLE High Performance H₂-O₂ Reusable Propulsion Systems for Orbit Maneuvering System (OMS) Applications

THEME / W.G. / TASK

NO.1,7,8,9,11,12/P-1/26

DATE 4 / 28 / 76

5. b) Mark 48 fuel and oxidizer pumps as part of FY '78 new start #119.

RECEST

(5 & 6 ) CONTINUATION (If Needed)

5. c) FY '78 new start #119, Reusable Cryogenic Engine Systems Test (RECEST)

d) Slush Cryogens - Evaluate methods of manufacture, storage, handling, pumping, and cost of applying to a flight system. Demonstrate these technology areas at moderate scale

e) Reusable cryogenic insulation systems - Continue LeRC program to provide technology on two approaches: (1) evacuated load bearing insulation systems; and (2) reusable purged multilayer insulation system

f) ASE with boost pumps - Add boost pumps and their drive system to the powerhead breadboard assembly tested under (c), above

6. cryogens are desirable to reduce tankage volume. High performance reusable cryogen insulation systems are needed that are rugged, have low heat leak, and are reusable for up to 50 missions.
1. **TITLE**  
High Performance LOX/Hydrocarbon Propulsion Systems for Booster Applications (Adv. Vehicle)

**DATE**  
4/28/76

2. **OBJECTIVE**  
Develop technology for high performance LOX/hydrocarbon propulsion systems including bell nozzle types, aerospike/linear engines, and plug cluster engines for booster vehicles.

3. **NEED ANALYSIS**

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<th>a) LEVEL NOW</th>
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b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL 5 FOR OPERATIONAL SYSTEM USE BY **DATE: 1990**

c) RISK IN ACHIEVING ADVANCEMENT:

- HIGH
- MEDIUM X
- LOW

d) CRITICALITY TO THE ACCOMPLISHMENTS:  
ENABLING X OR ENHANCING:  
MEDIUM X  
LOW

e) TASKS NEEDED:

- STUDY X  
- ANALYSIS X  
- RESEARCH X  
- GRD TEST X  
- AIR CRAFT TEST  
- SPACE FLIGHT TEST  
- OTHER (Specify)  

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

High performance LOX/hydrocarbon propulsion systems are needed for future booster applications that provide high specific impulse, compact size, high thrust/weight ratio, reusability, and use high bulk density propellants. A variety of engine cycles and configurations are applicable including high pressure bell nozzle engines, plug cluster, or linear/aerospike (plug nozzle) types that provide high specific impulse at sea level and throughout the flight by the use of altitude compensating nozzles.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Technology program should include: engine and vehicle studies; determination of relative advantages of various engine types; thrust chamber cooling studies with fuel, oxidizer or auxiliary coolant; studies of various candidate hydrocarbon fuels, such as methane, propane, RP-1, RJ-5 and other intermediate density or heavy hydrocarbon fuels to evaluate their (continued)

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

790-40-12, 506-21-11, 506-21-10
FY 79 New Start #305, "Plug Cluster Engine Demonstration"
FY 80 New Start #307, "Comp. Tech. for High Press. LOX/HC Booster Engine"

9. TECHNOLOGY SCHEDULES

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<th>TASK ITEM</th>
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<td>(e) Breadboard Engine Demo.</td>
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MANPOWER (M-Y)
INHOUSE
CONTRACT

FUNDING (10^6 $)
INHOUSE
CONTRACT
1. TITLE High Performance LOX/Hydrocarbon Propulsion Systems for Booster Applications

CONTINUATION (If Needed)

performance, cooling capability, and operational problems; engine component technology program, including design, fabrication, and testing of selected critical components, such as fuel and oxidizer rich preburners, main injector, thrust chamber, and main fuel turbopump; pressure-fed breadboard testing of preburner, main injector, and thrust chamber.

Supporting work is needed on low cycle thermal fatigue life of thrust chambers, turbopump bearings and seals, high temperature turbine materials, and cold and hot flow evaluation of plug cluster arrangements to determine nozzle performance losses.
# SPACE TECHNOLOGY NEED

**FORM NO. 1**

**PAGE 1 OF 3**

## 1. TITLE

High Performance Dual Fuel Engines for Booster Applications

(Adv. Vehicle)

**NO. 3:11.12/P-1/31**

**THEME / W.G. / TASK**

**DATE 4/28/76**

## 2. OBJECTIVE

Develop technology for advanced dual fuel engines for hydrocarbon/LOX/hydrogen propellants for use on advanced boosters using mixed mode propulsion.

## 3. NEED ANALYSIS

**NOTE:** 2 For Dual Throat Config.

- **a)** LEVEL NOW [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
- **b)** REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY **DATE: 1990**
- **c)** RISK IN ACHIEVING ADVANCEMENT:
  - HIGH [X] MEDIUM [ ] LOW [ ]
- **d)** CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [ ] OR ENHANCING: HIGH [X] MEDIUM [ ] LOW [ ]
- **e)** TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [X]
  - **GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]**
  - OTHER (Specify) [ ] (Check one or more)
- **f)** R&T BASE CANDIDATE [ ] Yes

## 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

________________________________________________________________________

________________________________________________________________________

## 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

Dual fuel engines are applicable to advanced boosters using mixed mode propulsion. The dual fuel engine burns high density propellants, such as LOX/hydrocarbon early in the flight and switches to LOX/LH₂ later in the flight. Various engine configurations are applicable, including: high pressure tripropellant engine, H₂ cooled; dual throat engine; split combustor aerospike, etc.
### SPACE TECHNOLOGY NEED

**TITLE**

High Performance Dual Fuel Engines for Booster Applications (Adv. Vehicle)

**NO.** 1, 7, 8, 9, 11, 12

**P-131**

**THEME / W.G. / TASK**

**DATE**

4/28/76

---

#### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Perform studies to evaluate use of mixed mode propulsion using dual fuel engines for advanced boosters. Perform engine system trade-off and parametric studies to determine fuel and oxidizer combinations, engine turbopump drive cycle, cooling method, and component preliminary design for selected thrust levels in the range from 500,000 to 1,500,000 pounds. (Continued)

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#### 7. ALTERNATIVE APPROACHES/OPTIONS

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#### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

- 506-21-11, 790-40-12, FY 79 New Start #305, "Plug Cluster Engine"
- FY 80 New Start #307, "Comp. Tech. for High Pressure LOX/Hydrocarbon Booster Engine"
- FY 78 New Start #117, "Advanced Dual Fuel Propulsion System"

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#### 9. TECHNOLOGY SCHEDULES

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<td>Engine Vehicle Studies</td>
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<td>Basic Subscale Component Research</td>
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<td>#307 Comp. Tech.</td>
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<td>#117 Dual Fuel System</td>
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- △: Technical Readiness
- ○: Funding

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#### MANPOWER (M-Y)

INHOUSE CONTRACT

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#### FUNDING (10^6 $)

INHOUSE CONTRACT
Perform component technology programs based on selection of critical components for the engine configuration and propellant combination selector.

The technology in this area is supported by work on high pressure H₂-O₂ booster engines and high performance LOX/hydrocarbon engines and also requires additional work on specific problem areas related to the use of two propellant combinations in the same engine.
1. TITLE  Composite Engine Technology

2. OBJECTIVE  
   Develop technology for composite (rocket/air breathing) engines for advanced horizontal take-off, horizontal landing (HTOHL) shuttle type vehicles.

3. NEED ANALYSIS
   a) LEVEL NOW [X], WILL BE LEVEL [X] UNDER EXISTING PLANS.
   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL [X] FOR OPERATIONAL SYSTEM USE BY DATE: 1990
   c) RISK IN ACHIEVING ADVANCEMENT:
      HIGH [X]  MEDIUM [ ]  LOW [ ]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING: HIGH [ ]  MEDIUM [X]  LOW [ ]
   e) TASKS NEEDED: STUDY [ ]  ANALYSIS [X]  RESEARCH [X]
      GRD TEST [X]  AIR CRAFT TEST [ ]  SPACE FLIGHT TEST [ ]
      OTHER (Specify) [ ]
   f) R&T BASE CANDIDATE [ ]

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
   The technology advancements required are dependent upon the engine concept selected (ducted rocket, ejector ramjet, scramjet, air turborocket, lace cycles, and others) but include, for example, engine cooling, afterburner design, and variable area inlet control.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Conduct vehicle/propulsion system analysis of HTOHL fully reusable two-stage-to-orbit shuttle vehicles for the post 1990 time period that utilize composite engines. Select engine concept and perform technology program to bring composite engine technology to maturity by 1985.

7. ALTERNATIVE APPROACHES/OPTIONS

Alternative approaches to the HTOHL concept are all rocket vehicles of one or two-stage-to-orbit design which generally have higher gross lift-off weight, higher propellant consumption, and higher launch cost per pound of payload.

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

None

9. TECHNOLOGY SCHEDULES

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|    | MANPOWER (M-Y) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
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|    | FUNDING (10^6 $) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | INHOUSE       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | CONTRACT      |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    | 10,15,20 |
### Space Technology Need

**1. Title**  NEP System Technology  
**NO12-10/P-1/ 41**  
**Theme / W.G. / Task**  
**Date**  4/1-27/76  

**2. Objective**  
- Develop system technology necessary for integration of thrust and power subsystems into high power level NEP spacecraft.  
- Examine ways of extending lifetimes to 25 years.  

**3. Need Analysis**  
- **a) Level Now**: □, will be level □ under existing plans.  
- **b) Required Advancement**: Should be technology ready at level □ for operational system use by **DATE: 1995**.  
- **c) Risk in Achieving Advancement**:  
  - High □  
  - Medium □  
  - Low □  
- **d) Criticality to the Accomplishments**:  
  - Enabling □  
  - Enhancing: High □, Medium □, Low □  
- **e) Tasks Needed**:  
  - Study □  
  - Analysis □  
  - Research □  
  - Grid Test □  
  - Aircraft Test □  
  - Space Flight Test □  
  - Other (Specify) □  
  - (Check one or more)  
- **f) R&T Base Candidate**  

**4. Complementary Technology Advancements Required for Use of This Technology**  
- Nuclear-thermonic power system - ion thruster technology.  

**5. Specify Technology Advancement Required to Accomplish Need**  
- A single size nuclear reactor of limited lifetime will most probably be developed for space applications. Vehicles that will require increased power levels will require multiple reactors. This effort will determine the interconnection of expected interactions between units. Lifetime limitations of the single reactor design will have to be extended to provide long-lived vehicles. Conduct initial system tests.  

---

**Level of State of Art**  
- 1. Model theory-based and required.  
- 2. Theory-tested by physical experiment or at least at the laboratory environment.  
- 3. Theory tested by physical experiment or at least at the laboratory environment.  
- 4. Mathematical model is characterized and demonstrated.  
- 5. Component or product tested in relevant environment.  
- 6. Model tested in aircraft environment.  
- 7. Model tested in space environment.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

1) Develop thrust subsystem concepts needed for high power NEP vehicles.
2) Determine modular techniques for incorporating multiple nuclear reactors in a NEP vehicle
3) Determine lifetime limitations & identify approaches to obtain a long-lived system.
4) Setup and conduct initial system tests.

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

Nuclear thermonic power subsystem technology.

9. TECHNOLOGY SCHEDULES

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</table>
1. **TITLE**  
   High Isp Ion Thruster System for Planetary Propulsion  
   NO. 10/P1/42  
   THEME / W.G. / TASK  
   DATE 4/28/76  

2. **OBJECTIVE**  
   Demonstrate the technology for an ion thruster thrust subsystem for planetary propulsion applications  

3. **NEED ANALYSIS**  
   a) **LEVEL NOW**: 4, **WILL BE LEVEL**: 5 UNDER EXISTING PLANS.  
   b) **REQUIRED ADVANCEMENT** – **SHOULD BE TECHNOLOGY READY AT LEVEL**: 7 FOR OPERATIONAL SYSTEM USE BY **DATE**: 1984  
   c) **RISK IN ACHIEVING ADVANCEMENT**:  
      - HIGH  
      - MEDIUM  
      - LOW X  
   d) **CRITICALITY TO THE ACCOMPLISHMENTS**:  
      - ENABLING X OR ENHANCING:  
      - MEDIUM  
      - LOW  
   e) **TASKS NEEDED**:  
      - STUDY  
      - ANALYSIS  
      - RESEARCH  
      - GRD TEST X  
      - AIR CRAFT TEST  
      - SPACE FLIGHT TEST X  
      - OTHER (Specify)  
   f) **R&T BASE CANDIDATE**  

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**  
   High power lightweight solar arrays.  
   Lt. wt. high eff. pwr processors  

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**  
   (1) **Ground test of complete systems**  
   (2) **Demonstration of system life**  
   (3) **Measurement of interactions between system elements and with spacecraft**
**SPACE TECHNOLOGY NEED**

**TITLE:** High Isp Ion Thruster System for Planetary Propulsion (SEP)  
**NO.** 10/P1/42  
**THEME / W.G. / TASK**  
**DATE:** 4/27/76

### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

1. Maintain Present Technology Program

2. Perform Flight Demonstration of Representative Technology
   - SPHINX B/C Propulsion Pallet Experiment w/TSS Array

### 7. ALTERNATIVE APPROACHES/OPTIONS

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

- RTOP 506-22-30, 506-22-40  
- SPHINX B/C, Propulsion Pallet Tests

### 9. TECHNOLOGY SCHEDULES

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| MANPOWER (M-Y) | 44 | 48 | 48 | 24 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| INHOUSE | CONTRACT |

| FUNDING ($10^8$) | 1.7 | 1.5 | 1.0 | 1.0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| INHOUSE | CONTRACT |
**SPACE TECHNOLOGY NEED**

**1. TITLE**  Solar Sailing Technology Program  
**NO.**  10 /P-1/ 44  
**THEME / W.G. / TASK**  
**DATE**  4 / 28 / 76  

**2. OBJECTIVE**  
Develop and demonstrate the capability to deploy and control a solar sail up to 1 sq km  

**3. NEED ANALYSIS**  
a) LEVEL NOW [2], WILL BE LEVEL [2] UNDER EXISTING PLANS.  
c) RISK IN ACHIEVING ADVANCEMENT:  
   HIGH [ ]  MEDIUM [X]  LOW [ ]  
d) CRITICALITY TO THE ACCOMPLISHMENTS:  
   ENABLING [ ]  OR ENHANCING:  
      HIGH [ ]  MEDIUM [X]  LOW [ ]  
e) TASKS NEEDED:  
   STUDY [X]  ANALYSIS [X]  RESEARCH [X]  
   GRD TEST [ ]  AIR CRAFT TEST [ ]  SPACE FLIGHT TEST [X]  
   OTHER (Specify) [ ]  
   (Check one or more)  

f) R&T BASE CANDIDATE [ ]  Yes  

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**  
   Deployment and/or assembly of large-light weight structures; control of large light-weight structures  

**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**  
1. Deployment, control of large space structures in space.  
2. Development of light-weight, long lifetime solar sail material capable of passing through the earth's radiation belts and be able to travel to within 0.2 AU.
### 6. Recommended Approach/Program Plan to Accomplish Need
Conduct feasibility design studies and component tests leading to a prototype demonstration flight test.

### 7. Alternative Approaches/Options
NEP, SEP

### 8. Current/Planned Related Activities (RTOP, OTHER)
None

### 9. Technology Schedules

| FY | SCHEDULE ITEM | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|----|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | TASK ITEM     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Analysis & Design |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Material Develop. |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Assembly Test |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | System Test |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Flight Test Ready |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Flight Test |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

### Manpower (M-Y)
- INHOUSE
- CONTRACT

### Funding (10^6 $)
- INHOUSE: 0.00 0.00 0.00 0.00 0.00
- CONTRACT: 0.50 0.00 0.00 0.00 0.00

*Not including launch vehicle*
1. TITLE Sterilizable Solid Propellant Rocket for Sample Return Propulsion

2. OBJECTIVE
Demonstrate solid propellant rockets that can withstand heat sterilization cycling to assure planetary quarantine for planetary probes or ascent from planet surfaces.

3. NEED ANALYSIS
a) LEVEL NOW [ ], WILL BE LEVEL [ ] UNDER EXISTING PLANS.
b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY DATE: 1990

3c) RISK IN ACHIEVING ADVANCEMENT:
HIGH [ ] MEDIUM [ ] LOW [ ]

d) CRITICALITY TO THE ACCOMPLISHMENTS:
ENABLING [X] OR ENHANCING: HIGH [ ] MEDIUM [ ] LOW [ ]

e) TASKS NEEDED:
GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]
OTHER (Specify) [ ]

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY
None

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
Formulate and demonstrate propellant with adequate thermal stability to resist degradation during sterilization heat cycling in a motor which has reasonably high mass fraction; demonstrate a propellant charge support system consistent with the mass fraction.
**Title:** Sterilizable Solid Propellant Rocket for Sample Return Propulsion

**No.:** 10/P-1/45

**Theme/W.G./Task:**

**Date:** 4/28/76

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### 6. Recommended Approach/Program Plan to Accomplish Need

Evaluate oxidizers and binders with high temperature stability and evaluate charge support designs which do not decrease mass fraction.

Heat-cycle propellant charges and complete motor systems, space-age the motors, and conduct verification tests at simulated altitude conditions.

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### 7. Alternative Approaches/Options

Use higher risk and lower performance chemical systems.

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### 8. Current/Planned Related Activities (RTOP, Other)

RTOP 506-21-32 (Advanced Solid Propulsion Concepts)

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### 9. Technology Schedules

| FY | SCHEDULE ITEM                        | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|----|--------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | TASK ITEM                            |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Propellant development               |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Charge Support                       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Test                                 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Full scale motor cycling             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Aging tests                          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Motor test firing                    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

| FY | MANPOWER (M-Y)                      |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
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|    | CONTRACT                             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

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1. TITLE: Space Storable Propulsion with Hydrogen Injection

2. OBJECTIVE: Demonstrate a flight-weight $F_2/H_2$ propulsion subsystem applicable to personnel orbital transfer vehicle and planetary spacecraft.

3. NEED ANALYSIS
   a) LEVEL NOW: [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
   c) RISK IN ACHIEVING ADVANCEMENT:
      HIGH [ ] MEDIUM [X] LOW [ ]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [ ] OR ENHANCING: HIGH [X] MEDIUM [ ] LOW [ ]
   e) TASKS NEEDED: STUDY [ ] ANALYSIS [ ] RESEARCH [ ]
      GRID TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]
      OTHER (Specify) [ ]
   f) R&T BASE CANDIDATE: YES

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
   Demonstration of pumps compatible with $F_2/N_2/H_2$ at engine thrust levels of about 3,000 lb; demonstration of components including injector to inject hydrogen as a tripropellant and to use it as an engine coolant; demonstration of increased Isp from 370s to 425s.
**Title:** Space Storable Propulsion with Hydrogen Injection

**Theme/Task Number:** NO10-12/P-1/46

**Date:** 4/28/76

**Recommended Approach/Program Plan to Accomplish Need:**

Complete the currently funded demonstration of $F_2/N_2H_4$ system for spacecraft and conduct component and subassembly tests to demonstrate the improvement from $H_2$ used as the third propellant element and as a coolant from $H_2$ boil-off; demonstrate redundant solenoid valves for reusable POTV main propulsion (as opposed to pyro-valves for spacecraft propulsion). Conduct system testing at simulated altitude.

**Alternative Approaches/Options:**

Use currently available propellants.

**Current/Planned Related Activities (RTOP, Other):**

RTOP 525-71-21

**Technology Schedules:**

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</table>
## 1. TITLE
Utilization of Indigenous Materials for Propulsion

### NO. 10-12/P-1/47

### THEME / W.G. / TASK

### DATE: 4/28/76

## 2. OBJECTIVE
Demonstrate the use of the mass of extra-terrestrial surface material, planetary atmosphere, and waste for propulsion.

## 3. NEED ANALYSIS

<table>
<thead>
<tr>
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<td>MEDIUM ☑</td>
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<td>d) CRITICALITY TO THE ACCOMPLISHMENTS:</td>
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<td>OR ENHANCING: HIGH ☐</td>
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<td>e) TASKS NEEDED:</td>
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<td>ANALYSIS ☑</td>
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<td>AIR CRAFT TEST ☐</td>
<td>SPACE FLIGHT TEST ☐</td>
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<tr>
<td>OTHER (Specify) ☐</td>
<td>(Check one or more)</td>
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</table>

| f) R&D BASE CANDIDATE | Yes |

## 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY
Adequate verification of the physical and chemical characteristics of the predicated lunar or planetary materials and planetary atmospheres.

## 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
Demonstrate the most applicable concepts for reacting indigenous materials with stored reactants and evaluate their characteristics; devise design criteria.

---

**Level of Art**

1. **100%**
2. **90%**
3. **80%**
4. **70%**
5. **60%**
6. **50%**
7. **40%**
8. **30%**
9. **20%**
10. **10%**

**Mathematical Model**

1. **100%**
2. **90%**
3. **80%**
4. **70%**
5. **60%**
6. **50%**
7. **40%**
8. **30%**
9. **20%**
10. **10%**

**Characteristic Described**

1. **100%**
2. **90%**
3. **80%**
4. **70%**
5. **60%**
6. **50%**
7. **40%**
8. **30%**
9. **20%**
10. **10%**
Utilization of Indigenous Materials for Propulsion

6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Identify concepts for reacting indigenous materials with stored reactants and evaluate their characteristics. Devise new schemes, compare concepts, test and develop the most applicable technologies.

7. ALTERNATIVE APPROACHES/OPTIONS

Carrying mass of propellant from Earth.

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

RTOP 506-21-43 (New Horizons in Propulsion)

9. TECHNOLOGY SCHEDULES

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| MANPOWER (M-Y) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| INHOUSE        |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| CONTRACT       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| FUNDING (10^6 $) |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| INHOUSE        |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| CONTRACT       |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
1. **TITLE** Propulsion in Planetary Atmospheres

2. **OBJECTIVE**
   
   Provide an efficient propulsion system for probe or attitude propulsion operating in very dense planetary atmospheres.

3. **NEED ANALYSIS**
   
   a) LEVEL NOW: \[\text{3} \] WILL BE LEVEL: \[\text{3} \] UNDER EXISTING PLANS.
   
   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL: \[\text{7} \] FOR OPERATIONAL SYSTEM USE BY: \[\text{DATE: 1990} \]
   
   c) RISK IN ACHIEVING ADVANCEMENT:
      
      - HIGH
      - MEDIUM \[\checkmark \]
      - LOW

   d) CRITICALITY TO THE ACCOMPLISHMENTS:
      
      - ENABLING \[\checkmark \]
      - ENHANCING:
         
         - HIGH
         - MEDIUM
         - LOW

   e) TASKS NEEDED:
      
      - STUDY
      - ANALYSIS \[\checkmark \]
      - RESEARCH \[\checkmark \]
      - GRD TEST \[\checkmark \]
      - AIR CRAFT TEST
      - SPACE FLIGHT TEST
      - OTHER (Specify)

4. **R&T BASE CANDIDATE**
   
   Yes

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

   Provide prototype detonation propulsion system using small charges of explosive repetitively detonated in an expanded nozzle to provide an impulse. This impulse is independent of atmosphere to the first order.
**SPACE TECHNOLOGY NEED**

**TITLE**  Propulsion in Planetary Atmospheres

**NO.** 10/P-1/48

**THEME / W.G. / TASK**

**DATE**  4 / 28 / 76

**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

Complete the component designs and tests and assemble a prototype which can be subjected to space- and planetary-simulated environmental exposure and operated in a simulated dense planetary atmosphere.

**7. ALTERNATIVE APPROACHES/OPTIONS**  Low efficiency chemical rockets

**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

RTOP 506-21-32 (Advanced Solid Propulsion Concepts)

**9. TECHNOLOGY SCHEDULES**

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**MANPOWER (M-Y)**

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## SPACE TECHNOLOGY NEED

### 1. TITLE
Hi Specific Impulse Ion Thrusters for On-Orbit Operations

### 2. OBJECTIVE
To develop Ion Thruster Systems to provide station keeping for orbital systems using low cost inert fuels

### 3. NEED ANALYSIS

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<th>UNDER EXISTING PLANS.</th>
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<th>c) RISK IN ACHIEVING ADVANCEMENT:</th>
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<th>d) CRITICALITY TO THE ACCOMPLISHMENTS:</th>
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<th>e) TASKS NEEDED:</th>
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<tr>
<th>f) R&amp;T BASE CANDIDATE</th>
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### 4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

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### 5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED

1. Scaling of present thruster systems to required sizes
2. Efficient operation demonstration with inert gases
3. Demonstration of total impulse and cyclic life
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

(1) Complete Hg Aux Thruster Program
(2) Define System Operating Requirements
(3) Design Thruster System
(4) Incorporate into Existing Technology Program
(5) Perform Directed R&T
(6) Demonstrate Critical Performance Parameters

7. ALTERNATIVE APPROACHES/OPTIONS

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
- SPHINX B/C Propulsion Pallet Experiment
- LeRC FY 78 New Initiative for Thrust Sub-System Tech. Dev.

9. TECHNOLOGY SCHEDULES

| SCHEDULE ITEM                  | FY 76 | FY 77 | FY 78 | FY 79 | FY 80 | FY 81 | FY 82 | FY 83 | FY 84 | FY 85 | FY 86 | FY 87 | FY 88 | FY 89 | FY 90 | FY 91 | FY 92 | FY 93 | FY 94 | FY 95 |
|--------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Tech. Ready, /MLB Hg           |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Define Req.                    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Design System                  |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Baseline R&T                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Directed R&T                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Critical Tests                 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Flight Application            |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| Pallet Tests                   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |

MANPOWER (M-Y)

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FUNDING ($10^6)

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</table>
1. **TITLE** MONOPROPELLANT HYDRAZINE PROPULSION FOR ON-ORBIT STATION-KEEPING

2. **OBJECTIVE**

   INCREASE THE OPERATIONAL LIFE OF \( \text{N}_2\text{H}_4 \) THRUSTERS WITH EMPHASIS ON IMPROVEMENT OF CATALYST BED DESIGNS FOR UNITS WITH THRUSTS RANGING FROM \( 10^{-3} \text{ LBF} \) TO \( 10^2 \text{ LBF} \). PROVIDE LOW-GRAVITY ACQUISITION SYSTEM.

3. **NEED ANALYSIS**

   a) LEVEL NOW \( 4 \), WILL BE LEVEL \( 4 \) UNDER EXISTING PLANS.

   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL \( 7 \) FOR OPERATIONAL SYSTEM USE BY DATE: 1982

   c) RISK IN ACHIEVING ADVANCEMENT:

      - HIGH
      - MEDIUM \( \mathbf{X} \)
      - LOW

   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING \( \mathbf{X} \) OR ENHANCING:

      - HIGH
      - MEDIUM
      - LOW

   e) TASKS NEEDED: STUDY \( \square \) ANALYSIS \( \square \) RESEARCH \( \square \)

      GRD TEST \( \mathbf{X} \) AIR CRAFT TEST \( \square \) SPACE FLIGHT TEST \( \square \)

      OTHER (Specify) \( \square \)

   (Check one or more)

   f) R&T BASE CANDIDATE \( \square \) YES

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

   NONE

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

   CHARACTERIZE HYDRAZINE CATALYST BEDS WITH RESPECT TO STRUCTURE AND REACTIVITY. DEMONSTRATE LONG LIFE THRUSTER. DEMONSTRATE CAPABILITY OF PROPELLANT ACQUISITION DEVICE TO OPERATE UNDER SIMULATED HIGH "G" ENVIRONMENT.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Utilize 'gas generators technology from space shuttle and planetary spacecraft. Determine service life of a radial flow hydrazine thruster. Determine optimum design to minimize refurbishment cost and/or maximize life. Design, fabricate & test a hydrazine propellant acquisition system employing a surface tension device. Integrate the two devices, test on ground, and in space environment.

7. ALTERNATIVE APPROACHES/OPTIONS

H-O auxiliary propulsion system, bi-propellant auxiliary propulsion system.

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

910-04-01; 910-04-02

506-21-51

9. TECHNOLOGY SCHEDULES

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TABLE 7: TECHNOLOGY SCHEDULES FOR FY 76-95
1. **TITLE** Photochemical Production of Hydrogen and Oxygen for Propellant Application
   
   **NO.** 12-1/P-1/52
   **THEME / W.G. / TASK**
   **DATE** 4/28/76

2. **OBJECTIVE** Demonstrate the feasibility of direct conversion of hydrogen and oxygen from water using solar radiation for propellant applications.

3. **NEED ANALYSIS**
   
   a) **LEVEL NOW** 2, **WILL BE LEVEL** 2 **UNDER EXISTING PLANS.**
   
   b) REQUIRED ADVANCEMENT - SHOULD TECHNOLOGY READY AT LEVEL 4 FOR OPERATIONAL SYSTEM USE BY **DATE: 1995**
   
   c) RISK IN ACHIEVING ADVANCEMENT: HIGH [x] MEDIUM [ ] LOW [ ]
   
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [x] OR ENHANCING: HIGH [ ] MEDIUM [ ] LOW [ ]
   
   e) TASKS NEEDED: STUDY [ ] ANALYSIS [ ] RESEARCH [x] GRD TEST [ ] AIRCRAFT TEST [ ] SPACE FLIGHT TEST [ ]
   
   Other (Specify) [ ]
   
   (Check one or more)

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY** None

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**
   
   Determine the feasibility and economics of direct conversion of water to hydrogen and oxygen without use of fossil fuels or nuclear sources in an energy-conservative method.
**Title:** Photochemical Production of Hydrogen and Oxygen for Propellant Application

**NO.:** 12-1/P-1/52

**THEME / W.G. / TASK:**

**DATE:** 4/28/76

**6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED**

Research the direct conversion of water by sea-level solar radiation to H₂ and O₂ via the photo-oxidation and reduction reactions in the presence of inorganic species.

**7. ALTERNATIVE APPROACHES/OPTIONS**

Conversion of coal by gasification methods (dependence on fossil fuel); nuclear powered electrolysis; thermochemical cycles.

**8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)**

None. (ERDA sponsoring some thermochemical cycle work at LaRC)

**9. TECHNOLOGY SCHEDULES**

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**CJ**
**1. TITLE**  Ion Thruster Baseline R&T  
**NO.**  1  /  F1 / 53  
**THEME / W.G. / TASK**  
**DATE**  4 / 28 / 76

**2. OBJECTIVE**  
To Maintain and Explore Advancement in Basic Ion Thruster Technology

**3. NEED ANALYSIS**

a) **LEVEL NOW**  3, **WILL BE LEVEL**  5 **UNDER EXISTING PLANS.**

b) **REQUIRED ADVANCEMENT** – SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY [DATE: ]

c) **RISK IN ACHIEVING ADVANCEMENT:**
   - HIGH [ ]
   - MEDIUM [ ]
   - LOW [X]

d) **CRITICALLY TO THE ACCOMPLISHMENTS:**
   - ENABLING [X]
   - ENHANCING: HIGH [ ]
   - MEDIUM [ ]
   - LOW [ ]

e) **TASKS NEEDED:**
   - STUDY [ ]
   - ANALYSIS [X]
   - RESEARCH [X]
   - GRD TEST [X]
   - AIR CRAFT TEST [ ]
   - SPACE FLIGHT TEST [ ]
   - OTHER (Specify) [ ]

f) R&T BASE CANDIDATE [ ]

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

(1) Research on Performance Enhancement
(2) Extension of Operating Life
(3) Simplification of Thruster System
(4) Understanding of Basic Phenomena
(5) Reliability Improvement
(6) Plume Definition and Control
**Title:** Ion Thruster Baseline R&T

**Theme/W.G./Task:**

**Date:** 4/28/76

**6. Recommended Approach/Program Plan to Accomplish Need:**

Maintain and/or Augment Present Baseline R&T

**7. Alternative Approaches/Options:**


**8. Current/Planned Related Activities (RTOP, Other):**

506-22-40

**9. Technology Schedules**

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1. **TITLE**  Ion Beam Applications Research (IBAR)

2. **OBJECTIVE**
   To Develop Unique Capabilities of Ion Thruster Technology for Non-Propulsive Applications

3. **NEED ANALYSIS**
   a) LEVEL NOW [ ], WILL BE LEVEL 5 UNDER EXISTING PLANS.
   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY AT LEVEL 5 FOR OPERATIONAL SYSTEM USE BY DATE: 
   c) RISK IN ACHIEVING ADVANCEMENT: HIGH [ ], MEDIUM [ ], LOW [X]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING: HIGH [ ], MEDIUM [ ], LOW [ ]
   e) TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [X] GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ] OTHER (Specify) [ ] (Check one or more)
   f) R&T BASE CANDIDATE

4. **COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

5. **SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**
   (1) Understanding of Sputter Process
   (2) Microscopic Cone Growth for: Biomedical App., Thermal Control, Adhesion
### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

1. Source Modification
2. Applications Investigation
3. User Involvement
4. Systems Development
5. Tech Transfer to User

### 7. ALTERNATIVE APPROACHES/OPTIONS

- [Blank]
- [Blank]

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

506-22-40, 506-22-43

LeRC FY78 new initiative to expand tech. program.

### 9. TECHNOLOGY SCHEDULES

| FY | SCHEDULE ITEM | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|----|---------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | TASK ITEM     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Source Mod.   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Appl. Inv.    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | User Involvement | | | | | | | | | | | | | | | | | | | | | |
|    | Baseline R&T  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Tech Transfer |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

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- **Note:** The table represents budget allocations for fiscal years starting from 1976 to 1995.
1. TITLE  Ion Beam Application to Space Manufacturing

2. OBJECTIVE
   To Provide Technology to Fabricate Unique Materials in Space

3. NEED ANALYSIS
   a) LEVEL NOW [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
   b) REQUIRED ADVANCEMENT – SHOULD BE TECHNOLOGY READY
      AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY [DATE 1982]
   c) RISK IN ACHIEVING ADVANCEMENT:
      HIGH [ ] MEDIUM [ ] LOW [X]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR
      ENHANCING: HIGH [ ] MEDIUM [ ] LOW [ ]
   e) TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [X]
      GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]
      OTHER (Specify) [ ] (Check one or more)
   f) R&T BASE CANDIDATE

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR
   USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO
   ACCOMPLISH NEED
   (1) Technology for deposition of large solar reflectors, thermal control
       surfaces, transparent conductive surfaces, in situ, from space
       platform.
   (2) Zero gravity fabrication of materials; to enhance growth of large
       crystals.
   (3) Deposition of high purity materials for in situ manufacture of thin
       film solar arrays.

   [Form continuation]
Space Technology Need

**Title:** Ion Beam Applications to Space Manufacturing

**Theme:** W.G. / Task

**Date:** 4/28/76

**Recommended Approach/Program Plan to Accomplish Need**

1. Correlate Unique Capabilities of Ion Beam Manufacturing to Requirements of Space Systems
2. Breadboard Demonstration on Ground
3. Shuttle Experiment Verification

**Alternative Approaches/Options**

8. **Current/Planned Related Activities (RTOP, Other)**
   - 506-22-43, 506-22-40
   - LEIR FY78 new initiative to develop technology to flight demonstration

**Technology Schedules**

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**Manpower (M-Y)**

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SPACE TECHNOLOGY NEED


2. OBJECTIVE: Provide constituent and component technology to enable the development of advanced space transportation system chemical propulsion systems.

3. NEED ANALYSIS
   a) LEVEL NOW [ ] WILL BE LEVEL [ ] UNDER EXISTING PLANS.
   b) REQUIRED ADVANCEMENT - SHOULD BE TECHNOLOGY READY AT LEVEL [ ] FOR OPERATIONAL SYSTEM USE BY [DATE 985+].
   c) RISK IN ACHIEVING ADVANCEMENT:
      HIGH [ ] MEDIUM [ ] LOW [ ]
   d) CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING: HIGH [ ] MEDIUM [ ] LOW [ ]
   e) TASKS NEEDED: STUDY [ ] ANALYSIS [X] RESEARCH [X]
      GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [ ]
      OTHER (Specify) [ ]
   f) NEXT BASE CANDIDATE: Yes

4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY

5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED
   Constituent and component technology will be conducted to enable advanced chemical system development. Advancements required are:
   1. Reduction of component cost
   2. Increase in component life (enhanced reuse)
   3. Increase in overall performance
   4. Decrease in component weight
   5. Easing of component checkout procedures to reduce operational complexity through automation.
### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

Component technology will be concentrated on improving the overall component performance to achieve the enhancements discussed for each of the following: Combustion Chambers, Nozzles, Injectors, Ignitors, Pumps, Turbine Drives, Valves, Gas Generators, Precursors and Hot Gas Manifolds. (Continued on next page)

### 7. ALTERNATIVE APPROACHES/OPTIONS

________________________

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)

________________________

### 9. TECHNOLOGY SCHEDULES

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1. **Title**: Enabling Technology for Chemical Rocket Systems to Improve Performance, Increase Life, Reduce Cost and Simplify Operations

**Continuation (If Needed)**

1. **Block No.**

   **1. Combustion Chambers** – To accomplish the advancements required, efforts will be directed to improving thrust chamber wall cooling, development of advanced materials and fabrication techniques. This program should provide the technology to increase chamber life, reduce fabrication cost, decrease chamber weight and ease refurbishment and checkout.

2. **Nozzles** – Significant performance increases can be realized through high area ratio nozzles in upperstage vehicles and through area ratio variability for launch vehicles. Novel approaches to nozzle design (e.g., external expanding nozzles) can provide improved vehicle/engine integration as well as altitude compensation for launch vehicles.

3. **Injectors** – Rocket engine combustion efficiency and stability are functions of injector parameters. Faceplate cooling improvements are needed to improve life, as well as new approaches to faceplate fabrication techniques and materials.

4. **Igniters** – Materials, cooling and fabrication techniques are known. Work must be directed toward exciter (spark plug and electronics) to extend life beyond present state-of-the-art. New techniques must be developed for ignitor systems in annular combustors such as traveling wave ignition.

5. **Pumps and Turbine Drives** – Advancements are required for high pressure pumps in the areas of bearings and seals to increase component life and enhance pump reusability. New fabrication techniques must be developed to ease the manufacturing costs.

6. **Valves** – Technology must be directed toward improvement in valves to allow significant increase in valve and seat life in an environment where contaminants are present in the working fluid.
1. TITLE: Enabling Technology for Chemical Rocket Systems to Improve Performance, Increase Life, Reduce Cost and Simplify Operation

7. Gas Generators - PRB Burners & Hot Gas Manifolds - Materials Fabrication and fluid flow areas must be studied to realize system improvement. Efforts will lead to ease of fabrication which is a cost reduction and improved life.

Constituent Technology will focus on enhancing chemical rocket engine performance in the areas of acoustic noise and vibrations, operations, checkout and maintenance, and engine vehicle optimization.

1. Acoustic Noise and Vibrations - Identification of sources of noise and vibrations in chemical propulsion systems will be made as a first step in a technology program to reduce levels.

2. Operations, checkout and maintenance - Essential to reducing overall costs, design approaches must be used to ease these functions and provide, where possible, automatic man-free activities.

3. Engine/Vehicle Optimization - Studies to identify engine/vehicle optimum configuration will be conducted which take advantage of engine variability and identify total system constraints and drivers.
**SPACE TECHNOLOGY ADDITIONAL INITIATIVE**

**TITLE**  Enabling Technology for Chemical Rocket Systems to Improve Performance, Increase Life, Reduce Cost and Simplify Operations

**DATE**  4/29/76

**OBJECTIVE**  Provide Constituent and Component Technology to Enable the Development of Advanced Space Transportation System Chemical Propulsion Systems.

**JUSTIFICATION**  Reduced cost and component weight, increased component life and performance, and operational simplicity must be achieved to realize the total benefit in advanced space transportation systems.

**TECHNICAL APPROACH/PLAN**  Constituent and component technology will be pursued focused on the above aspects for the following: thrust chambers, nozzles, injectors, igniters, pumps and turbine drives, valves, gas generators; acoustic noise and vibration, engine-vehicle optimization, and operations, checkout and maintenance.

**SCHEDULE**

| FY | Task                              | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|----|----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|    | Thrust Chambers                  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Nozzles                          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Injectors & Igniters             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Pumps, Turbodrive                |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Valves                           |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Noise & Vibrations               |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
|    | Ops/Checkout/ Maint.             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

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**PROPOSED LEAD CENTER**  Lewis Research Center

**RECOMMENDATIONS FOR FULLER DEVELOPMENT OF INITIATIVE STATEMENT**

...
**SPACE TECHNOLOGY NEED**

**TABLE 1**

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**2. OBJECTIVE**

Develop the technology for an Ion Thruster Subsystem for Planetary Propulsion Applications with NEP

**3. NEED ANALYSIS**

a) LEVEL NOW [3], WILL BE LEVEL [5] UNDER EXISTING PLANS.


c) RISK IN ACHIEVING ADVANCEMENT:

- CRITICALITY TO THE ACCOMPLISHMENTS: ENABLING [X] OR ENHANCING: HIGH [ ] MEDIUM [ ] LOW [X]

d) TASKS NEEDED: STUDY [X] ANALYSIS [X] RESEARCH [X]

- GRD TEST [X] AIR CRAFT TEST [ ] SPACE FLIGHT TEST [X]

- OTHER (Specify) [ ]

(Check one or more)

**4. COMPLEMENTARY TECHNOLOGY ADVANCEMENTS REQUIRED FOR USE OF THIS TECHNOLOGY**

Development of Nuclear Electric Power Source

**5. SPECIFY TECHNOLOGY ADVANCEMENT REQUIRED TO ACCOMPLISH NEED**

1. Scaling of present thruster systems to required sizes

2. Element interaction with power source and spacecraft defines

3. Demonstrate total impulse required for mission applications
### 6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED

1. Define System Requirements
2. Design Thruster System
3. Incorporate into Existing Technology Program
4. Perform Directed R&T
5. Demonstrate Critical Performance Parameters

### 7. ALTERNATIVE APPROACHES/OPTIONS

### 8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
- RTOP 506-22-30, 506-22-40
- SPHINX B/C, Propulsion Pallet Experiments
- LeRC FY79 new initiative to develop thrust subsystem tech.

### 9. TECHNOLOGY SCHEDULES

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#### MANPOWER (M-Y)
- INHOUSE
- CONTRACT

#### FUNDING (10^6 $)
- INHOUSE
- CONTRACT
# Solid Rockets for Planetary Spacecraft

### Objective

Demonstrate technology of high performance low cost solid propellant motors for use in upper stages or kick stages for planetary spacecraft escape propulsion, and specialized motors for penetrators and probes.

### Need Analysis

- **Level Now:** 4, will be level 4 under existing plans.
- **Required Advancement:** Should be technology ready at level 7 for operational system use by **Date:** 1985.
- **Risk in Achieving Advancement:** High [X]  Medium [ ]  Low [ ]
- **Criticality to the Accomplishments:** Enabling [X]  Enhancing: High [ ]  Medium [ ]  Low [ ]
- **Tasks Needed:** Study [ ]  Analysis [ ]  Research [ ]  GRID Test [X]  Aircraft Test [ ]  Space Flight Test [ ]  Other (Specify) [ ]

### Complementary Technology Advancements Required for Use of This Technology

- Chambers using carbon-fiber carbon matrix material so that inert case insulation can be eliminated and propellant placed in the volume that was occupied by the insulation; Class 2 propellants with high performance; thrust vector control system using lightweight moveable nozzles with low actuation power requirements; motors for possible tube-launched penetrators; motors for probes from planetary exploration facility to planets.

### Specify Technology Advancement Required to Accomplish Need

Chambers using carbon-fiber carbon matrix material so that inert case insulation can be eliminated and propellant placed in the volume that was occupied by the insulation; Class 2 propellants with high performance; thrust vector control system using lightweight moveable nozzles with low actuation power requirements; motors for possible tube-launched penetrators; motors for probes from planetary exploration facility to planets.
6. RECOMMENDED APPROACH/PROGRAM PLAN TO ACCOMPLISH NEED
Evolve this program from the on-going R&T program and exploit all DOD
technology advancements to minimize cost. Evaluate, design, and test
component (nozzles, cases, and insulation) and integrate into complete
motor. Explore specialized needs of planetary exploration facility to
include designs of capability to replace solid motors in a reusable
planetary lander.

7. ALTERNATIVE APPROACHES/OPTIONS
Liquid chemical systems, SEP or NEP.
(Liquids may not be compatible with AF/US and SEP and NEP are not
schedule compatible.)

8. CURRENT/PLANNED RELATED ACTIVITIES (RTOP, OTHER)
RTOP 506-21-32 (Advanced Solid Propulsion Concepts)

9. TECHNOLOGY SCHEDULES

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<p>| FUNDING (10^6 $) | | | | | | | | | | | | | | | | | | | | |
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**Form III**

**Working Group:** P-1

**Date:** 4/28/76
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Date: 4/28/76
NASA R&T Base: Y
Summary Priority Assessment: ✓ ✓
**SPACE TECHNOLOGY NEED PRIORITY ASSESSMENT**

(List in numerical order, 1 — Highest Priority)

**WORKING GROUP P-1**

**DATE 4/28/76**

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