NASA CSTI
Earth-To-Orbit
Propulsion R&T Program
Overview

Presented to the
Space Systems and Technology
Advisory Committee

By
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MSFC

June 26, 1991

Earth-To-Orbit Transportation

Earth-To-Orbit Propulsion

OBJECTIVES

Programmatic
Develop and validate technology, design tools and methodologies
needed for the development of a new generation of lower cost,
operationally-efficient, long-life, highly reliable ETO propulsion
systems

Technical
- High quality, low cost, inspectable
- Safe shutdown to fault tolerant ops
- Condition monitoring diagnostics
- Automated servicing and checkout
- Full flow, combined cycle, etc.

RESOURCES

<table>
<thead>
<tr>
<th>CURRENT</th>
<th>STRATEGIC AUGMENTATION</th>
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SCHEDULE

- 1992 Electronic engine simulation capability operational
- 1993 3D CFD codes for combustion, stability, nozzle and
  turbomachinery flows validated and documented
- 1995 Low cost manufacturing processes applicable to shuttle
  and NLS/HLV propulsion verified and documented
- 1996 System monitoring capability for safe shutdown and for
  enhanced preflight servicing and checkout demonstrated
- 1999 Probabilistic codes, fatigue methodology and life
  prediction/damage models validated and documented
- 2005 Advanced manufacturing processes and design
  methodologies applicable to fully reusable, long-life AMLS
  propulsion verified and documented; propulsion system
  monitoring and control for automated operations

PARTICIPANTS

- Marshall Space Flight Center
  Lead Center—Technology acquisition, test rig validation, large scale
  validation, technology test bed

- Lewis Research Center
  Participating Center—Technology acquisition, test rig validation

- Langley Research Center
  Supporting Center—Vehicle systems analysis

** Proposed Augmentation eliminated from the 3X program

April 25, 1991
DRS QUAD1
### NASA Earth-To-Orbit Propulsion R&T Program

**Purpose**
- Provide an up-to-date technology base to support future space transportation needs

**Objective**
- Continuing enhancement of knowledge, understanding, and design methodology applicable to the development of advanced oxygen/hydrogen and oxygen/hydrocarbon ETO propulsion systems

**Justification**
- Space transportation systems can benefit from advancements in propulsion system performance, service life and automated operations and diagnostics

<table>
<thead>
<tr>
<th>Contents</th>
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</thead>
<tbody>
<tr>
<td><strong>Analytical models</strong> for defining engine environments and for predicting hardware life (flow codes, loads definition, material behavior, structural response, fracture mechanics, combustion performance and stability, heat transfer)</td>
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<tr>
<td><strong>Advanced component technology</strong> (bearings, seals, turbine blades, active dampers, materials, processes, coatings, advanced manufacturing)</td>
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<tr>
<td><strong>Instrumentation</strong> for empirically defining engine environments, for performance analysis, and for health monitoring (flow meters, pressure transducers, bearing wear detectors, optical temperature sensors)</td>
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<td><strong>Engineering testing</strong> at subcomponent level to validate analytical models, verify advanced materials, and to verify advanced sensor life and performance</td>
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<tr>
<td><strong>Component/test bed engine</strong> for validation/verification testing in true operating environments</td>
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NASA Earth-to-Orbit Propulsion R&T Program

Work Breakdown

- Technology Acquisition phase
  - Seeks improved understanding of the basic chemical and physical processes of propulsion
  - Develops analyses, design models and codes using analytical techniques supported by empirical laboratory data as required
  - Results are obtained through ten discipline working groups
    - Bearings
    - Structural dynamics
    - Turbomachinery
    - Fatigue/fracture/life
    - Ignition/combustion
    - Fluid & gas dynamics
    - Instrumentation
    - Controls
    - Manufacturing/producing/inspections
    - Materials

ETO Propulsion Technology Approach

- Civil Space Technology Initiative (CSTI) program emphasizes validated technology delivered on schedule.
- Concepts, codes, techniques obtained in the Technology Acquisition Phase.
- Validated at the appropriate level by means of component subsystem or system level testing (TTB).
- OAET provides technology to TTB. OSF provides integration funds to incorporate technology items into TTB.
- Technology is transferred to industry via papers & conferences such as Biannual Propulsion Conference at MSFC and Biannual Structural Durability Conference at LeRC.
  - Technologists also are working flight programs
- Technology must be generic, but should be applicable to on-going or anticipated programs.
  - Goal is to provide a broad technology base that will support a wide variety of propulsion options
Earth-to-Orbit Propulsion Technology Program Work Breakdown Structure

### ETO PROPELLATION FUNDING SUMMARY - $K

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PR7-4
FY91
ETO FUNDING DISTRIBUTION
MSFC & LeRC

IN-HOUSE
25.5%

PRIME
CONTRACTORS
12.7%

UNIVERSITIES
16.9%

OTHER
CONTRACTORS
32.2%

GOVERNMENT
12.7%

ETO PROPULSION TECHNOLOGY
EMPHASIS
MSFC & LeRC
PY91

COMMON
5.8%

LOW COST
6%

PERFORMANCE
21%
Earth-To-Orbit Propulsion R&T Program Activities

- Conducted biannual ETO Technology Conference May 15-17, 1990. 123 papers presented. 400 attendees.
- Conducted Detailed ALS assessment of ETO Propulsion Project, March 1991, MSFC.
- Conducted 3rd screening of technology items for TTB March 8, 1991.
**NASA Earth-To-Orbit Propulsion R&T Program**

**Recent Program Highlights**

- Silicon nitride bearings have shown greatly extended life over SSME flight bearings in MSFC bearing tester.
- Completed assembly of a cryogenic rolling element bearing tester at LeRC.
- Turbopump test stand design complete. Stand is in MSFC FY94 C of F budget.
- First ever measurement of heat flux on a flight type rocket engine turbine blade with a plug type heat flux sensor.
- Management approval obtained for proceeding with advanced main combustion chamber technology (full scale program).
  - Concept adopted by STME and evolutionary SSME
- CFD Consortium turbine team is interactive with ALS Design Process

**What Earth-To-Orbit Does Not Address**

<table>
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<tr>
<th>TOPIC</th>
<th>COMMENTS</th>
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<tr>
<td>Aerospike nozzle</td>
<td>Small study efforts</td>
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<td>Airbreathing/Combined Cycle</td>
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<td>Storable propellants</td>
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<td>Hybrid propulsion</td>
<td>OEAT Workshop is planned</td>
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<td>Pressure fed</td>
<td>No identified requirement</td>
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<td>Commercial program; augmented for '95</td>
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<tr>
<td></td>
<td>Residual activity at MSFC, no further work planned after current contracts expire</td>
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## Focused Technology: ETO Propulsion

### Summary

**IMPACT:** The ETO Propulsion Technology Program supports all advanced engine programs. Half of the 200 tasks in the Program were judged by an ALS consortium contractor team to be directly applicable to ALS propulsion technology needs. ETO addresses the top 3 priority technology issues of the Office of Manned Space Flight.

**USER COORDINATION:** Closely tied to SSME/ALS. SSME review held at Tyson's Corner Va. Oct. 1989. ALS/SSME review held at MSFC February 1990. A special ALS review was held for ALS at MSFC in March 1991. Interagency coordination provided by Space Technology Interdependency Group (STIG).

**TECHNICAL REVIEWS:** Annual RTOP review held in Nov/Dec each year, Government only. Covers each task, technical and budget, in the program. Other reviews as required.

**OVERALL TECHNICAL and PROGRAMMATIC STATUS:** Activities are maturing. Technology items for validation are being developed, such as bearings, sensors, health monitoring algorithms.

**RATIONALE for AUGMENTATION:** Several areas require additional funding, Advanced Manufacturing, Propulsion System Studies and Additional Testing Capability. In addition the combination of budget constraints and the CSTI emphasis on validated technology starves the program of new technologies.

**MAJOR TECHNICAL/PROGRAMMATIC ISSUES:** Several propulsion options are available to the U.S. for the next generation of vehicles. The ETO program must maintain a broad base of technology to address a range of options. In addition, the absence of Program Advanced Development programs makes the ETO program the Nation's propulsion Advanced Development Program by default.