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

Presented to the

Space Systems and Technology

Advisory Committee

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Transportation Technology
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**

Manufacturing	-	High quality, low cost, inspectable
Safety	-	Safe shutdown to fault tolerant ops
Maintainability	-	Condition monitoring diagnostics
Ground Ops	-	Automated servicing and checkout
Performance	-	Max commensurate with life
Advanced Cycles	-	Full flow, combined cycle, etc.

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/HLLV 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 demonstrated

RESOURCES*

	CURRENT	STRATEGIC AUGMENTATION **
• 1991	$21.8 M	21.8
• 1992	$28.7 M	28.7
• 1993	$33.9 M	33.9
• 1994	$25.1 M	35.4
• 1995	$26.4 M	36.9
• 1996	$27.6 M	42.7
• 1997	$28.8 M	45.1

* Note: This element is closely coordinated with development efforts in NASA/OSF and other related government programs; resources shown are NASA/OAET only

** Proposed Augmentation elininated from the 3X program

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

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

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NASA Earth-To-Orbit Propulsion R&T Program

Contents

- Analytical models 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)
- Advanced component technology (bearings, seals, turbine blades, active dampers, materials, processes, coatings, advanced manufacturing)
- Instrumentation for empirically defining engine environments, for performance analysis, and for health monitoring (flow meters, pressure transducers, bearing wear detectors, optical temperature sensors)
- Engineering testing at subcomponent level to validate analytical models, verify advanced materials, and to verify advanced sensor life and performance
- Component/test bed engine for validation/verification testing in true operating environments

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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/producibility/inspection
    - Materials

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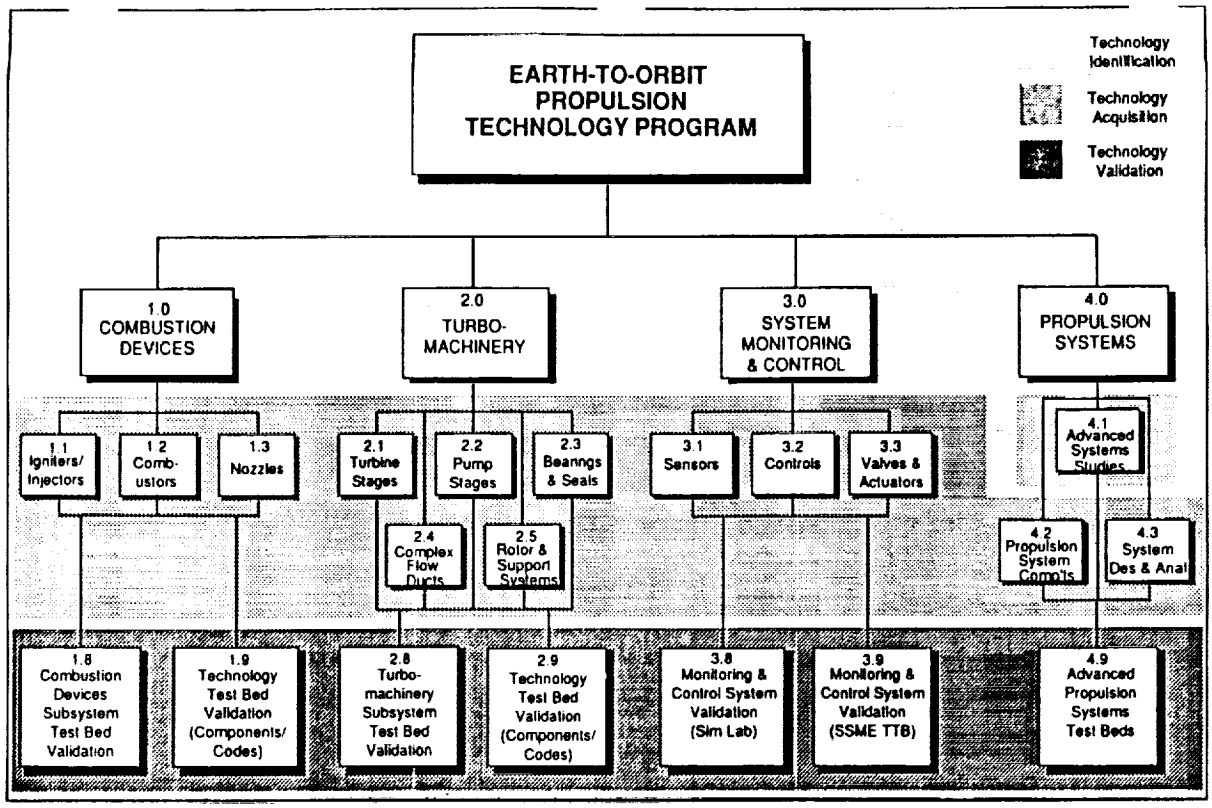
ETO Propulsion Technology Approach

- 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

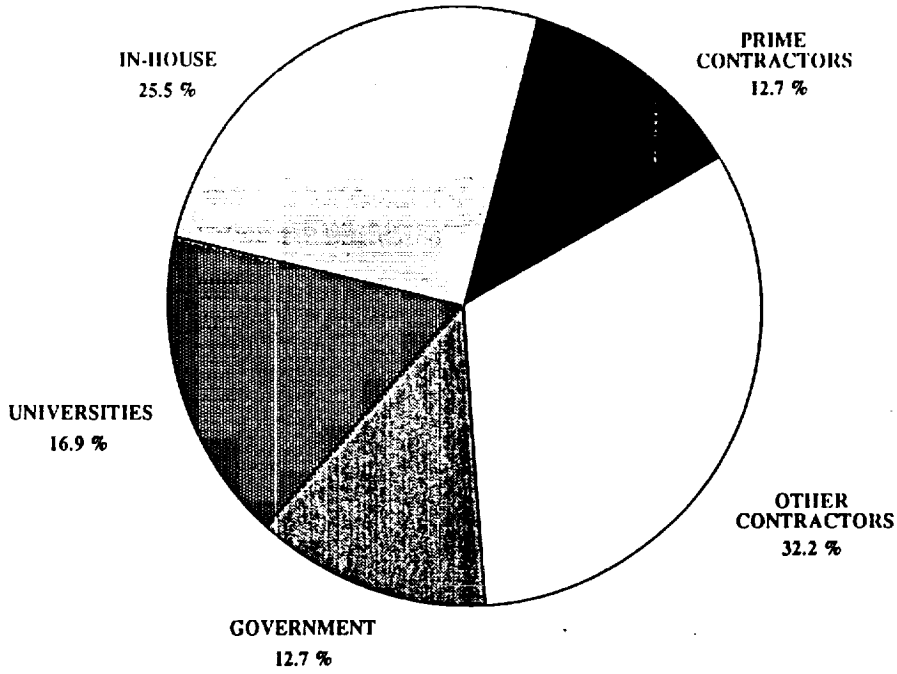


Earth-to-Orbit Propulsion Technology Program Work Breakdown Structure

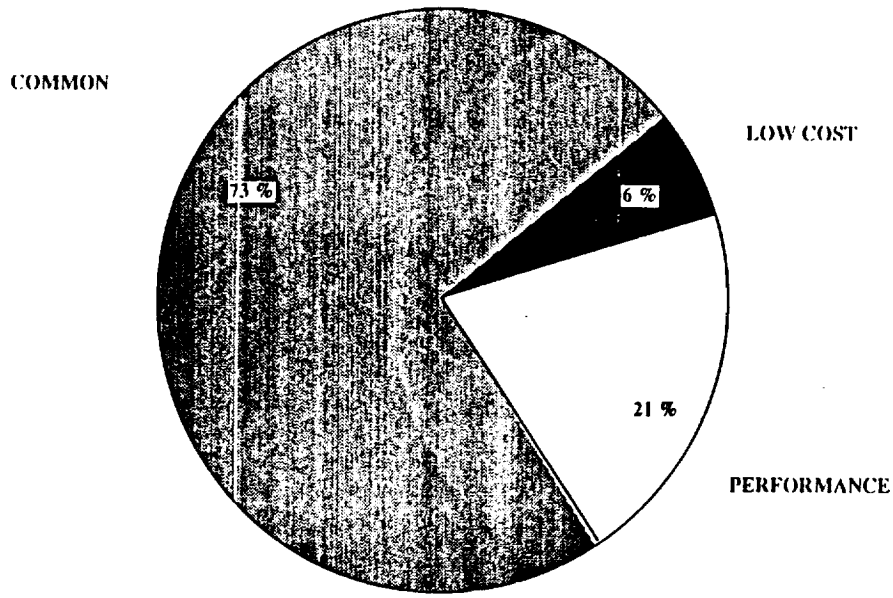
ETO PROPULSION FUNDIN IMMARY - $K 5/13/91

	FY89	FY90	FY91	FY92	FY93	FY94	FY95	FY96
TECHNOLOGY ACQUISITION								
BEARINGS	2093	1561	1562	1200	1200	800	1000	1200
STRUC. DYNAMICS*	1371	1162	1350	1400	1800	1500	1700	1700
TURBOMACHINERY*	1229	1137	1764	1600	1600	1100	1050	1200
FATIGUE/FRACTURE*	1285	837	1115	1200	1410	1200	1200	1200
COMBUSTION	3123	2875	1126	1700	1960	1200	1000	1200
FLUID & GAS DYN.	1600	989	1697	1300	1200	900	1000	1200
INSTRUMENTATION	1420	836	920	1100	1400	1000	1000	1200
CONTROLS	1753	1182	1455	1800	1600	1000	1050	1200
MANUFACTURING	763	835	1088	1100	1650	1300	1300	1400
MATERIALS*	1580	1020	1270	1000	1400	800	1000	1200
TOTAL TECH. ACQ.	16217	12434	13347	13400	15220	10800	11300	12700
VALIDATION								
COMBUSTION VALID.	2160	622	750	1100	1780	1100	1200	2000
TURBO. VALID.	5285	2412	4619	3000	4700	3600	3600	3600
SYS. MONITOR. VALID.	4578	4459	2606	8000	8800	6000	6500	5300
TOTAL VALIDATION	12023	7493	7975	12100	15280	10700	11300	10900
TOTAL PROGRAM	28240	19927	21322	25500	30500	21500	22600	23600
PMS	3375	3484	2616	3200	3400	3600	3800	4000
CENTER TOTALS	31615	23411	23938	28700	33900	25100	26400	27600

FY91
ETO FUNDING DISTRIBUTION
MSFC & LeRC



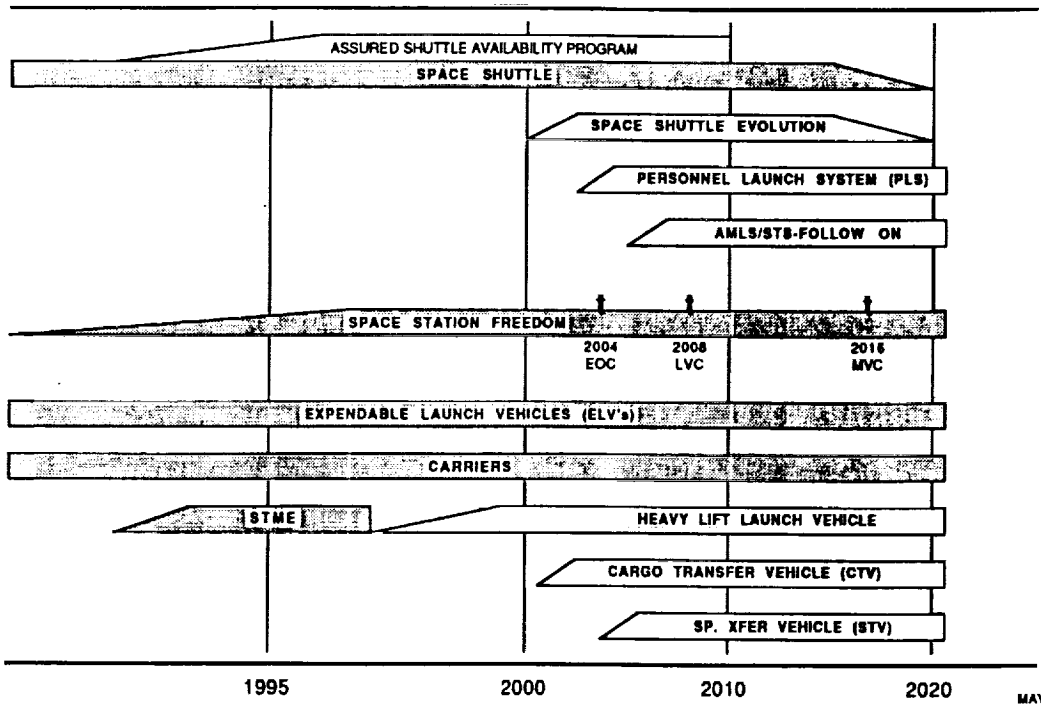
ETO PROPULSION TECHNOLOGY
EMPHASIS
MSFC & LeRC
PY91



FLIGHT PROGRAMS VISION

OAET

OFFICE OF SPACE FLIGHT



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Earth-To-Orbit Propulsion R&T Program Activities

- Conducted biannual ETO Technology Conference May 15-17, 1990. 123 papers presented. 400 attendees.
- Presented program to Space Technology Interdependency Group (STIG) November 29-30, 1990, Andrews A.F.B.
- Conducted Propulsion Program Review for OAET, December 10-12, 1990.
- Conducted Detailed ALS assessment of ETO Propulsion Project, March 1991, MSFC.
- Conducted 3rd screening of technology items for TTB March 8, 1991.
- Conducted biannual Structural Durability Conference at LeRC, May, 1991.

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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

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What Earth-To-Orbit Does Not Address

TOPIC	COMMENTS
• Aerospike nozzle	• Small study efforts • SDIO is spending significant funds on Aerospike SSTO
• Airbreathing/Combined Cycle	• NASP Program • OEAT Workshop is plannned
• Storable propellants	• No identified requirement
• Hybrid propulsion	• Commercial program; augmented for '95
• Pressure fed	• Residual activity at MSFC, no further work planned after current contracts expire

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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.

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