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INTEGRATED TECHNOLOGY PLAN FOR THE CIVIL SPACE PROGRAM

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SPACE CHEMICAL ENGINES TECHNOLOGY

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AGENDA

- INTRODUCTION/OVERVIEW/QUAD CHART
- TERMINOLOGY
- PROGRAM DESCRIPTION
- PROGRAMMATIC REVIEW
- CURRENT PROGRESS
- OBSERVATIONS
- SUMMARY CHART

Space Chemical Engines Technology

OBJECTIVES

PROGRAMMATIC

Provide the technology necessary to proceed in the late 1990's with development of moderate-thrust LOX/LH2 expander cycle engines for various space transportation applications.

TECHNICAL

Reliability:	Adequate Margins, Simplicity
Oper. Efficiency:	ICHM, Auto Servicing, Min Parts
Wide Throttling:	20:1 and Stable
Manufacturing:	Low Cost, High Quality, Inspectable
Performance:	Optimum vs. Other Factors
Materials:	Environ. Durable (Space&Oper.)
Maintainability:	Auto c/o (Space Maintainable)

SCHEDULE

- 1992 - Evaluate (study) modular system concepts
- 1992 - Advanced Expander Test Bed (AETB) DR
- 1996 - AETB Delivered
- 1996 - Complete critical sub-component technology efforts
- 1998 - AETB System characterized
- 1998 - Health Mgt. Sys. & Oper. Eff. Comps. characterized
- 1998 - AETB alternate components characterized
- 1998 - Modular engine system components characterized
- 1999 - Modular engine system characterized
- 1999 - 200 Klbf expander components characterized
- 2001 - 200 Klbf expander system test characterized

RESOURCES ($M)

	CURRENT	3X	STRATEGIC
FY91	4.0	4.0	4.0
FY92	9.0	9.0	9.0
FY93	12.6	14.9	15.0
FY94	13.2	16.7	24.0
FY95	14.0	19.6	31.0
FY96	14.7	20.2	45.8
FY97	15.4	28.0	42.4

PARTICIPANTS

LEWIS RESEARCH CENTER

Lead Center - Propulsion Studies, Technology Acquisition, Component Validation, Advanced Expander Test Bed (AETB)

MARSHALL SPACE FLIGHT CENTER

Participating Center - Propulsion Studies, Technology Acquisition, Component Validation, Test Bed

APPLICATIONS

- EARTH SPACE ORBIT TRANSFER
- SPACE EXPLORATION INITIATIVE

  LUNAR TRANSFER VEHICLE
  LUNAR EXCURSION VEHICLE
  MARS TRANSFER VEHICLE
  MARS EXCURSION VEHICLE
  UNMANNED PLANETARY AND ROBOTIC MISSIONS

- UPPER STAGES

  ATLAS
  TITAN

CRYOGENIC ENGINE OPTIONS

	RL10A-3-3A (Baseline)	RL10A-4	Advanced Space Engine
Vacuum Thrust, lbs	16,500	20,800	7,000 to 50,000
Vacuum Isp, sec	444.4	449.0	> 480
Life (TBO) - # Starts	20	15	> 100
# Hours	1.25	0.8	> 4
Weight, lbs	305	365	TBD
Length, in.	70.1	90	TBD
Thrust/Weight	54	57	TBD
Combustion Pressure, psia	475	578	> 1200
Expansion Ratio	61:1	84:1	> 600:1
Vac. Thrust Throttling Ratio	Not Specified	Not Specified	20:1
Mixture Ratio, O/F	5.0	5.5	6.0
Mixture Ratio Range, O/F	Not Specified	Not Specified	5.0 to 12.0
Basing	Ground	Ground	Space
Man-Rating	No	No	Yes
Hardware Changes from RL10A-3-3A	None	Modified Turbine Strengthened Chamber and Injector Improved Gear Train Modified LOX Pump Improved Injector 20" Nozzle Extension & Mechanism Fuel Pump Tolerance Improved Solenoids	Clean Sheet Design
Development Status	Operational	Flight Qualified	Technology Dev.

CUSTOMERS AND NEEDS

CUSTOMER / NEED	SEI 90-Day Study	SEI Early Lunar	ETO High Energy Upper Stage	ETO Commercial Upper Stage
High Reliability (includes man-rating)	Enabling	Enabling	Very Important	Very Important
Operational Efficiency	Enabling	Beneficial	Beneficial	Enabling
Throttling (to TBD level)	Enabling	Enabling	n/a	n/a
Low cost Manufacturing	Beneficial	Beneficial	Beneficial	Enabling
High Performance	Very Important	Beneficial	Very Important	Beneficial
Storable in Space Environment	Very Important	Very Important	n/a	n/a
Reusable	Very Important	n/a	n/a	n/a
Maintainable in Space	Very Important	n/a	n/a	n/a

SPACE CHEMICAL ENGINES TECHNOLOGY

INTEGRATED TECHNOLOGY PLAN REVIEW

- EMPHASIS IS ON FUTURE PLANS AND DIRECTION
- SOME HISTORICAL PERSPECTIVE IS NECESSARY
- PROGRAM CONTENT BASED ON A STRATEGIC RESOURCE PROFILE
  SATISFIES USERS NEEDS
- COMPARISONS MADE BETWEEN
  STRATEGIC AND CURRENT RESOURCE PROFILES

SPACE CHEMICAL ENGINES TECHNOLOGY

TERMINOLOGY

- ASE: ADVANCED SPACE ENGINE
  BASE R&T (EARLY 1970's)
- OTV: ORBIT TRANSFER VEHICLE (ENGINE TECHNOLOGY)
  BASE R&T (1982-1988)
- CTP: CHEMICAL TRANSFER PROPULSION
  PATHFINDER (1989-1990)
- SBE: SPACE BASED ENGINES
  EXPLORATION TECHNOLOGIES (1991)
- ASE: SPACE EXPLORATION INITIATIVE (1989 ONWARD)
  NEW ENGINE
  20-50 KLBF CLASS, 200 KLBF CLASS
  TRANSFER & EXCURSION VEHICLES (LUNAR, MARS)
- SCET: SPACE CHEMICAL ENGINES TECHNOLOGY
  PRESENT FOCUSED TECHNOLOGY PROGRAM

SPACE CHEMICAL ENGINES TECHNOLOGY

PROGRAM DESCRIPTION

CONCEPT

- CONDUCT A FOCUSED TECHNOLOGY PROGRAM IN SPACE ENGINES:
  - AS RAPIDLY AS RESOURCES PERMIT
  - AS RAPIDLY AS PRIORITIES DICTATE
- CONDUCT THE PROGRAM WITH THE WIDEST POSSIBLE PARTICIPATION
  - INDUSTRY
  - ACADEMIA
  - GOVERNMENT
- INVOLVE THE USERS AS SOON AS PRACTICABLE
  - REQUIREMENTS
  - TECHNOLOGY TRANSFER

PROGRAM DESCRIPTION

PURPOSE

- PROVIDE THE TECHNOLOGY NECESSARY TO CONFIDENTLY PROCEED, IN THE LATE 1990'S WITH THE DEVELOPMENT OF MODERATE THRUST (7.5 TO 200 KLBF) HIGH-PERFORMANCE, LIQUID OXYGEN/LIQUID HYDROGEN EXPANDER CYCLE ENGINES FOR VARIOUS SPACE TRANSPORTATION APPLICATIONS.

PROGRAM DESCRIPTION

MAJOR OBJECTIVES

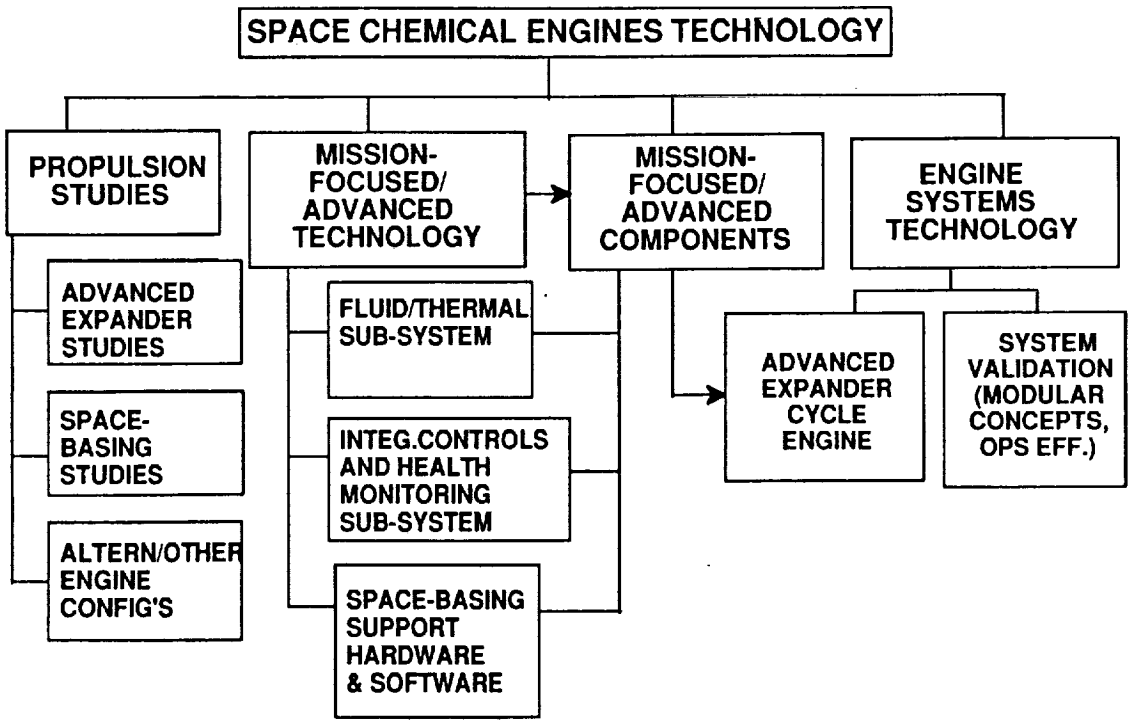
- IDENTIFY, ASSESS TECHNOLOGY REQUIREMENTS
- IDENTIFY, CREATE, AND/OR VALIDATE:
  - DESIGN & ANALYSIS METHODOLOGIES/SOFTWARE
  - MATERIALS WITH REQUIRED/DESIRABLE PROPERTIES
  - RELIABLE, COST-EFFECTIVE MANUFACTURING PROCESSES
- DEVELOP AND VALIDATE ENGINE AND SUPPORT EQUIPMENT SUB-COMPONENT, COMPONENT, AND SYSTEM TECHNOLOGIES FOCUSED ON (IN PRIORITY ORDER):
  - RELIABILITY
  - OPERATIONAL EFFICIENCY
  - WIDE-RANGE THROTTLING
  - LOW-COST MANUFACTURING
  - EFFICIENT PERFORMANCE
  - SPACE-ENVIRONMENT DURABILITY
  - REUSABILITY/OPERATION-ENVIRONMENT DURABILITY
  - IN-SPACE MAINTAINABILITY

PROGRAM DESCRIPTION

APPROACH

- PROPULSION STUDIES TO DEFINE PROPULSION TECHNOLOGY REQUIREMENTS
- TECHNOLOGY EFFORTS ADDRESSING THE TECHNOLOGY NEEDS
- DEVELOPMENT OF ANALYTICAL TOOLS, TECHNOLOGIES, DESIGNS
- VALIDATION IN AN ENGINE SYSTEM ENVIRONMENT

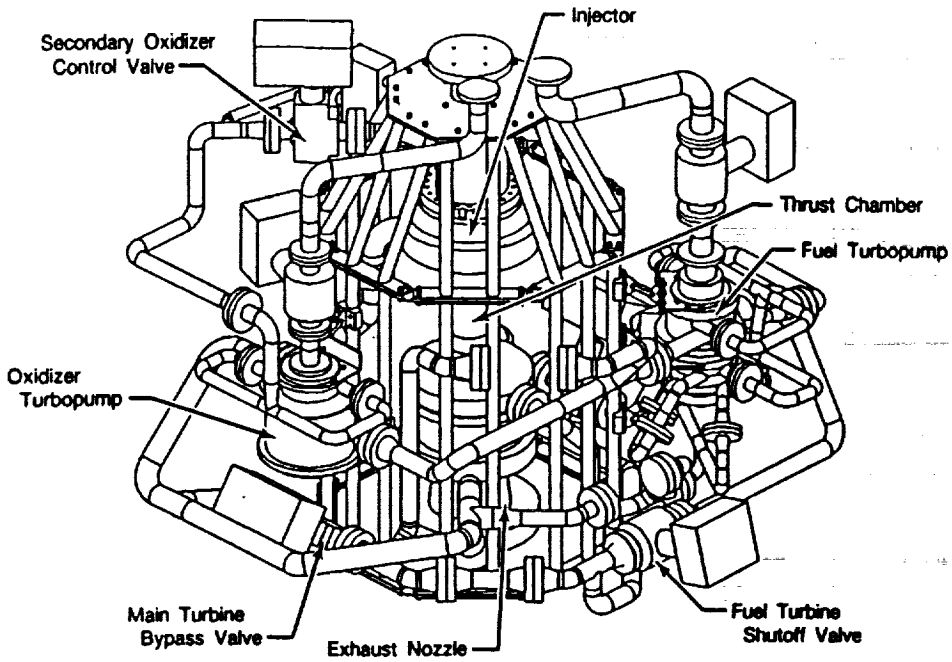
PROGRAM DESCRIPTION



ADVANCED EXPANDER TEST BED (AETB) CHARACTERISTICS

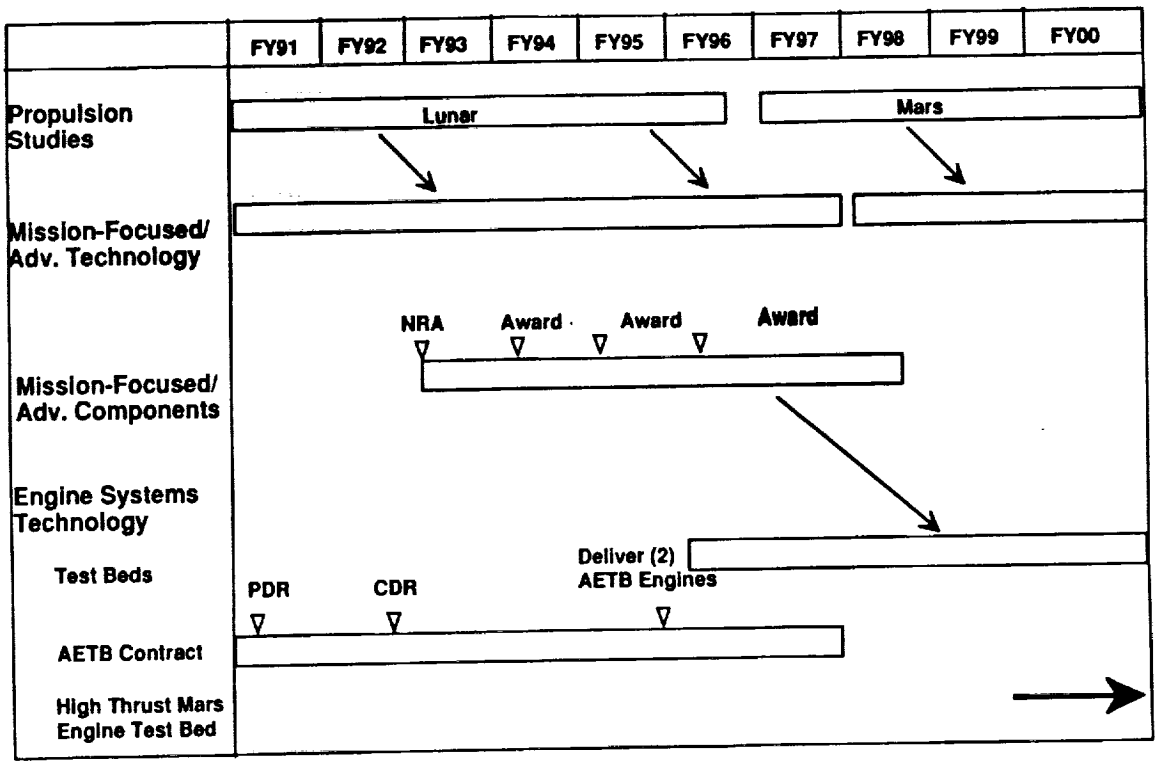
• PROPELLANTS:	HYDROGEN/OXYGEN
• CYCLE:	SPLIT EXPANDER
• THRUST:	25K (DESIGN) 20K (NORMAL OPN)
• CHAMBER PRESSURE:	1500 PSI (DESIGN) 1200 PSI (NORMAL OPN)
• THROTTLING:	125% TO 5% CONTINUOUS
• IDLE MODES:	PUMPED (LOW NPSP)
	TANKHEAD (NON-ROTATING)
• MIXTURE RATIO (O/F):	6.0 ± 1.0 12.0
• LIFE	100:STARTS/5 HOURS

ADVANCED EXPANDER TEST BED (AETB)



PROGRAM DESCRIPTION

STRATEGIC PROGRAM



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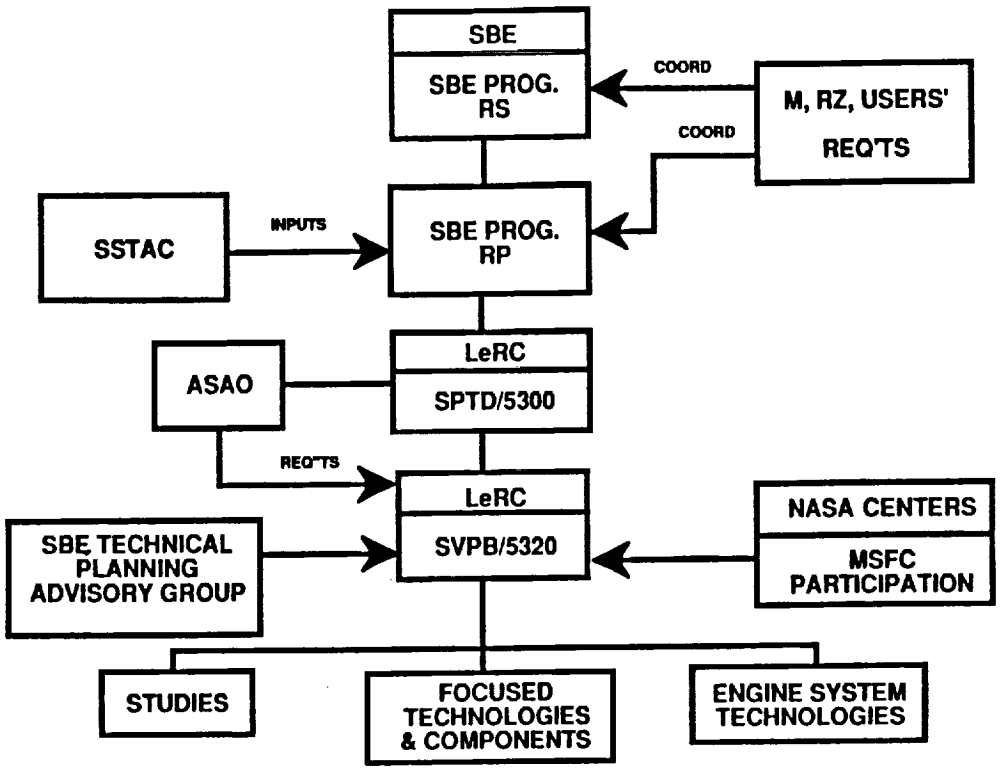


PROGRAM DESCRIPTION

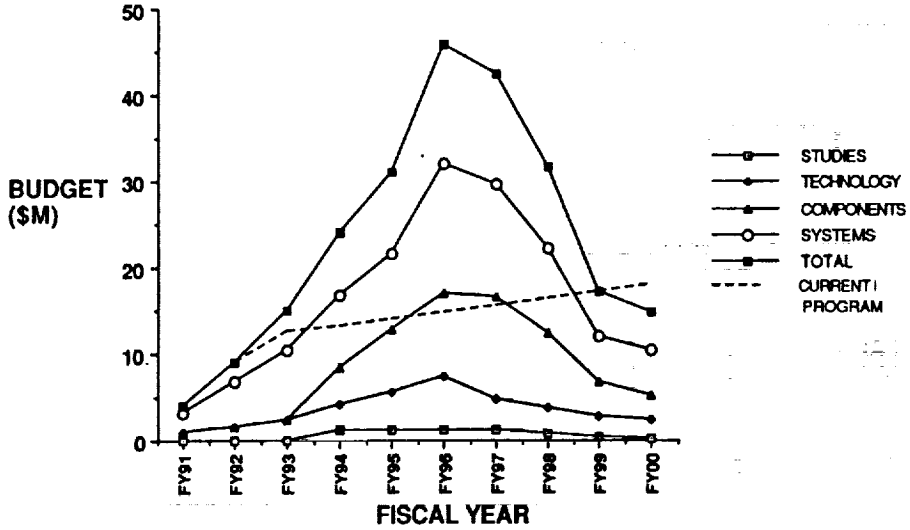
RESOURCE PROFILES

($M)

Program	FY91	92	93	94	95	96	97
Strategic	4.0	9.0	15.0	24.0	31.0	45.8	42.4
"3X"	4.0	9.0	14.9	16.7	19.6	20.2	28.0
Current	4.0	9.0	12.6	13.2	14.0	14.7	15.4

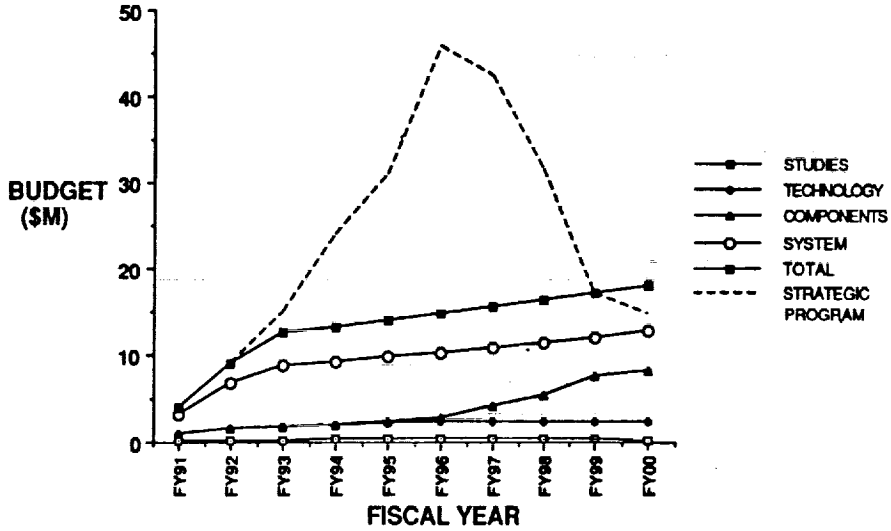
PROGRAM DESCRIPTION

STRATEGIC PROGRAM



PROGRAM DESCRIPTION

CURRENT PROGRAM



PROGRAMMATIC REVIEW

STRATEGIC PROGRAM

- PROGRAM STARTED IN FY89
  - PLANNING UNDERWAY IN FY88
  - PROGRAM CONCEPT FINALIZED
  - AETB PROCUREMENT STARTED
  - STRATEGIC PROGRAM RESOURCE REQUIREMENTS ESTABLISHED
- FY90-92 LEAN YEARS
  - REPLAN, "HOLD-ON" STRATEGY
  - AFFIRM EMPHASIS ON SYSTEMS TECHNOLOGY
- FY90-92 IMPACTS
  - MINIMIZED PARTICIPATION (OTV CONTRACTS, INDUSTRY, UNIVERSITIES)
  - OTV TASK ORDER CONTRACTS END, NRA'S DO NOT START: STRAINS INDUSTRY PARTICIPATION
  - IRREVERSIBLE SCHEDULE IMPACTS (AETB, NRA'S)

NEEDS	STRATEGIC	CURRENT
HIGH RELIABILITY	• 1996 AETB SYSTEMS TESTS • ALTERNATIVE CONFIG. SYSTEMS	• 1997 AETB SYSTEMS TESTS • ALTERNATIVE CONFIG. COMPONENTS
OPERATIONAL EFFICIENCY	• FOCUSED TECH & COMPONENTS • SYSTEM TESTBED • HEALTH MANAGEAMENT SYSTEM	• FOCUSED COMP ON AETB • HEALTH MANAGEMENT COMPONENTS
THROTTLING	• FOCUSED TECH & COMPONENTS • SYSTEM VALIDATION	• FOCUSED COMPONENT TURBOPUMP(S), • TURBOPUMP VALIDATION ON AETB
LOW-COST MFG.	• PUMPS, COMBUSTION DEVICES • SYSTEM VALIDATION	• FOCUSED TECHNOLOGY
HIGH PERFORMANCE	• AETB SYSTEM • FOCUSED COMPONENTS • SYSTEM VALIDATION • ALTERNATIVE SYSTEMS	• AETB SYSTEM
SPACE STORABLE	• MATERIAL VALIDATION • STORABLE COMPONENTS	• FOCUSED TECHNOLOGY
SPACE MAINTAINABLE	• SYSTEM VALIDATION	• STUDIES

STRATEGIC PROGRAM

- PROVIDES TECHNOLOGY TO MEET USER NEEDS
  - SYSTEMS LEVEL TECHNOLOGY (AETB, MODULAR SYSTEMS, OPERATIONAL EFFICIENCY)
  - ADVANCED/ALTERNATIVE COMPONENTS
  - SYSTEMS LEVEL VALIDATION
- ADEQUATELY MEET MOST USER SCHEDULAR NEEDS
  - COMMERCIAL NEEDS MARGINALLY MET
  - HIGH ENERGY UPPER STAGES
  - EXPLORATION MISSIONS
- PROMOTES TECHNOLOGY TRANSFER
  - WIDE NUMBER OF PARTICIPANTS (NRA) (INDUSTRY, ACADEMIA, GOVERNMENT)
  - PARTICIPATION IN PARALLEL
  - EXTENSIVE LEVELS OF PARTICIPATION (ALL ON SYSTEM MODEL LEVEL, ALL WITH COMPONENTS)
  - PERMITS SUBSTANTIAL, MEANINGFUL LEVEL OF PARTICIPATION BY MSFC
  - ENABLES PRODUCTIVE SYNERGISM WITH BASE R&T AND NON-SCET PROGRAMS

CURRENT PROGRAM

- MARGINALLY MEETS USER TECHNICAL NEEDS
  - AETB SYSTEMS TECHNOLOGY (1989)
  - ONE OR TWO ADVANCED COMPONENTS (TURBOPUMPS)
  - LIMITED FOCUSED TECHNOLOGY (COMBUSTION DEVICES, HEALTH MONITORING)
  - STUDIES (MAINTAINABILITY)
- MARGINALLY MEETS SOME USER SCHEDULAR NEEDS
  - COMMERCIAL NEEDS ARE IMMEDIATE (COST AVOIDANCE, EARLY MARKET ENTRY)
  - HIGH ENERGY UPPER STAGES NEEDED NEAR TERM (DOD, UNMANNED MISSIONS)
  - EXPLORATION MISSIONS MOST COMPLICATED, REQUIRE ADEQUATE TECHNOLOGY LEAD TIMES (SYSTHESIS GROUP IOC'S 2003, 2004, 2005)
- INHIBITS TECHNOLOGY TRANSFER ("HANDS ON")
  - VERY LIMITED NUMBER OF PARTICIPANTS (NRA) (ONE OR TWO COMPONENTS)
  - PARTICIPATION LIKELY IN SERIES (ONE OR TWO AT A TIME)
  - LIMITED LEVEL OF PARTICIPATION (STUDIES, FOCUSED TECHNOLOGY)
  - DIFFICULT INTERNASA CENTER TECHNICAL PLANNING (LERC/MSFC)

PROGRAMMATIC REVIEW

SPACE PROPULSION TECHNOLOGY

BASE R&T/FOCUSED R&T

- SPACE CHEMICAL ENGINE TECHNOLOGY REQUIRES A FLOW OF TECHNOLOGIES THROUGH LEVELS OF TECHNICAL MATURITY

- TECHNOLOGIES PASS FROM THE BASE PROGRAM TO THE FOCUSED PROGRAM WHEN THEY REACH ACKNOWLEDGED VIABILITY OF AN ACCEPTABLE LEVEL OF MATURITY

- BASE AND FOCUSED PROGRAMS ARE STRONGLY LINKED, BUT SEPARATE

PROGRAMMATIC REVIEW

SPACE PROPULSION TECHNOLOGY

BASE R&T

- BROAD UTILITY FOR A WIDE RANGE OF APPLICATIONS
- FUNDAMENTAL KNOWLEDGE THAT COULD BECOME PART OF A FOCUSED PROGRAM

  HIGH RISK/HIGH PAYOFF

- SPECIFICS:
  - NETWORK OF TECHNOLOGY INFORMATION
  - ENGINEERING AND SCIENTIFIC ANALYSIS AND DESIGN TOOLS
  - INSTRUMENTATION/DIAGNOSTICS
  - MATERIALS
  - PROPELLANTS
  - PROCESSES
  - SUBCOMPONENTS TO COMPONENTS TO SYSTEMS

PROGRAMMATIC REVIEW

SPACE PROPULSION TECHNOLOGY

FOCUSED R&T

- TECHNOLOGIES FOR SPECIFIC MISSION/PROGRAM/APPLICATION
- DEFINED DELIVERABLES, SCHEDULE, RESOURCE
- PRODUCT: TECHNOLOGIES TO SATISFY THE USER REQUIREMENTS
- MULTIDISCIPLINARY CONTENT, PROGRESSION TO A SPECIFIC TECHNOLOGY READINESS LEVEL
- EXTREMELY VISIBLE
- SPECIFICS:
  - STUDIES AND ANALYSES TO GUIDE PROGRAM
  - METHODOLOGIES FOR THE DESIGN OF PROPULSION SYSTEMS
  - COMPONENT AND SYSTEM MODELING
  - VALIDATED TECHNOLOGIES THAT MEET USER REQUIREMENTS
  - SYSTEM FOCUS
  - FLIGHT EXPERIMENTATION

ENGINE SYSTEMS

- TESTBED CONCEPT IS KEY TO SPACE CHEMICAL ENGINES TECHNOLOGY
- TESTBED VALIDATION RECOGNIZED FOCUSED TECHNOLOGY NECESSITY (ETO)
- TESTBED EMULATES HIGHLY SUCCESSFUL AEROPROPULSION PROGRAM
  - ATEGG (ADVANCED TURBINE ENGINE GAS GENERATOR (CORE))
  - JTDE (JOINT TECHNOLOGY DEMONSTRATOR ENGINE)
  - IHPTET (INTEGRATED HIGH PERFORMANCE TURBINE ENGINE TECHNOLOGY)
  - U.S. AEROPROPULSION LEADS THE WORLD
- AETB HAS WIDE APPLICABILITY

LERC/MSFC TECHNICAL PLANNING

- WE HAVE 2 DIFFERENT PERSPECTIVES
  - TECHNOLOGISTS (LERC)
  - DEVELOPERS (MSFC)
- WE COME FROM 2 DIFFERENT CULTURES
  - "BOTTOMS UP" (LERC)
  - "TOP DOWN" (MSFC)
- WE HAVE WORKED TO DIFFERENT END PRODUCTS
  - TECHNOLOGY MATURITY LEVEL, MULTIPLE USERS (LERC)
  - SPECIFIC HARDWARE DEMONSTRATION, SPECIFIC USE (MSFC)
- SPACE CHEMICAL ENGINES FOCUSED TECHNOLOGY PROGRAM
  - TECHNOLOGY PROGRAM
  - BLENDS PERSPECTIVES, CULTURES
  - BEST COMBINATION

CURRENT PROGRESS

- IDENTIFIED POTENTIAL CUSTOMERS
- IDENTIFIED CUSTOMER NEEDS
- IDENTIFIED MEANS OF MEETING NEEDS
- IDENTIFIED MOST IMPORTANT TECHNOLOGY PROGRAM ELEMENTS
- PLANNED AND COSTED PROGRAM ELEMENTS
- FINALIZING NEAR-TERM DETAILS, IMPLEMENTAION

OBSERVATIONS

- SPACE CHEMICAL ENGINES TECHNOLOGY PROJECT IN PLACE
- FY91 AND FY92 LEAN YEARS WITH IRREVERSIBLE EFFECTS
- PROGRAMS HAVE BEEN PLANNED FOR STRATEGIC/CURRENT PROGRAMS
- STRATEGIC PROGRAM HEALTHY (CONTENT, PACE, PARTICIPATION)
- CURRENT PROGRAM MARGINAL
- LERC AND MSFC DETAILED TECHNICAL PLANNING IN PROGRESS
- FY93 FUNDING DETERMINES MAJOR PROGRAM DIRECTION