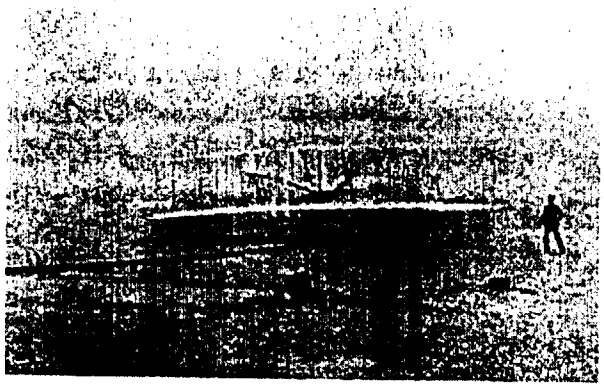
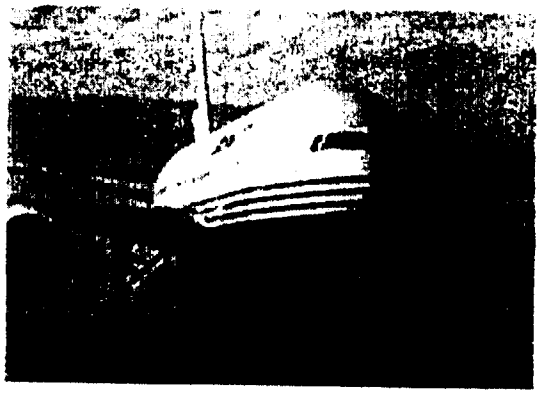
We Must Take the Next Steps Towards Safe, Routine Space Travel



Wright Flyer (1903)

6 1/2 Generations of Airplanes in a Century



Boeing 777 (Today)

1st Generation Reusable Launch Vehicle (1981 – Today)

Enterprise Goals

GOALS: Earth-to-Orbit

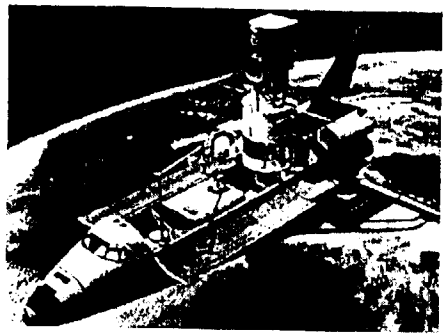
- Within 10 years,
  - Increase the safety by two orders of magnitude
  - Reduce the cost to NASA transportation of placing payloads in orbit by one order of magnitude.
- Within 25 years,
  - Increase the safety by four orders of magnitude.
  - Reduce the cost of placing payloads in orbit by two orders of magnitude.

GOALS: In-Space Transportation

- Within 15 years,
  - A factor of ten reduction in the cost of Earth orbital transportation.
  - A factor of two to three reduction in propulsion system mass and travel time required for planetary missions.
- Within 25 Years,
  - Enable bold new missions to the edge of the solar system and beyond by reducing travel times by one to two orders of magnitude.

SPACE TRANSPORTATION DAY

Generations of Reusable Launch Vehicles

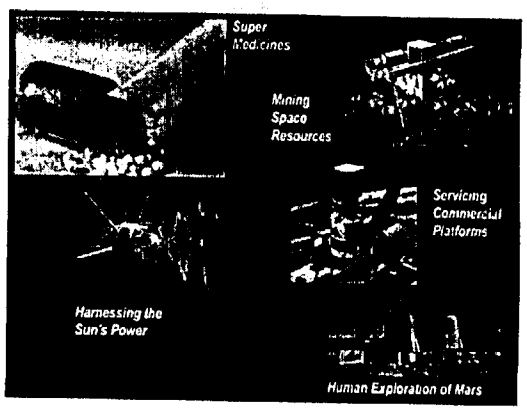


Today: Space Shuttle 1st Generation RLV

- Orbital Scientific Platform
- Satellite Retrieval and Repair
- Satellite Deployment

2010: 2nd Generation RLV

- Space Transportation
- Rendezvous, Docking, Crew Transfer
- Other on-orbit operations
- ISS Orbital Scientific Platform
- 10x Cheaper
- 100x Safer

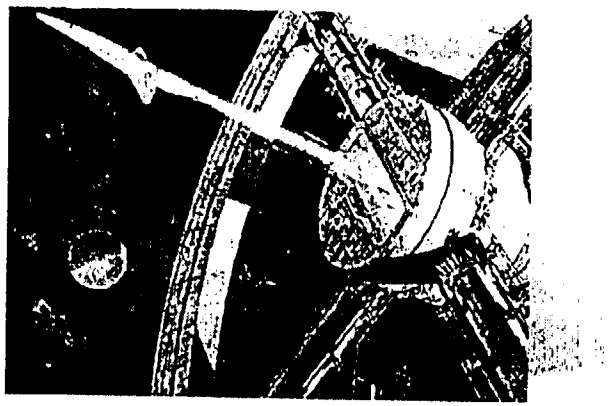


2025: 3rd Generation RLV

- New Markets Enabled
- Multiple Platforms / Destinations
- 100x Cheaper
- 10,000x Safer

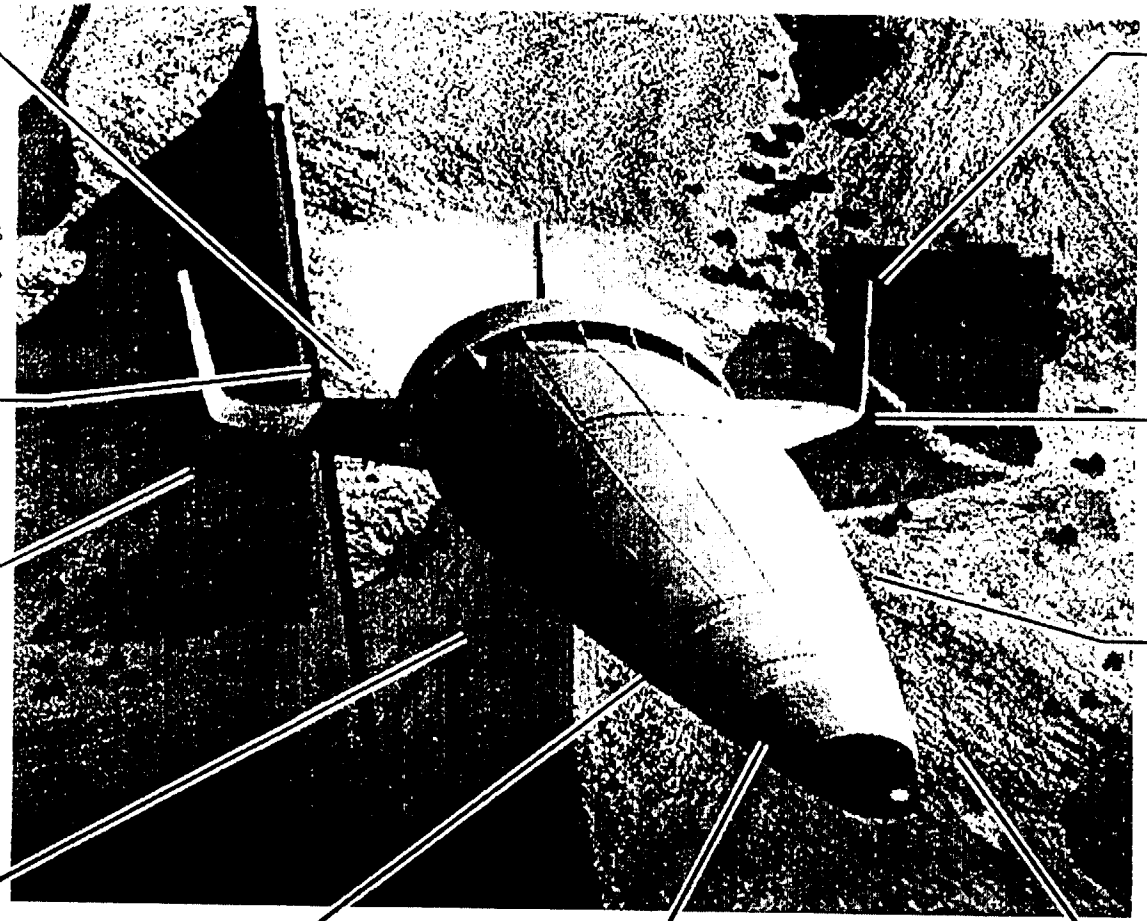
2040: 4th Generation RLV

- Routine Passenger Space Travel
- 1,000x Cheaper
- 20,000x Safer



SPACE TRANSPORTATION DAY

Space Transportation Across NASA



Ames Research Center
- Non Metallic Thermal Protection Systems
- Computational Tools
- Information Systems

Stennis Space Center
- Rocket Propulsion Testing

Kennedy Space Center
- Payload and Launch Operations
- Range Safety
- IVHM
- Cryo Testbed

Dryden Flight Research Center
- Atmospheric Flight Operations

Johnson Space Center
- Crew and Passenger Systems

Langley Research Center
- Airframe Design
- Integrated Thermal Structures
- Materials Research
- Combined Cycle Propulsion

JPL
- In Space Propulsion Concepts
- Microelectronics/ Sensors

Glenn Research Center
- Power Systems
- Advanced Propellants
- Propulsion Materials
- Combined-Cycle Propulsion

Marshall Space Flight Center (Lead Center)
- System Integration
- Propulsion Systems
- Avionics Systems
- Combined-Cycle Propulsion
- Vehicle Definition
- Structural and Mechanical Design and Integration
- Advance Manufacturing

Air Force Research Lab
- System Integration
- Propulsion Systems
- Avionics Systems
- Combined-Cycle Propulsion

Three Tiered Implementation Approach for Future Space Transportation Technology

CUSTOMER NEEDS

Trailblazer Class Demonstrators

- Integrated system technology flight demonstrators
- Responds to mission needs "pull"
- Verifies operability & programmatic viability
- May provide residual capability (science payloads)
- End users share in both decisions and cost

Flight When Required

future X

Pathfinder Class Demonstrators

- Narrow focus flight technology demonstrators
- Driven by technology
- Development similar to "Discovery" spacecraft series
- Less than ~ $100M each
- In test in less than ~ 3 years
- Allows for NASA and industry development

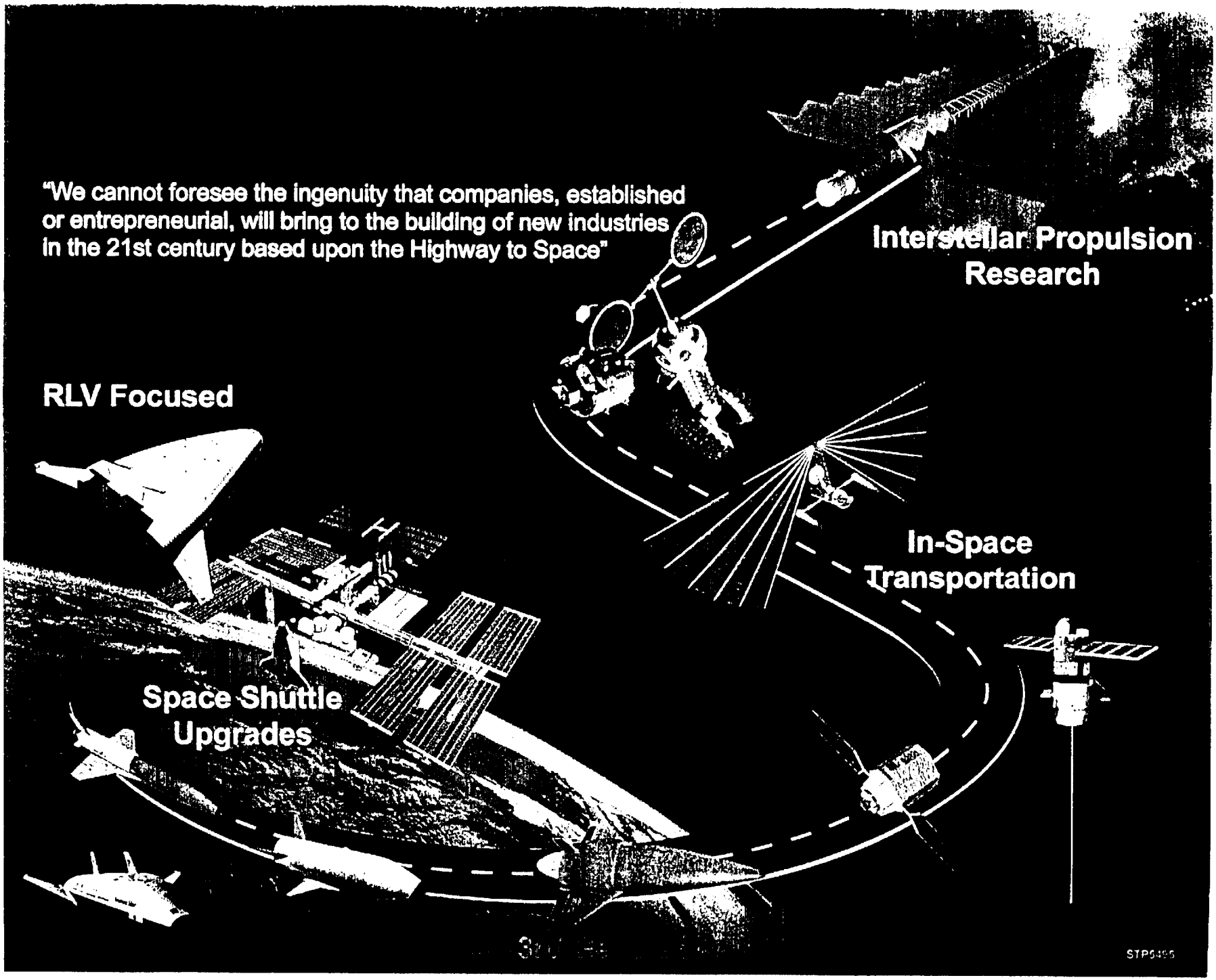
Focused

Core

Cross-cutting Technology Pipeline

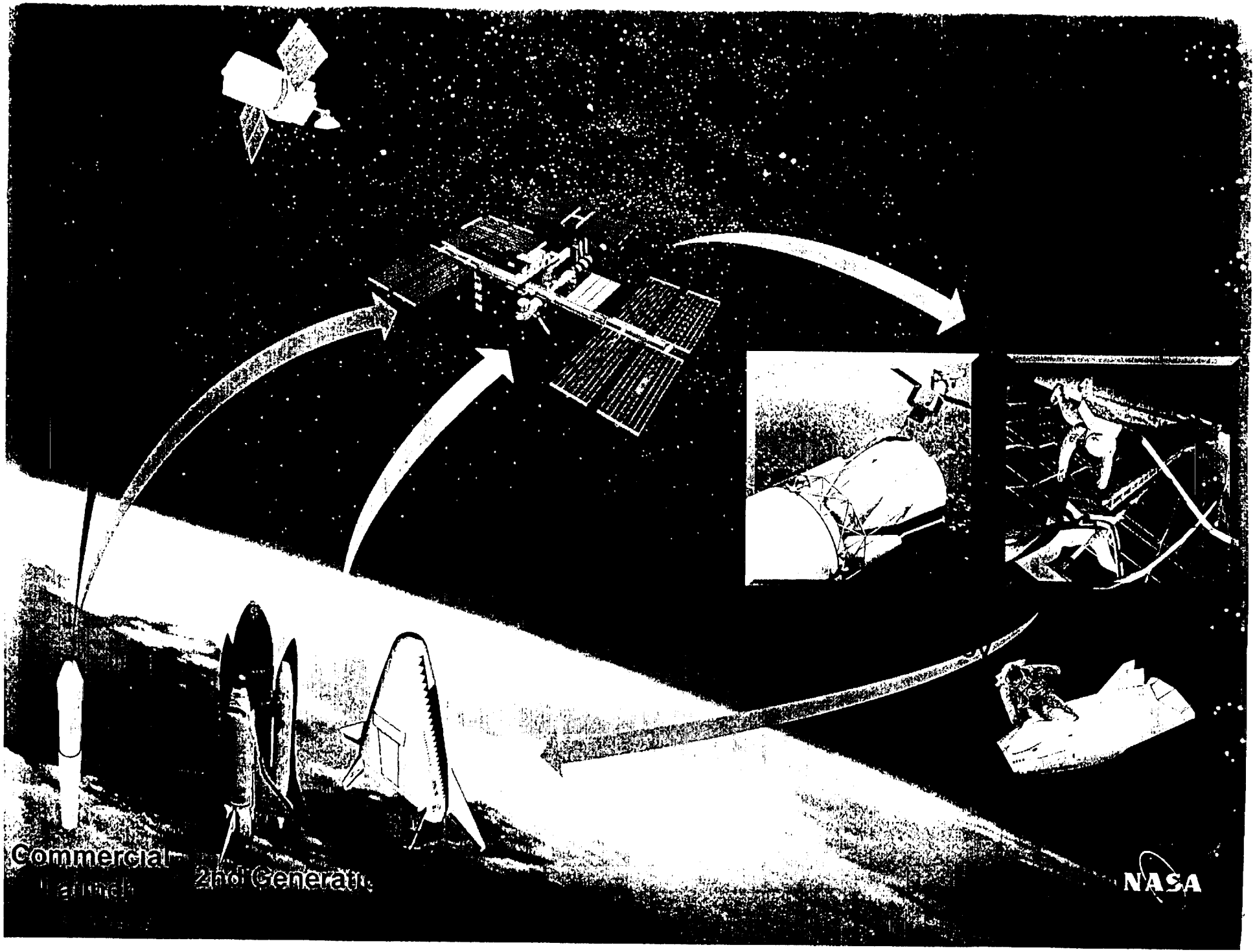
Aerospace Base Technology

Research

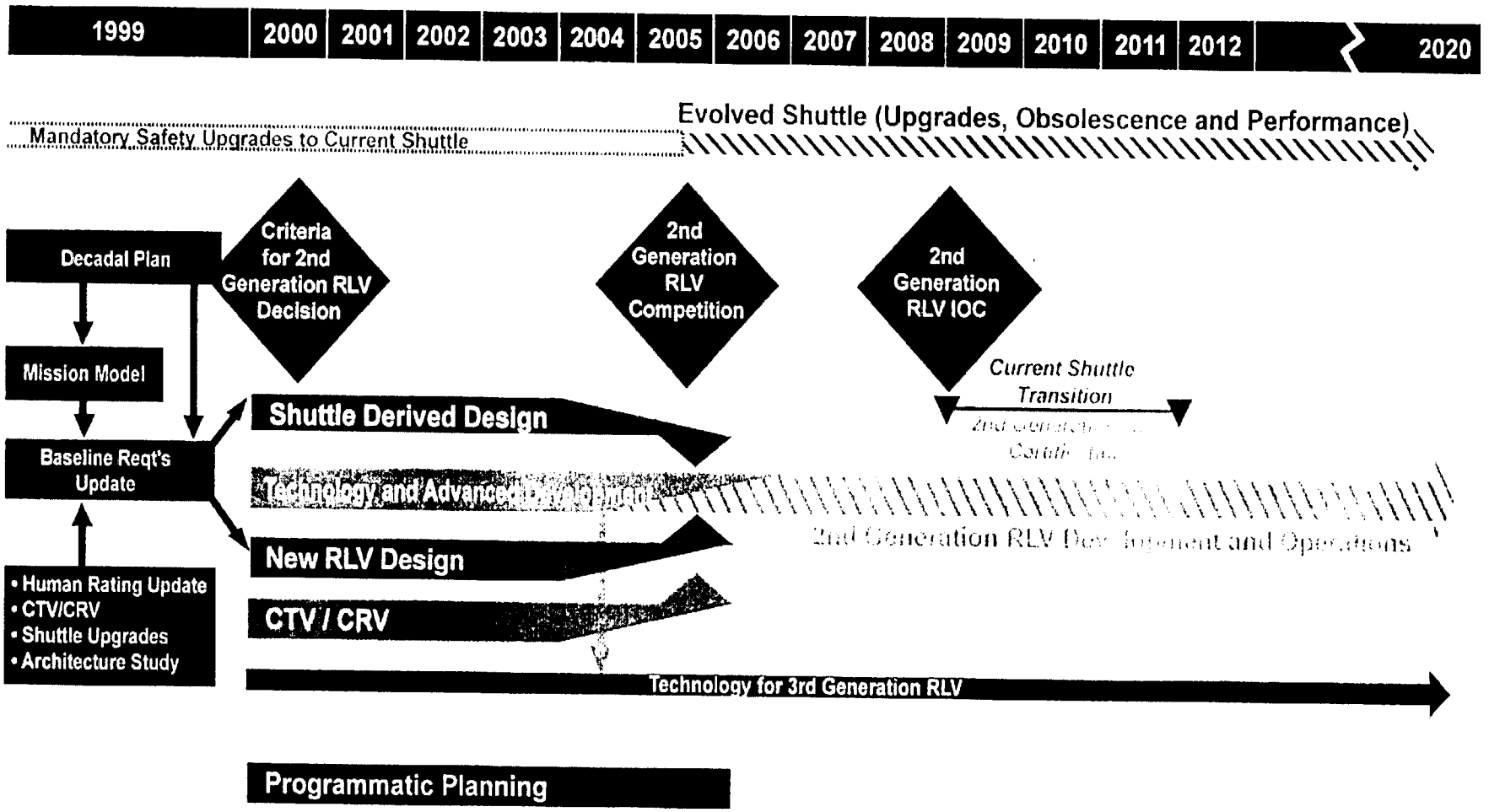

"We cannot foresee the ingenuity that companies, established or entrepreneurial, will bring to the building of new industries in the 21st century based upon the Highway to Space"
Interstellar Propulsion Research
RLV Focused
In-Space Transportation
Space Shuttle Upgrades
STP5486

Develop a Comprehensive, Agency Level Space Transportation Plan That Will Enable NASA's Strategic Plan

- ***Focus on Safety, Reliability, Cost and NASA mission requirements*** *while making maximum use of US aerospace industry capabilities and commercial market leverage*
- ***Enable a competition at an acceptable level of risk*** *for a 2nd generation Reusable Launch Vehicle (RLV) by 2005 which could include Shuttle-derived and new design RLV concepts*
- ***Secure NASA's future through investments in 3rd generation RLV technologies for Earth-to-orbit and in-space applications***
- *Ensure* ***Continued Safe Access to Space through Space Shuttle Safety Upgrades until a replacement alternative has been demonstrated***


Commercial
2nd Generation
NASA

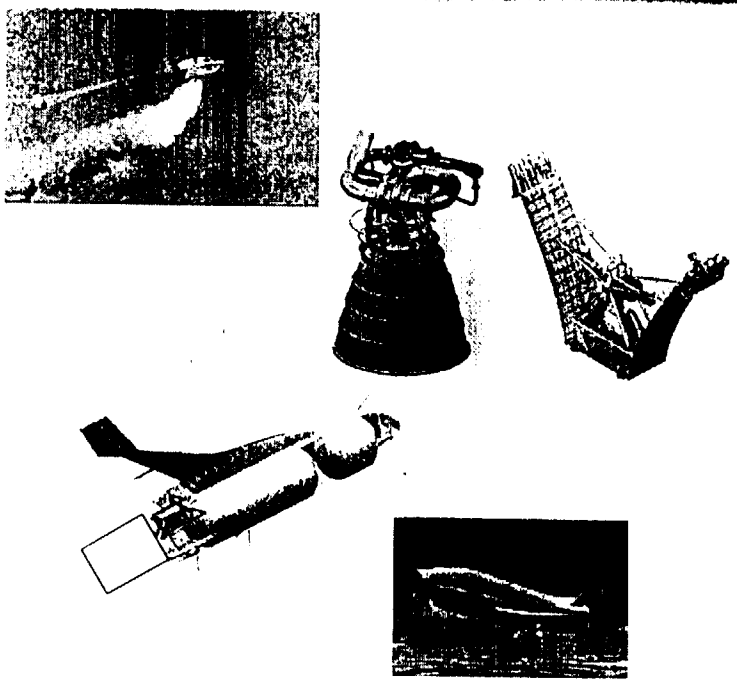
Timeline for Addressing NASA's Needs

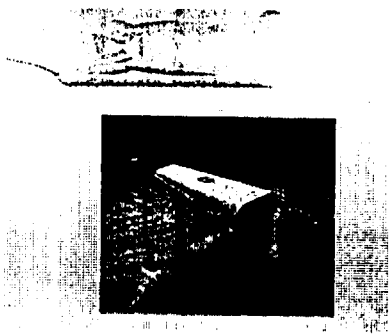


SPACE TRANSPORTATION DAY

Significant 2nd Generation Technology Drivers

- **Crew Escape and Survival**
  - Detection, separation, ascent/descent
- **Operable, Long-life H_2/O_2 and RP/O_2 Engines**
  - 200 mission life, 100 missions to overhaul
- **Long life, lightweight integrated airframe**
  - Critical integrated cycle testing (500 missions)
- **Advanced TPS, IVHM, and Operations**
  - Quick turn vehicle with intelligent data analysis
- **Ejector Ramjet**
  - Improved performance margin
- **SHARP Leading Edges**
  - Global crossrange from orbit



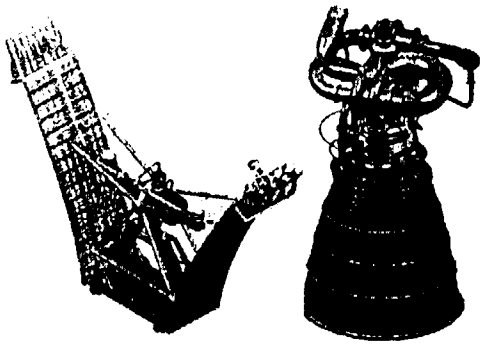


Cutting Edge for 2nd Generation

Significant Commonality Between Shuttle Derived and New Design RLV Needs

SPACE TRANSPORTATION DAY

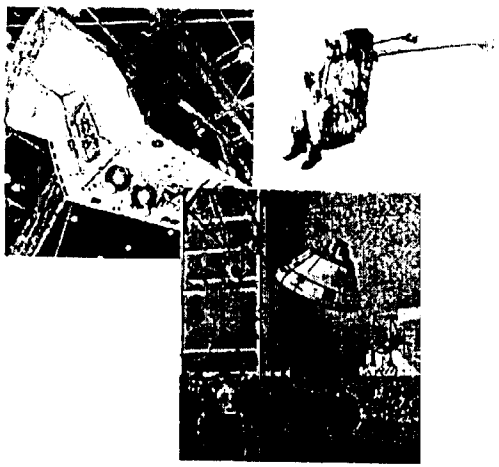
Example Large Scale Ground Demonstrations



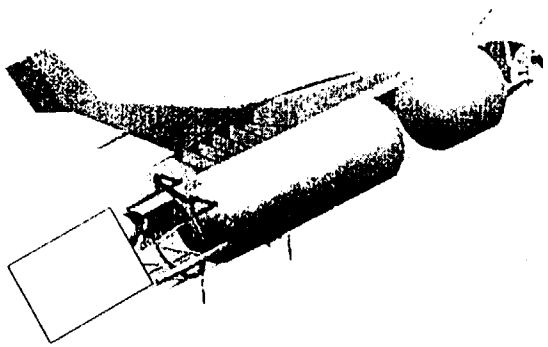
LOx/LH_2 Engine Prototypes

LOx/Hydrocarbon Engine Prototype

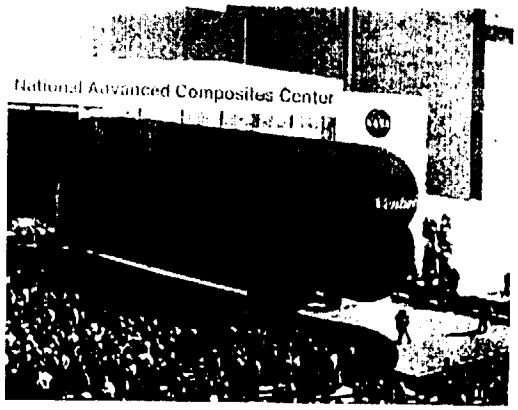
Ejector Ramjet Testbed



Crew Escape Demonstrations

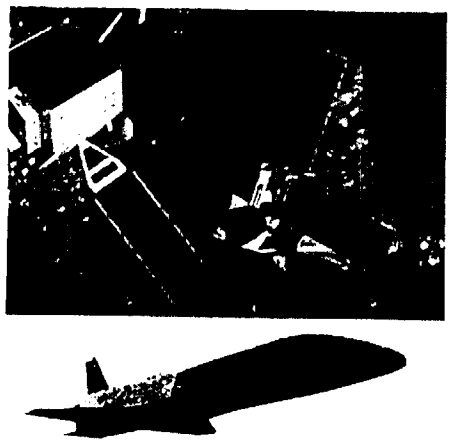


Integrated Airframe Life Cycle Testing

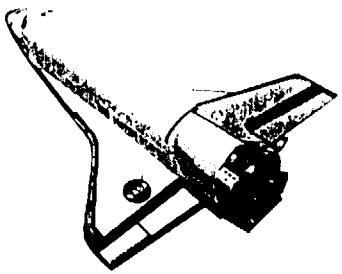


Large Scale Advanced Mfg

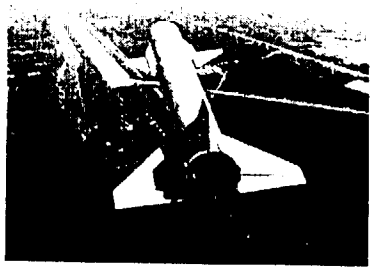
Example Pathfinder Demonstrations



Additional X-34 and X-37 Experiments And Demonstrations

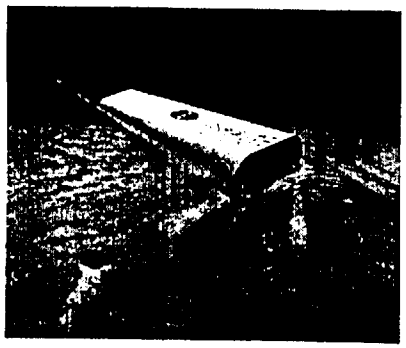


Space Shuttle Experiments

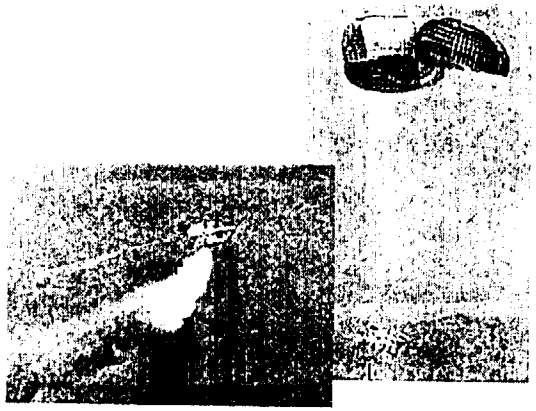


Reusable First Stage

Rocket Based Combined Cycle Experiments



SHARP Materials / High Lift/Drag Experiments

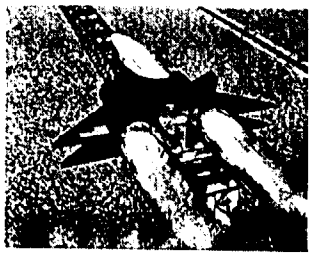


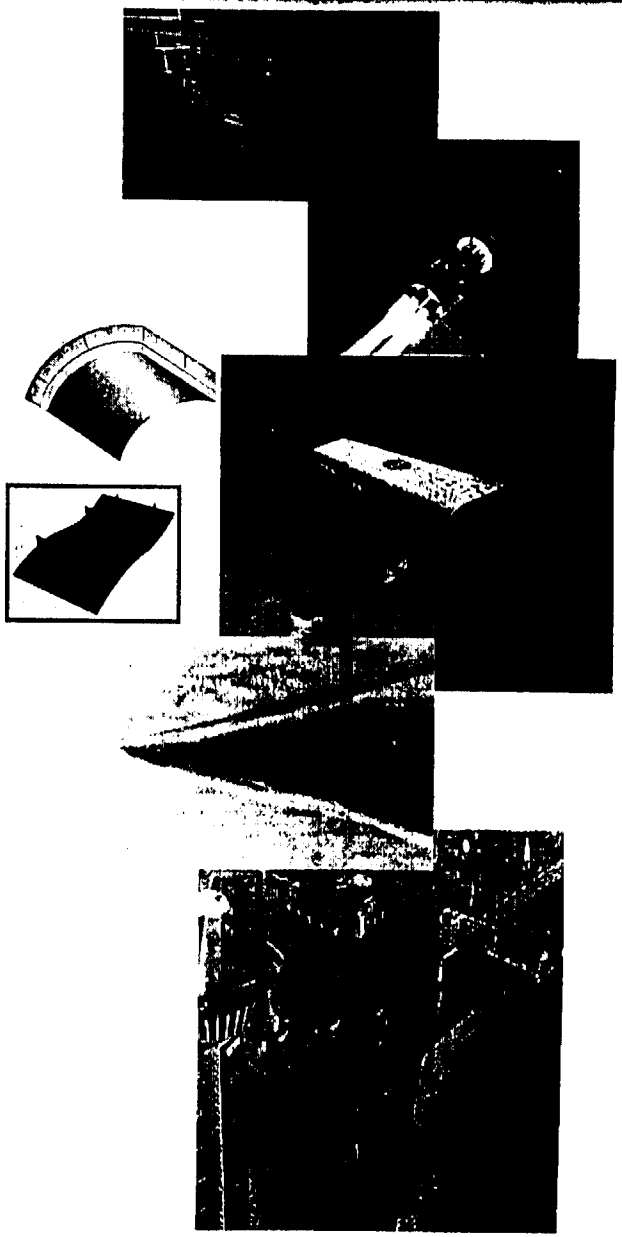
Crew Escape Demonstrations (Narrow Envelope / Subscale)

Rapid Operations Demonstrations

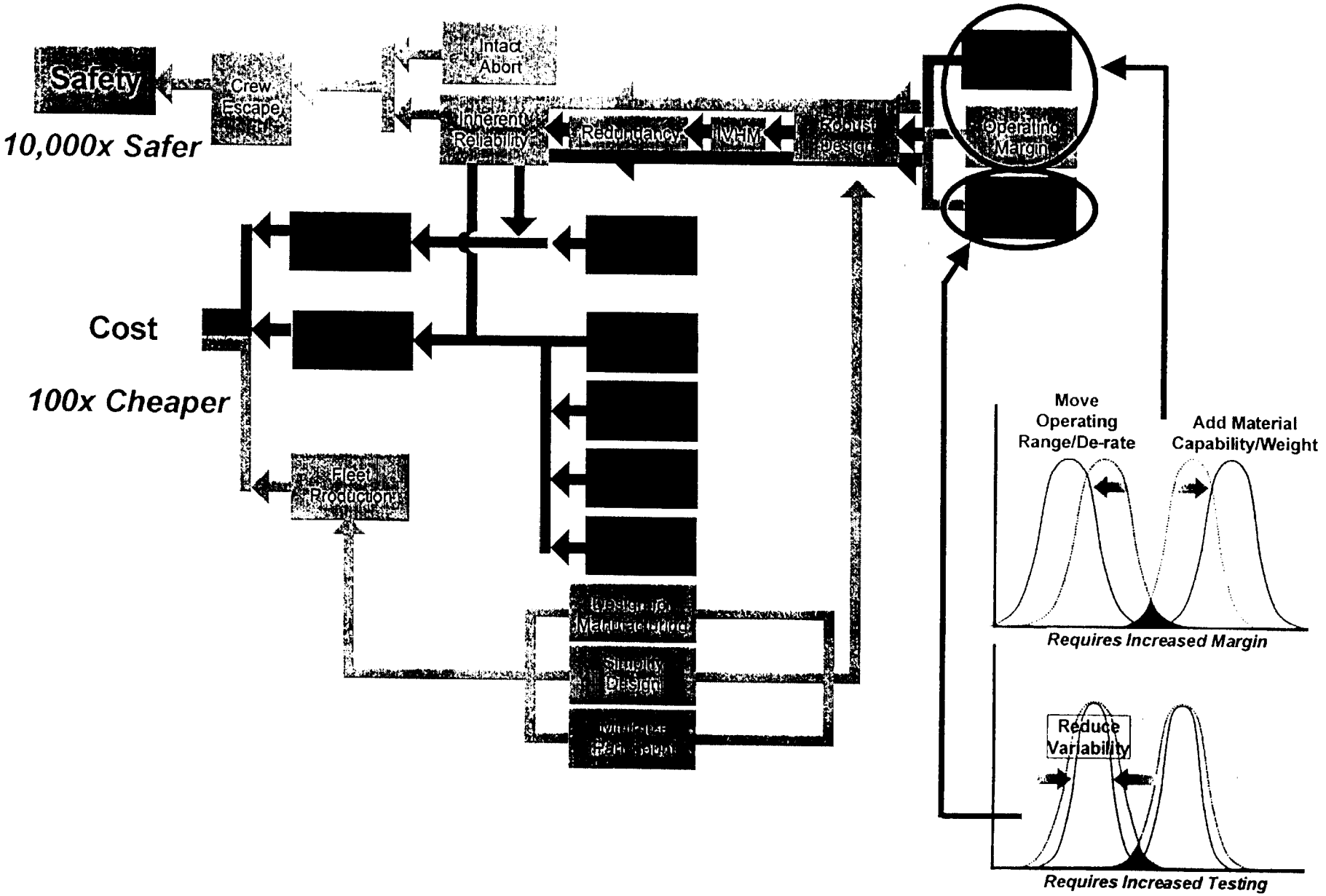
3rd Generation Technology Drivers

- **Dramatic Propulsion Performance Improvement**
  - RBCC/TBCC - Dual Mode Ramjet/Scramjet
  - PDE - Pulse Detonation Rocket Engine / Combined Cycle Engine
  - 500 mission propulsion component life
  - Magnetic Launch Assist
- **Low Drag aerodynamic structures**
  - SHARP ultra-high temperature ceramics
  - Integrated smart/adaptive thermal-structures
  - Morphing structures
  - Drag modulation through electromagnetics and flow physics
- **Adaptive Intelligent Systems**
  - Adaptive, self-diagnosis, self-healing thermal protection systems
  - Structurally integrated, wireless, micro/nano sensors and avionics
  - Regenerative sensors and system healing
  - Autonomous, adaptive control
- **Spaceport Range Operations**

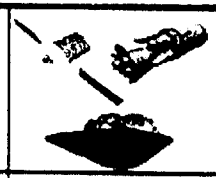
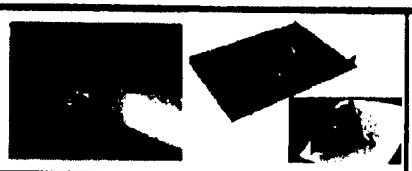




Systems Approach to Safety, Reliability and Cost

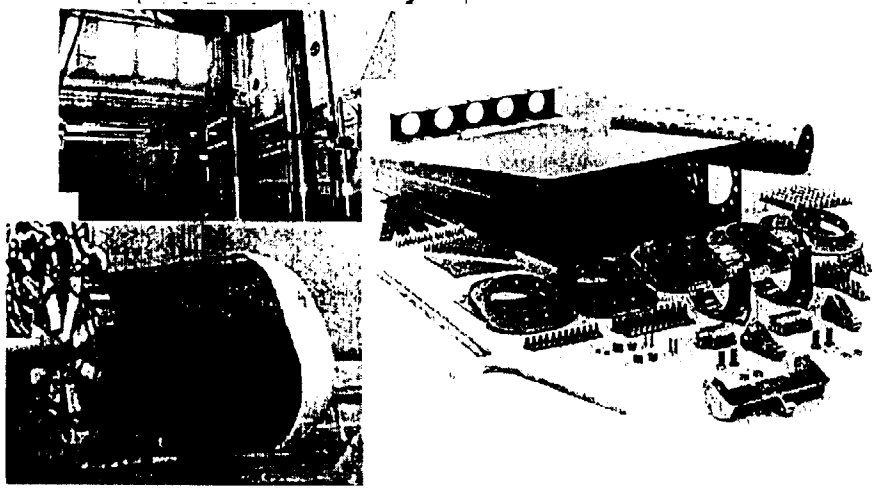


ASTP Organization is Driven By Goals

	Pillar 3					
						
Goal	Earth-to-Orbit	Earth-to-Orbit	In-Space	In-Space	Earth-to-Orbit	Earth-to-Orbit & In-Space
Investment Area	2nd Generation RLV		In-Space		Spaceliner 100 (3rd Generation RLV)	Space Transportation Research
Projects	Fastrac	RLV Focused	Upper Stages Space Transfer Technology	Interstellar Precursor	Propulsion IVHM Airframe Operations & Range Launch Vehicle	Breakthrough Propulsion Physics Advanced Propulsion Research

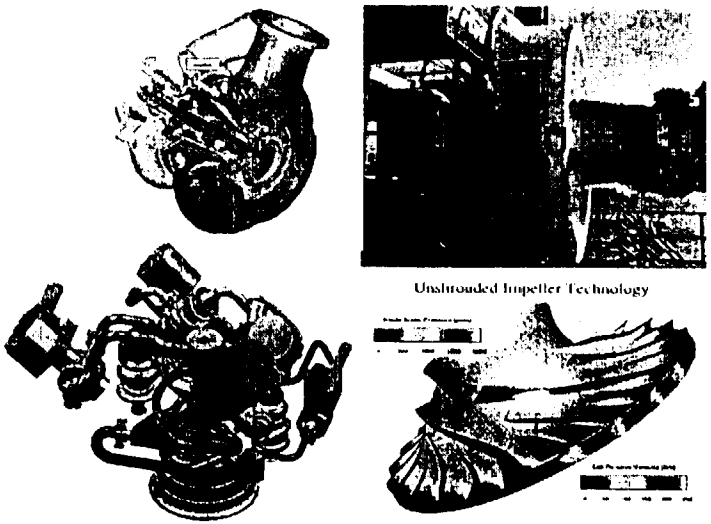
6-4239

Technical Challenges



Composite Tank and Structures (LaRC)

- Materials and Manufacturing Processes

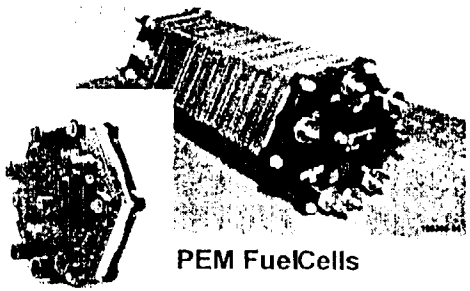


Propulsion (MSFC)

- Light weight, High-performance, Increased Safety Margins and Manufacturing

Propellant Densification (GRC)

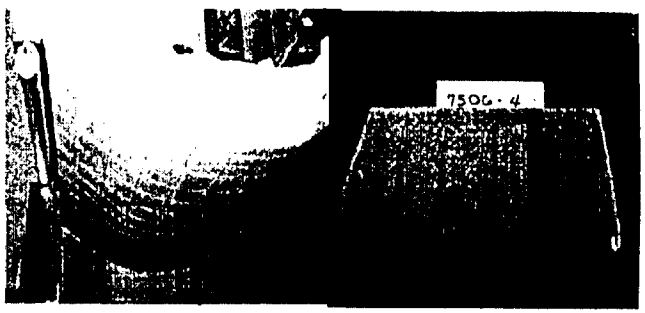
- Reduced GLOW



PEM FuelCells

Power (GRC)

- High Power Density and Reliability



TPS and Hot Structures (ARC/LaRC)

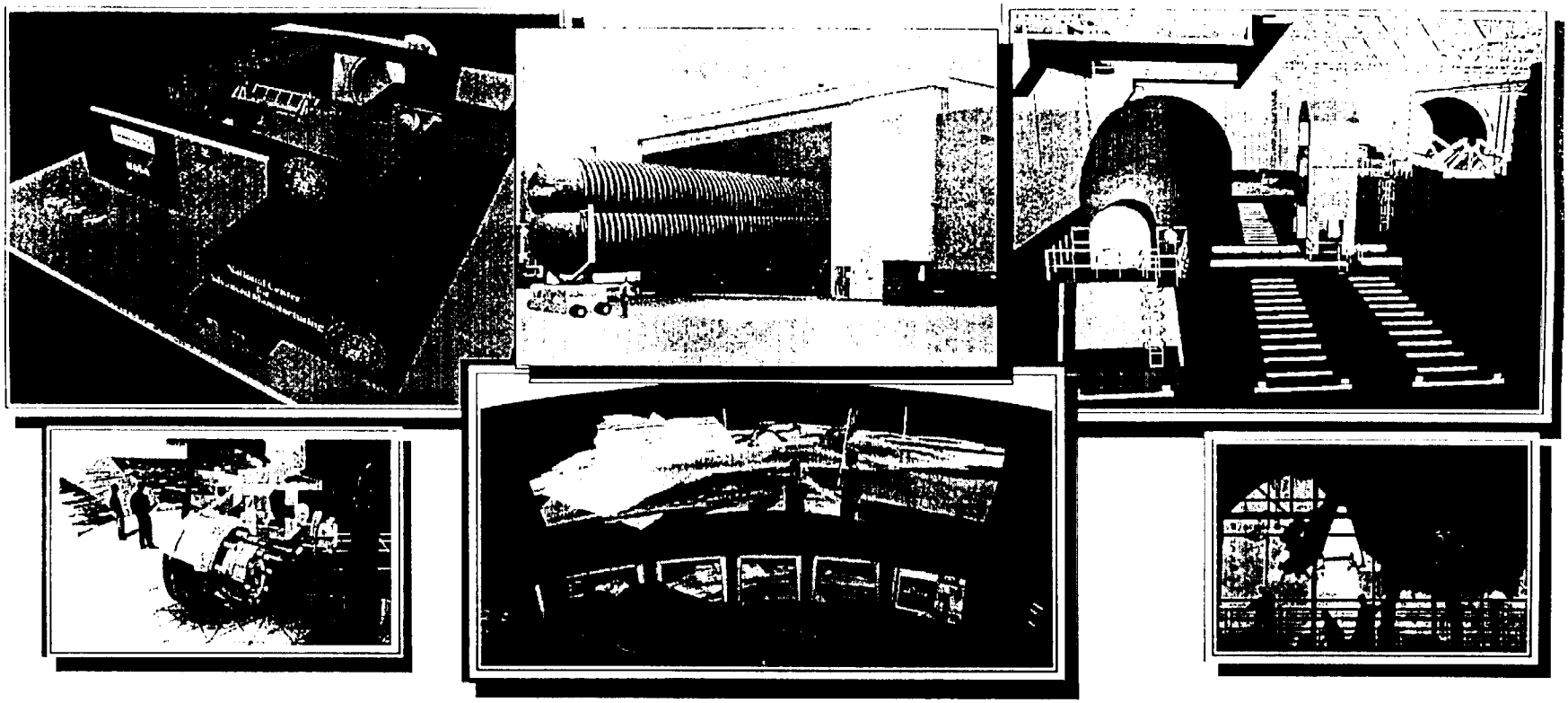
- Materials, Waterproofing,and Manufacturing

National Center for Advanced Manufacturing

Manufacturing Technology Development

RLV Focused Project

2000 PMC

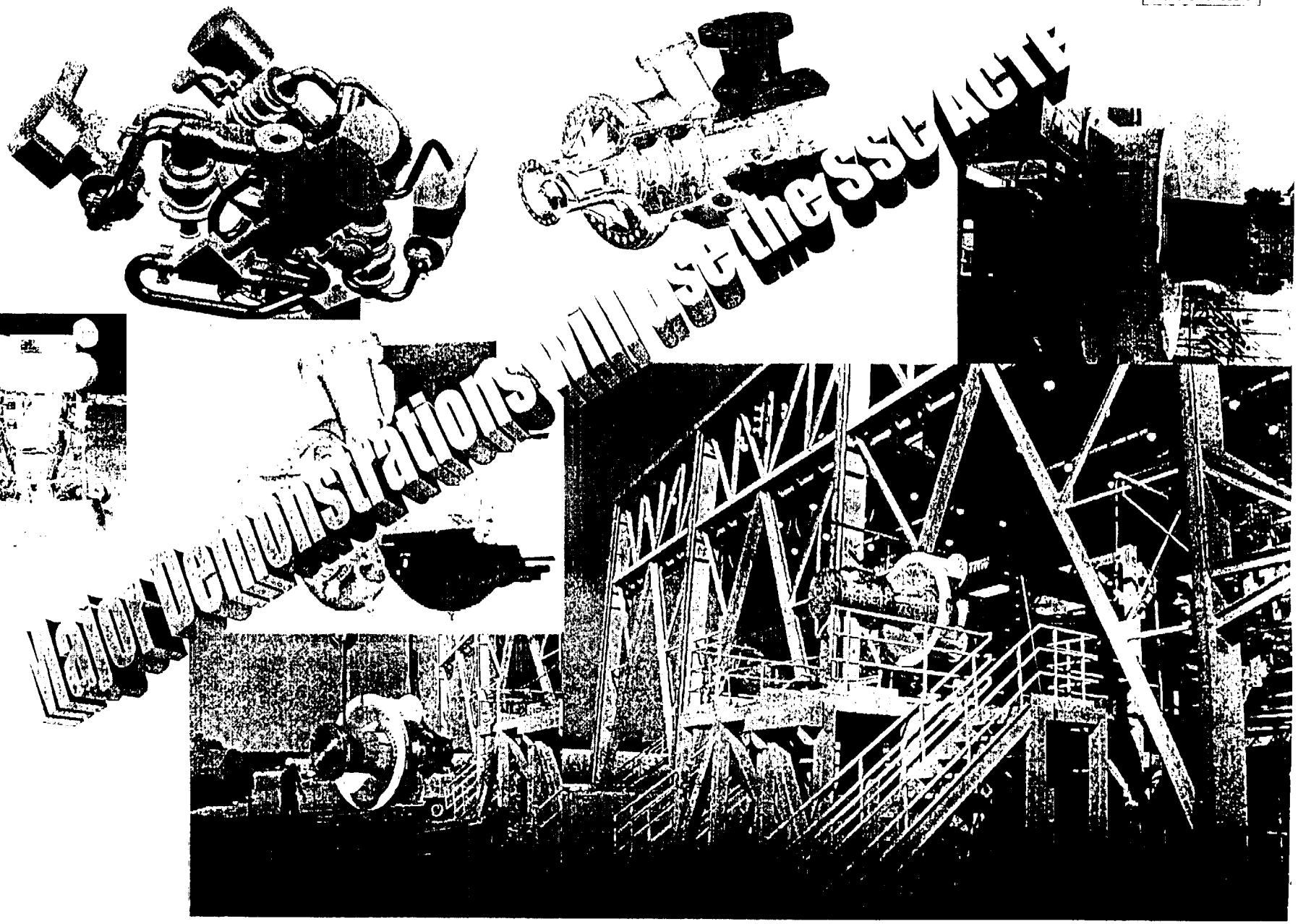


- ***Provide World Class Manufacturing Capability Enabling Future Space Transportation Systems***
- ***Strengthen U.S. Competitiveness in Aerospace/Commercial Markets***
- ***Create Federal, State, University and Industry Mfg. Partnerships***
- ***Enhance Educational Development***
- ***Effect a cultural change in Manufacturing to Intelligent-Collaborative Environment***

Large Scale Propulsion Testbeds/Demonstrations

RLV Focused Project

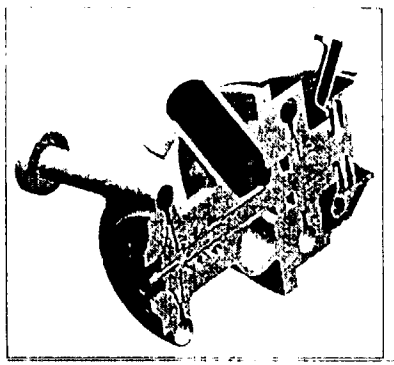
2000 PMC



Two Focused Investments

♦ Peroxide/RP Propulsion

AR2-3 Test Program
Boeing Rocketdyne SAA

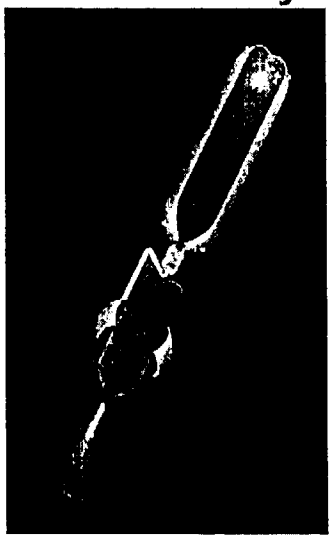


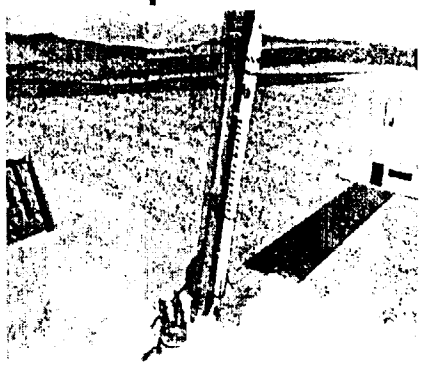
Advanced Catalysts, Ignitors, & Turbopumps
Boeing Rocketdnye CA
Aerojet CA
TRW/GK/Purdue FFPC
FMC FFPC

Upper Stage
Flight Experiment
- Pressure fed engine
- Common bulkhead composite structures

Orbital Sciences-IFCC

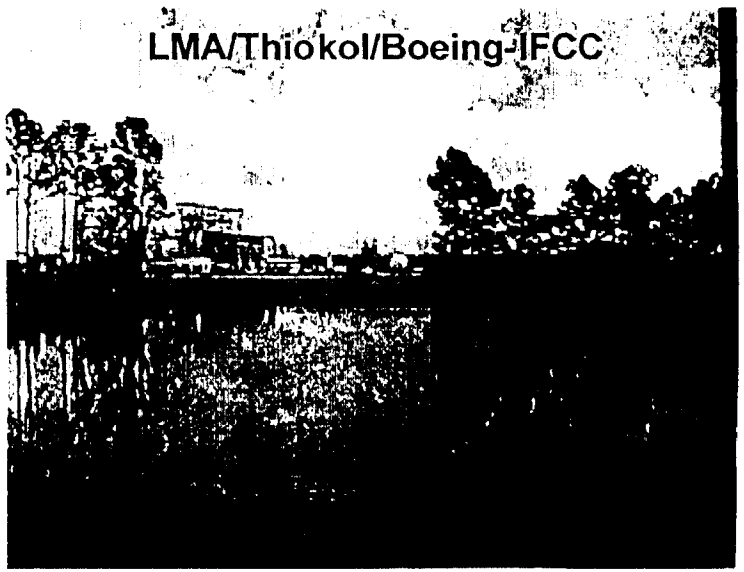
♦ Peroxide/Hybrid Propulsion





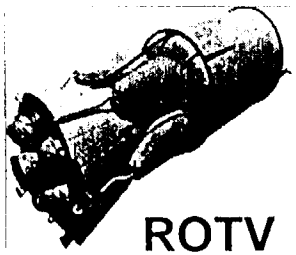
Hybrid Sounding Rocket (HYSR)
LMMSS-SAA

LMA/Thiokol/Boeing-IFCC

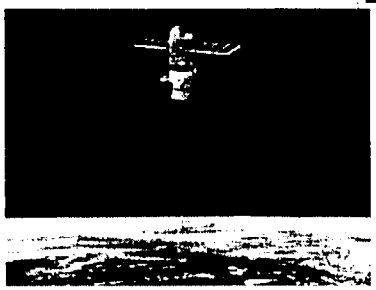


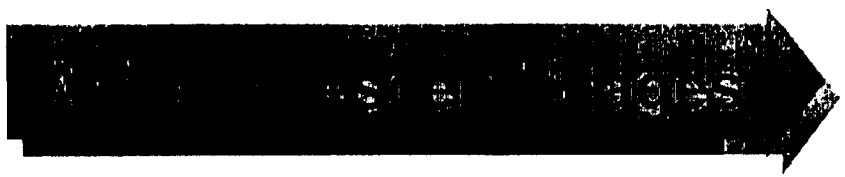
Scope of Space Transfer Technology Project

Orbital Transfer Vehicles

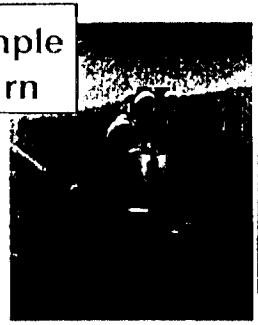


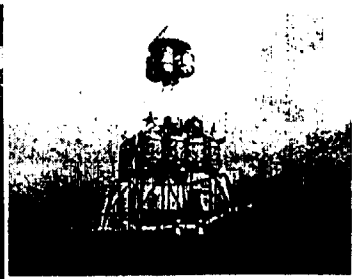
ROTV





Sample return

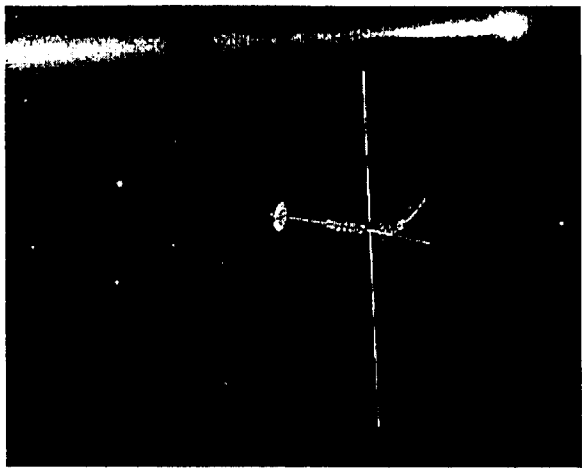




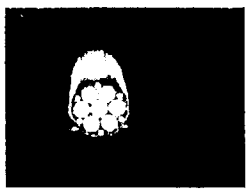
In-Situ Prop/
Ascent Chem
Prop Stage

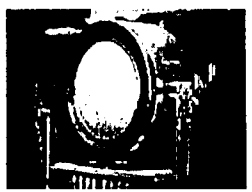
Interstellar Precursor Technologies

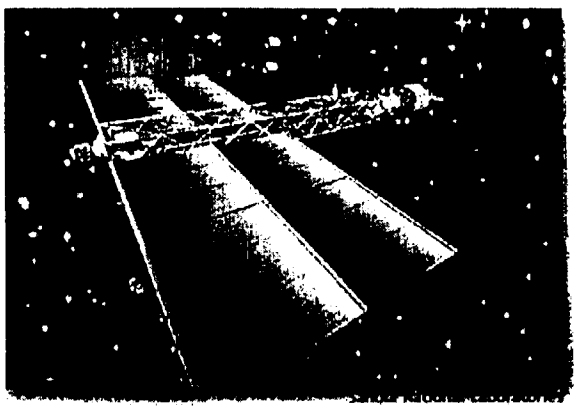
Solar Sails



Nuclear Electric Propulsion







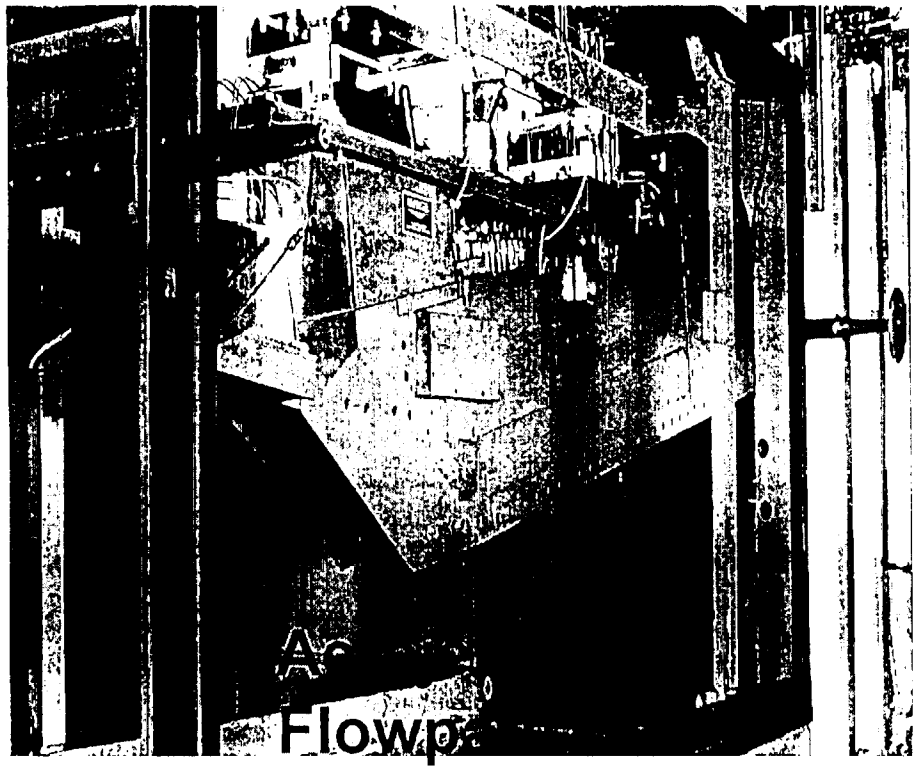
Technical Challenges

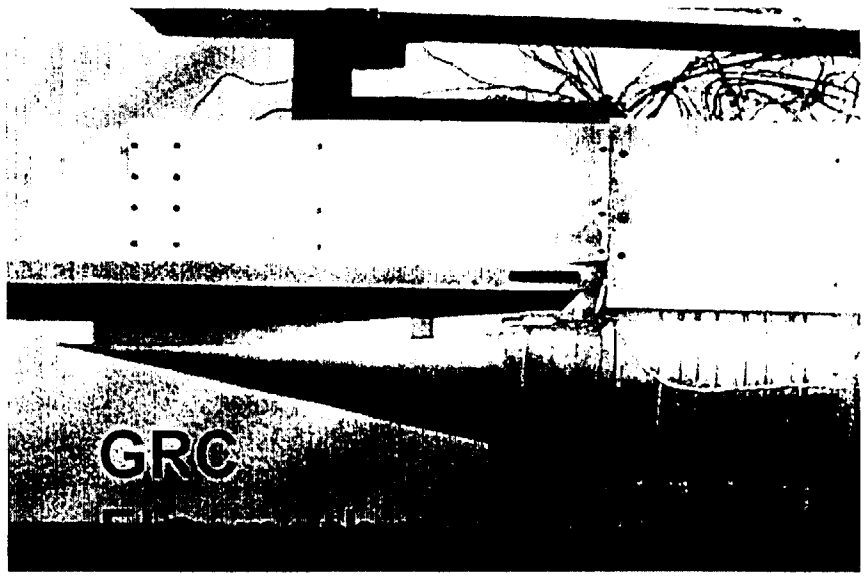
- Improved propulsion performance to specific impulse (Isp) > 500 sec using combined cycle air-breathing rocket propulsion
- Increased all propulsion system thrust-to-weight ratio through the use of metal matrix composites, ceramics, and other advanced materials
- Increased propulsion life cycle capability to 500 missions through advanced design techniques and materials
- Decrease development cost through advanced design techniques and robust testing

Accomplishments

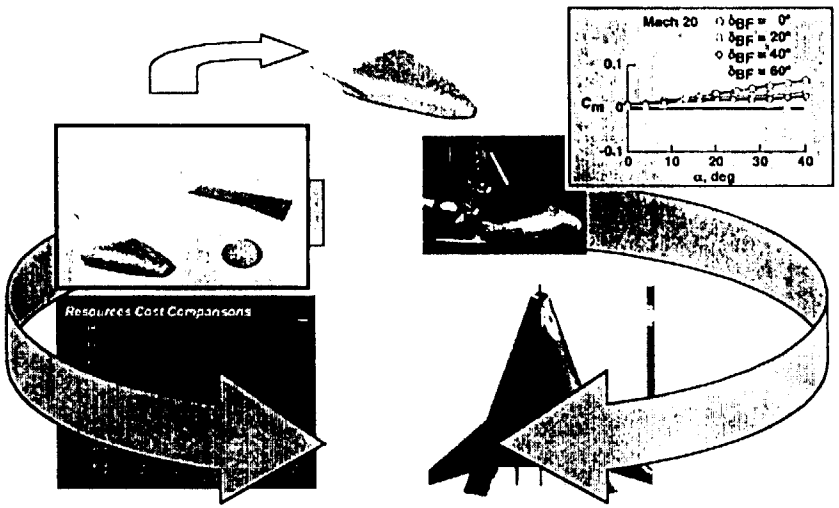
- Aerojet & Rocketdyne Flowpath Tested
  - Test Conducted From M 0 to Mach 8
  - Total Of 253 Test Conducted
  - Good Overall Performance
- Several First In Testing
  - Dynamic Trajectory Simulation (AAR -> RAM and RAM-> SCRAM))
  - SCRAM Testing @ High Dynamic Pressure (M8 @ 1,200 Psf)
- Parametric Test Performed By Pennsylvania State University
- Trailblazer Concept Development
  - Lead By Glenn Research Center
  - Currently Testing @ GASL
- System Studies
  - Various Vehicle/Engine Combinations Being Studied
    - RBCC
    - TBCC
    - PDE
  - Sensitivity Trades Being Made
    - Trajectories
    - Fineness ratio
    - Payload capability

RBCC Flowpath Test Hardware

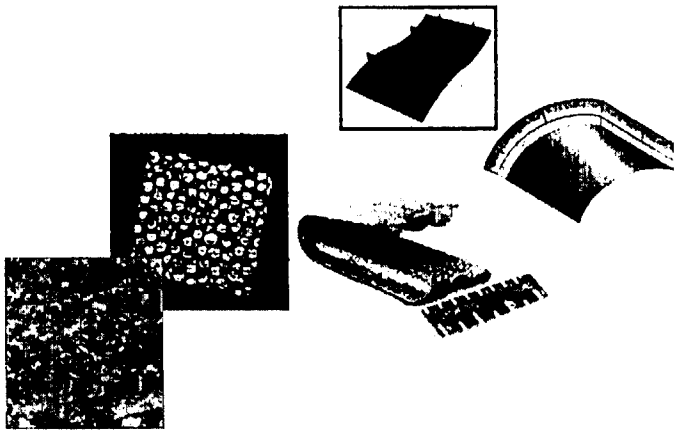




Airframe Technology Elements

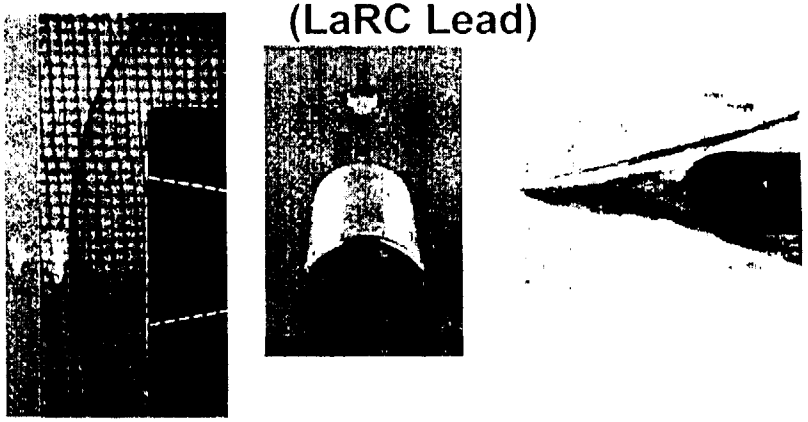


Integrated Airframe Design
(LaRC Lead)



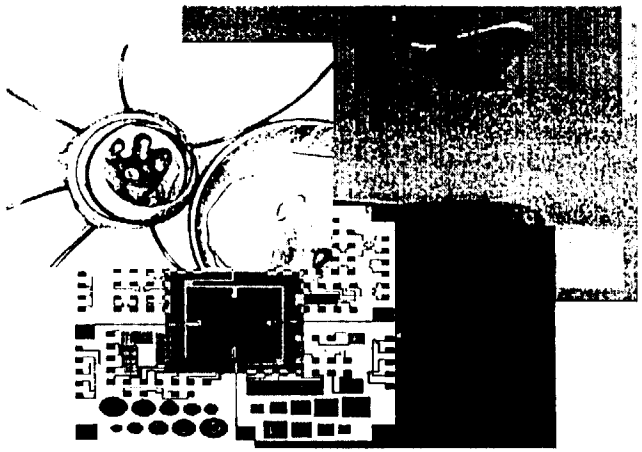
Integrated Thermal Structures and Materials
(LaRC Lead)

Thermal Protection Systems
(ARC Lead)

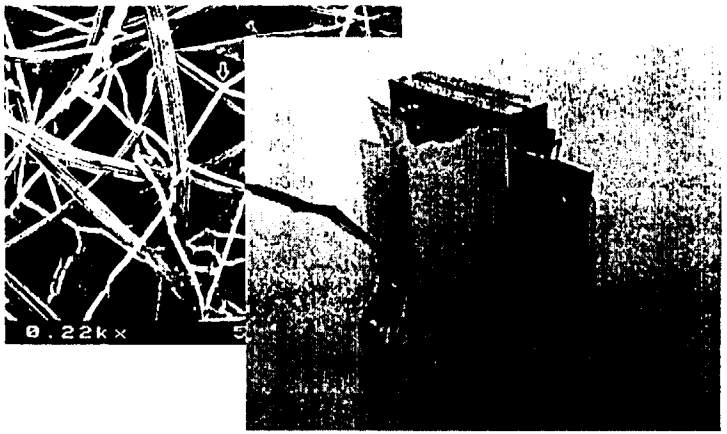


Aero/Aerothermo Enhancement
(LaRC Lead)
No FY00 Funding

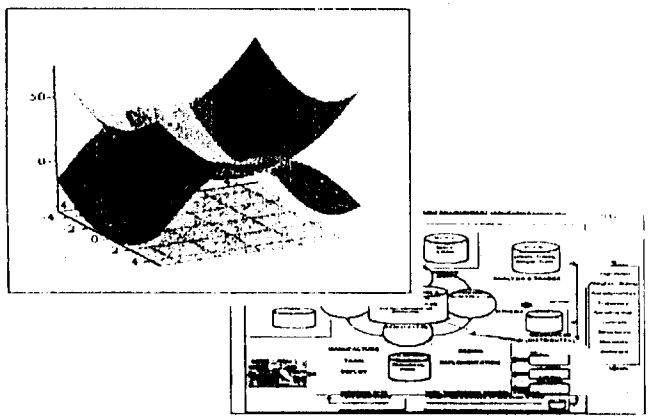
Launch Technologies Elements



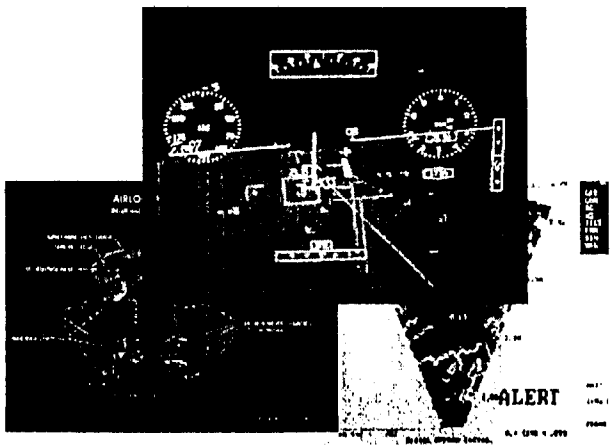
Avionics and Flight Control
Lead Center - MSFC



Power
Lead Center - GRC



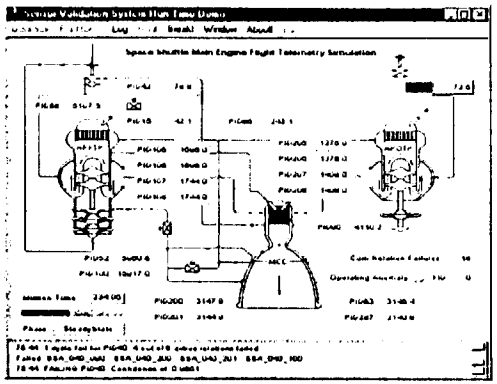
Integrated Design and Analysis tools
Lead Center - MSFC



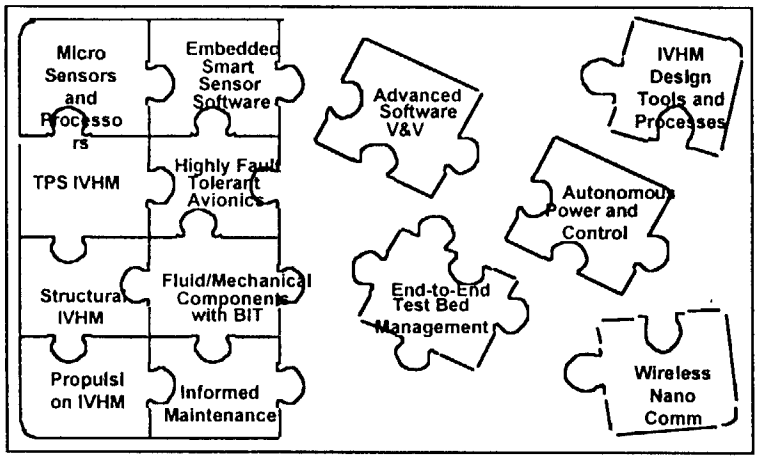
Crew Systems
(No FY00 Funding)

IVHM Elements

Core Technologies (ARC)
Information Technologies
Sensors
Communications



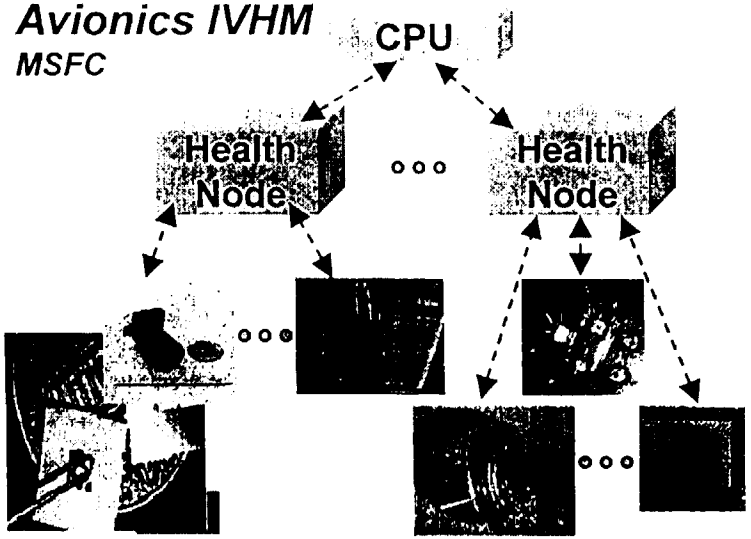
Propulsion IVHM
GRC and MSFC

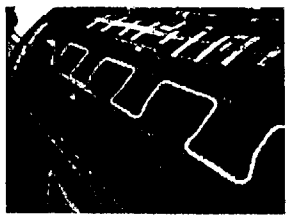


Systems Engineering and Integration IVHM
ARC

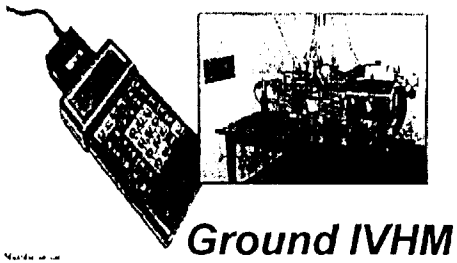
Power IVHM
GRC

Avionics IVHM
MSFC

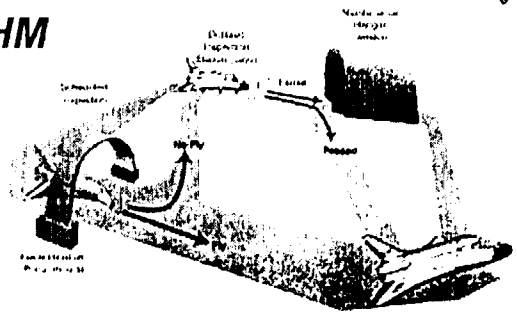




Structures IVHM
LaRC

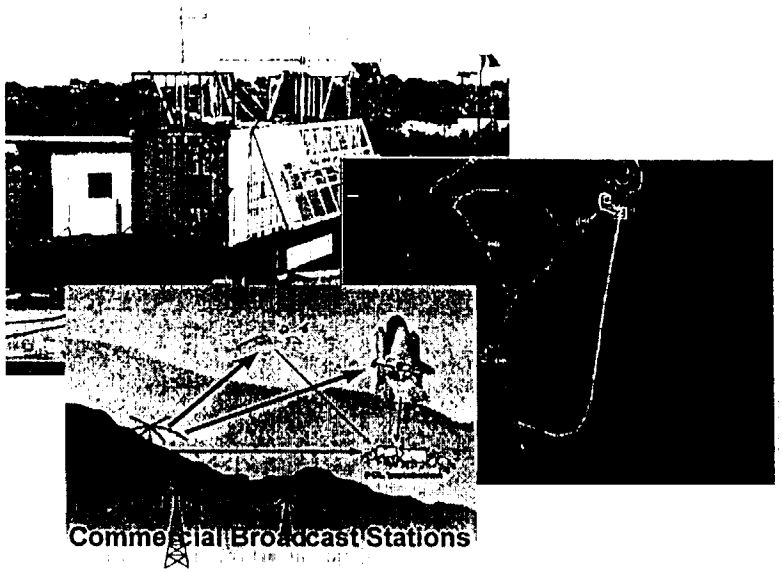


Ground IVHM
KSC



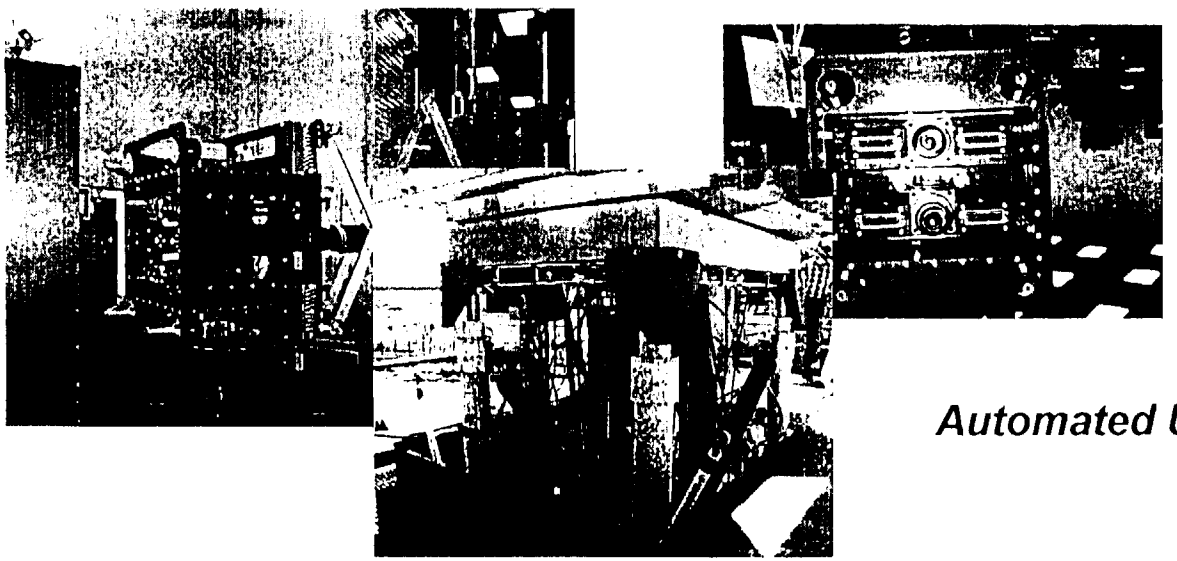
Thermal Protection Systems IVHM
ARC

Project Elements



Spaceport Range and Operations

MagLev Launch Assist



Automated Umbilical

Space Transportation Research

- Objectives - Space Transportation Research Investment Area
  - The Space Transportation Research Investment Area is responsible for developing the technologies to enable bold new missions.
  - Research will pursue proof-of-concept research in revolutionary technology areas that may lead to
    - Dramatic reductions in the cost of access to space or
    - Enable new interplanetary or interstellar space missions by reducing travel times by one to two orders of magnitude.
  - This investment area consists of the
    - Advanced Propulsion Research Project
    - Breakthrough Propulsion Physics Project.

- Areas
  - Advanced Chemical
  - Electromagnetic
  - Advanced Nuclear
  - Fusion / Antimatter
  - Interstellar Research
  - Breakthrough Propulsion Physics