NASA's Reusable [illegible] Technologies –
A Composite Materials Overview
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NASA's Earth-to-Orbit Space Transportation Program

A Materials Overview

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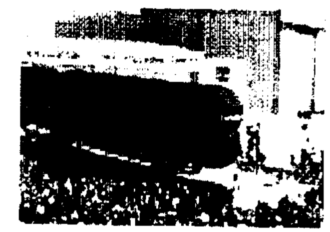
Earth to Orbit Goals and Challenges

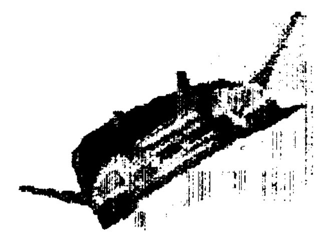
Goals

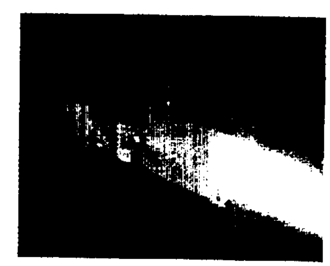
10x Cost Reduction by 2007

100x Cost Reduction by 2022

Challenge	Technology Objectives
Drive Down Operations Costs	Increased Reliability Increased Life Reduced Labor Reduced Processing Reduced Size Reduced Facilities/GSE Reduced Maintenance
Drive Down Manufacturing and Production Costs	Reduced Facilities Reduced Tooling Reduced Material Cost Reduced Labor
Drive Down Design, Development, Test and Evaluation Costs	Reduced Design Reduced Weight Reduced Complexity Increased Technology Readiness Level @ Insertion
Increase System Performance	Increased Engine Thrust/Weight Increased Mission Specific Impulse Improve Mass Fraction Improve Margins Increased Range (Cross and Down)







Notes

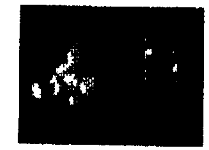
- Metrics developed from recent studies including: Access to Space Study ('93), Aerospace Future Spacelift Requirements Study ('97), Highly Reusable Space Transportation Study ('96 - '97) and Various Industry Inputs (Future X, etc.)

Space Transportation Program Structure

Access to Space

Earth to Orbit

In-Space



Flight Demos

Flight demonstration of experiments, test beds, systems, and prototypes

Reusable Launch Vehicle

- X-33
- X-34
- Pathfinder
- Trailblazer

Focused

Technologies focused on a specific application, configuration or vehicle

Advanced Space Transportation

- RLV Focused
- Small Payload Focused
- Upper Stage / In-Space

Core

Broad core technologies applicable to several applications or configurations

- Propulsion Systems
- Airframe Systems

Research

Research into emerging space transportation technologies

- Research

■ Earth-to-Orbit
In-Space Transportation

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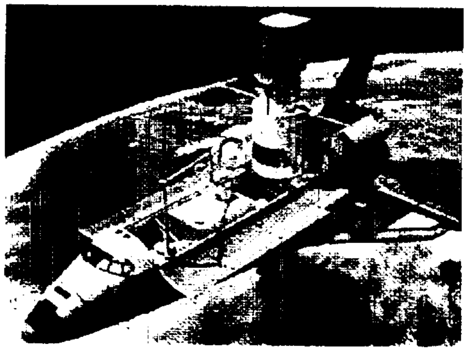
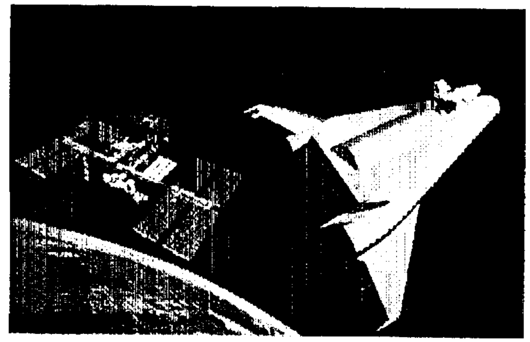
Generations of Reusable Launch Vehicles



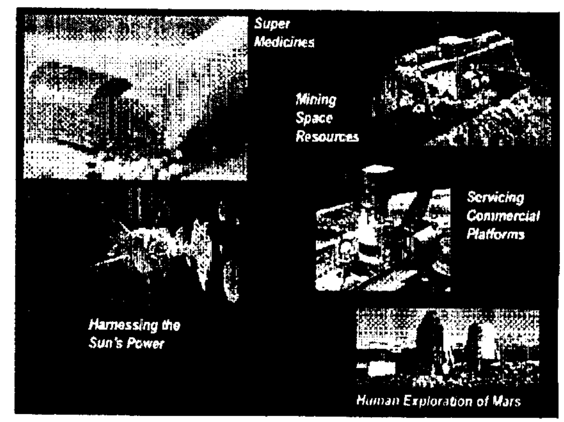
Today: Space Shuttle
1st Generation RLV

- 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



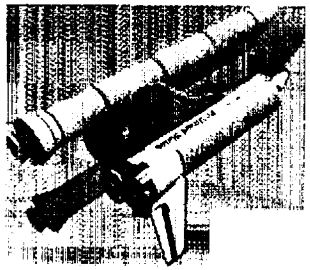
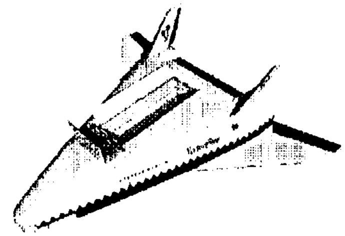
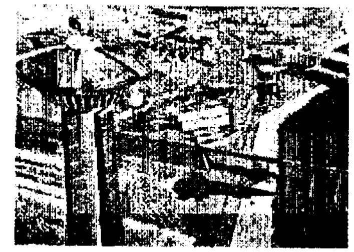
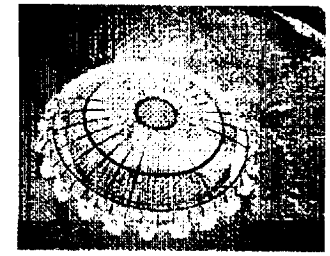
2025: 3rd Generation RLV

- 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 Derived Requirements

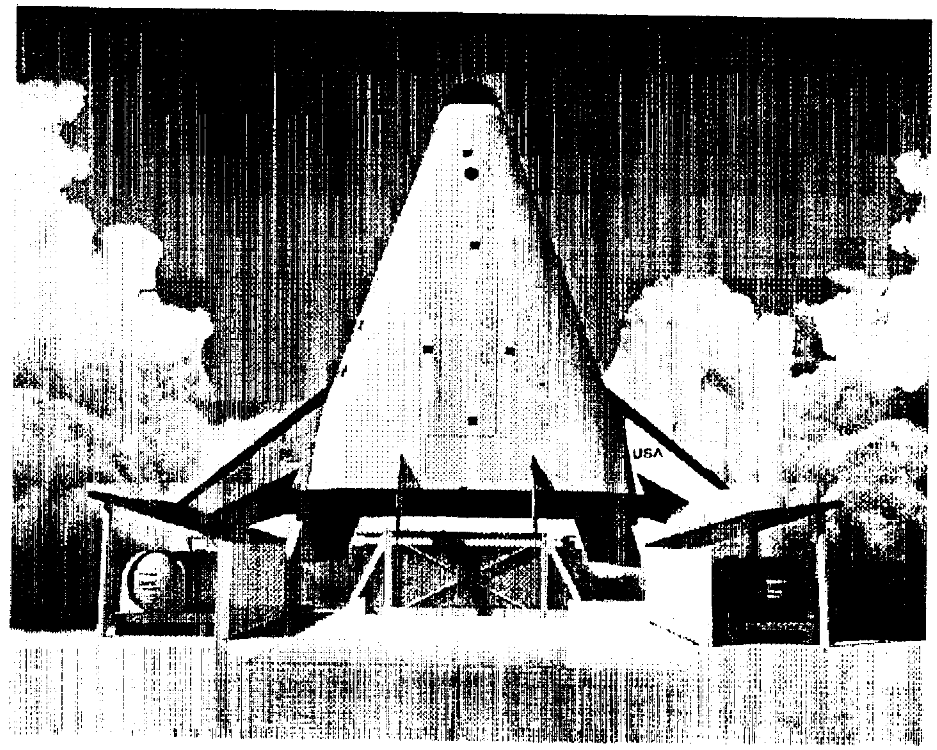
	1st Generation	2nd Generation	3rd Generation	4th Generation
• Cost:	~$10.000 per pound to orbit	$1,000 per pound to orbit (10x Cheaper)	$100 per pound to orbit (100x Cheaper)	$10 per pound to orbit (1,000x Cheaper)
• Safety:	Catastrophic problem very 200 missions	Catastrophic problem every 10,000 missions w/crew escape	Catastrophic problem every 1,000,000 missions w/crew escape	Catastrophic problem every 2,000,000 missions W/o crew escape
• Crossrange:	1.100 nmi (blunt body)	700-1,100 nmi (blunt body)	2,700 nmi (Sharp body)	TBD
• Payload:	50.000 lb to LEO	50,000 lb to LEO	20-40,000 lb to LEO	TBD lb to LEO
• Life:	100 Missions	500-1000 Missions	2,000-5,000 Missions	10,000-20,000Missions
• Depot Maintenance:	Every 10 Missions - 100 mission overhaul & recert 100 mission overhaul w/recert	Every 100 Miissions	Every 500 Missions	Every 1000 Missions
• Total Fleet Missions:	5 - 10 Per Year	100 Per Year	2,000 Per Year	10,000 Per Year
• Turnaround Time:	5 months	1 week	1 day	1 hour
• Launch Support Personnel:	1.000 (170 at KSC)	100	10	2
• Vehicle IQ: on ground	Limited - requires extensive human interrogation of systems	Sends vehicle status to ground prior to landing	On-board management systems adapt to changing environments	Vehicle systems self-heal in flight
• Range Control:	Unique for each flight / 48 hours required for reconfiguration	Mission class specific	Autonomous, Passive System	None - replaced by Aerospace Traffic Control Centers

Reusable Launch Vehicle

X-33 Demonstrator

Low-Cost Access to Space

- **Objectives**
  - Build & test a 53-percent scale prototype of an operational RLV
    - Realistic flight environment
  - Demonstrate technologies
    - Reusable cryogenic tankage
    - Composite structures
    - Durable TPS
    - Advanced avionics
    - Reliable propulsion systems
    - Aircraft–like operations



- **Long-term goal**
  - Reduce payload cost to low Earth orbit by factor of 10 within 10 years ($10,000 to $1,000)

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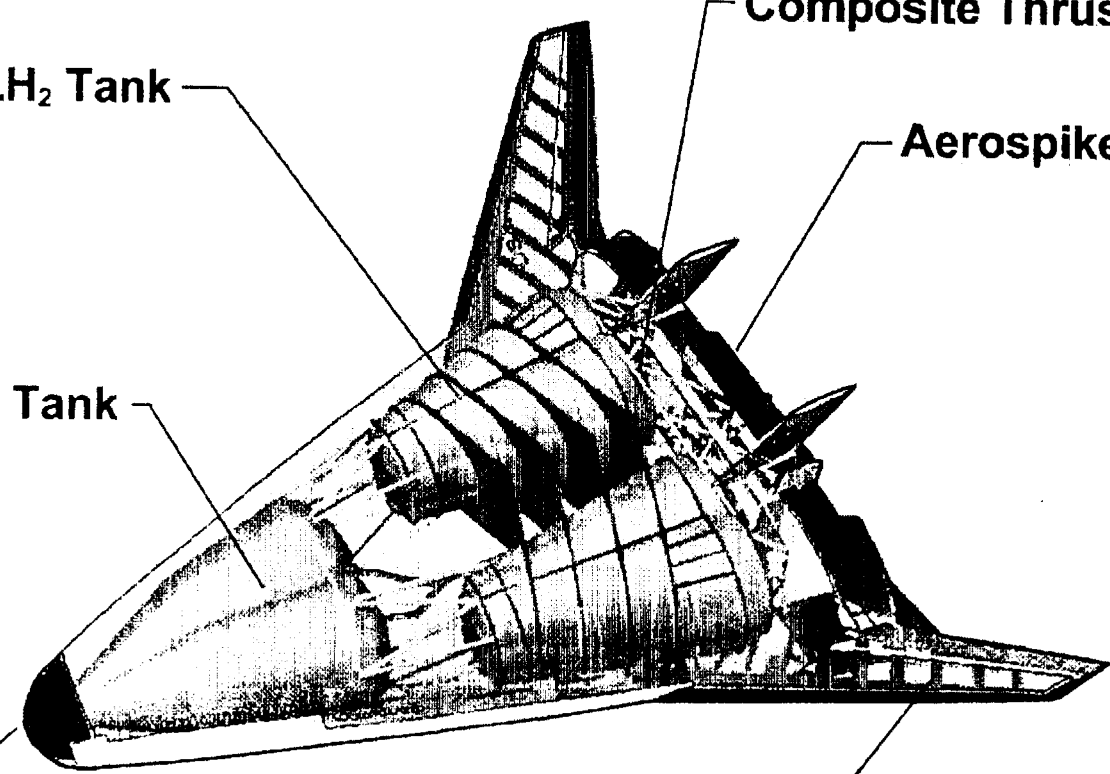
Reusable Launch Vehicle

X-33 Demonstrator Technologies



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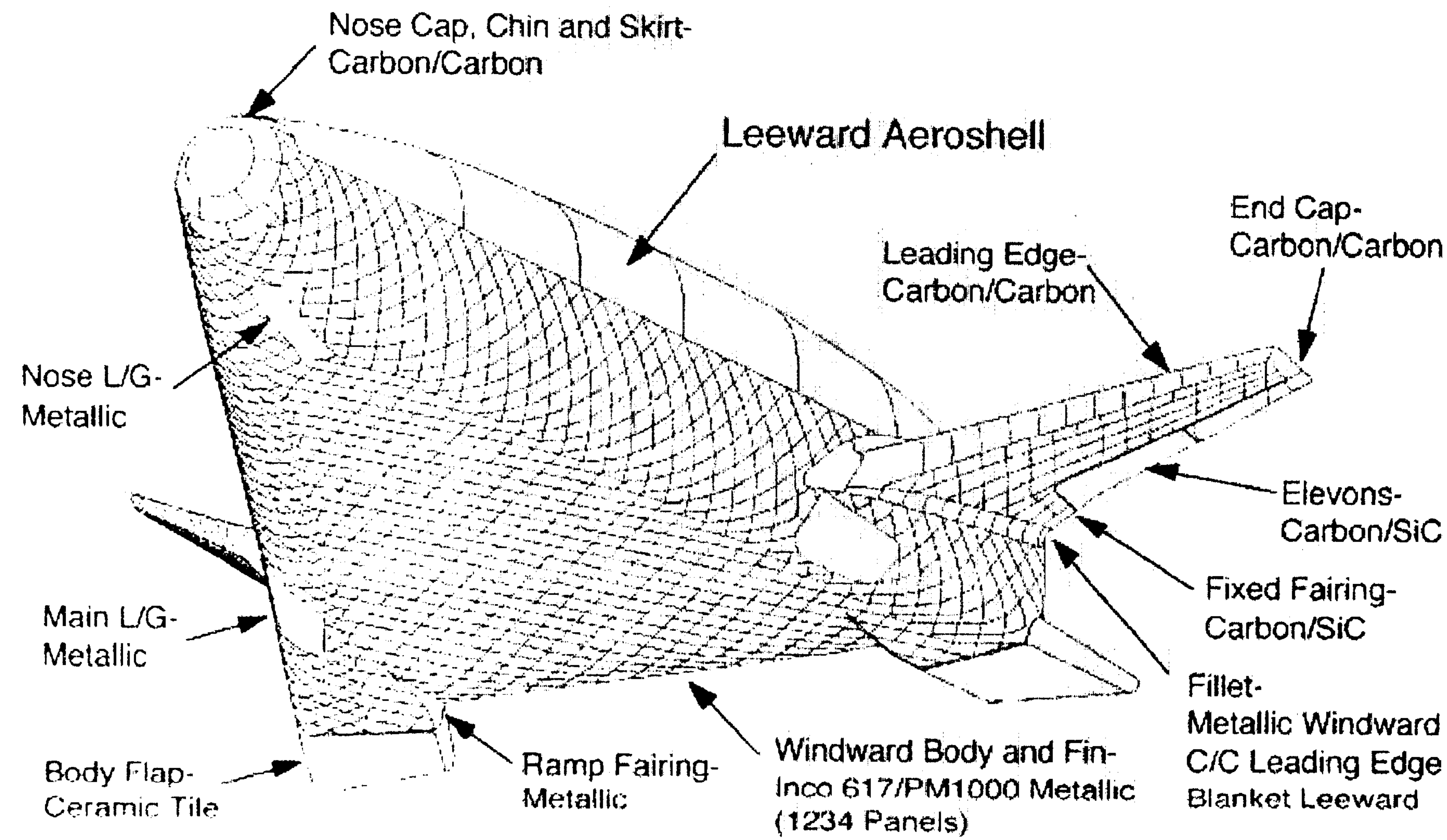
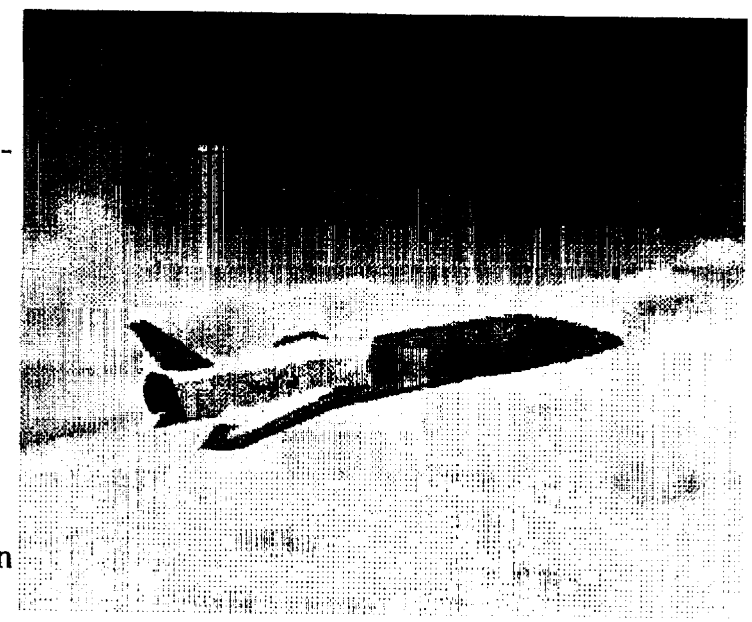
Reusable Launch Vehicle
X Demonstrator

TPS Configuration - Windward



Top Level Goals

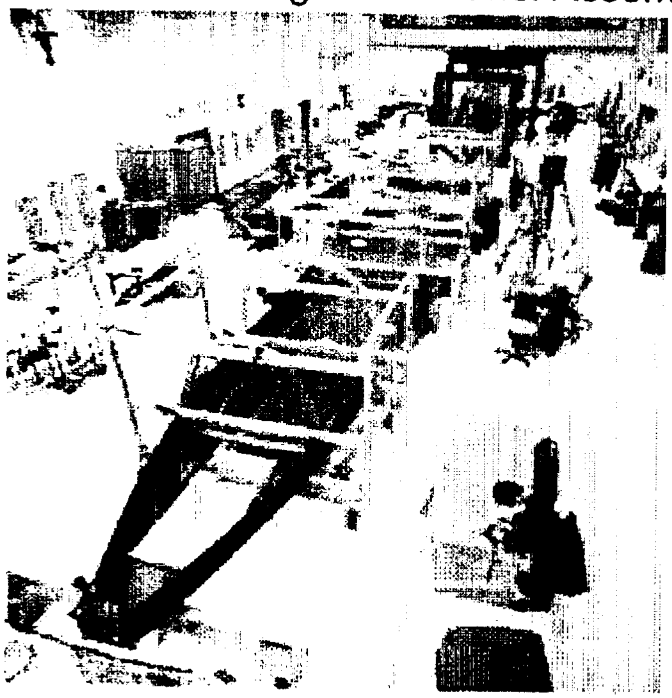
- Reusable Launch Vehicle (RLV) Goal: Significantly Reduce the Cost of Access to Space
  - X-34 is a Technology Testbed Supporting RLV Goal
  - X-34 is Catalyst for Commercial Development of Low-Cost RLV in Small Payload Class
- X-34 Program Goals
  - 1. Testbed Vehicle for Demonstrating Key RLV Technologies and Processes
  - 2. Testbed Vehicle for Aero Science Experiments
  - Focus Areas
    - A. New RLV Technologies Embedded in Vehicle Design
    - B. Investigation of New Methods for Low-Cost Operations
    - C. Testbed for Hosted RLV and Hypersonic Experiments



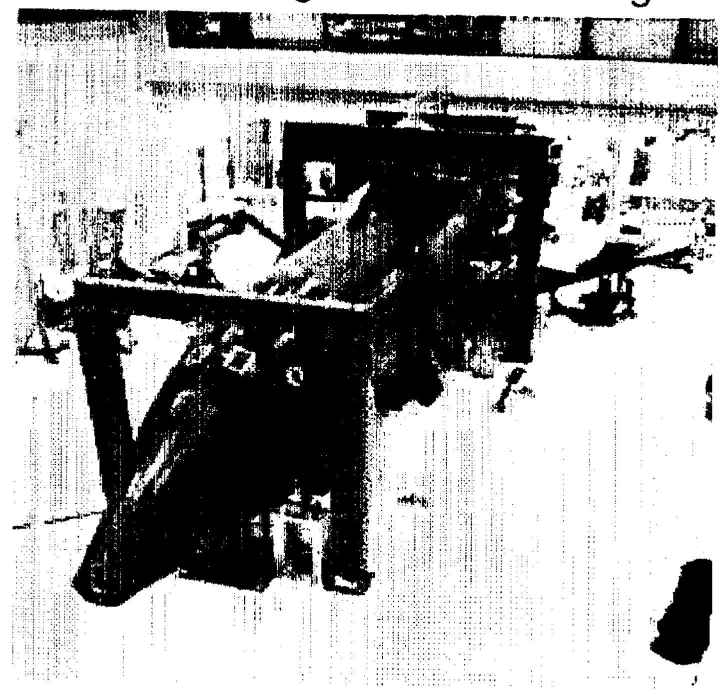
Reusable Launch Vehicle

X-33 Demonstrator

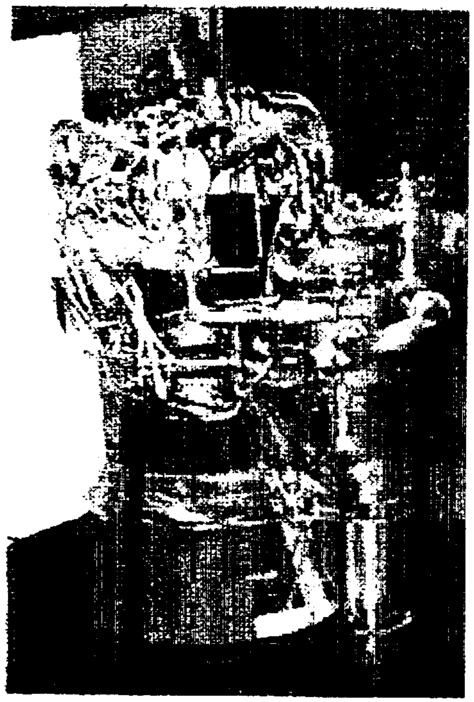
A-2 Vehicle Fuselage Skin Panel Assembly



A-1 Fuselage Mated with Wing



Reusable Launch Vehicle
X Demonstration
Fastrac Engine System



Fastrac 60K Engine

Recurring Cost
- **Fastrac 60K Engine Assembly = $700K**
- **Benchmark Cost = $5,000K**

Unique Design Features
- **Simple Cycle**
  - Lox/RP,Gas Generator
- **Design Based on Low-cost Concept Demonstrations**
  - Fastrac I and II (Sub-scale Demonstrators)
  - Simplex Turbopump (Concept Demonstrators)
- **Reduced Part Count**
  - Single piece ablative chamber/nozzle
  - Single turbopump
  - Components design with reduced part count
- **Simple Control System**
  - Open loop sequencer

Status
- **Engine assembly complete**
  - Testing at SSC has begun
  - Engine weight ~ 100 pounds under target weight

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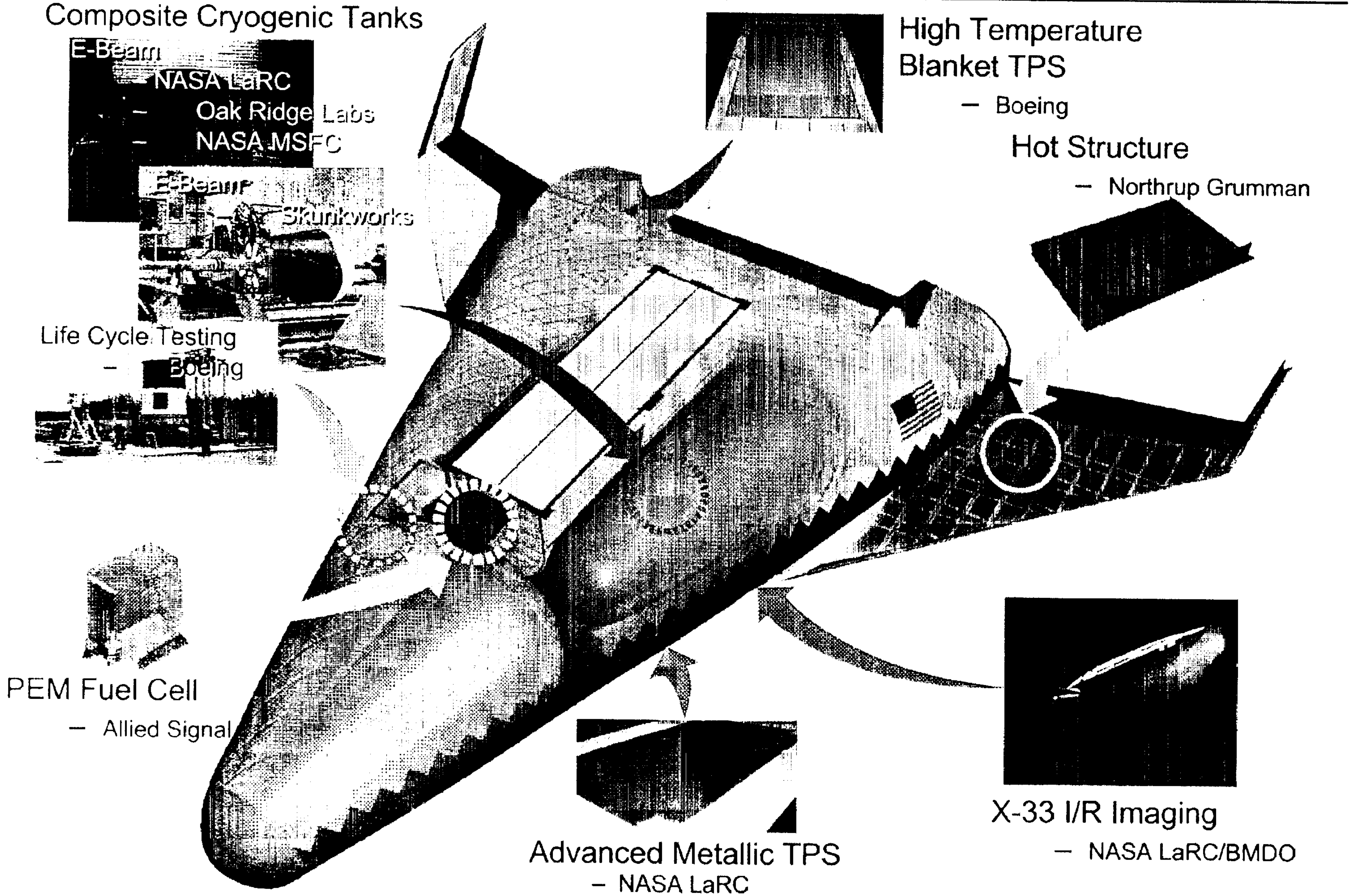
Advanced Space Transportation
Reuseable Launch Vehicle Focused Technologies
Airframe Systems



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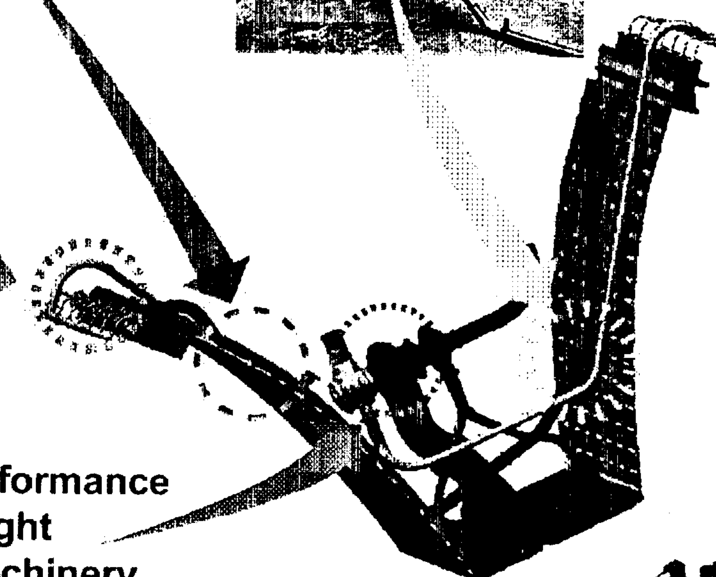
Advanced Space Transportation
Reusable Launch Vehicle Focused Technologies
Propulsion Systems

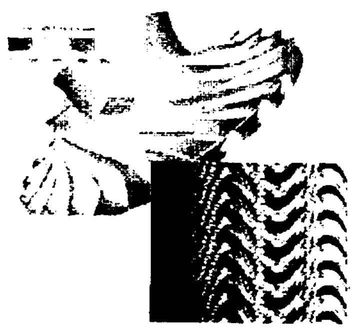
Lightweight Thrust Cells
- NASA LeRC, MSFC

Lightweight CMC Nozzle
- NASA MSFC,LeRC,LaRC

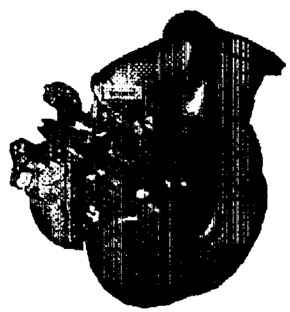
Composite Lines & Ducts
- NASA MSFC, LeRC



High-Performance Lightweight Turbomachinery

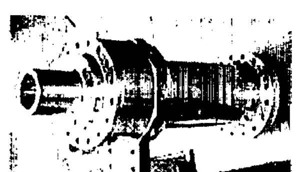


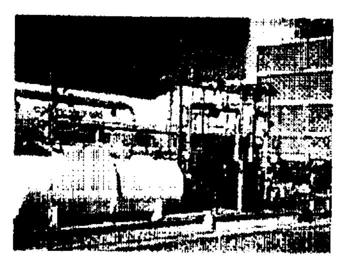
Turbopump Optimization
- NASA MSFC



MMC Housings
- Rocketdyne
- NASA MSFC

High-Performance Gas Generator
- NASA LeRC





Densified Propellants
- NASA LeRC

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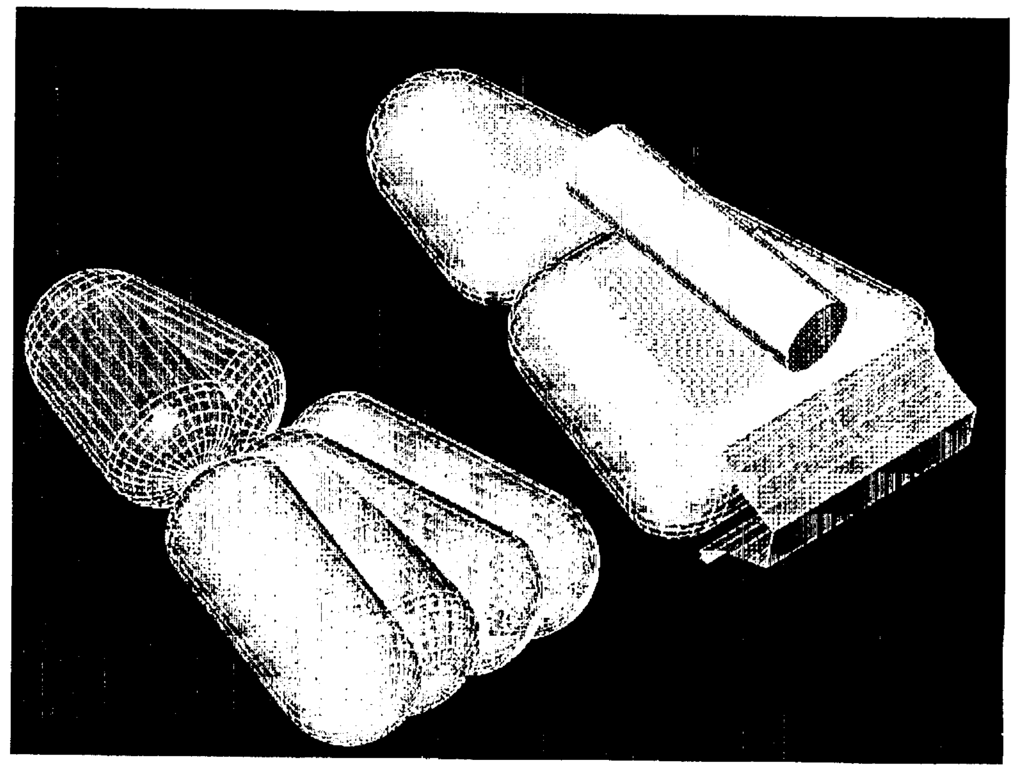
Advanced Space Transportation Spaceliner 100 Airframe Technologies

Cryotank Structures

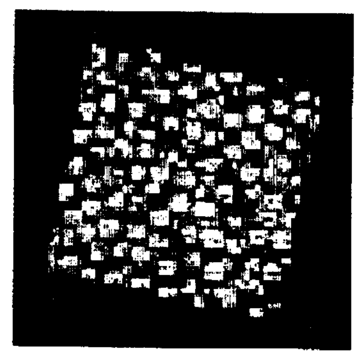
- LH2, LOX, LH2O2, and Methane tanks of advanced organic composites, and metallic alloys and metal matrix composites
- Advanced thermal-structural concepts incorporating cryo-insulation and sealants, domes/bulkheads, splice joints/design details, and TPS attachment
- "Leak-healing" sealants and structural concepts
- Integrated designs incorporating structural, thermal, environmental, durability, and damage tolerance/health monitoring/fail safety, propellant management and manufacturing requirements
- Analyses, and fabrication process development/scaleup validated by building block test programs

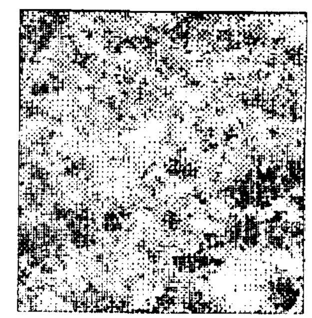


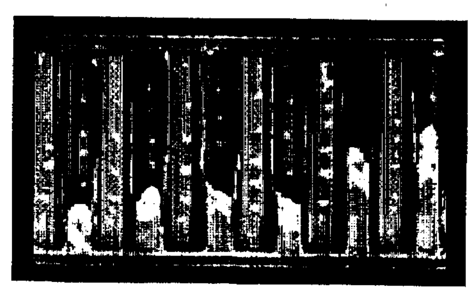
Advanced Space Transportation Spaceliner 100 Airframe Technologies

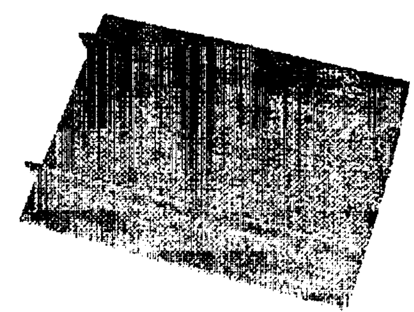
Advanced Materials, Fabrication, Manufacturing, & Assembly

- Development of new metallic and polyimide foams, metal alloys, CMCs, MMC and hybrid metallic and polymeric composites
- Nanoparticle modified matrices and adhesives (PMCs)
- "Leak healing" sealants and structures
- Large scale joining & fastening
- Large scale nonautoclave PMC manufacture
- Near net & free form manufacturing of large, unitized metallic structure
- Low cost, automated assembly technology





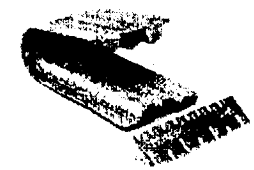


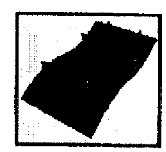


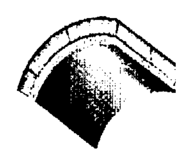
Advanced Space Transportation Spaceliner 100 Airframe Technologies

Hot and Cooled Airframe And Integrated Primary Structures

- Develop unitized, hot (up to 3000 F) and cooled airframe structures requiring no Thermal Protection System and utilizing advanced, high-temperature organic, ceramic, and metal matrix composites, metals and "hybrid" materials/structures (e.g., CMC/Metal heat pipes)
- Develop advanced and "smart/adaptive" thermal-structural concepts for primary and secondary airframe structures
- Develop integrated designs incorporating structural, thermal and cooling performance, aeroelastic/ acoustic/ dynamic, environmental, and safe structures designs requirements
- Develop scaleable CMC & C/C composite manufacturing



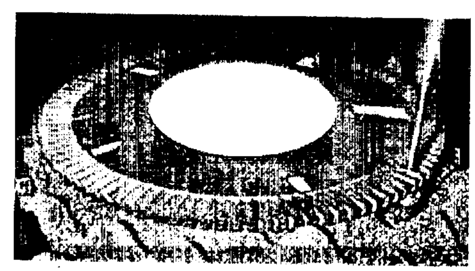



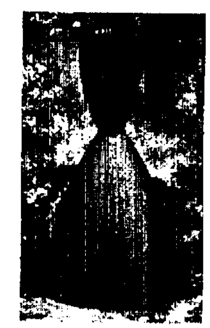


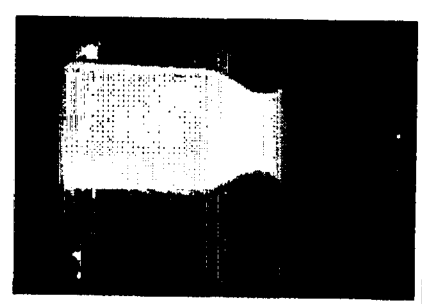
Advanced Space Transportation
Spaceliner 100 Propulsion Technologies

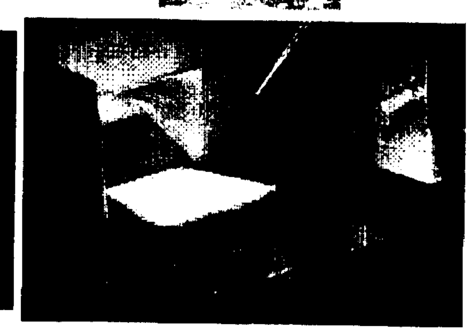
Ceramic Matrix Composite (CMC) & Ceramics

- Description: Ceramic matrix composite & ceramic processing & component technology for rocket engines.
- Objective: Demonstrate payoffs of CMC blisks,cooled & radiation cooled nozzles, thrust cells,& hot gas paths.
- Approach: Develop CMC fabrication processes, determine lifetime of materials, design, characterize, & test components thus proving payoffs.
- Benefit: Enable operation of some engine concepts, increase safety margins, thrust-to-weight, & reliability, & decrease costs.





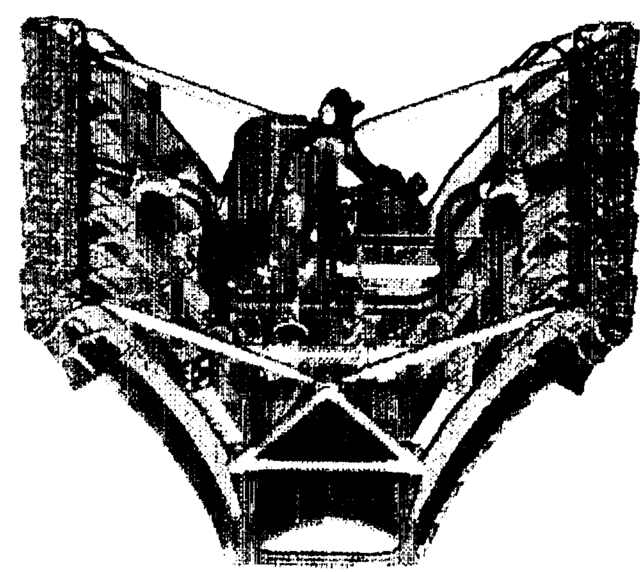




Advanced Space Transportation
Spaceliner 100 Propulsion Technologies

Ultra-High Temp Polymer Matrix Composites

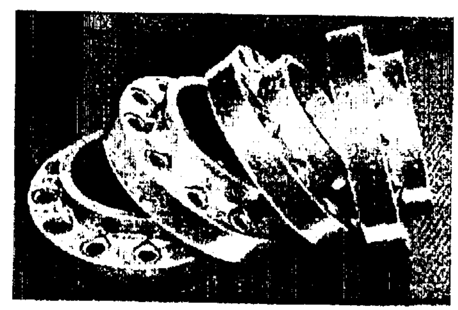
- Description: Fabricate, assess, characterize and predict the structural fatigue life of an advanced high temperature PMC system for fully reusable engine and airframe components subjected to ultra high temperature (UHT) conditions. Specific engine components targeted include support structures and assemblies, hot gas ducts, and turbopump housings.
- Benefit: Component weight reduction is a minimum of 20% in comparison to conventional alloys. SARTM fabrication will result in 30 to 50% reduction in component manufacturing costs.

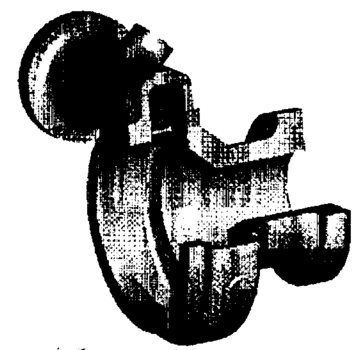


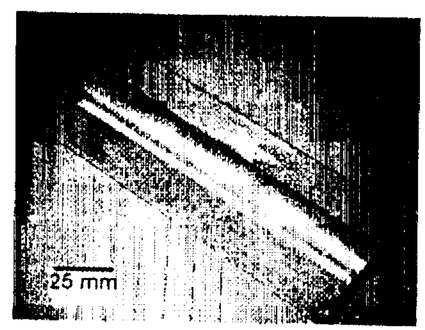
Advanced Space Transportation
Spaceliner 100 Propulsion Technologies

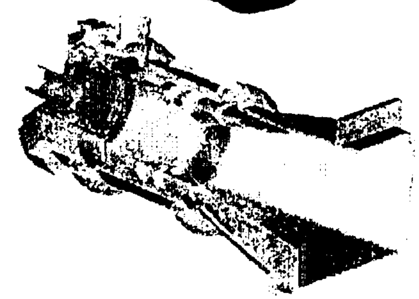
Metal Matrix Composites

- Description: Develop lightweight and high performance Al & Cu MMC materials.
- Objective: Lighweight Al & Cu MMC components compatible with oxygen, hydrogen & hydrocarbon.
- Approach: Investigate several net shaped casting Al & Cu MMC technologies for full scale component fabrication and testing.
- Benefit: Decreased acquisition cost, increased life, increased T/W, increase specific stiffness.





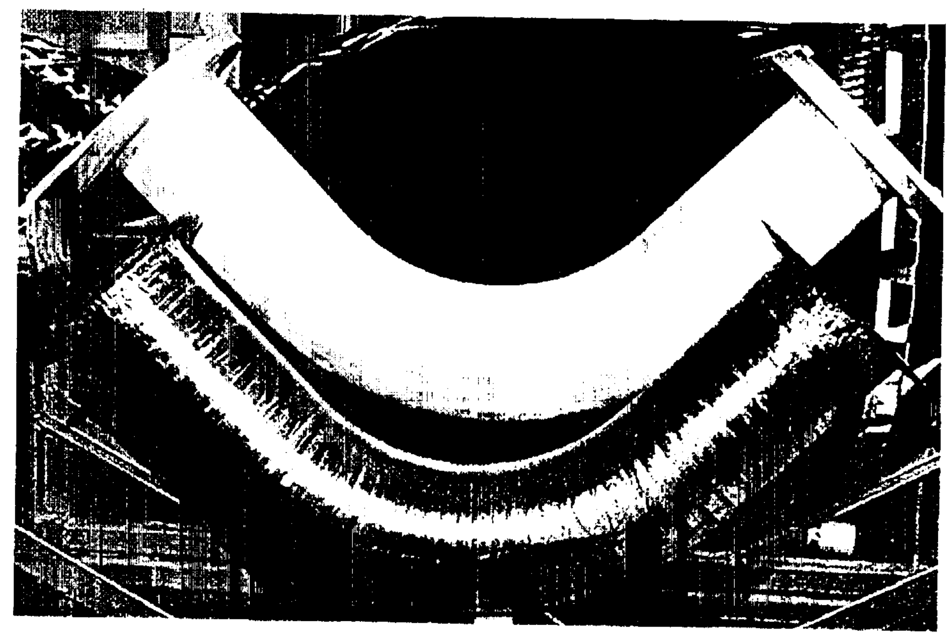




Advanced Space Transportation
Spaceliner 100 Propulsion Technologies

PMC Lines, Ducts, & Valves

- Description: Fabricate and test polymer matrix composite feedlines and ducts manufactured by autoclave curing, solvent assisted resin transfer molding (SARTM), electron-beam (E-Beam) curing and thermoplastic tape laying
- Objective: Compare the 4 manufacturing processes on a performance and cost basis. Demonstrate the capabilities to make feedlines with integral flanges and of complex shape.
- Approach: Manufacture test articles of composite feedlines. Testing of these lines will consist of burst strength, LOX compatibility, damage tolerance and resistance to permeability
- Benefit: Improved manufacturing techniques for PMC feedlines that reduces tooling costs and results in better performance hardware.



ETO Space Transportation Summary

- NASA's Space Transportation Program has developed a structured technology maturation approach to achieve low cost access to space.
  - Basic Research
  - Core Technologies
  - Focused Technologies
  - Flight Demonstrations
- Technology development will be accomplished by NASA, Industry Partners, U.S. Air Force, and Academia through periodic NASA research announcement opportunities.
- Materials and Processes technology development is enabling in many applications critical to achieving the aggressive cost and performance goals.
- Materials and Processes advancement dictates progress of technology.