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# Integrated High Payoff Rocket Propulsion Technology

ARC
Atlantic Research Corporation
A unit of Sequa Corporation

THIOKOL
SPACE • DEFENSE • FASTENING SYSTEMS


PRATT & WHITNEY
DEPENDABLE ENGINES

AEROSPACE COMPANY

BOEING
North American, Inc.
Rocketdyne Division

ALLIANTTECHSYSTEMS

TRW

UNITED
TECHNOLOGIES
CHEMICAL
SYSTEMS

KAISER
MARQUARDT

# Advanced Space Transportation Program Roadmap

Space Transportation Programs

## Customer Classes

**Near Term Innovative**
- <60k Payload
- Satellite
- 1X–3X Reliability
- 3X Cost Reduction

**Initial Deployment**
- 100K Payload
- Satellite/Cargo
- Large Payload Fairing
- >3X Reliability
- 10X–100X Cost Reduction

**Rapid Access**
- 5K–20K Payload
- Crew & Cargo
- High Launch Rate
- 100X Reliability
- Hours Turnaround

**Passenger Service**
- 40K Payload
- Passenger
- High Launch Rate
- >100X Reliability
- Days Turnaround
- 10X–100X Cost Reduction

Near Term — LEO Weight

Near Term — Number of Applications

>60K — <5K — LEO Weight

Months — Hours — Weeks — Turn-Around Time

100X — Price

Aircraft-like — 100X — Reliability

## Transportation Concepts

Upper Stages Required — Total Mission

Near Term

LCT – Low-Cost Technologies: *Reduce Hardware & Sub-system Cost/Lower Operations Cost*

ART – Advanced Reusable Technologies: *Highly Reusable Systems/Increased Performance/Lower Operations Cost*

STJ – Space Transfer Technologies: *Increased Performance/Highly Reusable Systems*

STR – Space Transportation Research: *Increased Performance (Breakthrough Concepts)*

ASTP

# Engine Cost Reduction Roadmap

Space Transportation Programs

| Item | Percent | Goal | Benchmark | Fastrac Project | Est. Cost after Fastrac | Component Development | Engine Upgrades | Est. Cost after Upgrades |
|---|---|---|---|---|---|---|---|---|
| Total Engine | | $301 | $3,214 | | $975 | | | $375 |
| Turbopump | 31% | $93 | $996 | Barber-Nicholds/MSFC Low-Cost Turbopump | $310 | NRA8-15 Turbopump Rocketdyne/Barber Nicholds Pratt & Whitney | | $96 |
| Thrust Chamber | 31% | $93 | $996 | Thiokol/MSFC Ablative Thrust Chamber Assembly | $110 | NRA8-15 Thrust Chambers Thiokol and Rocketdyne | Upgraded Engine* | $25 |
| Lines and Ducts | 16% | $48 | $514 | MSFC Design Commercial Practices | $105 | | | $100 |
| Valves | 7% | $21 | $225 | Allied Signal/MSFC Specifications | $225 | NRA8-15 Valves Rocketdyne/Hi Gear | | $40 |
| Misc | 12% | $36 | $386 | Lower Integ. & Assy Costs: Simplex Design, Commercial Practices | $225 | Lower Integ. & Assembly Costs: Simplex Design, Commercial Practices | | $71 |
| Accept Test | 3% | $9 | $96 | Lower Acceptance Test: Simplex Design, Large Calibration Tolerances | $43 | Lower Acceptance Test: Simplex Design, Large Calibration Tolerances | | $43 |

Fastrac Engine

*Upgraded Engine Tailored to potential customers need.
- X–34 — More reusable
- Bantam — Larger thrust

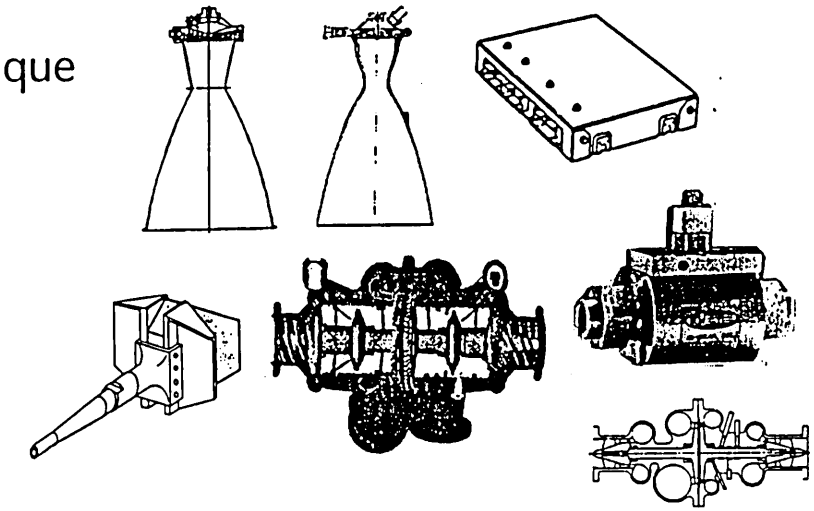
*Numbers are in thousands of dollars.*

STP—3365

1/8/98

# Small Payload Class Unique

■ **Description:** Development of technologies unique to small, UNEX class missions



■ **Example Products:**

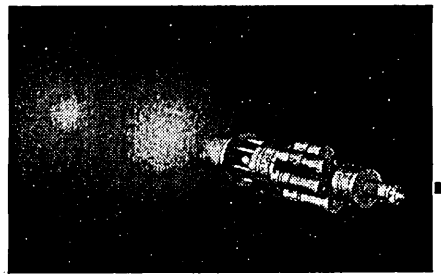
- Development of components, subsystems, and systems uniquely required for small payload class launch vehicles
  - Propulsion
  - Structures
  - Avionics

■ **Agency investigating use of joint sponsored research agreements**

# The Goals of the IHPRPT Program

)OST & ORBIT TRANSFER PROPULSION

INCREASE Isp + INCREASE THRUST/WEIGHT OR INCREASE MASS FRACTION + REDUCE FAILURE RATE AND IMPROVE REUSABILITY (MTBR) + REDUC COST

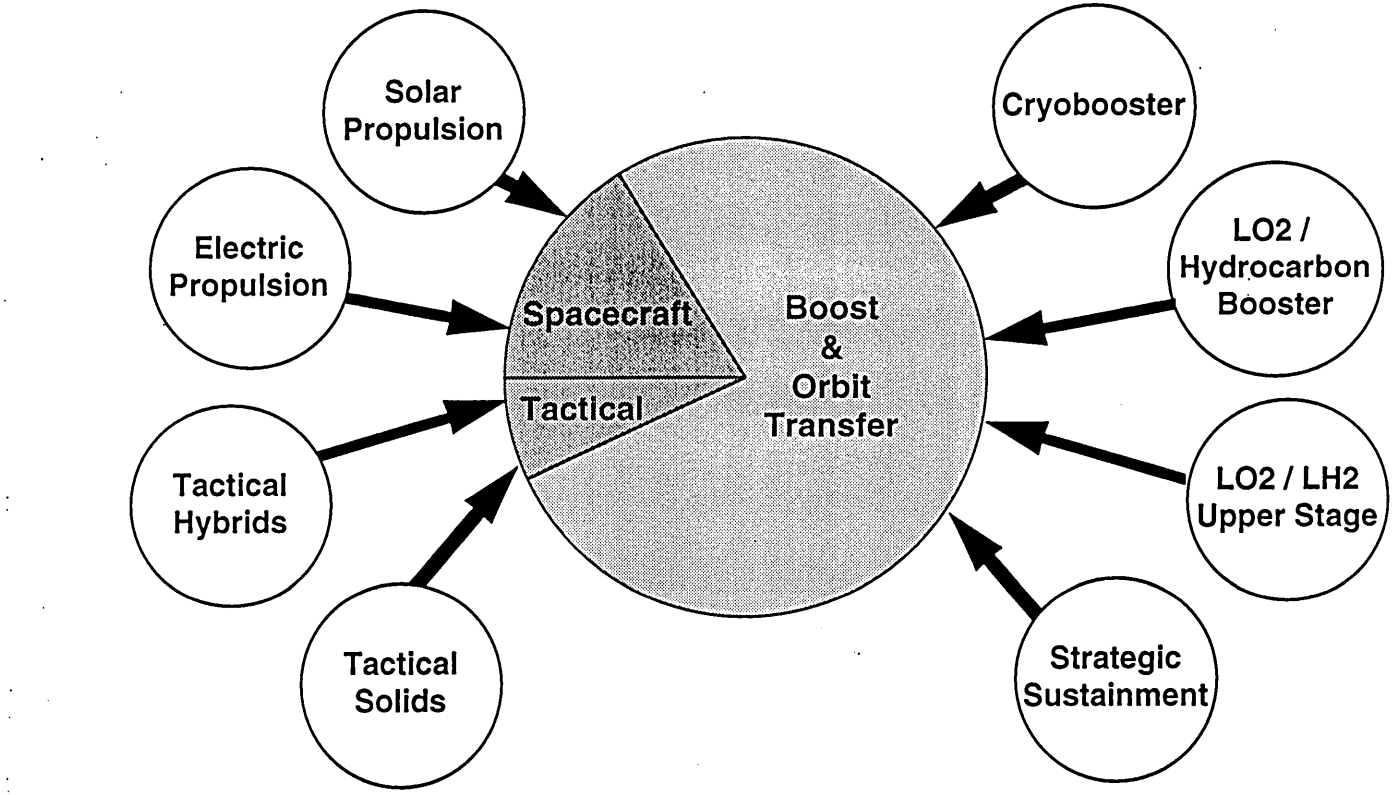


PACECRAFT PROPULSION

INCREASE Isp (Bipropellant, Solar Thermal) + IMPROVE MASS FRACTION (Solar Thermal) + IMPROVE $Isp_{(tot)}/Mass_{(wet)}$ (Electrostatic/ Electromagnetic) + IMPROVE DENSITY - Isp (Monopropellan

INCREASE DELIVERED ENERGY Isp + INCREASE PROPELLANT MASS FRACTION

# Propulsion Directorate
# Primary IHPRPT Focus Areas




| Advanced Concepts | Advanced Propellants | Materials Applications | Aerophysics |
|---|---|---|---|

# Space Transportation Technology– Objectives Expansion

Space Transportation Programs

This Top Level Mission

Expands into these Technology Objectives

***Reduce Space Transportation Costs, Improve Reliability, Operability, Responsiveness, and Safety.***

## Reduce the Vehicle Aquisition Costs

- Advanced Manufacturing
- Advanced Materials
- COTS Hardware
- Commercial Practices
- Simplified Designs
- Robust Margins

## Reduce the Vehicle Operating Costs

- Automated Self Test
- Informed Maintenance
- Advanced NDE
- One Time Certification
- Reduced Inspections
- Reduced Service

## Reduce Life Cycle Costs thru Reuse

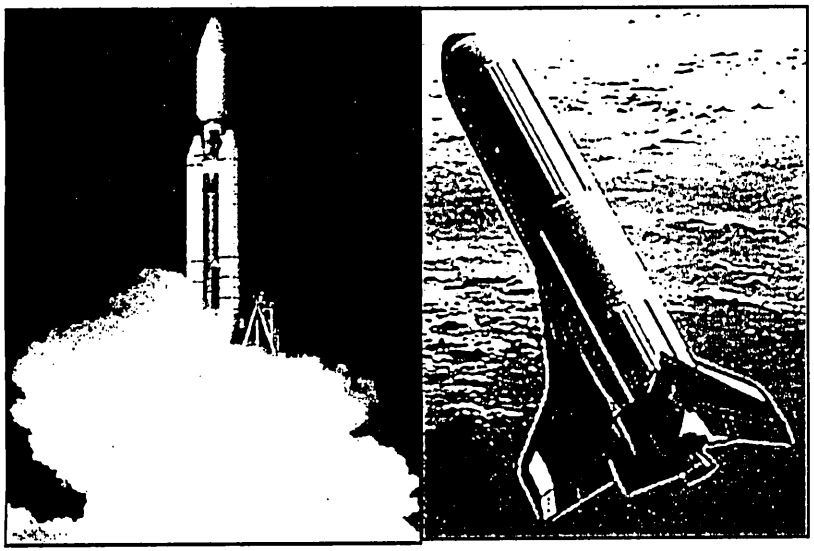
- Increased Service Life
  - Structures
  - Cryotanks
  - Thermal Protection
  - Propulsion Systems
  - Subsystems

## Increase Performance

- Increased Isp
  - RBCC, Alt Fuels
  - Nuclear, Electric
- Off Board Energy
  - Solar, Beamed Energy
  - Aero Assist, Tether
- Increased Capability
- Increased Mass Fraction

# Rocket Propulsion Investment Impacts

## MISSION AREA - SPACELIFT



- Affordable Space Launch
- Responsive Space Lift
- Global Mobility Via Space

### BOOST PROPULSION IS...

- 70-90% Takeoff System Weight
- 40-60% System Cost
- System Driver for Reusability/ Turnaround Time

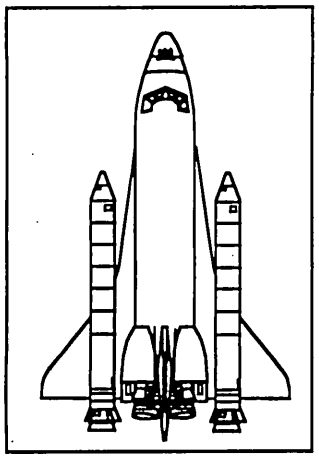
### PAYOFFS

- Reduce Launch Cost Up to 82%
- Increase Payload Up to 95%
- Reusable Turnaround Hours to Days

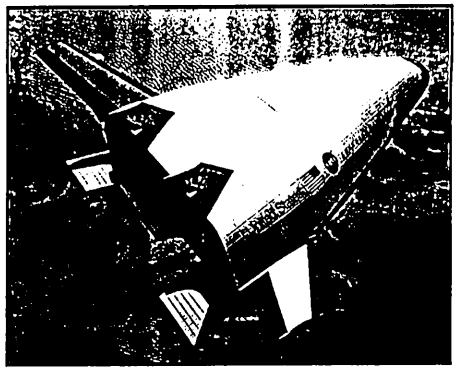
# IPD Technology

## SSTO

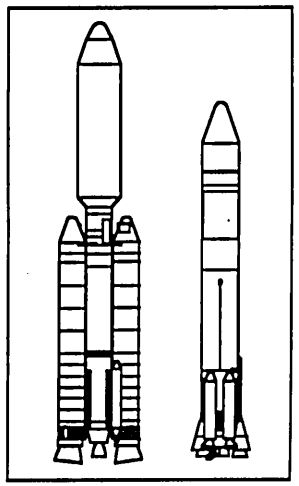
## Augmented SSTO



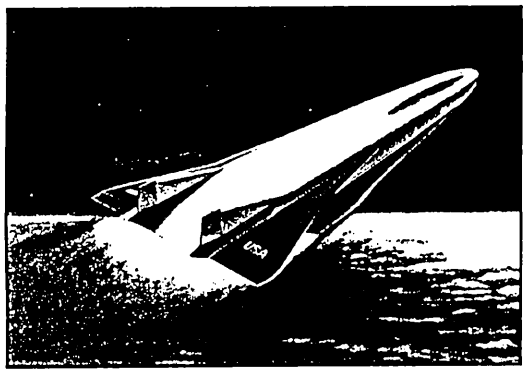
## X-33 / RLV



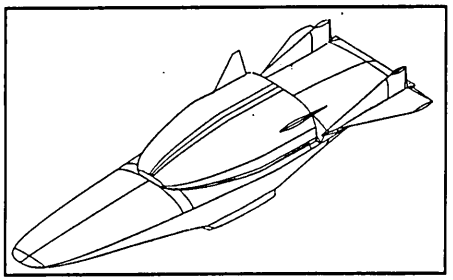
## EELV UPGRADE



## RBCC



## TSTO LOX / RP

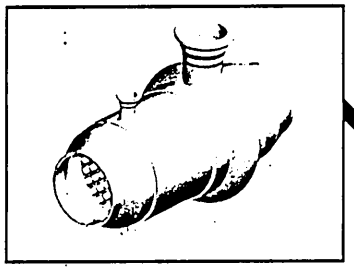


LIQUID PROPULSION INDUSTRY ADVANCEMENT GROUP

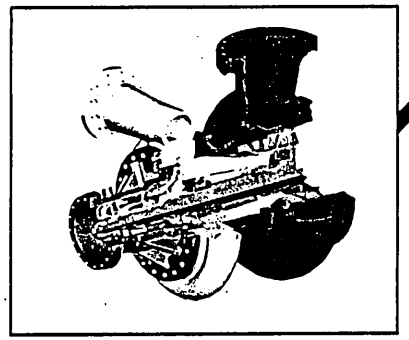
# Integrated Powerhead Demonstration (IPD) Program

- **Full flow staged combustion cycle engine**
- **LOX-Hydrogen propellants**
- **250K sea level thrust, 5:1 throttling**
- **200 mission life (MTBOH = 100)**
- **Sponsored by Air Force Phillips Laboratory**
- **IHPRPT Phase I project**
- **Rocketdyne is system integrator**
  - Also providing turbopumps & injector
- **Aerojet providing preburners, chamber/nozzle**

# Integrated Powerhead Demonstration

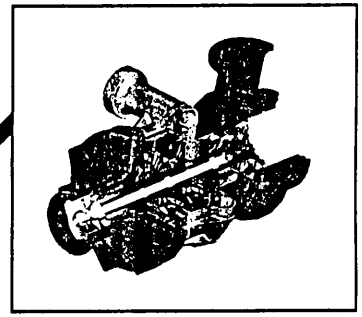


Oxygen Preburner

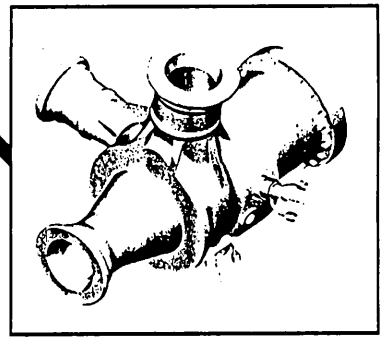


Oxygen Turbopump

**DESIGNED FOR LOWEST LIFE CYCLE COST**



Hydrogen Turbopump

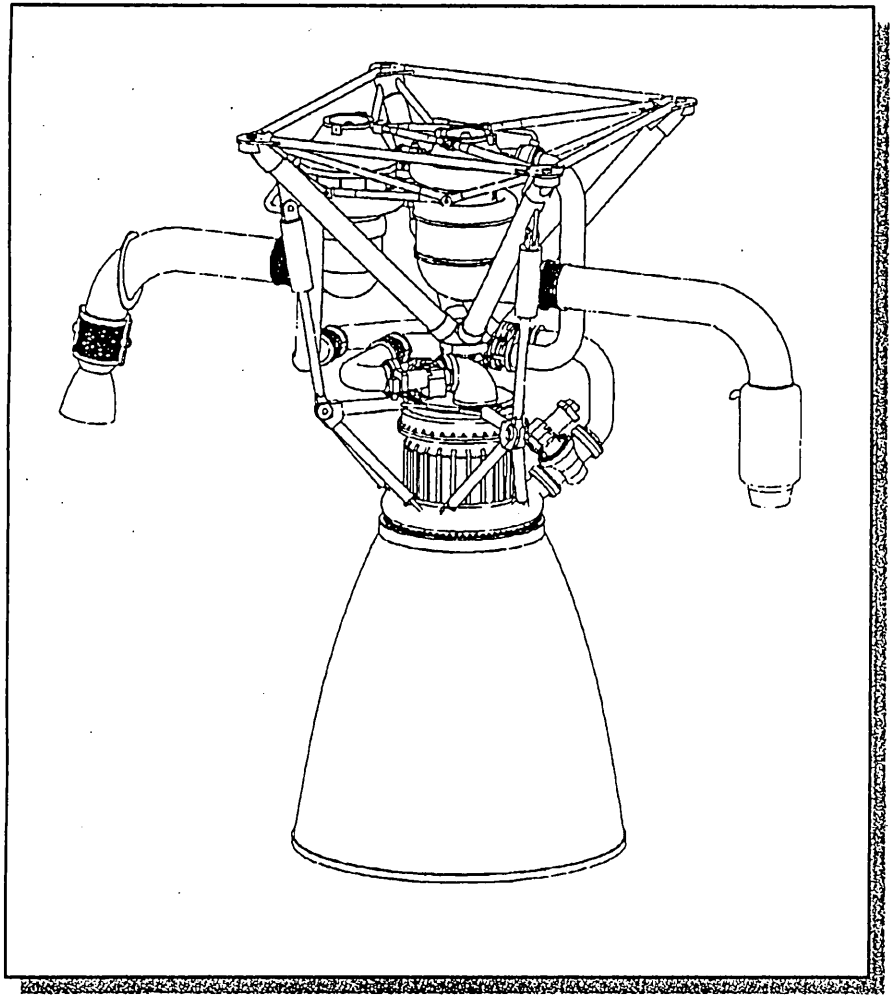


Hydrogen Preburner

**10X Increase in Engine Life**
**10X Reduction in Maintenance Cost**
**60% Reduction in Vehicle Size**
**Meets Military Spaceplane Requirements**

LIQUID PROPULSION INDUSTRY
ADVANCEMENT GROUP

# RS-68 Engine



- Expendable 650K $O_2/H_2$
- Simple gas generator cycle
- Lean development approach
  - Low risk design
  - Within experience base
  - Focused test program
  - Components in test
- Very low unit cost design
  - 94% parts reduction
  - 95% weld reduction
  - Commercial processes
  - Casting emphasis
  - Selected cost targets already achieved

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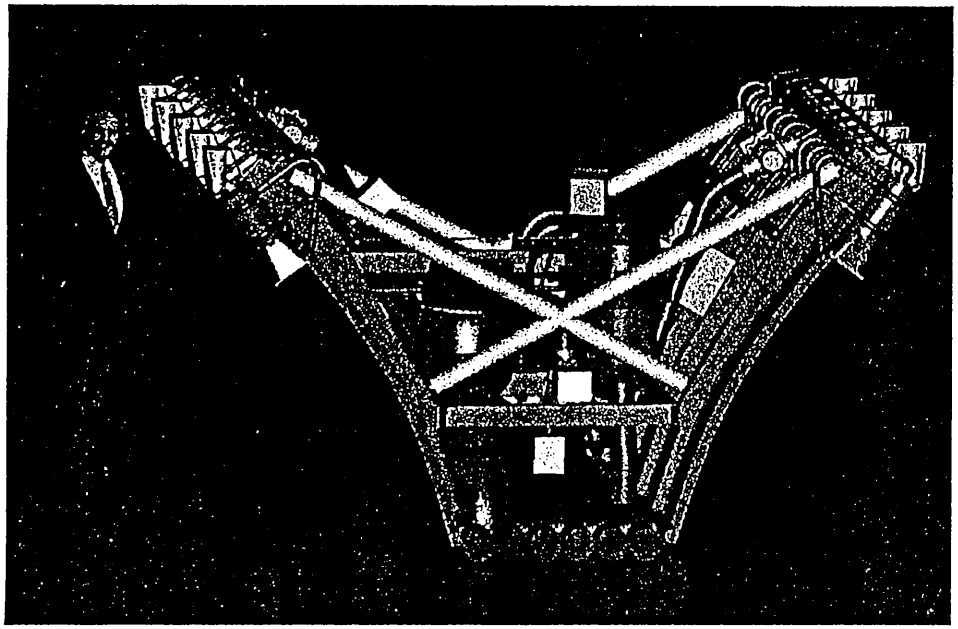
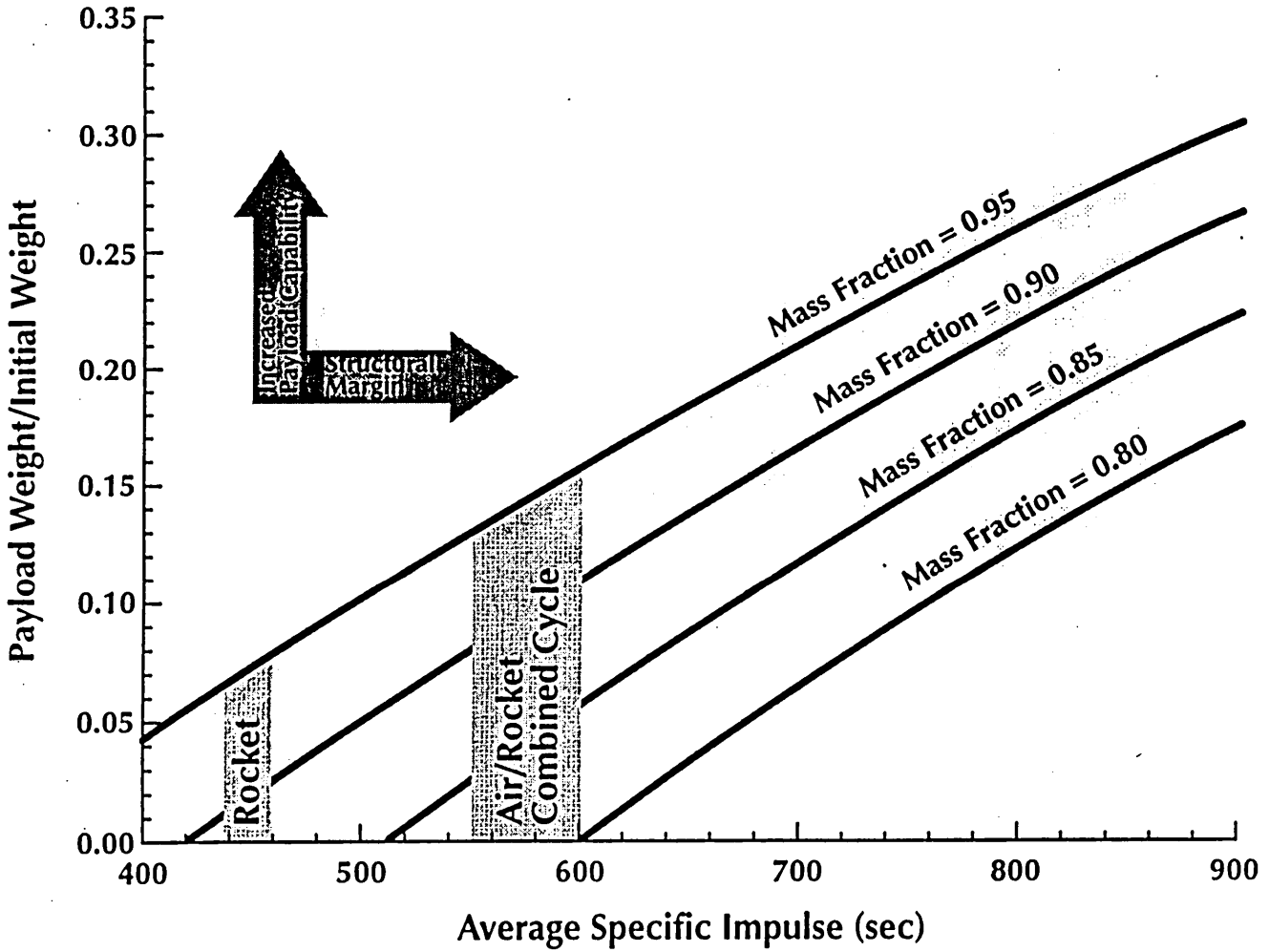
# X-33 Linear Aerospike



| | |
|---|---|
| F, sea level/vacuum, Klbf | 205.3/266 |
| Isp, sea level/vacuum, sec | 339/436 |
| Chamber pressure, psia | 857 |
| Area ratio | 58 |
| Thrust cells | 20 |
| Propellants | Ox/hydrogen |
| Mixture ratio, o/h | 5.5 |
| Cycle | Gas generator |
| Throttling, % thrust | 50-100 |
| Differential throttling | ± 15 % |
| Thrust/weight | 35 |
| Dimensions, inches | |
| Forward end | 133w x 88l |
| Aft end | 46w x 88l |
| Forward to aft | 79 |

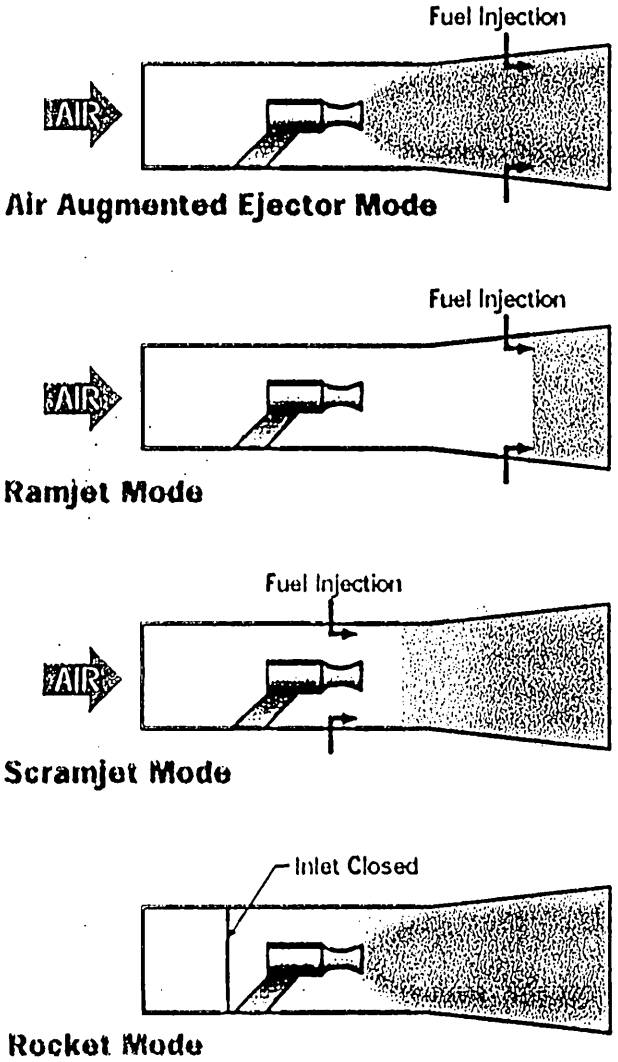
# Advanced Reusable Technologies

## SSTO Performance Parametrics

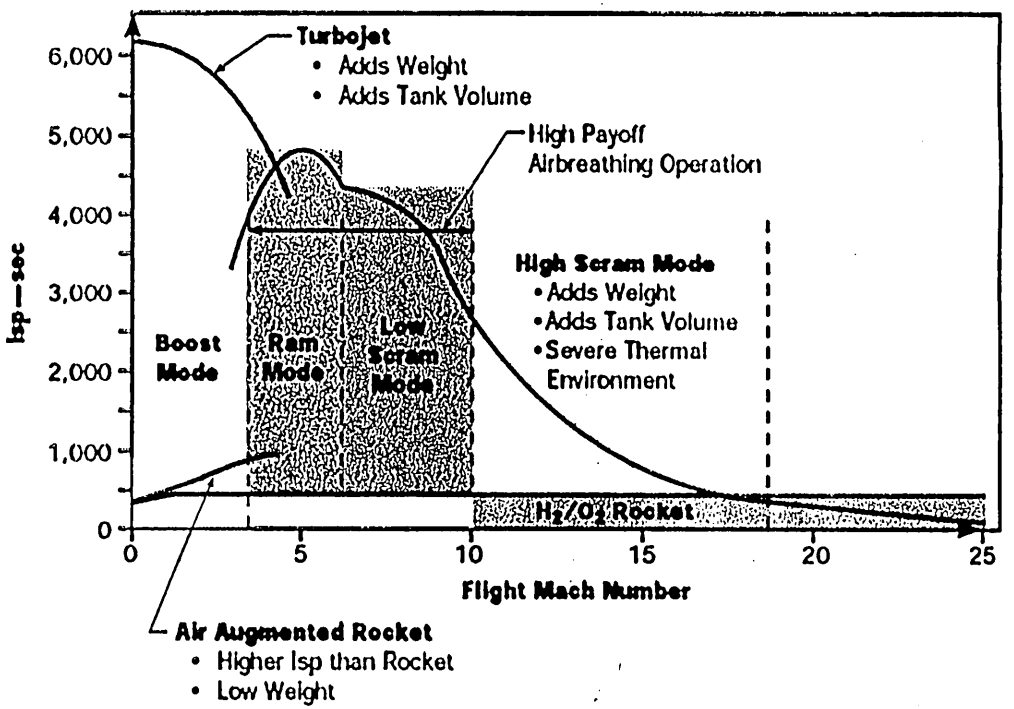


# Simplified Schematic of RBCC Operating Modes and Performance Benefits

## RBCC Operating Modes

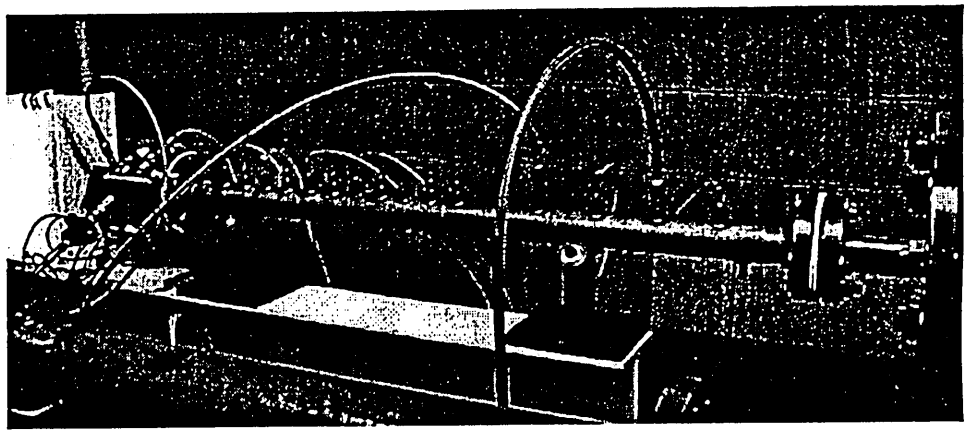



## Increased Mission Isp



Space Transportation Programs

# Pulse Detonation Wave Engine



## Vision

Low-cost, high-performance engines applicable to all size propulsion systems from boost phase to orbit maneuvering applications

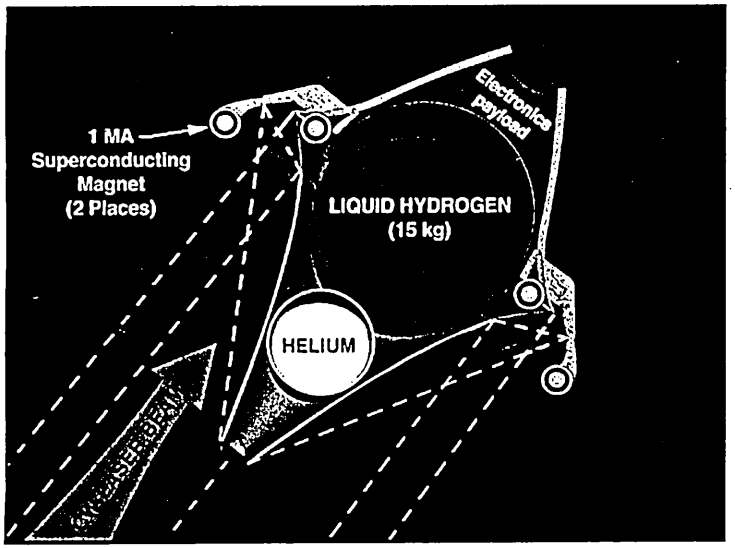
## Benefits

- $I_{sp}$ increase of 10 to 15 percent over conventional chemical rocket engines using the same propellants
- Significant reduction in pump discharge pressure requirements
- Compatible with combined cycle concepts
- Lighter weight, significantly lower cost, highly reliable, easily maintained, and reusable propulsion system

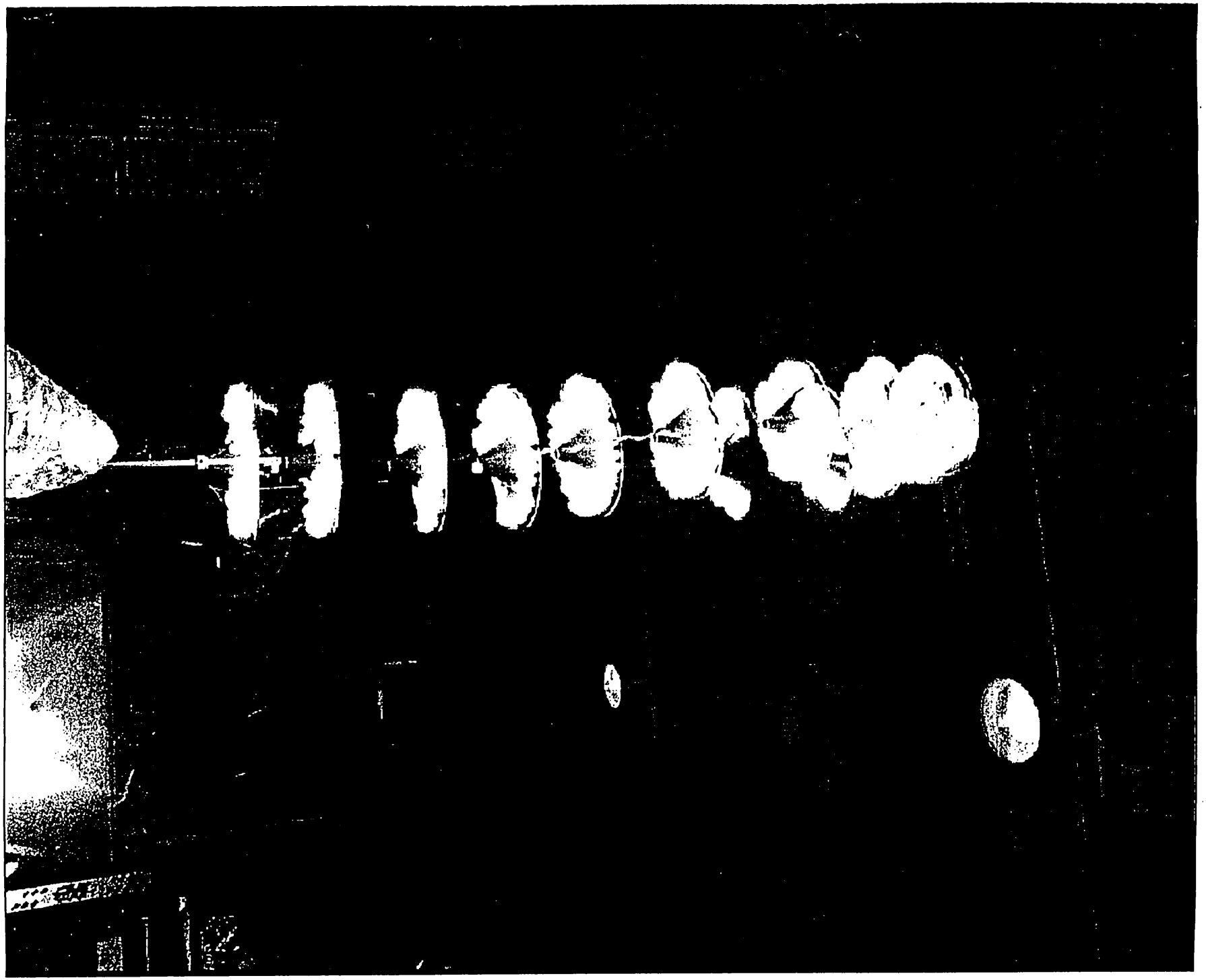
## Current Status

- Demonstrated in laboratory to TRL 2 to 3
- Various propellant combinations demonstrated
  - Oxidizers: air, GOx
  - Fuel: propane, hydrogen, RP, etc.
- Several ongoing SBIR's with NASA and DOD

# Laser Propulsion

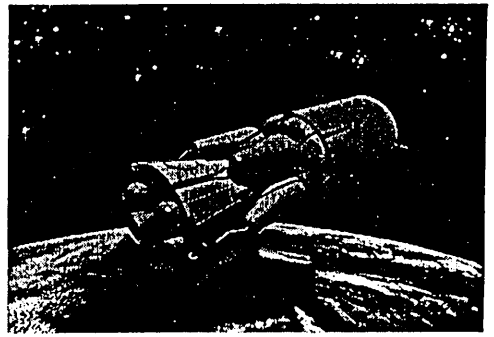



- Laser Propelled "Beam Rider"
  - Energy Source on Ground
  - Single Stage to Orbit
  - 30 to 50 kg Initial Weight
- Dual Mode Operation
  - Airbreathing to Mach 5 @ 30 km
  - Propellant Augmented Above 30 km
- 10 MW Class Infrared Laser
- Low Cost Space Access



# Low-Cost Upperstages

■ **Description:** Focused on the development and demonstration of technologies required for low-cost, near term upperstages for a Shuttle or RLV infrastructure while laying the groundwork for future needs.



■ **Example Products:**

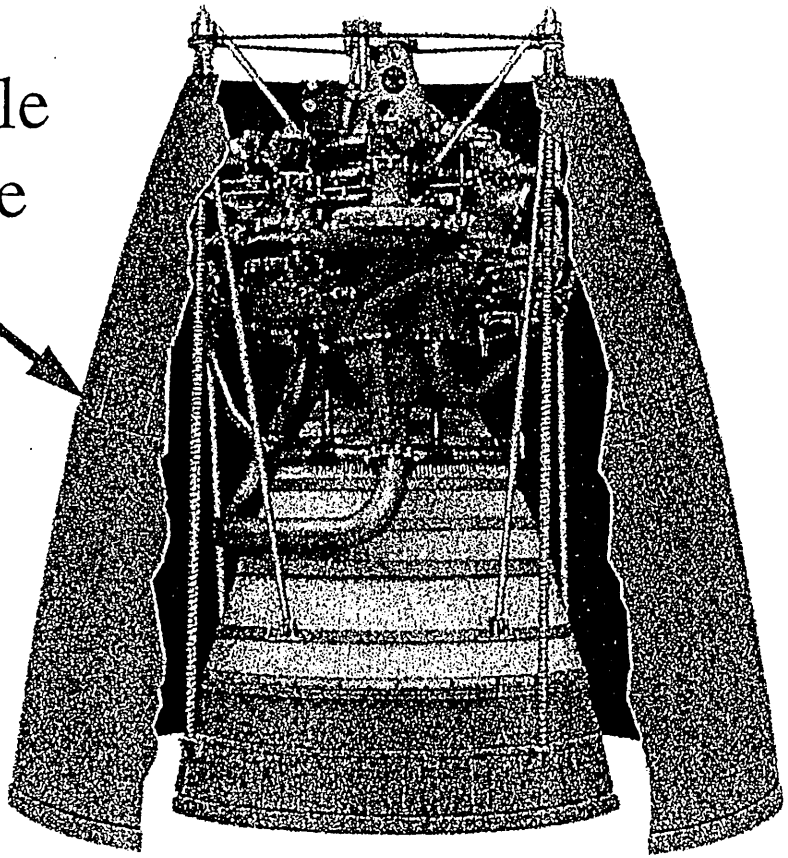
- Development of low-cost, lightweight, compact high performance rocket engine systems
- Development of zero-g cryogenic fluid management systems (acquisition and storage)
- Development of automated rendezvous and capture techniques
- Development of high performance in-space thrusters
  - Solar electric
  - Solar thermal

LIQUID PROPULSION INDUSTRY ADVANCEMENT GROUP

# RECENT TECHNOLOGY DEVELOPMENTS IN LIQUID ROCKETRY

## *RL10B-2 25K Upper Stage Engine*

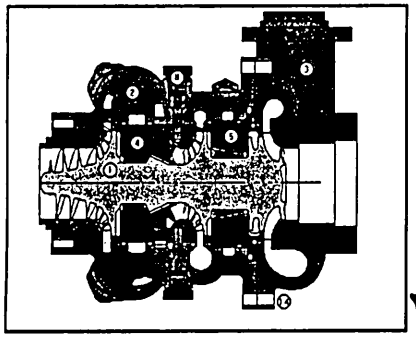
Deployable Composite Nozzle



| | |
|---|---|
| Thrust, lb | 24,750 |
| Isp, sec | 467 |
| Pc, psia | 645 |
| Area ratio | 285 |

FCD508921

# Advanced Expander Cycle Engine Demo

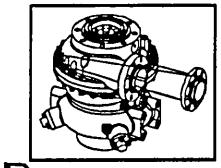


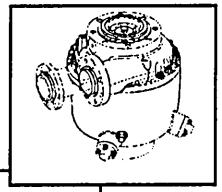
LH2 Turbopump

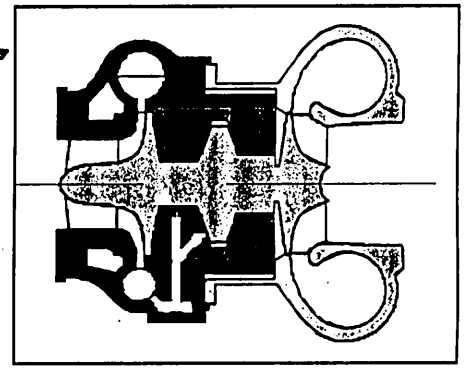
AFRL

**AFRL & P&W**

Upper Stage Demo

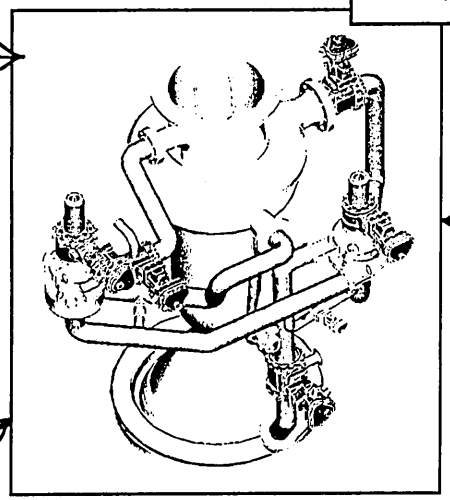






Lox Pump

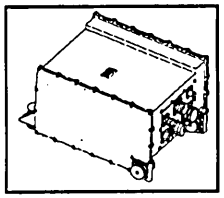
P&W



DEREC

EMA's

AFRL



AFRL

Combustor