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OMB No. 0704-0188

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FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-160
Dr. Quinn "AFRL Propulsion Directorate Briefing for Industry (Space Propulsion Thrust"
NAECON Briefing **(Statement A)**

20020823 043

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16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Leilani Richardson
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Unclassified	**Unclassified**	**Unclassified**			(661) 275-5015

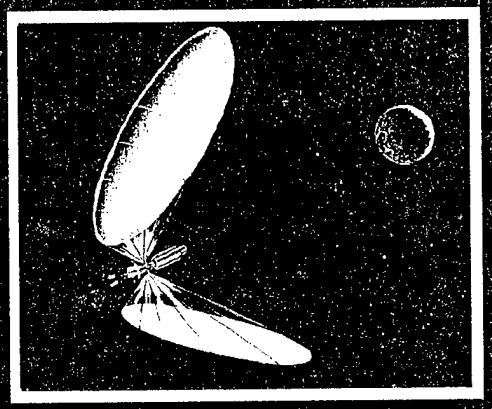
41 items enclosed

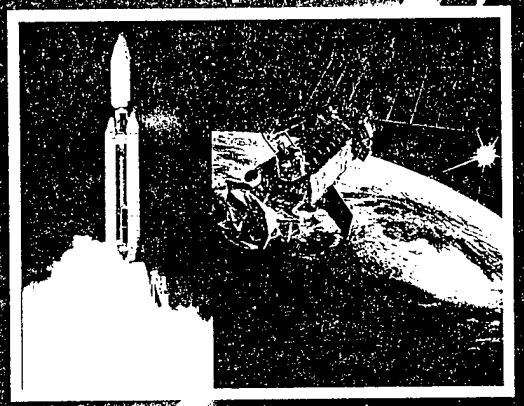
Air Force Research Laboratory

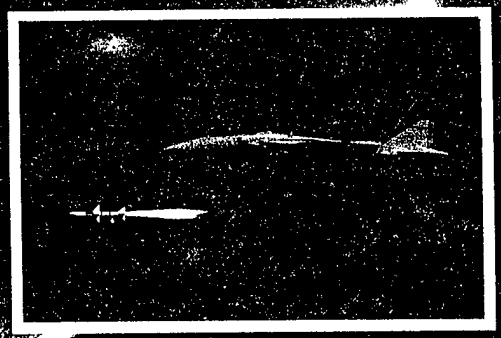
Propulsion Directorate

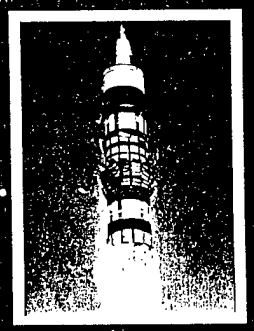
Rocket Propulsion Division

Dr. Lawrence P. Quinn

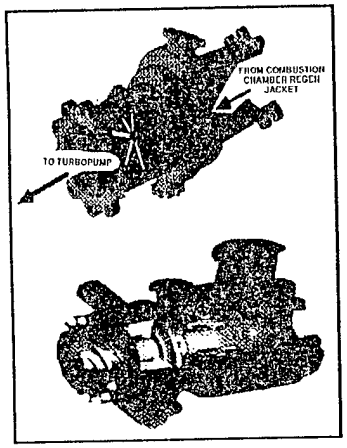








Air Force Research Laboratory
Rocket Propulsion Division

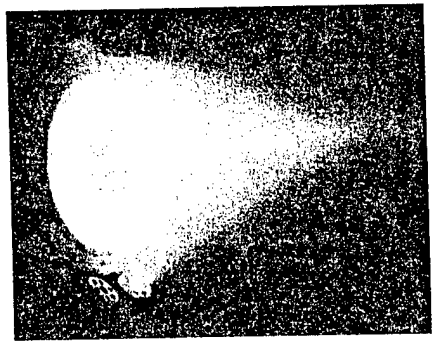


INTEGRATED POWERHEAD DEMONSTRATION

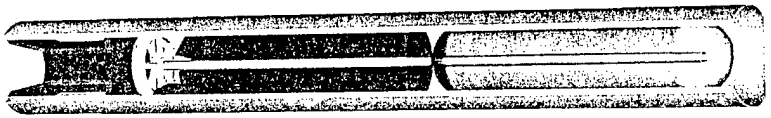
Mission Statement

Create Rocket Propulsion Technologies for the Warfighter to Control and Exploit Space & Air

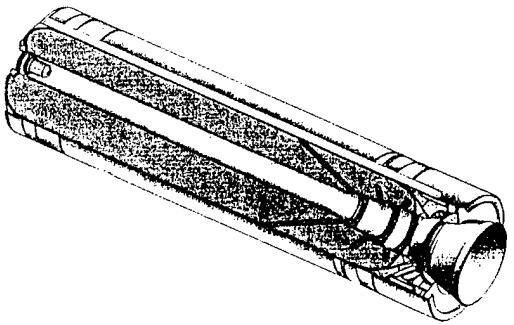
ADVANCED EXPANDER CYCLE ENGINE



HALL THRUSTER



HYBRID BOOST

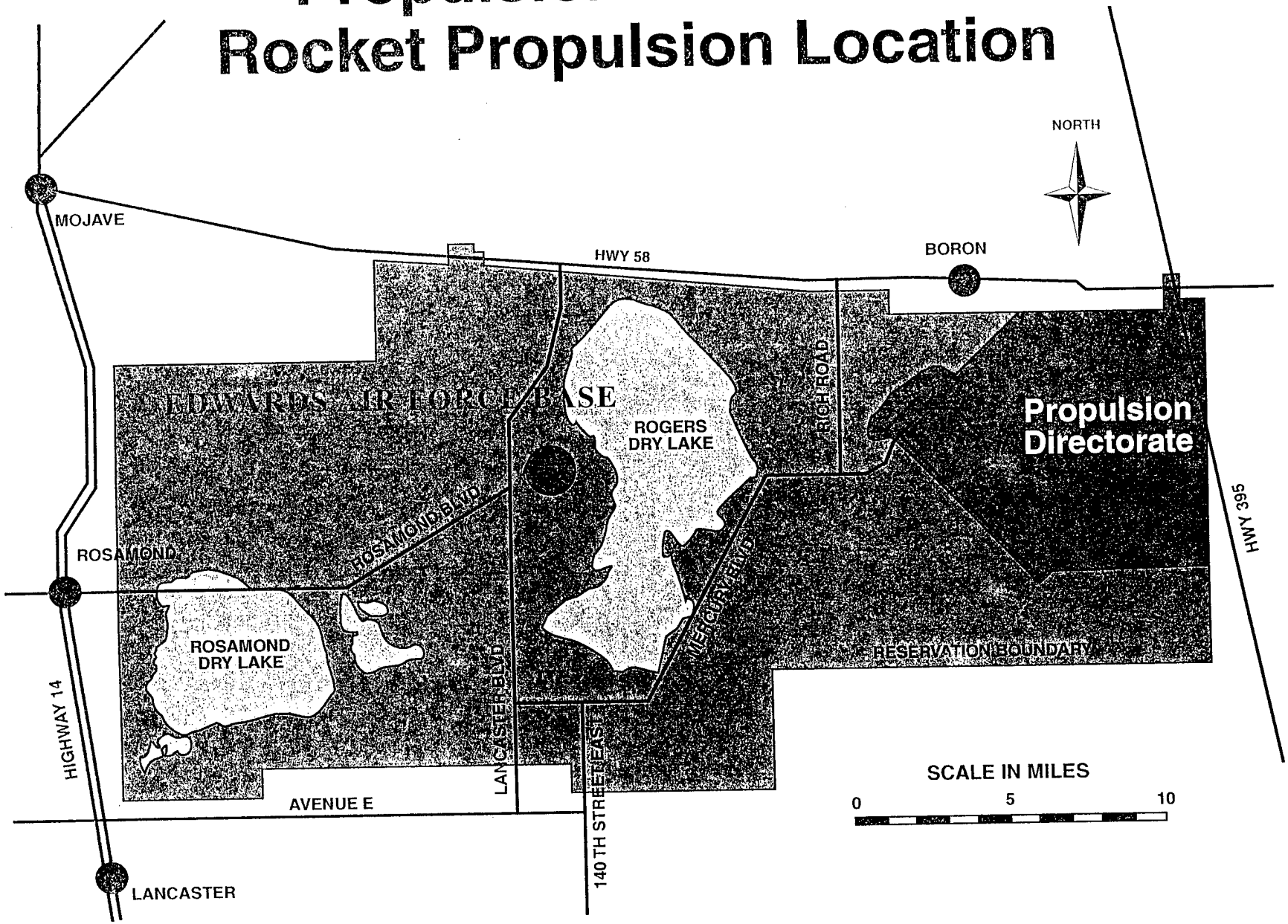


SUSTAINMENT MOTOR

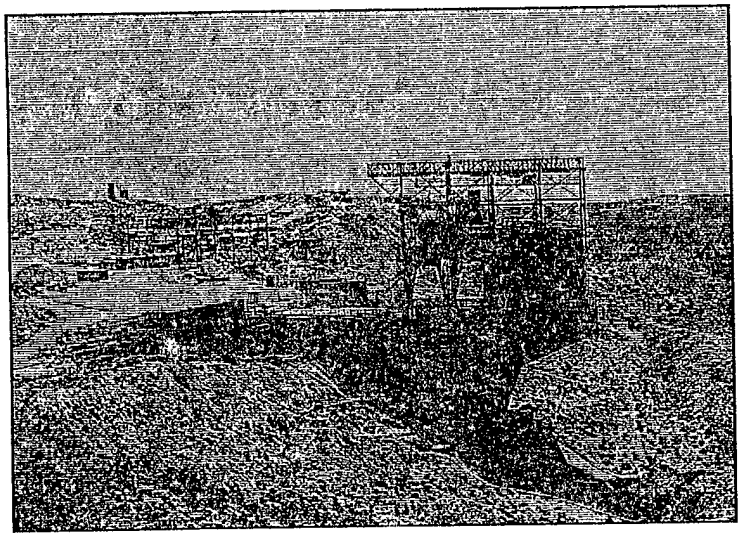
Outline

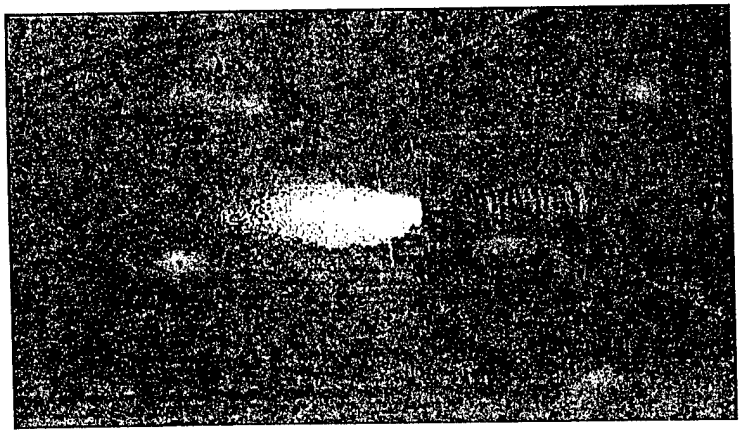
- Who Are We?
- What Have We Done?
- Integrated High Payoff Rocket Propulsion Technology
- What Are We Doing?

Propulsion Directorate
Rocket Propulsion Location

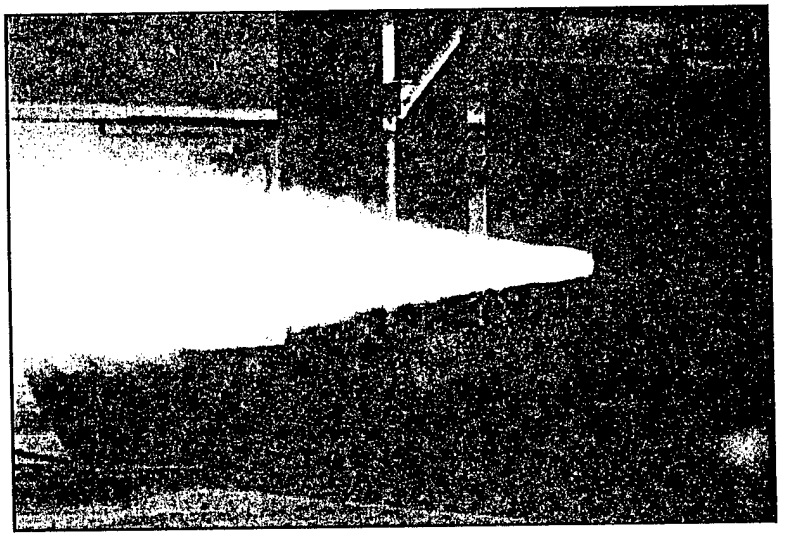


Facilities





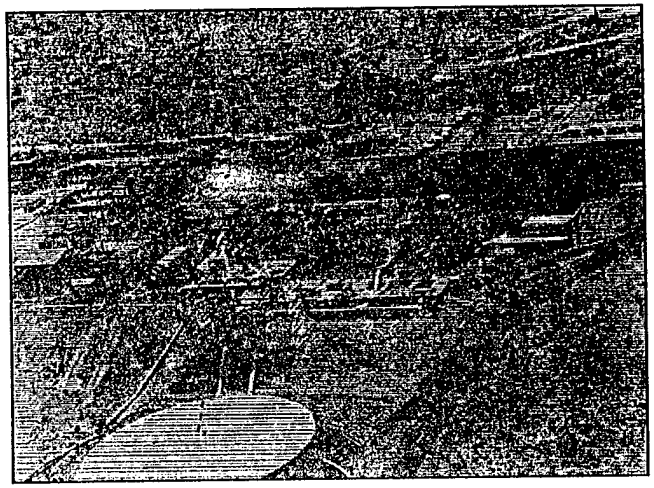
NINETEEN LIQUID ENGINE
STANDS TO 8,000,000 LBS THRUST

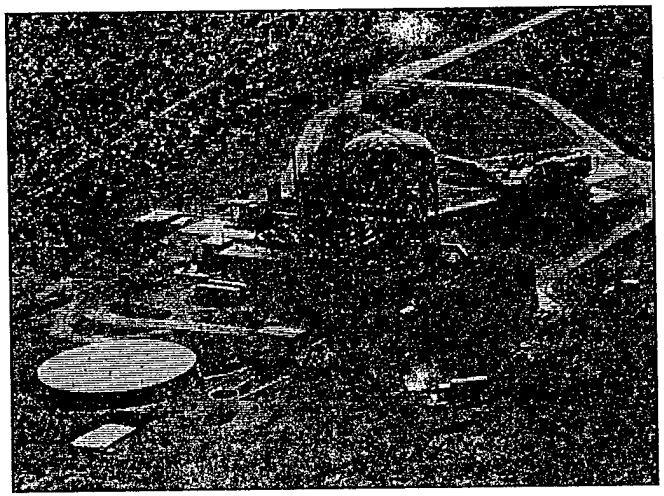


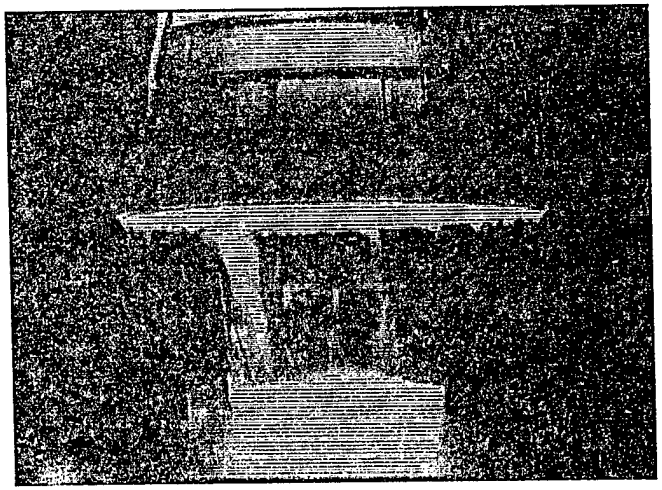
THIRTEEN SOLID ROCKET MOTOR
PADS TO 10,000,000 LBS THRUST

Altitude Facilities

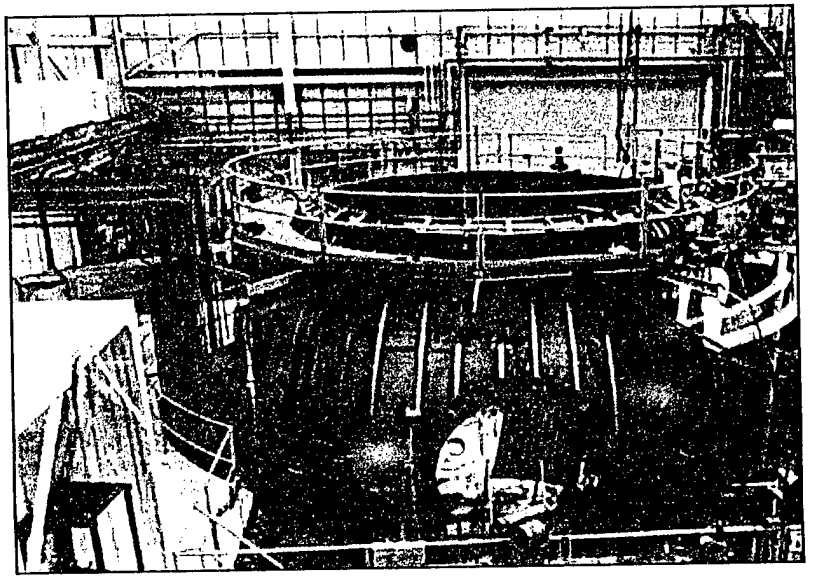
FROM MILLIPOUNDS TO 60,000 LBS THRUST





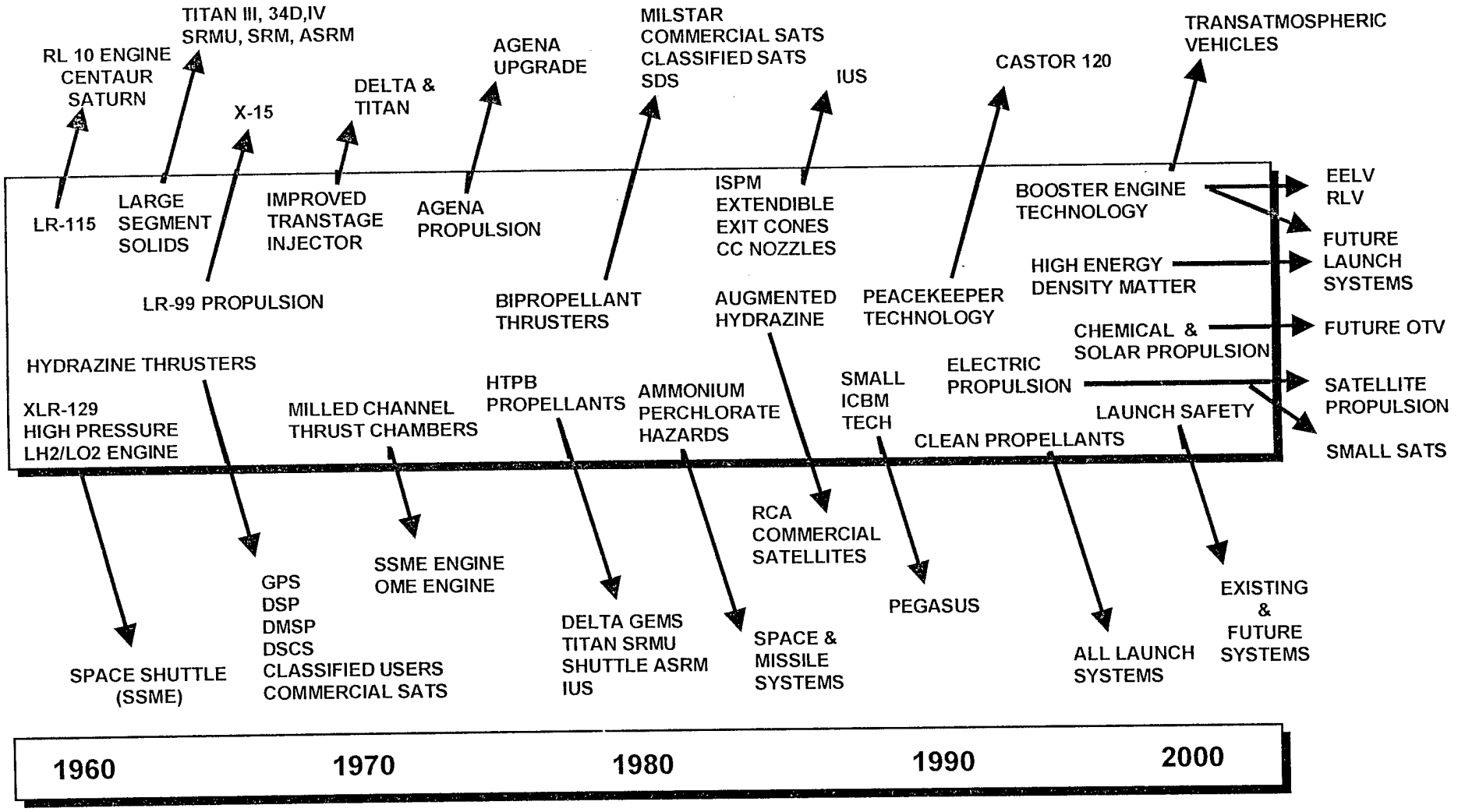


Combined Space Environment Simulation



30 FT DIAMETER LIQUID NITROGEN
COLD WALL QUARTZ LAMP SOLAR SIMULATION

Air Force Research Laboratory Space Propulsion Contributions



Air Force Research Laboratory Contribution to Air Force Satellite Propulsion

SPACE MOTOR

STAR 63D

MONO-PROPELLANT

HYDRAZINE MATERIAL COMPATIBILITY

HYDRAZINE THRUSTERS & FEED SYSTEMS

BI-PROPELLANT

BI-PROPELLANT THRUSTERS & FEED SYSTEMS

DUAL SEAT VALVES

ELECTRIC PROPULSION

PULSED PLASMA THRUSTERS

RESISTO JETS*

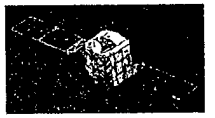
ARCJETS

GPS

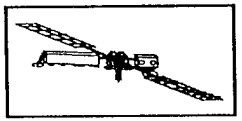
DSP

DMSP

DSCS



MILSTAR

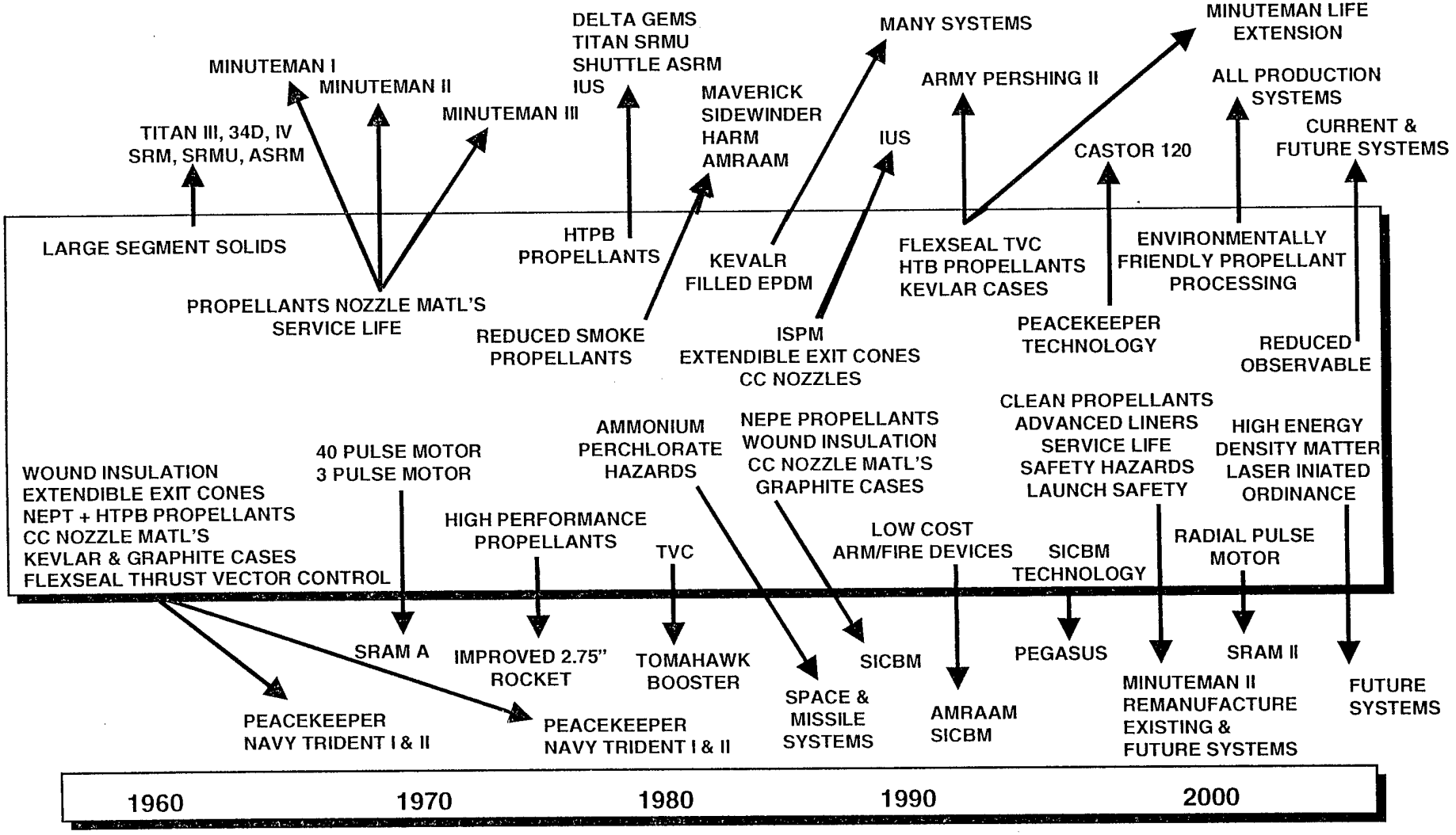


FUTURE AF SATELLITES

1960 1970 1980 1990 2000 2005

* $1M AFRL Investment Extended On-Orbit Life and Generated Over $1B Additional Income on Lockheed-Martin Commercial Satellites.

Air Force Research Laboratory
Solid Propulsion Motor Technology Contributions



Air Force Research Laboratory Contribution to Peacekeeper ICBM

PROPELLANT

*+ HTPB(HYDROXY TERMINATED POLYBUTADIENE)
NEPE(NITRATE ESTER POLYETHER)

STAGE 1,2
STAGE 3

NOZZLE

\+ CARBON-CARBON INTEGRAL THROAT INSERT
*‡ FLEXSEAL TVC
\+ EXPANDABLE EXIT CONES

STAGE 1,2, 3
STAGE 1,2, 3
STAGE 3

MOTOR CASE

LOW LENGTH-TO-DIAMETER KEVLAR
WOUND ELASTOMERIC INSULATION

STAGE 3
STAGE 3

PBPS

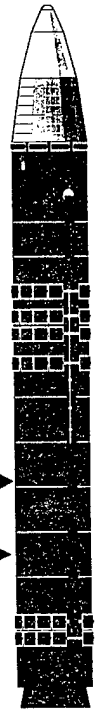
INJECTED MOLDED ATTITUDE
CONTROL ENGINE THRUST CHAMBER

STAGE 4

OTHER

NUCLEAR EFFECTS STUDIES
ORDINANCE TEST SUPPORT

ALL STAGES
ALL STAGES



Other Applications

* Pershing II
+ Inertial Upper Stage
‡ Trident I (C-4)
Titan IV SRMU

IOC
DEC 86

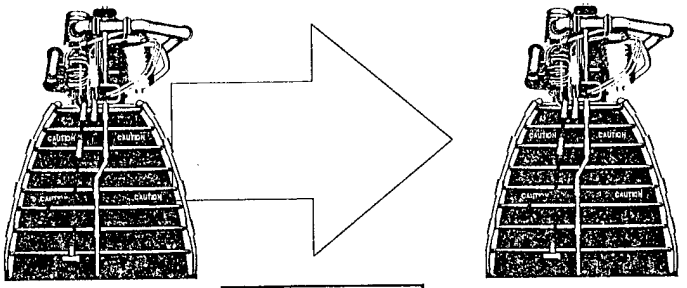
This technology increased the payload capability by 82% over MM III technology

1960 1970 1980

Propulsion Related AFSPC Deficiencies

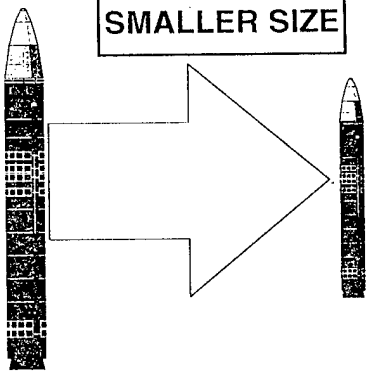
- Costly Spacelift
- Unresponsive Spacelift
- Satellite Repositioning
- Satellite Recovery & On-Orbit Service
- Global Mobility Via Space
- Lack of DoD Space System Protection Capability

IHPRPT is....



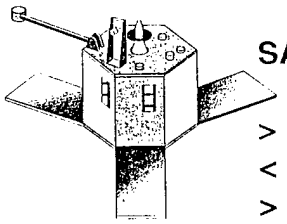
SAME SIZE

> Range / Payload
> Thrust
> Isp
< $

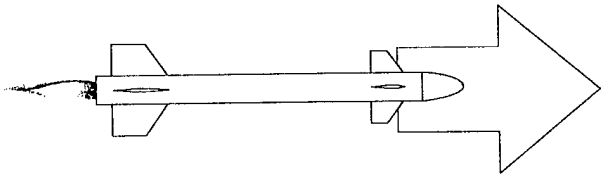


SMALLER SIZE

= Payload
= Thrust
> Isp
> M_f
< $



SATELLITE PERFORMANCE
SAME THRUST
> Isp or Thruster Efficiency
< $
> Life
> Repositioning Capability



THRUST CONTROL
> Range
> Warhead Delivery
> M_f

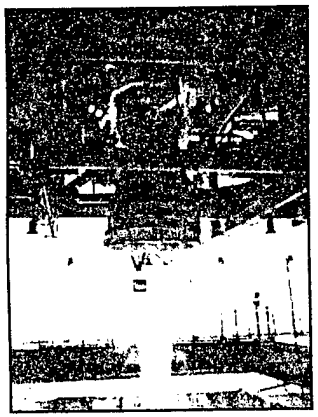
Double Rocket Propulsion Capability By 2010

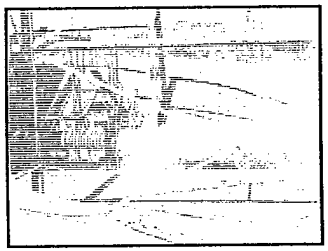
PROCESS FOR:
- Works First Time, Every Time
- High Performance Long Life
- Dual Use, Cost Effective
- Environmentally Compliant
- Insensitive, Safe
- Highly Efficient Operation

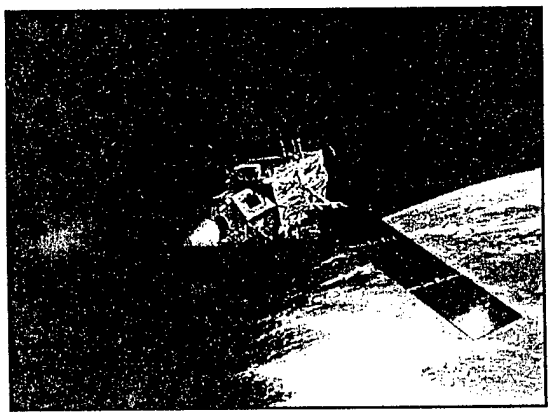
IHPRPT Investment Impacts

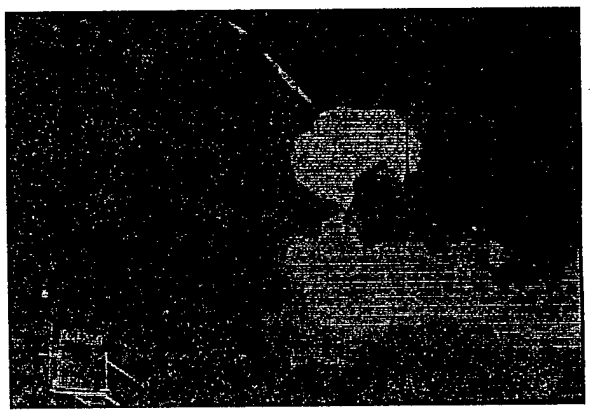
Propulsion Performance has Major Impacts on Vehicle Size/Weight

Propulsion Represents the Limiting Factor in Future Military and Commercial Capabilities









PROPULSION IS...

Boost

70-90% Takeoff System Weight

40-60% System Cost

Spacecraft

Life Limiting Factor

25-40% System Cost

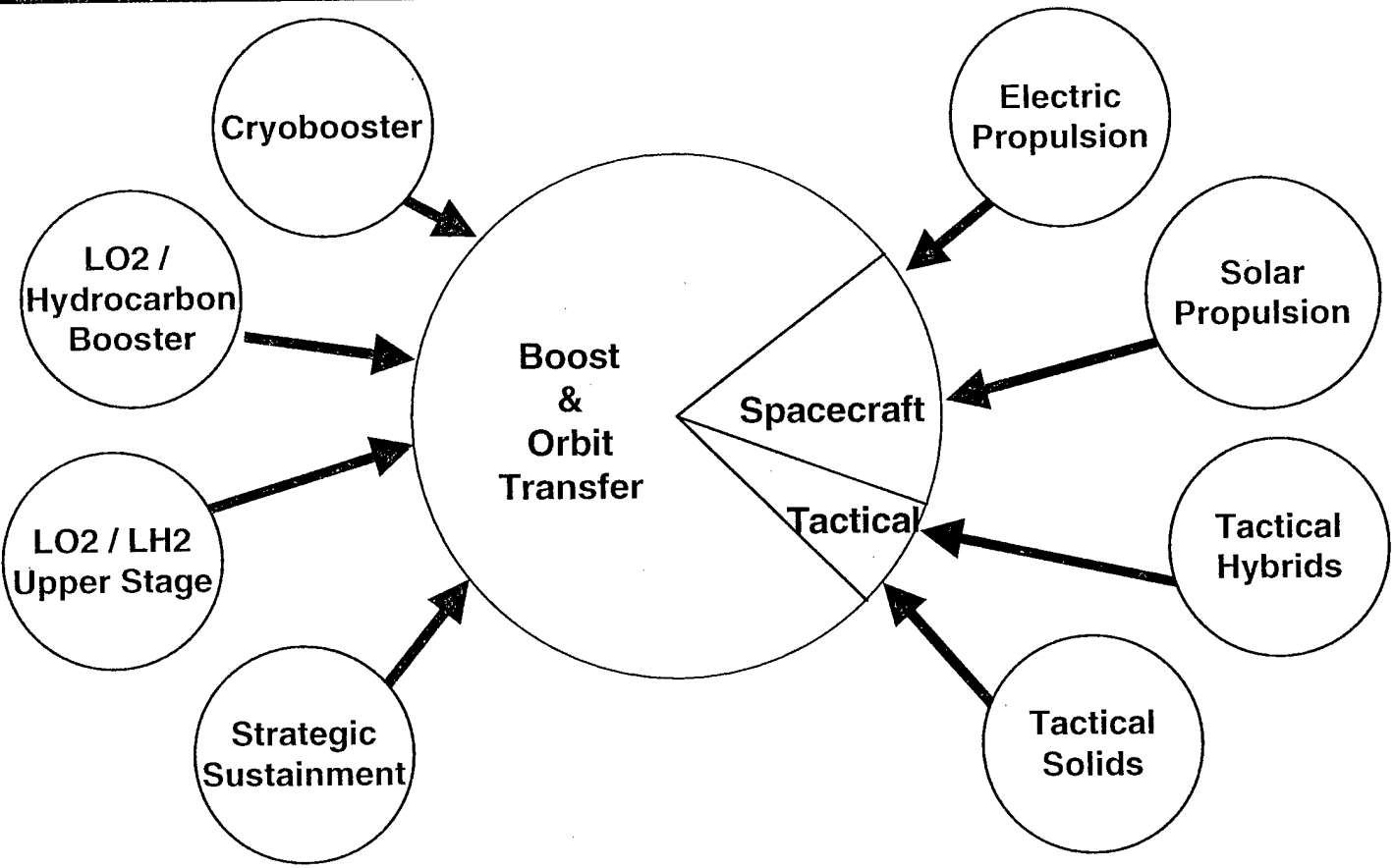
50-70% Satellite Weight

Tactical

60-80% Missile Weight

Critical Factor in Decreasing Time-to-Target

Propulsion Directorate Primary IHPRPT Focus Areas

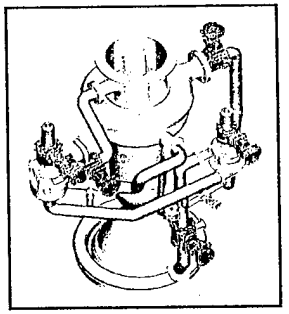


Advanced Concepts	Advanced Propellants	Materials Applications	Aerophysics

Rocket Propulsion Division Key Programs

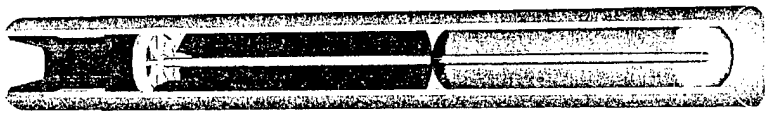
Integrated Powerhead Demo

- Develop Enabling Technologies for Advanced Cryogenic Engines
- Enables Reusable Space Launch Vehicles



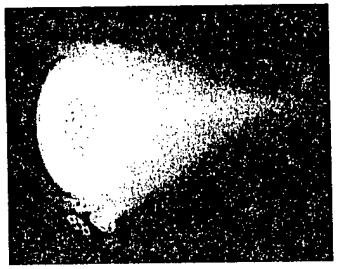
Advanced Expander Cycle Upper Stage Engine

- Develop Technologies for the Next Generation Upper Stage Engines
- Increased Reliability, Increased Payload, Decreased Cost



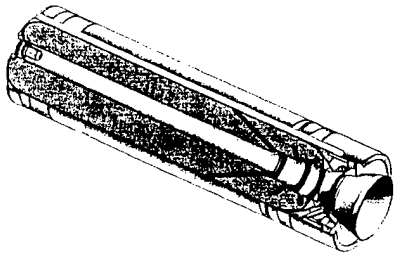
Hybrid Propulsion

- Develop Hybrid Propulsion for Tactical, Upper Stages and Boost Systems
- Increased Operational Effectiveness, Inherent Safety and Increased Performance



Electric Propulsion

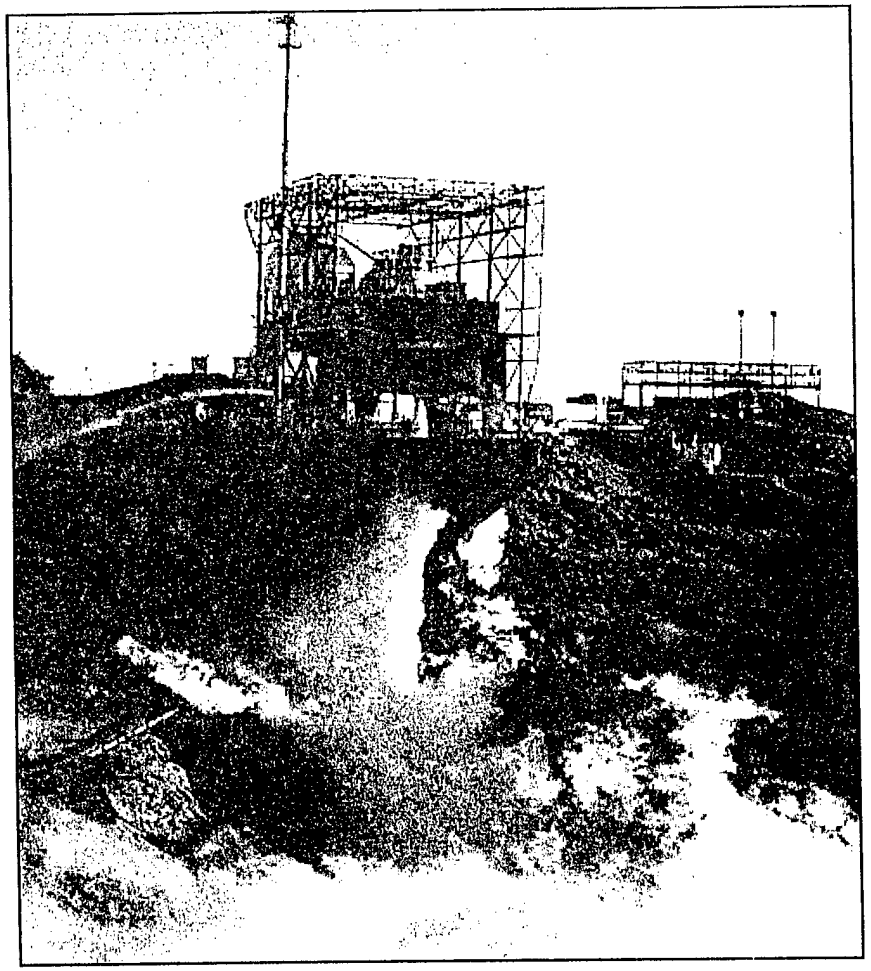
- Develop Advanced Spacecraft Propulsion
- Improved Orbit Transfer, Stationkeeping and Repositioning of Satellites



Strategic Sustainment

- Technology Efforts for Sustainment of Strategic Systems
- Sustainment of Existing Systems and Industrial Capacity

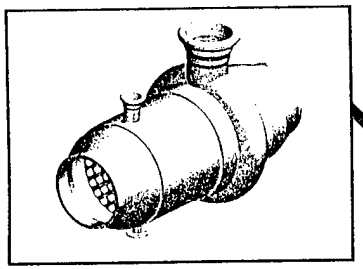
EELV Support



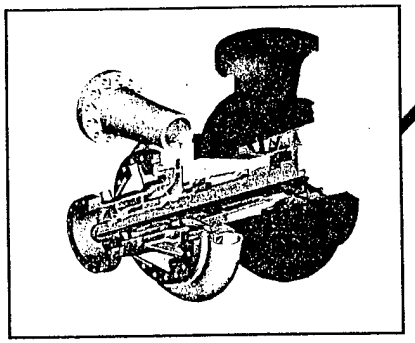
Facility System Test
9 Sep 97

- Activation of Large Engine Test Facility at Edwards AFB
- Provides EELV With Assured Engine Test Capability
- Modern World Class Rocket Engine Test Facility
- On Track to Test Rocketdyne RS-68 for Boeing EELV

Integrated Powerhead Demonstration

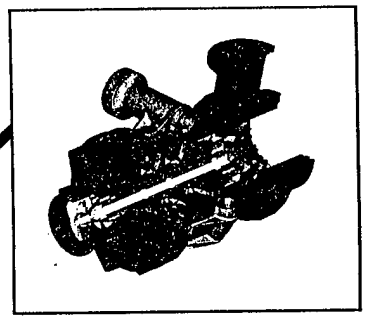


Oxygen Preburner

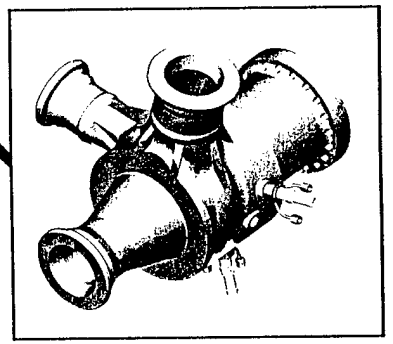


Oxygen Turbopump

DESIGNED FOR LOWEST LIFE CYCLE COST



Hydrogen Turbopump

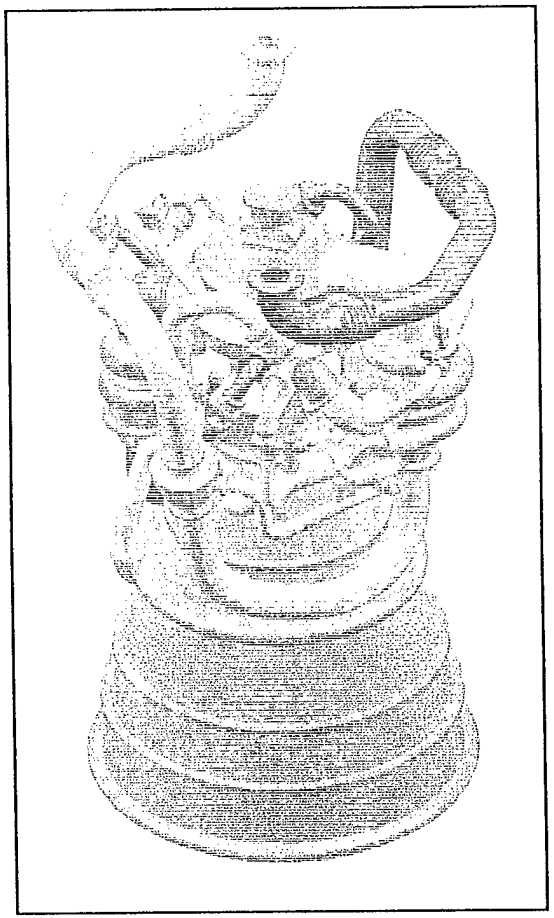


Hydrogen Preburner

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

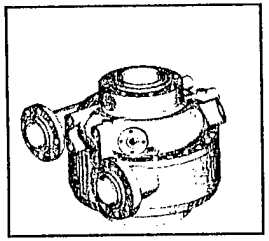
Integrated Powerhead Demonstration

- Reusable Space Engine Technology Program
- Baseline Approach for Military Spaceplane
- Unique Design Enables 100 Missions w/o Overhaul
- Low Cost, Low Part Count, High Reliability
- Component Fabrication Underway



250K LO_2/LH_2 BOOSTER ENGINE

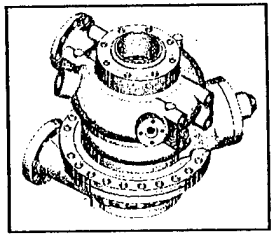
Advanced Expander Cycle Engine Demo



LH2
Turbopump

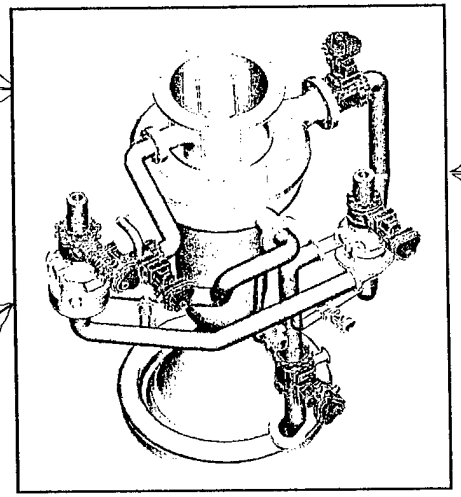
AFRL

AFRL & P&W
Upper Stage Demo



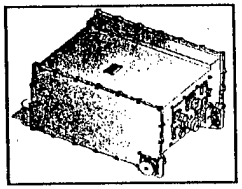
LO2
Pump

P&W



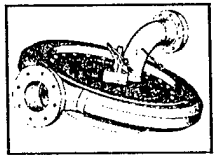
DEREC
EMA's

AFRL



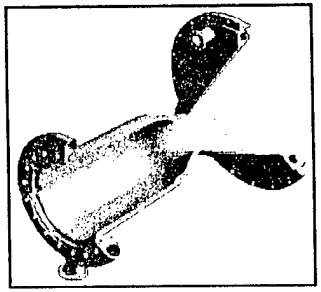
Injector

P&W



AFRL

Combustor



Advanced Expander Cycle Engine IHPRPT Phase I Payoffs

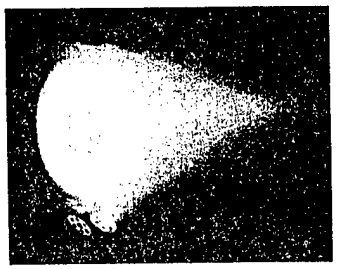
- Upper Stage
  - –Increase Payload 11%-16%
  - –Decrease Cost 5.6%
- Other Applications
  - –Booster
  - –Sustainer
  - –Military Space Plane

Future DoD/Commercial Satellite Trends

- Greater Repositioning Requirements
- Higher Specific Power
- Greater Resolution
  - Distributed Apertures
  - Large Deployables
- Orbit Insertion
- Electric Propulsion Approaches

Larger GEO Satellites

High Power Available
High Thrust Desired

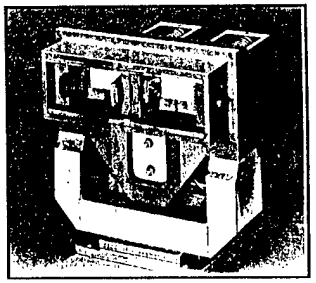


Hall
Thruster

Small Sats

Low Power (<200W)
Small Impulse Bit

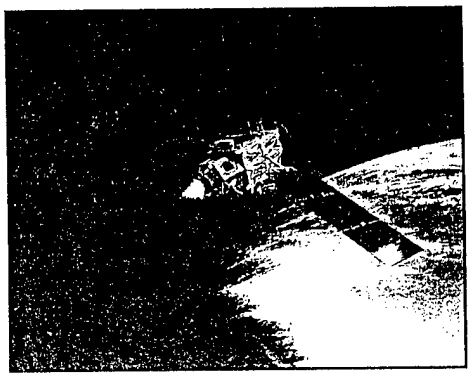
Pulsed
Plasma
Thruster

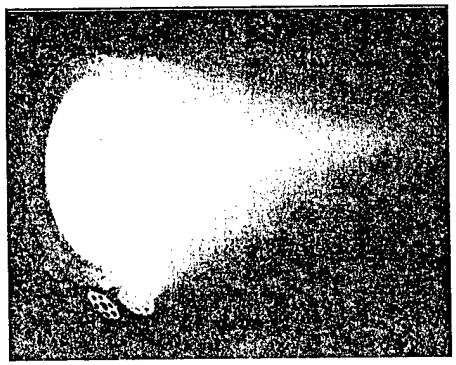


Electric Propulsion

SPACECAST 2020 - Critical Technology for Future of the Air Force

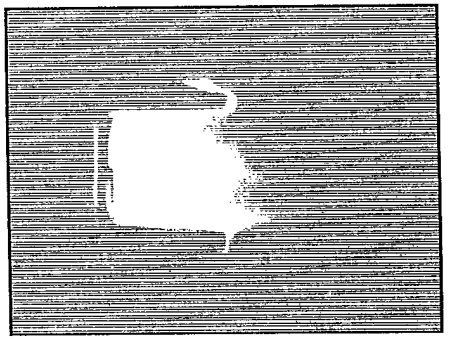
New World Vistas - Enabling technology, recommends aggressive R&D effort





- Propulsion Directorate demonstrating Hall & Pulsed Plasma Thrusters
- Leading agency conducting fundamental research on Electric Propulsion

- Enables dramatic increases in GEO payloads
  50 % near term and 300% far term increase
- Enables New Missions, Special Orbits
  500% increase in Maneuvering



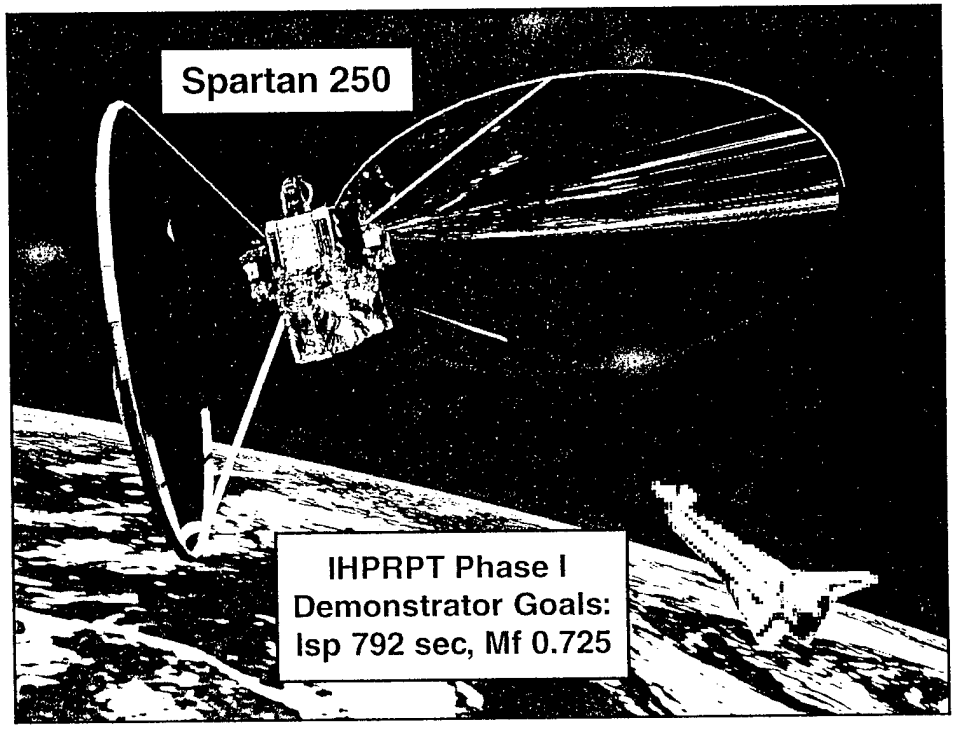
Solar Thermal Propulsion Critical Flight Experiment

CFE Objective

- Validate inflatable concentrators
  - Deployment and pressurization
  - Optical performance 2mrad
  - Space debris, AO, UV radiation
- Demonstrate Solar Thermal Propulsion System
  - Pointing and control .1 deg
  - Integrated engine and collector
  - Plume/mirror interactions
- Meet IHPRPT Performance Goals

Secondary Inflatable Experiments

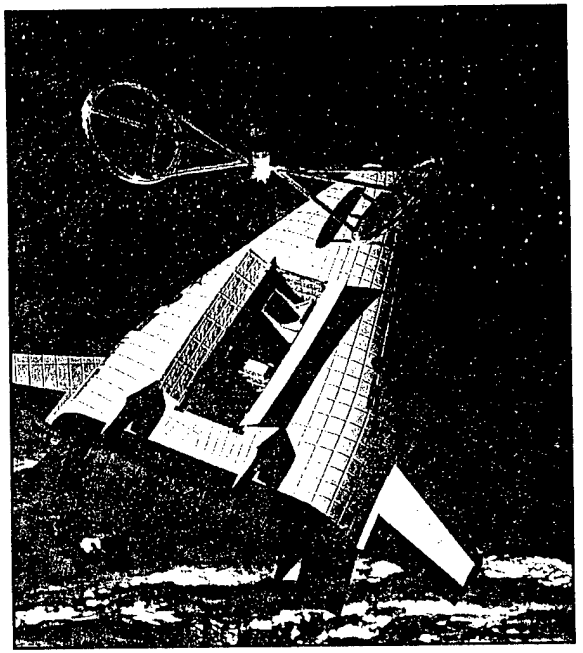
- Microwave Antenna Characterization
- PV array deployment



Flight Experiment

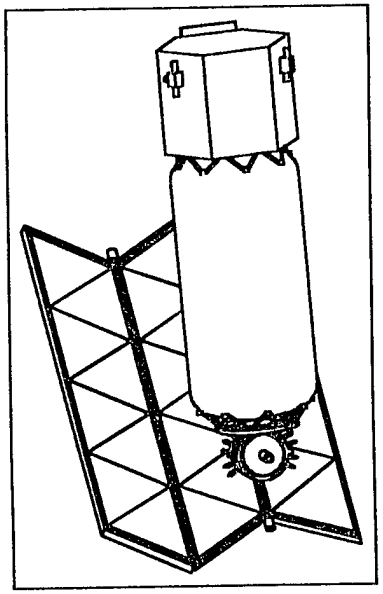
- Cooperative program with NASA
- Spartan/Shuttle launch
- Inflatable characterization
- Multiple GN2 burns
- Experiment recovered by shuttle

Solar Thermal Propulsion Critical Flight Experiment

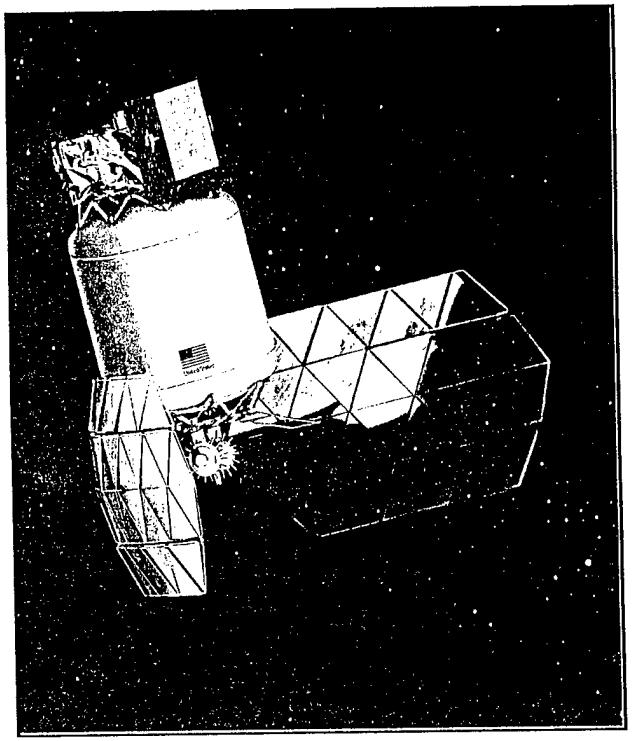


- Provides AFSPC with
  - Affordable Spacelift (2X payload to GEO)
  - Responsive Spacelift (Step down, <30 days)
  - Space Control (tug for repair,retrieval, denial)
  - Step toward high Isp Reusable OTV
  - Large aperture space antennas
- Alternatives
  - EP & chemical
  - Nuclear & Laser Thermal
  - AFRL SOTV/ISUS
  - NASA Shooting Star
- Need for Space Flight
  - Test 0g inflatable deployment dynamics and accuracy
  - Test 0g, free flight tracking and control for large inflatable structures
  - Quantify effects of LEO environment (Solar Flux, UV, AO, Debris)
  - Demonstrate solar thermal propulsion in operational space environment

AFRL SOTV



- Power and Propulsion
- Thermal storage cavity
- Single smaller rigid segmented concentrator
- Cryo H2 storage and delivery
- Tankage interaction
- Thermionic operation
- EELV 2002 launch



Strategic Sustainment

- **USSTRATCOM Initiated Program**
  - Meets the USSTRACOM Requirement for Sustainment of Strategic Technology
  - Funding Directed by Dr. Kaminski
  - $67M Fenced Funding from FY98 Through FY03
- **Coordinated with the MM SPO**
  - OO-ALC/M
  - SAF/AQS
  - SMC/XRT
  - USSTRATCOM/J541
  - HQ AFSPC/DRM, DOM
- **SPO PRP Deals with Existing System**
- **Strategic Sustainment Deals with**
  - Future Technology
  - Sustainment of Propulsion Development Capability

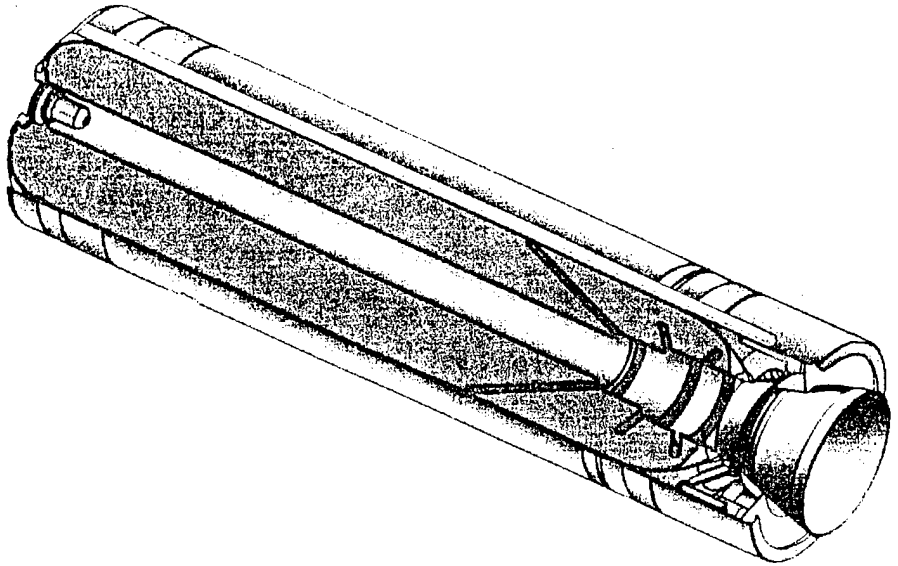
Strategic Sustainment and PRP

- **Two Different Programs with Two Different Objectives**

SS	PRP
Lab Program	SBICBM SPO Program
Technology Development	System Maintenance (Propellant Repour)
Sustains Motor Development Capability	Sustains Existing System
Component Design	Manufacturing

- **PRP Only Does that Technology Needed to Keep Minuteman Operating**

Strategic Sustainment Missile Propulsion

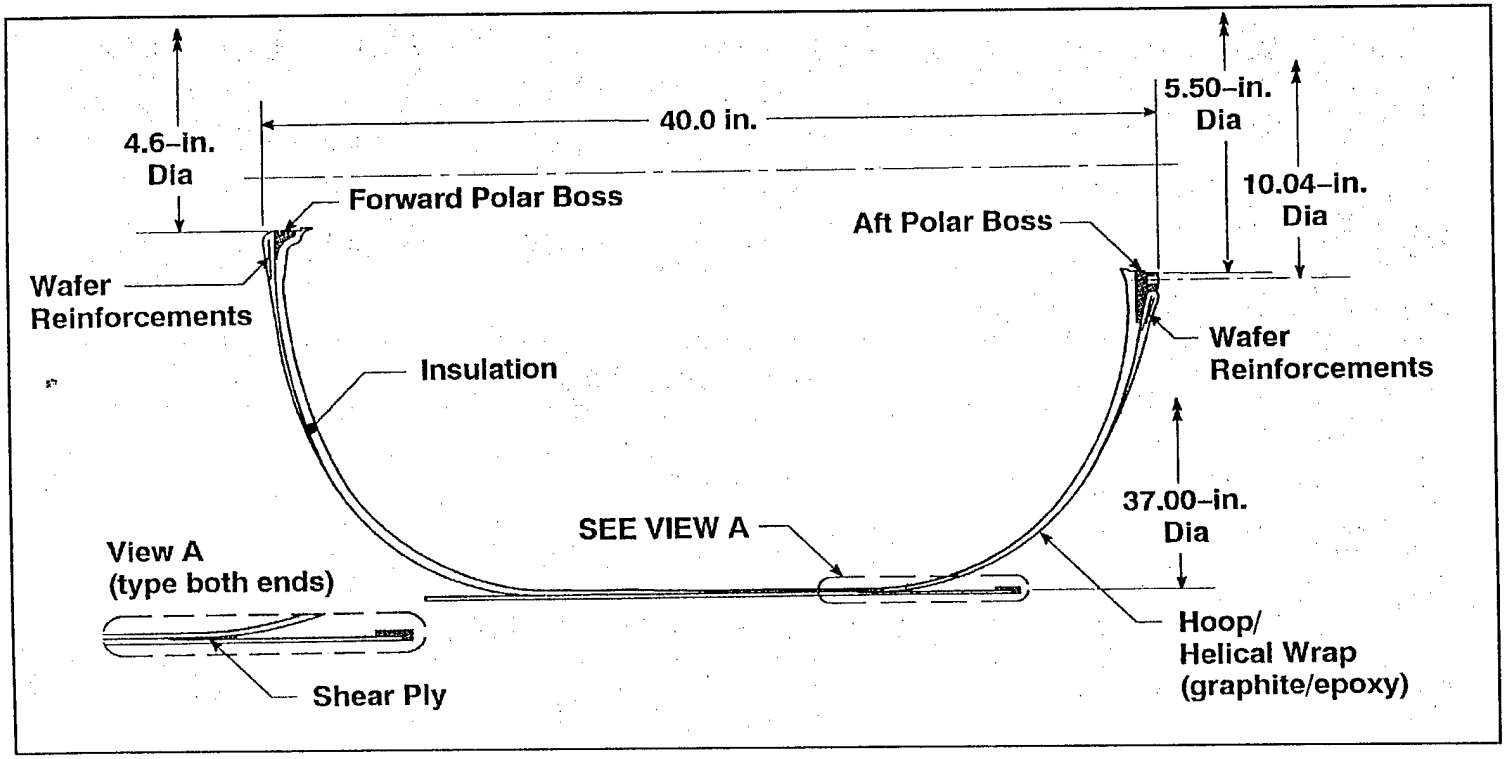


SUSTAINMENT MOTOR

- Propellant
  - Sustainable Ingredients
  - Reduced Hazards Class 1.3
- Nozzle
  - In-Situ Densification
  - Low Cost Ingredients
- Stronger, Lower Cost Case
- Electromechanical Actuators
- Support & Hardware Cost Reduction - 25%
- Inert Weight Decrease - 15%
- Isp Increase - 4% (10 sec)

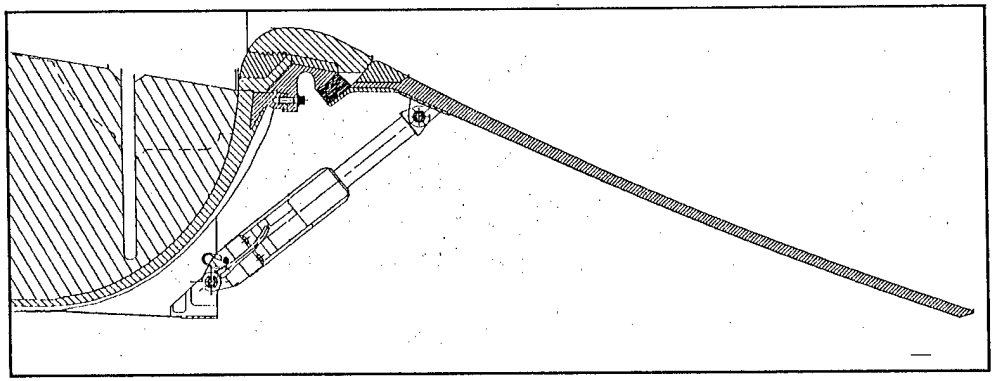
Case (Thiokol)

- Reduce Case Weight by 13.7% (Increase Castor 120 Mass Fraction 1%)
- Reduce Case Cost by 23% (Decrease Castor 120 Cost 6%)



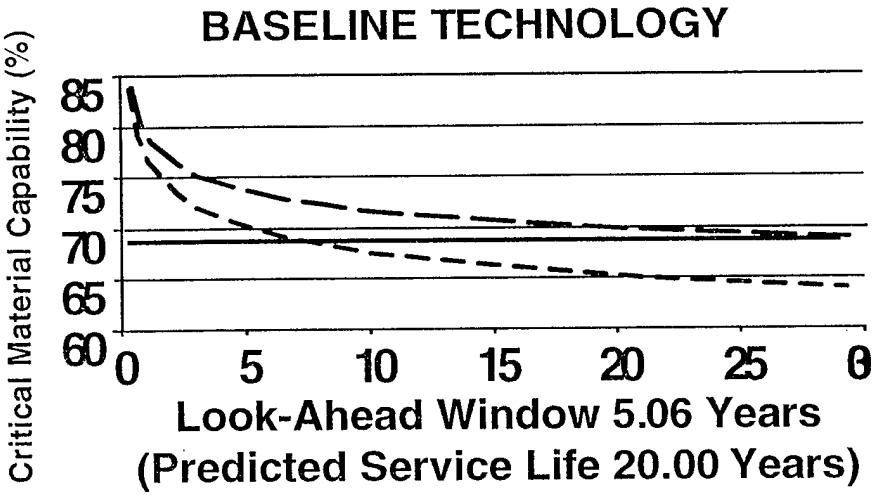
Supersonic Splitline Flexseal Nozzle

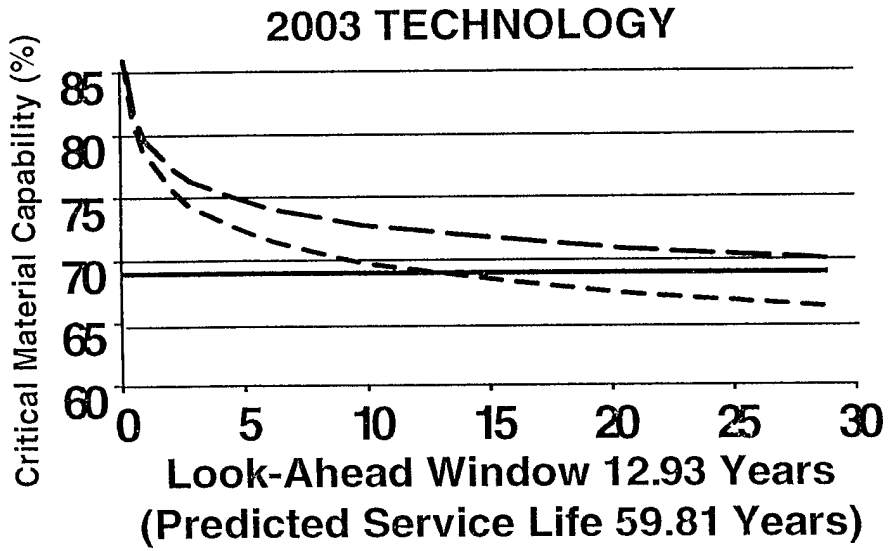
- Method to Build a Lighter and Less Complicated Nozzle
- Improves the Payload of an NMD Missiles' Second and Third Stage by 9% (even when the Length of the Missile was Constrained)
- Applied to the Orbus 1® Motor Which was used to Demonstrate the concept
  - Nozzle Weight can be Reduced by 43%
  - Nozzle Cost Can Be Reduced by 20%
  - Propellant Weight can be Increased by 1%



SUPERSONIC SPLITLINE FLEXSEAL APPLIED TO ORBUS-4 MOTOR

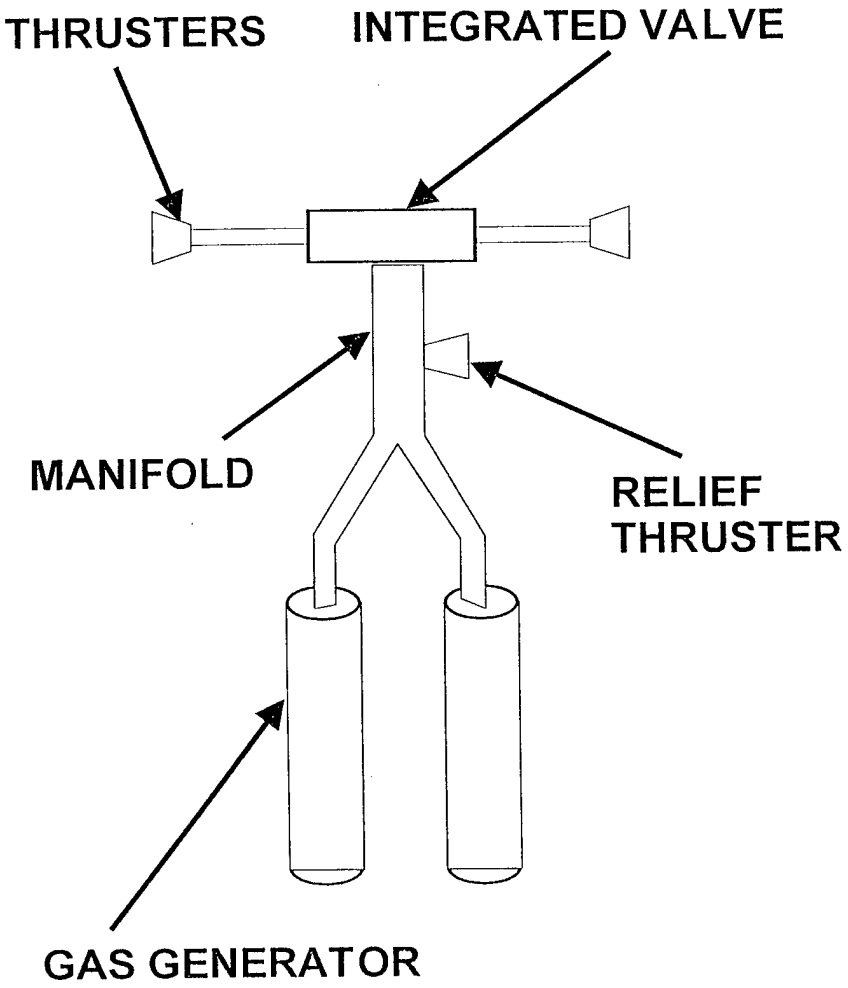
Strategic Sustainment Aging and Surveillance





- Address Both Analytical and Surveillance Technology
- Decrease Analysis Procedure, Aging Model & Material Characterization Uncertainties
- Extend "Look-Ahead" Window to 10 Years With 90% Confidence Level
- Develop Techniques That Permit Individual Motor Predictions
- Reduce Time and Cost for Non-Destructive Evaluation Data Processing by 50%

Strategic Sustainment
Post Boost MIRV Propulsion



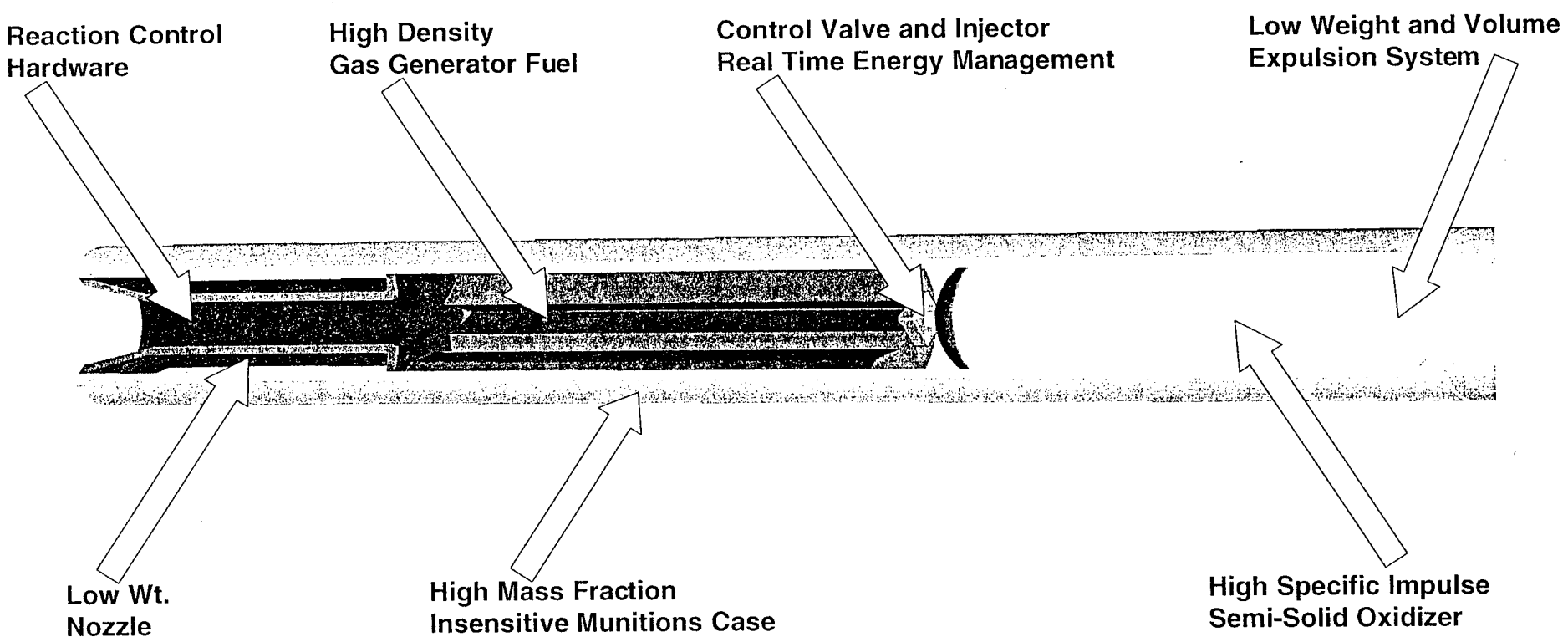
Solid System

- Uses Composite Materials
  - Eliminates Unique Materials
- Uses 1.3 Propellant
  - Reduces Hazards
- Reduces Cost by 25% While Maintaining Performance

Liquid System

- Uses Non-Toxic Propellants
- Reduces Cost 35%
- Reduces Weight 50%

Phase II
Tactical Hybrid Demonstrator Configuration



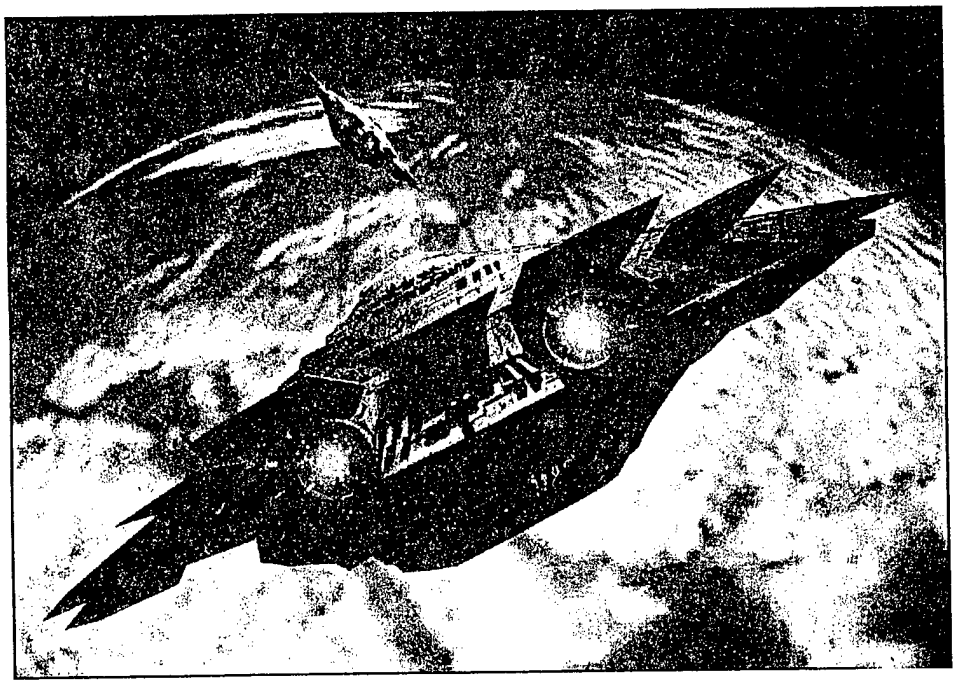
The Pay Off

- 16% Increase in Average Velocity
- 13% Increase in F-Pole
- 8% Increase in A-Pole

AFRL / PRR
6.2 & 6.3 New Project Starts

- **FY99**
  - Light Weight Engine Nozzle
  - Phase I Solid Boost Demonstrator (6.3)
  - Critical Defect Assessment Program
- **FY00**
  - High Temperature Oxygen Turbine Development
  - Single Stage High Discharge Pressure LH2 Turbopump
  - Electric Propulsion System for Orbit Transfer (6.3)
  - Strategic Sustainment Demonstration (6.3)

Propulsion Technology Enabling Future Space & Air Force Systems



- Low Cost Access to Space
- Airplane Like Operations
- Routine Space Transition Operations
- Satellite Maneuvering and Repositioning
- Missile Defense and Space Control
- New Space Based Systems
  - Space Based Radar

Conclusion

ROCKET PROPULSION DIVISION

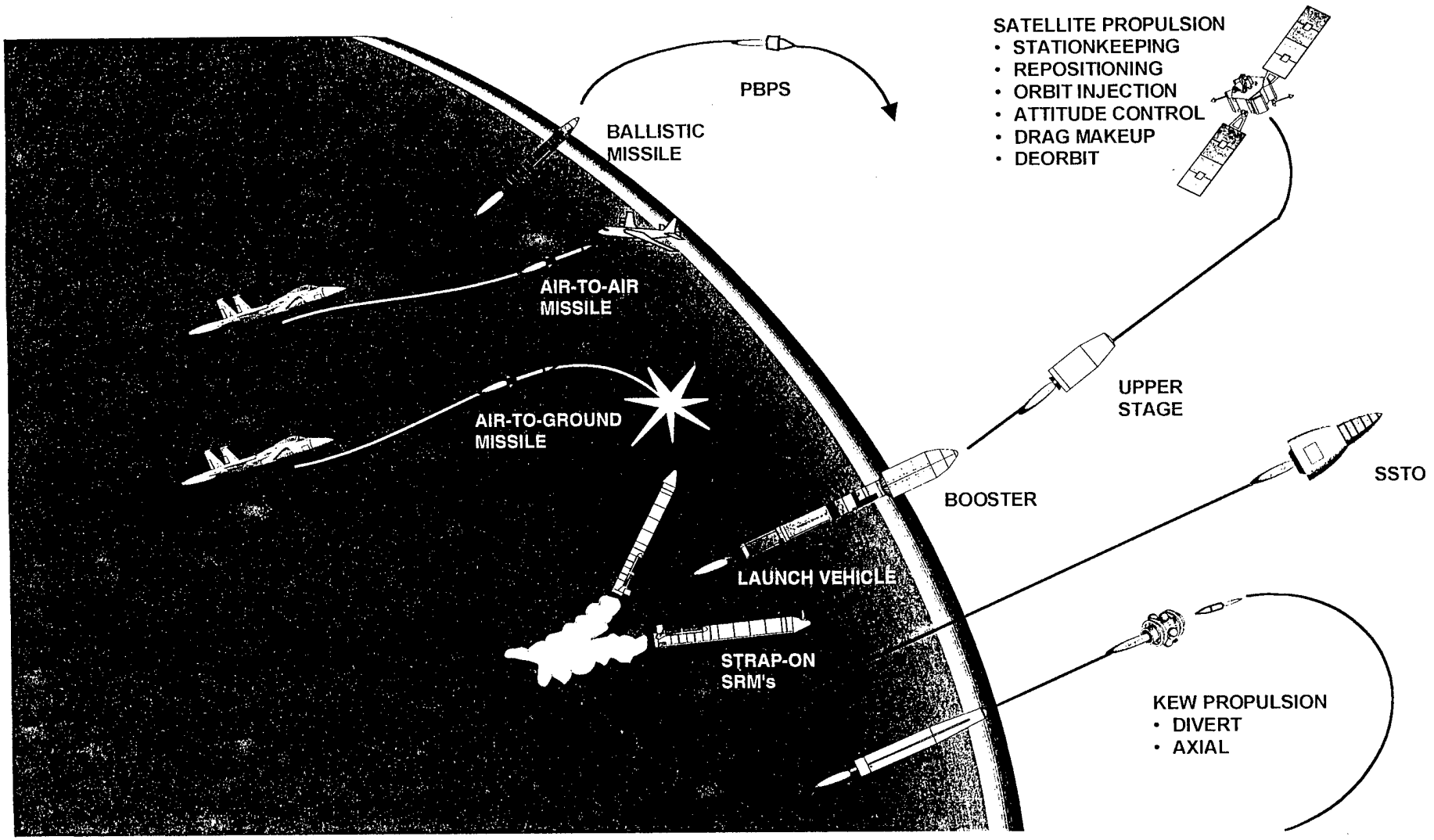
- GUARANTEED to support the warfighter
  - Close bond between PL and AFSPC
- Honest Broker / Expert Consultant
- One Place gives Full Spectrum Capability (Unique Facilities)
- A Center of Excellence for Propulsion
- Innovative Research
- Corporate Responsibilities

THE MAJOR NATIONAL LOCATION

FOR ROCKET PROPULSION

TECHNOLOGY

Rocket Propulsion Technology
Fundamental to all Space & Missile Systems



Tactical Propulsion Minimum Smoke Propellant Development

Objective

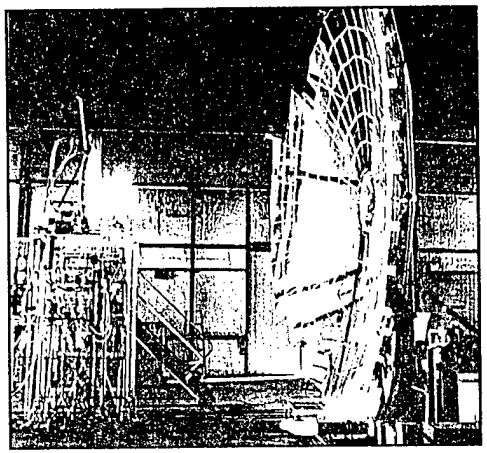
- Demonstrate Next Generation of Low Hazards, High Performance, Low Signature Propellants

Approach

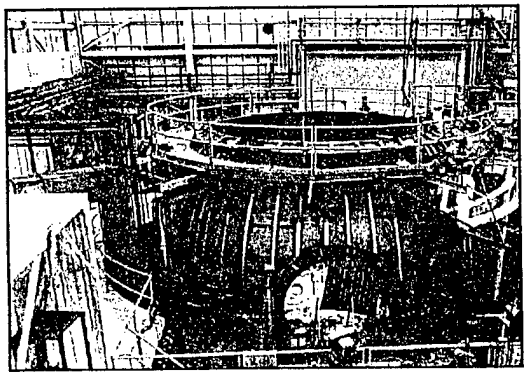
- Air Senior National Representative (ASNR) Sponsored Effort
  - France: Ballistics & Hazards
  - Germany: Formulation Characterization & Performance Calculations
  - United Kingdom: Mechanical Properties & Aging
  - U.S.: Formulation Characterization, Ingredient Analysis & Performance Calculations

Solar Propulsion Laboratory

World Class Facilities



- ONLY U.S. SOLAR FACILITY USING LH2
- 10000:1 CONCENTRATION RATIO
- 3400K GAS TEMPERATURE



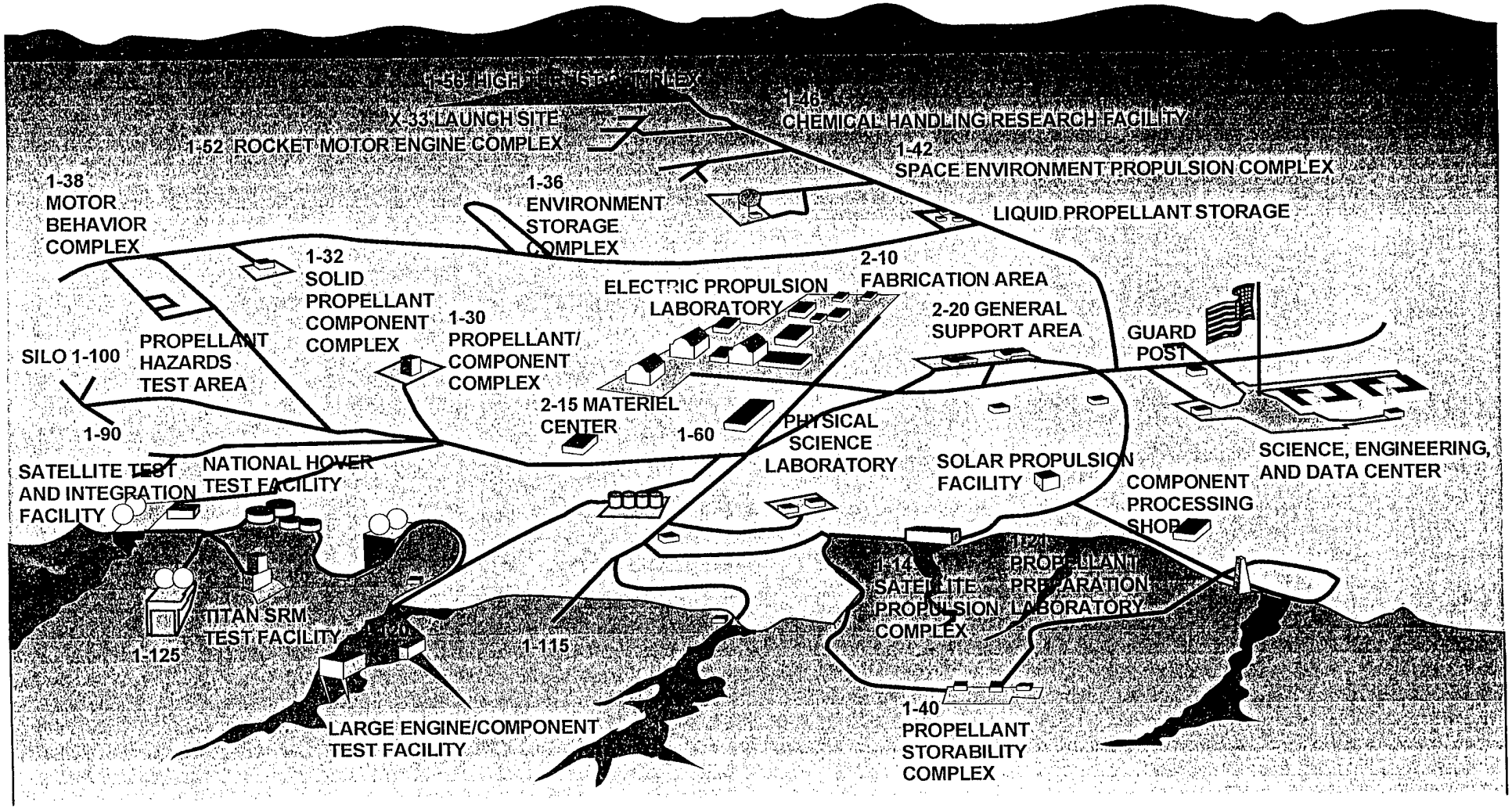
- 30 FOOT DIAMETER VACUUM SPHERE
- ONLY LARGE U.S. VACUUM FACILITY RATED FOR 100,000 LBS LH2

Center of Excellence for U.S. Solar Efforts

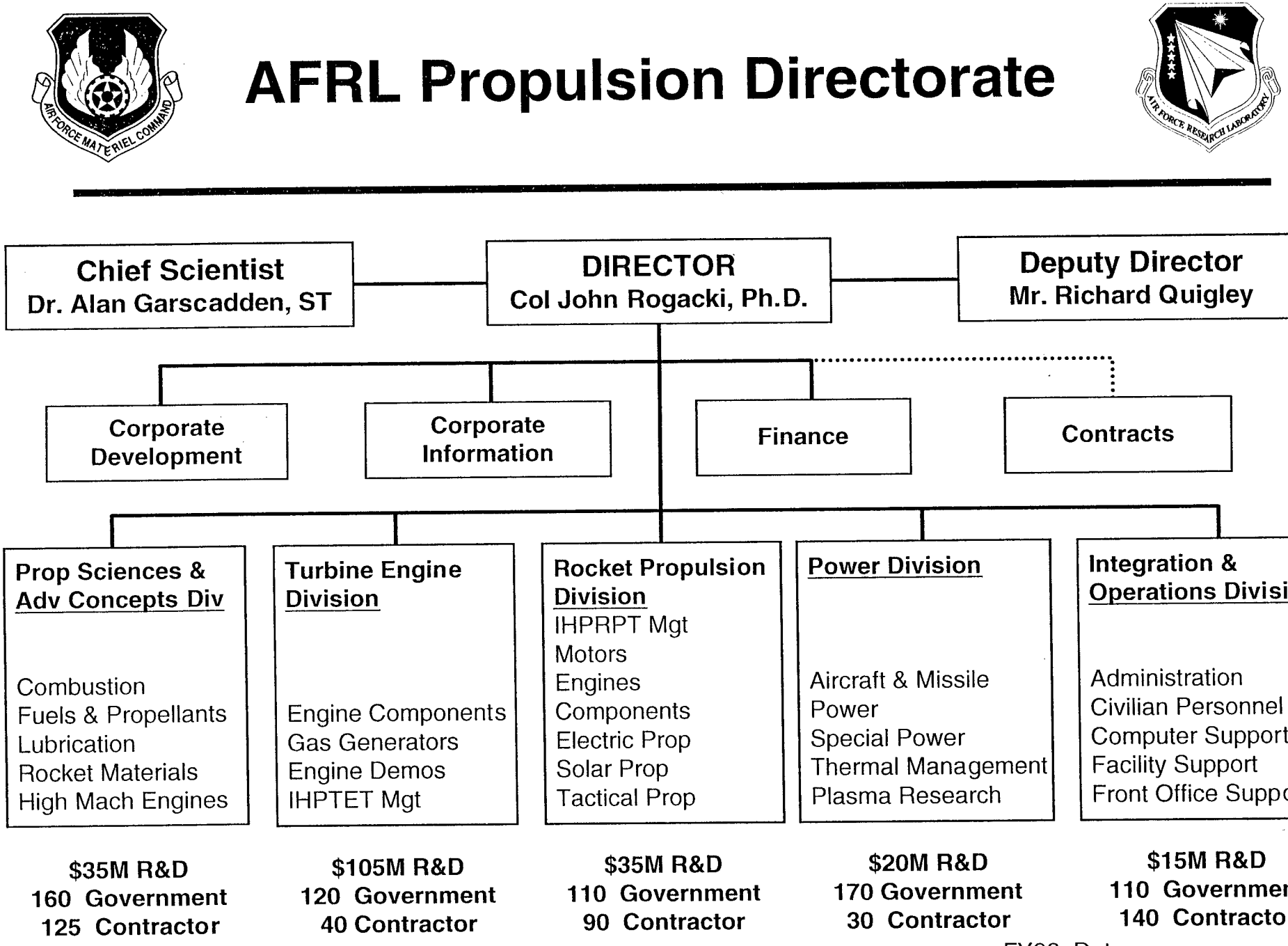
- Laser Power Beaming (PL/LI)
- Solar Bimodal Propulsion and Power (PL/VT)
- Industry / AF / NASA / University
  Solar Consortium CRDA
- Hercules CRDA
- Commercial Spin-Offs
  - High Temperature CC Springs
  - Holographic Embossed Thin Films for Medical CATscans
  - Compressed Natural Gas Bladders for Chrysler Corp.
  - Polyimide Concentrators for Space Based RF Antennas

Propulsion Directorate

Rocket Propulsion Facilities

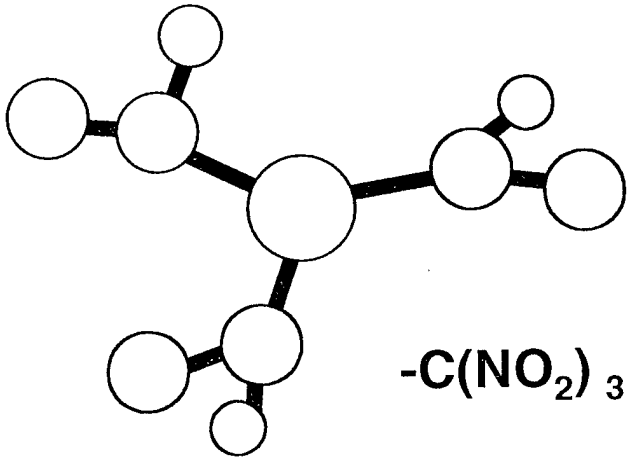


AFRL Propulsion Directorate



FY98 Data

New Energetic Monopropellants



Payoff

- Double Satellite On-Orbit Lifetime
- Non-Toxic Replacement of Hydrazine
- Candidate for Military Space Plane

Approach

- Low melting salts, dissolved in solvents
- Low volatility, low toxic

Status

- Several candidates synthesized
- Low shock sensitivity, low cost

Candidate Propellants	Isp (sec)*	p (g/cc)
• Hydrazine	198	1.00
• Peroxide	164	1.43
• XM46 (HAN/TEAN)	244	1.43
• RKS-M1	270	1.69

* Pc=1--- psi, Sea Level exhaust