5.2 Advanced Rocket Propulsion – Chuck J. O'Brien, Aerojet

Existing NASA research contracts are supporting development of advanced reinforced polymer and metal matrix composites for use in liquid rocket engines of the future. Advanced rocket propulsion concepts, such as modular platelet engines, dual-fuel dual-expander engines, and variable mixture ratio engines, require advanced materials and structures to reduce overall vehicle weight as well as address specific propulsion system problems related to elevated operating temperatures, new engine components, and unique operating processes.

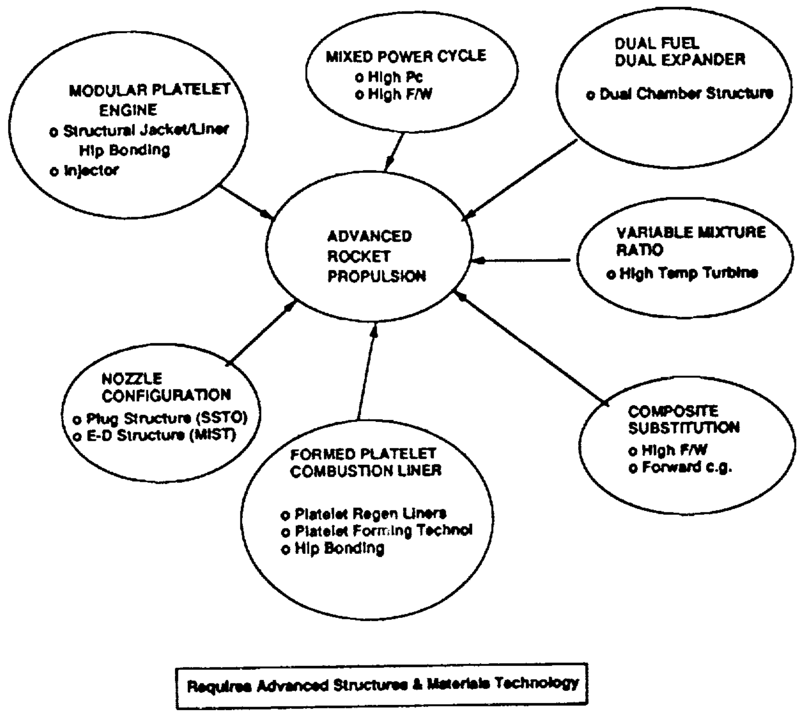
High performance propulsion systems with improved manufacturability and maintainability are needed for single stage to orbit vehicles and other high performance mission applications. One way to satisfy these needs is to develop a small engine which can be clustered in modules to provide required levels of total thrust. This approach should reduce development schedule and cost requirements by lowering hardware lead times and permitting the use of existing test facilities. Modular engines should also reduce operational costs associated with maintenance and parts inventories.

Advanced Rocket Propulsion Agenda

C.J. O'Brien
Aerojet Propulsion Division

- o Summary of Approaches
- o Modular Platelet Engine
- o Dual Fuel Dual Expander Engine
- o Variable Mixture Ratio Engine
- o Materials & Structures Issues

Advanced Rocket Propulsion Approaches

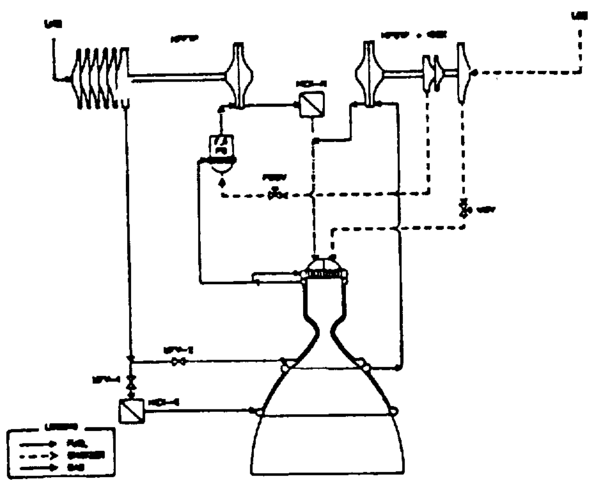


Advanced Propulsion Operating Parameters

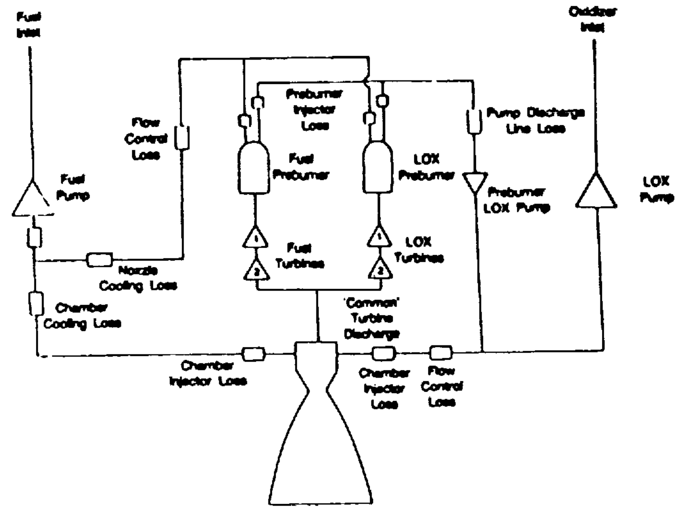
Engine	MPE	HPE	DUAL MR	DFDE	DFDE
Propellants	O2/H2	O2/H2	O2/H2	O2/C3H8/H2	O2/C3H8/H2
Cycle	AUG EXP	SC/EXP	SC	GG/SC	GG/SC
Pc, psia	2640	4887	4157/2736	6000/3000	14000/7000
FV, Klbf	135.8	500	525/376	284/89	278/86
Area Ratio	217	73/169	60/120	89/146	171/276
MR O/F	6	6	14/7	3.3/7	3.3/7
IsV, sec	464	466	346/465	384/461	400/471
H2 Pd, psia	6826	17762	9904/7046	7632	15894
O2 Pd, psia	6734	6536/15662	5080/3756	6685	14763
HC Pd, psia	NA	NA	NA	7166	15371
O2 Ttl, R	995 OR	484 FR	3130/1868 FR	1660 OR	1660 OR
H2 Ttl, R	896 FR	2500 FR	3130/1838 FR	1880 FR	1880 FR
FV/Wt	96	97	174	99/142	190
Technol Level	1992	ADVANCED	VERY ADV	1970/1990	VERY ADV
Source	APD SSTO	RKD AL-TR-90 -051	P&W AL-TR-90 -036	APD F04611-86 -C-0113	APD AIAA 91 -2049

Advanced High Pressure Cycles

LO_2/LH_2 Engines with Extendible Nozzles

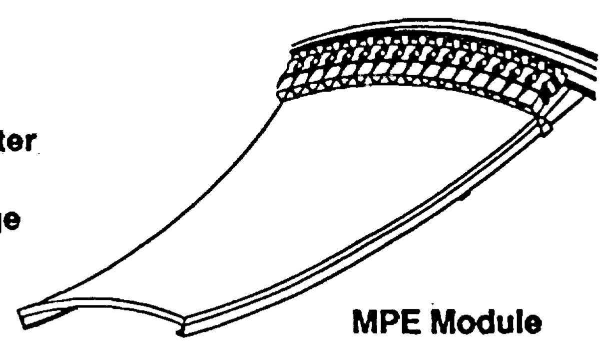


HPE (RKD) Fuel-Rich Hybrid
Cycle With Regenerator



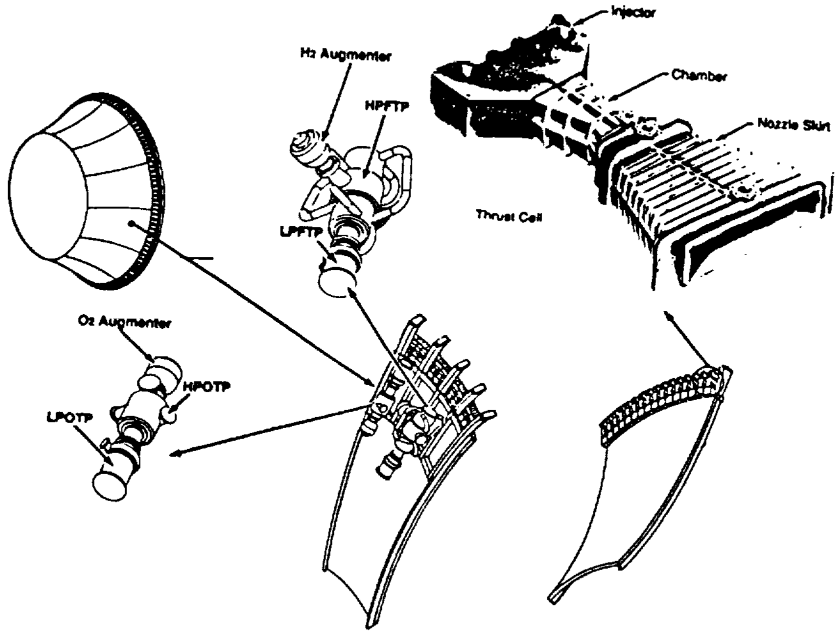
Dual MR (P&W) Cycle

Modularity is the Key to SSTO Engine Manufacturability and Maintainability

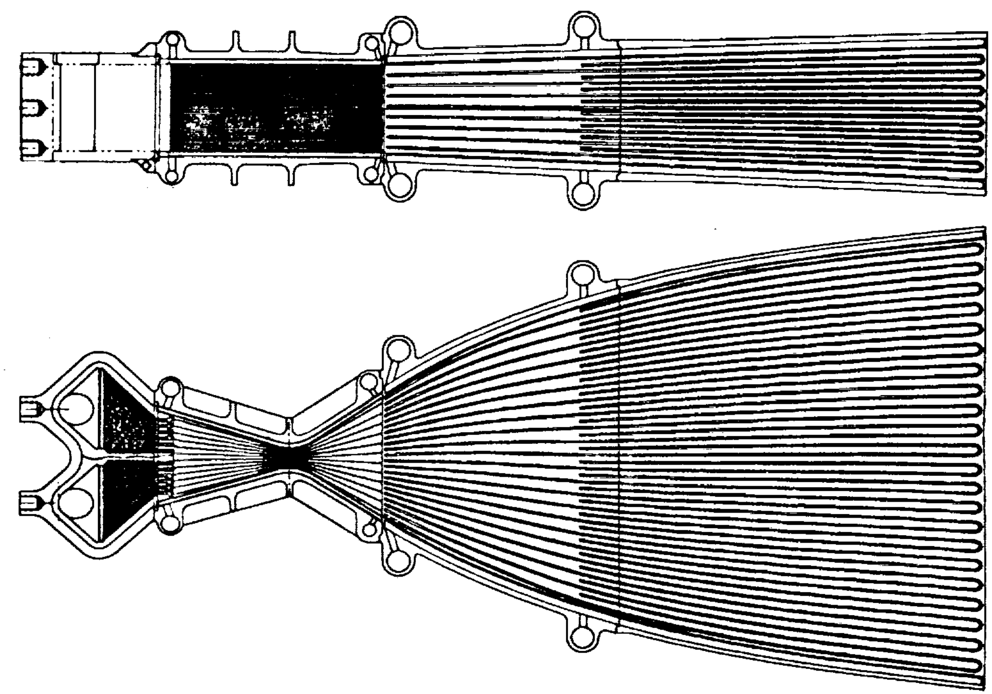


- **Develop a Small Engine and Cluster In Modules**
  - **100K lb vs. 1 M lb Thrust Range**
- **Benefits**
  - **Shorter Hardware Lead Times**
  - **Lower Development Hardware Cost**
  - **Available Test Facilities**
  - **Lower Testing Cost**
  - **Shorter Turnaround For Development Iterations**
  - **Lower Spares Cost/Inventory For Flight Program**
  - **Easier Handling, Lower Cost For Maintenance and Servicing**

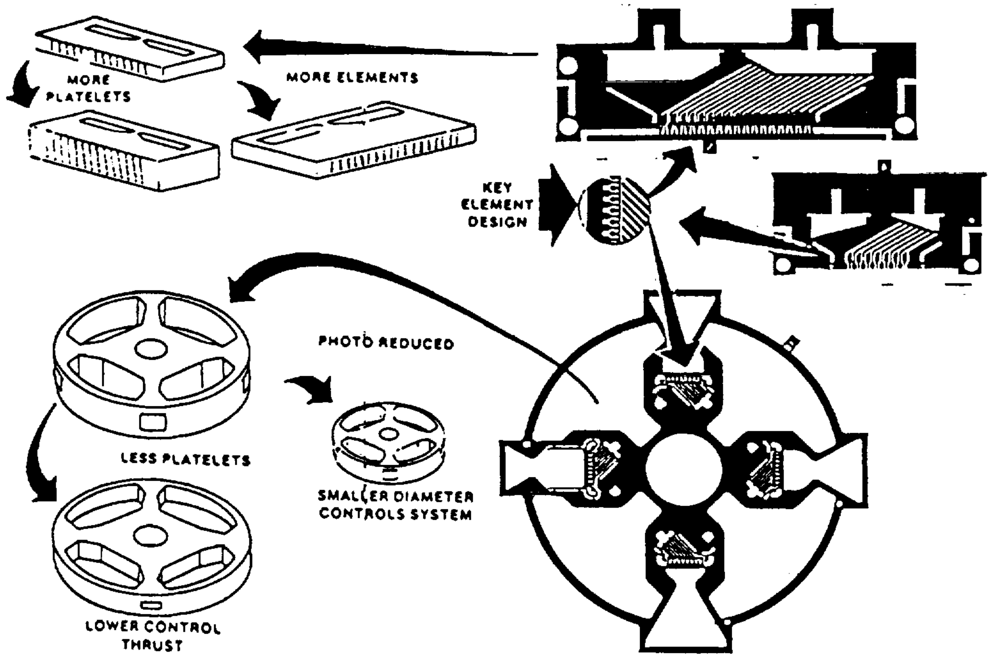
Composite Materials Needed For SSTO Weight Reduction



Thrust Chamber Assembly Fluid Passages Producibility

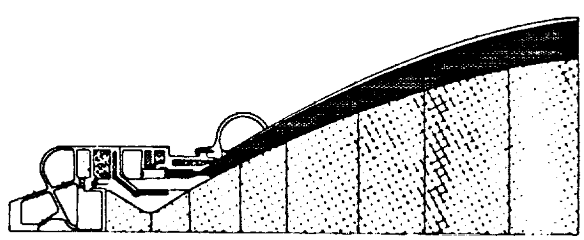


Platelet Structure Can Be Scaled Photographically
Or With More Or Less Platelets



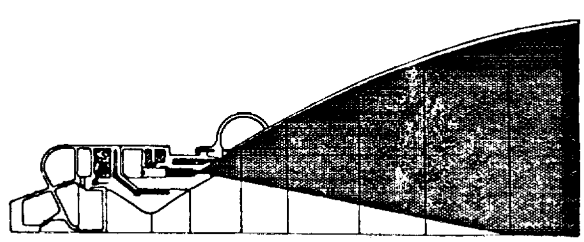
Dual Expander Operating Modes
Match SSTO Trajectory Requirements

High Thrust
at Sea Level



Dual Expander Chamber Mode 1 Operation

Low Thrust
at Altitude

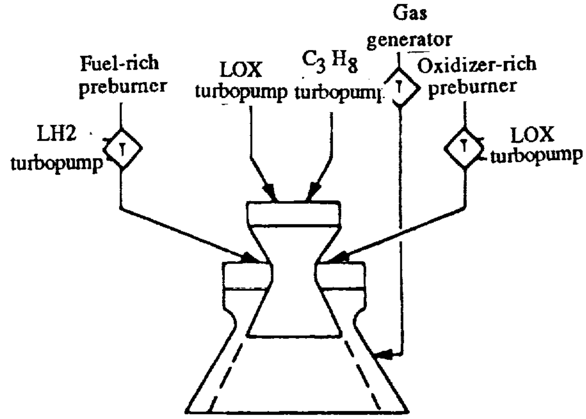


Dual Expander Chamber Mode 2 Operation

Dual Expander Engine Cycle Features

- Minimizes Use of LH2
- Mixed Gas Generator/Staged Combustion Cycle
  - Allows Hi Pc at Low Pump Discharge Pressure
  - Performance Penalty Small at Low Altitude
- LH_2 Cooled Chambers
  - Transpiration Cooled Inner Throat Section
- O_2/H_2 Stoichiometric Preburner/ Gas Generator
  - No Unburned Propellant Afterburning at Turbine
  - Low Temperature Turbine Possible
- Platelet Chamber Fabrication Maintains Throat Alignment

DUAL-EXPANDER ENGINE CYCLE CONCEPT

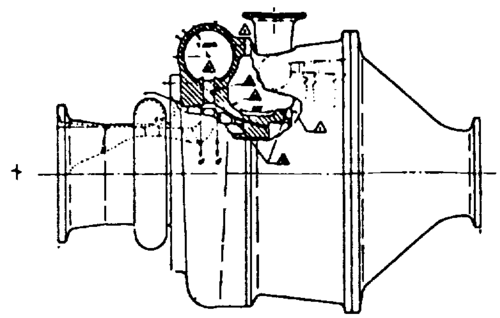


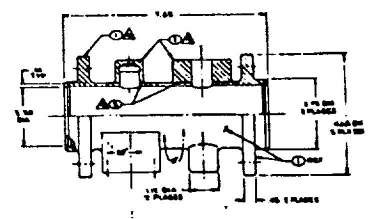
Formed Platelet Combustion Chamber Benefits

- Very Thin Hot Gas Walls
  - Higher Coolant Temperatures (Expander Cycle)
  - Increased Cycle Life - Lower Liner ΔT
  - Cooler Wall Temperatures - Higher Q to Coolant
- High Aspect Ratio Coolant Channels
  - Chamber Pressure Drop Savings
  - Large Number of Coolant Channels - More Uniform Temperature Distribution Through Liner
- Platelets Offer Design Flexibility
  - Complex Cooling Channel Designs
  - Ribbed Coolant Channels
  - Gas Side Wall Ribs Easily Incorporated
  - Lower Cost Fabrication

Composite Material Application to Liquid Rocket Engines

- Component Weight Savings up to 80% with Composite Material
- Engine Weight Savings up to 30% with 1980 Composite Technology
- Future Savings to 45%
- Composite Material Substitution Technology Needs Development
- Reinforced Plastic Composites Selected for Cost, Fabricability, and Specific Strength
- Metal Matrix Composites to be Considered for High Temperature Application
- Contracts NAS 8-34623 & NAS 8-33452





Advanced Rocket Propulsion
Structures and Materials Technology Issues Summary

Engine	Technology
• MPE APD	• Jacket Box Bond • Composite Material Substitution • Plug Nozzle Material • Lightweight Engine Vehicle Structure • Advanced Regenerator Material • O_2-Rich /Augmenter
• Dual MR P&W	• Oxidation Resistant Main Chamber Coating • Active Turbine Cooling With H_2 • Active Strain Management Chamber Structural Design • Altitude Compensating Nozzle • Dual Element Main Injector
• HPE RI/RKD	• Advanced High Temperature Wall Material • Composite Structural Shell & Nozzle • Protected/Coated Carbon-Carbon Nozzle • Cast Advanced Materials Injector • Composite Cold & Hot Ducts
• DFDE APD	• Dual Chamber Assembly/Structure • Oxidizer-Rich (Stoichiometric) Preburner • Composite Material Substitution