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

- Summary of Approaches
- Modular Platelet Engine
- Dual Fuel Dual Expander Engine
- Variable Mixture Ratio Engine
- Materials & Structures Issues
### Advanced Rocket Propulsion Approaches

**MIXED POWER CYCLE**
- High Pc
- High F/W

**DUAL FUEL**
- Dual Chamber Structure

**VARIABLE MIXTURE RATIO**
- High Temp Turbine

**NOZZLE CONFIGURATION**
- Plug Structure (SSTO)
- E-O Structure (MISS)

**FORMED PLATELET COMBUSTION LINER**
- Platelet Regen Liners
- Platelet Forming Technol
- Hip Bonding

**COMPOSITE SUBSTITUTION**
- High F/W
- Forward e.g.

Requires Advanced Structures & Materials Technology

### Advanced Propulsion Operating Parameters

<table>
<thead>
<tr>
<th>Engine Propellants</th>
<th>MPE</th>
<th>HPE</th>
<th>DUAL MR</th>
<th>DFDE</th>
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<tr>
<td>Cycle</td>
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<td>SC/EXP</td>
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<td>H2 Pd, psia</td>
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<td>FV/Wt</td>
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<td>APD</td>
<td>RKD</td>
<td>P&amp;W</td>
<td>APD</td>
<td>APD</td>
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</tbody>
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Advanced High Pressure Cycles
LO₂/LH₂ 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 BeScaled Photographically
Or With More Or Less Platelets

Key Element Design

Photoreduced

Smaller Diameter Controls System

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 High Pressure at Low Pump Discharge Pressure
  - Performance Penalty Small at Low Altitude
• LH2 Cooled Chambers
  - Transpiration Cooled Inner Throat Section
• O2/H2 Stoichiometric Preburner/Gas Generator
  - No Unburned Propellant Afterburning at Turbine
  - Low Temperature Turbine Possible
• Platelet Chamber Fabrication Maintains Throat Alignment

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

<table>
<thead>
<tr>
<th>Engine</th>
<th>Technology</th>
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<tr>
<td>MPE APD</td>
<td>• Jacket Box Bond</td>
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<td></td>
<td>• Composite Material Substitution</td>
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<tr>
<td></td>
<td>• Plug Nozzle Material</td>
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<tr>
<td></td>
<td>• Lightweight Engine Vehicle Structure</td>
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<tr>
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<td>• Advanced Regenerator Material</td>
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<tr>
<td></td>
<td>• O2-Rich /Augmenter</td>
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<tr>
<td>Dual MR</td>
<td>• Oxidation Resistant Main Chamber Coating</td>
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<tr>
<td>P&amp;W</td>
<td>• Active Turbine Cooling With H₂</td>
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<td>• Active Strain Management Chamber Structural Design</td>
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<td>• Altitude Compensating Nozzle</td>
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<td>• Dual Element Main Injector</td>
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<tr>
<td>HPE</td>
<td>• Advanced High Temperature Wall Material</td>
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<tr>
<td>RI/RKD</td>
<td>• Composite Structural Shell &amp; Nozzle</td>
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<td>• Protected/Coated Carbon-Carbon Nozzle</td>
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<td>• Cast Advanced Materials Injector</td>
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<td>• Composite Cold &amp; Hot Ducts</td>
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<tr>
<td>DFDE APD</td>
<td>• Dual Chamber Assembly/Structure</td>
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<td>• Oxidizer-Rich (Stoichiometric) Preburner</td>
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<tr>
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