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

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

- Modular Platelet Engine
  - Structural Jacket/Liner
  - Hip Bonding
  - Injector

- Mixed Power Cycle
  - High Pc
  - High F/W

- Dual Fuel Cycle
  - Dual Chamber Structure

- Dual Expander

- Variable Mixture Ratio
  - High Temp Turbine

- Nozzle Configuration
  - Plug Structure (SSTO)
  - E-O Structure (MIST)

- Composite Substitution
  - High F/W
  - Forward e.g.

- Advanced Rocket Propulsion

Advanced Propulsion Operating Parameters

<table>
<thead>
<tr>
<th>Engine</th>
<th>MPFE</th>
<th>HPE</th>
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Requires Advanced Structures & Materials Technology

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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

HIGH THRUST
at Sea Level

Dual Expander Chamber Mode 1 Operation

Low Thrust
at Altitude

Dual Expander Chamber Mode 2 Operation

Dual Expander Operating Modes
Match SSTO Trajectory Requirements
Dual Expander Engine Cycle Features

- Minimizes Use of LH2
- Mixed Gas Generator/Staged Combustion Cycle
  - Allows Hi Pd 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

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<tr>
<th>Engine</th>
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<td>• Lightweight Engine Vehicle Structure</td>
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<td>• Advanced Regenerator Material</td>
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<td>• Dual Element Main Injector</td>
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<td>• Cast Advanced Materials Injector</td>
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