MSFC Combustion Devices in 2001

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256-544-7079

The Pennsylvania State University
Propulsion Engineering Research Center
13th Annual Symposium on Propulsion
October 22 – 23, 2001
Huntsville, Alabama
TD61 - Functional Design Group

- TD - Space Transportation Directorate
- TD60 - Subsystem & Component Development Department
- TD61 - Functional Design Group, Henry Stinson - Group Lead
  - Combustion Devices Team
  - Turbomachinery Team
- Overall responsibility
  - Test requesting organization for technology and advanced liquid rocket engine component development activities
  - Support the SSME, ASTP, and Gen 2 organizations
- Examples of current combustion devices technology and advanced development activities
  - NRA8-21 Task for RLV Focus Technology
    - Lightweight, Long Life Thrust Cells
    - Lightweight Injectors
  - Liquid/Liquid Preburner Task
  - Vortex Thrust Chamber
TD61 – Functional Design Group

Combustion Devices Team

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NRA8-21 Task for RLV Focus Technology

Lightweight, Long Life Thrust Cells

Objectives:
Reduce thrust assembly weights to create lighter engines,
Increase cycle life and/or operating temperatures

Team:
Marshall Space Flight Center (MSFC)
Glenn Research Center (GRC)
Rocketdyne Division of The Boeing Company
Additional Contractors

Task Lead: Sandy Elam/MSFC TD61
# Material Options & Contractors

<table>
<thead>
<tr>
<th>Contractor</th>
<th>Material System</th>
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<tbody>
<tr>
<td>Hyper-Therm, Inc.</td>
<td>CMC           SiC/SiC liner</td>
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<tr>
<td>Ceramic Composites, Inc. (CCI)</td>
<td>CMC         C/C liner</td>
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<tr>
<td>Plasma Processes, Inc. (PPI)</td>
<td>PMC           Fiber/Epoxy Overwrap</td>
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<tr>
<td>Lockheed Martin Astronautics (LMA) Composite Optics, Inc. (COI)</td>
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<tr>
<td>Aerojet</td>
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<tr>
<td>Plasma Processes, Inc. (PPI)</td>
<td>MMC           VPS Al/SiC</td>
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<tr>
<td>MSE Technology Applications</td>
<td>MMC           Cast Al/SiC</td>
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GRCop-84 Liner was used in all PMC & MMC Units
MMC & PMC Subscale Units

Aluminum Metal Matrix Composite (Al-MMC) Jacket & Manifolds

Advanced Copper Alloy (GRCop-84) Liner Improves Life & Operating Temperatures

Polymer Matrix Composite (PMC) "Overwrap" Jacket

Cryogenic & Hot-fire Testing at MSFC Validated Materials

50% Lighter than Conventional Designs with Traditional Steel and Copper Alloys
CMC Subscale Liners

Hyper-Therm, Inc.
Silicon Carbide (SiC)/SiC Liner with Integral Cooling Channels

Ceramic Composites, Inc. (CCI)
Carbon (C)/C Liner Cooled with Bonded Copper Tubing

Hot-fire Testing Performed on Both Concepts at NASA-GRC
Hot Wall Temperatures > 3000 deg F
Full Size Chambers

Applying Selected Materials & Processes to "Full Size" Chamber Designs...

2 Designs
(1) MMC, (1) PMC Jacket

Planned Test Conditions
LOX/GH2 Propellants
LH2 Cooling
Pc = 2400 psia, MR ~ 6.0
Thrust ~ 15,000 lbs

Hot-fire Testing at MSFC in 2001
Test results will directly compare conventional chamber vs. lightweight design
Lightweight Linear Chamber

MSFC CDDF Task

Objective:
Demonstrate Versatility of “Lightweight” Chamber Technology Developed in NRA Task

Preliminary Design

- Applying PMC & MMC Concepts to Rectangular (2D) Chamber Design
- Fabricating 2 Complete Chambers to mate with existing 2D injector
  - No current plans to hot-fire test

Task Lead: Sandy Elam/MSFC TD61
Lightweight Injector Development

MSFC CDDF Task

Objective:
Apply Composite Materials to Injector Designs

• Approach:
  - Develop braze processes with material samples
  - Fabricate subscale composite injectors
  - Hot-fire test w/subscale chamber from NRA8-21

• Demonstrate 2 Designs for LOX/GH2
  - Coaxial Injector
  - Impinging Injector

• Material Candidates
  - Housing/Manifolding: Al MMC
  - Faceplates: Cu alloy
  - Interface rings: Stainless Steel

Test Assembly

Task Lead: Sandy Elam/MSFC TD61
Liquid/Liquid Preburner Task

MSFC Gen 2 Risk Mitigation Task

**Objective:**
Provide risk mitigation for development of a liquid oxygen/liquid hydrogen preburner

- **Approach:**
  - Perform CFD analyses on preburner injector designs based on RS-83 and COBRA preburner concepts
  - Perform single-element and multi-element testing at TS115
  - Anchor CFD model with data collected at TS115
  - Anchor CFD model with COBRA and RS-83 subscale test data

Task Leads: Amy Reeb/MSFC TD61 and Kevin Tucker/MSFC TD64
Liquid/Liquid Preburner Task

Planned Single-Element Test Conditions
LOX/LH₂ Propellants
Pc = 1800 psia (~28% power level), due to test facility limitations
Mixture Ratio = 0.67
Test Duration ~ 10 seconds

Liquid Oxygen System
LOX flowrate = 0.285 lbm/sec
LOX temp = 170 R

Liquid Hydrogen System
LH₂ flowrate = 0.426 lbm/sec
LH₂ temp = 91 R

GH₂ Barrier Flow
GH₂ flowrate = TBD lbm/sec
GH₂ temp = 532 R
Liquid/Liquid Preburner Task

Planned Multi-Element Test Conditions
LOX/LH₂ Propellants
7 Elements
Pc = 1800 psia, due to test facility limitations
Mixture Ratio = 0.67
Test Duration ~ 10 seconds Mainstage

Liquid Oxygen System
LOX flowrate = 1.34 lbm/sec
LOX temp = 170 R

Liquid Hydrogen System
LH₂ flowrate = 2.0 lbm/sec
LH₂ temp = 91 R

GH₂ Barrier Flow*
GH₂ flowrate = TBD lbm/sec
GH₂ temp = 532 R

*Unknown at this time whether GH2 will be required
# Liquid/Liquid Preburner Task Schedule

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<thead>
<tr>
<th>Task Name</th>
<th>Q1</th>
<th>Qtr 3, 2001</th>
<th>Qtr 4, 2001</th>
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<th>Qtr 2, 2003</th>
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<td>Jun</td>
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**Rocketdyne preburner inj tasks**
- Pre-test CFD analyses
- Facility/hardware prep
  - Primnry engineering
  - Procure long lead
  - MCTA Upgrades
- LOX/LH2 Preburner Injector
  - Design
  - Fab injectors
  - Asmbl/test
- Analysis
  - Rocketdyne PB PDR
  - Rocketdyne PB CDR

**Aerojet / P&W preburner inj tasks**
- Procurement
- Pre-test CFD analyses
- Testing at Aerojet
- Analysis
  - Aerojet PB PDR
  - Aerojet PB CDR
Objective:
Evaluate Vortex chamber concepts for liquid rocket engine applications

Team:
Marshall Space Flight Center (MSFC)
Orbital Technologies Corporation (Orbitec)
U.S. Army Missile Command

Approach:
- Design and test 1000 lbf thrust class Vortex thruster
  - MSFC and the Army to test Impinging Stream Vortex (ISVE) concept at MSFC TS115
    - ISVE hardware will also be used to demonstrate and validate:
      - Laser Ignition and combustion wave ignition for LOX/RP-1
      - Raman and emission/absorption exhaust plume measurement methods
  - Orbitec to test Vortex Combustion Cold Wall (VCCW) concept at Orbitec
- Anchor CFD models with test data
- Use validated models to optimize design of vortex chamber

Task Leads: Brad Bullard/MSFC TD61 and Huu Trinh/MSFC TD61
Vortex Chamber Concept:
Flow vortices are generated by injecting propellant tangentially to the chamber wall.

Due to the centrifugal force, relatively cooler propellant streams tend to flow along the chamber wall.

Vortex flow promotes the propellant mixing process.

Swirling flow motion creates a longer flow path.
Vortex Chamber Task

Test Hardware

ISVE Thruster Test Conditions
LOX/RP-1 Propellants
Pc = 1000 psia
Ideal Vacuum Thrust = 1250 lbf
Mixture Ratio = 2.6
Throat Dia. ~ 1 in
Chamber Dia. ~ 3 in
Nozzle Exit Dia. ~ 3.11 to 3.5 in