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2nd Generation Reusable Launch Vehicle
NASA Led Propulsion Tasks

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Space Transportation Technology Workshop

Agenda

- 2nd Generation RLV Propulsion Project
- Overview of NASA Led Tasks in Propulsion
- Gen2 Turbo Machinery Technology Demonstrator
- Combustion Devices Test Bed
- GRCop-84 Sheet For Combustion Chambers, Nozzles And Large Actively Cooled Structures

2GRLV NASA Led Propulsion Tasks

- The Propulsion Project has been formulated to reduce risk in support of a Full Scale Development decision as early as 2005
- Propulsion Project includes the following elements for Earth-to-Orbit Launch Vehicles
  - Main Engine
  - Main Propulsion System
  - Auxiliary Propulsion Systems
- Cryogenic Upper Stage Propulsion is included in the Propulsion Project

2nd Generation RLV Propulsion Project

- **The 2nd Generation RLV Program Has Provided for NASA-Led Tasks within the Projects**
- **'Gated' Selection Approach**

  - **Gate 1**
    - Does task address the Program Goals
      - Contribute to the safety and cost goals
  - **Gate 2**
    - Is task appropriate for NASA to lead
      - Gov't can do it better and cheaper than anyone else
      - If the Gov't doesn't do it, it won't get done
      - Cross-cutting ... supports multiple architectures
  - **Gate 3**
    - Does it need immediate start
      - Loss of a unique and necessary capability if not funded.
      - Schedule supports TRL6 by 05 ... OR
      - Task is needed to support the 2 year Program focusing

- **Only Tasks That Passed All Three Gates Were Selected**
- **The Propulsion Project Has Selected Eight Tasks for Execution in FY01.**

Final Selection Process

This Session Will Provide Information on Each of the NASA-Led Tasks Selected by the Propulsion Project

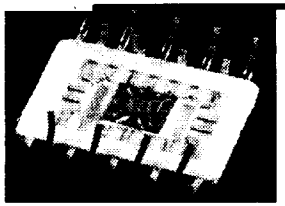
Summarized by Introduction

- Large Composite Valve Technology
- Actively Cooled Ceramic Matrix Composite Nozzle RampLOX/H2
- Smart Leak Sensor
- Test of Large Scale Liquid Hydrogen Propellant Densification Hardware
- Full Flow Staged Combustion Injectors

Presentations Following Introduction

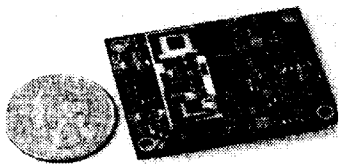
- GRCop-84 Sheet For Combustion Chambers, Nozzles And Large Actively Cooled Structures
- Combustion Devices Test Bed
- Gen2 Turbo Machinery Technology Demonstrator

Funded Task List for Propulsion



Microfabricated Hydrogen Sensor

Hydrogen Sensors on Space Shuttle

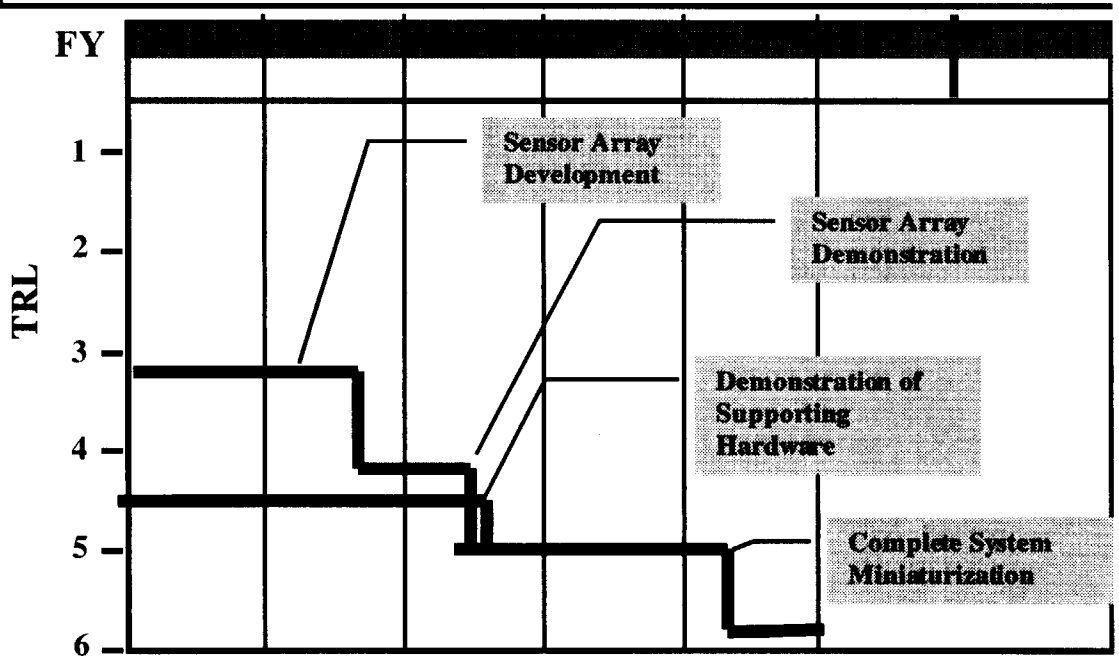


Prototype Hydrogen/Oxygen Sensor System with Electronics

Demonstrate Stand-alone Smart Leak Detection System With a Surface Area the Size of Postage Stamp

- **Products**
  - **Stand-alone Leak Detection System With a Surface Area the Size of Postage Stamp**
  - **Detection of Both Fuel and Oxygen at the Same Time**
  - **Integrated Signal Conditioning, Data Storage, Power, and Telemetry**
- **Benefits**
  - **Fundamental Need for Gen II vehicle for Increased vehicle safety, Increased reliability and maintainability, Reduced testing time and costs,**
- **Customers**
  - **Any 2nd Gen Vehicle**
- **Unique / Enabling and Enhancing**

- **Current State of the Art**
  - **Hydrogen sensor Shuttle-tested**
  - **Oxygen/Hydrocarbon sensors under development**
  - **Prototype hydrogen/oxygen sensor system fabricated with limited miniaturization of electronics**
- **Performance Metrics**
  - **20x decrease in individual sensor system size over present Shuttle tested technology/10x increase of sensor coverage**
  - **Reduction in Maintenance Time and Costs by an order of magnitude**
- **Risks**
  - Technology readiness of hydrocarbon sensor
- **USG Participants**
  - **GRC (Lead Center), KSC, Makel Engineering, Case Western Reserve University**



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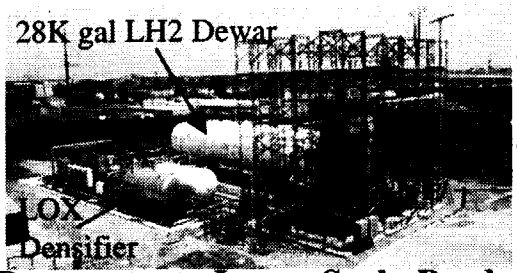
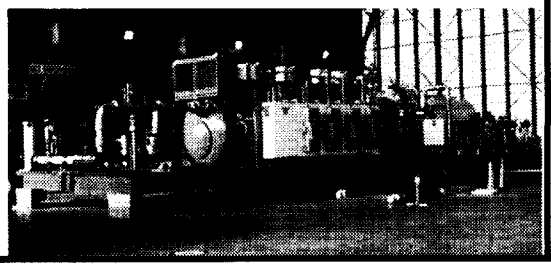
Miniaturized Smart Leak Sensor System



GRC South 40 Propellant Densification Test Site Configured for LOX Densification

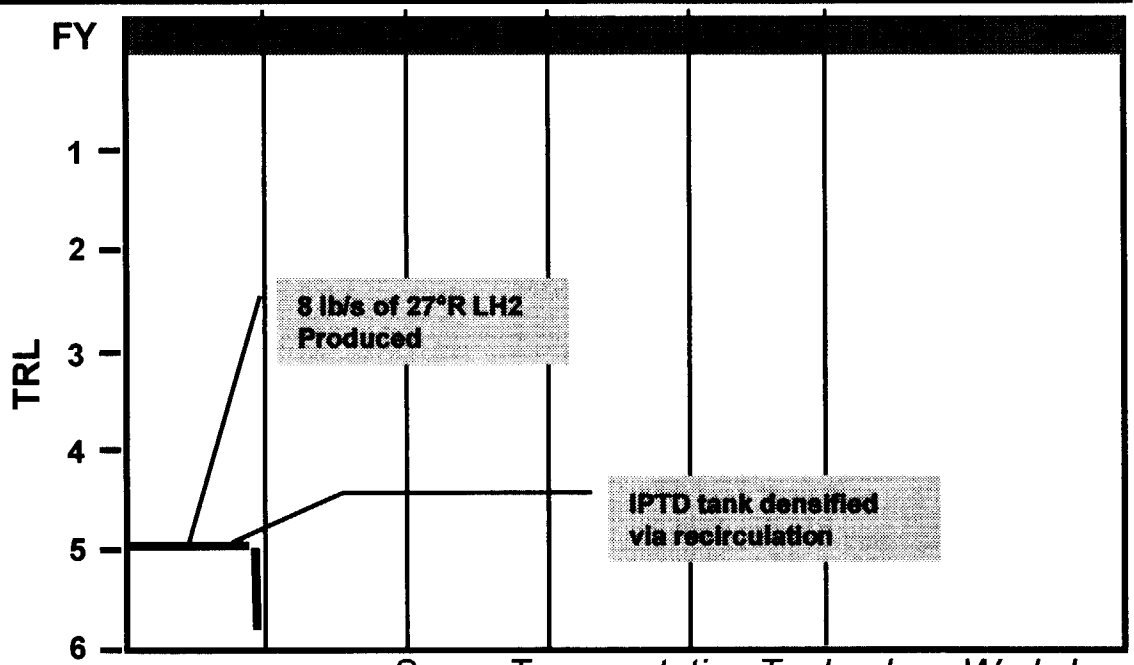
Demonstrate Large Scale Production and Tanking of 27°R LH2



8 lbm/sec LH2 Densification Unit in storage at GRC Hangar

- **Products**
  - Validation of LH2 densification process at large scale (TRL=6)
  - Operable (portable) densification skid available for flight experiment or engine test program
- **Benefits**
  - Densification can reduce vehicle weight significantly (RLV studies showed ~18% weight reduction)
- **Customers**
  - Multiple STAS vehicles utilize densified LH2

- **Current State of the Art**
  - TRL 5, Small Breadboard Densification Unit tested in 1996=>30°R LH2; X-33 scale unit fabricated and in storage
- **Performance Metrics**
  - 8 lbs/sec LH2 densification rate from 37°R to 27°R
  - Demonstrate recirculation tank loading process (thermal stratification)
- **Risks**
  - SOA 4-stage compressor performance
- **USG Participants**
  - GRC lead



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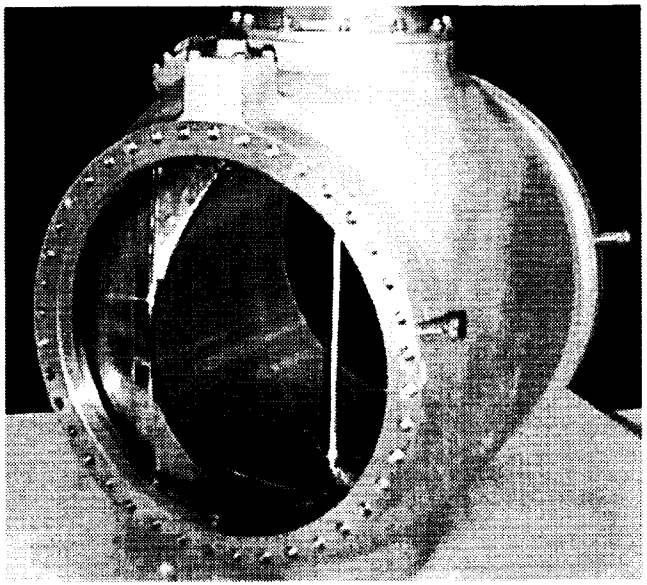
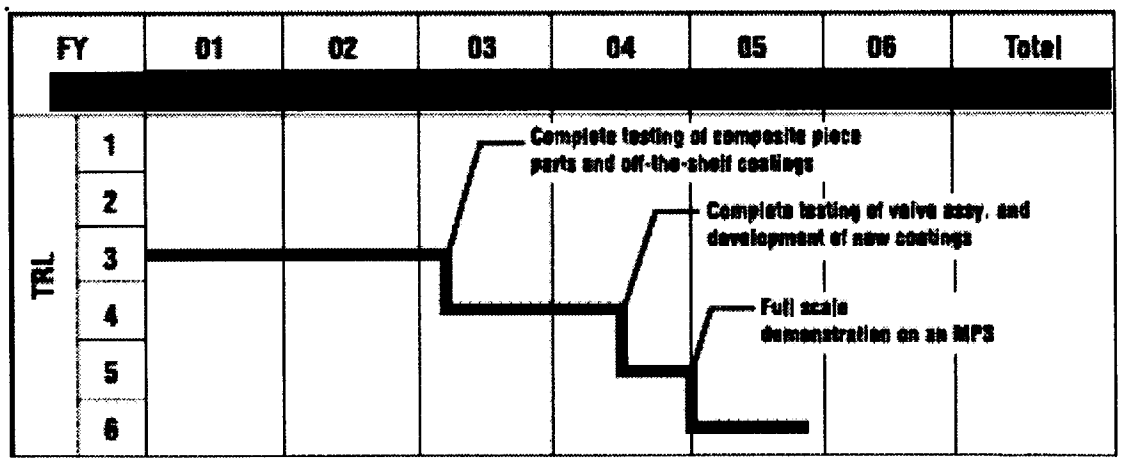
Test of Large Scale LH2 Densification Hardware



- **Products**
  - A large diameter LH2 valve made from PMC material.
  - A series of protective coatings that can be applied to composites and be used in a cryogenic environment. These coatings will increase the materials damage resistance.
- **Benefits**
  - The composite valve technology will enable weight reduction of large MPS components on a vehicle.
  - The coating technology will enable the program to operate at a higher confidence level since the risks of impact damage are greatly reduced.
- **Customers**
  - Second Generation Program, Shuttle, Aerospace Industry
- **Cross-Cutting Benefits**
  - Lightweight components are applicable to all present and future launch vehicles.

- **Current State of the Art**
  - Small PMC valve built for DC-XA vehicle
  - No large composite valves built
- **Performance Metrics**
  - Demonstrate a composite valve can be built and meet Shuttle requirements while at the same time reduce weight
- **Risks**
  - Composite parts and assembly do not meet Shuttle requirements.
- **USG Participants**
  - MSFC (Lead center), JSC



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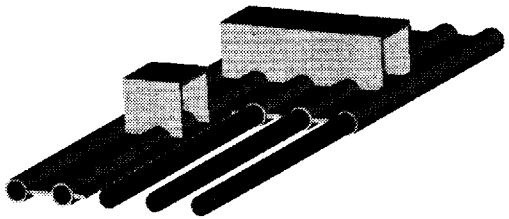
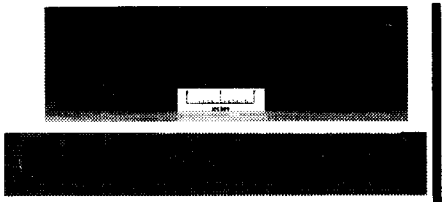
Large Composite Valve Technology

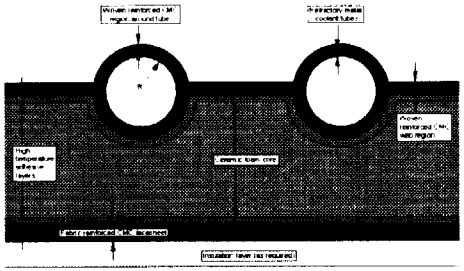
Refractory Composites Inc. Design



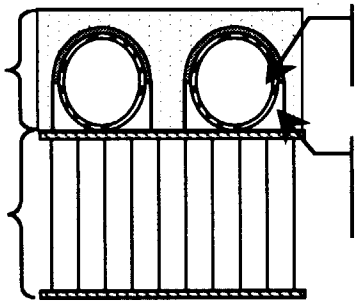
Rockwell Science Center



Honeywell Concept

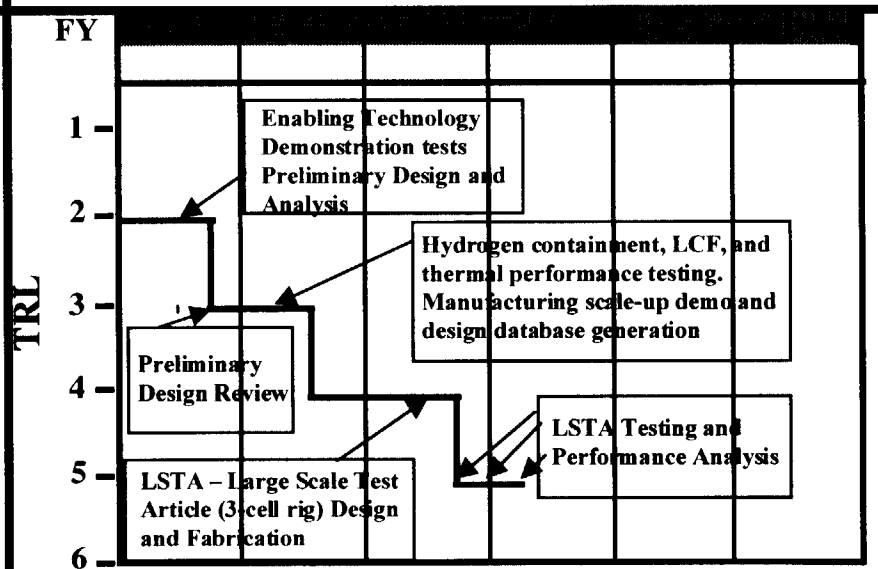


Snecma SEP Concept

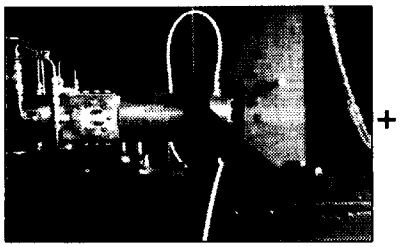


- Products
  - Design level mechanical, physical, and thermal property database
  - Test validated thermal and thermostructural models
  - Demonstrated thermal performance and ability to contain high pressure hydrogen
  - Demonstrated manufacturing scale-up and manifolding
- Benefits
  - Potential performance, operability, and safety pay-offs for high temperature capability CMC materials are high
  - Strength-to-weight of advanced CMCs at high temperature may provide a significant weight reduction at far aft end of vehicle where benefit is needed
  - High use temperature of CMCs provides additional temperature margin for uncooled reentry
  - High temperature capability expected to increase safety margins and allow significant simplification of aerospike engine features required for engine-out operation
- Customers
  - Primary industry customer, Lockheed Martin, has identified a wide variety of vehicles that would benefit from this technology including SSTO, TSTO, Shuttle Derived, CRV, CTV, and LFBB concepts
  - 3rd Generation RLV and all Rocket Based Combined Cycle (RBCC) propulsion concepts
- This project is essential to maintain viable technology development schedule consistent with 2nd Generation RLV

- Current State-of-the-Art (SOTA)
  - No other concepts existing or in development capable of meeting nozzle ramp requirements
  - These NASA-Funded concepts represent the SOTA
- Performance Metrics
  - Areal weight requirement is 2.0 lb/ft^2 with a goal of 1.5 lb/ft^2 for the heat exchanger
- Risks
  - Aggressive development schedule
  - Manufacturing scale-up to flight design (industry task)
- USG participants
  - MSFC (lead Center), LaRC, GRC, AFRL/ML



Actively Cooled Composite Nozzle



Single Element Testing

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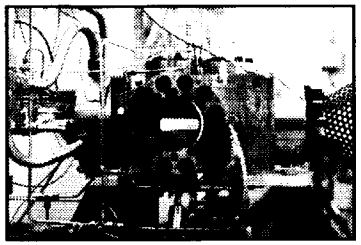

Multi-Element Testing

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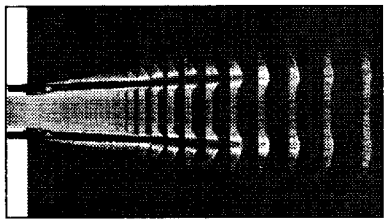

Validated Analysis Tools

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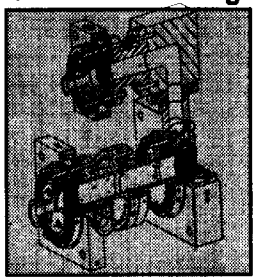


Robust 60K Injector Concepts

Products

- **Optimized MCC injector concept that fully meets Gen 2 operability, life and performance goals (timed to support concept downselect)**
- **Optimized MCC injector concept(s) that exceed Gen2 requirements**
- **Experience in design and operation of LOX-rich preburners**
- **Seamless injector design package with tools validated to TL RL 6-can be used to calculate environments for lie predictions**

Benefits

- **High performing injectors with manageable heat fluxes**
- **Lower part count that increases reliability and lowers costs**

Customers

- **Injector Element Concepts-2nd Generation RLV (FFSC cycle)**
- **Injector Design Package- all projected 2nd Generation RLV cycles, 3rd Gen and SSME**

Current State of the Art

- **Limited data base and empirical design methodologies create high-risk designs**

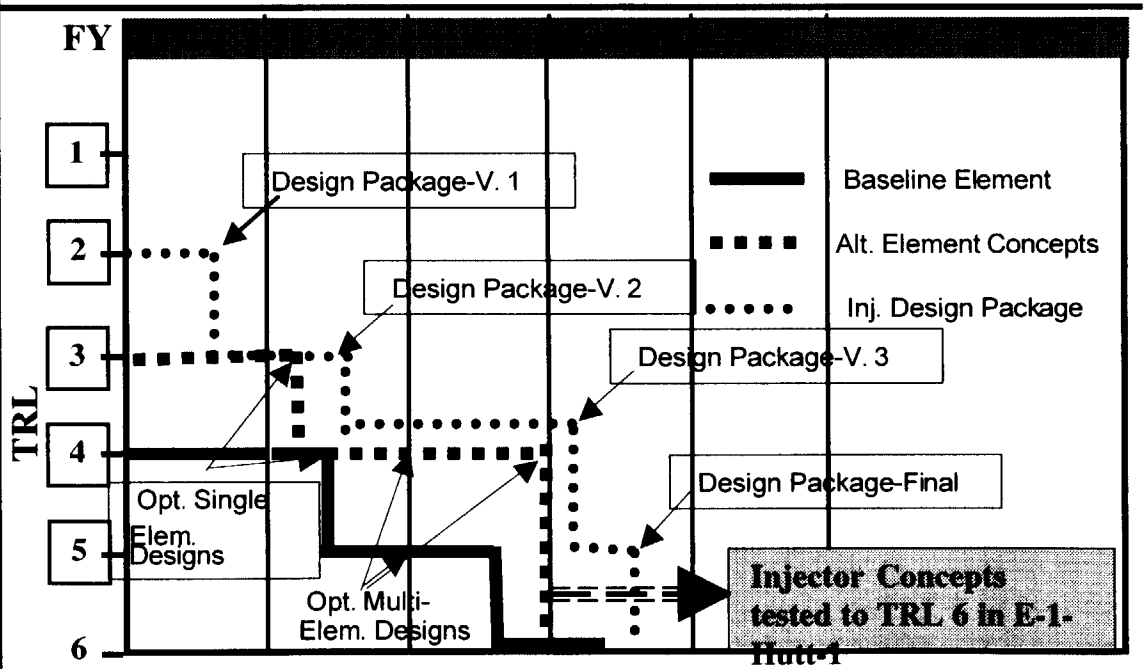
Performance Metric

- **Increase reliability by reducing part count (10x) and lowering heat fluxes (30%)**
- **Decrease injector development cost (2x), ops cost (2x) and weight (20%)**

Risks

- **Tight schedule to complete portions of task before cycle down-select**

USG Participants: **MSFC (Lead)/GRC**



Full Flow Staged Combustion Cycle Injectors