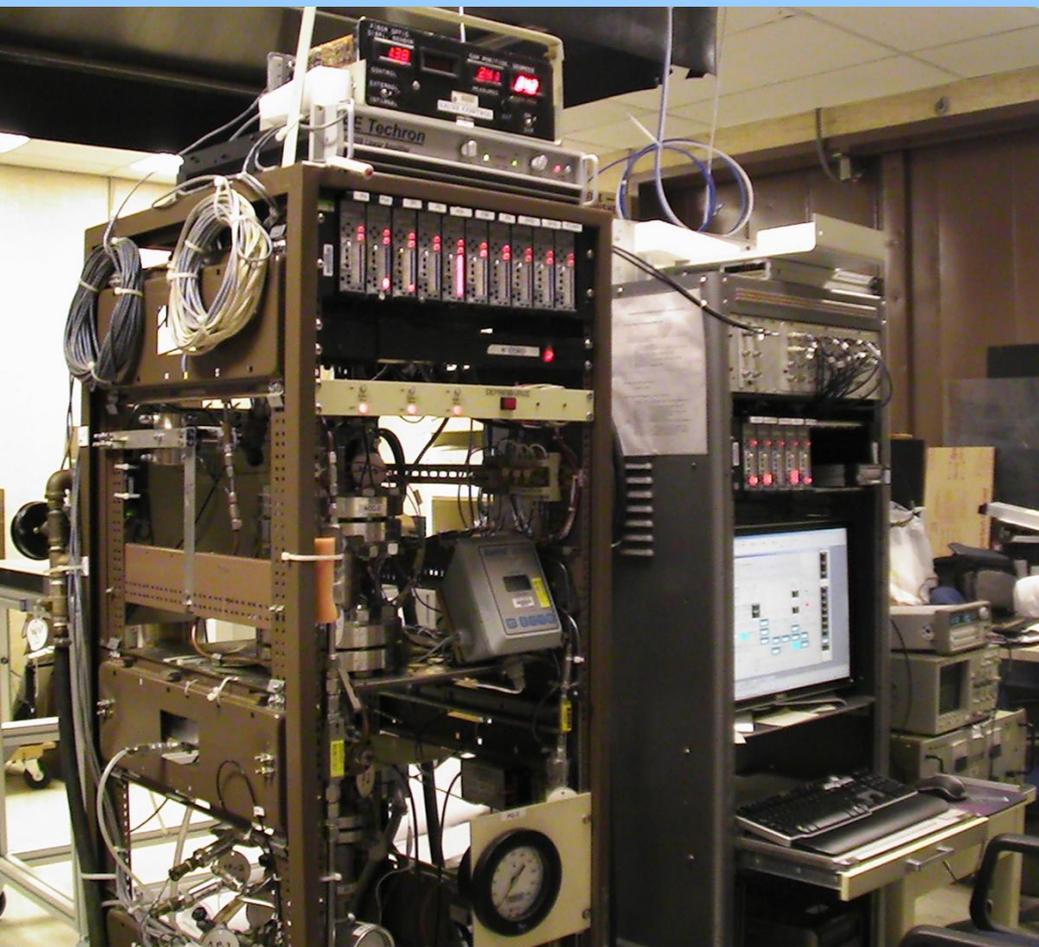




# Dynamic Performance Characterization For Advanced Fuel Modulator Designs



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Joseph R. Saus, NASA GRC

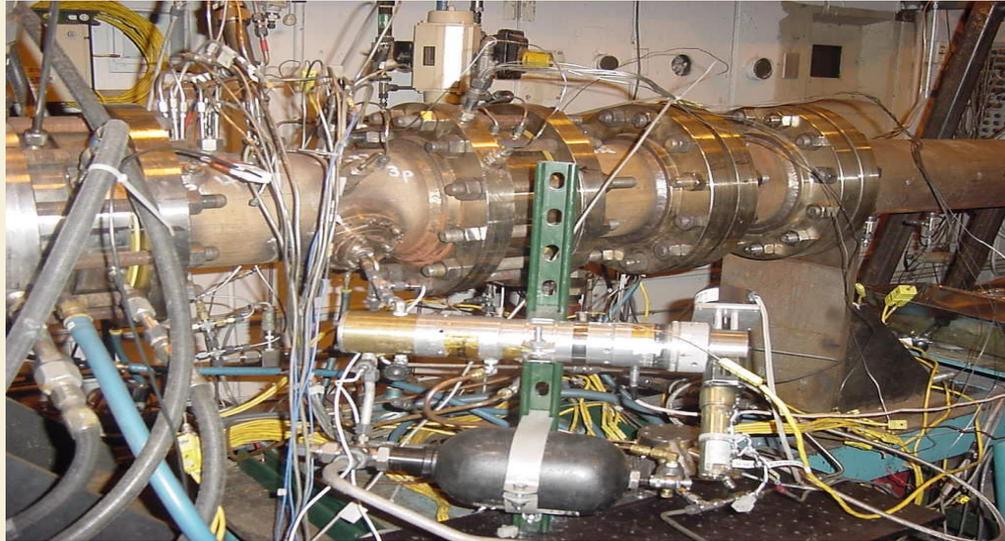
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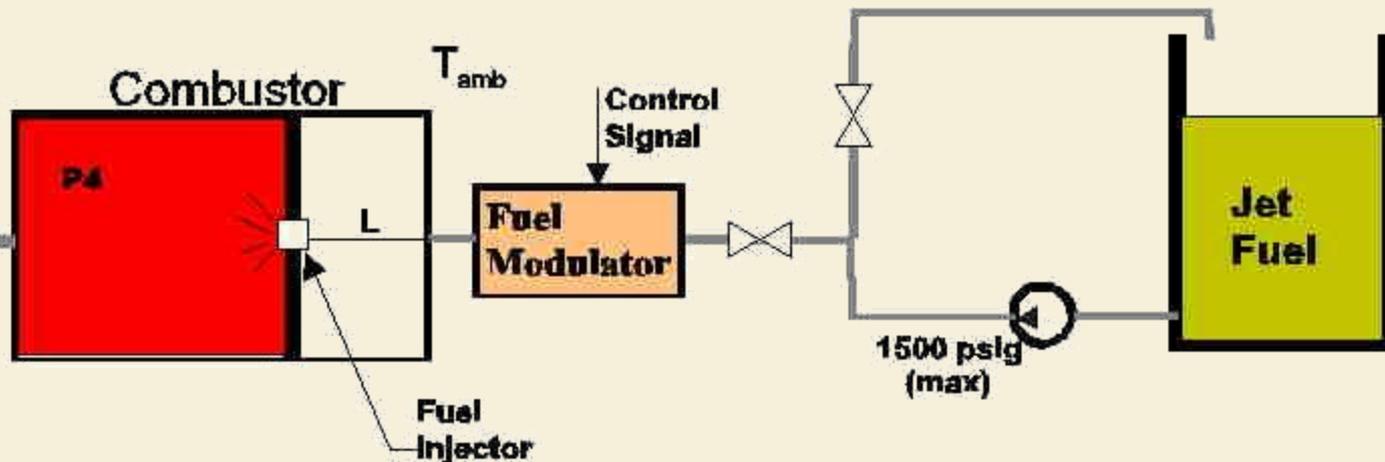
# OUTLINE

- Fuel Modulator Requirements for Active Combustion Control
- Identification Of Prospective Candidates
- Need for Dynamic Characterization Testing
- A Brief Description of the GRC Dynamic Characterization Rig
- Sample Data
- Conclusions

# Operational and Environmental Requirements Imposed By Combustor

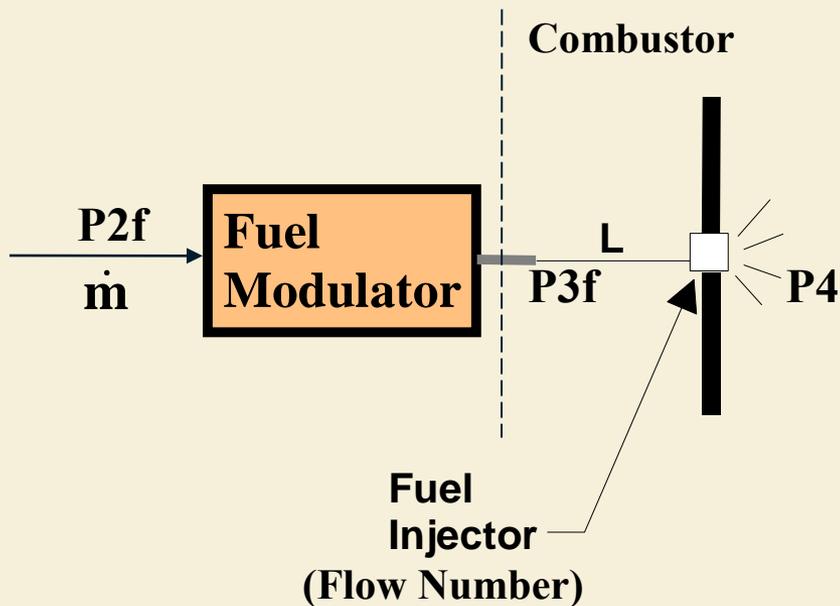


**Exhaust**





# Specifications for a Modulator Design



## Environmental Requirements

$$P_{2f_{\max}} = 1500 \text{ psig}$$

$$T_{\text{amb}} \approx 300 \text{ F}$$

$$L \geq 12'' ; \frac{1}{4}'' \text{ ID}$$

$$P_{4_{\max}} \approx 300 \text{ psi}$$

## Operational Requirements

**Bandwidth: 1kHz**

$$\text{Flow Number (FN)} = \frac{\dot{m} \text{ (pph)}}{\sqrt{P_3 - P_4} \text{ (psi}^{0.5}\text{)}}$$

**Historical FN: 110** (initial ACC research)  
**8** (current ACC research)  
**1 to 3** (future ACC research)



# Identification of Prospective Candidates

- Modulators identified in the literature and the Active Combustion Control (ACC) community
  - Georgia Tech identified a design of their own used in their research
  - NASA procured a copy for its initial ACC research (flow number = 110)
- NASA SBIR Program (preliminary designs)
- Companies sharing their preliminary designs with NASA
- In-house conceptual designs
- The Georgia Tech fuel modulator remains ...
  - only working device we have
  - been used for 1 successful ACC research effort and several dynamics investigations



# Dynamic Characterization Testing

## **PROBLEM:**

- Need to screen potential ACC fuel modulator candidates for their suitability
- Need to develop technologies for predicting in-situ behavior of the fuel modulators
- Using a combustion rig to perform these tasks would be expensive and it would pose unnecessary risk to the rig's health

**SOLUTION:** Design and build a dynamic characterization rig that simulates cold-flow combustion rig conditions



# GRC High Bandwidth Fuel Modulator Dynamic Characterization Rig\*

## Fluid Supply System

Supplies pre-conditioned and regulated working fluid to the Test Section

- working fluids: water or Jet A
- 600 psig max working press.

## Test Section

Consists of test candidate sandwiched between components that simulate combustion rig conditions

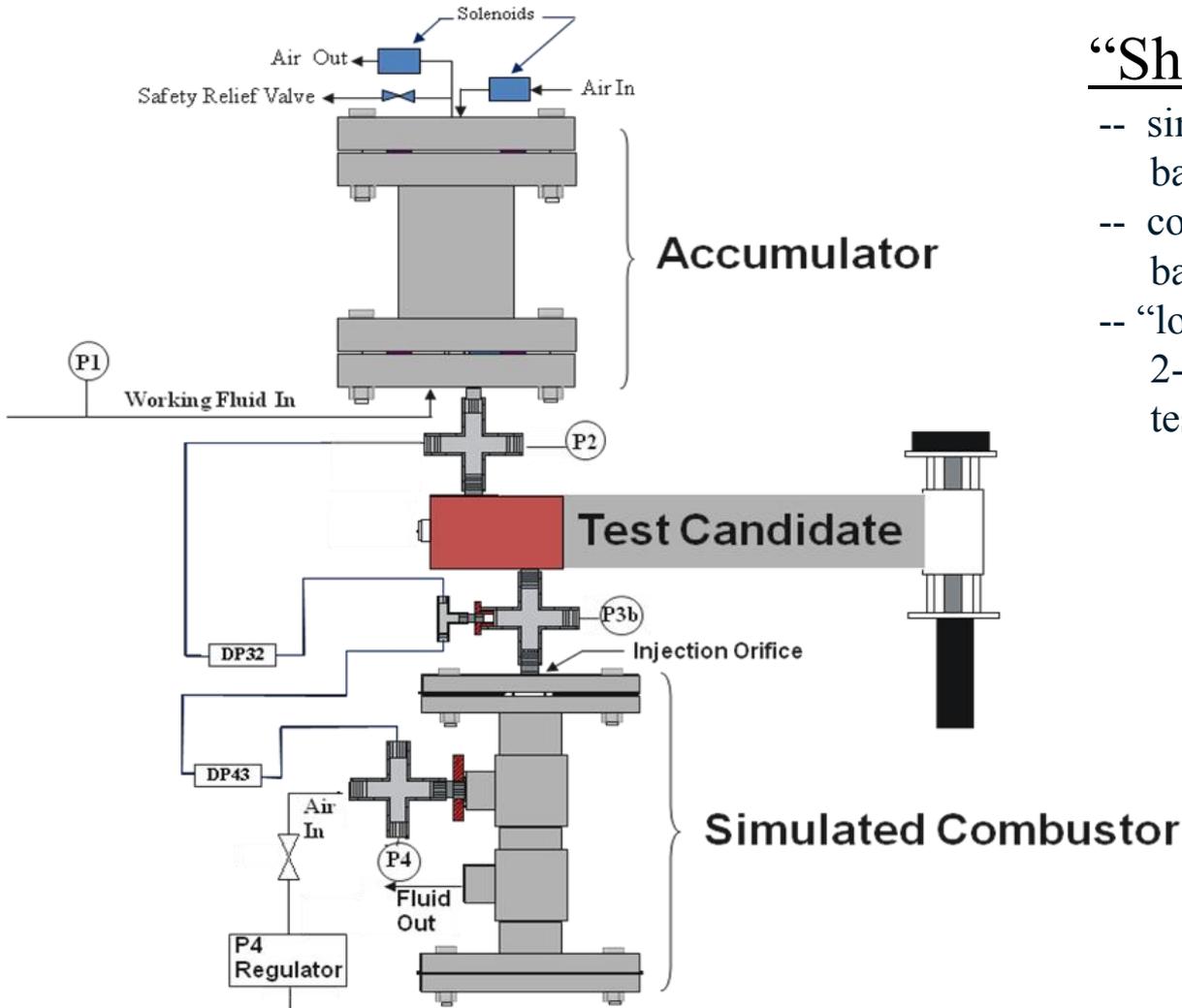
- *Accumulator*
- *Test Candidate*
- *Simulated Combustor*

## Ancillary System

Supplies regulated compressed air to Test Section components

\* “Design and Implementation of a Characterization Test Rig for Evaluating High Bandwidth Liquid Fuel Flow Modulators” AIAA 2009-4886

# Test Section



## “Short” Configuration

- simulates fuel injector and backpressure, but not line length,  $L$
- configuration used to collect baseline data
- “long” configuration (utilizes a 1-foot, 2-foot, 3-foot, etc) line length between test candidate and injection orifice



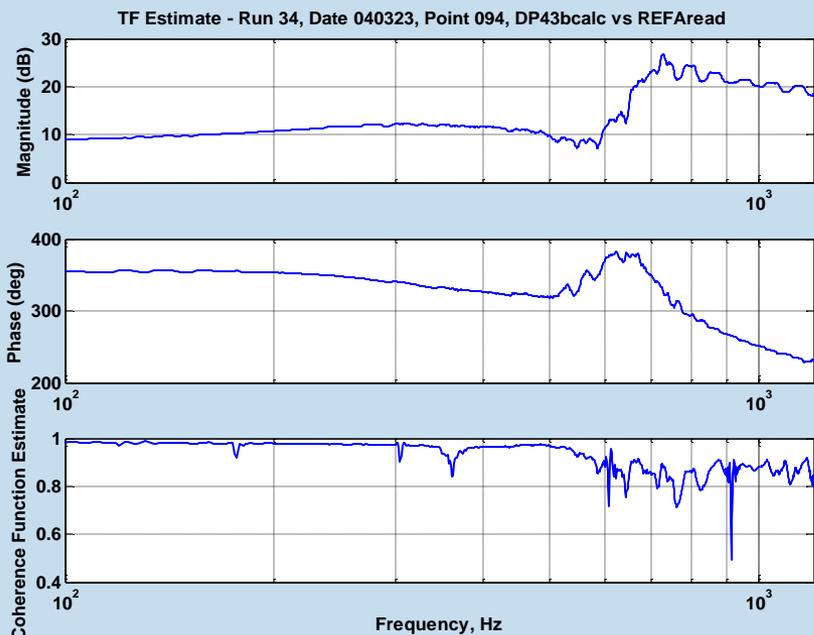
# Sample Data (short configuration)

## Transfer Function DP43/RefA\*

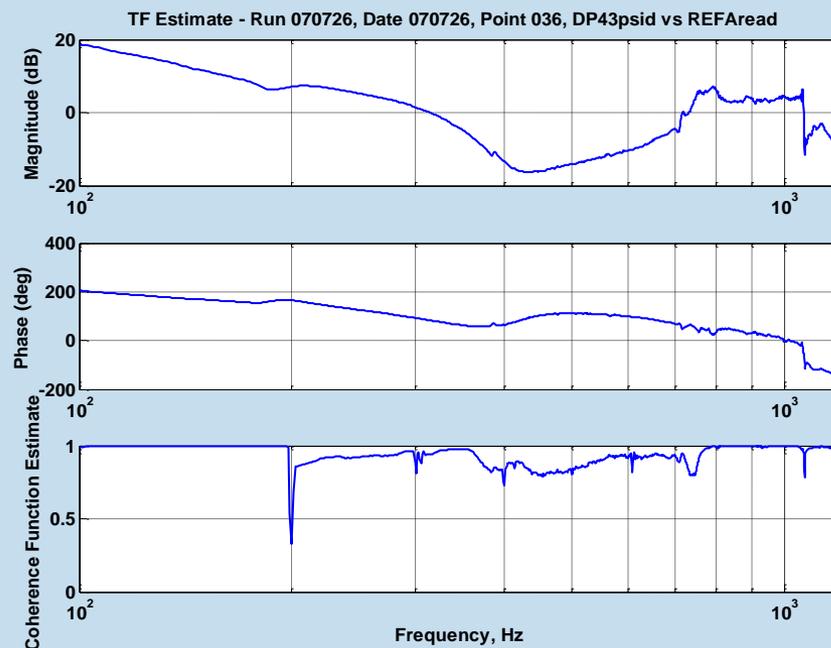
- measures the candidate's available bandwidth
- obtained from frequency sweep data

\*DP43: Delta P across injection orifice  
RefA : Valve command

### FN=110 Orifice



### FN=13 Orifice





# Conclusions

- Fuel modulators remain an enabling technology for ACC, but they lack “flight-ready” form and they are not capable of performing over a wide range of flow numbers.
- Identification of prospective candidates has been accomplished from the literature, NASA SBIR proposals, and independent contact with outside sources.
- NASA GRC developed a dynamic characterization rig that can evaluate prospective fuel modulator candidates subject to conditions that simulate a combustion rig environment.
- Sample data was shown for a candidate showing the degree to which the candidate’s performance depends on feed system configuration.
- Technology development continues ....