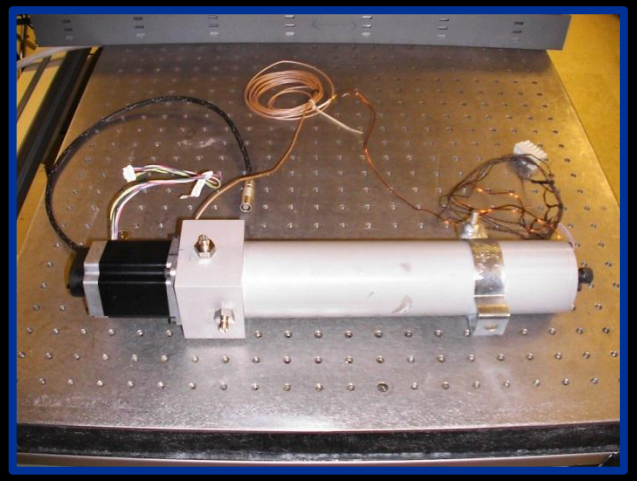
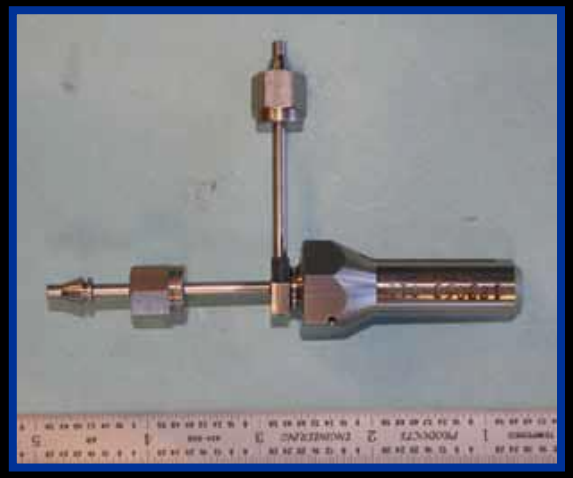
Next Generation Fuel Mod
For NASA GRC's ACC Re



Active Signal Technologies

Jansen Aircraft System Controls



WASK Engineering

Joe Saus
Propulsion Control & Dynamics Workshop
NASA Glenn Research Center
Cleveland, Ohio
December 11th and 12th, 2013

Flow Path

- **Driving Factors/Impediments for New Fuel Modulators**

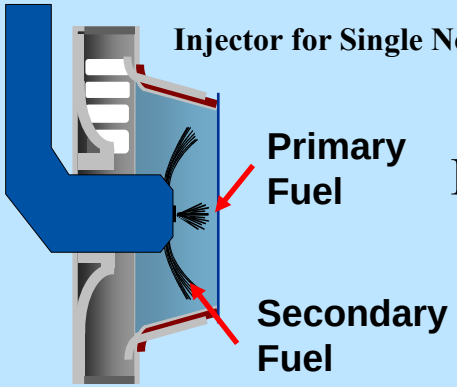
- **The New Fuel Modulators**
  - **-- Active Signal Technologies (AST)**
  - **-- Jansen Aircraft System Controls (JASC)**
  - **-- *WASK Engineering* (concept)**
  - **-- Others ***

- **Summary**

Driving Factors/Impediments for New Modulators

2000 ➡ 2004 **Conventional Rich-Burning Combustor (CRBC)**

Single Nozzle Combustor



- Georgia Tech Valve (GTV) procurement
- GTV characterization (in-house rig) for FN*= 110
- GTV implementation/characterization-validation with CRBC

In General:

- project money was available for a direct procurement of an unavailable COS item
- the GTV was operated at its design point (FN=110) for this application
- project demonstrated a successful implementation of ACC

No modulator issues!

*units for FN: $\frac{\text{lbm}}{hr \cdot psi^{0.5}}$

Driving Factors/Impediments for New Modulators cont'd

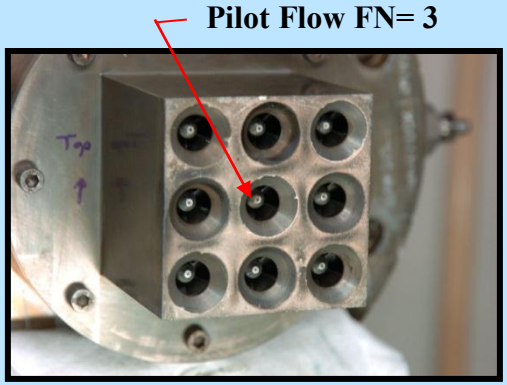
2006 ➡ 2010 Lean-Burning Combustor (LBC) (flametube combustor)

(similar to) LBC Injector

- new combustor, injector, modulation flow and FN
- had only 1 modulator in-hand; not designed for this application
- no project money available for direct procurement; had to use NASA SBIR's and NRA's to finance
  - -- bureaucratic hoops; slow turnaround
- used GTV for this application; suboptimal operation
  - -- poor demonstration of ACC

Many issues!

2011 Lean-Burning Combustor (LBC)



LDI injector

- new injector, same modulation flow, further reduction in FN
- Active Signal Technologies (AST) modulator delivered 7/2012
  - -- FN range: 3 to 8
  - -- modulator characterization in progress
- Jansen Aircraft System Controls (JASC) modulator delivered 11/2013
  - -- FN range: 3 to 5
  - -- modulation characterization in progress
- WASK Engineering proposing FN 1 to 8 design

Issues waning!

NASA GRC Fuel Modulators

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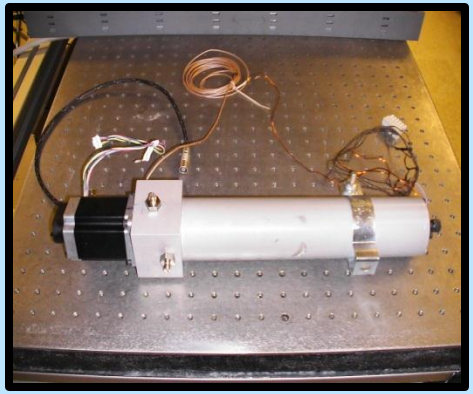
GTV

Magneto-strictive
Exterior Installation
Design Point: FN=110
FN Range: 20 to 110

Envelope: 12”x18”x2”
Weight: 20 lbs

Max Power In: 6 amps
Max Pressure In: 1500 psi
Max Temp.: 300 ^{o}F

AST



Magneto-strictive
Exterior Installation
Design Point: FN=5
FN Range: 3 to 8

Envelope: 4”x18”x4”
Weight: 10 lbs

Max Power In: 6 amps
Max Pressure In: 1500 psi
Max Temp.: 300 ^{o}F

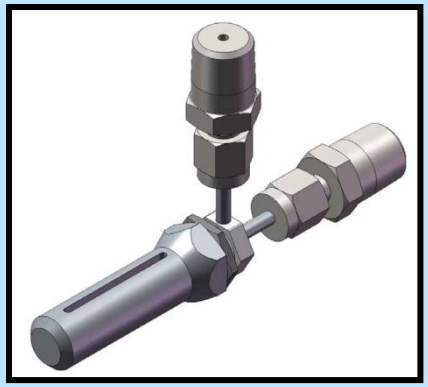
JASC

Translating-Rotary Flute
w/stationary flow port
Exterior Installation
Design Point: FN=4
FN Range: 3 to 5

Envelope: 2.6”x5.6”x2.6”
Weight: 3.5 lbs

Max Power In: 6 amps
Max Pressure In: 1500 psi
Max Temp.: 300 ^{o}F

WASK

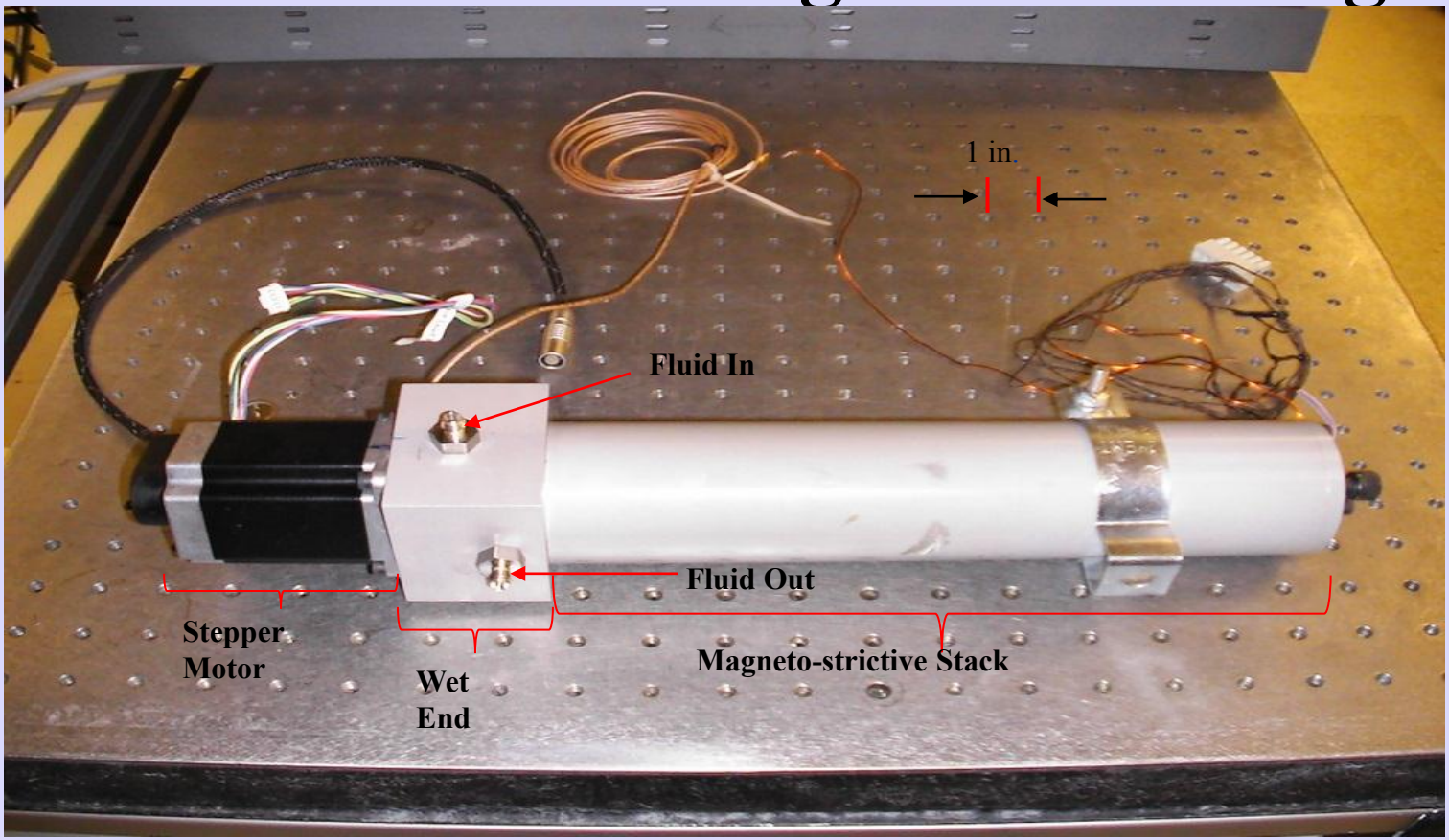


Piezoelectric
Interior Installation
Design Point: FN=4
FN Range: 1 to 8

Envelope: 2”x4.5”x1”
Weight: 1 lbs

Max Power In: 1 amp
Max Press. In : 1500 psi
Max Temp.: 1800 ^{o}F

Active Signal Technologies

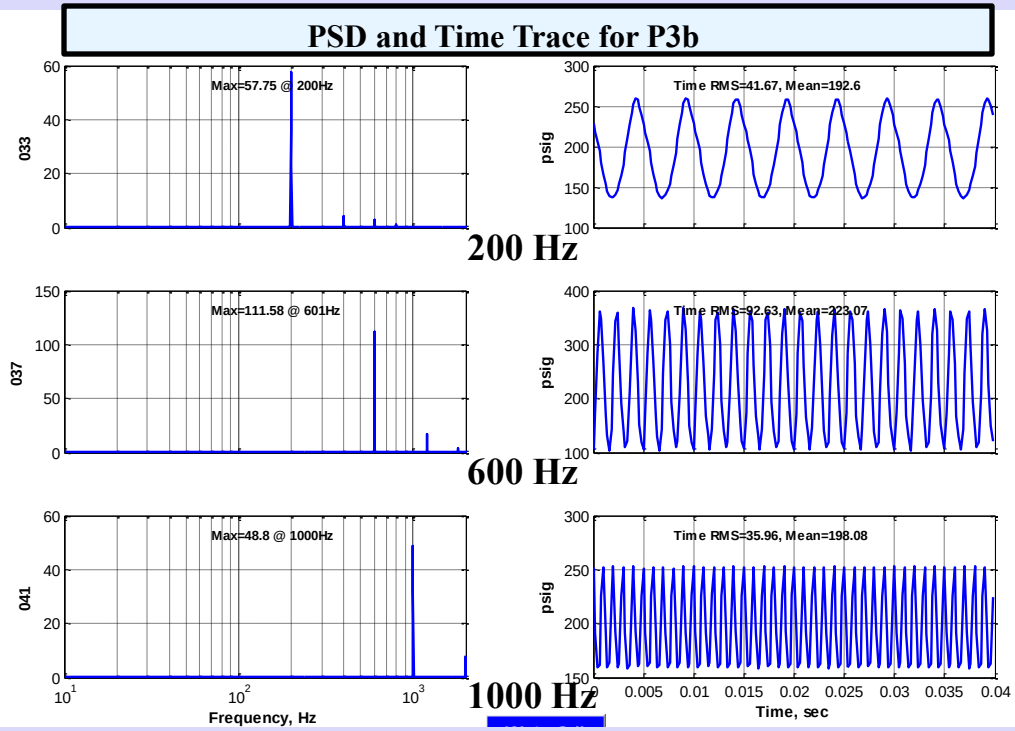


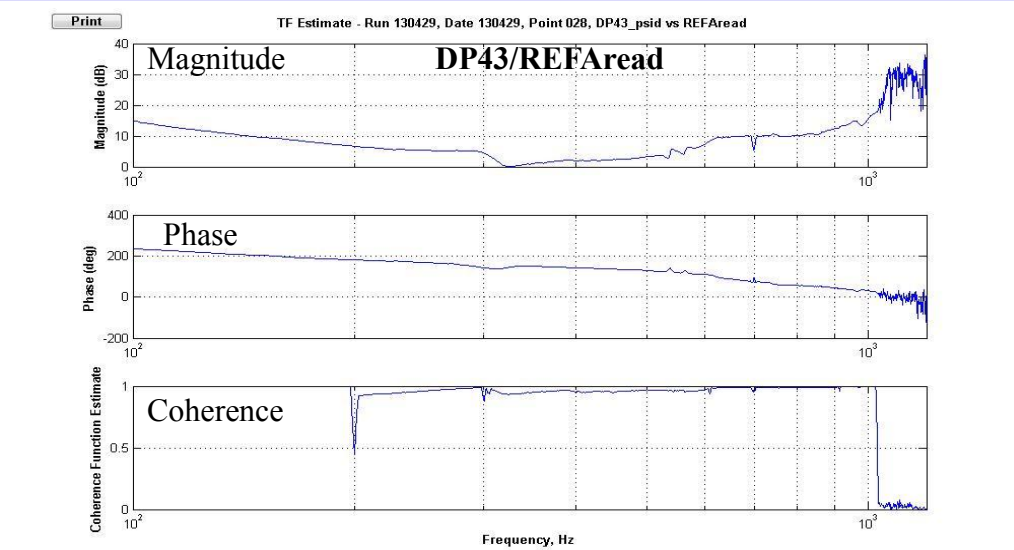
FN Range: 3 to 8

NASA SBIR Phase I: 1/22/09 to 7/22/09
NASA Combustion NRA: 2/22/11 to 6/29/12
-- marketable product

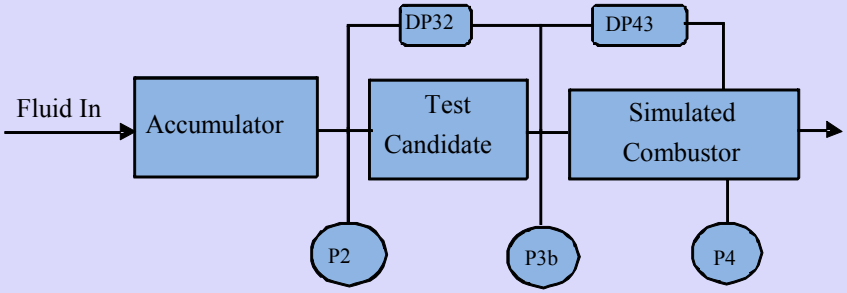
- Magneto-strictive Modulation
- Poppet Valve Wet End (Moog design)
- Stepper Motor Causes Change in Valve Flow Area

Active Signal Technologies, cont'd





Preliminary Performance Data (open loop)



Characterization Rig "Short Configuration"

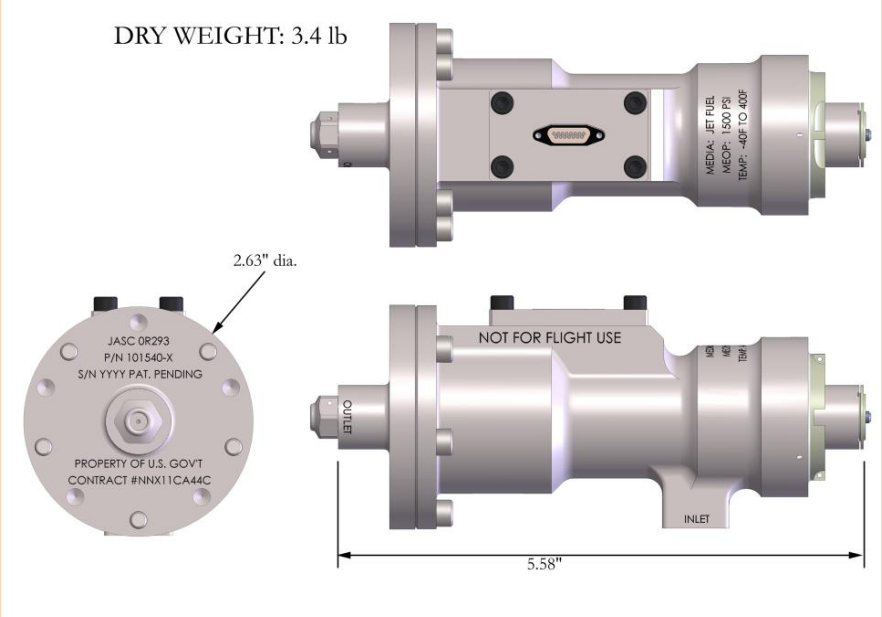
Test Conditions	Command
$\dot{m}$ = 18 pph	REFAread = $3\sin(2\pi ft)$
P2 = 268 psig	
P4 = 126 psig	
FN = 2.1 pph·psi$^{-0.5}$	

Result

$P3b_{200\ Hz}$ = 193 psig +/- 42 psig rms
$P3b_{600\ Hz}$ = 223 psig +/- 93 psig rms
$P3b_{1000\ Hz}$ = 198 psig +/- 36 psig rms

Sinusoidal Logarithmic Sweep
100 to 1200 Hz
No resonance in 1 kHz bandwidth

Jansen Aircraft System Controls (JASC)



Photos courtesy of JASC

NASA SBIR Phase I: 1/29/10 to 7/29/10
NASA SBIR Phase II: 6/29/11 to 11/29/13

-- marketable product

FN Range: 3 to 5

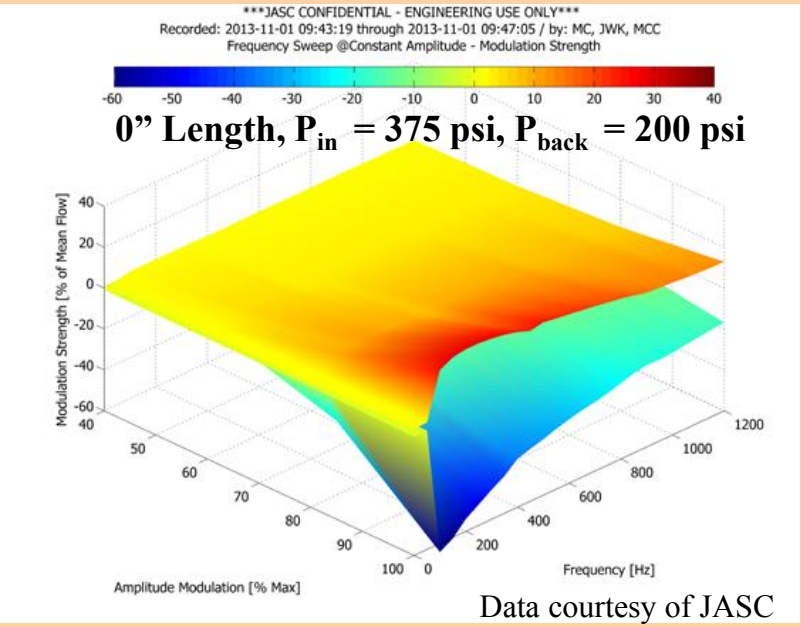
Electro-mechanical Design
-- utilizes a translatable rotary flute relative to a stationary flow port

-- motor/solenoid actuated

-- uses a novel displacement sensing device (linear & rotational) for determining the flute spool location

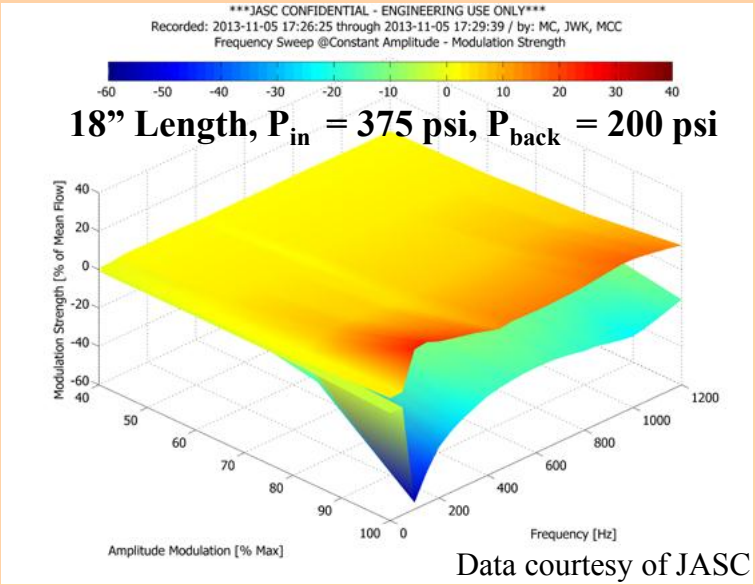
JASC, cont'd

Preliminary Performance Data



Data courtesy of JASC

FN=2.7 $\dot{m} = 34.5\ pph$



Data courtesy of JASC

Discrete Frequency Sweep (perturbations)

frequency $\in \{0, 50, 100, \ldots, 1200\}$ **Hz**

axial displ. $\in \{0.010, 0.015, 0.020, \ldots, 0.025\}$ ***inches***

1 sec data sample at each perturbation point

% Mod. Strength (peak) = **f(P_{in}, P_{back}, axial shaft displ., freq, length)**

$$= \frac{mean\,(\dot{m}_{max}) - mean\,(\dot{m}_{mean})}{mean\,(\dot{m}_{mean})}$$

$$\text{\% Ampl. Modulation} = \frac{\text{Axial Shaft Displ.}}{0.025''} \times 100$$

In General: modulation strength asymmetrical

0": +30% max; -40% min @ 100% axial shaft displ., 100 Hz

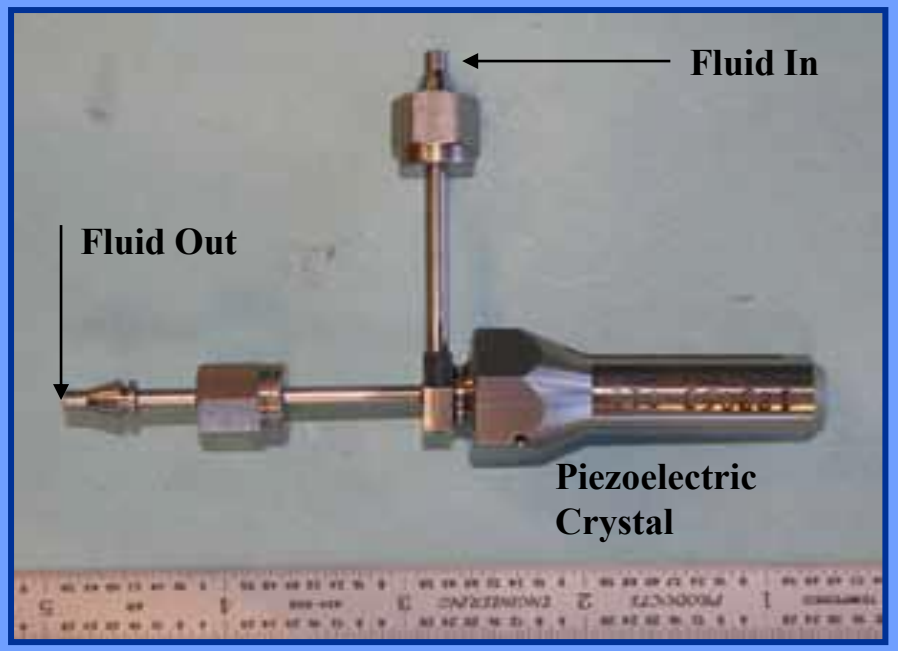
18": +20% max; -50% min @ 100% axial shaft displ., 100Hz

↑ Axial Position → ↑ %MS

↑ P_{in}, Freq, Length → ↓ %MS

WASK Engineering

Photos courtesy of WASK Engineering



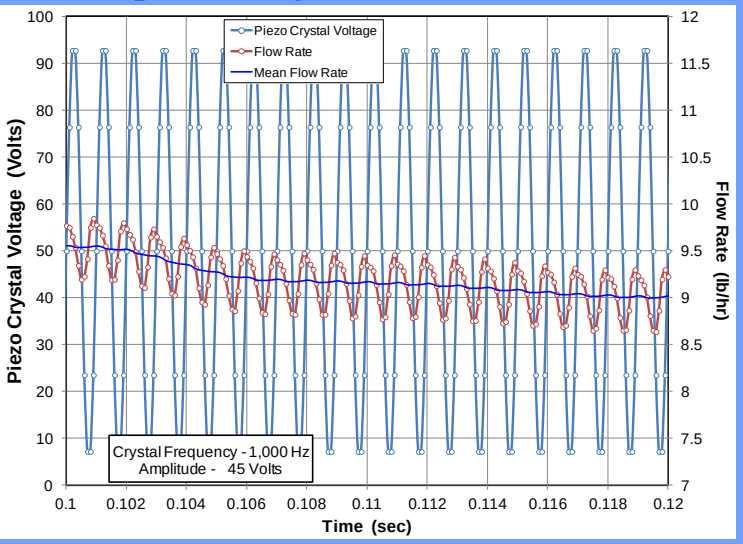
NASA SBIR Phase I: 5/23/13 to 11/23/13

FN Range: 1 to 8

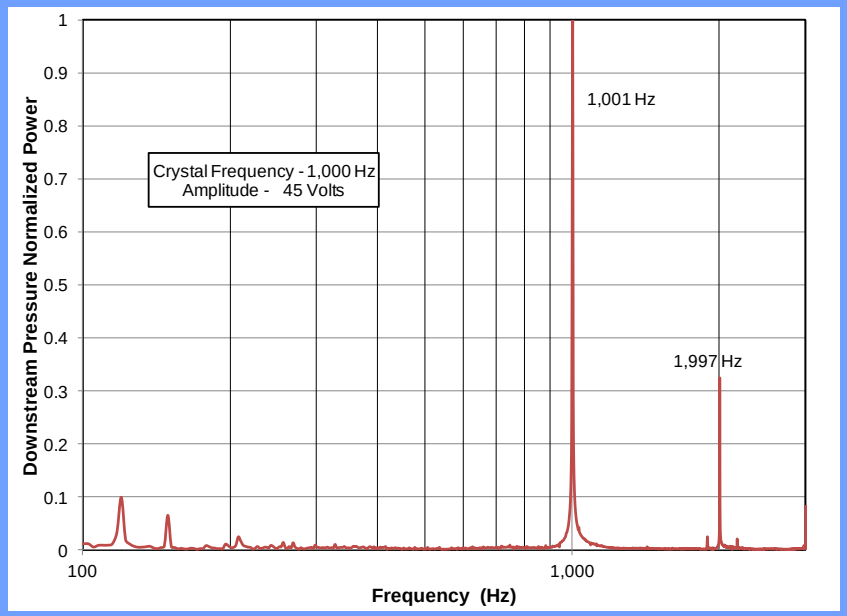
Modulator Conceptual Design
- -- piezoelectric
- -- compact; lightweight
- -- low power requirement
- -- intended for close-coupling with fuel injector
- -- verified through prototype testing

WASK Engineering, cont'd

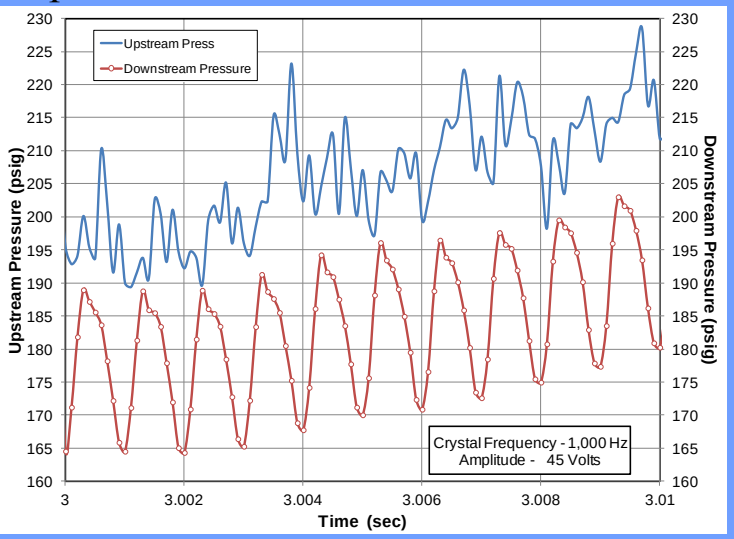
Input Voltage and Flow rate vs Time



Downstream Pressure Normalized Power vs Freq



Upstream and Downstream Pressure vs Time



Open Loop Testing of Prototype (no backpressure)

Modulation Strength ~ +/- 12.5% of mean pressure @ 1000 Hz for FN= 1.7

Other Potential Candidates in our Queue

- **Dressler Modulation Concept**
  - -- using CFDRC electro-mechanical actuator developed under a NASA SBIR Phase II
  - -- a novel concept; modulation not by means of a valve
- **Parker Hannifin (piezoelectric-based)**
  - -- NASA Combustion NRA deliverable
- **Mide Technology (piezoelectric-based)**
- **In-house (Dr. Robert Okojie, Sensors & Electronics Branch)**
  - -- piezoelectric-based

Summary

- Changes In ACC Research Objectives Have Driven Modulator Requirements
  -- change in flow number requirement
  -- change in rig installation location (interior versus exterior)

- Changes in ACC Research Budgets Have Required Alternative Procurement Strategies
  -- use of NASA SBIR and NRA contracts

- GRC Has Acquired 2 New Modulator Candidates for ACC Research
  -- AST
  -- JASC
  * WASK Engineering: to be pursued
  -- these devices are expected to serve as excellent tools in upcoming rig tests

- Other Modulation Concepts Have Been Identified for Later Examination

- Questions ??????????