Testing of a Liquid Oxygen/Liquid Methane Reaction Control Thruster in a New Altitude Rocket Engine Test Facility

Space Propulsion 2012 Conference
Bordeaux, France
May 7-11, 2012

Michael L. Meyer

Lynn A. Arrington, Julie E. Kleinhenz, and William M. MarshallNASA Glenn Research Center, Cleveland, Ohio, USA

NASA Glenn ACS Test Facility

- Facility was built as a relocation of LeRC (GRC) RETF Stand B
- New buildings with Test Cell, Control Room, Shops, and other support areas
- Reutilizing test tank, water cooled diffuser and water spray tank

- Test Chamber is 8 ft. (2.4 m) dia. x 14 ft. (4.3 m) long
- Nitrogen gas multi-stage ejector system with air ejector roughing pump system
- Conducts rocket engine test firings with LOX/LH_2/GO_2/GH_2 /LCH4 or RP capabilities; easily adaptable to others

NASA Glenn ACS Test Facility (cont.)

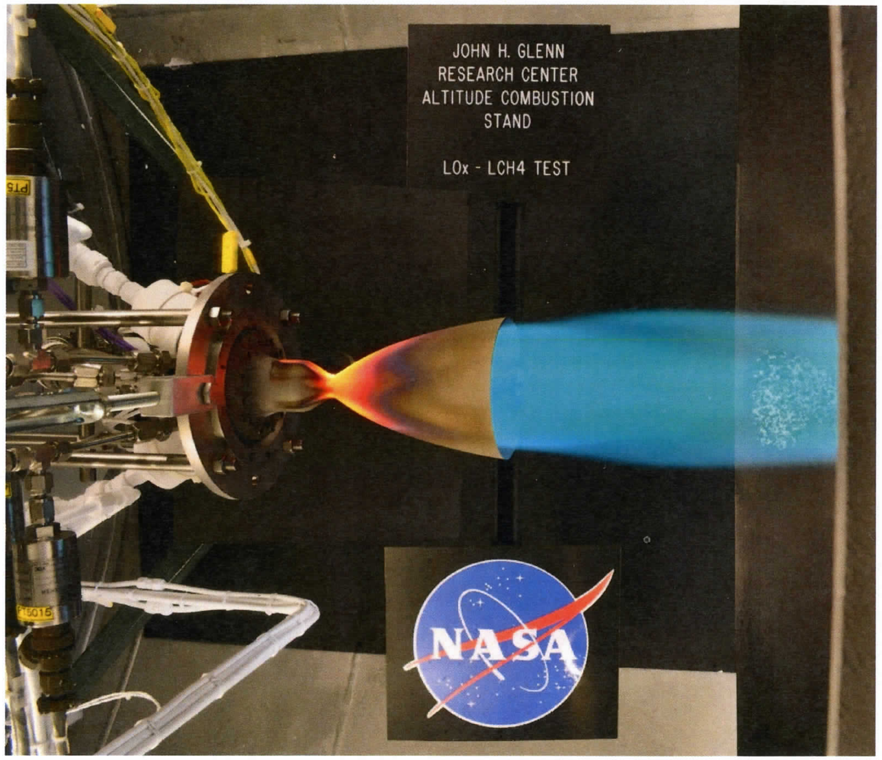
- Can accommodate up to 2000-lb_f (8.9-kN) class engine
- Chamber pressures up to 1000 psia (6.9 MPa)
- Can simulate altitude up to 130,000 ft (39.6 km)
- 3-9 min. max. run duration
- PLC/HMI controlled sequencing
- Video/Still optical access
- Data rates of 1000 Hz

Propellant Conditioning Feed Systems

- Designed by Sierra Lobo, Inc. to control propellant inlet temperatures
- Capable of maintaining propellant temperature ±5 °R
- Two systems – one for LO_2 and one for LCH_4
- Both systems consist of 60 gal. (227 L) run tank, cryogenic bath, cryogenic heater and vacuum jacketed lines
- Methane system includes a recirculation line

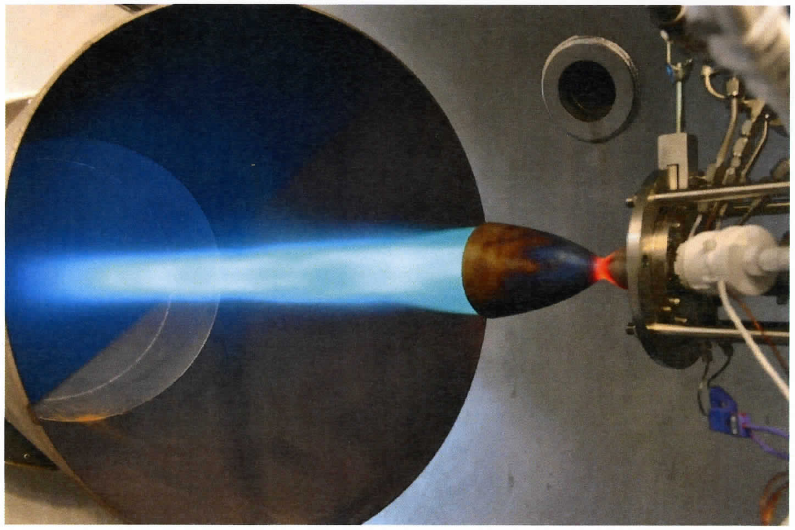
Reaction Control Engine Test Article

- 100-lb_f (445-N) LO_2-LCH_4 Reaction Control Engine (RCE) designed by Aerojet Corp.
- Chamber and nozzle are radiatively cooled columbium with oxidation resistant coating
- Nozzle is 45:1 exit ratio, 80 percent bell with 2.5 in. (64 mm) L′
- Injector is impinging style with fuel film cooling along chamber wall



Objectives of 100-lb$_f$ RCE Testing

- Interest in oxygen-methane as non-toxic propellant source
- Demonstrate steady-state performance (I_{sp} = 317 s at nom. conditions)
- Demonstrate min. impulse bit (Min. EPW = 80 ms; Min. I-bit = 4 lbf-s (17.8 N-s))
- Demonstrate repeatable, reliable ignition and characterize required spark energy

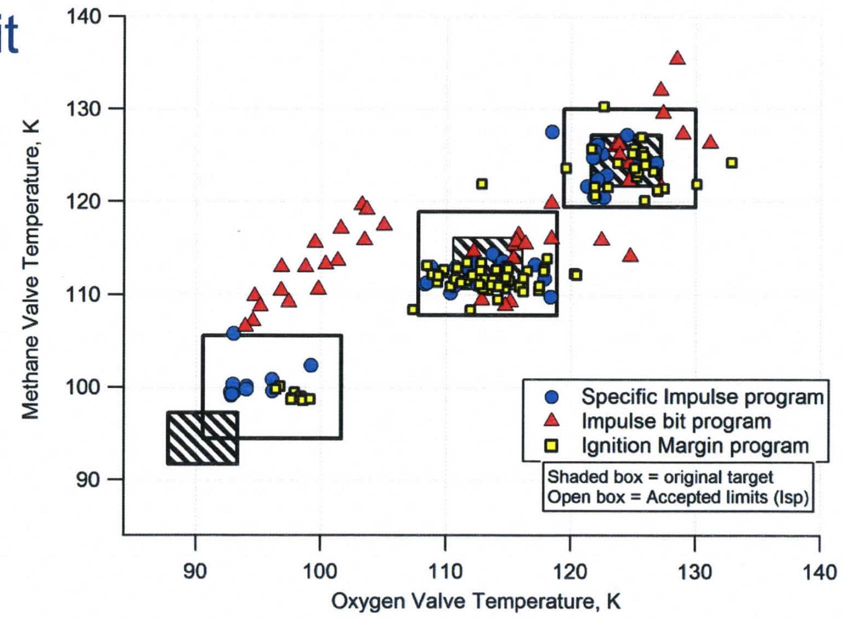


100-lb$_f$ Oxygen-Methane RCE
Results summary

- The engine performance met or exceeded programmatic goals and numerical predictions
  - I_{sp} = max: 317 s; min: 293 s
  - I-bit < 4 lb$_f$-s (17.8 N-s) *(40 ms pulse duration)*
  - Warmer propellant temperatures resulted in higher performance

- Ignition was repeatable and reliable, reducing perceived risks of this propellant combination.

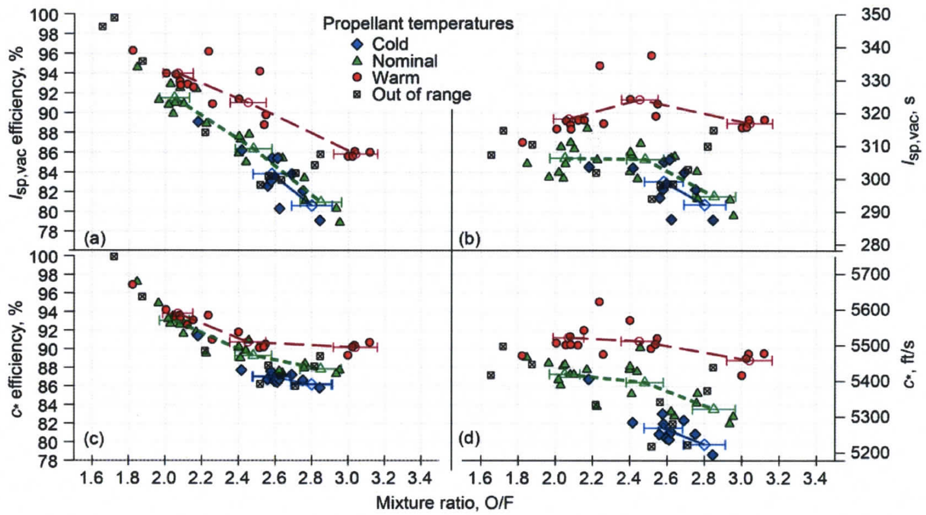
- A new flight-like compact exciter unit showed excellent performance
  - Exciter performance is different in an engine environment and impacts ignition reliability.

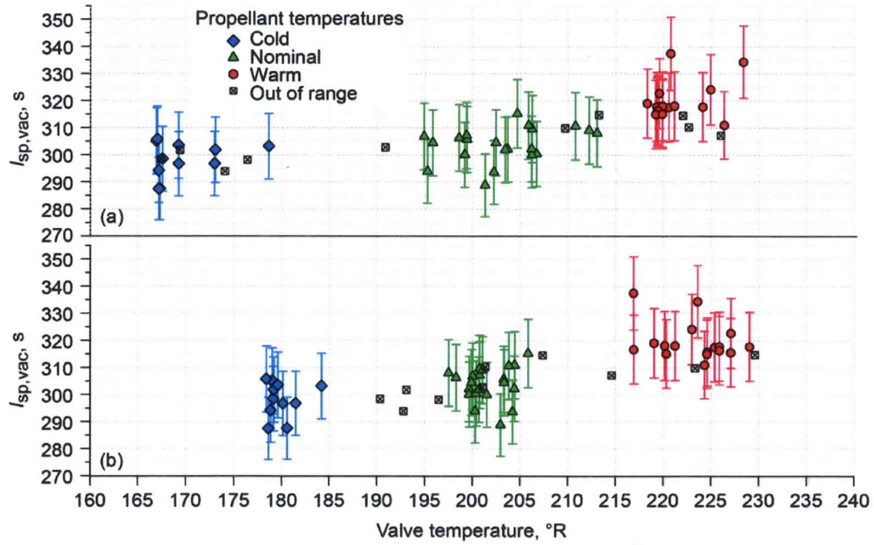


- 300 tests in 1 year's time
- Up to 24 tests in a single day

Performance Test Series

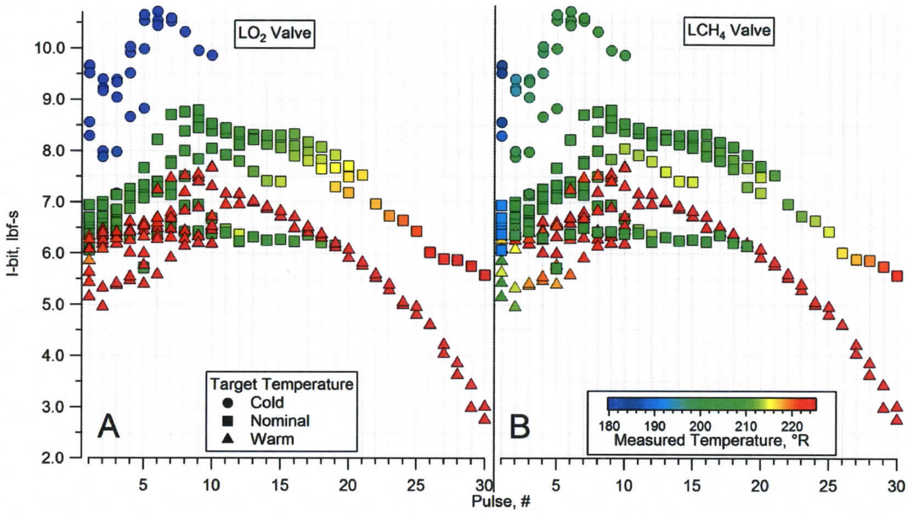
- Performance testing viewed I_{sp} and c* as function of propellant inlet conditions and mixture ratio
- Engine successfully met I_{sp} goal at nominal conditions
- Higher temperatures and lower mixture ratios had greater performance/efficiency – likely due to mixing characteristics of the injector

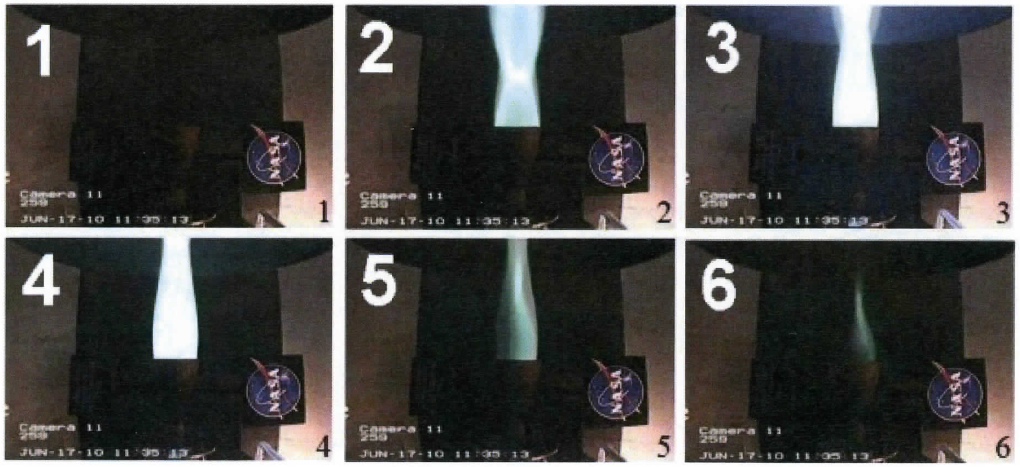




Pulse Test Series

- Pulse testing successfully demonstrated min. EPW (80 ms) and min. I-bit at EPW = 40 ms
- Temperature dependency seen for I-bit
- Warmer propellants showed improved performance (lower I-bits)

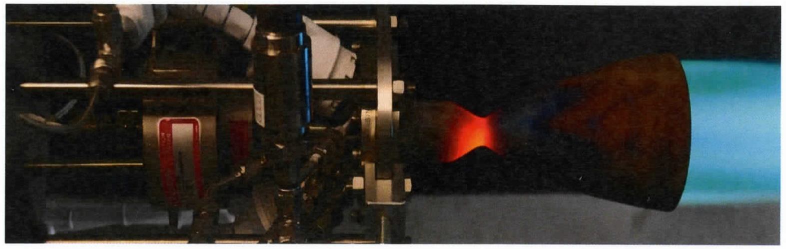




Ignition Margin Test Series

Objective:

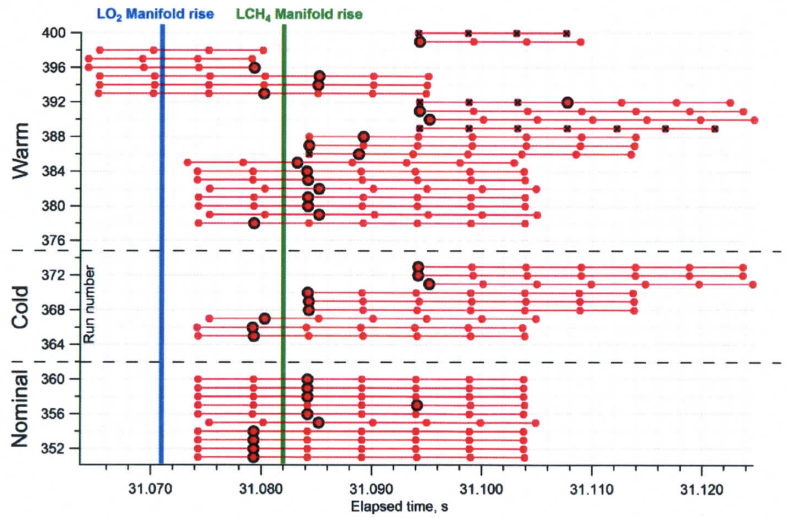
Identify ignition energy limits and characterize spark behavior in an engine environment



Unison Compact Exciter

- 4 exciter units were used to characterize different aspects of ignition
- High speed digital oscilloscope was used to capture waveform data, synchronized to engine pressure/flow data to determine ignition spark

Accomplishments



Spark timing relative to propellant flow. Outlined sparks triggered ignition.

- 86 tests performed varying spark rate, energy, and spark timing (initiation and duration)
- Spark behavior in an engine environment is highly variable as compared to room conditions.
- Appropriate spark timing can improve ignition probability, as an alternative to higher energy discharges
  - Optimum ignition timing was at initiation of propellant flow, when flow rate and pressures are low
  - A high spark rate during this time period will improve ignition

Summary

- The relocated Altitude Combustion Stand was activated in 2009
- ACS is a high-precision test facility with excellent test throughput for technology and advanced development
- ACS was crucial for extensive LO2/LCH4 RCE testing under the Propulsion and Cryogenic Advanced Development (PCAD) project
  - Characterized performance over an extreme propellant inlet condition range
  - Characterized pulsed mode operation
  - Investigated sensitivity to spark characteristics