National Aeronautics and Space Administration

Hydrocarbon Engine Development Activities

49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference

July 16, 2013

marshall

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SLS Advanced Booster

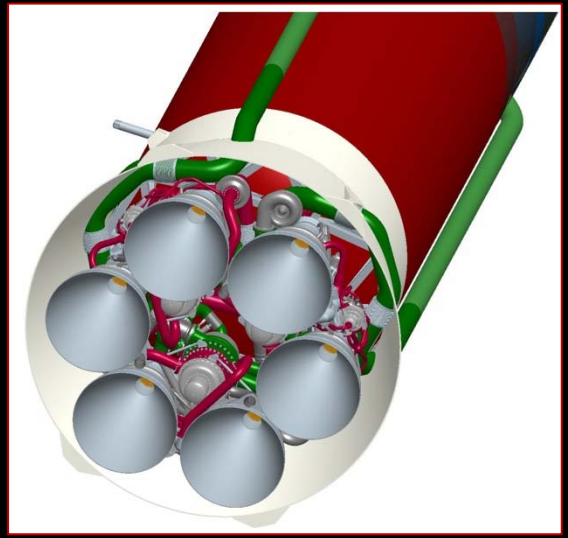
- SLS Program investigating potential hydrocarbon fueled systems for a future advanced booster

- Advanced Booster Engineering Demonstration and Risk Reduction (ABEDRR) building hardware and conducting tests

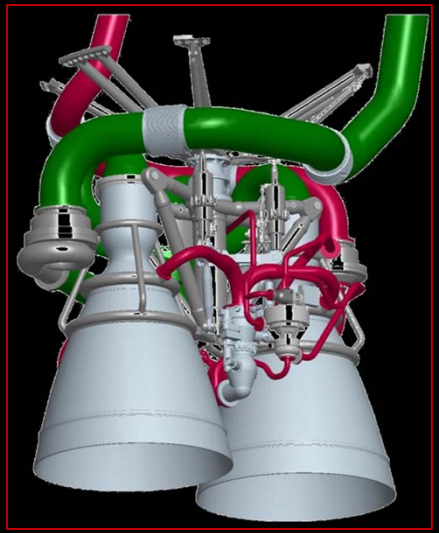
Aerojet Oxygen-Rich Staged Combustion

- **Proposed Booster:**
  - LOX/RP liquid engine booster
  - Engines – three 1.1Mlbf AJ1E6 engines per Advanced Booster
  - Oxygen Rich Staged Combustion cycle
- **Engine configuration:**
  - 1.1M lbf class Oxygen Rich Staged Combustion (ORSC) engine
    - Dual chamber design
- **Common engine solution for SLS, Atlas V, & Antares**

Three AJ1E6 engines in SLS configuration

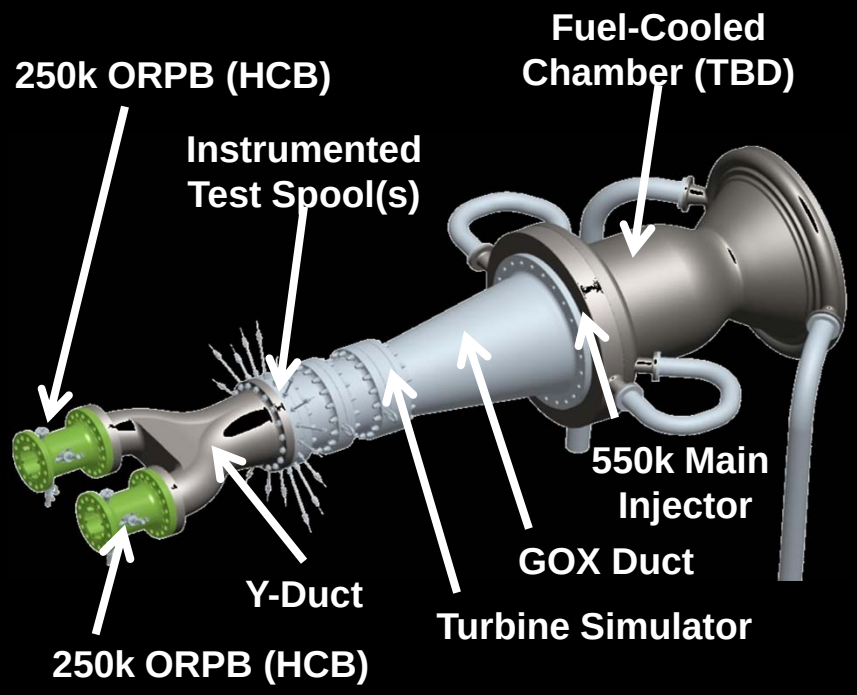


Single AJ1E6 in Atlas V configuration



Oxygen-Rich Staged Combustion Demo

- **Risk Reduction Task: Full scale combustion stability demonstration test (550 klbf thrust chamber)**
- **NASA and Air Force Collaboration**
  - NASA contract with Aerojet to fabricate and integrate test article
  - Air Force Research Laboratory (AFRL) to provide two oxygen rich preburners
    - Leverages and extends products from the AFRL Hydrocarbon Boost (HCB) program
- **Testing planned for FY16 at NASA Stennis test stand E-1**



Largest LOX/RP combustion stability test in U.S. since F-1A

Dynetics/PWR – Modernized F-1

- Gas Generator testing at Marshall complete
- Build simplified turbopump assembly
- Powerpack testing of GG and TPA at SSC spring 2016
- Build a modern Main Combustion Chamber spring 2015

F-1 Gas Generator Testing

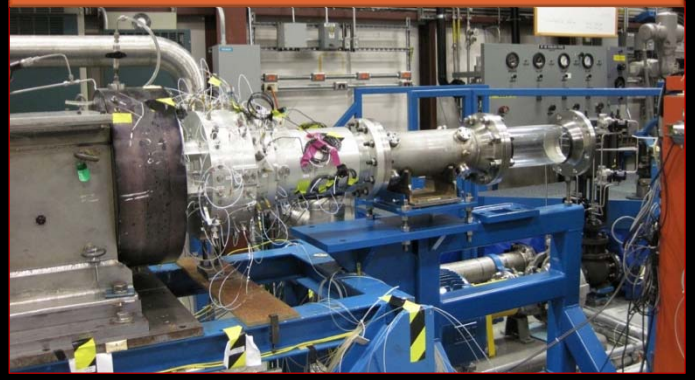
NASA and Air Force Collaboration on American Kerosene Engine

- NASA and USAF Space and Missile Systems Center (SMC) have partnered to study potential synergy on an American Kerosene Engine
- ABEDRR contractors to study extensibility of SLS Advanced Booster liquid engine concepts to AF EELV architectures
- Key study objectives –
  - Technical feasibility, DDT&E plans and risks
  - Cost and schedule estimates
- Results due late spring 2014

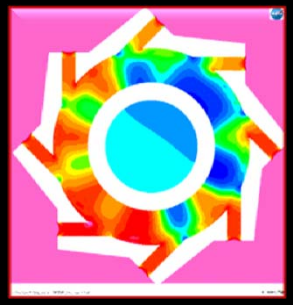
NASA & Air Force Collaboration on Hydrocarbon Boost Tech Demonstrator

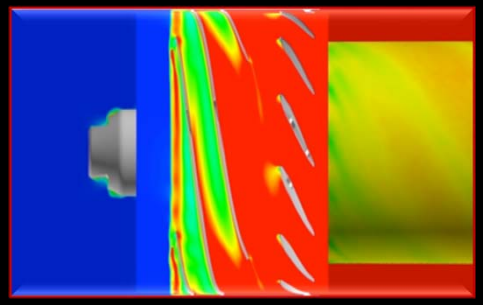
Partnership for water flow testing

NASA MSFC Inducer Test Loop Facility

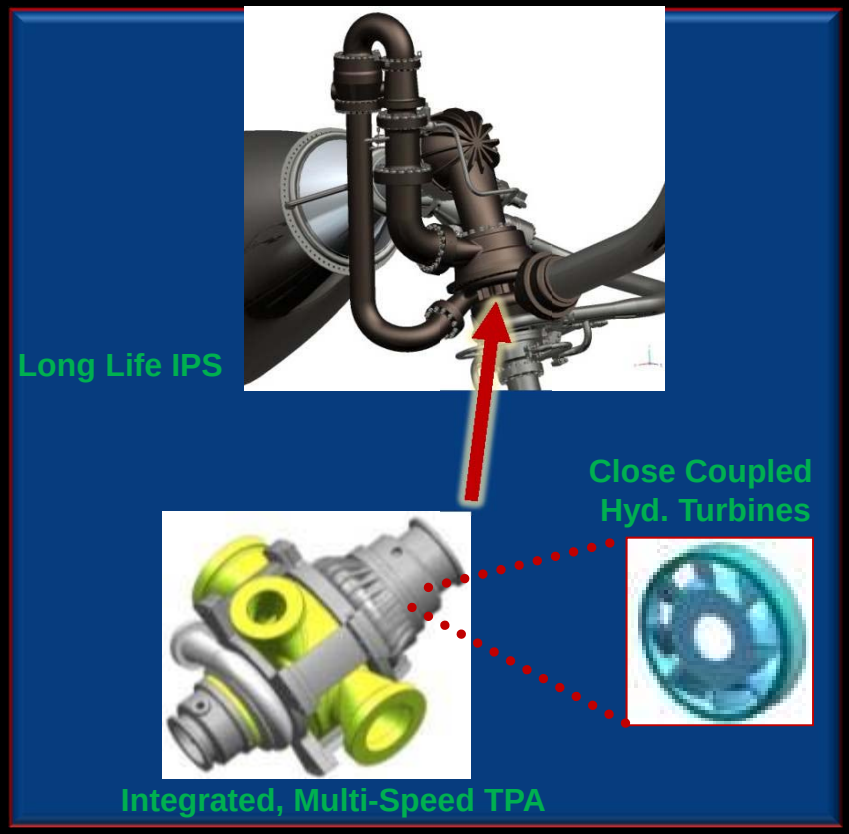


Collaborative modeling of liquid rocket engine environments



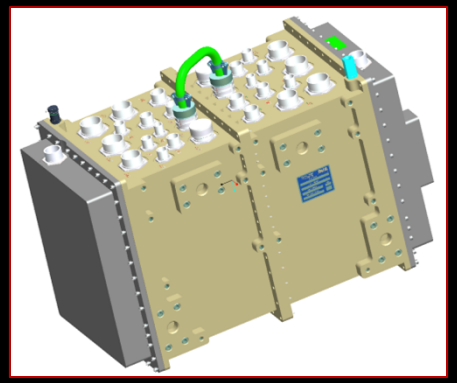


Leveraging technical NASA turbomachinery expertise



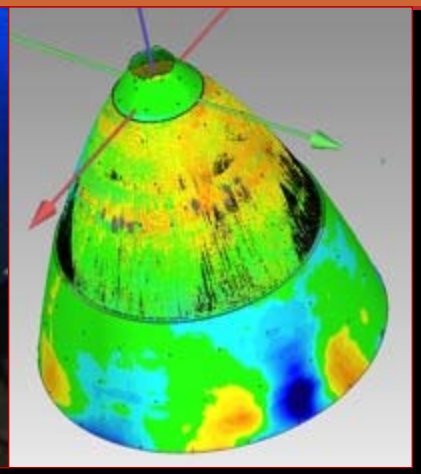
Engine Controller Long Range Vision - “Universal” Controller

- RS-25, J-2X, F-1 (candidate), etc.
- Single channel option
- Offers controller development efficiencies
- Reduces cost, schedule & development risk (design maturity)
- Economies of scale due to common parts across programs
- Configurable based on
  - Boards installed
  - Software loaded

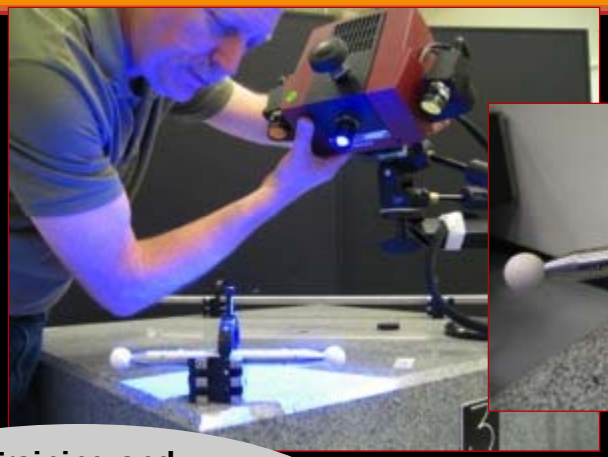


- Common Chassis/Backplane/Connectors
  - “Single Qual” option – populate with additional board types and Qual during a single Qual test
- Modular circuits
- Some common PWA designs between programs
- Modular software
- Common construction
- I/O & operation – tailored to specific program

Structured Light Scanning Development

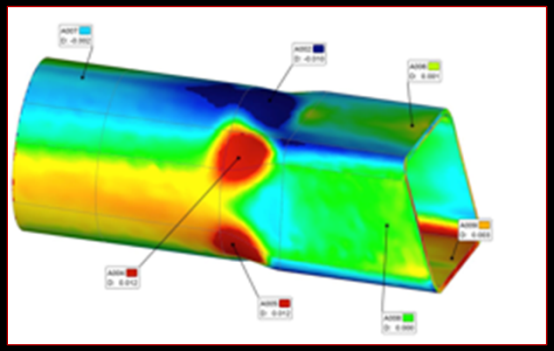


Replaced difficult measurements with scanning to help **reduce performance uncertainty** (throat and exit areas)

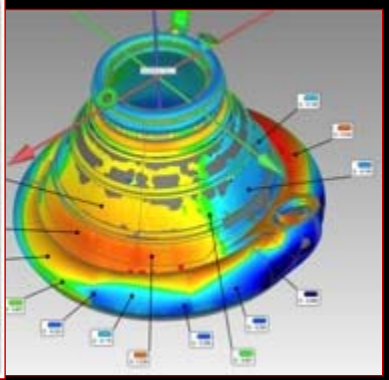


Training and Implementing as a new technique for Rocketdyne Personnel

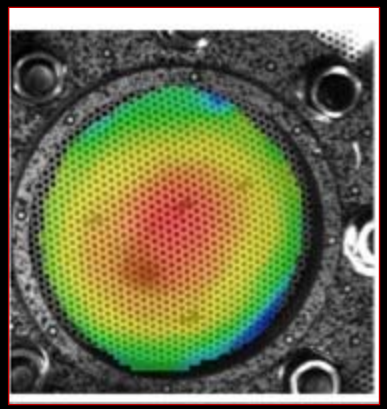
Completing study to advance structured light as a quality acceptance tool. **Implementing > 5:1 time savings.**



Structured light introduced to sub-tier vendors to modify tube dies to integrate **supply chain** (i.e. reduce turn around time for nozzle assembly



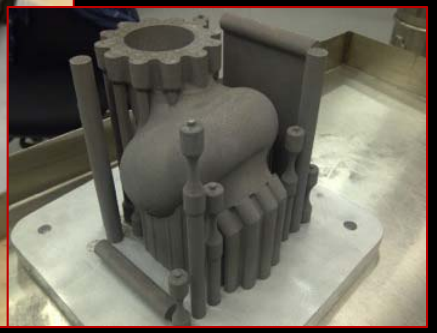
Structured light used to generate machining code and match machine at PWR

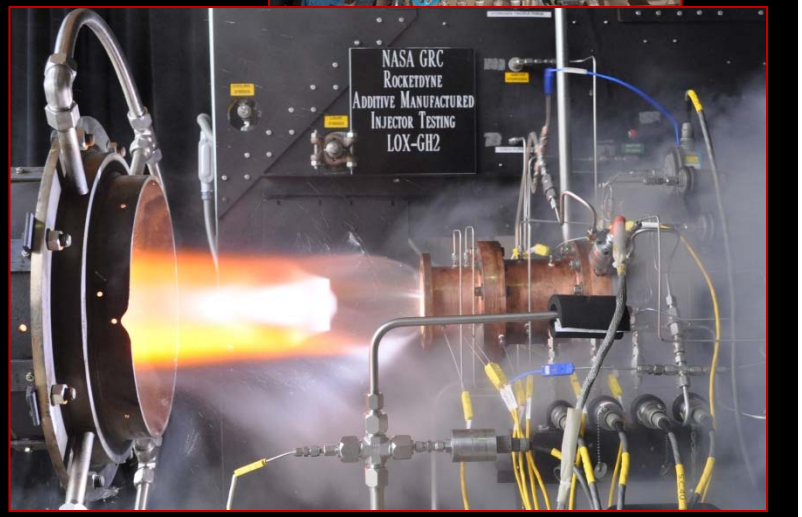


Developing new optical techniques to augment traditional engine measurements

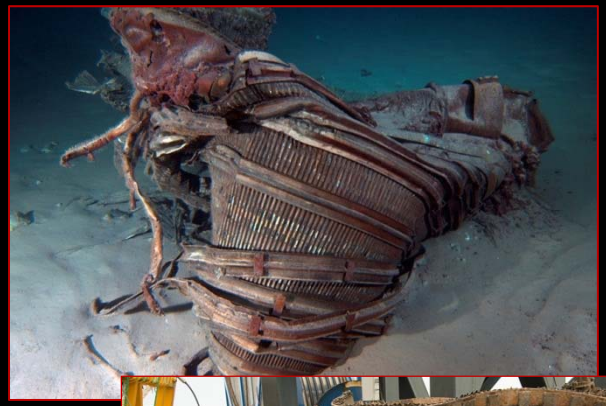
Reducing the Development Cycle for Hardware

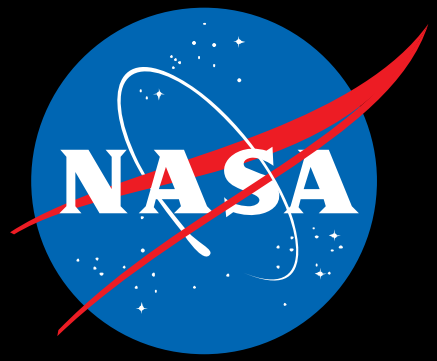
Selective Laser Melting Development





Ancient technology or youth movement?





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