

Advanced Booster Liquid Engine Combustion Stability

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Sponsoring Program(s)

Human Exploration and Operations Mission Directorate
Space Launch System Advanced Development

Project Description

Combustion instability is a phenomenon in liquid rocket engines caused by complex coupling between the time-varying combustion processes and the fluid dynamics in the combustor. Consequences of the large pressure oscillations associated with combustion instability often cause significant hardware damage and can be catastrophic. The current combustion stability assessment tools are limited by the level of empiricism in many inputs and embedded models. This limited predictive capability creates significant uncertainty in stability assessments. This large uncertainty then increases hardware development costs due to heavy reliance on expensive and time-consuming testing.

The objectives of this task are to advance the predictive capability of state-of-the-practice combustion stability methodologies and tools used for the Space Launch System (SLS) injector combustion stability assessment, facilitate more confident identification and characterization of combustion instabilities and efficient mitigation during SLS propulsion system development, and minimize SLS development costs and improve hardware robustness.

Notable Accomplishments

The following tasks have been accomplished: (1) Injector element design, scaling, testing, and computational fluid dynamics (CFD) simulation, including (a) element 1b—baseline element (testing is complete at both Air Force Research Laboratory (AFRL) (full-scale at 350–1,100 psia) and Purdue (subscale at 450 psia)); CFD analyses of both elements is complete; testing and CFD analysis at both scales showed an ~180 Hz chug instability; (b) element 1b4 (a redesign of element 1b to eliminate the chug instability; testing at AFRL is complete—both testing and CFD analysis indicate chug is still present, but at a considerably lower amplitude); and (c) element 1b5 (redesign of element 1b4 is being fabricated for testing at both AFRL and Purdue—CFD simulations indicate it should be stable; and (2) Demonstration of new capabilities on SLS Advanced Booster Engineering Design Risk Reduction (ABEDRR) injector, including 3D reacting flow CFD simulations of a seven-element representation of the ABEDRR injector completed (figs. 1 and 2), and data extracted from CFD simulations used to augment engineering stability assessment tools.

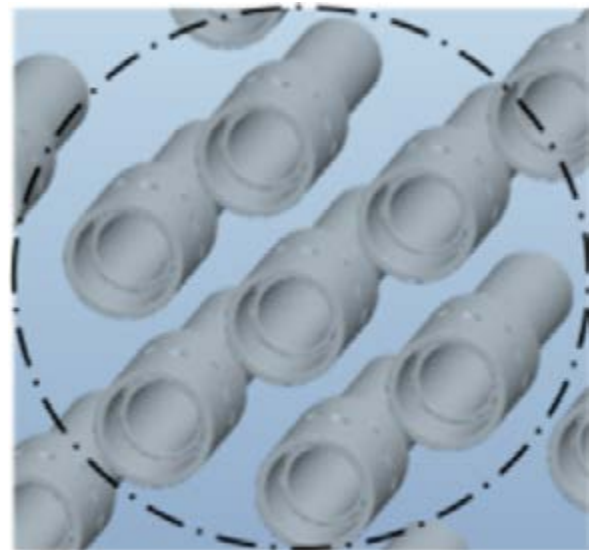


Figure 1. Seven elements from an ABEDRR injector.

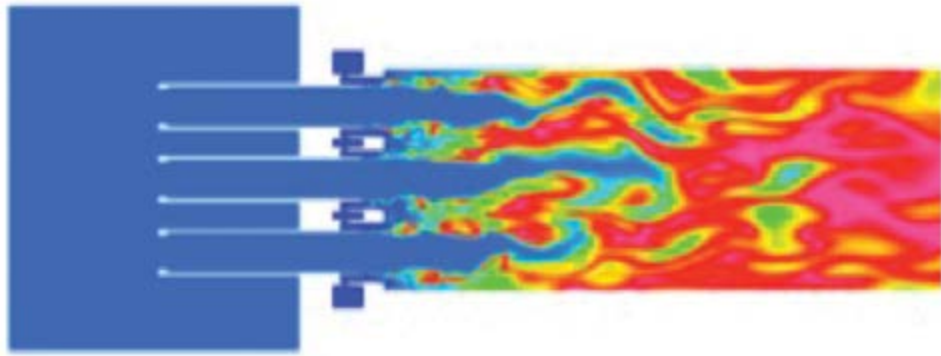


Figure 2. Two-dimensional cut of temperature field of seven-element injector.

References

Crumbly, C.M.; Bickley, F.P.; and Hueter, U.: "Space Launch System Spacecraft/Payloads Integration and Evolution Office Advanced Development FY 2014 Annual Report," NASA/TM—2015–218201, NASA Marshall Space Flight Center, Huntsville, AL, January 2015.