

## **Title: “CECE: Expanding the Envelope of Deep Throttling in Liquid Oxygen/Liquid Hydrogen Rocket Engines For NASA Exploration Missions”**

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As one of the first technology development programs awarded by NASA under the Vision for Space Exploration, the Pratt & Whitney Rocketdyne (PWR) Deep Throttling, Common Extensible Cryogenic Engine (CECE) program was selected by NASA in November 2004 to begin technology development and demonstration toward a deep throttling, cryogenic engine supporting ongoing trade studies for NASA’s Lunar Lander descent stage. The CECE program leverages the maturity and previous investment of a flight-proven hydrogen/oxygen expander cycle engine, the PWR RL10, to develop technology and demonstrate an unprecedented combination of reliability, safety, durability, throttability, and restart capabilities in a high-energy cryogenic engine.

The testbed selected for the deep throttling demonstration phases of this program was a minimally modified RL10 engine, allowing for maximum current production engine commonality and extensibility with minimum program cost. Three series of demonstrator engine tests, the first in April-May 2006, the second in March-April 2007 and the third in November-December 2008, have demonstrated up to 13:1 throttling (104% to 8% thrust range) of the hydrogen/oxygen expander cycle engine. The first two test series explored a propellant feed system instability (“chug”) environment at low throttled power levels. Lessons learned from these two tests were successfully applied to the third test series, resulting in stable operation throughout the 13:1 throttling range. The first three tests have provided an early demonstration of an enabling cryogenic propulsion concept, accumulating over 5,000 seconds of hot fire time over 27 hot fire tests, and have provided invaluable system-level technology data toward design and development risk mitigation for the NASA Altair and future lander propulsion system applications.

This paper describes the results obtained from the highly successful third test series as well as the test objectives and early results obtained from a fourth test series conducted over March-May 2010.