Future Robotic Lander Attitude Control and Descent Thruster Testing

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A series of thruster tests in support of the Robotic Lunar Lander Development (RLLD) Program were successfully completed in September 2010 at NASA Johnson Space Center's White Sands Test Facility (WSTF). The RLLD Program is a collaborative effort by NASA's Marshall Space Flight Center (MSFC), Johns Hopkins University Applied Physics Laboratory (Laurel, Md.), and Pratt & Whitney Rocketdyne (Canoga Park, Calif.). The program's objective is to develop the next generation of robotic lunar landers that NASA will use to enable future exploration of the moon's surface and the surface of other celestial bodies with little to no atmosphere. The thrusters tested will be used to maneuver and land the golf-cart-sized robotic landers.

The two thrusters tested were considered to be high thrust-to-weight ratio thrusters. One of the thrusters was a 100-pound-class thruster, which will be used for spacecraft control during descent operations. The other thruster was a 5-pound-class thruster and will be used for attitude control in the roll, pitch, and yaw degrees of freedom. These miniaturized thrusters were selected to meet the requirement of reducing overall spacecraft mass due to their light weight and ability to be integrated in a compact manner. Additionally, the requirement to reduce the mission cost was met as these thrusters were existing hardware obtained from the Divert and Attitude Control System (DACS) developed by the U.S. Missile Defense Agency of the Department of Defense.

The tests performed at WSTF were a critical step in reducing the propulsion technology risks associated with MSFC's robotic lander mission. The objective was to use the testing results to develop future plans associated with the lander's propulsion system design. Specifically, the fact that the thrusters were originally used for short-duration flights, and had not been qualified for space missions under the DACS program, made testing necessary to assess their capability for long-duration burns. The tests were also performed to evaluate thruster performance and combustion behavior in a simulated space environment with representative lunar mission profiles developed by the RLLD Program.

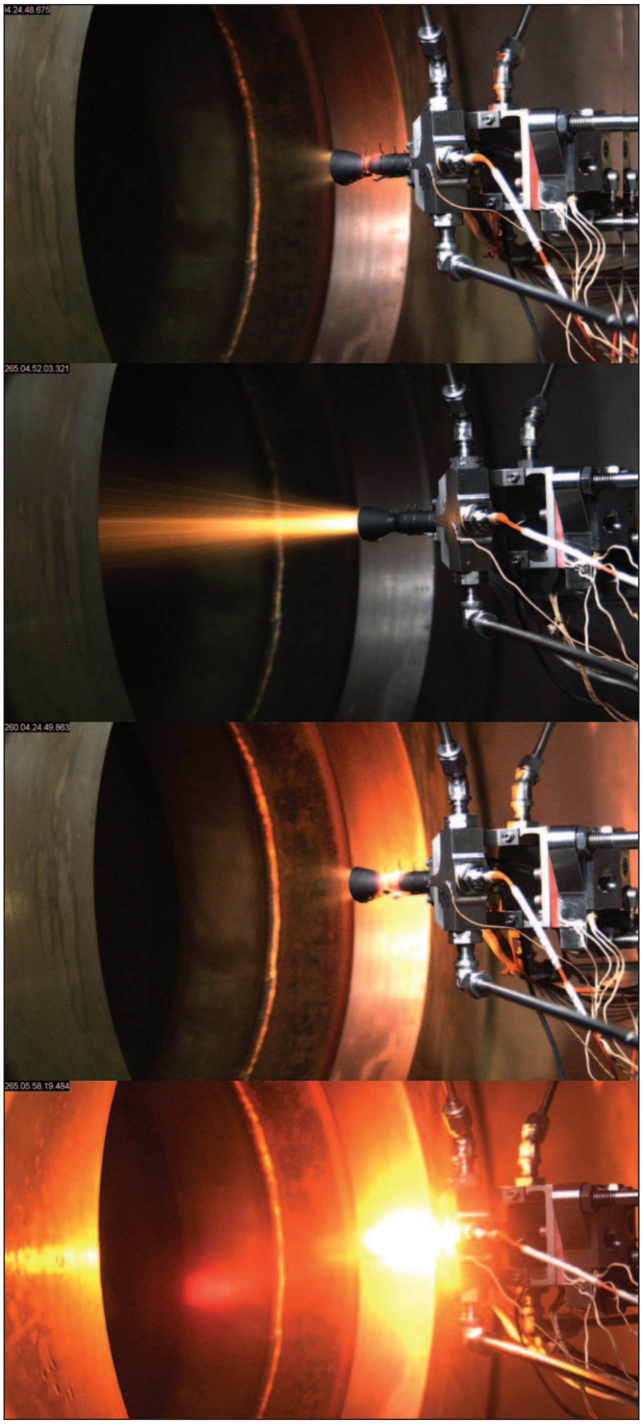

Fig. 1. *5-pound-class hot-fire test in Test Stand 406 at White Sands Test Facility.*

Thruster Testing

Engineers tested both thrusters in Test Stand 406 at WSTF. They selected this test stand for use due to its ability to provide an environment with little to no atmosphere through the use of the facility's vacuum pump system and Small Altitude Simulation System. The test stand's existing hypergolic propellant feed systems that were in place from the space shuttle Vernier Reaction Control System and Primary Reaction Control System fleet lead and qualification testing easily accommodated the 100-pound-class thruster testing. However, the 5-pound-class thruster testing required some modifications to the hypergolic feed systems. WSTF's expert technicians and engineers worked diligently to modify the system. The modifications involved rebuilding the interfacing system between the test article and the monomethylhydrazine (MMH) and nitrogen tetroxide mobile skids, which both have maximum allowable operating pressures of 1500 pounds per square inch (psi).

Additionally, engineers made modifications to the thrust stand to which the thruster was mounted to accommodate the 5-pound-class thruster's high-frequency pulsing mission duty cycle. They performed modal testing of the thrust stand to identify areas of the stand that required stiffening. This was done to ensure that the thruster's pulsing frequency was not near any of the thrust stand's resonant frequencies, as this situation could have led to over excitation of the thrust stand and resulted in structural damage.

Firing a pressure sweep from approximately 3.5 to 10 torr was achieved during tests of the 100-pound-class thruster using the facilities' small altitude simulation system, which strictly used the venturi effect to reduce test cell pressure. The pressure sweep in the test cell met the requirements levied by the RLLD Program, and mimicked the project's lander mission profile and operation scenarios. The test included the following: several trajectory correction maneuvers during the cruise phase; nutation control burns to maintain spacecraft orientation; thruster vector correction during the solid motor braking burn; and a terminal descent burn on approach to the lunar surface.

A simulated altitude of approximately 48,800 m (~160,000 ft) was obtained for the 5-pound-class thruster testing by using the facility's vacuum pump system (figure 1). The objective for the 5-pound-class thruster test was similar to the 100-pound-class thruster test with an additional emphasis on the thruster heating assessment due to the long-duration mission profile and operation with MMH fuel and a nitrogen tetroxide (75%)/nitrogen oxide (25%) (MON-25) oxidizer. Because the MMH/MON-25 propellant system has never been used in space, these tests allowed engineers to benchmark the test against other propellant systems.

The test program fully accomplished its objectives, including evaluation of combustion stability, engine efficiency, and the ability of the thruster to perform the mission profile and a long-duration, steady-state burn at full power. Stable combustion was exhibited in all scenarios and favorable temperature results were attained. The test results will allow the RLLD Program to move forward with robotic lander designs using advanced propulsion technology.