NASA's Robotic Lunar Lander Development. D.G Chavers[1] and C. D. Author[2], [1]NASA Marshall Space Flight Center (greg.chavers@nasa.gov) , [2]J. B. Olansen, NASA Johnson Space Center (Jon.Olansen@nasa.gov), [3]C.L.B. Reed, John Hopkins University Applied Physics Laboratory (Cheryl.reed@jhuapl.edu), D.J.Eisenman, Jet Propulsion Laboratory (david.j.eisenman@jpl.nasa.gov)

Introduction: NASA's Resource Prospector (RP) Mission to the Moon brings together the lander development efforts under the Science Mission and Human Exploration Directorates. The RP Mission will be the first In-Situ Resource Utilization (ISRU) demonstration on the lunar surface. RESOLVE is a miniature drilling and chemistry plant packaged onto a medium-sized rover to collect and analyze soil for volatile components such as water and hydrogen that can be used for human exploration efforts.

Background: Over the past seven years, NASA has invested in development and risk-reduction for a new generation of small-medium planetary landers capable of carrying instruments and technology projects to the lunar surface. NASA Marshall Space Flight Center (MSFC) and the John Hopkins University Applied Physics Laboratory (APL) have jointly implemented the robotic lander development. The project has made significant investments in technology risk reduction in focused subsystems. In addition, many lander technologies and algorithms have been tested and demonstrated in an integrated systems environment using the Mighty Eagle free-flying vertical test bed. These design and testing investments have significantly reduced development risk for lander, thereby reducing overall risk and associated costs for future missions.

Since 2010, the NASA Johnson Space Center (JSC) has been developing a vertical test bed to demonstrate autonomous landing and hazard detection technology and demonstrate green propellant propulsion systems. Work on several systems began in 2006, when NASA's focus was to plan a human return to the Moon (known as the Constellation Program). Morpheus is a large lander, and is designed to deliver 500 kg or more of cargo to the lunar surface. Morpheus utilizes a quad configuration liquid oxygen and liquid methane propulsion system. This propellant combination is of great interest and extensible to human exploration. It is possible that the Moon's resources could be utilized to someday produce this propellant from the lunar surface. Since the first hot fire in 2011, the Morpheus test vehicle has progressed to free-flight testing at the Kennedy Space Center.

SMD Lander Risk Reduction Status: Many of the risk reduction activities started during the International Lunar Network lander development have been completed [1]. Three of the activities have not completed yet and these include: 1) real time battery testing for 72 lunar day/night cycles, 2) variable conductance heatpipe (VCHP) design and demonstration, and 3) fabrication and testing of 100 lbf thrusters that operate using MMH/MON25. This propellant combination is of interest since it has a freezing point of – 52 C (as opposed to -11 C for conventional oxidizer). The lower freezing and operational temperature allows reduced heater power requirements for long duration missions. Two of these In-Space Engines (ISE100) are currently being fabricated as development units.

Low Cost Robotic Lunar Lander Status:

The lander teams have merged to develop a low cost robotic lander concept for the Resource Prospector Mission. During 2013, MSFC, JSC, APL, and JPL have begun integrating activities to develop a low cost lunar lander for delivering up to 400 kg of payload to the lunar surface, specifically for the Resource Prospector Mission.

The RP lander architecture is cost driven (design to cost) and the lander has minimal functionality once landed. This RP lander concept combines efforts from the International Lunar Network risk reduction activities, including the Mighty Eagle vertical test bed, and the Morpheus vertical test bed.

The RP lander will deliver the payload following trans-lunar injection (TLI) to the lunar surface after a nominal 5 day transit followed by direct descent. A solid rocket motor provides the braking to remove most of the delta V during initial descent. The empty solid casing is ejected and the remaining delta V is removed by a liquid propulsion system using sixteen RS34's. These are grouped in a quad configuration of four thrusters. The thruster mounting bracket and propellant manifold have been designed. NASA is currently receiving the RS34's from the Air Force and will be hot-fire testing a single thruster at White Sands Test Facility in November, 2014. Flight Software and GN&C uses existing architectures from Morpheus and Mighty Eagle. This reduces cost and risk. The 100 meter radius precision landing is accomplished using Terrain Relative Navigation (TRN) via optical techniques. The primary structure is a riveted sheet metal construction and arrives to the lunar surface with the rover situated on top similar to a pallet. The rover egresses from the lander using small fixed ramps (non-deployable) on either side of the lander. A pathfinder primary structure has been designed and fabricated for initial integration and interface definition. The flight structure is currently being designed. The avionics system leverages the existing design from LADEE. Landing site hazard analysis has been performed in the south pole regions to determine probability of success landing without using active hazard avoidance.