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Space resources

This year marked some significant changes in the NASA in-situ resource utilization (ISRU) project. The first change was renewed interest in development of the RESOLVE (regolith and environment science and oxygen and lunar volatile extraction) experiment to characterize lunar polar ice/volatiles and perform subscale oxygen extraction from regolith. The second change was the transition of technology development from the ETDP (exploration technology development program) to the ETDDP (enabling technology development and demonstration program) at the start of FY11.

Students at the University of Texas at El Paso investigated self-sustained combustion of JSC-1A lunar regolith simulant mixed with magnesium on a reduced gravity aircraft flight.

Development work on the third generation of RESOLVE began in June. The goal is to build a prototype unit that meets the expected lunar environmental and flight requirements by 2014. RESOLVE is being developed by four NASA centers (Kennedy, Johnson, Ames, and Glenn) in collaboration with the Canadian Space Agency (CSA) and its contractors: the Northern Center for Advanced Technologies, Neptec, and Xiphos. The Phase I effort will develop a RESOLVE unit that will undergo analog field testing in 2012, but the unit will meet as many of the lunar environment and mission requirements as possible. Phase II will refine the design to operate under simulated lunar environmental (vacuum and temperature) conditions.

The RESOLVE Phase I unit completed its preliminary design review (PDR) in May and its critical design review (CDR) in July. The unit will be tested on both a NASA and CSA rover, including an upgraded version of the Juno rover demonstrated at the 2010 analog field test on Mauna Kea. The analog field test will stress both the hardware and mission operations by simulating two different five-to-seven-day missions to the lunar poles with remote operations from both NASA and CSA centers.

Although ETDP focused solely on supporting lunar exploration and the Constellation program, the ETDDP scope includes other destinations of potential interest for human exploration, such as Mars and near-Earth objects. Several technologies to extract oxygen from regolith were successfully demonstrated in two previous analog field tests, so two new efforts were initiated over the past year to support the broader goal of exploring multiple destinations.

The larger of the new efforts is the Marco Polo project, which integrates atmospheric and soil-based ISRU with fuel cell power and cryogenic/gas storage to simulate a possible Mars ISRU demonstration on a 3-m-diam. lander. Marco Polo completed its PDR in April and its CDR in September with the goal of a field test in NASA Johnson's Mars 'rockyard' in August 2012. The other new effort is trash/waste processing to manufacture fuel.

Honeybee Robotics developed the LunarVader drill to obtain subsurface water-ice and mineral samples. The LunarVader was successfully tested to a depth of 1 m in a vacuum chamber with various formations, including a water-saturated lunar regolith simulant (JSC-1A) at -80 C, pure water-ice, and rocks. The system was also field tested in the lunar analog site on Ross Island near Antarctica. During the vacuum chamber and field testing, the LunarVader demonstrated drilling to 1 m in approximately 1 hr with roughly 100-W power and less than 100-N weight on bit. This corresponds to a total drilling energy of approximately 100 W-hr.

The NASA-sponsored Center for Space Exploration Technology Research at the University of Texas at El Paso (UTEP) demonstrated self-sustained combustion of JSC-1A lunar regolith simulant mixed with magnesium. This process could potentially be used to produce structural materials on the Moon. In June, UTEP's student team also investigated this process onboard reduced-gravity research aircraft at NASA Johnson.

by **Robert Gustafson**