December 2009

AEROSPACE AMERICA

2009

The year in review

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

11 AEROSPACE AMERICA DECEMBER 2009

AIAA

Space resource utilization

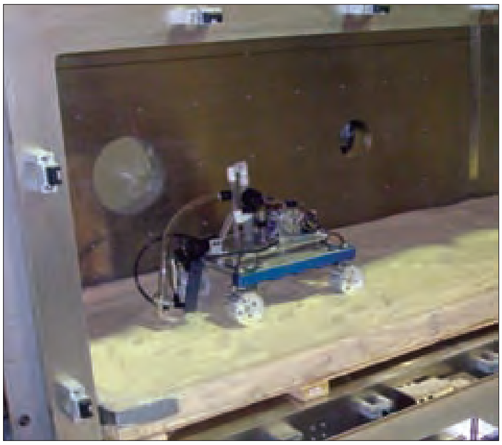
The ability to use local resources will be an enabling technology for future exploration of the Moon and beyond. This year was very exciting and marked important achievements for several lunar resource utilization technologies.

A field demonstration was held at the lunar analog test site on the slopes of Mauna Kea, Hawaii, from November 1 to 16. The test site, operated by PISCES (Pacific International Space Center for Exploration Systems), is located at an elevation of 9,000 ft and serves as a lunar analog in terms of terrain and soil composition. The RESOLVE, ROxygen, and PILOT projects all successfully operated prototype systems during the field demonstration.

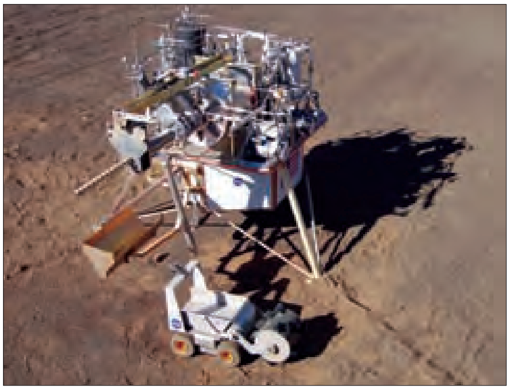
The RESOLVE system combined a rover and a drill to identify and extract water ice and volatile gases such as hydrogen, helium, and nitrogen that may exist in the permanently shadowed craters of the Moon's poles. Equipment from the Northern Centre for Advanced Technology extracted and crushed core drill samples that were then heated in a high-temperature reactor from NASA Glenn. The products released from the samples were analyzed using a gas chromatograph and captured with absorbent beds provided by NASA Kennedy and Johnson. The entire system was mounted aboard a rover built by Carnegie Mellon University. The field demonstration tested the capabilities of all the systems in this lunar prospector in a full end-to-end (roving, drilling, processing) operation.

The ROxygen project conducted by Johnson and Kennedy and the PILOT project from Lockheed Martin both demonstrated prototype systems to extract oxygen from lunar regolith using the hydrogen reduction process at a scale large enough to support a lunar outpost. During the test, Glenn's CRATOS rover was used to collect and deliver soil to the ROxygen system for processing. Lockheed Martin used a bucket drum excavator to collect and deliver soil to the PILOT system for processing. Both projects successfully extracted oxygen from the test site soil.

Two alternative methods to extract oxygen from the lunar regolith were also further developed. ORBITEC demonstrated the first carbothermal reduction of lunar regolith simulant to produce oxygen using direct solar energy. The carbothermal reactor is designed to be operated remotely and is scaled to produce oxygen at a rate of 1 MT/year. Physical Sciences built the hardware to collect and transmit the concentrated solar energy to the reactor through fiber optic cables. The integrated system will be tested at the PISCES lunar analog test site in February 2010.



The Honeybee Robotics/NASA Kennedy pneumatic mining system was tested on a NASA Ames robotic rover in a vacuum chamber with GRC-1 lunar soil simulant.



The PILOT system and the Lockheed Martin bucketwheel excavator were field tested.

Molten Regolith Electrolysis, a joint NASA/ASRC Aerospace/MIT/Ohio State University project, accomplished electrowinning of silica with an inert anode and performed withdrawal of molten ferrosilicon alloy from the reactor.

Five NASA in-situ research utilization projects were awarded reduced gravity aircraft flights under the FAST (Facilitated Access to the Space Environment for Technology Development and Training) program. These projects studied size sorting methods and hopper design assisting regolith flow using a pulsed magnetic field, tribocharged beneficiation of regolith, a pneumatic regolith transport device with electrostatically enhanced cyclone separators, and gas fluidization in a mock reactor. All projects were successfully tested. The data are being analyzed and the results are feeding directly into the next-generation ISRU oxygen production plants.

Honeybee Robotics, partnered with NASA Kennedy, developed pneumatic and percussive approaches to regolith excavation and transport. The pneumatic approach utilizes low-pressure gas to sort and loft regolith particles over long distances, while the percussive approach uses a high-frequency hammer to drive a scoop into regolith or push a dozer blade across the regolith surface. The main advantages of the pneumatic system are its lack of moving parts and high efficiency. The percussive system significantly reduces the excavation force required.

by **Robert Gustafson**