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SHAPING THE FUTURE OF AEROSPACE

Space resources community sets sights on the moon

BY MICHAEL HECHT, FORREST MEYEN AND LAURENT SIBILLE

The **Space Resources Technical Committee** advocates affordable, sustainable human space exploration using nonterrestrial natural resources to supply propulsion, power, life-support consumables and manufacturing materials.

The space resources community this year took steps to respond to the new focus on lunar missions embraced internationally and in the U.S. by White House Space Policy Directive 1 issued in late 2017. Also, decisive investments were made by large launch services companies and small start-ups intent on creating a cislunar economy using space resources. In September, the Luxembourg Space Agency was founded in part to focus on the expansion of the country's space resources initiative in cooperation with a new European Space Agency program on space resources. NASA endorsed the importance of resource utilization in its exploration planning. "We are continuing to learn about our Moon and the value its resources can provide for human exploration," said Jason Crusan, NASA's director of advanced exploration systems, in a May press release.

Among this year's research, **Contour Crafting Corp. demonstrated 3D printing of large concrete structures** in collaboration with NASA's Kennedy Space Center in Florida, Marshall Space Flight Center in Alabama and the U.S. Army Corps of Engineers. Competitors in NASA's 3D-Printed Habitat Centennial Challenge continued aiming to build full-scale structures with lunar regolith simulant. Honeybee Robotics of California in February tested its 1-meter-class drill TRIDENT (short for Regolith and Ice Drill for Exploration of New Terrain) deployed from KREX-2 rover in the Atamaca Desert of Chile with partner NASA's Ames Research Center of California. The device could someday drill for water ice on the moon. The University of Texas at El Paso demonstrated combustion joining of ceramic tiles made from regolith simulant while Michigan Technological University completed feasibility tests of water-jet excavation of gypsum for water production on Mars.

Heriot-Watt University, Scotland and European Astronaut Centre, Germany

Glass mirrors were made from simulated lunar regolith, possibly for use in a solar concentrator.

Developments in the in-situ resource utilization field also took place in the European Union, including work on the Lunar Volatiles Mobile Instrumentation rover. **In Belgium and Germany, scientists and engineers developed demonstration payloads for a commercial ISRU mission to be led by the European Space Agency**. Project RegoLight, in which researchers will attempt to 3D manufacture structures from lunar regolith, demonstrated sintering under vacuum with concentrated solar light. Meanwhile, Heriot-Watt University in Scotland used lunar regolith simulant to manufacture glass mirrors suitable for solar concentrators. Ispace, a Japanese company looking to exploit lunar water resources, finalized a $94.5 million Series A funding round in February and is planning a moon landing in 2021. In October, the company announced a partnership with Draper of Massachusetts to provide lunar landing guidance navigation and control software.

Mars isn't forgotten in NASA's ISRU plans either. **Engineers in October completed assembly of the Mars Oxygen ISRU Experiment, MOXIE, a 1:200 scale model of a device that might one day provide astronauts with oxygen propellant for their Mars ascent vehicle.** It's on track for delivery to the Mars 2020 rover by January 2019 for the first extraterrestrial ISRU demonstration in 2021. OxEon Energy LLC of Utah started development of a full-scale solid oxide electrolysis system, adding co-electrolysis of CO_2 and H_2O to produce O_2, CO, H_2, and ultimately CH_4 fuel. In May, NASA announced that OxEon Energy is among 10 companies and a university that will conduct studies and advance technologies to collect, process and use space-based resources for missions to the moon and Mars under the Next Space Technologies for Exploration Partnerships-2, NextSTEP-2, Broad Agency Announcement. Elsewhere, NASA is testing dust filters, carbon dioxide freezers and sorption pumps, solid oxide electrolyzers, Sabatier catalysts, excavation tools, and systems for extracting water from icy and hydrated soils on Mars.

A bellwether of the maturation of the field was the September debut at the Colorado School of Mines of the first graduate program focused on the exploration, extraction, and use of space resources. ★