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2019

YEAR IN REVIEW

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AIAA
SHAPING THE FUTURE OF AEROSPACE

International momentum for space resources ramps up

BY LAURENT SIBILLE AND FORREST MEYEN

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 MiniRASSOR** and the larger RASSOR 2.0, low-gravity excavators designed for educational outreach. NASA

The international focus on space resources is shaping the return to surface exploration of the moon and future exploration of Mars. High-level agreements of cooperation in space, including the **utilization of space resources** signed by Luxembourg with Belgium in January and with the United States in May followed by European Space Agency's **Space Resources Strategy** paved the way to agency-level agreements by Luxembourg Space Agency with NASA and ESA in October. The same month, Luxembourg Space Agency announced the establishment of a **space resource research center**.

This year also saw landing attempts on the lunar surface, including the **first far-side landing**, by China's Chang'e-4 in January. Communications failures in final approach plagued the attempts by **Israel's Beresheet** in April and **India's Vikram** in September that aimed at being the first to detect water ice in the subsurface.

In February, NASA's Science Mission Directorate selected three small agency-provided payloads specific to the detection of **water ice in the lunar polar geologic context** to be carried by the **Commercial Lunar Payload Services program, or CLPS,** under the **Artemis** program. The Near-Infrared Volatile Spectrometer System will image surface and subsurface hydration and surface composition of carbon dioxide and methane, and the **Neutron Spectrometer System** and the **Advanced Neutron Measurements at the Lunar Surface** will measure hydrogen abundance and bulk regolith composition.

Open University in August demonstrated water production by reacting **Apollo soil samples** with hydrogen in the ProSPA miniature laboratory for an ESA lunar resource prospecting payload to be carried by the Roscosmos Luna-27 mission planned for 2025.

NASA's Glenn Research Center in Cleveland and Honeybee Robotics of New York concluded tests in September of the **Polar Resources Ice Mining Experiments, or PRIME-1.** This was done in a simulated lunarlike cryogenic temperature and hard vacuum to integrate operations of TRIDENT, The Regolith and Ice Drill for Exploring New Terrain, with the Mass Spectrometer Observing Lunar Operations for the lunar volatiles prospector payload in the CLPS program.

Our knowledge of water on Mars increased in 2019 with new results published in March by two teams of **NASA's Mars Water Mapping Projects**. The Subsurface Water Ice Mapping project at the Planetary Science Institute in Arizona produced a northern hemisphere map showing **shallow ice deposits** (within 0 to 5 meters of the subsurface) extending equatorward as far as 30 degrees north latitude in some places. Researchers at JAXA, the Japan Aerospace Exploration Agency, and the University of Paris published the first global map characterizing and mapping the surface geometry and abundance of **several hundred thousand hydrated mineral sites**, dwarfing previous maps displaying on the order of 1,000 sites.

The **Mars Oxygen In-situ Resource Utilization Experiment, or MOXIE**, was installed in the **Mars 2020 rover** in March for a launch window opening in July 2020. NASA's Planetary Science and Technology from Analog Research-funded robotic deep wireline drill, the Wireline Analysis Tool for Subsurface Observation of Northern Ice Sheets from Honeybee Robotics, reached the depth of 111 meters in Greenland equipped with the **Deep UV/Raman spectrometer** developed by NASA's Jet Propulsion Laboratory. In August, the **NASA ISRU Technology Project** team completed many critical hardware tests on scroll pumps, scroll dust filter, electrolyzers with salts-contaminated water, digging forces in compacted granular material and including an integrated design study of a full-scale oxygen production mission using carbothermic reduction of lunar polar regolith. In May, NASA's Kennedy Space Center's Swamp Works completed endurance performance tests of its **low-gravity excavator RASSOR 2.0** and created MiniRASSOR, a miniature offspring in collaboration with a University of Central Florida student navigation team.

Innovations in materials processing advanced **in-situ construction technologies** of landing pads, habitats and other long-term off-Earth structures. In May, NASA concluded the third phase of its **3D-printed space habitat challenge**. New York-based team AI SpaceFactory took home the $500,000 grand prize for its Martian habitat dubbed "Marsha." Early in the year, researchers at the University of Canterbury, New Zealand, published the development of a magnesia-silica binder system that can be produced from Martian basaltic materials with similar properties to Portland cement. Pacific International Space Center for Exploration Systems produced high-strength defect-free basalt tiles with Hawaiian materials. ★