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CO_2 Watchdogs

Monitoring carbon dioxide emissions from orbit could someday hold polluters accountable. Will the US participate?

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AIAA Shaping the Future of Aerospace

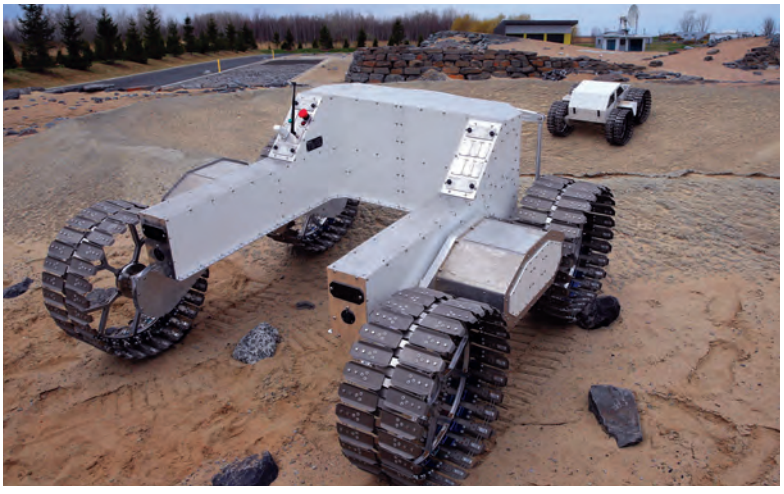
Testing resource utilization

BY JULIE KLEINHENZ

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

Growing interest in **in-situ resource utilization**, spurred activity in the space resources community in 2016. Lunar and Martian resources are of continued interest for human missions and outposts, and there is a growing focus on asteroid resources.

On the moon, the target resource is the water-ice that has been detected in permanently shadowed craters at the polar regions. Characterizing these resources is the focus of **NASA's Resource Prospector**, RP, rover mission and the European Space **Prospect drilling and sampling package** Technology development continues for these potential missions. In May, RP was put through its fourth thermal vacuum test at the NASA Glenn Research Center's Planetary Surface Simulation Facility. The drill (from Honeybee Robotics), the spectrometer (NASA's Ames Research Center), and sample crucibles (NASA's Kennedy Space Center) were tested with water-doped, frozen, lunar regolith simulant. These tests continue to refine hardware development, concepts of operations, and volatiles-detection methods. Meanwhile, the Canadian Space Agency accepted delivery of two lunar rover prototypes from contractor Ontario Drive and Gear. The larger one measures 1.6 meters X 1.6 m, has a mass of 112 kilograms, and a 1G payload of 160 kg, while the smaller 90 kg rover has a footprint of 1.2 m X 1.2 m and a 50 kg payload. Both platforms have a drivetrain that was subjected to dusty thermal vacuum testing at NASA's Glenn Research Center to achieve **Technology Readiness Level-6**.



▼ **The Canadian Space** Agency's Lunar Rover Drivetrain Prototype, foreground, and Small Planetary Rover Platform were driven across the agency's Mars yard near Montreal in 2016 to simulate conditions on the moon. Ontario Drive and Gear delivered the vehicles in April.

NASA's exploration plans are increasingly including ISRU. **NASA's Human Architecture Team** conducted system level studies to examine the impact of incorporating full-scale ISRU systems into human missions (namely the Evolvable Mars Campaign) using atmospheric and ground water resources. Likewise, the **Mars Water In-Situ Resource Utilization Planning** study led by NASA's Science Mission Directorate leveraged university, NASA, and commercial partners to identify potential Mars resources and the instruments and data still needed to fully characterize them for ISRU use. The NASA Capability Leadership Team continues to assess and plan for facilities and resources needed for future ISRU efforts, and a potential ISRU technology development program is in formulation under NASA's Advanced Exploration Systems.

NASA's Mars 2020 mission will include the **Mars Oxygen ISRU Experiment**, or MOXIE, payload that will demonstrate ISRU technologies to convert Mars atmospheric carbon dioxide into oxygen. Led by MIT, MOXIE completed instrument preliminary design review in January and is now working toward delivery in May 2018. Mars 2020 is the first mission that will fly an ISRU payload.

Asteroid resources are the focus of three university-led projects under NASA Early Stage Initiative awards, now in their second year. The **Robotic In-situ Surface Exploration System** (RISES) project at the University of West Virginia is looking at robotic systems and non-destructive tests for the strength of asteroid materials. At Missouri University of Science and Technology and the Colorado School of Mines, work is focused on volatiles extraction and capture, while Stanford University is examining characterization of asteroids using impact plasma detection.

On the commercial side, several companies are pursuing asteroid resources. Planetary Resources, Inc., PRI, has shipped their **A6 satellite**, a 6-unit cubesat that will demonstrate technologies to measure resources on water-rich asteroids, to Vandenberg Air Force Base with a scheduled launch date of late 2016. PRI also announced a partnership with the government of Luxembourg to advance technologies and businesses related to exploration and utilization of asteroid resources. Honeybee Robotics and the University of Central Florida developed a concept for a 6-unit cubesat that could extract water from hydrated asteroid regolith and use it to "hop" between asteroids via steam propulsion. In 2016, the extraction hardware for this cubesat recovered water from asteroid simulants during laboratory tests under a Small Business Technology Transfer project with Kennedy Space Center. ★