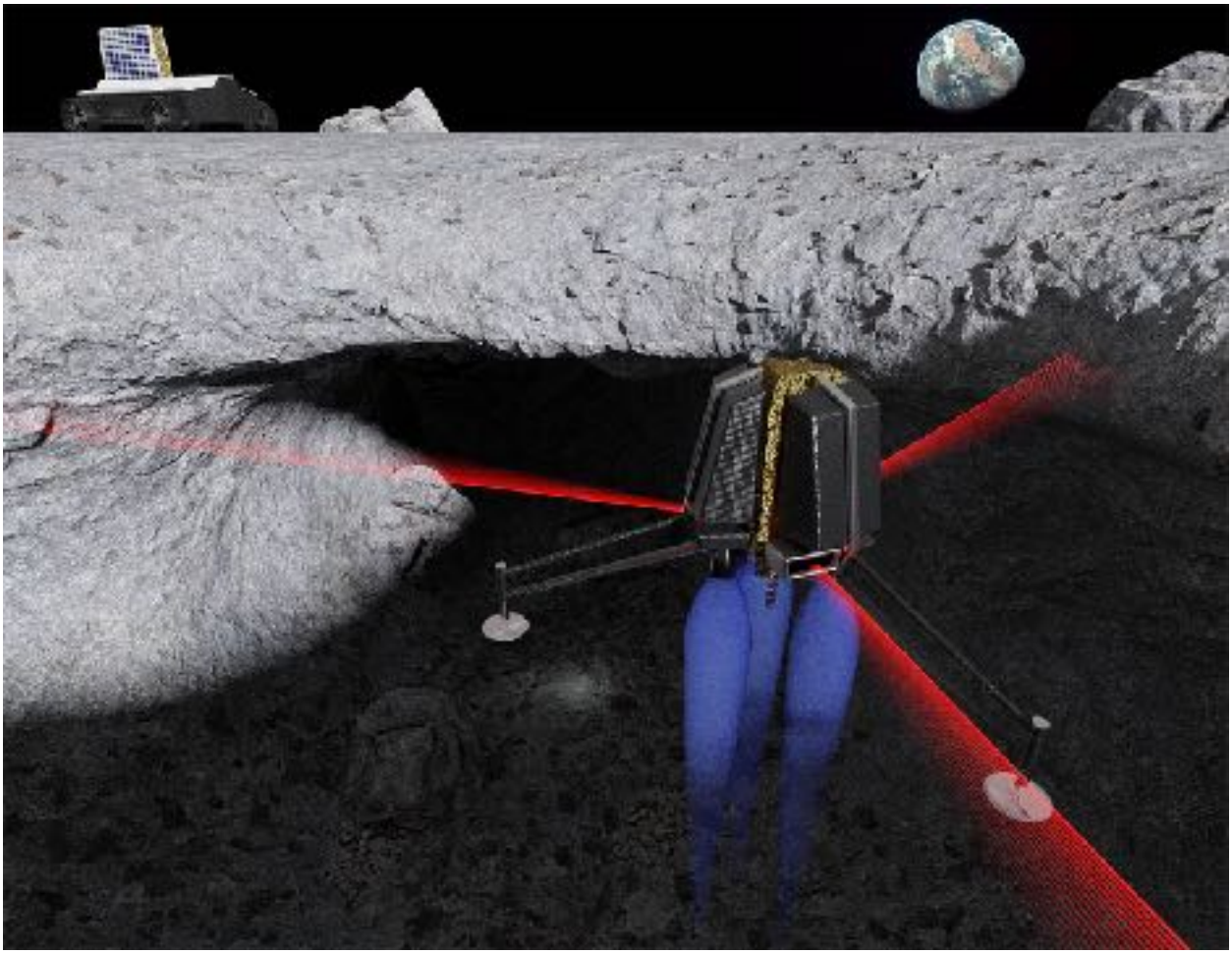
Astrobotic and RIS⁴E Demonstrate Technologies to Explore Extreme Lunar Environments



Astrobotic is developing navigation technologies to allow free-flying spacecraft to explore subterranean environments on the Moon, such as lava tubes.

September 18, 2018 - As America prepares to return to the surface of the Moon, Astrobotic Technology is partnering with scientists from the RIS⁴E node of NASA's Solar System Exploration Research Virtual Institute (SSERVI), led by Stony Brook University, to demonstrate the robotic technologies needed to explore and study our nearest neighbor's most interesting and challenging destinations.

Under a research contract with NASA, Astrobotic has developed a custom navigation software product, known as AstroNav, to give small free-flying spacecraft the ability to autonomously explore lunar lava tubes. Meanwhile, SSERVI researchers have been working to analyze the capabilities of compact and deployable instruments needed to collect and characterize geologic samples in the field. Advances in both areas are paving the way for future missions that are far more dynamic and autonomous than those possible today.

To explore sub-surface environments on the Moon, Astrobotic's AstroNav employs both stereo vision- and LiDAR-based navigation, works without GPS or previously stored maps (neither of

which exist in the target environment), and can operate in real-time while a free-flying spacecraft explores a novel environment at a high rate of speed.

The ability to utilize and fuse multiple of sensors is critical to exploring these challenging environments. While LiDAR can be used to explore pitch-black subterranean environments, and visual sensing can be used on the brightly lit surface of the Moon while using far less power, combining the sensing modalities allows a spacecraft to perform a seamless traverse over the lunar surface before dropping into a skylight from above.

Astrobotic field-tested their autonomous navigation in Aden Crater in the Potrillo Lava Fields, New Mexico. The geologic features in the field are an analog environment for the Moon or Mars. The team deployed with the SSERVI RIS4E team in March 2018.

A primary goal of Astrobotic's research is to demonstrate the capability to navigate and map, using both LiDAR and vision, and to seamlessly transition between the two sensing modalities mid-flight when environmental conditions change rapidly. If successful, AstroNav could enable a small spacecraft to explore these underground environments autonomously, returning from the darkness to send data back to Earth, return a sample to the surface, or refuel.

Video Link: Astrobotic teamed up with SSERVI scientists to explore lunar and Martian analog terrain in Potrillo, New Mexico

Lunar lava tubes are high-priority targets for scientific research because they provide access to geologic formations that have been shielded from space weathering for billions of years, and therefore may contain a preserved record of the conditions present during the formation of the lunar mare. Additionally, while these tubes are rich in scientific samples, they could also be ideal

locations for future human settlements because they provide natural protection from radiation and micrometeoroids. Both applications make lunar lava tubes appealing for further exploration.

While lava tubes are difficult to access because they are buried below the lunar surface, roof collapses, known as skylights, offer a tantalizing way to access the subsurface. Long hypothesized to exist, only in the past decade have numerous lunar skylights been detected from orbital imagery, and scientists have recently discovered that the Moon may host massive networks of lava tubes. In fact, radar data from the Japanese Spacecraft SELENE, currently in orbit around the Moon, indicates tubes that may be 50 km long and large enough to contain a colony the size of Philadelphia.

The Potrillo Lava Fields in New Mexico contain features that are thought to be analogous to the lava flows Moon and Mars, including skylights that could offer access to subsurface lava tubes.

Integrated, Interdisciplinary Preparation for Future Lunar Missions

Planning for robotic and human missions to explore lunar skylights is already underway in earnest, and this past April Astrobotic's Future Missions and Technology team joined the RIS^{4}E SSERVI team, led by Prof. Timothy Glotch from Stony Brook University, at a field test site in New Mexico to demonstrate a number of key technologies required for these missions. The field site, known as the Potrillo Volcanic Field, has volcanic features analogous to those found on the

Moon and Mars, and the collaboration between the teams sought to address the challenges of conducting extra-planetary geologic data and sample collection from autonomous aerial science platforms.

RIS⁴E team members deploy a portable hyperspectral infrared camera to investigate the mineralogy of volcanic rocks at Kilbourne Hole in the Potrillo Lava Fields.

Due to its unique features, the Potrillo Lava field has served as a venue for planetary geologists and NASA astronauts since the Apollo program. At Potrillo, RIS⁴E team members conducted geologic fieldwork, incorporating sophisticated hand-held scientific instruments, including a portable X-ray fluorescence spectrometer, an X-ray diffractometer, and a hyperspectral infrared camera, into geologic studies similar to what astronauts might one day perform on the Moon. Meanwhile, Astrobotic flew their custom uncrewed aerial vehicle (UAV) above the lava field, recording sensor data and developing detailed maps of areas of interest.

Testing together, the science and engineering teams were able to understand each other's goals and challenges, and refine a vision for lunar subsurface exploration. "Working with a leading commercial space exploration company like Astrobotic has given the RIS⁴E team a valuable perspective on how science an exploration can be best combined for future lunar missions. We look forward to future successful collaborations," said Dr. Glotch.

Fraser Kitchell, Director of Astrobotic's Future Missions and Technology team echoed the success of the collaboration. "Working with RIS⁴E allowed us to work side by side with the planetary geologists for the first time. These field tests gave us a much more practical

understanding of each other's needs and current capabilities, and as a result we can design better operational concepts, better technologies, and, ultimately, better missions."

"The Potrillo field site presented a challenging flight environment and a great demonstration of the capabilities of AstroNav," said Astrobotic Senior Research Engineer Kerry Snyder. "We are looking forward to the continuing to push the technology toward mission infusion."

Astrobotic's research was funded in part by NASA's Small Business Technology Transfer (STTR) program. Under this contract, Astrobotic will perform a field demonstration of AstroNav technology in lava tubes in the coming months.

The company has plans to further develop and expand their research into GPS-denied in-space navigation, with planned extensions to AstroNav that will enable spacecraft to land on unmapped planetary surfaces and perform satellite or asteroid rendezvous. The company is also actively developing the software to provide autonomous landing or subsurface navigation capabilities to terrestrial UAVs.

###

About Astrobotic Technology, Inc.:

Astrobotic Technology, Inc**.** is a space robotics company that seeks to make space accessible to the world. The company's lunar lander, Peregrine, delivers payloads to the Moon for companies, governments, universities, non-profits, and individuals at an industry-defining price of $1.2 million per kilogram. The company is also developing advanced space robotics capabilities such as terrain relative navigation, mobile robotics for lunar surface operations, and reliable computing systems for mission-critical applications. Astrobotic has more than 30 prior and ongoing NASA and commercial technology contracts, a commercial partnership with Airbus DS, a corporate sponsorship with DHL, and 12 signed deals for Peregrine's first mission to the Moon. The company is also an official partner with NASA through the Lunar CATALYST Program. Astrobotic was founded in 2007 and is headquartered in Pittsburgh, PA.

About RIS⁴E:

RIS⁴E field team is composed of faculty, students, and research scientists from Stony Brook University, NASA Goddard Space Flight Center, and several other institutions. RIS⁴E team members are engaged in a variety of activities, including laboratory spectroscopic studies, theoretical calculations, sample analysis, and geologic field work, designed to further NASA's science and exploration goals related to the Moon, the moons of Mars, and near-Earth asteroids. For more about RIS⁴E email timothy.glotch@stonybrook.edu

RIS⁴E is one of 13 teams within SSERVI, based and managed at NASA's Ames Research Center in California's Silicon Valley. SSERVI is funded by the Science Mission Directorate and Human Exploration and Operations Mission Directorate at NASA Headquarters in Washington. For more about SSERVI visit: sservi.nasa.gov

NASA's STTR programs fund innovative space exploration technologies that take us across the Solar System and beyond. STTR companies partner with Research Institutions to create their innovations. For more about the NASA STTR program visit: sbir.nasa.gov