Completed Project (2014 - 2015)

Asteroid and Lava Tube In Situ Resource Utilization (ISRU) Prospecting Free Flyer Project

Center Innovation Fund: KSC CIF Program | Space Technology Mission Directorate (STMD)

ABSTRACT

This project seeks to develop a small free flyer that can be used to safely and effectively prospect on an Asteroid while being controlled by the crew. This will enable the characterization of the Asteroid for the **In Situ Resource Utilization** (**ISRU**). Lava tubes can be explored remotely from the outside.

Asteroids can contain vast amounts of resources such as water for propellants and metals for feed stocks. Lava Tubes on Mars and the Moon may contain frozen volatile resources. Before the resources can be used, they must be found with a prospecting method.

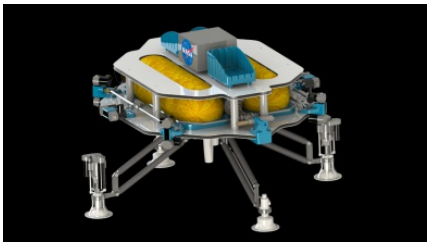
The NASA Agency Asteroid Grand Challenge seeks new ideas for Asteroid retrieval mission technologies for exploration and utilization of asteroids in a Distant Retrograde Orbit (DRO).

This project will develop a small free flying platform that can be used to safely and effectively prospect on an Asteroid with limited autonomy while being controlled by the crew. This will enable the characterization of the Asteroid for ISRU. Lava tubes can be explored remotely from the outside as well using this same technology.

ANTICIPATED BENEFITS

To NASA funded missions:

By prospecting and sampling multiple locations on an Asteroid or lava tube, then geologic mapping and resource characterization is enabled. The crew can control such free flyers with tele-operation without risking direct contact with an extremely dusty or hard to access surface locations. The first step in ISRU is prospecting and characterization of the accessible resources and this will lead to massive risk reduction for actual ISRU in follow- on missions



This small marsupial free flyer is designed to capture samples at an Asteroid for ISRU prospecting purposes.s

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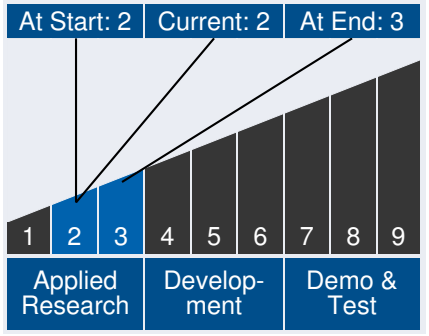
Technology Maturity



Some NASA technology projects are smaller (for example SBIR/STTR, NIAC and Center Innovation Fund), and will have less content than other, larger projects. Newly created projects may not yet have detailed project information.

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To NASA unfunded & planned missions:

By prospecting and sampling multiple locations on an Asteroid or lava tube, then geologic mapping and resource characterization is enabled. The crew can control such free flyers with tele-operation without risking direct contact with an extremely dusty or hard to access surface locations. The first step in ISRU is prospecting and characterization of the accessible resources and this will lead to massive risk reduction for actual ISRU in follow- on missions

To the commercial space industry:

Commercial space companies can mine resources in space to provide viable products which will start a new space economy.

To the nation:

This project enhances the nation's capability in ISRU prospecting technologies that will follow the current Lunar Resource Prospector Expedition which is manifested for a flight to the moon in 2019/20. Asteroid missions are the official NASA policy and this capability will enhance such missions by providing a tangible ISRU benefit by finding and mapping the Asteroid's resources.

DETAILED DESCRIPTION

A small free flyer or even multiple small free flyers are a low risk solution for prospecting and sampling an asteroid, or other Near Earth Objects (e.g. Comets). An evolved application is flying into Mars and lunar lava tubes to look for resources, map the sub surface cavities and acquire samples. Instead of risking a highly expensive main spacecraft bus in a rendezvous asteroid landing, the small free flyer can be used as a secondary spacecraft. The Rosetta mission recently demonstrated how difficult it is to autonomously land on a small body. A small free

Management Team

Program Executive:
- John Falker

Program Manager:
- Nancy Zeitlin

Project Manager:
- Robert Mueller

Principal Investigators:
- Michael Dupuis
- Robert Mueller

Technology Areas

Other Technology Areas:
- Robotics, Tele-Robotics & Autonomous Systems (TA 4)
- Human Exploration Destination Systems (TA 7)
- Modeling, Simulation, Information Technology & Processing (TA 11)

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flyer would have less inertia and be easier to control. The trend in modern spaceflight is towards miniaturization, as electronics and other components shrink in size and mass. The small size also has advantages in terms of maneuverability and access. Multiple small free flyers could provide redundancy and increase mission success probabilities, since an anomaly could be quickly corrected through the use of a second small free flyer.

By prospecting and sampling multiple locations on an Asteroid or lava tube, then geologic mapping and resource characterization is enabled. The crew can control such free flyers with tele-operation without risking direct contact with an extremely dusty or hard to access surface locations. The first step in ISRU is prospecting and characterization of the accessible resources and this will lead to massive risk reduction for actual ISRU in follow- on missions.

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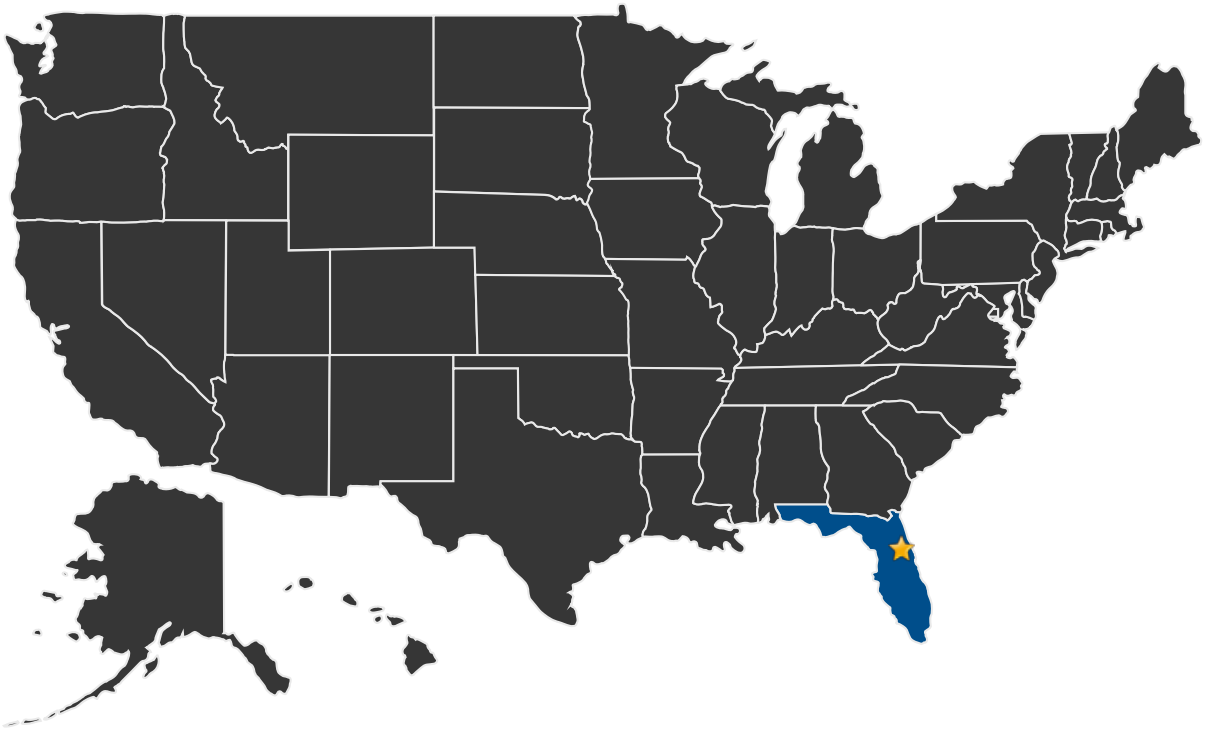
U.S. LOCATIONS WORKING ON THIS PROJECT



U.S. States With Work

Lead Center:
Kennedy Space Center

Contributing Partners:

- Embry Riddle Aeronautical University - Daytona Campus
- HONEYBEE ROBOTICS CRAFT MECHANISMS

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DETAILS FOR TECHNOLOGY 1

Technology Title

Cold Gas Reaction Control System and Regolith Sampling for a small Free Flyer

Technology Description

This technology is categorized as a hardware system for unmanned flight

A small free flyer or even multiple small free flyers are a low risk solution for prospecting and sampling an asteroid, or other Near Earth Objects (e.g. Comets). An evolved application is flying into Mars and lunar lava tubes to look for resources, map the sub surface cavities and acquire samples. Instead of risking a highly expensive main spacecraft bus in a rendezvous asteroid landing, the small free flyer can be used as a secondary spacecraft

Capabilities Provided

The Extreme Access project developed a flying platform prototype for lunar cold trap access. This platform was evolved to demonstrate a prototype that could fly with cold gas propulsion around an asteroid or inside a Mars lava tube, with a regolith sampling capability. The risky sampling can be performed by the small free flyer which is transported to the Asteroid on a larger spacecraft such as Orion or a separate mother ship spacecraft bus. Autonomous flight algorithms and fused sensors (LIDAR, vision, Inertial Measurement Unit) for Guidance, Navigation and Control (GNC) are being developed and adapted to a cold gas propulsion system free flyer platform to be developed & tested at KSC. Samples will be captured for “ground truth” and ISRU prospecting using a pneumatic sampling system, a micro drill and a drill tube sampler. Currently testing has been limited to the KSC Swamp Works labs, but in the future, the KSC Morpheus Hazard field will be used as a safe and effective test site for cold gas propulsion demonstrations of free flyer prospecting operations.

This project enhances the KSC core capability in ISRU prospecting technologies that will follow the current Lunar Resource Prospector Expedition which is manifested for a flight to the moon in 2019/20. Asteroid missions are the official NASA policy and this capability will enhance such missions by providing a tangible ISRU benefit by finding and mapping the Asteroid’s resources

Potential Applications

Asteroid ISRU prospecting

Lunar Cold traps water ice prospecting at the poles

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Mars Lava Tubes ISRU prospecting

Performance Metrics

Metric	Unit	Quantity
Regolith Sample Capture	grams	70

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