MEGAVOLT – Martian Exploration with Ground Autonomous Vehicles for Operation in Lava Tubes

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Mission Overview

The MEGAVOLT mission aims to explore Martian lava tubes. The mission utilizes a swarm platform to provide a highly robust fleet of robots, which can safely enter high-risk environments by utilizing mission redundancy. It is structured as a ride-along mission, so the fleet has been limited to a small total volume, allowing it to be carried by a parent rover. Modular payloads allow the fleet to carry a large variety of scientific tools, even though the individual robots are much smaller than a typical rover.

Scientific Objectives

This mission seeks to work towards each of NASA's four science objectives on Mars [2]: searching for life, characterizing the climate, characterizing the geology, and preparing for human exploration. These lava tubes may serve as the most likely environment for life to have existed [1], and the fleet will include a sampling payload to test this theory. The fleet will additionally carry a habitation payload which will be able to measure the temperature, radiation, and atmospheric composition inside the lava tubes and possibly test a small scale, expandable habitat. Finally, the geology will also be studied using sensors to map out and identify the internal structure of the lava tubes to assist the sampling payload in characterizing the geology.

Requirements

Many requirements were made to flesh out the mission concept and verify its feasibility. General requirements were produced for the mission, and more specific requirements were made for our scope. This includes the communication, navigation, structure, mobility, sensing payload, and habitation payload. Additionally, the sensing payload, computing systems, and mobility systems were further focused on to solidify exact requirements and provide possible architectures. The next section will further discuss these areas.

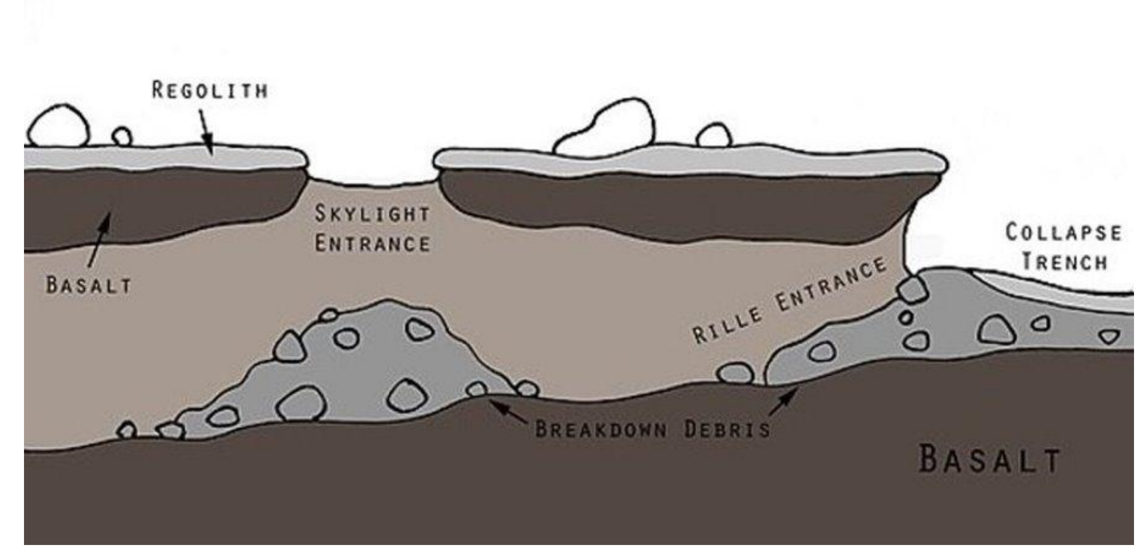

Figure 1: Artist's representation of the interior of a lava tube

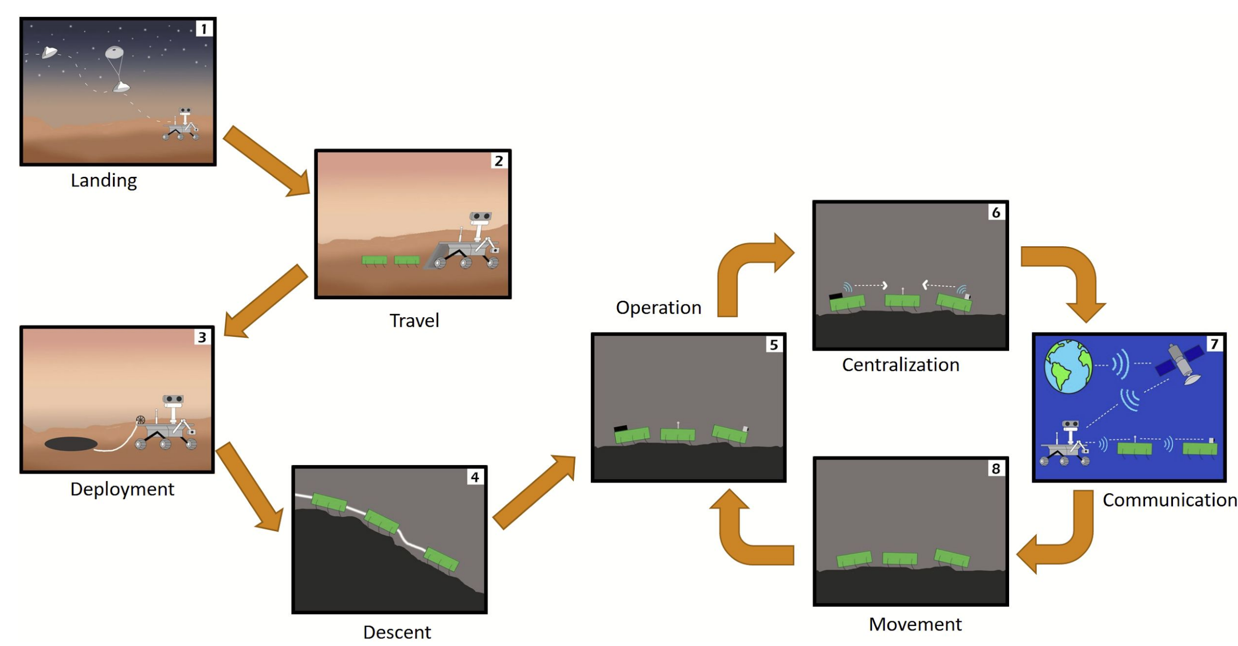

Figure 2: Proposed mission overview. Parent rover remains stationary for duration of the mission to provide power and a communications link for the robots in the lava tube.

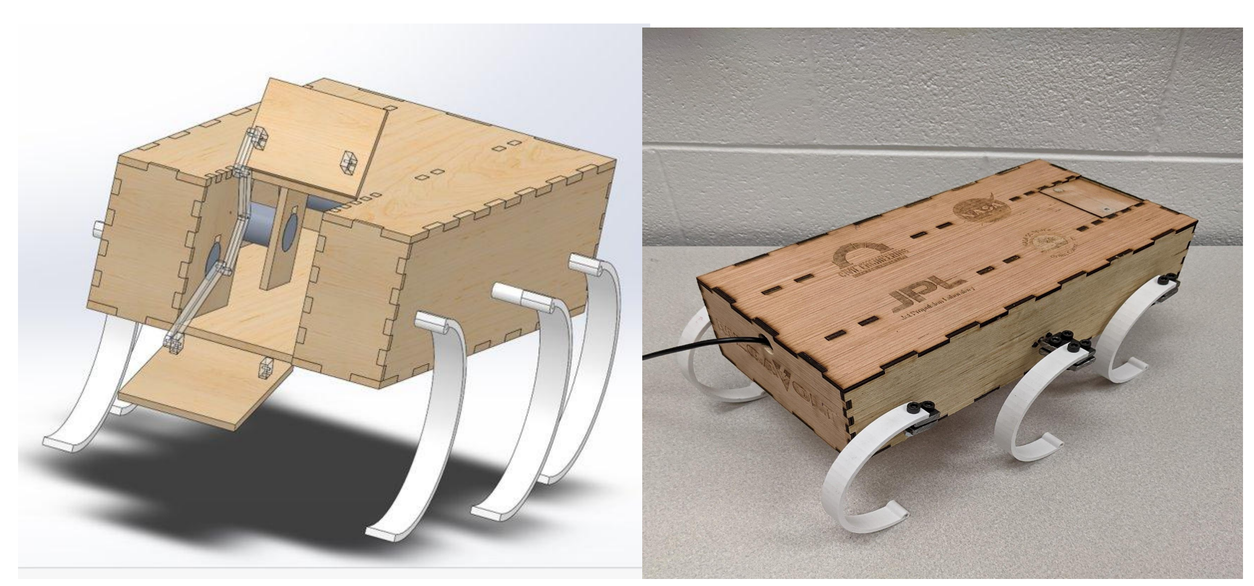

Figure 3: Side by side images of the CAD model and physical prototype.

Sensing, Failure Scenarios and Computing, Mobility

The sensing payload consists of cameras/sensors that will allow for data collection and mapping. Selection was based on requirements of the mission and features of each camera/sensor. The selected option is to use a sensor fusion approach with LiDAR and ultrasonic sensors.

Multiple failure scenarios were created to further mature the mission design. Some additional requirements were derived from these failure scenarios, mostly in the realm of computing. A basic list encompassing all computing tasks was created to further develop the computing requirements.

The leg design was studied and optimized with consideration from one of the original RHex leg studies[3]. Additionally, an optimized motion profiling for the tripod gait was determined using the energy analysis of the C-shaped wheels [4]. Finally, motor selection and specifications for the RPM, torque, and size requirements was performed.

Prototype

A prototype was created, which includes actuating motor systems, shown in Figure 3. The hexapod design uses "whegs" which take advantage of the compliance from the C-shaped design for robust, one degree-of-freedom navigation through unknown conditions. A front hatch mechanism allows for actuation of onboard payloads such as LiDAR, while also protecting the payloads because of their internal mounting.

Conclusion and Future Work

Through the course of this project, we have created a feasible and beneficial mission for NASA to consider implementing in a future mission to Mars. We have broken down the requirements needed for many of the systems and proposed a possible design for this mission with the prototype. The next steps for this project would be to continue flushing out and refining the requirements and iterating upon the prototype and design to bring it to a finished product.

References

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3. Moore, Edward Z. "Leg Design and Stair Climbing Control for The Rhex Robotic Hexapod." *McGill University*, 2002.
4. Vina, Andres, and Antonio Barrientos. "C-Legged Hexapod Robot Design Guidelines Based on Energy Analysis." *Applied Sciences*, vol. 11, no. 6, 2021, p. 2513., doi:10.3390/app11062513.