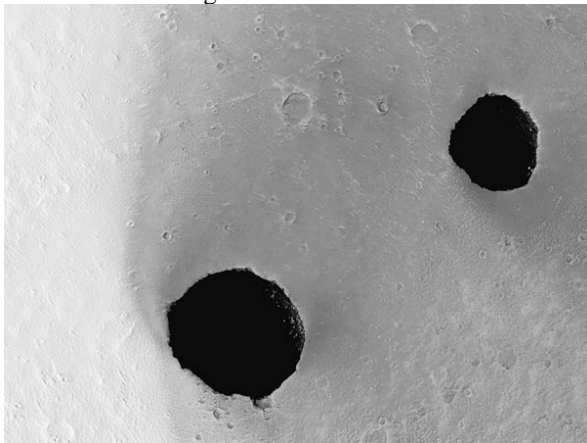


INTELLIGENT ZIPLINE DEPLOYMENT FOR MARTIAN CAVE EXPLORATION

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Introduction: Robotic reconnaissance to subsurface features on planetary bodies are excellent candidate exploration sites for a next generation of planetary missions for scientific investigations.

It is apparent from imaged features such as lava tube skylights and pit openings of Mars discoveries observed thus far, that to reach these cavernous voids, traverses down cliffs of great depths of 100 meters or more with difficult terrain are required for both robots and eventually human explorers. Negotiation of steep slopes and the climbing in and out of a hole presents technology challenges for accessibility and site characterization technologies.



Mars pits near Ascraeus Mons volcano - Accessibility to planetary cave approaches require ingress/egress technology solutions for robots and human explorers. (MRO HiRISE camera image)

Equally challenging is the need for planetary protection with first contact of these pristine environments with the reconnaissance technologies employed.

For example, a current NASA funded technology investigation of fusing flyover data with surface data to achieve site characterization of a skylight by means of a lander trajectory directly over the skylight hole during landing approach raises issues of site contamination from fuel plume exhaust being dispersed over the target feature. Subsurface caverns preserve unique geologic environments with access to fresh, dust free outcrops of volcanic rock, and in the case of Mars, potentially may provide astrobiologists with biogeochemical signatures. The risk of site contamination from man-made activity during early exploration stages of a cavernous site can be mitigated with a layered approach to intrusive technologies for acceptability of site disturbance. It is clear that basic scientific understanding of these geographic features are needed, as well as knowledge of the engineering constraints to determine viability of potential human habitation and emplacement of associated infrastructure elements.

Balancing the ever increasing encroachment of these activities with planetary protection is the premise of an Intelligent Zipline concept.

Concept: Intelligent Zipline (IZ) is a system architecture for robotic deployment of an intelligent cable system that is "shot" across the expanse of a skylight's pit hole opening from a mobile platform, possibly a robotic lander with traverse capability to position itself at an optimum anchoring site. Essentially, a harpoon cannon mounted on a lander shoots a ground penetrator for anchoring a zip line to the cliff walls of the pit. The mobile platform spools the cable feed and acts as primary anchoring point with a deployable mast for securing the cable line. The deployed zip line is then used for offloading science instrument packages from the lander to the center of the pit opening with drop lines for placing the payloads down to the pit floor, or in-situ investigations of the cliff wall as the instrument lowers. Offloading is accomplished either through tele-operation and/or autonomously. Intelligence is built into the harpoon projectile for targeting accuracy. Intelligence is built into the trolleys and cable for manipulating payload grappling, loading stress, braking, and tension along the zip line traverse. Power, data, & communications run through the cable.

Impact: Deployment of a zip line minimizes site contamination for investigative science, while being conducive to a concept of operations for site characterization of pit openings and achieving a means of ingress/egress of scientific instruments, robots, and eventually human explorers.

- prevents contamination of the pit from plume and fuel of a lander flyover or other intrusive robotic activity trying to traverse down the cliff walls.
- used to lower down instruments/equipment from center of hole opening (e.g., a LIDAR instrument could be lowered for 360° field of view laser measurements for a 3D point cloud of the entire pit).
- science investigations, site contamination mitigation, and initial infrastructure buildup of the site are all accomplished with the initial zip line science reconnaissance mission; essentially provides the first infrastructure emplacement at the site for an eventual development of an outpost (the zip line could be used as a leader line to build out an eventual gondola line and platform to get larger equipment and crew down; or zip line could be used as a tension line for deployment of other novel ingress/egress concepts).

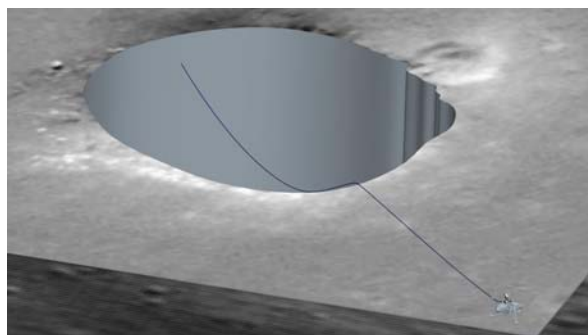
Planetary Protection Relevance: Planetary protection protocols developed on Earth for robotic missions are in place and further developments are under-

way to prepare us for even more sensitive missions to Mars that will return samples back to Earth. However, seeing beyond the robotic reconnaissance era of space exploration to future human missions, and their vastly greater potential for both forward and backward contamination of Martian sites requires a long term planning period.

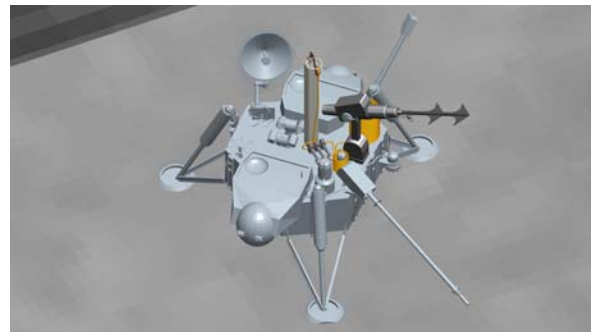
Lunar Test Bed Protocols: The opportunity that lunar exploration provides to develop and test protocols and other methodologies that pertain to Planetary Protection concerns and international treaty obligations will be invaluable. The moon is Planetary Protection Category I which requires documentation of activities only. Thus, testing Planetary Protection concepts there is a very low risk approach and will be a cost effective real test of such activities in a highly challenging environment but which is not significant astrobiologically.

Study: The Marius Hill skylight was assessed for a preliminary analysis of a reference mission architecture for the IZ concept. Located in the Marius Hills region on the lunar nearside, this hole is approximately 65 m in diameter and 45 m deep. The preliminary study used CAD modeling of an initial basic concept of operations (ConOps). Illustrations shown are not intended to be a point design, but a basis for identifying the core mission elements for a quick-look analysis to close the ConOps for concept viability. A safety factor of 50 m from the pit edge was used for the platform anchoring point. Precision landing to an anchoring point of 50 m to 100 m from the pit edge was ruled out due to plume and ejecta contamination.

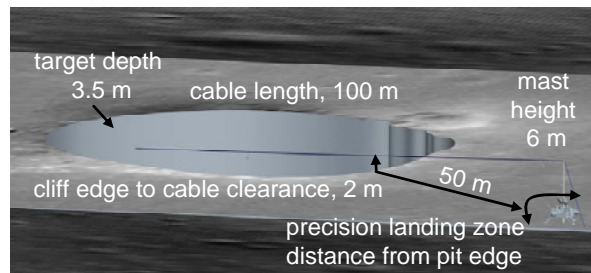
Forward studies will investigate system architecture elements and a mobility lander (crawler) or lander concept which carries a robotic platform containing the deployable mast and harpoon system, which offloads from lander and robotically traverses from landing site (e.g., greater than 200m away from pit edge) to location within 50 m or less for deployment of zipline and payload offloading of science instruments.



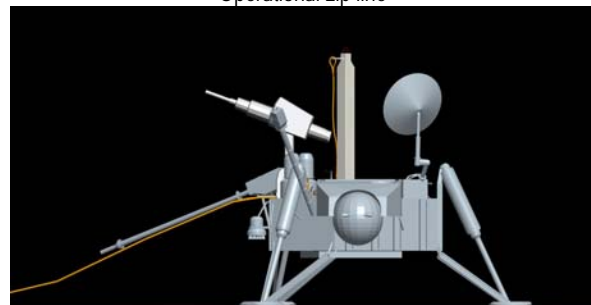
Initial cable deployment across the Marius Hills skylight pit



Landed configuration with harpoon cannon



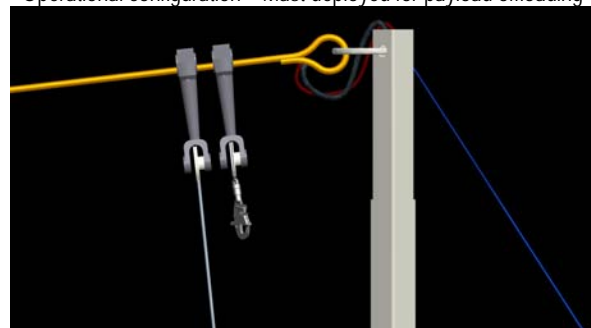
Operational zip line



Initial cable configuration after harpoon shot



Operational configuration – Mast deployed for payload offloading



Smart trolleys & powered cable for bi-directional robotic traverse