INTELLIGENT ZIPLINE - GREEN RECONNAISSANCE FOR LAVA TUBE SKYLIGHTS

Samuel W. Ximenes, Exploration Architecture Corporation, sximenes@explorationarchitecture.com

.

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 recently imaged features such as lava tube skylights and pit openings of both lunar and Mars discoveries observed thus far, that to reach these cavernous voids, traverses down cliffs of great depths of some 45 to 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.

Accessibility to planetary cave approaches require ingress/egress technology solutions for robots and human explorers.

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

For example, the idea 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 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 the Intelligent Zipline concept for green reconnaissance.

Concept: Intelligent Zipline 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 robotically. 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.

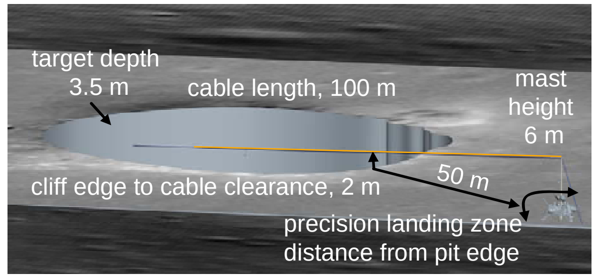
Impact: Intelligent Zipline (IZ) is green technology for minimizing site contamination for investigative science, while being conducive to a concept of operations for site characterization of pit openings and achieving a means of ingress/egress of scientific instruments, robots, and eventually human 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^{o} field of view laser measurements for a 3D cloud point 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; IZ essentially provides the first infrastructure emplacement at the site for 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).

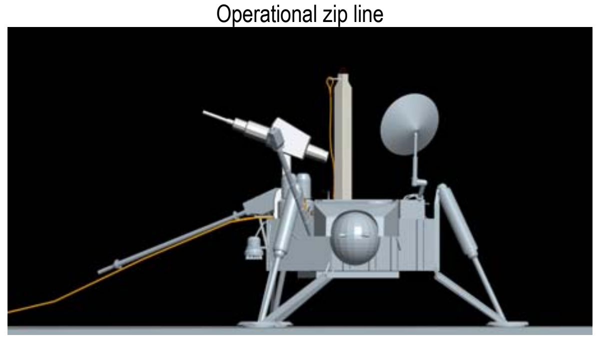
Study: The Marius Hill skylight is used for analysis of a reference mission architecture for the IZ concept. Located in the Marius Hills region on the lunar nearside, this hole is approximately 65 m in diameter and 45 m deep. A preliminary study was conducted using CAD modeling of an initial basic concept 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.

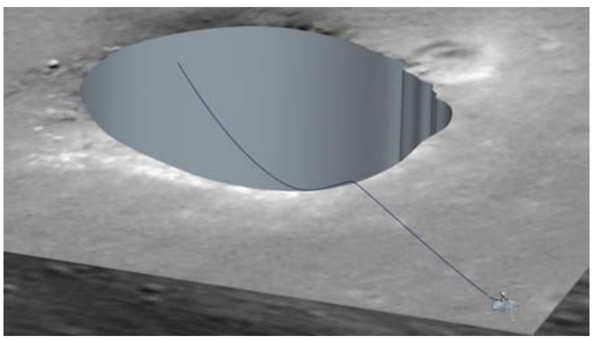
Forward studies will investigate system architecture elements shown in the table below, and a mobility lander (crawler) or lander concept which carries a robotic platform containing the deployable mast and harpoon system, which offloads from lander and robotically traverses from landing site (greater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



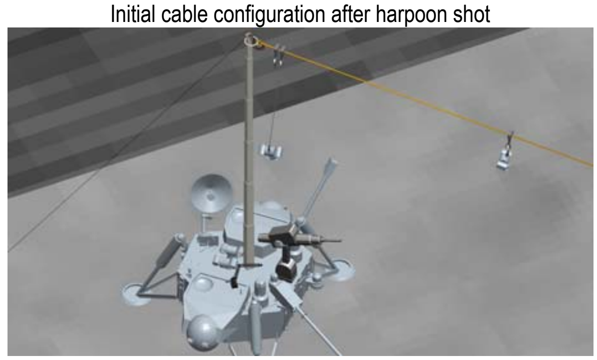
Operational zip line



Initial cable configuration after harpoon shot

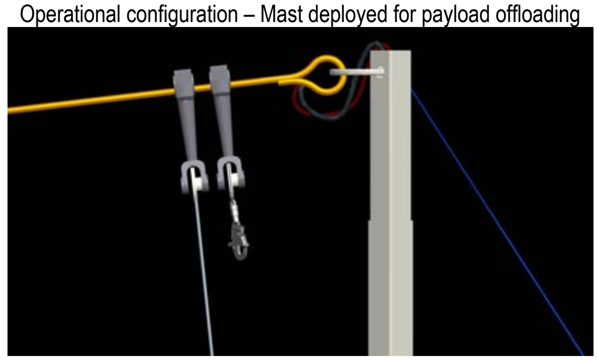


Initial cable deployment across the Marius Hills skylight pit



Operational configuration – Mast deployed for payload offloading

Platform configuration with harpoon cannon



Smart trolleys & powered cable for bi-directional robotic traverse

System Architecture Element	Phase I - System Study Investigation
Harpoon cannon	Energy to penetrate optimum depth; sizing explosive charge; leverage GSFC comet harpoon technology
Harpoon	Smart targeting and guided trajectory with trailing cable; imparted energy vs. penetration depth; harpoon mass, tip geometry, cross section; anchoring and stabilization with cable tension
Intelligent cable	Cable type/size; tension/load sensing and auto adjust; comm-power-data interface; trolley/cable interface
Intelligent trolley	Robotic traverse up and down cable length, braking, speed sensing; drop line targeting; zip line & drop line comm-power-data interface; payload spin stabilization; payload grappling
Mast concept and deployment	Telescoping or other means of extension; lightweight carbon fiber materials; inflatable mast; guy cable deployment, anchoring, and horizontal load transfer to compressive load
Cable management	Spooling concepts; length and mass; clearances (spacecraft and pit edge); drape and sag deflection
Scientific instruments	Instrument/sensor types; planetary protection concepts; packaging; drop line interface, connection/release
Landing site proximity	Precision landing; ejecta field safe zone; optimal landing location based on topography and slope advantage
Spacecraft lander	Size, configuration, major element integration; cannon and mast offset geometry; crawl mode mobility for precise positioning; anchoring; comm-power-data requirement and interface to zip line and trolleys