National Aeronautics and Space Administration

Recurring Slope Lineae (RSL) Exploration

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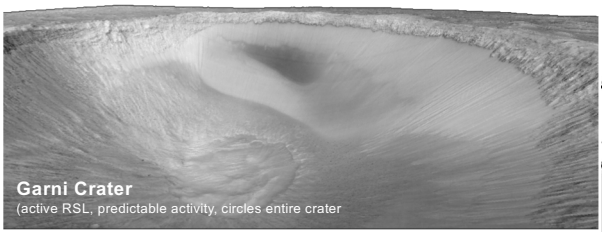
Program: Strategic

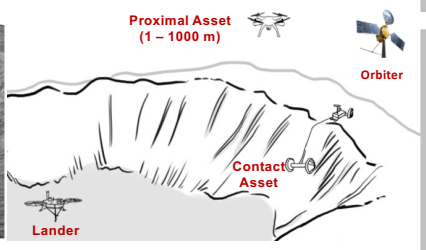
Background: *RSL* are seasonal, discolored linear features that *lengthen*, *fade* and *recur* on slopes during warm seasons. They were hypothesized to be flows of briny water, making them astrobiological targets of interest.

Project Objective:

- Enable **access to** and ***in situ* measurements of RSL** to disambiguate current hypothesis
- Mature and field technologies for surface access via rappelling and aerial access

Exploration Trades

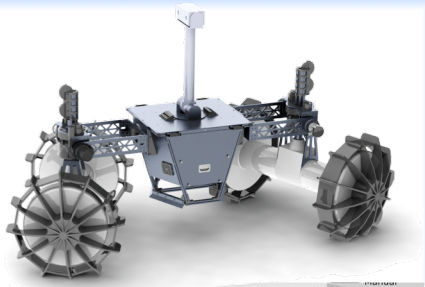


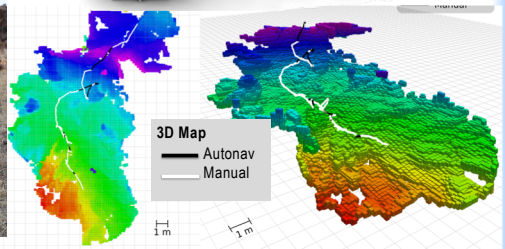


Surface Access via Rappelling

Axel and DuAxel Rovers

- Kilometer mobility to *RSL* site (DuAxel)
- Anchoring and deploying a tethered rover (Axel)
- Automated tether management for long distance
- Autonomous and remote operations on slopes

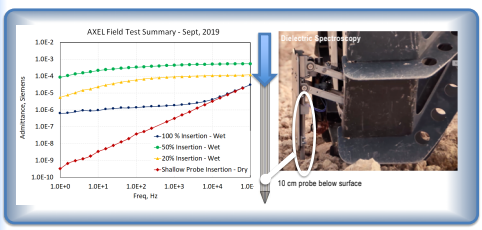




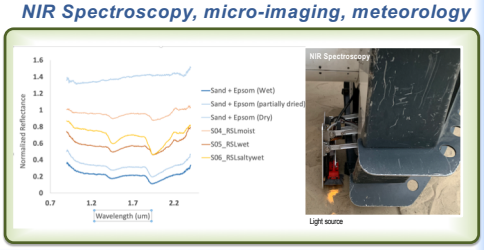
Findings

- Remote operations in extreme terrain viable but challenging; traverse rate: **1.5 – 2 m/sol**
- Requires situational awareness: 3D mapping, global registration, proprioceptive sensing
- Autonomous navigation would likely increase rate but requires further development

Dielectric measurements 10 cm below surface



NIR Spectroscopy, micro-imaging, meteorology



FY19 Results

- Demonstrated access and *in situ* dielectric and NIR measurements on RSL-like terrains
- Disambiguated wet and dry terrains including gradations in depth

Benefits to NASA and JPL

RSL exploration advances extreme terrain mobility and access to sites of high science potential. This capability has is applicable to lunar pit exploration (e.g. Moon Diver Discovery mission concept), Enceladus' tiger stripe vents, and Europa's crevasses.

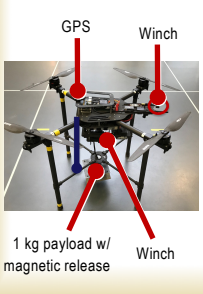
Aerial Access

Quadcopter

- Mass: 6.9 kg; Max thrust: 12 kg
- Delivers payload via (a) controlled winching or (b) targeted drop
- Visually servos on target
- Releases using electromagnets
- Delivers 1 kg payload on 35° slope

Findings

- Difficult to accurately target a surface location using manual control
- Automated winch release resulted in 0.4 m accuracy
- Automated drop release resulted in 0.15 m accuracy (initial impact only)



Publications:

- P. McGarey, W. Reid, I. Nesnas, " Towards Articulated Mobility and Efficient Docking for the DuAxel Tethered Robot System," 2019 IEEE Aerospace Conference. IEEE, March 5, 2019.
- Brown, T., Stefanini, A., Gergiev, N., Sawoniewicz, J. Nesnas, I., "Series Elastic Tether Management for Rappelling Rovers", IEEE Conf. on Intelligent Robots and Systems, 2018
- G. Meirion-Griffith, et al., "Accessing Mars Recurring Slope Lineae: Mobility Systems Analysis," Aerospace Conference 2018

New Technology Report

- NTR 50917: "Articulated Mobility and Efficient Docking for the DuAxel Tethered Robot System" – P. McGarey
- NTR 50795: "Series-Elastic Tether Management System for Rappelling Rovers" – T. Brown

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