SAMPLE RETURN FROM "WATER" SEEPS ON MARS. I.A. Nesnas[1], J. B. Matthews[1], J. W. Burdick[2], R. C. Anderson[1], and P.G. Conrad[3] — [1]Jet Propulsion Laboratory, M/S 198-219, 4800 Oak Grove Dr., JPL, Pasadena CA 91108, nesnas@jpl.nasa.gov; [2]California Institute of Technology; [3]NASA Goddard Space Flight Center.

Motivation: Some of the most intriguing science discoveries on Mars came from sites that are currently inaccessible for in-situ analysis and sample return. The recent discovery of recurring slope lineae (RSL), such as those observed in Newton crater, are on steep slopes (25° – 40°) that are hundreds of meters down from the crater rim. In-situ analysis and sample capture of outflow deposits that have interacted directly with water on Mars would be directly responsive to science priorities described in both the Decadal Survey [1] and the goals of MEPAG [2]. The requirement for liquid water in habitable environments makes the retrieval of outflow samples scientifically important for future return to Earth.

Challenges: Terrains where such features are observed have demanding topographies that are beyond the reach of current rovers. In-situ measurements across such steep and rugged terrains not only demand mobility with a high level of robustness to negotiate challenging features, but also an ability to recover from failures such as: tipping over, driving into sand traps, or high centering on rocks. Power and communication challenges must be addressed in light of topographic features that could occlude direct line-of-sight needed for communication and direct sunlight needed for solar energy.

Approach: We propose a mission concept for in-situ target characterization and sample retrieval using *novel field-demonstrated surface mobility* platforms: the Axel rovers. Axel is a two-wheeled rover with two large wheel-encased science bays and a boom (Fig. 1). Using its body-mounted tether and yoyo-like operation, it is capable of accessing extreme terrains. It combines mobility and manipulation functionality of a robotic arm with its science payload-populated turrets. A single 30 kg Axel can carry multiple science instruments and a small sample acquisition and handling system in its science bays. In essence, Axel is a mobile science kit capable of placing and orienting instruments on sloped targets. Fig. 1 shows the Axel rover acquiring spectroscopic measurements and microscopic images of stratigraphic layers on a 40° slope at Black Lava Point in Arizona. Due to the large payload volume to system volume ratio, a series of corroborative, yet independent optical spectroscopic plus mass spectrometric measurements are envisioned for this robotic stratigrapher.

Axel can be deployed by its tether either from a lander or another rover. It can also be configured as an independent dual Axel (DuAxel) rover that not only provides untethered mobility to the crater rims or canyon edges, but also provides redundant Axels.

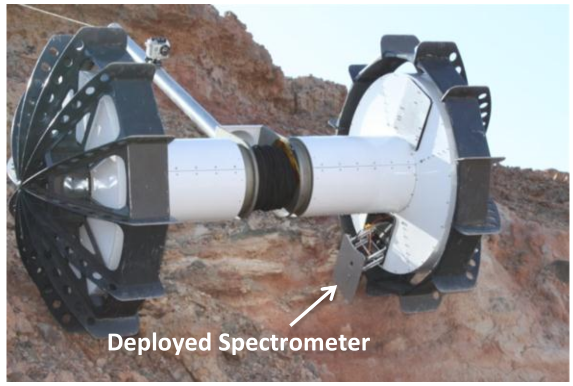

Figure 1: Axel deploying and acquiring infrared spectroscopic measurements and microscopic images from its instrument bay on exposed strata (40° slope).

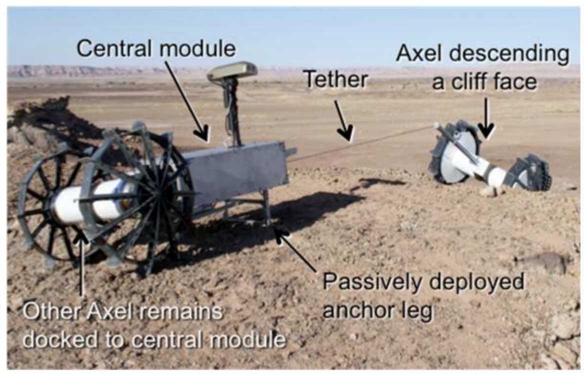

Figure 2: The DuAxel rover with one of its Axels undocking and about to rappel down a cliff face.

The DuAxel rover (Fig. 2) is formed by docking an Axel rover to either side of a central module. This allows untethered mobility to a crater's edge and serves as the mother ship and anchor to the Axel as it ingresses into a crater. Such operations can be executed along multiple descent paths and repeated at nearby craters.

The central module would use MER-heritage avionics, power system, mast and cameras. It would provide power and communication to the Axels by way of a permanently attached umbilical, thus addressing aforementioned power and communication challenges. The central module could also carry more sophisticated instruments than the Axels, such as mass spectrometers, to further analyze samples collected by the Axels.

The tethers guide the Axels to the central module, thus simplifying the undocking and re-docking process. The central module would contain and deploy the anchoring mechanism.

Axel Design: The Axel rover uses four primary actuators to control its wheels, the boom, and the tether spool. A single Axel could carry six to eight scientific instruments. Potential instruments would include high-resolution imagers as well as instruments for mineralogical and geochemical characterization. Axel drives over obstacles that are up to a wheel radius in height and maneuvers around larger ones. Using its tether, it can pull itself out of sand traps and overcome high centering. With its symmetric design, it can also operate from an inverted position, in the event it flips over on a steep slope. The Axel design co-locates its instruments, sensors, actuators, and avionics inside its cylindrical body. This provides compactness for launch, and robustness against environmental extremes. The Axel rover is also equipped with cameras and inertial sensors for autonomous navigation with obstacle avoidance, enabling us to leverage algorithms from prior missions.

With a target mass of 20–30 kg for each Axel and 100–160 kg for the DuAxel, such a platform could fit within the cost-cap of a Discovery-class mission. It could also be hosted as a payload on another mission.

Mission Concept: The launch and cruise stage would use heritage systems. To deliver such a platform safely to the vicinity of a recurring slope lineae, we would use heritage entry, descent and landing (EDL) systems. Guided entry significantly shrinks the landing ellipse; and by aligning the major axis along the crater rim with a safety margin, the DuAxel would reach the rim by crossing the minor axis and margin. When needed, the DuAxel rover could traverse several kilometers, to reach its destination, conducting an MER-like mission along the way. Once at the site selected from orbital imagery, the DuAxel rover would deploy its anchor at a safe distance from the cliff and undock one of the Axels, which would then drive to the cliff. During its guided descent of hundreds of meters along possibly very steep terrain, Axel would conduct stratigraphically-resolved in-situ measurements and collect samples into the science bays (Fig. 3). High-value samples that are obtained from these extreme terrains could be further analyzed by more capable instruments in the central module or sealed in canisters and deposited on the ground at locations suitable for future sample return missions.

A NASA OCT[†] focused technology program could mature the non-heritage elements of these cross-directorate capabilities for exploring extreme terrains in time for a 2020 in-situ characterization mission.

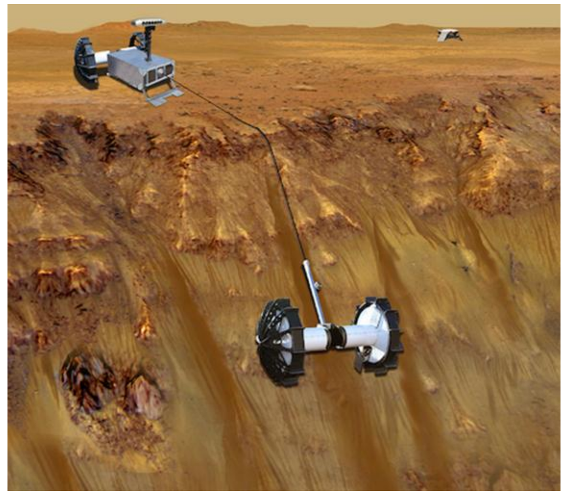

Figure 3: Artist rendition of a mission concept on recurring slope lineae (RSL) (assets not to scale)

Mission Relevance: Access to extreme terrains, such as craters, gullies, canyons, fissures and caves would enable in-situ investigations and sampling of exposed strata for insight into the composition, structure, and history of Mars. Such investigations are fundamental to our understanding of the solar system [2].

The Axel rover would also provide access to pit chains and collapsed lava tubes on Mars and the Moon. These would be of interest to the *human exploration* community as they could serve as potential habitats for astronauts and safe havens from solar flares [3].

Flight validation of extreme terrain mobility would open up its use on New Frontier, precursor, human exploration, and flagship missions. It has applicability to Mars and the Moon to explore caves and cold traps for characterizing volatiles [4].

Field Results We developed three generations of Axel rovers [5]. Multiple field tests have successfully demonstrated access, sampling, and in-situ measurements in extreme-terrains with a variety of topologies, rocks, and soils and against slopes ranging from 30°–85°. Docking and undocking has been repeatedly successful and tests with the tether indicated robustness of the approach. On-going work is focusing on maturing and demonstrating more autonomous operations. These results have raised our confidence in the viability of the approach for planetary exploration.

References: [1] S. Squyres et al. (2011), "Visions and Voyages," NRC Decadal Survey [2] J.R. Johnson, et al. (2010), "Mars Science Goals, Objectives, Investigations, and Priorities," [3] Horz, F. (1985) "Lava tubes – potential shelters for habitats," LPI, pp 405-412, [4] M.J. Wargo (2012), "Strategic Knowledge Gaps: Planning for Safe, Effective, and Efficient Human Exploration of the Solar System," NASA [5] I.A. Nesnas, et al. (2012), "Axel and DuAxel Rovers for the Sustainable Exploration of Extreme Terrains," Journal of Field Robotics.

† The National Research Council identified mobility in extreme terrains among NASA's *top priorities* for technology development for the next five years