SPRING MISSION: EXPLORING THE PAST AND ENABLING THE FUTURE OF MARS. J.R. Skok[1], J. Gaskin[2], J. Edmunson[2], K. Zacny[3], J. Blank[4], A. Williams[5], K. Cannon[6], M. Parente[7], J. Farmer[8] and S. Karunatillake[9].
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Introduction: The Surface Probe Rover Investigating New Ground (SPRING) Mission is a proposed mission concept designed to bring a scanning electron microscope (SEM) to the surface of Mars. The SEM would be able to investigate planetary science objectives related to astrobiology, geology, and engineering. The SPRING Mission would include the cameras, spectrometers, drones and probes required to map, select, collect and process the samples for SEM analysis.

Instruments: The core of the SPRING Mission is the Miniaturized Variable Pressure Scanning Electron Microscope (MVP-SEM) instrument [1]. The MVP-SEM instrument is capable of in-situ microimaging with a resolution of <100 nm. The MVP-SEM will also have compositional mapping capabilities with Energy Dispersive Spectroscopy (EDS). Microimaging at SEM resolutions are required for many types of observations including key biosignature detections (Fig. 1). The SPRING Mission will carry a suite of cameras, spectrometers and tools designed to select the optimal samples for the MVP-SEM depending on the specific mission objectives.

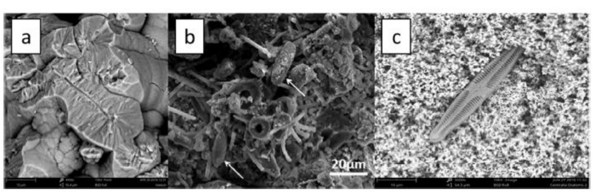

Figure 1. Biosignatures that can only be determined with SEM resolution. a) Iron Mountain microbial filamentous cell with surrounding iron oxide precipitation [Credit: A. Williams]; b) SEM image of a silica-coated biofilm, indicating "spindle-shaped diatoms" with arrows, located in El Tatio, Chile and resembling Home Plate on Mars [2] [Credit: Ruff and Farmer, 2016]; c) Caloneis Bacillium diatom surrounded by schwertmannite precipitate from the Centralia, Pennsylvania, acid mine drainage system, [Credit: A. Williams].

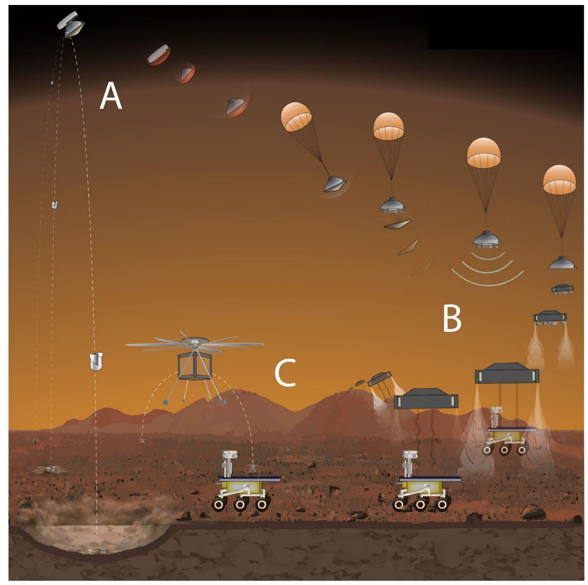

Figure 2. SPRING Mission Concept. A) Mars Surface Probes are released prior to landing on a targeted entry pathway to impact surface and excavate the subsurface. B) Rover is placed on surface and drives to impact site or science target. C) Drones are released to map units and select samples. Drones or rover can collect samples for on rover processing and SEM analysis. [Image Credit: Andre Stearns].

Concept of Operation: The SPRING Mission concept (Fig. 2) is developed around getting the MVP-SEM close to the primary study site with access to the samples of interest. Once there, it will be important to access a wide range of units. Biosignatures, in particular, might be best preserved underground. Digging or drilling on Mars for samples is notoriously difficult. To excavate larger units, SPRING will carry several Mars Surface Probes (MSP) attached to the mission aeroshell on its way to Mars. These will be deployed to the targeted landing site before the SPRING Mission reaches Mars. The MSP will then endure a hard impact at the targeted landing site to excavate material at depth. Once the impact debris settles down, the SPRING Rover will land to begin the primary mission.

In addition to the MVP-SEM, the SPRING Rover will carry a suite of instruments and drones designed to map, sample and process the materials for analysis in the SEM. The detachable Mars Mapping Drones (MMD) will be based on the JPL Mars Helicopter Scout to map the regional geology and collect small samples to return to the rover. The Rover will include cameras for geomorphic mapping, spectrometers for mineral mapping, a robotic arm for sampling and a sample processing station to prepare samples for the MVP-SEM analysis. The mission will repeat this process of mapping, roving, sampling and analysis to complete the mission objectives.

Potential Mission Target: The SPRING Mission microimaging capabilities are designed to provide valuable observations for a number of mission scenarios. Here we present one mission profile for reference. The search for biosignatures on Mars has been and is still an important motivation for exploration. While there are at least six type classes of potential biosignatures, two types, physical macrofossils and microfossils are ideally suited for detection with a camera suite and microimaging instrument package. Research at Mars Analogs [3], indicate that biosignatures preserved in hot spring sinter deposits would be dominated by physical microfossils. Previous work has identified potential preserved hot spring deposits at Home Plate in Columbia Hills [4] and Nili Patera (Fig. 3) in Syrtis Major [5]. We explore a potential mission concept to Nili Patera.

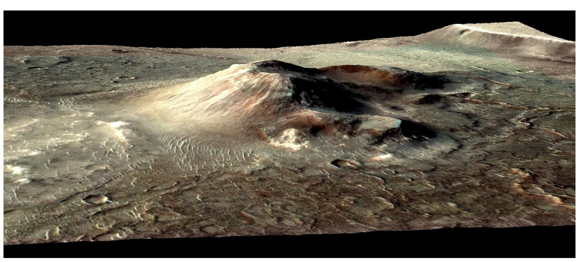

Figure 3. The Nili Tholus cinder cone (9.15N, 67.35E) in Nili Patera is surrounded by light-toned silica sinter deposits formed in an ancient hot spring environment. If life ever existed in this spring, it may be preserved as physical microfossils.

Mission Objectives: For the case study mission to Nili Patera, the SPRING Mission would be motivated by three science objectives that drive the instrument selections and mission configuration. Objective 1) Determine if the Martian spring deposits have evidence of physical biosignatures. Objective 2) Characterize the environmental conditions of the ancient spring system and its volcanic history. Objective 3) Map and characterize the surface resources in preparation for human exploration and in-situ resource utilization (ISRU). These objectives would be accomplished with the microimaging and compositional analysis capabilities of the MVP-SEM and supporting instruments and mission components. These objectives are motivated by high-level science goals from past Decadal Surveys and updates from NASA's CAPS report and the PSD Mid-Term Report.

Technology Development: The SPRING Mission concept is designed to take advantage of technological innovations already in development and spur on additional work with a specific use case. The MMD would be based on the development work of the JPL Mars Helicopter Scout, in development for inclusion in Mars 2020 [6]. The MSP would be based on the success of the Moon Impact Probe [7] and lessons from the Deep Space 2 mission [8]. This mission would require continued development of the MVP-SEM instrument through field testing and mission integration. SPRING would require additional development of Mars drone surface sampling techniques, precision surface landing for the impact drones and lander and networked communications for the rover and drone interactions. Each of these technological innovations would have wide applications for future planetary science and crewed mission capabilities.

Summary: The SPRING Mission concept would bring critical microimaging capabilities to the surface of Mars with applications for astrobiological, environmental and geological investigation. The Mission's ability to map, select and sample the surface would also provide important characterization of a location's resources for future human use. SPRING is built on substantial flight heritage while still driving instrumental, spacecraft and operational innovation that will open up exploration opportunities for future generation of robotic and human missions to Mars and beyond.

References: [1] Edmunson, J. et al., (2016) 47th LPSC, Abstract. [2] Ruff, S.W. and Farmer, J.D. (2016) Nature Communications, 7, 13554. [3] Hays, et al., (2017) *Astrobiology*, 17, 4. [4] Squyres et al., (2008) *Science*, 320, 5879, p1063-1067. [5] Skok et al., (2010) *Nature Geoscience*, 3, p838-841. [6] Balaram et al., (2018) *AIAA SciTech Forum*. 10.2514/6.2018-0023. [7] Goswami, J. N. and Annadurai, M. (2009) *Acta Astronautica*, 63, 11-12, p1215-1220. [8] Smrekar et al., (1999) J. Geophys. Res. 104, E11, 27013-27030.