The Mars Astrobiology, Resource, and Science Explorers (MARSE) Mission Concept. A. Z. Longo[1], Department of Earth, Marine, and Environmental Sciences, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599 (azlongo@live.unc.edu).

Introduction: Over the past two decades, NASA's Mars Exploration Program (MEP) has implemented a steady cadence of Mars orbiter, lander, and rover missions. These spacecraft have discovered that Mars harbors astounding geologic diversity and that multiple regions might have possessed habitable conditions during the Noachian and Hesperian periods. Despite this, our understanding of the planet and its history remains limited by terrestrial standards.

Thanks to remote sensing data, we have identified hundreds of hydrated mineral deposits which might be indicative of aqueous activity [1], as well as widespread morphologic features indicative of fluvial and lacustrine environments. Yet, most of these deposits could have formed as the result of multiple processes with varying implications for habitability [2]. We cannot differentiate between these processes with orbital data alone, nor can we determine how long liquid water persisted at each site. Beyond that, we do not know whether any of these environments preserve biosignatures.

This abstract presents a new mission concept which will leverage emerging technologies in development at JPL to take the next steps in addressing these knowledge gaps. The Mars Astrobiology, Resource, and Science Explorers (MARSE) mission will explore four of the most interesting sites on Mars, determine their geologic histories, and search for any biosignatures which might be present. MARSE is a multi-rover astrobiology mission designed to fit within the Discovery cost cap, and it therefore represents the next logical step in Mars exploration.

Scientific Rationale: The Perseverance mission illustrates the inherent difficulties facing the search for life on Mars and the limitations of orbital data. Its landing site in Jezero Crater was hypothesized to contain a Noachian river delta which persisted for thousands of years at minimum [3]. Ground truth data revealed that the putative deltaic landform is actually an alluvial fan which was deposited by flash flooding [4]. HiRISE imagery indicated that it was embayed by 2.6-Ga [5] lava flows on the crater flow, but RIMFAX radar data revealed that it was deposited on top of this unit [6]. Mars Sample Return (MSR) will enable the search for textural and chemical biosignatures which cannot be resolved with Perseverance's instruments. However, the suboptimal habitability of the sampling site suggests that it will only be the beginning of the concentrated search for life on Mars.

The available budget for planetary science in general and Mars exploration in particular is constrained by the substantial cost of MSR. A new Mars astrobiology mission must therefore fit within the Discovery Program's $500 million cost cap. The Mars 2020 experience demonstrates that a robust search for biosignatures cannot be tied to a single site. Landing site identification relies upon a series of assumptions about the geologic history of a location, the age of the targeted deposits, and the chemical properties of the water which was present. None of these parameters can be accurately assessed from orbit, making a single-site astrobiology mission scientifically risky.

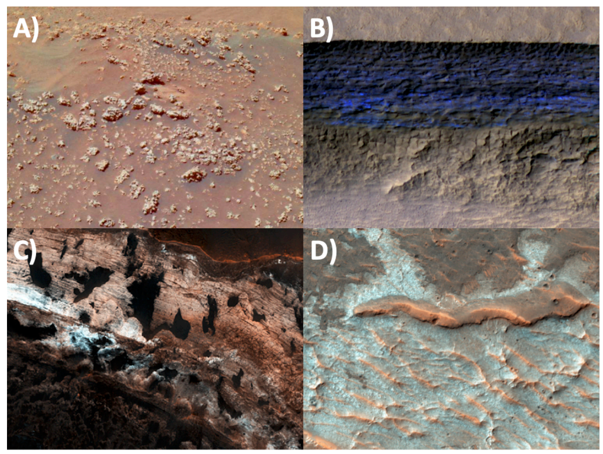

Figure 1. Proposed landing sites for the four MARSE rovers. A) Nodular-digitate silica deposits with potential biosignatures in the Columbia Hills. B) Ice-rich mid-latitude scarps in Milankovič Crater. C) Layered phyllosilicates in Mawrth Vallis. D) Chloride salt flats in Terra Sirenum.

MARSE will mitigate these risks by surveying four different sites in one mission. In addition to searching for biosignatures, it will return invaluable data on the geologic history of Mars and potential resources for human exploration. The mission's primary goal is to "Determine the nature, timing, and processes controlling the existence of past habitable environments on Mars, and search for signs of life in these locations" (derived from Section 10.7 in the Planetary Science Decadal Survey) [7]. MARSE will address four objectives, each of which is tied to a specific landing site (Figure 1).

1) Determine whether the opaline silica outcrops in the Columbia Hills contain robust biosignatures. The

MER Spirit rover discovered nodular-digitate silica outcrops in Gusev Crater. These are likely hot spring sinter deposits [8], and analog studies suggest that they might be biomediated microstromatolites [9]. However, other interpretations are plausible. Unlike Spirit's Microscopic Imager, MARSE's payload will be capable of detecting stromatolitic textures.

2) Determine the physical and chemical state of mid-latitude ice deposits. Milankovič crater, located in Mars' northern hemisphere, contains several ice-rich scarps which are 10s to 100s of meters thick [10]. These are likely exposed portions of a mid-latitude ice sheet. MARSE will probe the climate record preserved by these scarps and study layering at millimeter scales. In-situ data will inform crewed Mars mission concepts which rely on mid-latitude ice.

3) Determine the formation mechanism for the extensive clay deposits at Mawrth Vallis. The Mawrth Vallis region contains the most extensive phyllosilicate deposits on Mars [11]. However, these clays could have been deposited by precipitation, leaching, or aeolian transport. MARSE data will allow us to test these hypotheses.

4) Determine the habitability of chloride-forming environments. Chloride-bearing salt flats, such as the deposits at Terra Sirenum, were likely deposited in shallow saline lakes [12]. These are some of the youngest hydrated mineral deposits on Mars, but the pH and salinity of the source fluids is unknown. MARSE will refine our understanding of the history of water at these sites.

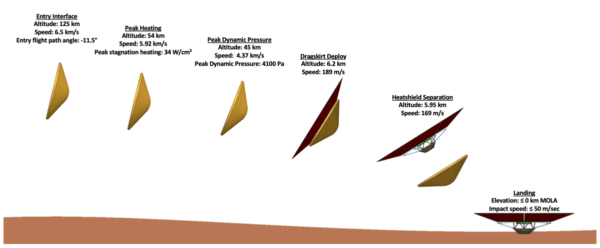

Figure 2: The Entry, Descent, and Landing (EDL) sequence for a SHIELD lander.

Implementation: MARSE is a novel architecture which enables the investigation of all four target locations. It leverages the Simplified High Impact Energy Landing Device (SHIELD) lander, which is currently in development at JPL [13]. SHIELD uses a low ballistic coefficient entry configuration, a low terminal velocity, and an impact attenuator to enable a survivable hard landing with an acceleration of less than 2,000 g. Each SHIELD lander is capable of carrying up to 20 kg of payload.

In the MARSE architecture, four SHIELD landers will launch together on an EELV-class launch vehicle. Each lander will have its own individual commercial cruise stage, which will perform phasing burns to target a specific landing site. Each SHIELD lander will contain a Sojourner-class rover with a mass of 15 kg. This will likely be a clean-sheet design ruggedized for hard landings. The <5 kg payload will include a Raman spectrometer and a hand lens imager derived from the SHERLOC/WATSON pairing. These contact science instruments will enable the characterization of fine-scale texture, organics, and mineralogy. Each rover will also carry a panoramic camera and possibly an infrared point spectrometer for context observations. The sole communications system on each rover will be a UHF antenna, so they will be reliant upon preexisting orbiters to relay data. Whereas Sojourner had a daily power budget of 170 W-h [14], we assume that MARSE will require 500+ W-h per Sol to close its mobility requirement. This power requirement might be satisfied by more efficient solar cells and/or deployable solar arrays.

The MARSE concept is currently in development for a potential submission to a future Discovery Request for Proposals. Current work includes the detailed study of landing sites, measurement requirements, and deployment mechanisms for the rover. Additionally, the SHIELD team is exploring how to reduce the diameter of the 80-kilometer landing ellipse by 50% or more. To close the traverse requirement for the Columbia Hills site, the rover must be able to traverse from the margin of the ellipse to its center. We are interested in partnering with any researchers who would like to contribute to this mission.

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