WHY MULTIPLE LANDED MISSIONS TO MARS ARE CRUCIAL TO UNDERSTANDING THE EVOLUTION OF TERRESTRIAL PLANET HABITABILITY: KEY NEXT STEPS IN ADVANCE OF THE DECADAL SURVEY.

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Prior white papers: A large number of members of the planetary science community have highlighted the importance of multiple missions of landed exploration on Mars to answer the most fundamental science questions about terrestrial planet evolution, including a 2018 white paper to the National Academies Astrobiology strategy committee [1; 15 authors], a *JGR-Planets* paper highlighting key questions about terrestrial planet evolution answerable on Mars and the measurements needed to address them [2; 46 authors], a report at the February 2017 Vision 2050 meeting [3; 19 authors], and multiple abstracts at the 2011 Mars Program Planning workshop [e.g., 4,5].

Rationale In Brief: Key questions about the evolution of terrestrial habitability include: What were the timing and effects of large impacts and stellar evolution on atmospheres of our solar system's rocky planets? What is the effect of loss of a magnetic field on atmospheric loss rates and composition? What has been the evolution of Martian atmospheric composition and volatiles? How does the history of volcanism and tectonics affect habitability? How do cycles of obliquity and eccentricity influence long-term climate?

Mars possesses a unique, continuous rock record from its first two billion years and is the only place in the solar system allowing access to a rock record that allows systematically addressing these questions. Key measurements, which can only be acquired in situ, are indicated in Figure 1.

Importantly, no single stratigraphy on Mars records all 2 billion years of time. Moreover, as on Earth, orbital data [6] has shown the record of Mars first two billion years is diverse, with multiple habitable environments, varying in space and time across the planet. Thus, interrogation of multiple geologic sections is needed to understand the time evolution of the Mars system and controlling processes.

Mission Concept Studies Required: Current costing paradigms present a quandary for Mars exploration. In internal JPL efforts, a 2 MER type rover mission is costed as more expensive than its actual executed cost adjusted for inflation, an outcome that is related to assumptions, which must be reexamined. Given that the drivers of cost growth on serial builds are new designs for capability (e.g. corer and instruments on M2020) and required modifications due to original component obsolescence, the experience of MER and logic dictates multiple simultaneous builds will realize cost savings relative to serial builds. Detailed, pre-set interfaces can also prevent cost overruns due to instrument redesigns for interface changes.

What is required is at least two studies with two thrusts: (1) examination by multiple centers and with experienced mission personnel minimalist multi-rover missions built to support capable in situ instrument payloads that make the measurements in Fig. 1 and (2) examination of novel smaller concepts like larger versions of Mars Drop [7] to vet alternative means of surface access and mobility by hoppers, helicopters or high-precision landings.

References: [1] Ehlmann et al. "Mars as a Linchpin for the Understanding the Habitability of Terrestrial Planets", white paper to the Natl. Academies Comm on the Astrobiology Science Strategy [2] Ehlmann et al., 2016, *JGR-Planets*, [3] Ehlmann et al., "Mars Exploration Science in 2050" abstract, presentation [4] Wray, 2011 "The Scientific Necessity of Landing at Diverse Sites on Mars" [5] Niles et al., 2011 "Multiple Smaller Missions as a Direct Pathway to Mars Sample Return" [6] Murchie et al., 2016. *JGR-Planets* [7] Staehle et al., 2014, Mars CubeSat/NanoSat Workshop, presentation

Fig. 1. Mapping scientific objectives to measurements needed to potential mission concepts which should be studied [see also 2].