Proposed White Paper

Expanding Mars Science Return in the MSR Era: The Need for, Capabilities of, and Challenges Associated with Small Mars Science Missions

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Overview: This proposed white paper will advocate for the creation of a new program to facilitate low-cost Mars science investigations during the "MSR Era", i.e., the period of time in which the majority of MEP funding is dedicated to MSR. What follows is a first draft of the proposed white paper. In the final white paper, we plan to provide more details on potential Mars mission architecture, linkages between science investigations and architectures, and more details on enabling technologies. We are asking for community input from all interested parties on these topics.

Given the likelihood of Mars Sample Return (MSR) being the dominant Mars exploration effort over the next decade and beyond, the Mars science community could find itself in a situation similar to what the astrophysics community has been in for over a decade. Namely, that a large, multi-$B mission (JWST) consumed most available resources at the expense of other valuable science investigations, along with the associated loss of expertise. Hence, there is a need for smaller programs to maintain a diverse Mars exploration science portfolio during the MSR Era (following the astrophysics analogy) with small, i.e., SMEX- or MIDEX-class ($125M - $250M) Mars missions.

Numerous small Mars mission architectures have been studied over the last 10 years including:

- MarsDrop, a Reentry Breakup Recorder (REBR)/Deep Space 2 (DS2) heritage entry system combined with a 1960s-era, proven, steerable Rogallo parawing enabling landed access to scientifically interesting, but potentially hazardous Martian terrain
- Other entry systems not relying on REBR/DS2 heritage and/or parawings, e.g., entry systems with other form factors, deployable entry systems, inflatable deceleration systems, hard landers, etc.
- CubeSat missions, i.e., extensions of the successful MarCO missions
- SmallSat missions, i.e., small spacecraft equivalent to 6U-12U CubeSats (or larger), but not relying on the CubeSat form factor
- Modular SmallSat designs that would allow for rapid mission development timelines (~1year)
- Miniaturized surface mobility systems (that would be delivered by one of the above entry systems), e.g., balloons, hoppers, Pop-Up Flat-Folding Exploration Robot (PUFFER), etc.

Diverse science objectives could benefit from these architectures including (with references to investigations listed in the new MEPAG Goals document):

- Determining if time-varying methane signatures are biogenic or non-biogenic in nature. [**I** B1.2, **II** A3.1]
- Understanding saltation and the effects of electrostatics (also relevant to future

human exploration of Mars). [**II** A2.1, **III** A2.5, **IV** B2.1, **IV** B3.1, **IV** B4.3]
- The nature of Mars' local diurnal hydrological cycle and deliquescence. [**II** A2, **III** A1.1]
- Understanding Mars' climate variation using records contained within polar layered deposits (PLD). [**II** A2, **II** B1, **III** A1.3]
- The search for water sources, e.g., *in situ* measurements at recurring slope lineae (RSL), candidate human exploration sites, etc. [**I** A2.1, **III** A1.1, **III** A4.3, **IV** A3, **IV** C2, **IV** D1.1]
- Determining Mars' geologic history from vertical exposures, i.e., crater walls, pits, chasms (e.g., Valles Marineris), etc. [**III** A3.1, **III** A4.5, **III** A4.7]
- Direct measurements of Mars winds/temperature/humidity/surface pressure using a network of mutually occulting satellites. [**II** A, **IV** B3, **IV** C2]
- Continuous monitoring of weather and documenting the temporal behavior of dust storm genesis on time scales shorter than one sol from areo-stationary orbit. [**II** A, **III** A2.4]
- *In situ* landing site characterization for human exploration. [**IV** A3, **IV** B, **IV** D2]
- Characterization of the Martian interior via deployment of a seismometer network. [**III** B1.2, **III** B2.1]
- Monitoring of modern surface processes with increased temporal monitoring from surface-based observations. [**III** A4.3]

All of these objectives could be met through the use of one or more of the above architectures, combined with new or maturing instruments. Currently, however, there are limited Mars launch opportunities, especially for co-manifested or ride-along payloads. NASA's Small Innovative Missions for Planetary Exploration (SIMPLEx) program is designed to provide such launch opportunities, however, SIMPLEx relies on commercial GEO launches and the limited number of NASA deep-space launches, neither of which will necessarily get a small mission to Mars.

Increasing the allowable propulsive capability of SIMPLEx missions, the number of appropriate and allowable ride-along missions and/or co-manifested launch opportunities, and the use of small launch vehicles that could place a small payload on a direct-to-Mars trajectory (combined with a small, high-efficiency transfer stage) would greatly open up the opportunity space for small Mars science missions. Of course, a commensurate increase in funding would also be required.

Compounding the lack of launch opportunities is the need for technology maturation associated with:

- Small propulsion systems capable of ~1-2 km/sec of ΔV (~10X greater than current capabilities)
- Flight-proven propulsive EELV Secondary Payload Adapter (ESPA) rings
- Small entry systems (including those with and without REBR/DS2 heritage)
- Deployable entry systems and other drag devices
- Steerable parawings combined with Terrain Relative Navigation (TRN) to achieve pin-point landings
- Miniaturized C&DH and other spacecraft subsystems

We therefore advocate the need for a balanced Mars science exploration program during the MSR Era: NASA should create a new, small Mars mission program within MEP chartered with developing SMEX-to-MIDEX-sized Mars missions (either launched by directly by NASA, or as ride-alongs or co-manifested payloads on military, commercial, and foreign missions/launch vehicles). This should be further supported with a Mars-specific, non-instrument, technology maturation program for small orbiting and landed spacecraft architectures funded through a new ROSES Program Element Appendix.