MULTIPLE SMALLER MISSIONS AS A DIRECT PATHWAY TO MARS SAMPLE RETURN.

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Introduction: Recent discoveries by the Mars Exploration Rovers, Mars Express, Mars Odyssey, and Mars Reconnaissance Orbiter spacecraft include multiple, tantalizing astrobiological targets representing both past and present environments on Mars. The most desirable path to Mars Sample Return (MSR) would be to collect and return samples from that site which provides the clearest examples of the variety of rock types considered a high priority for sample return (pristine igneous, sedimentary, and hydrothermal) [1].

Here we propose an MSR architecture in which the next steps (potentially launched in 2018) would entail a series of smaller missions, including caching, to multiple landing sites to verify the presence of high priority sample return targets through *in situ* analyses. This alternative architecture to one flagship-class sample caching mission to a single site (Fig. 1) would preserve a direct path to MSR as stipulated by the Planetary Decadal Survey [2], while permitting investigation of diverse deposit types and providing comparison of the site of returned samples to other aqueous environments on early Mars.

The proposed series of missions would be flown at every launch opportunity from 2018 until 2028 to identify, characterize, and collect samples for return. Depending on budgetary constraints, these launch opportunities could allow for 5-10 smaller MER-class rovers to be sent to multiple landing sites to explore locations of recent liquid flow features, and sulfate-, phyllosilicate-, carbonate-, and chloride-bearing deposits from ancient wet environments such as Valles Marineris, Mawrth Vallis, and Nili Fossae. In addition, 1-2 telecommunication orbiters with science capabilities would need to be launched to maintain the communication infrastructure and continue high resolution remote sensing of the surface.

The landers would share a common EDL system, mobility platform, and rover chassis to increase efficiency and control costs. The rover design would allow for modular or customizable competed science instrument packages (including a sample caching system) necessary to characterize the environment and identify potential high value samples at a given landing site.

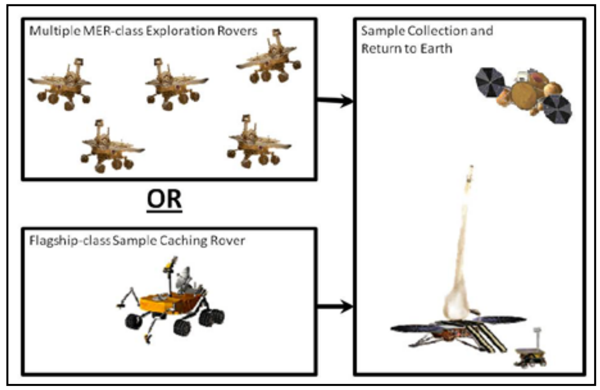

Figure 1. Mars Sample Return Architecture formulation where the Flagship class sample caching rover is replaced by smaller MER-class exploration rovers.

There are 8 reasons why a multiple mission approach to the identification and collection of a suitable sample suite would be more desirable than a single flagship sample caching mission:

1. Scientific Return: Many of the major questions about Mars that have been raised during the past ~5 decades of Mars exploration [3] remain unanswered such as: how much warmer and wetter was Early Mars? When did this clement period occur and how long did it last? Does the modern climate of Mars permit liquid water for life?

Modern water seepages have been proposed and discoveries of sulfates, phyllosilicates, carbonates, and chloride salts made from orbit point to geographic and temporal diversity of past habitable Martian environments. Discerning environmental conditions and their relevance to life requires landed missions to establish an historical and geological context which has been shown to be difficult to do with orbital data. The required details (petrographic relationships among minerals, rock textures and fabrics) are measurable only at the mm- to µm scale. While we know enough now about Mars to return scientifically interesting samples, it is unknown whether they will offer breakthrough discoveries. Multiple precursor missions exploring multiple exciting landing sites will substantially increase the probability for breakthrough MSR.

2. Breakthrough Discoveries: Landed missions provide the highest potential for breakthrough discoveries such as identification of organic material, detection of a biosignature, and/or the discovery of something unpredictable. These details simply cannot be discerned from orbit. The effects of a breakthrough discovery are difficult to predict, but could result in increased support for the Mars program (as evidenced by the discoveries surrounding ALH 84001), including strong public, scientific, and political support for further investigation. Future breakthroughs could even ignite the nation's interest in human exploration missions to Mars.

3. Programmatic Risk Mitigation: Because of high costs for each component, a weakness in the current MSR mission architecture is that a single mission failure would endanger the entire program. The program is especially vulnerable in the initial stages where a sample has yet to be identified. Multiple missions provide redundancy, the capability of recovering from a mission failure, and building technical expertise. This redundancy could also loosen the lander safety requirements and open up a larger portion of the Martian surface to exploration.

4. Synergy with Human Exploration: There is a wide range of objectives that need to be addressed by Mars surface missions as a precursor to human exploration. These do not often have high enough science priority to be included as SMD mission objectives because there are few opportunities for landed missions available. The large number of missions in this program could allow for synergistic investigations and/or missions to be conducted with HEOMD to sites important for accomplishing exploration objectives [2]. The scalability of the multiple mission approach would also allow this program to potentially take advantage of HEOMD resources (if available), such as launches of several spacecraft on the SLS rocket.

5. Budgetary Flexibility: Although multiple small missions may be more expensive to implement in aggregate than a single sample caching flagship mission on a decadal scale, the large cost and complexity of a flagship sample caching rover makes implementation very difficult (or impossible in the current budget) due to phasing and high demands on single year budgets. Thus a more sustainable program of smaller missions would provide substantial budget flexibility, spreading the costs over time and helping shield the overall planetary program from MSR budgetary pressures. This approach also offers a return to NASA's earlier successful philosophy of multiple missions to common targets (Mariner, Viking, Voyager, etc.). The scalability of this model will also allow the program to expand during periods of higher budget availability by simply adding additional missions. We argue that the economies of scale and flexibility realized from the small, multiple mission approach are vital to accomplishing the goals of NASA's Mars exploration efforts.

6. Cost Risk: The multiple mission approach would substantially drive down risks of going over budget since each mission would utilize many of the same systems and technology. This reduces the amount of development and testing required, while also reducing the amount of risk by utilizing proven spacecraft and operations systems. Furthermore the commonality of many of the spacecraft components would improve the reliability of cost models, driving down unpredictability, permitting greater cost control, and providing a stable platform for instrument developers.

7. International Cooperation: This new mission framework for MSR expands the scope of previous exploration and caching efforts allowing for a new alignment of U.S. and European (and perhaps other nations) international Mars exploration goals. Under this concept, for example, any European spacecraft that explores a high priority site on Mars would be directly contributing to the stated goals of MSR as defined by the Decadal Survey. The same would apply for craft from other spacefaring nations.

8. Technology Development: The establishment of a high-heritage, well tested, and optimized spacecraft design would provide a stable platform to pursue technology development for instruments and system improvements leading toward MSR. The costs and risks incurred by testing new technologies would be mitigated by utilizing them on a well-characterized spacecraft system. Advanced instruments may be included that are tailored to meet science goals specific to each site. The testing of more substantial technologies in preparation for future human exploration would likely fall outside of the MSR architecture described here necessitating additional missions that can utilize the high-heritage systems developed in this architecture.

Direct Pathway to Mars Sample Return: We argue here that the multiple mission approach to sample identification and caching is a more desirable alternative to the single large flagship model and thus provides an alternative MSR architecture. If such an approach can be implemented within available budget constraints, NASA would be able to pursue MSR in conformance with the intent of the Decadal Survey, even if not in the way that had been previously envisioned during the Survey's deliberations.

References: [1] MEPAG E2E-iSAG (2011) Planning for Mars Returned Sample Science: Final report of the MSR End-to-End International Science Analysis Group (E2E-iSAG), http://mepag.jpl.nasa.gov/reports/. [2] Committee on the Planetary Science Decadal Survey N. R. C. (2011) Vision and Voyages for Planetary Science in the Decade 2013–2022. [3] MEPAG (2010) Mars scientific goals, objectives, investigations, and priorities: 2010.