A FIRST, SINGLE-LAUNCH MARS SAMPLE RETURN MISSION: ACHIEVING THE KEY HUMAN AND SCIENCE EXPLORATION GOALS. M. M. Marinova[1,2], C. P. McKay[2], P. D. Wooster[3], J. S. Karcz[2], L. G. Lemke[2], J. L. Heldmann[2], C. R. Stoker[2], A. A. Gonzales[2], A. F. Davila[2,4], [1]Bay Area Environmental Research Inst. (margarita.m.marinova@nasa.gov), [2]NASA Ames Research Ctr, Moffett Field, CA, [3]SpaceX, [4]SETI Institute.

Summary: The Decadal Survey has identified Mars Sample Return (MSR) as the next key milestone in Mars exploration, as well as an important aspect of planetary exploration overall [1]. We will describe the rationale for a simple first sample return mission to Mars as an affordable means to provide meaningful science. This mission would collect samples from its immediate vicinity and directly return them to Earth within a single launch opportunity. The collected samples will answer the key questions relevant to the human and science exploration of Mars, and should fit within the current budget and cost limit set by the Decadal Survey for MSR [1].

Introduction: Mars Sample Return is a critical next step in the exploration of Mars, both for scientific reasons, as defined by the Decadal Survey [1], and as a precursor to human exploration [2]. Current sample return architectures require multiple missions over multiple launch opportunities, and a complicated choreography between rovers, landers, and cached samples. This results in a costly and protracted mission sequence. We propose the use of a simple, single launch window, first sample return mission to achieve the key human exploration and science exploration goals. This mission should be significantly lower cost (*MSR Science Steering Group* in 2002 reported <$2B [2]), and expeditious than the currently planned MSR mission and will provide a technical and programmatic path to more capable missions to multiple sites.

This first sample return mission would land on Mars, collect samples locally, and return these to Earth orbit, all within a single mission and launch opportunity (fig. 1). The single landed vehicle would contain all instrumentation for sample collection, as well as the Mars ascent vehicle (MAV) required to bring the samples back to Earth orbit. This single vehicle approach does limit the payload mass for sample collection and analysis equipment. The most likely scenario is for an arm, drill, or small rover collecting the samples, with simple analysis equipment, such as cameras (fig. 1).

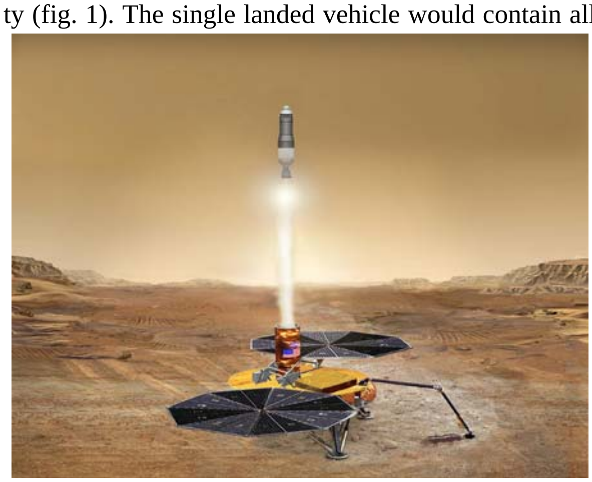

Figure 1. Using an arm to collect samples on a first sample return mission. *Credit: NASA/JPL*

The mission is expected to collect regolith and dust, small rock(s), and atmosphere; shallow subsurface samples may also be accessible to an arm with a scoop or a drill, such as the Icebreaker Drill [3]. Here we show that these local and pristine Mars samples are of high value for both human and science exploration.

Potential Impact: The scientific importance of sample return is extremely high. For over 3 decades this has been the primary science goal for Mars science [1], but it has always been delayed due to cost. The sample return concept defined here can return the first sample under current budgetary constraints [1,2]. Furthermore it will establish a technology that will enable repeated sample returns from Mars from multiple sites. Finally, sample return is a key step on the way to site certification for human exploration [1,2,4].

For human exploration: A sample return mission is a pre-requisite for human exploration. This is to assess toxicity and bio-hazard potential of the Martian environment, learn best practices for *in situ* resource utilization (ISRU), and demonstrate a round-trip mission [1,2,4]. The proposed first sample return mission, with locally-sampled material, would specifically address the following key objectives:

- Collect surface samples and dust, which are the materials that astronauts will be interacting with, for toxicity and bio-hazard analysis.
- Demonstrate a round-trip mission to Mars.
- Provide detailed understanding of the surface material which could be used for ISRU.
- Collect atmospheric sample for detailed toxicity and bio-hazard assessment.

Thus a simple sample return mission, with locally-derived samples that are not extensively pre-screened, would achieve most of the objectives required to pave the way for human exploration. The much lower cost of this type of sample return would also allow for multiple locations to be sampled before a landing site for a human mission is selected.

For science exploration: The ability to analyze Mars samples with the full range of instruments available in Earth laboratories has always been a major motivation for sample return. In addition to the obvious higher precision and detail which can be achieved, an important aspect is the ability to broadly analyze a sample – not just for the pre-conceived composition for which a few instruments are designed, as on a planetary mission – and to be able to follow up on findings on the timescale of weeks or months rather than launch windows and decades.

A first sample return would specifically address the following key science exploration objectives:

- Sample the ubiquitous dust on Mars, which is present on all surfaces and affects our interpretation of the entire surface of Mars and atmospheric properties.
- Detailed compositional and mineralogical analysis of surface material. In situ analyses inevitably perform targeted searches, which are based on pre-conceived notions of what should be present. The finding of perchlorate by Phoenix, and the possible interaction of the perchlorate with organics in the Viking experiments to give ambiguous results, demonstrates this need [5].
- Light element geochemistry. The distribution of the biogenic elements (C, H, N, O, P, S) and their compounds, as well as nitrates, carbonates, and phosphates, have not been accurately determined.
- Weathering history: The Martian soil is a product of chemical weathering. Various hypotheses have been suggested: e.g., acid fog (of Cl and S), liquid water, UV and oxidants. This question has important implications for the search for organics and understanding the environmental and geological history of Mars.
- Search for organic material without the effects of other soil components. For example, the separation of low levels of organics from the perchlorate-rich soil would be easily achieved in Earth labs.
- Atmospheric sample for methane and other trace gases analyses, and isotopic ratios of the gases which would allow a better understanding of accretional processes and the history of atmospheric cycling.
- Iron redox state: understanding its mineralogical state will help elucidate the weathering and oxidative history of the soil [6].
- Oxidant: The nature of the oxidant(s) in the Martian soil discovered by the Viking Biology experiments and the relation of these oxidants to the perchlorate remains unclear.

This proposed first sample return mission will certainly return samples that are relevant to the current environment, but it may not be possible to place the samples in a direct context of the geological history of Mars due to limited ability to sample rock outcrops and conduct detailed analyses. However, especially for human exploration objectives, it is in fact the easily-transported surface material that is of most interest in toxicity, bio-hazard, and some ISRU studies [2,4]. For science exploration objectives, obtaining a pristine sample with no (extensive) terrestrial contamination, and gaining an understanding of the ubiquitous dust, would be of high value, as shown by the list above.

The sample will have a provenance constrained to a few hundred kilometers and known contextual setting. The importance of such a sample analyzed in Earth labs is easily gleaned by looking at how the Martian meteorites found on Earth have provided a wealth of information about Mars without *any* contextual information on where they come from.

Cost: A sample return mission that requires a single launch opportunity and uses developed EDL platforms is expected to significantly reduce the cost of the first sample return. While the Decadal Survey stressed the importance of sample return, it also recommended that the mission be pursued only if the price is right [1]: a single-launch sample return should comfortably fit in the prescribed cost envelope, while the currently proposed multi-launch mission does not.

Technical aspects: Recent analysis [7] suggests that a MAV with a mass of less than a tonne could return about a kilogram of sample to Earth orbit. Such a MAV could be delivered to the Martian surface by a Red Dragon landing system [7]. Other landing systems may also be possible, and the MAV design will be optimized as necessary, but the key is that currently high TRL systems are available to deliver the instruments and MAV to Mars, and to collect the samples. The main development will be the MAV – a small rocket which can be extensively tested on Earth.

Concluding summary: A first, single-launch window sample return mission provides a cost-effective, near-term, and relatively low risk method of obtaining pristine Martian samples, which will be of high value for both human exploration and science exploration objectives. The mission will demonstrate the capability for a round-trip mission to Mars, help quantify toxicity and reverse-contamination risks, and answer a slew of science questions which require sample analysis back on Earth. This first sample return will set the stage for future more elaborate Mars sample return missions and for the human exploration of Mars.

References: [1] Squyres S. et al. (2011) *NRC Decadal Survey report*. [2] MacPherson G. et al. (2002) *Mars Sample Return Science Steering Group Report*. [3] Zacny et al. (2012) JAE doi:10.1061/(ASCE) AS.1943-5525.0000212. [4] McLennan S. M. (2011) *MEPAG E2E-iSAG report*. [5] Navarro-González R. et al. (2010) *JGR 115*, E12010, doi:10.1029/ 2010JE003599. [6] Quinn R. C. et al. (2011) *GRL 38*, L14202, doi:10.1029/ 2011GL047671. [7] Lemke L. et al. (2012) *Concepts and approaches for Mars exploration (this meeting).*