MARS RETURNED SAMPLE SCIENCE: SCIENTIFIC PLANNING RELATED TO SAMPLE QUALITY.

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Introduction: There is no such thing as a perfect sample. All samples are degraded in ways small or great. Even the act of taking a sample has an effect. Fortunately, sample scientists have learned over the years to recognize and account for small amounts of degradation, and this is a normal part of sample science business. However, as the amount of damage of different kinds increases, our ability to use a sample to answer scientific questions becomes impacted, and at some point, prevents meaningful use at all. A challenge is that the whole issue of sample quality is a gray scale. Nevertheless, in order for MSR, as an engineering enterprise, to be able to proceed, we need to find ways to establish quantitative thresholds that can be used for formulating requirements. Furthermore, in a budget-constrained environment, which is always the reality, we need to have a common understanding of priorities in the area of sample quality so that as implementation proceeds, the engineers/technologists can make investments and decisions that are optimized.

We have evaluated the set of measurements central to addressing the science goals [1] for MSR, and developed a list of the factors that would affect the usefulness of the samples for scientific investigations. Previous reports from various science analysis groups (e.g., [1-4]) formed the basis and provided guidelines for our activity. This topic was discussed in detail in a pre-LPSC (2014)workshop with ~30 participants.

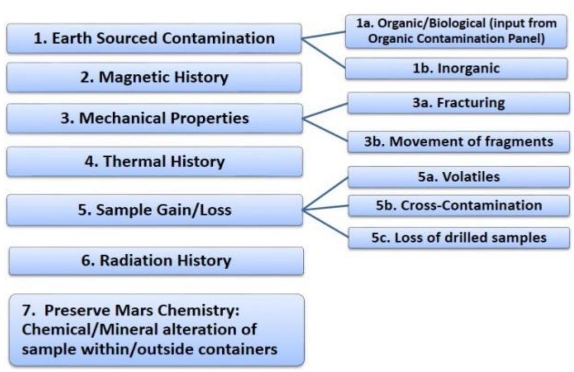

Figure 1. Factors that may affect sample quality.

Factors affecting the science value of returned samples: Considering the entire set of returned sample science investigations [2-4], we have identified 11 sample quality factors, which can be organized into 7 groups (Fig. 1). Our goal is to develop quantitative requirements in each area.

1. Earth-sourced Contamination may compromise high priority investigations such as biosignature and planetary evolution of Mars. The risk to science interpretation from these contaminants can be mitigated through proper documentation of flight hardware and materials plus the inclusion of "blank" samples in the caching mission.

1a) Organic and biological contamination. The search for biosignatures and investigations of habitability are most dependent on the correct evaluation of organic and biological (if present) components in returned samples. Earth-sourced organic contamination may be introduced by hardware or hydrazine fuel in the landing system. Whole cells or fragments of cells from Earth-sourced biology could lead to false positives of life detection.

1b) Inorganic contamination. Materials used for drilling and sample encapsulation may introduce elements that are important for geochemistry/astrobiology (e.g., Li, B, Mg, P, S, Cl, Sc, Mn, Co, Ni, Zn, Y, Br, Cs, La, Ce, Eu, Gd, Zr, Nb, Ta), and geochronology (e.g., K, Rb-Sr, Sm-Nd, Lu-Hf, W-Hf, Re-Os, U-Th-Pb). The acceptable level of contamination is ~1% of a representative shergottite (intermediate in trace element abundances) for geochemistry/astrobiology, and 0.1% for geochronology.

2. Magnetization History. Paleomagnetic properties of Martian rocks may contain information about planetary core formation/evolution and sedimentary environments. The current magnetic field on Mars is essentially zero. Since samples would end up on Earth, there is little point worrying about fields of this strength or lower. Artificial fields (electric motors, materials used for drill, X-ray radiation) associated with the missions, may impart false magnetic signals.

3. Mechanical Integrity refers to ***3a) fractures*** *in the sample and* ***3b) the relative movement of broken pieces***. Several high priority investigations (e.g., biosignatures and (near-)surface processes involving water) are dependent on investigating rock fragments large enough to exhibit the rock's texture and the relationships of the individual grains to each other. The strategy to minimize damage to the mechanical integrity is to conduct tests of sampling procdures on a set of rocks of different mineralogy, grain size, and mechanical strength, and ensure the best performance is achieved on a medium-durability reference sample that resembles rocks previously seen on Mars.

4. Thermal History. Samples may be damaged in two ways by low levels of heating: 1). Dehydration of certain kinds of minerals (e.g. poly-hydrated sulfates such as $MgSO_4 \cdot nH_2O$, [2-3]), and decomposition of certain organic molecules. Our ability to understand the effects of heating are dependent in part on whether and how the samples are sealed. Our ability to reach unambiguous scientific interpretations is more at risk with heating of unsealed samples than with sealed samples. Thus, a more stringent constraint is proposed for unsealed samples. For sealed samples, it is assumed to be acceptable for the temperature to reach the local maximum at the landing site chosen.

5. Sample Gain/Loss refers to change to a sample during or after collection and encapsulation in a container.

- ***5a)*** *Volatile gain or loss.* Some of the key objectives of MSR relate to volatile components of the rock/ regolith samples, especially water. It is very important that these volatiles be preserved with the sample until the sample tubes are opened. In addition, it is very important that other volatiles (either from adjacent volatile-rich samples, or from the Earth's atmosphere after landing on Earth) not be allowed to leak into the sample. Either scenario could result in significant misinterpretations.
- ***5b)*** *Cross contamination between samples* refers to residual material in the sampling system from a previous sample ending up in a subsequent sample. Planned high priority investigations are not highly sensitive to this sort of contamination, so it would appear that requirements in this area do not need to be strict.
- ***5c)*** *Loss of drilled samples* refers to loss of small fragments during sample collection/encapsulation and handling. This can happen in any sample transfer step, and is a form of mechanical fractionation. Given the astrobiology objectives of the mission, heterogeneous rocks would certainly be targeted. Samples with highest scientific value in astrobiological investigations may be multilayered with varying mechanical properties (e.g. a layer or a vein of soft materials). Missing materials from one portion of the sample could lead to inaccurate interpretations. Thus, ensuring recovery of a large portion of the intended sample is crucial for biosignature and habitat investigations.

6. Radiation History. Radiation (e.g., proton, neutron, gamma-ray, X-ray) can damage the structure of microorganisms, and affect a variety of sample characteristics such as color and thermoluminescence properties [5]. Neutron radiation could change some isotope ratios (e.g., INAA uses neutron radiation to produce specific isotopes of elements for chemical analysis). Fortunately, current experience with surface and space radiation [7-8] and various calculations suggest the total dosage would be very low (8 krads, [9] & personal communication, Shawn Kang, 2014) for the expected duration in such environments (~20 yrs). Thus, natural and artificial radiation with current rover and orbiter design should not cause significant concerns to inorganic chemistry of samples.

7. Exchange with non-Mars environments may reduce the scientific value of samples so that they would no longer adequately represent the conditions on Mars. Processes include, but are not limited to, oxidation/reduction, dehydration/hydration, and surface chemistry of grains. Such exchange would likely occur at any sample receiving facility, and consideration is required to minimize the effects.

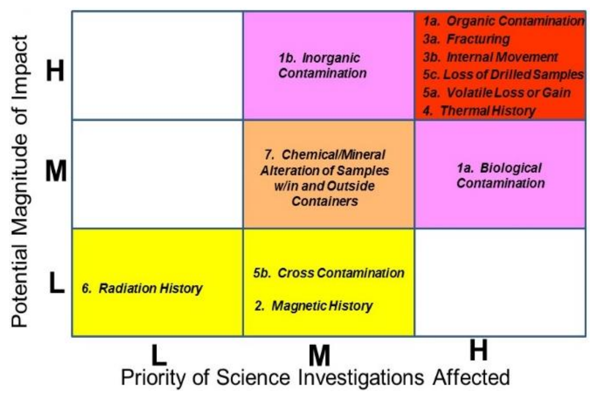

Figure 2. Draft sample quality matrix.

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References: [1] McLennan, S.M. et al. (2011). Astrobiology 12: 175-230. [2] Mars 2020 SDT (2013). MEPAG. [3] Borg, L.E. et al. (2008) Astrobiology 8: 489-535. [4] MacPherson, G. J., et al. (2001) ND-SAG Appendix III. MEPAG. [5] Allen C. C. et al. (1999) *JGR*, *104*, 27043-27066. [6] Farley, K. A., et al. (2014) *Science*, 343. [7] Zeitlin C. et al. (2013) *Science*, *340*, 1080-1084. [8] Hassler D. M. et al. (2013) *Science*. [9] MSL Mission Total TID Table 8