SAMPLE SCIENCE INTEGRITY CONSIDERATIONS FOR THE MARS SAMPLE RETURN PROGRAM.
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Introduction: The Mars Sample Return (MSR) campaign is comprised of three elements: 1) the Mars 2020 mission [1], 2) the MSR program, and 3) the Sample Receiving Project (SRP). The MSR campaign was initiated with the successful landing of the Mars 2020 Perseverance rover on Mars on February 18, 2021. At the time of writing, the Mars 2020 (M2020) mission had successfully sealed and stored one witness and collected and stored six samples in Returned Sample Tube Assemblies (RSTA) in the Adaptive Caching Assembly (ACA) on the Perseverance rover. The sealed and stored samples include one RSTA that contains martian atmosphere and five RSTAs that contain rock cores from three different rocks (the Montdenier and Montagnac cores from Rochette, the Salette and Coulettes cores from Brac, and the Robine core from Issole) in Jezero Crater; one additional rock core (Pauls) from Issole has been collected and is still being processed. Up to a total of four more witnesses and 32 more samples are expected to be collected and sealed over the course of the prime and extended M2020 mission. It is anticipated that the M2020 mission will create sample caches for potential return to Earth by the MSR program [2,3].

Current status of the MSR program: As a follow on to the M2020 mission, the MSR program is the second element of the MSR campaign. The goal of this multi-mission program is to bring a scientifically return-worthy set of martian samples back to Earth for scientific investigation and discovery. In this regard, it is important to note that the MSR program must be implemented such that it meets the following Level 1 requirement of the MSR campaign: The MSR campaign shall be capable of delivering the samples to Earth avoiding environmental extremes that would compromise the scientific integrity of the samples and providing knowledge of the environmental conditions that the samples experience until recovery.

The MSR program is a collaborative effort being planned by NASA and the European Space Agency. The main components of the program would be: 1) a Sample Retrieval Lander (SRL) provided by NASA (but with an ESA-provided Sample Transfer Arm) that would deliver an ESA-provided Sample Fetch Rover (SFR) and NASA-provided Orbiting Sample (OS) container and Mars Ascent Vehicle (MAV) to the surface of Mars, with a launch date no sooner than 2026, and 2) an Earth Return Orbiter provided by ESA that would include a NASA-provided Capture, Containment, and Return System (CCRS) and Earth Entry System (EES), also with a launch date no sooner than 2026. As of December of 2020, NASA approved the MSR program to advance to the Concept and Technology Development phase (Phase A).

Sample science considerations: To maximize the science return from MSR, ideally the goal would be to preserve the science integrity of the samples such that these samples would be returned in conditions no worse than what they experienced on Mars. As such, the following sample science integrity considerations need to be taken into account:

- Contamination control and contamination knowledge.
- Mechanical integrity of the samples as well as that of the RSTA seal.
- Magnetic field limits and magnetic environment characterization.
- Temperature and temperature history.

The following provides a brief summary of the rationale for why each of the sample science integrity considerations noted above is important for meeting high priority science objectives for MSR (as defined by the recent iMOST report [4]).

Contamination control and contamination knowledge.

Minimizing Earth-sourced contamination is critically important for geochemical, isotopic (including geochronological), and astrobiological investigations. The M2020 mission had specified limitations on allowable organic, inorganic, and biological contamination for sample intimate hardware, as well as a contamination knowledge program for pre-flight contamination (Appendix 3 in [4]). Moreover, incorporation of witness assemblies will provide knowledge of contamination throughout the life of the M2020 mission. To have confidence in the results of future analyses of the MSR samples, it will be important for the MSR program to continue to both limit contamination that can enter the RSTAs, and to provide knowledge of the potential contamination environments that the samples may experience. Because the MSR program flight missions would be expected to interact with well-sealed RSTAs, the main focus of the contamination control and knowledge requirements is on limiting and obtaining knowledge of volatile species that could potentially enter the RSTAs.

Mechanical integrity of the samples as well as that of the RSTA seal.

Several high priority investigations are dependent on investigating rock fragments that are large enough to display the rock's texture, and the relationship of the component grains to each other. Although it would be desirable to collect fully intact cores, the percussion drill mechanism on M2020 will induce some fracturing, as would a hard landing of the sample container on Earth. The M2020 mission and MSR program requirements are intended to minimize fracturing such that at least 65% of a core (if assumed to be a medium durability rock) would be in pieces with their longest dimensions ≥ 10 mm, and that no more than 25% of the core would be comprised of pieces with their largest dimensions ≤ 2 mm.

Another aspect of mechanical integrity is related to the integrity of the RSTA seals. It is critical that the integrity of the seals be maintained to the greatest extent possible to prevent escape of any martian material, including volatiles, from the RSTAs, and to prevent contamination from entering the RSTAs. Therefore, the M2020 mission and MSR program requirements are intended to maintain the integrity of the RSTA seals.

Magnetic field limits and magnetic environment characterization.

The nature and history of the martian magnetic field are poorly understood given that the only samples from Mars currently available for laboratory-based investigations are the martian meteorites, which lack geologic context (such that their location/orientation on Mars is unknown) and most of which have relatively young ages. Study of the samples collected by M2020 mission and returned by the MSR program should enable detailed paleomagnetic studies in Earth-based laboratories. However, in order to maximize the science potential of these studies, the samples must be protected from any magnetic fields that could be superimposed on the natural remanent magnetism of the samples (i.e., fields stronger than 0.5 mT). The MSR program requirements are additionally intended to characterize any magnetic fields stronger than 0.2 mT so as to understand any potential alteration induced by magnetic fields between 0.2-0.5 mT.

Temperature and temperature history.

It is expected that some species of interest in the samples collected by the M2020 mission will be vulnerable to alteration or degradation if exposed to temperatures higher than they have experienced on Mars for an extended duration of time. These may include some organic molecules (including potential biosignatures), volatiles, and hydrated minerals. Also, while it is not possible to predict in advance the nature and chemistry of the samples that will collected by the M2020 mission, there is evidence for the presence of oxidants and other potentially reactive species in martian surface materials [5,6]. Reaction rates for alteration reactions are expected to increase as a function of temperature. Moreover, it is not only the temperature, but the duration of heating, that is of significance when considering alteration resulting from exposure to higher temperatures.

In light of the above, and to minimize alteration of the samples in the RSTAs, the goal is to keep the surface temperatures of the RSTAs well below +30 ºC through much of the MSR program activities. However, there are expected to be a few limited short-duration periods when there may be unavoidable operational events when the temperature of some part of an RSTA may be raised beyond +30 ºC. The MSR program requirements are intended to keep such temperature excursions well below +60 ºC (the accepted maximum temperature requirement for M2020) and of relatively short duration. There are also intended to be requirements for ground testing and modeling to understand the temperature history of the RSTAs while in the custody of the MSR program.

Disclaimer: The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for informational purposes only.

References: [1] Farley K. A. et al. (2020) *Space Sci. Rev., 216,* 142 and companion papers in the same issue. [2] Herd C. D. K. et al. (2021) *LPS LII,* Abstract #1987. [3] Meyer M. A. Et al. (2021) *LPS LII,* Abstract #1708. [4] iMOST (2019) *Meteoritics & Planetary Sci.*, 54 (3), 667-671. [5] Lasne J. et al (2016) *Astrobiology,* 16 (12). [6] Carrier B. L. et al. (2017) *JGR Planets*, 122, and references therein.