MARS SAMPLE RETURN SCIENCE PLANNING UPDATES.

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Introduction: The ESA and NASA Mars Sample Return (MSR) Campaign represents one of the most ambitious undertakings in planetary science. The analysis of contextualized samples could serve to provide profound insights about the formation, evolution, and habitability of Mars.

The Mars 2020 *Perseverance* rover has been assembling an outstanding set of samples for potential return by the MSR Program. After samples arrive on Earth, the initial phase of scientific research on the samples would be performed by the MSR Sample Receiving Project (SRP). While the delivery of samples to Earth could occur no earlier than the 2030s, it is critically important to plan and execute a variety of scientific activities in the immediate term.

In 2021, ESA and NASA collaboratively commissioned a Joint Science Office (JSO) to plan and manage scientific precursor activities to maximize the impact, utility, and integrity of the eventual sample analyses. Here, we report recent progress on a selection of those efforts.

MSR Campaign Science Group (MCSG): The MSR Campaign Science Group (MCSG) comprises 20 internationally competed scientists representing eight countries. This group provides general inputs on all MSR-related scientific activities, reporting directly to the NASA and ESA MSR lead scientists with coordination provided by the JSO.

Periodically, the MCSG are asked to lead certain initiatives. A brief description of selected examples is given below, with additional detail provided in [1-4].

Sample Receiving Project (SRP) Science Objectives: A key rationale for MSR pertains to the power and diversity of analyses that can be conducted in terrestrial laboratories versus those conducted with *in situ* instrumentation at Mars.

To clearly articulate and provide targets for the initial analyses to be carried out during the SRP, the MCSG was tasked with refining the scientific objectives for such analyses. MCSG proposed an initial set of proposed objectives in 2023 [1] and updated these objectives following an open community workshop in September 2024. As outlined in [2], four overarching objectives comprising 16 sub-objectives have been articulated.

Analogue Sample Collection: As part of preparatory engineering and scientific efforts, the MCSG was asked to identify a preliminary set of terrestrial samples that replicate critical physical and scientific characteristics of the samples collected by the Mars 2020 rover.

As described by [3], five sets of samples have been collected, providing representative material for the martian regolith, sedimentary, and igneous samples. In total, several tens of kilograms of terrestrial analogue material has been collected, to be curated at the University of Oslo in Norway. Allocations of these samples can be requested by the science community at: *https://www.mn.uio.no/geo/english/research/projects/msr-asl-analogue-sample-library/msr-asl/index.html*. Future field campaigns will collect additional analogue samples to better reflect the diversity of samples that have been collected by *Perseverance.*

Public Engagement / Strategic Communications: The MSR Independent Review Board-2 report [5], recommended strengthening of efforts to communicate the strategic and high scientific value of MSR.

In response, the MCSG has undertaken efforts to generate publicly accessible messaging surrounding the science and importance of MSR. Additional details are provided in [4].

Measurement Definition Team: Upon return to Earth, the martian samples would be transported to a highly contained facility, termed the Sample Receiving Facility (SRF). Scientists within the SRF would be required to carry out measurements and procedures supporting research, curation, and safety needs.

To minimize the footprint, cost, and complexity of the SRF, it is critical to properly define the measurements (and thus the instruments) that are required within it. A joint ESA/NASA Measurement Definition Team (MDT) has been internationally competed to: (i) define an overarching investigation strategy; (ii); define the required measurements traceable to science, safety, and curation objectives; (iii) provide a reference set of instruments, and; (iv) outline a concept of operations.

The final report of the group was submitted in winter 2025 and is expected to be published later this year. Interim results were described in greater detail in [6-13] and final results will be presented at this meeting [14-15].

Sample Safety Assessment Protocol Tiger-Team: While the probability of extant life existing in the returned samples is low, it is non-zero. As such, tremendous precautions must be taken to ensure that Earth's ecosystem is protected from any potential interaction with such organisms.

Within the SRF, a series of interrogations of the sample would be required to experimentally determine whether or not the samples could be potentially hazardous to terrestrial biomes. This test protocol is commonly referred to as the "Sample Safety Assessment Protocol" (SSAP).

In September of 2023, a team of international experts spanning expertise in sample analysis, public health, and regulatory policy was tasked with proposing the sequence of activities required to carry out the SSAP. The group's final report is expected in Fall 2024.

Because of the interconnected nature of the activities, the SSAP and MDT activities were closely coordinated. All efforts were made to ensure that sample usage would be minimized and that overlaps in measurement needs between safety and science would be identified to prevent unnecessary duplication of efforts.

SRF Contamination Panel: Significant portions of MSR research could be affected by Earth-sourced contamination that is either misinterpreted as being of martian origin, or masks a martian signal.

Potential contamination is likely to be most significant during two primary phases of the Campaign: (i) During sample acquisition and storage by the Mars 2020 (M2020) Perseverance Rover, and; (ii) During each sample's residence inside the Sample Receiving Facility (SRF).

M2020 had stringent requirements on biological, inorganic, and organic contamination to prevent unacceptable sample contamination during sample caching and transport. The SRF Contamination Panel (SCP) was tasked with proposing terrestrial biological, organic and inorganic contamination limits for the samples from Mars during residence of the samples inside the SRF that would be needed to protect the scientific integrity of the returned samples.

The final report of the SCP was delayed in order to incorporate considerations related to the draft SRF instrument list proposed by the MDT and is now expected in early 2025. This report will feed forward into contamination control requirements for the SRF.

Gas Sample Panel: Measuring the composition of a dedicated Mars atmospheric sample could significantly increase our understanding of the climatic (and possibly habitability) history of Mars. To carry out the required analyses, it will be critical to extract the maximum quantity of gas from the tubes with as little contamination as possible.

In 2023, a team of 11 internationally recognized scientists was assembled to support engineering developments in potential gas-extraction processes and procedures. The final report was delivered in 2024. Select findings from this team have been combined with information from the SRP MDT Atmospheres and Volatiles sub-team for presentation at this meeting [16].

Community Engagement: The MSR JSO has also been actively involved in engaging with the community where opportunities arise. Because MSR is a community endeavor, it is crucial that inputs are required at every step.

Conference presentations, townhalls, inputs to analysis and advisory groups, and public panels at venues such as the American Geophysical Union, Lunar and Planetary Science Conference, Astrobiology Science Conference are but a few examples. The community is encouraged to participate in future activities wherever possible and may contact the authorship of this abstract to provide inputs.

Future Work: As the MSR architecture continues to evolve, it is important to continue science activity planning and execution. Near-term planning for MSR science will include SRF requirements development, science input into technology and architecture development, sample-specific mapping of MSR objectives to samples, and augmentation of the analogue sample collection.

References: [1] Kminek G. et al. (2024), *Abstract #3172, 10th Intl. Conf. on Mar*. [2] Proposed SRP Science Objectives (Updated): http://bit.ly/3BAMe2K [3] Thorpe M. T. et al. (2025), *Abstract #2109, this meeting*. [4] Harris et al. R. L. (2024), *Abstract #2561, this meeting.* [5] O. Figueroa et al., (2023); [6] Sefton-Nash E. et al. (2024), *Abstract #3173, 10th Intl. Conf. on Mars*. [7] Bridges J. C. et al. (2024), *Abstract #3283, 10th Intl. Conf. on Mars*. [8] French K. L. et al. (2024), *Abstract #3289, 10th Intl. Conf. on Mars*. [9] Schwenzer S. P. (2024), *Abstract #3293, 10th Intl. Conf. on Mars*. [10] Hausrath E. M. et al. (2024), *Abstract #3302, 10th Intl. Conf. on Mars*. [11] Debaille V. et al. (2024), *Abstract #3313, 10th Intl. Conf. on Mars*. [12] Carrier B. L. et al. (2024), *Abstract #3199, 10th Intl. Conf. on Mars*. [13] Rampe E. B. et al. (2024), *Abstract #3317, 10th Intl. Conf. on Mars*. [14] Sefton-Nash E., et al (2025), *Abstract #2301, this meeting*. [15] Carrier B. L. et al. (2025), *Abstract #2307, this meeting*. [16] Schwenzer et al. (2025), *Abstract #1581, this meeting*.

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