CURRENT STATUS AND FORWARD PLANNING FOR MSR RETURNED SAMPLE SCIENCE. B. L. Carrier¹, D. W. Beaty¹, G. Kminek², M. A. Meyer³, L. E. Hays¹, F. Thiessen², T. Haltigin¹, ¹Jet Propulsion Laboratory, California Institute of Technology, ²European Space Agency, ³NASA Headquarters, ⁴Canadian Space Agency.

Introduction:
The NASA and ESA Mars Sample Return (MSR) Campaign is intended to retrieve samples that have been scientifically-selected by NASA’s Mars 2020 Perseverance rover (M2020), return them to Earth, and analyze them in the world’s best laboratories. Through one of the most ambitious planetary exploration endeavors to date, Mars samples would become available to the international science community to address some of the most fundamental questions about the formation and evolution of the solar system, and potentially the origins of life.

Significant advance planning is needed in order to maximize the science potential of the samples intended to be returned from Mars. Over the next years we plan to involve the science community in various issues related to MSR returned sample science planning. The purpose of this abstract is to highlight recent and ongoing activities related to MSR Returned Sample Science (RSS) planning, to highlight anticipated upcoming activity, and to solicit community feedback.

Recent Activity:
MSR Science Planning Group 2 (MSPG2):
ESA and NASA jointly chartered an openly competed membership of the MSR Science Planning Group 2 (MSPG2) to provide inputs to an end-to-end MSR Science Program and to define the needed functionalities and design requirements for a Sample Receiving Facility (SRF). The challenges for the first samples brought from another planet include preserving samples in pristine condition and maintaining biological containment until the samples are demonstrated to meet safety criteria. The MSPG2 produced six reports outlining 66 findings [1 & references therein].

The five high-level MSPG2 summary findings are:
1. A long-term NASA/ESA MSR Science Program, along with the necessary funding and human resources, will be required to accomplish the end-to-end scientific objectives of MSR.
2. Traditional curation of extraterrestrial samples involves cleanroom operations, but MSR curation would need to be done concurrently with BSL-4-level containment. This would lead to complex first-of-a-kind curation implementations and require further technology development.
3. Most aspects of MSR sample science could, and should, be effectively performed on samples deemed safe (either by test or by sterilization) in uncontained laboratories outside of the SRF. However, other aspects of MSR sample science would be both time-sensitive and sterilization-sensitive, including the search for life, assessment of habitability, and volatile exchange processes, and would need to be carried out in the SRF.
4. To meet the unique science, curation, and planetary protection needs of MSR, and even with an explicit goal of performing as many MSR sample analyses as possible outside of biocontainment, substantial analytical and sample management capabilities would be required in an SRF.
5. The schedule required to have an SRF designed, constructed, and ready to receive the MSR samples has a longer lead time than perhaps anything previously attempted by NASA/ESA. It is important that preparations begin immediately; a potential delay in the return of the samples does not impact the overall science program planning beyond some shift in the mid-term activities.

MSR Operational Scenarios Definition Team (MOSDT):
The MOSDT, a small NASA & ESA directed group, were charged with creating an operational workflow for samples in the Sample Receiving Facility (SRF). The MSPG2 report [1] served as a major input to this activity and the work was focused on infrastructure purposes, with particular attention paid to operations that would be most important as input for facility planning. In addition to creating a main workflow (a visual representation of the sample operations pathway), and a list of instruments identified for sample analysis, a final report was produced, that included a detailed list of future work. Among the top level items here are studies of the facility operational trade space (e.g. science prioritization of instruments), technology development (e.g. double-walled isolators) and engineering developments.

Ongoing Activities:
SRF Planning:
As noted by MSPG2 and in numerous previous MSR planning documents, one of the components of the MSR ground activities requiring the longest planning and implementation timeline is the SRF. Trade and scoping studies are currently getting underway (see companion abstract by Harrington et al., 2022, this meeting) to evaluate the potential implementation op-
tions for a BSL-4 facility in which the sample tubes can be removed from the Earth Entry System, the samples can be extracted, and initial investigations, including biohazard tests, can begin. This activity is being conducted using the recent MSPG2 & MOSDT reports as inputs, as well considerations related to the conducting the sample safety assessment.

**Temperature-Time Tiger Team:**

A tiger team has been chartered by NASA & ESA to inform upcoming decisions related to sample temperature requirements for the MSR Program, in particular to evaluate the cumulative science impacts of potentially exposing the MSR samples to temperatures above +30°C, for different amounts of time. This team is expected to produce a report evaluating the science risks of these types of temperature excursions in Spring, 2022.

**Potential Upcoming Activities:**

**Contamination Control Planning:**

A significant challenge is to formulate a set of contamination control requirements that can be applied to the SRF. This will feed into the facility costing and budgeting exercises that will be conducted in the near-term.

One aspect of the contamination control problem is relatively well-understood: the desire for the contamination environment inside the pristine isolators to be equivalent to (or better than) that associated with the flight intimate hardware of the M2020 sample-collecting rover. The feasibility of achieving this goal, from an engineering standpoint, is something that needs to be evaluated. If this goal cannot be met, what compromises need to be considered?

The conduct of the Sample Safety Assessment Protocol (SSAP), a crucial part of planetary protection, requires certain measurements to be made to detect if there is martian life in one or more of the samples. In order for this protocol to be meaningful, contamination by Earth-sourced biology needs to be controlled to the point that these tests do not return false positives. The contamination requirements will be driven by the sensitivity of the instruments involved in the protocol, and the efficiency of the sample extraction procedures. Some of this work may be possible in pristine isolators, but is impractical (or even impossible) for some aspects.

A key implication is that different approaches may be required to maintain contamination control for both forward and back contamination and still achieve a biosafety determination of the samples. Technologies will need to be developed for pristinely measuring samples while isolating the surrounding environment from the samples.

**Sample-mechanical:**

There are several topics that were identified by MSPG2 as having a need for follow-up work, such optimizing the removal of the headspace gas and solid samples from their sample tubes. Potential options for extraction of the headspace gas and solid samples have been previously identified as part of the M2020 and MSR formulation and development process, but further optimization is needed to ensure that the properties of the samples are not negatively impacted by the proposed processes. These issues could potentially be grouped together, and worked via a joint science-engineering team.

**Summary and Conclusion:** Significant progress has been made in the area of MSR science planning over the past several years, and will likely continue to accelerate over the next few years. Several open questions and planning issues have been identified by MSPG2 and other recent planning groups, and we are open to community input on these issues. We are interested in community feedback on the above topics, and also to solicit indications of interest in volunteering to participate in future MSR science planning activities.

**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.