A Framework for Mars Returned Sample Science Management

Submitted by the MSR Science Planning Group (MSPG). Co-chairs M. Meyer and E. Sefton-Nash; facilitation D. W. Beaty and B. L. Carrier; and Members D. Bass, F. Gaubert, M. M. Grady, T. Haltigin, Y. Liu, D. Martin, B. Marty, R. Mattingly, S. Siljeström, E. Stansbery, K. Tait, M. Wadhwa, L. White; working under Terms of Reference provided by NASA and ESA.

The preparation of this document was led by the MSPG "Science Management" team, primarily during the period May-September, 2019 (Members: Tim Haltigin, David Beaty, Michael Meyer, Monica Grady, Brandi Carrier, Deborah Bass and, Elliot Sefton-Nash).

November 14th, 2019

This report represents a proposal for a Framework for Mars Returned Sample Science Management for NASA/ESA agency consideration, not a set of decisions. All information is pre-decisional and is being made available for planning and discussion purposes only. The decision to implement Mars Sample Return will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process.

Recommended Bibliographic Citation

MSPG (MSR Science Planning Group: co-chairs M. Meyer and E. Sefton-Nash; facilitation D. W. Beaty and B. L. Carrier; and D. Bass, F. Gaubert, M. M. Grady, T. Haltigin, Y. Liu, D. Martin, B. Marty, R. Mattingly, S. Siljeström, E. Stansbery, K. Tait, M. Wadhwa, L. White), 2019, A Framework for Mars Returned Sample Science Management. Unpublished white paper, posted 12/11/19 at https://mepag.jpl.nasa.gov/reports.cfm?expand=mspg.

If you have questions or concerns about the content of this report, please contact David Beaty (dwbeaty@jpl.nasa.gov), Elliot Sefton-Nash (esefton@cosmos.esa.int), Michael Meyer (michael.a.meyer@nasa.gov) or Brandi Carrier (bcarrier@jpl.nasa.gov).

This page is intentionally left blank

Table of Contents

Executive Summary

For decades, the science community has advocated for Mars Sample Return (MSR) as an endeavor that would fundamentally advance our understanding of the history of our solar system and its evolution and about the past and current habitability of Mars. The benefits of MSR include potentially historic discoveries enabled by applying current and future technological capabilities to the analysis of martian samples, as well as the enormous educational and inspirational impacts to the public.

NASA and ESA signed a Joint Statement of Intent in April 2018 to seek ways to carry out MSR by means of an international partnership. One of the keys to success of such a partnership is to establish the foundation for a Science Management Plan that can be implemented on an international basis that would give all partners fair opportunity to participate in the scientific discovery process. Should MSR be confirmed, a Memorandum of Understanding (MOU) between NASA and ESA will further define the respective roles and responsibilities of each agency.

In this document we propose a framework for the required Science Management Plan. Our goal was to ensure that the framework sufficiently details the high-level structures, bodies, and processes such that near-term actions can be implemented by MSR partners following mutual approval of the campaign. We also considered a planning horizon far enough in the future to account for science management activities throughout the entire MSR campaign. One planning horizon consequence was the realization of the need to establish an international Council, with the authority to charter several groups in the near-term that are necessary to fully develop the Science Management Plan and the requirements for the Mars Sample Receiving Facility.

In developing the framework, emphasis was placed on holding scientific excellence and equitable access to samples as fundamental and principal objectives, at the same time ensuring that invested stakeholders can identify and make preparations for scientific opportunities for their communities now and into the future. The process of developing this framework involved:

- Review of previously published options and strategies for the management of MSR returned sample science;
- Review of historical precedents from other sample return missions;
- Fact-finding regarding management strategies for other large and complex international scientific enterprises;
- Definition of the required functionalities of the Science Management Plan;
- Establishment of guiding principles that constitute required/desired attributes of the solution;
- Understanding key interfaces that need to be managed in order to achieve MSR scientific success;
- Systematic engagement with the scientific community, on both sides of the Atlantic, to understand their needs and priorities.

The proposed framework is organized into three categories.

- **Management and Management Planning:** These are entities and processes involved in the oversight of returned sample science, and offer guidance for operational functions such as curation (including sample preservation) and planetary protection.

- **Planning for Facilities of Interest to Science:** A number of scientific considerations must be taken into account in defining some of the facilities associated with MSR. The science community thus needs to participate in the requirements definition.
- **Returned Sample Science Processes:** These are the processes associated with making the samples available to the sample science research community, in a fair and consistent way, and with enabling sample-based scientific discoveries.

Each of the above categories involves multiple components, consisting of planning committees, processes (workshops, conferences, competitions, etc.), facilities, and management groups. In this framework, we propose rationale, composition, key outputs, and timing for each of the major components.

Collectively, these components represent a proposed implementation of the science of MSR, and would allow members of the science community to be active participants in elements of sample science planning and management. Perhaps most importantly, the descriptions show how scientific opportunities can be generated and coordinated to enable world-changing discoveries, and lay out the landscape of opportunities so that individual scientists can decide on the extent and mode of their engagement with these various opportunities. In some cases, where multiple options exist, we examine a range of possible mechanisms or arrangements for consideration.

Finally, we conclude with some considerations related to the initial implementation of a science management plan, to be undertaken after the signing of the international MOU.

1 Introduction

1.1 Context

As documented in the Statement of Intent signed in July 2019 (Appendix A), NASA and ESA have been actively exploring options for forming a partnership to achieve Mars Sample Return (MSR). Through the developing partnership, two critical primary subjects need to be defined:

- How respective responsibilities for the flight elements should be assigned across the potential partnership and;
- How to identify options to manage returned sample science (RSS) in such a way as to optimize the potential science return and ensure that the benefits are properly extended to all of the investing parties.

Regarding the latter, it is crucial to determine how scientific access to the samples would be managed and how opportunities for the international community to participate in the RSS process will be made available. The overarching purpose of this report is to propose a framework for planning and implementing processes relating to RSS management that could establish the basis of a mutually acceptable partnership between NASA and ESA on MSR.

1.2 The Internationalization of MSR: History and Path Forward

MSR has been consistently recommended for scientific reasons for more than four decades (see iMOST, 2019 and references therein). In 2007, the International Mars Exploration Working Group (IMEWG) began discussion of strategies for cooperation and collaboration related to MSR by means of chartering the iMARS-1 team (iMARS, 2008), a multidisciplinary international team of scientists and engineers. An important question that iMARS addressed was whether the space-faring nations could form a partnership to fly the missions needed to complete the MSR campaign. This was followed up by the following five additional steps that specifically supported and encouraged the internationalization of MSR:

- CNES sponsored the First International Conference on MSR, held in Paris in July, 2008. The agenda was dominated by the report from iMARS, and in this venue it received very broad international attention.
- MEPAG followed up by carrying out the E2E-iSAG study (completed in 2012), using a deliberately internationalized working group. This group developed consensus positions on the tricky topic of sample size and number to achieve a broad package of scientific objectives (MEPAG E2E iSAG, 2012), which have become foundational for subsequent planning.
- IMEWG chartered the iMARS-2 team in 2014 to follow up on certain internationalization recommendations of iMARS-1 (iMARS-2, 2018).
- IMEWG chartered the International MSR Objectives and Samples Team (iMOST) in November 2017, comprising ~ 70 scientists representing 15 nations and diverse scientific disciplines to address certain key science planning questions.
- Finally, ESA sponsored the Second International Conference on MSR, held in Berlin in 2018. The agenda featured both the report from iMOST, as well as a major re-analysis of the flight architecture.

In attempting MSR, the world's planetary exploration community stands to make historic discoveries with the first samples returned from another planet. It is through the shared scientific objectives and balance of programmatic interests that international cooperation can be achieved and that the full benefits from this ambitious campaign can be realized. As concluded in April 2018 at the 2nd International Mars Sample Return Conference:

> *"We have the opportunity and motivation to make the Mars Sample Return campaign an international endeavor and a reality for humankind."*[1]

An important scientific basis for inter-agency cooperation is the shared scientific objectives (iMOST, 2019). The iMOST report delineated specific ways in which sample studies are uniquely valuable to each objective, details the rich scientific potential of returned samples, and sets a baseline for the nature of RSS investigations and analytical capabilities.

1.3 This Report

As the MSR mission campaign would necessarily require international coordination, so too would development and implementation of the RSS processes that accompany it. A major challenge of RSS management is to develop a framework in a way that allows for stakeholders to demonstrate a return on investment while ensuring fair and open access for the international scientific community to participate in sample investigations.

To address this issue, NASA and ESA established the MSR Science Planning Group (MSPG) to develop a stable foundation for international scientific cooperation regarding returned samples from Mars. Throughout its deliberations, the MSPG identified issues and concerns for potential international partners and outlined the mechanisms through which the international scientific community can achieve the shared scientific objectives of MSR.

A fundamental premise of an international MSR partnership is that scientists representing the countries involved would have equitable access to samples. This would ensure that the scientific benefits and discoveries are shared amongst the partners, representing a return on the investments made in the MSR campaign that will have enabled the selection, cache, return, curation and analysis of the samples.

The objectives of this work are part of the mandate to MSPG in their Terms of Reference (ToR; Appendix B), but can be broadly summarized as follows:

- **Develop a framework upon which the formal MSR Returned Sample Science (RSS) Management Plan can be formulated.** Even at this early planning stage for MSR, we can already identify the major tasks that must be accomplished, the expertise and authority needed for those tasks, and the structure of the timeline in which these tasks should be organized to yield a successful science operations phase.
- **Ensure that the framework sufficiently details the high-level structures and processes required such that near-term actions can be implemented by MSR partners following mutual approval of the proposed MSR campaign.** The framework must define currently-known needs for RSSprocess development, but must also permit flexibility in its structure and content such that

[1] https://atpi.eventsair.com/QuickEventWebsitePortal/2nd-international-conference-on-mars-sample-return/home

subsequent additions (e.g., working groups chartered for specific tasks over short timeframes) may be added without major disruption.

- **Aim for a planning horizon to be far enough in the future to account for science management activities throughout the entire MSR campaign.** The framework must not only exist during facility development, planning for initial analyses, or competed Announcement of Opportunities (AOs), but also for the foreseeable future in which the returned Mars samples will continue to provide science benefits to the worldwide community.

Following the conceptual development outlined in Figure 1, this report describes the Framework for a Mars Returned Sample Science Management Plan (referred to hereafter as simply "the Framework"). The Framework proposes a strategy for scientific community involvement in the management of Mars Returned Sample Handling (MRSH). MRSH is utilized as a term that broadly encompasses the steps required to manage the samples after they have been returned to Earth. Note that this report has focused on only the science elements of international MRSH management. Absent from the report are in-depth discussions of planetary protection and curation considerations. Such content was beyond the scope of the Terms of Reference assigned to MSPG, though natural linkages amongst the three are identified throughout.

The management system we have proposed is clearly not the only way to achieve the end goals of RSS. Where multiple options exist, we have used the multi-disciplinary, multi-national perspectives within MSPG to guide decision-making. We applied the criteria of maximizing the science return from the samples, maximizing the opportunities for the international science community to participate, and treating this community as fairly and openly as possible, to generate a reasonably specific proposal. In some cases, however, we have flagged multiple options for which we believe that further discussion, perhaps including additional expertise, would be of benefit before reaching a final decision.

Included within the Framework are the identification of required/desired committees and other decision-making or recommendation-forming entities, and how their outputs may be scheduled relative to the major milestones of the MSR flight systems. After iteration with the MSR sponsors and upon approval of the MSR campaign, it is our intent that the Framework be followed by a full RSS Management Plan that contains significantly more detail than is described here.

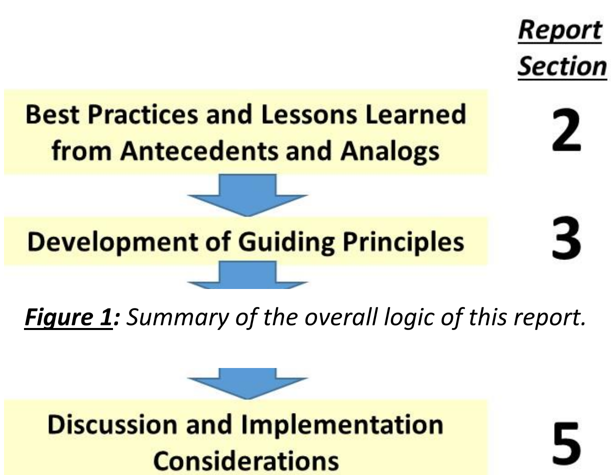


***Figure 1**: Summary of the overall logic of this report.*

Near the conclusion of the process of developing the Framework described in this report, MSPG sent the document to six senior external scientists (from the U.S., Canada, and Europe) for review. This resulted in the reinforcement of certain positions, valuable suggestions for ways to clarify and simplify the messages, and ways to better focus the findings. We thank them for their help.

2 Inputs into Planning for the Management of MSR Returned Sample Science (RSS)

2.1 MSR Reference Architecture

The NASA-ESA MSR campaign is presently being defined as a set of three flight missions that would result in the samples returning safely to Earth along with a series of post-landing activities collectively termed Mars Returned Sample Handling (MRSH). The elements of the proposed "3 + 1 architecture" (iMARS-II, 2018) are shown in Figure 2.

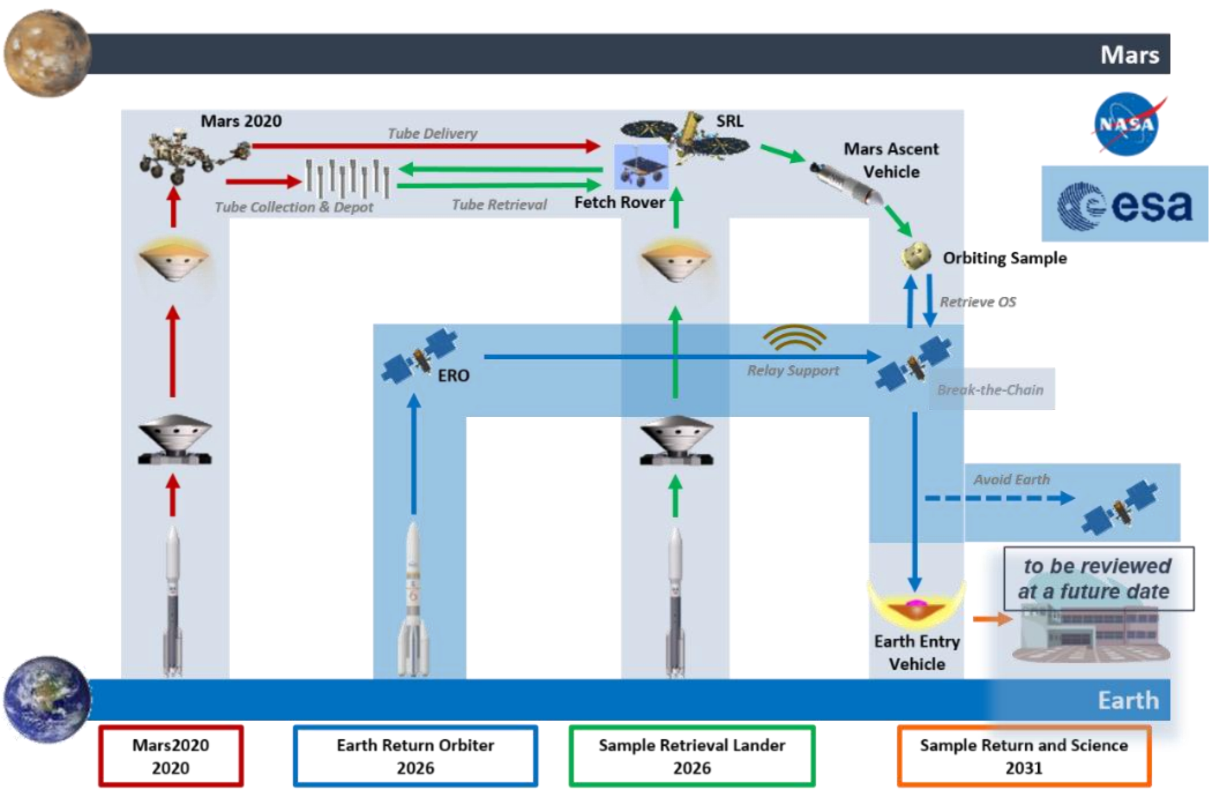


***Figure 2**: Overview of the proposed "3+1 architecture" outlining the flight elements proposed to return samples from Mars (from Lock, 2019; see this document for additional details). Key flight elements shown on this diagram are abbreviated acronyms throughout this report: SRL—Sample Retrieval Lander; SFR—Sample Fetch Rover; MAV—Mars Ascent Vehicle; OS—Orbiting Sample; ERO—Earth Return Orbiter.*

The timeline of the proposed campaign and its notional missions (Figure 3), can be summarized as follows:

- **Sample Collection:** the M2020 mission is expected to launch in July 2020 and arrive at Jezero Crater on Mars in February 2021. After landing, it will identify and collect a set of martian samples that are intended to be returned to Earth (see Farley and Williford, 2017).
- **Sample Retrieval:** the NASA-led Sample Retrieval Lander (SRL) mission, including an ESA-led Sample Fetch Rover (SFR), would launch in 2026 and arrive at Mars in 2028. The samples collected by M2020 would be delivered into an Orbiting Sample (OS) container and launched into Mars orbit by a Mars Ascent Vehicle (MAV).

- **Earth Return:** the ESA-led Earth Return Orbiter (ERO) mission, including a NASA-provided Capture/Containment and Return payload, would launch in 2026 and arrive at Mars in 2027. The ERO would orbit Mars and provide relay services for the SRL and Mars 2020 during sample retrieval. The MAV would launch from Mars' surface in 2029 and release the sample-containing OS into low Mars orbit. The ERO is then expected to rendezvous with and capture the OS in orbit, carefully contain the OS in an Earth Entry Vehicle (EEV), leave Mars orbit and return to Earth in 2031. The ERO would release the Earth Entry Vehicle (EEV) for a ballistic reentry through the Earth's atmosphere and would then proceed to a heliocentric orbit after releasing the EEV, to prevent impact with Earth.
- **Ground Retrieval and Processing:** upon successful EEV landing (expected to be in the U.S.), NASA would retrieve the contained EEV and transfer it to a Sample Receiving Facility (SRF) at a to-be-determined location. Activities conducted within the SRF would be governed by a future agreement amongst the international MSR partners, taking into consideration recommendations from the scientific community and best practices for scientific analysis, and Earth safety.

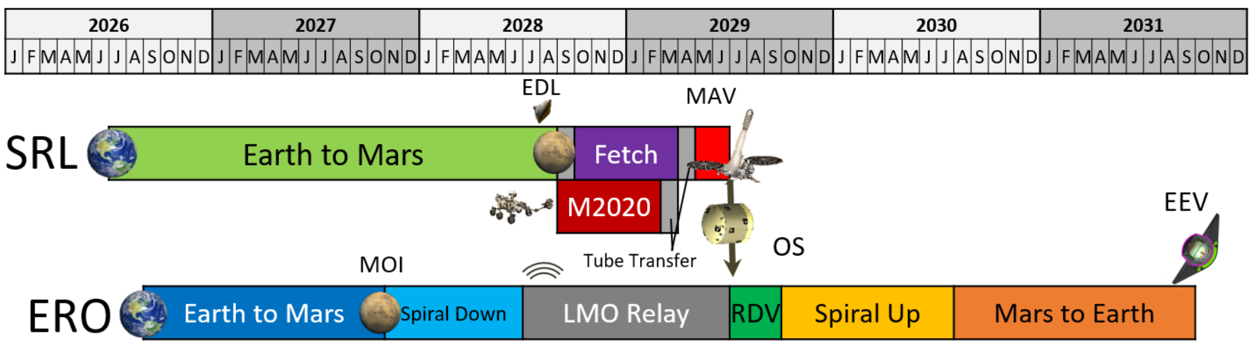


Figure 3: *Current working reference timeline for the conceptual MSR flight elements (modified after Lock, 2019). Key concepts illustrated here include interfaces between the SRL, M2020, and ERO. LMO – Low Mars Orbit; RDV – Rendevous.*

2.2 The Scientific Importance of MSR

The main purpose of the iMOST study (iMOST, 2019) was to re-evaluate the scientific value of MSR, given the now-known realities of the M2020 sampling system, recent discoveries from Mars that have been made during the past decade, and evolving priorities in astrobiology, geology, and geochemistry.

The most important conclusions of the iMOST study are summarized as follows:

- There is tremendous interest throughout the international science community in completing MSR, and there is consensus that the samples to be collected by the M2020 rover would be extremely valuable for these purposes and should be returned.
- The science discoveries that can be made via MSR cannot reasonably be expected to be made via in situ and orbital missions.
- There are seven main objectives around which the science investigations can be organized: Geology, Life, Geochronology, Volatiles, Planetary Evolution, Understanding Hazards to Human Habitation of Mars, Preparing for in situ Resource Utilization.

- Hundreds of individual types of measurements could be made on returned martian samples that would serve to answer many pressing questions about Mars evolution, geology, and past and present astrobiological potential.

With the iMOST team having emphatically endorsed the scientific importance of MSR as an international endeavour, it follows that an RSS Management Plan is required to maximize the number of opportunities for the science community to be involved and to ensure that the international community is fairly represented (iMOST, 2019).

2.3 MSR Stakeholders

The MSR science management structure should be set up to permit and optimize the connections within and among its various components. The structure thus needs to be developed with careful agreement from the stakeholders that make the campaign possible.

As benefactors or beneficiaries to the MSR campaign (indeed, most groups are some measure of both), a number of top-level stakeholders in the proposed MSR campaign can be identified:

Agencies: NASA and ESA have been charged by their respective political sponsors and advisory committees to evaluate implementing the MSR campaign as well as MRSH and long-term curation. For the initial (and possibly follow-on) agency signatories of the Memorandum of Understanding (MOU), there is an expectation to fund or coordinate science on returned Mars samples (ESA does not fund scientific research directly, its member states fund research via their national science agencies), as well as to fund specific agreed-upon elements. For NASA, this includes provision of flight elements and establishing an SRF as well as a possible subsequent uncontained cleanroom curation facility in the U.S. For ESA, this includes provision of flight elements, and possibly contributions to the MRSH infrastructure in terms of equipment or coordination with any additional facilities in Europe.

Nation States: Space agencies implement space programs on behalf of their chartering governments. NASA acts on behalf of the U.S. government, and ESA acts on behalf of 22 member states, as well as nine other cooperating and associated states. Importantly, in the U.S., NASA's Research & Analysis program funds the majority of planetary science. In Europe, however, countries fund their own national research programs via their national science funding agencies. It is thus important to develop a structure whereby each represented nation is assured of balanced and equitable participation in critical science planning activities and AOs.

Industry: Implementation of the MSR campaign is overseen by agencies who act as customers when they contract to industrial partners. As a result, the industrial capability of a company and consequent benefits to that company's national economy can be improved by participation. This concept of 'geo-return' must be acknowledged, such that a wide range of competed and other types of opportunities for industrial participation should exist in the campaign. While this is not directly linked to science return, nation states may seek scientific involvement in return for any industrial investment.

Science Community: Sample science management and management planning must be based on the priorities and recommendations expressed by the scientific community, where the greatest expertise on Mars science and sample analysis lies. Whether appointed, selected via AO, or openly invited, delegates from the science community should play a critical role in the science management structure, with expertise and experience being appropriate for the task at hand. An appropriate science management structure should thus balance scientific authority and opinion with the interests and boundaries of stakeholders.

The Public: The MSPG recognizes that the general public is an important stakeholder and we want them to be as excited about the prospect of MSR as the science community would be. We should expect that some members of the public may have concerns about returning the samples to Earth in a safe manner. Informing them about the goals and purpose of MSR, and the project's bio-containment and safety philosophy, should be a priority. This area can be addressed with an effective communications and engagement campaign, using the basic principles of risk communication, such as: be open, be accurate, be clear, be respectful, foster interaction. The make-up of the science management structure itself, as well as details about the sample handling, analysis, and safety protocols, may provide helpful information in developing effective communications with the public. Finally, public engagement that provides inspiration through discovery will help foster enduring support for analysis of the MSR collection.

In summary, while scientific excellence must be the overarching goal of MSR, it must also be acknowledged that the campaign science management structure requires that the needs of all stakeholders be addressed. As input to formulating the RSS Framework, we have noted two particularly important stakeholder considerations:

- The space agencies and their respective nation states put a priority on return on investment that can be relevant and visible to the public; this can manifest both as industry engagement as well as access for scientists.
- The science community has repeatedly expressed an interest in having multiple points of entry to participate in the RSS process, including for RSS management, RSS planning, and access to samples for science investigations.

2.4 Historical Precedents from Other Sample Return Missions

RSS planning must be informed by experience gained through several prior space science sample return missions, including the six-mission Apollo program, Hayabusa, Genesis, and Stardust. Currently in flight are two additional sample return missions that have not yet returned to Earth: OSIRIS-REx, and Hayabusa2. The science of each of these missions has been managed in somewhat different ways, and the similarities and differences are instructive.

The Apollo Program was driven primarily by political and engineering objectives, rather than by scientific objectives. It was not planned by a Science Definition Team (SDT), it was not proposed in a scientific competition, and it did not have sample-related scientific objectives. However, scientists, led by an group informally known as the Four Horsemen (Jerry Wasserburg, Jim Arnold, Bob Walker, Paul Gast), worked tirelessly and very successfully to introduce science and science funding into Apollo.

Work on Apollo 11, the first mission of the set, pioneered a set of sample investigation processes that were then subsequently refined for the other Apollo missions. Close similarities to what is needed for MSR includes the need for containment (quarantine; note that this process was suspended after Apollo 14), low-contamination environments for handling the samples, preliminary examination behind the quarantine barrier, selection of a unique group of international and multidisciplinary scientists, and unique analytical instrumentation. For Apollo 11 an embargo period of about three months (mid-September to December, 1969), after the end of quarantine, was applied to ensure simultaneous release of the initial sample investigation results at the Apollo 11 Lunar Science Conference (see Appendix C for more details).

Key Science Management Lessons Learned from Apollo:

- Prior to receipt of the first samples, the widespread development of scientific capabilities (scientists and instrumentation) is crucial;
- There is great value to allocating samples to a wide diversity of laboratories, with most being located outside of containment;
- An embargo period, followed by simultaneous first release of sample investigation results at a major conference, is a promising strategy, and;
- The establishment and on-going operation of extra-terrestrial curatorial and sample allocation processes is highly important.

Most of the other missions (the exception being Hayabusa) named above originated in scientific competitions and were led by a Principal Investigator (PI) who proposed particular scientific objectives that were judged to be of higher value than that of their competitors (see Appendix D for additional details on Stardust, one example of such a mission). All of the proposals were framed around the PI's project team having an embargo period to access the samples to achieve their promised objectives, then making the samples available to the sample research community at large only afterwards.

Key Science Management Lessons Learned from PI missions:

- For an objective-driven sample return mission, it is important that the initial investigations are focused on achieving the promised objectives.

MSR has attributes of both types of missions. Like the competed missions described above, MSR is being advocated on the basis of the scientific objectives that can be achieved. However, like the Apollo Program, there is no overall campaign-level PI. Perhaps more importantly, all of the above missions were carried out by one national space agency, whereas MSR is under consideration for implementation by means of a major international partnership. Achieving mutually satisfactory international governance will require attributes drawn from both of the above examples.

FINDING #1: The overall strategies for meeting the unique challenges of establishing an international management system for MSR returned sample science must be informed by important lessons learned from both the Apollo Program and various PI-led sample return missions (e.g.,Stardust, Genesis, OSIRIS-REx, etc.).

2.5 The Management of Other Large and Complex International Scientific Enterprises

Planetary sample return missions are not the only example of a scientific endeavor requiring significant international governance. For MSR, a particular concern is the balance between transparency and equal access to samples with the protection of investment from the various national agencies. Achieving such balance can potentially be informed through analogy to a variety of international science bodies.

iMARS Phase 2 (iMARS-2, 2018) identified a number of parallels between developing an international governing body for MSR and the structure currently in existence with the International Ocean Discovery Program (IODP). Because MRSH is not just an organization for allocating observing or usage time, but rather is an integration of scientific access with sample retrieval, preliminary examination, embargo data periods, etc., IODP is a particularly compelling model to consider.

The IODP (https://www.iodp.org) is an international collaboration to explore Earth's history and dynamics through the use of scientifically-driven, competed research expeditions that use ocean drilling platforms. The IODP has three ocean-going vessels, with five contributing agencies that represent 23 nation states whose scientists staff the research expeditions. Through this organization, multiple international partners share responsibility for planning drilling cruises, collecting and curating cores, and splitting and competing the collected samples.

IODP has a multi-layered structure that manages their primary ocean-going platforms, a robust and active competed research program, as well as operations for long -term curation and preservation of retrieved sample cores. Its organizational structure consists of eight program offices, three IODP Facility Boards, two major advisory panels, a well-staffed Science Support Office, and a large (50-member) science evaluation panel. IODP Program Member Offices (PMOs) from each participating country manage and fund the participation of researchers from member states.

Many of its activities are similar to those expected of MSR RSS. For example, newly-acquired samples retrieved by research expeditions are protected by a embargo period, after which IODP provides open access to all samples and associated data. IODP investigations are based on proposals that support a set of objectives reviewed and revised on a regular basis. Research proposals are evaluated by combined advisory panels elected by the PMOs (https://www.iodp.org/iodp-organization-diagrams/file).

Other international models for sharing and managing limited resources, such as the European Organization for Nuclear Research (CERN) (https://home.cern/), have also been considered, and a comparison with the IODP is given in Appendix E. CERN allows for significant international participation with co-operation agreements with 37 countries and scientific contacts in 18 others.

The "Council" is CERN's senior decision-making authority and is composed of two delegates from each of its 23 Member States, one representative from the national government and one from the nation's scientific community. The Council determines CERN's policy in scientific, technical and administrative matters, defines its strategic programmes, sets and follows up on its annual goals, and approves its budget. The Council is chaired by the President of CERN, aided by the Director-General who is the Organization's chief executive officer, legal representative and manages the day-to-day activities of CERN. S/he is supported by five Directorates; Directorate heads are proposed by the Director-General and appointed by Council.

The Council has two main advisory bodies: The Scientific Policy Committee (SPC) and the Finance Committee. The Scientific Policy Committee evaluates the scientific merit of activities proposed by physicists and makes recommendations on CERN's scientific program. Its members are scientists elected based on scientific merit by their colleagues on the SPC and appointed by Council. Some members are also elected from Non-Member States. The Finance Committee is composed of representatives from Member States and deals with all issues relating to financial contributions by the Member States and to the Organization's budget and expenses.

In addition, there is an Audit Committee comprised of Council and Finance Committee representatives and distinguished external experts to provide oversight of the Organisation's governance, risk management and internal control arrangements. Although CERN does not manage samples, it has a series of policies regarding the selection of experiments, data management, and moratoria before publication that have parallels with how MRSH might operate.

As such, there are aspects within IODP and CERN that can provide guidance upon which to develop an overarching set of scientific processes for RSS. A summary of organizational characteristics is provided in Appendix E. “Best practices” identified include:

- The organization of the CERN Council. Particularly notable is that each country is represented on the Council by two members—one a program manager, and the other a scientist. This ensures that overall the Council has much scientific expertise so that its decisions are scientifically defensible.
- IODP’s multi-tiered structure, where individual nation states have oversight of their own scientists’ funding and contribute expertise to science advisory panels
- IODP has developed effective use of a standing, internationally-sourced, science evaluation panel

FINDING #2: Examples of long-running international scientific organizations focused on terrestrial research have been identified that have developed “best practice” strategies and methods that could be productively emulated for the purposes of international MSR returned sample science management.

2.6 Previous RSS Management Efforts: Review of iMARS Phase 2

Over the past two decades, significant effort has been dedicated to planning various aspects of the MSR campaign, including science objectives (e.g., MEPAG ND-SAG, 2008; E2E-iSAG, 2012; MEPAG, 2018; iMOST, 2019), flight elements (e.g., Mattingly et al., 2005; iMARS, 2008), and sample curation (e.g., Beaty et al., 2009; Euro-CARES, 2018). However, relatively little attention has been devoted to RSS management.

In 2006, IMEWG chartered the international Mars Architecture for the Return of Samples (iMARS) Phase 1 team to outline the scientific and engineering requirements for an international MSR architecture. In its final report, the group recommended the formation of an international science institute to provide scientific oversight of the returned samples (Beaty et al., 2008).

IMEWG then chartered a new incarnation of iMARS in 2014. As part of its task, the iMARS Phase 2 team was charged with defining such an institute as part of an RSS implementation plan. Ultimately, the team proposed an overarching management structure and supporting processes and procedures that seek to deliver effective governance of the MSR campaign (iMARS-2, 2018).

The MSPG was asked to consider the iMARS Phase 2 findings and recommendations, and to incorporate the relevant aspects into its analysis of a RSS management plan. Note that the iMARS Phase 2 scope included topics related to science management, engineering, sample handling, and curation, but here we restrict our analysis to science management subjects only.

The MSPG has concluded that most of the science management aspects of the iMARS Phase 2 efforts are an excellent foundation, and it has incorporated many of them into this proposed Framework. The topics on which MSPG concurs with iMARS Phase 2 can be organized into three categories, described in more detail in Appendix F:

- **Already completed:** findings or recommendations that have already been acted upon by the MSR sponsoring partners;

- **Incorporated into this proposed Framework:** findings or recommendations that have guided MSPG deliberations and are being included in the present document, and;
- **Endorsed by MSPG, but have not yet been implemented:** findings or recommendations that are consistent with Framework development but have not yet been incorporated or acted upon by the MSR partners, most typically because formal approval is still pending.

In addition, there are four specific points in which MSPG has reached conclusions that differ from those of iMARS Phase 2. Several of these differences are minor. Summarized briefly below, the iMARS finding/recommendation is paraphrased in boldface type, followed by the MSPG-recommended modification.

1. ***An international MSR Science Institute should be established as part of the overall science governance scheme*:** While MSPG concurs that high level executive oversight is required to manage RSS processes, MSPG concluded that for reasons related only to science planning, a formalized Institute is unnecessary, although there may be other compelling reasons to use such a format. Alternatively, a coherent set of management and working groups could be established and coordinated. As part of the Framework, we propose a set of such bodies in Section 4.
2. ***A science management group should be co-located at the sample facility*:** Certainly we concur that an overarching project team is required to manage day-to-day operations of MRSH (see Section 4.2.2.). However, requiring co-location at the SRF or other curation facilities is not consistent with the possibility of multiple facilities on different continents. Temporary co-location of personnel at the initial SRF in the U.S. may be desired, or representatives from the SRF facility(-ies) may be included in the management group, but follow-on activities for the group are largely expected to be conducted remotely.
3. ***The Preliminary Examination Team (PET) should be provided with financially-supported time away from SRF obligations to prepare papers for publication:*** Participation on the PE team may be one of the most highly sought activities by the scientific community. This privileged first access to the samples would reveal critical information about the sample collection. However, as discussed in detail in MSPG (2019a) and in Section 4.4.3 of this report, we do not believe the PET should be assigned sample research responsibilities resulting in scientific publications. Rather, we propose that the primary deliverable of the PET be a catalogue that proposing researchers could use to properly request samples for subsequent competed investigations. Although the PET will clearly need to be financially-supported, research objectives should be the remit of the competed sample investigation teams. Whether and how the PET members may be part of these later objective-driven investigation requires further discussion (see also Section 4.4.4).
4. ***Scientific access to the samples should be driven by scientific excellence, independent of the financial contributions of the proposer's home country:*** Unquestionably, the driving motivation behind MSR must be the scientific excellence of investigations performed on the returned collection. However, making the samples immediately available to the entire world would necessarily disincentivize investment in the MSR campaign by other potentially interested nations or agencies. Based on historical precedent of other sample return missions, we propose that certain activities throughout the process – most notably PE and the initial investigations – remain embargoed to partners that have invested in the MSR flight architecture. Samples would later be made available to the rest of the world based on scientific merit (see Section 4.4.5.).

2.7 Key RSS Implementation Issues—the 2019 MSPG Workshops

In addition to addressing elements of the Framework, the MSPG was also charged with ensuring that planning activities undertaken by the two space agencies in support of MSR are coordinated and consistent. As part of its purview, the MSPG was to produce reports establishing and documenting positions amongst a diverse set of sample scientists related to planning assumptions and/or potential requirements involving the handling and analyses of returned samples.

To assess the level of consensus amongst the community, the MSPG held two international workshops. The first workshop – *"Science in Containment"*, held January 2019 in Columbia, MD, U.S. – was focused on investigations that need to be performed while "in containment" (i.e., under biological quarantine) (MSPG et al., 2019a). The second workshop – "*Contamination Considerations*", held May 2019 in Leicester, UK – focused on the logic associated with setting contamination control specifications at different levels (MSPG et al., 2019b). Encouragingly, the outcomes from the workshops demonstrated consensus on key topics and are consistent with almost any proposed science management structure.

The "Science in Containment" workshop examined the scientific procedures needed to be performed while under biological quarantine: Basic Characterization (BC) plus Preliminary Examination (PE), time-sensitive science (i.e., measurements of properties which would be subject to change after the sample tubes are opened), and sterilization-sensitive science. Sterilization-tolerant science could either be done inside or outside of containment. For most of the questions discussed, the workshop participants were in strong agreement (MSPG et al., 2019a). It is anticipated that the report would be used to support future planning, including international partnership formation and SRF costing exercises.

The "Contamination Considerations" workshop determined high-level strategies related to the future preparation of contamination control (CC) and contamination knowledge (CK) requirements associated with sample receiving facilities and activities. This is seen as an essential input to functional requirements definition and cost/schedule estimation of campaign facilities. The contamination control requirements are expected to be a first-order driver on cost of the SRF, stemming from the workshop report's nine technical findings statements.

An important process outcome of the two MSPG workshops is that the U.S. and European science communities reached consensus on some important technical planning questions. On none of the issues discussed did the workshop groups become polarized along international lines. Although there are certainly differences of opinion amongst the scientists in planning workshops like these, they do not represent systematic geopolitical differences.

Key considerations raised in MSPG Workshops that have been integrated into the RSS Framework:

- The importance of being able to work on samples outside of containment, either after they have been sterilized (appropriate only for sterilization-tolerant science) or determined to be safe (appropriate for all science measurements)
- The definition of the desired functionality of the Preliminary Examination Team

2.8 Community Engagement

Throughout its efforts, the MSPG has established multiple opportunities for discussion of RSS management issues with the Mars exploration and sample research community's at large. As the

Framework is intended to benefit the international science community, it was critically important that the community was able to provide suggestions and recommendations for overall improvement.

The engagement effort included townhall meetings at three major international-scale conferences in both North America and Europe (American Geophysical Union, Dec. 10-14, 2018; Lunar and Planetary Science Conference, March 18-22, 2019; and European Geosciences Union, April 7-12, 2019). In addition, relevant posters were presented at the Lunar and Planetary Science Conference and the Meteoritical Society meeting to help catalyze community discussion of these key topics, and an invited talk was given at the Astrobiology Science Conference 2019.

A more refined draft of our proposed science management planning was presented and discussed in poster format at the 9th International Conference on Mars (see Haltigin et al., 2019), which triggered many constructive and detailed interactions with the conference participants. Useful feedback was received in response to all of the above, and it has been synthesized and incorporated into this analysis. Additionally, a presentation/discussion was given at the European Planetary Science Congress-Division of Planetary Sciences Joint Meeting in September, 2019 (Sefton-Nash et al., 2019). Finally, MSPG has requested and received reviews of this Framework from esteemed sample scientists from the United States, Europe, and Canada who have long advocated for MSR.

3 RSS Management: Essential Components

3.1 Defining the Required Functionalities

MSR RSS management is expected to require a variety of processes that require different implementation entities (e.g., panels, working groups, conferences). We envision three basic categories of activities that will need to be executed:

- **Management and Management Planning Bodies:** These are entities and processes involved in the oversight of RSS, and offer guidance for operational functions such as curation and planetary protection.
- **Planning for Facilities of Interest to Science:** A number of scientific considerations must be taken into account in defining some of the facilities associated with MSR. The science community needs to participate in the requirements definition phase of these activities.
- **Returned Sample Science Processes:** These are the processes associated with making the samples available to the sample science research community in a fair and consistent way and with enabling sample-based scientific discoveries.

Building upon this notion, we have identified a number of core functionalities that are required to achieve the overall sample science management objectives (Table 1). Drawing heavily from the CERN and IODP models for management and oversight of samples and science investigations, Section 4 outlines a set of committees and teams to manage the functions of receiving the samples, completing their initial evaluation, informing requirements for long-term curation of the returned samples, and engaging in the investigations leading to potentially historic scientific discoveries.

__Table 1__: Core functionalities required for successful RSS management

<table>
<tr><th colspan="3">Functionality</th></tr>
<tr><th>Overall Management</th><th>Facilities Planning</th><th>Science Operations</th></tr>
<tr><td>Authority to charter required science-related planning or implementation committees</td><td rowspan="3">Define High-Level SRF Reqs that feed into SRF cost estimate and timeline</td><td>Prioritize samples for return</td></tr>
<tr><td>Authority to select personnel to populate and lead science-related required planning or implementation committees</td><td>Write RSS Analysis & Implementation Plan</td></tr>
<tr><td>Authority to approve selection of PIs</td><td>Define objectives and priorities for initial round of PI-led sample investigations to feed into AO</td></tr>
<tr><td>Authority to consider and approve necessary budgets</td><td rowspan="3">Write RSS Analysis & Implementation plan, which defines lower-level SRF requirements</td><td>Determine science criteria for mission success</td></tr>
<tr><td>Manage the timeline, budget to ensure objectives are achieved</td><td>Perform initial examination and characterization of MSR samples</td></tr>
<tr><td rowspan="3">Write-up full RSS Management Plan, for editing/approval by NASA-ESA (and any other stakeholders defined in the MOU)</td><td>Evaluate scientific merit of proposals requesting sample allocation</td></tr>
<tr><td rowspan="2">Prepare AO for investigations inside SRF (could include instrumentation and other factors affecting laboratory design within the SRF)</td><td>Make sample allocation decisions</td></tr>
<tr><td>Perform science investigations on MSR samples</td></tr>
</table>

3.2 Constructing the Framework of a Science Management Plan

3.2.1 Guiding Principles

In developing the Framework and designing RSS processes and timelines, we have formulated five guiding principles that serve as the foundation of our strategies. Summarized below, these principles are based on the previous RSS management recommendations, best practices from other major international science partnerships, the need for the financial sponsors of MSR to achieve a return on their investment, the technical need to engage large numbers and diversity of sample scientists to achieve the scientific potential of MSR, and historical precedents from other sample return missions/programs.

- **Transparency:** Access to samples must be fair and the processes defining sample access must be as transparent as possible.
- **Science maximization:** It is imperative that the science management and sample-related processes optimize the scientific productivity of the samples via careful selection of science investigations.

Sample preservation, in several different respects, will be an important factor in maximizing the integrated science productivity over time.

- **Accessibility:** International scientists must have multiple opportunities to participate throughout the MSR process in a variety of capacities (e.g.,sample management, sample analysis).
- **Return on investment:** Agencies providing the investments required to execute the MSR campaign should receive demonstrable benefits for enabling the samples' return.
- **One return canister : One collection:** The returned samples should be managed as a single collection even if the samples are physically housed in different facilities, and sample ownership should not be pro-rated according to investment.

A more complete explanation of some of these guiding principles are provided in the following sections.

3.2.1.1 Generating Opportunities for the Scientific Community

One of the metrics for success in RSS planning has been to maximize the opportunities for international scientists to get involved in the potential MSR Campaign. In developing the Framework, we have attempted to define multiple opportunities of many different characteristics and functionalities. Some of the opportunities would be launched by formal Announcements of Opportunity, others will involve membership in committees, and at least one will be a completely open workshop/conference. As many of these opportunities as possible will be competed, whereas others will be appointed (or will be filled by ex officio personnel).

For some of the opportunities, eligibility for the openings would be restricted to the MSR partners, as defined by the signers of the MOU (and subsequent additions, if any); for others, any qualified scientist in the world would be eligible. The opportunities to participate are expected to evolve with time and it will be possible for individual scientists to be involved in more than one of the activities over the course of the MSR enterprise.

FINDING #3: A number of opportunities for the international scientific community to participate in different aspects of the returned sample science process have been identified. A compilation showing how these opportunities evolve with time has been prepared, so as to help individual scientists and their teams to find the roles they want, and to enable scientific program managers to plan appropriately (see Appendix G).

3.2.1.2 Ensuring Fair Balance in the Scientific Discovery Process for the Agency Partners in MSR

The returned samples will be extremely precious. As a world-class endeavor, one of the key challenges is balancing two competing demands: (i) the desire of scientists across the world to access the samples and (ii) sponsoring countries managers' desire to generate opportunities for their own scientists.

While the intent of MSR is to maximize the scientific return of the sample analyses by seeking the best scientists using the most advanced analytical laboratories on Earth, it is recognized that considerable investment will have been made by the MSR partners in delivering the samples. It is therefore important to recognize specific advantages to early MSR architecture investment.

Judging by precedents set by previous sample return missions (e.g., Apollo, Stardust, OSIRIS-REx), we anticipate that participation in certain RSS activities would be highly sought-after. This includes, but is not limited to: overall scientific decision-making, preliminary examination, and initial sample scientific analyses.

We thus propose that certain activities throughout the MSR process be limited to individual scientists sponsored by MSR partner agencies. By limiting such positions to selection by MSR partners, the scientific benefits will serve as an important return on investment for NASA and ESA, especially as realized through preliminary examination and the initial objective-driven investigations. Such benefits may serve as an incentive for other nations to join this initial partnership.

3.2.1.3 Rationale Against Pro Rata Sample Ownership

One proposed mechanism for providing return-on-investment for the MSR partners would be to allocate sample ownership pro rata based on the value of the initial investment. Such a philosophy has been utilized in prior internationally collaborative sample return missions such as OSIRIS-REx, where Canada will receive 4% of the sample in return for its contribution of the OSIRIS-REx Laser Altimeter (OLA) instrument.

However, we believe that such an arrangement would be detrimental to the overall science value of the MSR collection, and runs counter to the guiding principle of Science Maximization (see Section 3.2.1).

In order to realize the full scientific potential of MSR, it would be necessary to go far beyond that which can be learned from individual, geologically unrelated samples. It is expected that sample "suites" (defined as a set of samples that are connected by one or more biological, geological, and/or physical processes) will be strategically designed, selected, cached and returned using the best available context data and full understanding of the science objectives that we hope to achieve (first pointed out by MEPAG E2E-iSAG, 2012, followed up by Carrier et al., 2018; iMOST, 2019).

A key premise of the collected sample suites is that the differences between given samples may be as important as the absolute characteristics of any individual sample. With the multi-year forethought involved in sample collection during the mission and the contextual relation between each of the samples, it is paramount that the returned samples be treated as a single collection to balance the interests of the contributing partners, to achieve fair and open competition for sample analyses, and to maximize science return.

FINDING #4: The returned sample collection will have been optimized for its geologic diversity, in large part through its organization into sample suites. As part of the design of the sample suites, the similarities and differences between samples will be at least as important as the attributes of the individual samples. As such, to optimize the scientific potential of the returned samples, they need to be managed as a single collection in all phases of Mars Returned Sample Handling.

3.3 Essential Related Aspects to be Managed Outside the RSS Management Plan

There are three key functionalities that would not be directly managed as part of the RSS Management Plan: Mars 2020 sample collection, sample curation, and planetary protection. Although these functionalities will be managed separately from RSS science, there will be significant interdependencies between them, and overall management of MRSH will need to be cognizant of all of them. Effective interface management will be essential.

3.3.1 Sample Collection at Mars by the M2020 Mission

Independent of the internationalization discussions outlined in Section 1.2, NASA chose to proceed on its own with a sample-collecting rover known by the working name of Mars2020, or M2020. The concept of a sample-collecting rover mission was first proposed by the MEPAG MRR-SAG (2009), endorsed (in somewhat modified form) by the Decadal Survey (NRC, 2011), and defined by the Mars2020 SDT (2014). The M2020 mission has subsequently been budgeted, designed, its instruments competed, and mostly built; and as of this writing, it is in the ATLO process. However, delivering the cached samples to Earth still requires multiple flight missions with associated opportunities for international partnership (see Section 2.1).

As implemented, the M2020 rover (launch July 2020) is planned to have a primary mission phase of one Mars year (~ two Earth years) potentially followed by an extended mission phase. This will be a NASA-managed mission, for which almost the entire cost will have been borne by the United States[2]. This mission represents a crucial first step in the MSR flight architecture, though because initiation of Mars 2020 project pre-dates the formation of a dedicated set of MSR flight missions, M2020 has its own independent management structure and authority that is autonomous with respect to other MSR flight missions.

Of greatest importance for MSR, the M2020 science team will have the responsibility for selecting the samples that are cached, and for documenting their context. As an aside, it does represent an additional opportunity for international scientists to become part of the MSR process: NASA has competed the Returned Sample Scientist Participating Scientist positions and is expected to run another Participating Scientist competition in 2020.

The rover will carry 43 sample tubes, of which four will have been irreversibly pre-configured as procedural blanks (Farley et al., 2019). The tube arithmetic originated with E2E-iSAG (2012), who considered a full OS to contain 31 tubes (based on tube packing geometries that existed at the time), and who concluded that it would be highly valuable for reasons of sample acquisition decision-making to be able to over-sample by ~25% and then down-select to final highest priority set of 31. This implies the use of 37 sample tubes from which to choose, some of which are almost certain to be blanks. The additional six tubes allow for the possibility of engineering failures (such as incomplete sample recovery) that need to be discarded.

Elements of the Framework have thus been developed under the assumption that more samples will be collected in the field than can be returned, and that a fundamental future decision is which samples to return.

3.3.2 Sample Curation

Effective sample curation protocols, processes, and facilities are essential to ensuring science integrity and to enabling the maximum amount of science output, both in the near- and the long-term. Curation includes documenting, preserving, handling, and distributing samples. Curation of astromaterials begins before sample acquisition to ensure that appropriate systems are in place to collect and subsequently store the samples without damaging them and lasts throughout the scientific lifetime of the samples. Preservation is an important aspect of curation that ensures sufficient material is retained for posterity, both to enable future scientific investigations and to ensure safety of the collection against potential hazards (e.g., earthquakes). Samples must be carefully curated and allocated for destructive analysis only in accordance with prioritization of science objectives agreed by the community. This approach

[2] There are some important exceptions involving instruments which were selected in 2015 through open international competition.

would permit enduring benefits from the collection over time, allowing future, more sensitive instruments to fulfill new science goals.

The process of curating sample-relevant Mars 2020 flight Contamination Knowledge (e.g., hardware and witness/blank material) has already begun through the efforts of the Astromaterials Acquisition and Curation Office (AACO) at Johnson Space Center (JSC) within NASA. How this effort would be broadened to include curation organizations and expertise at ESA or its component organizations in response to the MSR MOU as the MSR Campaign enters the RSS phase is outside the scope of this document.

However, since the curation of samples and sample science itself are intertwined topics where each both depend on and influence the other, there is a crucial interface here that has to be well-managed. The curation team needs to be involved from initial Sample Receiving Facility design, through initial sample receiving and allocation, and long into the future at the various facilities and PI laboratories as long as the samples are still deemed scientifically useful.

We envision a formal Curation Planning Team (CPT) that would be an essential partner in planning for RSS implementation. Key curation planning topics may include the requirements for handling, analyzing, storing, and distributing samples. Also important will be definition of the materials and records that should be curated prior to MSR launch, through flight systems development and operations, continuing into the steps required to prepare for receiving the samples, description of involvement in the preliminary examination and basic characterization steps, and adequate storage. Finally, the planning of the sample receiving facility and possible uncontained curation facilities and PI laboratories will be of essential interest to science.

As a special note, preservation of the scientific value of the sample collection is a central tenet of MSR. Thus, maintaining a certain proportion of the sample collection in pristine condition for future investigation, nominally 40% as suggested by E2E-iSAG (2012) will be critical. However, despite its importance, we believe that determining the final percentage of preserved sample mass and how the preserved portion is selected is not appropriate for the science management plan. However, there are technical aspects of planning for sample preservation that may need to be assigned to some of the working groups described in this plan (for example the MSR Analysis Planning Team—MAPT) that will require coordination with the Curation Planning Team, should such a team be formulated.

3.3.3 Planetary Protection

There are several aspects of planetary protection (PP) that relate to the MSR campaign; for the purposes of this document, the most important requirement is that the returned samples be held in containment until it can be determined whether or not they are safe for release; via biohazard testing or sterilization. The operating assumption of the MSPG and others (e.g., iMARS-2, 2018) is that the first stage of MRSH would require a Bio-Safety Level (BSL) category 4 containment curation facility that we refer to by the functional name Sample Receiving Facility (SRF).

It has been agreed by NASA and ESA that an SRF would exist in the United States. Additional facilities may be built in Europe funded either by individual or groups of countries or other financing for science infrastructure (e.g. the European Union). Such facilities may or may not have biocontainment and would be built only with agreement of their involvement in MRSH. In the current state of planning, ESA does not expect to directly fund these facilities, but must have a coordinating role between MSR science planning and new facilities. However, MSPG asserts that no matter the number of curation facilities

(BSL-4 or otherwise), for the integrity of the science investigations all Mars returned samples would be treated as a single collection for allocation to scientists initially sponsored by MSR investing partners, then scientists across the globe.

Similar to the procedures used for the Apollo 11, 12 and 14 missions, samples in the SRF would need to be subjected to a set of tests to determine whether or not they are hazardous. Past work on the test protocol for returned Mars samples was carried out in 2002 through a linked set of workshops and committees, and reported on by Rummel et al. (2002). More recently, a new COSPAR-chartered committee the "Sample Safety Assessment Protocol Working Group", or SSAP-WG, is reconsidering these issues as of this writing.

There is a key science interface issue relating to the use of pristine samples. The test protocol would consist at least in part of a set of scientific measurements on the samples that will be applied to the planetary protection problem, but they would also be applied to our understanding of martian astrobiology. In addition, the utility of "sterilized" samples distributed outside the SRF (see further discussion below) would be dependent on the planetary protection determination of what constitutes sterilization.

Without commenting further at this time, future planning teams are going to need to carefully consider how to manage the above interface issues. This will require the engagement of both the U.S. and the European communities.

FINDING #5: Certain functional elements that are essential to the success of the MSR enterprise are not addressed in the Framework for Mars Returned Sample Science Management, most importantly the M2020 sample-collecting rover, sample curation, and planetary protection. However, it is expected to be critical for the returned sample science managers to work closely with representatives of each of these elements in defining and implementing the Science Management Plan. Future planning teams should carefully consider how these interfaces should be managed.

4 Structure of a Proposed Science Management Plan

4.1 Overview

The overall logic of the Science Management Plan needs to include a top-level body within which:

i. high-level strategy can be discussed,
ii. financial and legal authority can be sourced and delegated,
iii. multi-agency decisions can be reached and certified,
iv. high-level oversight can be provided, and
v. responses are derived to high-profile sample-related recommendations from science working groups.

Also necessary is an international implementation organization, which can provide implementation leadership, including scheduling, budgeting, contracting, personnel management, coordination of communications, and oversight over the various science working groups. Finally, a number of science working groups need to form, do their work, and dissolve, in response to a carefully choreographed set of sequential relationships. These primary bodies and their corresponding responsibilities are shown in Figure 4.

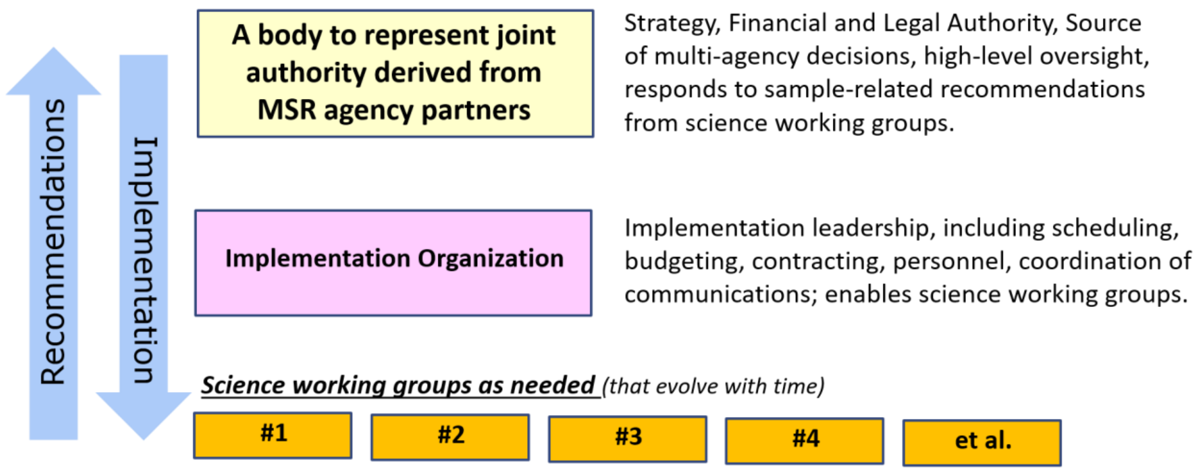


***Figure 4**: Overview of the high-level relationships involving internationally-sourced financial and legal authority ,an implementation leadership organization, and the multiple science-related working groups that would evolve with time.*

MSPG has identified a number of core functions that would be essential to the successful management of RSS (see Table 1), falling into three general categories: (1) Management and management planning; (2) Planning for facilities to enable scientific investigation and (3) Planning for and carrying out RSS. In the following sections we present our collective proposal for a Science Management Framework. Our approach begins by deriving an inventory, organized by each of the above categories, of key tasks that must be accomplished, their input, output, dependencies/pre-requisites, timeline constraints and the expertise required to perform them.

In a second stage, we collate these tasks such that they are performed by specific groups or committees, and via particular processes. The result of that exercise leads us to define a baseline set of groups and their basic attributes, such as their membership, timing, and deliverables (Sections 4.2.-4.4. and overview in Figure 5). Further, we are then able to construct a preliminary timeline, graphically representing an implementation of the overall Science Management structure with respect to MSR flight missions and critical sample science events (see Sections 4.5 and 5).

Note that in considering the formation of the multiple committees involved in MRSH, each would need to be populated by membership that reflects the diversity of knowledge, experience, and other factors needed for the task at hand. Committee formation would need to take into account the international nature of the project and the usual concerns of equality and diversity. Another concern is potential conflict of interest. The need for science representation must be balanced such that the committees do not have members that would directly and specifically benefit from committee decisions.

Committee/Group	Function
MSR Science Planning Group (MSPG)	Writes Returned Sample Science Management Framework - COMPLETED
MSR Science Planning Group Phase 2 (MSPG-2)	Complete Returned Sample Science Management Plan
International Operations & Requirements Definition Team (iORDT)	Define high-level SRF Reqs
MSR Analysis Planning Team (MAPT)	Write RSS Implementation & Analysis Plan: drives lower-level SRF Reqs and feeds into iSDT and other science planning
Sample Prioritization Workshop	Prioritize collected samples for return
International Science Definition Team (iSDT)	Outline criteria for AO for initial sample investigations inside & outside SRF; determine science criteria of project success based on knowledge of collected samples
Preliminary Examination Team (PET)	Perform initial examination of the samples to inform sample catalog
Science Evaluation Panel (SEP)	Evaluate scientific merit of research proposals requesting sample allocation
Sample Allocation Committee	Combine data from SEP with other considerations to make sample allocation decisions
Objective-Driven PIs	Perform initial science investigations on the MSR samples during embargo period
Opportunity-Driven PIs	Perform subsequent science investigations on MSR samples

***Figure 5**: Overview of the committees, groups, and functions proposed in this Framework in order to carry out the functions necessary for managing RSS. Committees would exist at different points in time (see timeline-Figure 10) and would be chartered by and provide deliverables to the MRSH Council. In this overview management planning entities are shown in blue (see section 4.2), facility planning entities are shown in orange (section 4.3), and RSS entities are shown in green (section 4.4)*

4.2 Management and Management Planning Bodies

4.2.1 MRSH Council

Rationale: A high-level steering group is needed with the authority to implement the science management structure and operations at the behest of the MSR MOU signatories and any additional contributing partners. Because of major investments by the partners and the challenge of balancing the investment with equitable authority, the overarching authority (termed here as the MRSH Council) would function similarly to a 'Board of Directors', providing management oversight of the handling of the collection. The key responsibility of the MRSH Council should be to provide oversight of RSS, enabling it via their managerial authority. They are expected also to provide guidance in other areas of MRSH, including curation, planetary protection, and facilities management (Table 2 and Figure 6).

MRSH Council

Essential Purpose: Overall international management, approvals, oversight

Composition: In principle, the Council should comprise the highest level of decision-makers associated with the MSR campaign, as its purview may reach beyond just RSS into subjects such as curation, safety, policy, and law. As such, extensive consideration must be taken into its design, structure, and membership. We provide a selection of initial options in greater detail in Section 5.1.

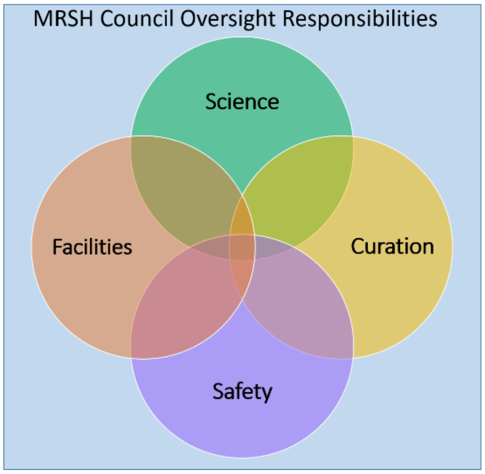


***Figure 6**: Overview of the overlapping oversight responsibilities of the MRSH Council.*

Key Outputs: The MRSH Council would serve as the ultimate authority and decisional body on all scientific matters. In addition, the MRSH Council would have the authority to charter advisory committees, provide financial authorization, and be the selecting authority for science teams and investigations. The details of budgetary authority may be addressed as part of partner agreements, but it is expected that the MRSH Council will operate as one authority representing multiple stakeholders for science management, regardless of the degree of budgetary independence between contributing partners.

Timing: As the MRSH Council would have such a broad set of responsibilities, especially in the earliest stages of approving and monitoring the RSS processes, it is strongly recommended that its formation begins as soon as possible following signature of the MSR MOU, and that it remain in existence on an ongoing basis.

FINDING #6: A key oversight role for the science management plan is assumed to be provided by the Mars Returned Sample Handling (MRSH) Council. The Council would provide management oversight, delegation of authority and responsibility, and budgetary support not only for returned sample science, but also curation, planetary protection, and facilities management, and ensure that the terms of the inter-agency MOU are effectively implemented. The MRSH Council should be initiated as soon as possible after the MOU is signed, and it is envisioned to ensure long-term continuity.

4.2.2 Project Leadership Team (PLT)

Rationale: We envision that the initial phase of MRSH will consist of a Project-like structure, analogous to the structure that oversees flight missions. This MRSH Project phase would be defined by a set of science related objectives that would drive requirements for facilities as well as for planning for the initial science investigations.

Project Leadership

Essential Purpose: Lead the implementation of the MRSH Project

While the MRSH Council would have the authority to designate personnel to lead international science-related planning and implementation committees, the day-to-day management of the schedule, budget, and implementation planning for initial sample science should be organized at the Project level (Table 2). The team designated to work at this level is termed the Project Leadership Team (PLT). This Project would encompass MRSH activities beginning from receipt of samples on Earth throughout the initial examination of the samples and initial RSS investigations, and would end when the Project scientific objectives are met. The success criteria will be recommended initially by the MAPT (Section 4.3.2) and later refined by the iSDT (Section 4.4.2) once more is known about the characteristics of the samples that have been collected by M2020.

An important distinction between the MRSH Council and Project Leadership Team is that the Council must exist for as long as the samples exist, given that they have overall authority for the fate of the samples, whereas the Project Leadership Team would be dissolved once the Project scientific objectives have been met. After this point, the MRSH Council would continue to oversee the non-objective-driven phase of RSS activities, which would continue for as long as the samples exist.

Composition: The Project Leadership Team would be composed principally of high-level managers in MSR partner agencies, with the responsibility and authority to drive schedule and control budget. Their mandate to deliver the MRSH infrastructure on time and within budget is paramount to the success of MSR RSS. The responsibility of appointing the Project Leadership Team lies with the MSR partner agencies via their representatives on the MRSH Council and/or with the agency's respective Offices (e.g., NASA's Astromaterials Acquisition and Curation Office with respect to NASA's Mars Sample Curator or ESA's curation authority equivalent with respect to ESA's Mars sample curator).

In addition to lead management roles, the team should include Project Scientist(s), Project Curator(s), and Project Managers/Lead Engineers of major components of the MRSH infrastructure, including the SRF(s), other curation facility(-ies), large equipment procured or acquired for use specifically in the MSR campaign, and instruments.

Typically, projects have finite schedules and deliverables and thus it is key to note that, with the exception of top-level leadership, advisory and oversight roles, the precise composition of this group at any given time depends upon the projects that are active at that moment (e.g., SRF design and construction, development of additional curation facilities, development of key systems to be installed inside the SRF).

While key members of the Project Leadership Team would have long-term/perpetual appointments (e.g., Project Scientists), new members may be appointed as new activities begin, and some may complete their duties and may leave the team as projects are delivered. Members of the PLT would be expected to participate in/interact with science working groups that are tasked with formulating recommendations or requirements for various parts of the MRSH project. This would help to ensure that the recommendations made are implementable within the scope of the project.

Key Outputs: The Project Leadership Team must ensure success regarding the schedule, budget, and implementation in order to fulfill the requirements of Basic Characterization and Preliminary Examination, and enable the achievement of the science objectives laid out by the international Science Definition Team (iSDT; Section 4.4.2).

Timing: Given that the Project Leadership Team is assumed to be responsible for driving forward planning and budgeting, they must be appointed relatively early. They need to become aware of the long-lead planning elements associated with RSS, and deal with them appropriately. Note that because of the historical fact that M2020 team/project was organized about five years ago with the responsibility and authority to decide which samples to cache, and a very large international science team specifically designed to carry out this task, the Project Leadership Team's role is to react to their sample acquisition decisions, and not in influencing those decisions. It is expected that the Project Leadership Team would complete their primary responsibilities when the embargo period for the initial returned samples has been completed (notionally 2033, if the samples can be released from containment relatively quickly), and "Project success" has been declared.

FINDING #7: A Project Leadership Team would need to be established, with the responsibility of leading the implementation of MRSH, of which returned sample science would be a component, including schedule management, budget planning and implementation, staffing, and overall coordination

4.2.3 Mars Sample Planning Group – 2 (MSPG-2).

Rationale: The primary purpose of the current iteration of MSPG was to provide sufficient context and structure regarding the internationalization of MSR to support potential partnership formation between ESA and NASA. However, recognizing that the present document is intended as the *framework* of a science management plan, it will, by necessity, be missing many important details.

MSPG-2

Essential Purpose: Write the full RSS Management Plan

It is not possible at this time to write a full Science Management Plan for several reasons: (1) the specific terms of the MOU are not yet known; (2) there is insufficient time to complete a full management plan in advance of the MSR partnership-forming discussions and (3) the current MSPG planning team may not have the most appropriate configuration to do the required work. However, it is clear that soon after the MSR Partnership is formed a body needs to be organized and given very specific Terms of Reference to prepare the draft of a full RSS Management Plan.

It is assumed that the plan developed carries the status of a proposal to the MRSH Council, who would then have approval authority. This plan would be most valuable if it could be developed relatively early, and in our view should be possible to complete within approximately 6-12 months.

Composition: MSPG-2 would benefit from the continuation of some of the original MSPG members and adding new members from agencies or countries called out in the MSR MOU to supplement any required expertise.

Key Outputs: The MSPG-2 would begin with the framework identified by MSPG while taking into account feedback from NASA and ESA, and would further clarify particular sections that could not be articulated in detail by the first MSPG in order to develop the complete RSS Management Plan.

Because this initial RSS Management Plan would be generated approximately 10 years prior to the samples returning to Earth, it is likely that future modifications may be required. It is thus recommended that the MRSH Council account for possible revisions of this document taking into consideration any major timely developments.

Timing: It would be preferable for MSPG-2 to begin after the formation of the MRSH Council. However, in the event that the launching of the Council is delayed for some reason, because the work of MSPG-2 is on the critical path it would be best not to postpone it unnecessarily. Ideally, MSPG-2 would be able to begin its work in early 2020, with the work complete 6-12 months after commencing (target: mid- to late-2020). If the formation of the Council is significantly later than the first part of 2020, we propose that MSPG-2 be started under a ToR that is approved by NASA/ESA, but require that its concluding report not be finalized until it is accepted by the Council. It would be ideal to complete this work before launching the international Objectives and Requirements Definition Team (iORDT) and the MSR Analysis Planning Team (MAPT), in part because the RSS Management Plan would provide necessary inputs to both groups and also because these activities may require some of the same personnel.

Table 2: *Core functionalities required for the management planning elements of an MSR campaign.*

WHAT NEEDS TO BE DONE	**WHEN**			**WHO**
Overall Management				
Functionality	**Precedent(s)**	**Complete Before**	**Appx. Start**	**Proposed Responsibility**
Authority to charter required international science-related planning or implementation committees	Initiate action with the Ministerial decision, finalize with NASA-ESA MOU.	on-going	Jan 2020	MRSH Council (4.2.1)
Authority to select personnel to populate and lead required international science-related planning or implementation committees	NASA-ESA MOU	on-going	Jan 2020	MRSH Council (4.2.1)
Authority to approve selection of PIs	NASA-ESA MOU	on-going	Jan 2020	MRSH Council 4.2.1)
Authority to consider and approve necessary budgets	NASA-ESA MOU	on-going	Jan 2020	MRSH Council (4.2.1)
Manage the timeline, budget to ensure objectives are achieved	Project enters Phase A	End of embargo period, declaration of "mission" (scientific) success	2021	Project Leadership Team (4.2.2)
Write-up full RSS Management Plan, for editing/approval by NASA-ESA (and any other stakeholders defined in the MOU).	Chartering by MRSH Council	Chartering + 6 months	Jan 2020	MSPG-2 (4.2.3)

4.3 Planning for Facilities to enable Scientific Investigation

MRSH is assumed to require facilities of two different general types. First, is the need for facilities driven by centralized planning processes, most importantly a high-containment Sample Receiving Facility (SRF) and one or more additional curation facilities that are either associated with the SRF or are independent of it. As per the ToR for this study (Appendix B), we have been asked to assume one SRF located in the U.S. and possibly one or more additional curation facilities. Whether they are contained or uncontained, located in the U.S. and/or Europe is yet to be determined.

Second, RSS would need state-of-the-art analytical facilities and instrumentation. These need to be in part within the SRF and curation facilities, and in part in external laboratories that are not led by centralized processes, but instead by individual PIs. Currently existing PI labs and instruments will be significantly more than a decade old by the time samples become available, and in need of refurbishment, new instrumentation and new scientific staffing. Funding support will be needed for all of the above.

Although the functional requirements of an SRF may change as they are evaluated in more detail, it has been clear for at least two decades that the facility described by the currently-known requirements would likely be the largest cost element within MRSH, the one requiring the longest planning lead time, and the one with the greatest schedule risk. All of these are a source of significant management concern.

In order to ensure that the SRF facility design meets the needs of its users, it is assumed that most of the SRF requirements originate from a combination of three sources: Planetary Protection, Science, and Curation. RSS specifically has an essential interest in the design of the SRF, since a number of important scientific measurements on the martian samples would be made there and would probably provide the information to address the requirements of the eventual safety protocol. We propose that the scientific interests in the MSR-related facilities can be refined by the iORDT and the MAPT (

Table 3).

As per a key conclusion of MSPG (2019a), a critical part of facility planning is that research laboratories around the world be upgraded to the minimum required specifications to be able to receive and analyze portions of returned martian samples. This may require significant facilities investment on the part of the research institutions and/or MSR partner agencies.

***Table 3*:** Core functionalities required for the science related facilities planning elements of an MSR campaign.

WHAT NEEDS TO BE DONE	WHEN		WHO
Facilities Planning			
Functionality	**Precedent(s)**	**Appx. Start**	**Proposed Responsibility**
Define Level 1 and 2 requirements for the SRF, and other planning inputs needed for its budgeting and timeline	Chartering by MRSH Council	mid-late 2020	iORDT (4.3.1)
Write the RSS Implementation & Analysis Plan	Chartering by MRSH Council; Completion of RSS Management Plan & iORDT Report	Early 2021	MAPT (4.3.2)
Prepare AO for science investigations to take place inside SRF	RSS Implementation & Analysis Plan complete, knowledge of samples collected to date	2025	iSDT (4.4.2)

4.3.1 International Objectives and Requirements Definition Team (iORDT)

Rationale: The iORDT would be charged with writing the high-level facility-related requirements for the SRF as input to the design process. It is assumed that most of the requirements will originate from planetary protection, from science and from curation. The design work may or may not have competitive dimensions to it—that will be decided by the stakeholder entities and communicated to the Council. It will be the responsibility of the iORDT to develop a first-order understanding of the financial implications of their recommended requirement set and to ensure that the trade space involving requirements and realistic budgets has viable solutions within it. It is essential that the iORDT is involved in planning of the SRF from the start to ensure that the SRF is fit for its purpose.

iORDT

Essential Purpose: Define SRF objectives & requirements that are consistent with cost, schedule, and other constraints

Within the NASA system, an ORDT and an SDT are broadly similar, with the difference being the degree of focus on science planning. The most recent ORDT in the NASA system was the one carried out to define the Lunar Reconnaissance Orbiter (LRO). In that case, the ORDT-defined objectives can be found in Vondrak (2004).

Composition: By analogy with past committees of this sort, the iORDT is likely to consist of facilities engineers, scientists and experts in curation, planetary protection and contamination control. Membership should overlap with that of the MAPT (Section 4.3.2) for continuity and consistency. Members would be appointed by the MRSH Council based on recommendations made by MSR partners, but if specific technical expertise were required, there would be a process (overseen by the MRSH Council) for appointing non-MOU-signatory committee members.

Key Outputs: The iORDT would produce a report of the high-level requirements for aspects of the SRF that relate to sample handling and analysis. This will help develop a cost estimate that can feed into a potential SRF AO (if that is the decided method) and a procurement strategy for instruments and other equipment, and will provide the high level requirements that the MAPT (Section 4.3.2.) will decompose into lower level requirements for incorporation into an RSS Implementation and Analysis Plan (RIAP).

Timing: Because the timeline for the SRF is very long, potentially up to 11 years from conception to sample receipt (e.g., iMARS-2,. 2018), the iORDT should be engaged as soon as possible. However, there would be some advantage in having the full Science Management Plan in hand (or at least a stable draft) before this activity is launched. There will be an intense period, probably commencing after a successful landing of the M2020 spacecraft, during which the SRF will be designed. As per Section 4.2.3., this would imply beginning in mid- late-2020 (see Figure 7). The work is expected to take ~ 6 months, and could notionally be completed by the early- to mid-2021.

4.3.2 MSR Analysis Planning Team (MAPT)

Rationale: A critical step in facility planning is determining the priority of scientific analyses that should be performed within the SRF and what measurements are needed in support of sample distribution, including (but not limited to):

- decisions on the identity of the measurements to be made by the PET
- the identity and priority of the time-sensitive measurements described by MSPG et al. (2019a)

- the relationship between planetary-protection-specified measurements and the sterilization-sensitive measurements (see MSPG, 2019a)
- the specifics of how the sample tubes would be opened, and ensuring that any necessary hardware is designed and built
- establishing the methodologies for sample sterilization
- establishing the requirements for the qualification of external laboratories to be able to receive allocated samples (potentially, by judicious use of sterilization, independent of completion of the safety assessment).

The order of the performance of the above activities would be considered, as well as analysis of preparation techniques required for analysis.

The MSR Analysis Planning Team (MAPT) should be responsible for planning for how the different phases of sample analysis will be executed, starting from arrival of the sample capsule at the recovery site to ensure that the integrity of the returned material is not compromised during opening of the capsule. It would also include planning for a variety of contingencies (e.g., if the samples are not releasable or if the state of the sample is different from what was expected).

It is acknowledged that specific analyses would also be required to fulfill planetary protection requirements. The MAPT will work closely with both planetary protection and curation to ensure that decisions about sterilization of samples, if needed, and that their subsequent release to the scientific community occurs in a timely fashion with due consideration for safety and security and impacts on sample integrity.

MAPT

Essential Purpose: Prepare specific plans for the analysis of the MSR samples

Composition: The MAPT should consist of a combination of scientists and experts in curation, planetary protection and contamination control. It would be desirable for some members of MAPT to overlap with that of the iORDT for continuity and consistency. Members would be appointed by the MRSH Council considering recommendations made by MSR partners. The MAPT may require specific expertise and members could be at-large, but must be approved by the MRSH Council.

Key Outputs: Drawing on the findings of the iMOST Report (iMOST, 2019), the anticipated iORDT Report, the MSPG reports (MSPG 2019a,b), and the upcoming Sample Safety Assessment Protocol (SSAP) report, the group would ultimately produce the RSS Implementation and Analysis Plan (RIAP), which would feed forward into the work of the iSDT (Section 4.4.2).

Timing: The MAPT should begin its work as soon as possible after the iORDT (Section 4.3.1) has delivered the facility's high-level requirements (Level 1-2), anticipated in early 2021 (see Figure 7). Generating the flow into lower level requirements is a large piece of work that we estimate will take at least 12 months.

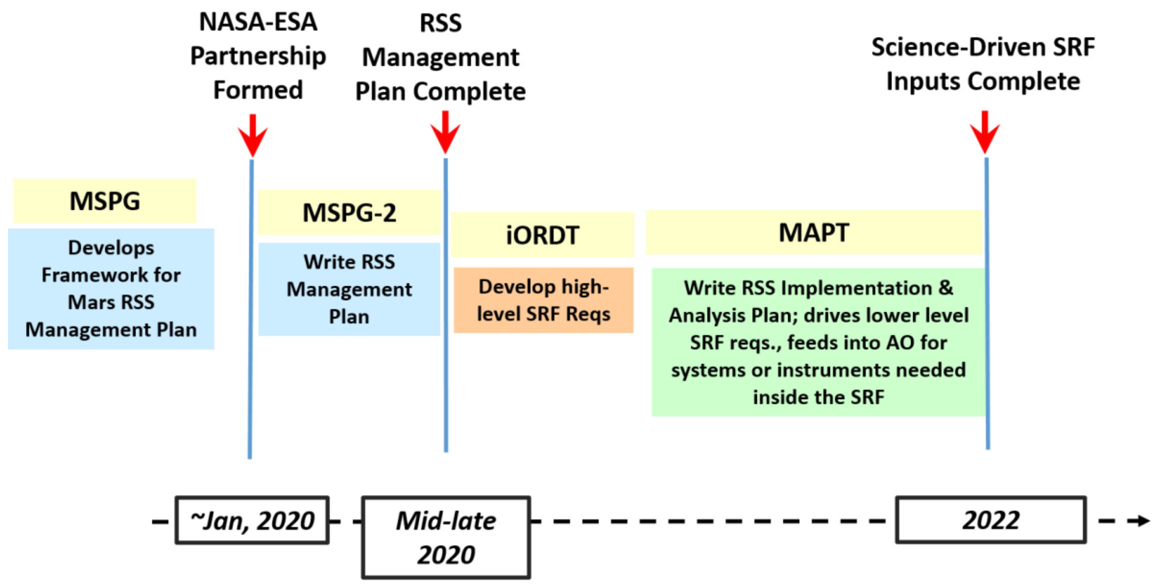


***Figure 7**: Notional schematic representation of the key timing relationships between approximately 2020 and 2022. The most important initial activities for MRSH are the formation of the MRSH Council, and the construction of a full RSS Management Plan. Essential near-term committees are the iORDT (international Objectives & Requirements Definition Team), MSPG-2 (MSR Science Planning Group 2), and the MAPT (Mars Analysis Planning Team). Critical science-related activities are highlighted in yellow.*

4.4 Returned Sample Science Bodies

The schedule for the MSR flight elements (Figure 3) contains two dates that are key to RSS planning: the date of the MAV launch (approximately March, 2029) and the date of receipt of samples on Earth (approximately September 2031 ± 3 months). The former of these dates is when the science community would know specifically which of the samples that had been collected by M2020 are on their way to Earth; the latter is when we would know the details of number, size, and mass of the samples.

Functionally, these dates define two key stages. Prior to the MAV launch, it would be known that some samples may be coming, and the community needs to be prepared in a generic way. After the MAV launch, the samples being returned and their date of return would be precisely known. At that point our planning for RSS operations would required increased specificity. MSR is ultimately a science-driven endeavour; it is appropriate that there would be a number of opportunities for scientists to get involved (Table 4 and Appendix G).

4.4.1 Sample Prioritization Workshop(s)

Rationale: The M2020 sample-caching rover will carry 43 sample tubes, of which four have been pre-configured as blanks (and that configuration cannot be changed after launch). It has not yet been determined how many tubes (either sample or blank) the MSR flight system will be capable of returning—there are complex system engineering trades that relate to the size and mass of key SRL/ERO flight elements (e.g., the OS, MAV, and CCRS) that are still under evaluation as of this writing.

Sample Prioritization Workshop(s)

Essential Purpose: Prioritize the samples cached on Mars as input to finalizing a recovery/return strategy

However, it is the intent of the science community (see E2E-iSAG, 2012) that the number of tubes available to be returned would exceed the number that can physically be returned, and that a sample down-selection and high-grading process would increase the quality of the overall sample collection. Once the science community has established its sample priorities, it would be necessary to use these priorities as inputs for the sample retrieval plan, including a traverse plan for both the SFR and for M2020, beginning with the choice of a landing site for SRL. Hypothetical scenarios for both sample retrieval and sample depots are already being worked as of this writing. This will be an ongoing study for some time as the M2020 mission progresses and notional SFR/SRL requirements are modified with time.

Composition: We envision that the sample prioritization workshop would take place by means of one or many large, community-based workshop analogous to the landing site workshops that have been run by NASA and ESA for M2020 and the ExoMars rover, respectively. Such a process is an ideal way to get as broad a spectrum of the community as possible engaged. We propose that attendance at this workshop would not be limited to the MSR partners, but instead would be open to scientists from anywhere in the world.

Given the cost of the MSR investment and the high science implications of the sample prioritization, it may not be realistic (or even desirable) to reach these prioritization ratings in a single workshop; further discussion on this point is warranted.

Key Outputs: The formal output of the sample prioritization workshop(s) would be a set of priorities for the retrieval/return of the samples. It would be up to a successor engineering-led process to use these priorities to optimize the landing site for the SRL mission, and also to optimize the traverse (potentially of both the fetch rover and M2020). In addition, there are significant contingency scenarios that could develop well after this proposed workshop that could alter the traverse planning. Such contingencies may affect which samples are even viable to return, including loss of M2020 mobility, failure of SFR egress, or loss of SFR during its traverse.

Timing: Determining the ideal timing for the workshop is challenging. On one hand, it needs to happen before the surface traverse plan of the fetch rover is finalized (Figure 3). This may affect the specific choice of landing site for the SRL mission, which would play a role in optimizing the sample retrieval planning. Conversely, it needs to happen after all (or at least a very large majority) of the samples have been acquired by the M2020 sample-caching rover. Given that the landing of SFR is scheduled for ~ July, 2028 (Figure 3) and pending input from the flight engineers on when they need to know the landing site, for the purpose of long-range planning we propose that the first workshop be scheduled for ~ July, 2027.

4.4.2 International Science Definition Team (iSDT)

Rationale: MSR has been presented to the world as a campaign of missions that are driven by scientific objectives; the initial competition for sample access must therefore be objective-driven. For planetary missions, it is traditional to operate a Science Definition Team (SDT) to develop the scientific inputs into the necessary Announcement of Opportunity (AO). In this case, the SDT would need to be international in scope, so we use the acronym iSDT. For the purposes of MSR, the iSDT would need to establish the scientific objectives so that the proposing community can write effective proposals, and so that criteria can be established to evaluate and distinguish between proposals.

> **iSDT**
>
> Essential Purpose: Prepare inputs to the AO that drives the competition for initial access to the samples.

As summarized by MSPG et al. (2019a), scientific access to the samples can be organized into three categories: (i) Investigations that are so time-sensitive that they must be done quickly in the SRF; (ii) Investigations involving sterilization-sensitive science, or that will produce information of relevance to the Sample Safety Assessment Protocol—these also must be done in containment and (iii) investigations that are not time or sterilization-sensitive. There are two obvious ways to implement the scientific competition:

1. 1-Step process. There is only one iSDT and one AO, and the scope includes science in all three categories above. This would be relatively simple to implement, and it would allow for fair processing of the proposals for which this categorization is unclear. However, a consequence of this is that the analysis timeline would be driven by the investigations that need to be done inside the SRF, requiring that the scientific competition be scheduled before the design of the SRF analytical laboratories is finalized. We anticipate that this would be before the MAV launch from Mars (at which point we would know with certainty which samples are heading towards Earth). This would require a second step for PIs to submit sample allocation priorities based on knowledge of actual samples to be received.
2. 2-Step process. The investigations that have to be performed in the SRF are competed separately from those that need not be in containment. This would be more work, and would probably be a less "clean" solution, but by delaying the second AO until after the MAV has launched, the proposals can be much more specific, and the budgeting and planning processes can receive far more commitment.

Although the MSPG endorses a 1-Step process for the reasons stated above. And this is how we have represented it on Figure 8, this is a topic for which we would encourage more discussion before a decision is finalized.

Composition: For reference, we envision that the iSDT would likely have a size and composition approximately similar to the SDT that was used to define the science of the M2020 mission (see M2020 SDT, 2014), which had a chair and 19 additional members of the community. This population was balanced for diversity in all of its relevant dimensions. In this case, of the above 20 people, 18 were Mars scientists, and two were human spaceflight engineers (these two were included because in this example, one of the mission objectives related to humans-to-Mars). Finally, the SDT was assigned to the Mars Program Office at the Jet Propulsion Laboratory (JPL) for implementation, facilitation, logistics, and documentation, and they assigned three additional scientists for this purpose. For the iSDT, the science population would need to be international in breadth in order to represent the MOU-defined agency stakeholders. In addition, curation experts would need to be represented in the team. The membership would be appointed rather than competed, and should be selected by the MRSH Council. Membership would be limited to MSR partners, rather than being open to the world.

Key Outputs: The formal product of the iSDT would be a report that would define the scientific inputs to the AO that would drive the critical competition for initial access to the returned samples.

Timing: Investigations in Categories (i) and (ii) above would need to be conducted inside the containment barrier of the SRF, which means that their timeline will be driven by the development schedule of the SRF. Some of the scientists selected to carry out the investigations may propose instruments or sample preparation systems, and these will have to be installed after the point of completion of construction ("beneficial occupancy") and before the closing of the bio-barrier. Assuming a sample arrival in ~Sept. 2031, these two dates have been estimated at about 2028 and Sept. 2029, respectively. The competition for investigations and instrumentation would need to happen well in advance of that so that the instruments can be procured, installed, and tested. For planning purposes, we suggest that this competition would take place in ~ 2027, implying that the iSDT would need to complete its work late 2026. These timing relationships are illustrated in Figure 8.

The Category (iii) winners of the sample access competition would need time to get their teams in place and to configure their laboratories. For many academic laboratories, for example, it will almost certainly be necessary to improve both the contamination control and the physical security aspects, relative to the standards that are used to analyze terrestrial samples. If the AO is released in mid-2027, with selections by the beginning of 2028, that should allow sufficient time for the PI-led teams to get ready.

At the time of the MAV launch from Mars in 2029 (approximately 2.5 years before receipt of samples at Earth), we would know exactly which samples will be coming to Earth. Beginning with this event, the sample investigation PIs would have an important opportunity to express their priorities for which samples they want to work on. Although we would only later know exactly what the samples are as a result of the Preliminary Examination process, this information would be available too late to begin the Sample Allocation process.

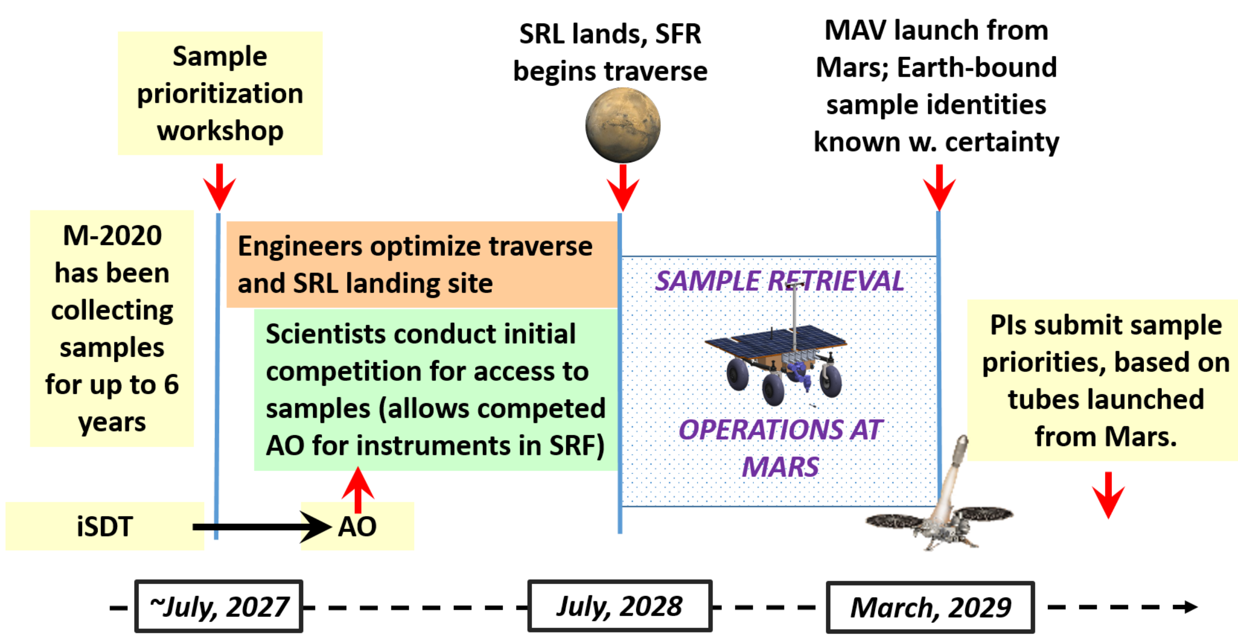


Figure 8: *Schematic representation of key notional activities and dependencies in the 2027-2029 timeframe. The science community's prioritization of samples would inform the sample retrieval decisions and processes.*

FINDING #8: At the time of the Mars Ascent Vehicle (MAV) launch from Mars, approximately 2.5 years before the arrival of samples at Earth, we would know precisely how many and which samples are being sent to Earth. At this point some important elements of returned sample science planning and budgeting can become very specific. However, this is not sufficient lead time to implement all of the required activities; many processes would need to begin well before the MAV launch occurs.

4.4.3 Preliminary Examination Team (PET)

PET

Essential Purpose: Prepare a descriptive catalog of the returned samples.

Rationale: A critically important role beginning immediately after sample receipt is documenting and characterizing the samples before and after the tubes are opened. This initial description of the material is a two-stage process of Basic Characterisation (BC) and Preliminary Examination (PE) (MSPG, 2019a). The measurements to be made by the Preliminary Examination Team (PET) cover both of these stages and are assumed to be planned for by the MAPT, so that the necessary instruments can be accommodated within the SRF. It is expected that the descriptions of the PET do not "scoop" the research of the competitively-selected PIs, but instead consist of sample descriptions that are necessary to develop the forward investigation, sample allocation, and curation plans. Whether and how the PET members may be part of later objective-driven investigations requires further discussion.

Composition: The PET would need to contain enough technical diversity to develop quality descriptions of all of the sample types that could be returned, and in all of the technical dimensions that have been planned for. Because much of the work of the PET feeds into and draws from Curation requirements and outputs, a large fraction of the PET should be Curation specialists, and it is expected that any personnel who will interact with the samples inside the SRF will have to undergo substantial training in both biohazard safety as well as curation techniques. It is important to note that M2020 will prepare, for each sample, an "initial report" document and a detailed digital dossier of information, and such information can form the basis of sample description prior to preliminary examination. However, the observations of the PET are not expected to be available in time to be used in the initial competition for access to samples, which would need to take place while the samples are en-route from Mars to Earth (see Section 4.4.4.). Nevertheless, these observations are expected to be an essential aspect of final sample allocation decisions and also all subsequent sample request proposals (see Sections 4.4.5. and 4.4.7.).

We recommend that the PE team is populated through open competition, with final membership decisions being taken by the MRSH Council. Because of the public visibility of this activity, we also recommend that membership be limited to scientists primarily sourced from any of the MSR partners.

Open competition is preferable to direct appointment for two key reasons. First, these jobs will be historically significant, and there is likely to be very widespread interest in them. Second, the members of the PET are expected to have challenging jobs, including, potentially, significant time spent training and working behind the barrier in the SRF, and accepting timing constraints inexorably driven from elsewhere (for example, timing driven by the Sample Safety Assessment Protocol). Open competition ensures that members of the PE team voluntarily accept the constraints.

Key Outputs: The output of the Basic Characterization (BC) and Preliminary Examination (PE) process is a detailed catalog that describes the samples so that future researchers can understand what is in the collection and what they might request for their own studies (see MSPG et al., 2019b). This information can also be used for planning how to manage the sample collection. The specific kind of information needed to achieve that will be planned by the MAPT Committee, and the instruments necessary to achieve that plan will need to be included in the SRF.

Timing: The PET needs to be formed sufficiently in advance of the arrival of samples at Earth to become familiar with their instruments and processes, to develop their internal teamwork, and to work closely with on-site curation laboratory technicians and operators. It may be desirable to have the PE team participate in the SRF certification process, which will take place from 2029-2031. Given a sample arrival date of Sept. 2031, we assume they should be selected not later than mid-2029, and perhaps as early as 2028, to participate in training and setting up of the SRF operations. The PET is a one-time activity; once the samples have been described, the PET can be dissolved, and its members can move on to other activities.

4.4.4 Objective-Driven PIs

Rationale: To achieve the stated scientific objectives of MSR, as defined by the iSDT, the samples would need to be investigated by an initial set of PI-led science teams who have won the right to receive an allocation of the returned Mars samples through competition (see iSDT Section 4.4.2.). It is expected that this collective set of initial investigations, once completed, would allow NASA and ESA to declare MSR scientific success. The initial set of investigations would be followed by on-going follow-up competitions (see Section 4.4.5).

<u>Objective-Driven PIs</u>
Essential Purpose: Make initial fundamental scientific discoveries using the Mars samples.

Composition: The PIs are expected to be selected in response to the AO process that will be set in motion by the iSDT (see Section 4.4.2.). As outlined by MSPG et al. (2019a), and alluded to above in connection with the iSDT, it is expected that PIs are organized into three categories: (i) those working on time-sensitive science; (ii) those working on sterilization-sensitive science, and (iii) those working on time-insensitive and sterilization-tolerant science. The PIs in Categories (i) and (ii) are be expected to design their investigations such that they would be completed inside the SRF. However, it is important to note that it is not necessary that the Category (iii) group of investigations be performed in containment—this science can be done in uncontained laboratories (including, in many cases, at the Principal Investigators' home institutions). This is by far the most cost-effective way to implement this science (since high-containment floor space is incredibly expensive to build and operate), and it creates conditions within which laboratory scientists can most easily maintain science quality. However, this solution is available only if **one of two things happens:**

a) **a notional sample sterilization protocol can be defined and accepted (pending verification on actual Mars samples), or**
b) **there is a willingness to wait until unsterilized samples can experimentally be determined to be safe (which may potentially be a long time, depending on experimental results)**.

Even though the above two options logically exist, and both have been talked about publically, as a planning issue, they are not really a trade-off with each other. Option a) can be definitively planned and implemented. In contrast, Option b) is a strategy of hope, since we cannot know in advance that some, all, or any of the samples will be able to pass a safety assessment. This would not be likely to be acceptable for an enterprise as large and publically visible as MSR. A further issue with Option b) is that it would entail waiting an indeterminate period of time before the samples could be analyzed. Such a waiting period with no predictable end would not meet the needs of most of MSR's stakeholders. If neither Option a) or b) is possible (for either technical or political reasons), all RSS investigations would need to be conducted within containment, which would require a significant increase to the scope and budget of the SRF, as well as forcing significant compromises on the sample-analyzing science community.

FINDING #9: A critically important element of returned sample science strategy is to have the ability to analyze samples in uncontained laboratories, including in labs at PIs' home institutions. Implementing this planning requires that the samples can be determined to be safe or can be rendered safe by means of a sample sterilization protocol that has yet to be defined.

The PIs would have a proposal-based team of Co-Is, collaborators, affiliates, etc., depending on the guidelines in the AO. Note that consortia involving multiple PIs are likely to be encouraged if they would result in efficiency improvements such as the consumption of less sample mass.

Based on historical precedent from other sample return missions (see Section 2.4), access to the samples for the initial competition should be limited to the MSR partners (the specifics of how this applies to PIs, Co-Is, collaborators, affiliates, etc. needs further discussion, probably by MSPG-2). It is estimated that this embargo period could run for approximately 6 months, but the final duration of the embargo period should be discussed further by MSPG-2. The specifics of the timing of the embargo period are likely to be dependent on the outcome of the sample safety assessment. The time-sensitive science would need to proceed immediately upon the opening of the sample tubes, but the majority of the investigation work on the samples will need to wait until either the samples have been deemed to be safe by means of experimental test, or they have been rendered safe by means of sterilization. The embargo period should be structured to accommodate the large number of scientific teams who would be anticipated to work on the samples outside of containment.

It is expected that the proposals received in response to the AO would be reviewed by the Science Evaluation Panel (SEP) (see Section 4.4.6). It is presumed that a number of factors play a role in proposal evaluation, including science merit, quantity of sample mass required, whether the test is destructive or not, degree of uniqueness of the investigation, etc.—these factors will be further defined by the iSDT. A key additional factor implied by the political organization of MSR is that some sort of balance related to the sponsoring entities is applied (this needs to be refined by future discussion). It is assumed that formal selections would be made by the MRSH Council based on reviews and ratings from the SEP. The Sample Allocation Committee would have the responsibility of preparing specific sample allocation recommendations (Section 4.4.7.).

Key Outputs: Detailed scientific investigation of the returned samples would collectively result in the achievement of the MSR campaign's scientific objectives. At the end of the embargo period when the initial investigations have been completed, we propose that a major scientific conference be convened at which all of the PIs would be expected to report their initial results. This conference is analogous to the Apollo 11 Lunar Science Conference, which was held approximately six months after receipt of the first Apollo samples. This conference should be the trigger for the 2nd call for proposals (see Opportunity-driven PIs; Section 4.4.5.).

FINDING #10: An embargo period should be granted to the scientific teams who receive the initial allocations of samples. We propose that this be followed by an international Mars Returned Sample Science Conference, where all results from these initial allocations are simultaneously made public.

Timing: The PIs would be selected in response to the AO released in follow up to the iSDT (Section 4.4.2.). If the AO is released in 2027, it can be assumed that these PIs are selected by the beginning of 2028. Work that must be conducted within the SRF would likely need to begin very shortly after the receipt of samples in Sept. 2031. It may be desirable to have the Categories (i) and (ii) PIs participate in the SRF certification process, which happens from 2029-2031. It is assumed that most/all of the PIs in Category (iii) would perform their investigations in laboratories outside of containment, and the timeline leading to release of the samples is uncertain. We would hope that at least a subset of the samples would be ready for external release ~ 6-12 months after they are first received in the SRF (i.e., mid-2032). These timing relationships are illustrated in Figure 9.

4.4.5 Opportunity-Driven PIs

Rationale: The initial competition for scientific access to the samples we refer to as "objective-driven" (Section 4.4.3), consistent with MSR itself as an objective-driven activity. However, by analogy with other objective-driven sample return space missions (e.g.,Stardust, Genesis, Hayabusa, OSIRIS-REx), the samples are made available to the scientific community at large after an initial set of objective-driven scientists have done their work during an embargo period. At that point, it is expected that the original MSR scientific objectives are no longer a constraint, and that further proposals can pursue any meritorious scientific purpose. We refer to this phase of sample analysis as "Opportunity-Driven" research.

Opportunity-Driven PIs

Essential Purpose: Make fundamental scientific discoveries using the Mars samples.

Composition: These opportunities would be available only after the embargo period, and we suggest that there be no restriction relating to affiliation with the agencies that signed the original MSR MOU. It is very important that scientists from other countries will be given fair opportunity within this competition—we explicitly want the best ideas for ways to investigate these priceless samples.

Several options exist for sample access opportunities after the embargo period would be triggered by a single AO, by recurring periodic AOs, or by some other on-going, rolling process. By the time of the post-embargo period, there will have been a significant amount of time to assess whether the samples are safe or not. By this point, it may thus be possible for all scientific work to be done in PI home laboratories, or in uncontained curation facilities, in which case bio-contained research in the SRF may either be completed or be winding down.

Alternatively, the sample safety assessment tests may have delivered either ambiguous results, or positive results, in which case bio-contained work in the SRF and scientific proposals to do follow-up research work there may be required. The PIs may have a proposal-based team of Co-Is, collaborators, and other kinds of personnel. In addition, PIs may group together in the form of consortia, which may improve the scientific return per unit of sample mass.

Key Outputs: Scientific investigations of the returned samples, and interpretation of their relevance to the big scientific questions relating to Mars, to Earth, and to the Solar System at large, would continue on an on-going basis. As evidenced by samples returned from the Apollo missions, new and exciting discoveries can be expected for 50 or more years after return.

Timing: The PIs would be selected in response to a triggering action after the embargo period (perhaps an open conference followed by AO), and the declaration of mission success. For the purpose of long-lead planning, by extension of the timeline for the Objective-Driven PIs (Section 4.4.4.), we assume that the selection process for the first round of opportunity-driven PIs can begin after the embargo period (approximately beginning 2033).

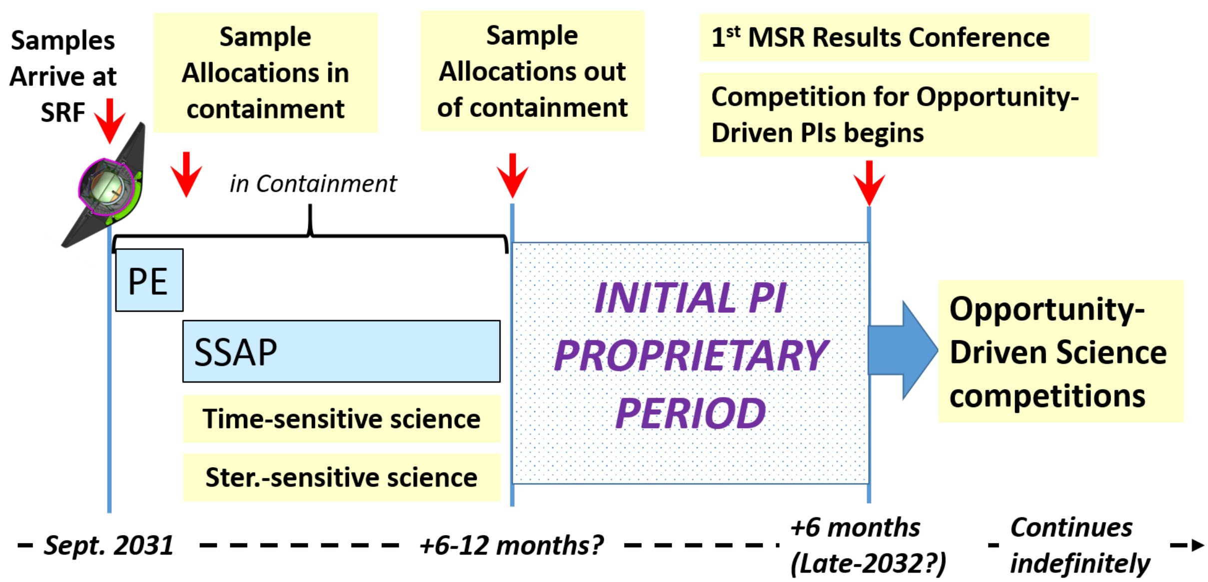


Figure 9: *Notional Schematic representation of the key timing relationships between the receipt of the samples on Earth, and the opening of access to the samples to opportunity-driven PIs. This is thought to translate to approximately Sept. 2031 to the end of 2032. Note that a 6-month embargo period is defined for the PIs who are defined as recipients of the initial sample allocations. At the end of that period, all PIs are expected to release their results simultaneously at a major international MSR conference, at which all discoveries would be announced together. After this point, it is envisioned that any prospective PI with a good idea can compete for sample access. Critical science-related activities are highlighted in yellow.*

4.4.6 Science Evaluation Panel (SEP)

Rationale: A best practice that could be adopted from the IODP is the formation of a standing Science Evaluation Panel (SEP) (https://www.iodp.org/program-organization/science-evaluation-panel). In the case of MSR, the pace of activity would progressively increase until the samples are received, at which point complex decisions will need to be made quickly and effectively. The existence of a pre-established review capability would expedite the decision-making process.

SEP

Essential Purpose: Evaluate MSR-related scientific proposals.

A review panel would provide three benefits:

- By forming this panel early, time can be taken to adjust the reviewer population for breadth of expertise that extends across all areas of RSS, as well as for all other diversity factors
- Having such a group would allow experienced and knowledgeable review panels to be formed quickly
- It constitutes another pathway for a significant number of the members of the science community to get involved in RSS.

Although it is envisioned that this panel would primarily be used to review proposals to request access to the MSR samples, it could potentially advise on other scientific topics.

Composition: The implementation used by IODP may be a good model for MSR needs. They use a relatively large group (currently numbering 54 scientists, two of whom are designated as the co-chairs) structured as an advisory body composed of volunteer domain experts from IODP member countries. The panel size is determined by scientific need. The SEP Co-chairs work to maintain balance of expertise and diversity in its broadest terms, and to ensure regular rotation of its membership. SEP members normally serve terms of three years. Candidates for SEP membership are recommended by the Program Members.

Key Outputs: Review services to evaluate the expected large number of proposals submitted in response to MSR AOs. A key customer for these review processes is the Sample Allocation Committee (see Section 4.4.7.), who would need to form a recommended allocation plan incorporating two key inputs—proposal quality, and sample availability/priority. The recommended allocation plan would be approved by the MRSH Council.

Timing: This group needs to exist in time to evaluate the responses to the AO triggered by the iSDT (see Section 4.4.2.). AO release draft timing is mid-2027, so the SEP should be formed at about that time. The SEP would evaluate all of the initial proposals for Objective-Driven PIs and first round of Opportunity-Driven PIs, but could possibly be replaced with a different review process after the initial rounds of investigation have been completed and the number of necessary reviews slows down.

4.4.7 Sample Allocation Committee (SAC)

Rationale: Sample allocations are expected to be highly coveted. As per the iMOST study, investigations in many different technical areas would need to be carried out. Although many of these can be done on relatively small samples (i.e., sub-mg-scale), some key investigations were flagged by E2E-iSAG as requiring allocations of 1-2 g (specifically including detailed organic geochemistry, for which sample extractions are needed, and internal isochrons, for which high-purity mineral separates are needed). Several investigations can make use of a single, especially useful preparation—the polished section, which can be made from a single chip of rock less than 0.5 mm in thickness. It is crucial that the usage of the limited sample mass be carefully planned. Despite the fact that the spectrum of analyses for the MSR samples is likely to be more diverse than it was for Apollo 11 (because of the astrobiological significance of the Mars samples), MSR is expected to return at most a total of 450 g, whereas Apollo 11 returned 21.5 kg

<u>Sample Allocation Committee</u>

Essential Purpose: Prepare sample allocation recommendations.

(Appendix C), a difference of a factor of 50. This would likely be partially compensated for by the progress made in analytical techniques since the Apollo 11 era.

The Sample Allocation Committee would need to merge the ratings of the proposals for scientific merit (which would come from the Science Evaluation Panel, and which would include consideration of whether the specific investigation has already been proposed by other teams; see Section 4.4.6.), the quantity of sample requested in each proposal, whether the tests are destructive or not, the amount of each sample that is deemed to be available for allocation in a given allocation round, and long-term curation planning considerations in order to prepare an allocation recommendation. The allocation problem will certainly be over-constrained, and balancing priorities amongst all of the above factors will be challenging but essential. Because the sample allocation decisions are expected to be highly political, we propose that the SAC prepare a recommendation for the MRSH Council, and that the latter have the authority to make the actual decision.

The design of the Sample Allocation Committee should be informed by the structure and function of the Curation and Analysis Planning Team for Extraterrestrial Materials (CAPTEM). CAPTEM (originally the Lunar Sample Analysis and Planning Team; LSAPT) is a standing review panel, charged with evaluating proposals requesting allocation of all extraterrestrial samples contained in NASA collections. Committee membership is for 3 years (but is renewable) and is not restricted to US-based scientists. Proposals for sample-based investigations are solicited by the Johnson Space Center (JSC) Astromaterials Acquisition and Curation Office and are evaluated by committee members on scientific merit. Additional information about CAPTEM is available at: https://www.lpi.usra.edu/captem/. Although the governance and reporting structure of CAPTEM may not be appropriate for an international MSR partnership (CAPTEM is solely funded by NASA, and appointments are overseen by NASA), it does provide a valuable example of how proposal solicitation, peer-review and sample allocation can be harmonized within a curation environment.

Composition: Because there would need to be decisions about whether sample mass is used for one type of scientific investigation or another, it would be prudent to populate the committee with representatives of each of the scientific technical areas described by iMOST. Each sub-discipline needs to be a part of the process. Curation management will also be an essential factor in sample allocation planning.

Key Outputs: Recommended sample allocation plan.

Timing: The allocation decisions for time-sensitive science need to be made in time so that the actual investigations can begin immediately after Preliminary Examination. For investigations that are not time-sensitive, the SAC should wait for the results from the PET (Section 4.4.3.), which should be available in late 2031.

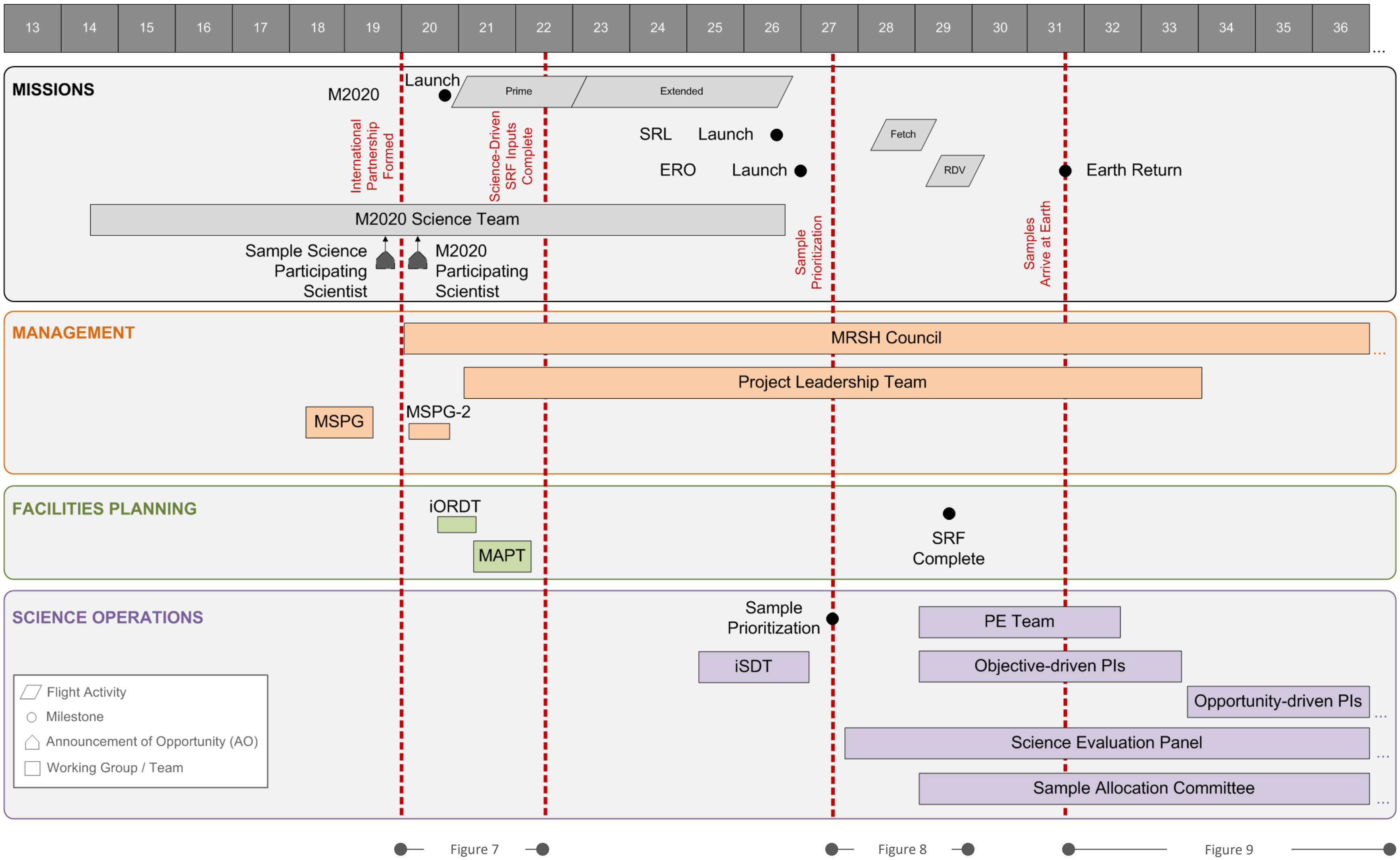
4.5 Integrated Timeline

Since the array of opportunities described throughout Section 4 may be challenging to follow in its entirety, a graphical compilation is presented in Figure 10. The intent is to allow the scientific community to identify the array of activities in which they may participate throughout the MSR process, while providing a useful planning tool for science managers to prepare adequate funding, schedule, and resources for populating committees and running the necessary competitions.

Table 4. *Core functionalities required for the science operations elements of a conceptual MSR campaign.*

WHAT NEEDS TO BE DONE	WHEN		WHO
Science Operations			
Functionality	**Precedent(s)**	**Appx. Start**	**Proposed Responsibility**
Prioritize samples for return	M2020 collects samples	2027	Sample Prioritization Workshops with final decision or acceptance of priorities made by MRSH Council (4.4.1)
Define objectives and priorities for initial round of PI-led sample investigations. Determine the criteria for MSR campaign scientific success.	M2020 collects samples	2025	iSDT (4.4.2)
Generate the inputs to an international AO to compete for initial allocations of the MSR samples	M2020 collects samples, MAV is loaded and launched	2026	iSDT (4.4.2)
Prepare a catalog of the samples received in the SRF, with descriptions sufficient to form the basis for the initial sample allocation competition.	Samples received in SRF	2031	PE Team (4.4.3) and Curation Team
Review sample investigation proposals and rate the scientific merit	proposals received in response to AO	2027	Science Evaluation Panel (4.4.6)
Merge ratings for scientific merit with additional constraints including available funding, available sample mass, and long-term curation planning to prepare an allocation recommendation	Proposal review, PET results, knowledge of funding availability	2031-2032	Sample Allocation Committee (4.4.7) and Curation Team
Approve release of samples to investigators, along with necessary funding to investigate them	Sample Allocation Committee recommendation	2031	MRSH Council (4.2.1)
Perform the initial science investigations on the returned samples. Make discoveries, and achieve the stated campaign scientific objectives	Initial sample allocations	2031-2032	Objective-driven PIs (and their respective science teams), consortia (4.4.4)
Perform second round and beyond investigations to maximize the science return from the sample collection	end of embargo period	2032	Opportunity-driven PI/team/consortia (4.4.5)

Figure 10: *Notional overall timeline showing key science-related activities associated with the MSR enterprise. Not all of the boxes on this diagram need to be "managed" as a part of the Science Management Plan; some are illustrated here because they define the science timeline, and others are shown because interface management would be essential*



5 Discussion and Implementation Considerations

5.1 Responsiveness of the Proposed Framework to the Guiding Principles

MSPG's approach to developing the Framework presented in this report was to take the mulitiple inputs, priorities, and constraints described in Section 2 and blend them together into a workable structure. This includes beginning with a number of organizational recommendations from iMARS-2, incorporation of several key conclusions from the 2019 MSPG workshops, adoption of several critical lessons learned from Apollo and other sample return missions, the use of best practices identified in the management of other major international scientific collaborations, and soliciting input from various stakeholders on their needs and priorities. Inputs were synthesized into five guiding principles (see Section 3.2.1), repeated immediately below for the convenience of the reader.

- **Transparency**: Access to samples must be fair and the processes defining sample access must be as transparent as possible.
- **Science maximization**: It is imperative that we choose science management and sample-related processes that optimize the scientific productivity of the samples, now and in the long-term.
- **Generating Opportunities for the Scientific Community**: International scientists must have multiple opportunities to participate throughout MSR in a variety of capacities (including science planning, sample selection, sample management, and sample analysis/interpretation).
- **Ensuring Fair Balance in the Scientific Discovery Process for the Agency Partners in MSR**: There must be what is deemed to be fair balance for scientists associated with the multiple agency partners in MSR to participate in RSS.
- **One Return Canister: One collection**: In order to realize the full scientific potential of MSR, it is necessary to go far beyond that which can be learned from individual, geologically unrelated samples. It is expected that sample "suites" (defined as a set of samples that are connected by one or more biological, geological, and physical processes operating in an area) will be key.

The Framework proposed in this report responds to these guiding principles in the following ways:

- **<u>Formation of multiple science committees that would be active for different purposes at different times.</u>** This would result in creating maximum number and diversity of opportunities for scientists to participate. Having multiple people involved would greatly enhance our ability to achieve proper international and technical balance. We have also proposed one major workshop (or perhaps a workshop series) to prioritize the samples that had been collected on Mars, and at least one major open conference, to discuss initial scientific results. These committees, workshops, and conferences support the goal of creating as many opportunities for the science community to participate in the process as possible.
- **<u>For the full spectrum of activities associated with RSS, which would play out over more than a decade, opportunities for scientists to be involved have been mapped out.</u>** This includes science planning (MSPG-2; MAPT; iORDT; iSDT), sample selection (sample prioritization workshop), and sample analysis/interpretation (PIs, PET, SEP, SAC). As such, scientists with varying skillsets and interests would have different types of opportunities throughout the process.

- **Where possible, scientific access to the samples would be granted based on competition.** This would ensure that the best and the brightest scientists are involved. The specific criteria for how these competitions would be judged need to be determined by successor entities, but key factors are presumed to include things like maximizing the quantity and quality of scientific investigations, minimizing the consumption of precious sample mass, and avoiding unnecessary repetition of tests, all of which lead to maximizing the total science return.
- **The scientific competitions would be conducted as openly as possible**, in order to increase fairness and transparency, and would prioritize investigations that aid in science maximization and sample mass preservation.
- **MSPG proposes managing the sample collection, and the entire RSS process, by means of an international governance body that we refer to as the MRSH Council.** The returned samples would be managed as a single undivided collection, regardless of whether or not they are curated in more than one location, possibly under the supervision of more than one curation organization. Mars samples are not a commodity to be bartered or traded, but rather the opportunities to study samples are a mechanism by which benefits for MSR partners and their science communities can be realized.
- **MSPG's proposal that some elements of the RSS process be reserved for the scientists representing agencies that form the MSR partnership, and not be made available openly, is important in supporting the fourth guiding principle above.** The MSR partners need to be able to show a "return on their investment" in the form of preferred treatment for their scientists. This incentive is very important to the initial partnership formation, and is based on historical precedent from other solar system sample return missions.
- **Sample preservation would be supported by the use of competitive processes to select the sample investigations.** This would allow several mass-preserving criteria to be used in investigator selection, including minimizing of use of sample mass, minimizing destructive testing, and avoiding unnecessarily repetitive measurements. The key decisions on how to hold sample mass for future investigators can be accommodated within this framework.

5.2 Implementation of the MRSH Council

The MOU is expected to be signed more than a decade before the arrival of samples at Earth, which may convey the false impression that MRSH planning activities do not need to start for a few years. However, Figure 10 shows quite clearly that in order to manage the RSS timeline such that all of the necessary entities are prepared to receive and act upon the samples should they arrive in 2031, significant effort is required essentially immediately. Various planning committees need to be launched, their leadership and membership selected, and budgets need to be made available for the bodies that need them.

Therefore, a critical early action for the MOU signatories would be to form a body that has the authority to charter committees, establish their Terms of Reference that describe deliverables and deadlines, and provide financial authorization as needed. It is be necessary that this group remain in place for the duration of science activities envisioned throughout the entire RSS timeline. We have been referring to this with the working term "MRSH Council", though other terminology may be preferable to the ultimate decision-makers.

In order for the MRSH Council to represent adequately its multiple stakeholders, and to have sufficient technical expertise to do its work well, it will need to have substantial membership. It is worth thinking, therefore, how this group might be organized and led. In the interest of helping to catalyze thinking by the decision-makers with NASA and ESA, MSPG has developed some options for their consideration.

<u>One-Tiered Implementation Approaches</u>. The simplest configuration would be to contain all members in a single decision-making body (an analogy might be the United Nations, although not so large!). Questions then arise as to who should be part of this body. Two extreme cases can be derived from such a scenario.

- The first is where the Council members consist of representatives from the implementing partner agencies, is accompanied by other 'Stakeholders'. These representatives may include nominated experts from the science, curation or technical communities; major contributors to MRSH architecture; ESA member state national agencies or programmes that fund European elements; or regulatory agencies.
- The second extreme case would involve a lean Council composed of only a small number of members. The Executive Board would then interface to Stakeholders who are external to the Council, but interaction (reporting, advisory, decision making) is via established lines of communication.

Advantages: Maximum visibility and decision-making input to stakeholders. Simplified Council structure. ***Disadvantages***: Disproportionate representation between ESA and NASA affiliated states compared to MSR campaign investment. Complex communication and decision-making environment. Potential for reduced connection of stakeholders to Council activities. Potentially unacceptable level of interaction with Council for heavily invested Stakeholders.

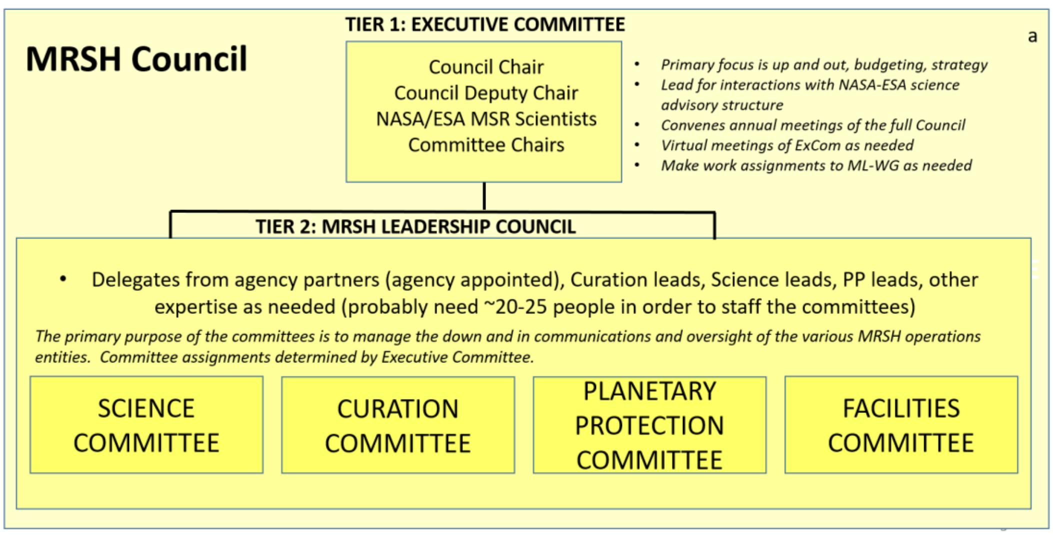
<u>Two-Tiered Implementation Approaches</u>. Based on hybrid approaches adopted by other international science organizations, as well as by typical corporate boards of directors, **a two-tier configuration for the Council appears to be more favorable**. We have recognized two functional concepts for a two-tiered Council.

- In the first (Figure 11-a), the upper tier is represented by an Executive Committee, and the second by members who represent the benefactors and beneficiaries of MSR. In the CERN model each contributing member country is represented by a scientist and a program manager. For MRSH this upper tier could analogously be comprised of as few as one scientist and one program manager from both of NASA and ESA. The second Tier could incorporate nominated science, curation, technical or program representatives from MSR partner countries (i.e. ESA- or NASA-affiliated). Chairs from committees in this tier could be incorporated into the Executive Committee, as shown in Figure 11-a)—this would ensure that Executive Committee discussions are well-informed technically. In this kind of arrangement, agreements on the criteria for membership of the Council, as well as any limits on the number of members in Tier 2 should be agreed as part of the MOU. Clearly there is a large disparity between the number of countries represented by NASA and by ESA. A two-tier scheme allows invested countries to participate in MRSH management without creating a large imbalance in voting power between NASA and ESA states.
- A second option (Figure 11-b) represents a somewhat inverse scenario, whereby the upper tier is populated by a combination of executives and stakeholders, while the lower tier comprises a

handful of key personnel. This model is based on an increasingly popular strategy for organizing Boards of Directors in Europe. Here, the upper tier is the highest level of authority, and is primarily focused on long-term strategic planning. Typically populated by 12-20 people, this Supervisory Committee represents MSR stakeholders, 'business partners' in the form of other investing nations, external experts, and representatives from the key MSR functional groups (science, curation, safety, and facilities). The lower tier, or Executive Committee, serves as the interface between the Supervisory Committee and the implementation organization (in this case, the Project Leadership Team). Key responsibilities include a focus on tactical issues and sustainable management of the overall RSS process.

Advantages: Permits increased visibility and involvement of Stakeholders in Council activities and decisions, and addition of second Tier enhances the range of levels of participation for Stakeholders of different commitments. **Disadvantages:** Details of participation modes in Tier 2 must be agreed amongst stakeholders to set up Council.

Regardless of the configuration, as the implementing and coordinating agencies of MSR, NASA and ESA's representation as the first tier 'Executive' should be given veto power.



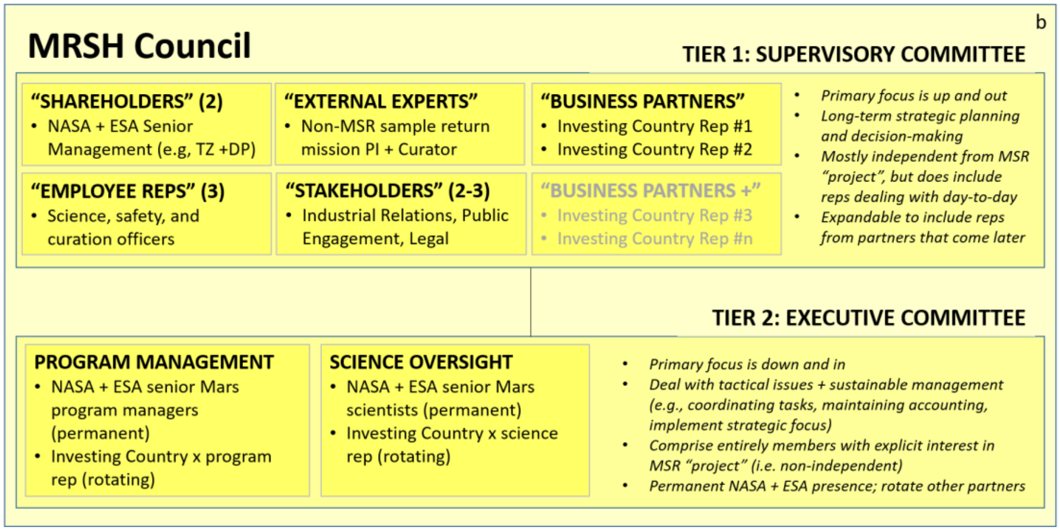


Figure 11: *Two possible configurations of a notional MRSH Council with a two-tiered approach.*

5.3 Initial MSR RSS Implementation Steps

Regardless of the precise implementation of the Council, we identify a list of immediate actions to be carried out after the signing of the MSR MOU, in order for MSR Science Management to proceed in the frame of the joint Campaign:

1. Most importantly, the **MRSH Council** needs to be formed and its authority defined. In the event of a significant lag between the time when it is known that the MSR partnership would happen and the actual signing of the MOU, we encourage formation of the Council as early as possible. Even if the Council does not officially have authority until the MOU is formally signed, initiating the mechanics of Council formation would help expedite the following.

Three entities would likely need to begin work before the formation of the Council:

2. The **Project Leadership Team** (Section 4.2.2.) is needed to lead the day-to-day management of the range of activities within the scope of MRSH, including schedules, and budgets. While higher-level elements of this group are likely to be specified in the MOU, the actual staffing of the positions and initiation of activities is required.
3. A post-MSPG study team, which can continue to advance RSS and MRSH planning, which is able to operate quickly and at low-cost.
4. The **MSPG-2** (Section 4.2.3.) is needed to produce the complete Science Management Plan, consistent with the terms of the MOU and to expand on the present document that serves as a *framework* of the Science Management Plan. MSPG-2 can additionally follow up on certain key issues described by the two 2019 MSPG workshops.
5.

Two entities need to be chartered relatively quickly after the formation of the Council:

6. The **iORDT** (Section 4.3.1.) is needed to initiate the planning for the SRF. It would be best if this started as soon as possible after completion of the Science Management Plan, discussed above.
7. The **MAPT** (Section 4.3.2.) is needed to formulate and refine requirements at Level 3 and below. This would include reaching decisions on a number of finely detailed and extremely important

matters (e.g.,how to open the sample tubes). Because the Level 1 and 2 requirements are required as inputs, it is recommended to run this committee in series with the iORDT rather than concurrently.

The structural relationship for the above-described entities is represented in Figure 12. While the precise start dates for the remainder of activities outlined in Figure 12 may be modified as time goes on, we believe it is critical to commence the above-mentioned groups as soon as is feasible.

FINDING #11: Two functional groups are needed as quickly as possible following approval to proceed with the MSR Campaign: the MRSH Council and the MSR Science Planning Group 2. MRSH as an overall entity is expected to face significant schedule risk, and these two groups are needed to minimize loss of schedule early in the process.

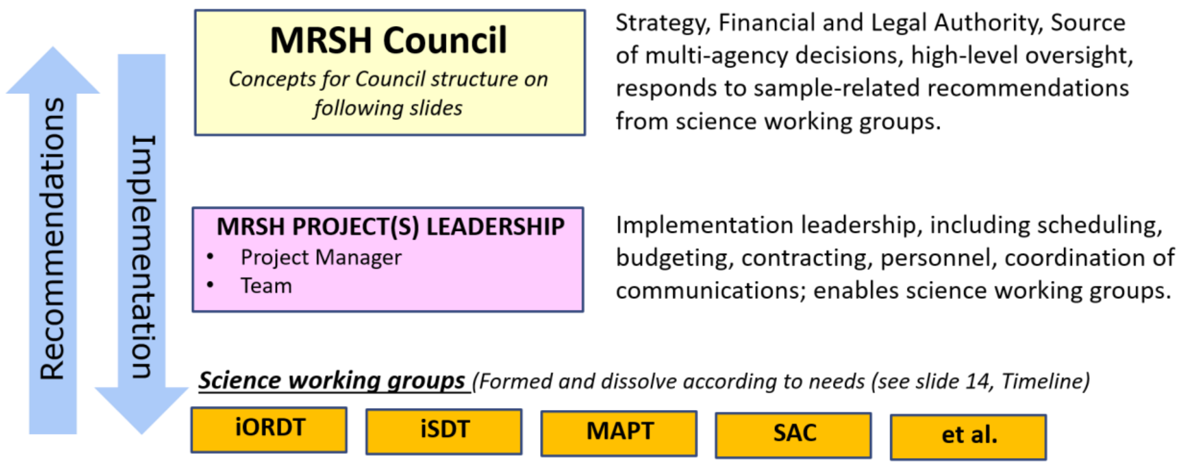


Figure 12. Structural and functional relationship between the notional MRSH Council, Project Leadership Team, and Science Working Groups.

6 Discussion and Conclusions

6.1 International Cooperation on MSR Science Elements

Over the past 2 years there has been abundant evidence that NASA and ESA are more than able to cooperate and support each other in the area of MSR science. First, the iMOST (2019) study of RSS objectives, involving about 70 Mars scientists, equally balanced between the US and European scientists. The many different technical positions described there were reached by transcending notions of any national interests, but in the interest of advancing understanding via scientific analysis.

The same was true of the MSR planning workshops carried out by MSPG. Participants in each of these workshops were carefully balanced between the US and European nations, and even though complex issues were tackled, agreement on almost all issues was reached relatively easily.

Such elements of consensus were also consistent in the development of the Framework we propose, where international MSPG members and external reviewers converged upon the structure outlined in this report.

In summary, the Framework includes:

- a high-level description of tasks to enable samples science of the MSR campaign;
- the councils, committees and other groups that must be created, and to which authority should be bestowed, and from which deliverables should be requested, and;
- a concept for a timeline over which the MSR campaign is expected to progress.

Together, these elements constitute a Proposal for a Framework for MSR Sample Science Management. Note that there are specific elements that MSR Partner agencies must consider an immediate priority in order to begin the science implementation effectively and positively.

There is more than one way to implement some of the processes described throughout the Framework. In several cases, multiple options are suggested, as is a preferred option. After the various MSR stakeholders provide feedback on the proposed Framework, this feedback can be used to expand this document into a complete science management plan.

6.2 Summary of Findings

The key report findings are summarized below.

FINDING #1: The overall strategies for meeting the unique challenges of establishing an international management system for MSR returned sample science must be informed by important lessons learned from both the Apollo Program and various PI-led sample return missions (e.g.,Stardust, Genesis, OSIRIS-REx, etc.).

FINDING #2: Examples of long-running international scientific organizations focused on terrestrial research have been identified that have developed “best practice” strategies and methods that could be productively emulated for the purposes of international MSR returned sample science management.

FINDING #3: A number of opportunities for the international scientific community to participate in different aspects of the returned sample science process have been identified. A compilation showing how these opportunities evolve with time has been prepared, so as to help individual scientists and their teams to find the roles they want, and to enable scientific program managers to plan appropriately (see Appendix G).

FINDING #4: The returned sample collection will have been optimized for its geologic diversity, in large part through its organization into sample suites. As part of the design of the sample suites, the similarities and differences between samples will be at least as important as the attributes of the individual samples. As such, to optimize the scientific potential of the returned samples, they need to be managed as a single collection in all phases of Mars Returned Sample Handling.

FINDING #5: Certain functional elements that are essential to the success of the MSR enterprise are not addressed in the Framework for Mars Returned Sample Science Management, most importantly the M2020 sample-collecting rover, sample curation, and planetary protection. However, it is expected to be critical for the returned sample science managers to work closely with representatives of each of these elements in defining and implementing the Science Management Plan. Future planning teams should carefully consider how these interfaces should be managed.

FINDING #6: A key oversight role for the science management plan is assumed to be provided by the Mars Returned Sample Handling (MRSH) Council. The Council would provide management oversight, delegation of authority and responsibility, and budgetary support not only for returned sample science, but also curation, planetary protection, and facilities management, and ensure that the terms of the inter-agency MOU are effectively implemented. The MRSH Council should be initiated as soon as possible after the MOU is signed, and it is envisioned to ensure long-term continuity.

FINDING #7: A Project Leadership Team would need to be established, with the responsibility of leading the implementation of MRSH, of which returned sample science would be a component, including schedule management, budget planning and implementation, staffing, and overall coordination

FINDING #8: At the time of the Mars Ascent Vehicle (MAV) launch from Mars, approximately 2.5 years before the arrival of samples at Earth, we would know precisely how many and which samples are being sent to Earth. At this point some important elements of returned sample science planning and budgeting can become very specific. However, this is not sufficient lead time to implement all of the required activities; many processes would need to begin well before the MAV launch occurs.

FINDING #9: A critically important element of returned sample science strategy is to have the ability to analyze samples in uncontained laboratories, including in labs at PIs' home institutions. Implementing this planning requires that the samples can be determined to be safe or can be rendered safe by means of a sample sterilization protocol that has yet to be defined.

FINDING #10: An embargo period should be granted to the scientific teams who receive the initial allocations of samples. We propose that this be followed by an international Mars Returned Sample Science Conference, where all results from these initial allocations are simultaneously made public.

FINDING #11: Two functional groups are needed as quickly as possible following approval to proceed with the MSR Campaign: the MRSH Council and the MSR Science Planning Group 2. MRSH as an overall entity is expected to face significant schedule risk, and these two groups are needed to minimize loss of schedule early in the process.

6.3 Next Steps

Certain functional groups in our organizational timeline would need to be chartered immediately following approval to proceed with the MSR Campaign, i.e., within one year. Partner agencies must identify as soon as possible suitable appointments of personnel, resources, and logistical support for the following groups:

Mars Returned Sample Handling (MRSH) Council: The highest-level steering group with oversight authority of the science management structure and operations at the behest of the MSR MOU signatories, and any additional contributing partners. The MRSH Council could be formed in line with the description in Section 4.2.1 & 5.2. This body has chartering authority for other groups in this Framework.

MSR Science Planning Group 2 (MSPG-2) (Section 4.2.3): This group is a natural continuation and elaboration from MSPG. MSPG-2's principal role would be to elaborate the Returned Sample Science Management Framework into a complete Science Management Plan. This plan would be derived from the information in the Framework document, from NASA/ESA management feedback on this document, and from the terms of the MOU. The group would be charged with either adopting strategies within the Framework, or proposing suitable alternatives. Although planning for the formation, composition and terms of reference of most of the successor working groups are not expected to be time-sensitive, a key task is be completing the definition of the Council. If MSPG-2 or an alternative working group is asked to prepare recommendations in this area, they would need to precede the formation of the Council.

6.4 Future Work

This Framework makes a number of general assertions relevant to the overall campaign:

- MSR partner agencies should identify and assure participation of suitable representatives in key campaign areas where mutual discussion between expert counterparts is required, such as curation, science, planetary protection, contamination control and containment.
- To form groups with competed membership, an approach is needed for MSR partners to jointly operate or closely coordinate announcements of opportunity, proposal reviews and selection.

As a general framework of science management, this proposed plan requires input and feedback from the primary stakeholders before it can be developed into the complete science management plan. The details of how the pieces could fit together are, in many cases, dependent on that high-level feedback. In order to implement a plan based on the framework described in this report, a number of activities need to be set in motion.

1. Write the full <u>MSR Returned Sample Science Management Plan</u>.
2. <u>Curation and Planetary Protection</u>. Establish effective liaisons and interface management agreements between RSS and both Curation and Planetary Protection.
3. <u>Public communications plan.</u> As discussed by Klug (2018) and Heward (2018) in their papers at the Berlin MSR conference, a well-designed public communications plan is an essential component of MSR in general, and RSS in particular.
4. <u>SRF planning.</u> In this report, we can describe with specificity the timing by which the SRF would need to be ready relative to the date of sample arrival. However, it is outside the scope of our work to determine the actual date of when work on the SRF needs to begin in order to meet that target. However, MSPG is aware that the planning timelines for facilities of this general

character can be surprisingly long (depending how they are implemented), and MSPG strongly encourages early attention to the planning.

5. PI Laboratory Support. Design and endorse programs that make funding available to potential MSR PIs, whose labs are in need of refurbishment, new instrumentation, and new scientific staffing.
6. Major open technical issues.
    - Penetrative imaging (e.g.,CT scans, synchrotron imaging, etc.). This kind of imaging can be done through the walls of sealed sample tubes, and although it generates data that is useful for some purposes, it may also create irreversible damage for some potential users of the samples. Even though it is clear this *could* be done, additional thought must be undertaken to reach a considered decision regarding whether this *should* be done, or even more strongly, *must* be done.
    - Sterilization-sensitive science. Establishing the relationship between the Sample Safety Assessment Protocol and sterilization-sensitive science. How much overlap would there be, and how will that overlap be managed?
    - Preliminary Examination. Determine the specific analyses that accompany the first phases of PE for anticipated classes of samples (see MSPG et al., 2019b).
    - Sample sterilization protocol. The impacts of heat and radiation sterilization on geological samples needs urgent and detailed investigation. Establishing permissible sample sterilization parameters is an essential factor in getting the samples out of the SRF, and into as many science research laboratories as possible, early (see MSPG et al., 2019a).
    - Time-sensitive measurements. The possible degradation with time of the scientific attributes of martian geological samples in response to exposure to terrestrial environments needs urgent and detailed investigation.
    - Contamination. Investigate how different procedures and analysis techniques contaminate samples (see MSPG et al., 2019b).
    -

Note that the above list is not exhaustive, nor is it necessarily in priority order, but rather representative of a few key first step towards implementing the MSR science program and making the potentially historic discoveries that would be enabled by it.

7 References

Beaty, D. W., C. C. Allen, D. S. Bass, K. L. Buxbaum, J. K. Campbell, D. J. Lindstrom, S. L. Miller and D. A. Papanastassiou (2009). Planning Considerations for a Mars Sample Receiving Facility: Summary and Interpretation of Three Design Studies. Astrobiology, 9(8), pp 14, DOI: 10.1089/ast/2009.0339.

Carrier, B. L., D. W. Beaty, H. McSween, M. M. Grady, E. Sefton-Nash, & iMOST Team (2018). The Importance of Scientifically Selected Sample Suites to Achieving Mars Returned Sample Science Objectives (abs.), AGU Fall Meeting, Washington, D. C.

Euro-CARES Team (2018). Euro-Cares D7.2: Final technical report. 165 pp. Retrieved from http://www.euro-cares.eu/reports.

Farley, K. A., and K. H. Williford (2017). Seeking signs of life, and more: NASA's Mars 2020 mission, *Eos, 98,* https://doi.org/10.1029/2017EO066153. Published on 11 January 2017.

Farley, Kenneth A., Kenneth H. Williford, Kathryn Stack, & Mitchell D. Schulte (2019). Mars 2020 as the First Step in a Potential Mars Sample Return Campaign (abs.), AGU Fall Meeting, San Francisco, CA.

Haltigin, T. W., M. A. Meyer, E. Sefton-Nash, D. W. Beaty, D. S. Bass, B. L. Carrier, M. M. Grady, and the MSR Science Planning Group (MSPG) (2019). Developing a Potential International Science Program for Samples Returned From Mars: Strategies and Considerations Return (abs.), Ninth International Conference on Mars (LPI Contrib. No. 2089), abs. #6244.

Heward, A.R. (2018). Concepts and Planning for MSR public outreach (abs.). 2nd International Mars Sample Return Conference (LPI Contrib. No. 2071), abs. #6091.

iMARS (2008). D. W. Beaty and M. M. Grady (co-chairs), and the iMARS Working Group (D. J. P. Moura, M. Walter, C. Muller, F. Daerden, V. Hipkin, J.-P. Bibring, E. Flamini, G. G. Ori, M. Kato, T. Hode, P. Mani, J. Bridges, F. Jordan, G. Kminek, B. Gardini, J. D. McCuistion, M. Khan, A. Pradier, A. Santovincenzo, C. Conley, L. May, M. Meyer, R. Fisackerly, F. Westall, C. Allen, K. Buxbaum, S. Hayati, R. Mattingly, and P. Stabekis), *Preliminary Planning for an International Mars Sample Return Mission: Report of the International Mars Architecture for the Return of Samples (iMARS) Working Group*, 60 p, posted by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/iMARS_FinalReport.pdf.

iMARS-2 (2018). T. Haltigin, C. Lange, R. Mugnolo and C. Smith (co-chairs), H. Amundsen, P. Bousquet, C. Conley, A. Debus, J. Dias, P. Falkner, V Gass, A.-M. Harri, E. Hauber, A. B. Ivanov, A. O. Ivanov, G. Kminek, O. Korablev, D. Koschny, J. Larranaga, B. Marty, S. McLennan, M. Meyer, E. Nilsen, P. Orleanski, R. Orosei, D. Rebuffat, F. Safa, N. Schmitz, S. Siljeström, N. Thomas, J. Vago, A.-C. Vandaele, T. Voirin, and C. Whetsel. *Astrobiology*, 18 (S1). http://doi.org/10.1089/ast.2018.29027.mars

iMOST (International MSR Objectives and Samples Team: co-chairs: D. W. Beaty, M. M. Grady, H. Y. McSween, E. Sefton-Nash; documentarian: B. L. Carrier; team members: F. Altieri, Y. Amelin, E. Ammannito, M. Anand, L. G. Benning, J. L. Bishop, L. E. Borg, D. Boucher, J. R. Brucato, H. Busemann, K. A. Campbell, A. D. Czaja, V. Debaille, D. J. Des Marais, M. Dixon, B. L. Ehlmann, J. D. Farmer, D. C. Fernandez-Remolar, J. Filiberto, J. Fogarty, D. P. Glavin, Y. S. Goreva, L. J. Hallis, A. D. Harrington, E. M. Hausrath, C. D. K. Herd, B. Horgan, M. Humayun, T. Kleine, J. Kleinhenz,

R. Mackelprang, N. Mangold, L. E. Mayhew, J. T. McCoy, F. M. McCubbin, S. M. McLennan, D. E. Moser, F. Moynier, J. F. Mustard, P. B. Niles, G. G. Ori, F. Raulin, P. Rettberg, M. A. Rucker, N. Schmitz, S. P. Schwenzer, M. A. Sephton, R. Shaheen, Z. D. Sharp, D. L. Shuster, S. Siljestrom, C. L. Smith, J. A. Spry, A. Steele, T. D. Swindle, I. L. ten Kate, N. J. Tosca, T. Usui, M. J. Van Kranendonk, M. Wadhwa, B. P. Weiss, S. C. Werner, F. Westall, R. M. Wheeler, J. Zipfel, and M. P. Zorzano) (2019), The Potential Science and Engineering Value of Samples Delivered to Earth by Mars Sample Return, Meteoritics & Planetary Science, vol. 54 (3), p. 667-671 (executive summary only), https://doi.org/10.1111/maps.13232; open access web link to full report (Meteoritics & Planetary Science, vol. 54, S3-S152): https://doi.org/10.1111/maps.13242.

Klug Boonstra, S. (2018). Mars Sample Return: The Critical Need for Planning AaMeaningful and Participatory Public Engagement Program (abs.). 2nd International Mars Sample Return Conference (LPI Contrib. No. 2071), abs. #6092.

Lock, Rob (2019). Preliminary Mars Sample Return Campaign Description Document. JPL D-101374.

Mars 2020 SDT (2013). Committee members: Mustard, J.F. (chair), M. Adler, A. Allwood, D.S. Bass, D.W. Beaty, J.F. Bell III, W.B. Brinckerhoff, M. Carr, D.J. Des Marais, B. Drake, K.S. Edgett, J. Eigenbrode, L.T. Elkins-Tanton, J.A. Grant, S. M. Milkovich, D. Ming, C. Moore, S. Murchie, T.C. Onstott, S.W. Ruff, M.A. Sephton, A. Steele, A. Treiman, 2013, Report of the Mars 2020 Science Definition Team, 154 pp., posted July, 2013, by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/MEP/Mars_2020_SDT_Report_Final.pdf.

Mattingly, R., Hayati, S., &Udomkesmalee, G. (2005). Technology development plans for the Mars Sample Return mission. In: Proc. 2005 IEEE Aerospace Conf., Inst. Electrical and Electronics Engineers, Piscataway, NJ. 14 pp.

MEPAG E2E-iSAG (2012). Committee members: McLennan, S.M. and Sephton, M.A. (co-chairs), Allen, C., Allwood, A.C., Barbieri, R., Beaty, D.W., Boston, P., Carr, M., Grady, M., Grant, J., Heber, V.S., Herd, C.D.K., Hofmann, B., King, P., Mangold, N., Ori, G.G., Rossi, A.P., Raulin, F., Ruff, S.W., Sherwood Lollar, B., Symes, S., and Wilson, M.G., 2012, Planning for Mars Returned Sample Science: Final report of the MSR End-to-End International Science Analysis Group (E2E-iSAG), *Astrobiology, 12,* 175–230; DOI: 10.1089/ast.2011.0805. Can also be accessed on the MEPAG web site at https://mepag.jpl.nasa.gov/reports/E2E-iSAG_FINAL_REPORT.pdf.

MEPAG MRR-SAG (2009). Committee members: Pratt, L. M. (chair), C. Allen, A. C. Allwood, A. Anbar, S. K. Atreya, D. W. Beaty, M. H. Carr, J. A. Crisp, D. J. Des Marais, J. A. Grant, D. P. Glavin, V. E. Hamilton, K. Herkenhoff, V. Hipkin, B. Sherwood Lollar, T. M. McCollom, A. S. McEwen, S. M. McLennan, R. E. Milliken, D. W. Ming, G. G. Ori, J. Parnell, F. Poulet, C. G. Salvo, F. Westall, C. W. Whetsel, and M. G. Wilson, 2009, Mars Astrobiology Explorer-Cacher: A potential rover mission for 2018, Final report from the Mid-Range Rover Science Analysis Group (MRR-SAG), *Astrobiology, v. 10(2),* 127-163. doi:10.1089/ast.2010.0462.

MEPAG ND-SAG (co-chairs: Borg, L., David Des Marais; facilitation: Beaty, D.W.; committee members Oded Aharonson, Steve Benner, Don Bogard, John Bridges, Charles Budney, Wendy Calvin, Ben Clark, Jennifer Eigenbrode, Monica Grady, Jim Head, Sidney Hemming, Noel Hinners, Vicky Hipkin, Glenn MacPherson, Lucia Marinangeli, Scott McLennan, Hap McSween, Jeff Moersch, Ken Nealson, Lisa Pratt, Kevin Righter, Steve Ruff, Chip Shearer, Andrew Steele, Dawn Sumner, Steve Symes, Jorge Vago, and Frances Westall (2008). Science priorities for Mars Sample Return. *Astrobiology*, 8(3): 489-535. doi:10.1089/ast.2008.0759.

MEPAG (2018). Mars Scientific Goals, Objectives, Investigations, and Priorities. D. Banfield, ed., 81 p. white paper posted October, 2018 by the Mars Exploration Program Analysis Group (MEPAG) at https://mepag.jpl.nasa.gov/reports.cfm.

MSPG (MSR Science Planning Group: co-chairs M. Meyer and E. Sefton-Nash; facilitation D. W. Beaty and B. L. Carrier; and D. Bass, F. Gaubert, T. Haltigin, A. D. Harrington, M. M. Grady, Y. Liu, D. Martin, B. Marty, R. Mattingly, S. Siljeström, E. Stansbery, K. Tait, M. Wadhwa, L. White) & C. C. Allen, H. Busemann, M. Calaway, M. Chaussidon, C. M. Corrigan, N. Dauphas, V. Debaille, D. P. Glavin, S. M. McLennan, K.Olsson-Francis, R. Shaheen, C. L. Smith, J. Thieme, T. Usui, M. A. Velbel, S. C. Werner (2019a) The Relationship of MSR Science and Containment. Unpublished workshop report, posted 04/01/19 at https://mepag.jpl.nasa.gov/reports/Science%20in%20Containment%20Report%20Final.pdf

MSPG (MSR Science Planning Group: co-chairs M. Meyer and E. Sefton-Nash; facilitation D. W. Beaty and B. L. Carrier; and D. Bass, F. Gaubert, M. M. Grady, T. Haltigin, A. D. Harrington, Y. Liu, D. Martin, B. Marty, R. Mattingly, S. Siljeström, E. Stansbery, K. Tait, M. Wadhwa, L. White), & A. M. B. Anesio, L. Bonal, A. Bouvier, J. C. Bridges, J. R. Brucato, K. L. French, U. Gommel, H. V. Graham, J. M. C. Holt, G. Kreck, R. Mackelprang, F. M. McCubbin, K. Olsson-Francis, A. B. Regberg, A. Saverino, M. A. Sephton, & C. K. Sio (2019b) Science-Driven Contamination Control Issues Associated with the Receiving and Initial Processing of the MSR Samples. Unpublished workshop report, posted 09/20/19 at https://mepag.jpl.nasa.gov/reports/MSPG%20Contamination%20Control%20Report%20Final.pdf

National Research Council (NRC) (2011). Vision and Voyages for Planetary Science in the Decade 2013-2022. In Committee on the Planetary Science Decadal Survey, (ed.). NRC Space Studies Board, Washington, DC. 400 pp.

Rummel, J. D., M.S. Race, D.L. DeVincenzi, P. J. Schad, P.D. Stabekis, M. Viso & S. E. Acevedo (eds.), (2002). A draft test protocol for detecting possible biohazards in martian samples returned to Earth, NASA publication CP-2002-211842, NASA, Washington, DC. This report, along with summaries of four component workshops, can be accessed at https://planetaryprotection.nasa.gov/summary/DraftTestProtocol.

Sefton-Nash, Elliot, Michael A. Meyer, Brandi Carrier, and David W. Beaty (2019). Science Planning for a Potential Mars Sample Return Campaign, EPSC Abstracts Vol. 13, EPSC-DPS2019-1503-1, 2019 EPSC-DPS Joint Meeting 2019.

Vondrak, Richard R. (2004, 2008 Lunar Reconnaissance Orbiter (LRO), unpublished presentation posted at https://lunar.gsfc.nasa.gov/library/vondrak0904.pdf.

APPENDICES

Appendix A: NASA/ESA Joint Statement of Intent (2019-07-02)

Joint Statement of Intent
between the National Aeronautics and Space Administration
and the European Space Agency
on Mars Sample Return Campaign Science Benefits

July 2, 2019

Considering the Joint Statement of Intent on Mars Sample Return (MSR) signed between NASA and ESA in April 2018,

Acknowledging the involvement of European scientists in the recommendation of the landing site of NASA's Mars 2020 mission, which will collect samples intended to be returned to Earth by the NASA Sample Retrieval Lander and ESA Earth Return Orbiter missions of the proposed MSR campaign,

Recognizing that the establishment of the MSR Science Planning Group (MSPG) co-chaired by NASA and ESA will advance science objectives of an MSR campaign and the establishment of clear roles and principles governing the science in an envisaged MSR partnership,

Recognizing that in the course of discussions between NASA and ESA about an approach for Mars Returned Sample Handling (MRSH), the following guiding principles have been identified for further elaboration between the agencies:

- Mars samples contained in the Earth Entry Vehicle (EEV) will be returned to US soil and transferred to a sample receiving facility located in the US which will be under international management and include equitable participation of the campaign partners;
- The use of an additional biocontainment receiving facility in Europe for pristine samples during the quarantine period shall be subject of further mutual discussion with a view to enabling more and better science as well as campaign redundancy. This facility would also be under international management and include equitable participation of the campaign partners;
- Campaign partners will create a group independent of the MSR campaign to provide long-term guidance and support for MSR science, engage researchers around the world, and disseminate MSR data;
- MSR campaign partners will have equitable access to the samples while in the sample receiving facilities and for a proprietary period following confirmation of safe release of samples, with the duration of the initial proprietary period to be mutually agreed by the campaign partners;
- After the proprietary period, access to the Mars samples will be open to the international community based on scientific merit;
- During all phases of the analysis, due to their scientific and historic value, the samples returned from Mars will be treated as one collection, even if housed in multiple facilities.

NASA and ESA, as part of the joint MSR plan referred to in the Joint Statement of Intent of April 2018, intend to advance further the definition of the science management planning for MSR and of the implementation conditions underpinning the Mars Returned Sample Handling in the MSR partnership based on the guiding principles mentioned above; all these elements will be reflected in an international agreement to be developed between the two agencies.

Thomas H. Zurbuchen **Associate Administrator** **for Science** **NASA**	**David Parker** **Director** **Human and Robotic Exploration** **ESA**

Appendix B: MSPG ToR

Terms of Reference

MSR Science Planning Group (MSPG)

Introduction

As per the April, 2018 Statement of Intent regarding MSR, NASA and ESA are seeking to establish a partnership to return the M-2020 samples from Mars. A fundamental premise of this partnership is that scientists working in the US, Europe, and in any future partner entities, would equitably share access to the samples so that the scientific benefits and discoveries are joint. This document establishes the MSR Science Planning Group (MSPG) to develop a stable foundation for international scientific cooperation on samples returned from Mars. MSPG will accomplish this by suggesting the mechanisms through which the scientific community can share and achieve our collective goals, leading to recommendations being made to the NASA and ESA executive that will help inform programme decisions on MSR. They are community experts and agency representatives charged with convening with other members of their field, with support from partner agencies, to advise on open issues regarding MSR sample science management.

An important scientific basis for inter-agency cooperation on the science of MSR is the recent work by the International MSR Objectives and Samples Team (iMOST) on a proposed set of consensus scientific objectives for MSR. The iMOST team was sponsored by IMEWG (International Mars Exploration Working Group). Its leadership was drawn from NASA, ESA, and the U.S. and European academic communities. The Team was very large to cover an unusually wide range of scientific disciplines and internationally diverse (at least 30 scientists from each of the U.S. and Europe, along with important contributors from several other nations). As iMOST did its work, it was careful to report to the community at regular intervals, and to generate and incorporate feedback, including at the Berlin MSR conference (April, 2018), at COSPAR (July, 2018), at MetSoc (July, 2018), and at MEPAG (June, 2018). iMOST completed its final report on Aug. 1, 2018 (https://mepag.jpl.nasa.gov/reports/iMOST_Final_Report_180814.pdf). The purpose of iMOST was to update/establish consensus positions within the Mars exploration international community regarding the scientific objectives of MSR, and to analyze the specific ways in which sample studies are uniquely valuable to each objective. Although this work is believed to be the scientific basis upon which to build inter-agency planning, there are a number of additional key topics relating to handling of the samples upon return to Earth that need to be discussed and agreed for a joint plan to be submitted to stakeholders for approval.

Over the past several years, independent planning processes of relevance to MSR science, and especially planning for the Sample Receiving Facility (SRF) and curation, have been carried out in both the U.S. and in Europe. Various documents have been generated, with various embedded assumptions, that have not been shared between agencies until now. In order to establish a stable partnership between NASA and ESA, it will be necessary to revisit these assumptions, and to align the science-related functional requirements with the outcome of iMOST. This in turn should form the basis of a mutually acceptable set of implementation plans, budgets, schedules, and work processes.

Assumptions

MSPG's work is constrained by the following assumptions:

1. The scientific objectives of MSR are those described by iMOST (2018)—this report considers and incorporates all prior work.
2. The sample-related facility scenario will be as follows:
    a. Overall sample science and facility management (of any and all facilities that host samples returned from Mars) will operate under a TBD model of international governance.
    b. A "BSL-4" rated SRF in the U.S. will be responsible for sample containment until such time as they are deemed safe for release or transfer under containment to another equivalently rated facility.
    c. Additional curation facility(s) in the US or Europe will exist. A European facility would be able to receive a subset of samples after initial receipt by the US-based SRF. The European facility may or may not have equivalent containment to the SRF. If it does, then investigations regarding life that are dependant on bio-containment, could be performed in Europe. If it does not, receipt of samples by a European facility would occur after transfer criteria are met to permit transfer out of contained US facility (e.g. sterilization).
    d. Analytic laboratories, led by PIs, located around the world in academic institutions, research institutes, government laboratories, and elsewhere, will desire access to the SRF and curation (primary) facilities, and eventually if safe, access to samples distributed outside the primary facilities.
3. The decision on where to locate the U.S. SRF or a European biocontained facility will need to be made in the context of the local and national laws and optimizing for capabilities; thus, this is not known (or knowable) at this time.

<u>Actions Requested</u>

1. Define and prioritize the primary science-related issues that need to be addressed to establish the basis of a mutually acceptable partnership between NASA and ESA on MSR. Examples include, but are not limited to:
    a. We need to establish a clear understanding of the science benefits of the MSR collaboration to all international stakeholders, especially in terms of access by European and American scientists to the Mars returned samples. What are strategies/concepts to achieve this?
        i. Develop a concept for competitive and fair scientific participation and access to the samples, including for both PI-driven science and the Preliminary Examination process.
        ii. Formulate a strategy for scientific access to the samples, that is fair and consistent for both U.S. and European scientists.
        iii. iMARS-2 proposed an approach to sample management – Is this the desired approach?

    b. Propose functional requirements for the science-related attributes of a SRF that can be used as the basis for cost and schedule estimation (assume additional independent requirements will come from planetary protection).
        i. To what extent does science need to be done in containment?
        ii. How do the science requirements translate into functional requirements of a SRF (including Contamination Control and robotics requirements)?

iii. Evaluate certain prior planning documents that have been developed either by NASA, ESA, or third parties (e.g. IMEWG) as input to developing jointly acceptable assumptions and requirements.

c. A list of options and priorities for contingency samples that could increase or secure science return.

2. Address these issues by means of convening representatives from the scientific community, conducting workshops, establishing topical committees, directed work, and/or the MSPG's own internal efforts. Emphasis is placed on the responsibility of this group to represent the view of the international science community and other stakeholders of Mars Sample Return science output.
3. Interim results are requested by March 31st, 2019; Finalized results requested by October 1st, 2019, along with reports of topical activities (e.g. workshop reports) as they happen.
   a. It is anticipated that PPT-formated reports will be sufficient initially for both of the above delivery points.
   b. A community discussion feedback loop will be at the December, 2018 AGU meeting, and possibly requested at other venues identified by MSPG, or by its NASA-ESA stakeholders.
   c. The finalised reports, including the findings of the MSPG and the science community feedback, shall be submitted to the NASA Associate Administrator for Science and the ESA Director for Human and Robotic Exploration.

Team, logistics

- Co-chairs will consist of NASA and ESA representatives.
- The logistics for the team will be managed by the Mars Program Office, at JPL, and will be supported as needed by NASA and ESA.
- For reasons of both cost and time, it is expected that most/all of the MSPG's work will be carried out using e-mail and teleconference processes, although as needed, 1-2 face-to-face meetings can be scheduled. The team is encouraged to take advantage of opportunities when most/all of the team will be in the same place at the same time (e.g. at major conferences) to meet.

James G. Watzin (NASA) and Bernardo Patti (ESA).

J Watzin
2-7-19

B Patti
Digitally signed by Bernardo Patti
DN: cn=Bernardo Patti, o=ESTEC, ou=ESA, email=bernardo.patti@esa.int, c=NL
Date: 2018.11.26 16:30:23 +01'00'

Appendix C: Facts and Figures from the Initial Allocation of the Apollo 11 samples.

- The total amount of Apollo 11 sample that was initially allocated was 7 kg (out of 21.5 kg that was returned).
- About 2 kg of that was completely consumed in analytical testing.
- The biological tests conducted at the Lunar Receiving Laboratory (LRL) for the purpose of quarantine consumed 700 g.
- About 200 thin sections were prepared.
- The lunar sample investigators were selected by the Space Science Steering Committee of the Office of Space Science and Applications through the efforts of its subcommittees and their working groups. Initial sample allocations were made to 142 Principal Investigators for scientific investigation.
- The various sample splits were distributed by NASA for scientific investigations on the basis of recommendations by the Lunar Samples Analysis Planning Team (LSAPT).
- LSAPT used the following guidelines:
    - Duplication of work on the same or similar samples was minimized.
    - Duplication of measurements that required relatively large amounts of sample and degraded the material for other uses was avoided.
    - Some duplication appeared desirable for the verification of those measurements that would be used by many individuals in the interpretation of their own results.
    - Such duplication was easily justified for those measurements that required very small amounts of sample.
    - Information on petrography and on bulk chemical composition was desired the interpretation of most experimental data obtained on samples. The distribution plan assured that this information was obtained for most samples.
- The Lunar Sample Preliminary Examination Team (LSPET) consisted of about 30 scientists, who were asked to work in less than optimum conditions.
- Following the initial publication by LSPET, a self-imposed moratorium on the publication of scientific results was observed by the scientific investigators until the time of the Apollo 11 Lunar Science Conference, which was held in Houston January 5-8, 1970. That meeting was attended by several hundred scientists.

Appendix D: Facts and Figures from the Initial Allocation of the Stardust samples.

There were two sample collections made from the Stardust spacecraft – coma grains from Jupiter family comet Wild 2, and fresh interstellar grains. For the appendix I will only discus the Cometary samples.

- The total amount of Wild 2 sample that was initially allocated was about 5% of the total sample, all or portions of 50 of the 1000 collected particles (collected into tracks in aerogel). None of the largest 10 samples were examined during PET.
- About 1% of the total collected coma samples was completely consumed or lost during PET.
- Approximately 1000 TEM grids containing microtomed thin sections were prepared – there were usually multiple thin sections on each grid.
- The sample investigators were initially selected by the Stardust Science team, but at the 1 -year PET effort progressed any qualified scientists who volunteered to join the effort were selected. All PET participants had to agree to abide by a few simple rules. None of the participants broke any of the rules. Thus, the PET team grew from effectively 5 persons at launch, to 10 at sample return, to 206 by the end of PET. The PER was organized into 6 overall teams (Min-Pet, Optical Properties, Cratering, Bulk Composition, Isotopes, Organics), with numerous subteams. 59 separate sample allocations were made during this period to 51 different team leaders.
- The various sample splits were distributed by NASA for scientific investigations on the basis of recommendations by the core Stardust Science Team.
- The Stardust Science team used the following guidelines in approving investigations:
    - No work was permitted on the 10 largest returned samples.
    - Duplication of work on the same or similar samples was not minimized, in the interest of verifying results.
    - Duplication of measurements that required relatively large amounts of sample and degraded the material for other uses was avoided unless there was an important justification.
    - Information on petrography and on bulk chemical composition was desired the interpretation of most experimental data obtained on samples. The distribution plan assured that this information was obtained for most samples. In general analyses were planned to begin with non-destructive, more through minimally destructive, and finally arrive at the most destructive. Exceptions to this rule were permitted for some analyses where prior investigation would compromise the later investigations. For example, many organic analyses had to be performed on pristine, otherwise unanalyzed grains or microtomed slices.
- By giving any qualified investigators access to samples state of the art measurements were routine.
- A self-imposed moratorium on the publication of scientific results was observed by the scientific investigators until the time of the LPSC, in March of 2006. Since abstracts for that conference were due one day before sample return there were no observations or measurements reported in the conference abstracts (by special permission by the conference organizers). The first actual publications were seven papers in Science magazine (one introductory paper and one from each of the subteams).

Thanks to Mike Zolensky for compiling this information.

Appendix E: Comparison of Management Attributes of Other International Organizations

TOPIC	RELEVANCE TO MSR	IODP	CERN
Organization and Advisory Structure	Provides model for interface between management involving international partners and sample science community.	An independent management corporation with strong science advisory structure. Progaram Governing Board represents member nations. Central management office, scientific avisory structure and implementiong organizations (platform operators). PGB has ultimate authority over funding requiremnets, responsibilities, etc. Program Member Offices (PMOs)/"advisory committees" manage and fund participation of researchers working in a member country. PMOs nominate scientists for expeditions, 3 year terms for serving on boards, panels. IODP-level SAS evaluates proposals from PMOs	The CERN council is the highest authority and is led by the Director-General. The council is comprised of two delegates from each of the 23 member states - one from the national government and one representative from the nation's scientific community. Issues are decided by simple majority, and the council takes advice from the Scientific Policy Committee (who assess the scientific merit of proposals and whose members are elected by existing members of the committee, with confirmation from the CERN council), and the Finance Committee (which consists of delegates from member states and deals with all budgeting and funding). There are various departments which have departmental heads appointed by the Director-General.
International Participation	Provides model framework for international participation in MSR, including how to evaluate "contributions".	25 nations with well-defined roles/responsibilities and sample/data rights. Individual PMOs/nations fund their own scientists. Competative process and selection identified thorugh PMO and then IODP panels.	23 member states; CERN allows for significant international participation with agreements with three observer states (US, Russia and Japan) and co-operation agreements with 37 countries as well as scientific contacts in 18 others, and with international organisations. Many experiments such as ATLAS have a strong international collaborative element.
Sampling Strategies	Provides model for "suite-specific sampling strategies" recommended in this report.	For each expedition, "leg-specific sampling strategies" are tuned to science questions being addressed and sample types being recovered (sediment, igneous, paleo-climate). Science goals are updated every 10 years by an international panel of scientists.	N/A
Moratorium Period	Provides example of dealing with restrictive sample access during preliminary examination phase of Mars samples and during sample containment in general.	Each expedition has a moratorium period lasting one year after the end of cruise, in which only shipboard scientists (and shore based collaborators) have access to samples and data.	Moratorium periods are set by the individual experiments. Generally, access to data is restricted until the data is published by the experiment.
External Scientists	Provides model for coordinating external expertise for MSR, personnel aspects for the SRF (e.g., guest scientist programs) and preliminary examination teams.	Each expedition is staffed by temporary expert scientists (including lead scientists) who work with extensive permanent technical staff and a small permanent science staff.	Unclear, Application submitted to Scientific Policy Committee or the various management of the individual experiments is the best bet. Usual procedure is to write a joint proposal with someone who is already a member of the experiment, to be submitted to the co-ordinator or project leader of the experiement in order to gain an STA (Short-term association) agreement or a variant of.

Preliminary Examination	Provides guidance on designing preliminary examination protocols for samples from different suites.	Protocol-driven preliminary examination includes standard measurements on all cores and site-specific measurements (derived from sampling strategies). Data must be submitted for publication within 20 months of expedition	N/A
Analytical Facilities	Provides model for staffing and operating extensive analytical facilities at SRF, including preliminary examination and planetary protection analyses.	Drilling ships operate extensive, sophisticated analytical facilities during cruise for preliminary examination and onboard research, staffed by permanent technical and science staff.	Accelerator Complex includes LINAC 2 and 3, Proton Synchronisation Booster, Low Energy Ion Ring, Proton Synchrotron and Super Synchrotron, Antiproton Decelerator, Online Isotope Mass Seperator (ISOLDE), Compact Linear Collider and AWAKE experiment (a plasma Wakefield accelerator). This provides facilities for accelerating range of ions and fundamental particles, which are collided in the LHC for seven different experiments.
Sample Distribution	Provides basis for designing the sample allocation boards proposed in this report.	Well-established procedures involve sample allocation committees and an oversight advisory board for appeals and special requests. Samples are associated with an expedition and have a moratorium period to start. Older cores are also distributed after the moratorium has expired through a competative process evaluated by PMOs and then the IODP-SAS.	N/A
Nature of Samples / Curation	Mars samples will be more than one order of magnitude smaller, but otherwise will bear many similarities to ocean core samples; provides example of long-term curation of precious samples that are very highly sought for research.	Samples are geological", retrieved as cores and sub-sampled/distributed in accord with geological context (bedding, fragmental, texture); long-term sample curation (>50 yrs) at multiple localities; Curatorial Advisory Board; reserve of about 50% of drill core for future research. Three sample repositories in 3 separate nations based on geographical location of coring.	Samples are produced on site using the various accelerators and ionised hydrogen gas. Some samples with a greater atomic weight are brought in from elsewhere before being accelerated in the LINAC 3, LEIR, PSB, PS and SPS accelerators.
Data Archiving	Provides model for data archiving and making data obtained from Mars samples during preliminary examination / characterization accessible to different categories of researchers.	Extensive web-based system for posting data in accessible format with two levels of access (password protected Moratorium phase; public access post-Moratorium). Survey data related to sample site and publications related to samples are also archived.	Each experiment sets their own data policy, all data which is published is also uploaded to the CERN Open Data Portal for distribution and access by anyone once the "embargo" period is over. Much of the raw data and data that wasn't published is also available this way. This embargo period is set by the experiment. Data policies for the various experiments broadly store data in accessible formats in multiple locations and pass their data on to CERN when the experiment collaboration comes to an end. Data policies can usually be found in PDF form on the experiments' websites.

Appendix F: Responses to iMARS Recommendations

Status	Recommendation	iMARS Report Section	Comments
Completed	A Planetary Protection Protocol should be prodcued as soon as it is feasible by an international working group under the authority of COSPAR or other international body	2.5.3	Sample Safety Assessment Protocol Working Group currently working on this
	Interested nations should sign a declaration of interest in MSR to allow further development of a mission architecture and governance scheme	3.4.1	Berlin Statement of Intent and subsequent NASA-ESA Science Statement of Intent have been signed
	it is necessary to define a flexible and adaptable model for ccoperation and a coordinated decision-making process that encourages long-term commitments by participating organisations and demostrates clear benefits to them	3.4.1	Subject of the MSPG Science Management Framework
	Sample science, planetary protection, and curatorial expertise should inform the sample collection mission development	4.2.1	Extensive input from all elements has been given to M2020 mission
Incorporated into the Framework	IODP should be consulted in planning for overall science management approach	2.7	This was done (see section 2.5)
	avoid the "stuck in containment" scenario	2.5.2	validated by MSPG Workshop 1
	two guiding principles: open competition for access to samples and research + transparency and engagement in returned sample handling and science results	4.1	retained as guiding principles of MSPG, but added to with others (see section 3.2.1)
	Science management "Council" needs to be established early in processs (populated by key agency stakeholders)	4.1.2	This is a key recommendation of this Framework
	Multiple entry points for scientists must be established throughout the MSR process	4.1.1	adopted as a guiding principle
	SRF timeline could be up to 12 yrs. A detailed implmentation plan should be put in place for desigining, constructing and operating the SRF.	4.1.4	recommended that iORDT is established as soon as possible after MOU

	Access to samples should be drvien by scientific excellence, independent of the financial contributions of the bidder's home country. Proportional return could instead come in the form of membership in <Council> decision-making bodies	4.1.5	MSPG recommends that sample ownership is not pro-rated, but that decision-making appointments and proprietary activities are associated with investing agencies
	Science management structure should be able to accommodate peer-reviewed competition for sample access within the SRF + competitions for external scientists	4.2.1	Agreed (see sections 4.4.2, 4.4.4 & 4.4.5)
Not yet acted upon but endorsed by MSPG	Int'l partners must declare their interests, define a cooperation framework, and determine their contributions		Statement of Intent has been sigend, and MOU anticipated if campaign is confirmed by NASA and ESA.
	The cooperation model should be flexible and adaptable, encouraging long-term commitments by participating organisations, and allowing partners to contribute in line with their respective prioirities and budgets		To be further defined by MSPG-2
	Advisory bodies need to be established (science, back contamination, public consultation)	4.1.1	must be incorporated into structure after Council formation
	Because public support will be desirable for MSR flight missions and crucial for SRF development, the MSR campagin will require a formal public engagement strategy	4.1.2	Agree that this is important, but is not a part of science planning
	Organization of science teams, sample allocation, and test protocol development should be specific to each sample suite returned by the mission	4.1.2	Samples should be managed as one collection; further definition of science teams to be further MSPG-2 and MAPT
	SRF design and infrastructure should be highly adaptable	4.1.4	To be defined by iORDT
Recommended modifications	An international MSR Science Institute should be established as part of the governance scheme	4.1	doesn't require a dedicated institute, but does necessitate high-level coordination and oversight i.e. MRSH Council
	Science management needs to be co-located at SRF	4.1.1	MSPG does not view this as a requirement (see section 2.6)
	PET should be provided with financially-supported time away from SRF obligations to prepare papers for publication	4.2.1	PET should generate catalogue but not be responsible for initial scientific research. A proprietary period will be competed separately to conduct obejctive-driven

			investigations. (PET members opportunities to contribute to subsequent investigations will be further defined by MSPG-2)
	Scientific access to samples should be driven by scientific excellence, independent of the financial contributions of the bidder's home country	4.1.5	Based on precedent from previous sample return missions, certain activities should remain proprietary to investing partners (see Guiding Principles 3.2.1. Return on Investment).
	internally-funded discipline scientists should be the leads of suite-specific virtual teams		Not discussed by MSPG
	multi-tiered sample allocation approach	4.2.3	Will be further discussed by MSPG-2
	additional research must be conducted on the methods and doses required to adequately sterilize samples returned from Mars, including a definition of the effects of these techniques on geological samples	4.3.2	Discussed by MSPG Workshop #1; Statement is agreed to
	a portion of the returned samples, nominally 40%, should be stored at a location other than the primary SRF< with at least one of the "blanks" left in a pristine, unopened state	4.3.3	Not discussed by MSPG
	For SRF management and operations and science participation, dedicated programmatic working groups should be created to define cooperation models and guidelines for the application of standards	3.4.1	Not discussed by MSPG
	Data should be made publicly available in readily accessible formats as soon as feasible for each stage of analysis	4.2.4	Not discussed by MSPG

Appendix G: Summary of Opportunities for Scientists

WHAT NEEDS TO BE DONE	WHEN		WHO	OPPORTUNITIES FOR SCIENTISTS
Functionality	Start	End	Proposed Responsibility	Comments
Overall Management				
Authority to charter required iORDTs, iSDTs, and any other international science-related planning or implementation committees	Jan 2020	n/a	MRSH Council	some scientists needed at the Council level
Authority to select personnel to populate and lead required iORDTs, iSDTs, and any other international science-related planning or implementation committees.	Jan 2020	n/a	MRSH Council	
Authority to select PIs (on an international basis)	Jan 2020	n/a	MRSH Council	
Authority to consider and approve necessary budgets	Jan 2020	n/a	MRSH Council	
Manage the timeline, budget to ensure objectives are achieved	2020	~ 2033	Project Leadership Team (Proj. Mgr(s), Proj. Sci(s), Proj. Eng(s), Proj. Curator(s), etc)	Project Scientist(s) and team
Write-up full Science Management Plan, for editing/approval by NASA-ESA (and any other stakeholders defined in the MOU).	Jan 2020	Jul 2020	MSPG-2	Multiple scientists needed for this committee
Sample Collection / Documentation				
Identify, collect, document, and cache samples of interest	xx 2021	xx 2023	M2020 Science Team	M2020 science team has >200 scientists
Identify, collect, document, and cache samples of interest	xx 2023	xx 2026	M2020 Science Team - extended	
Facilities Planning				
Write the RSS Implementation & Analysis Plan	July 2020	2021	MAPT	Major science committee, multiple scientists needed
Define high-level requirements for the SRF, and other planning inputs needed for its budgeting and timeline	July 2020	Dec. 2020	iORDT	Multiple scientists needed for this committee
Propose necessary scientific instrumentation for SRF	2027	2032?	iSDT	PI-and co-I opportunity
Science Operations				
Select final samples for return	2027	2027	Sample Prioritization Workshop(s) with final decision or acceptance of recommendations made by the MC.	Opportunity for the entire Mars community to engage
Define objectives and priorities for initial round of PI-led sample investigations. Determine the criteria for MSR campaign scientific success.	2026	End of 2026	iSDT	Multiple scientists needed for this committee
Generate the inputs to an international AO to compete for initial allocations of the MSR samples	2029	End of 2029	iSDT	

Prepare a catalog of the samples received in the SRF, with descriptions sufficient to form the basis for the initial sample allocation competition.	2031	2032	PE Team	Multiple hands-on sample scientists needed for this committee
Review sample investigation proposals and rate the scientific merit	2032	2032	Science Evaluation Panel	Multiple scientists needed for this
Merge ratings for scientific merit with additional constraints including available funding, available sample mass, long-term curation planning to prepare an allocation recommendation	2031-2032	on-going	Sample Allocation Committee	Multiple scientists needed for this committee
Approve release of samples to investigators, along with necessary funding to investigate them	2031-2032	on-going	MRSH Council	some scientists needed at the Council level
Perform the initial science investigations on the returned samples. Make nobel-prize worthy discoveries, and achieve the stated campaign scientific objectives	2031	2032	PIs (and their respective science teams), consortia	Each sample investigation team will need multiple scientists, including postdocs and grad students
Perform second round and beyond investigations to maximize the science return from the sample collection	2032	on-going	Opportunity-driven PI / team/ consortia	Each sample investigation team will need multiple scientists, including postdocs and grad students

Appendix H: Acronyms & Abbreviations

Acronym	Definition
AACO	Astromaterials Acquisition and Curation Office
AO	Announcement of Opportunity
ATLO	Assembly Test and Launch Operations
BC	Basic Characterization
BSL	Bio-safety Level
CAPTEM	Curation and Analysis Planning Team
CC	Contamination Control
CK	Contamination Knowledge
CCRS	Capture/Containment Return System
CERN	European Council for Nuclear Research
CNES	Centre National d'Études Spatiales
Co-I	Co-Investigator
COSPAR	Committee on Space Research
CPT	Curation Planning Team
CT	Computerized Tomography
E2E-iSAG	End-to-End International Science Analysis Group
EDL	Entry, Descent and Landing
EEV	Earth Entry Vehicle
ERO	Earth Return Orbiter
ESA	European Space Agency
IMEWG	International Mars Exploration Working Group
iMARS	International Mars Architecture for the Return of Samples Working Group
iMOST	International MSR Objectives and Samples Team
IODP	International Ocean Discovery Program
iORDT	International Objectives and Requirements Development Team
iSDT	International Science Definition Team
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LMO	Low Mars Orbit
LRL	Lunar Receiving Laboratory
LRO	Lunar Reconnaissance Orbiter
LSAPT	Lunar Samples Analysis Planning Team
LSPET	Lunar Sample Preliminary Examination Team
M2020	Mars 2020
MAPT	MSR Analysis Planning Team
MAV	Mars Ascent Vehicle
MEPAG	Mars Exploration Program Analysis Group
MOI	Mars Orbital Insertion
MOU	Memorandum of Understanding
MRR-SAG	Mid-Range Rover Science Analysis Group
MRSH	Mars Returned Sample Handling
MSPG	MSR Science Planning Group
MSR	Mars Sample Return
NASA	National Aeronautics and Space Administration

NEPA	National Environmental Policy Act
NRC	National Research Council
OLA	OSIRIS-Rex Laser Altimeter
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification - Regolith Explorer
OS	Orbiting Sample container
PE	Preliminary Examination
PET	Preliminary Examination Team
PI	Principal Investigator
PLT	Project Leadership Team
PMO	Program Member Office
PP	Planetary Protection
R&A	Research & Analysis
RDV	Rendezvous
RIAP	RSS Implementation and Analysis Plan
RSS	Returned Sample Science
SAC	Sample Allocation Committee
SDT	Science Definition Team
SEM	Scanning Electron Microscope
SEP	Science Evaluation Panel
SFR	Sample Fetch Rover
SoI	Statement of Intent
SPC	Scientific Policy Committee
SRF	Sample Receiving Facility
SRL	Sample Retrieval Lander
SSAP	Sample Safety Assessment Protocol
ToR	Terms of Reference
WG	Working Group

Appendix I: MSPG Members

Name	Affiliation
Michael Meyer (Co-Chair)	NASA Headquarters
Elliot Sefton-Nash (Co-Chair)	European Space Agency-ESTEC
David Beaty (Facilitation)	Jet Propulsion Laboratory, California Institute of Technology
Brandi Carrier (Facilitation)	Jet Propulsion Laboratory, California Institute of Technology
Francois Gaubert	European Space Agency-ESTEC
Monica Grady	Open University
Timothy Haltigin	Canadian Space Agency
Dayl Martin	European Space Agency
Bernard Marty	Université de Lorraine, CRPG-CNRS, France
Richard Mattingly	Jet Propulsion Laboratory, California Institute of Technology
Sandra Siljeström	RISE Research Institutes of Sweden
Eileen Stansbery	NASA Johnson Space Center
Kimberly Tait	Royal Ontario Museum, Canada
Meenakshi Wadhwa	Arizona State University
Deborah Bass (Support)	Jet Propulsion Laboratory, California Institute of Technology
Yang Liu (Support)	Jet Propulsion Laboratory, California Institute of Technology
Lauren White (Support)	Jet Propulsion Laboratory, California Institute of Technology