Mars Exploration and Planetary Protection

Curiosity Sol 1896 Dec 2017

Credit: NASA/JPL/Ken Kremer/Marco Di Lorenzo

Michael Meyer
Lead Scientist, Mars Exploration Program

PPIRB-NASEM, Nov. 21, 2019

Disclaimer

- The presentation does not reflect NASA or Planetary Protection Policy

- Induced Special Regions Workshop
- Mars Sample Return (MSR Science Planning Group (MSPG)
- Comments on the PPIRB

Report of the Joint Workshop on Induced Special Regions

Michael Meyer, Corien Bakermans, David Beaty, Douglas Bernard, Penelope Boston, Vincent Chevrier, Catharine Conley, Ingrid Feustel, Raina Gough, Timothy Glotch, Lindsay Hays, Karen Junge, Robert Lindberg, Michael Mellon, Michael Mischna, Clive R. Neal, Betsy Pugel, Richard Quinn, Francois Raulin, Nilton Rennó, John Rummel, Mitchell Schulte, Andrew Spry, Pericles Stabekis, Alian Wang, Nathan Yee

Life Sciences in Space Research,
https://doi.org/10.1016/j.lssr.2019.09.002

Joint Workshop on Induced Special Regions

- Scientists and planetary protection experts convened to assess the potential of inducing special regions through lander or rover activity.
  - Convenors: Cassie Conley, Robert Lindberg, Michael Meyer, and Clive Neal
- For the workshop's purpose, a Special Region is defined as a place where water activity and temperature are sufficiently high and persist for long enough to plausibly harbor life.
- The Workshop was requested by both the former Planetary Protection Subcommittee and the Planetary Science Subcommittee

Purpose and Scope

The outcome of this workshop is to inform ongoing and future missions as to where there might be Special Regions, if a spacecraft can inadvertently create a Special Region, and what buffer zone should be considered in approaching a Special Region.

Thorough discussions focused on three areas of Special Regions: capabilities of Earth organisms, natural conditions on Mars, and how spacecraft could alter condition on Mars.

Pre-Workshop Questions

Recognizing that the participants were approaching the concept of induced special regions from very different perspectives, the conveners decided to distribute a set of questions, to be answered by participants beforehand. Submitted answers were then anonymized and distributed back to the participants before the Workshop.

- **Questions about capabilities of Earth organisms: what do we know, and what additional information would be useful?**
- **Questions about natural conditions on Mars: what do we know, and what additional information would be useful?**
- **Questions about how spacecraft could alter condition on Mars: what do we know, and what additional information would be useful?**

Example from 26 Pages of Anonymized Answers

1. Questions about capabilities of Earth organisms: What do we know, and what additional information would be useful?

As an overall comment, generalization to "Earth organisms" may not always be helpful, as it always pushes the accommodations to the extreme cases. A structure that allowed consideration of "Earth organisms" in different bins might be useful (I'll let the microbiologists determine what those might be).

a) Under what circumstances could the surface or spacecraft-accessible subsurface of Mars support growth of terrestrial microbes?

temperatures of -20°C and above, access to water ($a_w > 0.61$), no oxidants/UV/toxins that damage cells, nutrients available (C, N, O, P, S, Fe). There isn't much new information since the SR-SAG2 report.

- Temperatures at or above -18°C (Bakermans, 2017)
- Water activities at or above 0.6 (Rummel et al., 2014; Stevenson et al., 2016)
- Presence of sufficient nutrients (fuel/oxidants, Rummel et al., 2014) for energy generation and growth (either chemoautotrophic [more likely]; or chemoheterotrophic)
- Shielded from UV exposure (Rummel et al., 2014)
- Solute type and concentrations that do not impede or are toxic for terrestrial microbial growth (depends on the type and concentration of solutes)

Many circumstances could support growth of terrestrial microbes. "Environmental factors restrict the distribution of microbial eukaryotes but the exact boundaries for eukaryotic life are not known. " Extremophiles, 13, 151–167 (2009)

Three Workshop Questions

- **What is a safe stand-off distance, or formula to derive a safe distance, to a purported Special Region?**
  - What is viability/distance for micro-organism transport?
  - Is there a residence time for a lander on Mars by when a rover/lander will be "safe"?
- **Questions about RTGs, other heat sources, and their ability to induce special regions:**
  - Can a rover RTG on the surface induce a special region? Under what specific conditions?
  - Can a buried RTG induce a special region? Does it pose a long-term contamination "threat?"
- **Is it possible to have an infected area on Mars that does not contaminate the rest of Mars?**
  - What would be a proper buffer zone?

Workshop Process

- After the presentations, the participants were divided into three subgroups, each possessing a balance of different expertise and personalities.
  - All three subgroups addressed each question separately, and presented their answers in plenary sessions.
  - Workshop conveners hoped to create an environment where everyone in the subgroups would have a voice, and each of the subgroups would have the opportunity to develop unique answers, in order to highlight areas of consensus and divergence.
- The resulting presentations from each group provided the opportunity for in-depth discussion in areas of disagreement with all expertise represented.
- On the final day, the participants were remixed into three new groups
  - Each group synthesized the responses to one of the workshop questions from material developed over the previous two days, with the goal of deriving the consensus view.
- In the final plenary session, the answers to the questions were reviewed, discussed, and consensus achieved.

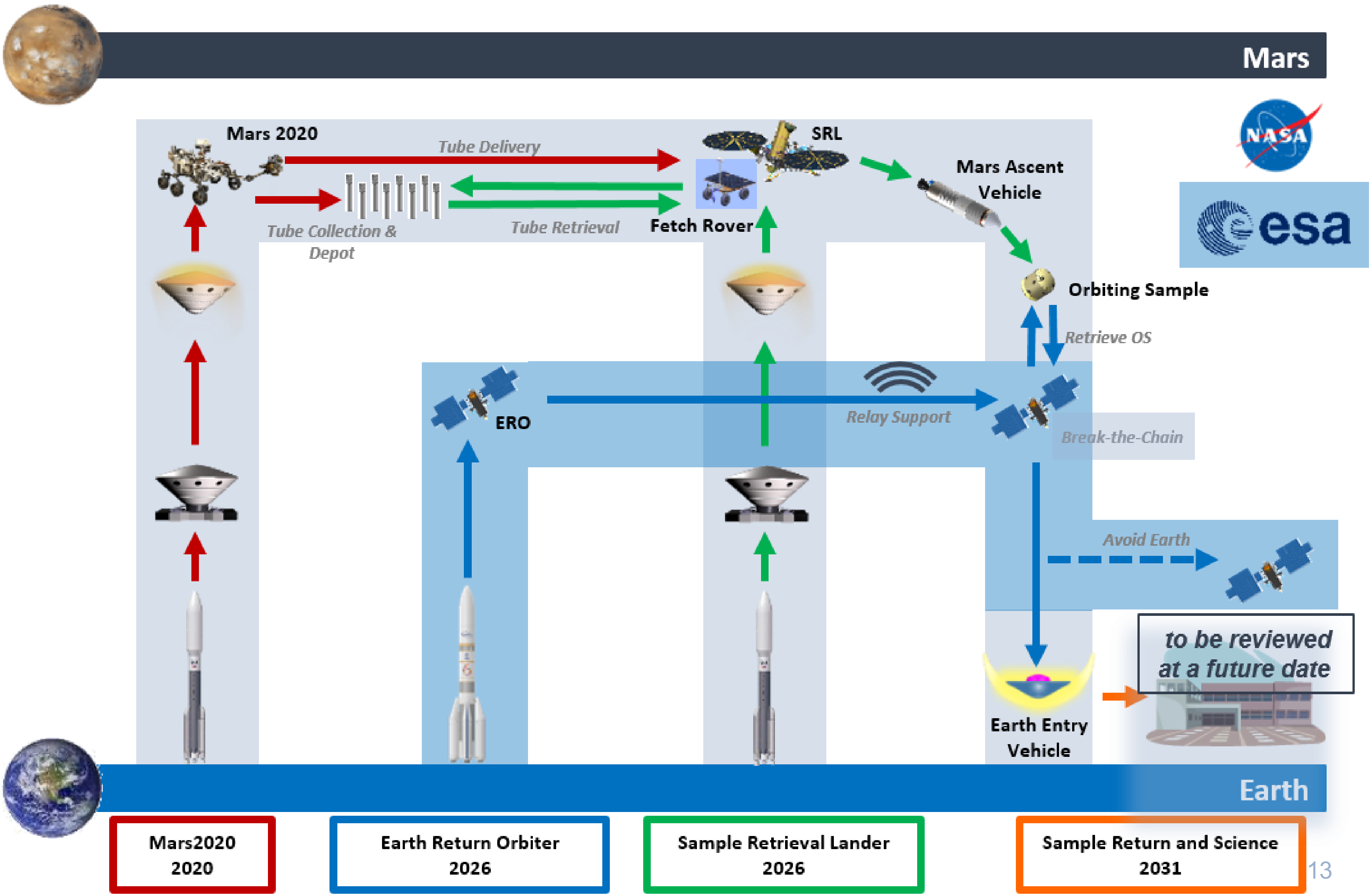
Findings

- While a spacecraft on the surface of Mars may not be able to explore a special region during the prime mission, the safe stand-off distance would decrease with time because the sterilizing environment that is the martian surface would progressively clean the exposed surfaces.
  - However, the analysis supporting such an exploration should ensure that the risk to exposing interior portions of the spacecraft (i.e., essentially unsterilized) to the martian surface is minimized.
- An RTG at the surface of Mars would not create a Special Region but the result depends on kinetics of melting, freezing, deliquescence, and desiccation.
- While a buried RTG could induce a Special Region, it would not pose a long-term contamination threat to Mars, with the possible exception of a migrating RTG in an icy deposit.
- Induced Special Regions can allow microbial replication to occur (by definition), but such replication at the surface is unlikely to globally contaminate Mars. An induced subsurface Special Region would be isolated and microbial transport away from subsurface site is highly improbable.

Additional Research

- Although the end state of each of the situations described in this report are reasonably well known, kinetics determines the intermediate state in the transition and should be studied
  - For example, during an induced heating - how long, if at all, is water available in the liquid state? Does the ice only sublimate instead of also melting?
- Models are needed to understand details of atmospheric processes for surface transport rates
- Data are also needed on the abilities of Earth organism propagules to facilitate airborne dispersal and survival during dispersal
- Data are needed to understand small-scale features within the first 5 meters of the subsurface and if there are deep groundwater systems

Potential Mars Sample Return Campaign Overview



Pre-Decisional - For planning and discussion purposes only

MSR Science Planning Group (MSPG)

MSPG established by NASA and ESA to help develop a stable foundation for international scientific cooperation for the purposes of returning and analyzing samples from Mars.

Terms of Reference derived jointly between ESA and NASA MSR teams based on science planning needs. Guiding questions:

- What are the science-related attributes of a Sample Receiving Facility(-ies) (SRF) that can be used as the basis for cost and schedule estimation?
- What are the mechanisms whereby MSR partner-affiliated scientists will be given equitable access to the returned samples?

MSPG Workshops

- The main science-related cost drivers for a **Sample Receiving Facility (SRF)** are thought to be:
  1. The challenge of conducting science activities inside high-containment space (Bio-Safety Level [BSL]-4)
  2. Contamination control
- Two workshops were held to address top-level questions:

WORKSHOP #1

To what extent does MSR science need to be done in containment?

Universities Space Research Association (USRA) HQ, Columbia, MD, USA (14-16 Jan 2019)

WORKSHOP #2

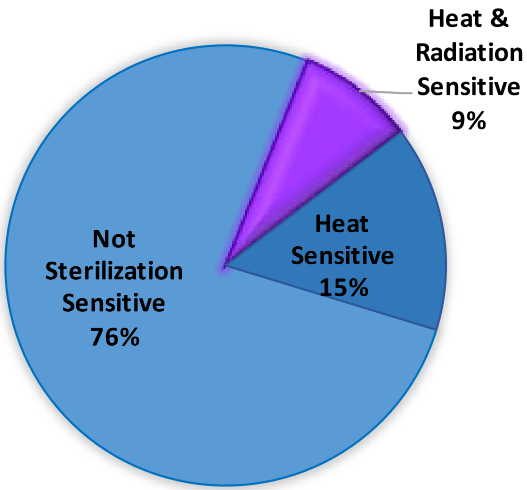
How do the science objectives affect SRF contamination control requirements?

University of Leicester, UK, (1-3 May 2019)

Workshop #1: Science in Containment

- **What role does contained space need to play in ensuring that all MSR scientific objectives are met?**

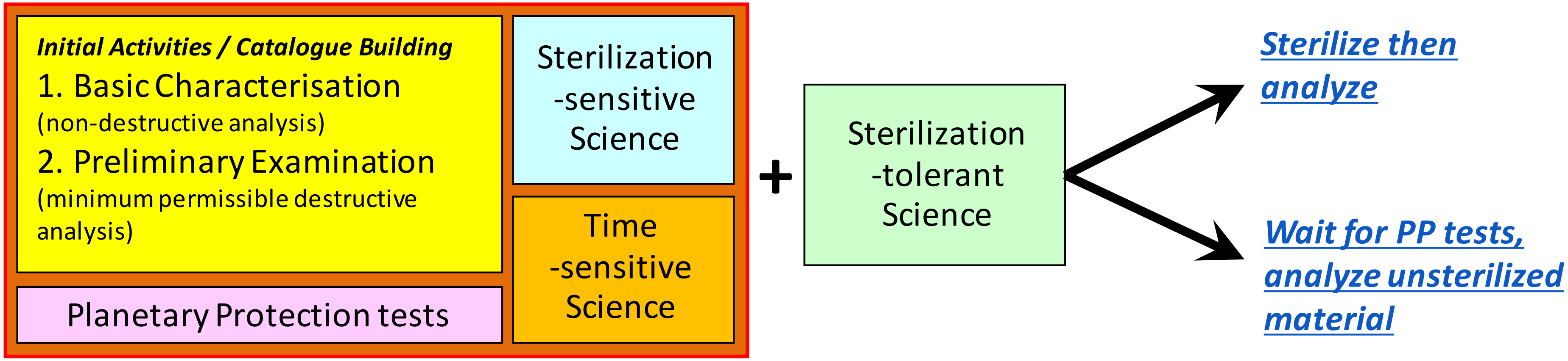
SENSITIVITY OF MSR INVESTIGATIONS TO SAMPLE STERILIZATION



MAJOR FINDING: A large majority of the MSR-related science investigations, as identified by iMOST (2019), could be acceptably performed on sterilized samples, thus potentially enabling the analysis of MSR samples in uncontained laboratories without a dependency on the results from planetary protection testing.

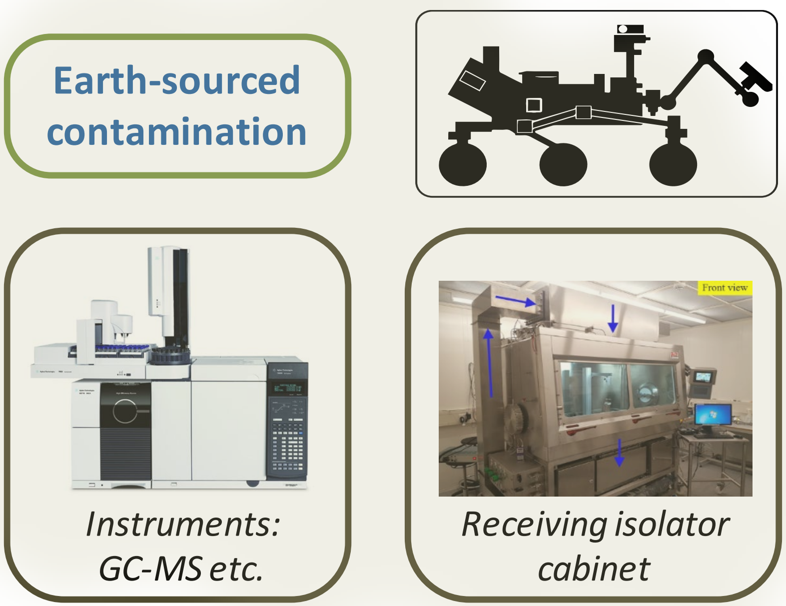
Workshop #1: Science in Containment

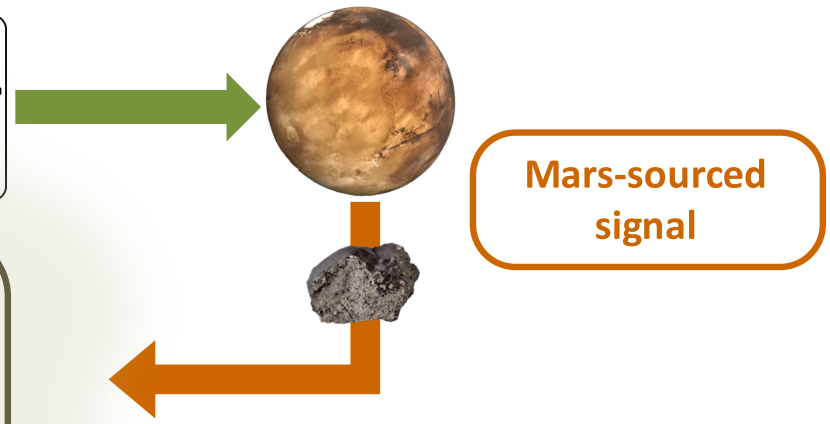
- **What role does contained space need to play in ensuring that <u>all</u> MSR scientific objectives are met?**



<u>MAJOR FINDING</u>: The scientific community, for reasons of scientific quality, cost, timeliness, and other reasons, strongly prefers that as many sample-related investigations as possible be performed in PI-led laboratories outside of containment.

Workshop #2: Contamination Control (CC)





What are our strategies to achieve MSR science objectives, given SRF-related contamination?

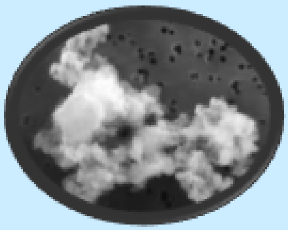
Workshop #2: Contamination Control (CC)

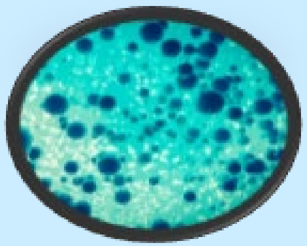
Potential SRF Sample-Intimate Hardware Cleanliness Requirements

Viable Organisms (<1)

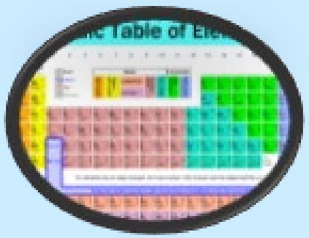
Outgassing (~1 ng/cm2/hr)

Particulate (PCL 50-300)

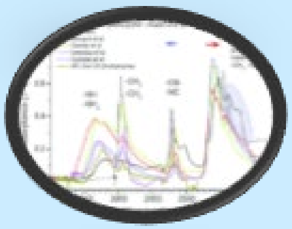




Total Organic Carbon
Tier 1 Compounds: 1 ppb
Tier 2: 10 ppb, TOC: 10ppb

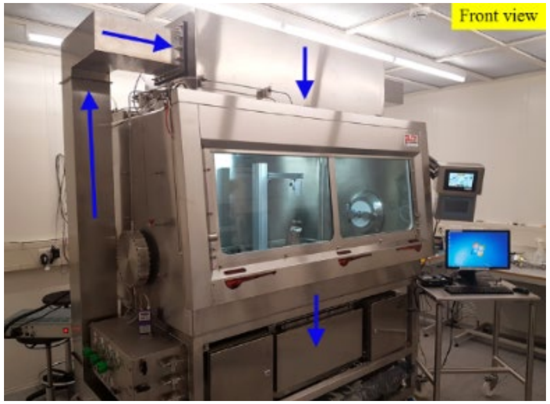


Inorganics pg-mg of 34 elements



Non-volatile residue (<100 ng/cm2)

Notional sample-receiving isolation cabinet inside SRF (example only)



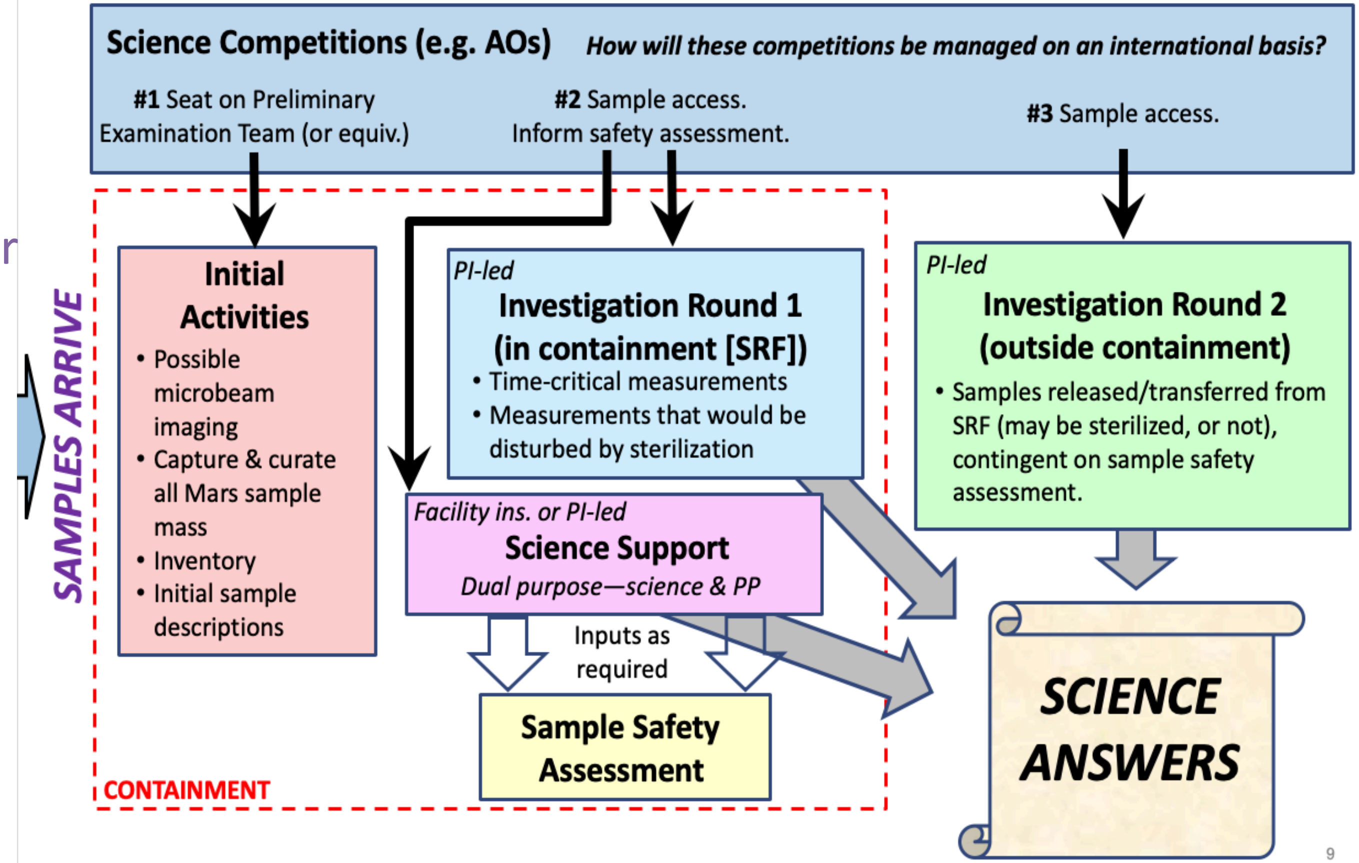
For the SRF, requirements have not yet been established. Some should be stricter than for Mars 2020.

Concept for Opportunities for Science

Multiple access points for scientists.

To these activities (after sample return), and to the precursor working groups:

- **Membership** can be open to partners, or worldwide.
- **Selection** can be appointed, competed, or open.



Science Management: Guiding Principles

Transparency:

- Access to samples must be fair and the processes as transparent as possible.

Science maximization:

- It is imperative that the science management and sample-related processes optimize the scientific productivity of the samples.

Accessibility:

- International scientists must have multiple opportunities to participate in MSR.

Return on investment:

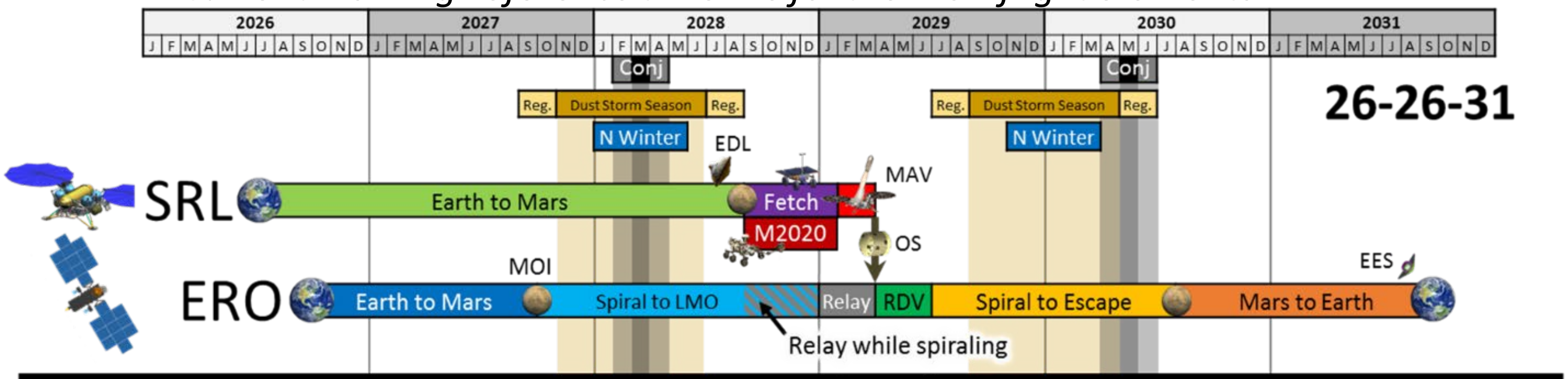
- Agencies funding the MSR campaign should benefit for enabling the samples' return.

One Return Canister : One Collection

- Samples must be treated as a single collection, regardless of whether or not there is more than one curation facility

Science Integrated with Flight Schedules

Current working reference timeline for the MSR flight elements.



Science needs to provide sample priorities for SFR traverse planning, landing site optimization.

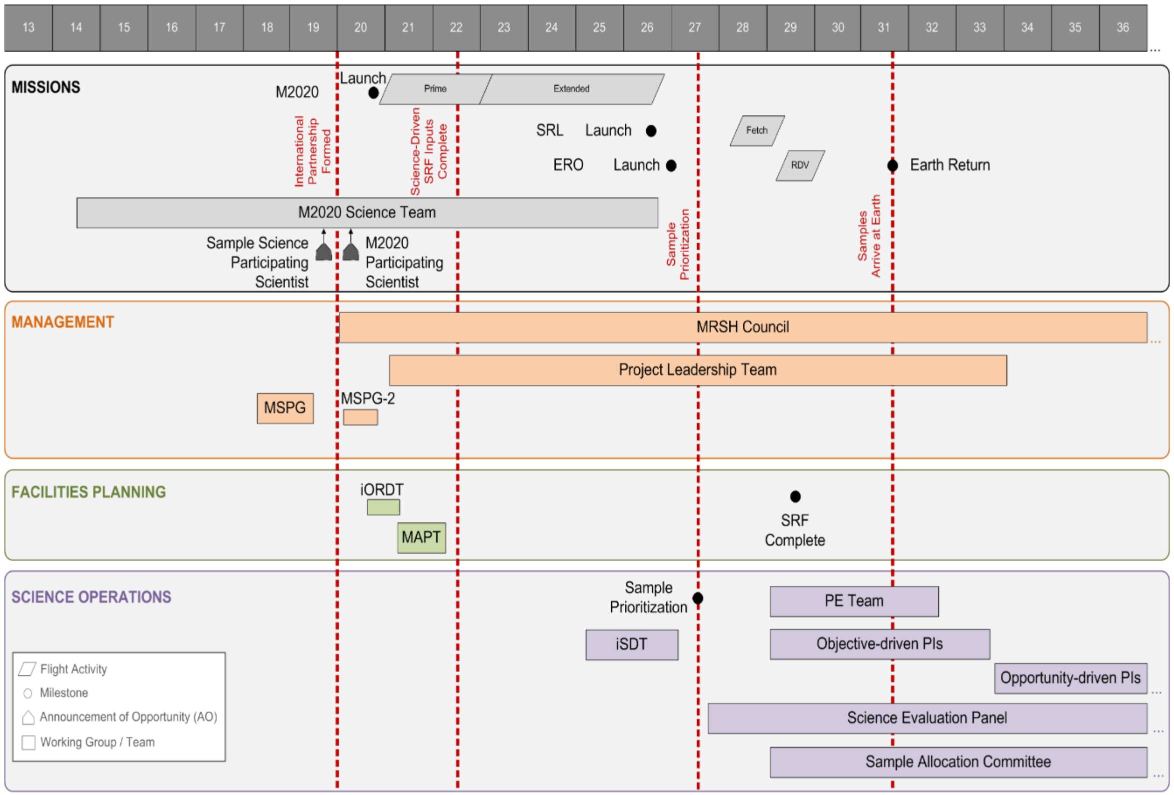
We know which, and how many, samples will be returned.

We know exact details of sample mass, state.

FINDING – The Science Planning timeline must be coordinated with the MSR flight project timeline

MSR Science-Related Committees as a Function of Time

- MSPG has defined a conceptual timeline for the major science bodies to conduct MSR Science.
- Details include formation mechanism, composition, authority, tenure and objectives.
- Based on needs for specific input and decision-making at key points in development of MRSH infrastructure, and science planning.



MSR Science Groups with Impending Starts

- **MSR Science Planning Group 2 (MSPG-2)** – Turn the Science Management Framework into a Science Management Plan. Use inputs from MoU terms, results of ongoing working groups etc..
- **international Operations and Requirements Definition Team (iORDT)** – Initiates requirements for receiving facilities
- **Curation Planning Team** – Define procedures and standards for storing, handling, analyzing etc.. to be applied throughout sample handling.
- **MSR Analysis Planning Team (MAPT)** – Formulate detailed science requirements e.g. How to open the sample tubes.

KEY POINT: THESE ACTIVITIES NEED NEAR-TERM MANAGEMENT ATTENTION

MSPG Conclusions

- **Sample Science Receiving Facility is challenging but manageable**, requirements scoped for science, requirements for Curation and Planetary Protection pending
- **Sample science management can be effectively internationalized** amongst MSR partner countries/agencies – the returned sample must be treated as one collection.
- **Opportunities for scientists are expected beginning in 2020.** Funding for MSR flight missions first needs to be secured, including at ESA Ministerial Council meeting in Nov 2019.
- **A key element in the flow of authority and responsibility needs to originate in the MRSH Council**, which would be a source of multi-agency decisions and high-level oversight.
  - **Key interfaces between science, curation and planetary protection** will need to be managed
  - **A series of science working groups** with different objectives will need to form, several in 2020
- **National research programs must support preparation for MSR** where needed: e.g. sensitivity of science potential to sterilization techniques, develop hypotheses to test, advance analytical techniques for small sample masses.

Comments On PPIRB

Comments on PPIRB Specific Recommendations and Findings

- **Major Recommendation:** PP requirements on missions should be written to define PP intent, rather than detailed implementation methods, thereby allowing projects to select and/or develop implementations most suitable to meet their PP requirements from a systems standpoint.
- Yes, for example: Mars 2020 and the requirements for potential sample return

Comments continued

- **Supporting Finding:** For many of NASA's scientifically driven planetary exploration missions to astrobiologically relevant targets, scientific cleanliness requirements often exceed PP bioburden requirements.
- For example: Baseline - 1ppb for specific organic compounds, 10ppb for total organic carbon

Comments continued

- **Supporting Recommendation:** For both forward and backward contamination requirements, NASA should continue to allow novel approaches, such as crediting for time spent in the harsh space environment or on harsh planetary surfaces (e.g., UV, radiation, temperature extremes, lack of liquid water). To enable this, NASA should support quantitative laboratory studies of such approaches to demonstrate quantitative PP credits.
- Induced Special Regions report

Comments continued

- **Major Recommendation:** NASA should reconsider how much of the Martian surface and subsurface could be Category II versus IV by revisiting assumptions and performing new analysis of transport, survival and amplification in order to reassess the risk of survival and propagation of terrestrial biota on Mars.
- The Induced Special Region report found that in general the surface of Mars is inimical to terrestrial life, and more research on transport processes is suggested.

Comments continued

- **<u>Major Recommendation:</u>** NASA should consider establishing (i) high priority astrobiology zones, i.e., regions considered to be of high scientific priority for identifying extinct or extant life, and (ii) human exploration zones, i.e., regions where the larger amounts of biological contamination inevitably associated with human exploration missions, as compared to robotic scientific missions, will be acceptable.
- The size of the buffer zone needs to be determined

Comments continued

- **<u>Major Recommendation:</u>** NASA's MSR PP approach should take into account the findings of the recent National Academies' Consensus Study Report on sample return from the Martian moons. In particular, the risk of adverse effects Martian material poses to the terrestrial biosphere should be re-evaluated in light of the ongoing, established, natural transport of Martian material to Earth.
- Martian material selected and cached on Mars to be returned to Earth is not the same as martian material blasted onto a martian moon and cached, or blasted back to Earth

Comments continued

- **Major Recommendation:** Planning for a Mars Sample Receiving Facility (MSRF) should be accelerated, or at least maintained on schedule, and should also be kept as pragmatic and streamlined as possible so that it does not unduly drive the schedule or cost of MSR.
- That has been the intention of the MSR Science Planning Group and we hope to expand on that work in the coming year (see slide on impending starts)

Comments continued

- **Major Recommendation:** NASA should begin work with other government agencies to develop a MSR PP public outreach, communications, and engagement plan. Government agencies such as the National Institutes of Health and the Food and Drug Administration have significant experience in crafting public communications policies that could be beneficial to NASA in educating the public about the realities of MSR missions.
- Good idea

Comments continued

- **<u>Supporting Finding</u>**. Significant work is being done to study the MSRF and whether an entirely new facility should be built, and where, or whether the MSRF should be an add-on to an existing Biosafety Level 4 (BSL-4) facility.
- Some consideration has been given in the MSPG #2 workshop – the challenge is potential contamination from existing structures and international access (”owner” of the facility)

Comments continued

- **Supporting Recommendation:** NASA should carefully trade the implications of the degree and types of PP sterilization techniques for Mars samples with the implications for various types of science measurements.
- **Supporting Recommendation:** NASA should continue to engage experts from the medical, pharmaceutical, and personal care industries to advise on effective sterilization protocols. Such engagement provides meaningful insights from adjacent fields, demonstrates NASA's due diligence to the public, and offers lessons on effective communication to non-experts regarding safety for both robotic sample return and for future human missions to Mars.
- Heat and gamma-radiation seem to be the leading methods, potentially least damaging to the specific science, but more research is needed.

Questions