**TOURS OF HIGH-CONTAINMENT AND PRISTINE FACILITIES IN SUPPORT OF MARS SAMPLE RECEIVING FACILITY DEFINITION STUDIES.** R. L. Mattingly[1], A. L. Smith II[1] ,M. J. Calaway[2] and A. H. Harrington[3], [1]Jet Propulsion Laboratory/California Institute of Technology , 4800 Oak Grove Drive, Pasadena, CA 91109 (rmatt@jpl.nasa.gov), [2]Jacobs at NASA Johnson Space Center, Houston (JSC)TX 77058-3696. [3]ARES, NASA Johnson Space Center, Houston (JSC)TX 77058-3696 (andrea.d.harrington@nasa.gov),

**Introduction:** During 2019 and 2020, the NASA Tiger Team RAMA (acronym of the authors names) toured several high-containment biosafety laboratories and pristine space-mission facilities worldwide to better understand their practices, capabilities, and lessons-learned to aid in planning a Sample Receiving Facility (SRF) in support of Mars Sample Return (MSR). The team also included tours of a manufacturer of mobile and modular high-containment facilities as well as manufacturers of isolators and gloveboxes. In addition, the team visited European Space Agency (ESA) facilities already developing a novel double-walled isolator (DWI) and robotic handling techniques in support of a potential MSR SRF. The RAMA team visits covered several possible construction modalities for an MSR SRF: (1) a new traditional brick-and-mortar facility; (2) use of an existing brick-and-mortar Biosafety Level 4 (BSL-4) facility; (3) a novel modular BSL-4 approach; and (4) a hybrid combination of brick-and-mortar, modular, and existing facilities. The facility descriptions, observations and findings are published in Reference 1: "Tours of High-Containment and Pristine Facilities in Support of Mars Sample Return (MSR) Sample Receiving Facility (SRF) Definition Studies". This abstract is adapted from the executive summary of that document.

**Observations:** The RAMA team's observations and findings illustrate that constructing an MSR SRF would combine the complexity of both high-containment and pristine facilities. Although merging negative-pressure biocontainment and positive-pressure cleanroom technology would be challenging, it is achievable. Furthermore, while adopting the Returned Sample Science requirements of the Mars 2020 Mission for contamination control (e.g., reduction of organics and bioburden) is particularly challenging for an MSR SRF, it is feasible with the utilization of novel techniques and technologies. For example, ESA has begun developing a DWI breadboard that may turn out to be a key technology in providing both containment and cleanliness in conjunction with a pristine containment facility.

Depending on the complexity, traditional brick-and-mortar BSL-4 facilities can nominally take a decade or more to design, build, and commission even without unexpected delays. Due to the proposed pressure regimes for the SRF, the RAMA team estimates that an MSR SRF from design to commissioning could take 8 to 12 years depending on construction modality. In order to provide adequate schedule reserve, the RAMA team encourages NASA to start the design definition phase for the potential MSR SRF as soon as possible. Based on the notional MSR campaign schedule for return, construction options may already be time limited, especially if the initial design phases are delayed.

Through these tours and subsequent conversations, the RAMA team discovered that some BSL-4 facilities have experienced significant delays during design, construction, and commissioning (e.g., five or more years), which could represent a significant programmatic risk to MSR. Schedule delays have been caused by new requirements levied by regulatory agencies to reduce loss of containment risks, government funding availability/programmatics, poor design/construction practices, the use of inexperienced subcontractors, and poor community engagement. It is critical that NASA begin MSR SRF community engagement as part of site selection and continue through facility design, construction, commissioning, and receiving of samples. In addition, it is equally critical for NASA to begin engagement with regulatory agencies and science stakeholders to set firm requirements before the facility design phase begins.

NASA could leverage an existing BSL-4 facility for at least some SRF activities; however, if anticipated contamination control and science requirements for the facility hold, many of the proposed SRF functions were not deemed feasible in any of the toured BSL-4 facilities. Providing enough lab space, accepting large equipment, keeping an MSR lab clean, and assuring adequate isolation from other labs so that unsterilized samples could be safely released (pending biohazard assessment) are a few of the challenges. Therefore, in order to utilize any of the toured facilities, MSR science goals and notional contamination control requirements may need to be descoped. Furthermore, given the disparate nature of the proposed biohazard testing for MSR versus traditional terrestrial biohazard testing, techniques and analytical equipment needed for MSR were not available in the labs visited. However, given the potential benefit of leveraging high-containment expertise and infrastructure, existing community buy-in, and possible cost and schedule savings, this option could be further explored once the minimum science requirements are better understood.

**Thoughts on SRF Modalities:**

*New Brick-and-Mortar.* An MSR SRF new brick-and-mortar approach can be tailored to MSR's needs and is the approach used by all U.S. BSL-4 laboratories constructed to date. However, this approach could be the most expensive modality, take the longest to implement, and have significant programmatic risk of delay, as stated above. Given the current MSR campaign timeline to return samples, it is unclear if this option is still viable.

*Existing BSL-4 Facility.* The utilization of an existing BSL-4 facility may be possible depending on the final contamination control and science requirements for an MSR SRF. Due to the internal dimensions of the labs visited and facility structural requirements, it is unlikely that any modification can be made to the facility to meet cleanliness requirements, as stated above. Furthermore, due to possible construction delays, possible capacity issues, and cross contamination vectors, there may also be significant programmatic risks for sharing an existing facility.

*Modular Facility.* Another approach is building a contemporary modular facility. The modular elements would be installed in a traditional building or shell structure. While this approach has only been used for BSL-3/3Ag facilities, it appears feasible. A modular facility has many advantages over a traditional brick-and-mortar facility with lower costs, shorter design/construction/ commissioning schedule, and flexibility for easier retrofits and future expansion.

*Hybrid Approach.* Finally, a hybrid approach of combining the use of either: (1) a modular facility inside a new brick-and-mortar building or (2) a modular and/or brick-and-mortar BSL-4 annex in conjunction with an existing BSL-4 space should be considered. The advantage of a hybrid approach is that the facility could leverage the strengths of each other's approaches.

**SRF Technologies:** Beyond facility construction approaches, the RAMA team investigated two technologies for isolating and handling Martian samples. ESA has been studying and developing a DWI breadboard along with other sample-handling technologies. NASA and ESA should collaborate as these technologies are developed in tandem with an SRF design. The research and development investment for clean, remote manipulation and robotics at the start of the facility design phase would be beneficial to MSR.

**Conclusions:** The report lays out a summary of the 18 facilities toured, and includes 43 observations, 18 findings, and 22 areas of possible follow-up that the RAMA team and others could pursue to enable further findings. The potential scope and challenges of an SRF are highly dependent on the science, contamination control, and planetary protection requirements currently being defined. The RAMA team plans to have regular interaction with science advisory and regulatory groups to provide feedback and seek answers to questions already posed.

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

**Reference:** [1] Mattingly R.L., Smith II A.L., Calaway M.J., Harrington A.D. (2020) JPL/NASA Report http://hdl.handle.net/2014/50446