DEFINING THE SCIENCE AND CURATION FUNCTIONALITIES FOR A MARS SAMPLE RETURN (MSR) SAMPLE RECEIVING FACILITY (SRF). B. L. Carrier[1], D. W. Beaty[1], A. L. Smith[1], A. Hutzler[2] and the MSPG2 Committee (M. A. Meyer[3], G. Kminek[2], T. Haltigin[4], C. Agee[5], H. Busemann[6], B. Cavalazzi[7], C. S. Cockell[8], V. Debaille[9], D. P. Glavin[10], M. M. Grady[11], E. Hauber[12], B. Marty[13,14], F. M. McCubbin[15], L. M. Pratt[3], A. B. Regberg[15], C. L. Smith[16], R. E. Summons[17], T. D. Swindle[18], K. T. Tait[19], N. J. Tosca[20], A. Udry[21], T. Usui[22], M. A. Velbel[23], M. Wadhwa[24], F. Westall[25], M.-P. Zorzano[26]). [1]Jet Propulsion Laboratory, California Institute of Technology, [2]European Space Agency, The Netherlands, [3]NASA HQ, [4]Canadian Space Agency, [5]U. of New Mexico, [6]ETH Zurich, [7]U. of Bologna, [8]U. of Edinburgh, [9]U. Libre de Bruxelles, [10]NASA GSFC, [11]Open University, [12]DLR, [13]CRPG-CNRS, [14]Université de Lorraine, [15]NASA JSC, [16]Natural History Museum, London, [17]Massachusetts Institute of Technology, [18]U. of Arizona, [19]Royal Ontario Museum, [20]U. of Cambridge, [21]U. of Nevada, Las Vegas, [22]JAXA, [23]Michigan State University, [24]Arizona State University, [25]CNRS-Orleans, [26]Centro de Astrobiologia (CAB).

Introduction: For the past several years NASA and the European Space Agency (ESA) have been working towards establishing a partnership to make Mars Sample Return (MSR) a reality. In October 2020, NASA and ESA formalized this partnership to plan the remaining elements of the MSR Campaign following the caching of samples by the Mars 2020 rover Perseverance. The last of those elements is the “Ground Segment”, which would include a sample receiving facility (SRF), and all of the capabilities and processes associated with working on and maximizing the science return of the samples, including potential secondary facilities. Here we present the state of the science and curation functionalities currently envisioned for the potential SRF.

In 2019 NASA and ESA chartered the MSR Science Planning Group to help develop a stable foundation for international scientific cooperation for the purposes of analyzing samples from Mars. This group produced reports related to what types of science and curation activities would need to be done while the samples are still in containment (i.e., inside an SRF).

The MSR Science Planning Group Phase 2 (MSPG2) [1] was chartered in 2020 to work on the next stages of MSR planning, including developing a working list of high-level requirements for an SRF. This has led to a refinement of the overall concept of an SRF and its required functionalities.

Sample Receiving Facility Overarching Purpose and Goals: The primary purpose of a SRF is to receive the MSR samples and keep them safely in containment until they are proven not to pose any risk to Earth’s biosphere. There is a spectrum of potential implementations that could be imagined for such a facility, with one end-member being an SRF in which all possible curation activities and scientific analyses of the samples could be done, and the other being a facility in which only the biohazard assessment and potential sterilization would take place.

One of the key findings of the first MSPG report [2] was that “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.” This principle has also been endorsed by the MSPG2, and has served as a starting point for defining a proposed SRF that is minimalistic in nature.

Multiple findings of MSPG and MSPG2, and confirmed by broader discussion with the science community and facilities experts, have led to a list of functionalities that would need to be included in SRF planning in order to most effectively protect the samples and the science we hope to derive from them. These functionalities collectively constitute our vision for an SRF. It remains for facilities architects and engineers to determine ways to achieve these functionalities, and how to optimize facility design.

Proposed SRF Functionalities:

Building Engineering and Infrastructure: An SRF design would need to support the facility and infrastructure needs for a high-value scientific research and curation facility. This would include physical security, IT infrastructure, office space for permanent and visiting staff, and the capability to engage observers outside the containment lab.

Earth Entry Vehicle Receiving and De-integration: An SRF would need to be capable of receiving the complete Earth Entry Vehicle (EEV) as collected and packaged at the recovery site, and to carry out the opening and de-integration of various layers of packaging and the EEV containment system to access the sample tubes. This would need to be done under highly controlled conditions.

Planetary Protection: An SRF would need to be able to meet all relevant planetary protection requirements intended to prevent inadvertent contamination of Earth’s biosphere, including biosafety containment of all martian material until it has been determined to be non-hazardous (or rendered so by sterilization). The samples could be determined to be non-hazardous after completion of the Sample Safety Assessment Protocol (SSAP) so the facility would need to be equipped to perform all necessary sample preparation steps and analyses related to the SSAP. If the SSAP results are inconclusive, or if evidence of extant martian life is found, an SRF would need to be able to sterilize sample splits before they could be analyzed in external labs. For this reason, an SRF would need to be equipped to sterilize sample splits, potentially by a variety of methods that might include heat sterilization, gamma irradiation, acid hydrolysis or other extraction methods which would render the extracts sterile. This would ensure that sample analysis outside of an SRF would not be delayed indefinitely by potential findings of evidence of martian life.

Sample Scientific Integrity: The MSR samples would be incredibly valuable scientifically, and much time, effort, and money will have been invested into designing the Perseverance sample caching system and other MSR flight missions to limit contamination of the samples, or exposure of the samples to extreme environmental conditions. An SRF would also need to have the capability to control the environmental conditions to which the samples are exposed and to limit sample contamination to within acceptable limits. This would include the ability to control environmental conditions such as temperature, magnetic field exposure, relative humidity, etc. to which the samples would be exposed to minimize degradation or alteration of sample properties. It would also be very important to limit organic, inorganic, biological, and particulate contamination at all times (and maintain knowledge of any such contamination through contamination knowledge strategies) so that all of the desired measurements can be carried out with minimal interference from terrestrial contamination. These controls would apply at all times including during sample characterization, analysis, and storage [3].

Initial Sample Characterization: MSPG2 is currently envisioning a three-phase protocol for initial sample characterization that would lead to preparation of a sample catalog and support for further science investigations and a community-focused sample allocation process. These phases include:

- Pre-Basic Characterization (Pre-BC) which would consist of measurements made on the sealed sample tubes prior to opening.
- Basic Characterization (BC) which includes a small number of non-destructive processes such as photographing and weighing the pristine samples, which would inform the Preliminary Examination.
- Preliminary Examination (PE) would consist of a more detailed analytical process to inform sample subdivision and develop the sample catalog.

An SRF would need to include all materials, instruments, and isolators necessary to carry out these processes. More information will be available on these phases in a future MSPG2 report.

Time-Sensitive Science Measurements: Certain sample properties were flagged by the MSPG [2] as being subject to alteration once the sample tubes are unsealed. The samples will be in contact with the martian headspace gas inside their tubes. Once the sample seals are opened and the headspace gas is removed, the samples will begin to interact with the environment within their isolators. This can lead to dehydration of salts and other mineral phases, loss of additional volatile and reactive species, and other types of alteration reactions. For this reason, an SRF would need to be equipped to carry out high-priority measurements deemed to be time-sensitive.

Sterilization-Sensitive Science Measurements: MSPG and MSPG2 have identified a number of types of sample properties that would be subject to potential alteration by sterilization techniques such as dry heat or gamma irradiation. These measurements would also need to be accommodated inside an SRF, or risk them being delayed indefinitely if the samples cannot quickly be determined to be non-hazardous. The investigations that would need to be done inside an SRF include microbiological investigations as well as investigations related to the sterilization-sensitive attributes of samples that formed via low-temperature geological processes (e.g. amorphous, hydrous and redox-sensitive materials).

Sample Preparation, Packaging, and Shipping: In order to be able to meet the desire to allow most sample investigations to be performed in external laboratories, an SRF would need to be equipped to prepare and ship sample splits. An SRF should include the functionalities for transferring both sterilized sample splits, as well as samples or sub-samples with biological containment (in case this is deemed necessary for specific measurements that cannot be accommodated inside an SRF, such as measurements using synchrotron radiation).

References: [1] MSPG2 (2021) Mars Sample Return Science Planning Group Phase 2 (MSPG2): Overview and Interim Report. *LPSC XII*. [2] MSPG (2019) The Relationship of MSR Science and Containment. https://mepag.jpl.nasa.gov/reports/Science_in_Containment_Report.pdf [3] MSPG (2019) Science-Driven Contamination Control Issues Associated with the Receiving and Initial Processing of the MSR Samples. https://mepag.jpl.nasa.gov/reports.cfm.