CONNECTING COMMUNITY SCIENTIFIC HYPOTHESES TO MARS SAMPLE SCIENCE. M.A. Mischna[1] V.E. Hamilton[2], P. Heck[3], Y. Liu[1], L. Hallis[4], J. Filiberto[5], and B. Carrier[1] [1]Jet Propulsion Laboratory, California Institute of Technology, michael.a.mischna@jpl.nasa.gov, [2]Southwest Research Institute, Boulder, CO, USA, [3]Field Museum, Chicago, IL, USA, [4]School of Geographical and Earth Sciences, University of Glasgow, Glasgow, Scotland, UK, [5]NASA Johnson Space Center, Houston, TX, USA.

Introduction: The proposed Mars Sample Return (MSR) program seeks to bring back to Earth a set of specially curated samples from the surface of Mars. The first segment of the MSR program is presently underway; the Mars 2020 rover *Perseverance* has, to date, collected 24 samples of martian rock, regolith, and atmosphere within Jezero crater. Its geologically diverse rock sample set can provide insight into the time evolution of the Jezero environment, including the possible preservation of ancient biosignatures. Presently, a cache of 10 samples has been deposited in the Three Forks region on the floor of Jezero crater. These samples, deemed scientifically return worthy by the Mars science community [1], are intended as a contingency sample set, as *Perseverance* has subsequently obtained more samples, and is therefore storing a more comprehensive and scientifically valuable set of samples that will grow as the rover ascends to the rim of Jezero crater.

The return of samples from Mars has been identified as the highest priority planetary mission in the past three National Academies Decadal Surveys [2-4]. Substantial work has gone into establishing science objectives for an MSR program, an overall framework for sample retrieval and analysis, and the expected impact on future Mars science and exploration (e.g., [5]). These objectives have been established at a relatively high level, e.g., "Interpret the primary geologic processes and history that formed the martian geologic record, with an emphasis on the role of water." (Objective 1 in [5]) and are designed to encapsulate the broad scientific priorities of, and lay the groundwork for, investigation strategies and measurements to be conducted by a future MSR program. It is from this overarching framework that the *Connecting Community Scientific Hypotheses to Mars Sample Science* workshop ('The Workshop') was conceived, with the purpose of distilling these high-level scientific objectives into discrete, testable hypotheses across a range of scientific disciplines. The output of the workshop is meant to be a 'hypothesis document' serving as a starting point for cataloging and condensing specific hypotheses for consideration by the scientific community. The template for this approach is based on the "driving hypotheses" developed by the OSIRIS-REx team as part of their Sample Analysis Plan [6].

Workshop Format: In discussion with members of the planetary science community, it was noted that, in several scientific disciplines, there is uncertainty about the value of samples to one's research. The question was often raised, "What can samples do for me—I study *X*, not samples?" While such concerns were more often raised among Mars scientists, a similar refrain was echoed by members of the sample science community as well, in, "What can *Mars* samples do for me—I study *X*, not Mars?" Leadership of the Mars Exploration Program Analysis Group (MEPAG) and the Extraterrestrial Materials Analysis Group (ExMAG), in joint discussion, realized that messaging about the value of Mars samples to their respective communities was not reaching its full potential, leaving some scientists lukewarm, at best, to the value of sample science.

With this in mind MEPAG and ExMAG jointly convened The Workshop to serve as a focused activity to demonstrate the value of Mars sample science to interested members of both communities. The target audience for The Workshop were scientists who do not study Martian meteorites and those in those disciplines not traditionally served by extraterrestrial sample analysis. For example, climate science, geophysics, or solar system origins may not have an immediately recognizable linkage to martian samples. Many 'skeptics' were found in these, and other, fields that have what may be underappreciated synergies with sample science. A specific effort was made to reach out to, and engage, scientists in these fields among The Workshop attendees.

The emphasis of The Workshop was not strictly on returned samples from Jezero crater. Rather, The Workshop discussions considered notional samples from *anywhere* on Mars, independent of a specific mission implementation. Certainly, for example, cryosphere or polar scientists may question the notion of obtaining value from samples from tropical Jezero crater; however, volatile samples from high latitudes may serve their science quite well. By expanding consideration of samples from anywhere on the planet, The Workshop was designed to reach a broader target audience.

'Entry' into The Workshop required registrants to answer two questions, "What is one testable scientific hypothesis you look forward to testing with a returned sample from Mars (Jezero or elsewhere)?" and, "What is one hypothesis that may prove challenging to test with returned samples from Mars (Jezero or elsewhere)?" Anonymized answers to these questions, with corresponding references to the literature, were used to seed discussion at The Workshop and identify those areas potentially 'underrepresented' in sample science. Responses were binned by theme and are shown in Fig 1.

Agenda: Day 1 was designed to serve as an initial foray into how returned samples from anywhere on Mars

could advance various fields of Mars science and produce testable hypotheses. A series of short overview presentations was given on the following topics:

- Astrobiology and Organics
- Atmospheric and Climate Science
- Early Solar System Evolution
- Geophysics
- Igneous Mars
- Noble Gases
- Polar Science
- Water and Volatile Reservoirs

Additionally, a presentation on the scientific impact of the Apollo samples was given, to provide context on the continual, long-term value of samples across generations, and their ability to provide breakthrough discoveries in solar system science.

Day 2 began with an overview of the Jezero crater samples that have been collected by *Perseverance* to date, followed by open discussion amongst workshop attendees to develop a draft hypothesis document. At this stage, the aggregated responses were reviewed by the participants, and representative hypotheses were identified across seven different themes that captured the range of participant input:

- Crust/mantle evolution / geochronology
- Atmosphere and atmospheric evolution
- Climate and water history
- Alteration and fluid-rock interactions
- Ices and the cryosphere
- Organics and potential biosignatures
- Planetary origins

Representative examples of the many hypotheses generated during The Workshop include:

- The martian mantle is not well-mixed by convection and is laterally and/or vertically inhomogeneous.
- Mars atmospheric pressure declined rapidly following the shut-off of the dynamo resulting in substantial climate change.
- A large impactor between 1000-2000 km struck early Mars producing the global dichotomy and the so-called Borealis basin.

For these and other examples, analysis of sample material from Mars can confirm or refute the underlying hypothesis. The output hypothesis document of The Workshop will catalog those questions discussed at the workshop that can be addressed via sample science analysis techniques. The document is not comprehensive and can be updated to reflect additional hypotheses and evolution of the current state of understanding of Mars. It can be augmented to distinguish hypotheses that can be addressed by samples from Jezero from those addressed by samples elsewhere.

Conclusion: The Workshop was envisioned to be the first of many opportunities for the Mars and sample science communities to learn more about the value of Mars samples across a range of disciplines. The two-day activity in April 2024 exposed participants to a wide range of science that can be conducted with samples from Mars, and yielded several dozen preliminary hypotheses that can (or cannot) be addressed with samples. For those hypotheses that remain challenging to address with samples, future investments in R&A and/or technologies may help to yield parity in scientific progress. Future workshops are anticipated and will continue outreach to community members to highlight the important value of samples to Mars research and exploration.

References: [1] Czaja, A.D. et al. (2023) *LPSC LIV*, Abstract #2523. [2] National Academies of Sciences, Engineering, and Medicine, *New Frontiers in the Solar System*, (2003), 248pp. [3] National Academies of Sciences, Engineering, and Medicine, *Visions and Voyages*, (2011), 399pp. [4] National Academies of Sciences, Engineering, and Medicine, *Origins, Worlds, and Life*, (2022), 800pp. [5] Beaty, D.W. et al. (2019), *Meteoritics and Planet. Sci.*, 54, S3-S152. [6] Lauretta, D.S. et al. (2023), arXiv:2308.11794, 274pp.

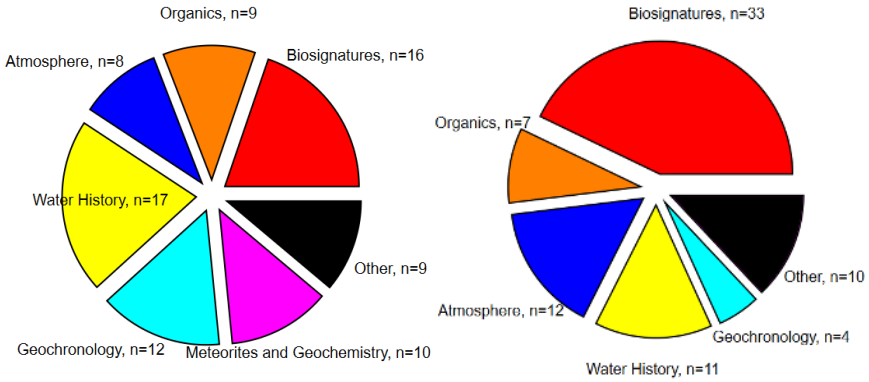

Figure 1: Thematic distribution of hypotheses that The Workshop attendees (left) looked forward to testing with a returned sample (from Jezero or elsewhere), and (right) felt may prove challenging to test with a returned sample.