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Report

Report of the Science Community Workshop on the proposed First Sample Depot for the Mars Sample Return Campaign

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Abstract–The Mars 2020/Mars Sample Return (MSR) Sample Depot Science Community Workshop was held on September 28 and 30, 2022, to assess the Scientifically-Return Worthy (SRW) value of the full collection of samples acquired by the rover Perseverance at Jezero Crater, and of a proposed subset of samples to be left as a First Depot at a location

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 planning and information purposes only.

within Jezero Crater called Three Forks. The primary outcome of the workshop was that the community is in consensus on the following statement: The proposed set of ten sample tubes that includes seven rock samples, one regolith sample, one atmospheric sample, and one witness tube constitutes a SRW collection that: (1) represents the diversity of the explored region around the landing site, (2) covers partially or fully, in a balanced way, all of the International MSR Objectives and Samples Team scientific objectives that are applicable to Jezero Crater, and (3) the analyses of samples in this First Depot on Earth would be of fundamental importance, providing a substantial improvement in our understanding of Mars. At the conclusion of the meeting, there was overall community support for forming the First Depot as described at the workshop and placing it at the Three Forks site. The community also recognized that the diversity of the Rover Cache (the sample collection that remains on the rover after placing the First Depot) will significantly improve with the samples that are planned to be obtained in the future by the Perseverance rover and that the Rover Cache is the primary target for MSR to return to Earth.

INTRODUCTION/EXECUTIVE SUMMARY

As the Perseverance rover explores the Jezero Delta Front and continues to add to its on-board sample collection, NASA and ESA are further advancing their planning for the retrieval and transportation of samples to Earth. It has been determined that the probability of success is maximized if the collected samples are divided into subsets, with "success" defined as the delivery of one of those subsets of samples (hereafter "caches") to Earth.

This strategy can be implemented by Perseverance placing a *First Depot* (a Depot is a cache placed on the ground) in Jezero Crater within the rover's qualified lifetime (1.5 Mars years), its cache comprising one member of each of the paired samples Perseverance has collected so far. The second of each of the paired samples would then be retained on board as the *Rover Cache*, and this group of on-board samples would be augmented by the future collection of additional samples, potentially over multiple years (depending on Perseverance's future state of health). However, this strategy depends on each sample collection being independently scientifically return-worthy (SRW).

Mars 2020 Project Science and the Mars Sample Return (MSR) Campaign Science Group (MCSG) are of the opinion that the Mars 2020 mission has assembled a sample collection that meets the SRW definition and can be successfully placed in a First Depot at a location known as Three Forks along the Jezero Delta Front. The goal of this workshop was to inform the science community of this opinion, present the reasoning behind the opinion, and to solicit their input on the definition of SRW and on whether the proposed set of samples for the First Depot meets the definition of SRW. This input has been incorporated into this report as a community opinion to be put forward to NASA and ESA decision-makers.

The Mars 2020/Mars Sample Return Sample Depot Science Community Workshop was organized by the MCSG and held on September 28 and 30, 2022. It was run on Webex as a virtual meeting and the total number of active attendees reached a maximum of 189 (the total number of unique individuals was not tracked). Prior to the workshop, the scientific community received a package of accompanying information for their own assessment (called the pre-workshop participant information package, or PPIP). To facilitate participation and inclusion, feedback was accepted throughout the 3 days of the workshop via (1) open *viva voce* questions, (2) a real-time online interface (Mentimeter) to write questions and feedback, (3) real-time clarifications through the Webex chat, and (4) an online, open questionnaire for free form feedback during the day in between, September 29 (Google Form). At the end of the workshop, findings were summarized and presented to the community for confirmation. All findings were accepted by the community and have been included in this report. This report also includes a description of the final collection of samples and witness tubes that this group recommends including in the First Depot.

The primary outcome of the workshop, as moderated by the MCSG, was that the community is in consensus on the following statement: The proposed set of 10 sample tubes that includes 7 rock samples, 1 regolith sample, 1 atmospheric sample, and 1 witness tube constitutes a SRW collection that (1) represents the diversity of the explored region around the landing site, (2) covers partially or fully in a balanced way all of the International MSR Objectives and Samples Team (iMOST) scientific objectives that are applicable to Jezero Crater, and (3) the analyses of samples in this First Depot on Earth would be of fundamental importance, providing a substantial improvement in our understanding of Mars. At the end of the meeting, there was overall community support for forming the First Depot as described at the workshop and placing it at the Three Forks site. The community also recognized that the diversity of the Rover Cache will significantly improve with the samples that are planned to be obtained in the future by the Perseverance rover and that the Rover Cache is the primary target for MSR to return to Earth. We anticipate that the iMOST objectives applicable to Jezero Crater would be fully covered with that expanded collection.

SRW BACKGROUND

The concept of SRW in relation to MSR was first formally defined by the Caching Strategy Steering Committee (CSSC) in early 2021 (MSR CSSC, 2021), with input from the science community. The MCSG reviewed this definition and made minor edits. The MCSG also reviewed the set of samples collected by the Mars 2020 science team, and the accompanying documentation provided by the Mars 2020 team, to determine whether the collection to be placed in the First Depot meets the definition of SRW.

Determination of a sample set as SRW means that the sample collection has enough scientific value to justify the time, money, and effort for the MSR Campaign to proceed and to retrieve those samples. The formation of a First Depot that is SRW serves as a risk mitigation measure to ensure that the MSR Campaign has a collection of samples to target for retrieval, should recovery of the Rover Cache become unattainable in the future.

SRW ASSUMPTIONS AND DEFINITION

SRW Assumptions (modified slightly from that of the CSSC)

1. SRW is a property of a collection of samples and not a property of an individual sample, except in extraordinary circumstances.
2. A sample suite is a collection of related samples intended to address one or more science objectives. Individual samples may be part of multiple suites and may address multiple science objectives.
3. An SRW sample collection is the minimal collection of samples that could be used to address major science objectives of MSR described by iMOST (iMOST, 2019), including the history and evolution of the Jezero Crater region.
4. The definition of an SRW sample collection applies to any/all sample collections, regardless of whether it is on the ground (i.e., a depot) or on a rover.
5. We can reasonably expect—based on orbital data—that a diverse collection of samples from Jezero Crater would satisfy the requirements for an SRW sample collection.
6. The scientific aim for MSR is to maximize the science return and to go beyond the minimal SRW sample collection. This could include returning a sample collection that contains samples from outside Jezero Crater.

SRW Definition (modified slightly from that of the CSSC)

An SRW sample set should:

1. Include distinct sample suites or individual samples selected to represent the diversity of an exploration area to address the science objectives of MSR described by iMOST, in general, and the astrobiological potential, geologic history, and evolution of Mars as reflected in the Jezero Crater region, in particular.
2. Be accompanied by in situ data and information sufficient to understand the geological and environmental context of the samples, including sampling conditions, as documented by Mars 2020.
3. Include at least one, and preferably two, witness samples.

Finding 1: After discussion of the assumptions and definition of SRW at the community workshop, there was consensus that these were appropriate metrics with which to determine the scientific return-worthiness of Mars 2020 sample collections.

SRW EVALUATION OF PROPOSED FIRST DEPOT

The MCSG prepared a Sample Science Traceability Matrix (SSTM) (see Appendix B for the SSTM and Appendix C for a link to an Excel worksheet with greater detail) by assessing the merits of the existing sample collection against the previously defined MSR science objectives, sub-objectives, and investigations as described by the iMOST group (Beaty et al., 2019; and summarized below). The iMOST strategy consists of seven objectives, with multiple sub-objectives. Each sub-objective can have one or multiple investigations. For each investigation, a specific type of sample or samples is defined, as identified in the iMOST report, which was described so that it could apply to any site on Mars. If, based on our current understanding of the samples (including contextual data collected by Perseverance), we foresee that all the investigations of one specific sub-objective can be addressed by a sample, then this is indicated in the matrix as "full" circles. If some (maybe even all but one) of the investigations can be addressed, this is indicated in the matrix as "half-filled" circles. If none of the investigations can be addressed by a specific sample, then it is indicated in the matrix as "empty" circles.

Summary of iMOST objectives of the MSR campaign, samples suggested by iMOST to meet those objectives, and how these are addressed by the Mars 2020 First Depot samples (please refer to the report by Beaty et al. (2019) for full details and definitions of the objectives):

Objective 1: Interpret the primary geologic processes and history that formed the Martian Geologic Record, with an emphasis on the role of water.

This objective contains multiple sub-objectives, each of which could be at least partially addressed by the proposed Mars 2020 First Depot samples.

Sub-Objective 1.1: Characterize the essential stratigraphic, sedimentologic, and facies variations of a sequence of Martian sedimentary rocks.

- Samples: a suite of aqueously deposited sedimentary rocks of various grain sizes, eolian-deposited sediments and sedimentary rocks, and regolith.
- Mars 2020 has collected (or will have collected) a sample of almost all of these by the time of the placement of the First Depot, and thus will have samples to address five out of six of the investigation categories.

Sub-Objective 1.2: Understand an ancient Martian hydrothermal system through study of its mineralization products and morphological expression.

- Samples: various hydrothermally emplaced and hydrothermally altered rocks.
- Mars 2020 is not expected to encounter such rocks until later in the mission (if at all) but has collected samples of aqueously altered igneous rocks from the crater floor; alteration that occurred under currently unknown conditions. These samples address one out of five of the investigation categories.

Sub-Objective 1.3: Understand the rocks and minerals representative of a deep subsurface groundwater environment.

- Samples: those collected from deep subsurface environments.
- Mars 2020 is not expected to encounter such rocks until later in the mission, outside of Jezero, but has collected samples of aqueously altered igneous rocks from the crater floor. These samples address one out of four of the investigation categories.

Sub-Objective 1.4: Understand water/rock/atmosphere interactions at the Martian surface and how they have changed with time.

- Samples: rocks/sediments/regolith of any type that have experienced alteration/weathering.
- All rock and regolith samples so far collected by Mars 2020 have experienced alteration/weathering, so all of the investigation categories can be addressed.

Sub-Objective 1.5: Understand the essential attributes of a Martian igneous system.

- Samples: in-place and transported igneous rocks of various compositions
- The crater floor igneous samples and the regolith samples to be collected are suitable, so all of the investigation categories can be addressed.

Objective 2: Assess and interpret the potential biological history of Mars including assaying returned samples for the evidence of life.

This objective includes multiple sub-objectives, each of which could be at least partially addressed by the proposed Mars 2020 First Depot samples, including the witness tubes.

Sub-Objective 2.1: Assess and characterize carbon, including possible organic and pre-biotic chemistry.

- Samples: any type of rock/sediment with evidence of organic carbon and also rocks and regolith to understand exposure history.
- All of the rock samples so far collected and rocks and regolith soon to be collected are appropriate to address three out of four of the investigation categories.

Sub-Objective 2.2: Assay for the presence of biosignatures of past life at sites that hosted habitable environments and could have preserved any biosignatures.

- Samples: any rocks/sediments/regolith that could preserve biosignatures, which includes all of the samples so far collected and planned to be collected.
- The igneous crater floor samples were aqueously altered and contain salts. The sedimentary delta samples are composed of coarse- to fine-grained material that was sub-aqueously deposited. Thus, they all could have hosted habitable environments and contain minerals that could preserve biosignatures and are thus appropriate to address all of the investigation categories.

Sub-Objective 2.3: Assess the possibility that any life forms detected are still alive, or were recently alive.

- Samples: any rocks/sediments/regolith that could preserve modern biosignatures
- It is unlikely Mars 2020 will sample any living or recently living Martian life, but Sample Safety Assessment investigations and present-life-related research will nonetheless be performed on all returned samples, so all samples are appropriate to address all of the investigation categories.

Objective 3: Quantitatively determine the evolutionary timeline of Mars.

- Samples: igneous and sedimentary rocks of various types, levels of alteration, and with good orientation.
- All samples so far collected and planned to be collected can address one or more of the investigation categories, in such a way that all of investigation categories can be addressed.

Objective 4: Constrain the inventory of Martian volatiles as a function of geologic time and determine the ways in which these volatiles have interacted with Mars as a geologic system.

- Samples: an atmospheric gas sample or samples, igneous and sedimentary rocks (particularly those that show interaction with the atmosphere), and regolith.
- The sample set includes all of these types of samples, including an atmospheric sample and a witness tube (which also contains Martian atmosphere), so all investigation categories can be addressed.

Objective 5: Reconstruct the processes that have affected the origin and modification of the interior, including the crust, mantle, core, and the evolution of the Martian dynamo.

- Samples: suites of well-oriented igneous rocks and sedimentary rocks, as well as rocks from the ancient crust and impact breccias.
- The orientation of the igneous and sedimentary samples so far collected has been documented and are appropriate to address two out of four of the investigation categories.

Objective 6: Understand and quantify the potential Martian environmental hazards to future human exploration and the terrestrial biosphere.

- Samples: dust, regolith, and rock samples to characterize as many Martian surface materials as possible.
- All samples so far collected and planned to be collected are appropriate to address one or more of the investigation categories, in such a way that 100% of investigation categories can be addressed.

Objective 7: Evaluate the type and distribution of prospective in situ resource utilization feedstocks to support potential future Mars exploration.

- Samples: a regolith sample or samples, sedimentary rocks with hydrated minerals, air fall dust, and ore.
- The collection will include a regolith sample and several sedimentary rock samples with hydrated minerals. Atmospheric samples can also be used as proxies for the water cycle. Thus, there are sufficient samples to address 75% (three out of four) of the investigation categories.

After presenting the sample collection, the iMOST objectives and the rationale of the SSTM, and after different iterations with the community, the following findings were reached, presented to, and agreed upon by the members of the science community in attendance at the depot workshop:

Finding 2: "The strategy of using a Science Traceability Matrix to assess the SRW of the depot by mapping the Mars 2020 samples to the MSR science objectives is valid."

Finding 3: "The samples that have been collected so far can either fully or partially address each of the Mars Sample Return science objectives."

In summary, the planned Three Forks cache (First Depot) has sufficient scientific value to justify its return should acquisition of the rover's onboard cache become infeasible. The Rover Cache always has higher scientific value than the First Depot cache and is therefore always both return-worthy and the scientifically superior target for MSR. Deploying the First Depot mitigates risk to completion of MSR should the Rover Cache become unattainable (e.g., due to Perseverance failure), and allows Perseverance to continue its mission of exploration of the Jezero Delta, crater rim, and beyond to create an extraordinary and even more diverse sample collection for return.

DECISION GUIDELINES FOR PAIRED SOLID ROCK SAMPLES

The Mars 2020 mission has had a strategy to date of collecting paired samples from each geologic unit of interest for the express purpose of creating two sample collections (caches) for risk mitigation. The question then becomes "Which sample of each pair should go into which sample collection?" The MCSG developed a set of decision guidelines to answer this question:

1. If there is a significant (>5%) difference in the estimated length of each core, then the longer sample should be considered the higher priority.
2. If there is an insignificant (<5%) difference in core length between paired samples, then observable features should be considered. In this case, the smaller length sample could be considered the high priority of the pair if it contains potentially scientifically important features. The MCSG noted that such a decision could only be based on core surface features imaged by CacheCam, and therefore any potential interior features would be unknown to inform sample priority. Note: Once these decision guidelines were actually implemented, differences in rock outcrop features proximal to each core were also used to inform selection between the paired cores.
3. If visible features are exceptionally interesting, then features may trump core length, and the significantly smaller core may be deemed the higher priority sample of the pair.

Guideline 1: The Mars 2020 mission measures the length of each core with a probe that presses each sample into the furthest extent of its tube. Due to uncertainties in the degree of fracturing and rotation of fragments of each core, it is not possible to know whether the measured lengths contain void space. Thus, the measured lengths are considered estimates. The MCSG used these estimated core lengths, the measured diameters, and approximate rock densities to estimate the mass of each sample. These data are presented in Table 1.

Guidelines 2 and 3: Based on an evaluation of the available data of each sample (initial reports, published images, public presentations, and press releases), the MCSG determined that none of the samples contained visible features that would raise a shorter sample of a pair to higher priority than the longer one.

Based on these three guidelines, the MCSG suggests that the longer core of each pair should be considered a higher priority for return than the shorter core sample.

The MCSG also considered whether the higher priority samples, lower priority samples, or a mix of each type should be included in the First Depot. These strategies are listed in Table 2 along with pros and cons of each.

Once Perseverance collects its next sample after leaving the First Depot, the Rover Cache inherently becomes the more scientifically valuable sample collection and therefore higher priority to return. Based on this reality and the guidelines presented above, the MSCG made the following finding, which was accepted by the community at the workshop:

Finding 4: "The shorter sample of each pair should be included in the First Depot, and the longer sample of each pair should be retained on-board Perseverance as the Rover Cache."

DECISION GUIDELINES FOR THE ATMOSPHERIC AND REGOLITH SAMPLES

Although atmospheric and regolith samples are not explicitly required in the definition of SRW (see above), iMOST research objectives 1, 2, 3, 4, 6, and 7 include proposed investigations that can be addressed partly or wholly by an atmospheric sample or samples (including, both pure atmospheric samples and the headspace gas of tubes with rocks or regolith) and/or loose surficial

TABLE 1. Mars 2020 sample lengths, calculated volumes, estimated masses, and selection of higher priority samples.

Sample name	Rock type	Core length (cm)	Core volume (cm^3)[a]	Core length comparison[b] (%)	Mass estimate (g)[c]	Higher priority
Montdenier	Igneous	5.98	8.4	97	24.3	
Montagnac	Igneous	6.14	8.7		25.2	✓
Salette	Igneous	6.28	8.9	53	25.8	✓
Coulettes	Igneous	3.30	4.7		13.6	
Robine	Igneous	6.08	8.6	50	24.9	✓
Malay	Igneous	3.07	4.3		12.5	
Hahonih	Igneous	6.50	9.2	96	26.8	✓
Atsah	Igneous	6.00	8.5		24.5	
Swift Run	Sedimentary	6.69	9.4	93	20.8	✓
Skyland	Sedimentary	5.85	8.3		18.2	
Hazeltop	Sedimentary	5.97	8.4	98	18.6	
Bearwallow	Sedimentary	6.24	8.8		19.4	✓

[a]Rock volume estimates are from initial Mars 2020 reports (See Appendix C).
[b]Percentages are calculated as length of shorter core/length of longer core × 100.
[c]Estimated based on calculated volume and approximate densities of basalt, 2.9 g cm^{-3}, for the igneous rocks, and of mudstone (2.2 g cm^{-3}) for the sedimentary rocks.

TABLE 2. Decision strategies for placing cores in the First Depot.

Strategy	#1: Place Higher Ranked Samples in First Depot	#2: Place Lower Priority Samples in First Depot	#3: Mix and Match High and Low Priority samples in First Depot
Mentality	"Bird in hand"	"Save the higher ranked for last"	"Hedge our bets"
Pros	Build confidence in backup plan that higher priority samples are in an accessible depot	The Rover Cache is the target cache, so the higher priority samples are more likely to be returned	The higher priority samples are distributed, and the First Depot and Rover Cache are equally scientifically compelling
Cons	Perseverance continues and MSR focuses on the Rover Cache. Lose out on potentially higher priority sample	Higher risk of keeping higher ranked samples together with the Rover Cache—all our "eggs" in one mobile basket	The Rover Cache is plan A for MSR, so this strategy will not return all of the higher ranked samples

material (e.g., regolith). Furthermore, because of their unique nature, these samples may serve as controls for the research performed on other samples: the analysis of the gaseous sample(s) can be used as a control for the headspace gas in the sample tubes to understand how the headspace gas composition has been modified via interaction with the solid sample (e.g., volatiles that may have moved between the solid and gas phase during sample storage and transport); the individual grains of regolith samples, due to their increased surface to volume ratio, may also be more prone to absorb volatile contaminants, and since the grains are independent they can also be used to implement multiple studies in parallel, without breaking a solid sample, which may be especially interesting during the early phases of sample collection analysis. Therefore, the MCSG suggests that these types of samples are important to include in any returned sample set because they increase the number of iMOST objectives that can be met and the diversity of the collection. The nature of eolian bedforms as observed at Jezero Crater by Perseverance and the diversity of materials that form them (local, rounded coarse grains on their surface, fine-grained material comprising the bedform, eolian dust and some crust-induration agent) was presented during the workshop. The community agreed with this assessment at the Depot Workshop and the following findings were made.

Finding 5: "An atmospheric sample should be included in the First Depot."

Finding 6: "A regolith sample (a sample acquired at an eolian bedform with the "regolith" bit) should be included in the First Depot."

DECISION GUIDELINES FOR WITNESS SAMPLES

Contamination Control (CC) minimizes the overall contamination load of samples, and Contamination Knowledge (CK) documents the inventory of contaminants that samples are exposed to. Both CC and CK are required for scientists to accurately discriminate between materials that are indigenous to a sample and those that are introduced via contamination. CC and CK also enable scientists to respond to unexpected results. Documentation of potential spacecraft hardware contamination during Assembly, Test, and Launch Operations (ATLO) through ground witnesses and materials archiving, and Mars 2020 flight witnesses are all integral to the CK strategy for MSR.

Perseverance carries five identical flight witness tube assemblies (WTAs) that can collect particulate and vapor contamination during various phases of the Mars 2020 mission (Moeller et al., 2021). The first witness, referred to as the bit carousel WTA (WB1), was activated by puncturing a foil seal exposing witness materials inside the WTA prior to loading the tube in the bit carousel during ATLO. WB1 was exposed to possible contaminants associated with launch, cruise, and entry, descent, and landing (EDL) before it was sealed on Sol 120 during surface operations. The other four WTAs (WB2, WB3, WB4, and WB5) are designed to be punctured and carried through the bit exchange, drilling and sealing procedures so that they experience sample processing similar to the Mars samples, except for drill bit-on-rock interaction. Only two standard WTAs (WB2 and WB3) will have been activated and sealed during the early phase of Mars 2020 (i.e., prior to the First Depot formation), while two WTAs (WB4 and WB5) are available for use during later phases of M2020. Perseverance also carries a one-time use drillable blank assembly (DBA) to provide additional CK of the sample drilling process, but the DBA was not under consideration for the First Depot and will not be considered further in this report.

According to the definition of SRW, a sample collection should contain at least one WTA, and preferably two WTAs. Several considerations guided how the MCSG settled on scenario 2 (see Table 3) for assigning WTAs to the First Depot versus the Rover

TABLE 3. Scenarios for caching witness tubes among the First Depot and the Rover Cache. The community was in consensus with MCSG's proposal to proceed following Scenario 2.

Witness tubes	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Bit Carousel WTA (WB1)—activated in ATLO and sealed in Jezero on Sol 120	First Depot	Rover Cache	Rover Cache	Rover Cache
WB2—activated/sealed in Jezero on Sol 499	First Depot	Rover Cache	First Depot	First Depot
WB3—activated/sealed in Jezero on Sol 586	Rover Cache	First Depot	First Depot	Rover Cache
WB4 (no current plan for activation/sealing prior to First Depot	Rover Cache	Rover Cache	Rover Cache	First Depot
WB5 (no current plan for activation/sealing prior to First Depot	Rover Cache	Rover Cache	Rover Cache	Rover Cache
Notes about scenarios	WB1 provides a unique record of contamination from ATLO through EDL; no guarantee of return to Earth of WB1 if part of First Depot	Only one ordinary WTA (either WB2 or WB3) in First Depot, all others in Rover Cache	Two ordinary WTAs exposed in Jezero in First Depot, but only early Jezero witness in Rover Cache would be WB1	Two ordinary WTAs exposed in Jezero in First Depot, but only one unused WTA available for later phase

Note: The MCSG followed a different nomenclature convention during the workshop and in the PPIP, which has now been standardized with M2020 nomenclature. The equivalence is the following: WTAb (previous MCSG nomenclature) = WB1 in the Initial Reports (this tube was opened on Earth during ATLO and sealed by Perseverance on Mars on Sol 120), WTA1 (previous MCSG nomenclature) = WB2 (activated and sealed by Perseverance on Mars on Sol 499) and the soon to be activated and sealed WTA2 (previous MCSG nomenclature) = WB3 (activated and sealed on Mars on Sol 586).

Cache. First, the contamination environment of Perseverance will evolve over time. Therefore, multiple WTAs should be used to document the time variance of contamination over the life of the mission. This factor is more important for sample collections that contain samples acquired over longer periods of time, such as the anticipated Rover Cache, compared to sample collections acquired over shorter periods of time, such as the First Depot. Second, the First Depot and the Rover Cache will each contain samples that were collected during the early exploration of Jezero Crater. As a result, each sample collection should contain at least one ordinary WTA that was exposed and sealed in Jezero Crater prior to the formation of the First Depot as controls for the samples that were acquired during this early phase of the mission. Lastly, only one bit carousel WTA (WB1) exists, which provides a unique record of contamination from ATLO through EDL for Mars 2020. Neither the First Depot nor the Rover Cache have a greater need for the specific CK that the WB1 provides. In addition, because WB1 is a unique, one-of-a-kind witness, its inclusion in a sample collection cannot be used to elevate that sample collection to SRW as this would eliminate the other sample collection from meeting the SRW standard. The MCSG constructed several witness caching strategies based on these considerations (Table 3).

Based on these guiding factors, MCSG proposed following scenario 2 and placing a single WTA (either WB2 or WB3) into the First Depot, while all other WTAs would remain in the Rover Cache, including WB1. This WTA allocation meets the minimum SRW definition, even if a second WTA is preferred. The benefits of this WTA allocation are threefold. First, as a unique sample, the WB1 is best retained in the Rover Cache where it would have the highest probability of return. Second, scenario 2 delivers CK of the early phase of the mission to both sample collections. Third, it provides a spare WTA onboard Perseverance to record the contamination environment of the late phase of the mission if the final WTA activation and sealing is not successful. Alternatively, it provides the option for multiple WTAs (WB4 and WB5) to record the contamination environment during the remaining phases of the mission.

The community was in consensus with this proposal of scenario 2 with the preference to assign WB3 to the Rover Cache. The community consensus was that WB2 and WB3 likely contained similar contamination information. However, WB2 was identified as a higher priority witness sample over WB3 because WB2 was opened and sealed earlier in the mission such that it may have captured more volatiles and particulates from the spacecraft compared to WB3. Thus, we made the following finding:

Finding 7: "Mars 2020 should place WB3 in the First Depot and retain all other WTAs in the Rover Cache."

REVIEW OF THE SAMPLE DOCUMENTATION

One of the requirements of SRW is that the returned samples should be accompanied by in situ data and information sufficient to understand the geological and environmental context of the samples, including sampling conditions. For every sample acquisition, the Mars 2020 team systematically performs a set of activities, termed the Standardized Observation Protocol (STOP) list to fully document the sample context using the entire rover science payload. All the required data have been released to the Planetary Data System and have been summarized in the sample "Initial Reports" which are archived at the Planetary Data System (a link to the IRs in the PDS is provided in Appendix C). The initial reports summarize a preliminary analysis of the observations provided by the rover at the abraded patches (for the solid core samples) and in the vicinity of the sample for the regolith sample. They also include details about the drilling and sealing process, including the drilling bit and sample tube numbers, and the estimated environmental conditions at the time of sealing. The content of these documents was also shared with the community to demonstrate that the accompanying documentation is sufficiently relevant to understand the environment and the analysis of the abraded patches.

Finding 8: "The samples are sufficiently documented by accompanying in situ data and information to understand the geological and environmental context of the samples, including sampling conditions, as documented by Mars 2020 in the Initial Reports (IR) and with the STOP list observations that are archived in the Planetary Data System."

PROPOSED SAMPLES IN FIRST DEPOT

The Mars 2020 leadership proposed a list of rock samples that would be included in the First Depot. The MCSG performed its own evaluation of the rock samples and the witness tubes, as described above. The combined list was presented to the scientific community at the depot workshop and there was agreement. The consensus list of

TABLE 4. Samples proposed to be placed in the First Depot, as of September 2022.

Sample	Rationale
Rock samples:	
Montdenier	Shorter core (<5% difference) than *Montagnac*; no visible differences in features for differentiation
Coulettes	Shorter core (≫5% difference) than *Salette*; no perceived exceptional features
Malay	Shorter core (≫5% difference) than *Robine*; no perceived exceptional features
Atsá (aka "Atsah")	Shorter core (<5% difference) than *Hahonih*; no visible differences in features for differentiation
Skyland	Shorter core (>5% difference) than *Swift Run*; Interesting feature in this sample does not outweigh the length difference
Hazeltop[a]	Shorter core (<5% difference) than *Bearwallow*; no visible differences in features for differentiation
(Amalik sample TBD)[b]	(These samples are being collected at the time of the writing of this report so there is insufficient information to make a recommendation.)
Regolith sample: TBD[c]	(These samples will be collected soon, the regolith sample contains a variety of materials including fine grain, atmospheric dust, and small local pebbles.)
ATM sample: Roubion	The only atmospheric sample collected so far
Witness Tube: WB3	The second "ordinary" witness tube collected during the Delta Front campaign. Possibly collected fewer contaminants than WB2 because WB3 was collected later than WB2

[a]Hazeltop was substituted by Bearwallow, after discussion within the M2020 Project Science and MCSG, because Hazeltop was sampled from a part of the rock that after close examination appeared more scientifically interesting, in spite of being shorter.

[b]Amalik samples were Mageik and Shuyak. It was recommended that the Mageik sample should be placed in the First Depot. Although the Mageik core was longer than the Shuyak core, Mageik spent an extended period in an unsealed state prior to being successfully sealed. It was determined by M2020 and MSR that this period of off-nominal storage for Mageik resulted in it being the lower priority sample of the pair.

[c]Regolith samples collected were Crosswind Lake and Atmo Mountain. Crosswind Lake was the sample placed in the First Depot.

samples that the community agreed should be placed in the First Depot is shown in Table 4:

SUMMARY

The community agreed with the following broad findings proposed by the MCSG:

Finding 9: "The proposed First Depot sample collection is scientifically return-worthy."

Finding 10: "There is overall community support for forming the First Depot as described at the workshop and placing it at the Three Forks site."

The primary outcome of the workshop can be summarized with the following consensus statement: The proposed set of 10 sample tubes that includes 7 rock samples, 1 regolith sample, 1 atmospheric sample, and 1 witness sample constitutes a SRW collection that (1) represents the diversity of the explored region around the landing site, (2) covers partially or fully in a balanced way all of the iMOST scientific objectives that are applicable to Jezero Crater, and (3) the analyses of samples in this First Depot on Earth would be of fundamental importance, providing a substantial improvement in our understanding of Mars. The community also recognizes that the diversity of the Rover Cache will be significantly improved with the samples that are planned for collection in the future by the Perseverance rover and that the Rover Cache is the primary target for MSR. We can anticipate that the iMOST objectives applicable to Jezero Crater will be fully covered with that extended collection.

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Data Availability Statement—Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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APPENDIX A
ACRONYM LIST

ATLO	Assembly, Test, and Launch Operations
CC	Contamination Control
CK	Contamination Knowledge
CSSC	Caching Strategy Steering Committee
EDL	Entry, Descent, Landing
ERO	Earth Return Orbiter
iMOST	International MSR Objectives and Samples Team
MCSG	MSR Campaign Science Group
MLS	Mars Launch System
RSTA	Returnable Sample Tube Assembly
SRH	Sample Recovery Helicopter
SRL	Sample Retrieval Lander
SRP	Sample Receiving Project
SRW	Scientifically return-worthy
SSAP	Sample Safety Assessment Protocol
SSTM	Sample Science Traceability Matrix

Sample Science Traceability to iMOST and M2020 Objectives

iMOST Objectives (Shorthand)	WB1*	Sample 1 (Rubion) ATM	Samples 2&3 (Rochette) *Basaltic Ign. Cores*	Samples 4&5 (Brac) *Cumulate Ign. Cores*	Samples 6&7 (Issole) *Cumulate Ign. Cores*	Samples 8&9 (Sid) *Basaltic Ign. Cores*	Samples 10&11 (Skinner Ridge) *Coarse Detrital Sedim. Cores*	WB2	Samples 12&13 (Wildcat Ridge) *Fine Detrital Sedim. cores*	Samples 14&15 *TBD (fine?)*	WB3	*Samples 16&17 TBD (Regolith?)*
	Crater Floor Campaign						*Delta Front Campaign*					
1. Geol. Environ. (Jezero)												
1.1 Sedimentary System	○	○	○	○	○	○	●	○	◐	◐	○	◐
1.2 Hydrothermal	○	○	◐	◐	◐	◐	○	○	○	○	○	○
1.3 Deep groundwater	○	○	◐	◐	◐	◐	○	○	○	○	○	○
1.4 Subaerial	○	◐	◐	◐	◐	◐	●	○	●	●	○	◐
1.5 Igneous terrain	○	○	●	●	●	●	●	○	○	○	○	●
2. Life												
2.1 Carbon/organic chem.	◐	○	◐	◐	◐	◐	●	◐	◐	◐	◐	◐
2.2 Ancient hab./biosig.	◐	◐	◐	◐	◐	◐	●	◐	●	●	◐	●
2.3 Modern hab./biosig.	◐	◐	●	●	●	●	●	◐	●	●	◐	●
3. Geochronology	○	○	●	●	●	●	●	○	○	◐	○	◐
4. Volatiles	●	●	◐	◐	◐	◐	◐	●	○	○	●	◐
5. Planetary Scale Geol.	○	○	◐	◐	◐	◐	◐	○	◐	◐	○	○
6. Environmental hazards	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	◐	●
7. ISRU	○	◐	○	○	○	○	◐	○	◐	◐	○	◐

*Bit Carousel Witness Tube Assembly (WB1) activated pre-launch and sealed on Mars on Sol 120, contamination exposure much longer than sample tubes and ordinary WTAs. WTAs alone won't directly address objectives, but serve as an important control for iMOST Objectives 2 and 4. Possibility of also achieving some Mars atmospheric science objectives with a WTA currently under study.

With anticipated analyses, iMOST key MSR questions: ● can be fully addressed; ◐ can be partially addressed; ○ cannot be addressed

Pre-Decisional - for planning and discussion purposes only.

STS	Sample Transfer System
ToR	Terms of Reference
WTA	Witness Tube Assembly
WB1	Bit Carousel Witness

APPENDIX B
SAMPLE SCIENCE TRACEABILITY MATRIX

This is the version of the Sample Science Traceability Matrix (SSTM) presented at the workshop and agreed to by the community. A link to an Excel worksheet used to guide the determination of the extent to which the samples could address the iMOST objectives, can be found in Appendix C, the Pre-workshop Participant Information Package (PPIP). (*Note that this version of the SSTM has not been updated to reflect the two new samples (14 and 15) collected by Mars 2020 since the workshop*).

APPENDIX C
PRE-WORKSHOP PARTICIPANT INFORMATION PACKAGE (PPIP)

This PPIP has been compiled for the convenience of the participants. It includes links to publicly available materials including M2020 publications to date, related websites, past reports and other information. Please note the following key elements of interest:

- An explanation of the term "scientifically return-worthy" (SRW)
- Evaluation of the proposed samples for the first depot against the SRW definition.
- A sample science traceability matrix (SSTM).
- Links to information about the samples themselves.

MCSG Workshop Materials
MCSG Workshop Slides.
M2020 Workshop Slides.
MSR Workshop Slides.
M2020 Initial Reports Cover with M2020 recommendations.
Feedback Form.
Mentimeter Link.
Mentimeter Instructions.

MCSG Workshop Prep Materials
Acronym Cheat Sheet.
Scientifically Return-Worthy Introduction, Definition, and Evaluation.
Sample Science Traceability Matrix (SSTM) Excel File.

Related Sample and other background info
Mars 2020 initial reports.
Mars Rock Samples—NASA Mars Exploration.
Mars Sample Return Caching Strategy Steering Committee Report.

NASA to Host Briefing on Perseverance Mars Rover Mission Operations—NASA Mars Exploration.

Websites

Mars 2020 Perseverance Rover—NASA Mars.

Mars Rock Samples—NASA Mars Exploration.

News - NASA Mars.

Images from the Mars Perseverance Rover—NASA Mars.

Photojournal: NASA's Image Access Home Page.

PDS Geosciences Node Data and Services: Mars 2020 Mission (wustl.edu).

Social media

NASA's Perseverance Mars Rover (@NASA Persevere)/Twitter.

#SamplingMars - Twitter Search/Twitter.

Briefing

NASA to Host Briefing on Perseverance Mars Rover Mission Operations—NASA Mars Exploration.

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