Mars Sample Return Caching Strategy Workshop

Jan. 21, 2021

Organized by the Caching Strategy Steering Committee (CSSC)

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.
Introduction

Gerhard Kminek and Michael Meyer

Jan. 21, 2021
Introduction

• The Perseverance rover is scheduled to land on Mars on February 18, 2021, representing the first step in the collection of Mars samples for possible return to Earth

• There are multiple possible scenarios for creating caches and depots for sample delivery to the Mars Ascent System (MAS)

• The Caching Strategy Steering Committee (CSSC) was chartered by NASA & ESA to review a set of draft scenario-based decision guidelines that are meant to inform operational decision for future MSR systems and provide strategic guidance for Perseverance
Introduction

- **Purpose of this Workshop:** To seek input on sample caches, depots, and recovery planning, and to use the workshop results to catalyze improved agreements on decision guidelines that can be implemented by NASA and ESA.

- **Desired Workshop Outcomes:**
  - Inputs to a broadly considered MSR sample caching strategy that are robust and flexible. The strategy adopted should maximize the science for Mars exploration.
  - The science community is informed, engaged, and able to participate in the process.
  - Community feedback is documented and used to develop an advisory report to NASA/ESA within approximately one month of the workshop.
Assumptions

• Draft caching strategies have been proposed by the MSR Program, and reviewed by Mars 2020 leadership and the Caching Strategy Steering Committee, in advance of the workshop

• Discussion topics within scope for the workshop:
  – Criteria for designating a cache ‘Scientifically Return Worthy’
  – Approach to taking duplicate samples
  – What/when are the decision points for caching/depot formation
  – Consider # of caches

• Not within scope for the workshop:
  – Debate which samples should be taken
  – Debate which specific samples must be in any specific cache
  – Debate rover trafficability and landing site criteria
  – Be overly prescriptive

• Decision guidelines will be reviewed on at least an annual basis and updated as necessary
# Proposed Objectives

<table>
<thead>
<tr>
<th>Objective 1</th>
<th>Geology</th>
<th>Interpret the primary geologic processes and history that formed the martian geologic record, with an emphasis on the role of water.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-Obj. 2.1</td>
<td>Carbon chemistry</td>
<td>Assess and characterize carbon, including possible organic and pre-biotic chemistry.</td>
</tr>
<tr>
<td>Sub-Obj. 2.2</td>
<td>Biosignatures-ancient</td>
<td>Assay for the presence of biosignatures of past life at sites that hosted habitable environments and could have preserved any biosignatures.</td>
</tr>
<tr>
<td>Sub-Obj. 2.3</td>
<td>Biosignatures-modern</td>
<td>Assess the possibility that any life forms detected are still alive, or were recently alive.</td>
</tr>
<tr>
<td>Objective 2</td>
<td>Life</td>
<td>Assess and interpret the potential biological history of Mars, including assaying returned samples for the evidence of life.</td>
</tr>
<tr>
<td>Objective 3</td>
<td>Geochronology</td>
<td>Determine the evolutionary timeline of Mars.</td>
</tr>
<tr>
<td>Objective 4</td>
<td>Volatiles</td>
<td>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.</td>
</tr>
<tr>
<td>Objective 5</td>
<td>Planetary-scale geology</td>
<td>Reconstruct the history of Mars as a planet, elucidating those processes that have affected the origin and modification of the crust, mantle and core.</td>
</tr>
<tr>
<td>Objective 6</td>
<td>Environmental hazards</td>
<td>Understand and quantify the potential martian environmental hazards to future human exploration and the terrestrial biosphere.</td>
</tr>
<tr>
<td>Objective 7</td>
<td>ISRU</td>
<td>Evaluate the type and distribution of in situ resources to support potential future Mars Exploration.</td>
</tr>
<tr>
<td>Time</td>
<td>Agenda Item</td>
<td>Presenter(s)</td>
</tr>
<tr>
<td>-----------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>8:00 AM</td>
<td>Introduction/Context/Goals of the Workshop</td>
<td>Kminek /Meyer</td>
</tr>
<tr>
<td>8:10 AM</td>
<td>Questions</td>
<td></td>
</tr>
<tr>
<td>8:20 AM</td>
<td>Perserverance operational scenarios &amp; constraints of relevance to caching &amp; retrieval</td>
<td>Farley</td>
</tr>
<tr>
<td>8:30 AM</td>
<td>Questions</td>
<td></td>
</tr>
<tr>
<td>9:05 AM</td>
<td>Geology &amp; Potential Sampling Opportunities (Includes notional mission traverse &amp; timeline)</td>
<td>Gupta</td>
</tr>
<tr>
<td>9:15 AM</td>
<td>Questions</td>
<td></td>
</tr>
<tr>
<td>9:45 AM</td>
<td>Break</td>
<td></td>
</tr>
<tr>
<td>10:00 AM</td>
<td>Draft Decision Guidelines</td>
<td>Meyer</td>
</tr>
<tr>
<td>10:10 AM</td>
<td>Discussion: Feedback on Draft Decision Guidelines</td>
<td></td>
</tr>
<tr>
<td>10:20 AM</td>
<td>Scientifically-Return Worthy</td>
<td>Kminek</td>
</tr>
<tr>
<td>10:40 AM</td>
<td>Discussion: Scientifically-Return Worthy criteria</td>
<td></td>
</tr>
<tr>
<td>10:50 AM</td>
<td>Implications of Draft Decision Guidelines (e.g. duplicate sampling, number of caches, key decision points)</td>
<td>Haldemann</td>
</tr>
<tr>
<td>11:10 AM</td>
<td>Discussion</td>
<td></td>
</tr>
<tr>
<td>11:40 AM</td>
<td>Concluding the workshop, next steps</td>
<td>Meyer/Kminek</td>
</tr>
</tbody>
</table>
Logistics

• We encourage use of the chat box for questions and discussions throughout the workshop. Please keep your microphone muted until you are called on to speak.

• Please keep if your video off unless you are speaking

• During question and discussion periods comments from the chat box will be relayed by the moderators (Dave Beaty & Brandi Carrier) and people will be called on to speak verbally as time permits

• Feedback will also be collected after the workshop via a Google form through January 25th: https://bit.ly/3bXHR2q
Mars 2020 and MSR

Ken Farley
Mars 2020 Project Scientist
Caltech
1/20/2021
Mars 2020 Sample Tubes

- *Perseverance* carries 43 sample tubes
  - 5 are witness tubes for contamination knowledge acquisition
  - 38 can be used to collect rock or regolith

After collection, tubes:
- are returned to rover interior
- are assessed for acquired volume, imaged, hermetically sealed, and stowed
- can be deposited on to martian surface singly or in groups (random access) in a carefully selected depot site

After deployment to the martian surface
- tubes *cannot* be picked up by *Perseverance* again
- tubes and seals remain viable on Mars (and in orbit) for decades
- maximum temperature on surface <40°C at Jezero and vicinity
- depot location will be known with cm-level precision relative to ground-imaged landmarks
Other Important Considerations

- **Perseverance's**
  - Prime Mission is 1 Mars Year = 2 Earth Years
  - Qualified Lifetime is 1.5 Mars Year = 3 Earth Years

- **Perseverance** has a *capability* requirement to collect 20 samples in Prime Mission
  - drove efficiency improvements over *Curiosity*
    - quicker daily operational timeline (ultimately to about 5 hours)
    - faster autonav (and new wheels)
    - "land-on" capability with Terrain Relative Navigation (TRN) during landing
"A Jezero to Midway traverse is an ambitious undertaking with enormous potential for scientific discovery and for preparing a truly compelling sample cache.

Simultaneously it maintains flexibility to respond to the evolving MSR landscape.

This recommendation is consistent with the final landing site workshop assessment and was unanimously endorsed by the Project Science Group and Project Management"
Mars 2020 Strategic Process

For the last few years, the Mars 2020 Science Team has worked collectively to:

- Critically assess literature and orbital data on Jezero to:
  - develop a thorough working understanding of geologic features
  - create a team-consensus geologic map
  - develop geologic hypotheses and identify open questions

- And based on this study
  - identify tests for hypotheses and key surface-acquirable data to address questions
  - identify the most compelling outcrop locations to address hypotheses/questions
    - consider what questions can be addressed at each outcrop and what observations are likely required
  - identify the most compelling targets for sample collection, mapped to specific MSR questions and objectives (e.g., iMOST and E2E iSAG documents)
    - identify required "field notes" data to adequately document each sample

- And then **Prioritize**
In December 2020, the Science Team held an internal workshop to identify notional traverses that string together prioritized outcrops

- Three different landing site starting locations
- Endpoint ultimately on Nili Planum ("Midway Area")
- Realistic time constraints drove prioritization
- MSR-acceptable depot locations in Jezero and on Nili Planum were required

The result is a set of notional traverses that identify

- The highest priority (and realistically accessible) localities for exploration
- The key questions that can be addressed on such a traverse
- A likely sample cache to be acquired in Jezero, and beyond Jezero

*Of course this is all a planning exercise, subject to change once on the ground…*
**What is "Double Sampling"?**

*Perseverance* is likely to create two depots, only one of which will likely be returned. - notionally, one in Jezero Crater and one somewhere on Nili Planum

The Science Team believes that the only way to have the complete collection in a second depot is to "double sample" critical (all?) samples prior to first depot deployment.

Under extraordinary circumstances the Mars 2020 Science Team may choose to take two samples to increase the amount of mass to be returned to Earth. We might refer to this as "mass enhancement duplication" to distinguish from the above usage of "double sampling".
Witness Blanks

*Perseverance* carries 5 witness tubes:

- Each tube captures an instantaneous picture of the blank environment
- Identical except for one tube that was exposed during launch - cruise - EDL
  - That tube will be sealed sometime in first 90 sols
- Remaining tubes will be deployed at times dictated by events on the ground
  - After possible contamination events
  - After collection of especially promising samples for organics
  - After a defined time has elapsed since last witness blank collection
- It is obvious that one or more witness tubes should be returned to Earth
  - Thought is required in creating multiple depots and or modes of delivery to ensure adequate contamination knowledge is ultimately available
Discussion

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Caching Strategy Considerations

David Spencer, Jet Propulsion Laboratory, California Institute of Technology
Juan Delfa, European Space Agency
Sydney Do, Jet Propulsion Laboratory, California Institute of Technology

January 21, 2021

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The following considerations provide the framework for establishing a caching strategy:

- **In the nominal scenario where Perseverance is healthy at the time of the Sample Retrival Lander (SRL) arrival, it is desirable to have two possible vectors for delivery of samples to SRL: Perseverance and the Sample Fetch Rover (SFR).**

- **SFR is likely to access at most one sample cache and return these samples to SRL.**
  - The SRL surface timeline is limited due to power and thermal constraints.
  - SFR traverse capability is limited to a subset of the paths accessible to Perseverance.

- **Should Perseverance have a scientifically return-worthy set of samples onboard and begin to show signs of failure, there will be motivation to move Perseverance to the nearest depot location to deposit a sample cache.**
Caching Strategy Considerations (2 of 2)

- SFR cannot retrieve samples from inside Perseverance.
- Perseverance cannot retrieve sample tubes previously placed on the surface.
- The Mars Sample Return Program will determine the SRL landing site no later than 9 months prior to SRL’s arrival at Mars.
  - Prior to depositing a sample cache, Perseverance will provide imaging of the candidate landing site for SRL.
- Concept of Operations Guidelines Agreement has been signed by the Mars Exploration Program/Mars 2020 Project and the Mars Sample Return Program.
  - The agreement documents guidelines for depot placement, and characterization of potential landing sites and depot locations by Perseverance.
  - Feedback from this Sample Caching Strategy Workshop will inform future versions of Conops guidelines.
  - Depot placement strategy will continue to be worked in Joint Conops exercises between M2020 and MSR.
The Sample Fetch Rover (SFR) is one of the 3 major elements of the European contribution to MSR.

It constitutes one of the two pathways to bring the samples back to the lander alongside M2020.

SFR Surface Mission must be completed in a limited period of time driven by the landing date and the latest MAS launch opportunity.

SFR design is driven by several factors: power efficiency, fast navigation, autonomous operations, compact volume.
The SFR Surface mission is structured in the following phases:

**Traverse**
SFR would have to cover several kilometers in its return trip from the Landing Site to the Depot and back, driving several hundreds of meters per sol. To comply with the different terrains and the limited time, SFR design is focusing on fast locomotion and high level of autonomous navigation. Among its intended features there is the capability of absolute global localization and fast computation of terrain and navigation data.

**Fetch**
SFR is designed to pick up to 30 tubes from a depot. This is achieved with an onboard autonomous robotic acquisition system (multi dof robotic arm with gripper driven by onboard visual based detection system), capable of identifying the sample tubes (RSTA) in the depot and collecting them without the need of human intervention in a variety of terrains.

**Tube Transfer**
SFR would carry the tubes in the RSTA Storage Assembly, from where they can be easily retrieved by the robotic arm in the lander.

**MAV Launch**
In addition to its primary goal, SFR would also record in video the MAS launch.
• SFR would be constrained to operate within green pathways (benign terrain types with low rock coverage and slopes)
  – Currently mapped by HiRISE, eventually ground truth from Perseverance
• Mapping of the JZW region allows identification of green pathways:
  – Green Zone
    • Flat, smooth regions with little rock coverage as observable from HiRISE images and inferred from interpretation of surrounding geology
    • Suitable for SRL landing (>40 m diameter) and depot creation
  – Green Blobs
    • 4+ Green Zones connected by wide, green drives
  – Green Pairs
    • 2 - 3 Green Zones connected by green drives
  – Green Tendrils
    • 1 green zone, connected by a green drive to a depot area that is outside the pluming radius

Pre-Decisional Information -- For planning and discussion purposes only.
Example Surface Images
Representative of Green Pathways

Class 3: Partial Ripples on Smooth Outcrop/Regolith (ES-2 on Bedrock)

Class 6: Rough Outcrop and/or Rough Regolith, No Ripples (ES-4/Bedrock Mixed)

Class 7: Smooth Outcrop, No Ripples (Bedrock)

Class 8: Smooth Regolith, No Ripples (ES-4)

Pre-Decisional Information -- For planning and discussion purposes only.
Green Pathways Overview

LEGEND
- M2020 Landing Point Cloud
- Green Zones
- M2020 Reference Traverse Path Network (Notional)
- MSR Green Pathways

MDW M2020 Extended Mission Target

M2020 Landing Ellipse

Pre-Decisional Information – For planning and discussion purposes only.
### Example of a Green Pathway

#### Criteria

<table>
<thead>
<tr>
<th><strong>SRL Landing Zone</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions &amp; Terrain</td>
<td>50m x 100m</td>
</tr>
<tr>
<td>Max local:</td>
<td>6°</td>
</tr>
<tr>
<td>Smooth</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Depot Area Dimensions &amp; Terrain</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions &amp; Terrain</td>
<td>50m x 100m</td>
</tr>
<tr>
<td>Max local:</td>
<td>6°</td>
</tr>
<tr>
<td>Smooth</td>
<td></td>
</tr>
</tbody>
</table>

#### Drive from SRL Landing Zone to Depot

<table>
<thead>
<tr>
<th><strong>Straight-Line Distance (for dust pluming)</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>260 ctr-to-ctr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Max slope on drive</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Max CFA on flat</td>
<td>5%</td>
</tr>
<tr>
<td>Max CFA on max slope</td>
<td>CFA5% on 5°</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Ripples on Smooth (Class 3)? How much and how harsh?</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence of Rough Regolith? How much and how harsh?</td>
<td>None</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Concerns?</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
</table>

#### Goals

<table>
<thead>
<tr>
<th><strong>Depot substrate</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depot surface albedo</strong></td>
<td>?</td>
</tr>
<tr>
<td><strong>RSTA local slope</strong></td>
<td>Slightly N facing</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Certified? (Y/N)</strong></th>
<th><strong>Value</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-Decisional Information -- For planning and discussion purposes only.</strong></td>
<td>Y</td>
</tr>
</tbody>
</table>
Example of a Green Pathway
(More Complex, Borderline Case)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRL Landing Zone Dimensions &amp; Terrain</td>
<td>40m x 60m</td>
</tr>
<tr>
<td>Max local: 6°-7°</td>
<td>Smooth</td>
</tr>
<tr>
<td>Depot Area Dimensions &amp; Terrain</td>
<td>45m x 75m</td>
</tr>
<tr>
<td>Max local: 6°-7°</td>
<td>Smooth</td>
</tr>
<tr>
<td>Drive from SRL Landing Zone to Depot</td>
<td></td>
</tr>
<tr>
<td>Straight-Line Distance (for dust pluming)</td>
<td>A-B: 185m ctr-to-ctr</td>
</tr>
<tr>
<td>(likely okay with 8m mound)</td>
<td></td>
</tr>
<tr>
<td>Max slope on drive</td>
<td>&lt;10°</td>
</tr>
<tr>
<td>Max CFA on flat</td>
<td>10%</td>
</tr>
<tr>
<td>Max CFA on max slope</td>
<td>10% on 5°</td>
</tr>
<tr>
<td>Distance through CFA10%</td>
<td>50m</td>
</tr>
<tr>
<td>Ripples on Smooth (Class 3)?</td>
<td>None</td>
</tr>
<tr>
<td>How much and how harsh?</td>
<td></td>
</tr>
<tr>
<td>Presence of Rough Regolith?</td>
<td>Yes, but benign for up to 50m</td>
</tr>
<tr>
<td>How much and how harsh?</td>
<td></td>
</tr>
<tr>
<td>Concerns?</td>
<td>None</td>
</tr>
<tr>
<td>Goals</td>
<td></td>
</tr>
<tr>
<td>Depot substrate</td>
<td>No - Regolith</td>
</tr>
<tr>
<td>Depot surface albedo</td>
<td>?</td>
</tr>
<tr>
<td>RSTA local slope</td>
<td>Mostly flat</td>
</tr>
<tr>
<td>Certified? (Y/N)</td>
<td>Y (but track bottleneck)</td>
</tr>
</tbody>
</table>

Terrain Layer Legend
- Low slope CFA10% requiring ~50m GITL for a ~Ø55cm SFR
- Preferred Depot
- 8m high mound
- Preferred SRL Landing Spot
- 185m

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Discussion

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Draft Decision Guidelines

Michael Meyer, on behalf of the CSSC team

Jan. 21, 2021
1. Prior to beginning the climb to the crater rim, the Mars 2020 team will create an initial depot at a green zone within Jezero if a scientifically return-worthy (SRW) sample collection has been acquired.

Rationale: The traverse from Jezero crater to the crater rim is through difficult terrain, and the traverse path lengths between green zones are ~5 km or greater. As a risk reduction measure, an initial depot should be placed before attempting the climb out of Jezero crater. If the set of samples acquired prior to exiting Jezero is not SRW, the samples should be retained for future depot placement, or for direct delivery to SRL.

* In this context, a green zone is one of many MSR-defined potential depot locations that is connected via a green path to a potential SRL landing zone.
2. At the discretion of the Mars 2020 team, duplicate sampling will be implemented for select high-value samples to enable the establishment of the initial depot, while retaining duplicate samples for later depot placement or retention on-board Perseverance for direct delivery to SRL.

Rationale: Acquiring duplicates of select samples preserves maximum science value of both the initial depot and any subsequent depot or direct delivery to SRL.
3. While Perseverance remains healthy, a set of samples with high science value will be retained on-board.

Rationale: This approach allows the potential for direct delivery of high science value samples from Perseverance to SRL, and mitigates the risk of potential SFR failure. Perseverance does not have the capability to pick up sample tubes placed on the surface, so if SFR fails, any samples previously placed on the surface by Perseverance are not recoverable.
4. If Perseverance contains a SRW sample collection and experiences significant degradation that could result in compromised mobility or sample placement capability, Perseverance will be moved to a green zone and will create a depot. The urgency of this effort will be commensurate with the perceived risk, including details of Perseverance health, the science value of samples on board Perseverance, and whether a SRW cache has already been deposited.

Rationale: Loss of mobility or depot placement capability could result in the absence of a SRW cache as target for SRL.
Recommended Updates to Depot Placement Guidelines

Review by the Caching Strategy Steering Committee has resulted in the following recommended updates to the guidelines:

- Update Guideline 1 to state that a depot will be placed prior to completion of the Perseverance qualified lifetime and before departing Jezero Crater.
- Remove phrasing "high value samples." All samples collected will be high value.
- Combine Guidelines 3 & 4 into a single guideline.
- Clarify that in the nominal scenario, a SRW depot may be placed for retrieval by SFR, and a SRW sample set may be directly delivered by Perseverance to SRL.
1. Prior to beginning the climb to the crater rim or before reaching the Mars 2020 qualified lifetime of 1.5 Mars years, the Perseverance team should create an initial depot at a green zone within Jezero Crater of a scientifically return-worthy (SRW) sample collection.

Rationale: The traverse from Jezero crater to the crater rim is through potentially difficult terrain, and the traverse path lengths between green zones are ~5 km or greater (see slide 19). As a risk reduction measure, an initial depot should be placed before attempting the climb out of Jezero crater. Similarly, to reduce risk associated with hardware failure, this cache should be deployed within the qualified lifetime of Perseverance.

If the set of samples acquired prior to exiting Jezero and within the qualified lifetime is not SRW, the samples should be retained for future depot placement, or for direct delivery to SRL.

See Slide 19

*These are draft revisions for discussion purposes only
2. If the health and priorities of Perseverance enable it to do so, as part of its extended mission, it should assemble a second SRW sample set to be either placed in a second depot or directly delivered to SRL. An important activity to support this strategy is the acquisition of select duplicate samples early in the M2020 mission timeline. This would allow duplicates of some samples to be placed in each of two depots. Decisions related to which samples to duplicate will be managed by the Mars 2020 team.

**Rationale:** Having two sample depots would mitigate a significant program-level risk associated with single point failure. Acquiring duplicates would allow for the potential return of a sample collection that includes samples from both inside and outside of Jezero Crater. This may maximize the science value of both the initial depot and any subsequent sample set deposited or delivered directly to SRL.

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3. To maximize the probability that a sample set the meets or exceeds the SRW threshold will be delivered to the SRL, both possible sample transportation pathways should be kept available whenever feasible. While Perseverance remains healthy, at least some samples should be retained on-board. If Perseverance experiences significant degradation that could result in compromised mobility or sample placement capability, Perseverance should create a depot which is recoverable by SFR, and to which Perseverance could then add samples if it is able.

Rationale: This approach allows the potential for delivery of high science value samples to SRL by SFR and Perseverance. Perseverance does not have the capability to pick up sample tubes placed on the surface, so if SFR fails, any samples previously placed on the surface by Perseverance are not recoverable. On the other hand, SFR cannot retrieve samples directly from Perseverance so loss of mobility or depot placement capability could result in the absence of a SRW cache as target for SRL. The urgency of the effort to remove samples from Perseverance will be commensurate with the perceived risk, including details of Perseverance health, the science value of samples on board Perseverance, and whether a SRW cache has already been deposited.

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Proposed Definition of Scientifically Return-Worthy

Gerhard Kminek, on behalf of the CSSC team

Jan. 21, 2021
1. Scientifically Return Worthy (SRW) is the property of a collection of samples and not the property of an individual sample, except in extraordinary circumstances.

2. Sample suites are a set of astrobiologically, geologically or petrologically related samples.

3. A SRW cache is the minimal collection of samples that could advance our understanding related to major science objectives of MSR described by iMOST, including the history and evolution of Jezero Crater.

4. The definition of a SRW cache applies to any/all caches. Note that a cache can be on the ground (i.e. a depot) or on a rover.

5. We can reasonably expect that a diverse collection of samples from Jezero Crater would satisfy the requirements for an SRW cache.

6. The scientific aim for MSR is to maximize the science return and to go beyond the minimal cache of samples by returning a collection that also includes samples from outside Jezero.
What makes a SRW cache?

1. Distinct sample suites or individual samples selected to represent the diversity of the exploration area and addressing the science objectives of MSR described by iMOST, including the history and evolution of Jezero Crater.

2. *In-situ* data and information to understand the geological context of the samples.

3. Inclusion of one or more witness sample.
Discussion

• We encourage use of the chat box for questions and discussions throughout the workshop. Please keep your microphone muted until you are called on to speak.

• During question and discussion periods comments from the chat box will be relayed by the moderators (Dave Beaty & Brandi Carrier) and people will be called on to speak verbally as time permits.

• Feedback will also be collected after the workshop via a Google form through January 25th:
  https://bit.ly/3bXHR2q
Potential Implications of Draft Decision Guidelines

Albert Haldemann, on behalf of the CSSC team

Jan. 21, 2021
Assemble an SRW cache in Jezero Crater. While doing so, obtain duplicates that will be strategically valuable to a later 2nd SRW sample set. Place Depot #1 at a safe site for SRL/SFR in Jezero. Possibly about 8-12 unique samples/blanks. Leave Jezero or stay? Leave, begin building a 2nd SRW sample cache. Stay (Mars 2020 Decision).
Scenario-Based Implications Summary

**Leave Jezero**
- Begin collecting samples from terrain outside Jezero
- On board cache includes duplicates from Jezero

**Stay in Jezero**
- Continue sampling in Jezero, triggered by spectacular discoveries early in the mission or by vehicle limitations

**Depending on M2020 health, on terrain risks, and on what is found:**
- Hold some of 2nd sample set on M2020
- Establish a new depot
- Add to 2nd depot
- Add to 1st depot
- Establish 2nd depot
- M2020 delivers some samples directly to SRL

**DECISION GUIDELINE #3**
- An SRW sample set ends up at the MAV

**Scenario attributes:**
- SRL lands outside Jezero
- No further interaction w. 1st depot
- SFR recovers 2nd depot
- Option: M2020 delivers some/note of 2nd SRW sample set to SRL
- SRL lands in Jezero
- Option: all samples end up in one depot, (1st SRW is augmented), recovered by SFR
- Option: samples divided between two depots in Jezero; one recovered by SFR
- Option: M2020 delivers some/note of 2nd SRW sample set to SRL

Pre-Decisional - For planning and discussion purposes only
Discussion

• We encourage use of the chat box for questions and discussions throughout the workshop. Please keep your microphone muted until you are called on to speak.

• During question and discussion periods comments from the chat box will be relayed by the moderators (Dave Beaty & Brandi Carrier) and people will be called on to speak verbally as time permits.

• Feedback will also be collected after the workshop via a Google form through January 25th: https://bit.ly/3bXHR2q
Concluding the Workshop, Next Steps

Gerhard Kminek and Michael Meyer

Jan. 21, 2021
Next Steps

• Feedback will be accepted through Monday, January, 25th through the google form (https://bit.ly/3bXHR2q)

• The CSSC will review all feedback from the workshop and the google form and prepare a report with updated recommended decision guidelines for NASA & ESA Review

• The CSSC report will be finalized and made publicly available (targeting the end of February)
Backup Slides

Pre-Decisional Information -- For planning and discussion purposes only.
Green Pathways Development Process

1. HiRISE Image Acquisition

2. and 3. Potential M2020 Traverse Paths and Green Zone Mapping

4. Terrain Classification

5. Mobility Hazard Interpretation & Capability Assessment

6. Green Pathways Scenario Building

Pre-Decisional Information -- For planning and discussion purposes only.
Process for Building Traverse Paths (Steps 2 and 3)

The design of MSR is strongly driven by M2020 Extended Mission Performance. As such, MSR worked with M2020 Science throughout 2019 to develop an understanding of where M2020 could traverse throughout its lifetime. It is expected that this Joint Conops activity will continue to evolve throughout MSR development and M2020 ops.

1. Work with M2020 Science to Understand Locations of Science Targets/Regions of Interest
2. Identify regions of untraversable terrain (ripple fields, scarps, high slopes) that can be used to inform where traverse paths can/cannot access
3. Construct strategic traverse paths connecting science targets that go through the most benign terrains available
4. Search for green zones along and in the general vicinity of the traverse paths
5. Where possible, update the strategic traverse paths to go through/near green zones to minimize overall terrain complexity

Findings
- There is only one route out of JEZ crater and up the crater rim
- There is only one route that connects the Western side of the crater rim to MDW
- During the prime mission, M2020 intends to visit both the top and base of the delta
  - If M2020 lands on top of the delta, it will make its way down to the base before traversing towards the crater rim
- M2020 expects to be in the vicinity of the beginning of the climb to the crater rim (between GZ3 and GZ3a) at the end of its prime mission
Picking Out a Green Pathway

- A Green Zone (suitable for SRL landing) – flat (≤10º) smooth (Class 7 or 8) terrain, at least Ø40m area, no visible rock (to ensure ≤19cm tall SRL obstacle constraint)
- A suitable depot area
  - Ideally flat (≤10º) smooth (Class 7 or 8) terrain
    - 1 visible rock or sand ripple every ~20m acceptable
  - Area:
    - If green zone: minimum Ø40m
    - If tendril: min 15m x 300m
  - At least 220m away from SRL landing spot
    - We are tracking candidate green pathways that have separation distances down to 100m
- A green drive connecting the identified potential SRL landing spot and depot area

Each green pathway candidate is reviewed in a “Terrain Party” where a multidisciplinary team of geologists, system engineers, mobility experts, and rover ops planners jointly examine and decide whether or not to certify a candidate.
Survey of green pathways has yielded numerous sites distributed across the Jezero-Midway region that are suitable for landing and depot placement:
- 36 green pathways identified. 16 of these delivered to SFR as representative (bounding) cases for performance evaluation.
- Roundtrip traverse distances are < 4 km.

A preliminary assessment of the one-way traverse timeline for SFR is ~35 sols, including operational margins:
- Detailed timeline analysis for each of the 16 representative traverse paths is currently being developed.

Overall Assessment: The green pathways approach provides a viable strategy for accessing depots from safe SRL landing sites. Depot placement strategy is integral to this approach.

### SFR Traverse Requirements

<table>
<thead>
<tr>
<th>Ref Path</th>
<th>Traverse Start</th>
<th>Traverse End</th>
<th>Region</th>
<th>Location</th>
<th>Rationale for Inclusion as Reference Path</th>
<th>Dominant Terrain Classes</th>
<th>Slope</th>
<th>Rocks</th>
<th>One-Way Distance [km]</th>
<th>Concern [meters]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1a</td>
<td>Jezro Floor</td>
<td>West Landing Strip</td>
<td>Example of Landing Strip Green Blob</td>
<td>100% N/A N/A</td>
<td>Green</td>
<td>100%</td>
<td>N/A</td>
<td>1.43</td>
<td>0</td>
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<tr>
<td>2</td>
<td>2k</td>
<td>Jezro Delta</td>
<td>Near the On-Ramp, Transition from Jezro Delta to W Jezro</td>
<td>Unique strategic relevance, otherwise uninteresting</td>
<td>100% N/A N/A</td>
<td>N/A</td>
<td>0.61</td>
<td>0</td>
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<tr>
<td>3</td>
<td>2p</td>
<td>Jezro Delta</td>
<td>South of Kilometer Crater</td>
<td>Largest number of rough/rocky segments in one green pathway</td>
<td>55% 22% 17%</td>
<td>N/A</td>
<td>1.05</td>
<td>180</td>
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<tr>
<td>7</td>
<td>2c</td>
<td>Jezro Delta</td>
<td>Northeast Delta</td>
<td>2nd longest traverse, also includes rocky segments</td>
<td>76% 24% N/A</td>
<td>N/A</td>
<td>1.60</td>
<td>54</td>
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<td></td>
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<tr>
<td>8</td>
<td>11d</td>
<td>Jezro Delta</td>
<td>Northeast Delta</td>
<td>Example of partial risples on smooth</td>
<td>42% 35% 23%</td>
<td>N/A</td>
<td>1.45</td>
<td>0</td>
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<td>10</td>
<td>11h</td>
<td>Jezro Floor</td>
<td>Jezro floor north of main delta</td>
<td>Worst UHF relay visibility due to south horizon mask</td>
<td>59% 41% N/A</td>
<td>N/A</td>
<td>0.80</td>
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<td>13</td>
<td>2n</td>
<td>Jezro Delta</td>
<td>Northwest Jezro</td>
<td>Unique strategic relevance, rocky/slope bottleneck</td>
<td>84% 9% 8%</td>
<td>N/A</td>
<td>0.48</td>
<td>46</td>
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<td>15</td>
<td>3f</td>
<td>N Jezro</td>
<td>Far western Channel</td>
<td>Unique strategic relevance, high slopes, poor UHF visibility</td>
<td>100% N/A N/A</td>
<td>N/A</td>
<td>0.54</td>
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<td>16</td>
<td>3g</td>
<td>Crater Rim</td>
<td>North Crater Rim</td>
<td>Longest traverse</td>
<td>96% 2% 1%</td>
<td>N/A</td>
<td>1.77</td>
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<td>17</td>
<td>4a</td>
<td>Crater Rim</td>
<td>Central Crater Rim</td>
<td>Highest slope traverse</td>
<td>88% 8% 5%</td>
<td>N/A</td>
<td>1.32</td>
<td>75</td>
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<td>20</td>
<td>4d</td>
<td>Crater Rim</td>
<td>South Crater Rim</td>
<td>Example with large fraction of benign rough outcrop</td>
<td>51% 26% 21%</td>
<td>N/A</td>
<td>1.00</td>
<td>31</td>
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<td>21</td>
<td>5h</td>
<td>Intereclipse</td>
<td>North Intereclipse</td>
<td>Unique strategic relevance, small patch of smooth fractured</td>
<td>58% 21% 17%</td>
<td>N/A</td>
<td>0.68</td>
<td>108</td>
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<tr>
<td>24</td>
<td>5d</td>
<td>South Crater Rim Block</td>
<td>Example of South Crater Rim Block, small patch of rough terrain</td>
<td>91% 9% N/A</td>
<td>N/A</td>
<td>1.21</td>
<td>101</td>
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<td>6c</td>
<td>Intereclipse</td>
<td>Central Intereclipse</td>
<td>Unique strategic relevance and a rough/slope bottleneck</td>
<td>100% N/A N/A</td>
<td>N/A</td>
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<td>51</td>
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<td>27</td>
<td>7a</td>
<td>Intereclipse</td>
<td>East Side of Utopia Green Blob</td>
<td>Example of Utopia Green Blob</td>
<td>79% 20% N/A</td>
<td>N/A</td>
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<td>36</td>
<td>10c</td>
<td>MDW</td>
<td>South MDW</td>
<td>Example of MDW, example of smooth outcrop</td>
<td>55% 27% 17%</td>
<td>N/A</td>
<td>0.94</td>
<td>0</td>
<td></td>
<td></td>
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</tbody>
</table>
CSSC Membership

→ NASA MSR science lead: Michael Meyer
→ ESA MSR science lead: Gerhard Kminek

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→ Mars 2020 Program Scientist: Mitch Schulte
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