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A PROPOSED JOINT NASA-ESA ARCHITECTURE FOR THE RETURN OF MARTIAN SAMPLES

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1. Introduction

The analysis in Earth laboratories of scientifically selected samples returned from Mars has been a long-standing priority of the Mars science community and would enable investigations far beyond the capabilities available to *in situ* instruments. The National Research Council's most recent planetary science decadal survey [1] strongly endorsed the objective of Mars Sample Return (MSR) and placed a caching rover mission, the first element of a multi-mission MSR campaign, as its highest priority flagship mission for the decade 2013-2022. That sample caching mission is now under active development as NASA's Mars 2020 Rover mission and is currently scheduled for launch in July-August 2020.

On April 26, 2018, NASA and ESA signed a Statement of Intent [2], declaring that "NASA and ESA intend to develop a joint MSR plan and to complete the studies needed to reach the level of technical and programmatic maturuity required to pursue an effective partnership, specifically defining the respective roles and responsibilities sufficient to lead to an international agreement between the two agencies in time to be submitted for approval to their respective authorities at the end of 2019."

This abstract refers to the MSR science objectives identified by the International MSR Objectives and Samples Team (iMOST) [3], and presents the high-level reference architecture of the MSR campaign, which forms the basis on which ESA and NASA have been performing joint studies since early 2018.

2. MSR Science Objectives

Building on previous studies and incorporating recent research, science objectives that could be accomplished with returned samples from Mars were detailed by the iMOST co-authors in 2018 [3].

These objectives, summarized in Table 1, were flowed through to specific scientific measurements that could be made on Mars samples. Such measurements will be supported in terms of geologic context by in-situ science performed on sample material by NASA's Mars 2020 rover mission, as it caches samples at the Jezero/Midway landing site. Collectively, this large body of potential measurements represents a fundamental next step in advancing our understanding of Mars, the history of the inner solar system and our preparations for future robotic and human exploration.

Table 1: Major science objectives from the iMOST report

1) Interpret the primary geologic processes and history that formed the Martian geologic record, with an emphasis on the role of water.
2) Assess and interpret the potential biological history of Mars, including assaying returned samples for the evidence of life.
3) Quantitatively determine the evolutionary timeline of Mars.
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.
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.
6) Understand and quantify the potential Martian environmental hazards to future human exploration and the terrestrial biosphere.
7) Evaluate the type and distribution of in situ resources to support potential future Mars exploration.

3. The MSR reference architecture

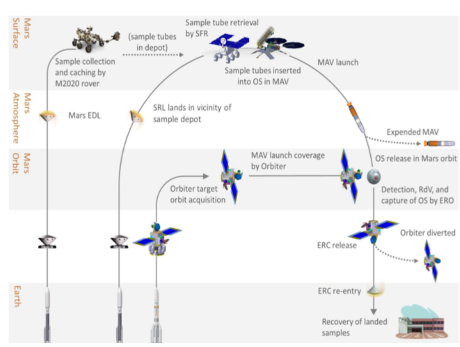

Figure 1: Notional MSR reference architecture for a proposed joint NASA-ESA MSR campaign

The architecture would be based on three major flight elements and one ground element as depicted in Figure 1. The flight elements would include the Mars 2020 sample caching rover, a Sample Retrieval Lander (SRL) and an Earth Return Orbiter (ERO); once samples would arrive at Earth, the Mars Returned Sample Handling (MRSH) ground element would be responsible for sample recovery, sample receiving and long-term sample curation. We briefly describe each element below.

Mars 2020: The Mars 2020 rover mission, which would be the first element of this campaign, is already in full flight development and is planned for launch in 2020 with a nominal 1.25 Mars-year mission to collect, analyse and cache samples for possible later retrieval. Mars 2020 has selected Jezero Crater as its landing site; in an extended mission the rover could climb out of the crater and traverse towards the Midway landing site to explore a separate geologic unit. Selected samples will be cached in one or more depot locations on Mars, for subsequent retrieval. Mars 2020 could also retain some samples onboard and independently deliver them to the Sample Retrieval Lander.

Sample Retrieval Lander: The Sample Retrieval Lander (SRL) element is assumed to be led by NASA and would carry the Mars Ascent Vehicle (MAV), as well as two ESA-provided elements, the Sample Fetch Rover (SFR) and the Sample Transfer Arm (STA). SRL would be responsible for deploying the SFR to retrieve samples cached by Mars 2020 at one or more depot locations, receiving additional samples retained on and independently delivered by Mars 2020, using the STA to load these into an Orbiting Sample (OS) container on the MAV, and launching the OS into low Mars orbit.

Earth Return Orbiter: The Earth Return Orbiter (ERO) element is assumed to be led by ESA and would carry a NASA-provided Capture, Containment, and Return System (CCRS) including an Earth Entry Vehicle (EEV). ERO would be responsible for locating the OS in Mars orbit, rendezvousing with and capturing the OS, securely containing it, tranfering it to the EEV, and returning to Earth to release the EEV towards a selected landing site.

Mars Returned Sample Handling: MRSH responsibilities would include initial recovery of the EEV at the Earth landing site, transport to a secure Sample Receiving Facility for sample safety and initial science assessments, and ultimately to one or more Sample Curation Facilities.

A key driver for the MSR campaign will be the backward planetary protection requirements, as it falls under the COSPAR Category V "Restricted Earth Return" categorization.

4. Campaign Timeline

For the purposes of the joint studies, launch dates as early as 2026 for both the SRL and ERO missions are being considered. The tightly coupled nature of the SRL and ERO missions demands close coordination of the mission design for each element. As a representative example, Figure 2 illustrates a notional timeline for SRL and ERO in which both missions would launch in the 2026 Mars launch opportunity. The SRL surface mission would be phased to take place during the Martian northern hemisphere spring/summer seasons and to avoid dust storm seasons. This scenario would call for a MAV launch in 2029, an ERO departure from Mars in 2030, and delivery of samples to Earth in 2031.

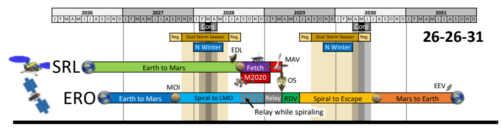

Figure 2: Notional MSR timeline, illustrating a scenario with SRL and ERO launching in 2026 and with samples returned to Earth in 2031

The information provided about possible Mars sample return architectures is for planning and discussion purposes only. At the time of writing, NASA and ESA have made no official decision to implement Mars Sample Return.

Acknowledgements

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