Options for post-landing extraction of solid-core samples from the NASA-ESA Mars Sample Return mission.

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NASA-ESA are planning to collect and transport from Mars to Earth a set of samples of martian materials for the purpose of scientific investigation [1]. The samples will have been collected by the Perseverance Rover [2] and consist of a variety of rocks, regolith, and atmospheric gas. Samples will be contained within Ti sample tubes, which will be sealed at the martian surface with a compression-style cap.

The rocks sampled thus far collected by the Perseverance Rover comprise magmatic rocks like basalt and olivine cumulates that experienced various degrees of secondary aqueous alteration, water-laid detrital sedimentary rocks that show various levels of induration, and regolith that could contain grains originating from outside the Jezero region. Additional samples may include hyrothermal rocks or impact breccias. Two main considerations weigh on the strategy that should be adopted for opening the sample tubes when returned on Earth:

1. Important information is contained in the vertical successions and textural characteristics of layers in sediments, which can provide important clues for interpreting the depositional setting. For example, in terrestrial lakes, vertical gradation in grain size can reflect the relative density of depositional and lacustrine fluids or gradations in organic matter content can reflect seasonal changes in biological productivity. Fine laminations can sometimes reflect the presence of microbial mats. The method used for opening the tubes must imperatively preserve those fine structures.
2. Some critical measurements are sensitive to contamination either from the tube, the apparatus used for cutting the tubes, or surrounding potential contaminants present in the isolator. Organic matter is of particular concern given the high stakes involved in any claim for the presence of any form of biotic or prebiotic chemistry on Mars. Inorganic trace element isotopes may provide dates on when Mars was habitable, and these are also vulnerable to contamination. Magnetic contamination should also be minimized during cutting operation and sample handling.

Beginning in 2022, an engineering team was tasked with developing the processes needed to open the sample tubes and to extract the solid and gaseous samples. The engineering team was asked to develop engineering priorities associated with this process. Two science teams were asked to develop parallel science priorities: The “Gas Team” evaluated the priorities related to all returned gaseous samples (including the head gas), and the “Rock Team” (the authors of this contribution) evaluated the priorities associated with solid materials contained within the sample tubes. Both teams work under the oversight of a third committee, the Mars Campaign Science Group (MCSG).

The solid samples returned from the martian surface will be the basis for answering the main scientific questions of Mars Sample Return [3]. The rock samples will all have been collected from various outcrops (or perhaps very large blocks of float rock). However, at least some of the rocks are relatively weak (*i.e.* low compressive strength), and are vulnerable to fracturing during drilling and during several dynamic events during the return phase (most importantly, at Earth landing). The regolith sample is unconsolidated. It is anticipated that the mechanical state of each sample, as received in the laboratory on Earth, will be assessed by a method like computed tomography (CT) scanning prior to opening. The decision on how to open each sample tube can therefore be based on geological data collected by the M2020 team, tests done on analogue samples, as well as the penetrative imaging data obtained on Earth during basic characterization.

Finding: The Rock Sample Team concludes that a single approach will not be applicable to all the rock samples returned, but instead a flexible and bespoke approach will be needed for each sample tube opening, with all three of the above options available. As a general principle, minimal cutting is favoured as this will also minimize potential contamination. However, an overriding consideration is that the structural integrity of the rock sample is key to understanding its petrology, and this should remain intact, even if this requires more processing.

For regolith samples, a single radial cut followed by tipping out the grains is likely to be appropriate, since this will minimize contamination and there is no need to preserve spatial relationships within the tube. For well consolidated (e.g., some igneous) samples, a radial cut perhaps followed by a second radial cut may be required to extract the sample completely. For sedimentary rocks, and any friable igneous rocks, the decision is more complex because a longitudinal cut may be necessary to observe and preserve structural relationships, but this must be weighed against potentially contributing more contamination.

The physical state of each core (consolidated or friable) will not be known for certain until the samples are bought back to Earth, where CT will reveal the fine structure of the samples and help guide the strategy to be adopted for tube opening. In the next stage of our working group, we will identify analogue samples representing the samples collected by M2020 for engineering and science testing (e.g., related to extracting the solid samples from the tubes).

Disclaimer: The decision to implement MSR will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is for informational purposes only.

[1] G. Kminek, M. A. Meyer, D. W. Beaty, B. L. Carrier, T. Haltigin, and L. E. Hays. Astrobiology, **22** Issue S1-S4 (2022)
[2] K. A. Farley and K. Stack (2022) Mars 2020 Initial Reports, Crater Floor Campaign, August 11, (2022).
[3] iMOST report: https://mepag.jpl.nasa.gov/reports.cfm