POTENTIAL MARS SAMPLE RETURN: THE NEXT REALLY BIG CHALLENGE IN PLANETARY INSTRUMENTATION.

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Introduction: This presentation looks ahead to the possible return to Earth of samples collected by the Mars 2020 mission. We specifically address the measurements and types of instruments that could provide the initial characterization and sample preparation required for planetary protection.

The Mission: The Mars 2020 rover mission has four science objectives that support the goals of NASA's Mars Exploration Program:

Looking for Habitability:	Identify past environments capable of supporting microbial life
Seeking Biosignatures:	Seek signs of possible past microbial life in those habitable environments, particularly in special rocks known to preserve signs of life over time
Caching Samples:	Collect core rock and soil samples and store them on the Martian surface
Preparing for Humans:	Test oxygen production from the Martian atmosphere

The mission design envisions preparing as many as 40 rock, soil, and blank samples, measuring approximately 1 cm in diameter and 8 cm in length, and caching them on the Martian surface. These samples could be retrieved by potential future missions, and could ultimately be transported to Earth for detailed analysis. The samples in the Mars 2020 cache could thus become the first Martian samples to be selected for Earth return based on specific scientific criteria and measurements, and with carefully documented field context.

Between extensive analyses of Martian meteorites and the *in-situ* studies carried out by the Viking, Pathfinder, Spirit, Opportunity and Curiosity landers and rovers we understand a great deal about the materials to be expected in the Mars 2020 landing zone. The Mars 2020 rover will carry a suite of instruments to measure mineralogical and elemental composition as well as surface organics. These measurements will feed into the selection of samples for coring and caching. We anticipate that the materials in the Mars 2020 cache will be the best-characterized planetary samples ever selected.

Planetary Protection: The requirements imposed by international planetary protection policies for any future sample return mission from Mars will be specific to that mission. However, current policies suggest that Mars samples would be carried to Earth in containers designed to prevent any accidental release of samples to Earth's environment. Those containers would only be opened in a sample receiving facility (SRF) with protection equivalent to that of a high-level biosafety laboratory. Initial studies of a representative subset of the samples would be required to determine if they contained extant Martian life, and/or if they represented a hazard to the terrestrial biosphere.

The Challenge: There are two primary candidate strategies for operating the SRF: 1). The human operators are inside biosafety suits, and the instruments are out on benches (or for larger instruments, in the middle of the rooms) and the samples are dealt with in the open; 2). The samples are dealt with inside isolator cabinets, with humans on the outside manipulating them with gloves or robots. Although #2 above is far preferable from the point of view of protecting the unique value of the samples (for example, minimizing contamination), substantial technical questions remain about how to integrate modern high-vacuum, high-voltage instrumentation with a biosafety cabinet. These anticipated requirements present a challenge to laboratory, sample preparation system and instrument designers that is unique in the history of planetary science. We need a technology development program in this area.

The Beginnings of an Approach: The instruments for initial rock and soil characterization in the sample receiving laboratory could be complementary to sample measurements on Mars. These include elemental composition, mineralogy and the presence of organics, all measured at the cm- to mm-scale to support detailed subsampling. In addition, knowledge of the internal physical structures of the rock cores would be an invaluable guide for subsampling. To minimize alteration and contamination, the instruments should require little or no physical contact with the samples. The instruments should be capable of remote operation in a controlled environment which preserves sample pristinity while providing a high degree of biosafety protection.

Mineralogical composition: The major minerals in a rock can generally be determined optically, with the required resolution being determined by the rock's grain size. Visible, UV and near-IR spectrometers, operated thru optical windows, can preserve the samples from alteration and contamination while not interfering with biosafety barriers. Optical spectrometers and spectrophotometers have been flown on numerous planetary missions. The Mastcam-Z instrument on Mars 2020 will help to determine the overall mineralogy of Martian rocks and soils to support rover operations and sample selection.

Such instruments can only sense the samples' surfaces, however, and can be frustrated by optically thick layers of dust or drilling fines. X-ray instruments such as a micro-CT scanner can image mm-scale crystals and show their locations throughout the volume of a rock core. Minerals can be differentiated based on their densities, and the instrument can be calibrated to provide mineral identification. Micro-CT instruments can analyze samples placed in X-ray transparent containers, which can be made compatible with high-level cleanliness and biosafety. A micro-CT system has recently been installed in the curation suite at JSC to characterize the internal mineralogy of lunar and meteorite samples.

Elemental Composition: Identification and characterization of a mineral is considerably enhanced by knowledge of its elemental composition. Non-contact alpha-proton x-ray spectrometers have been flown on all of the Mars rovers to date. The PIXL instrument on Mars 2020 will be an X-ray fluorescence spectrometer that will also contain an imager with high resolution to determine the fine scale elemental composition of Martian surface materials. A modification of this design, operated thru an X-ray transparent window, could provide detailed information on Martian rock and soil cores within the containment of a sample receiving laboratory.

The micro-CT system described above also incorporates detectors which provide X-ray fluorescence analysis. This micro-XRF technology allows the determination of elemental compositions and locations of sub-mm crystals. As noted, this instrument can successfully analyze samples within X-ray transparent containers which could be designed to minimize contamination and provide biosafety protection.

An alternative technique for determining elemental composition remotely is laser-induced breakdown spectroscopy (LIBS). A high-power laser beam interacting with a rock surface produces a plasma with a spectral signature characteristic of the target's composition. The CHEMCAM instrument on Curiosity uses LIBS to analyze rocks at cm to mm resolutions, and could be modified for laboratory use thru an optical window.

Organic analysis: Sample selection for planetary protection would be greatly enhanced by the detection of organic material concentrations. Optical techniques using the natural fluorescence of organics illuminated by specific wavelengths of light have been developed in several laboratories. The SHERLOC instrument on Mars 2020 is a spectrometer that will provide fine-scale imaging and uses an ultraviolet laser to determine fine-scale mineralogy and detect organic compounds. SHERLOC will be the first UV Raman spectrometer to fly to the surface of Mars.

Internal physical structure: The Mars 2020 instruments analyze surfaces, but the core drill will provide samples from as deep as 8 cm into the rock. Knowledge of the internal structure of each core will be critical to the selection of material for subsampling. Cracks and vesicles, perhaps not visible from the sample surface, could provide the most promising sites for the preservation of organics or past life. A micro-CT scanning instrument, discussed above, could provide three-dimensional maps of the internal structure of rocks at the sub-mm scale.

Subsampling: Subsampling soil and rock are two very different challenges. Asteroid dust particles collected by the Hayabusa mission, many smaller than 100 μm, are selected and mounted for analysis in JAXA and NASA curation laboratories. The work is done using micromanipulators inside nitrogen gloveboxes.

Removing selected portions of rock from a core held in biological isolation has yet to be demonstrated. However, computer-controlled microsurgery is an advancing field with technologies clearly applicable to geological investigations.

Looking Ahead: The possibility that samples selected and cached by the Mars 2020 mission could one day be brought to Earth brings issues of sample integrity, contamination and planetary protection into sharp focus. In the case of Mars 2020, the technologies for analyzing, collecting and caching the samples on Mars are essentially locked in. The technologies for dealing with the samples if they are one day brought to Earth, however, require considerable advance planning, laboratory and instrument development, and verification.

We have outlined one approach to one part of the problem – providing data sufficient for planetary protection subsampling. We strongly recommend that a program of laboratory and instrument development be initiated, in order to be ready if the people of Earth are ready to receive samples from the planet Mars.