CONTAMINATION KNOWLEDGE STRATEGY FOR THE MARS 2020 SAMPLE-COLLECTING ROVER.

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Introduction: The Mars 2020 rover will collect carefully selected samples of rock and regolith as it explores a potentially habitable ancient environment on Mars. Using the drill, rock cores and regolith will be collected directly into ultraclean sample tubes that are hermetically sealed and, later, deposited on the surface of Mars for potential return to Earth by a subsequent mission. Thorough characterization of any contamination of the samples at the time of their analysis will be essential for achieving the objectives of Mars returned sample science (RSS). We refer to this characterization as contamination knowledge (CK), which is distinct from contamination control (CC). CC is the set of activities that limits the input of contaminating species into a sample, and is specified by requirement thresholds. CK consists of identifying and characterizing both potential and realized contamination to better inform scientific investigations of the returned samples. Based on lessons learned by other sample return missions with contamination-sensitive scientific objectives, CC needs to be "owned" by engineering, but CK needs to be "owned" by science.

Contamination present at the time of sample analysis will reflect the sum of contributions from all contamination vectors up to that point in time. For this reason, understanding the integrated history of contamination may be crucial for deciphering potentially confusing contaminant-sensitive observations. Thus, CK collected during the Mars sample return (MSR) campaign must cover the time period from the initiation of hardware construction through analysis of returned samples in labs on Earth. Because of the disciplinary breadth of the scientific objectives of MSR, CK must include a broad spectrum of contaminants covering inorganic (i.e., major, minor, and trace elements), organic, and biological molecules and materials.

The overarching CK strategies and plans for MSR can be broken down into three distinct phases with different implementation, timing, and connectivity to the Mars 2020 Project:

Phase 1. Knowledge of the sate of contamination of the sample-contacting (and potentially-contacting) spacecraft hardware through the time the relevant systems undergo final assembly during com mencement of assembly, test, and launch operations (ATLO). After this point any further contamination can be directly characterized only after samples are returned to Earth.

Phase 2. Knowledge of all aspects of contamination occurring during the Mars 2020 mission up to the point the samples are deposited on the surface.

Phase 3. Knowledge of contamination occurring between the time when the samples are placed on the Martian surface and their ultimate analysis, incuding the following stages: sample retrieval, Earth-return, delivery to the Mars sample receiving/curation facility, preliminary examination/hazard assessment, and scientific analysis.

Acquisition of CK during Phases 1 and 2 is clearly the responsibility of the Mars 2020 science and engineering teams, and the CK strategy for these phases is discussed below. A Phase 3 plan will presumably be developed by the teams associated with the follow-on missions, the receiving/curation facilities, and the analysis laboratories for the returned Mars samples.

General Considerations: The Mars 2020 team defines contamination as any terrestrial substances unintentionally present in the sample tubes or on the samples themselves. We identify two broad modes of contamination that may affect returned samples: substances that are intrinsic to the hardware that contacts the samples, such as the chemical constituents of the sample tube and the drill bit; and substances introduced on to sample-intimate hardware or samples via vapor-phase or particulate transport. The Mars 2020 CK strategy was developed by considering both of these modes and the specific timing and vectors of contamination occurring over the lifetime of the mission.

Phase 1 - Knowledge of the state of contamination up to and at the time of spacecraft assembly will be acquired through a combination of direct measurements of hardware (e.g., chemical analysis of lot-identical components), and measurements of particulate and vapor deposition to which sample-intimate hardware may have been exposed via analysis of, e.g., witness plates and flight-hardware swabs. This effort will include inorganic, isotopic, organic, and biologic measurements, as well as a genetic inventory of microbial contamination. In addition to measurements, the Mars 2020 project will archive relevant lot-identical hardware, witness plates, and swabs for possible future contamination assessment. This undertaking is outlined in the Mars 2020 project curation plan, which will be completed by the Project's Critical Design Review (CDR) in early 2017.

Phase 2 - The CK strategy for Phase 2 is centered on the use of witness tubes, tubes specifically designed and operated to capture known vectors of particulate and vapor-phase contamination to which the samples may be exposed during the mission. These tubes will be identical to sample tubes, but filled with materials selected to passively accumulate contamination. Although still under assessment, likely candidates for this material are alumina and Ti-nitride mesh (because sample tube interiors are also Ti-nitride). Witness tubes will be exposed during the surface mission in the same fashion as the tubes used for sample collection, including exposure to the ambient near-rover environment, rotary percussive actuation of the drill, and passage through the robotic system that evaluates and hermetically seals the tubes. The Mars 2020 mission will carry 6 witness tubes (out of a total complement of ~40 tubes). The schedule upon which these tubes are exposed and sealed during the mission will be at the discretion of the science team. A notional strategy is to seal a tube immediately upon arrival at Mars, and periodically thereafter to capture any evolution of the contamination environment. It may also be desirable to seal a witness tube after acquisition of a particularly interesting sample, e.g. one in which organic biosignatures may be anticipated.

Additional Considerations: An aspect of the Phase 2 CK strategy that has generated substantial debate within the Mars 2020 science team and the broader community is the absence of an ultraclean material to be drilled on Mars, analogous to the organic check material (OCM) on the Curiosity rover. While the Phase 2 strategy captures recognized pathways of contaminantion, it does not completely mimic the sampling process, in particular the abrasive contact between rock and sampling hardware during drilling. While all agree that a drillable blank would be desirable, especially for organic geochemistry, there is a range of opinions among the coauthors of this abstract over the necessity of its inclusion.

In contrast, there is no doubt regarding the engineering complexity, risk, and costs of including such a capability on the rover. A Mars 2020 drillable blank would require a new highly fault-resistant active mechanism to contain the ultraclean material and to expose it only at the desired time (the foil cover of the OCM could not be penetrated sufficiently cleanly by the coring bit to meet the strict Mars 2020 contamination requirements). Additionally, space on the front of the rover, where the drillable blank(s) would have to be mounted, is highly congested by the subsystem which handles the drill bits and assesses and seals the sample tubes; one or at most two single-use drillable blanks were thought possible by the Mars 2020 engineers. Concerns were also raised over the additional mass required to support drillable blanks; landed mass has been an ongoing concern for Mars 2020

The Mars 2020 Project Science team evaluated the trade-offs among these CK strategies individually or in tandem, and concluded that the witness strategy alone could provide adequate CK knowledge when combined with additional approaches to be undertkane in the laboratory. For example, for many contaminant-sensitive species spatially-resolved methods can be used to eliminate contaminantion concerns, as is routinely done with terrestrial samples. In addition, further effort by the Mars 2020 project can eliminate some of the perceived shortcomings of the witness strategy (below). The decision against drillable blanks also led to an increase of five in the number of sample tubes to be carried to Mars.

Concerns over the absence of a drillable blank fall into three areas: 1) the witness blanks do not constrain contaminant transfer coefficients from hardware to samples; 2) additional but currently unknown contamination pathways may be activated during drilling with bit-on-rock that are not captured by the witness tubes; 3) reactions may occur between contaminants and rock during the act of drilling, potentially obscuring their contaminant origin because such reactions are absent in the witness tubes.

All three of these concerns can be at least partially mitigated through laboratory studies using a flight-identical drilling system. For this reason Mars 2020 will create a fully functioning "contamination model" of the drill as part of its CK plan. Mars-analog testing in an ultraclean testbed featuring this device would be invaluable for understanding the modes and characteristics of contamination and reactions occurring in the drill-on rock setting. Testing on Earth has the advantage that geologic materials with a range of properties that encompass those of the samples obtained on Mars can be systematically evaluated, e.g., to develop contaminant transfer coefficients. Similarly, compounds that are detected in returned samples but are potential contaminants can be the focus of dedicated experiments with the testbed using the same analytical protocols employed on the samples themselves. Design and execution of contamination-related experiments on such a testbed could occur over many years as knowledge of the sample suite grows.