9.5 Appendix 5: Evaluation of Draft Mars 2020 Mission Organic Contamination Requirements and Methodologies

This appendix contains a set of working concepts for the eventual Mars 2020 Contamination Control Plan, along with feedback on those concepts from the Organic Contamination Panel. This information is intended to constitute input to the development of the actual plan—this appendix is not the plan itself. Section 1.1 below was prepared by the Mars 2020 project team, and Sections 1.2 and 1.3 constitute feedback on this information by the OCP.

It is important to recognize that these early concepts and ideas are incomplete and that the eventual Mars 2020 implementation will undoubtedly be different in some respects. The Contamination Control Plan will need to interface with many other aspects of the project, and critical project information about these other areas will be determined later. Once the actual Contamination Control Plan has been written, it will supersede everything in this appendix. Future readers should therefore recognize that the information in this appendix will shortly become useful only for historical purposes. In the preparation of this report, we have encountered the confusion this situation can create when trying to understand what Viking and Apollo thought about vs. actually did. Similarly, the feedback material in Sections 1.2 and 1.3 will hopefully be valuable as input to writers of the actual contamination control plan, but afterwards, we strongly encourage readers to refer to the actual plan, not this appendix.

9.5.1 Draft Concepts for a Mars 2020 Contamination Control Plan

The Mars 2020 contamination control program would be based heavily on heritage MSL practices so as to leverage the similarities between the two missions. Despite the similarities however, there are a number of differences between MSL and Mars 2020: Some key similarities and differences are listed in Table 9.

MSL constructed a contamination control program intended to enable the in-sample contamination requirements for the SAM instrument. From the science and engineering requirements, requirements are derived for surface cleanliness of the sample transfer chain, the Rover in general, and the remainder of the flight system and launch vehicle interface. The flight system would be separated into 'contamination zones' based on an assessment of the efficiency of potential transport of (terrestrial) contaminants to the samples collected. An example of the concept used on MSL is shown in Figure 21. Hardware comprising the solid sample acquisition system could be identified as 'Zone-1," having the highest potential opportunity to contamination solid samples; regions further removed from the sample path are designated as lower risk, therefore allowing a relaxation of hardware cleanliness requirements relative to Zone-1.

A similar requirements derivation process would be applied to the Mars 2020 system, with the proposed encapsulated samples as the driving element of system contamination sensitivity. Focused mitigations would be applied to meet the contamination sensitivity of the other payloads and engineering systems comprising the mission.

As with MSL, Mars 2020 would identify all foreseeable locations or transport paths for contamination to get into the sample, and formulate a valid, verifiable requirement on it based on a credible transport mechanism model. The vectors for potential introduction of terrestrial contaminants into sealed samples are presented pictorially in Figure 21. Also in common with MSL, contamination transport models would play a role in the Mars 2020 mission. That said, it is worth emphasizing that the Mars 2020 sample transfer chain, including the samples and their unique cleanliness constraints, would be dramatically different from the MSL system. While some of the underlying generalized physical models of contamination transport used to conduct MSL analyses (e.g., free molecular flow in the vacuum regime; convection and diffusion for surface operations) apply to Mars 2020, these must be tailored to the specific science objectives, configurations (with special emphasis of non-heritage elements), environments, and contamination vectors of the Mars 2020 mission.

Table 9. Some Similarities and differences between MSL and Mars 2020

Similarities	Differences
• Similar process used to produce requirements for allowable in-sample contamination – OCSSG in the case of MSL – OCP in the case of Mars 2020 From the start, the Project acknowledgement of the importance of contamination control to the success of achieving mission objectives • The system architecture is highly similar for both missions; configuration largely decouples sample cleanliness from rest of the flight system • Modeling tools and methodologies for flight and surface operations used on MSL are applicable to Mars 2020 • System-level contamination control approach emphasizes control and knowledge (characterization) of contaminants • Contamination transport models play a role in verification • Close coordination between CC and PP	• Mars 2020 is able to leverage heritage from a very similar recent mission • Much simpler sampling system • Sampling system is a result of a long technology program with cleanliness a key driving factor • Different PP requirements, associated with sample cache, for both bioburden and organic contamination • Expected minimal use of dilution cleaning • Challenging cleanliness requirements for the Cache; implications for Flight System • May have additional contamination vectors in the form of: Additional numbers or different composition of calibration targets Addition of in-situ Resource Utliization payload element which processes gases and would add to the "plume" of contamination around the rover Different thermal paint Potential differences in drill seal material

In addition, there would be a particular focus on fault tolerance to identify points in the design that may present a risk to Science objectives in the event of an anomaly. This process may be informed by ground-based hardware development tests using flight-like hardware and contaminant analogs.

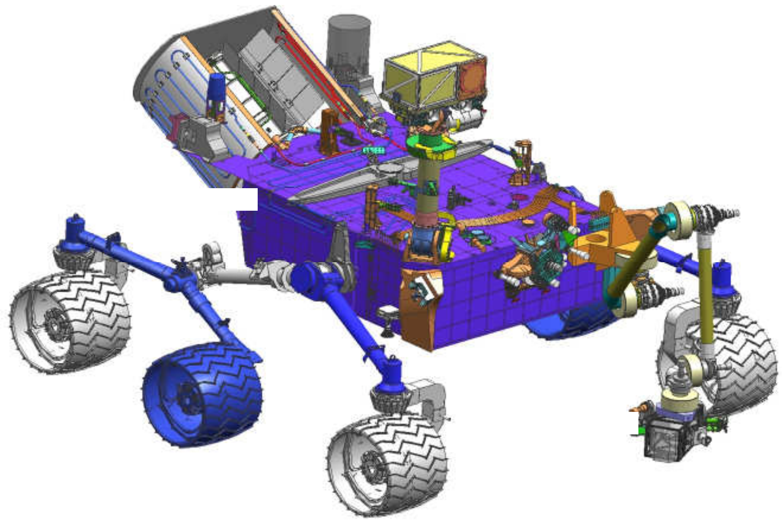

__Figure 21:__ Contamination Zones on MSL

Zone 1: Closest proximity to SAM solid and atmospheric inlets. Includes sampling system, arm and everything forward of the Rover suspension rocker.

Zone 2: Includes everything on the exterior of the Rover aft of the suspension rocker; extends upward to the descent stage when flight system in cruise configuration.

Zone 3: Inside the Rover chassis (WEB)

Zone 4: Everything else

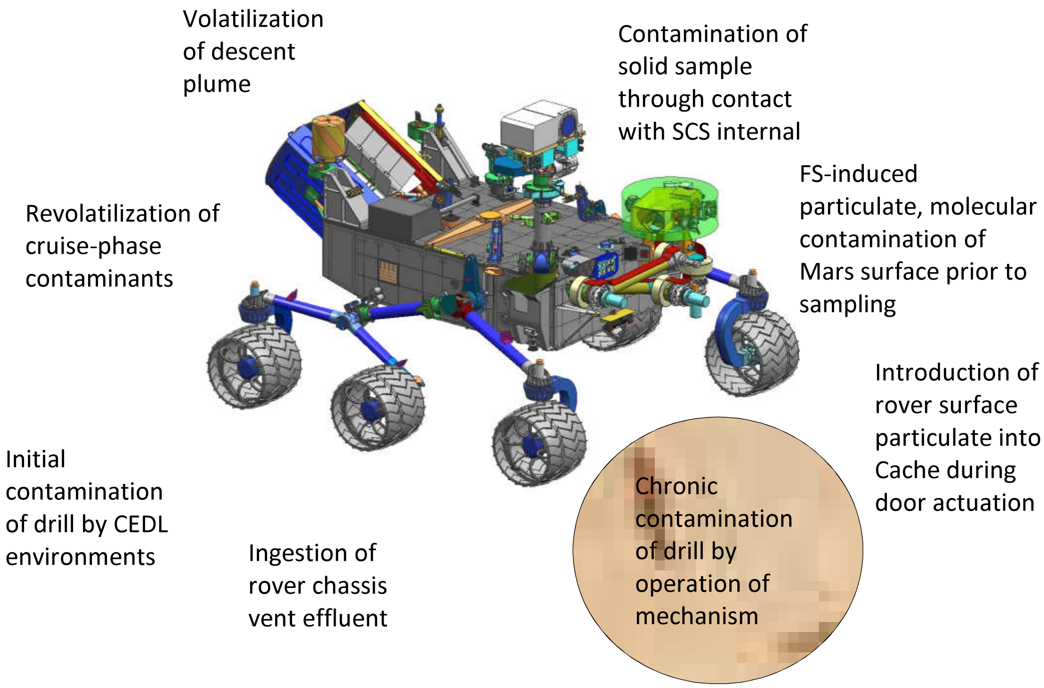

__Figure 22.__ Vectors for potential introduction of terrestrial contaminants into cached samples.

9.5.1.1 Science and Contamination Requirements Linkage

Contamination transport models provide the linkage between the science requirements and the hardware cleanliness requirements. Bounding calculations are used to derive conservative hardware cleanliness requirements—outgassing and surfaces—from the driving Science requirements. A rigorous and systematic program of direct measurements of hardware cleanliness is planned to verify compliance at the component, sub-system and system levels. The formal hardware delivery process requires documentation of compliance with CC requirements before acceptance of hardware for higher level integration. Measured values for hardware cleanliness subsequently become inputs to the transport models as an element of the verification process showing that the as-flow system enables the science requirements.

9.5.1.2 Design Process

The Mars 2020 project has articulated a system architecting and design process that emphasizes the vital importance of achieving a high degree cleanliness for the samples (Fig. 22). The Mars 2020 system architecture exploits the decoupled nature of the sampling system from the rest of the flight system. Further, there has been placed a special emphasis on controlling or eliminating potential sources of contamination within the hardware elements that make up the sample caching system (SCS). Contamination control is an integral aspect of the SCS design trades currently underway; this is an iterative process wherein allowable in-sample contamination levels and contaminant transport mechanisms inform the design process and function as one of the discriminating criteria amongst competing designs within the trade space.

9.5.1.3 Hardware cleaning

The Mars 2020 project as undertaken an extensive literature search to learn the lessons from Apollo, Viking, Genesis, and other missions (and other industries which require elevated levels of cleanliness) with respect to cleaning flight hardware cleaning methodologies. (Many of relevant references are included elsewhere in this report.) The Project has also been kept informed of institutional technology development efforts in the areas of cleaning and recontamination prevention. The project has taken ownership of some of the more promising activities and would be deciding which to carry forward in further development. At this time, the specific cleaning methods have not been selected. However, whatever process ultimately selected would be validated against the Tier-I, Tier-II contaminants identified elsewhere in the report. A notional process flow for cleaning and acceptance of critical sample contact hardware is shown in Figure 24. To prevent recontamination after cleaning, no polymeric bagging materials would be allowed to come into direct contact with SCS hardware: fired foil or stainless steel containers would be allowed.

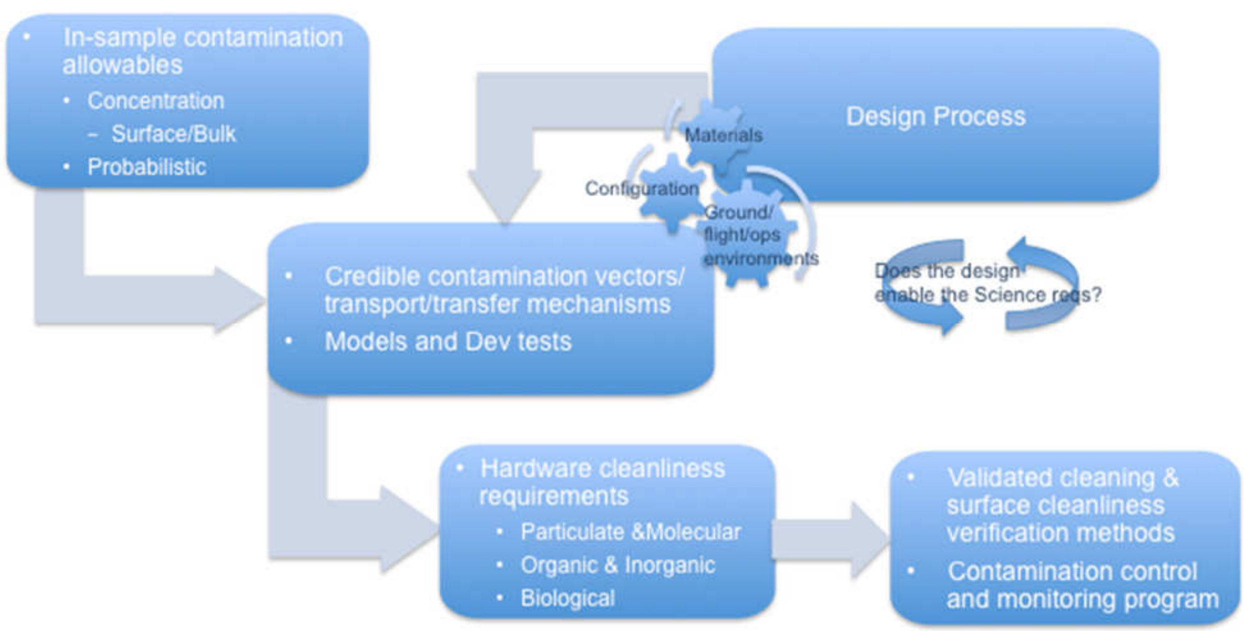

__Figure 23.__ The system architecting and design process emphasizes the vital importance of achieving a high degree cleanliness in samples taken for the Cache.

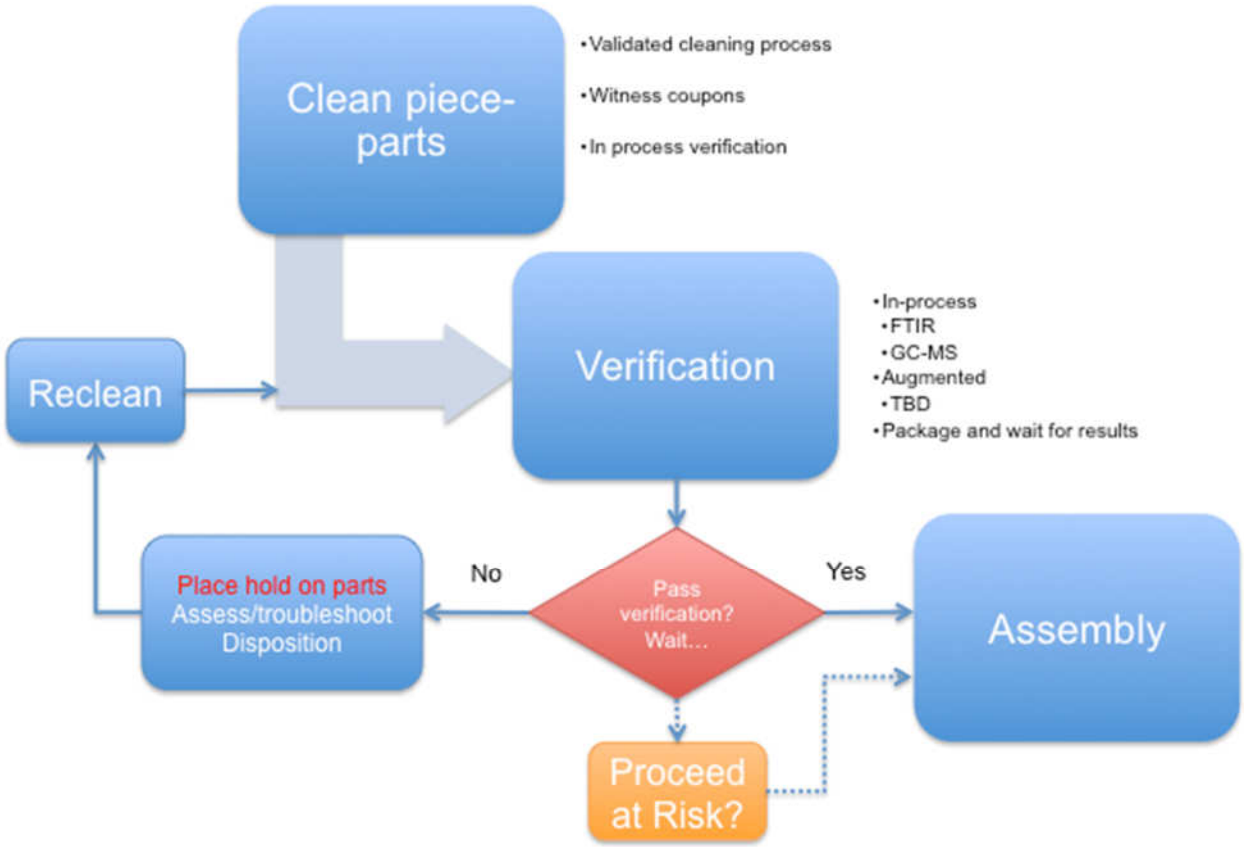

__Figure 24.__ Notional process flow for cleaning and acceptance critical sample contact hardware.

9.5.1.4 Sample System Development

The Mars 2020 project plans to undertake sample system hardware development under Class 1000 (FED-STD-209 Class M4.5; ISO 14644-1 Class 6) protocols. No co-location with other projects would be permitted and the facility would be accessible only by trained personnel. If the venue is to involve the conversion of an existing facility, the facility would first be surveyed to determine whether the native contamination background is acceptable with respect to cleanliness needs of the hardware processing activity or whether a prospective facility can be brought into compliance with project cleanliness requirements. It is anticipated that the development of the sample system would take place off-line in parallel with flight system development (notionally depicted in Fig. 24) so as to maintain a higher level of contamination control until it is integrated late in the system integration flow at the launch site.

It is anticipated that system-level assembly test operations would be conducted in an existing facility operated under Class 10000 (or better) protocols. Real-time monitoring of airborne particulate and similar capability on-line for condensables is planned. The Project is investigating implementation of real-time particle fallout monitoring (http://www.pmeasuring.com).

Figure 24. *Notional parallel paths for sample system development and flight system development, with late integration into the flight system.*

9.5.1.5 Witness plates, Controls & Blanks

The Mars 2020 project recognizes the importance of witness coupons in establishing an adequate data set describing the potential contamination background in returned samples. A comprehensive witness coupon monitoring program would be designed into the hardware processing flows. The design of the monitoring program must be purposeful and provide sufficient contamination knowledge, while at the same time be implementable. Witness plates would follow critical hardware through cleaning process for cleanliness verification. These coupons or analysis results would be archived. Analysis of terrestrial and flight system contaminant sources would be performed and an archive of flight system materials would be collected as a reference for contamination signatures. The Project expects to leverage the lessons and practices of other space sample curation facilities and described elsewhere in this report.

9.5.1.6 Hardware Cleanliness Verification

A suite of measurements have been identified as the set of measurements to be done for cleanliness verification of critical sample system hardware (Table 10); critical being defined as that which contacts sample and or has a credible direct path to samples.

Sampling of surfaces for cleanliness verification is always challenging. So-called analyte recovery efficiency needs to be taken into consideration. Sampling strategy would be determined when requirements are defined, however several novel methods are available for consideration:

- Experiments using solvents show the swab sampling efficiency to be ~70% for adventitious carbon. (The Project is currently performing experiments with slightly acidic solvents that would dislodge the last monolayer; noting the organic acids reacting with the metal surface forming organic acid salts are the most common, tightly bound form of AC.)

- Witness plates can be measured directly with no solvents via GA-ATR FTIR. The GA-ATR can readily monitor the sampling efficiency of other analytical methods.
- It is possible to abrasively sample surfaces using KBr powder and avoid solvents altogether for DRIFT/FTIR. This method has shown a very high sampling efficiency (90% +)

Table 10 Broad-spectrum assay procedures to detect organic contamination

	Sample Treatment	**Extract treatment**	**Calibration Method**	**Concern Trigger**	**Comments**
Surface spectroscopic imaging	none	NA	?	>1ng/cm^2	Detects fibers, organic particulates, macromolecular OM
FTIR-Microscope/Raman microprobe	Direct	N/A	Known compounds	TBD	Detects fibers, organic particulates, macromolecular OM
Gas Chromatography-High Resolution Mass spectrometry	IPA/DCM wash	Ionization by electron impact, analyze by scanning MS	External standards	>10 ng/g	Detects polar molecules such as hydrocarbons, chlorinated solvents, plastics, etc
DRIFT (FTIR)	swab/rinse	Deposit on KBr	Known compound classes	TBD	Sampling ε can be referenced to direct methods, e.g. GATR
DART-MS	Direct or extract	Optional derivatization	Mass standards	TBD	Broad range of low-volatility materials
Liquid Chromatography-High Resolution Mass spectrometry	IPA/Water wash	ESI and APCI conditions, scan MS and search for masses of targets and unknowns	External standards	>10 ng/g	Detects polar and high-MW molecules Method development

9.5.1.7 Contamination transport analyses

Contamination transport mechanisms differ between the vacuum of space and the Mars surface environment; thus requiring different modeling approaches. Mars 2020 would leverage the analytical tools used to perform the cruise-phase and surface operations phase contamination transport analyses for MSL. Contamination transport models are typically deterministic to a stated level of uncertainty. For Mars 2020, some of the model results may also be expressed probabilistically to be comparable with some prior work done and reported in this manner; for example, Hudsen et al. 2010.

9.5.1.7.1 Cruise-EDL Models

Contamination transport analyses would be done to estimate the redistribution of particulate and molecular contamination during the launch, cruise, entry, descent and landing events. Molecular and particulate redistribution calculations use pre-flight measurements prior art, and flight environments as inputs to models. These analyses provide the basis for establishing the datum for the initial hardware surface contamination levels at the beginning of operations on Mars.

9.5.1.7.2 Mars surface models

Unlike the cruise phase where molecular contamination transport is in the free molecular flow regime, on Mars, transport in the martian atmosphere determines relationship between sample contamination requirements and hardware outgassing requirements. Molecular transport an atmosphere, ~6 to 8 torr, is described by fluid equations; molecules move with the wind (ten Kate et al., 2008; Blakkolb et al 2008). Some of the many questions answered by transport models included temporal and spatial variation of ammonia concentration effects: timing of the first sample acquisitions; and contact science.

Analysis of the Descent Stage plume constituents physical and chemical interactions with Mars atmosphere and soil were done for MSL to assess in-sample contamination risk. Also, since the Descent Stage impacts Mars at ~100mph, assume the propellant system ruptures and hydrazine is released. MSL modeled the gas-phase reaction N_2H_4 and Mars $CO_2 \rightarrow$ carbazic acid: $NH_2NHCOOH$. Solid "ash" and sublimation gasses are carried by wind. Transport model calculations including chemistry with martian soil and atmosphere include the effects of N_2H_4 reactions with the surface minerals and with the CO_2 in the atmosphere. Gas phase reaction rate of N_2H_4 and CO2 were measured in the laboratory at JPL as model inputs. The 3-D simulation included estimates of mixing in turbulent boundary layer. The modeling tools developed for are generalizable such that analyses done for Mars 2020 would be specific to the requirements and conditions of the mission.

Redistribution of particulate debris by winds on Mars during surface operations has also been identified as a potential contamination vector to the sample hardware. The Project has near term plans to undertake bounding analyses to understand the magnitude of redistribution by the saltation mechanism and by physical erosion of surface system materials (so called "sputtering.") Depending on the outcome of these early studies, more detailed calculations and tests may be undertaken.

9.5.1.8 Conclusion

The Mars 2020 project is in the early phase of its development. As such, details of many aspects of the contamination control implementation are still TBD at this time. However, a significant benefit accrues to Mars 2020 due to the similarity with the recent, largely successful, MSL mission. While the project readily acknowledges the additional challenges presented by the sample hardware, many of the tools and processes used for MSL may be applied as-is or leveraged to form the basis of the Mars 2020 implementation. Contamination control engineering is fully engaged with the hardware design and systems engineering teams and Project management appears fully committed to enabling a successful contamination control program. We strongly encourage, however, that project be proactive in undertaking the necessary development efforts that would be needed to bring new cleaning and cleanliness verification methods on-line with the necessary validation.

9.5.2 Feedback on the Mars 2020 Conceptual Contamination Control Plan

As requested by its charter, the OCP reviewed the Mars 2020 Project's concepts for a contamination control plan (Section 9.5.1 of this report), and has prepared the following feedback.

9.5.2.1 Mars 2020 Sample Return and Heritage from MSL

In Section 9.5.1 it is stated that the Mars 2020 contamination control program is expected to be based heavily on heritage MSL practices. However, MSL was strictly specified as **not a life detection mission**, from the perspective of both science and planetary protection. This mission definition minimized the level and extent that contamination control and planetary protection needed to be accounted for on the mission. Mars 2020, by the addition of the sampling system and sealable sample tubes and the potential for a future restricted Earth return, would be an entirely different mission with different Level 1 mission requirements. As discussed in this report, the Mars 2020 mission should carry requirements that prevent the contamination (biological, organic and particulate) from having an adverse impact on the scientific and planetary protection evaluation of the potential returned samples. MSL had no such requirements, therefore it was possible to accept additional risk of contamination of the samples as a matter of operation. (If a sample is too contaminated, take more samples until a sufficiently clean sample can be acquired to provide useful data.)

- Mars 2020 has a much simpler sampling system, which should help it to be able to meet the much stricter requirements relating to potential sample return.
- Unlike MSL, Mars 2020 is unlikely to make extensive use of dilution cleaning (see also Section 2.1.3 of this report). Looking for known proven methods for cleaning and protecting surfaces from contamination, particularly those that do not have geometric restrictions to their efficacy is the only reasonable course of action. Some cleaning processes, such as ozone cleaning, carbon dioxide snow cleaning, and laser cleaning, have issues with mated surfaces and deep holes. As a result their applicability to real hardware is limited. Known proven methods for removing volatile organic materials, organic particles and biota should be accepted and tested to assure that there is capability to achieve the required levels on all of the hardware as it is developed and assuring that the protection schemes are adequate to assure the contamination levels on delivery to Mars.
- The Mars 2020 samples would need to be considerably cleaner than were the samples collected prior to dilution cleaning on MSL

9.5.2.2 Contamination Control Best Practices

In the conceptual contamination control plan (Section 9.5.1), reference was made to carrying out cleaning, assembly and testing operations of the sensitive hardware in class 1000 or class 10,000 and class 100,000 cleanroom environments, and extensive studies showing long term accumulation of molecular contamination and evaluating real-time particle fall out monitors. OCP endorses these studies. In addition, however, when Mars 2020 writes its contamination control plan, we encourage close attention to strategies to protecting the hardware to decrease the rate of recontamination. Additionally, OCP advises measuring and monitoring the microbial, organic and particle source strength variation in the proposed facilities and their adjacent areas prior to committing to them. This can avoid uncontrolled or poorly controlled environmental conditions and random contamination events, such as diesel forklifts idling next to the air inlets and activities such as spraying lubricant on ground support equipment, trucks idling in truck locks, etc.

9.5.2.3 Contamination Control Plan

Separate processing areas for the sample acquisition hardware and the sample caching hardware should be utilized, using the best available facilities, such as an ISO-5 clean bench in an ISO-7 Cleanroom utilizing hydrocarbon assimilation filters, and following best practices for keeping hardware covered at all times that work is not actively being carried out on it. This would include the use of combustion-cleaned aluminum foil and/or stainless steel containers to decrease the exposure of the hardware to the environment. Periodic reviews of the contamination control practices and facilities could prove invaluable.

9.5.2.4 Combustion Cleaning

The use of combustion cleaning to clean the hardware and storage materials to minimize the molecular organic contamination, the particulate organic contamination and the biological contamination is highly recommended. This is standard practice in terrestrial laboratories doing research on trace microbial species and trace organic chemistry. A starting point for Mars 2020 to consider is the placement of the hardware on clean aluminum foil in an air atmosphere furnace and heating to 550°C and dwelling at this temperature for two hours followed by a slow cool down over 12-16 hours to approximately 50-100°C, in the furnace. At that time the hardware should be wrapped with the foil to minimize recontamination by airborne contaminants. The cost impact of potential redesign of hardware to allow combustion cleaning is very likely less than the cost of development and/or verification of another process and the risk of failure of the other method.

It is well known that decreasing the conductance of the path for contamination provides a good method of prevention of contamination. Simple clean metal foil coverings of hardware decreases the transfer rate of all contaminants to surfaces. The highly constrainable paths reduce the transfer rates by orders of magnitude at the simplest level of approximation. The actual levels of contamination transport are actually constrained significantly more than predicted and the simple approximation level due to the highly complicated and poorly understood interactions of materials on exceedingly clean surfaces.

Finding #31: Baking all sampling hardware in air at >500°C and for >8 hours, followed by rapid isolation from contact with air, potentially provides a means to achieve orders-of-magnitude lower levels of organic contamination. We suggest that the Mars 2020 project substantively investigate this possibility while evaluating sample hardware design options.

9.5.2.5 Blank Standards

As emphasized in Section 5.3 of this report, blank standards that can be field sampled on Mars and included as part of the sample collection are critical to the ability to obtain meaningful information from the samples. These are at least as valuable as the samples, because contamination processes can be random and variable, and the only way of distinguishing sample from contaminant is by use of blank standards. These materials should have similar physical properties and be readily analyzed for trace organics. Mars 2020 needs further discussion on the design of these blank standards. However, a factor to consider is that they should have a carefully chosen permeability to allow penetration of organic contamination into the interior of the blank in a manner that is sufficiently similar to the natural samples. Consideration should also be given to whether these blanks should be drilled and handled in different orientation to determine whether or not there are gravitationally induced effects on the sampling. As has been pointed out elsewhere (e.g. Mustard et al. 2013), without appropriate blank standards the samples would almost certainly not be worth returning in a scientific sense.

9.5.2.6 Witness Plates

OCP would like to emphasize the points made in Section 5.2 of this report regarding the importance of witness plates. Witness plate sets should include multiple identical plates to allow the quick contamination control measurements as well as measurement of the more time consuming contamination knowledge measurements to identify the compositions of the contamination. Work needs to begin soon on evaluating the requirements of the archiving facility not only for the returned samples but for assuring the ability to maintain the witness plates and materials samples required for the sample return mission, which may also include bioburden samples either processed or preserved (see discussion in Section 5.4 of this report). These archiving processes need to be verified and validated prior to collecting materials to be archived. The archive facility needs to be properly budgeted.

9.5.2.7 Additional Planning to Improve Contamination Knowledge

OCP strongly encourages more planning for acquiring contamination knowledge, which we consider extremely high priority (see Findings #3, #5 of this report). This includes how and what is sampled, how and what is measured, who is going to do the measurements, quality control, verification and validation of methods and procedures, etc. This information may potentially be exceptionally important to future investigators, and it is essential that it be collected properly during the project's development phase.

9.5.2.8 Contamination Verification Plan

The contamination verification as provided above is in line with the suggestions and the philosophies of the OCP. It is expected that this would continue to be developed further and that the processes and methods would be verified and validated following the further identification of the total landed system's requirements are identified and that the effort is funded. The proposed scheme for quantifying the organic contaminants seems to be a good starting point.

9.5.2.9 Total Organic Carbon

The project would need to propose a way of measuring Total Organic Carbon. The traditional method for determining total organic carbon in geological samples is by pyrolysis, although as discussed in this report, detection limits of current analytic systems are nowhere near good enough for this application (the pathway to creating such an instrument in the future is clear, so OCP has not worried about this). There are alternate means for measuring the concentration of trace organic molecules on metal surfaces. An additional problem is that analysis of metal surfaces by pyrolysis can result in false signals from metal carbide that is part of the alloy. The Mars 2020 project would need to choose one or more methods (there are TOC analyzers that would reach the necessary detection sensitivity, and ones that would not be interfered with by the metal carbides, but these may be separate instruments). There was a preference within OCP to measuring TOC directly on witness coupons rather than measuring from swab samples and that witness coupons be made preferably from spacecraft or sampling system materials. Multiple material types were also advised as the adsorption of organics on surfaces is material dependent.

Due to the significance of the contamination and planetary protection requirements and the extremely low expectable levels of contaminants in the sample caching systems as well as the additional specific measurements required, verification and validation of the sampling and measurement techniques is called for. Development of the measurement and monitoring techniques well in advance of the actual measurements on the hardware is called for. This in effect buys down the risk of the planned contamination control and planetary protection requirements by allowing verification and validation of the planned cleaning and recontamination protection, reducing mission risk.

9.5.2.10 Relationship to Planetary Protection

Based upon the differences between MSL and the Mars 2020 rover mission, particularly with respect to the expected Planetary Protection driven requirements, it is absolutely necessary that the PP requirements and their impacts on the Contamination Control requirements and implementation be entirely understood across the entire mission, and that potential impacts on systems be explained to the individual system and subsystem leads. It would be a great concern if any of the subsystem leads have inadequate understanding of the rationale behind the planetary protection and contamination requirements. An attitude of "here's my hardware, clean it and get it to meet your PP and CC requirements" would almost certainly lead to difficulties. It is crucial that the subsystem leads accept and be held accountable to designing and delivering hardware meeting these requirements, and that they understand the principles of how to meet the requirements. Organic contamination control is central to the objectives of Mars 2020, and it needs to be embraced by the entire science and engineering teams.

9.5.2.11 Selection and Characterization of sampling system materials

The fundamental physics and chemistry of the materials matters in considering the effects of organic contamination. Many of the contamination issues boil down to a materials issue—some materials are better than others with respect to how they chemisorb, physisorb, or desorb organics. Appropriate material selection accounting for potential Contamination and Planetary Protection issues and limitations should be included as part of the hardware design from the beginning, which would enable the attainment of the requirements.

It is imperative that sample container materials are characterized in a way that allows for accurate understanding of the interactions between them and the martian environment. Without this, defining a verifiable requirement for organic cleanliness may be challenging. During the review process for this report, concerns were raised about the behavior of the sample container in the martian environment, such as the effects of temperature cycling & seal lifetime, winds, radiation, humidity, insertion of heated Martian rock post-coring. Early testing would be beneficial. A factor that specifically should be considered is the corrosion or other deleterious effects by martian soil (e.g. perchlorates, acid sulfates and other reactive components).

9.5.2.12 Final Cleaning of Hardware

Consider final cleaning of hardware that touches samples with ultrapure water. This would reduce organic residues from solvents. Detailed optical inspection before and after traditional cleaning of stainless steel hardware can show the addition of film-like material (presumably organic from organic solvent) and particles. Ultrapure water has been used for prior sample return missions at other NASA Centers. For example, UPW was used in ISO Class 4 to clean Genesis hardware for flight.

Other techniques such as the utilization of cleaning techniques and technologies that are well known for their ability to remove diverse materials from surfaces, including combustion cleaning, sub-critical water cleaning, supercritical fluid extraction, etc. which are well developed in other industries.

9.5.2.13 Modification of sampling system surfaces

Surface modification for some Mars 2020 surfaces may be appropriate. OCP discussed at length the possibility of adding of a thin surface coating to the sample-contact surfaces to decrease surface energy, as a strategy to decrease the accumulation of adventitious carbon. From the point of view of the samples, this would be equivalent to adding a known contaminant to gain the benefit of reducing the unknown contaminants (“the devil you know is better than the devil you don’t know”). Although the members of this committee had mixed opinions on the consequences of this strategy to the possible eventual sample-based investigations, we agreed as a group that the reasons to oppose it are at least as strong as the reasons to support it, so as a group we agreed to recommend against this approach.