Mars 2020 Sample Caching System Contamination: How to Clean Hardware and Keep it Clean

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***Abstract*—The Mars 2020 Rover will have the capability to collect and cache samples for potential Mars sample return. Specifically, the sample caching system (SCS) is designed for coring Mars samples and acquiring regolith samples as well as handling, sealing and caching on Mars. As the potential first Martian samples that could be returned to Earth, assuring low levels of terrestrial contamination is of the utmost concern. In developing the SCS, the project prioritizes limiting sample contamination in organic, inorganic and biological areas. The focus of this paper is on the strategies being implemented to clean the assemble the sampling hardware to meet and maintain stringent contamination requirements.**

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1. INTRODUCTION

A common mantra of return-sample contamination control "clean it, keep it clean" (1). While the design of the hardware is critical to meeting the sample cleanliness requirements, implementation becomes an equally difficult challenge, as it is the "keeping it clean" portion of mission. The Mars2020 Cleaning Team has developed stringent cleaning, handling, bagging, storage and other assembly procedures in order to meet the sample cleanliness requirements. Furthermore, the team is working to create unique cleanrooms for assembly of the adaptive caching system (ACA) and subassemblies.

While cleaning and maintaining cleanliness in one area (e.g. particulate) may be easily achieved via traditional spacecraft cleanliness practices, achieving this for the multiple areas required for the Mars 2020 mission must rely on new and improved strategies. Previously we described the three key and driving Mars 2020 contamination requirements for return sample science which are as follows:

1.Organic Contamination. "The Mars 2020 landed system must be capable of encapsulating samples for return such that the returned sample meets the organic cleanliness standards." This includes keeping "Tier 1" compounds below 1 ppb in the sample. The Tier 1 compounds are specific organic compounds of astrobiological significance (e.g. DNA), and keeping total organic carbon (TOC) below 10 ppb.

2. Inorganic Contamination. Inorganic requirements on the acquired samples includes 33 specific elements and mandates that, depending on the element present, their concentration be no greater than 0.1% or 1% of their average concentration measured previously in classes of Martian meteorites known as shergotty nakhla chassigny (SNC) and are shown in Table 1.

*3. Biological Contamination. "*The Mars 2020 landed system must be capable of encapsulating samples for return such that each sample in the returned sample set has less than one viable Earth-sourced organism."

While much effort has gone into designing the hardware for mitigating against all three areas of contamination (ref previous paper), cleaning all of these piece parts and maintaining that cleanliness through launch is equally challenging. Thus, the focus of this paper is to describe strategies for cleaning and "keeping clean" the SCS hardware.

2. SAMPLE INTIMATE AND SAMPLE HANDLING HARDWARE

In order to derive cleanliness requirements for hardware, the sample caching system hardware is partitioned into three categories: Sample Intimate Hardware (SIH), Sample Handling Hardware (SHH) and ACA general hardware.

As the name implies, SIH is hardware which comes into direct contact with the sample. Specifically, SIH includes the following:

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Table 1: Inorganic Contamination Requirements for Mars 2020 samples

	Target % of SNC	Allowable Contamination (g/g)
Mg	1	1.75E-03
K	0.1	1.66E-07
S	1	1.10E-05
P	1	2.20E-05
Cl	1	6.30E-07
Br	1	4.00E-09
Li	1	2.10E-08
B	1	1.00E-08
Sc	1	3.90E-07
Mn	1	3.70E-05
Co	1	5.80E-07
Ni	1	2.70E-06
Zn	1	6.30E-07
Rb	0.1	3.40E-10
Sr	0.1	3.30E-08
Y	1	1.40E-07
Zr	1	2.10E-07
Nb	1	2.50E-09
Cs	1	1.50E-10
La	1	3.00E-09
Ce	1	1.10E-08
Nd	0.1	1.50E-09
Sm	0.1	9.74E-10
Eu	1	4.50E-09
Gd	1	1.80E-08
Lu	0.1	1.80E-10
Hf	0.1	9.10E-10
Ta	1	1.38E-10
W	0.1	4.10E-11
Re	0.1	1.70E-11
Os	0.1	1.10E-10
Pb	0.1	2.00E-10
Th	0.1	2.40E-11
U	0.1	7.00E-12

- Sample Tube
- Hermetic Seal Components
- Volume Probe
- Coring, Regolith and Abrading Bit Assemblies

Sample Handling Hardware is defined as hardware that comes into close proximity to the sample or in directly contact or close proximity to SIH. Specifically, SHH includes the following:

- Gloves
- Covers
- Sample Tube Storage Assembly (STSA) (Tube Housing)
- Hermetic Seal Dispenser Assembly
- Volume Probe Housing
- Bit Carousel
- Vision Assessment Station (Baffle and illuminator)

ACA general hardware includes all other components within the ACA. Figures 1 and 2 shows images of all three types of hardware for cleanliness.

3. CLEANING APPROACHES

In order to meet the strict organic, inorganic and biological requirement, SIH and SHH as well as ACA hardware have derived cleanliness requirements. These are described in Table 2. SIH has the most stringent cleanliness requirements post cleaning and SHH is less and ACA the least.

All ACA piece parts must be cleaned down to 100 ng/cm^2 and particulate cleanliness level (PCL) (per IEST-STD-CC1246E) 50-300 as well as maintained at those levels until launch – no simple task for hardware assembly.

To achieve these cleaning levels, the hardware assembly flow is designed to include multiple cleaning steps and mitigations. The general flow for SIH and SHH hardware is shown in Figure 3 where hardware is machined, sampling occurs to understand what contamination is present that must be removed and the hardware goes through “coarse” cleaning to remove machining oils and visible surface contamination. After coarse cleaning, the hardware receives precision or “ultra” cleaning down to the 100 ng/cm^2 and PCL 50 (or 100) part. Verification of this cleaning is essential before moving forward in the assembly and therefore a “hold” is placed on the hardware until the cleanliness is verified to acceptable levels and it either moves on to the assembly flow or is re-cleaned until the required levels are reached.

The final cleaning step for SIH and most SHH hardware, denoted as “SIH bakeout”, is a combustion cleaning of the hardware at 350°C in an oxygen-rich environment to combust any remaining monolayers of organic contamination on the surface as well as essentially “kill” any viable organisms remaining. Once that step is complete, the hardware remains hermetically sealed in a clean storage case until it is installed at last access (at KSC prior to launch).

4. ASSEMBLY AND MAINTAINING CLEANLINESS

Once the hardware is cleaned, Mars 2020 has prepared ISO 5 (Class 1000) clean rooms with vertical laminar flow for hardware assembly in order to maintain the “ultra” cleaning of the hardware. For SIH and most SHH, the hardware is assembly on ISO 5 flow benches within the ISO 5 cleanroom.

Bagging as well as tooling is also important for maintaining cleanliness during assembly and storage. Therefore, special GSE is designed for some SIH to minimize direct contact

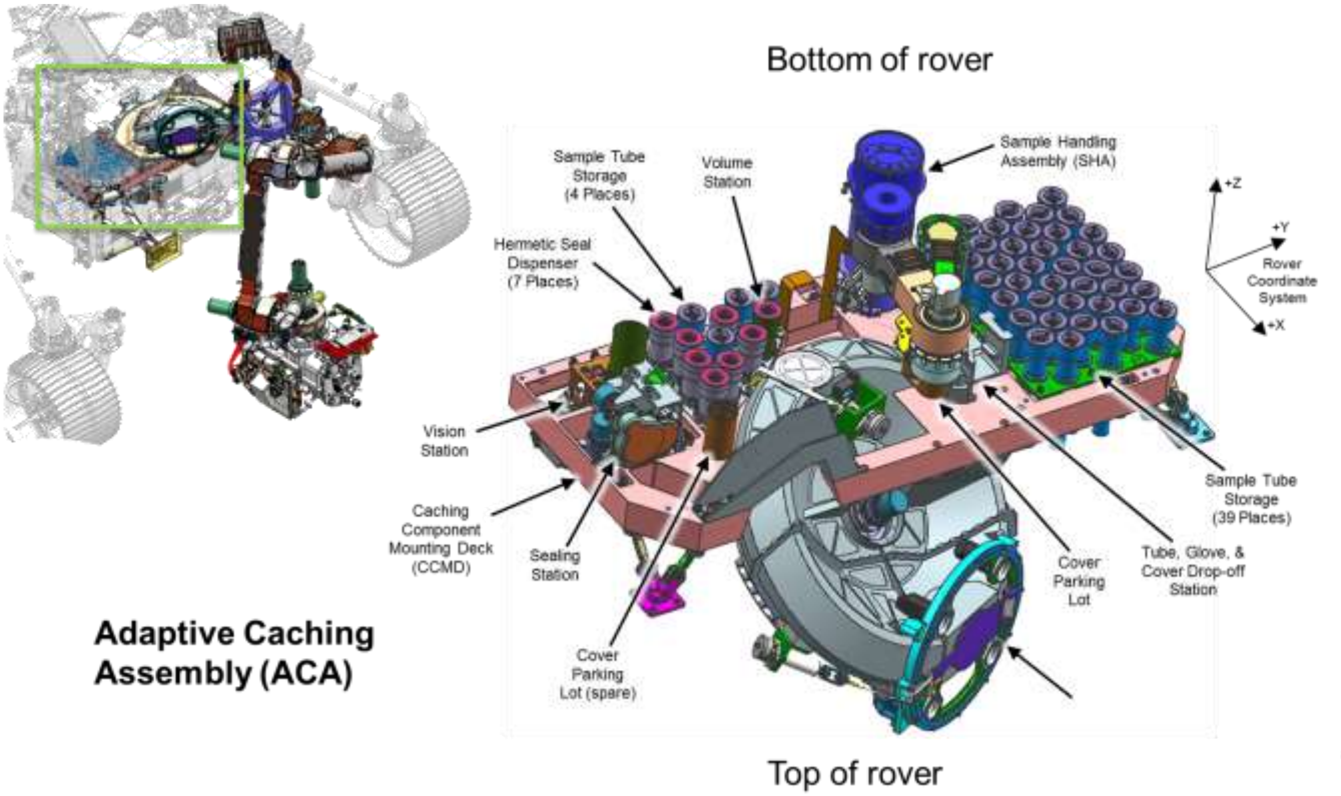

Figure 1: Overview of the Sample Caching System (SCS) and the Adaptive Caching Assembly (ACE) which houses the sample intimate and sample handling hardware.

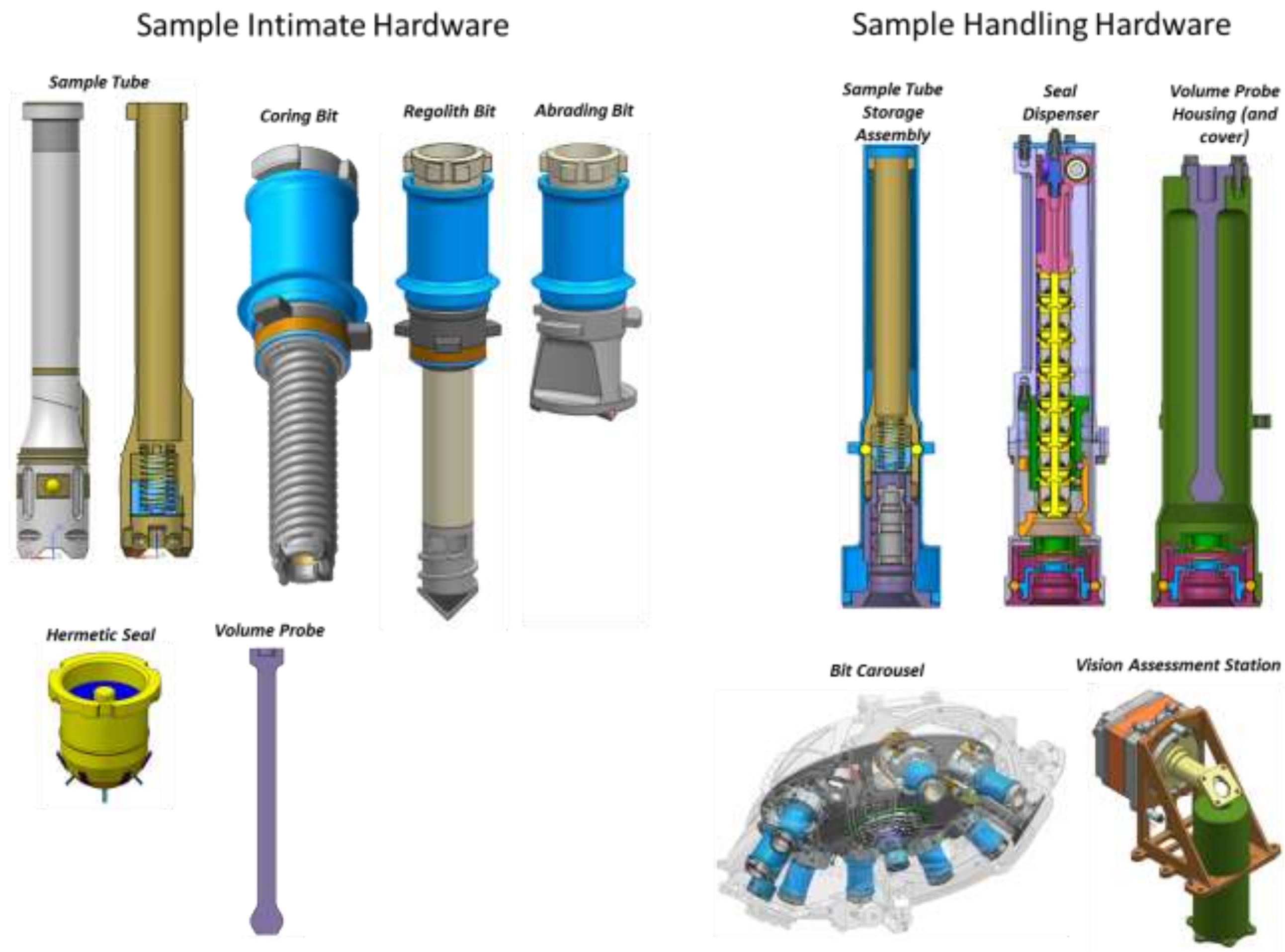

Figure 2: Overview of Sample Intimate Hardware (SIH) and Sample Handling Hardware (SHH)

with the hardware once the ultra cleaning is complete. For example, hermetic seals are held in place by pre-cleaned GSE throughout the cleaning and assembly process and therefore direct contact and handling which could risk recontamination is highly reduced. Where GSE is not used, handling of all SIH and SHH require specific sterile gloves on flow benches during assembly. Multiple types of sterile and low NVR gloves were tested in order to validate the handling approach. For example, Kimtech G3 sterile gloves are compatible with both biological and NVR requirements since test results show that NVR levels attributed to the glove are at ~0.02 ug/cm2. Finally, post cleaning or storage of SIH and SHH hardware requires three layers of protective wrapping to maintain cleanliness, which are: an innermost layer of pre-fired UHV aluminum foil and two heat-sealed layers of ESD "amerstat" bags. Tests were also performed to show no significant organic, biological or particulate contamination is transferred to metal surfaces from these materials.

Table 2: Derived Cleanliness requirements for SIH, SHH and ACA hardware

Hardware	Average Organic Surface Cleanliness (ng/cm²)	Particulate	Outgassing Rate (ng/cm2/hour)
SIH	<0.3	50	1
SHH	100	100	1
ACA (general)	100	300	1

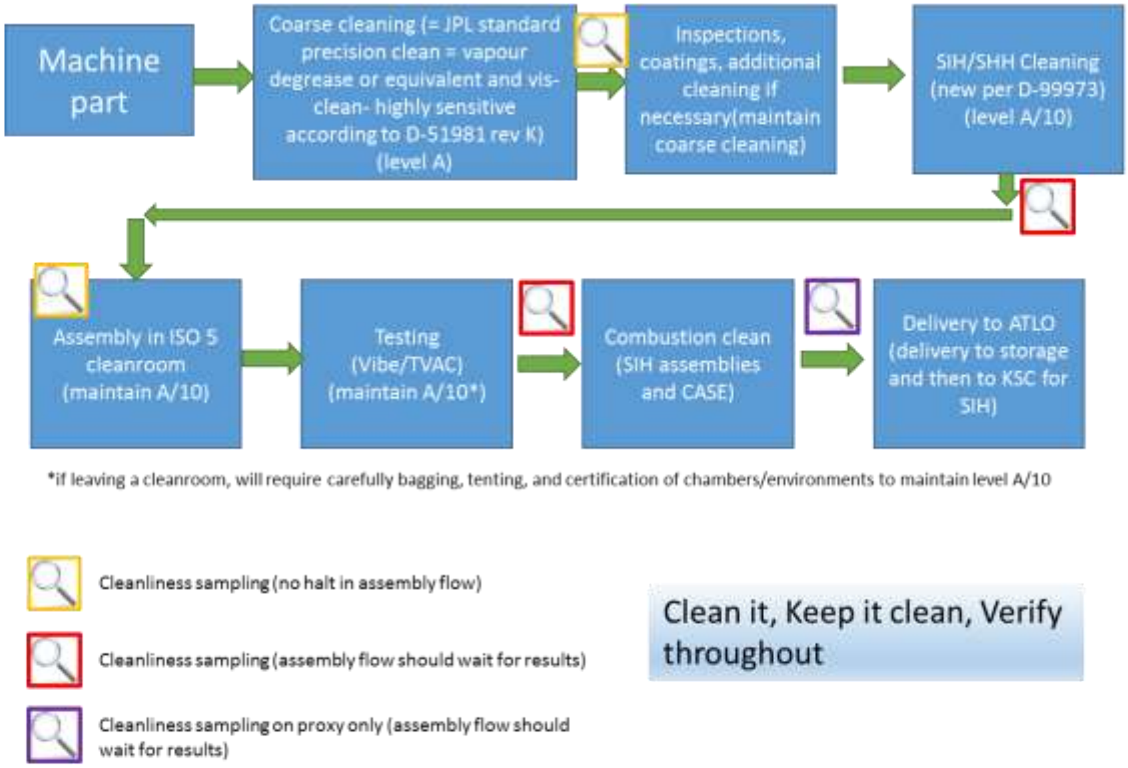

Figure 3: **Schematic showing the general cleaning flow for SIH and SHH hardware.**

5. CLEANING AND STORAGE ENCLOSURE (CASE)

As described earlier, the final cleaning step for SIH hardware is the "SIH bakeout" in a combustion environment. To accomplish this, assembled hardware will be placed in the cleaning and storage enclosure (CASE) which is a GSE box capable of maintaining a hermetic seal up to 400°C. The CASE (shown in figure 4) is designed to hold the SIH hardware during the combustion cleaning and ultimately maintain a hermetic seal with a final G_{N2} purge of the box for storage until the CASE is opened at KSC for installation of the hardware at last access. The CASE allows protection of the hardware against the combustion oven and provides a protective GN_2-purged storage environment so that the final cleanliness of the hardware can be maintained. Once the hardware is placed in the CASE, the hermetic seal is not broken until the hardware is installed at KSC.

Verification of the final combustion cleaning will be accomplished by processing non-flight proxy hardware (exactly similar to flight assemblies) through the ultra and SIH bakeout cleaning in a separate CASE under the same conditions (same gas sources, within 48 hours, etc.). The CASE containing the flight hardware can also accommodate witness plates (see figure 4) which will be sampled when the unit is opened at KSC for installation of the SIH hardware.

6. ATLO PURGE AND MOLECULAR ABSORBER

Once the hardware is installed to the ACA at KSC, the threat for re-accumulation of contamination still exists. Therefore, Mars 2020 will utilize a T=0 purge to create a high flow through the ACA until launch. This purge consists of pre-filtered ultra clean nitrogen gas and is designed to flow through the entire volume of the ACA at a rate of ~ 1 L/sec. Analysis of the purge shows that it will minimize accumulation of organic contamination while reducing particulate fallout during ATLO.

Recontamination from outgassing within the ACA is also a threat during the long nine-month cruise to Mars where the purge is no longer active. Therefore Mars 2020 is employing the use of a molecular absorbant material, called Tenax, specifically designed to absorb any outgassed molecular contamination (2). The ATLO purge is also useful for keeping the Tennax "getter" in its activated. Maintaining its activation through launch will increase the capacity for

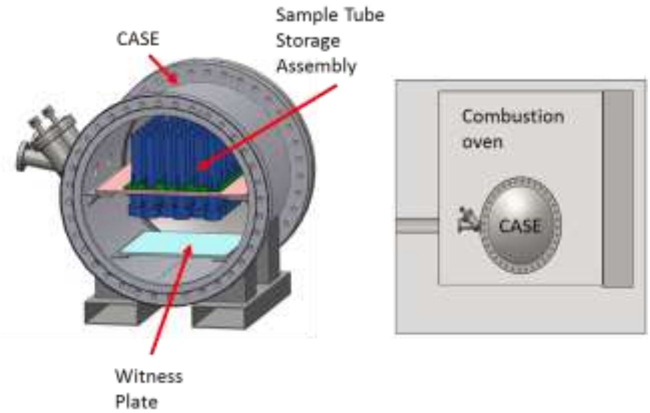

Figure 4: the Cleaning and Storage Enclosure (CASE) for final cleaning and storage of SIH and SHH hardware

absorbing organic contamination during cruise and therefore reduce the risk of saturation prior to landing on Mars.

7. CONCLUSIONS

Cleaning and keeping clean hardware from organic, inorganic and biological contamination at the levels required for Mars 2020 is a challenge not yet met by any previous NASA mission. For this reason, Mars 2020 has carefully employed multiple strategies for cleaning hardware and maintaining cleanliness. Careful cleaning procedures has been established to clean hardware down to 100 ng/cm^2 and

PCL 50-300. ISO 5 cleanroom environments are used to maintain this ultra cleaning through the assembly of the hardware. Special GSE and test validated materials for tooling, handling (gloves) and wrapping are also employed to mitigate against re-contamination. Finally, the CASE provides the ultimate protection of the hardware until final installation at the cape where a purge will maintain cleanliness through launch. Using the strategies described above as well as continues sampling throughout the cleaning and assembly process will provide a robust and unique plan for meeting the contamination requirements on Mars 2020. Ultimately, this plan will allow for obtaining pristine samples from Mars which, potentially, would be returned as the first Mars sample return.

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Biography

Lauren White *received a B.A. in Chemistry from Texas A&M University in 2007 and a Ph D in Chemistry from UC Santa Barbara in 2013. She worked as a scientist and microscopy engineer at Johnson Space Center studying Martian meteorites and as a scientist at the Jet Propulsion Laboratory focusing on origin of life experiments. Lauren has worked as a systems engineer at JPL for 3 years and currently is the deputy contamination control lead for the Mars 2020 project.*

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Keith Rosette is a graduate of Virginia Tech where he earned a B.S. in Aerospace Engineering in 1991 and an M.S. in Mechanical Engineering in 1994. He has developed and delivered hardware in support of numerous programs involving both human and robotic space exploration, from Hubble Space Telescope Servicing at Goddard Space Flight Center to the Mars Science Laboratory Curiosity Rover at JPL. He has served in roles from mechanical design engineer to spacecraft lead system engineer. Keith currently serves as the Product Delivery Manager responsible for the design, fabrication, test, and delivery of the Sampling and Caching Subsystem for the Mars 2020 Rover.