THE IMPORTANCE OF CONTAMINATION KNOWLEDGE IN CURATION – INSIGHTS INTO MARS SAMPLE RETURN. A. D. Harrington[1], M. J. Calaway[2], A. B. Regberg[1], J. L. Mitchell[1], M. D. Fries[1], R. A. Zeigler[1], and F. M. McCubbin[1], [1]Astromaterials Research and Exploration Sciences (ARES) Division, NASA Johnson Space Center, 2101 NASA Parkway Mail Code XI2, Houston TX 77058, Andrea.D.Harrington@NASA.gov, [2]Jacobs, NASA Johnson Space Center.

Introduction: The Astromaterials Acquisition and Curation Office at NASA Johnson Space Center (JSC), in Houston, TX (henceforth Curation Office) manages the curation of extraterrestrial samples returned by NASA missions and shared collections from international partners, preserving their integrity for future scientific study while providing the samples to the international community in a fair and unbiased way. The Curation Office also curates flight and non-flight reference materials and other materials from spacecraft assembly (e.g., lubricants, paints and gases) of sample return missions that would have the potential to cross-contaminate a present or future NASA astromaterials collection. These materials are primarily collected during the assembly, test, and launch operations (ATLO) phase and after flight during the recovery and curation phase. In addition, the Curation Office curates non-flight, flight-like, and flown witness plates for sample return missions. These reference materials and witness plates provide the scientific community with the fundamental ability to reconstruct the contamination/alteration history of the sample collection through the course of the mission, with the overall goal of guiding and strengthening the scientific conclusions drawn from the study of returned materials. The information gained from characterizing the physical, biological, inorganic, and organic chemical properties of reference materials and witness plates is defined as the Contamination Knowledge (CK) of the sample collection.

The Mars 2020 mission is the first step of a possible multi-mission campaign to return martian samples to Earth. By collecting and caching an array of drill core and regolith samples, along with the geologic context provided by the *in situ* analyses, the Mars 2020 mission will set the stage for future mission(s) to return the cached samples to Earth. Scientists will use these samples to better understand: 1) the geological processes that formed Mars' astrobiologically-relevant ancient environments and geologic diversity, 2) the habitability of Mars' ancient environments and signs of past life (if present), and 3) the unique requirements for future human exploration of Mars [1].

Scientific investigations of returned samples are highly sensitive to terrestrial contamination, especially where studies of extant or extinct extraterrestrial life are concerned. The proper collection, storage, and cataloging of CK associated with the production and assembly of the spacecraft, rover, and sample and caching subsystem (SCS) will be vital to these investigations. Without a well-constructed and curated CK collection, the baseline for contamination within the returned samples cannot be established.

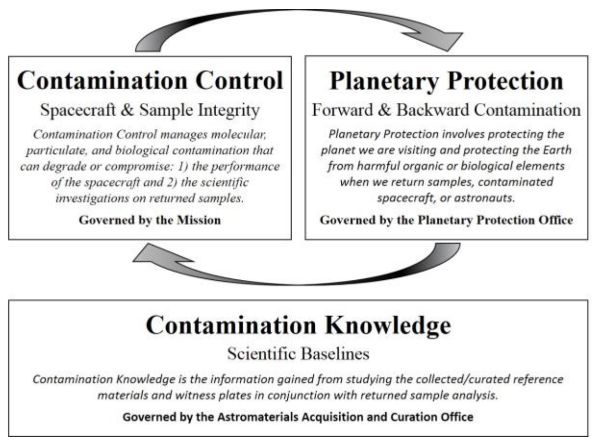

Fig. 1: Roles of CC versus PP versus CK
Depiction of the main roles of Contamination Knowledge, Contamination Control, and Planetary Protection.

CC versus PP versus CK: As with all missions, minimizing the amount of contamination on the spacecraft is important. However, the contamination standards for the Mars 2020 mission are even more stringent since Mars is "a body deemed by scientific opinion to be of significant interest to the process of chemical evolution and/or the origin of life (Category V; Restricted Earth-Return) [2]." Contamination Control (CC) and Planetary Protection (PP) are tasked with ensuring the spacecraft contamination standards are met (Figure 1). Unlike CC and PP, CK is exclusively concerned with preserving reference materials and witness plates for study by future scientists upon sample return. Although data collected for CC and PP purposes is complementary to CK, they are two separate data sets with distinct objectives. A robust collection of CK is necessary to allow the martian material in a returned sample to be distinguished from terrestrial contamination.

Lessons Learned from Recent Sample Return Missions: Although always treated as CK, OSIRIS-REx is the first sample return mission to explicitly differentiate curated witness materials from CC and group them with reference materials. This change in nomenclature is due to the disparate purposes of the witness materials, the increasing complexity of the sample return missions, and the need to ensure an adequate CK collection. The necessity of CK to mission success is demonstrated by the last two NASA sample return missions: Genesis and Stardust. In their own ways, these missions demonstrate that as long as proper controls are in place (e.g., CK), the presence of contamination will not hinder a well-designed scientific investigation.

Genesis. Genesis was launched in 2001 to collect solar wind at the Earth-Sun Lagrange Point, L1. On September 8, 2004, a hard landing at the Utah Test and Training Range (UTTR) resulted in a breach of the science canister which exposed samples to contamination from the spacecraft and UTTR lacustrine environment. In addition, unknown contamination adhered to the samples during the mission at L1 from the combination of spacecraft outgassing and solar irradiation damage. The CK enabled scientists and curation experts to make great strides in identifying and quantifying the degree of sample contamination, decontaminating each sample, extracting solar wind elemental signatures, and creating correction models for the composition of the sun, thereby allowing the primary science of the mission to be completed despite the non-nominal landing.

Stardust. Launched in 1999 and returned to UTTR in 2006 (nominal landing), Stardust was designed to collect dust from comet Wild 2 and interstellar space. After successfully returning to Earth, scientists found that the aerogel designed to capture the dust particles contained amino acids. After extensive study utilizing both non-flight and flown CK, scientists determined that the amino acids found within the comet-exposed aerogel were primarily from Wild 2, with only trace amounts of organic contamination from the aerogel itself [3-5]. This finding would not be possible without adequate CK.

The Unique CK of Mars 2020: The classification of Mars sample return as Category V Restricted Earth Return not only adds more CC and PP constraints, it also broadens the scope of required CK to include biological witness materials. Unlike other collections, which only require storage in an inert ultra-pure nitrogen gaseous environment, the biological CK for Mars 2020 will also require samples to be frozen.

Planning for evolving technology. Technological advancements to instrumentation are continually progressing with greater precision and accuracy for sample measurements, especially in the field of microbiology. The Curation Office must ensure that an array of CK samples are available to scientists once the samples cached by Mars 2020 are returned to Earth. Some of the types of biological CK samples the Curation Office requires include:

1.) Un-analyzed swabs and wipes in sterile containers stored at ≤ -80°C.
2.) All recirculation filters from the clean rooms used for rover and rover hardware assembly and all filters from the laminar flow benches used to assemble sample intimate hardware. Packaged in sterile Teflon bags and frozen at -80°C.
3.) Witness plates collecting airborne contamination within the assembly cleanrooms stored at ≤ -80°C.

Collecting and curating unanalyzed samples will minimize the possibility that current analysis and extraction techniques destroy or alter the samples or otherwise inhibit yet to be developed measurements. It has been Curation Office policy since the Apollo missions to preserve as many pristine samples as possible for future scientific research [6,7].

Temperature Constraints. To date, there have not been any conclusive studies indicating the most effective long-term storage for microbiological samples. Cryogenic temperatures (below the glass transition point for water < -137 °C) are the standard for biological preservation. However, some short-term studies indicate that -80°C is preferential since cryogenic temperatures actually break down some biological material, limiting analyses of DNA [8]. Therefore, subsets of CK biological witness materials will be cataloged and stored at either -80 °C or cryogenically.

Conclusions: Although CK is required to be collected for all stages of the Mars sample return campaign, the CK for the Mars 2020 mission is the most critical for understanding contamination in the returned samples given the intimacy between the samples and the Mars 2020 hardware. Rigorous collection of CK and derived blanks for all possible contamination sources and pathways particularly those in the SCS, is essential for mission success. Without adequate CK data, the baseline for contamination within the returned samples cannot be established.

References: [1] http://mars.nasa.gov/mars2020/mission/science/goals/. [2] https://planetaryprotection.nasa.gov/categories. [3] Sandford S.A. et al. (2010) *Meteoritics & Planet. Sci., 45, Nr3,* 406-433. [4] Glavin D. P. et al. (2008) *Meteoritics & Planet. Sci., 43, Nr ½,* 399-413. [5] Elsila J.E. et al. (2009) *Meteoritics & Planet. Sci., 44, 9,* 1323-1330. [6]. NASA 1965 *Summer Conference on Lunar Exploration and Science, Falmouth, Massachusetts,* 421. [7] Allen C. et al. (2011), *Chemie der Erde – Geochemistry, 71,* 1–20. [8] Smittle R. B. et al. (1972) *Applied Microbiology, 24, 4,* 551-554.