MARS SPACE SUIT MATERIALS TESTING USING SHERLOC CALIBRATION TARGET DATA: THE MAX-CF PROJECT.

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Introduction: The Mars 2020/"Perseverance" rover carries a suite of space suit materials as part of the SHERLOC* calibration target [1]. The materials are periodically analyzed by SHERLOC as part of a regular calibration routine and are generating a rich data set regarding their degradation in the martian surface environment. The Maximization of Calibration Fabrics (Max-CF) project will effectively turn SHERLOC data into a measure of space suit material service lifetimes by exposing a second set of materials in a Mars chamber, replicating SHERLOC measurements using the analogous ACRONM** instrument at JSC, and then performing materials testing to include tensile testing. These data can be used to inform space suit design and/or materials development, improving crew safety for future Mars missions. This will partially address NASA's Strategic Knowledge Gap 8 (Mars Surface Technology) which identifies a need to develop technologies to "sustain humans on the surface of Mars [and] enable human mobility and exploration" [2]. This abstract describes the overall Max-CF project and progress on the laboratory-based study to date.

Figure 1: Image taken by the SHERLOC/WATSON camera on the Mars 2020 rover, on Sol 26 of the mission, showing the five space suit materials on Mars. (PDS)

Background: *Mars Measurements:* The SHERLOC instrument's calibration target includes a suite of five space suit materials including four fabrics: "orthofabric", Teflon, nGimat-coated orthofabric, Vectran, as well as a polycarbonate disk cut from JSC extravehicular activity (EVA) suit stock (*Fig. 1)*. At present these materials are exposed to the martian surface environment as the rover performs its mission. As of the date of this abstract, the SHERLOC calibration target was interrogated by SHERLOC on Sols 59, 89, and 181 and will be targeted on regular intervals through the duration of the mission. Max-CF will utilize these SHERLOC data which are available through the NASA Planetary Data System (PDS).

*Acronym for "Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals"
** Acronym for "Analogue Complimentary Raman for Operations oN Mars"

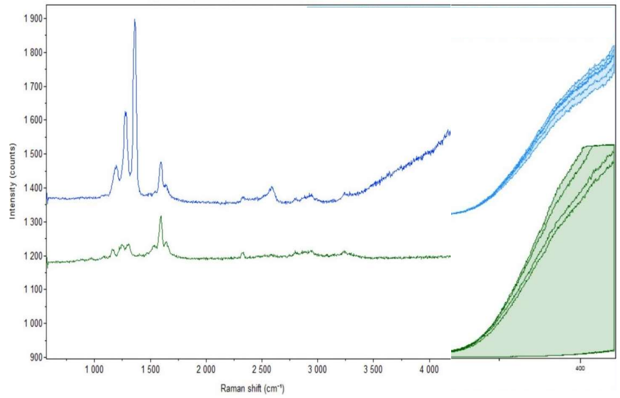

Figure 2: Example SHERLOC-analogue spectra of nGimat-coated orthofabric before (blue) and after 12,000 hours of Mars chamber exposure [3]. The Raman (left) and fluorescence (right) spectra are offset for clarity. Notice Raman peak intensity decrease and shift in some peaks, and overall increase in fluorescence. Intensity of the fluorescence signal is approximately 30x that of the Raman spectroscopy response (y axis not shown).

Previous Work: A previous study by Larson and Fries (2017) [3] exposed the materials used in this study to Mars analogue conditions and showed that degradation of the samples was measurable in SHERLOC spectra. The samples also retained their function as usable calibration targets during the simulated 12,000 hours of exposure (Fig. 2).

Max-CF Analytical Plan: The Max-CF study will expose a suite of the same materials present on the SHERLOC calibration target to known conditions in a Mars simulation chamber, collect SHERLOC-analogue spectra (using ACRONM, *Fig.3*), and then perform tensile testing (for all samples) and optical transmission testing (for the polycarbonate) to quantitatively assess material property changes in the samples. These data will be published to allow quantitative assessments of the allowable service lifetimes of space suit components in terms of total exposure to the Mars surface environment.

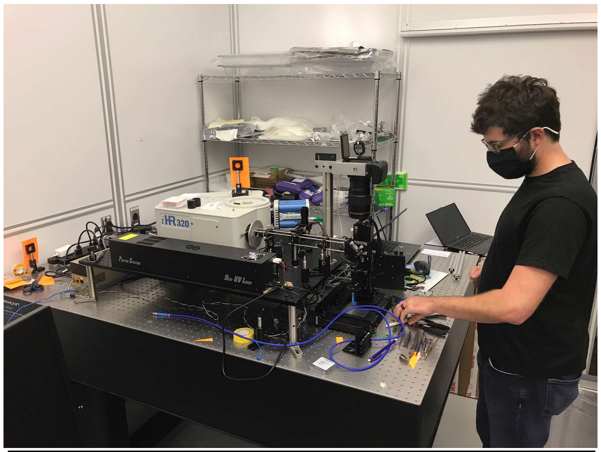

Figure 3: The ACRONM instrument during assembly. ACRONM is housed in an ISO 7 cleanroom at NASA ARES, Johnson Space Center.

The Mars chamber used in this study will be analogous to Mars in terms of temperature, pressure, gas composition, and illumination. This study does not address other factors like dust accumulation or the chemical action of perchlorates and other environmental chemicals. However, by calibrating spectra collected by SHERLOC to analogous spectra collected on Max-CF samples by ACRONM, environmental factors such as these can be mathematically accommodated without knowing them in detail. Additional studies may introduce these and other factors to refine the result.

Max-CF will expose suites of materials to differing times in the Mars chamber. There will be six exposure times, sufficient to produce a statistically robust fit to changes in materials properties over time. The time steps chosen for Max-CF are 1, 10, 100, 500, and 1000 hours of exposure on Mars, assuming "high noon" insolation. Converting to 12-hour insolation/sol with varying flux (i.e. less than "high noon" equivalent) through the course of the day yields a total simulated martian surface exposure of 579 sols, or ~1.6 martian years at the Mars 2020 landing site. It is assumed that this period is sufficient to observe degradation over a sufficiently long period to accurately observe the degradation behavior and extrapolate longer exposure times if necessary. If this assumption proves inadequate then Max-CF may be amended with additional, longer Mars chamber exposure times. A series of calculations on actual illuminance during a martian day, reflectance from surrounding terrain, and the geometry of the SHERLOC calibration target produce an estimated conversion factor of 0.14 for insolation on Mars versus that in the chamber under a 1000W full-spectrum source. This number may be subject to refinement through a more detailed examination of illumination of the moving, vertically-mounted SHERLOC calibration samples over the course of the rover's mission.

Max-CF will analyze all five material types with six replicates for each of the six time-steps (five steps plus one control sample set), for a total of 180 samples. The Mars chamber identified for this study accommodates 10 samples per trial, and samples are sized for tensile testing. A customized sample holder will be used to expose all samples to equal illumination. In total, the Mars chamber work will require 29 days of chamber time plus sample change-out and other preparatory work.

Optical transmission through the polycarbonate samples will be measured immediately following exposure in the Mars chamber, and tensile testing will be performed as soon as possible after exposure. Samples will be stored in a light-proof container between exposure and testing. Results will be plotted as exposure vs. instrumental response and a best-fit routine performed to extract material response versus time in the Mars chamber. To convert this to time on Mars, SHERLOC and ACRONM spectra will be used to calibrate for any difference in degradation behavior between the SHERLOC calibration target and Max-CF sample suites. For both sample suites, Raman spectral band widths, peak positions, appearance of/intensity of defect-derived peaks, and changes in fluorescence intensity (as seen in *Fig.* 2) will be measured using standard spectroscopy software. Curves for variation of these features over time will be calculated and used to build a conversion factor for SHERLOC calibration target samples versus Max-CF samples.

Summary: The Max-CF project will generate the first calibrated data set measuring degradation of space suit materials on another world. This product will inform space suit design to improve crew safety and enable exploration. The calibration function using measurements made by SHERLOC on Mars will also produce a Mars-calibrated environmental chamber which can be used for additional testing.

References: [1] Bhartia et al, *Space Science Reviews* 217, no. 4 (2021): 1-115. [2] Precursor Strategy Analysis Group (P-SAG), 2012. [3] Larson, K. and Fries M., (2017) 47th International Conference on Environmental Systems.

Acknowledgements: This work received critical support from visionary XI3 manager John Alred and is posthumously dedicated in his honor. John was an uncommonly courageous gentleman.