DURABILITY OF SPACE SUIT MATERIALS UNDER MARTIAN CONDITIONS.

K. N. Davis[1], M. D. Fries[2], E. K. Lewis[3], A. S. Burton[2], A. J. Ross[1], T. G. Graff[4], K. K. John[4], R. Bhartia[5] and L. Beegle[5]; [1]NASA Johnson Space Center, Space Suit & Crew Survival Systems Branch, 2101 NASA Parkway, Houston, TX 77058, [2]NASA Johnson Space Center, Astromaterials Research and Exploration Science Division, 2101 NASA Parkway, Houston, TX 77058, [3]NASA Postdoctoral Program Sr. Research Fellow, Administered by USRA, NASA Johnson Space Center, Houston TX 77058, [4]Jacobs JETS Contract, NASA Johnson Space Center, Houston, TX 77058, [5]Jet Propulsion Laboratory, Pasadena, CA 91109.

Introduction: Sending humans to the surface of Mars will require a better understanding of how space suit materials, especially those made of "soft good" fabric materials, perform in the harsh environment. Ultraviolet radiation, temperature extremes, oxychlorine oxidizers in the soil [1], a carbon dioxide based atmosphere, and martian dust could degrade and damage the materials on an Extravehicular Activity (EVA) space suit. It is essential to know how these materials will perform on the Mars surface long before any human depends on them for life support.

To understand how space suit materials would degrade on Mars *in-situ*, the Advanced Space Suit team at Johnson Space Center (JSC) has included space suit materials on the calibration target for the Scanning Habitable Environments with Raman & Luminescence for Organics and Chemicals (SHERLOC) instrument on the Mars 2020 rover [2]. The calibration target will be built at JSC as a contribution to the Mars 2020 rover. These space suit materials will serve two purposes: samples of organic polymers necessary for calibration of the SHERLOC instrument, and as a stand-alone experiment to measure the degradation rates and service lifetimes of space suit materials.

Pilot Test: In the summer of 2016, a pilot study was conducted at JSC to select which materials would be used for the calibration target and confirm that results could be obtained from this study. Nine space suit materials were irradiated with ultraviolet (UV) radiation for an equivalent of 2500 martian hours in chambers at Marshall Space Flight Center (MSFC). The radiation output of the lamps was between 230 and 500 nanometers. In comparison, the most damaging rays of Mars UV radiation that the soft goods materials will receive is between 190 and 410 nanometers. [3] Before- and after-exposure, samples were measured for mass, ultimate strength, elongation, and chemical composition. The mechanical properties were measured at JSC's Advanced Materials Laboratory. Jet Propulsion Laboratory (JPL) measured the chemical composition with a laboratory version of the SHERLOC instrument.

This pilot study showed that all nine candidate could be studied with the SHERLOC instrument (*i.e.*, were deep-UV Raman active; see below for more details) and, in the future, could be correlated to ground results of mechanical strength and elongation. Changes could be seen in the chemical composition; results from the Teflon sample are shown in Figure 1. Mass loss was insignificant among the materials; most samples lost tensile strength after UV radiation and became more brittle coupled with loss of elongation. All materials yellowed, including polycarbonate which became less transparent.

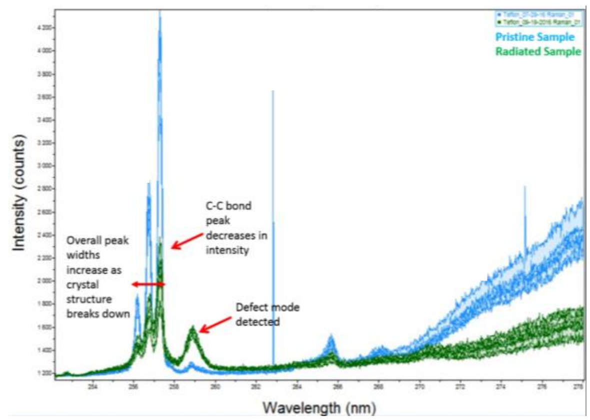

Figure 1: SHERLOC chemical analysis before (blue) and after (green) UV radiation of Teflon. *Note changes in peak intensities, and differences in the fluorescence background on the right side of the spectra. These changes can be used as metrics for chemical degradation of the space suit materials on the SHERLOC calibration target on Mars 2020.*

Material Selection Criteria: The pilot test showed that any of the nine materials used in the pilot experiment would provide valuable information for spacesuit durability under martian conditions. Thus, other factors were used to down select to the final five used on the target. Priority was placed on materials that would be on the outermost layer of the space suit. In addition, strict outgas requirements for the rover eliminated some of the materials. The minimum requirements the materials had to meet were the ASTM E595 Total Mass Loss (TML) of <1.0% and Collected Volatile Condensable Materials (CVCM) of <0.1% and be non-shedding. Considering this information, the final five materials selected were Orthofabric, Teflon, nGimat coated Teflon, Vectran, and polycarbonate. The polycarbonate to be used is the same stock used for the current Extravehicular Mobility Unit (EMU), Makrolon UC with a SDC MP-101 hard coat.

Mars 2020 Operations: The SHERLOC instrument is a deep-UV Raman/fluorescence instrument designed to detect and characterize carbon-bearing compounds on Mars. As such, it is capable of measuring the chemical composition of polymers such as the space suit materials, as well as measuring changes in those materials over time. Once the Mars 2020 rover lands on Mars, SHERLOC will periodically collect spectra from the space suit materials. Those spectra provide a valuable instrument calibration function, as they provide authentic spectra of a wide range of known organic chemical compositions, to guide the classification of native martian organic compounds. Spectra will be collected at intervals while the space suit materials are exposed to the martian surface environment. Changes in the spectra will be used as metrics of chemical change in the materials. Concurrently with rover operations, a second suite of space suit materials will be exposed to simulated martian conditions at JSC. Spectra will be collected from those samples using a laboratory SHERLOC instrument analogue, and the same spectral change metrics will be used to calibrate degradation behavior of both sets of samples. The samples at JSC will be periodically used for materials properties testing, i.e. tensile testing and measurement of optical properties of the polycarbonate. In this way, the degradation behavior and service lifetimes of space suit materials can be tested using the JSC-developed SHERLOC calibration target.

Future Testing: The team is continuing to develop greater ground test capabilities to better replicate the martian surface environment. Modifications have been made to the chamber at MSFC to mimic the atmosphere, pressure, and temperature (in the sunlight) of Mars along with the UV radiation. Testing is underway to see if this alters chemical changes or mechanical proprieties of the space suit materials as compared to only irradiating the materials with UV.

At JSC, a small martian chamber is also being built to provide dedicated, cost-effective support for this time-intensive test series. The Mars 2020 rover will be certified for operation for one martian year, which will result in over 8000 hours of daytime UV radiation. Extended rover missions may extend this exposure time significantly. Therefore, a robust ground capability must be built up to support many hours of material testing to create an equivalant exposure to what the materials will experience on Mars. In brief, it is expected that the ARES JSC Lunar/Mars (LuMa) chamber will be capable of testing materials under martian and lunar analogue pressure, temperature, and UV irradiation. The goal is to accelerate the sample test iteration and work towards testing single fibers along with woven materials and composites. Alongside testing samples in the fabric-strip method according to ASTM D5035-11, testing with single threads according to ASTM D2256-10 will provide an ability to test an increased number of samples together because of the drastically reduced space needed in UV spot. The fabric-strip tests will provide insight into degradation of the woven fabric, while single-fiber tests will provide a large number of tensile tests for statistically robust analyses. These tests can be expanded into dust- and oxychlorine-specific analyses, wherein a single fiber could be coated with Mars-analog regolith and be exposed to martian conditions in the LuMa chamber. Before- and after-exposure tensile testing and chemical analysis would be completed to investigate the effects of individual and multiple deleterious conditions, and provide a rich knowledge of materials behavior under a martian environment. Additionally, these tests could be extended to non-fabric components, materials, and assemblies under analogue martian conditions, using the SHERLOC space suit materials as calibrants to assure an exposure profile that is demonstrably analogous to that of the martian surface.

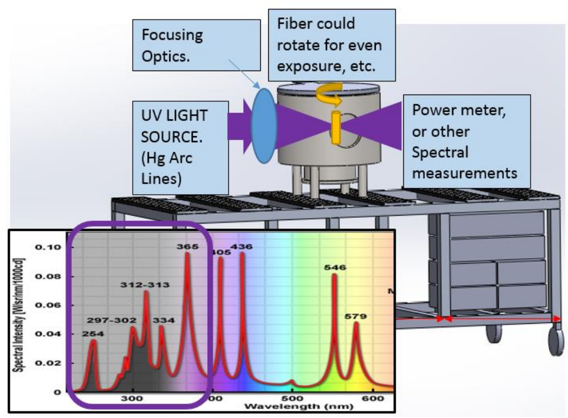

Figure 2 Space Suit Fiber UV Exposure Configuration *Graph from http://zeiss.magnet.fsu.edu/articles/lightsources/images/mercurylampsfigure1.jpg. [4]*

The performance data of the material sent to Mars can validate the ground test methods that can be used to test future materials used for space suits, habitats, life support systems, and rovers to support a future human presence on Mars.

References: [1] Navarro-González, R., Vargas, E., de La Rosa, J., Raga, A.C. and McKay, C.P., 2010. *JGR: Planets*, *115*(E12). [2] Larson, K. and Fries, M., 2017. *47th Int'l Conf. on Env. Systems*. [3] Patel, M., Zarnecki, J., & Catling, D. (2002). Planetary and Space Science, 50(9), 915-927. doi:10.1016/s0032-0633(02)00067-3. [4] "Mercury Arc Lamp Spectral Distribution," by Michael W. Davidson, Zeiss. Retrieved January 4, 2018, from http://zeiss.magnet.fsu.edu/articles/lightsources/images/mercurylampsfigure1.jpg.