THE CALIBRATION TARGET FOR THE MARS 2020 SHERLOC INSTRUMENT: MULTIPLE SCIENCE ROLES FOR FUTURE MANNED AND UNMANNED MARS EXPLORATION.

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Introduction: The Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC) instrument is a deep ultraviolet (UV) Raman/fluorescence instrument selected as part of the Mars 2020 rover instrument suite. SHERLOC will be mounted on the rover arm and its primary role is to identify carbonaceous species in martian samples, which may be selected for inclusion into a returnable sample cache. The SHERLOC instrument will require the use of a calibration target, and by design, multiple science roles will be addressed in the design of the target. Samples of materials used in NASA Extravehicular Mobility unit (EMU, or "space suit") manufacture have been included in the target to serve as both solid polymer calibration targets for SHERLOC instrument function, as well as for testing the resiliency of those materials under martian ambient conditions. A martian meteorite will also be included in the target to serve as a well-characterized example of a martian rock that contains trace carbonaceous material. This rock will be the first rock that we know of that has completed a round trip between planets and will therefore serve an EPO role to attract public attention to science and planetary exploration. The SHERLOC calibration target will address a wide range of NASA goals to include basic science of interest to both the Science Mission Directorate (SMD) and Human Exploration and Operations Mission Directorate (HEOMD).

SHERLOC Calibration: The SHERLOC instrument is a deep-UV Raman/fluorescence instrument that utilizes a 248.6 nm pulsed laser source and performs measurements over a wavelength range of 245-360 nm. The instrument operates in either a point-measurement mode or in a scanning mode that can image a 7x7 mm area. The instrument is specifically designed to identify trace-level organic species in a rock matrix. Two advantages arise from this method that are particularly useful to the Mars 2020 mission. For one, SHERLOC can identify trace-level (ppb in bulk material) organic species without the need for a heating step, which has been identified as problematic for the detection of martian organics due to oxidation by perchlorates [1]. Secondly, SHERLOC analyses are performed *in situ* and preserve the mineralogical context of any detected carbonaceous species, which is advantageous in the search for biosignatures, e.g. [2]. In order to suit SHERLOC mission requirements, then, the SHERLOC calibration target is required to serve as a calibrant in terms of *spectral accuracy, organic species sensitivity, auto-focus accuracy, laser power quantification, and imaging fidelity*. The SHERLOC calibration target will be identical to the Mars Science Laboratory (MSL) MAHLI calibration target in form, size, and the inclusion of a step wedge for autofocus calibration (Figure 1). The SHERLOC target will differ in terms of the target materials used, however. A boron nitride target will be used for laser power calibration. A grid of calibration targets will the color calibration targets and penny used on the MAHLI target. The MAHLI target area is 135x50 mm and SHERLOC will use this area to mount a 3x4 grid of twelve calibration targets. This is sufficient area for eight full 7x7 mm SHERLOC macro scans per calibration target without re-scanning a portion of the target. Organic species sensitivity will be calibrated using a trio of synthetic carbon-bearing silicates, a carbon-rich carbonaceous chondrite target, and the martian meteorite target. Imaging fidelity calibration will be maintained through scans of carbonaceous and martian meteorite targets, which feature fine (sub-mm scale) textures that

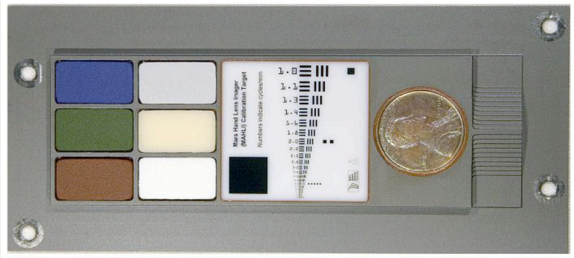

Figure 1: The calibration target for the MAHLI imaging instrument on MSL. Targets include color targets (six coupons at left), visual calibration target (center), a US penny (right), and a stepped auto-focus target to the right of the penny. The SHERLOC instrument will leverage the flight heritage of this hardware. The auto-focus target will remain in the SHERLOC calibration target, but the other targets will be replaced with targets to include carbon-bearing glass targets, EMU material samples, two meteorites (carbonaceous and martian) as described in the text.

will be imaged thoroughly prior to flight. The carbon in these targets is predominantly present in the form of reduced carbon species as opposed to organic molecules. In order to calibrate the instrument using the full spectrum of carbonaceous species to include organics, solid samples of polymers are also required. Samples of polymers used in modern NASA space suits were selected in order to perform the dual duties of calibrating SHERLOC's instrumental response for a wide range of organic species and enabling an EMU materials study to assist with future manned exploration of Mars.

EMU ("Space Suit") Materials Study: The need for solid polymer calibration targets represents a fortunate confluence of needs between the practical, calibration needs of SHERLOC and the strategic needs of both SMD and HEOMD. The SHERLOC calibration target will incorporate a suite of EMU materials to study their degradation behavior in the martian surface environment, directly informing materials requirements for future space suit design. The use of space suit materials as combination calibration targets/exposure test coupons addresses the following NASA Strategic Knowledge Gaps (SKGs), as quoted from "Analysis of Strategic Knowledge Gaps Associated with Potential Human Missions to the Martian System", MEPAG and SBAG 2012) [3]:

SKG Group B, #4: *Dust Effects on Engineered Systems.* We do not understand the possible adverse effects of martian dust on surface systems. (p.30)

SKG Group B, #8: *Technology: Mars Surface*. In addition to the specific challenges listed above, we do not have the required technology available to: … (2) sustain humans on the surface of Mars; (3) enable human mobility and exploration of the Mars surface environment; all within acceptable risk (p.31).

SKG Group D, #2: *Technology*: In addition to the specific challenges listed in **B-8**, we do not have the required technology available to: … (2) sustain humans on the surface of Mars for long durations (multiple martian years) (p.33).

Additionally, the P-SAG document states:

Finding #3: "The early robotic precursor program needed to support a human mission to the martian surface would consist of at least: …A lander/rover-based <u>*in situ*</u> set of measurements (which could be made from a sample-caching rover)… (p.17)

"Elements of the MSR campaign could be augmented to address: … Environmental exposure… dust mitigation..." (p.21)

The P-SAG panel clearly indicates that SKGs exist in the area of long-term survival of critical hardware on the martian surface, with respect to degradation in response to martian surface conditions and dust exposure. The panel also suggests that the then-notional Mars 2020 rover could assist in closing some SKGs, as stated on page 22: "A lander/rover could make the following technology demos: …environmental exposure…dust mitigation". The SHERLOC calibration target will assist with closing these SKGs through inclusion of modern NASA space suit materials. The SHERLOC team envisions a research study wherein identical material coupons will be exposed in a "Mars chamber" to simulated martian conditions over a similar time period to that experienced by the SHERLOC calibration target on the Mars 2020 rover. SHERLOC is capable of directly measuring chemical changes in polymeric materials brought on by exposure to the martian environment. SHERLOC analyses of the space suit materials on Mars will yield a series of chemical change per unit time curves for each of the materials. The same changes should be seen in the materials stored in the Mars chamber on Earth, and those coupons will be subjected to materials properties tests such as tensile strength, shear strength, transmissive properties of visor material, and other analyses. The samples on Earth will then serve as a proxy for the SHERLOC calibration target samples, allowing measurement of the physical properties of these materials in response to their observed degradation rates on the martian surface. From this data set, the service lifetimes of NASA space suit materials can be estimated for use on the martian surface. Any anomalous behavior can be addressed through a re-thinking of materials selection. As an additional benefit, once the Mars chamber conditions used in this study are essentially calibrated to SHERLOC observations of calibration target materials, additional materials can be tested under simulated "Mars chamber" conditions with improved confidence in the fidelity of those conditions to the actual martian surface environment.

A suite of EMU materials was chosen for inclusion in the SHERLOC calibration target.

Material	Current Use in NASA Space Suits
Orthofabric	Outer layer for most of EMU
3 oz. Teflon fabric	Outer layer for glove, back of hand, gauntlet
Polycarbonate	Helmet bubble
RTV Silicone	Glove palm
Vectran	Glove palm
Spectra	EMU structural element
6 oz. polyester	EMU restraints

This suite of materials includes space suit fabrics, visor, glove, and boot material. All of these critical components are subject to wear in normal use.

Martian Meteorite Sample: One calibration target will be a martian meteorite sample. The purpose of this sample is to provide a well-characterized, carbon-bearing rock to calibrate the organic species sensitivity and imaging fidelity of the SHERLOC instrument. Previous work shows that the martian meteorites sampled to date contain ~20±6 ppm of reduced carbon predominantly in the form of macromolecular carbon within igneous host minerals [4]. This carbon species is not a biosignature as it precipitated from a cooling parent magma, but it is important as it is found across the suite of martian meteorites and may be encountered by the Mars 2020 rover. The Mars 2020 mission will need to differentiate this carbon from potential biosignatures, necessitating a need to carry a sample of abiogenic martian carbon in the SHERLOC calibration target. The mineral texture of the meteorite coupon will also serve as a test of instrumental imaging function by comparing SHERLOC images collected during Mars 2020 operations to the same scans collected prior to the mission. And as far as we know, the martian meteorite in the SHERLOC calibration target will be the first rock of any type to make a round trip between planets. This fact will attract popular visibility to science and planetary exploration.

References: [1] Navarro-González, Rafael, *et al*, *JGR: Planets* (1991–2012) 115, no. E12 (2010). [2] Allwood, Abigail C., *et al*, *Precambrian Research* 158, no. 3 (2007): 198-227. [3] P-SAG (2012) Analysis of Strategic Knowledge Gaps Associated with Potential Human Missions to the Martian System: Final report of the Precursor Strategy Analysis Group (P-SAG), D.W. Beaty and M.H. Carr (co-chairs) + 25 co-authors, sponsored by MEPAG/SBAG, 72 pp., posted July 2012, by the Mars Exploration Program Analysis Group (MEPAG) at http://mepag.jpl.nasa.gov/reports/. [4] Steele A., *et al*., *Science Express*. (2012) 10.1126/science.1220715.