SUPERCAM REMOTE SENSING ON THE MARS 2020 ROVER: SCIENCE GOALS AND OVERVIEW

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Introduction: The Mars 2020 Science Definition Team (SDT) Report [1] emphasized the importance of fine-scale measurements, suggesting that the numerous pin-point observations made at remote distances by ChemCam was a very desirable capability. However, the 2020 SDT made it clear that the new rover's remote sensing needed to have strong capabilities in mineralogy [1], which is covered only minimally on MSL via ChemCam's passive 0.4-0.85 µm [2] and Mastcam multispectral observations [3]. The SuperCam instrument suite that was selected for Mars 2020 provides five remote techniques: two for mineralogy, one for chemistry, one for morphology, and one acoustic. These techniques are, respectively, remote Raman spectroscopy, passive visible and infrared (VISIR) reflectance spectroscopy, laser-induced breakdown spectroscopy (LIBS), color remote micro-imaging (RMI), and a microphone. All of the optical spectroscopy techniques plus the imaging are co-bore sighted, fulfilling a desire stated by the SDT for multiple co-registered observations [1]. In this presentation we give an overview of the science objectives and the implementation. A separate presentation provides technical details of SuperCam's mast unit [4].

Science objectives:

1) *Rock Compositions*: Detailed mineral, chemical, textural, and acoustic characterization of rocks will help to determine the geological diversity of the site, to identify key processes relevant to its aqueous history, and to document the context of the sample cache.

2) *Sedimentary Stratigraphy*: Characterization of the texture, hardness, and composition of the sedimentary structures will provide strong constraints for the aqueous processes as well as its potential habitability.

3) *Organics and Biosignatures*: SuperCam will analyze astrobiologically relevant materials without requiring contact, determining the best area for contact science and caching, and will allow exclusive interrogation of areas inaccessible to the rover arm.

4) *Volatiles*: SuperCam will constrain the aqueous processes involving volatiles and provide data on volatile content for the documentation of cached material.

5) *Context Morphology and Texture*: High resolution color images will provide detailed information on dust covering and a visual approach to oxidation states of layers relevant for aqueous processes.

6) *Coatings and Varnishes*: Analyses of coatings will allow the identification of late-stage weathering and its relationships to exobiological material.

7) *Regolith Characterization*: SuperCam will address soil diversity at the landing site and will characterize the soil potential for biosignature preservation. Additionally, LIBS detection of hazardous elements in dust will provide important data for future human exploration.

8) *Atmospheric Characterization*: Column density measurements of atmospheric molecules, water ice, and dust characteristics will address the radiative balance of the Mars atmosphere. Acoustic sampling will help understand local instabilities (wind gusts).

Remote Sensing and Sampling Scales; Dust Removal: All of the techniques operate within the arm work zone, with a closest distance from the instrument of 2.0 meters, looking straight down. Fig. 1 shows the distance extent of each of the different techniques, giving a range of capabilities depending on the sample distance. Observational footprints are ~0.8 mrad for Raman, ~1.0 mrad for VISIR, 0.3-0.5 µm for LIBS, and an RMI field of view of 20 mrad and pixel FOV of 19 µrad. As such, the RMI provides the highest resolution remote imaging of all of the rover cameras. The LIBS laser shock wave brushes dust from the rock surface over an area large enough for the analytical footprints of all of the spectral techniques, providing unique and important access to the surface of the rock (Fig. 2).

Implementation of Techniques: *LIBS* is performed much the same as on ChemCam [5, 6] with similar laser wavelength and energy, a similar telescope, and a similar spectral range. Two of the three

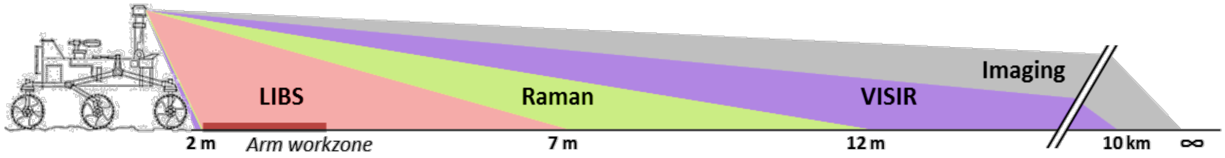

Fig. 1. Extent of SuperCam analytical capabilities. All techniques work within the arm work zone. The microphone (not shown) senses the laser shock waves to 4 m.

spectrometers are exact copies of ChemCam, while the third uses a higher-resolution spectrometer (Fig. 3) with an intensified, gated CCD which will allow time-resolved LIBS. *Remote Raman spectroscopy* is performed with a frequency-doubled YAG laser at 532 nm (green) in time-resolved mode, which eliminates much of the interfering fluorescence. The exposure can also be delayed, facilitating time-resolved fluorescence studies. The spectral resolution is ≤ 10 cm^{-1}, provided by the transmission spectrometer shown in Fig. 3. The *VISIR reflectance spectroscopy* is provided by the visible-range spectrometers used for LIBS and Raman spectroscopy (0.40-0.46, 0.53-0.85 µm) along with a wavelength-scanning AOTF infrared spectrometer that covers 1.3-2.6 µm, providing many important mineral signatures. The *RMI* imager employs a CMOS device with a Bayer color filter and high-dynamic-range (HDR) software. The *Microphone*, a Knowles electret identical to the ones installed (but never used) on Mars 98 and Phoenix, is mounted on the mast. Its primary purpose is to record the laser shock waves, which provide information on the hardness of the rock. It can also record wind and rover sounds.

Architecture: The SuperCam architecture is shown in the block diagram in Fig. 4. Overall, it is similar to ChemCam, consisting of separate Mast and Body Units built in France and at Los Alamos, respectively. The Mast Unit (MU) consists of a 110 mm diameter telescope, RMI camera, laser, and IR spectrometer. Light is provided to the Body Unit (BU) spectrometers via a fiber optic cable. The BU provides overall control and data handling for the instrument, with a number of functions handled in the MU. In addition, a significant effort is underway on the on-board calibration targets, ~28 geological and color standards designed for calibration of all three spectral modes and imaging.

Status: Prototypes of all subsystems have been built. A first end-to-end test was carried out with development unit parts in May, 2016, demonstrating Raman spectroscopy to 12 m along with LIBS. A more comprehensive test is scheduled for October, with a qualification unit being built in early 2017 and the flight unit in 2018.

References: [1] Mustard et al. (2013): Report of the Mars 2020 Science Definition Team. [2] Johnson J.R., et al. (2015) Icarus 249, 74-92 http://dx.doi.org/10.1016/j.icarus.2014.02.028. [3] Bell J.F. III, et al. (2012) Mastcam multispectral imaging on the Mars Science Laboratory rover: Wavelength coverage and imaging strategies at the Gale crater field site. Lunar Planet. Sci. XLIII, 2541. [4] Deleuze M., et al. (2016) The SuperCam Mast Unit on the NASA Mars2020 Mission, this meeting. [5] Wiens R.C., et al. (2012) Spa. Sci. Rev. 170, 167-227, doi 10.1007/S11214-012-9902-4. [6] Maurice S., et al. (2012) Spa. Sci. Rev. 170, 95-166, DOI 10.1007/s11214-012-9912-2.

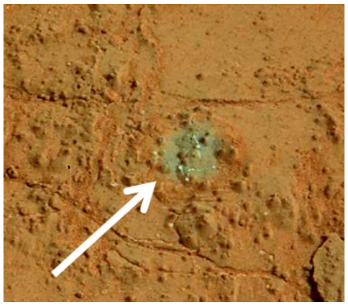

Fig. 2. ChemCam dust removal (2x2 raster) reveals gray mudstones in Gale. All SuperCam techniques will benefit from dust removal.

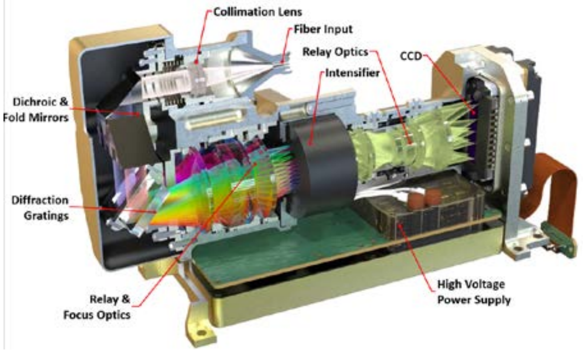

Fig. 3. SuperCam transmission spectrometer covers 535-850 nm (150-4000+ cm^{-1}) range with 10 cm^{-1} resolution.

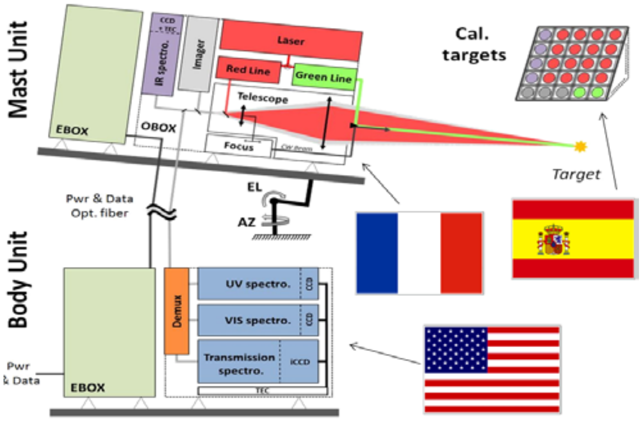

Fig. 4. SuperCam schematic diagram.