SUPERCAM BASELINE PERFORMANCE PRIOR TO THE LAUNCH OF MARS 2020. S. Maurice[1], R.C. Wiens[2], P. Bernardi[3], S. Robinson[2], P. Caïs[4], T. Nelson[2], O. Gasnault[1], P. Pilleri[1], F. Rull[5], P. Willis[6], I. Gontijo[6], V. Sridhar[6], O. Beyssac[7] and the SuperCam team. [1]Institut de Recherche en Astrophysique et Planétologie, Toulouse, France (sylvestre.maurice@irap.omp.eu), [2]Los Alamos National Laboratory, Los Alamos, NM, [3]Laboratoire d'Etudes Spatiales et d'Instrumentation en Astrophysique, Meudon, France, [4]Laboratoire d'Astrophysique de Bordeaux, Bordeaux, France, [5]Universidad de Valladolid, Valladolid, Spain, [6]Jet Propulsion Laboratory, Pasadena, CA, [7]Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, Paris, France.

Introduction. Built upon the scientific success of the MSL/ChemCam instrument, SuperCam [1] for the NASA Mars 2020 Rover is a multifaceted facility supporting six remote-sensing techniques. Like its predecessor, SuperCam carries out remote micro-imaging (RMI) and laser induced breakdown spectroscopy (LIBS) [2,3]. Using LIBS spectrometers, passive spectroscopy below 1 µm can also perform. New capabilities for SuperCam include remote Raman spectroscopy, a microphone, and extension of the passive range to the near-infrared range (hereafter VISIR). The Raman spectroscopy also includes a time-resolved luminescence (TRLS) mode. See Table 1 for overall characteristics, such as distance range for each capability and field-of-view (FOV). Two overarching requirements are essential: two independent (redundant) autofocus methods and co-boresighting of all techniques at the center of the imager field-of-view.

LIBS (1.5 m – 7 m range)
< 600 µm spot size, up to 14 mJ on target at 1064 nm
1 – 150 shot bursts @3 Hz laser
245 – 853 nm range, 0.15 – 0.65 nm resolution
Raman – Fluorescence (1.5 m – 7 m range)
~0.7 mrad FOV, > 9 mJ on target at 532 nm
1 – 200 shot bursts @10 Hz laser
150 – 4400 cm^{-1} range, < 12 cm^{-1} resolution
Time sweep: 100 nsec windows, delays up to 10 msec
VISIR Reflectance Spec. (1 m to ∞ range)
~0.7 mrad FOV, 400 – 853 nm range, 0.15 – 0.65 nm res.
~1.2 mrad FOV, 1.3 – 2.6 µm range, < 32 cm^{-1} res., and 256 spectels max. sampling
Remote Micro-Imaging (1 m to ∞ range)
19 mrad FOV, iFOV 10 µrad, standard RGB color filtering
Spatial resolution < 80 µrad, distance = 563 mm, f/5
Contrast > 20% at 20 line pairs/mm over half-FOV
Microphone (< 4 m range)
100 Hz – 10 kHz range, sampling at 25 kHz or 100 kHz
Standalone mode (2.7 min rec. max)
LIBS shot recording (up to 150 shots)

Table 1. SuperCam key characteristics.

SuperCam's RMI provides morphology and texture context for spectroscopic techniques. LIBS yields elemental compositions for all major elements to high precision, and minor and trace elements including Li, B, C, N, Cr, V, Mn, Ni, Cu, Rb, Sr, Ba are detected and quantified. To support other techniques, LIBS analysis removes surface dust, enabling a clear view of the surfaces. VISIR and Raman spectroscopies can jointly detect silicates, carbonates, sulfates, phosphates, sulfides, and organic molecules. TRLS determines the presence of trace and rare-earth elements. Lastly, the microphone determines the physical properties of the targets from the acoustic signal of the LIBS laser interaction with the surface [4], and can also be used for characterization of atmospheric turbulence (wind gusts, dust devils).

At the back of the rover, at 1.56 m distance, SuperCam includes an extensive calibration target assembly with some 28 targets, including mineral separates, rock, and glasses that have been crushed and flash sintered for homogeneity [5,6] for LIBS calibration primarily, but some for Raman, plus dedicated targets for VISIR and RMI.

Performance tests. By early July 2019, all parts of SuperCam had been delivered to JPL, and integrated into the rover. Numerous tests were conducted to check the instrument health, all functionalities, and the rover pointing capability. In October, the spacecraft underwent several weeks of environmental testing in JPL's 25-foot chamber at Mars pressure (N_2) with shroud temperatures ranging from -125°C to +55°C, yielding the first flight-like status of its performance.

Focus & Co-alignments. Both autofocus methods perform nominally. The RMI-based technique works at any distance but with a tighter distance seed (~5% of the true distance) whereas the continuous laser-based technique performs below 7 m with a seed of several tens of percent. The distance seed will be given by the rover Navcams. All techniques are co-aligned at cold temperature to better than 0.35 mrad.

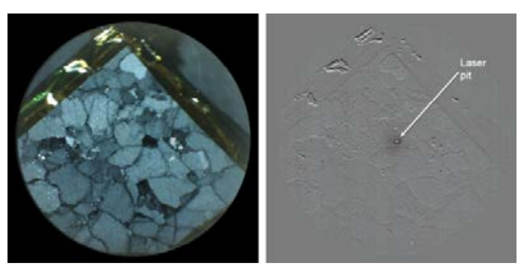

Figure 1. RMI image at 4.5 m of ilmenite/hematite rock. RGB colors (left). Difference before/after LIBS laser shot (right).

RMI. Several images were acquired under the Sun simulator, tuned for Mars distance. Images show many visible details, including a laser pit (Figure 1). Basic performance (SNR, FOV size, spatial resolution) is nominal. Further characteristics (saturation, flat field, etc.) allow us to set a pre-processing scheme.

LIBS. Calibration targets (1.56 m distance) and rocks at 2.5 m and 4.5 m were shot at low to high energy, by burst of 30 shots. Performance (resolution, FOV) are as expected, similar to ChemCam (see Figure 2).

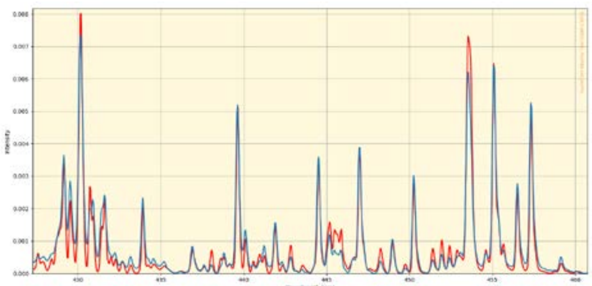

Figure 2. LIBS spectrum of Ti cal. Target. (blue) ChemCam data (Red), SuperCam STT data

Raman. Spectrum quality depends on numerous parameters: green laser energy, number of co-adds on the CCDs, intensifier gain, delay and gate size. Not all combinations could be tested. On a diamond included in the cal. target assembly, the resolution meets specifications, and the signal is very intense with strong fluorescence. On an organic target (Ertalyte), also on the rover, the time sweep was tested to separate Raman from fluorescence. Other targets were also sampled up to 4.5 m. As expected, Raman is challenging at remote distances on fine-grain targets with mixed mineralogies. See [7,8] for details.

VISIR. Passive spectroscopy was tested with the Sun simulator. The signal in the VIS range is very strong; quantitative assessment is still under investigation (see [9] for details). The IR portion was fully characterized earlier and its integration did not change its performance: SNR, FOV, and resolution meet specifications, with excellent spectral registration. Relative and absolute spectral calibrations are addressed in [10].

Microphone. Shock waves generated by the plasma on the Ti and ferrosilite calibration targets were recorded. The capability performs as expected (band pass, dynamics, sampling rate) with 4 gain settings. The sensitivity is sufficient to record the LIBS shock wave at 4 m distance. There is electromagnetic-induced noise when the lasers are warmed-up, but the signal-to-noise ratio after data processing does not affect the LIBS science objectives. In the standalone mode, the noise floor is excellent, in line with what is expected. Recording of rover induced noise, when driving for instance, will be performed early 2020.

Conclusions. SuperCam performs nominally within the thermal ranges expected on Mars. From these tests at JPL and former characterization at subsystem levels, we find that:

– RMI performance is similar to ChemCam but with colors. White-balanced images, obtained from onboard calibration targets, and false-color images (when advantageous) provide adequate context for all techniques. The RMI resolution is equivalent to or better than other remote sensing cameras (Navcam, Mastcam-Z), with a narrower FOV.
– LIBS performance is very similar to ChemCam, but a larger set of onboard calibration targets will allow better quantification. The advantage of time-gating LIBS above 535 nm (made possible by the Raman-driven intensified spectrometer) is still to be explored.
– Remote Raman is challenging because of fluorescence. The best operating parameters are still to be defined. A possibility is a two-step observation strategy: first, a small number of laser shots (~100), long gate, to see if there is signal and fluorescence; then, on a few points, a short gate (100 nsec) and several hundred laser shots. The TRLS mode, yielding time-decay, is very original and promising.
– The VISIR capability will benefit a lot from dust removal by LIBS. Its implementation will depend on local time and atmospheric opacity. The performance is very promising.
– In conjunction with LIBS, the microphone yields a clean shock wave shape, whose intensity carries target information [4]. Atmospheric studies will be worked with MEDA. As an example, the speed of sound can be measured; it allows us to retrieve the surface layer temperature gradient [11].

SuperCam is a very flexible instrument for geochemistry. Multi-technique rasters are being developed as baseline activities.

References: [1] Wiens R.C., et al. (2017) Spectroscopy 32: 50-55. [2] Wiens R.C., et al. (2015) Elements 11: 33-38. [3] Maurice S., et al. (2016) J. Anal. At. Spectrom. 31, 4, 823 – 1050. [4] Chide, B., et al. (2019). Spec. Chim. Acta B 153, 50-60. [5] Cousin A., et al. (2017) 48th LPSC, abs. #2082. [6] Montagnac G., et al. (2018) J. Raman Spect., 49, 9, 1419 – 1425. [7] Beyssac O., et al. (2020) this meeting. [8] Torre I., et al. (2020) this meeting. [9] Legett C., et al. (2020) this meeting. [10] Royer C., et al. (2020) this meeting. [11] Chide B., et al. (2020) this meeting.