WHAT SUPERCAM WILL SEE: THE REMOTE MICRO-IMAGER ABOARD PERSEVERANCE.
O. Gasnault[1], C. Virmontois[2], S. Maurice[1], R.C. Wiens[3], S. Le Mouélic[4], P. Bernardi[5], O. Forni[1], P. Pilleri[1], Y. Daydou[1], W. Rapin[1], and P. Caïs[6], [1]IRAP (ogasnault@irap.omp.eu, Université de Toulouse – France), [2]CNES (Toulouse – France), [3]LANL (Los Alamos, NM – USA), [4]LPG (CNRS UMR6112 - Université de Nantes – France), [5]LESIA (Observatoire de Paris – France), [6]LAB (Université de Bordeaux – France).

Introduction and Investigation Goals: The objectives of the Mars 2020 mission include the characterization of a new landing site, in the Jezero crater on Mars, and the investigation of its habitability and the potential preservation of prebiotic signatures [1]. Its rover, *Perseverance*, will also assemble a returnable cache of samples. *SuperCam* is part of the scientific payload that combines laser-induced breakdown spectroscopy (LIBS), Raman, passive visible and infrared spectroscopy, sound recording and imaging [2, 3, 4]. SuperCam contributes to the objectives of the mission through rock identification and characterization of geologic records, search for organic signatures, monitoring of volatiles, and atmospheric studies. Among SuperCam's subsystems, the Remote Micro-Imager (RMI) provides high-resolution color images that give the local context to the instrument's millimeter-scale observations, and also complements the rover's other cameras to study stratigraphy, outcrops, and the morphology of the rocks and soils surrounding the rover. In this work, we give some details on the characteristics of the RMI.

SuperCam Camera Performance: SuperCam's RMI is a 2048x2048 pixels CMOS camera (based on a CMV4000 sensor), with Bayer color filters, mounted on the back of SuperCam's 110-mm diameter Schmidt Cassegrain telescope, with a focal length of 563 mm. The RMI underwent a series of functional and performance tests, as well as verification activities, at various stages of the instrument integration, from which the following attributes were confirmed.

Spectral response and signal-to-noise model. Only a fraction of the light collected by SuperCam is directed to the RMI. A near infrared 650 nm cutoff filter placed in front of the camera helps to balance the three color bands (~40% in the blue band and ~30% in the green and red bands for a white source), knowing that on Mars the spectra is redder. Ninety-nine percent of the response function is between 375 and 655 nm. A numerical model has been developed integrating the transmission of the optical system, the efficiency of the sensor, and some spectra of rocks typical of Mars. This model was used to estimate the signal-to-noise ratio and typical exposure times, which are in the range of 2 to 35 msec for these examples.

System flat field and field-of-view. The vignetting of the instrument is significant with an attenuation between the center of the image and the edges. It will be corrected on the ground by dividing the images with the instrument response to a flat field. The latter has been measured in the laboratory and will be re-examined on Mars a few weeks after landing by looking at the sky. The CMOS sensor is larger than the projected aperture of the telescope and, consequently, the field-of-view (FoV) appears circular in the images (Figure 1). The center of the useful FoV is slightly offset from the center of the CMOS and its diameter has been conservatively determined to be 18.8 mrad, where the response to the flat field is ~4.7 times less intense than at the center. The corners are masked on the ground and are used to evaluate the dark level of non-illuminated pixels, which is low with this device, especially at martian temperatures (~3% of the total dynamic range of the sensor).

Figure 1: RMI image of SuperCam's calibration targets [5] with a diamond slice at the center (4 mm in diameter for scale) used in Raman calibration, a sample of Ertalyte (top right) for time-resolved Raman spectroscopy, a cyan tile for color balance, and a sample of apatite (bottom) for LIBS.

Image resolution and depth-of-field. The angular size of the SuperCam's RMI pixels (iFOV) is just under 10 μrad, but the point spread function covers at least 2x2 pixels [2]. The effective image resolution is defined here as a minimum contrast of 20% on a USAF target, and it easily reaches 80 μrad or better on half of the FoV. This represents 0.24 mm at 3 m.

The depth-of-field is defined by a >20% contrast reduction when the focus changes. This depends directly on the position of the secondary mirror, but is not linear with the target distance. The RMI depth-of-field is ~2.5 mm at the distance of the calibration target (1.56 m, Fig. 1), ~9.5 mm at 3 m, or ~10.5 cm at 10 m.

On board Functions for the imager: There are functions implemented on board that use or support the imager. The first two, inherited from ChemCam on Curiosity, can be combined (autoexposure, autofocus).

Autoexposure. SuperCam can take up to four images with different exposure times and pick the best exposure for later use.

Autofocus. SuperCam can take a series of images with different focus and pick the best position for later use by the RMI or other subsystems of the instrument.

Focus stacking. SuperCam can merge images taken at different focusing distances to increase depth-of-field. But since there is no attempt to correct the individual images, it is limited to a few frames.

High-Dynamic Range (HDR). SuperCam can also combine multiple images with different exposure times or adopt a multi-linear response function to light. The resulting image will have a better dynamic range in both dark and light tones (Figure 2).

Rover services: Compression and sub-framing. The rover computer can crop SuperCam RMI images, and compress them using ICER or JPEG algorithms.

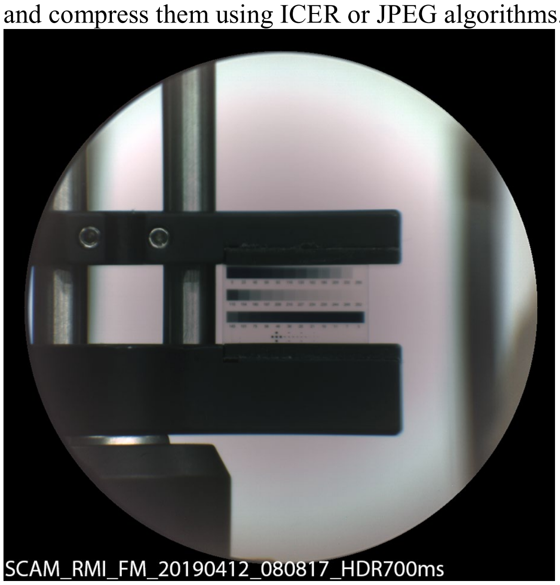

Figure 2: RMI image of on board target using HDR.

Application on Mars: SuperCam was turned on during the cruise to Mars and dark images were taken, proving that the system is fully functional. A similar activity will be repeated just after landing. Afterwards, images of the calibration targets on board can be taken to adjust the pointing coordinates and the focus parameters, before imaging a martian rock to test the SuperCam laser. These commissioning examples illustrate the key role played by the RMI in the SuperCam activities (pointing, focusing, documentation). Other characterization activities will be planned early in the mission to repeat some of the pre-launch tests, adjust some parameters (autoexposure, HDR…), verify the flat field, etc.

The experience with ChemCam's RMI [6] gives an idea of the scientific applications of SuperCam's RMI. SuperCam observations will generally be organized in series of points [3], e.g. successive points with LIBS laser shots that will be documented with RMI images taken before and after. The images are then assembled into annotated mosaics. These images will provide information on the nature of the target at the laser investigation scale (submillimeter pits): Bedrock, massive or stratified, pebbles, veins, concretions, soil, grain size, etc… The same applies to Raman and passive spectroscopy, but since these techniques do not alter the target, it will not be necessary to take images before and after, except to build the annotated mosaic. The RMI can also be used on its own, for example to study a distant outcrop perhaps not visited by the rover or steep faces offering better ground exposure than seen from orbit. In the landing ellipse of ~4 km radius, the resolution of the RMI is better than that of current orbital images and can therefore help in the investigation of any structure that would be visible from the landing point, such as delta remnants, delta front, buttes, crater walls, valleys or geologic contacts (Figure 3).

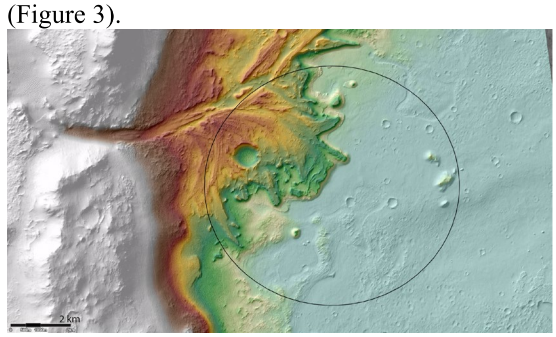

Figure 3: Perseverance landing area in Jezero crater.

Conclusion: The RMI of SuperCam supports the other SuperCam techniques and contributes to the mission objectives as one of the many cameras on the Perseverance rover [1]. We expect to take images of about 10 different targets per week with the RMI. The raw images will be immediately available to the community, and the processed images a few months later on the Planetary Data System.

References: [1] Farley K.A. et al. (2020) *SSR, 216,* 142. [2] Maurice S. et al. (in revision) *SSR*. [3] Wiens R.C. et al. (in revision) *SSR*. [4] Wiens R.C. et al. (this issue) *LPS LII*. [5] Manrique J.A. et al. (2020) *SSR, 216,* 138. [6] Le Mouelic S. et al. (2015) *Icarus, 249,* 93-107.