PRELIMINARY EVALUATION OF THE MARS 2020 ROVER'S SUPERCAM DEVELOPMENT UNIT: CO-ALIGNED CHEMICAL AND MINERALOGICAL ANALYSES. A. M. Ollila[1], R. C. Wiens[1], R. Perez[2], A. Nelson[1], M. Bodine[1], S. Maurice[3], S. Sharma[4], P. Gasda[1], J.-M. Reess[5], T. Fouchet[5], E. Cloutis[6], J. Johnson[7], S. Bender[8], F. Montmessin[9], P. Bernardi[5], J. Frydenvang[1,10], K. Mccabe[1], P. Cais[1,11], [1]Los Alamos National Laboratory, Los Alamos, NM USA, [2]CNES, France, [3]IRAP, Toulouse, France, [4]University of Hawaii, HI USA, [5]LESIA-Observatoire de Paris, [6]University of Winnipeg, Winnipeg, Canada, [7]Johns Hopkins University Applied Physics Laboratory, Laurel, MD USA, [8]Planetary Science Institute, USA, [9]Labatoire Atmospheres, Milieux, Observations Spatiales, Guyancourt, France, [10]University of Copenhagen, Denmark, [11]LAB, Bordeaux, France

Introduction: Scheduled to be launched in July/August 2020, the next Mars rover will continue the geological and astrobiological exploration of the martian surface. One of the selected instrument suites on its science payload is called SuperCam. SuperCam will have five science techniques that it will deploy remotely to study the chemistry, mineralogy, and small scale morphology of Mars. These techniques include laser-induced breakdown spectroscopy (LIBS) for chemistry, Raman/time resolved fluorescence (TRF) and visible-near infrared (VISIR) spectroscopy for mineralogy, a microphone to support the LIBS analyses, and a color remote micro imager (RMI) for context imagery and textural analyses [1].

Mars 2020 Mission: There are four primary science objectives the Mars 2020 mission seeks to accomplish: 1) identify habitable environments, 2) look for biosignatures, 3) collect and cache samples for later retrieval, and 4) prepare for human exploration by testing oxygen production from the atmosphere. To achieve these goals, an advanced science payload has been selected. The payload includes seven instruments: MastCam-Z (imaging/mineralogy), MEDA (environmental sensor), MOXIE (oxygen production), PIXL (chemistry), RIMFAX (ground penetrating radar), SHERLOC (mineralogy/organic detection), and SuperCam (imaging/chemistry/mineralogy). There will be a drill for coring samples to be cached for possible retrieval at a later time.

SuperCam Instrument Suite: SuperCam will be able to provide remote co-located chemical and mineralogical analyses through the multiple techniques of LIBS, Raman/TRF, and VISIR spectroscopy. The LIBS analyses will be similar to that provided by the ChemCam instrument on the Curiosity rover. Semi-quantitative analyses of all major elements and many trace elements (e.g. Li, Ba, Sr, Rb), depending on concentration, will be obtained. The LIBS will operate at a distance of 1.4-7 m with an analytical spot size of 300-500 µm. Raman spectroscopy will be able to identify a number of minerals including calcite, olivine, quartz, and gypsum. Raman and TRF analyses will be obtained at distances of 1.4-12 m with a spot size of 0.9 mrad, slightly larger than the LIBS spot. VISIR reflectance spectroscopy will also provide mineralogical information, identifying such minerals as carbonates, clays, and sulfates. VISIR will operate between 1.4 m and 10 km with a spot size of ~1.15 mrad, slightly larger than the Raman spot. The RMI has a spatial resolution of 50 µrad at the center of the filed of view. Operationally, it is anticipated that these instruments will be used in sequence, with the LIBS laser pulses clearing the dust from the surface, followed by either/both VISIR and Raman spectroscopy. RMI images will be acquired before and after the analysis to observe the laser pits and context.

Instrument Development: The SuperCam instrument is being developed at the Los Alamos National Laboratory (Los Alamos, NM) and by a consortium of French laboratories (IRAP, LAB, LESIA, LATMOS) led by the IRAP research institute (Toulouse, France) and supported by the CNES. Recently, the engineering development unit (EDU) was completed and several tests of its capabilities were conducted. While this model is very similar to what will be the flight model, some parts of the instrument are inferior to the flight model. One major difference is in the design of the transmission spectrometer, for which the flight model will have significantly better spectral resolution [2] This spectrometer covers the wavelength range from 536-853 nm, affecting the LIBS, Raman, TRF, and VISIR capabilities. Construction of the engineering qualification model is underway.

Capabilities Testing: The EDU was used to test each of SuperCam's capabilities. These tests include demonstrations of the 1) LIBS technique using an andesite and gypsum target, 2) Raman technique using selenite and barite targets, 3) TRF mode using ruby, 4) IR spectroscopy using a blackbody source (full VISIR analyses on rocks and minerals are pending).

Preliminary Results:

LIBS: Two of the three spectral ranges used for LIBS analyses are the same as ChemCam, covering ~241-340 nm (UV) and 382-469 nm (VIO). The transmission spectrometer used by SuperCam will cover 536-853 nm (VNIR). An example spectrum (VIO and VNIR ranges) of andesite (AGV-2) taken at ~1.5 m is presented in Fig. 1; major peaks are labeled. The

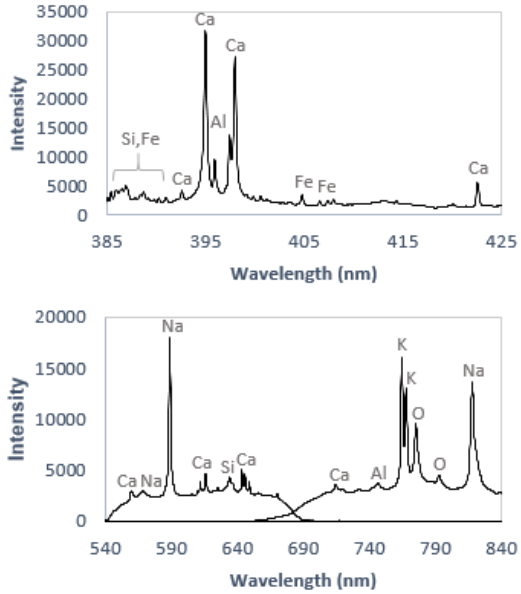

Fig. 1: LIBS spectrum of AGV-2 (andesite), (Top) portion of VIO range, (Bottom) portion of VNIR range using the preliminary version of the transmission spectrometer with the two band design (crossover between bands at ~680 nm).

spectrum was produced by averaging 30 spectra and the dark spectrum was removed. For convenience, this data was taken under ambient conditions. LIBS analyes are sensitive to the atmospheric pressure and composition, particularly the atmospheric components (e.g. O), so these spectra will look different than spectra take under the appropriate martian atmosphere.

Raman: Raman spectra of several minerals have been collected at distances of 1.5, 3, 5, 7, 10, and 12 m. Fig. 2 shows spectra of selenite (hydrated Ca-sulfate) and barite (Ba-sulfate). These spectra were collected at 1.5 m, have had a dark current spectrum removed, and 100 shots averaged. The barite and selenite spectra exhibit the ν_1 symmetric stretch vibration of SO_4 tetrahedra [3] at 988 and 1007 cm^{-1}, respectively. Selenite has peaks at 1136 cm^{-1}, corresponding to the ν_3 asymmetric stretch vibration mode [3], as well as O-H stretching modes at 3409 and 3486 cm^{-1} [4].

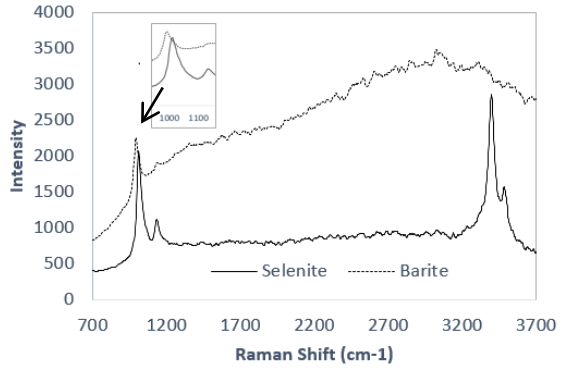

Fig. 2: Raman spectra of selenite ($CaSO_4.2H_2O$) and barite ($BaSO_4$); the barite spectrum exhibits significantly more fluorescence than the selenite and thus has been divided by two for clarity. Vibrational modes associated with sulfate (~1000 cm^{-1}) and gypsum water doublet (~3404 and 3492 cm^{-1}) are shown.

TRF Mode: The transmission spectrometer has the capability to obtain temporally resolved spectra. The first test of this capability was conducted on a ruby. Ruby exhibits a long inorganic fluorescence lifetime due to the present of Cr^{3+}, easily distinguishable from organic luminescence [5]. Fig. 3 shows the R-line at 693 nm, and the 707 and 714 nm peaks, which are due to Cr ion pairs and lattice defects [6]. This spectrum was taken with a delay of 61.15 µs and has had a dark current spectrum removed; 10 spectra were summed.

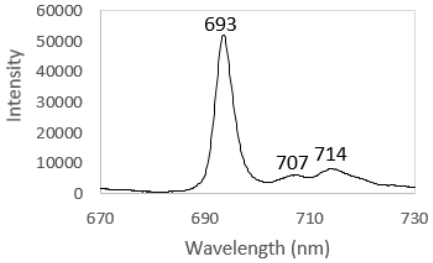

Fig. 3: Time-resolved fluorescence observation of ruby.

VISIR: The current model of the IR spectrometer has been tested using a blackbody light source operated at 1000˚C. The unit requires cooling to reduce the noise level allowing spectra of minerals and rocks to be obtainable. At this time, our test facility does not allow the unit to be properly cooled. Further models of the spectrometer will be tested in the relevant environment.

Conclusions: SuperCam will be part of the Mars 2020 rover mission to Mars. It will provide remote chemical and mineralogical analyses of the martian surface using LIBS, Raman, TRF, and VISIR spectroscopy. A development unit has been constructed and various capabilities have been tested.

References: [1] Wiens, R.C. et al. (2016) *Spectroscopy*, in press [2] Wiens, R. C. et al. (2017) *LPSC* [3] Buzgar, N. et al. (2009) *Annalele Stiintifice ale Universitatii*, 55, 5-23 [4] Sharma, S. K. et al. (2013) Eur. J. Mineral. 25, 715-720. [5] Sharma, S. K. (2007) *Spectrochim. Acta A*, 68, 1008-1022 [6] Toyoda, T. et al. (1998) *Materials Sci Eng*, 54, 33-37.