SuperCam on the Perseverance Rover for Exploration of Jezero Crater: Remote LIBS, VISIR, Raman, and Time-Resolved Luminescence Spectroscopies Plus Micro-Imaging and Acoustics

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SuperCam on the Perseverance Rover for Exploration of Jezero Crater: Remote LIBS, VISIR, Raman, and Time-Resolved Luminescence Spectroscopies Plus Micro-Imaging and Acoustics

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Introduction: NASA's Perseverance rover carries 7 instruments and a Sample Cache System. This mission has 4 major goals: a) explore an astrobiologically relevant ancient environment, b) assess bio-signature preservation potential, c) cache samples for eventual return to Earth, and d) advance technologies for human exploration [1]. SuperCam provides a wide range of remote observations to support the first 3 goals. Here we describe SuperCam's capabilities as shown prior to launch; presentation at the meeting may report the status a month after landing at Jezero crater.

Instrument Description: SuperCam uses remote laser-induced breakdown spectroscopy (LIBS) to obtain quantitative elemental compositions to 7 m and provides high-resolution images of the targets, like its predecessor [2, 3]. Coboresighted with the LIBS, SuperCam returns mineralogy via a combination of remote time-resolved Raman (to ~7 m) and visible and infrared (VISIR) reflectance spectroscopy (any distance). The LIBS shock wave removes dust for all spectral techniques, giving access to the targets' surfaces. The hardware built for Raman spectroscopy also allows time-resolved luminescence (TRL) spectroscopy, which remotely provides signals from rare-earth elements (REEs) [4, 5]. Passive spectroscopy can also be used to study atmospheric gases, ice, and dust [6]. Finally, SuperCam performs acoustic spectral sensing to study wind phenomena [10] and to be used with the LIBS shock waves to study the physical properties of the targets [7-9].

SuperCam follows ChemCam's architecture [2, 3], consisting of two separate units—one on the rover's mast and one in the body—as well as a set of calibration targets (Fig. 1). The Mast Unit (MU) contains a Nd:YAG pulsed laser, a 104 mm dia. telescope, a wavelength-scanning infrared spectrometer (1.3-2.6 µm, 256 channels), a high-resolution Remote Micro-Imager (RMI; 2k x 2k CMOS with Bayer filter), and a microphone (100 to 20k Hz) [11].

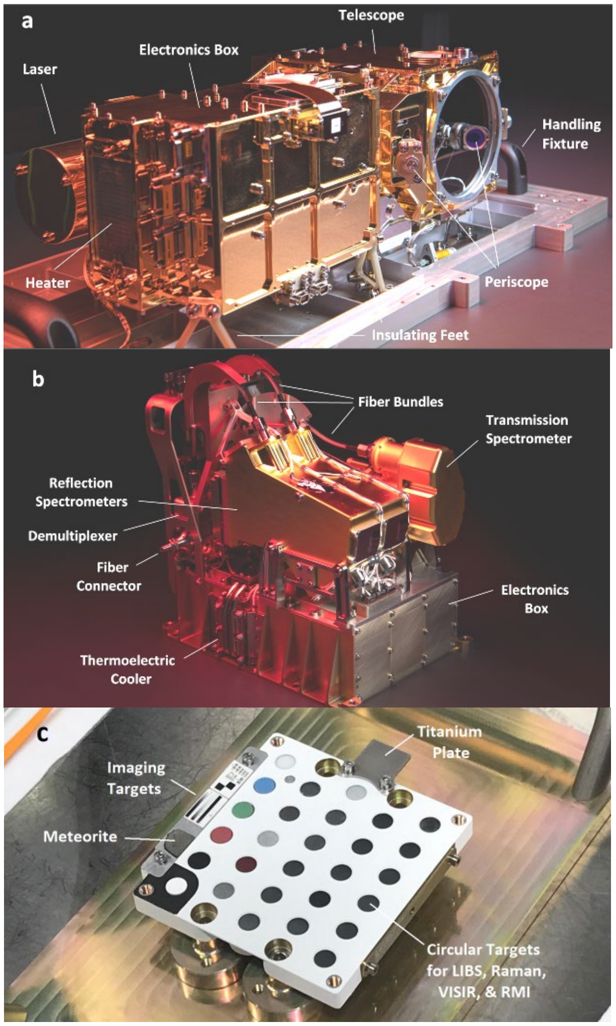

Fig. 1. SuperCam Mast Unit (a), Body Unit (b), and Calibration Target Assembly (c). Long dimensions of each unit are 383, 221, and 110 mm, respectively.

Light collected by the telescope in the 245-855 nm range is sent via a 6 m optical fiber from the mast to the Body Unit (BU), which contains three optical spectrometers. The UV (245-340 nm) and violet (385-465 nm) spectrometers are replicas of ChemCam's, while the third one (535-855 nm; 110-7100 cm^{-1}) is a high-efficiency transmission spectrometer containing a time-gated (to 100 ns) optical intensifier, enabling the time-resolved Raman and luminescence measurements, as well as the LIBS and passive visible-range spectroscopy [12]. An expanded set of calibration targets are mounted at ~1.55 m distance on the back of the rover [13]. These targets were selected with Jezero crater in mind, including carbonates, serpentine, and olivine.

Pre-Launch Performance: Tests were performed at the integrated instrument level and on the rover to calibrate [23] and demonstrate its capabilities. LIBS performance is expected to meet or exceed that of ChemCam. Some spectral regions have higher resolution and the intensifier allows some new tests for time-resolved LIBS [12]. The LIBS laser beam has slightly smaller diameter at best focus, e.g., 200-450 μm [11]. LIBS performance is highlighted in a separate presentation [14].

Time-resolved Raman spectroscopy tests at various distances ≥ 2 m [12] showed observation of peaks identifying various minerals. They included minerals of astrobiological interest due to their high preservation potential on Earth [22], such as carbonates (calcite, dolomite, magnesite, siderite, ankerite) and sulfates. Other observed minerals included phosphates, fluorite, apophyllite, and various silicates (olivine, quartz, diopside, labradorite, microcline, oligoclase). Studies were also made of organic mixtures [15]. Grain-size studies indicate that performance will be best on medium to coarse sand on the Wentworth scale. Remote TRL studies showed the presence of Sm, Nd, Eu, and other REEs in REE-rich mineral grains (e.g., apatite, zircon). Raman and TRL performance is highlighted in a separate presentation [15]. Separate studies at this meeting highlight LIBS-Raman synergies on carbonates, observed in the laboratory [24].

The SuperCam IR spectrometer was calibrated prior to integration with the instrument [16]. Testing of the VISIR systems at the integrated level was confined to the rover system thermal test (STT) due to the need for the spectrometer to be cold. During that test, observations of the rover calibration targets and other mineral targets demonstrated excellent performance comparable to laboratory instruments [12]. VISIR performance is highlighted in a separate presentation at this meeting [17].

Imaging tests with SuperCam's RMI were carried out largely prior to instrument integration, showing its 18.8 mrad field of view and ~80 μrad resolution, limited by the telescope design rather than pixels [11]. A separate presentation shows the RMI's performance [18].

Acoustic testing was carried out with the Microphone at various stages including near Mars pressure on the rover during STT, when a measurement of the speed of sound was obtained [19]. Initial microphone observations should be able to resolve long-standing questions about frequency-dependent attenuation of sound waves in the Mars atmosphere. A separate presentation on acoustics will be given at this meeting [20].

A separate presentation on atmospheric observation capabilities will also be given at this meeting [21].

SuperCam Initial Checkout on Mars: If the landing is successful, health checks are planned before and after deployment of the rover's mast and installation of surface software in the first week on the surface. Initial observations will be done by the RMI and passive techniques to verify proper commanding of the mast position prior to use of the laser-based techniques. Initial observations will concentrate on the onboard targets to establish initial calibrations (wavelength, focus, white reference target for VISIR, and eventually compositional calibrations for LIBS); initial sound recordings and spectral rasters on the Mars surface in the first several weeks will test operational sequences. Science targets should become interleaved with checkouts as time progresses. First results may be reported at the meeting.

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