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ChemCam Instrument for the Mars Science Laboratory (MSL) Rover

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Overview: ChemCam is a new type of active remote sensing instrument to investigate details of the Martian geochemistry. It is one of the experiments recently selected for the mobile Mars Science Laboratory (MSL) rover, scheduled for launch in 2009. The ChemCam science objectives are described in a companion paper by Wiens et al. [1].

ChemCam uses laser interrogation to remove dust layers and to depth profile through weathering layers. The same laser pulse is used to perform an elemental analysis, based on the Laser Induced Breakdown Spectroscopy (LIBS) technique [2-4], at distances from 2 m to 13 m from the rover. Simultaneously, a remote micro-imager (RMI) provides context imaging, with resolution better than 80 microradians.

Instrument Baseline Design: The ChemCam suite consists of two separate units: "Body Unit" and "Mast Unit". See Figure 1 for the instrument block diagram.

The Mast Unit focuses laser beam on target, generates a series of laser-produced plasmas, and collects the plasma light for the LIBS analysis, ambient light for imaging. It is mounted atop the MSL mast to benefit from the mast pointing capability. It consists of a laser, an imager, a telescope, and a front-end electronics.

Laser. The technology of infrared solid state lasers is highly developed and perfectly suited for LIBS analytical requirements (>1 GW/cm² deposited to the target per pulse [2,5]). The ChemCam laser design is based on the commercially-sold Diva Nd:YAG laser from Thalès laser, France. A new crystal replaces the YAG to boost the gain and enlarge the thermal acceptance (operations over 40°C temperature range with no thermal control). From the existing prototype, the beam quality (M^2) is better than 3 and the pulse duration shorter than 8 nsec. The energy output per pulse is commandable between 5 and 30 mJ, powered by a stack of ultra-capacitors.

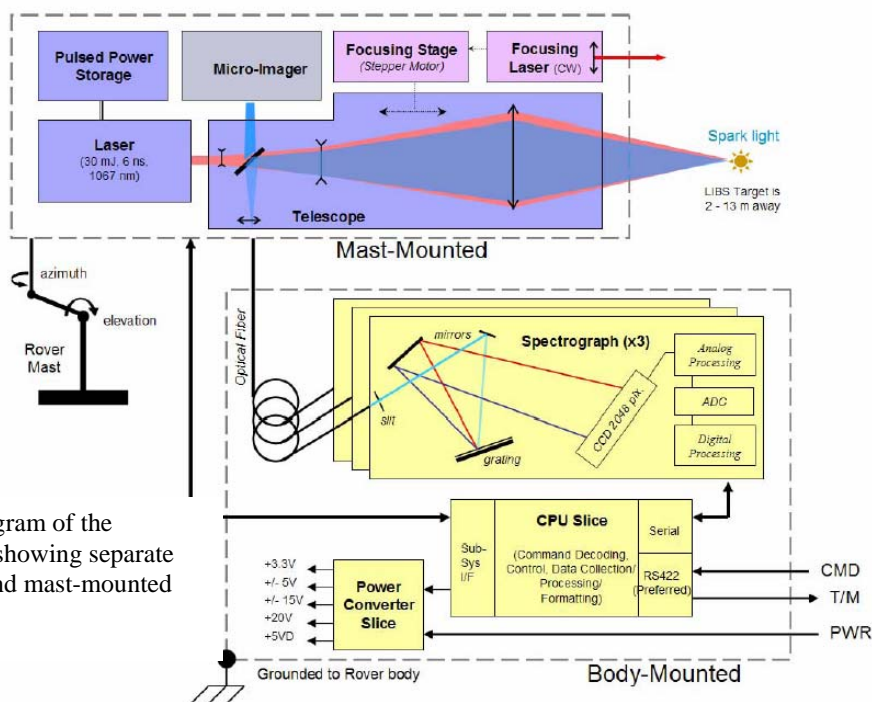


Fig.1: Block diagram of the ChemCam suite showing separate body-mounted and mast-mounted units.

Telescope. The telescope is required to concentrate the laser beam onto the target, to collect laser-induced plasma light, and to collect light for the RMI. The optical design is a simple and compact Schmidt telescope. The primary mirror is 100 mm diameter. The secondary mirror is 32 mm diameter. Optical paths for the outgoing laser and incoming light have the same optical axis (no parallax). The whole design is achromatic. Focus is achieved by mounting the secondary mirror on a translation stage with a stepper micro-motor covering a 10 mm range, giving a focus from 2 m to infinity. The auto-focus capability uses a small CW laser to illuminate the target.

Imager. The heart of the RMI instrument is the flight qualified CCD and associated electronics which were developed for Smart-1, Rosetta, and Mars Express [6]. The 1024x1024 pixel CCD has pixel size 14x14 μm , 10 bits/pixel. Exposure times are between 2 msec and 8 sec.

The Body Unit collects light for spectral analysis. It also commands the whole instrument, exchanges data with the rover, and distributes power. It is located within the rover body, where temperature is regulated. It contains the spectrographs, a data processing unit, and a power buffer.

Spectrographs. The ChemCam spectrographs consist of three separate units covering separate spectral ranges: UV/225-320 nm, Blue/381-471 nm, Red/497-928 nm [7]. In addition to LIBS, the spectrographs are capable of yielding passive UV-VIS reflectance spectra. Each spectrograph unit is a modified version of Ocean Optics, Inc. commercial model HR2000. The fiber optic cable used to bring plasma light from the telescope is trifurcated to supply each spectrograph with light. The three spectrograph units are nearly identical, with the exception of different gratings, bandpass filters, and mirror coatings, yielding spectral resolutions of the order of 3000, 2000 and 1500 for the three units. The spectrograph requires no thermal control other than that provided by the rover. Pixel sizes for the CCD's are 14x200 μm . The integration times range from 5 ms (used for LIBS per spectrum) to 65 s.

Data Acquisition: ChemCam is expected to see high use, as it is a remote sensing suite that not only fulfills scientific objectives [1], but is also very important as an operational tool to select targets for in-situ analysis and help displacements of the rover. One typical operation sequence is outlined in Fig. 2. The instruments are pointed using the elevation and tilt of the mast platform. Targets are selected from

either science team input or, if available, autonomous target recognition. The ChemCam operation sequence is designed to be adapted to different analysis scenarios by changing the number of laser shots, the number of images collected, the order these actions are performed, to the geochemical environment under study. For instance, rapid rock identification will be obtained from 75 shots, while depth profiling can require more than 1000 shots.

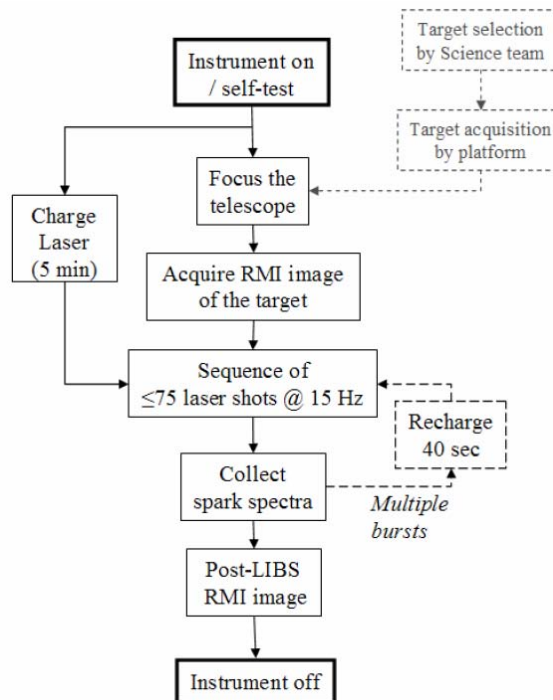


Fig 2. One ChemCam typical analysis sequence. Its duration is on the order of 6 minutes.

Resources: The ChemCam instrument is expected to be below 7 kg and 9 liters. Depending on mission scenarios, it is expected to provide roughly 7 analyses per sol for a total of ~20 minutes/sol. Its power consumption is ~5 W-hr/sol and it produces ~13 Mb/sol of data.

References: [1] Wiens et al. (2005) this volume. [2] Cremers D. A. (1987) *Appl. Spectrosc.*, 41, 1042. [3] Developing LIBS for Future Planetary Exploration (2004) *Appl. Spectrosc.*, 58/8. [4] Knight A. K. et al. (2000) *Appl. Spectrosc.*, 54, 331-340. [5] Brennetot et al. (2003) *Appl. Spectrosc.*, 57, 744. [6] Josset J. L. (1999) *DPS meeting 31st*, #21.08. [7] Sallé et al. (2004) *LPSC 35th*, #1263.