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The Exploration of Mars With the ChemCam LIBS Instrument and the Curiosity Rover

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The Mars Science Laboratory (MSL) *Curiosity* rover landed on Mars in August of 2012 and has been exploring the planet ever since. MSL's main goal is to characterize past environments that may have been conducive to the evolution and sustainability of life. With a sophisticated set of 10 science instruments, it is a complex robotic field geologist. It is driving within Gale Crater, a location on Mars that once held liquid water and contains a large central mound with a stack of layers 3 times thicker than that in Earth's Grand Canyon. The rover has driven through sequences of sedimentary rocks recording fluvial, deltaic, lacustrine, and aeolian environments and, as of this writing, is exploring an active field of basaltic sand dunes.

The suite of Curiosity science payload includes cameras, a hand lens imager, analytical in situ instruments, a neutron detector, and those for environmental and radiation characterization. A drill and scoop allow the sampling of rocks and fines, respectively. Bridging remote sensing and analytical capabilities, the Chemistry & Camera (ChemCam) instrument is the first Laser Induced Breakdown Spectrometer (LIBS) to operate on another planetary surface (Figure 1). Jointly developed and operated by teams in the United States and France, ChemCam's optics are also employed for imaging using the Remote Micro Imager (RMI), the highest angular resolution camera on the payload. Mounted on the rover's mast, the Nd:KGW 1067 nm laser can fire at rock and soil surfaces up to 7 m away. Targets are generally interrogated with a 5 or 10 point line-scan or 3x3 to 5x5 point grids, each consisting of 30-50 shots covering 0.3-0.6 mm size that serves to both penetrate beneath surface dust and provide depth profiles into the target. The emitted light from the laser-induced plasma is fed into three spectrometers ranging from 240 to 850 nm wavelengths from which diagnostic emission lines of major and minor elements are identified. The spectrometers can also be used in passive mode to obtain spectra of the surface and atmosphere.

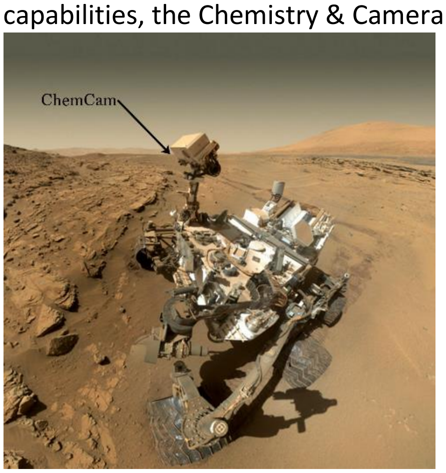

Figure 1: A self portrait of MSL at the Kimberly outcrop in Gale Crater, Mars. The ChemCam instrument is on the mast.

As of this writing, ChemCam has analysed over 1200 rocks and soils and fired the LIBS laser more than 300,000 times along *Curiosity*'s 12 km (so far) traverse in Gale Crater. ChemCam's contributions to the science return from MSL have been fundamental and critical to understanding the geology and other aspects of Gale Crater and Mars. It has found that most of the measured sedimentary rocks and soils come from a basaltic protolith, with the nearly ubiquitous detection of hydrogen, particularly in soils and dust, indicative of varying degrees of alteration in the presence of water. Diagenetic features in the form of silica-rich zones associated with fractures, manganese-rich fracture fills, Ca-sulfate veins, and magnesium-rich cm-scale ridges provide further evidence of water-rich fluids interacting with rocks after deposition. Igneous rocks are found within the population of floats that were transported from the rim of Gale Crater, with some rich in alkali feldspars and fluorine, indicating more mature magmatic evolution than had been expected, including a possible contribution of ancient Martian crust analogous to early continental crust on Earth. In addition to making direct discoveries of its own, ChemCam serves as a crucial chemistry reconnaissance instrument to assess outcrops for more intensive contact and in situ study. Many of MSL's findings by other instruments were achieved because ChemCam first identified regions of interest. This keynote talk will review the goals and results of the MSL mission, focusing on ChemCam, and provide a context of the findings into the overall exploration of Mars.