

Thermal Design Trade Study for the Mars Science Laboratory ChemCam Body Unit

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ABSTRACT

The Mars Science Laboratory will be the next Martian mobility system that is scheduled to launch in the fall of 2011. The ChemCam Instrument is a part of the MSL science payload suite. It is innovative for planetary exploration in using a technique referred to as laser breakdown spectroscopy to determine the chemical composition of samples from distances of up to about 9 meters away. ChemCam is led by a team at the Los Alamos National Laboratory and the Centre d'Etude Spatiale des Rayonnements in Toulouse, France.

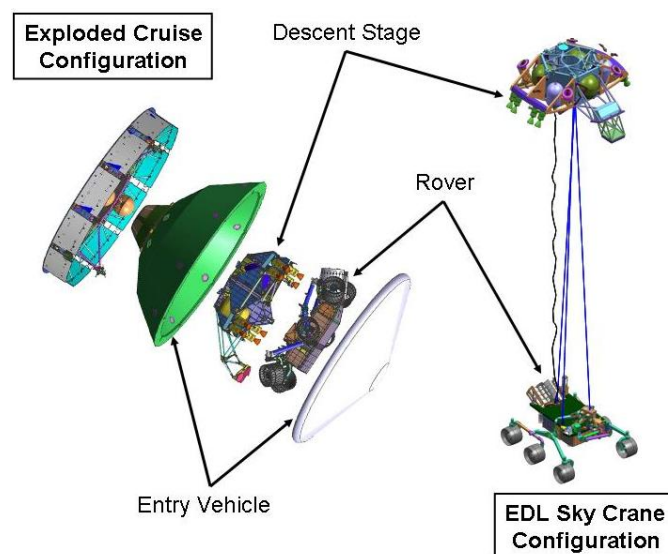
The portion of ChemCam that is located inside the Rover, the ChemCam Body Unit contains the imaging charged-coupled device (CCD) detectors. Late in the design cycle, the ChemCam team explored alternate thermal design architectures to provide CCD operational overlap with the Rover's remote sensing instruments. This operational synergy is necessary to enable planning for subsequent laser firings and geological context. This paper will present the CCD thermal design trades that would increase the CCD operational window. Due to the minimum lead time to implement design modifications, the passive control techniques were identified for implementation.

INTRODUCTION

THE MSL MISSION

Scheduled to launch in the fall of 2011, the Mars Science Laboratory (MSL) is part of NASA's Mars Exploration Program, a long-term effort of robotic exploration of the red planet. MSL is a rover that will assess whether Mars ever was, or is still today, an

Figure 1 - MSL Explored Cruise and EDL Configurations



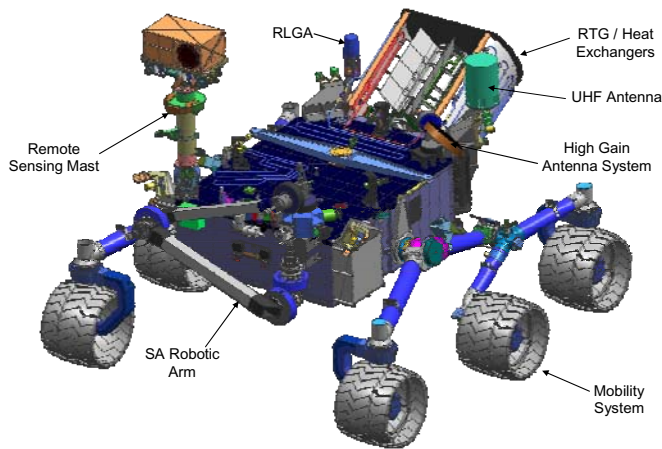


Figure 2 - MSL Rover Configuration for Surface Operations

environment able to support microbial life.

The spacecraft will descend on a parachute and then, during the final seconds prior to landing, lower the upright rover on a tether to the surface, much like a sky crane. Once on the surface, the rover will be able to roll over obstacles up to 75 centimeters (29 inches) high and travel up to 90 meters (295 feet) per hour. On average, the rover is expected to travel about 30 meters (98 feet) per hour, based on power levels, slippage, steepness of the terrain, visibility, and other variables.

The rover will carry a radioisotope power system that generates electricity from the heat of Plutonium's radioactive decay. This power source gives the mission an operating lifespan on Mars' surface of a full Martian year (687 Earth days) or more, while also providing significantly greater mobility and operational flexibility, enhanced science payload capability, and exploration of a much larger range of latitudes and altitudes than was possible on previous missions to Mars.

The spacecraft design for Mars Science Laboratory consists of:

- Cruise Stage for travel between Earth & Mars. The Rover will be tucked inside a tightly packaged cruise stage and aeroshell with a heat shield (see Figure 1).
- Entry, Descent, & Landing (EDL) System for entry into the Martian atmosphere. The EDL System includes the aeroshell and a "sky crane" lander structure. The Rover will extend its wheels similar to the way an airplane unfolds its landing gear just before touchdown (see Figure 1).
- Rover: A wheeled vehicle with science instruments for discoveries on the Martian surface (see Figure 2).

The spacecraft design for the MSL mission is based largely on the successful twin Viking landers sent to

Mars in the 1970s. The rover design is based on the Mars Exploration Rovers, which landed on Mars in early 2004. The system for entry, descent, and landing is entirely new.

THE CHEMCAM INSTRUMENT

ChemCam is a suite of two remote sensing instruments. One, the Laser-Induced Breakdown Spectrometer (LIBS), provides elemental compositions of rocks and soils within 9 or more meters from the Rover. The LIBS technique can detect essentially all elements, with high resolution detection limits for most elements. Important in the Mars context, ChemCam uses a laser beam to remove dust from rock surfaces, enabling remote sensing unhindered by the ubiquitous Mars dust. The LIBS laser also provides sufficient depth profiles in solid rocks using repeated laser pulses on the same spot. The depth profiles can be used to study weathering coating.

The second instrument, the remote micro-imager (RMI) provides close-up context images of the analysis spot, as well as generally providing the highest resolution images in non-contact operation.

ChemCam addresses four of the five MSL mission objectives, including: (1) characterizing the geology of the landing region, (2) investigating planetary processes relevant to past habitability, (3) assessing the biological potential of a target environment, and (4) searching for materials that would present toxic hazards to humans.

Figure 3 depicts a high-level functional block diagram of the ChemCam suite. The package consists of two separate units—the Body Unit (CCBU) and the Mast Unit (CCMU), which are further broken down into modular components: the spectrographs, power, and electronics are in the CCBU, while the laser, imager,

Figure 3 - CCBU Functional Block Diagram

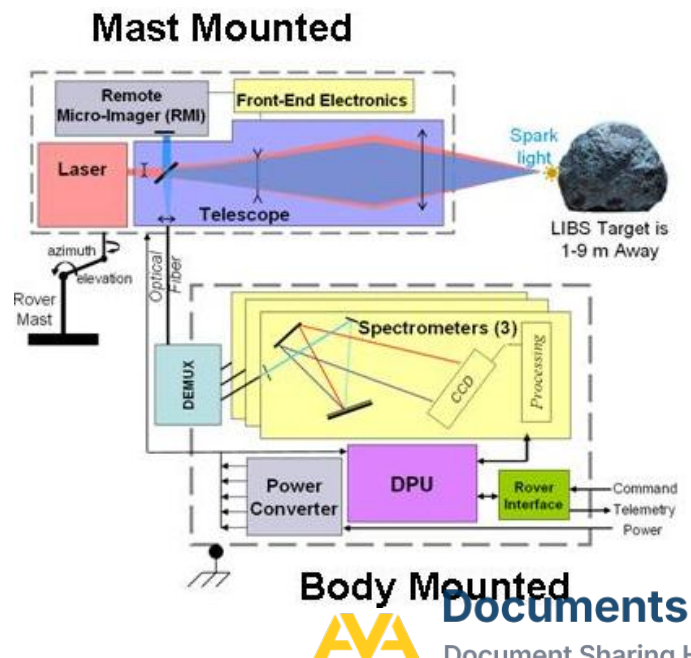


Table 1 - ChemCam Thermal Environment Definition

Design Case	Landing Latitude	Season	Effective Sky Temp, °C	Ambient Temp, °C	Ground Temp, °C	RAMP Temp, °C	Rover Side Temp, °C
Worst Hot Operation	27.5 S	Summer	-130 to -96	-78 to 13	-81 to 38	6 to 49	-48 to 24
Expected Hot Operation	27.5 S	Spring	-143 to -113	-91 to 10	-94 to 15	4 to 38	-54 to 11
Worst Cold Operation	27.5 S	Winter	-165 to -147	-113 to -61	-117 to -41	5 to 12	-62 to -10
Worst Cold Non-Operation	30.0 S	Winter	-170 to -153	-120 to -70	-123 to -54	-37 to -21	-129 to -84

telescope, and focus laser are in the CCMU. The Mast Unit is provided by Centre d'Etude Spatiale des Rayonnements (CESR) (funding from Centre National d'Etudes Spatiales [CNES]), while Los Alamos National Laboratory (LANL) is building the CCBU. The Mast Unit (CCMU) consists of a telescope with a focusing stage, a pulsed laser and its associated electronics, a micro-imager CCD and front-end electronics, and a small diode laser to aid in focusing the telescope. The locations of the CCMU & CCBU relative to the Rover are shown in Figure 4.

The CCBU (see Figure 5) consists of three spectrographs covering the UV and visible ranges needed for LIBS, as well as the instrument's power supplies and data processing unit (DPU). The CCMU and CCBU are connected by a fiber optic cable as well as signal and power cables.

CCBU CCD COOLING ISSUE

The Initial CCBU Thermal Design

Since it resides within the Rover, the CCBU's thermal design leveraged the Rover's mechanically pumped cooling loop known as the Rover Heat Rejection System (RHRS)¹. The CCBU would be mounted to one of the main RHRS heat exchangers, the Rover Avionics Mounting Plate (RAMP). As the name implies, the Rover electronics were thermally connected to the RAMP in order to maintain the equipment's allowable flight

temperature limits (AFTs). The RAMP's temperature would be maintained between -40°C and 20°C during the Martian year. The ChemCam instrument was initially envisioned for intensive use each Martian day (known as a "sol"), as it serves important remote sensing needs for the selection of targets for other instruments. However, the instrument team learned late in the design development that meeting the science requirements with the CCBU spectra requires operating the instrument with the CCBU CCDs below 0°C for acceptable performance, with good performance below -10°C. Until this time, the instrument team had established a maximum operating allowable flight temperature of 20°C for the CCDs. Furthermore, when the CCDs are non-operational, they are permitted to reach -50°C. The CCBU AFT requirements are summarized in Table 1.

Table 2 - CCBU Allowable Temperature Requirements (°C)

Component	Operating	Non-Operating
CCD	<-10 (goal)	-40 to 50
	< 0 (acceptable)	
Spectrometer (excluding CCDs)	-5 to 50	40 to 50
DPU	-40 to 50	-40 to 50

Figure 4 - CCMU and CCBU Locations on the Rover

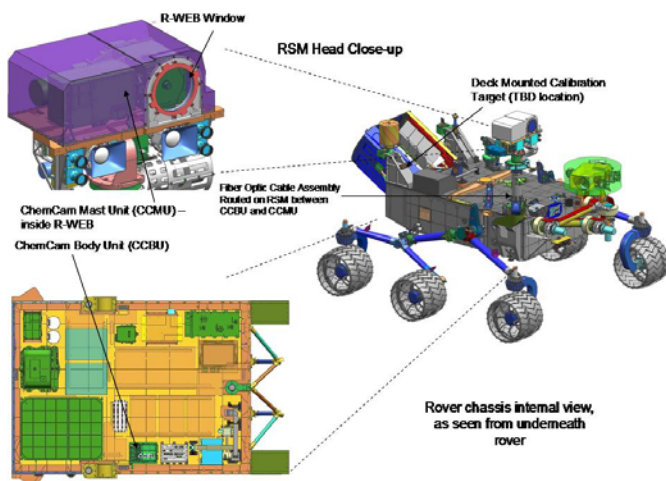


Figure 5 - CCBU Mechanical Configuration

