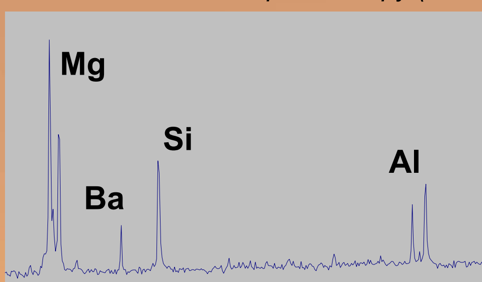
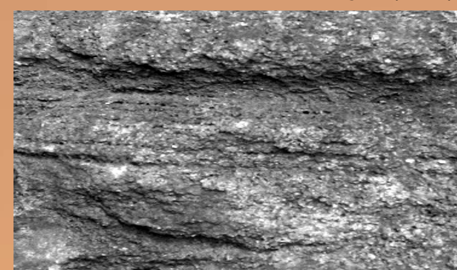
ChemCam

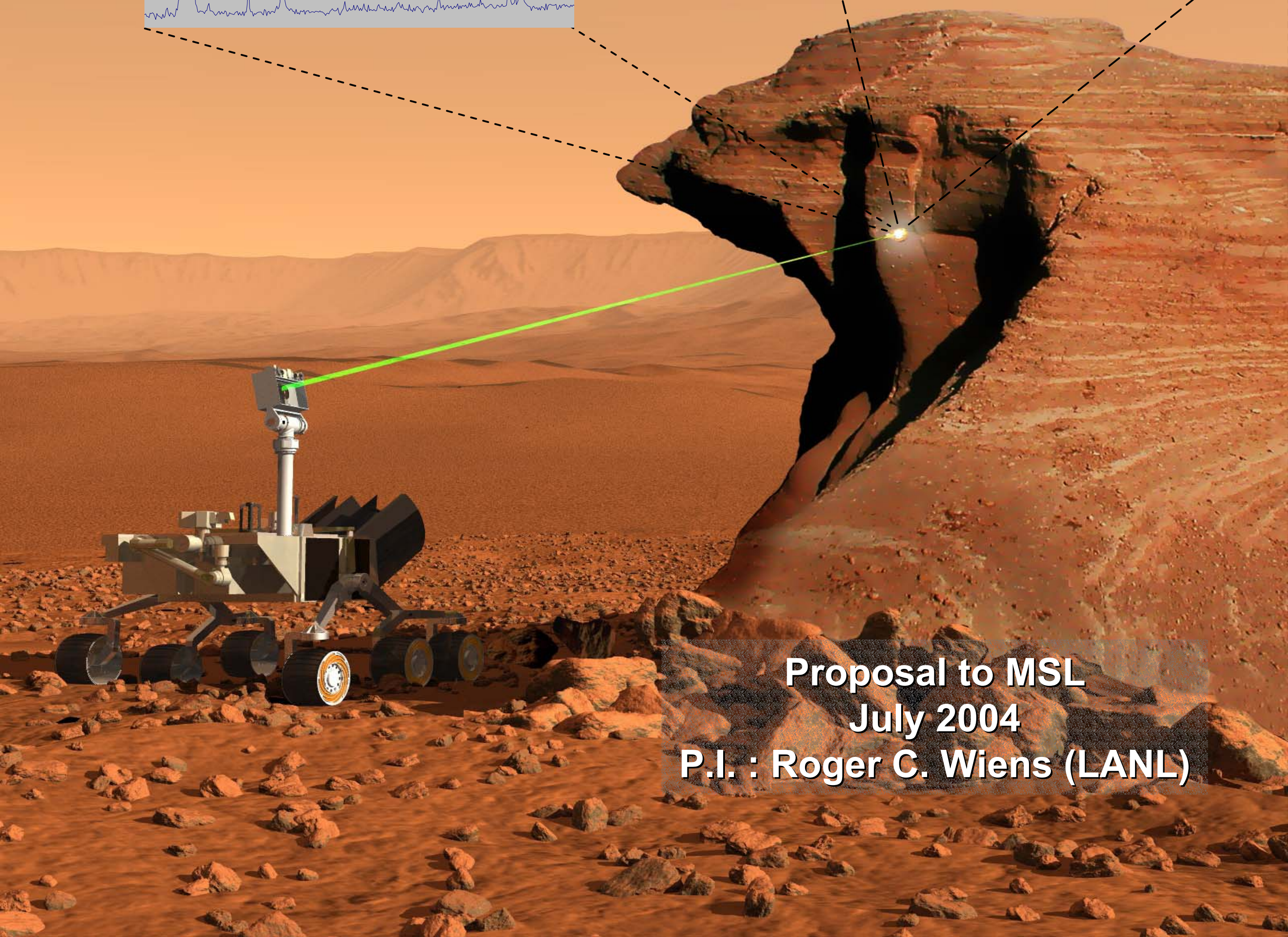
Laser-Induced Remote Sensing for Chemistry and Micro-Imaging

Elemental Abundances from Laser-Induced Breakdown Spectroscopy (LIBS)



Most Detailed Remote Images Ever from the Remote Micro-Imager (RMI)





Proposal to MSL

July 2004

P.I. : Roger C. Wiens (LANL)

Science Objectives

(1) Characterize the geology of the landing region,

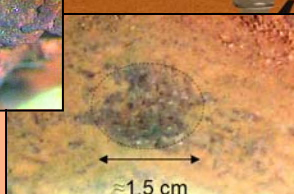
(2) Investigate planetary processes relevant to past habitability,

(3) Assess the biological potential of a target environment,

(4) Check for toxic materials.

As a remote sensing instrument, ChemCam's primary objective is to rapidly characterize rocks and soils, and to identify samples of greatest interest for further investigation by the contact and analytical laboratory instruments.

Depth Profile



Dust Removal

<u>Science Team</u>:

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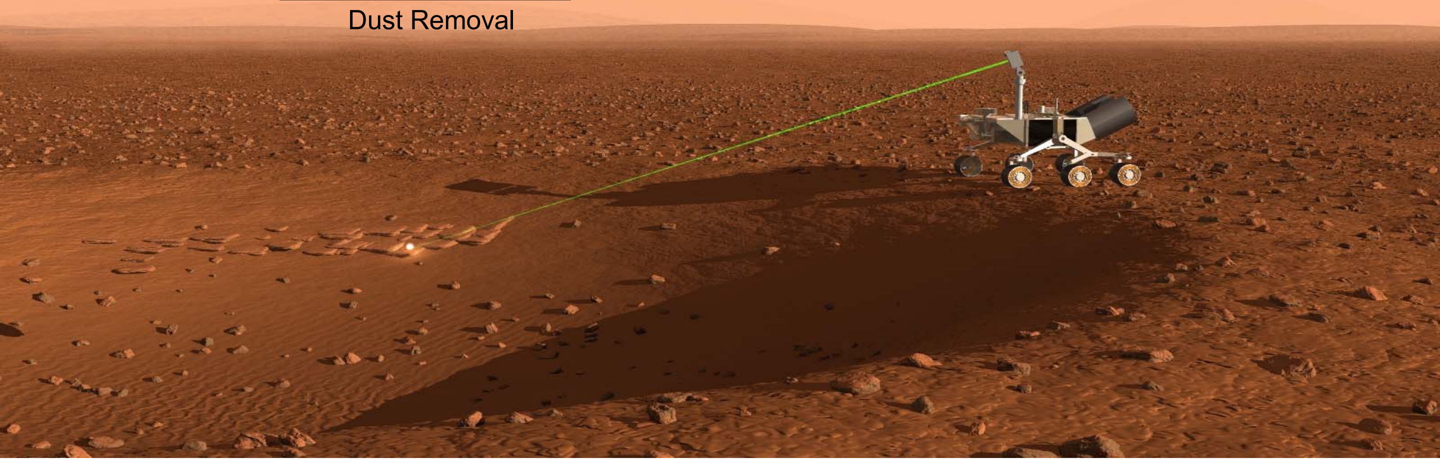
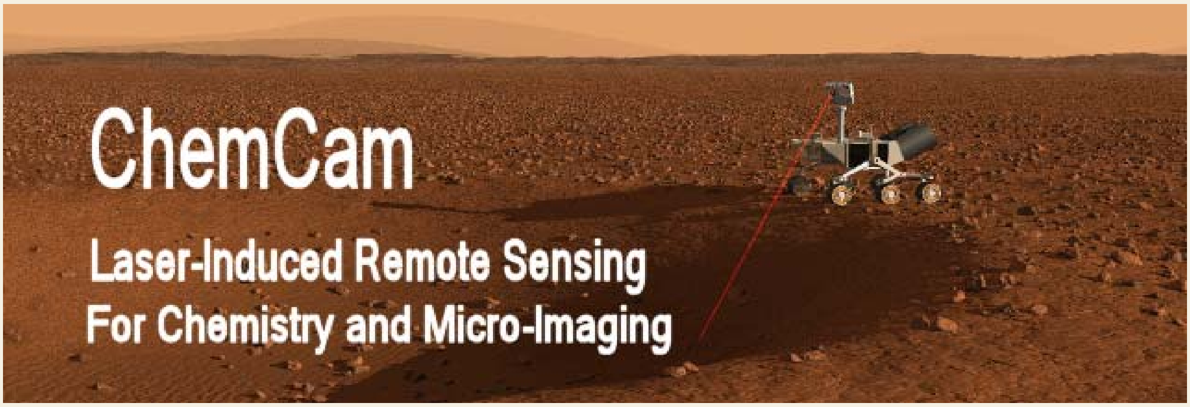
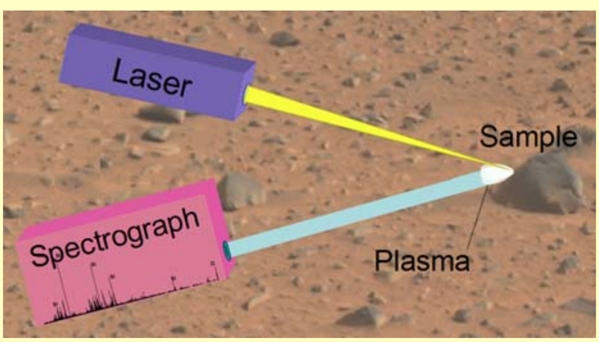




ChemCam uses a laser beam to remove dust from rock surfaces, enabling remote sensing unhindered by the ubiquitous Mars dust. The suite combines LIBS elemental analyses with a remote micro-imager (RMI) yielding the highest resolution images ≥ 2 m from the rover.

Laser-Induced Breakdown Spectrograph
LIBS focuses powerful laser pulses onto a sample, causing ablation of atoms in excited states, which emit light. LIBS determines elemental compositions by spectrally resolving and measuring the emission lines from the ablated material.

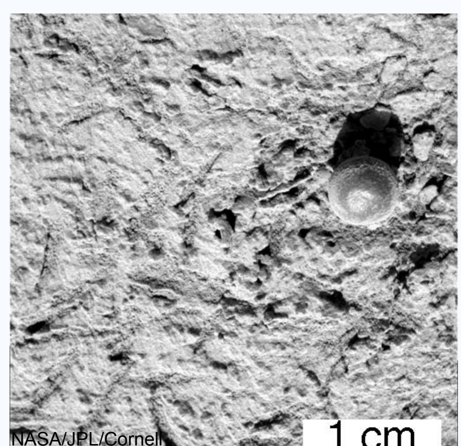


LIBS has the following characteristics:

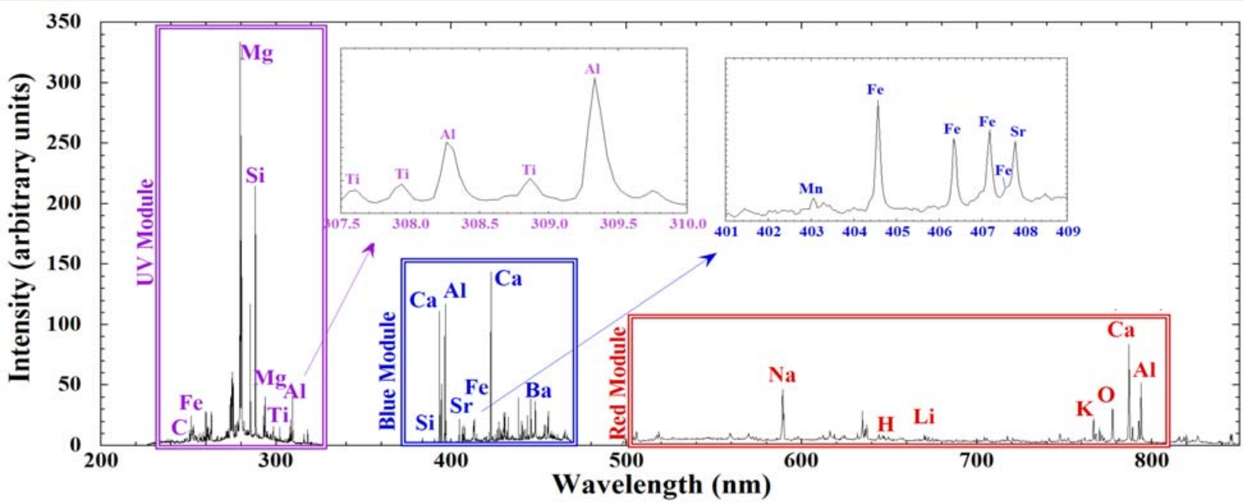
- No sample preparation required
- Rapid analysis technique
- Operates at a distance (2-13 m)
- Removes dust from surfaces
- Provides depth profiles
- Detects all elements
- 10 ppm detection limits for some elements
- Laser requires only 3 Watts of power

LIBS has been applied for over 20 years; its use in laboratories and industry has increased rapidly in recent years.

Remote Micro-Imager
The RMI will provide very high resolution images of targets. Its pixel field of view is 21-22 μrad, much finer than any remote camera that has operated on Mars. Its effective resolution exceeds that of MER Pancam by a factor of 5 to 10. Resolution in the near-field is within a factor of 2-3 of MER MI (at closest-focus distance of 2 m for RMI vs. 6 cm for MI), but still sufficient to see many diagnostic sedimentary structures and other features at the sub-millimeter scale. Sub-meter-sized objects at the Mars horizon will be visible.



Above is a MER MI image at a resolution simulating RMI at a distance of 3m. Only half of the RMI field of view is illustrated.



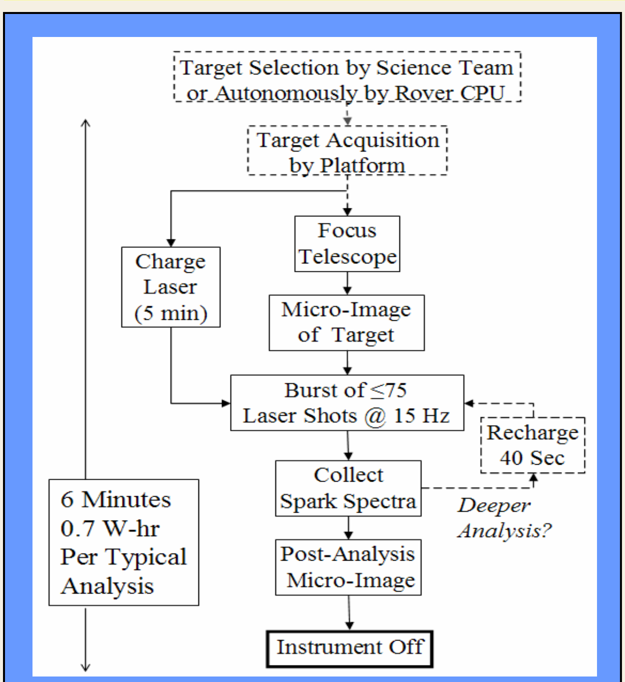
LIBS soil spectrum recorded at a distance of 5.3 m shows fifteen elements ranging in abundance down to a few ppm. The three modules correspond to the ChemCam spectrographs.

ChemCam Science Objectives

ChemCam addresses **four of the five MSL mission objectives**, including (1) characterize the geology of the landing region, (2) investigate planetary processes relevant to past habitability, (3) assess the biological potential of a target environment, and (4) look for toxic materials. As a remote sensing instrument, ChemCam's primary objective is to rapidly characterize rocks and soils, and to identify samples of greatest interest for further investigation by contact and analytical laboratory instruments.

ChemCam's science and operational investigations are as follows:

1. Rapid remote rock identification (ID)
2. Complement other techniques for rock ID in cases of dust and weathering
3. Soil and pebble composition surveys
4. Quantitative analyses, including trace elements, to support science objectives
5. Detection of hydrated minerals
6. Rapid remote ID of surface ices
7. Depth profiles of rock weathering coats
8. Geomorphology and imaging science
9. Remote analysis of inaccessible rocks
10. Assist arm and drill or corer sampling
11. Remote ID of organic materials
12. Check for abundances of elements above hazardous limits for humans



ChemCam Analysis Sequence

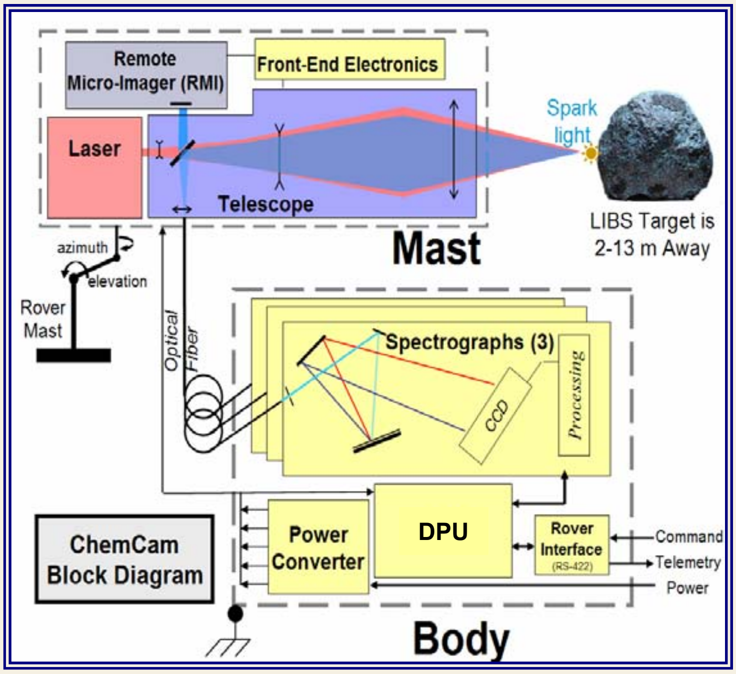
The flow chart shows a typical analysis sequence. After target acquisition by the rover mast, the telescope is focused and the target is micro-imaged. A burst of up to 75 laser shots (30 mJ) is fired at a ≤ 1 mm spot on the target. The spectrum from each spark is collected. Deeper analyses utilize additional laser bursts.

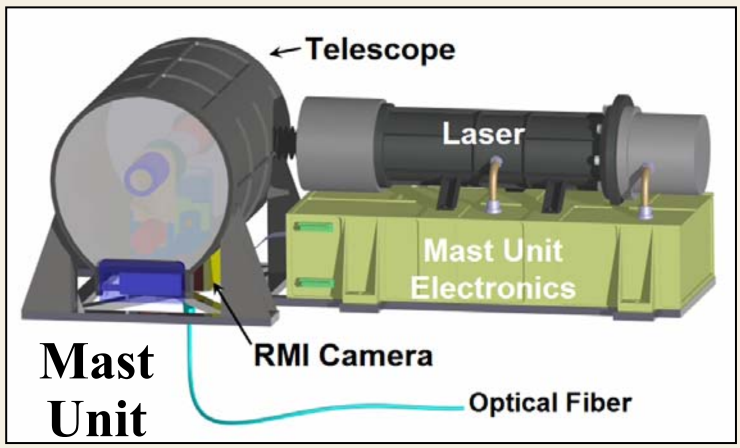
A typical analysis takes 6 min. and 0.7 W-hr, compared with up to 3 sols for analogous dust-free analyses requiring sample contact.

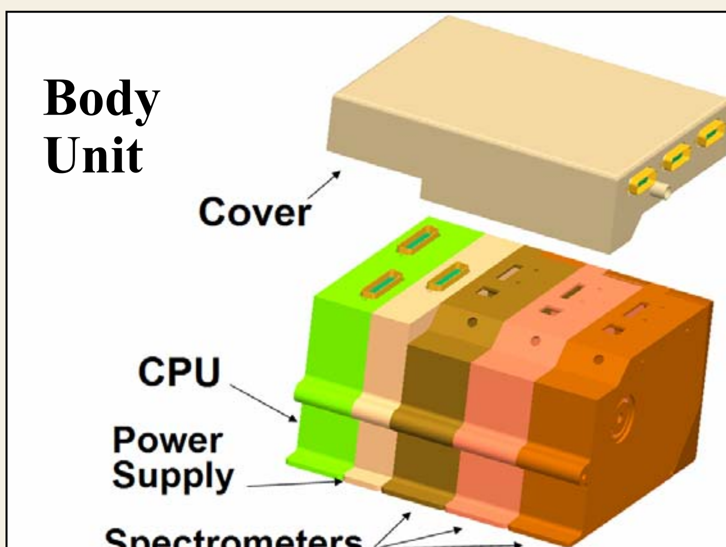
Instrument Suite Description

As shown in the block diagram, the suite consists of two boxes: the Mast Unit contains the telescope, laser, remote micro-imager (RMI), and front-end electronics, while the Body Unit contains three spectrographs, the DPU, power supply, and rover interface.

LIBS	
Range	2-13 m
Depth Profile Rate (basalt & sand)	~0.4 μm/pulse ~0.1 mm/pulse
Analysis Spot	0.5-1 mm dia
Laser	
Power	30 mJ/pulse
Wavelength	1067 nm
Pulse Rate	15 Hz
Pulses per Burst	75
Recharge Rate	40 sec/burst
Spectrographs (3)	
Design	Czerny Turner
Range	240-800 nm
Resolution	0.09-0.3 nm
CCDs, # pixels	Linear, 2048
Signal/Noise	250
RMI	
Optics design	Schmidt
Aperture	100 mm dia
Range	2 m – infinity
Spatial resolution	80 μrad
Wavelength range	800-1000 nm
Exposure range nominal	2 ms – 8 s 75 ms
MTF at Nyquist	0.10 – 0.44
Overall	
Mass	5.62 kg (+cable)
Volume	8904 cc
Power (6.7 W ave)	3.9 W-hr/sol
Data Volume	12.0 Mb/sol







Science Requirements for LIBS include obtaining major element abundances to ±10%, along with minor and trace element characterization (including H,Li,Be,C,N,S), some to as low as 10 ppm.

Data Volume covers nearly 5,000 LIBS elemental analyses and a similar number of micro-images over the course of one Mars year.

Component	Provider	Flight Heritage
Laser	Thales	ESA LIDAR project
RMI & Telescope	3D-Plus & CESR	Rosetta, Smart-1, others
Spectrograph	Ocean Optics, Inc.	Other OOI spectrographs
DPU, Pwr Supply	LANL & 3D-Plus	Numerous instruments
Integration	LANL	> 450 flight instruments
Team Leadership	LANL	Numerous instruments

Objectives for E/PO and New Technology: ChemCam will capture the public imagination *like no other instrument*. Both the highest resolution images and the innovative laser-gun analyses give high inherent appeal. ChemCam E/PO includes an interactive website that allows the public to view images and analyses along the rover route, teacher training both locally and at AAPT meetings, and public interactions by the nationally distributed team. E/PO is directed by Dr. Stephanie Shipp of the Lunar and Planetary Institute in Houston.

Management Overview. ChemCam is developed by Los Alamos National Laboratory (LANL) and CESR in Toulouse, France. LANL has developed a long line of NASA instruments, including for Cassini, Lunar Prospector, Genesis, Mars Odyssey, and DAWN, and the ChemCam management team has direct experience in all of these. The PI, Dr. Roger Wiens, managed three of the Genesis instruments, and delivered these instruments on time and within budget. LANL's no-nonsense approach properly balances science return, cost, and risk.

ChemCam utilizes the very close relationship between French Chemcam lead, Dr. Sylvestre Maurice, and LANL, which has resulted in over 30 joint publications. LANL has a State Department license for joint international development of LIBS for space, and has been collaborating with CESR for several years. LIBS instrumentation is CNES' top planetary science development priority.

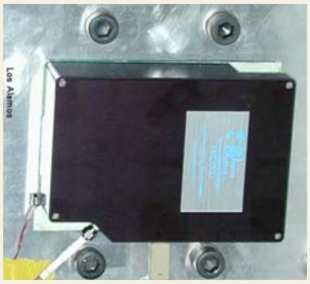
COST	RY$
Phase A/B	1.0M
Phase C/D	4.7M
A-D Reserves 20%	1.2M
NASA TOTAL A-D	**6.9M**
Phase E	5.4M
E Reserves 10%	0.5M
NASA TOTAL	**$12.8M**
CNES Contrib. A-D	3.4M

A dusty Mars needs ChemCam analyses.

Readiness: RMI uses flight-heritage imager; LIBS funded by MIDP since 1998; field tested; environmental testing of all prototype parts to be complete by time of selection.

Prototype Laser

Breadboard Telescope



Spectrograph on Vibration Table

Schedule	
Start	11/04
PDR	10/05
CDR	10/06
Deliver EM	04/07
Deliver FM	02/08
Launch	11/09
Begin Roving	05/10
Mission End	05/12
Project End	03/13