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Title:	A Tale of 2 Missions (And Hopefully 2 Different Landings)
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Genesis
A Tale of 2 Missions
(And Hopefully 2 Different Landings)
Curiosity
Roger C. Wiens
July 17, 2012
LANL

Abstract

This talk, to be given at the LANL IGPP Annual Review dinner in Santa Fe, NM on July 17, 2012, highlights two important NASA missions LANL played a key role in: The Genesis mission was the first to return to Earth from beyond the Moon, bearing solar particles to help understand the composition of the Sun; and Curiosity, a 1-ton Mars rover launched to the red planet in 2011 with a suite of instruments from LANL called ChemCam.

There are 2 embedded videos in this presentation: The first is a short clip on the crash landing of the Genesis capsule, edited by John Bass at LANL, and the second is a < 10 second clip showing a close-up image of laser-induced breakdown plasmas, which has been shown in other LAUR'd presentations.

Apollo Solar Wind Composition Experiments

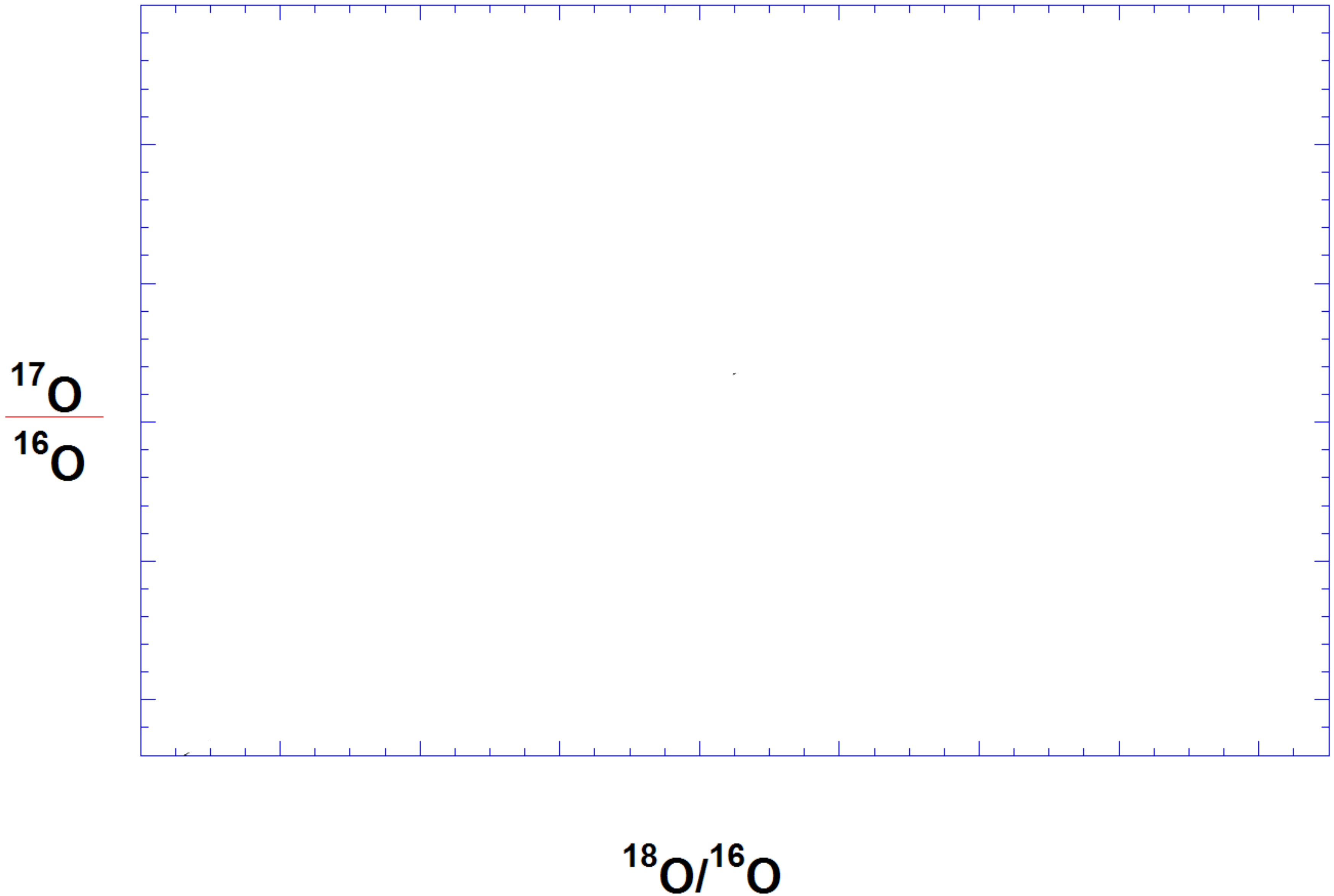
- *Collected solar wind ions implanted in foil*
- *Determined solar He & Ne isotopes*
- *Was the impetus for Genesis—a longer, purer solar-wind collection*

GENESIS Science Objectives

- *To Collect Samples of the Solar Wind and Return them to Earth*

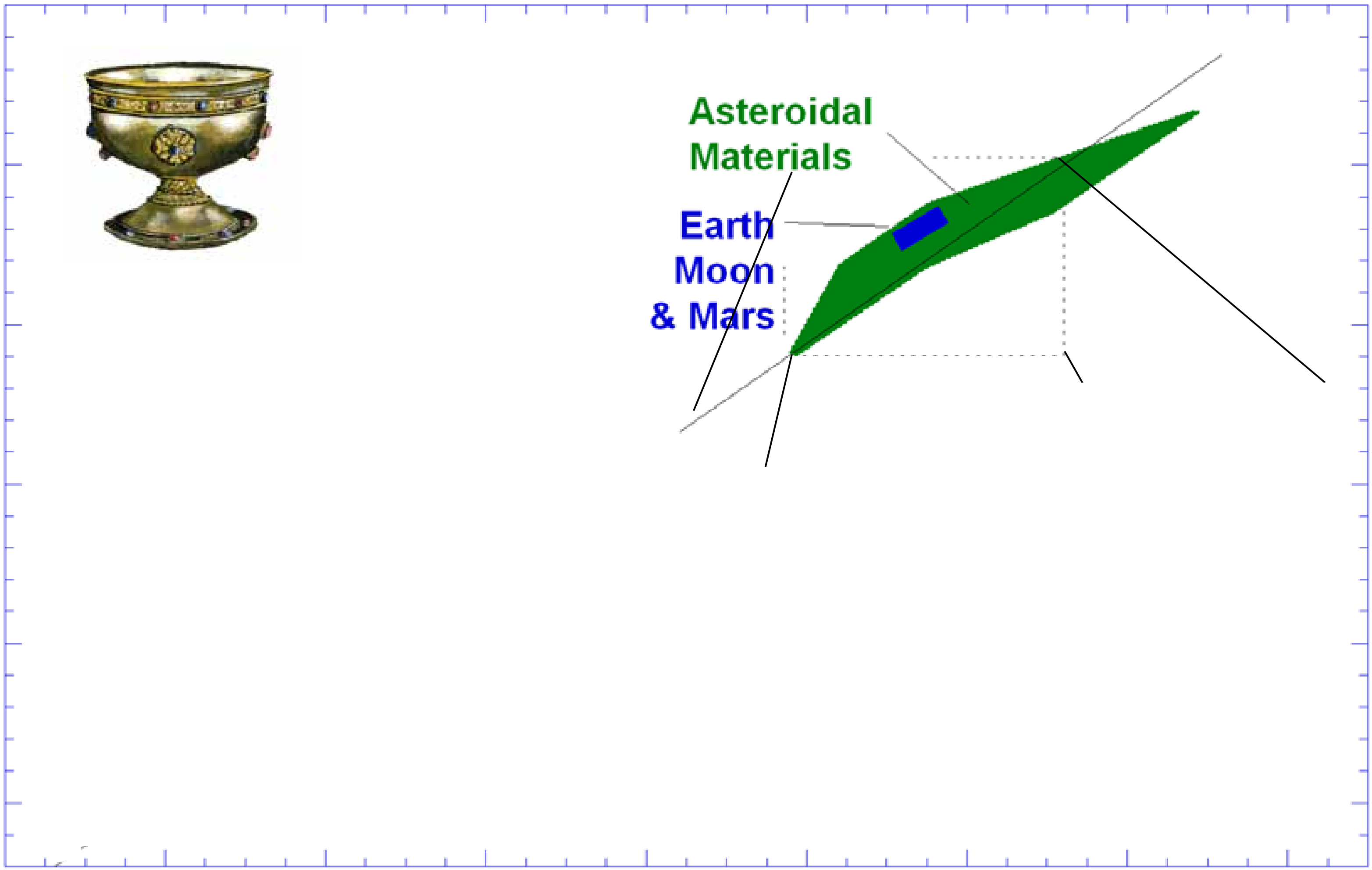
- *To accurately determine the Composition of the Sun*

Oxygen Isotope Map of Solar System



Oxygen Isotope Map of Solar System

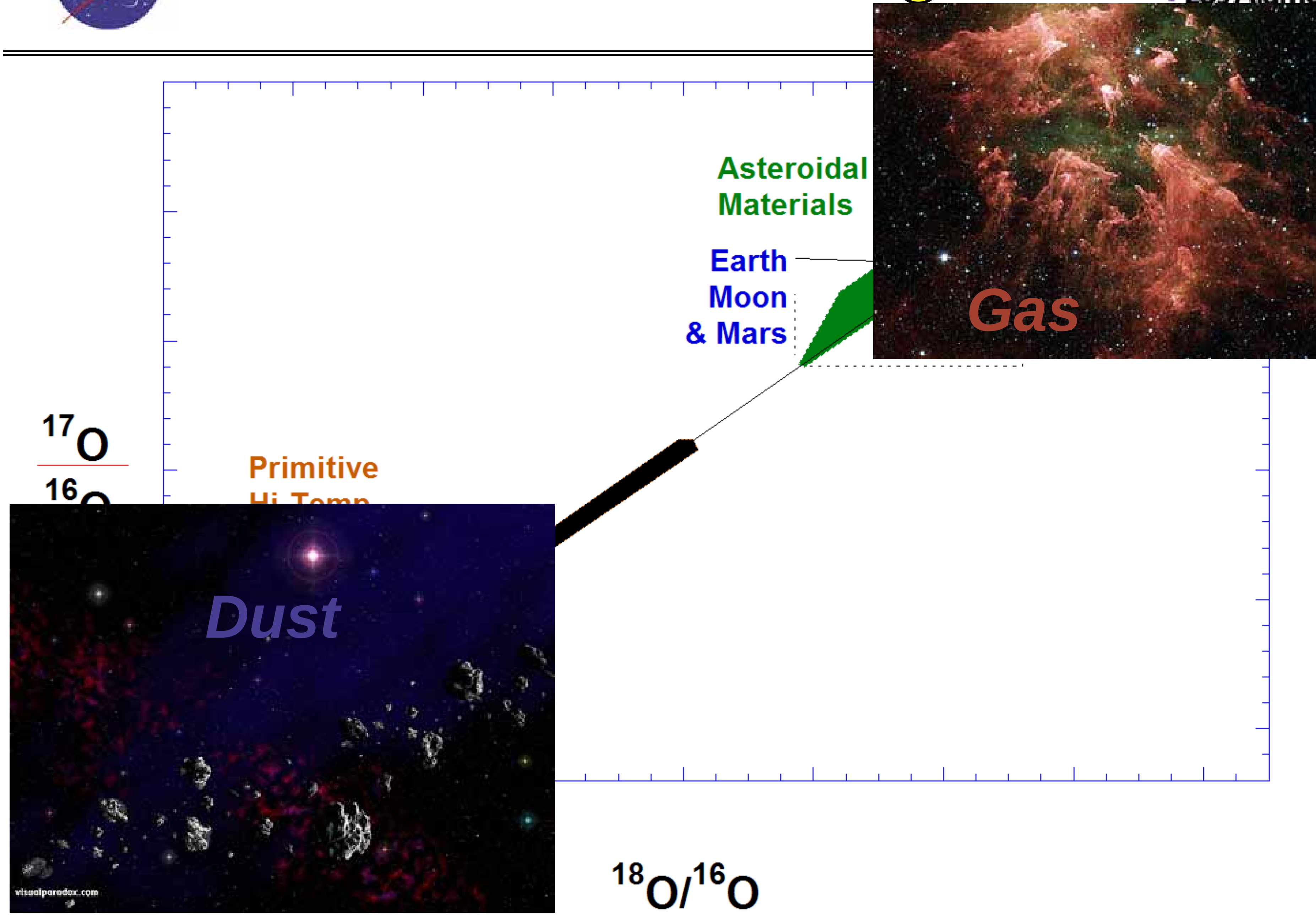
$^{17}O / ^{16}O$



8% Effect è BIG!

$^{18}O/^{16}O$

Solar Predictions



Testing Space Hardware at the Rifle Range

(Faster, better, cheaper…)

NASA

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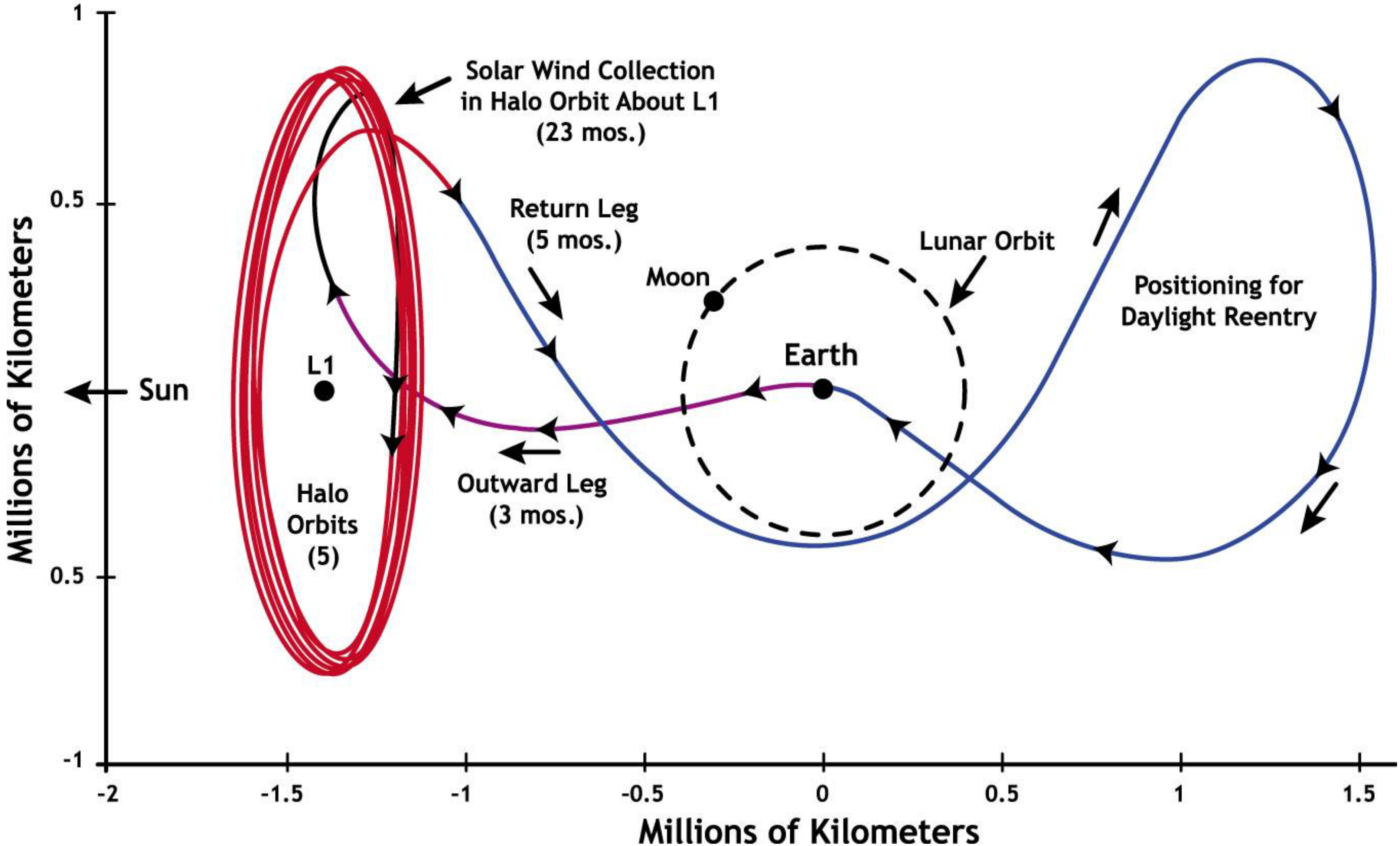
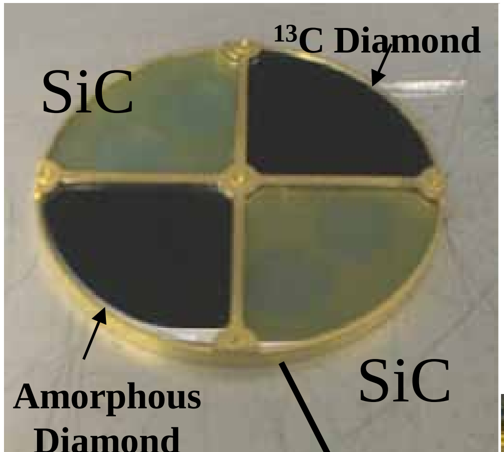
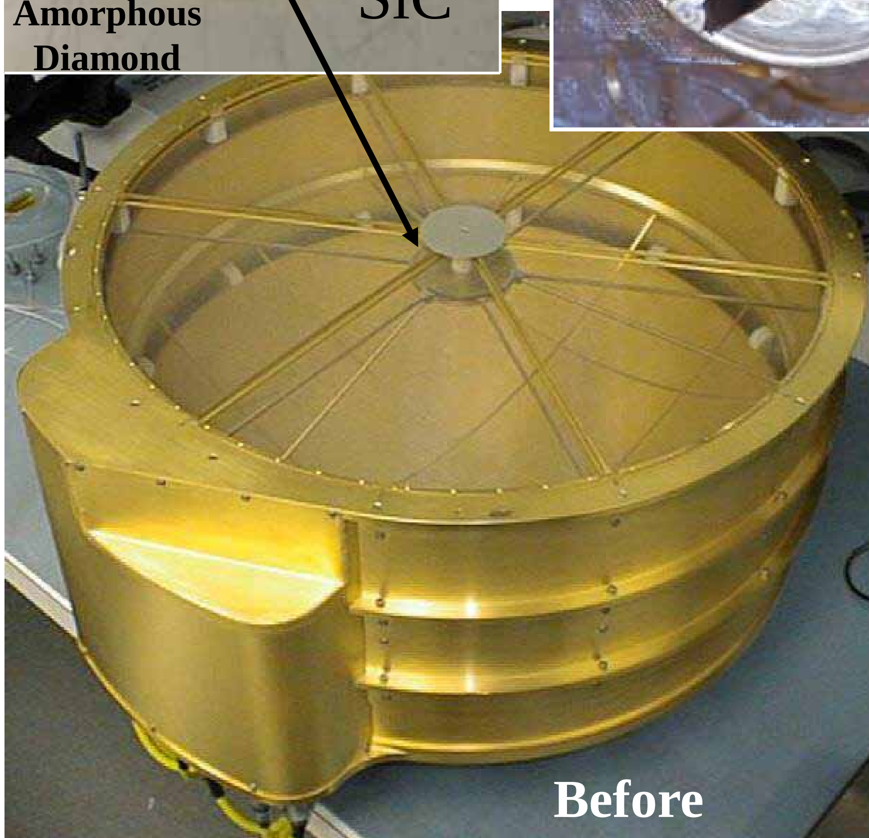
GENESIS MISSION TRAJECTORY: 2001 — 2004



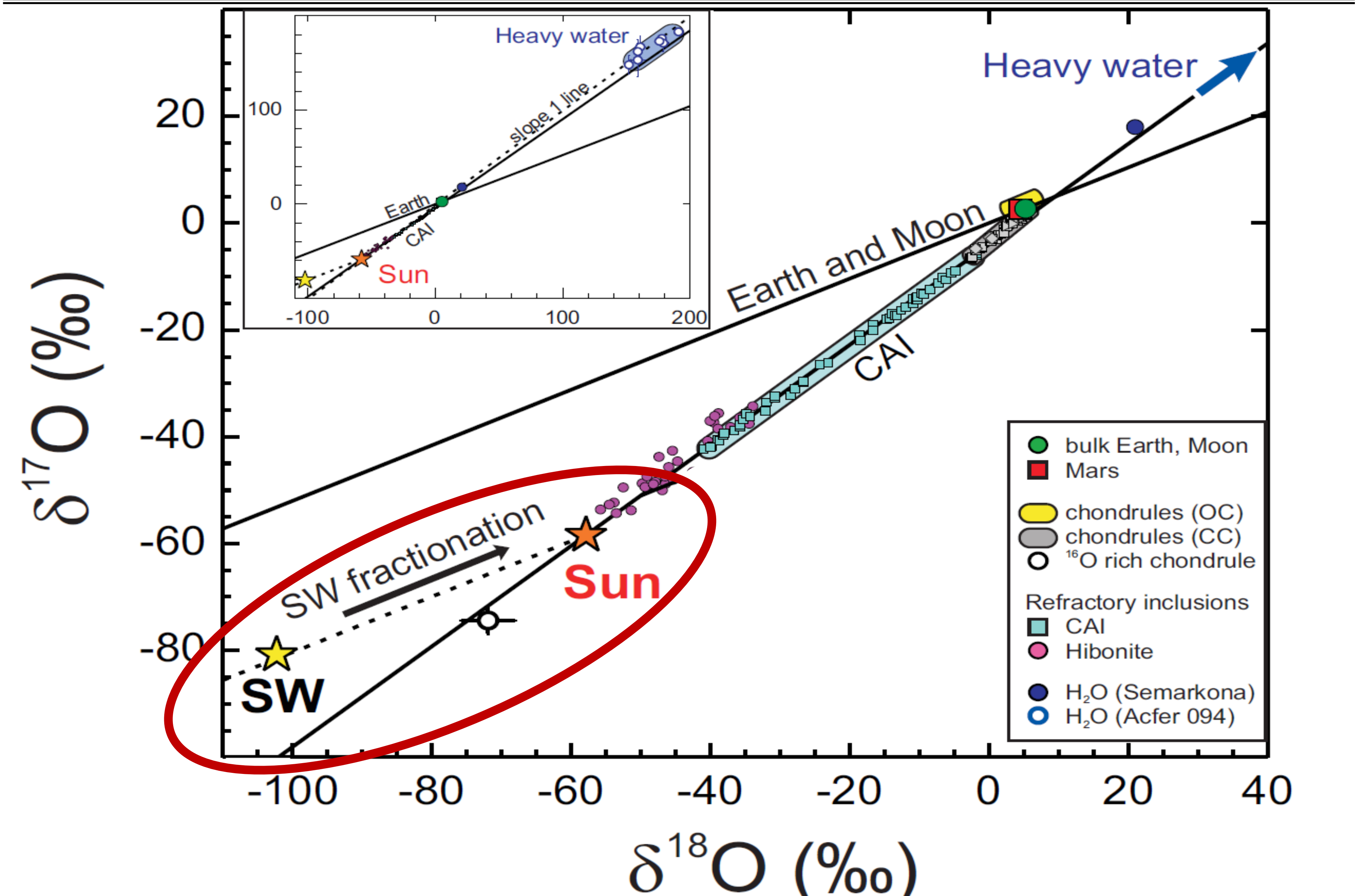
LANL Solar Wind Concentrator

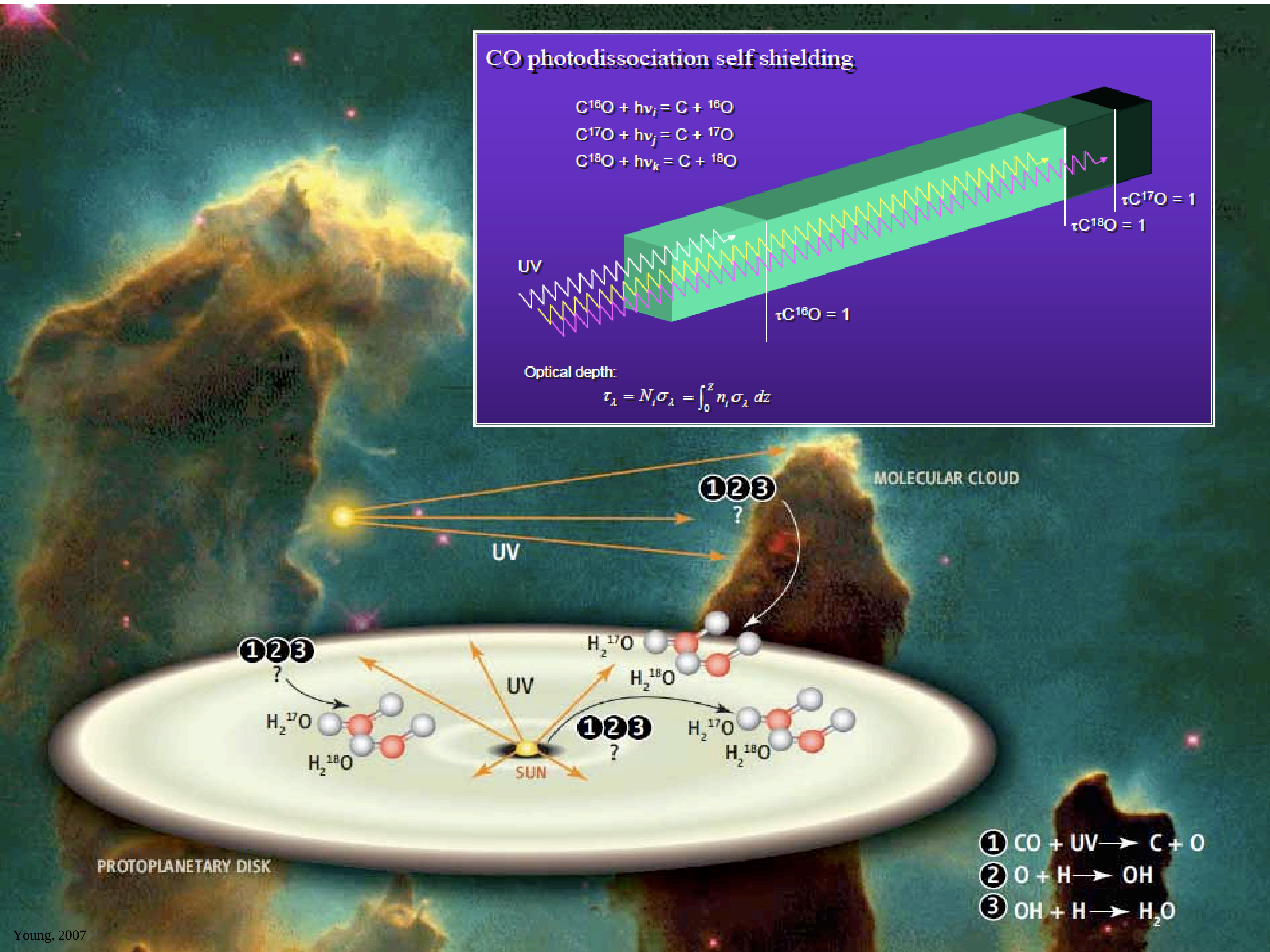


Over 90% of Target Recovered!



Solar System Oxygen



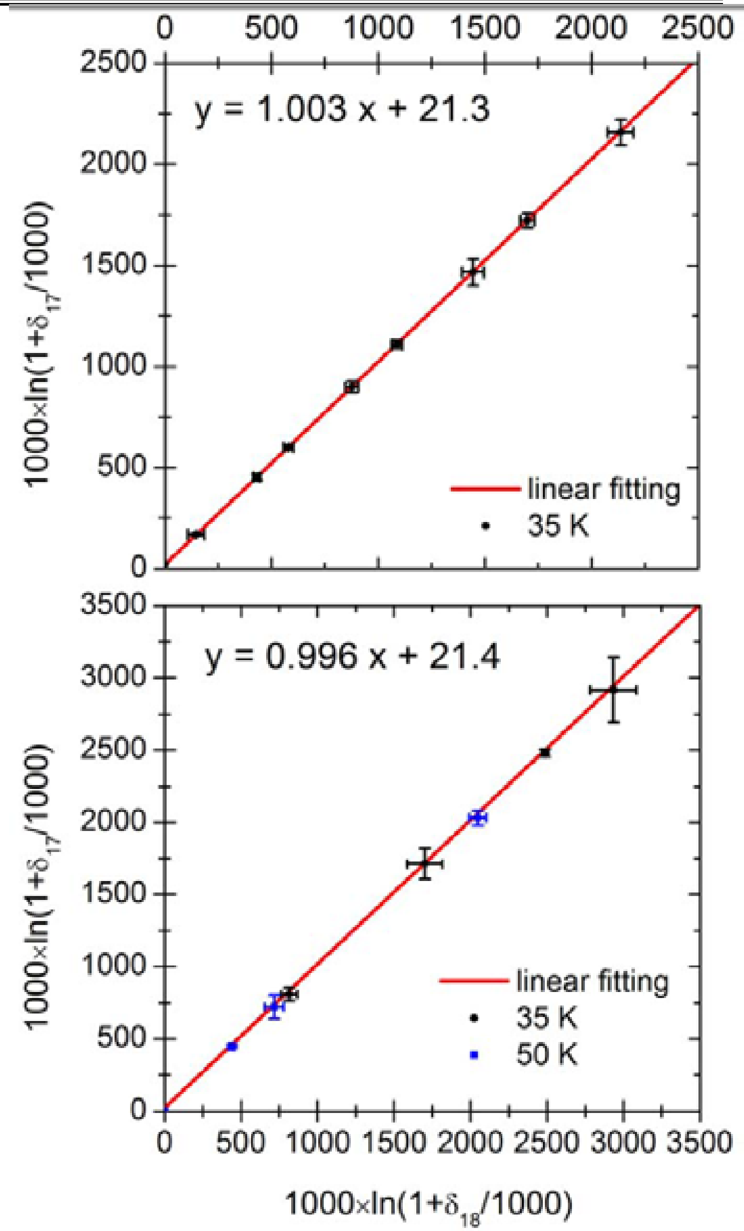


CO photodissociation self shielding
$C^{16}O + h\nu_i = C + {}^{16}O$
$C^{17}O + h\nu_j = C + {}^{17}O$
$C^{18}O + h\nu_k = C + {}^{18}O$
UV
$\tau C^{16}O = 1$
$\tau C^{18}O = 1$
$\tau C^{17}O = 1$
Optical depth:
$\tau_\lambda = N_i\sigma_\lambda = \int_0^z n_i\sigma_\lambda\, dz$
MOLECULAR CLOUD
1 2 3 ?
UV
$H_2{}^{17}O$
$H_2{}^{18}O$
UV
SUN
PROTOPLANETARY DISK
1 $CO + UV \rightarrow C + O$
2 $O + H \rightarrow OH$
3 $OH + H \rightarrow H_2O$

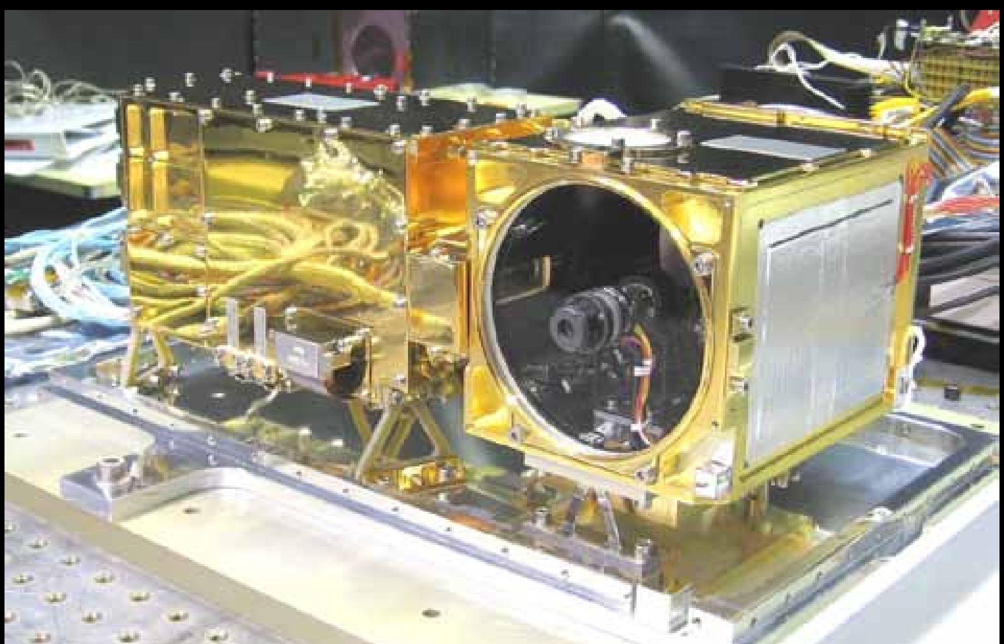
Young, 2007

Laboratory Self Shielding & N_2 Story

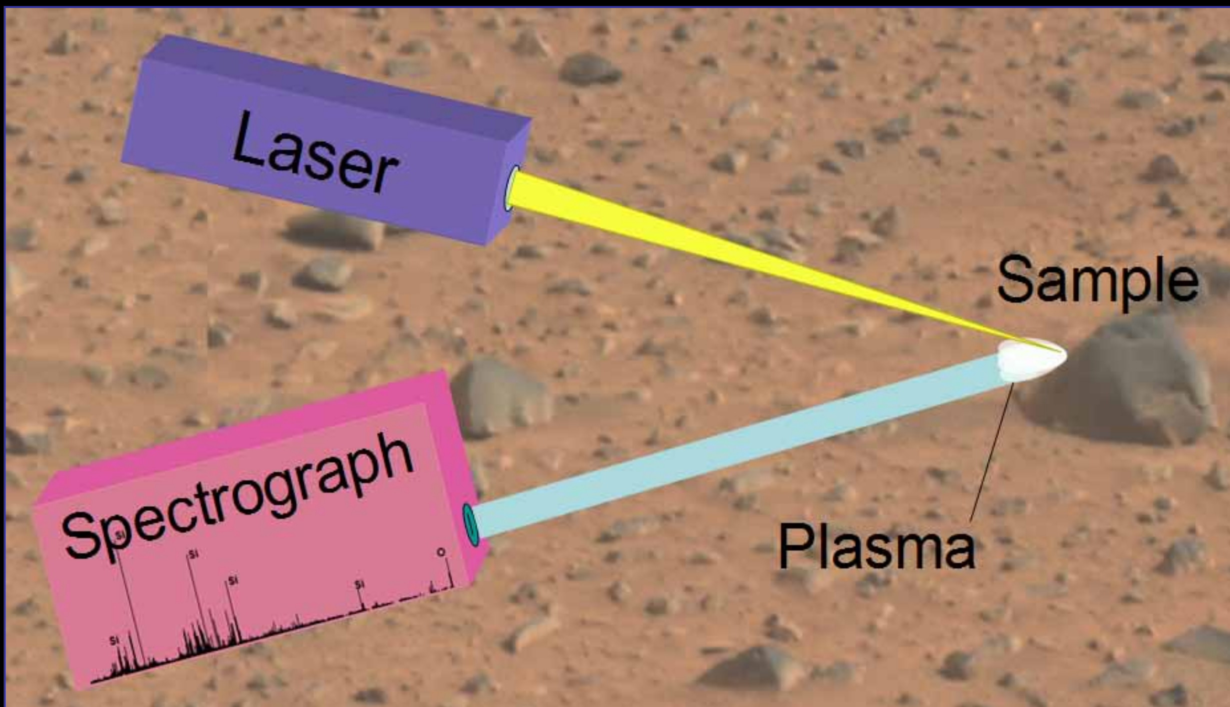
- **IGPP funding supported laboratory verification of the self-shielding effect for oxygen (rt.)**
- **The Genesis Concentrator also permitted solar nitrogen isotopic analyses**
  - **The result: ^{15}N is even more isotopically depleted in the Sun than the rare O isotopes**
  - **IGPP-supported work at UC Davis showed that UV-dissociated N_2 is more reactive than O, resulting in a 5x stronger self-shielding capture effect for nitrogen**



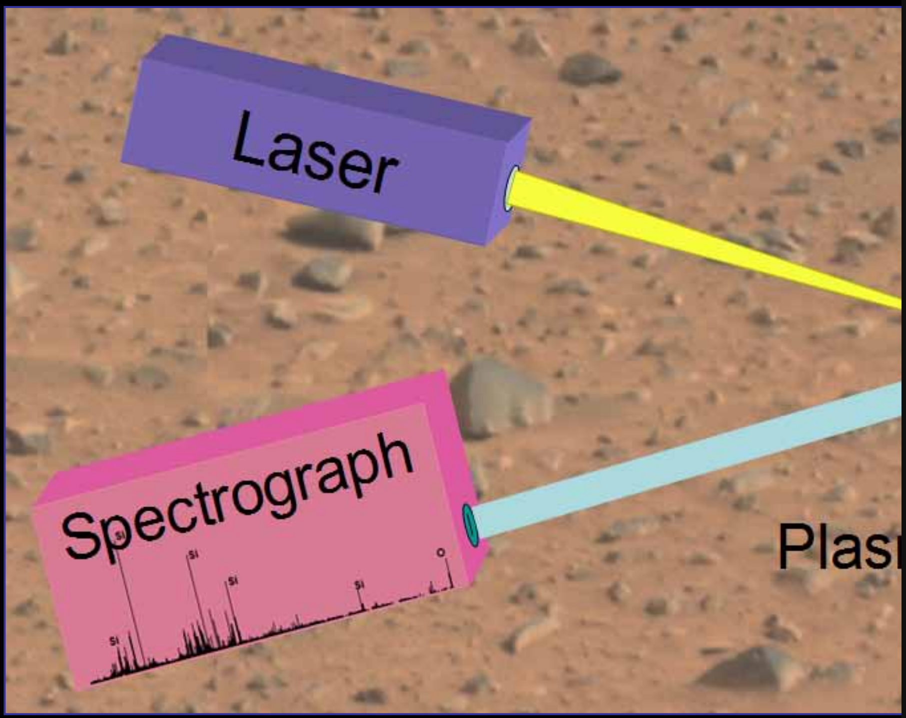
ChemCam



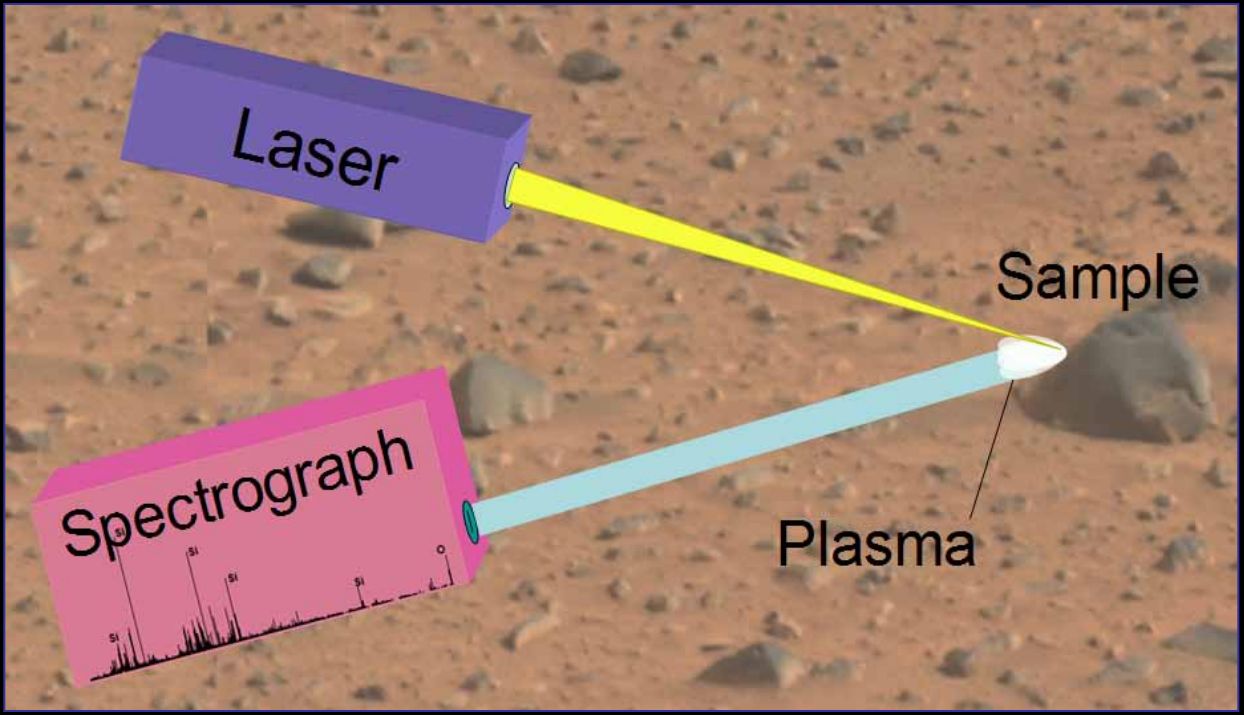
Laser-Induced Breakdown Spectroscopy (LIBS)



Laser-Induced Breakdown Spectroscopy (LIBS)



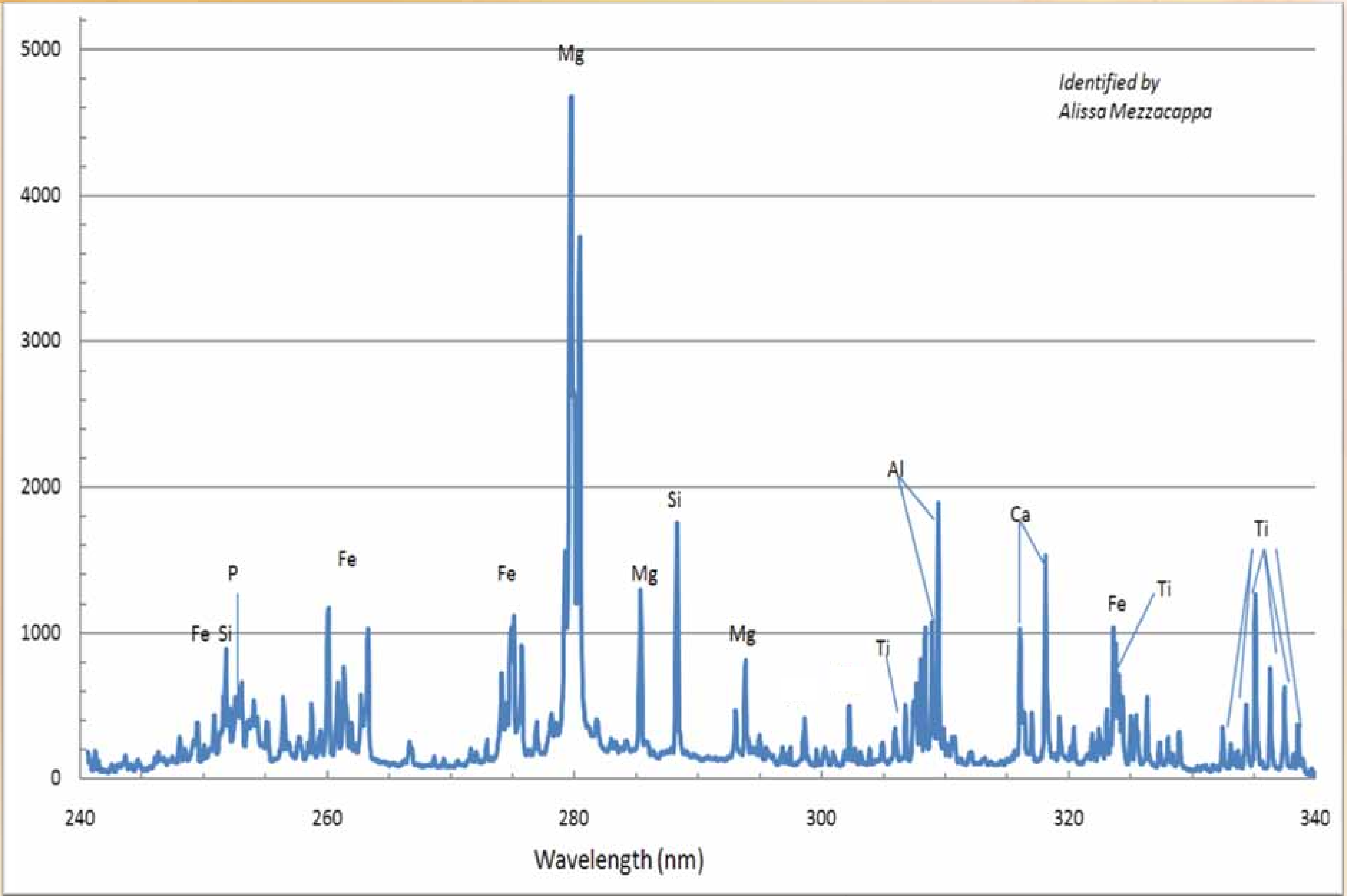
Laser-Induced Breakdown Spectroscopy (LIBS)



Aluminum Copper Basalt

Sirven et al., JAAS

LIBS Spectrum (1 of 3)



Taken at LANL

Why LIBS on Mars?

Eagle Crater, First Sedimentary Outcrop Observed on Mars

- Mars is a Difficult Place For Remote Sensing
  - Surfaces Typically Covered by Dust and/or Weathering Coatings
  - Active Remote Sensing Much Better Than Passive Under These Circumstances
    - Eagle Crater Sedimentary Rocks Not Initially Identified by Remote Sensing on the Opportunity Rover
    - Most Samples Had to Be Brushed Off Before Identification

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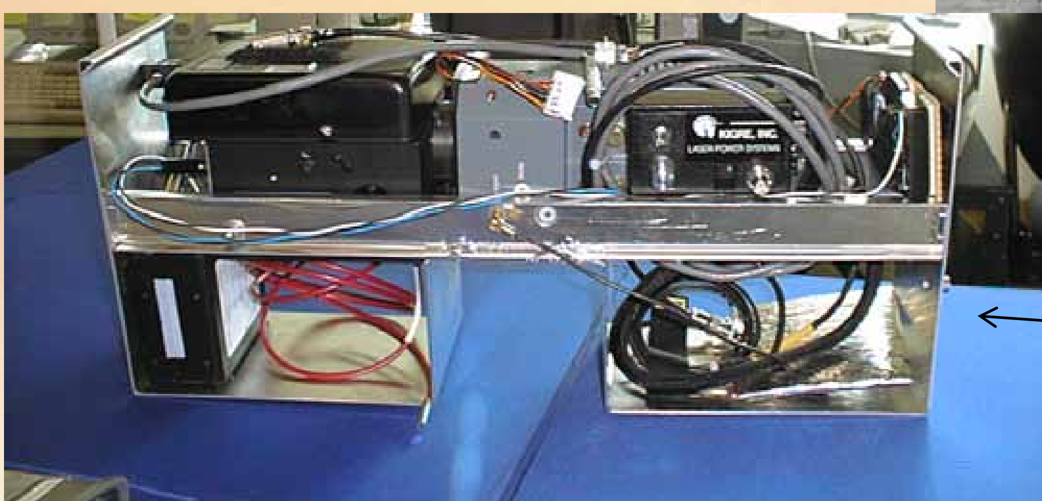
K9 Rover Test

- *LIBS integrated on a NASA rover testbed*
- *Our opportunity to prove the usefulness of LIBS!*
- *Scheduled for May 11, 2000*

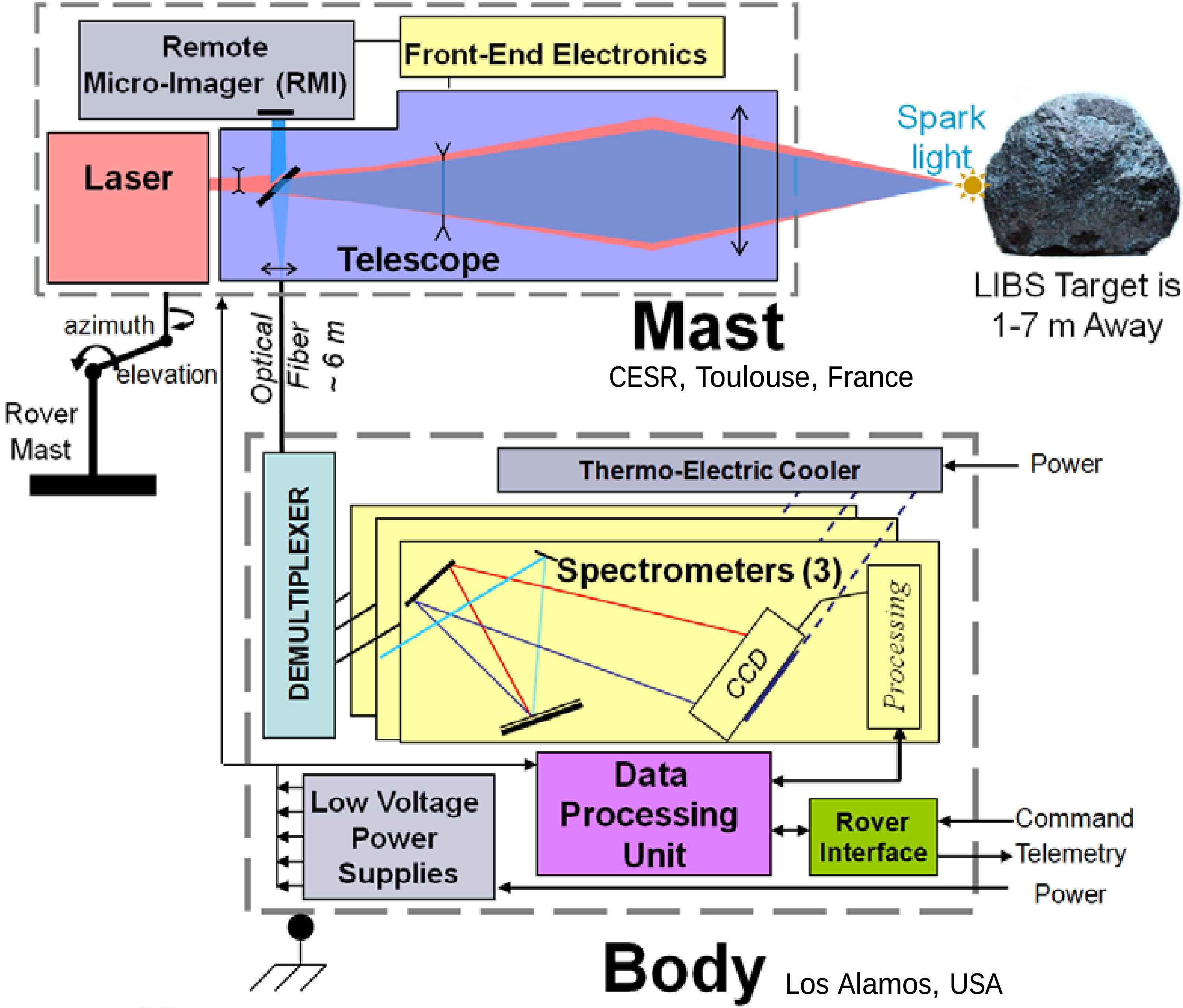


Spectrometers (inside rover body)

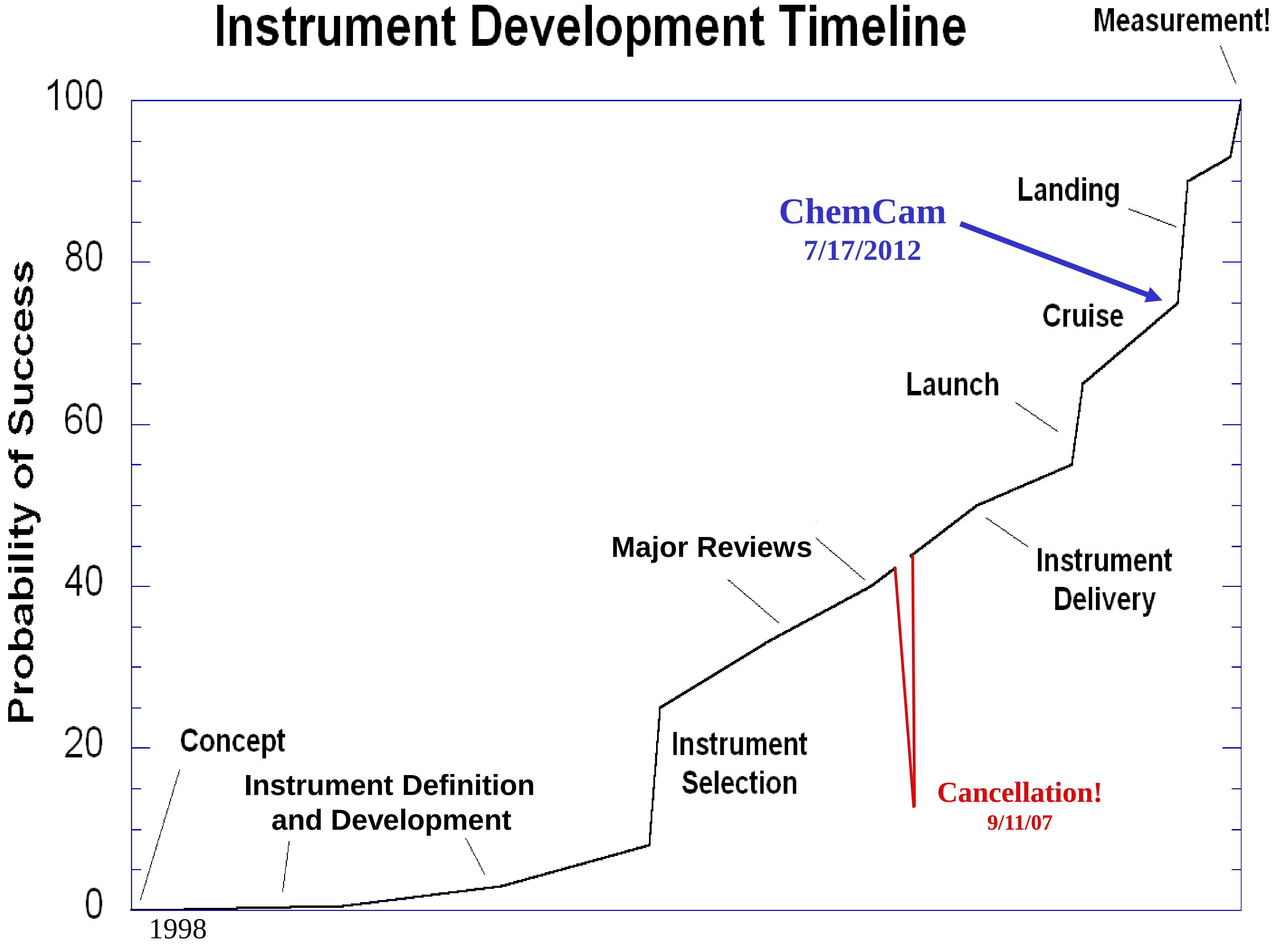
Cerro Grande Fire

The fire evacuation prevented us from participating in the rover tests!!

ChemCam Instrument Schematic



Instrument Development Timeline



ChemCam Micro-Imager Performance

$1 @ 10 ft distance

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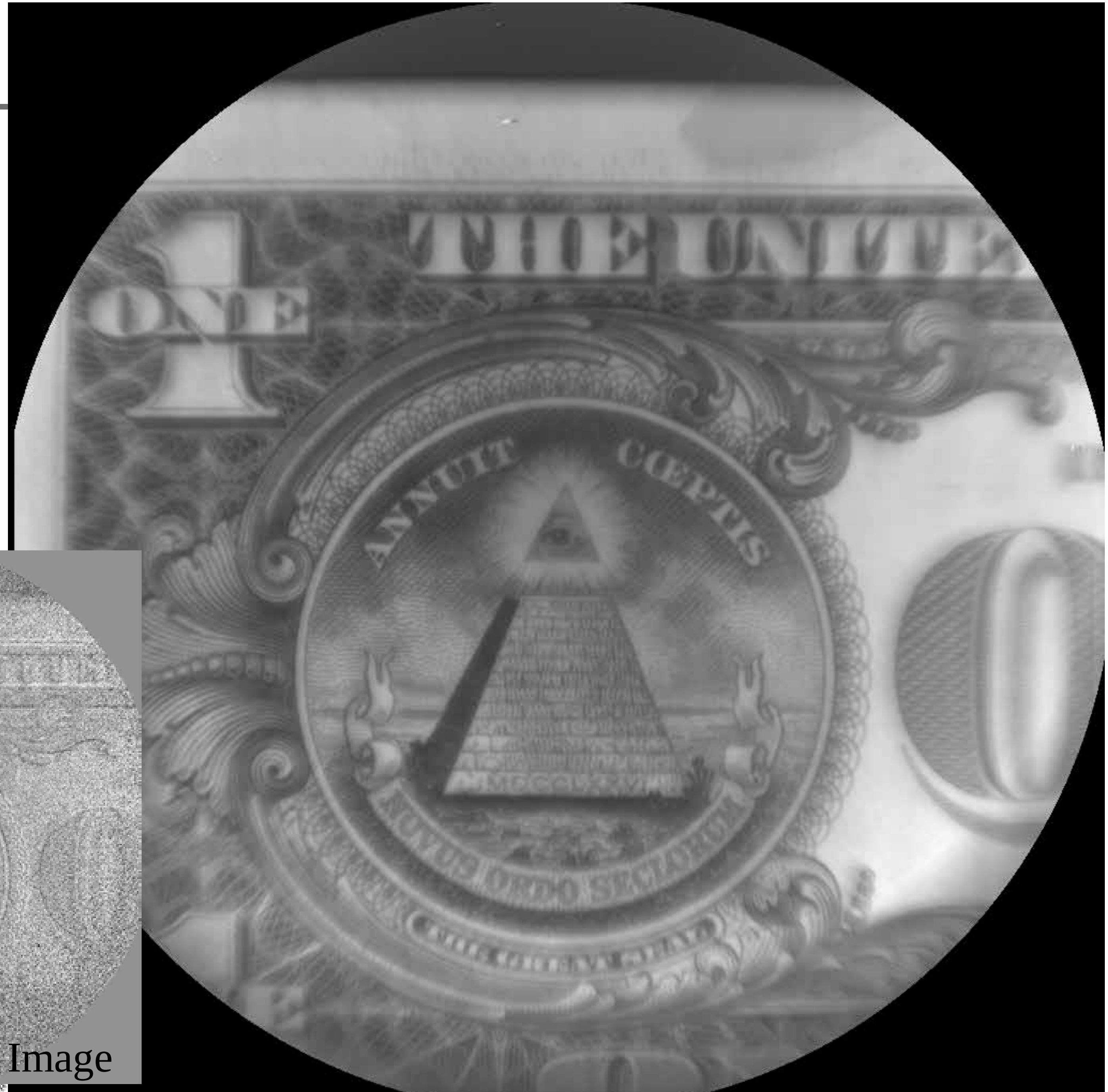
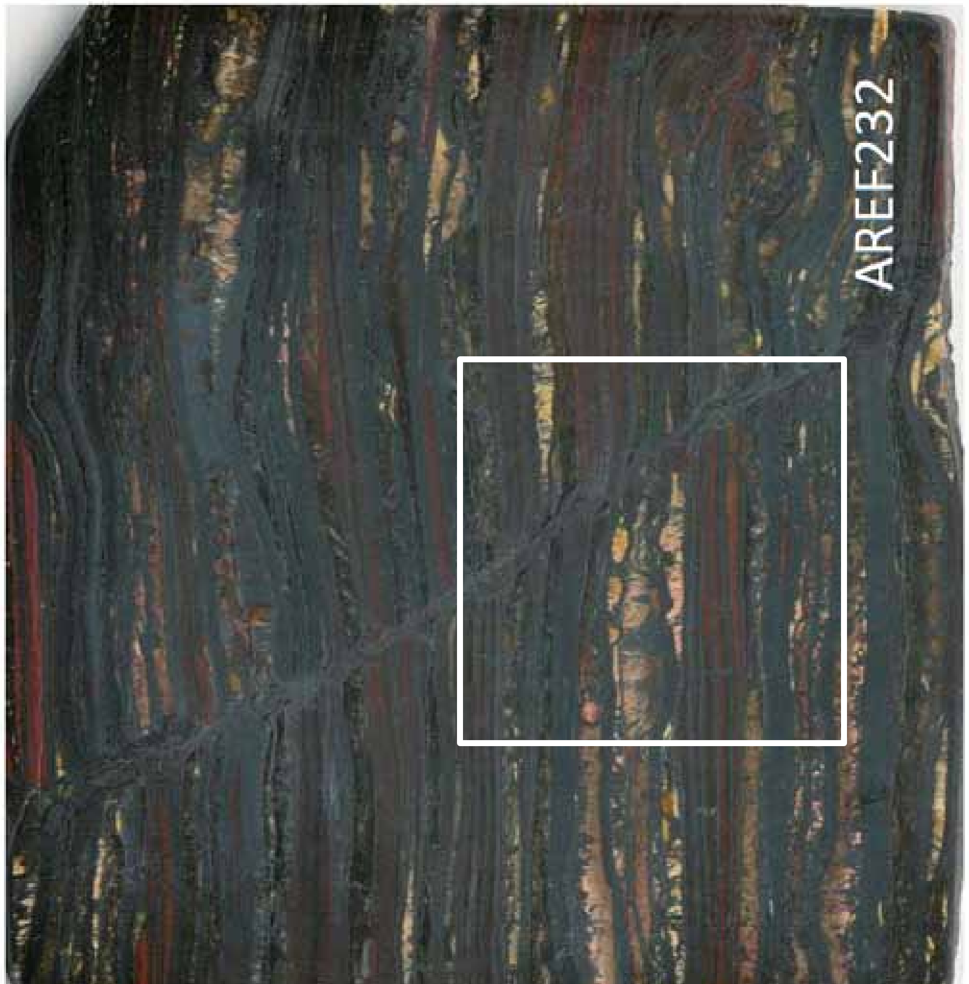
ChemCam Micro-Imager Performance

Stretched Difference Image



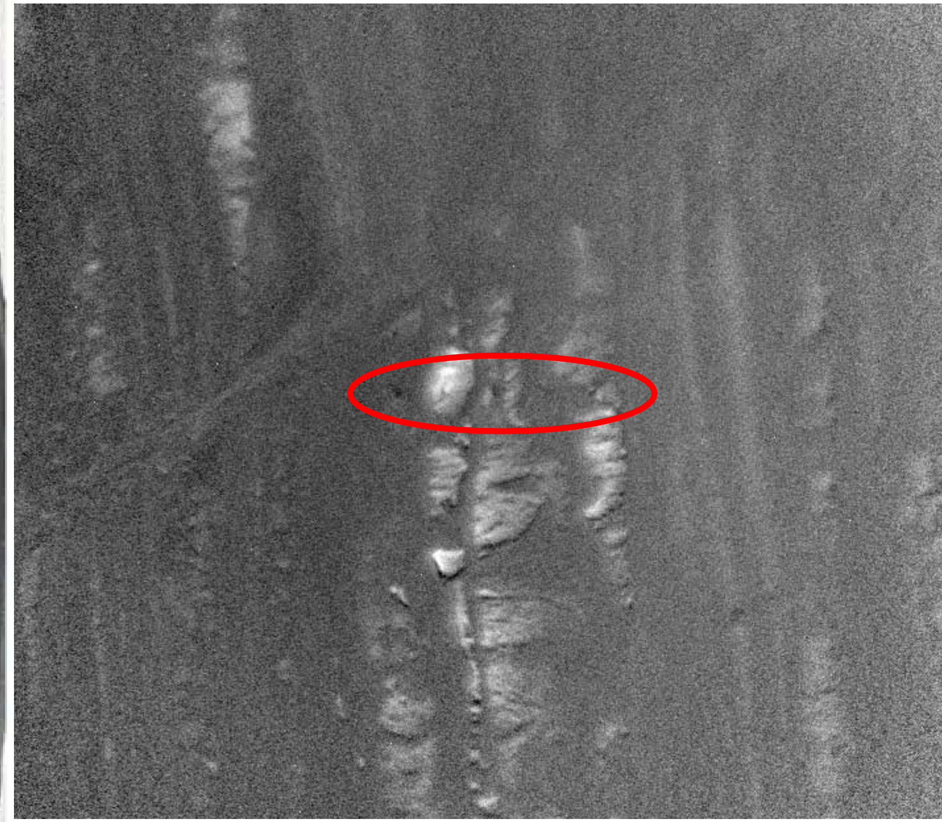
Chemostratigraphy Example: Banded Iron Formation

Rover test @ 3 m

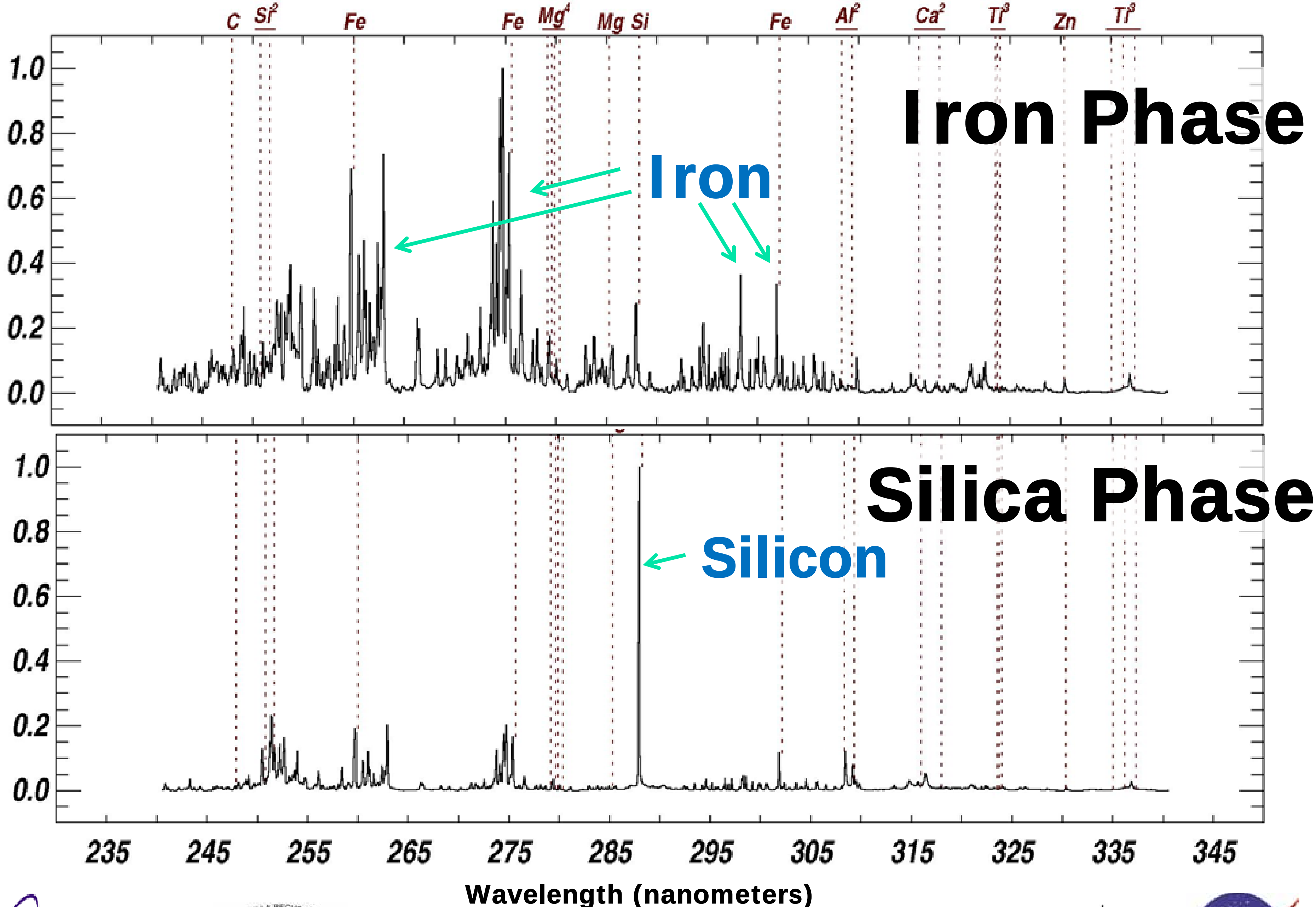


10 x 10 cm

ChemCam
RMI Subframe Stretched



Distance between analysis points ~2 mm



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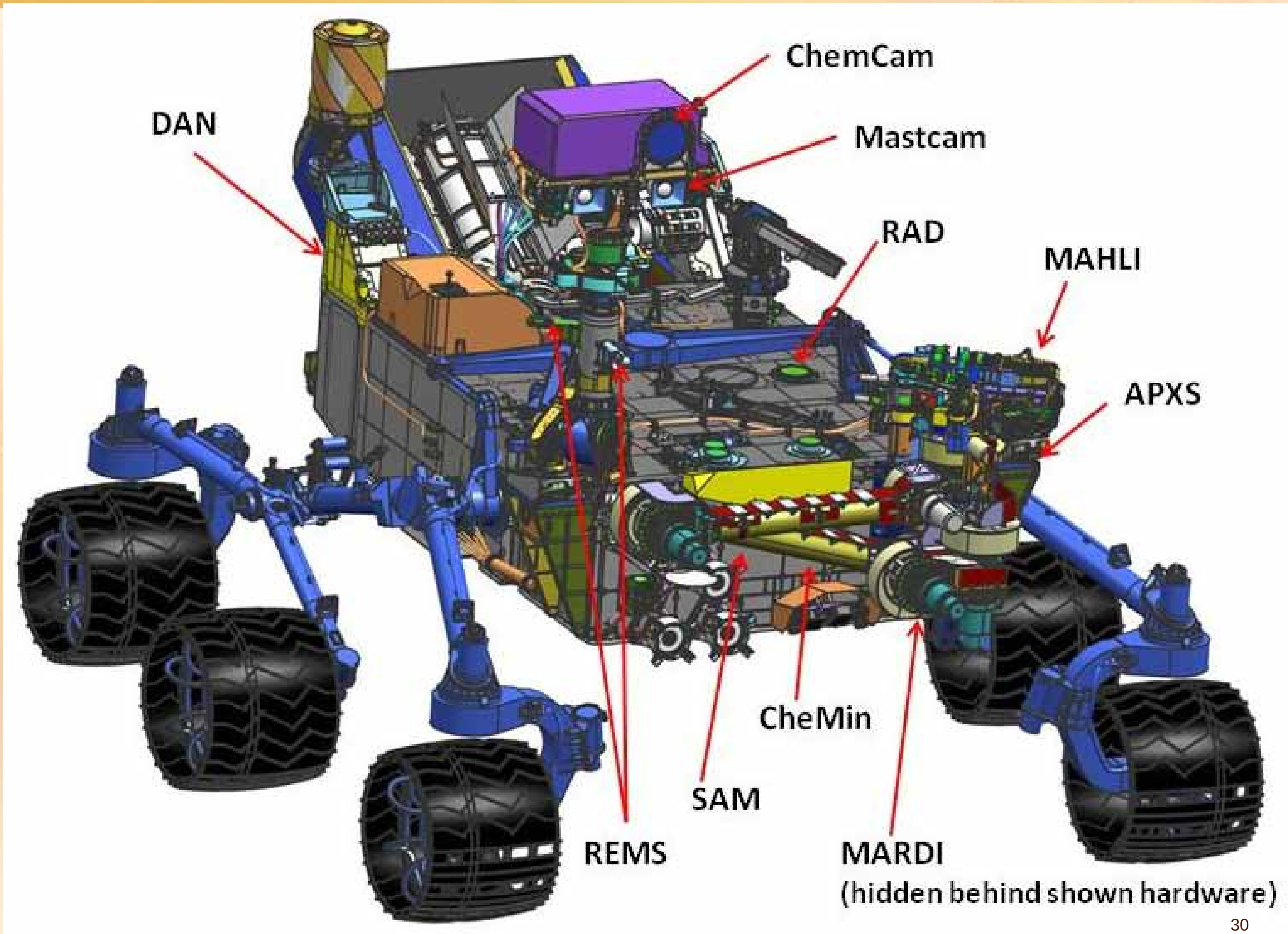
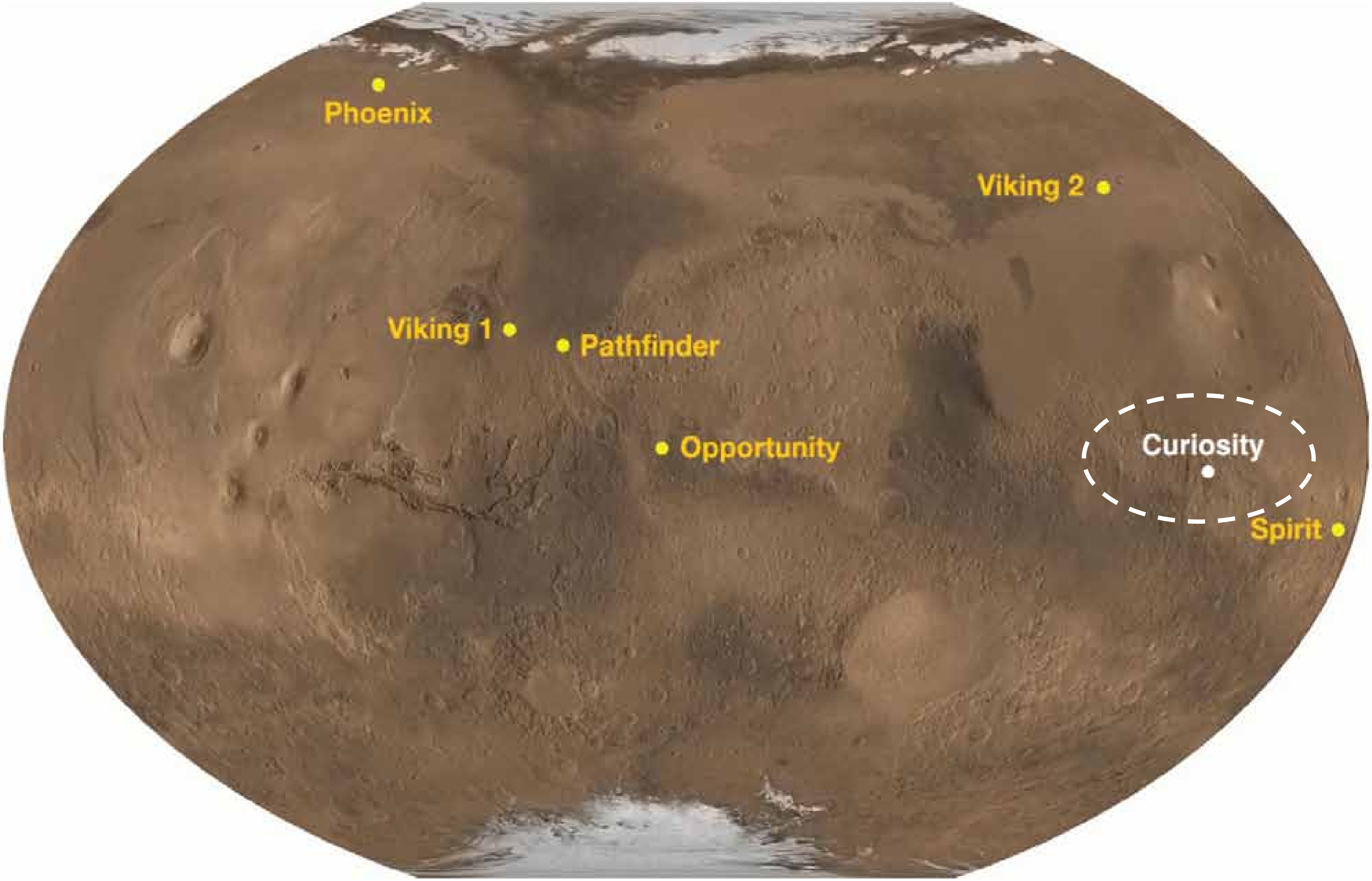
NASA

Curiosity Rover

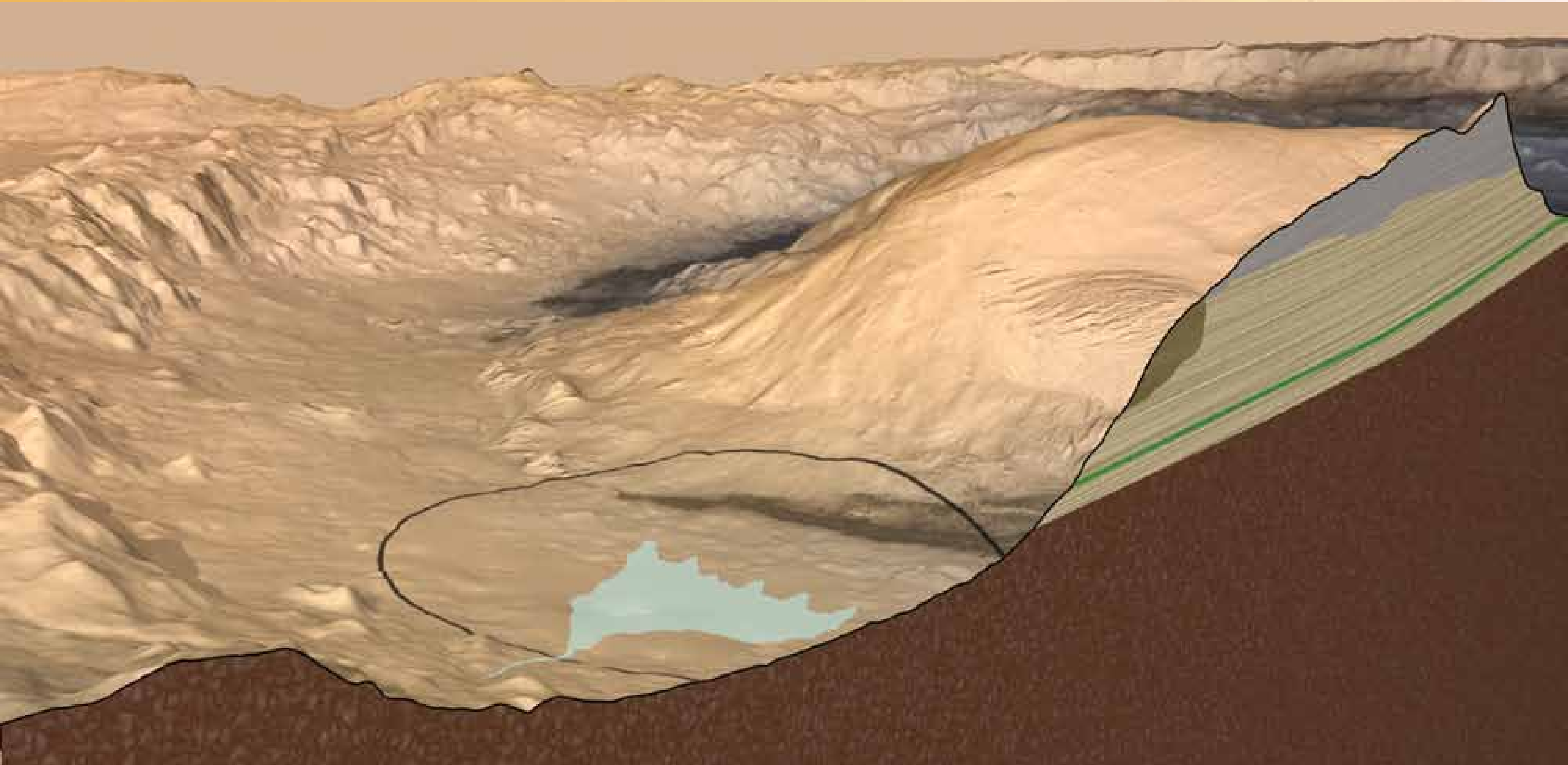
Curiosity Instruments



Previous and Future Mars Landing Sites



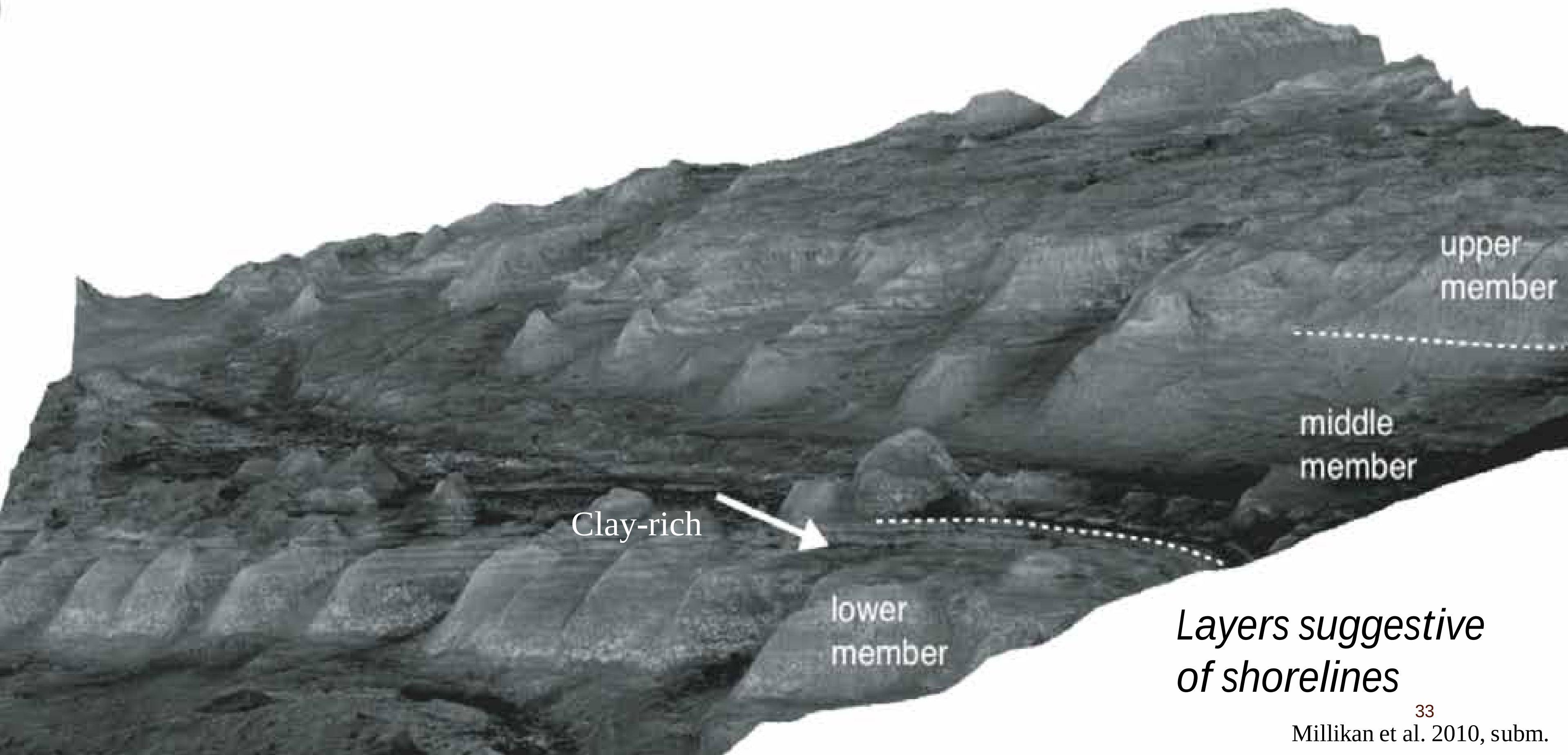
The Strata of Gale Mountain



Gale Crater contains a 5-km high mound of stratified rock. Strata in the lower section of the mound vary in mineralogy and texture, suggesting that they may have recorded environmental changes over time. Curiosity can investigate this record for clues about habitability, and the ability of Mars to preserve evidence about habitability or life.

Gale Crater *(4.5 °S, 137 °E, -4.5 km)*

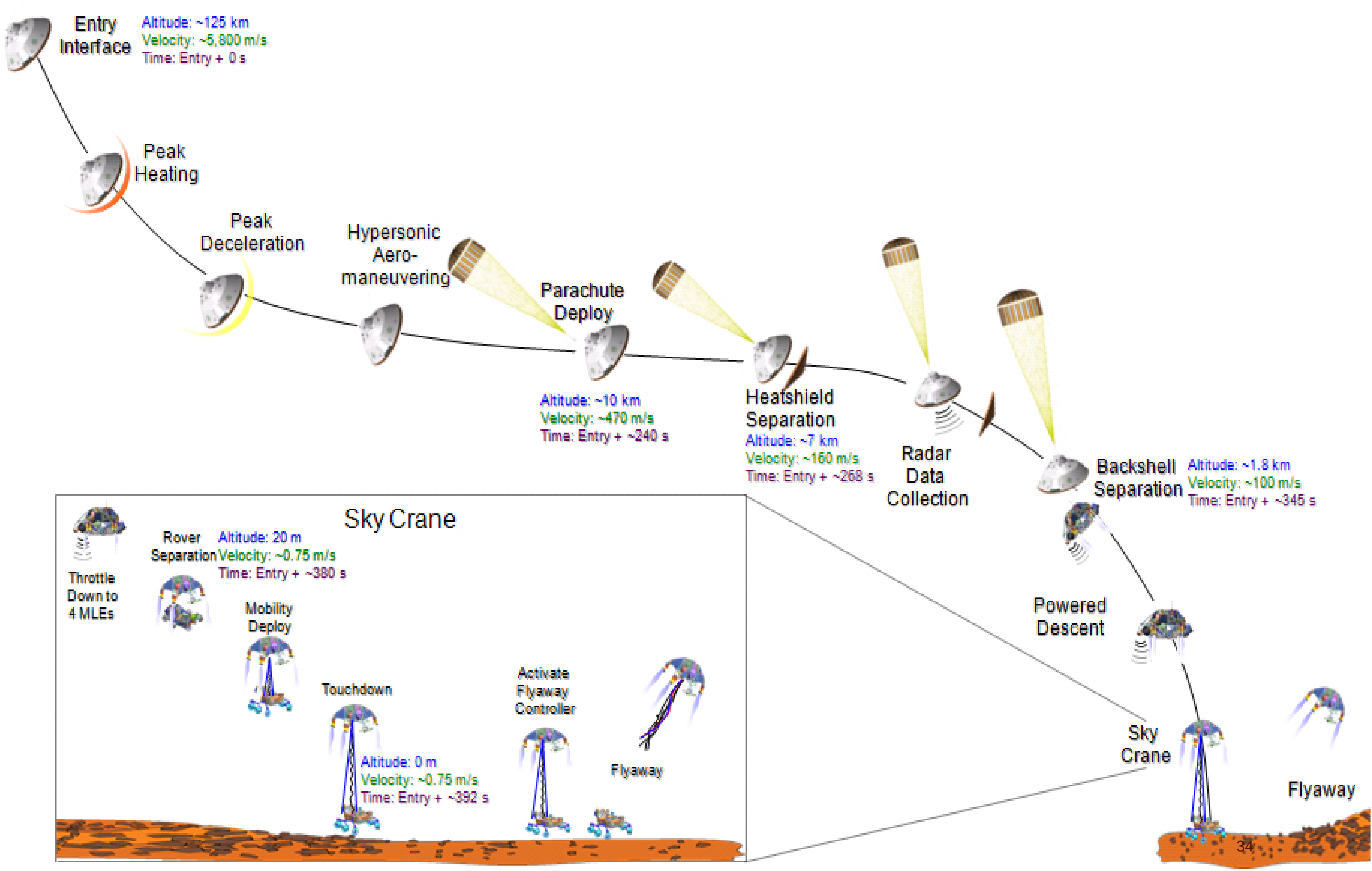
- *3-mile thick sequence of rock layers*
- *Clay-rich near the bottom, sulfates at higher elevations.*



Layers suggestive of shorelines

Millikan et al. 2010, subm.

Mars Landing



Summary

Curiosity will be an exciting mission, going beyond finding water, to surveying the habitability and climate history of Mars

Thank you for hosting this presentation

…and thanks to the many people at Los Alamos and elsewhere who contributed to these missions!

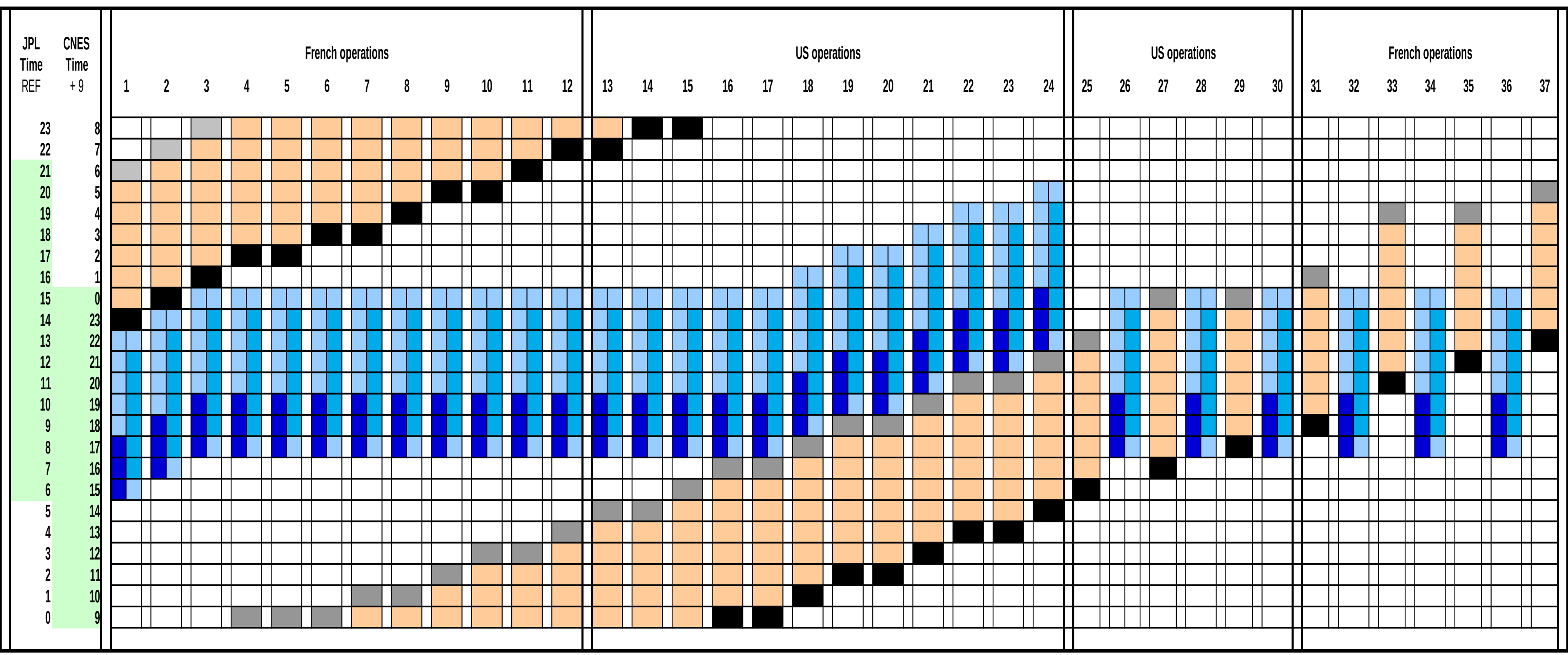
Additional Slides

ChemCam Science Measurements

- *Weathering Coatings on Rocks*
- *Depth Profiles in Soils*
- *General Elemental Compositions of Rocks/Soils*
- *Particular Emphasis on Elements Not Analyzable by Other Means:*
  - *Hydrogen (i.e., clay minerals)*
  - *Carbonates*
  - *Li, Be, B, N, Rb, Sr, Ba*
- *Tactical Support/Reconnaissance for Rover Team*
- *Passive spectroscopy*
- *Atmospheric Ozone Studies (Passive Observation in the UV)*
- *Support for LIDAR studies of atmospheric dust and water vapor*

ChemCam Operations

- *First 90 days: Operate at Jet Propulsion Laboratory, on Mars time (24 hr, 38 minute days)*
- *After that, operate from home. Operate ½ from France, ½ from US on 37 day cycles (36 Mars sols = 37 days)*



Rover Arm

Aeroshell “Fit Check”

LMCO/JPL

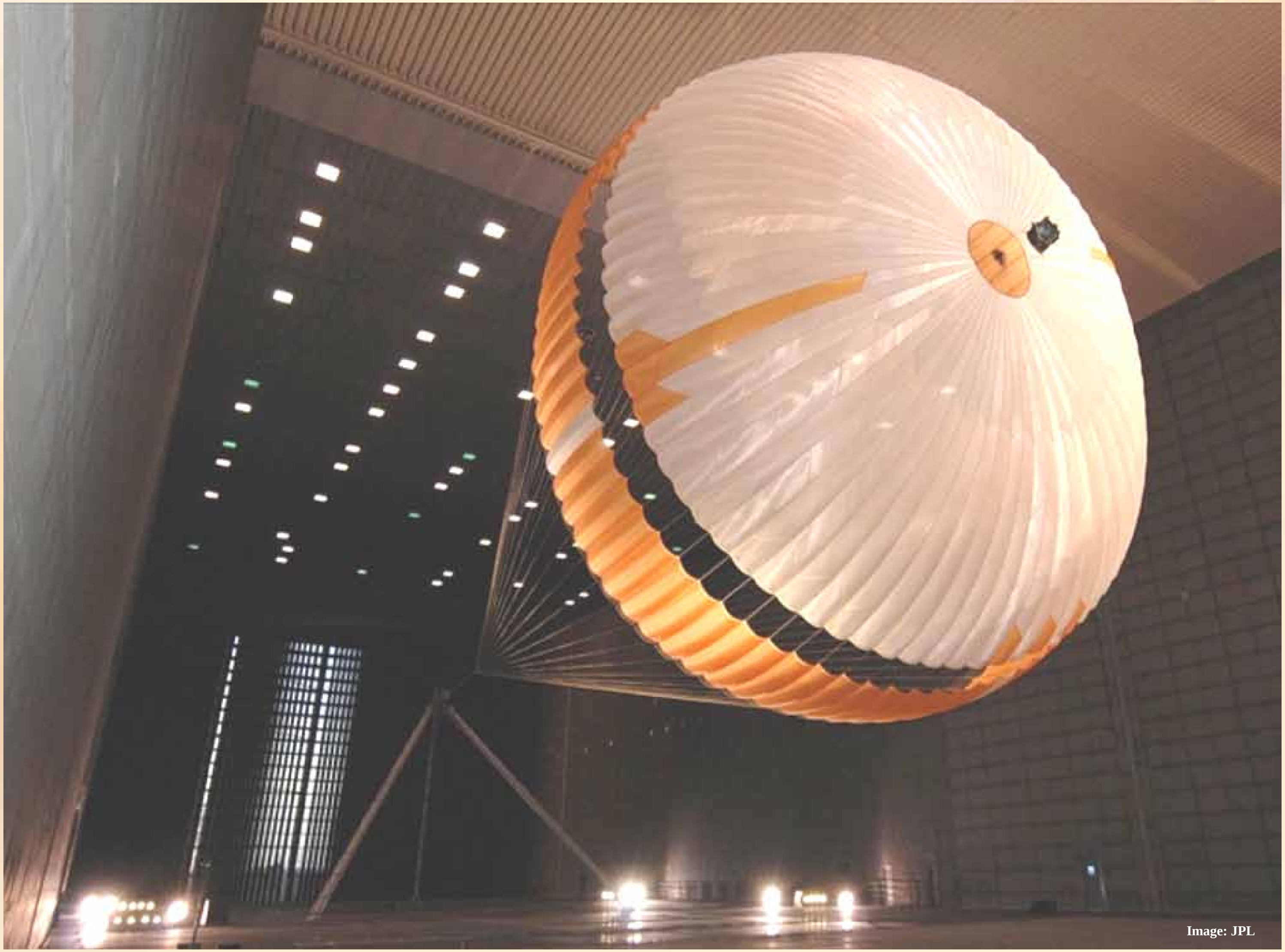


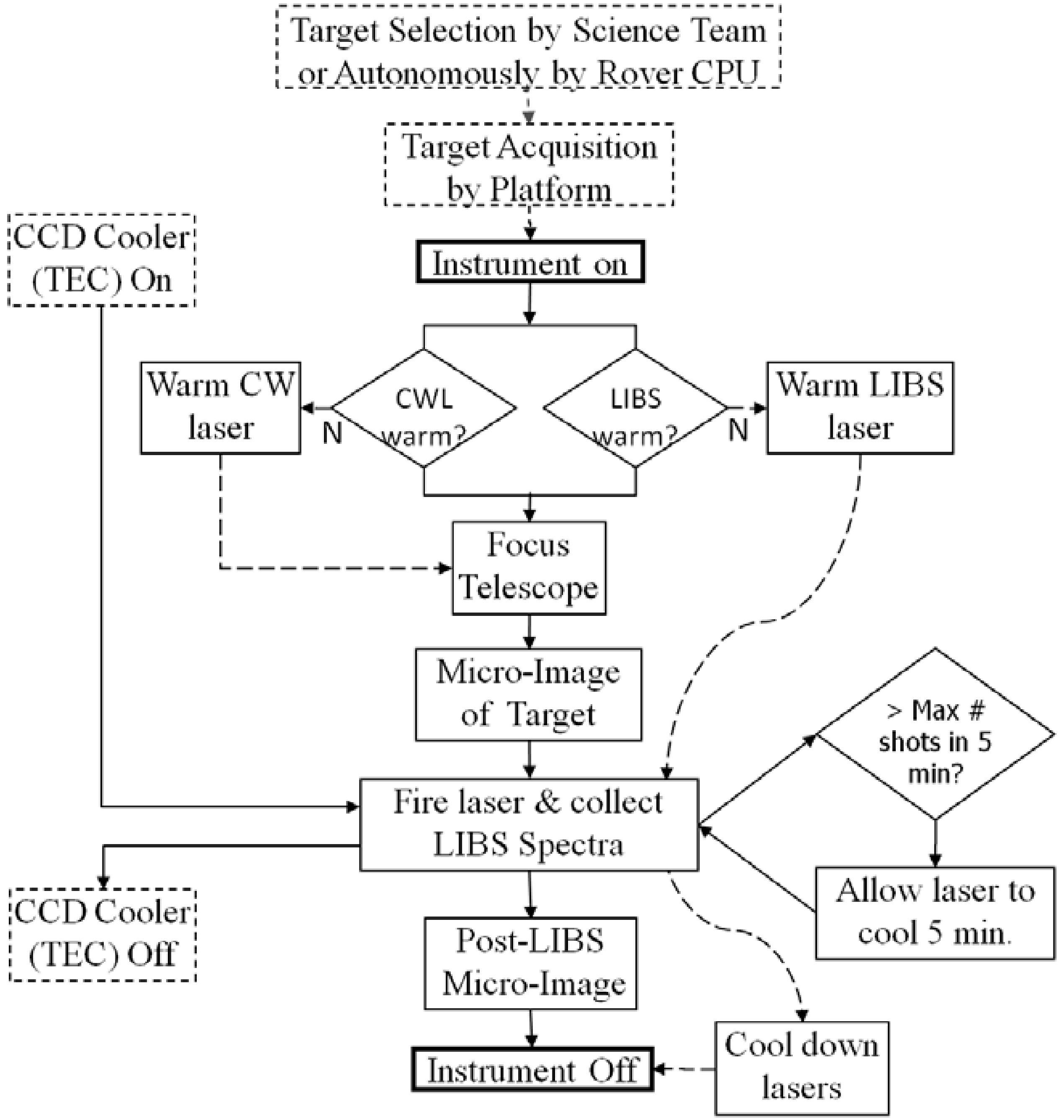
Image: JPL

Buildup for Launch: Rover and EDL Stage

Rover in Capsule

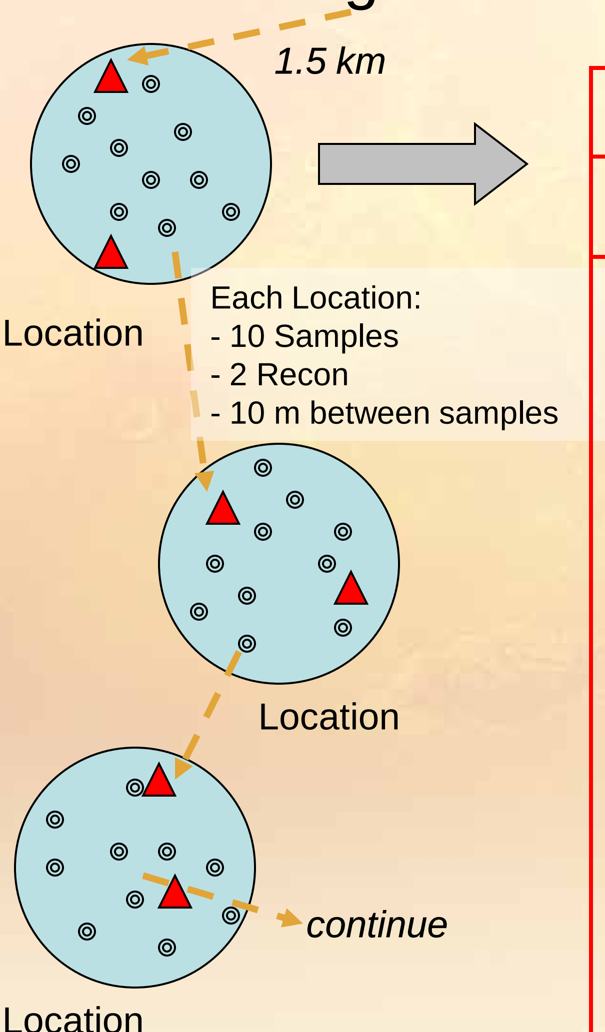
Typical analysis sequence

6 Minutes,
2 W-hr
Per Typical
Analysis



Surface Operations Overview

Mission Segment:



Sol Types / Decision Points

Traverse:
Decision 1: Is there an area of interest based on untargeted remote sensing data?

Recon:
Decision 2: Is there an interesting science target based on targeted remote sensing data?

Approach:
Decision 3: Are there specific targets in the workspace to analyze?

Contact:
Decision 4: Based on contact suite data, is the target worth sampling?

Coring:
Decision 5: Based on core contact suite data, is the core worth analyzing?

Analysis:
Decision 6: Drive away from target site?

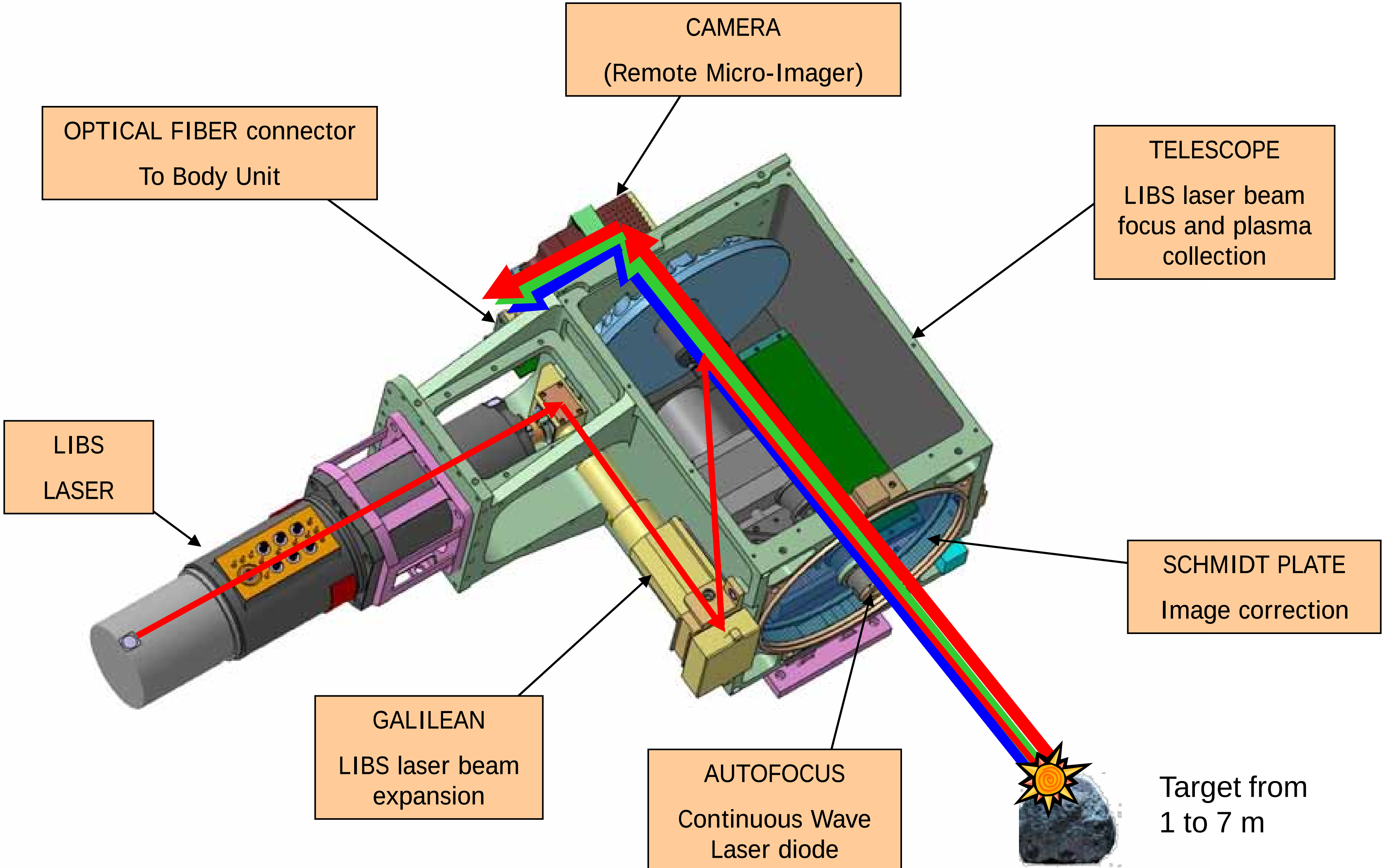
Top-Level ChemCam Requirements

- Measure major elements to ±10% accuracy
- Analysis distances to 7 m
- Capable of up to 10 measurements/day
- Provide depth profiles to 1 mm deep
- Individual shot analyses
- Provide context images for analyses
- Provide rapid analyses (goal 5 min./analysis)

Derived ChemCam Requirements

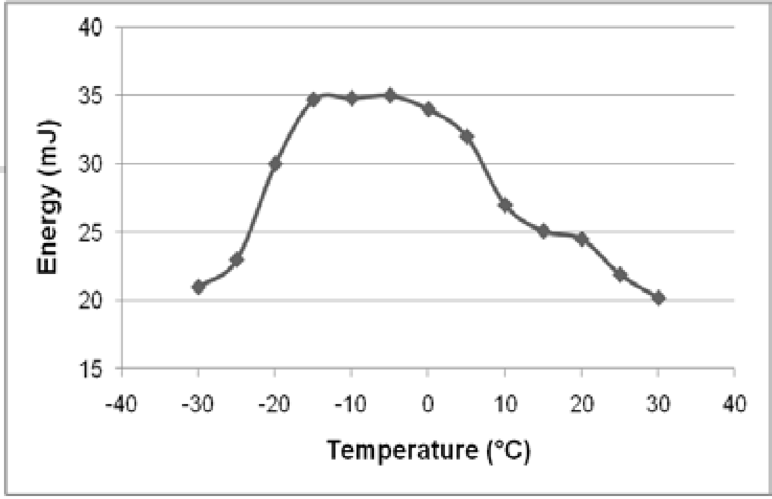
- Spectral range 242-800 nm
  - To cover C (strongest line 248 nm) and O (strongest line 777 nm)
- Spectral resolution
  - < 0.20 nm FWHM for $\lambda < 470$ nm
    - Separates 248 nm C line from Fe interference and 407.7 nm Sr line from Fe interference
  - < 0.65 nm FWHM for $\lambda > 470$ nm
    - Fewer and more widely spaced interferences in this spectral range
- Laser power density > 10 MW/mm^2
  - Needed to create LIBS sparks
- Imager resolution $\leq 100\ \mu$rad
  - To image LIBS analysis pits
- Laser rated to 5 million shots, passively cooled
- Requirements on transmission and signal-to-noise

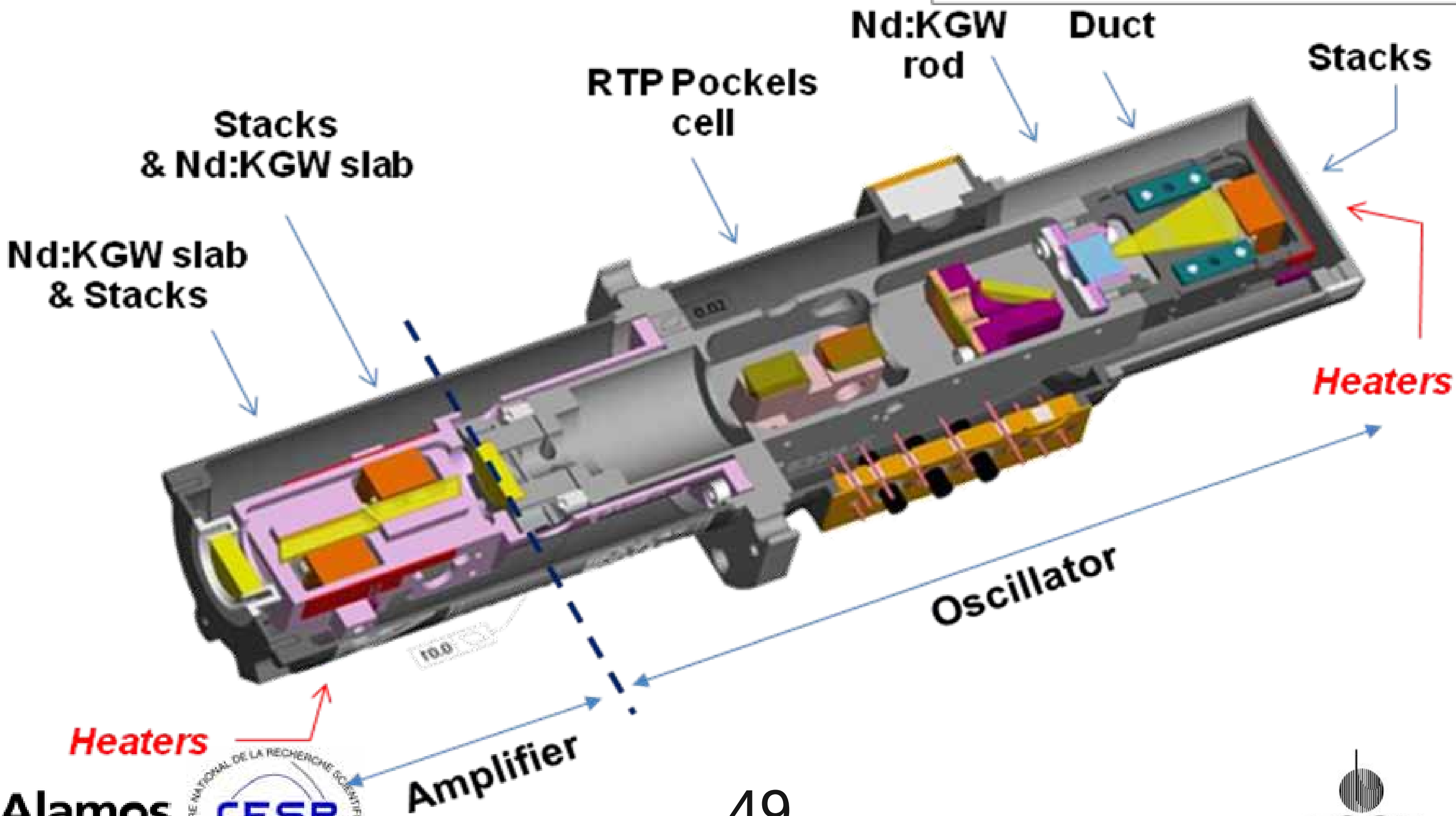
ChemCam Mast Unit : Optical Box



Laser

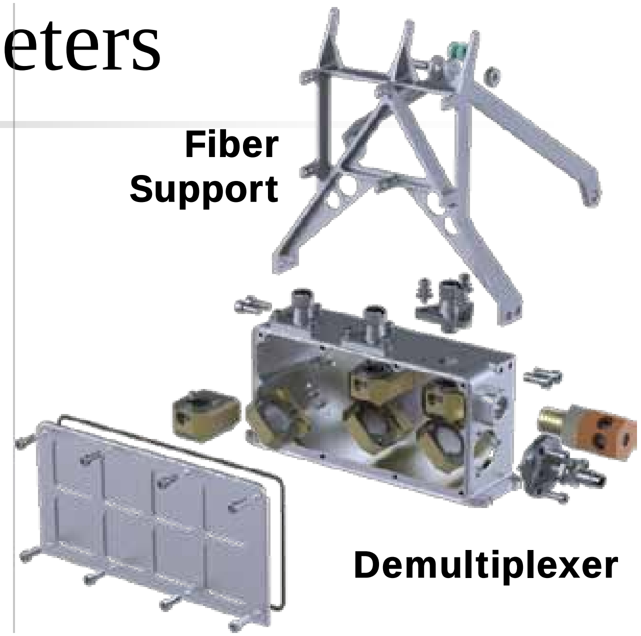
- **Passively cooled**
- **Up to 35 mJ output**
- **~500 g**

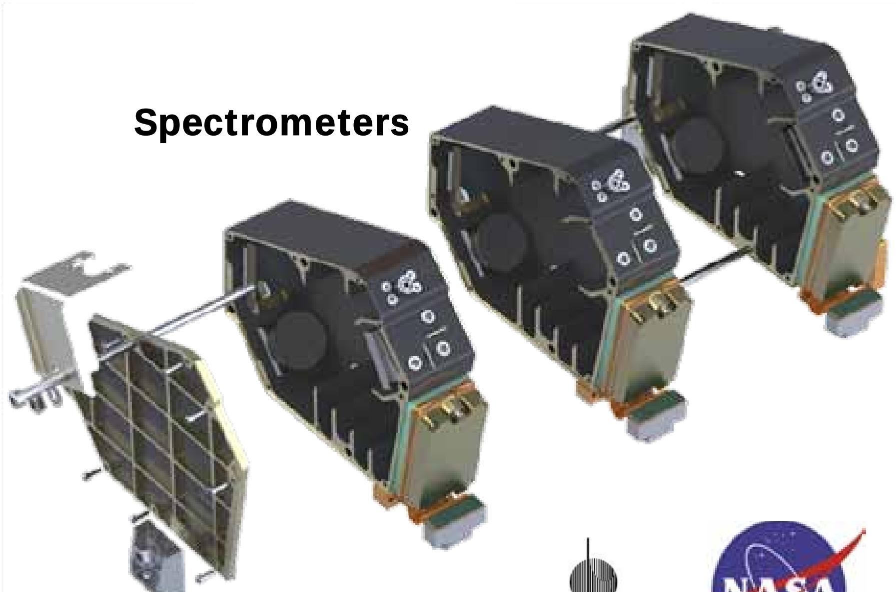




Demultiplexer and Spectrometers

- Optical demultiplexer receives light from Mast Unit, optimizes light going to each spectrometer
  - Output feeds fiber bundles linearly aligned to spectrometer slits
- Spectrometers are identical structurally, but with different gratings and surface coatings
- Spectral ranges
  - 240-335 nm @ < 0.2 nm FWHM
  - 385-465 nm @ < 0.2 nm FWHM
  - 500-850 nm @ < 0.45 nm FWHM





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3. Projection and clustering methods

Igneous rocks at 5 m thermo-vacuum tests

Non-linear Bi-dimensional projection minimizing:

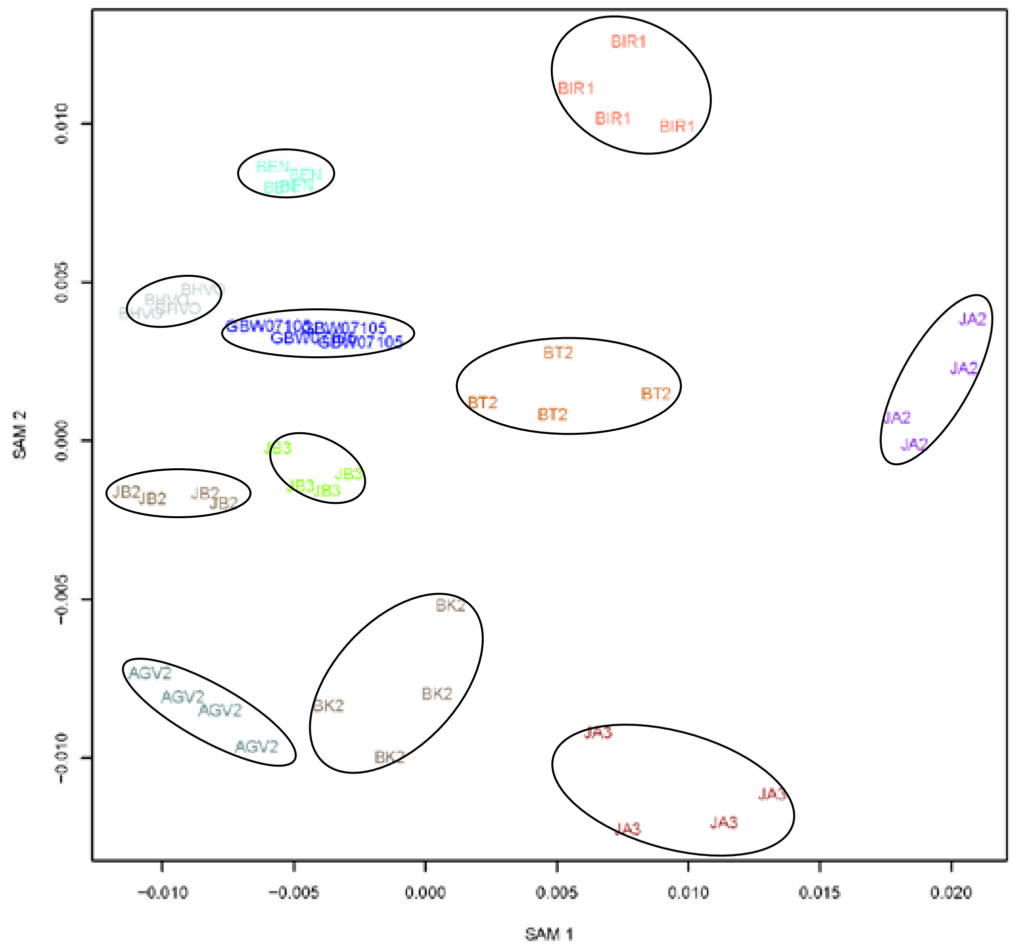
$$E = \frac{1}{\sum_{i<j} d^*_{ij}} \sum \sum_{i<j} \frac{(d^*_{ij} - d_{ij})^2}{d^*_{ij}}.$$

d_{ij}=initial space distance between i and j
d^*_{ij}=map distance between i and j

•In this case 2 times better than PCA for visual representation of the dataset.

ICA planned to be used by ChemCam

Sammon's map



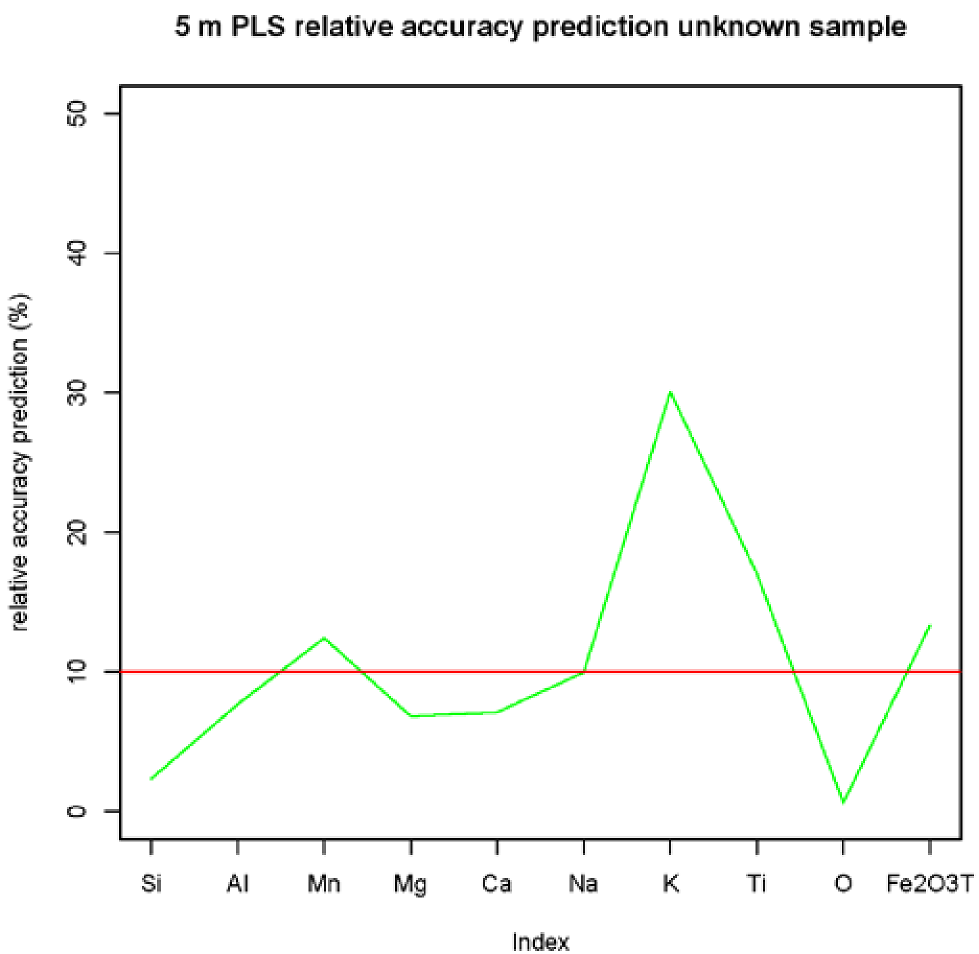
Quantification of elemental composition

Results PLSR at 5 m thermo-vacuum tests for 11 igneous standards

Using PLSR, the median of the relative accuracy predictions for unknown samples is shown (one sample left out statistics).

The accuracy of the predictions are typically of the order of 10% or lower.

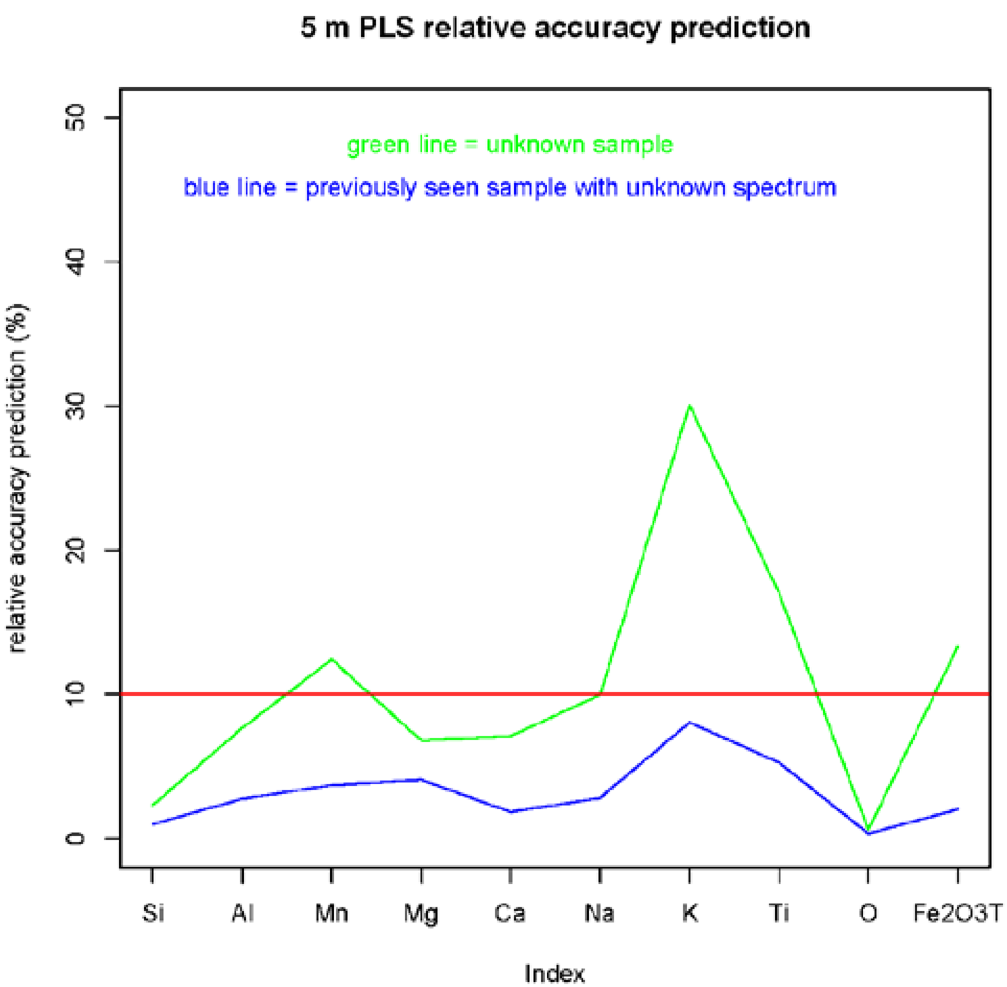
The quantities of Mn, K, Ti to be predicted are the lowest ($<10^{-3}$) which can explain the relative accuracy increase.



Quantification of elemental composition

Results PLSR at 5 m thermo-vacuum tests

- Here, the PLS model includes some spectra of the sample we are trying to predict.
- The accuracy of the predictions are 10% or lower for all elements.
- The predicted spectrum is never used to generate the model.
- Calibration based on most similar analogues will give best results.



Mars Science Laboratory Goals

- Assess Mars' biological potential by
  - Searching for organic carbon compounds,
  - Looking for the chemical building blocks of life,
  - Identify biologically relevant clues.
- Characterize the geology of the landing region
- Investigate Mars' past habitability (including the role of water)
- Characterize the human hazards on Mars