Mars 2020 Project

Informational Webinar

Sylvestre Maurice

1. Project investigation and goals

25-February-2020

Agenda

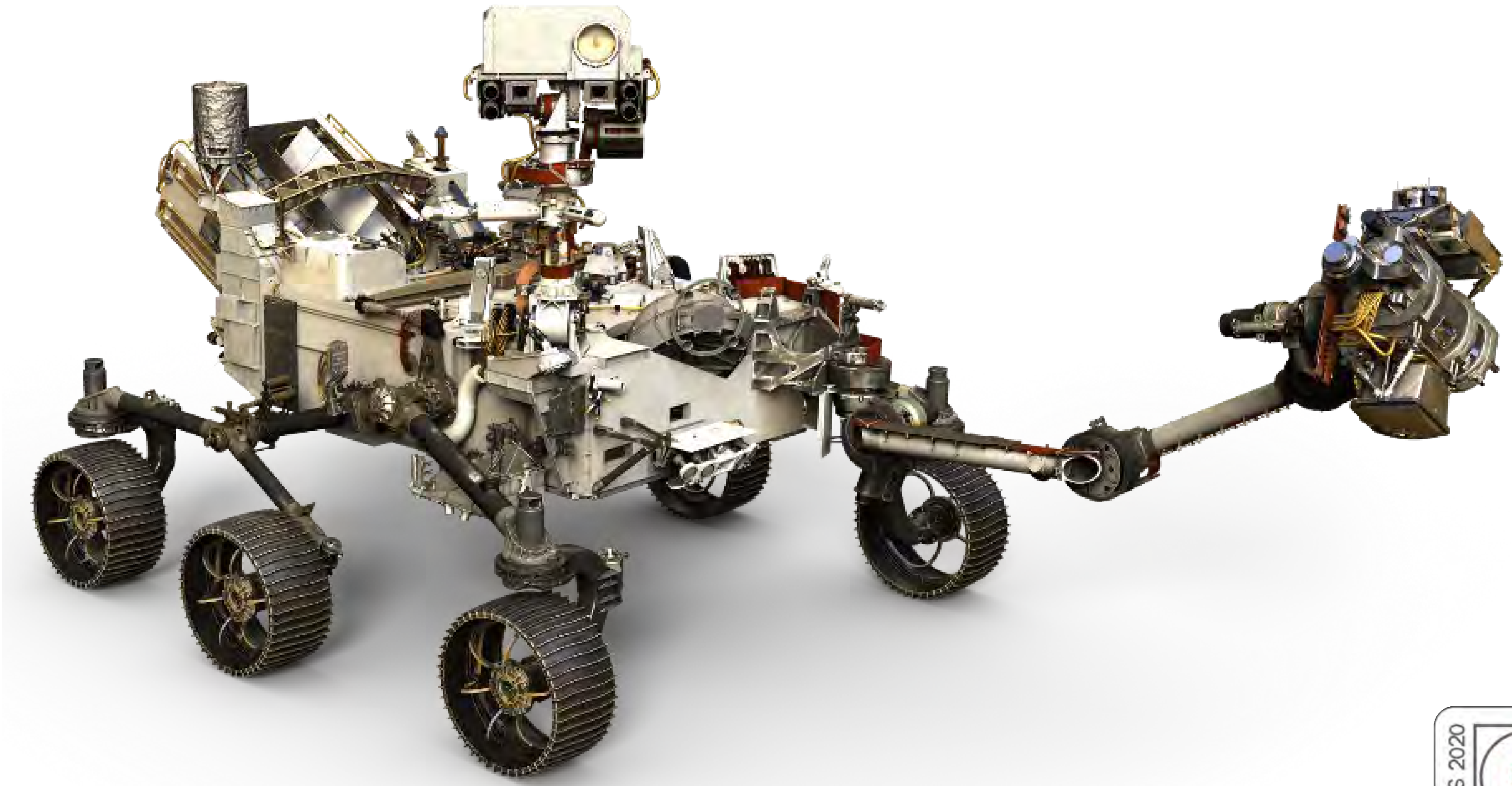
Time	Duration	Topic	Presenter
9:00	0:30	Project investigations, goals	Sylvestre Maurice
9:30	0:25	Instrument description	Roger Wiens
9:55	0:25	Data, results, calibration	Ann Ollila
10:20	0:15	Operations	Olivier Gasnault
10:35	0:15	Q&A	
10:50	0:10	Margin	

Other notes:

- People are welcome to log into webex as “anonymous” if they wish
- We plan to record the session. If anyone has a problem with that, let us know.

Record

Seeking Signs of Past Life on Mars



Mission objectives

LAUNCH

- Atlas V 541 vehicle
- Launch Readiness Date: July 2020
- Launch window: July/August 2020

CRUISE/APPROACH

- ~7 month cruise
- Arrive Feb 2021

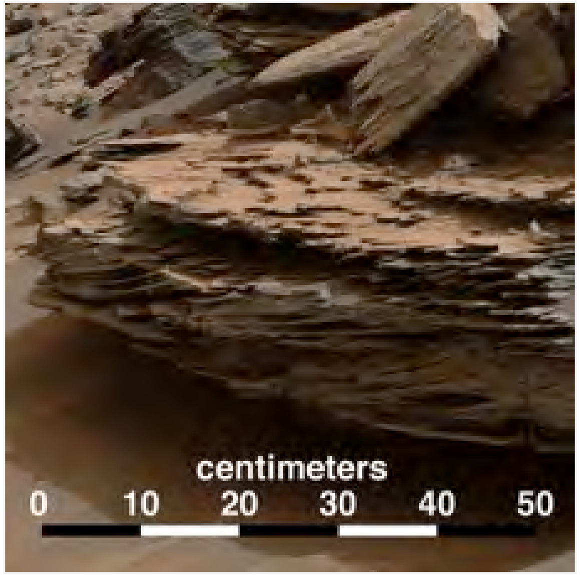
ENTRY, DESCENT & LANDING

- MSL EDL system (+ Range Trigger and Terrain Relative Navigation): guided entry and powered descent/Sky Crane
- 16 x 14 km landing ellipse (range trigger baselined)
- Access to landing sites ±30° latitude, ≤ -0.5 km elevation
- Curiosity-class Rover

SURFACE MISSION

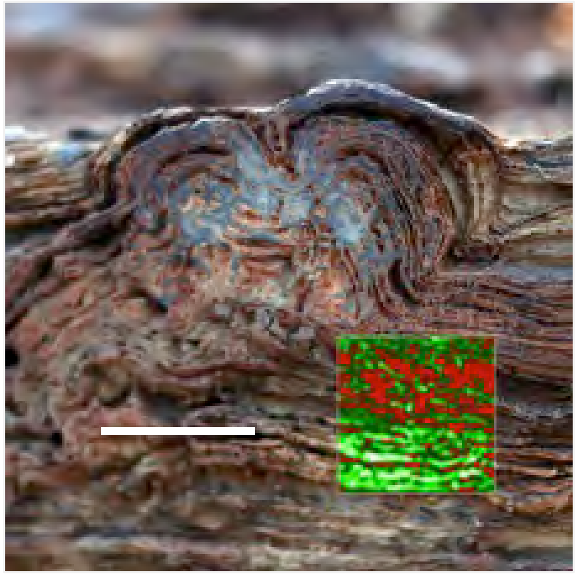
- 20 km traverse distance capability
- Enhanced surface productivity
- Qualified to 1 Martian year lifetime
- Seeking signs of past life
- Returnable cache of samples
- Prepare for human exploration of Mars

Mission Overview



GEOLOGIC EXPLORATION

- Explore an ancient environment on Mars
- Understand processes of formation and alteration



HABITABILITY AND BIOSIGNATURES

- Assess habitability of ancient environment
- Seek evidence of past life
- Select sampling locations with high biosignature preservation potential

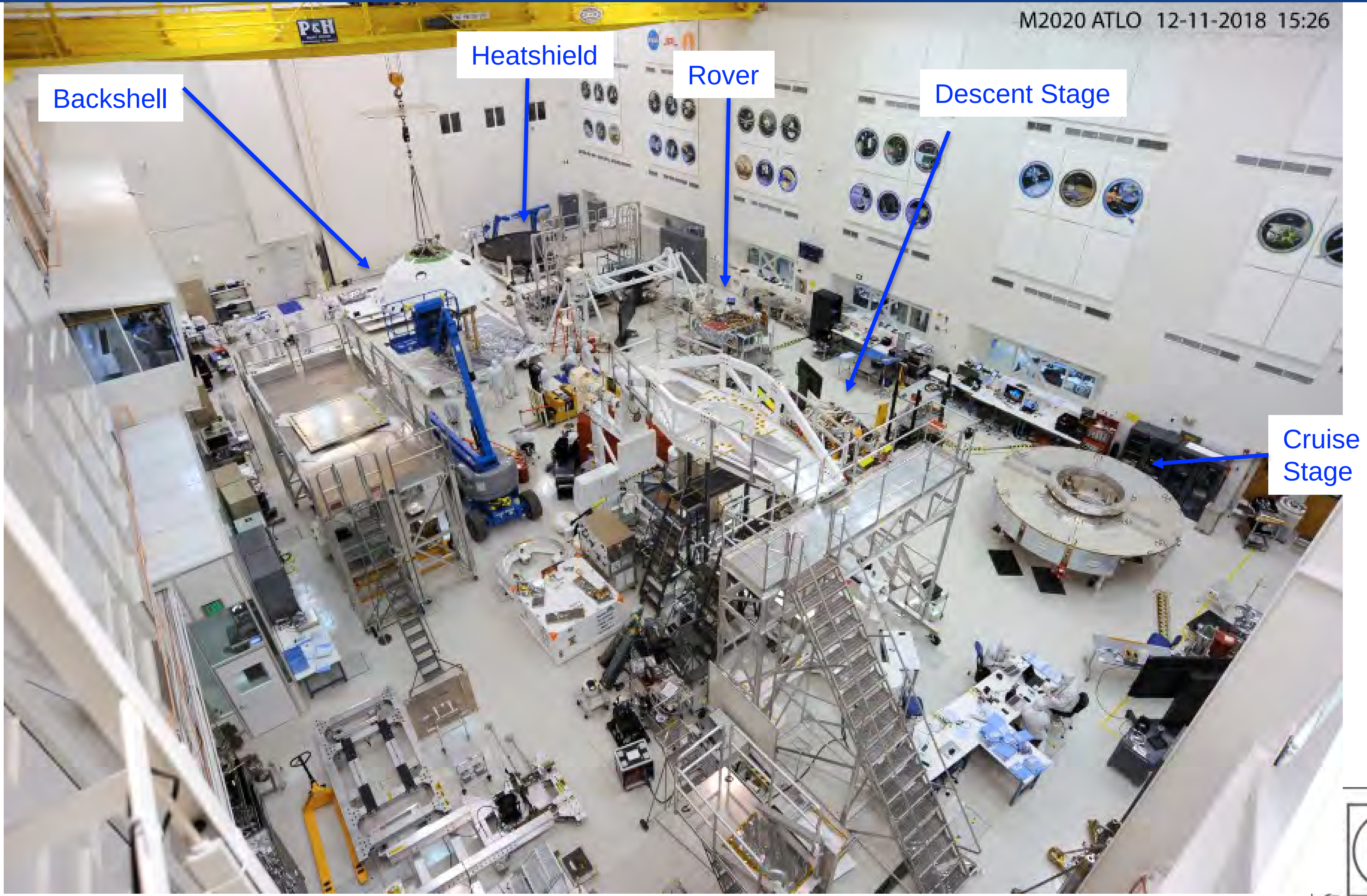
PREPARE A RETURNABLE CACHE

- Capability to collect ~40 samples and blanks, 20 in prime mission
- Include geologic diversity
- Deposit samples on the surface for possible return

PREPARE FOR HUMAN EXPLORATION

- Measure temperature, humidity, wind, and dust environment
- Demonstrate In Situ Resource Utilization by converting atmospheric CO_2 to O_2

Multi-spacecraft Assembly

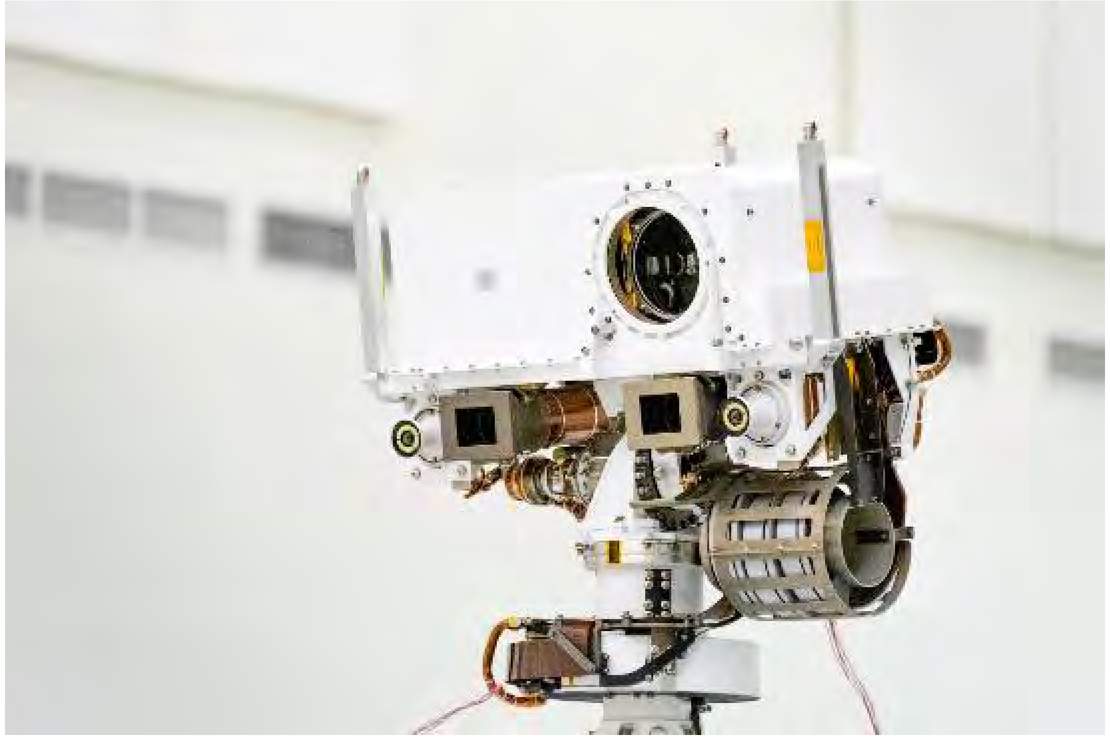


JPL-Caltech

Rover

JPL-Caltech

Top of the Mast, SuperCam/MU



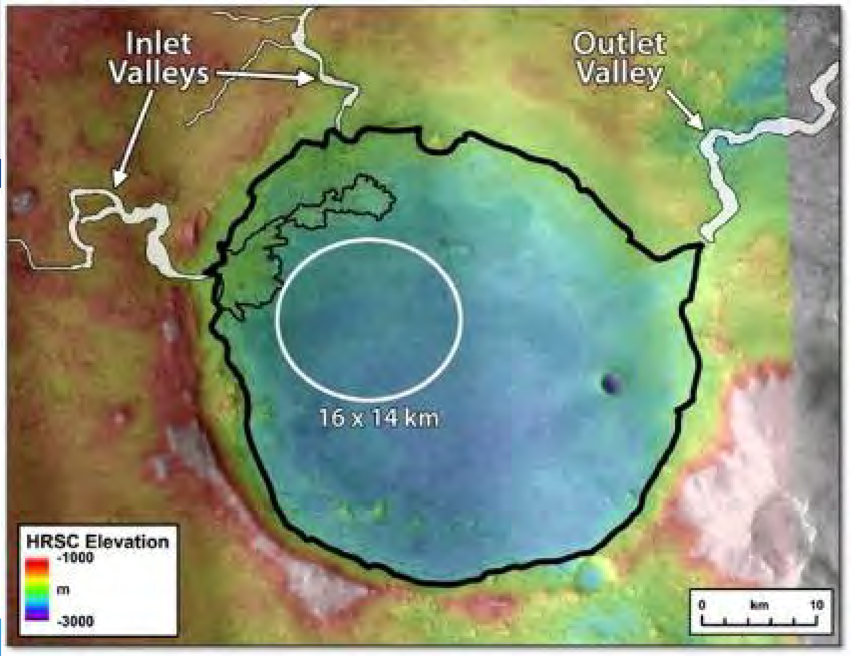
JPL-Caltech

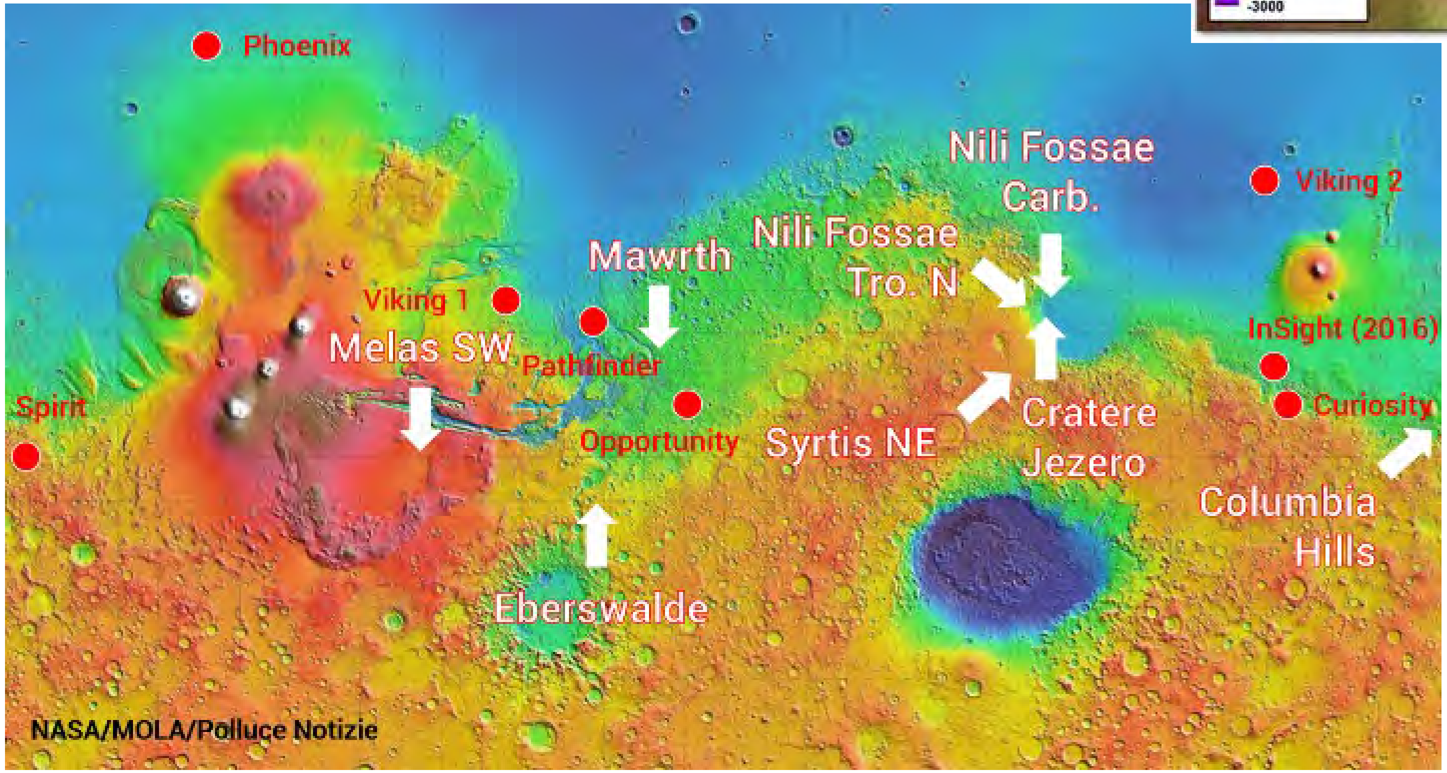
JPL-Caltech

- SuperCam/BU is in the rover body
- SuperCam/SCCT are on the rover deck

Jezero Crater

Water filled and drained away from the crater on at least two occasions. More than 3.5 billion years ago, river channels spilled over the crater wall and created a lake. Scientists see evidence that water carried clay minerals from the surrounding area into the crater after the lake dried up. Conceivably, microbial life could have lived in Jezero during one or more of these wet times. If so, signs of their remains might be found in lakebed sediments.

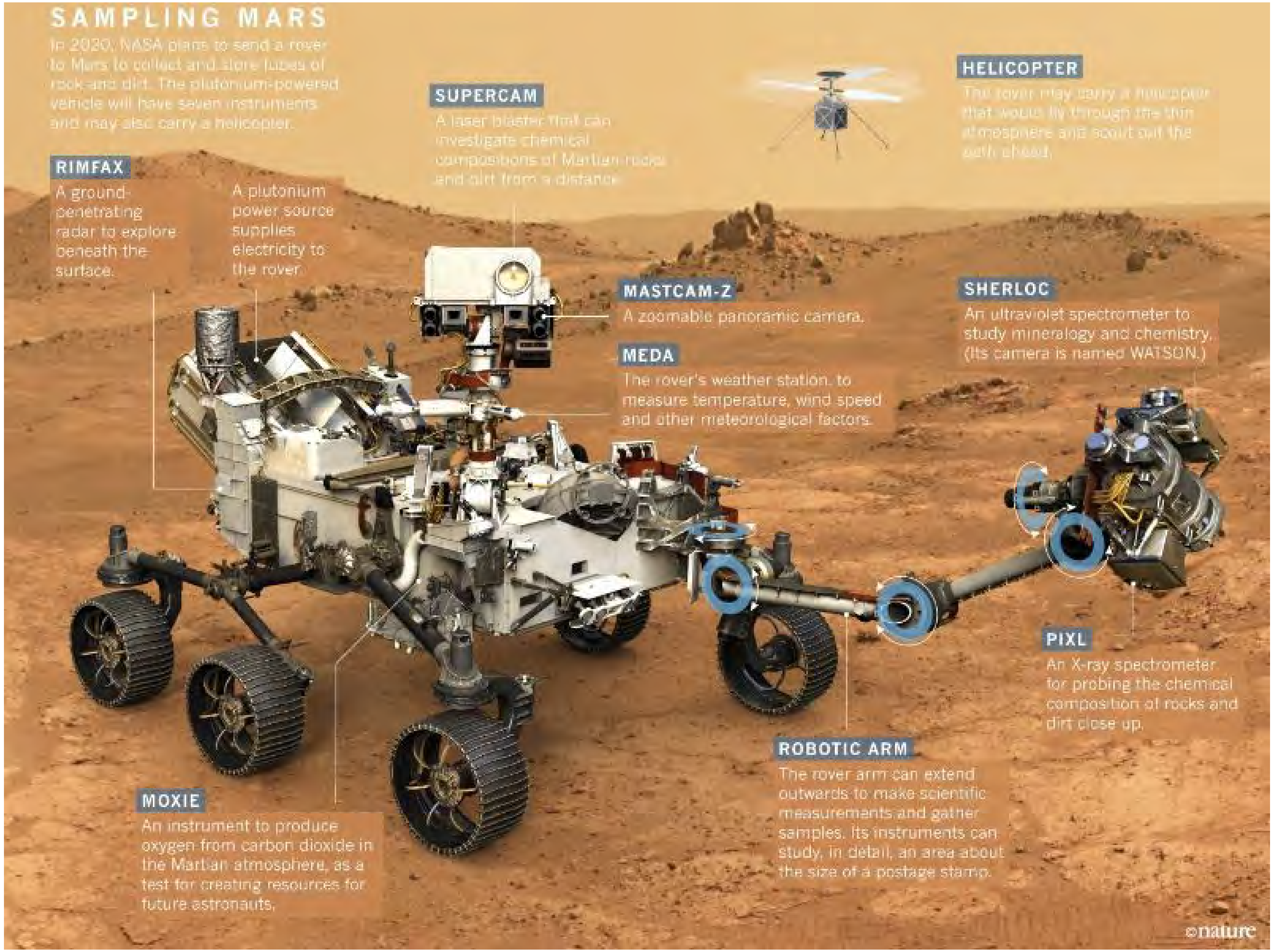




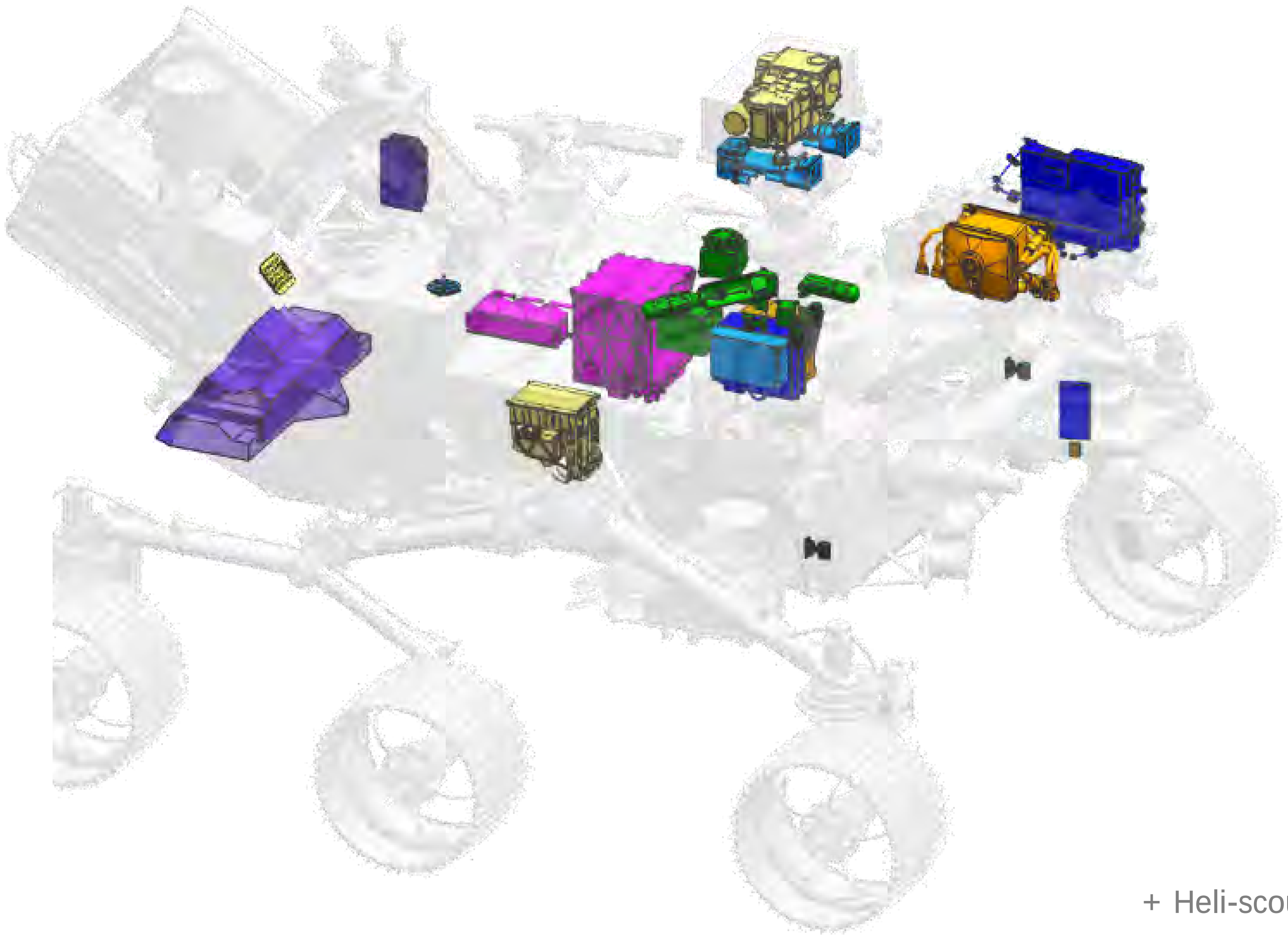
MARS 2020 SUPERCAM

Mars 2020 Rover

Mars 2020 Project
SUPERCAM

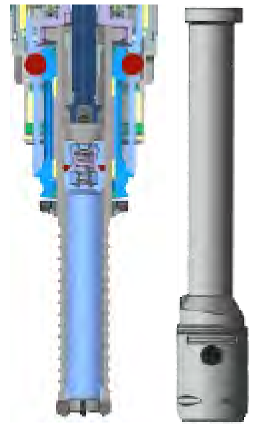


Mars 2020 payload



+ Heli-scout

Adaptive cache



Mastcam-Z
Stereo Imager
And zoom

MEDA
Mars Environmental
Measurement

MOXIE
In-Situ Oxygen
Production

PIXL
Microfocus X-ray
fluorescence
spectrometer

RIMFAX
Ground Penetrating
Radar

SHERLOC
Fluorescence,
Raman,
context imaging

SuperCam
LIBS, Raman,
IR and Imager

SuperCam Objectives

SuperCam provides rapid, synergistic, **fine-scale** mineralogy, chemistry, and color imaging after removing obscuring surface dust.

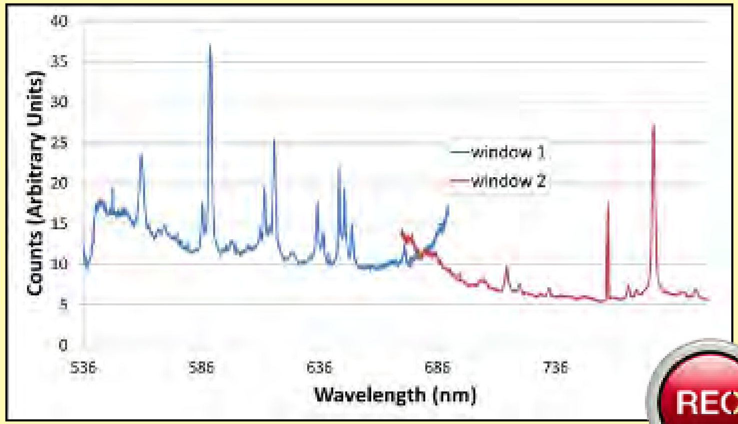
Mission Goals	SuperCam Goals: 1. Rock identification	2. Sediment stratigraphy	3. Organics & biosignatures	4. Volatiles (H, halogens)	5. Morphology and texture	6. Coatings & Varnishes	7. Regolith charact.	8. Atmosphere charact.
A. Geologic diversity								
B1. Habitability								
B2. Bio-signatures								
B3. Past life								
C. Cache samples								
D2. Dust								
D3. Weather								

SuperCam Goals to Science Objectives

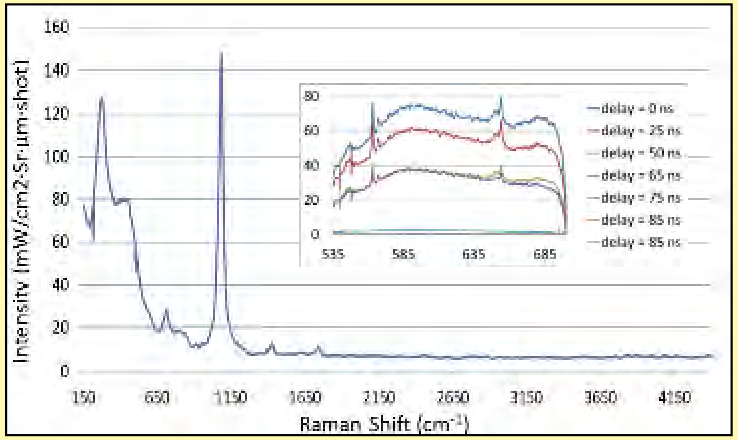
Mission Goals	1. Rock Identification	2. Sediment Stratigraphy	3. Organics & Biosignatures	4. Volatiles (H, Halogens)	5. Morphology and Texture	6. Coatings and Varnishes	7. Regolith Charact.	8. Atmospheric Charact.
A. Geologic Diversity								
B1. Habitability								
B2. Bio-Signatures								
B3. Past Life								
C. Cache Samples								
D2. Dust								
D3. Weather								
Chemistry	a. Major Element Quantification b. Minor/trace Element detection/quantification (d. Halogens Cl, F)	a. Major Element Quantification b. Minor/trace Element detection/quantification (d. Halogens Cl, F) f. depth	c. Org elts C, H, N, O, P, S d. Halogens Cl, F	c. Org elts C, H, N, O, P, S d. Halogens Cl, F		(a. Major Element Quantification) b. Minor/trace Element detection/quantification d. Halogens Cl, F	g. ID Primary Minerals (h. ID Secondary Minerals) (d. Halogens Cl, F) e. Hazardous Cd, Cs, Pb	
Mineralogy	g. ID Primary Minerals h. ID Secondary Minerals (i. ID (O)H-rich minerals)	(g. ID Primary Minerals) h. ID Secondary Minerals i. ID (O)H-rich minerals	i. ID (O)H-rich minerals j. Detect Org Minerals	(i. ID (O)H-rich minerals)		(g. ID Primary Minerals) h. ID Secondary Minerals	(g. ID Primary Minerals) h. ID Secondary Minerals i. ID (O)H-rich minerals	k. Quant atmos const
Imaging	l. Small scale texture	l. Small scale texture (m. Far Dist Imaging)	(l. Small scale texture)		l. Small scale texture m. Far Dist Imaging	l. Small scale texture		

5 techniques

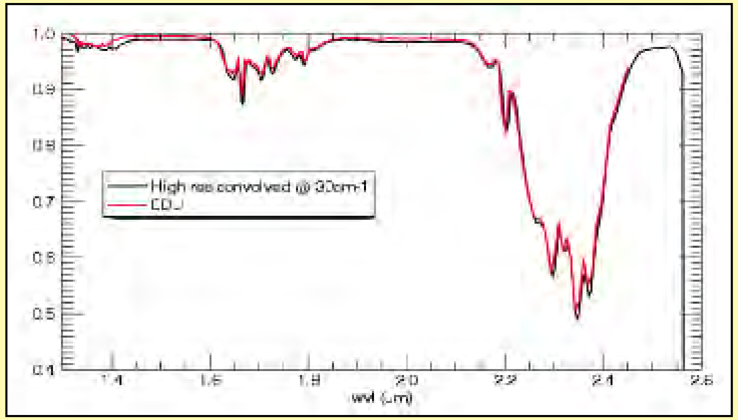
Laser-Induced Breakdown Spectroscopy



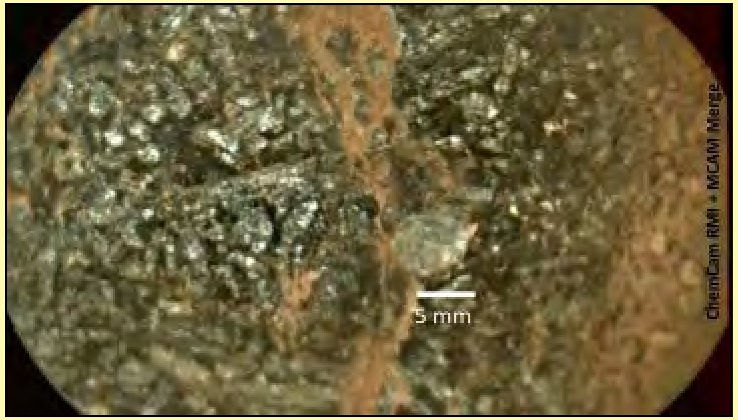
Time-Resolved Raman/ Fluorescence Spec.

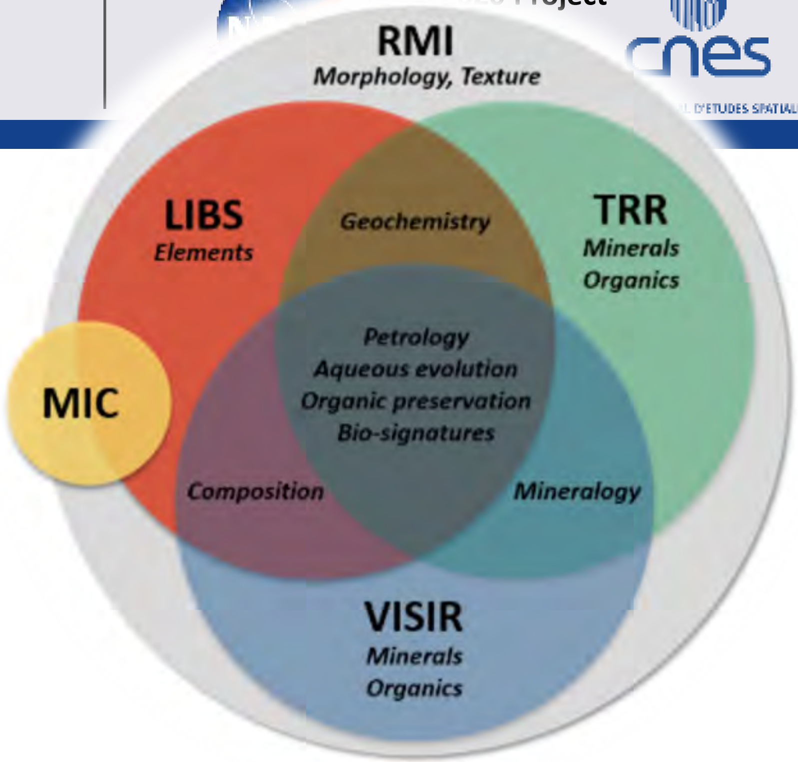


Visible – Infrared Spectroscopy



Color Remote Micro-Imaging

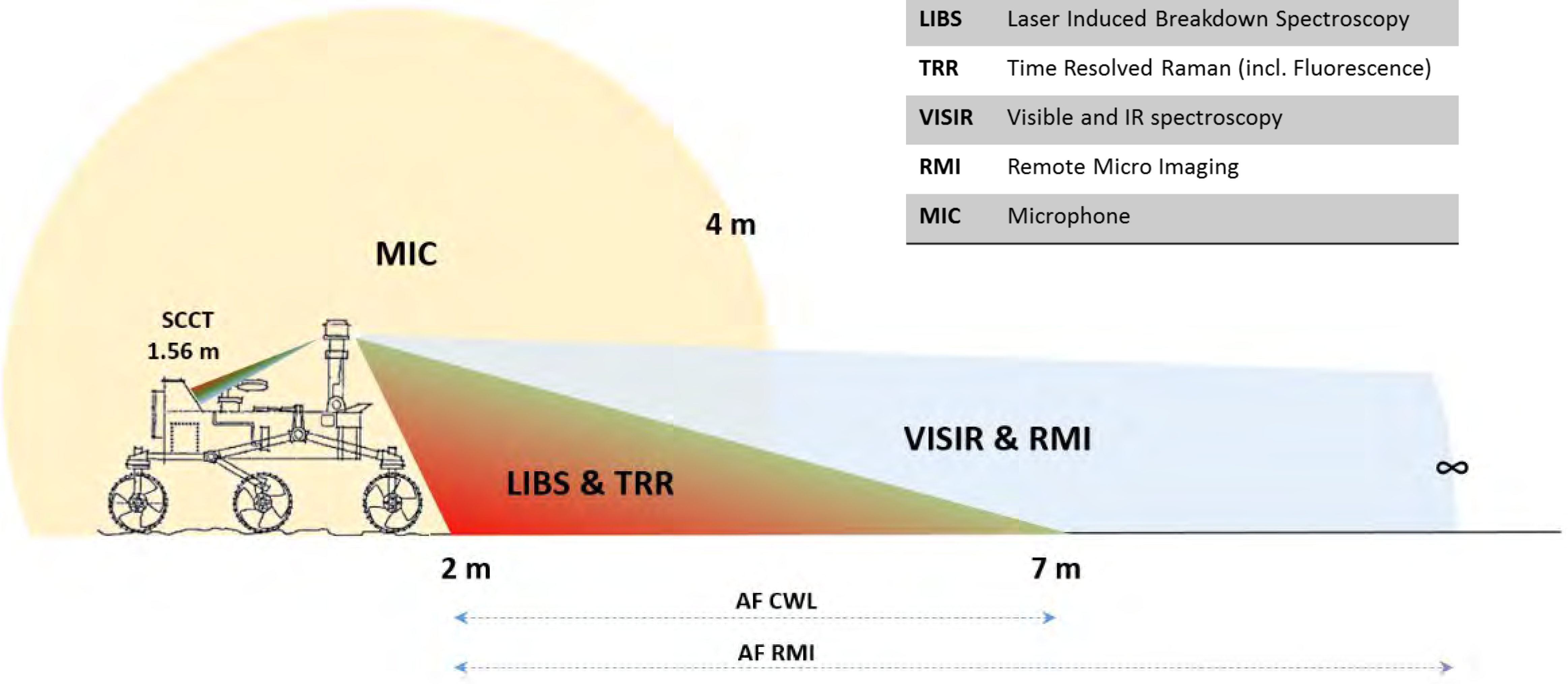




LIBS	Laser Induced Breakdown Spectroscopy
TRR	Time Resolved Raman (incl. Fluorescence)
VISIR	Visible and IR spectroscopy
RMI	Remote Micro Imaging
MIC	Microphone

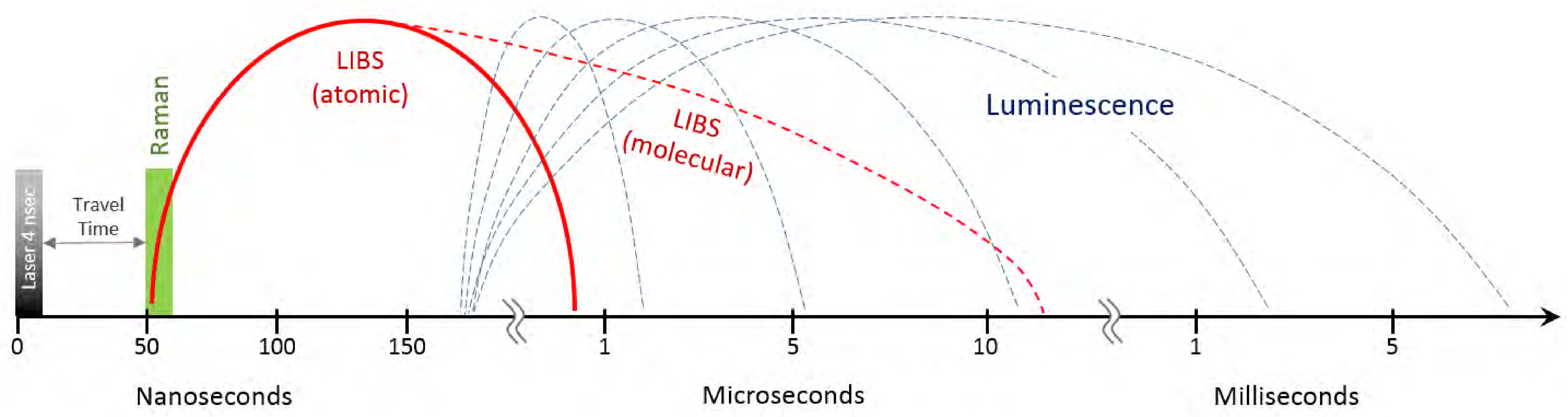
Remote sensing requirements

LIBS	Laser Induced Breakdown Spectroscopy
TRR	Time Resolved Raman (incl. Fluorescence)
VISIR	Visible and IR spectroscopy
RMI	Remote Micro Imaging
MIC	Microphone

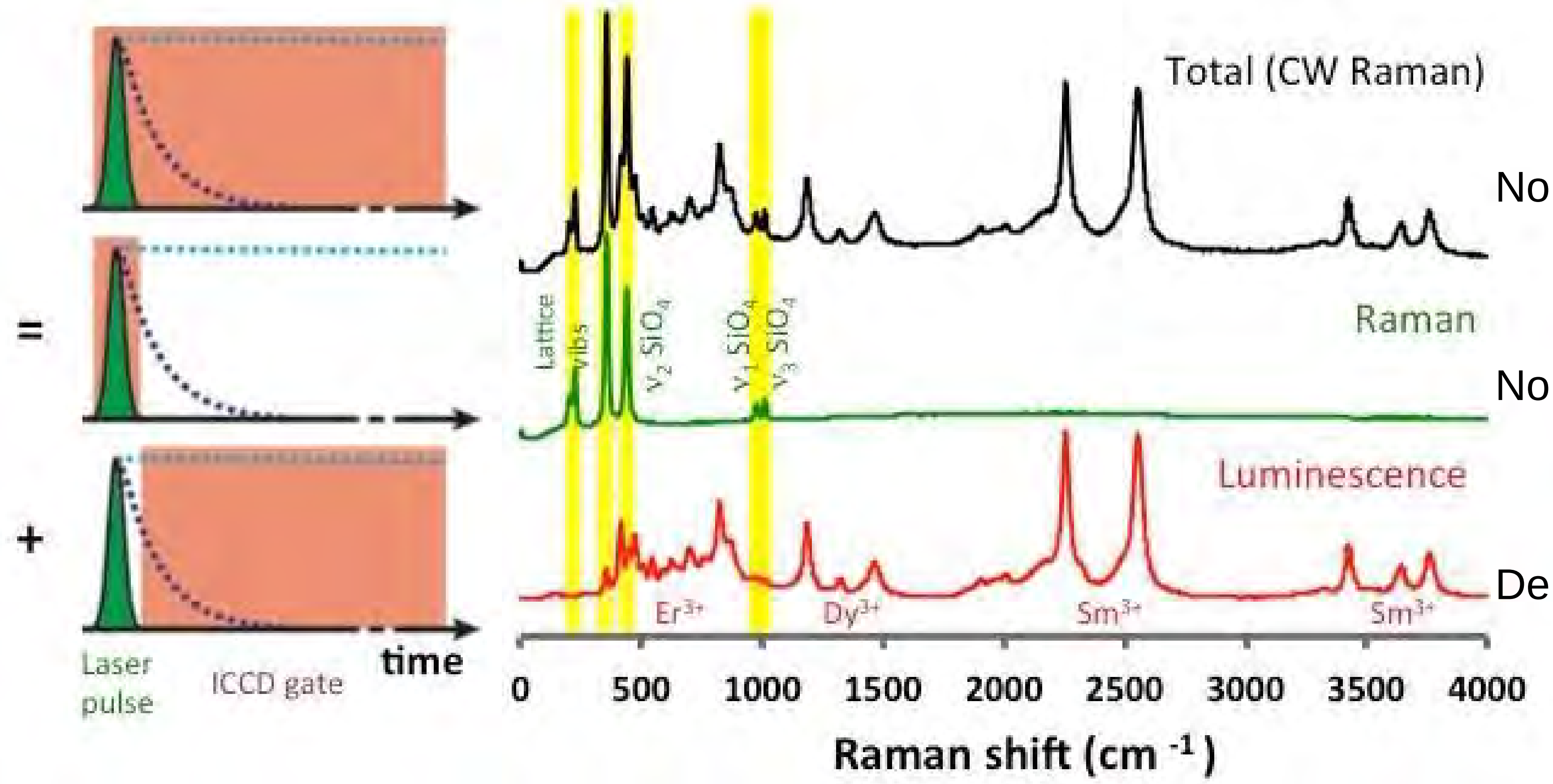


Timing of LIBS and TRR

Both techniques are laser-induced
But they are very different to implement.



Principle of Luminescence detection



No delay; long exposure

No delay; short exposure

Delay; long exposure

Time-resolved Raman and luminescence spectroscopy of a zircon grain. Left: schematic illustration of the synchronization between the laser pulse and the ICCD gate to catch Raman only (green), luminescence only (dashed pale and dark blue: long and short lifetime respectively) or both. Right: Total (continuous-wave excitation), Raman (peaks highlighted in yellow) and luminescence (here, due to REE^{3+}) spectra.

From O. Beyssac et al., Elements, To appear, 2020

Elemental composition requirements

LIBS	Elemental composition		
Elements	**DL 3 m**	**DL 5 m**	**Precision & accuracy**
O, Na, Mg, Al, Si, K, Ca, Fe, Ti		1000 ppm	±10%
S, C, P, F, Cl, N	5%		±20%
Cr, Ni, Cu, Zn, Rb, As, Cd, Pb, H, Mn	2000 ppm		±20%
Li, Sr, Ba		100 ppm	±20%

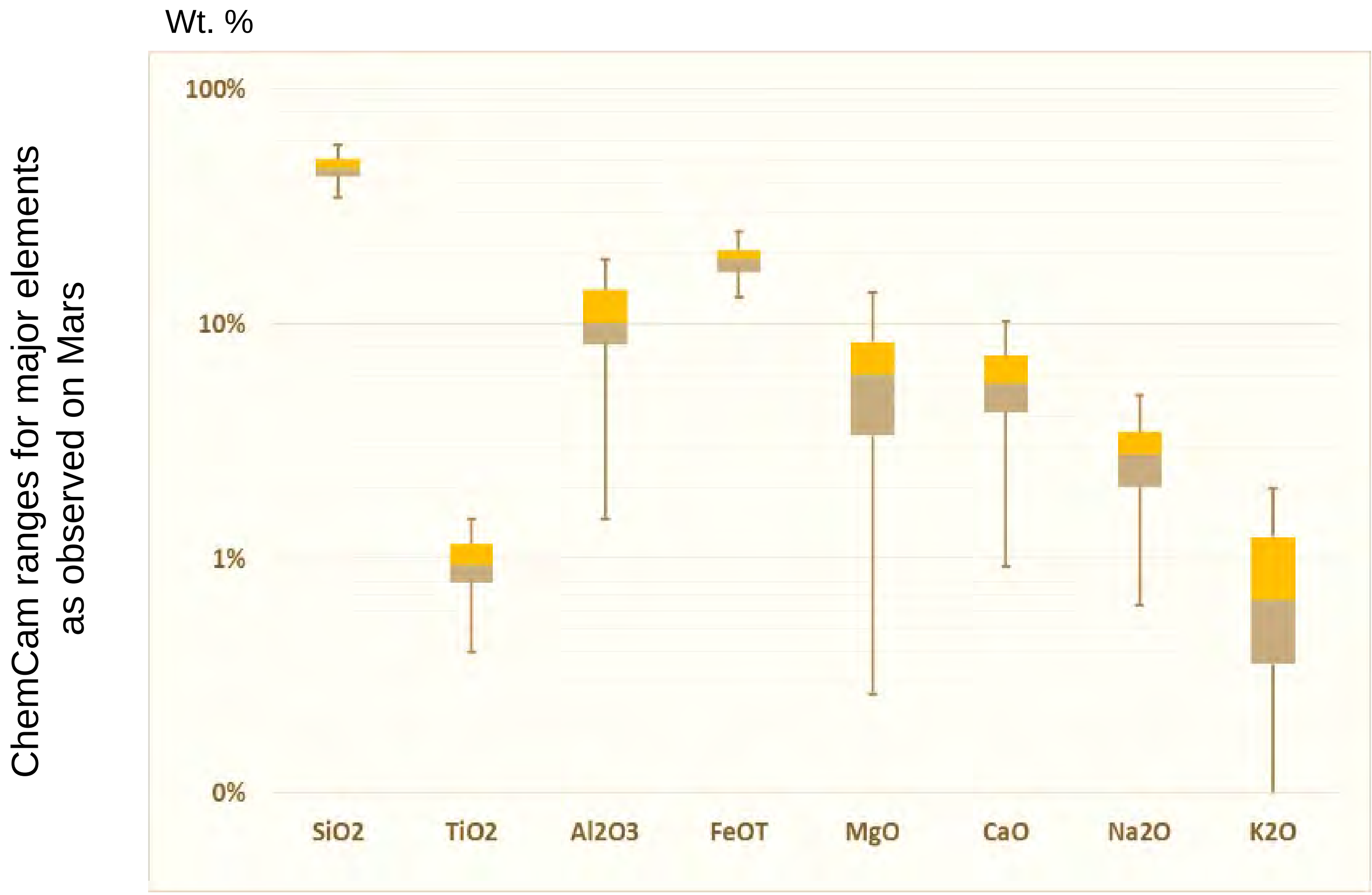
DL = detection limit

	Atmospheric constituents		
Molecules	**DL/Precision (±)**	**Unit**	**Wavelength range**
O_2	200 ppm/±100 ppm	vol. mixing ratio	759-766
H_2O	3/±0.5 precipitable microns	column mass	715-735, 810-835, 1800-1950
CO_2	0.5% changes	vol. mixing ratio	780-795, 1900-2200
CO	400 ppm/±200 ppm	vol. mixing ratio	2300-2500

Covered by the “elemental” requirements

LIBS objectives

Req. Let's do as well as ChemCam… (so far 740,000 spectra) !



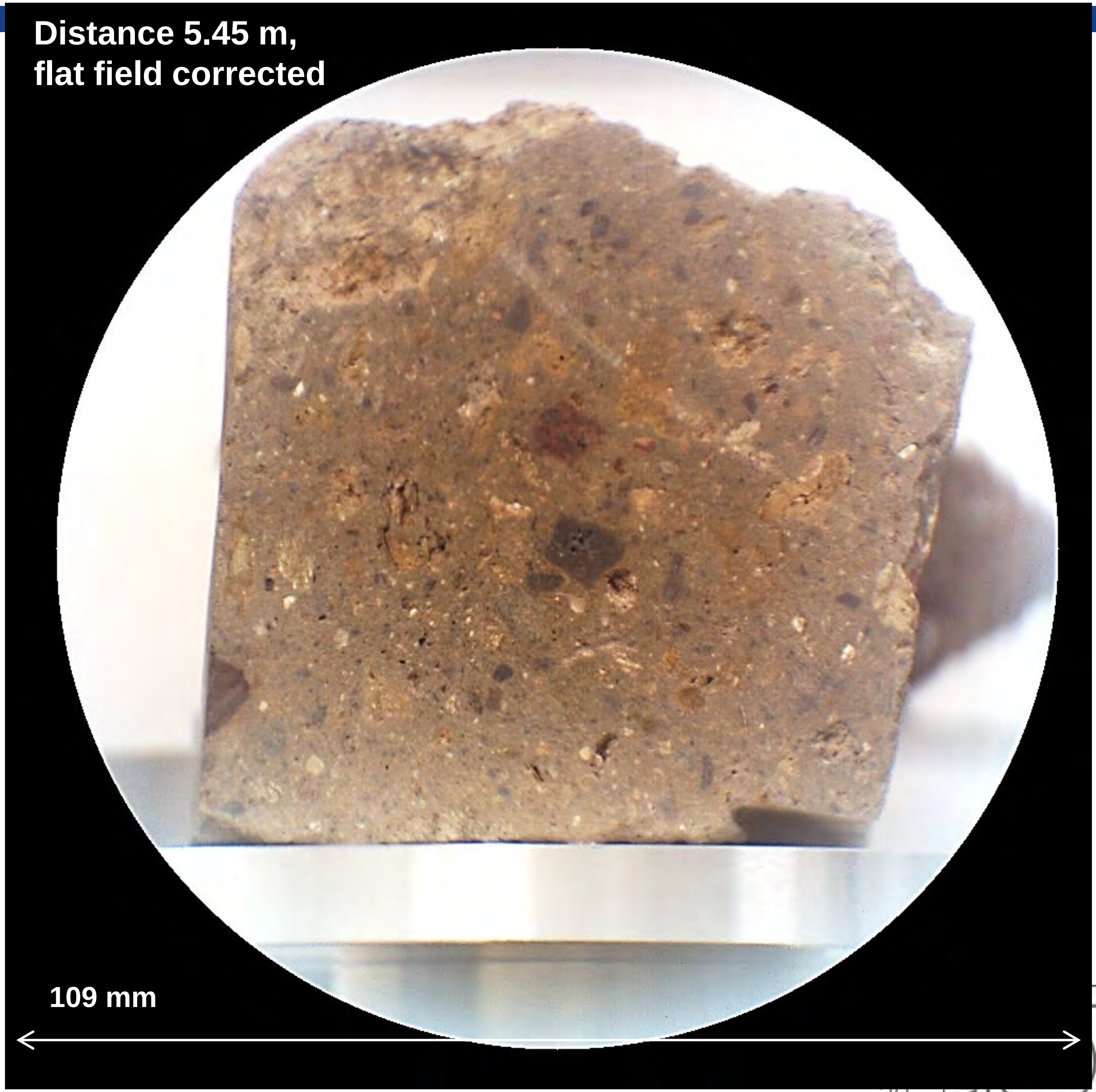
Precisions (from ChemCam)

SiO2	0.45 – 1.91 wt. %
TiO2	0.02 – 0.11 wt. %
Al2O3	0.24 – 1.74 wt. %
FeOT	0.61 – 1.65 wt. %
MgO	0. 26 – 0.66 wt. %
CaO	0.45 – 2.12 wt. %
Na_2O	0.10 – 0.2 wt. %
K_2O	0.006 – 0.28 wt. %

LOD

Li	**~20 ppm.**
Rb	**~10 ppm**
Sr	**~50 ppm**
Ba	**~100 ppm**
Cr	**~50 ppm**
MnO	**~0.06 wt. %**
Ni	**> 1000 pm**
ZnO	**~0.7 wt. %.**
F (CaF)	**~0.2 wt. %**
Cl	**TBD (CaCl)**
SO_3	**5% – 10%**
P_2O_5	**TBD**
C, H	**Complex story**

RMI Objectives



RMI context image.
Similar to ChemCam w/ RGB colors

Res. 80 µrad (MTF > 0.2 at 16 l/mm)
Radiometric cal. +/-20%
FOV ~ 19 mrad

Mineralogy: Raman and VISIR

Mars 2020 Project
SUPERCAM

		Mineral and organics detection	
Minerals family	**Examples**	**Bands & Regions cm^{-1}**	**Bands & Regions cm^{-1}**
	--------------------	**INORGANICS**	--------------------
Carbonates	Calcite	150-300, 1087	C-O (2.3 µm, 2.5 µm)
	Aragonite	150-300, 1085	
	Magnesite	200-400, 1095	
Chain -silicates Silicates	Pyroxenes	~700, ~1000	1.0 µm 2.0 µm
silicates Silicates	Olivine	823-855 doublet, ~1000	1.0 µm
Sheet silicates	Serpentines, Smectite, Talc, Kaolinite, Zeolites	200, 1000, 3500-3700	OH (1.4 µm), Al-OH (2.2 µm), Mg-OH (2.3 µm)
Framework silicates	Alcali-fedspars	~500	
	Plagioclase	~500	
	Quartz	464	
Sulphates	Gypsum	1009, 3500-3700	OH (1.4 µm), H_2O (1.9 µm) (b)
	Anhydrite	400-700, 1015	SO_3 (2.4 µm)
Sulphides	Pyrite	300-400	
Phosphates	Apatite	960	
	Merrilite	959, 974 doublet	
Ices	Water	2800-3800	H_2O (1.56, 1.9 µm)
	Hydrates salts	2800-3800	OH (1.4 µm), H_2O (1.9 µm) (b)
	CO_2	1278-1385	CO_2 (1.6, 2.0, 2.6 µm)
Oxides	Hematite	200-500, 1300	(0.65 µm, 0.85 µm)
	Goethite	200-600	
	Magnetite	666	
	Ilmenite	676	
	Rutile	447, 612	

	--------------------	**ORGANICS**	--------------------
Aromatics	Kerogenes	1300-1600	
	PAHs		
Complex bio-molecules	Carotenoids Amino-acides	C=C and C-C 600-1800	
		CCN sym. Stretch 800-900	1.7 and 2.3-2.5 µm (CH_2-CH_3)
CN		C≡N 2220-2260 med	OH (1.4 µm), H2O (1.9 µm)
		C=N 1610-1680 str	
CH		2800-3000 strong	
NH		3300-3500 medium	

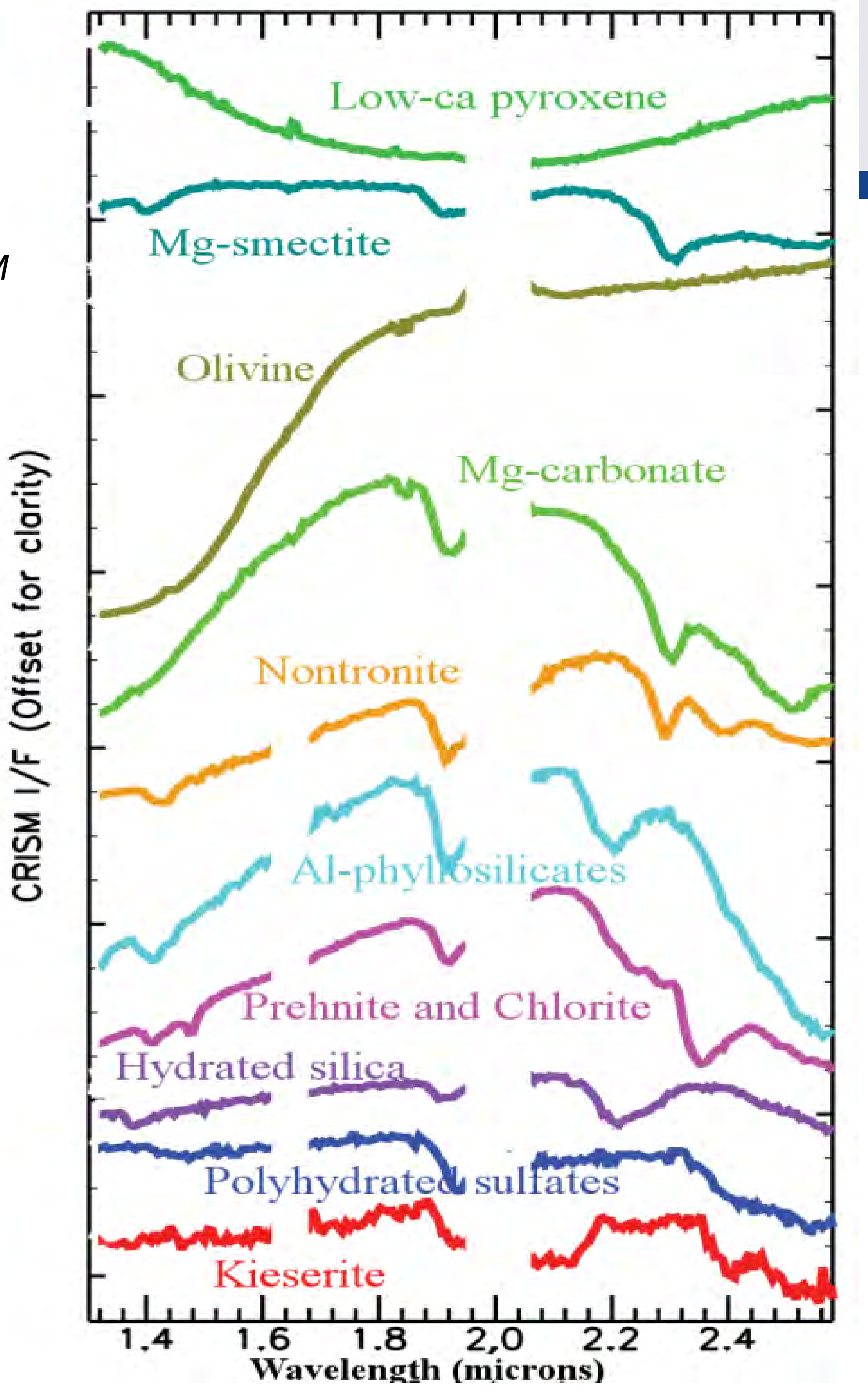
IR Objectives

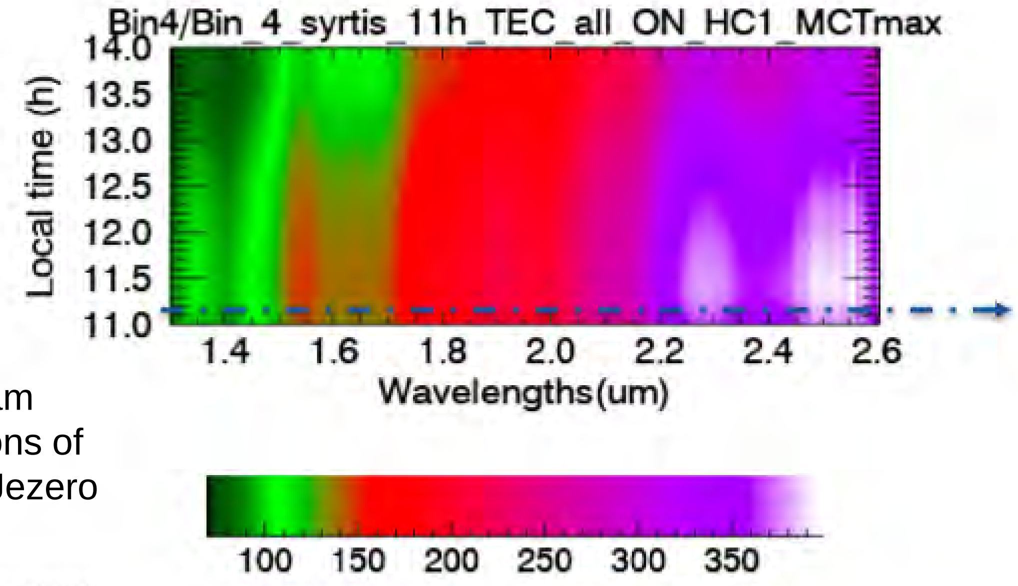
New.

First time on the surface
Benefits dust removal by LIBS

1.3 – 2.6 µm coverage
Better than 30 cm^{-1} resolution
SNR > 80 (time of day dependent)

Data from CRISM





SuperCam simulations of SNR at Jezero

12/06/19

Raman emission lines

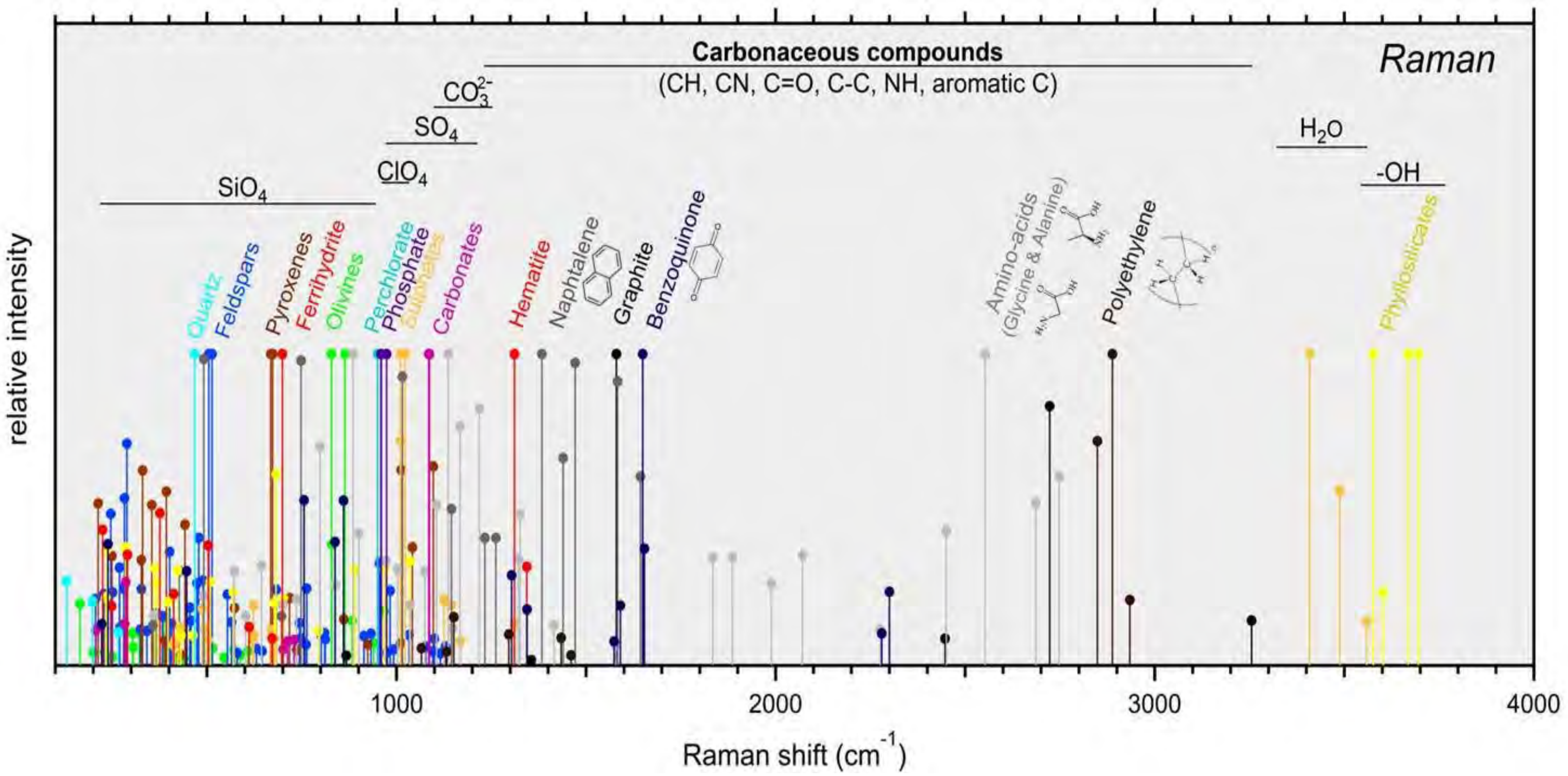
New.

Results will depend on size of mineral phases.

Resolution 12 cm^{-1}

Range
150 cm^{-1} – 3800 cm^{-1}

Luminescence is promising
(see Data presentation)

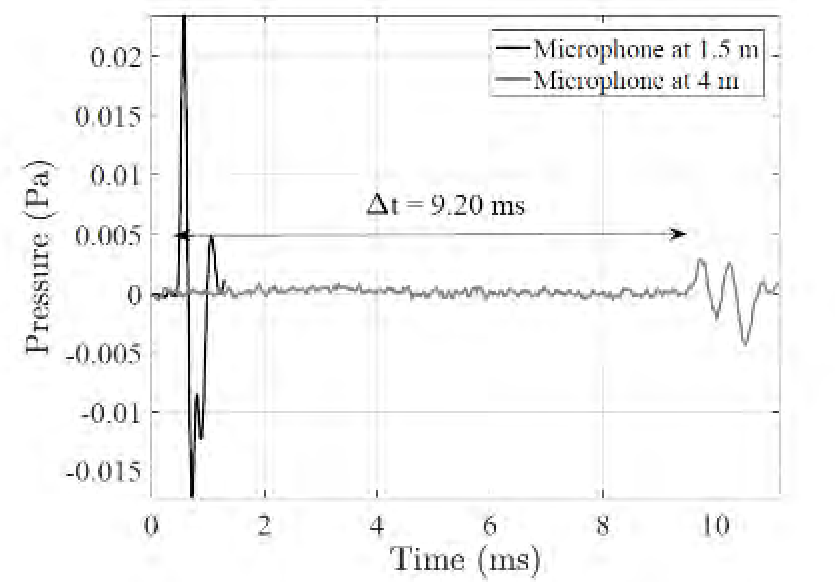


Microphone objectives

<u>Requirement:</u>
SuperCam shall be able to record audio signals from 100 Hz to 10 kHz on the surface of Mars, with a sensitivity large enough to monitor a LIBS impact at 4 m.

<u>Applications:</u>
- LIBS impacts and target properties
- Atmospheric science

Tests conducted in a controlled Martian atmosphere (Aarhus wind tunnel)

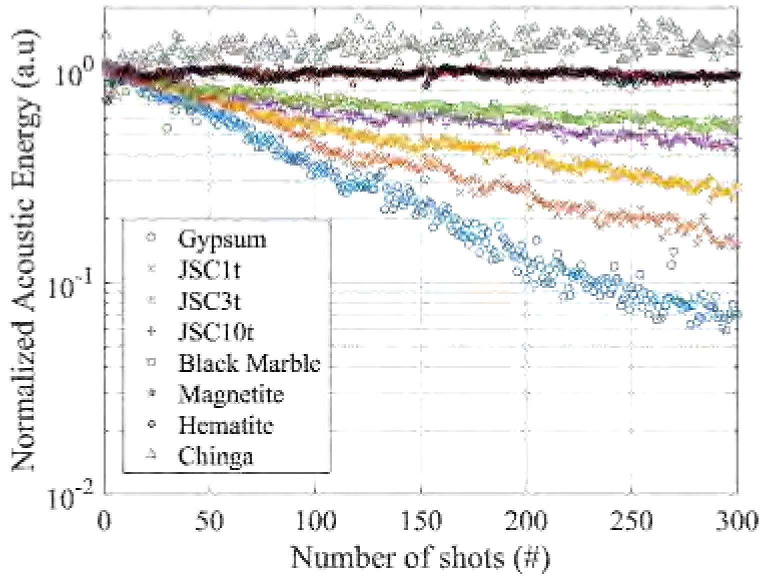


LIBS acoustic signal is recordable up to a distance of 4m from SuperCam (actually 7 m works also)

Murdoch et al., 2018
doi:10.1016/j.pss.2018.09.009

LIBS acoustic signal to infer target hardness

Increasing hardness



The decrease of the acoustic energy as a function of the number of LIBS shots is steeper as the target is softer

Chide et al., 2019
doi:10.1016/j.sab.2019.01.008

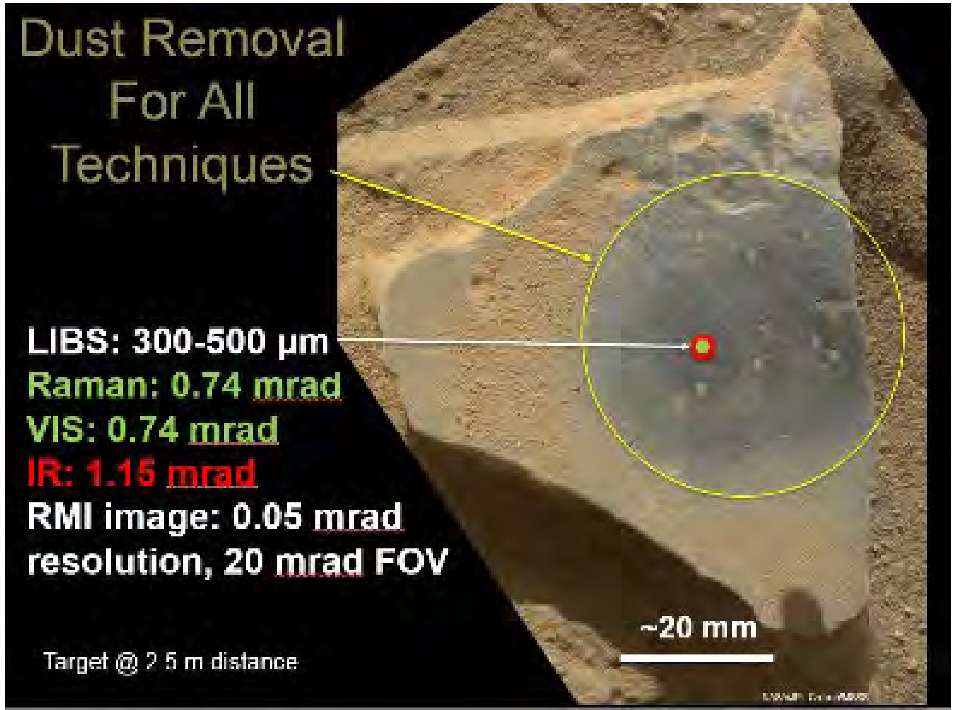
MARS 2020 SUPER CAM

Footprints

FOV	2.5 m	7 m	30 m	Notes
LIBS	200 µm	400 µm		Given by spot size
TRR	1.9 mm	5.2 mm		Given by fiber (0.74 mrad)
VIS	1.9 mm	5.2 mm	22.2 mm	Giver by fiber (0.74mrad)
IR	2.9 mm	8.0 mm	34.5 mm	Given by periscope (1.15 mrad)
RMI	4.7 cm	13.2 cm	56.4 cm	Fixed at 18.8 mrad

Capability driven
+ alignment dependent

- LIBS: sub-mm
- TRR: mm
- VIS: mm (12 m) cm
- IR: mm (9 m) cm
- RMI: cm



Summary of science requirements/perfos

LIBS (1.5 m – 7 m range)
< 600 µm spot size, up to 14 mJ on target at 1064 nm
1 – 150 shot bursts @3 Hz laser
245 – 853 nm range, 0.15 – 0.65 nm resolution

Raman – Fluorescence (1.5 m – 7 m range)
~0.7 mrad FOV, > 9 mJ on target at 532 nm
1 – 200 shot bursts @10 Hz laser
150 – 4400 cm-1 range, < 12 cm-1 resolution
Time sweep: 100 nsec windows, delays up to 10 msec

VISIR Reflectance Spec. (1 m to ∞ range)
~0.7 mrad FOV, 400 – 853 nm range, 0.15 – 0.65 nm res.
~1.2 mrad FOV, 1.3 – 2.6 µm range, < 32 cm-1 res., and 256 spectels max. sampling

Remote Micro-Imaging (1 m to ∞ range)
19 mrad FOV, iFOV 10 µrad, standard RGB color filtering
Spatial resolution < 80 µrad
Contrast > 20% at 20 line pairs/mm over half-FOV

Microphone (< 4 m range)
100 Hz – 10 kHz range, sampling at 25 kHz or 100 kHz
Standalone mode (2.7 min rec. max)
LIBS shot recording (up to 150 shots)

ORIGINAL PROPOSED TEAM

CoI Name	Funding: Nasa Contrib.		Instit.	Role and responsibilities	LIBS	Raman/Fluor.	Imaging	VISIR	Data Proc.	Science expertise
R. Anderson	US	N	USGS	LIBS PLS1 Algorithm, Imaging	X		X		X	CCAM compositions, MER imaging
O. Beyssac	FR	C	IMPMC	Raman spec., Calibrations, Data processing		X			X	Organic compounds
L. Bonal	FR	C	IPAG	Raman expertise, Calibration, Interpretation		X		X		Primitive cosmomaterials
S. Clegg	US	N	LANL	Remote Raman, LIBS definition & calibrations	X	X				Anal. Chem., CCAM LIBS
L. DeFlores	US	N	JPL	Scan mode, fine pointing definition		X			X	Raman, IR, CCAM validation
G. Dromart	FR	C	LGLTPE	Strategic overview, Analytical synergy			X			Sedimentary processes
W. Fischer	US	N	Caltech	Astrobiology, early Earth analogs			X			Early Earth; rise of life; atm. Interaction
O. Forni	FR	C	IRAP	Data reduction and validation, IR expertise	X			X	X	Geology and geochemistry
O. Gasnault	FR	C	IRAP	Flight operations, Data processing	X		X		X	Martian surface composition
J. Grotzinger	US	N	Caltech	Calibration, Landed operations.			X			Mars sedimentary stratigraphy
J. Johnson	US	N	JHUAPL	Passive spectroscopy, imaging calibration				X		Mars imaging & passive spectroscopy
J. Martinez-Frias	ES	C	UVA-CSIC	Raman, calibration activities	X	X			X	Hydrothermal and hydrocarbon systems
N. Mangold	FR	C	LPGN	Landing site and in situ geology context	X		X			Mars geology
S. Maurice	FR	C	IRAP	(DPI) Mast Unit lead. Data processing	X	X			X	Surface composition, Hydration
S. McLennan	US	N	S. Brook	Elemental geochemistry	X					Mars geochemistry
F. Montmessin	FR	C	LATMOS	VISIR expertise, tests, calibration				X	X	Mars atmosphere & water cycle
F. Rull	ES	C	UVA-CSIC	Cal. target assembly lead, Raman expert	X	X		X		SNC, analogues, mineralogy
S. Sharma	US	N	HIGP	Remote Raman-fluorescen expertise, calibration	X	X		X		Biomarkers, organics
R. Wiens	US	N	LANL	(PI) Overall leadership	X	X			X	SNC, Gale geochemistry

Mars 2020 Project

Informational Webinar

Roger Wiens

2. SuperCam Instrument Description

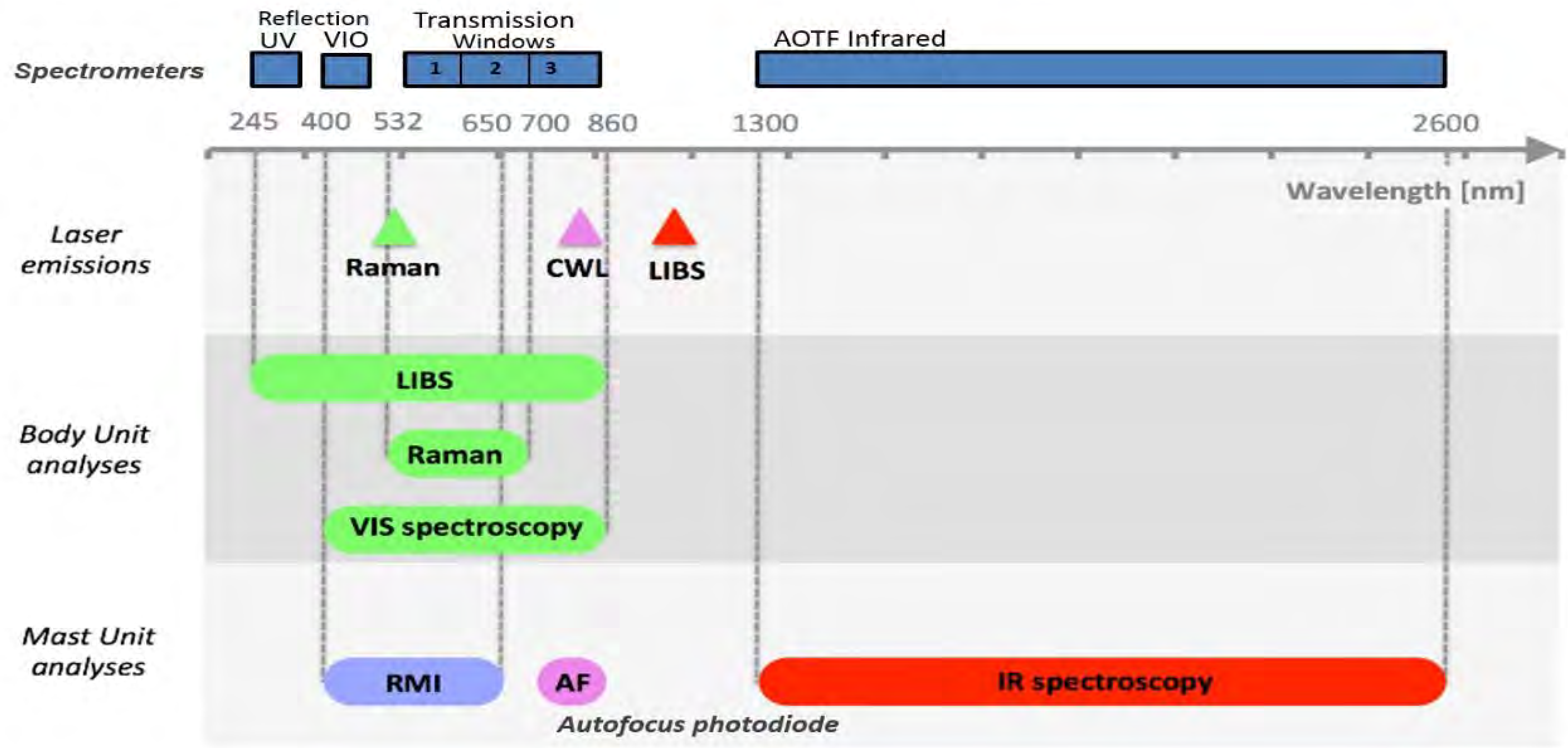
25-February-2020

Agenda

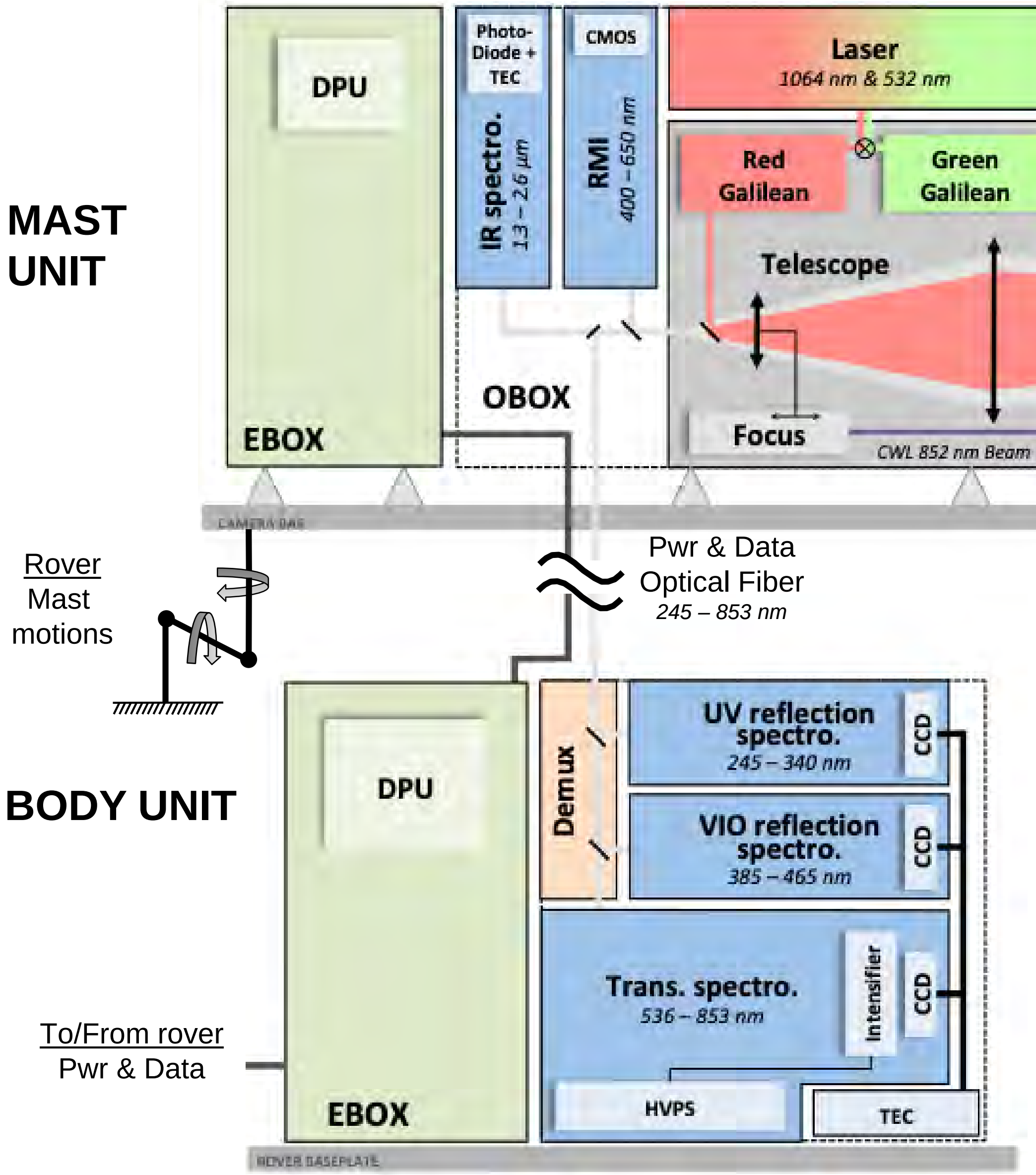
Time	Duration	Topic	Presenter
9:00	0:30	Project investigations, goals	Sylvestre Maurice
9:30	0:25	Instrument description	Roger Wiens
9:55	0:25	Data, results, calibration	Ann Ollila
10:20	0:15	Operations	Olivier Gasnault
10:35	0:15	Q&A	
10:50	0:10	Margin	

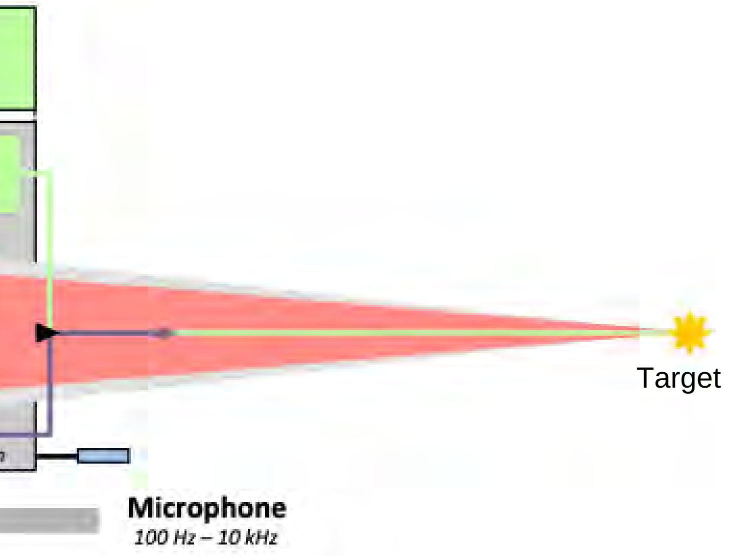
SuperCam Wavelengths

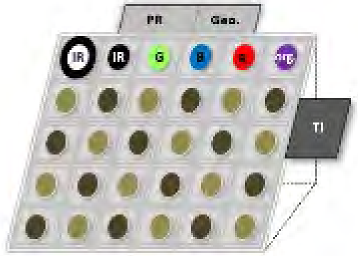
Mars 2020 Project
SUPERCAM



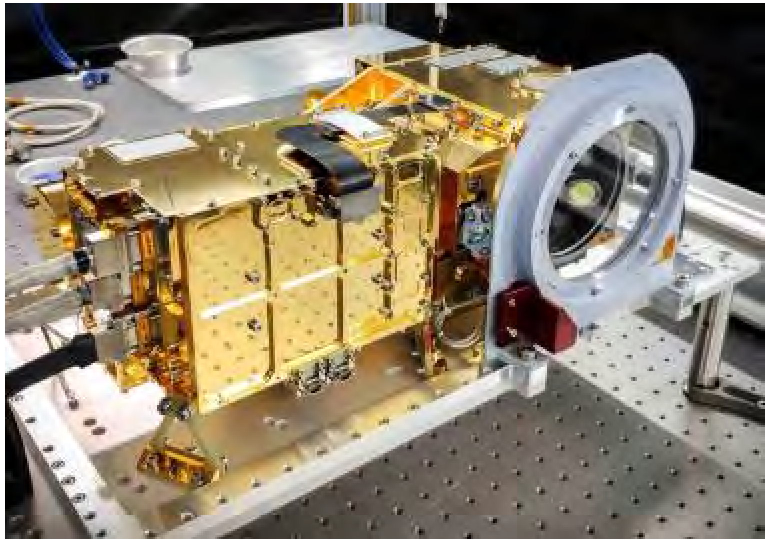
Instrument Block Diagram

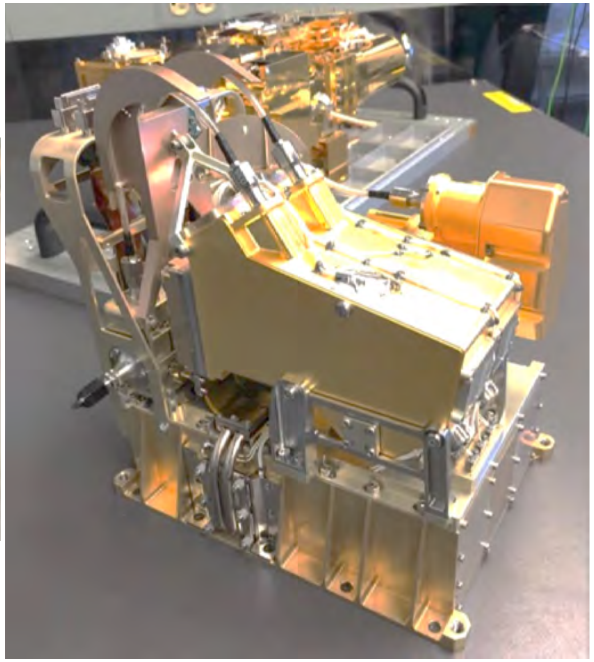






CAL. TARGETS





Overall Properties, Spectrometer Properties

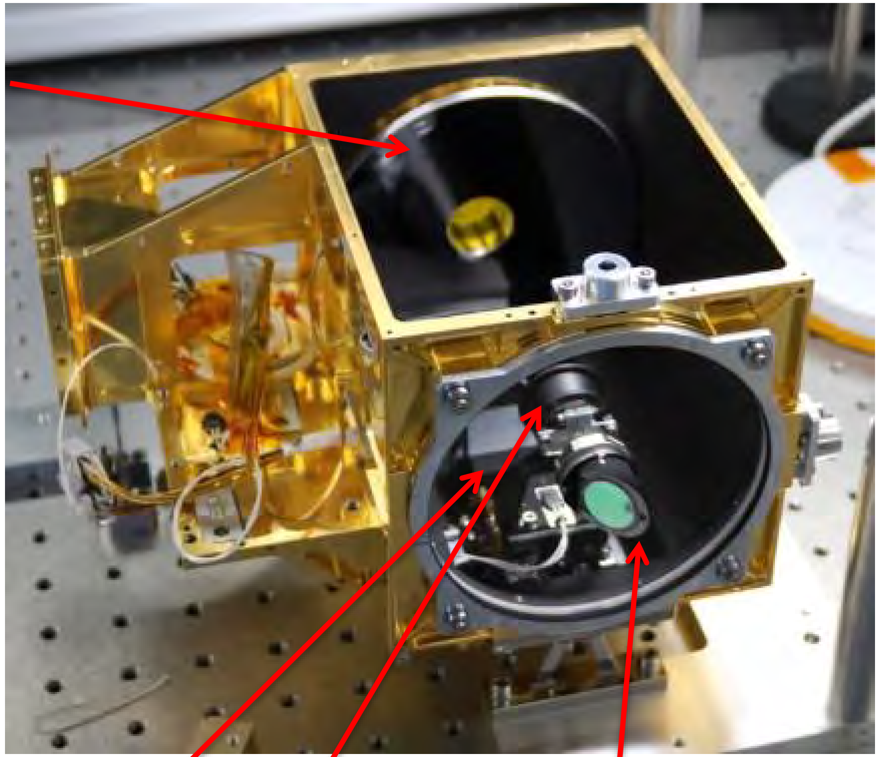
	Mass (kg)	Dimensions l x w x h (mm)	Max Power (W)
Mast Unit	5.91	383 x 214 x 163	24.5
Body Unit	4.44	221 x 157 x 205	47.0*
Cal. Target	0.24	110 x 85 x 11	0.0
TOTAL	10.59		71.5

*Includes thermo-electric cooler (TEC)

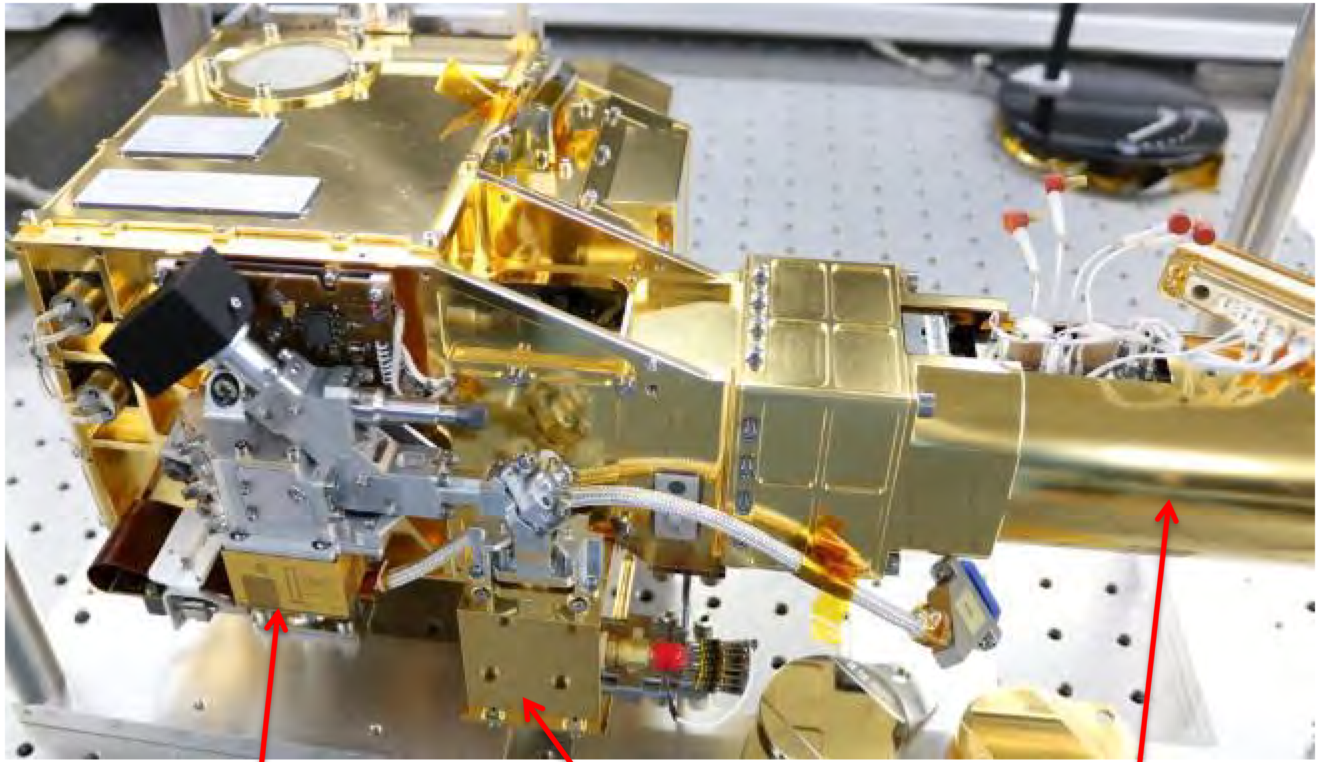
Spectrometer	Ultraviolet	Violet	Transmission	Infrared
Type	Czerny-Turner	Czerny-Turner	Transmission	AOTF
Location	Body	Body	Body	Mast
Function	LIBS	LIBS, VISIR	Raman, LIBS, VISIR	VISIR
Detector	CCD	CCD	ICCD	Photodiode
Range (nm)	240-340	385-475	535-855 (150-7000 cm^{-1})	1300-2600
# Channels	2048, 16 bits	2048, 16 bits	6000, 16 bits	256
Resolution, FWHM	<0.20 nm	<0.20 nm	0.3-0.65 (12 cm^{-1})	20-30 cm^{-1}
Field of view	0.74 mrad	0.74 mrad	0.74 mrad	1.15 mrad
Exp. duration	≥3 ms	≥3 ms	≥100 ns	(80 s full scan)

Mast Unit Optics (OBOX)

OBOX Telescope

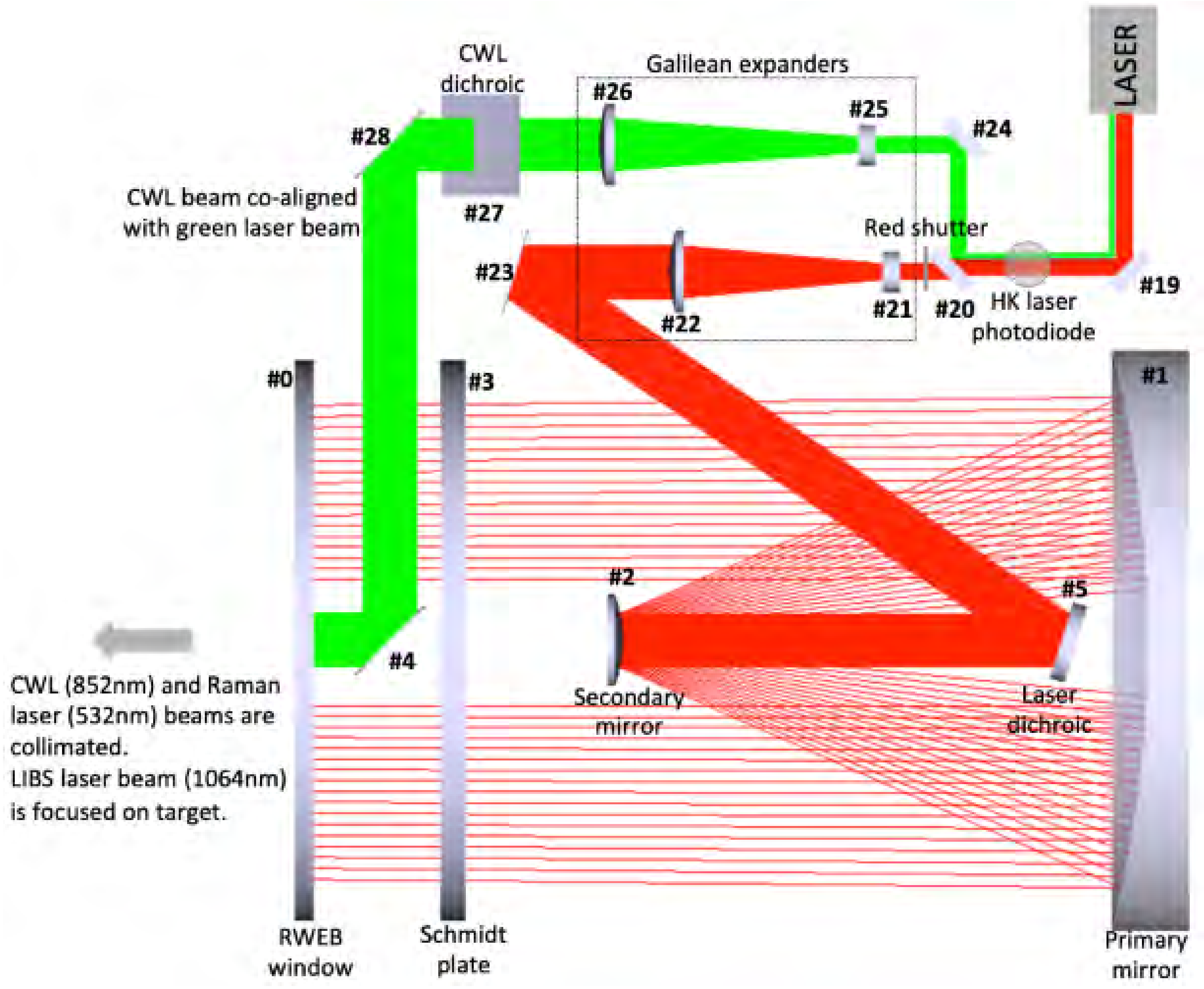


OBOX rear view



- 2 telescope autofocus modes implemented: CWL and RMI
- AF up to infinity (with RMI)
- AF duration ≤ 2 min

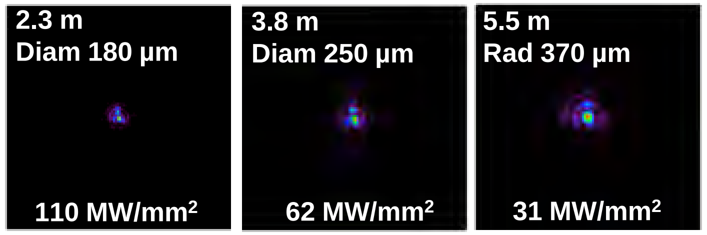
Mast Unit Optical Configuration & Operation



LIBS emission

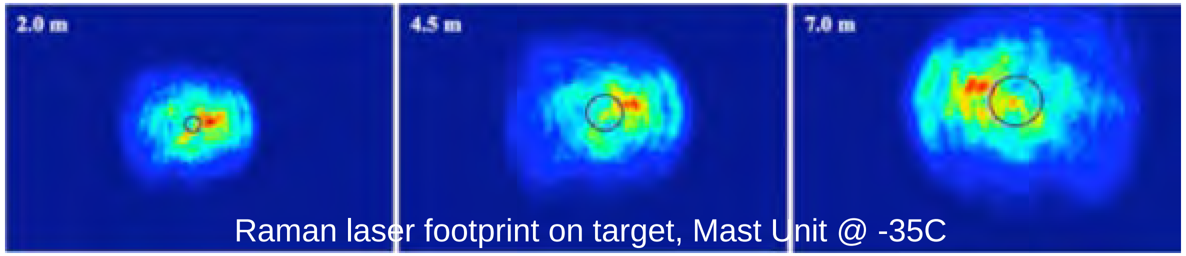
- Energy on target ≥ 12 mJ @1064 nm (11 mJ for burst of 20 shots)
- Laser energy: variation ≤ 3% rms
- Irradiance on target ≥ 10 MW/mm^2 (130 MW/mm^2 @ 2 m, -35C)

LIBS spot on target, Mast Unit @ -25C



Raman emission

Raman laser wvl calibrated vs temperature
Energy on target ≥ 9 mJ @532 nm
Irradiance on target: 15-30 kW/mm^2 @-35°C, 4.5 m; ~10-15 kW/mm^2 @-35°C, 7 m



Raman laser footprint on target, Mast Unit @ -35C

Blue circle is 0.74 mrad spectrometer FOV
Always smaller than laser beam

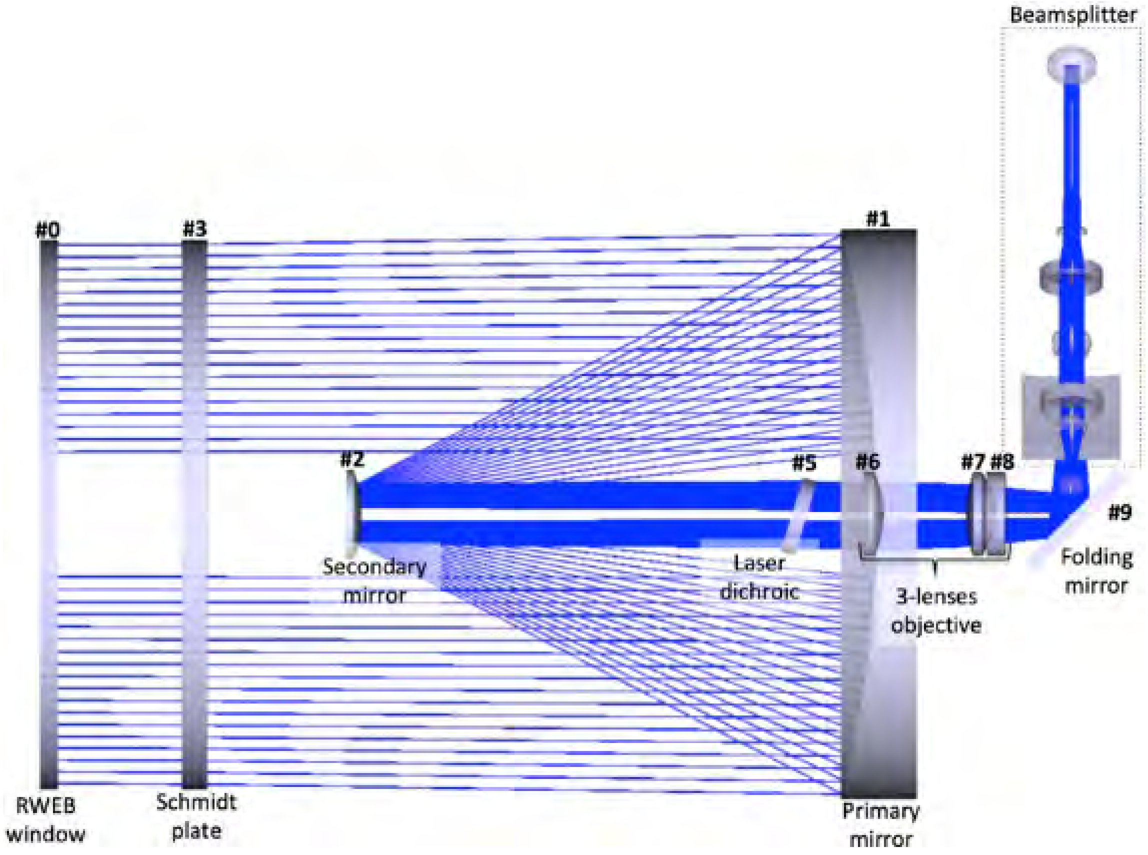
Operational constraints

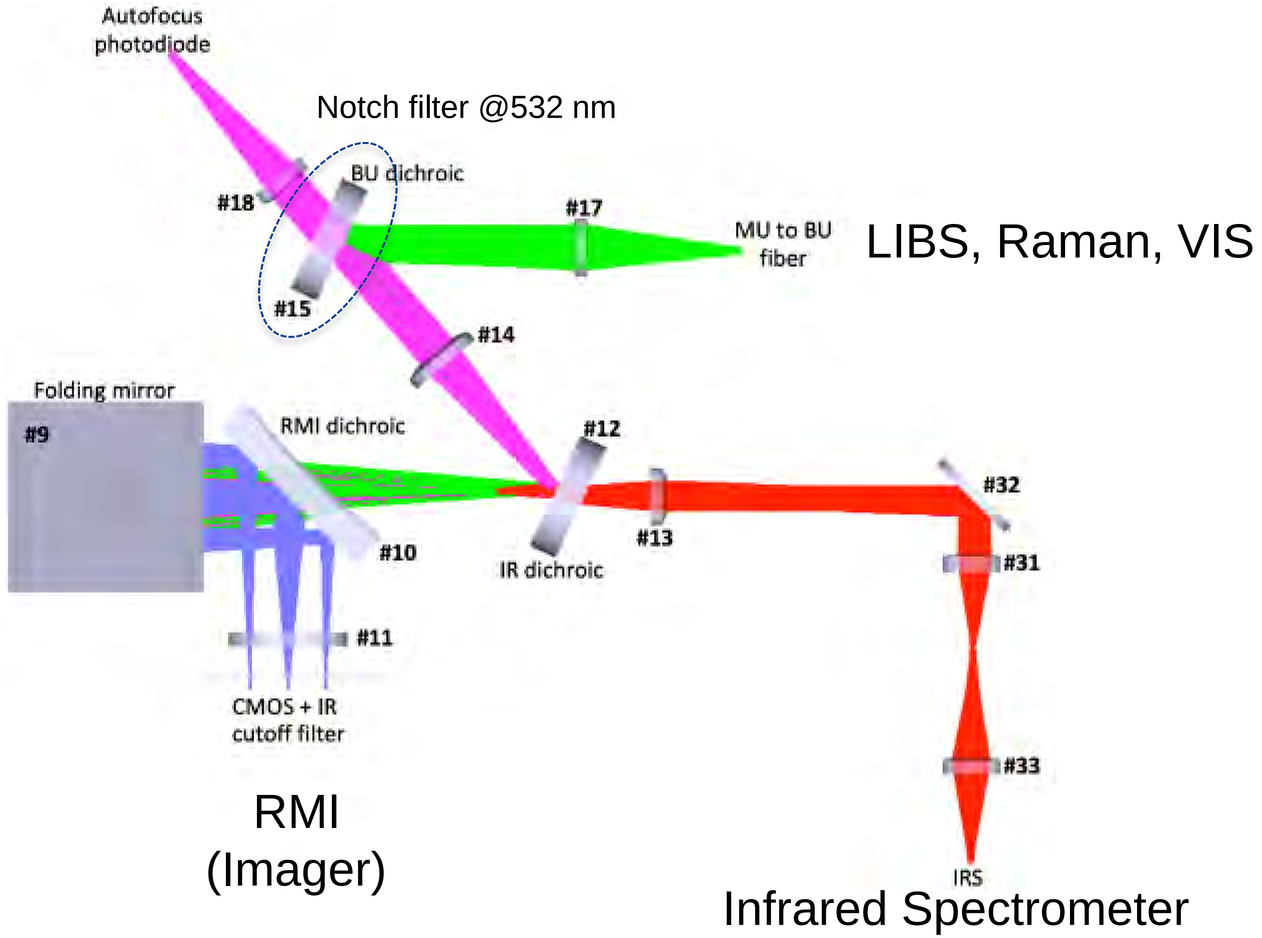
- Rest times required between large numbers of laser shots, mostly applicable for LIBS depth profiles and Raman
- Shutter activation ≤ 2 min (allows long Raman bursts of 1000 shots @ 10 Hz)

Mast Unit Optical Collection Paths

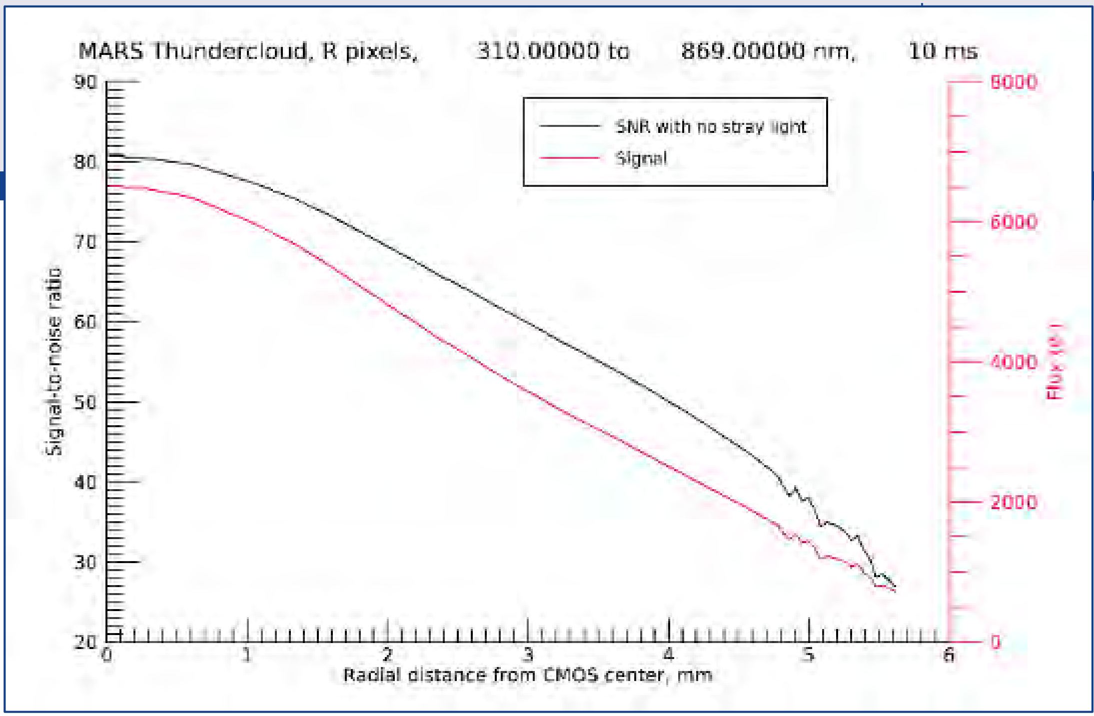
Materials changed since ChemCam to transmit the 245 – 2600 nm light

- 40 optical elements (w/o laser)
- High laser fluence
- Complex dichroic plates



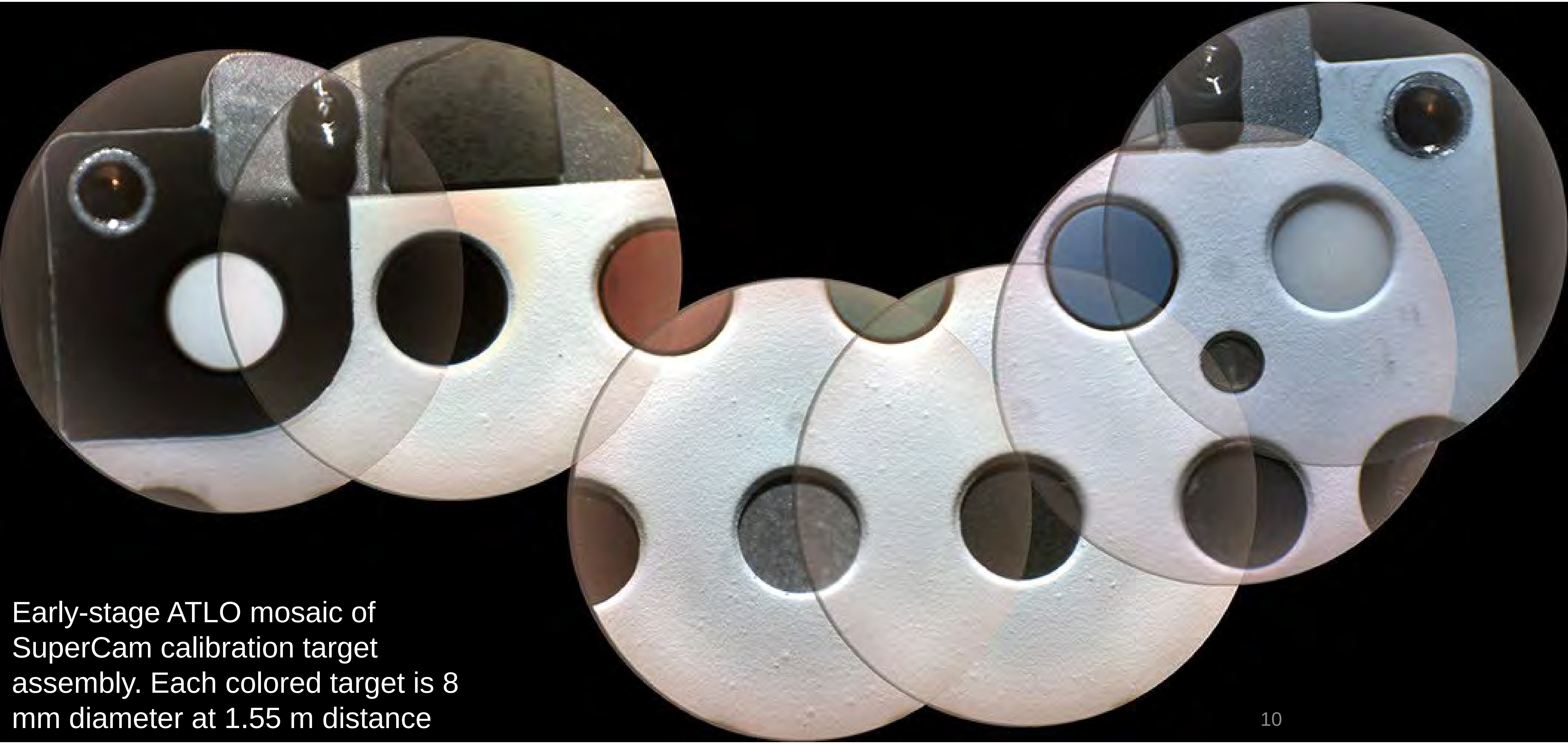


Remote Micro-Imager (RMI)



- 2048 x 2048 CMOS device with RGB Bayer filter
- 19 mrad field of view; ~80 microrad resolution*
- Focuses 1.1 m from SuperCam to infinity
- Incorporates high-dynamic-range (HDR) mode
- HDR can generate 12 or 13-bit images
- Uses normal lossy (minimized) or lossless compression
- Co-boresighted with Navcam and Mastcam
- Telescope vignetting results in factor of 6.5 lower flux at edge of FOV relative to center (see plot)
- Positions of LIBS, Raman, and VISIR observational fields are precisely known within the RMI FOV
- Used to document all spectral observations; also can be used stand-alone
- Mosaics are typically made of all targets (see next page)

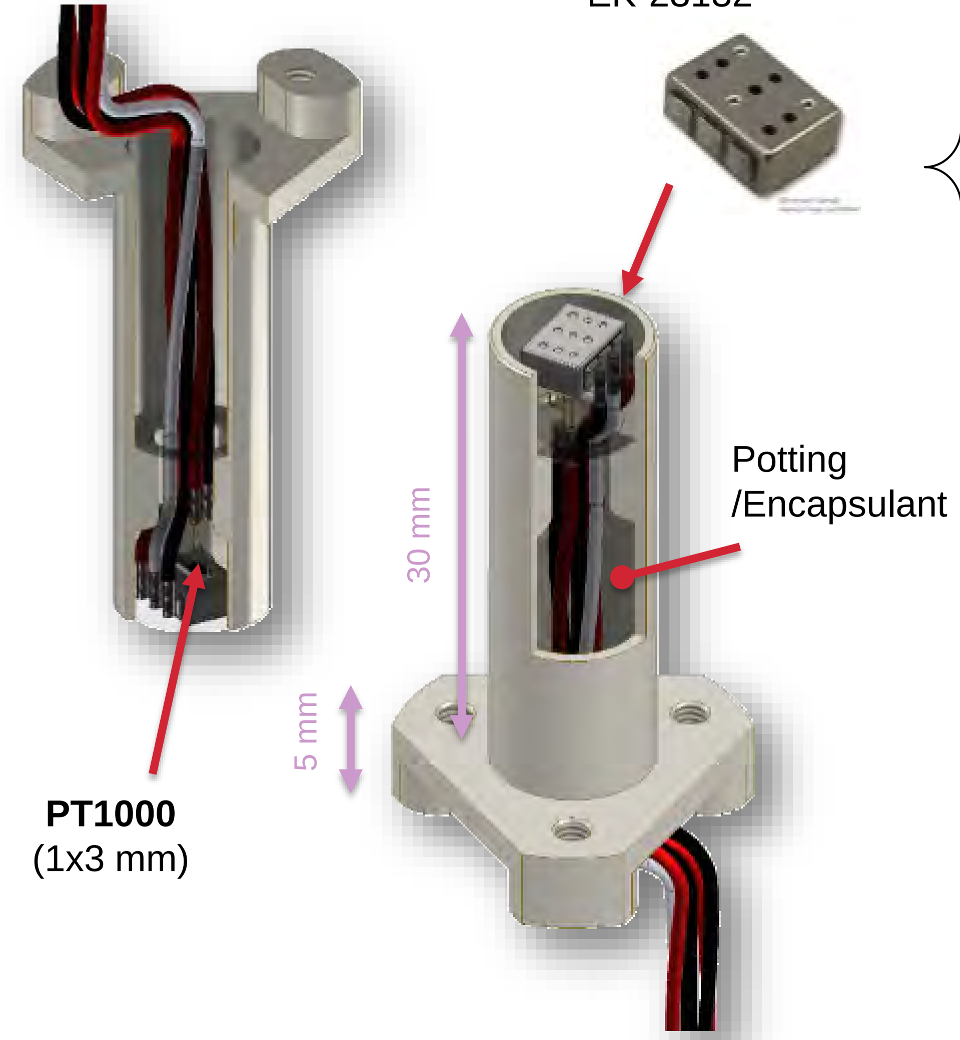
Remote Micro-Imager (RMI)



Early-stage ATLO mosaic of SuperCam calibration target assembly. Each colored target is 8 mm diameter at 1.55 m distance

Microphone

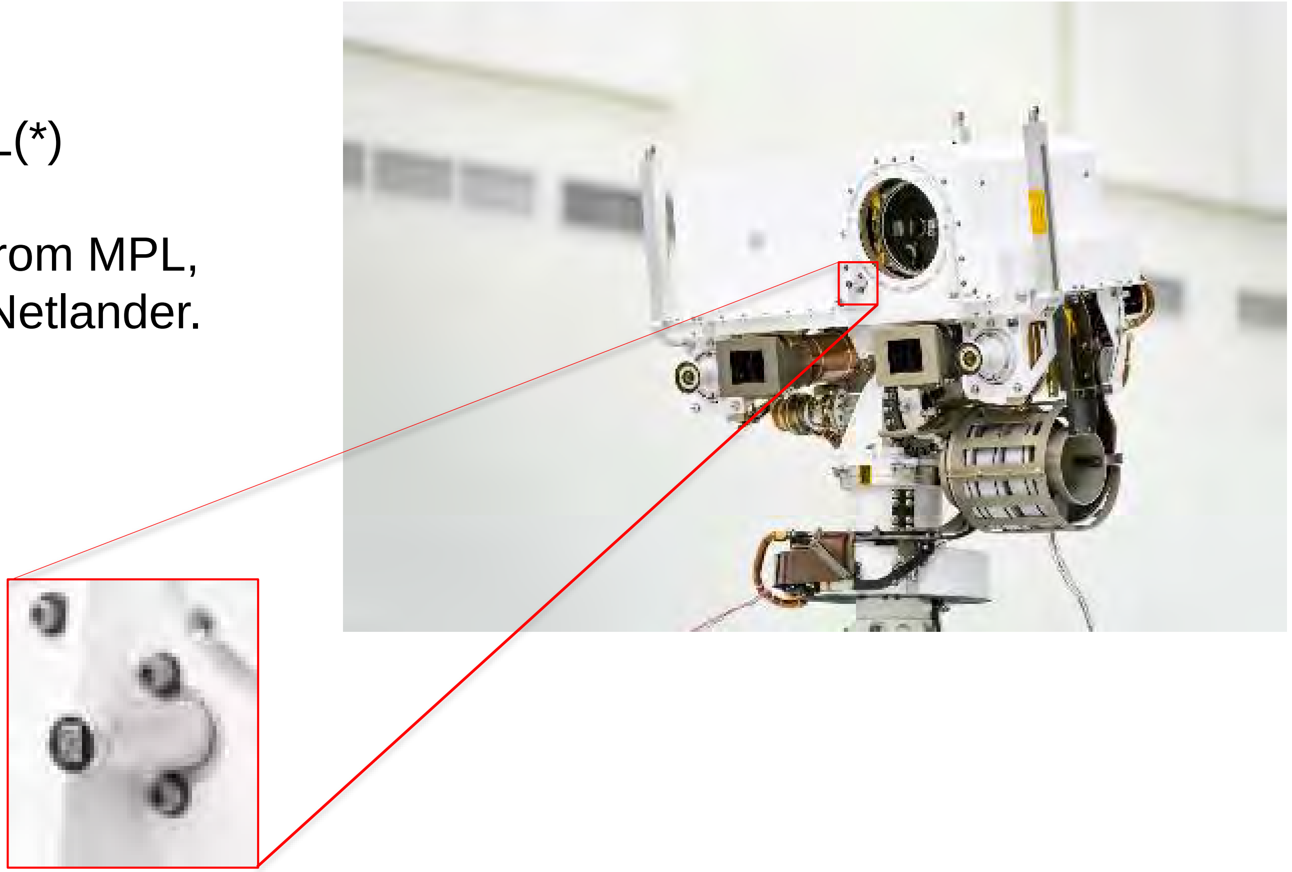
Micro Knowles Acoustics
EK-23132



Frequency Range
100Hz ~ 10kHz

Sensitivity
74dB SPL(*)

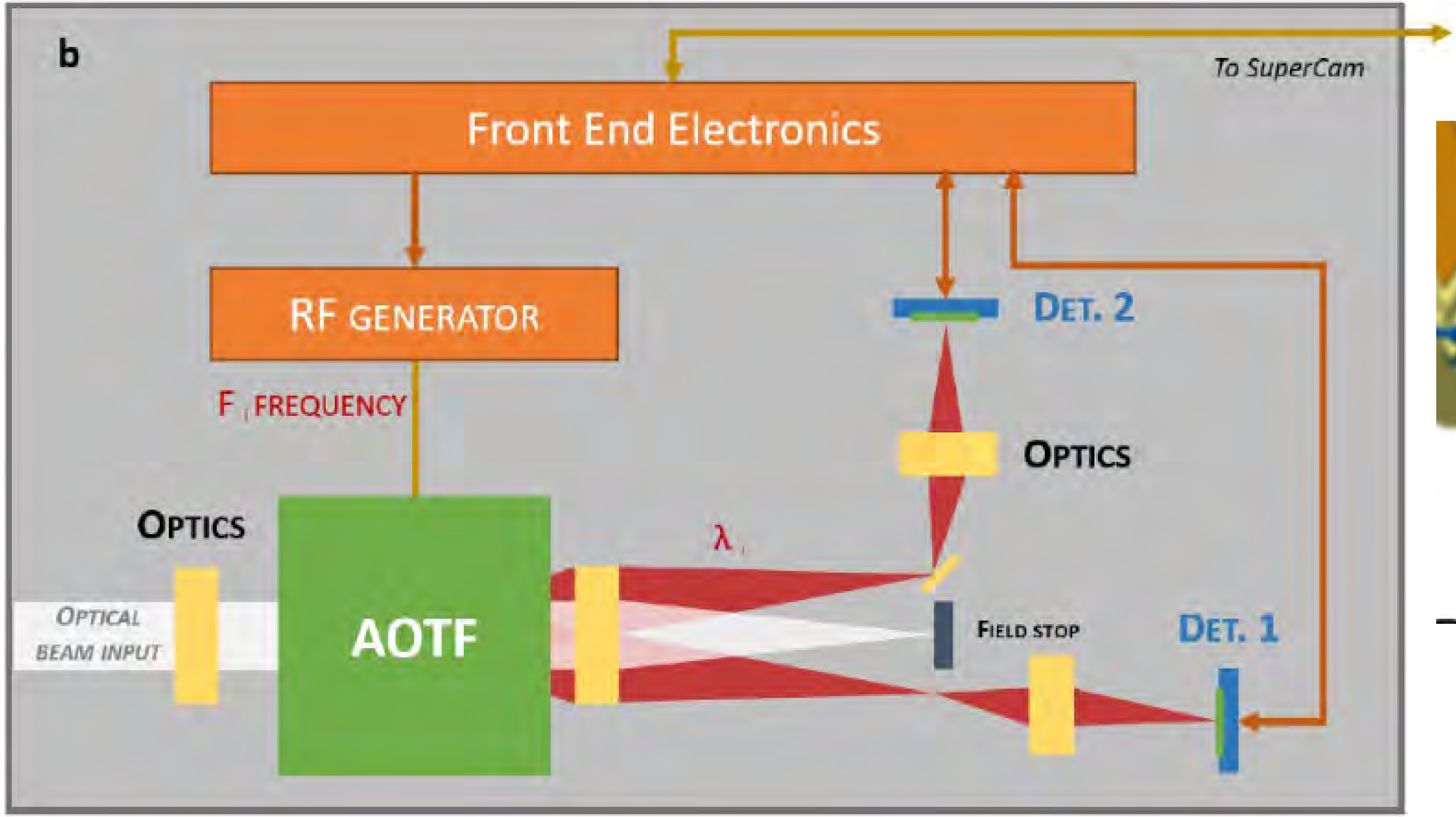
Heritage from MPL, Phoenix, Netlander.



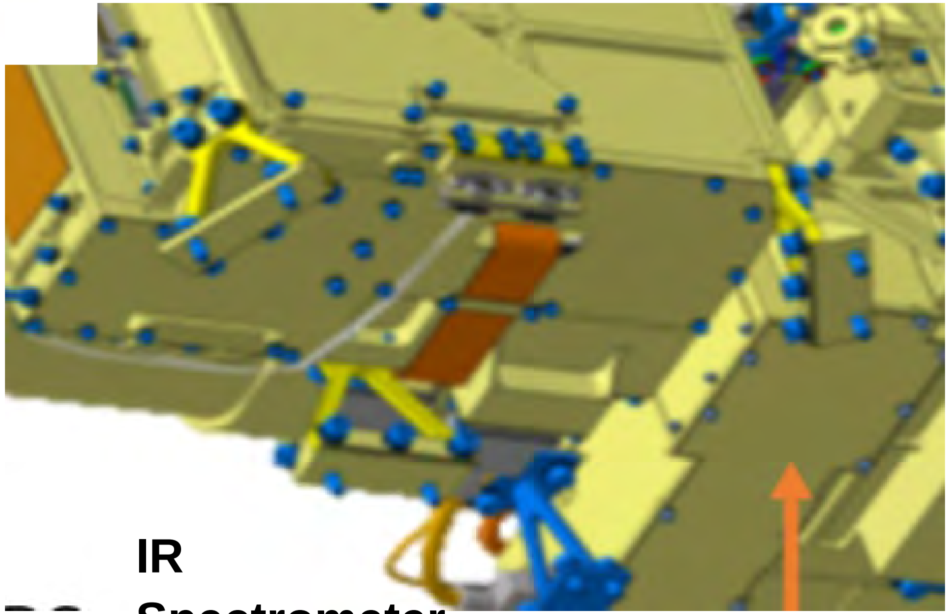
Cheat sheet (*) dB SPL = 20 $\log_{10}(P_1/P_0)$ where p1 is the **sound pressure level** of a given sound, and p0 is a reference value of 20µPa, (lowest hearing threshold of reference)

Infrared Spectrometer

- IR spectrometer is wavelength-scanning using an acousto-optic tunable filter (AOTF) driven by a radio-frequency (RF) generator. It has 2 photodiodes (Det. 1 & 2; #2 is backup). Its footprint is 1.15 mrad, co-boresighted with LIBS, Raman, VIS, and RMI.



Royer et al., submitted; see also LPSC abstract

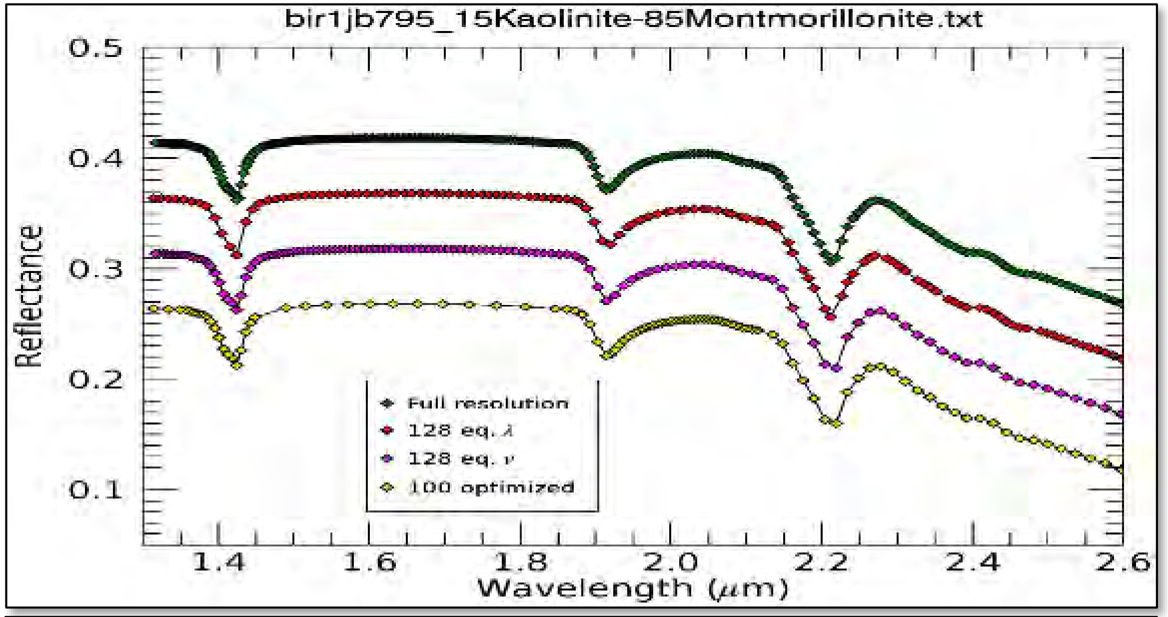


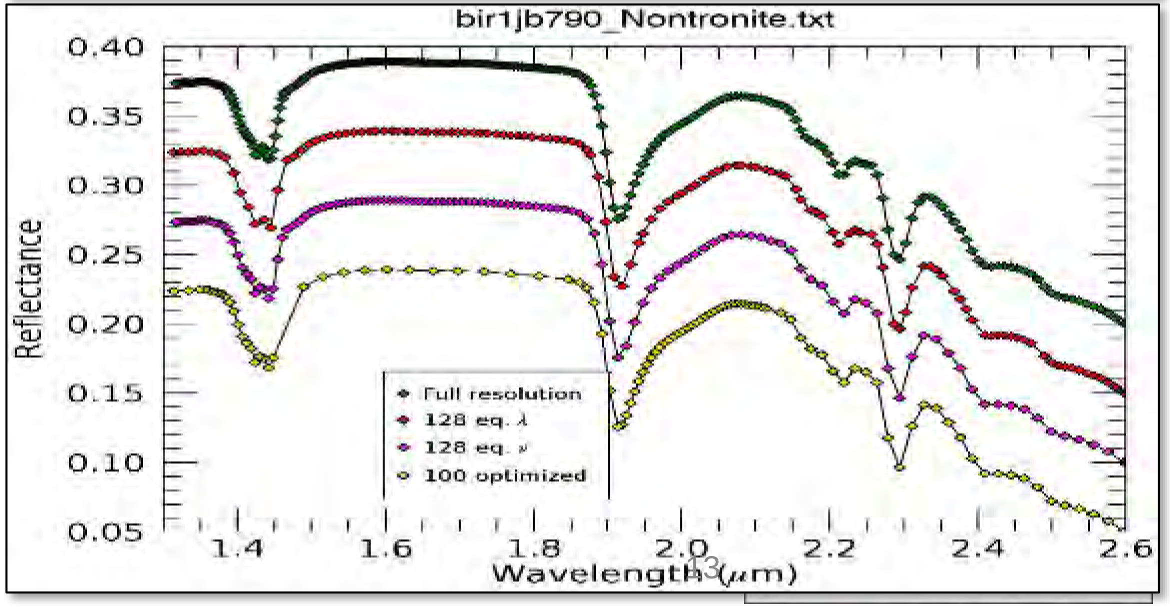
IR Spectrometer (next to telescope Under laser beam paths)

IR Tables and Spectral Resolution Optimization

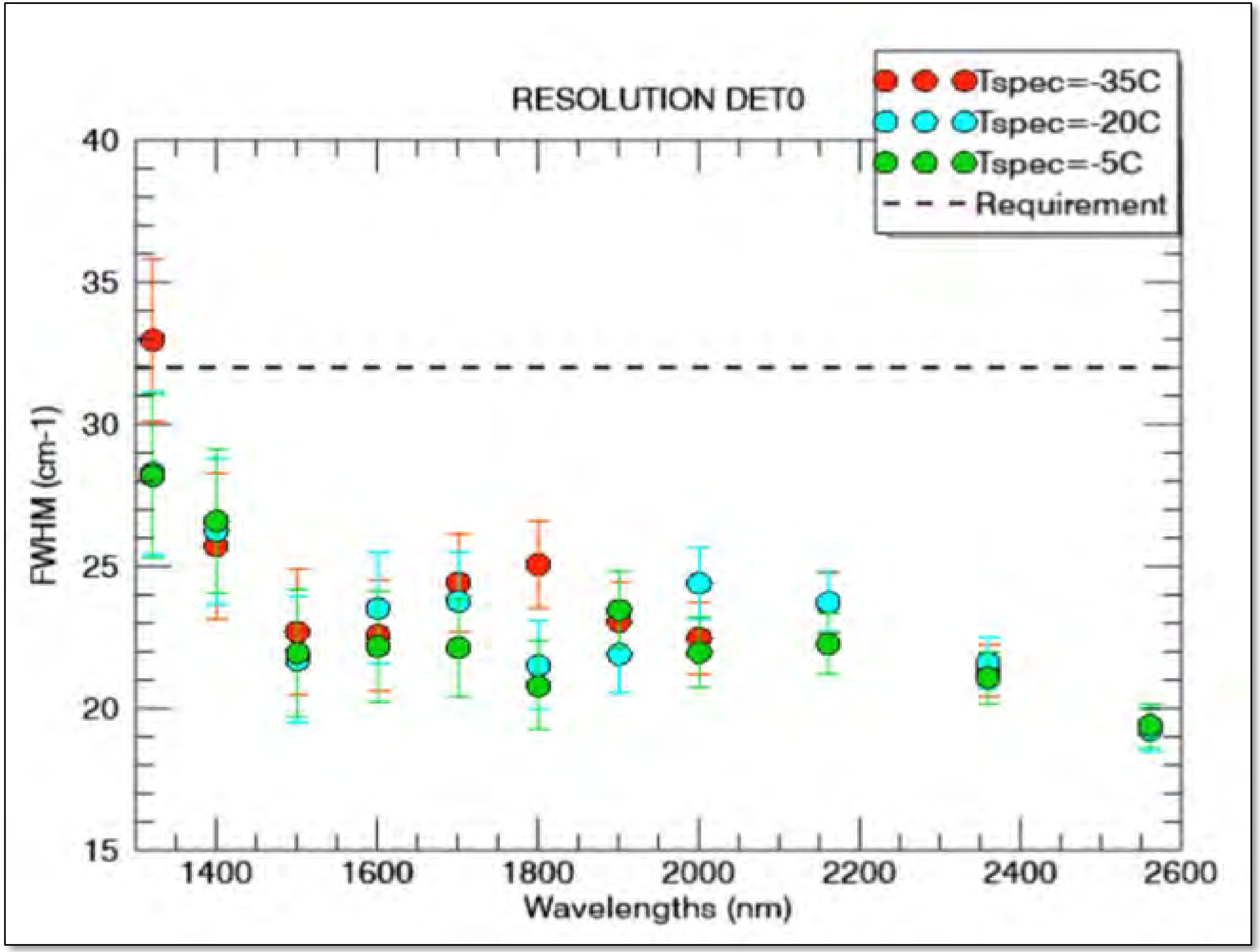
Tables

- The nominal 86 spectels optimized for mineralogical bands sampling
- The “preferred” 100 spectels optimized for mineralogical bands and atmospheric CO_2 sampling
- Dedicated tables for 2.5-µm, 2.3-µm, 1.9-µm and 1.4-µm rapid sampling
- Dedicated tables for Atmospheric gas, ices and dust sampling





IR Resolution

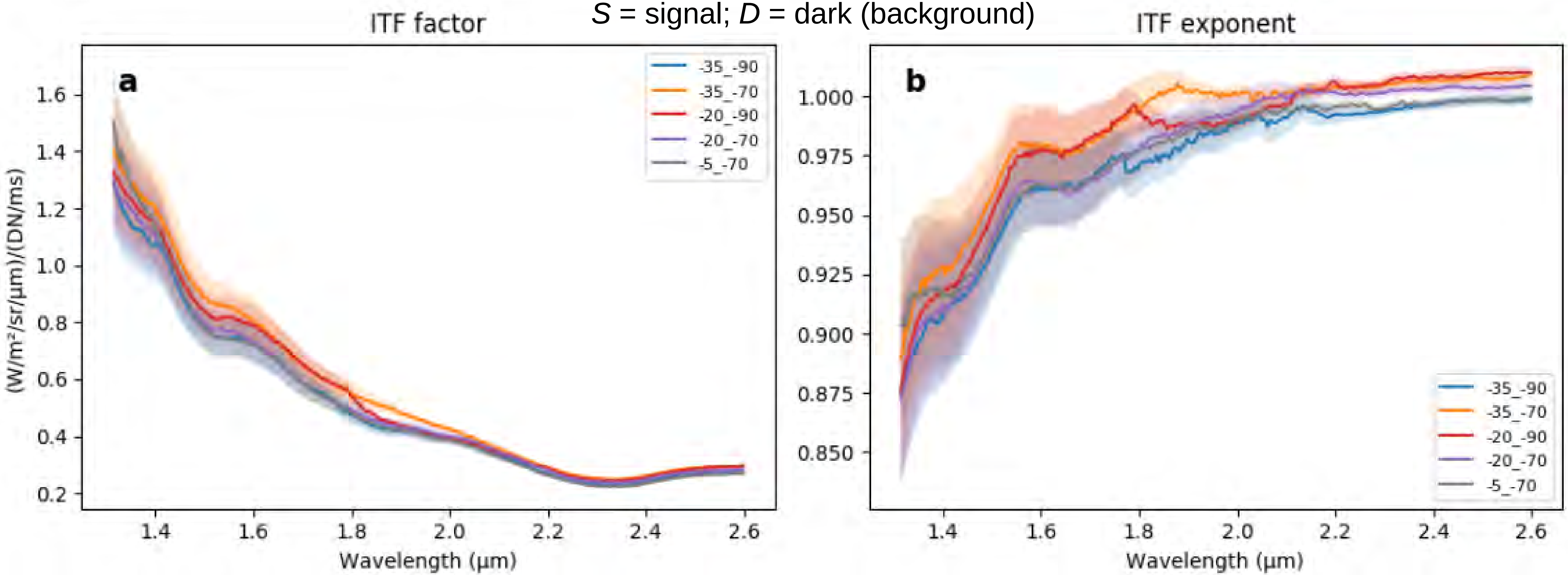


Infrared Spectrometer Instrument Response

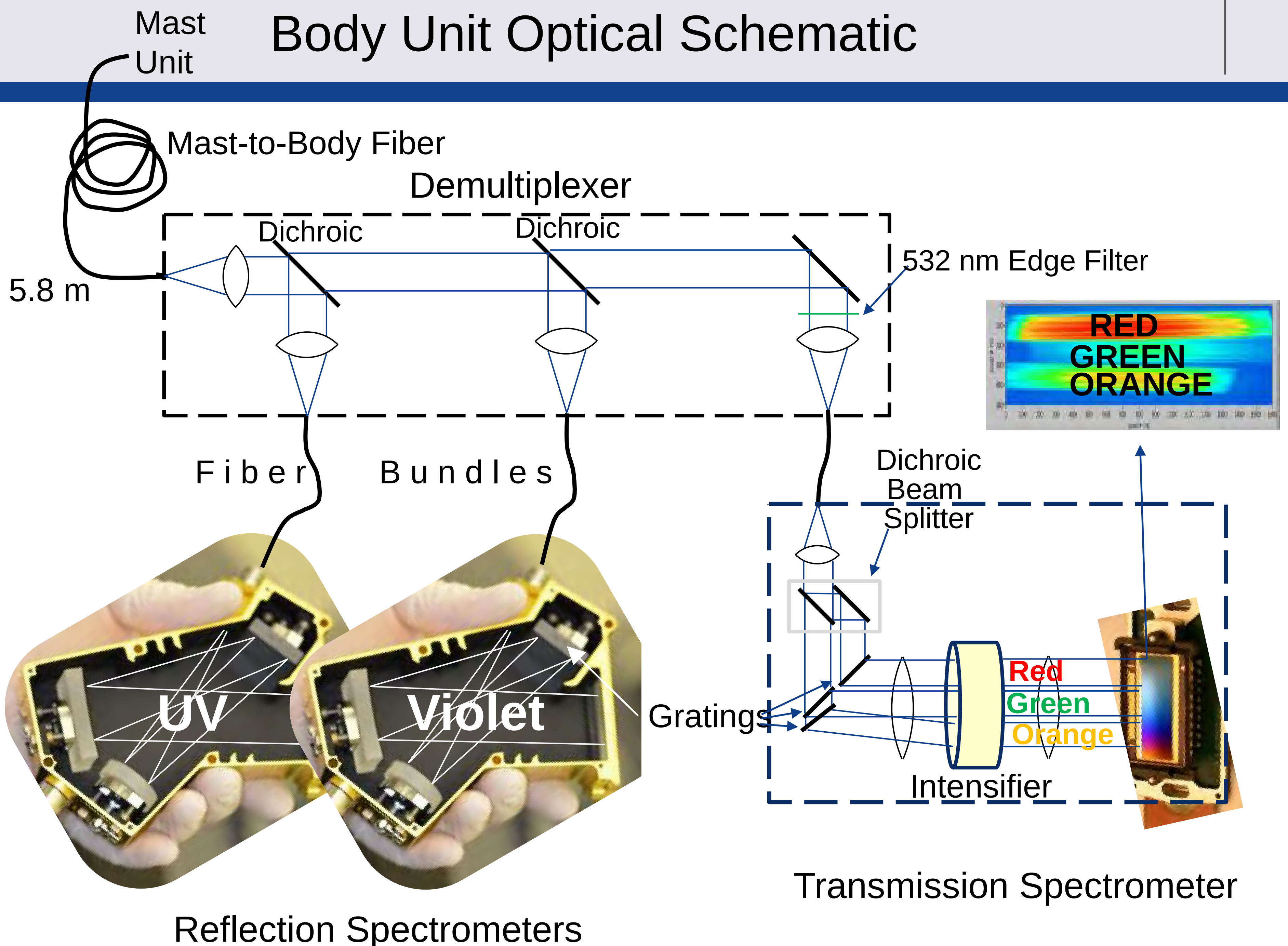
- Instrument transfer functions for Photodiode #1. Each color corresponds to a thermal dataset: "-35_-90" means spectrometer at -30, photodiode at -90, which are normal expected operating temperatures.

$$S - D = ITF_{fac} \times t_{int} \times \phi^{ITF_{exp}}$$

S = signal; *D* = dark (background)



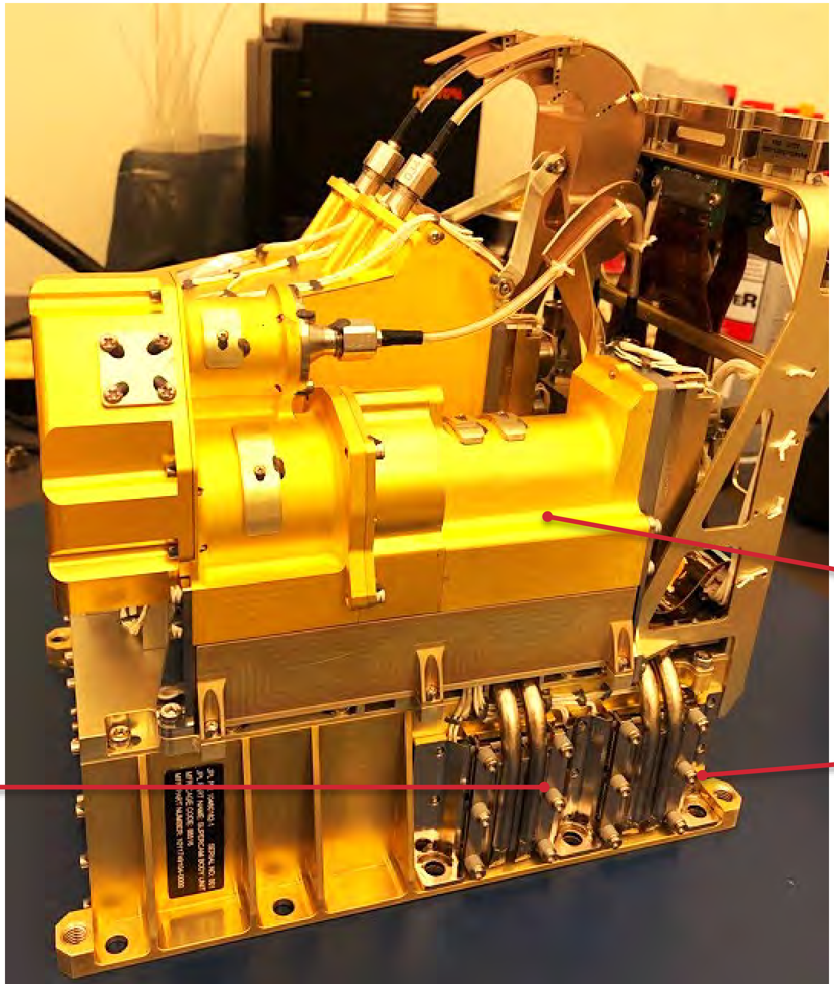
Body Unit Optical Schematic

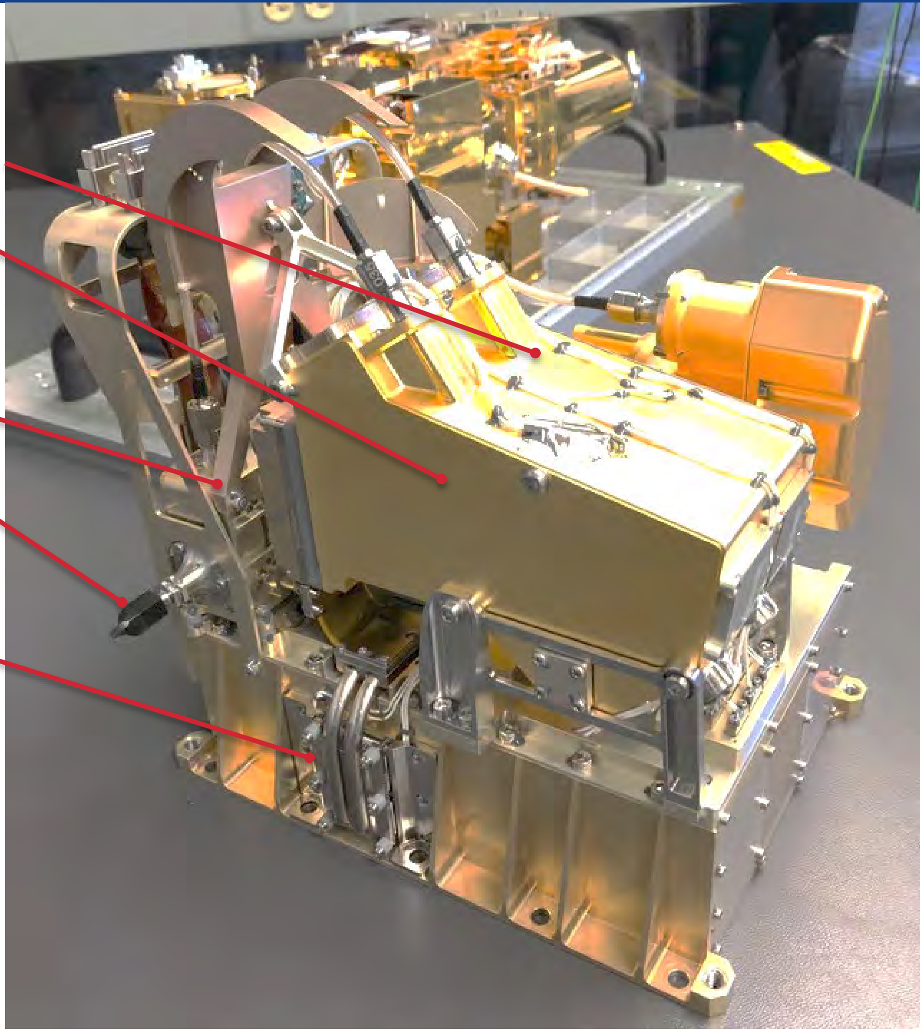


SUPER CAM MARS 2020

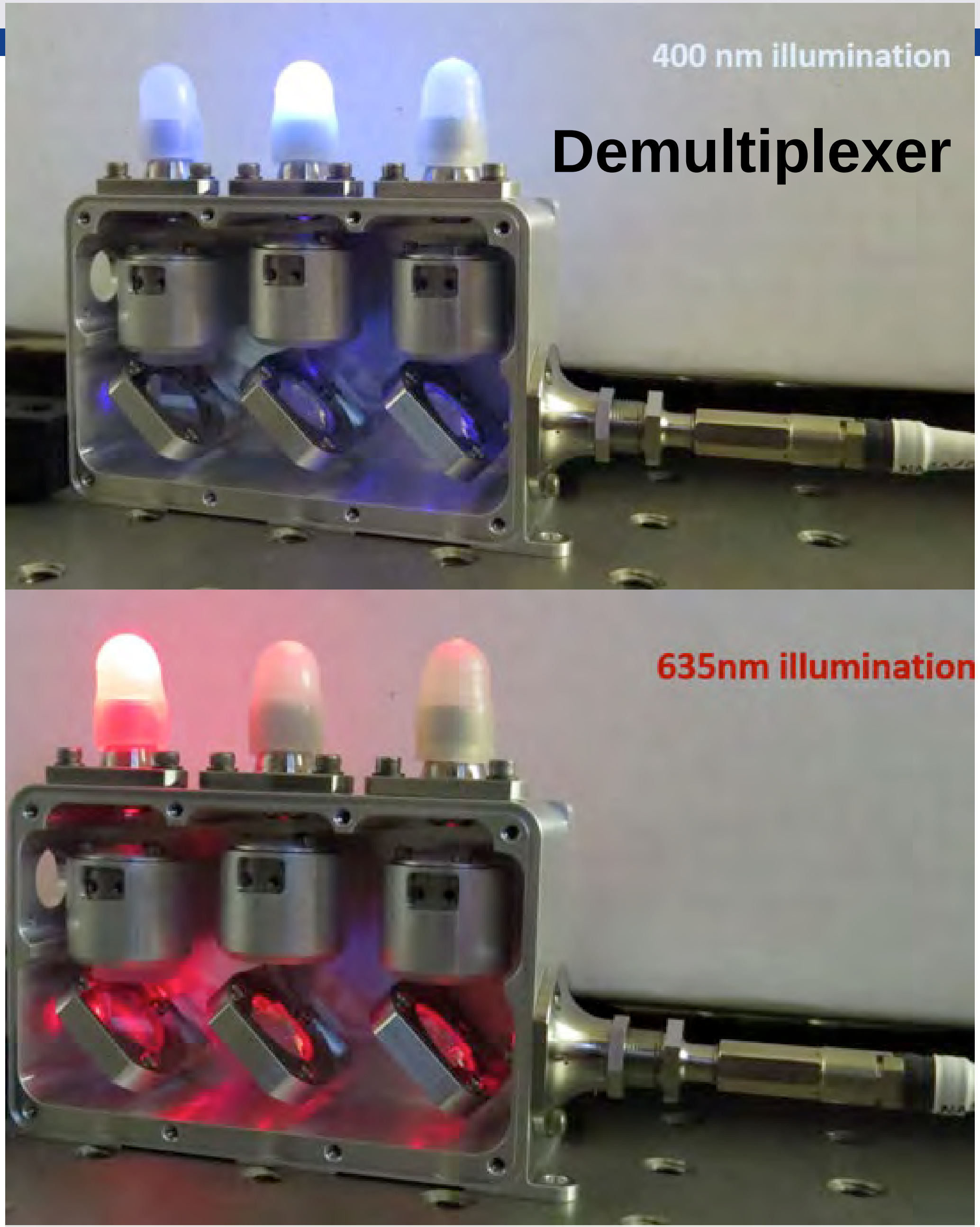
Body Unit

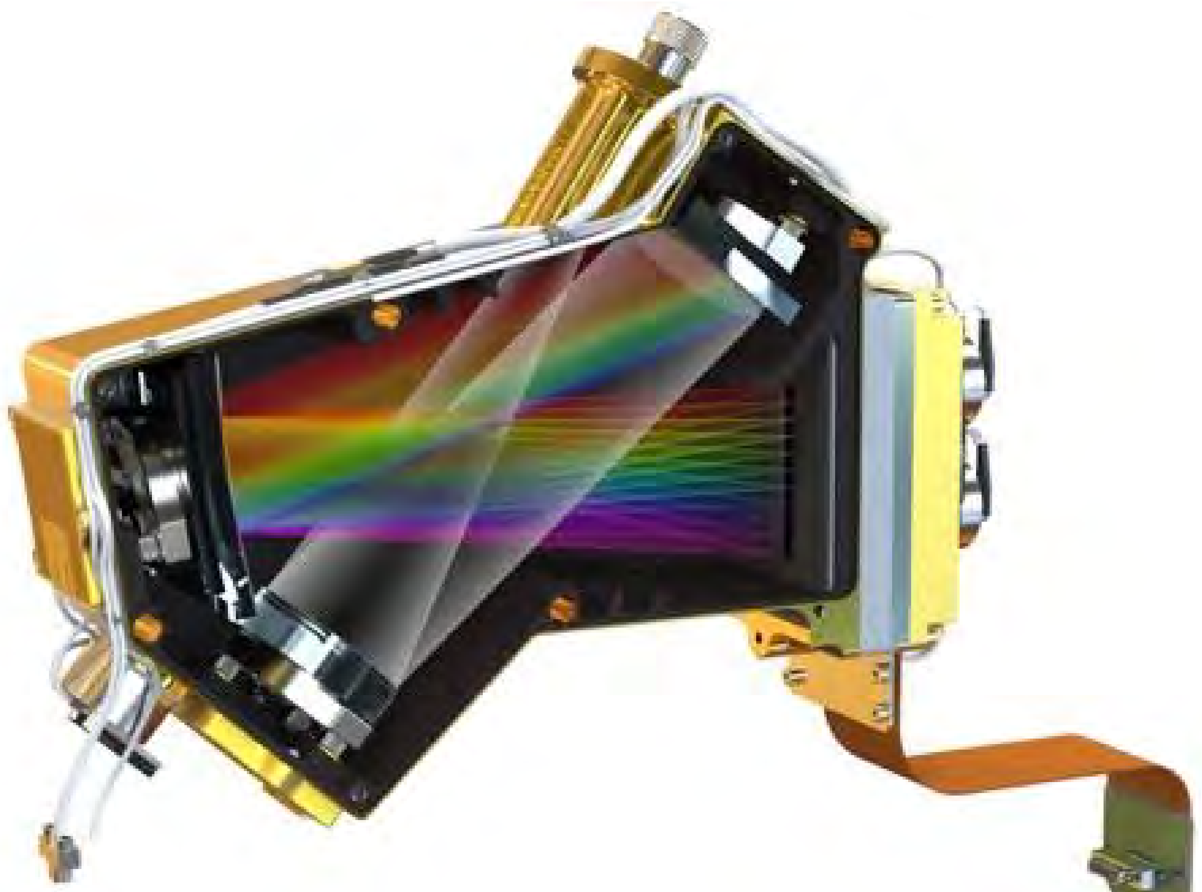
- CCDs are cooled using Thermal Electric Coolers (TECs) & Heat Pipe assemblies that provide ~20° cooling over Rover Accessory Mounting Plate (RAMP) temperature. CCD temperatures are expected to be generally 0-10 degrees on Mars.





Body Unit: Demultiplexer & Reflection Spectrometers



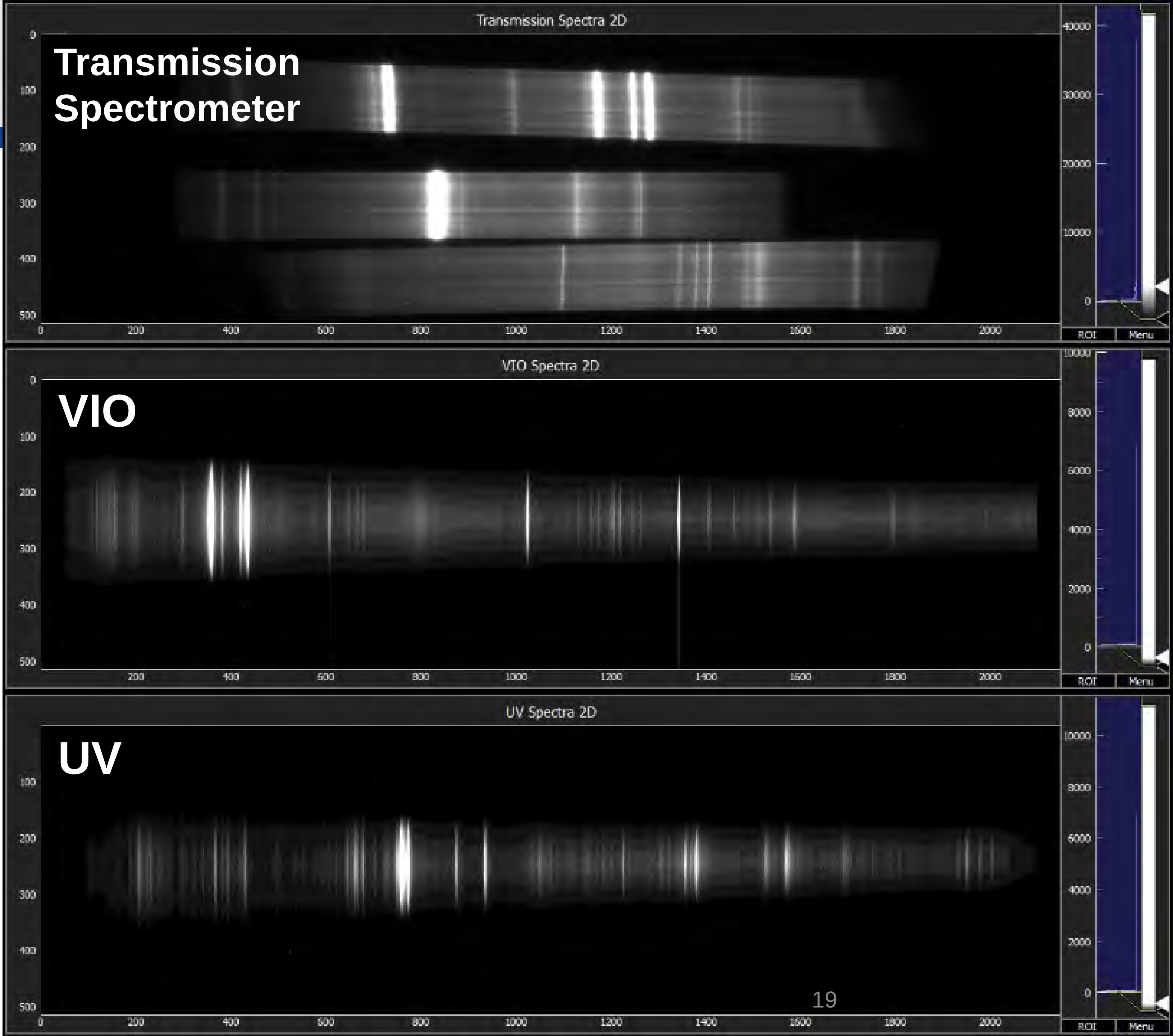


Reflection spectrometers

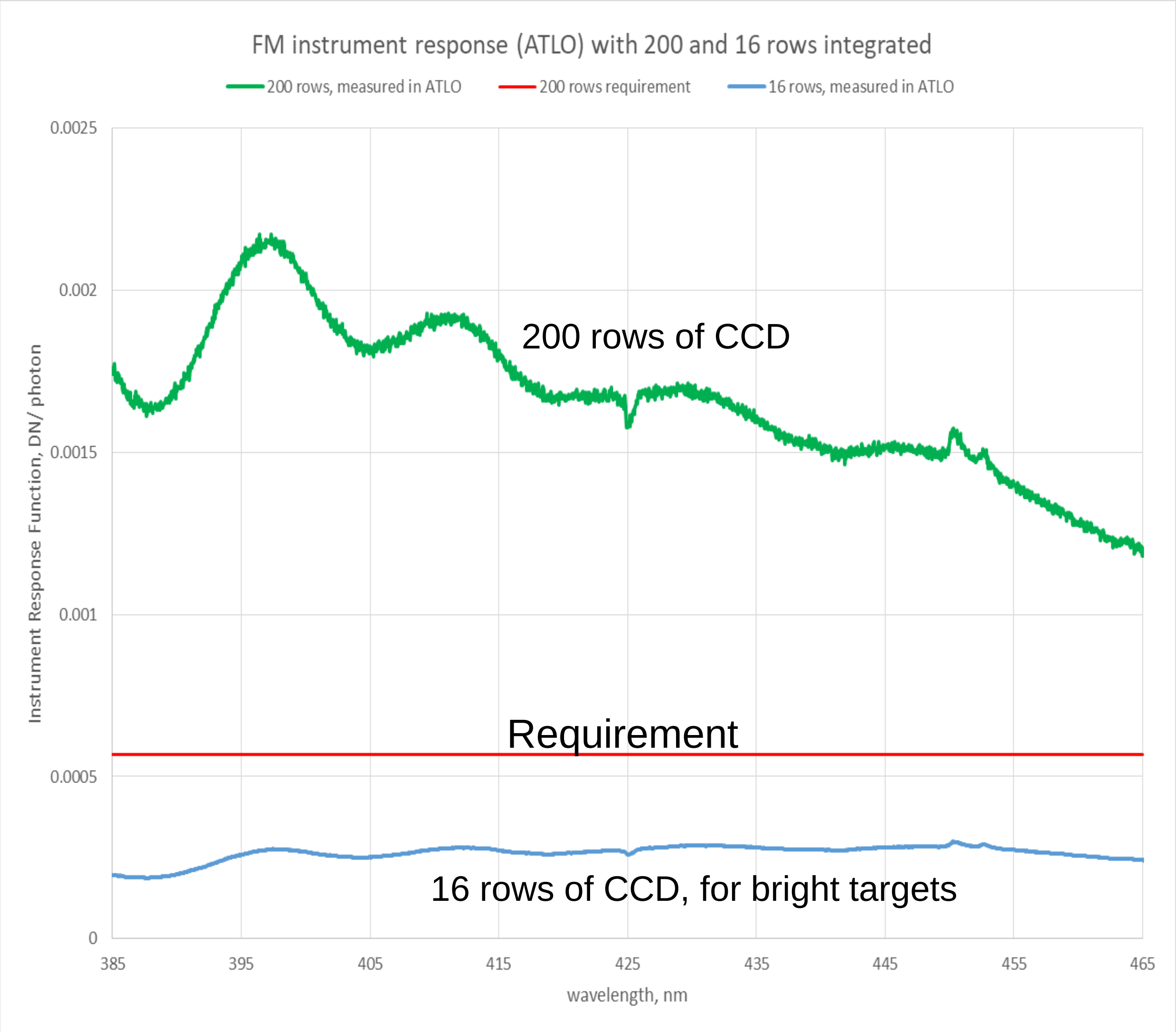
Same design as ChemCam.
Same design for UV and VIO spectrometers.

Spectral Projections on BU CCDs

- This is a LIBS spectrum of JA3 andesite.
- Each Body Unit CCD has a 2048 x 515 pixel array.
- UV & VIO spectrometers project one image each. Normally 200 rows are integrated, but we have also calibrated for 40 and 16 rows.
- The transmission spectrometer projects 3 images (green, orange, and red spectral ranges)
- Images are collapsed and read out as 1D spectra, 16 bits

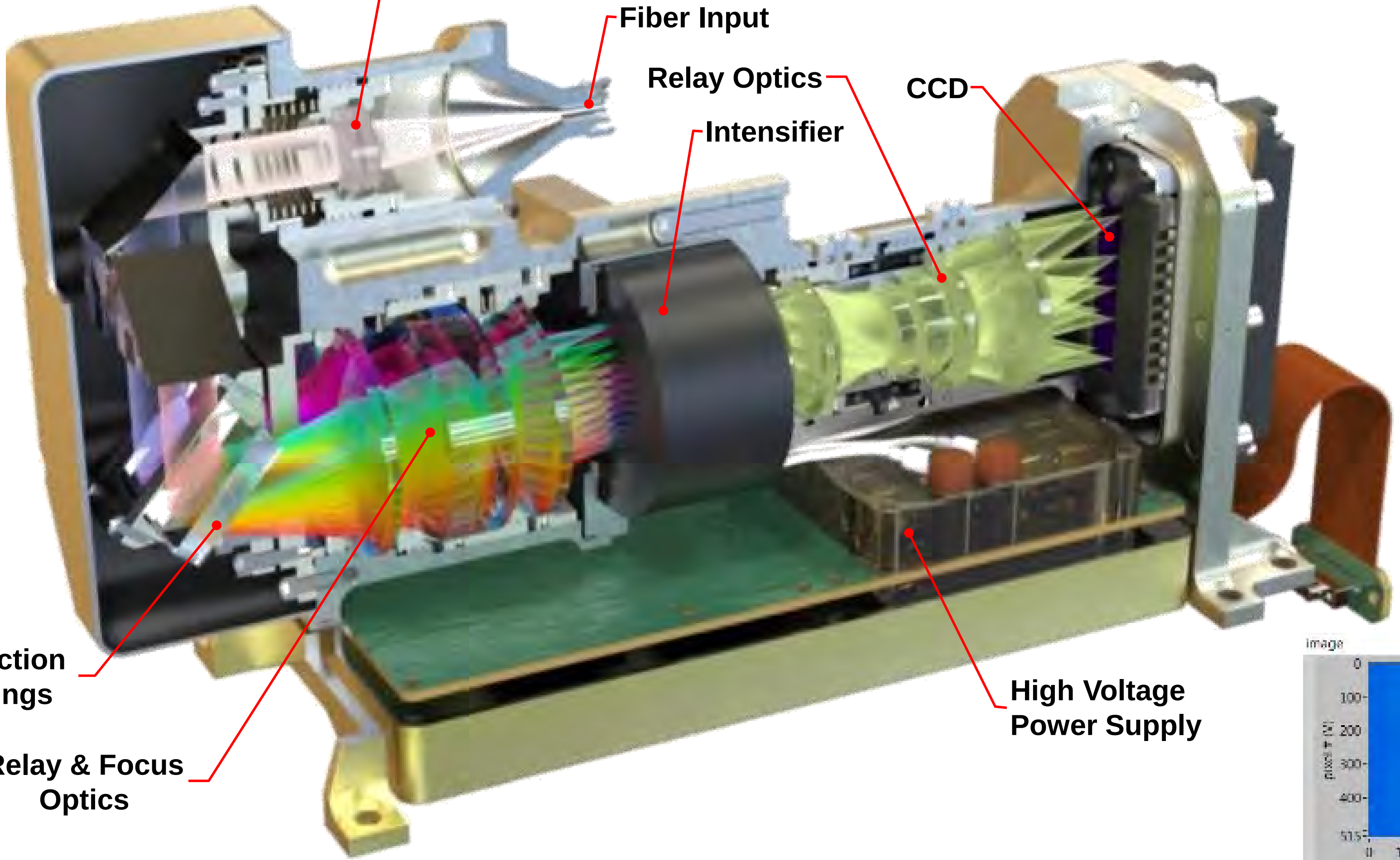


Instrument Response Function: UV & VIO



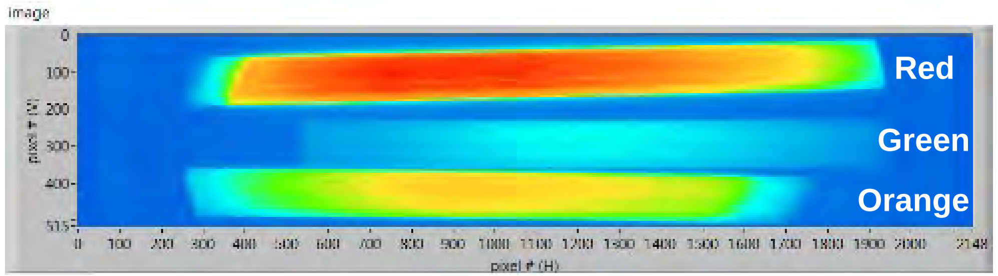
Results from R.Newell (LANL)

Body Unit: Transmission Spectrometer



The spectral band is separated into 3 orders on the CDD:

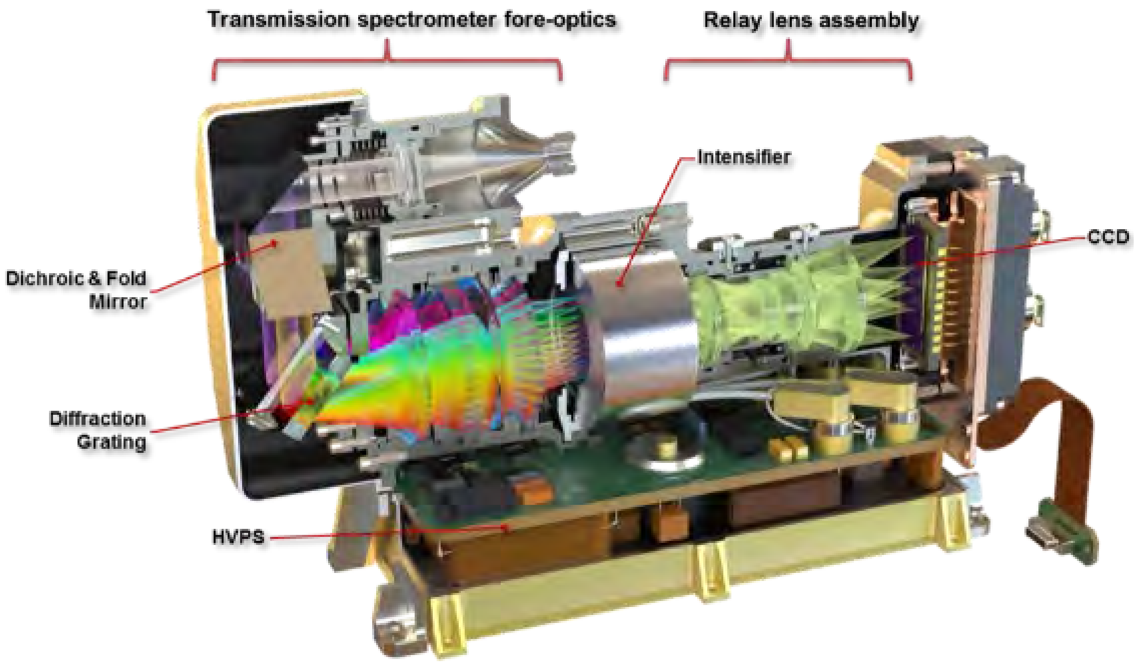
- Green: 535 – 620 nm (150 – 2668 cm-1)
- Orange: 615 – 720 nm (2537 – 4400 cm-1)
- Red: 715 – 853 nm



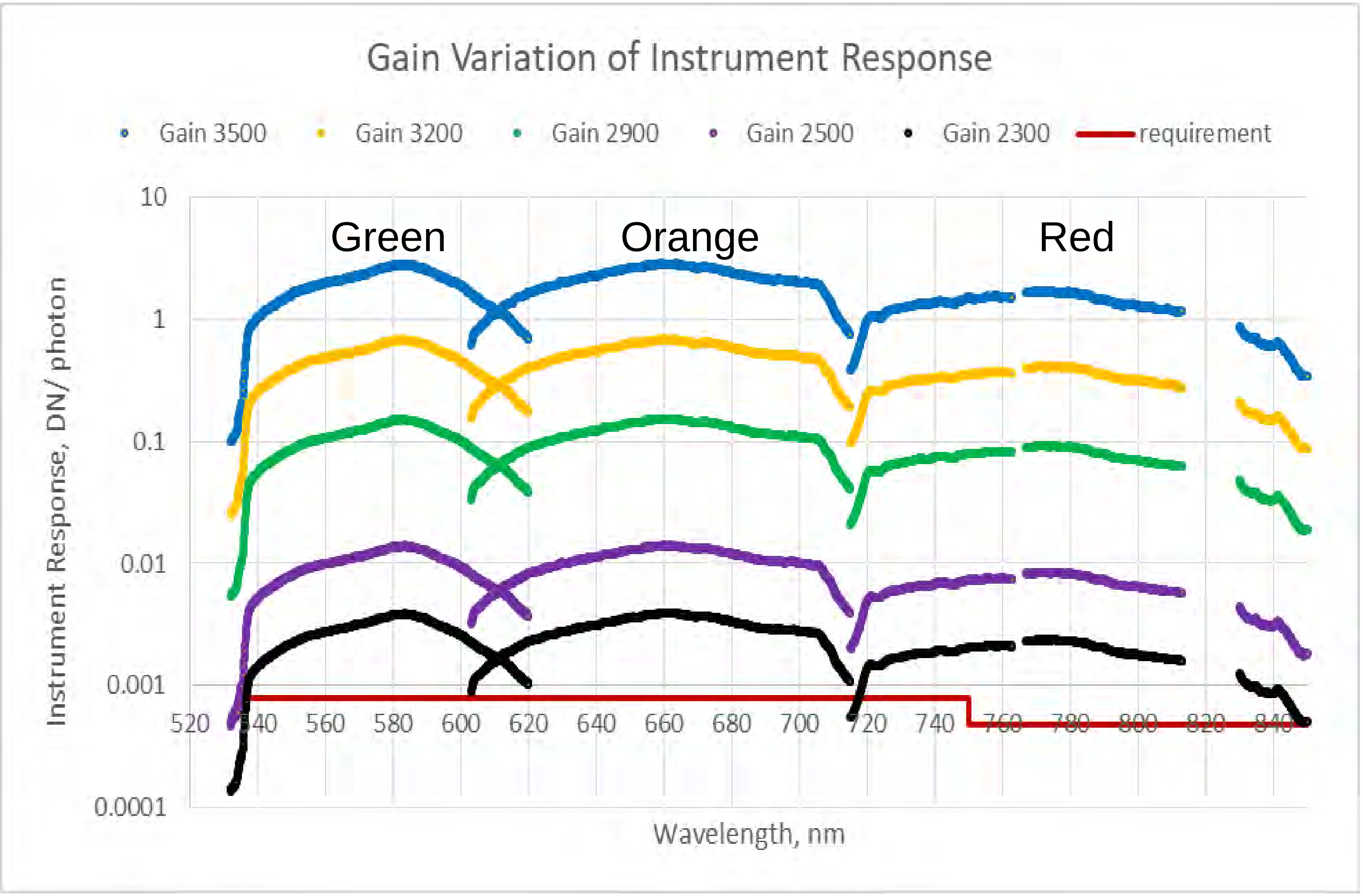
Halogen lamp

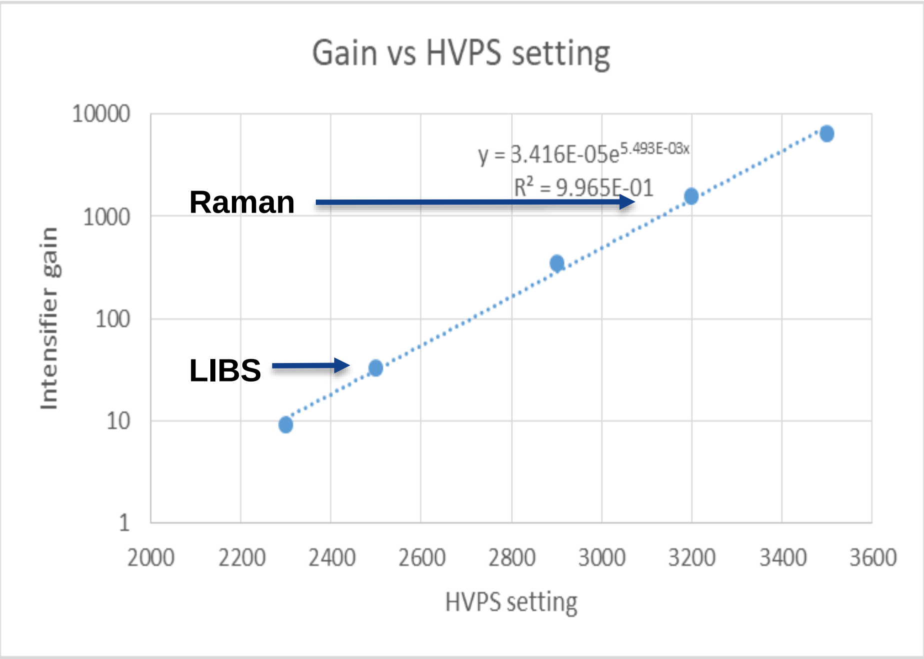
Body Unit: transmission spectrometer

- New high-transmission spectrometer design for SuperCam
- Incorporates an image intensifier powered by a High Voltage Power Supply (HVPS)
- Signal from the Body Unit electronics to the HVPS controls the optical shutter and gain of the intensifier
- Timing:
  - Laser pulse is 4 ns long
  - Timing of shutter has 10 ns increments
  - Min exposure is 100 ns, max exposure is 42.9 sec
  - Delay has 10 ns increments
  - Min delay is 10 ns; max delay (e.g., for TRLS) is 0.33 sec
- Gain (DAC settings):
  - *hvpsGain* = 2300 DAC counts is the minimum
  - *hvpsGain* = 2500 is a typical setting for LIBS
  - *hvpsGain* = 3200 is a typical setting for Raman
  - *(see plot next page)*



Instrument Response Function: Transmission Spectrometer

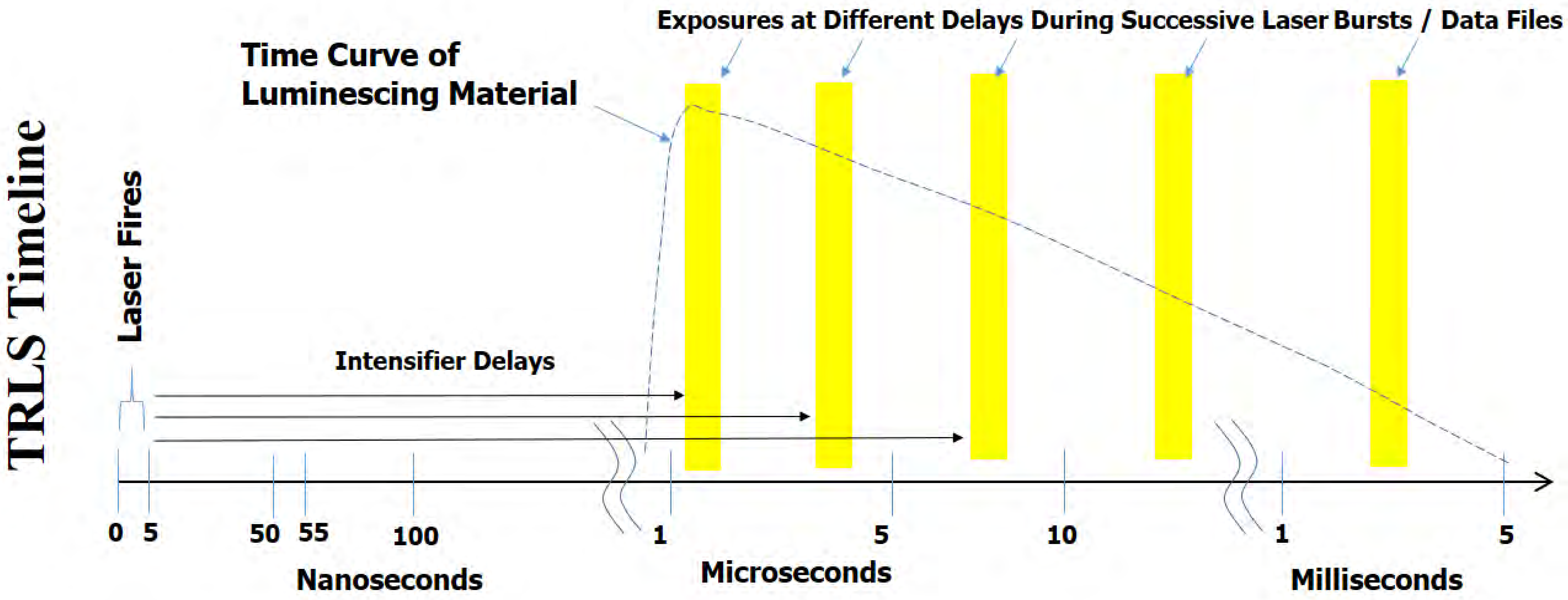




Gain is exponential with HVPS setting

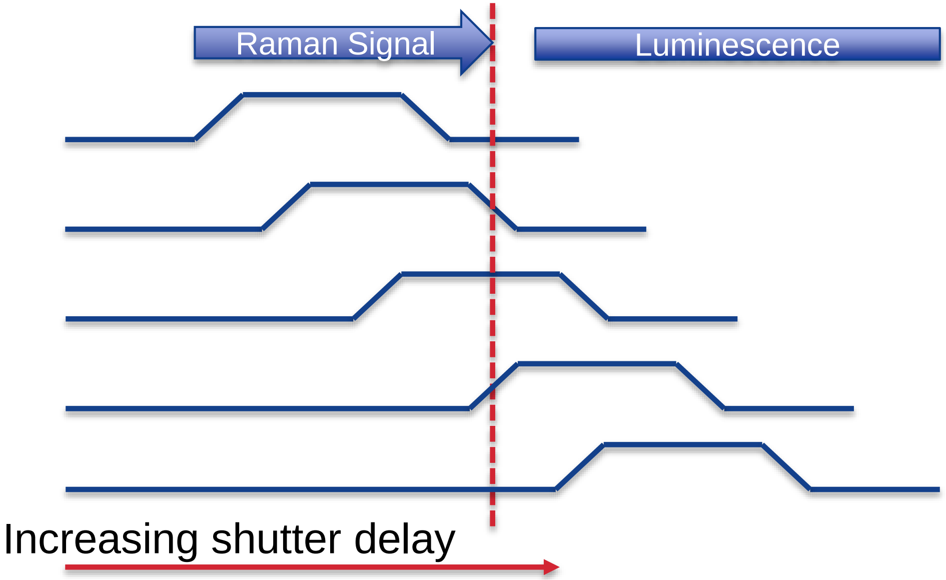
Results from R.Newell (LANL)

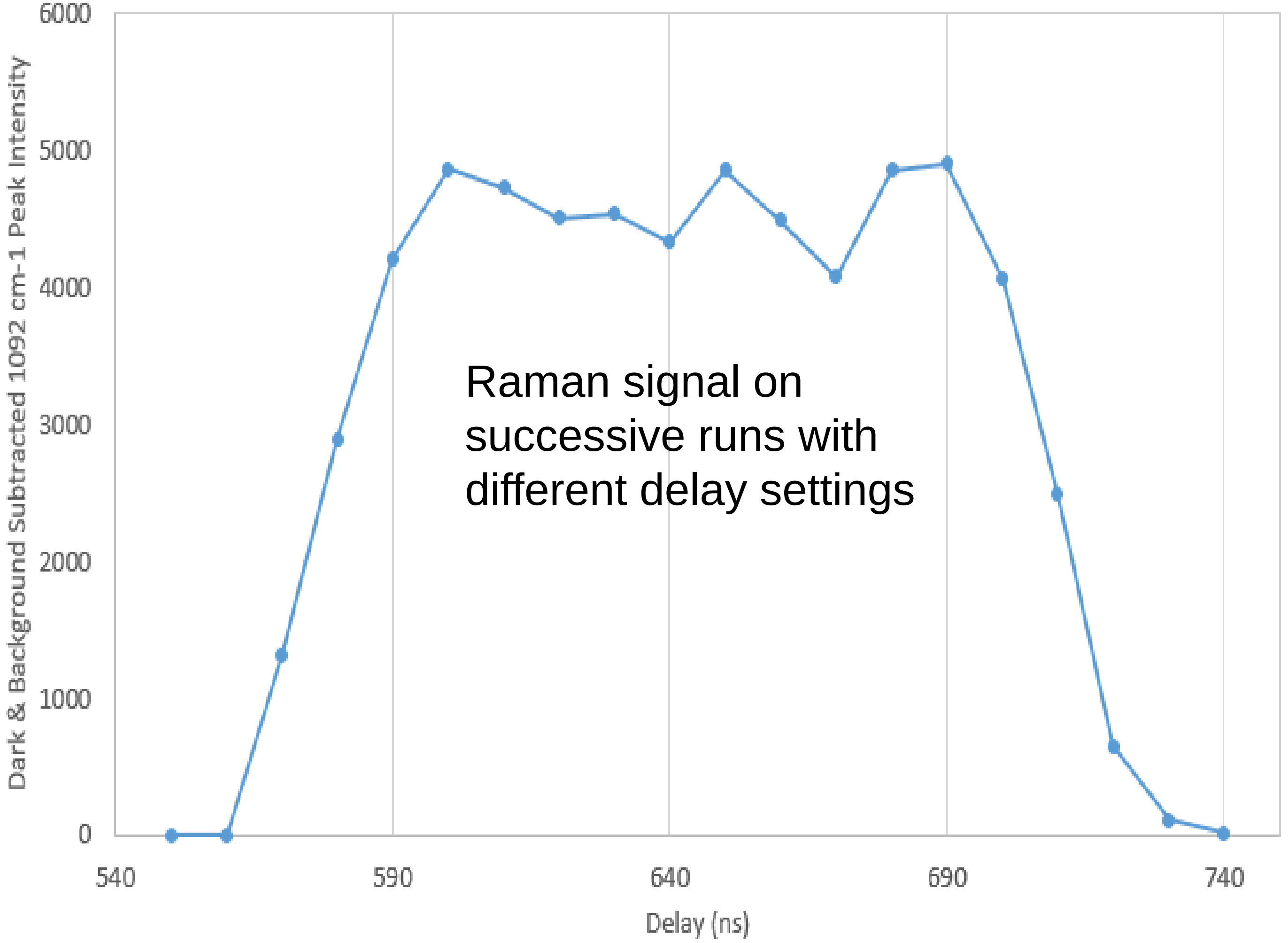
Luminescence Uses Successive Collects with Different Delays



Raman Time Sweep

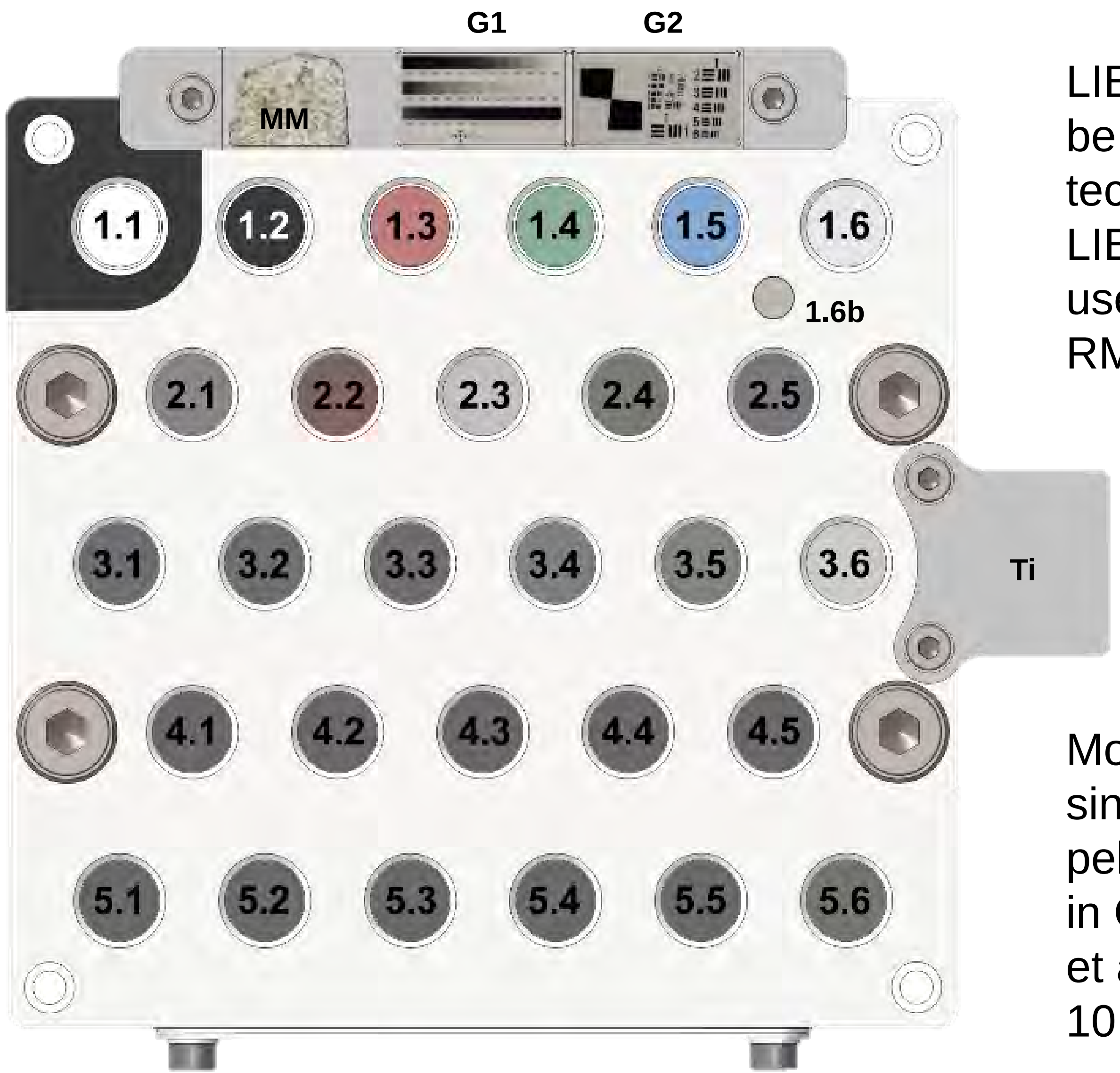
- To check laser-to-spectrometer timing, a series of Raman spectra with successively longer shutter delay times were collected during testing.
  - Shutter delay, stepped at 10 ns intervals.
  - Exposure duration was held constant at 100 ns.
- The chart plots the maximum peak intensity from a calcite target at 5 m, minus the baseline
- Longer delay times would collect luminescence if it was present





(Zero is arbitrarily offset to be well before the laser fires)

Rover Calibration Targets



LIBS targets can be used by other techniques.
LIBS cannot be used on VISIR, RMI

Most targets are sintered pressed pellets, described in G. Montagnac et al., 2018, doi: 10.1002/jrs.5406

Target assembly is mounted 1.55 m from SuperCam, at back of rover

PLACE	DESCRIPTION	PURPOSE
1.1	White (Aluwhite98)	VISIR
1.2	Black (AeroglazeZ307)	VISIR
1.3	Red (LUCIDEON)	RMI
1.4	Green (LUCIDEON)	RMI
1.5	Cyan (LUCIDEON)	RMI
1.6	Ertalyte organic sample (PET)	Raman
1.6b	Diamond	Raman
2.1	Sulfur rich target (K sulfate)	LIBS +
2.2	Chert	LIBS +
2.3	Calcite (Ca Carbonate)	LIBS +
2.4	Ferrosilite (orthopyroxene)	LIBS +
2.5	Apatite (phosphate)	LIBS +
3.1	Orthoclase (feldspar)	LIBS +
3.2	Diopside (Clinopyroxene)	LIBS +
3.3	Olivine (silicate)	LIBS +
3.4	Andesine (plagioclase)	LIBS +
3.5	Enstatite (pyroxene)	LIBS +
3.6	Serpentine	LIBS +
4.1	Basalt BHVO2	LIBS +
4.2	Soil analog JSC-1	LIBS +
4.3	Ankerite (Ca, Fe, Mg, Mn carbonate)	LIBS +
4.4	Siderite	LIBS +
4.5	MN1 (manganese nodule standard)	LIBS +
5.1-5.5	Glasses doped in Li, Cr, Mn, Ni, Cu, Zn, Rb, Sr, Ba	LIBS
5.6	Shergottite synth. glass (ChemCam)	LIBS
MM	Mars meteorite NWA10170	RMI
G1	Geometric target 1 (gray scale)	RMI
G2	Geometric target 2 (USAF)	RMI
Ti	Metal plate for wavelength calibration	LIBS

LIBS+ Targets

Rock-Powder standards
- Basalt *BHVO2*
- Soil Analogue *JSC*
- Mn-rich *JMN-1*
- Chert

Minerals
- Olivine
- Enstatite
- Ferrosilite
- Diopside
- Orthoclase
- Andesine

Minor-doped silicates
- NTE01 *Cu*
- NTE02 *Cr, Mn, Zn, Ba*
- NTE03 *Zn, Rb*
- NTE04 *Li, Sr*
- NTE05 *Ni*

Phosphates
- Apatite *TAPAG*

Carbonates
- Calcite *Ca*
- Ankerite *Mg*
- Siderite *Fe*

Sulfates
- Mixture K2SO4/BHVO2 basalt

Hydrated silicate
- Serpentine

ChemCam Souvenir
- Shergottite

Sample Characterization

Homogeneity

XRF image: elemental composition, homogeneity

532nm **Raman** Imaging: microstructure, homogeneity

UPV EHU

Micro-imaging: identify cracks before/after testing

Quantitative composition

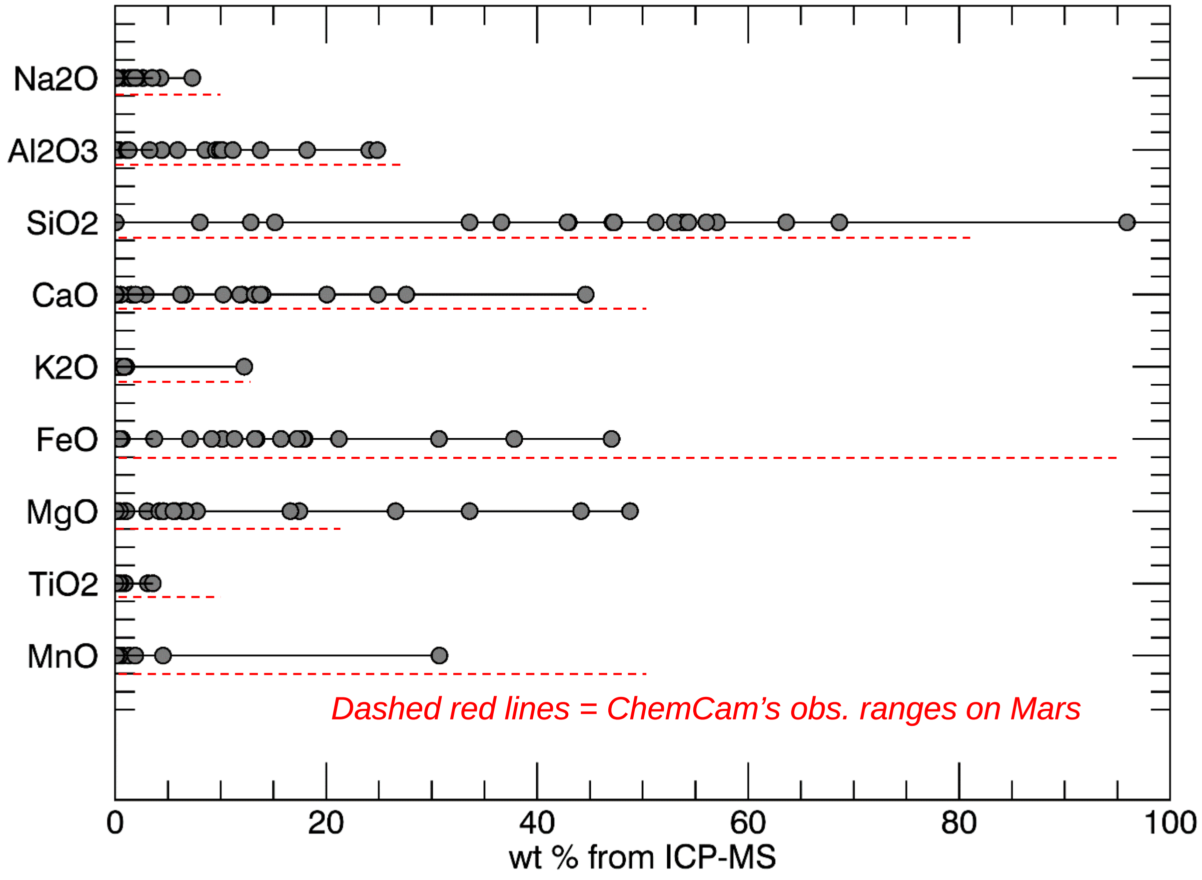
LIBS (Mars conditions): LIBS homogeneity, spectral evaluation

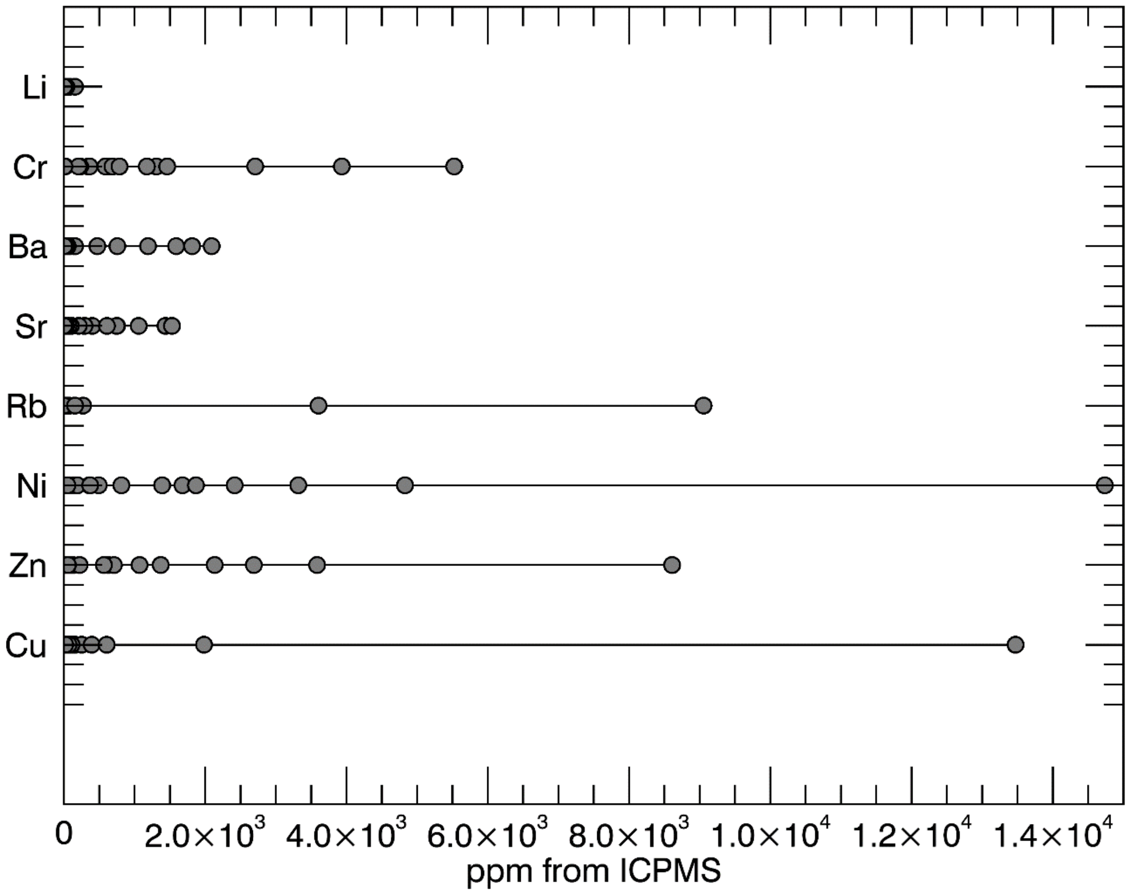
Microprobe: homogeneity, chemical composition

LA-ICPMS: exact chemical composition

Sample Compositions

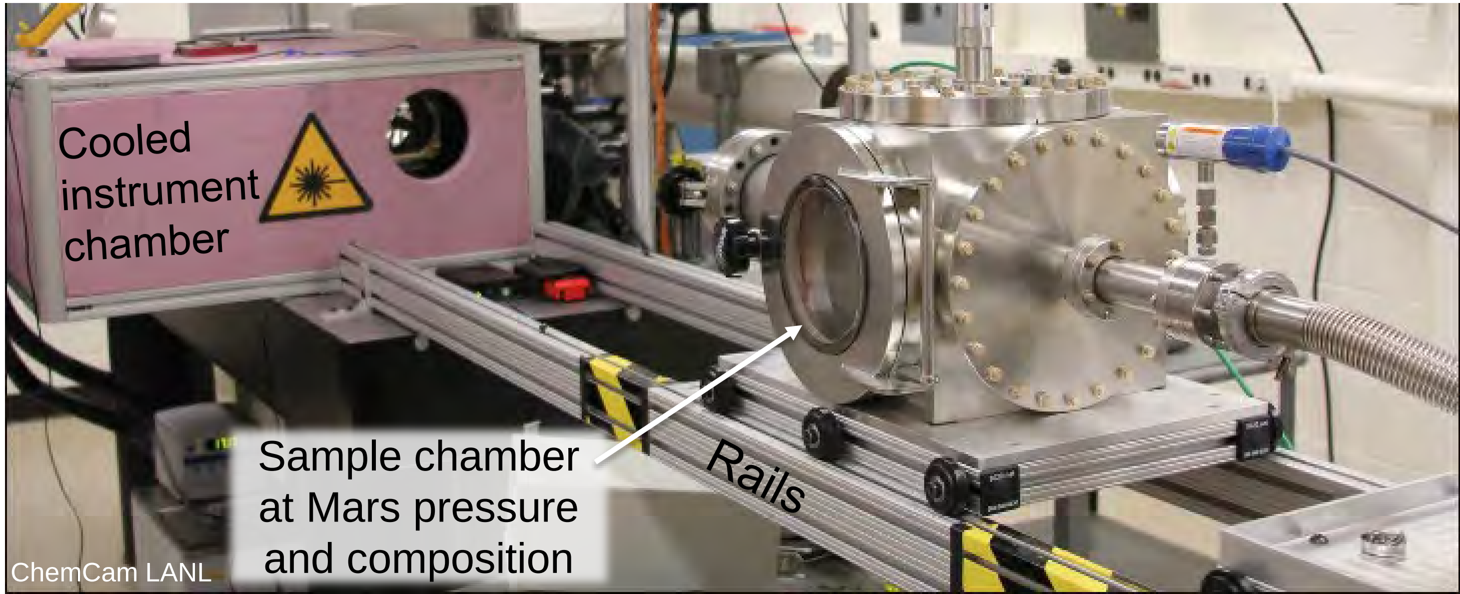
Range of compositions from ICPMS results





Laboratory Instruments

- We are working on having 2 lab clones of SuperCam, one in Toulouse and one in LANL
- Capabilities
  - Lab clones are expected to be fully functional in LIBS, Raman, and RMI
  - Lab clones will operate in air; Toulouse clone at room temperature; LANL at -10
  - Neither clone is expected to have an IR spectrometer
    - It would not work unless at Mars temperature (around -30) anyway
  - Neither clone is expected to have a microphone mounted like on SuperCam
    - Must be done with mic in a Mars chamber; see next page
  - LANL has > 500 standards, sufficient for any additional LIBS calibration work
- Availability
  - Completion time frames are late this year
  - Treated generally as user facilities; seen as collaborative; scientists can request to bring samples for analysis if they have a good rationale



Laboratory Instruments II

- For microphone and IR experiments (these will not be physically attached to the clones)
  - We expect to set up a microphone in a chamber, likely at LANL and other places. Challenges include
    - Echos off chamber walls. Echos may be discriminated against via arrival time.
    - Experiments other than LIBS acoustics (e.g., sound speed, T gradients, wind sounds) may require large chambers. There is a multi-meter-size chamber within the team (located in Europe), so it may well be feasible to collaborate with that set-up.
  - For IR experiments, we expect to have IR spectrometers that will mimic SuperCam's capabilities, and we think we can simulate co-bore-sighted capabilities, e.g., by placing an aperture to limit IR FOV to that of SuperCam. These experiments will require some time for set-up, including proper illumination, etc.
- Samples: For LIBS (Mars atmosphere chamber), samples need to be small but not tiny (e.g., 1-3 cm optimal). We use a turret to load many samples and analyze without breaking vacuum. For non-LIBS, samples are less constrained in size, but keep in mind the analytical footprint sizes.
- General collaborative protocol
  - It is useful to visit the facility to understand constraints and capabilities, although trained personnel will run the samples.
  - We would likely agree to run a very few samples (e.g., half a dozen) initially, and potentially run more upon seeing the outcome.
  - We will prioritize experiments based on the needs of the mission and science

Mars 2020 Project
SUPERCAM

Mars 2020 Project

Informational Webinar

Ann Ollila
Data, Results, Calibration

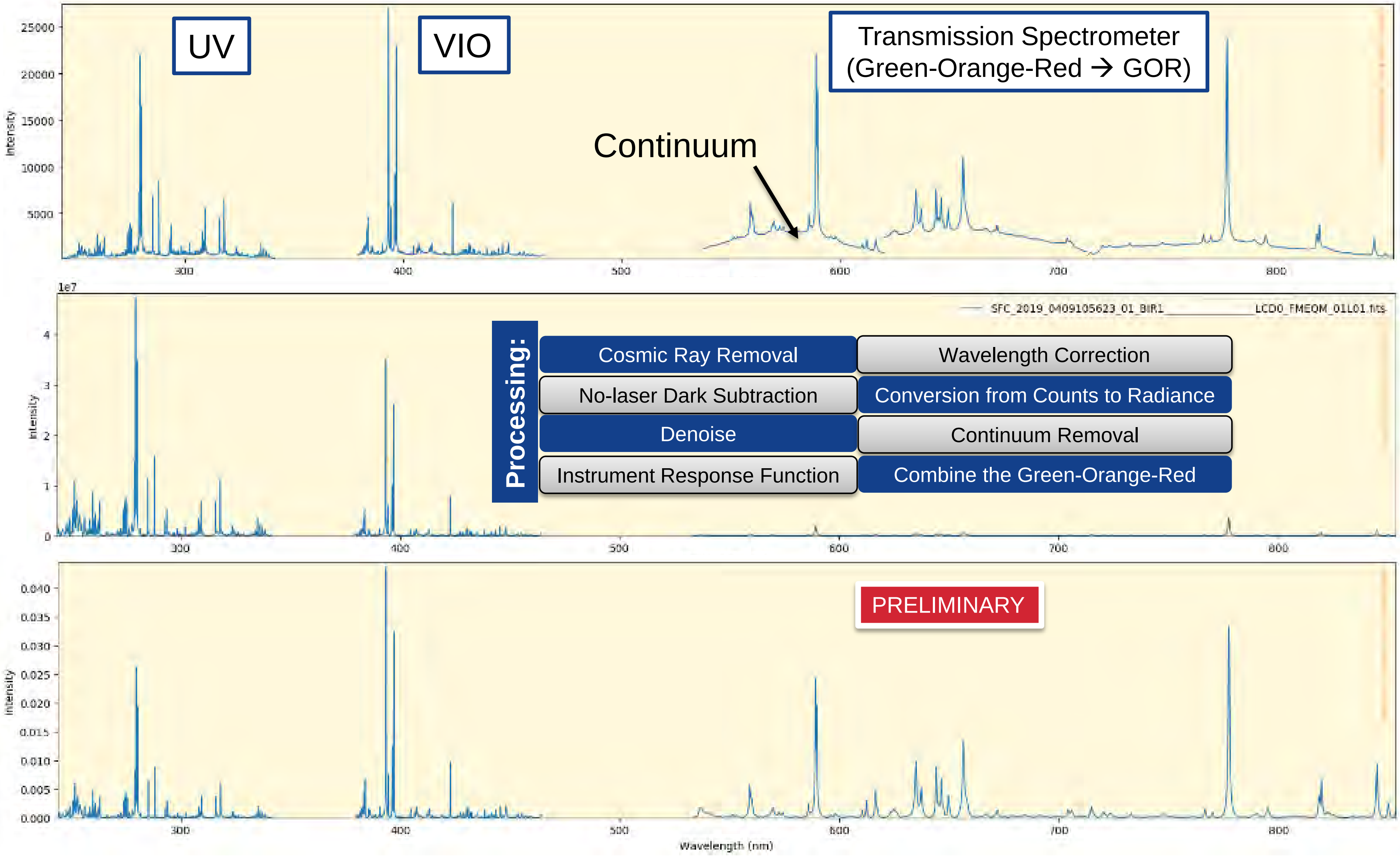
25-February-2020

Agenda

Time	Duration	Topic	Presenter
9:00	0:30	Project investigations, goals	Sylvestre Maurice
9:30	0:25	Instrument description	Roger Wiens
9:55	0:25	Data, results, calibration	Ann Ollila
10:20	0:15	Operations	Olivier Gasnault
10:35	0:15	Q&A	
10:50	0:10	Margin	

LIBS Processing Pipeline: Example USGS Basalt (BIR1)

Mars 2020 Project
SUPERCAM



XDR: Experimental Data Record
-Essentially unprocessed
-Wavelength ordered
-Overlapping regions clipped
-Intensity units: Counts

CDR: Calibrated Data Record
-Processed
-Output in FITS format
-Intensity units: Radiance (photons/pulse/mm^2/sr/nm)

Final Step:
Normalization
-Divide by the sum of the total emission (all or by spectrometer)

LIBS: Data Collection and Quantitative Modeling

- LIBS data are generally collected as 30 laser shots/analysis point. The initial ~5 shots are typically contaminated with dust and are removed from averages. Depth profiles of up to 500 shots may be conducted to search for coatings/thin layers.
- Both multivariate and univariate modeling are being explored for the quantification of major and minor/trace elements [e.g. Wiens et al, 2013].
- Multivariate analysis (MVA) modeling is generally employed for quantification of major elements and those minor/trace elements that reach major element-like concentrations (% level, e.g. Mn, Cr, etc). [e.g. Clegg et al., Spectrochimica Acta B, 2017; Anderson et al., Spectrochimica Acta B, 2017]
- Univariate modeling (peak area calibration curves) are generally used for minor/trace elements when they are at low (<1 wt. %) concentrations [e.g. Payre et al., JGR, 2017; Ollila et al., JGR, 2014].
- Shortly after landing, it is expected that compositions for major elements (SiO_2, Al_2O_3, FeOT, TiO_2, CaO, MgO, Na_2O, and K_2O) and several trace elements (e.g. Li, Ba, Sr, and Rb) will be made available.
- Other elements will be modeled as needed based on the compositions of the martian targets (e.g. Cu, Zn, CaF, Ni). Additional standards may need to be added to the spectral library to allow for modeling of other elements. To ensure compatibility with the SuperCam flight instrument, these spectra must be collected on one of the SuperCam lab units.
- Models built using library spectra will be tested using spectra collected from the calibration targets; these will be analyzed in stages as resources allow and therefore compositional results may not be available immediately. However, basic information (e.g. Si-rich, alkali-poor, or Fe-rich) will be available immediately.
- The literature is rich in new modeling techniques to explore! We will initially test a number of models (e.g. PLS and LASSO) to find the optimal one but there are many others that could be explored with this rich dataset.

LIBS Spectral Library: Overview

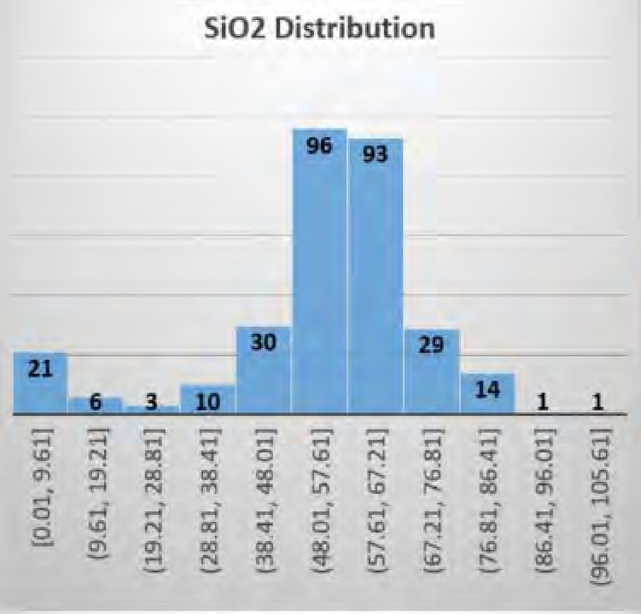
- A suite of ~306 geological materials (pressed pellets) plus the on-board calibration targets were analyzed in April 2019 with the Flight Model of the Body Unit and the Qualification Model of the Mast Unit at 2.8 m. The calibration targets were also analyzed at 1.55 and 4.25 m.
- This is the best available dataset for modeling until such time as the lab units are available.
- Once the spectra collected on the lab units have been calibrated to match the flight model spectra (as assessed by comparisons of spectra taken on the calibration targets), additional targets may be added to the library for new modeling.
- Overview of the compositions of the geological materials analyzed (excludes the previously discussed calibration targets):

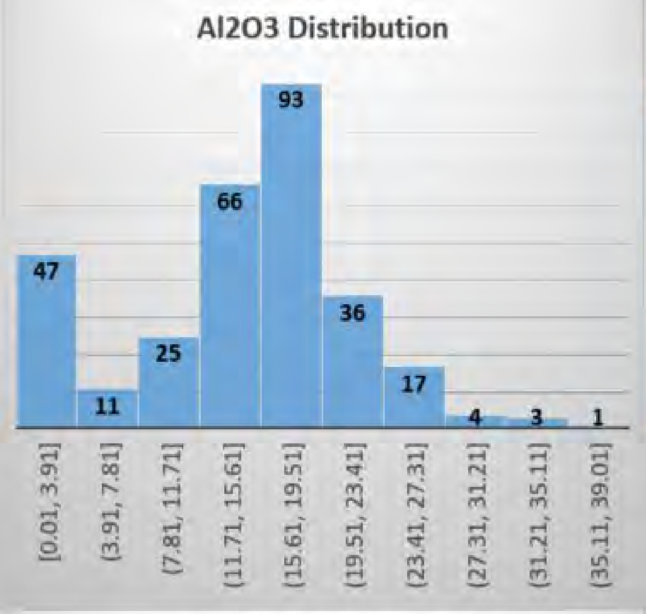
Igneous, Primary	16	Andesite/diorite
	45	Basalt/gabbro/dolerite/norite
	5	Rhyolite/granite
	6	Olivine
	15	Feldspar-rich (Anorthosite, labradorite, anorthite, bytownite, trachyte, syenite)
	10	Pyroxenes (Augite, diopside, enstatite)
Sedimentary, Secondary, Accessory	8	Phyllosilicates (Nontronite, kaolinite, serpentine, mica, griffithite)
	4	Sulfates (gypsum)
	6/3	Stream/marine sediments
	8	Fe-rich (Hematite, ilmenite, magnetite, BIFs)
	11	Carbonates (Limestones, dolomites, magnesite, C-org rich shale, C-rich sediments)
	13	Mn-rich (e.g. hollandite, todorokite, heterosite, rhodonite, psilomelane, ores)
	135	Sedimentary rocks (provided by S. McLennan, from Australia, Greenland, Africa, New Mexico, Colorado, etc.)
Other	11	Misc. (e.g. Sodalite, flint, obsidian, tuff, glass, scoria, silicrete)
	8	ChemCam Calibration Targets (Glasses: Shergottite, Norite, Picrite, Macusanite; Ceramics: NAU2-High Sulfur, NAU2-Medium Sulfur, NAU2-Low Sulfur, KGa2-Medium Sulfur)

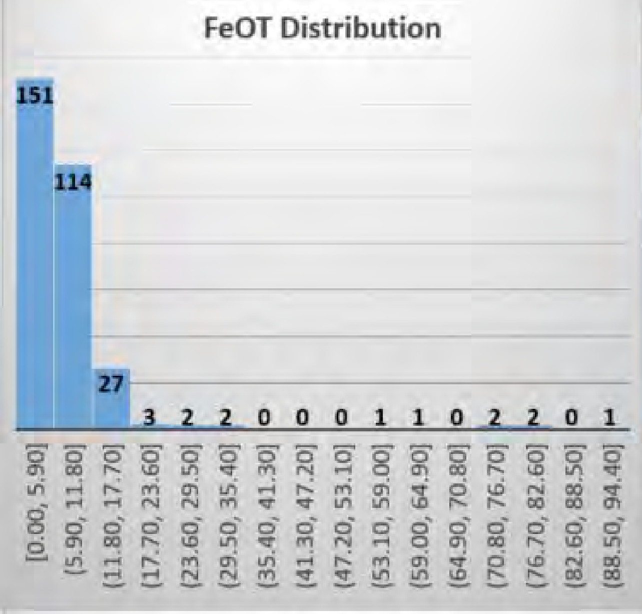
LIBS Composition Database: Major Element Distributions (wt. %)

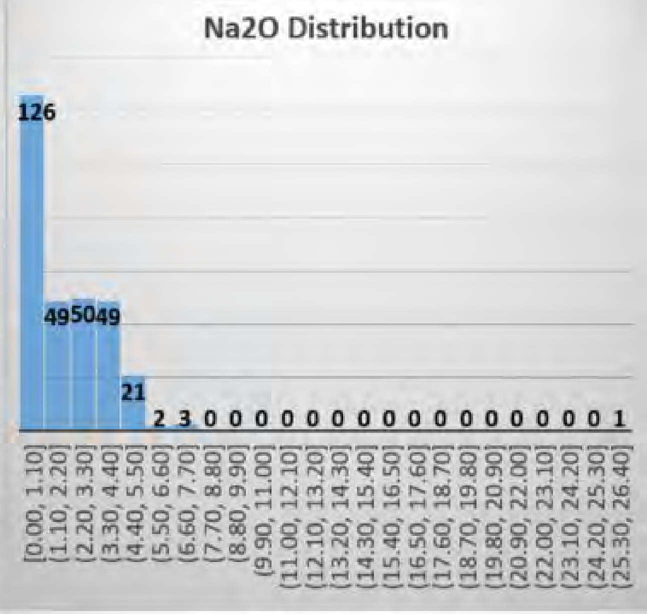
Mars 2020 Project
SUPERCAM

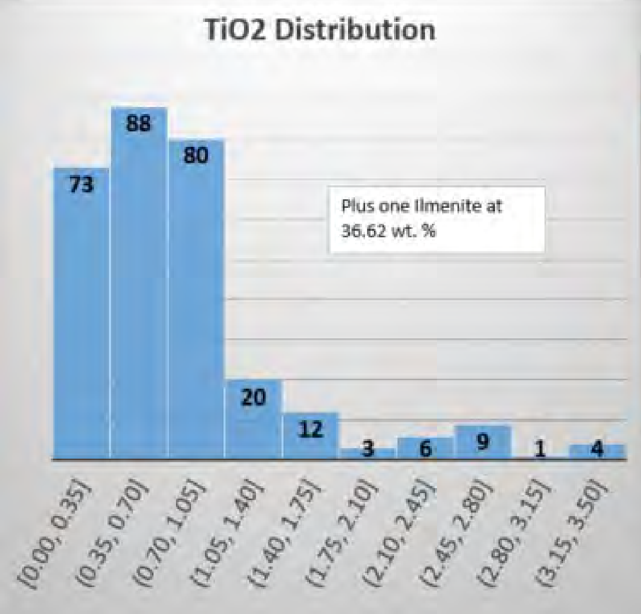
CENTRE NATIONAL D'ETUDES SPATIALES

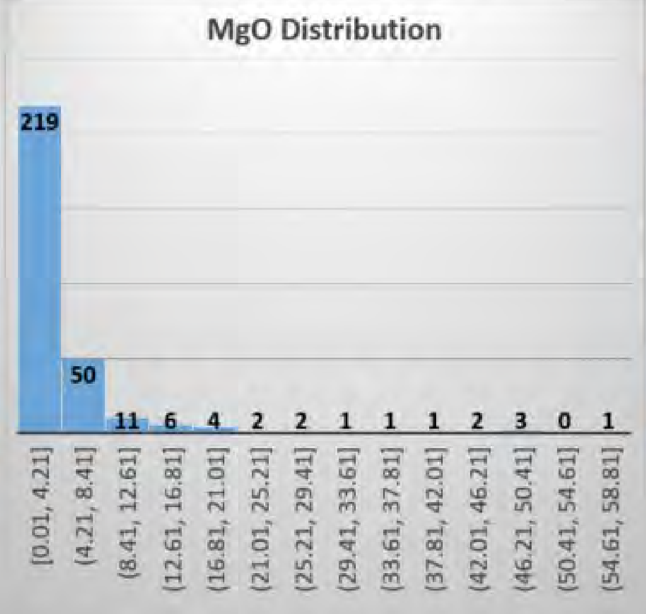


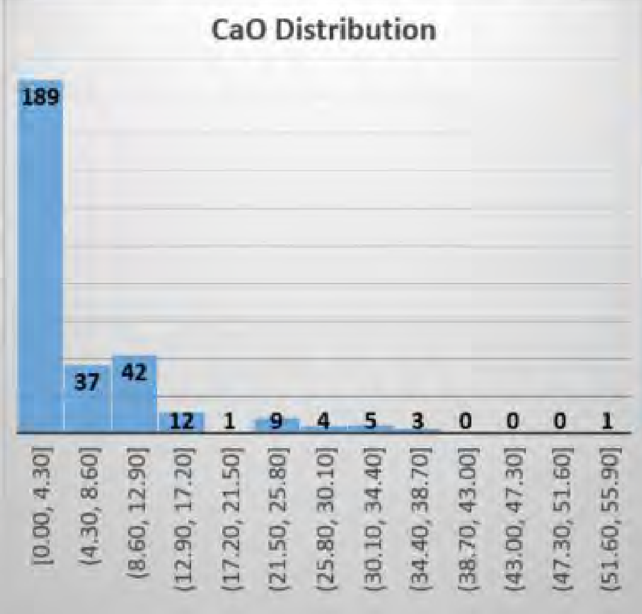






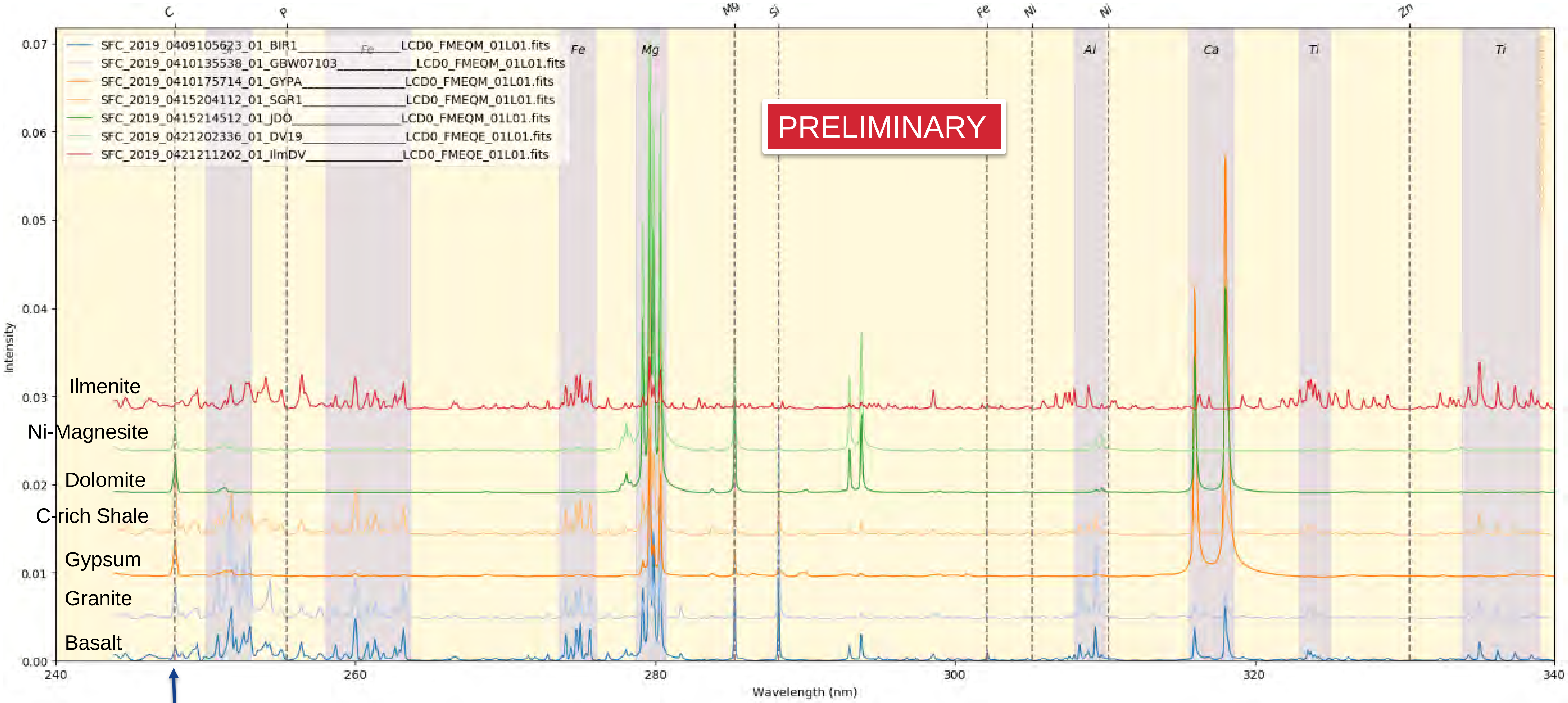






Example LIBS Spectra: UV Region

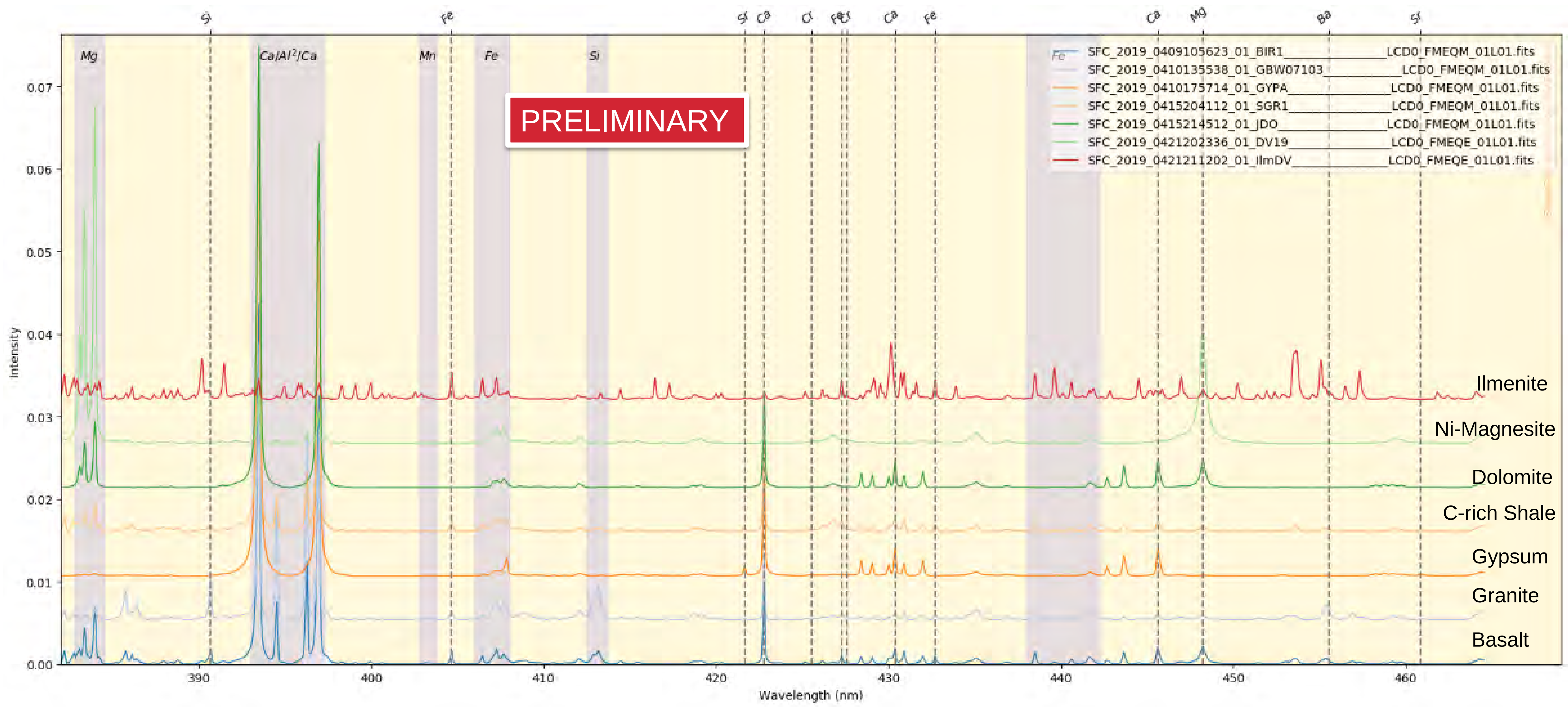
Mars 2020 Project
SUPERCAM



C present in all spectra –
atmospheric breakdown

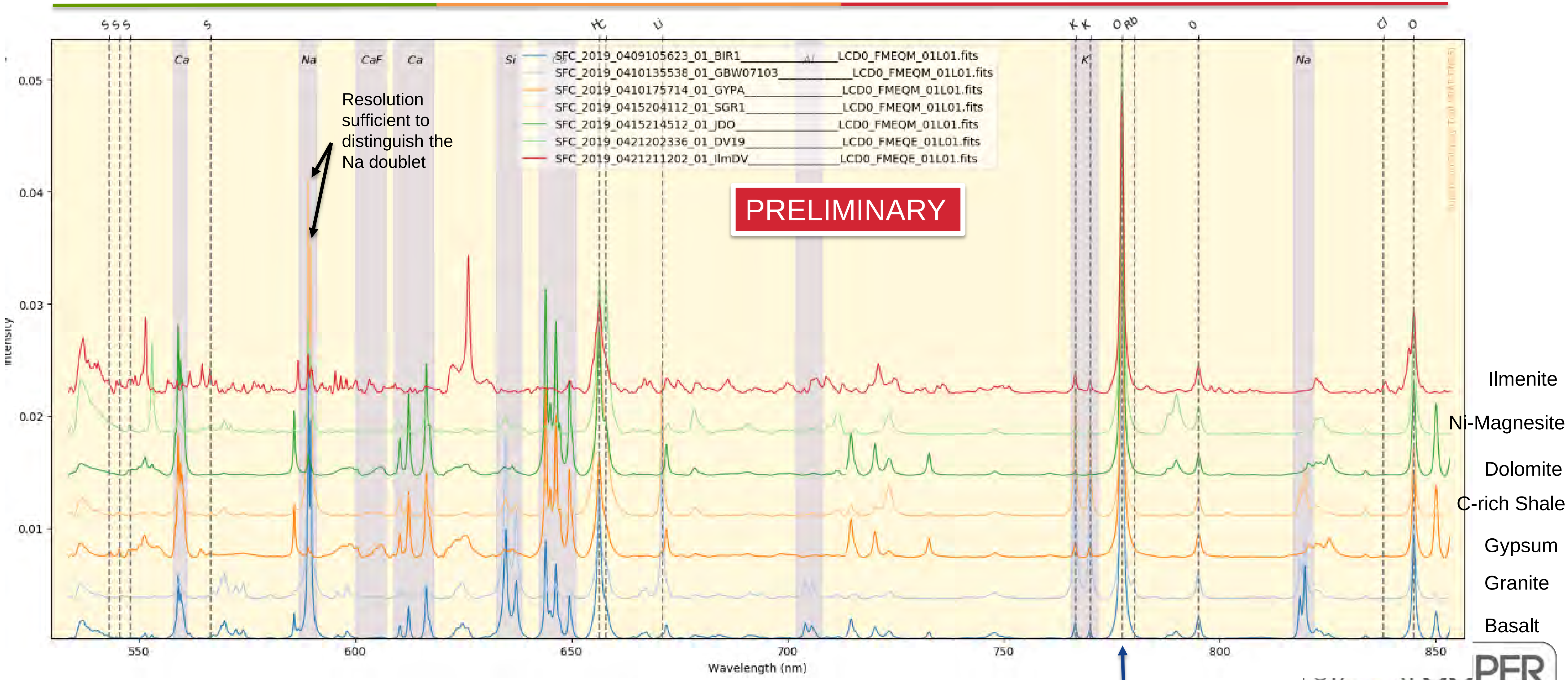
Example LIBS Spectra: VIO Region

Mars 2020 Project
SUPERCAM



Example LIBS Spectra: GOR (Green-Orange-Red) Region

Mars 2020 Project
SUPERCAM



O present in all spectra – sample + atmospheric breakdown

Raman Spectroscopy: Overview

- Minerals will be identified but not quantified.
- Spectra will likely be collected as averages of up to 200 single shots. There is the option to do co-additions (continuous collection on the CCD) or combinations of co-additions and single shots (e.g. 10 co-adds 10 times).
- Processing will be minimal: Non-laser dark subtraction, wavelength calibration (based on LIBS with input from the Raman-active calibration targets), instrument response function, denoise.
- Raman spectra were collected with several instrument configurations but mostly EQM-EQM and FM BU-EQM MU.
- Challenges: Fine-grained materials and opaque minerals

Minerals Analyzed (note: not all have independent mineralogical confirmation and detections are highly sample dependent)

Raman Features Present:

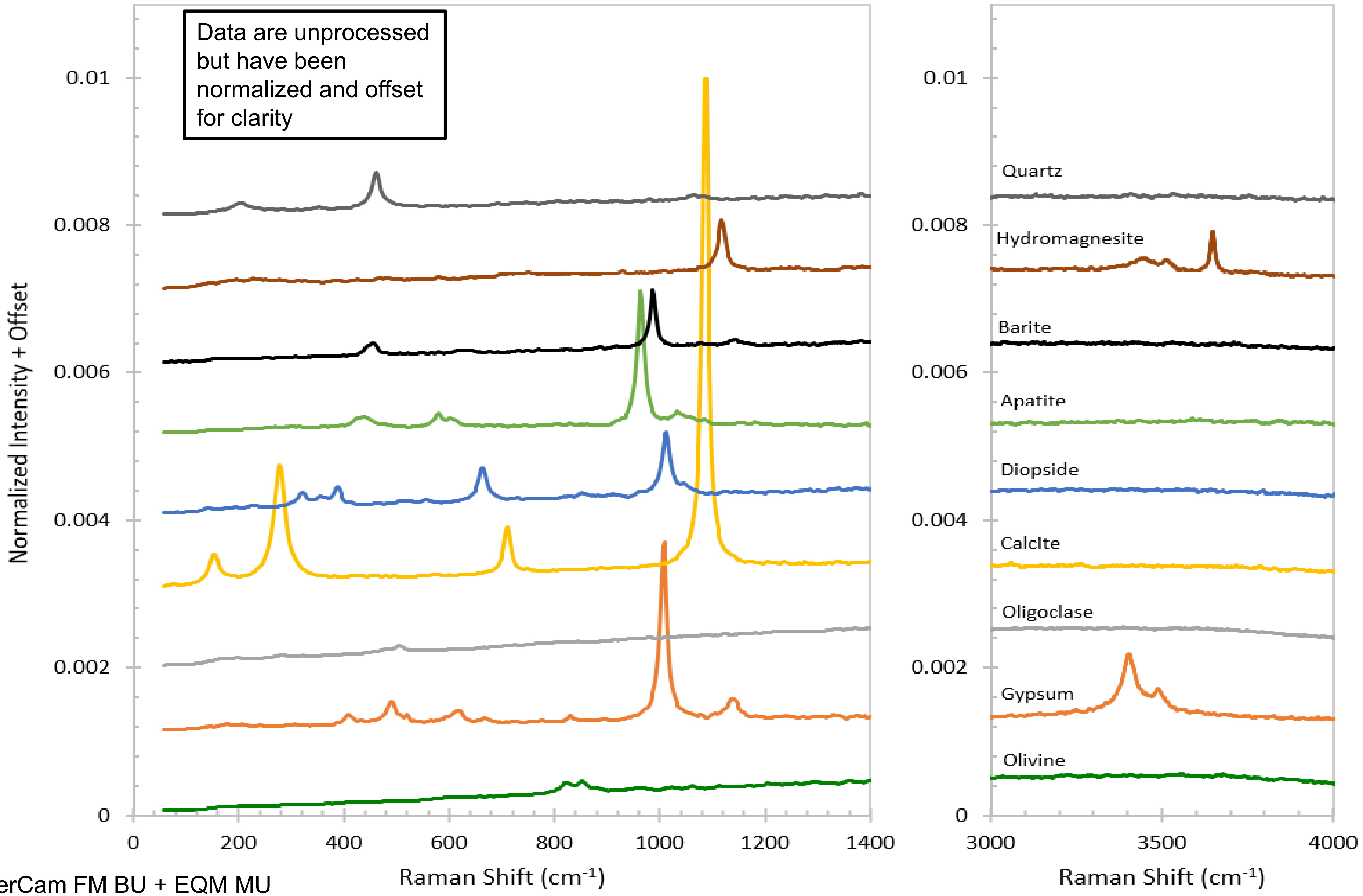
- Apatite
- Gypsum (chemical powder, selenite)
- Calcite
- Quartz
- Hydromagnesite
- Barite
- Olivine (forsteritic)
- Magnesite
- Diopside
- Coquimbite
- Labradorite
- Siderite
- Zircon
- Talc
- Dolomite
- Anhydrite
- Microcline
- Fluorite
- Oligoclase
- Topaz
- Rutile (~maybe~)
- Apophyllite

No Raman Features Present (generally consistent with lab units that use 532 nm laser excitation):

- Bytownite
- Sanidine
- Chlorite
- Enstatite (~maybe~)
- Hornblende
- Antigorite
- Pyrite
- Tremolite
- Muscovite
- Orthoclase
- Vermiculite
- Andesine
- Aragonite (~maybe~)

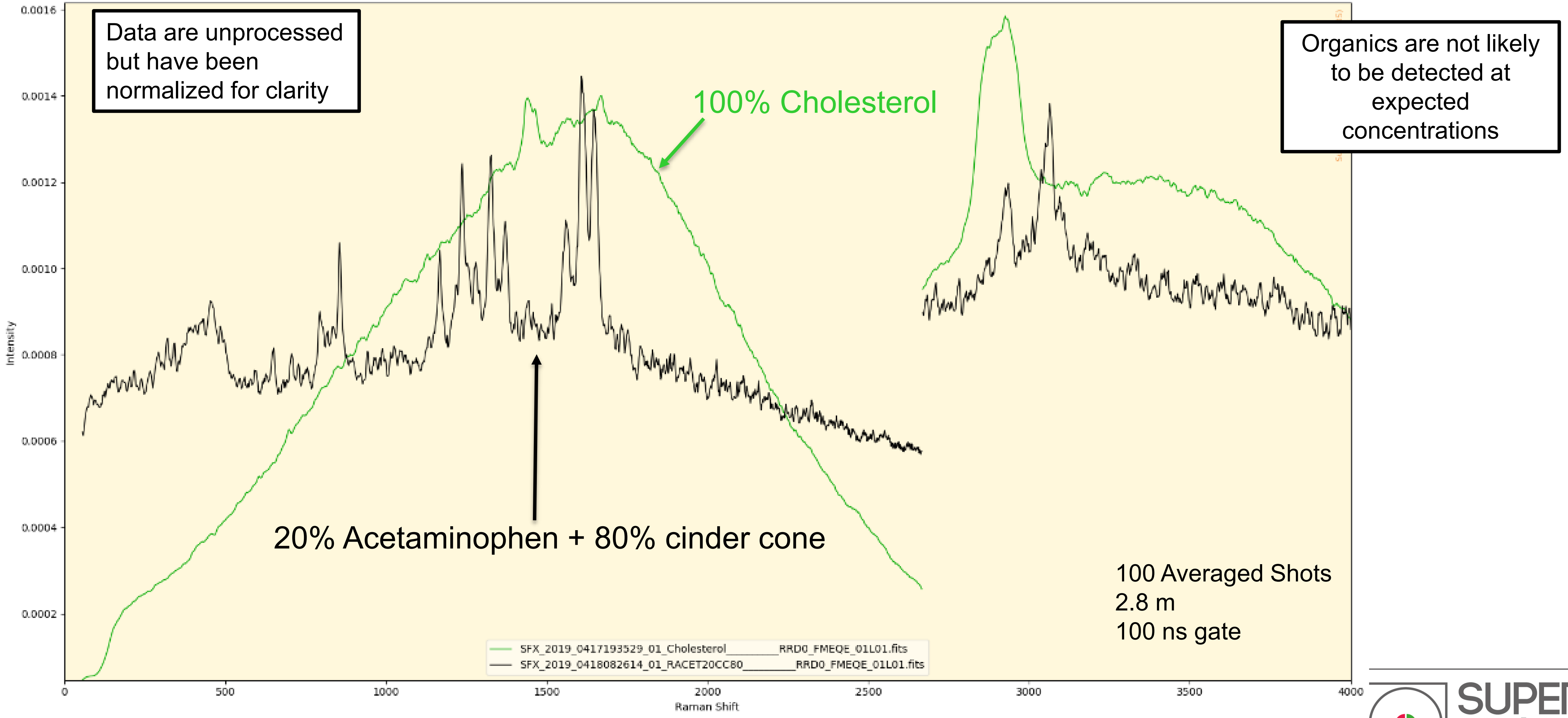
100 Averaged Shots
2.8 m
100 ns gate

Raman Spectra Examples



SuperCam FM BU + EQM MU

Raman Spectra Examples: Organics



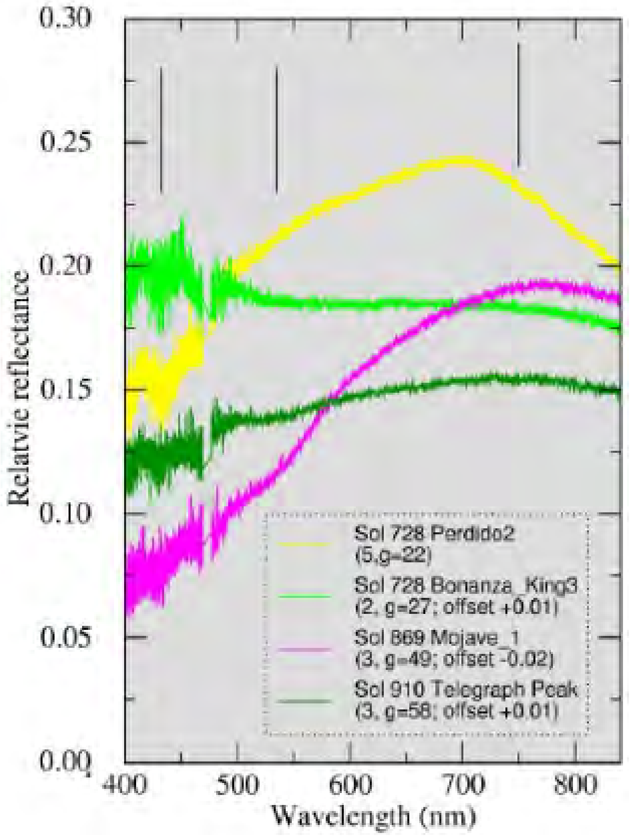
VISIR Spectroscopy

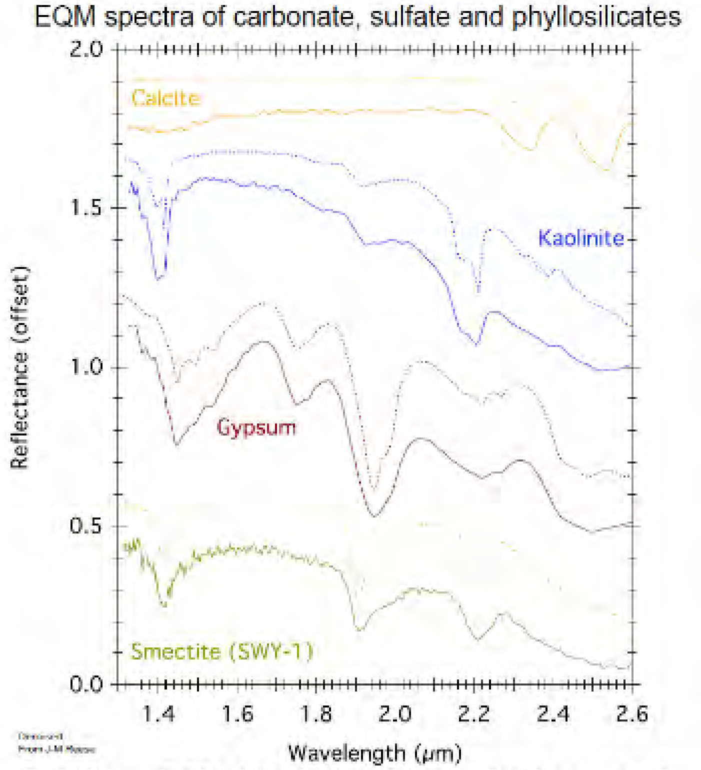
- SuperCam is able to collect reflectance spectroscopy observation
- Two main ranges are available:
  - The VIO+GOR (Green-Orange-Red) spectrometers that range from 0.4 microns to 0.9 microns
    - This mode is similar to the ChemCam mode [Johnson et al., Icarus, 2014]
  - The new IR mode that ranges from 1.3 microns to 2.6 microns
    - This mode uses an AOTF spectrometer with 256 channels.
    - It has a resolution of 26 cm^{-1} (i.e. 5 nm @ 1.4 microns and 20 nm @ 2.4 microns)
- Dedicated calibration targets are available on-board:
  - White target (Aluwhite98)
  - Black target (AeroglazeZ307)
- A library of VISIR spectra imported from the CRISM database (https://pds-geosciences.wustl.edu/missions/mro/spectral_library.htm) and resampled at the IR resolution is also available for comparison.

VISIR Example Spectra

- The IR and VIO+GOR data may be collected alone or together in succession.
- The IR spectrometer has an autoexposure function to set the exposure time while the VIO+GOR must be manually set to the desired integration time.
- A limited suite of IR data was collected with SuperCam and no VIO+GOR data was collected.

Example of VIO+VNIR passive data from ChemCam of drill tailings and fresh surfaces [modified from Johnson et al., Icarus, 2014; parenthetical notes refer to raster location number and phase angle of observation]





Solid lines=EQM data; Dashed lines= database spectra

Example of IR Data from SuperCam taken with the EQM compared with library spectra

IR Spectral Parameters

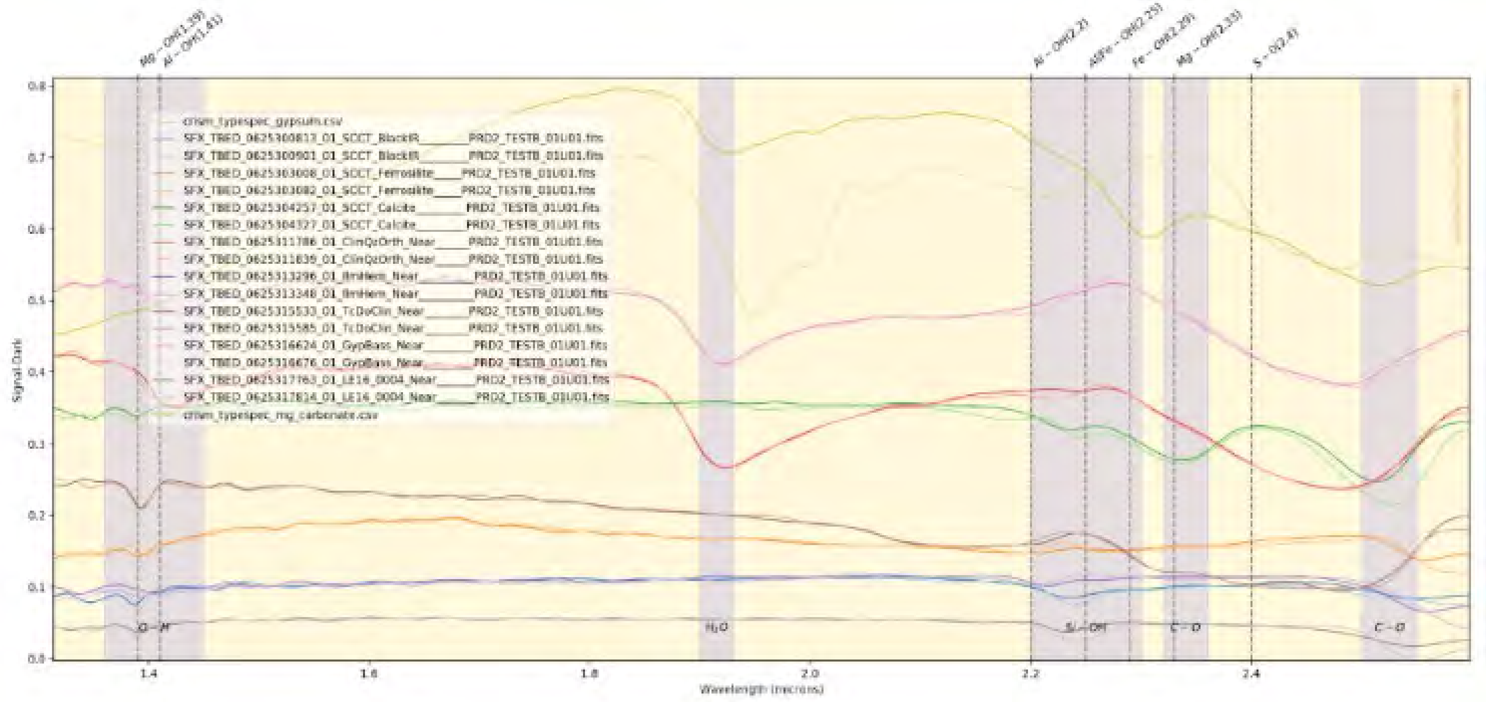
Mars 2020 Project
SUPERCAM

CENTRE NATIONAL D'ETUDES SPATIALES

- A set of spectral parameters as defined in Viviano-Beck et al. (2014) are available
- Examples from data collected during thermal testing are shown here.

Filename	BD1400	BD1750	BD1900	DB2200	BD2100	BD2265	BD2290	BD2355
SFX_TBED_0625303082_01_SCCT_Ferrosilite_____PRD2_TESTB_01U01,fits	-0,014	0,001	-0,011	0,011	0,011	0,014	0,023	0,005
SFX_TBED_0625304327_01_SCCT_Calcite_________PRD2_TESTB_01U01,fits	-0,011	0,016	0,005	-0,049	-0,07	-0,009	-0,017	0,086
SFX_TBED_0625311839_01_ClinQzOrth_Near______PRD2_TESTB_01U01,fits	0,087	-0,003	0,177	-0,045	-0,056	-0,103	-0,038	0,011
SFX_TBED_0625313348_01_IlmHem_Near__________PRD2_TESTB_01U01,fits	-0,022	0,009	0,025	0,024	0,015	-0,093	0	0,029
SFX_TBED_0625315585_01_TcDoClin_Near________PRD2_TESTB_01U01,fits	-0,079	-0,001	-0,044	-0,178	0,144	-0,165	0,054	0,048
SFX_TBED_0625316676_01_GypBass_Near_________PRD2_TESTB_01U01,fits	0,046	0,003	0,093	-0,025	0,018	-0,101	-0,029	-0,004
SFX_TBED_0625317814_01_LE16_0004_Near_______PRD2_TESTB_01U01,fits	-0,201	-0,001	-0,005	0,212	-0,587	0,267	-0,331	-0,013

Mineralogy of Targets:
Ferrosilite = Ferrosilite
Calcite = Calcite
IlmHem = Ilmenite + hematite
TcDoClin = Talc + dolomite + clinochlore
GypBass = Gypsum + basanite
LE16_0004 = Olivine + Serpentine
ClinQzOrth = Clinoptilolite + Quartz + Orthoclase



SuperCam spectra taken with the FM during thermal testing at JPL

MARS 2020
SUPER CAM

Time-Resolved Luminescence Spectroscopy (TRLS)

- Both minerals and organics may produce luminescence (organic luminescence is generally referred to a fluorescence).
- Organic fluorescence is typically intense and short-lived (several ns) while mineral luminescence has variable intensity and may occur on the nanosecond scale (rarely) up to milliseconds.
- Due to the minimum gate width of 40-100 ns and ~10 ns of jitter in timing, identifying organics may be difficult but prompt fluorescence due to organics may be observed.
- However, mineral luminescence, which is generally caused by trace element impurities or radiation damage, is prevalent in SuperCam data, e.g. in phosphates, carbonates, and silicates.
- REE luminescence from Sm^{3+}, Dy^{3+}, Nd^{3+}, Pr^{3+}, etc have been observed by SuperCam in apatites and zircon. Mn^{2+} luminescence has been seen in carbonates and Fe^{3+} has been observed in feldspars.
- Luminescence data collection on Mars will likely consist of 40-100 single shots at a time delay just after the Raman signal has disappeared (to avoid confusion with Raman signals) or as a 5 (equidistant) step time delay series with 40 shots per step.
- A substantial number of samples were analyzed with the EDU model and a smaller set of samples were analyzed to test functionality using subsequent SuperCam models.

Samples with and without luminescence (SuperCam EDU Data)

Observed Luminescence

- Adamite (1)
- Andesine (1)
- Apatite (11)
- Apophyllite (1)
- Aragonite Red (1)
- Artinite (1)
- Barite (3)
- Bustamite (1)
- Bytownite (1)
- Calcite (7)
- Cookeite (1)
- Fluorite (9)
- Garnet, Grossular (3)
- Gypsum (1)
- Hackmanite (1)
- Hausmannite (1)
- Hedenbergite (1)
- Hydromagnesite (1)
- Kyanite (4)
- Magnesite (3)
- Microcline (4)
- Mimetite (1)
- Monazite (1)
- Natroalunite (1)
- Oligoclase (2)
- Olivine (Peridot, 1)
- Opal (2)
- Orthoclase (1)
- Pollucite (1)
- Prehnite (1)
- Pyrolusite (1)
- Rhodochrosite (1)
- Ruby (3)
- Scheelite (2)
- Sepiolite (1)
- Smithsonite (1)
- Spinel (1)
- Spodumene (4)
- Talc (1)
- Titanite (1)
- Topaz (3)
- Tremolite (1)
- Tyuyamunite (1)
- Zircon (3)

No Observed Luminescence

- *Allophane (1)*
- *Anhydrite (1)*
- *Aragonite, Twin (1)*
- Aragonite, White (1)
- Augite (1)
- Azurite (1)
- *Beryl Unk (1)*
- Beryl Brazil (1)
- Beidellite (1)
- *Brucite (1)*
- Calcite (2)
- Celestite (1)
- *Chlorite (1)*
- Dolomite (1)
- Fluorite (1)
- *Halite (1)*
- Hornblende (1)
- Illite (1)
- Inderite (1)
- Manganite (1)
- Mn-oxides (bio, 1)
- Muscovite (1)
- *Opal (1)*
- Psilomelane (1)
- *Selenite – Gypsum (1)*
- Stilbite (1)

(x) = number of samples

Italics = possible

- 44 distinct minerals with luminescence
- 91 minerals total with luminescence
- 9 minerals with possible luminescence
- 18 minerals with no luminescence

Example of Luminescence Lifetimes

Mars 2020 Project
SUPERCAM

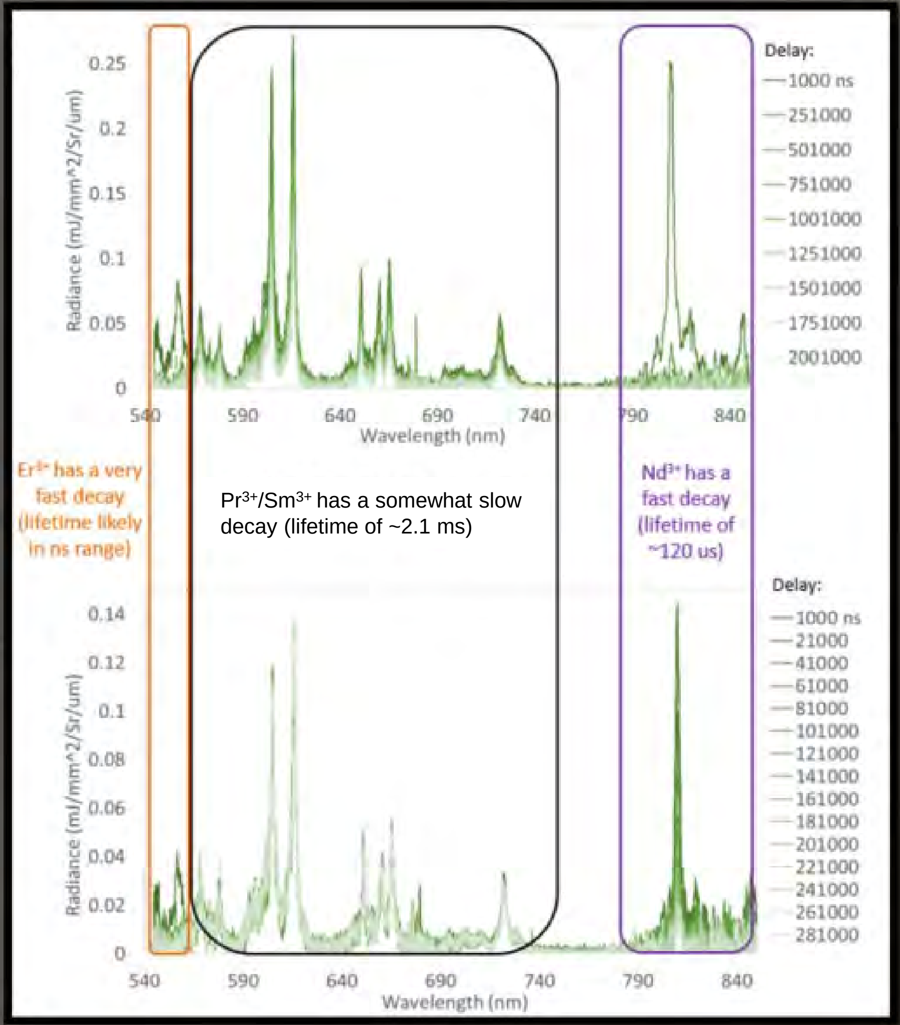
CENTRE NATIONAL D'ETUDES SPATIALES

Example: Zircon

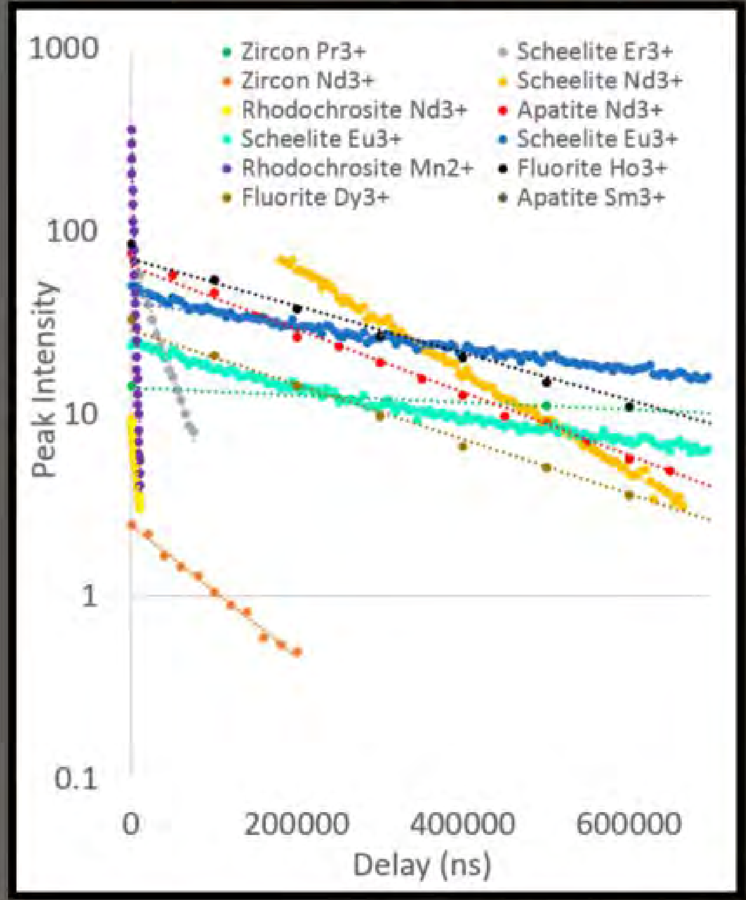
Er^{3+} → Faster

Sm^{3+}/Pr^{3+} → Slower

Nd^{3+} → Intermediate



Additional Decay Curves

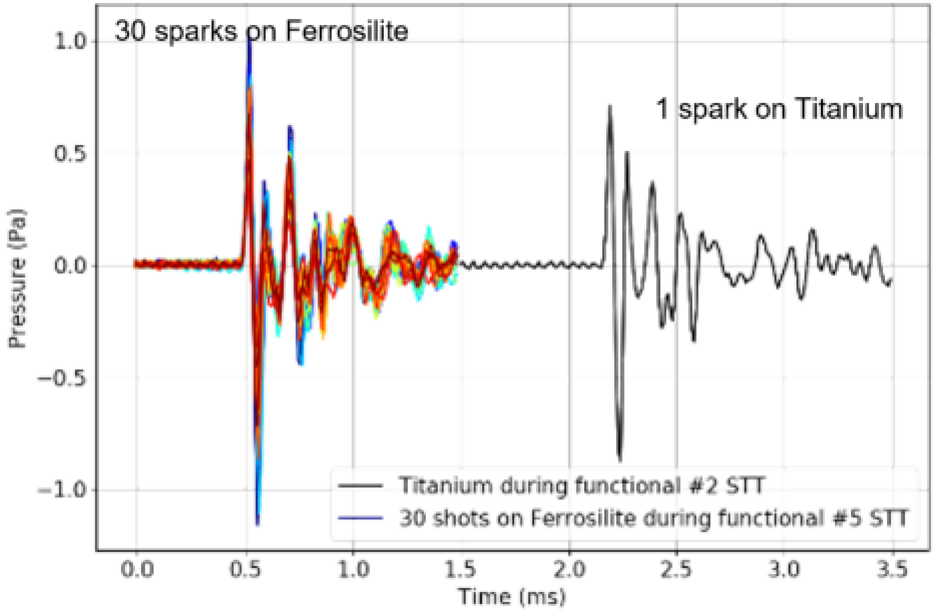


Example of LIBS Shots as Heard by the Microphone

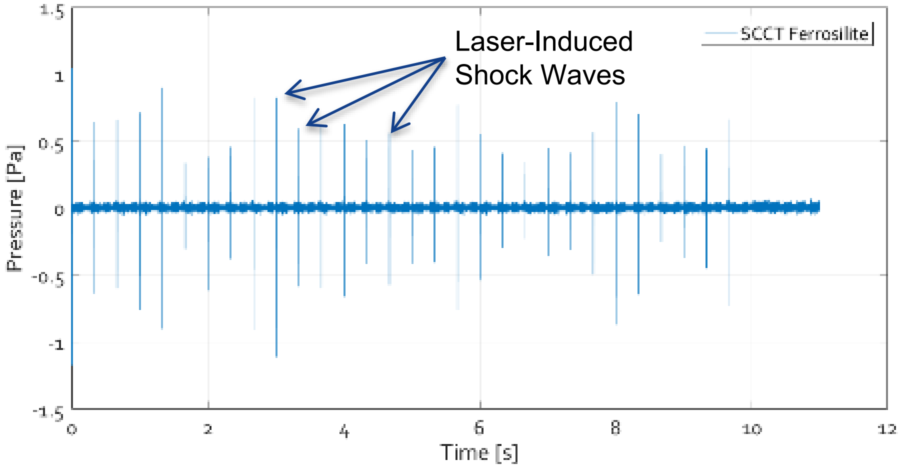
Mars 2020 Project
SUPERCAM

- The microphone may be used to record the LIBS shots, atmospheric turbulence, and to the rover.
- It can operate continuously or selectively (“pulsed mode”) around the LIBS shots.
- The acoustic data from the LIBS shots may be used in a variety of ways:
  - Measure the speed of sound → calculate the atmospheric temperature [Chide et al., 2020, LPSC#1366]
  - Determine the hardness of a material and target physical properties by tracking the shot-to-shot evolution of the shock wave [Chide et al., 2019].
  - Detecting changes in material properties as the laser penetrates a coating or thin layer [Lanza et al., 2020, LPSC #2807]

LIBS+Mic Data Collected on Calibration Targets During STT



Automatic detection and synchronization of the 30 sparks recorded for the SCCT ferrosilite (blue to red) compared with the spark recorded for the SCCT Ti (black). Time offset only for display

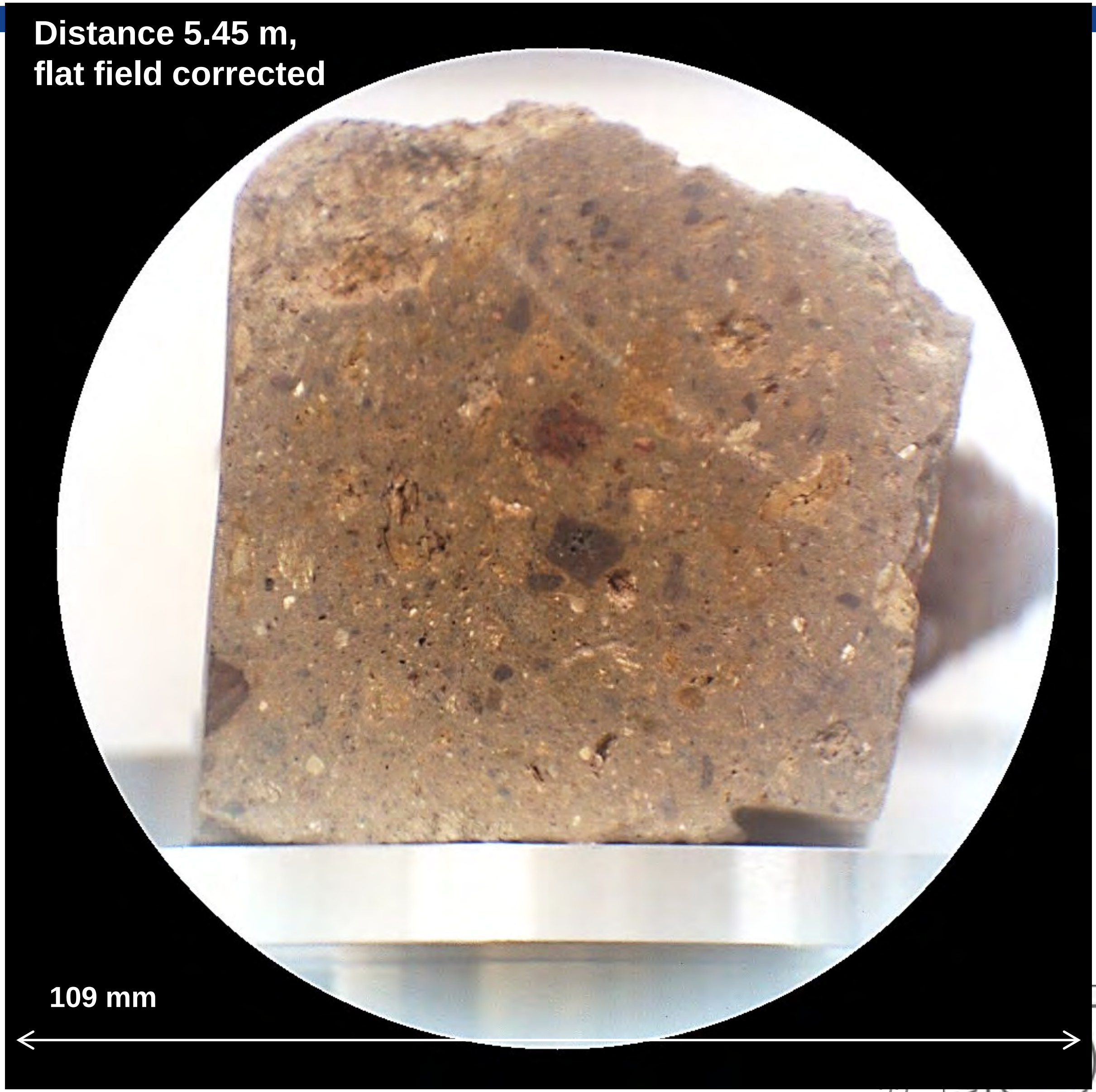


A .wav file of data collected during ATLO – reconstructed from “pulsed” data collected under ambient conditions with spaces inserted to distinguish the different shots is available where these slides are posted.

MARS 2020 SUPER CAM

RMI

RMI context image. Similar to ChemCam w/ color.
Spatial resolution of 65 µrad at -25°C (req. is 80 µrad)



Mars 2020 Project
SUPERCAM

CENTRE NATIONAL D'ETUDES SPATIALES

MARS 2020 SUPER CAM

Mars 2020 Project

Informational Webinar

Olivier Gasnault, IRAP – Toulouse - France

SuperCam Operations

25-February-2020

Agenda

Time	Duration	Topic	Presenter
9:00	0:30	Project investigations, goals	Sylvestre Maurice
9:30	0:25	Instrument description	Roger Wiens
9:55	0:25	Data, results, calibration	Ann Ollila
10:20	0:15	Operations	Olivier Gasnault
10:35	0:15	Q&A	
10:50	0:10	Margin	

Mars2020 General Concept for Operations

- Science operations after landing consist in
  - finding rocks that can be used to address one of the mission objectives, such as candidates for depot caching, for context documentation of this samples, or for any other objective of the on-going campaign.
  - conducting atmospheric survey to study the modern environment.

"Clues for Mars in the Australian Outback" (Image Credit: NASA/JPL-Caltech)

- Like a field trip, we start with hypotheses and goals that will likely be revisited as we are discovering the landscape and making measurement.
- Like in the Apollo geologic backroom, the interaction with the field is indirect, time is limited, and chances for go-backs are limited.
- It requires a strict organization, a quick preliminary analysis of the data, an informed choice of the activities.
- One task is to document those choices.
- Mars2020 Science Operations will be organized in four levels: **Strategic** (over the whole mission), **Campaign Planning** (for the next few months), **Campaign Implementation** (for the coming weeks), and **Tactical** (for the next day).

SuperCam Operations Context

Mars 2020 Project
SUPERCAM

CENTRE NATIONAL D'ETUDES SPATIALES

- After the colocation period at JPL, SuperCam will be **operated remotely** following the process and timetable of the Jet Propulsion Laboratory.

- **Each day** the core operating team for SuperCam will include engineers, scientists, and a coordinator.
  - Scientists will perform a first quick **data analysis** for the tactical process, and a more in-depth analysis for the campaign process.
  - They will also help to **select new targets**, component of activities, and optimize the observation parameters.
  - For a given day, this core operating team will be located either in the US or in Europe, with a rotation approximately every 9 days (TBC). Other scientists are expected to **participate to the debates** about the science results and objectives.
  - It is a necessary **collaborative work** as an integrated team.

- **The participating scientists will be supporting daily mission operations, including serving as downlink and uplink roles, or to define the long-term science operations strategy.**
  - Contributing to the uplink is a great opportunity to push your favorite activities and targets in the plan.
  - Participating to the downlink is the best occasion to become familiar with the data.
  - In all cases, it is an advantage to understand the context of these observations.
  - It implies to participate to training exercises for one or more operational roles.

MARS 2020 SUPER CAM

SuperCam Activities

- Most SuperCam activities will be a **raster** of observation points closely spaced on a same target.
  - On each point, one or several SuperCam techniques (RMI, LIBS, Raman, IR, etc.) can be used to **address the science intent** of that activity. Generally the same series of technique is used on each point of a same raster to have a consistent set of data.
  - Generally, an image will be taken on the first and last point to make a small mosaic on which the intermediate points will be annotated with the techniques used.
- Some activities are organized differently, such as sky observations in passive mode, long scans with IR, or calibrations.

Simplified example of SuperCam series of commands in an activity

1. **Instrument ON** (and thermal control)
2. **Point and focus at target**
3. **RMI image "before"**
4. **Take darks, fire laser & collect LIBS spectra**
5. **Take darks, fire laser & collect Raman spectra**
6. **Collect VISIR spectra**
7. **RMI image "after"**
8. **Instrument OFF** (and thermal control)

Some tips to be aware of

- SuperCam activities will be pre-defined by instrument experts and operations leads. However it is expected that new activities can be created during the mission after review and approval.

- There are constraints to respect at the rover and instrument levels when planning activities that will be detailed in trainings. For example, it is not possible to point SuperCam at the Sun, unless it is focused at 2 meters.

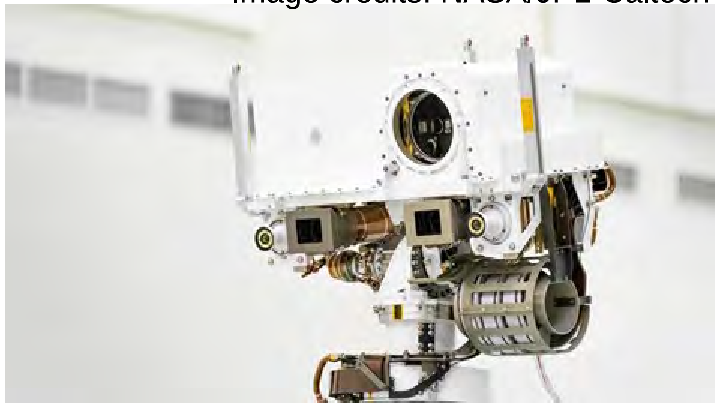
- As a reference, a typical day of Curiosity includes one or several science blocks going from a few tens of minutes up to 2.5 hours (more rarely). Some additional time can be given for thermal control. ChemCam is used on average 5 days a week, 100,000 shots per year.
- For SuperCam, **preliminary duration estimates** give:
  - ON/OFF takes about 7 min plus up to 20 min for spectrometer cool down.
  - It is expected that a standard 5x1 raster with only LIBS and RMI takes 14 min.
  - A 5x1 with all the techniques (LIBS, RAMAN, TRLS, IR, RMI) is estimated at 32 min.
  - A long raster of IR spectra (48 points, 3 spectels each) may take 16 min.

Conclusion on SuperCam Operations

Mars 2020 Project
SUPERCAM

CENTRE NATIONAL D'ETUDES SPATIALES

Image credits: NASA/JPL-Caltech



- Participating scientists are expected to contribute to the science operations.

- SuperCam is a complex instrument to operate but that offers many possibilities.

- Most SuperCam activities will be rasters of typically 5 or 10 points using one or several techniques of the instrument based on the science intent. They will also be documented with MastCam-Z context images. Some atmospheric activities are also planned.

- Each activity will usually takes more than 10 min and up to a few tens of minutes to obtain several measurement points per target. Therefore the number of unique targets per sol is limited, but we expect SuperCam to be used very regularly all along the mission. This will result in a large database of chemistry, mineralogy, and environmental data.