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COMMUNITY USER WORKSHOP ON PLANETARY LIBS (CHEMCAM) DATA

The ChemCam Remote Micro-Imager (RMI)

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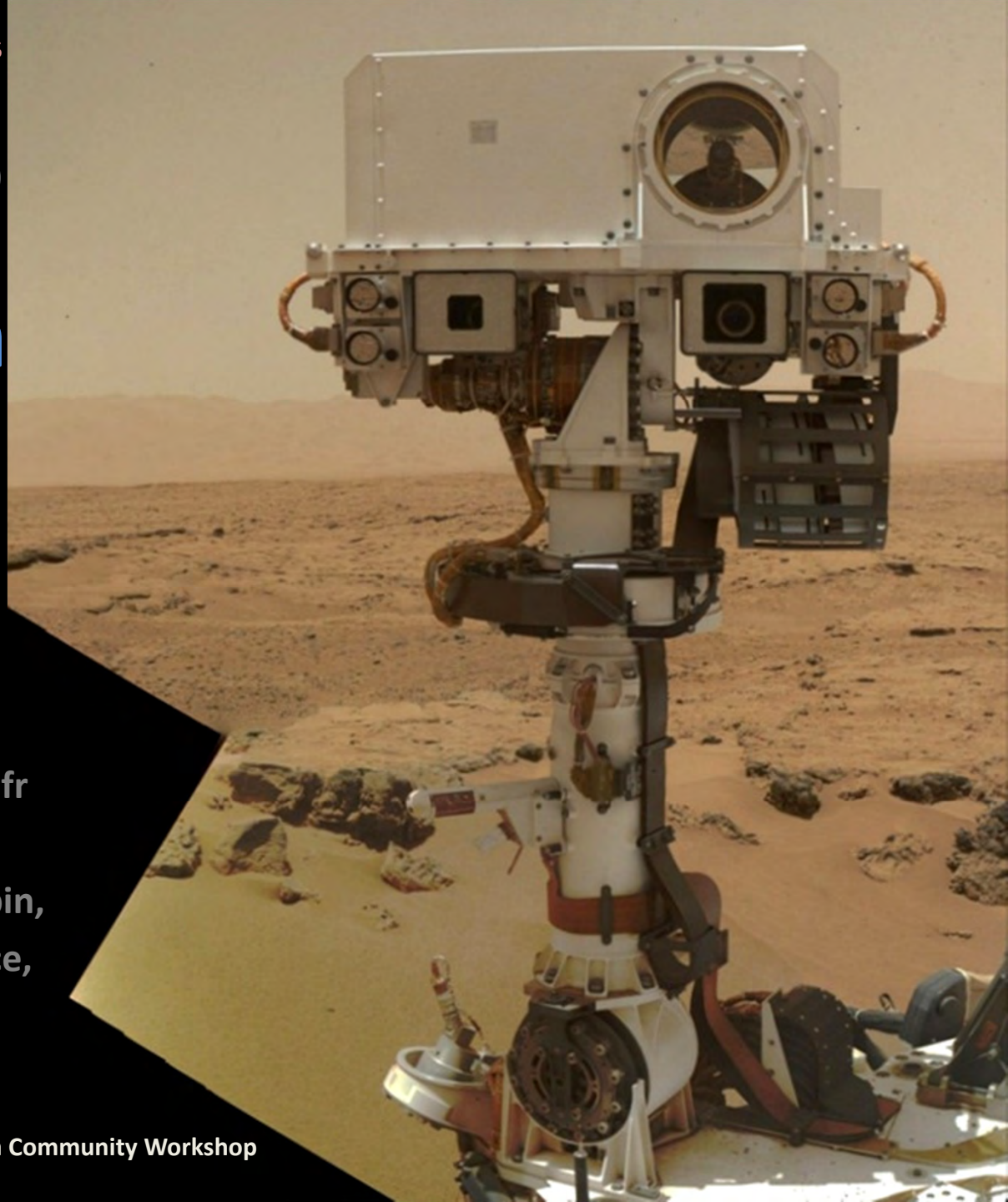
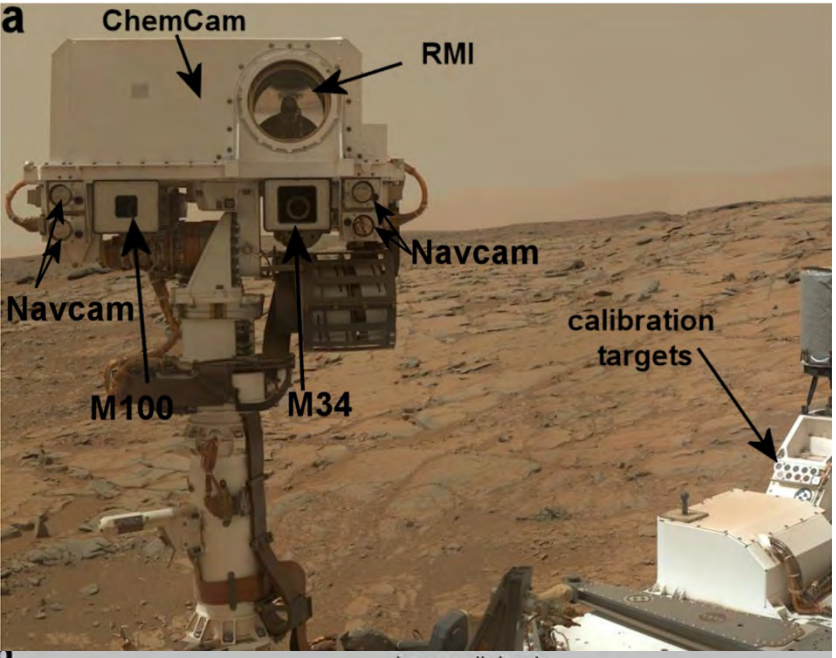
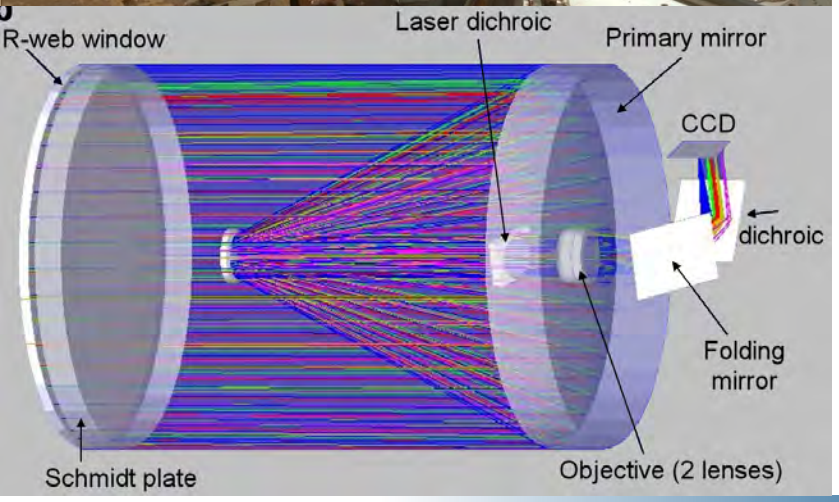


See details in Maurice et al. 2012 and Le Mouélic et al. 2015

RMI Description

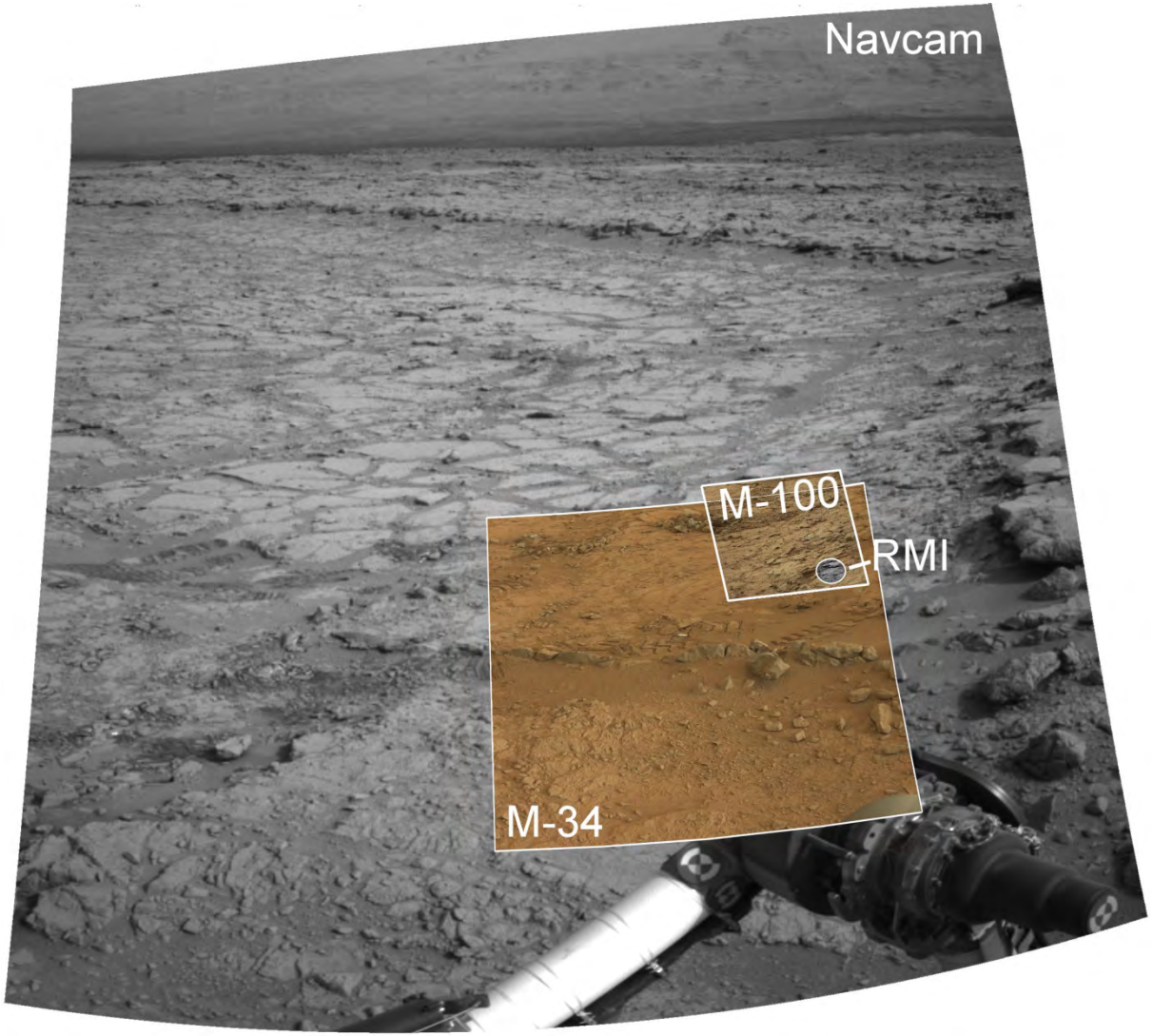




- Co-aligned with the other mast-mounted cameras, though the point of view is slightly different.
- A Schmidt Cassegrain telescope dually used for laser and imaging (compromise design).
- Highest-resolution imager on remote sensing mast.

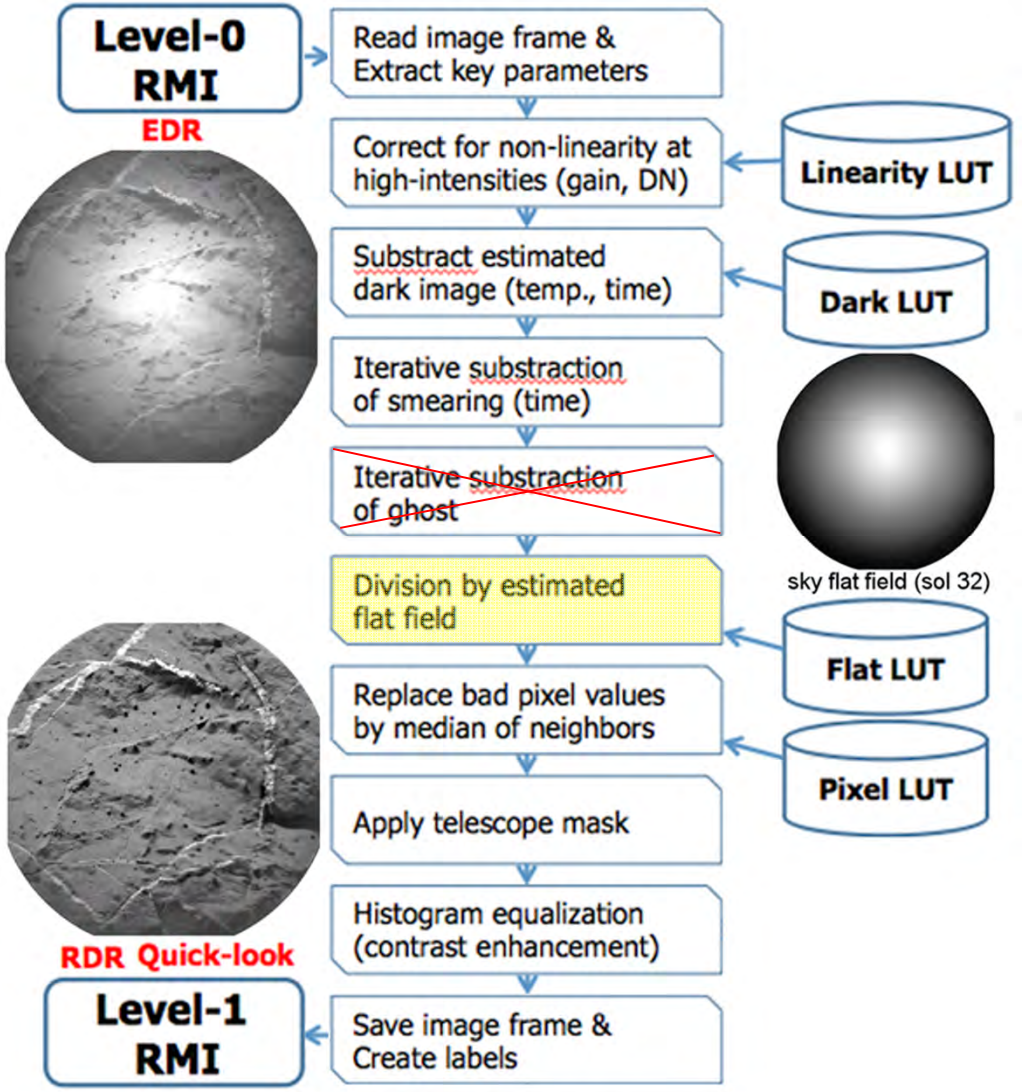
Aperture	110 mm
f/	4
Focus Range	1.2 m to infinity
Detector size	1024x1024 image pixels of 14x14 µm
Pixel scale and resolution	19.6 µrad/pixel (resolution of 2 pixels, i.e. ~80 µm at 2 m, 4 mm at 100 m)
Field of view	20 mrad (1024x1024 image pixels)
Wavelength range	400-900 nm (panchromatic)
Exposure range	2 ms – 65 s
MTF at Nyquist	0.10-0.44 (based on specular reflections, TBC)
Radiometric precision	10 bits/pixel
Depth of field	~2 mm at 2 m; 1.2 cm at 7 m
SNR	>200:1 for well-exposed images

Field of view: the narrowest



(Relative sizes and locations of the mast cameras –data taken around Sol 171– function of target distance)

Partial Radiometric Corrections (PRC)



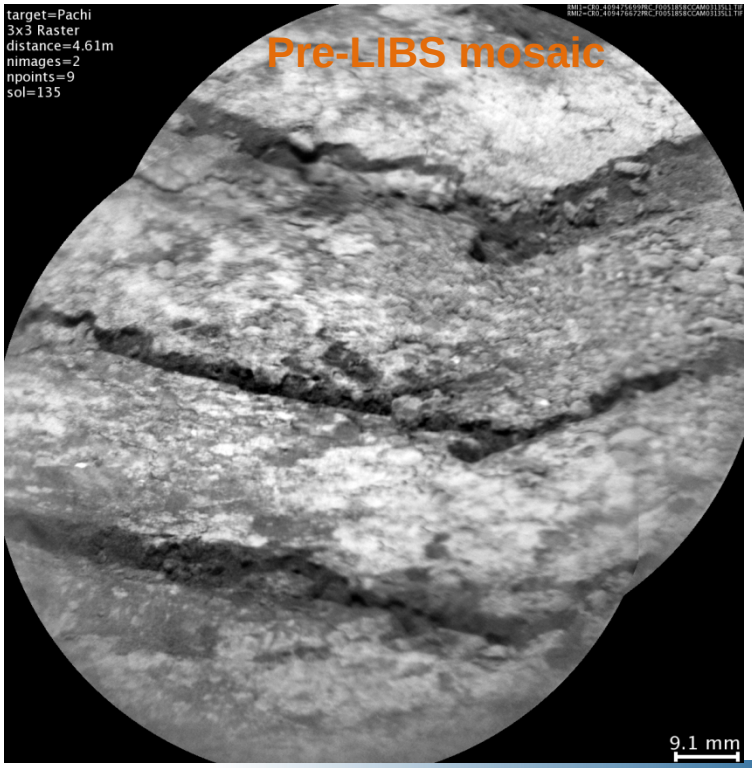
*LUT: Lookup table

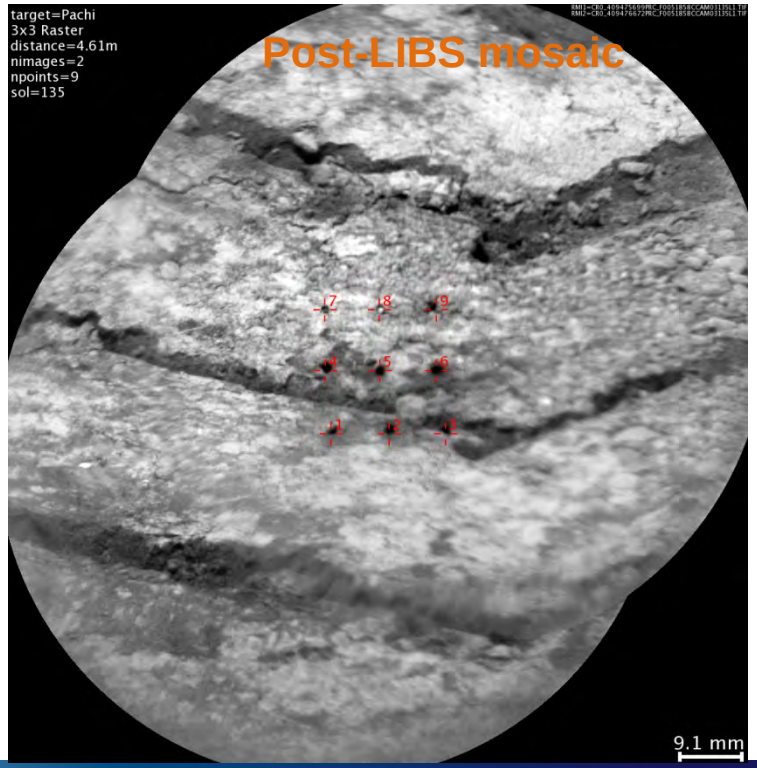
- The first objective of these products is the provide **high-resolution context images** of the laser pit localizations;
  - ➢ But the quality of each image make it a science product by itself.
- The default processing:
  1. does not apply a full radiometric calibration, and does not necessarily preserve the original dynamic range.
  2. does not apply the ghost correction, which is most of the time negligible.
  3. uses a flat field estimate derived for a focus position at 2m (Sol 32 sky flat)
     - Similar sky flat measurements were made on Sol 612 (2m), 617 (56.44m), 618 (6m), 620 (19.97m), and 627 (4m).
- **This processing pipeline will improve in the future. Check for updates!**

Before/After: Localization of laser pits and mosaics

- Context for LIBS shots, with images taken **before and after** laser shots
  - Default activity: RMI image, LIBS spectra (raster), RMI image;
  - The spacing between two successive images is chosen to cover the LIBS area in both images.
- LIBS and RMI are boresighted (same optics), therefore the laser position in the image is known.
- Custom mosaics can be computed using a stitching software such as **Hugin** (free), **Image Composite Editor** (free), **Photoshop**, or **Ptgui**, or they can be directly found in **ChemCam's website**
  - **http://results.msl-chemcam.com** (after LIBS annotated mosaics, scaled at 75% and compressed to 75% JPEG for the website).

Target "Pachi" (soil in rover tracks)





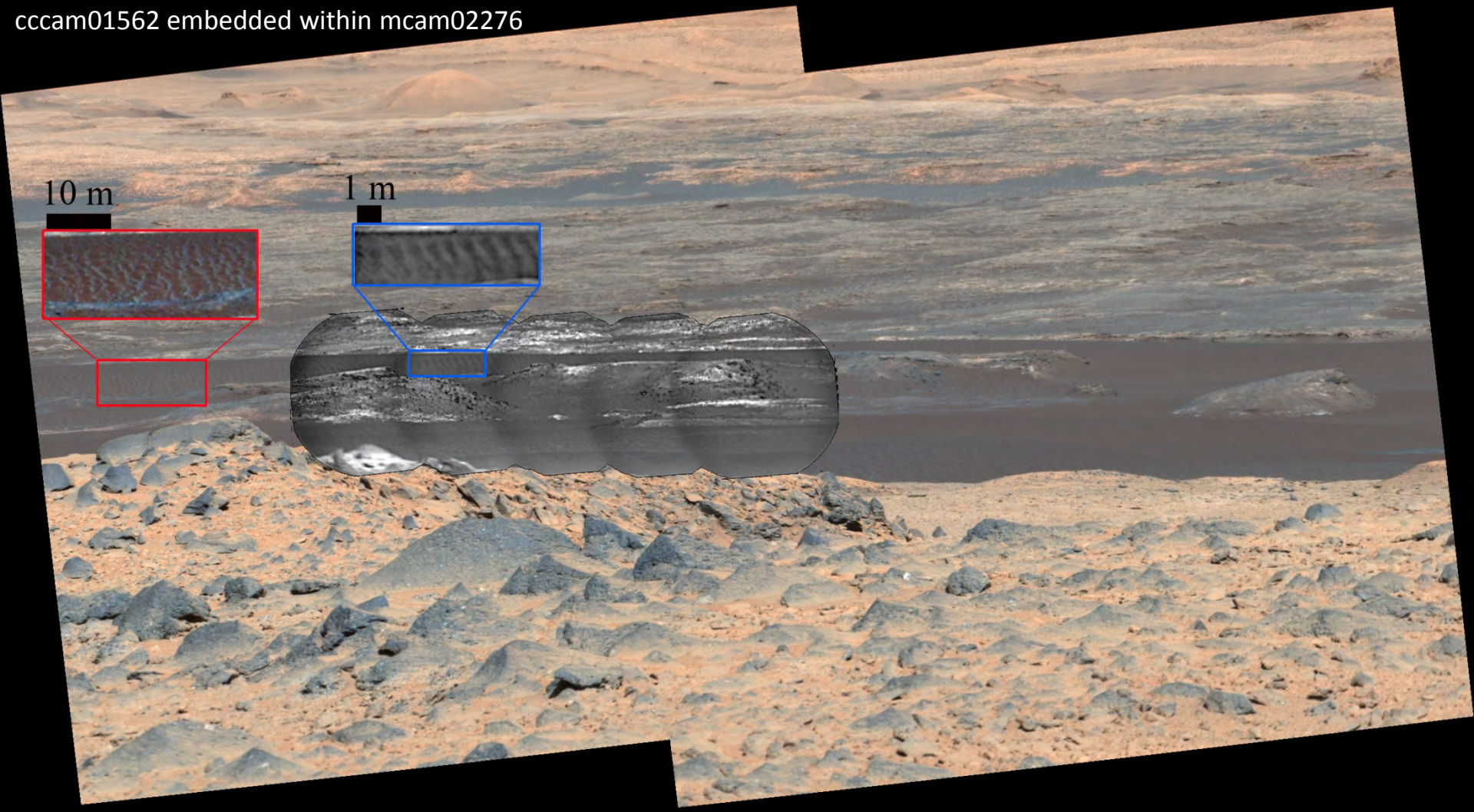
Special Products:
Color merges

(Black & white RMI merged with MastCam color image)

Williams et al., *Science*, 2013

Special Products:
Color merges

Far distance survey of dune ripples (N. Bridges)
cccam01562 embedded within mcam02276



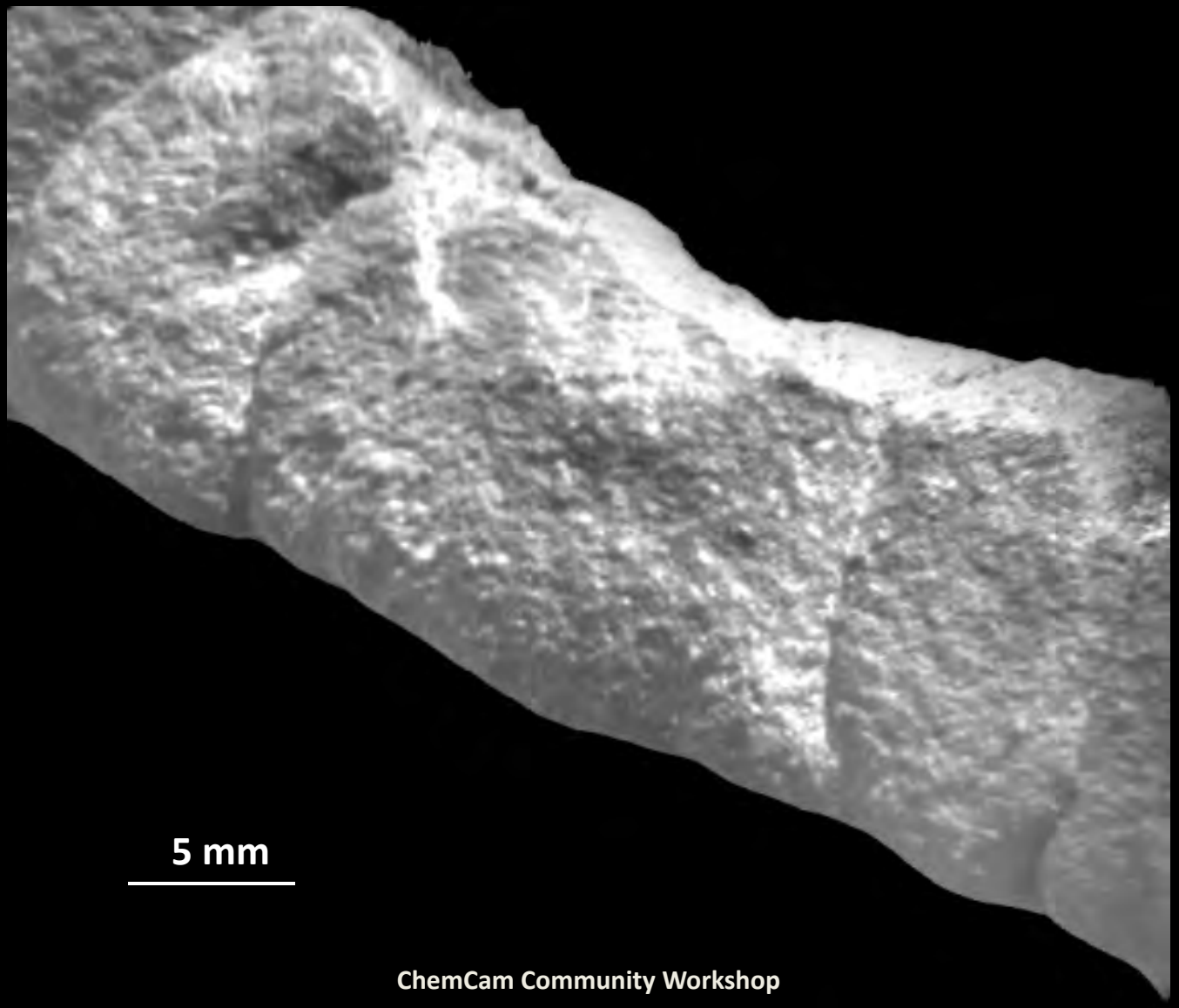
Special Products:
Imaging up to infinity

Mount_Lowe, Sol 890, target at 160m.
Reconnaissance of rock textures and morphologies

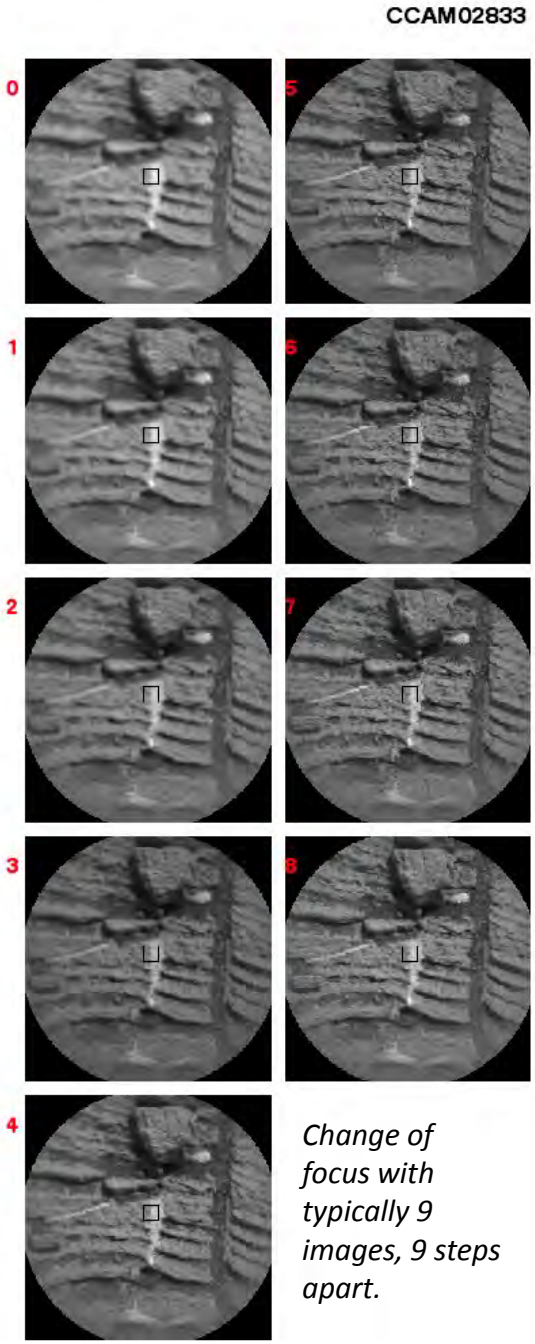
Special Products:
Z-stacking and 3D information

Tindir_1, Sol 159

Series of RMIs acquired with varying focus distance to increase the depth of field and retrieve the 3D shape

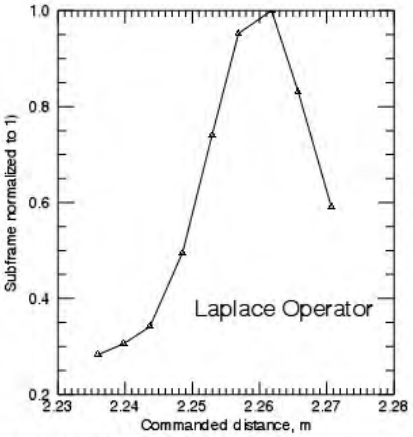


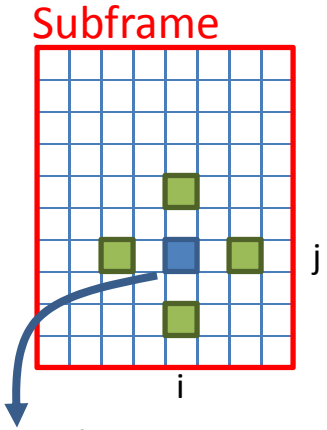
RMI z-stacks in Season-2 and RMI autofocus in Season-3



Change of focus with typically 9 images, 9 steps apart.

- Since Sol 815 (Nov. 2014), ChemCam started a new period of data acquisition with no use of the CWL autofocus, known as Season-2
  - These data will start to be available in 3 months.
  - During that period, most of the measurements are made with z-stacks, i.e. series of images taken at different focus distances.
  - Not all the images are in focus, but they can be merged with tools such as **Helicon Focus** or **Zerene Stacker** (free) to improve the depth of field.
- In Season-3 of ChemCam data (date TBD), the RMI series will be used to find the best focus position onboard (RMI autofocus) and all the individual frames will not be download on Earth anymore
  - The best focus is determined by calculating a Laplacian score on every other pixels in a small subframe centered on laser pit location.





Laplacian score

$$\Sigma \text{ abs}[4xP_{ij} - P_{(i+2)j} - P_{(i-2)j} - P_{i(j+2)} - P_{i(j-2)}]$$

More Information…

- Posters:
  - **Determination of the first level Image processing of the ChemCam RMI instrument for MSL**, *Dufour et al.,* International Conference on Space Optics, 2010
    - http://www.msl-chemcam.com/doc/documents/585/Dufour2010_poster.pdf
  - **Mars imaging by the ChemCam Remote Microscopic Imager (RMI) onboard Curiosity: The first three months**, *Le Mouélic et al.*, Lunar and Planet. Sci. Conf. 44th, 1213, 2013
    - http://www.msl-chemcam.com/doc/documents/586/Poster_LPSC2013_Lemouelic_ChemCamRMI.pdf
  - **Using ChemCam Remote Micro-Imager Onboard MSL for Long Distance Reconnaissance Campaigns**, *Le Mouélic et al.*, Lunar and Planet. Sci. Conf. 45th, 1361, 2014
    - http://www.hou.usra.edu/meetings/lpsc2014/pdf/1361.pdf
  - **Grain size analysis with simulation of digital images from Mars Science Laboratory testbed imagers**, *Ha et al.*, Lunar and Planet. Sci. Conf. 46th, 2201, 2015
    - http://www.hou.usra.edu/meetings/lpsc2015/pdf/2201.pdf

- References:
  - **The ChemCam instrument suite on the Mars Science Laboratory (MSL) rover: body unit and combined systems** , *Wiens et al.*, Space Sci. Rev., 170 :167-227, 2012
    - http://dx.doi.org/10.1007/s11214-012-9902-4
  - **The ChemCam instrument suite on the Mars Science Laboratory (MSL) rover : Science objectives and mast unit description**, *Maurice et al.*, Space Sci. Rev., 170 :95-166, 2012
    - http://dx.doi.org/10.1007/s11214-012-9912-2
  - **The ChemCam Remote Micro-Imager at Gale crater: Review of the first year on Mars** , *Le Mouélic et al.*, Icarus, 249: 93-107, 2015
    - http://dx.doi.org/10.1016/j.icarus.2014.05.030

Visit the ChemCam website : http://msl-chemcam.com/

Backup: Note on target distances and RMI field-of-view

- The distance to the target is computed by converting the focus stage position through a lookup table. That distance is reported in the MSL_CCAM_OBS.CSV file.

- However, for targets beyond 40m the “distance” must be understood as a command parameter, not a real distance.

- The team is working on a conversion table to compute the actual distances. Based on several experiments in flight and the comparison with long-range NavCam stereo distances (with a precision TBC), the preliminary results suggest the following:
  - Let’s call D the command parameter representing the distance beyond 40 m.
  - For a command between 40 and 46m, to obtain the real distance in meters (within 20%), apply:
    - real=0.85*EXP(0.094*D)
  - For a command between 46 and 53m, to obtain the real distance in meters (within 30%), apply:
    - real=0.0064*EXP(0.199*D)
  - There is not enough data beyond a command at 53m for the moment, but 56.5m is considered to be the infinity focus position of ChemCam telescope.

Thank You!