Curiosity's Mars Hand Lens Imager (MAHLI): Initial Observations and Activities

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MSL landed in northern Gale crater on Sol 0, 6 August 2012. This presentation describes the uses for which the rover's Mars Hand Lens Imager (MAHLI) was employed during the first 100 martian days (i.e., Sols 0–100).

The MAHLI is a 2-megapixel focusable macro lens color camera on the turret at the end of Curiosity's robotic arm. The MAHLI investigation centers on stratigraphy, grain-scale texture, structure, mineralogy, and morphology of geologic materials at the Gale crater field site. MAHLI acquires focused images at working distances of 2.1 cm to infinity. For reference, at 2.1 cm the scale is 14 μm/pixel; at 6.9 cm it is 31 μm/pixel, like the Spirit and Opportunity Microscopic Imager (MI) cameras.

Most MAHLI usage during Sols 0–100 was focused on instrument, rover, and robotic arm engineering check-outs and risk reduction, including:

(1) interrogation of an eolian sand deposit (Rocknest Sand Shadow) for suitability to be used for scooping, terrestrial decontamination of the CHIMRA (Collection and Handling for In-Situ Martian Rock Analysis), and first solid sample delivery to the Chemistry and Mineralogy (CheMin) and Sample Analysis at Mars (SAM) instruments;

(2) documentation of the nature of this sand (Rocknest Sand Shadow);

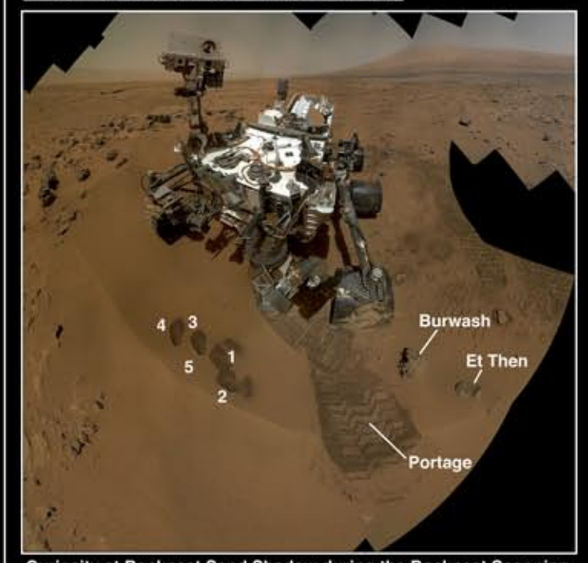
(3) verification that samples were delivered to SAM and passed through a 150 μm mesh and a 2 mm funnel throat in the CheMin inlet;

(4) development of approaches for future robotic arm positioning of MAHLI and the Alpha Particle X-Ray Spectrometer (APXS); and

(5) use of MAHLI autofocus for range-finding to determine locations to position the scoop before each scooping event.

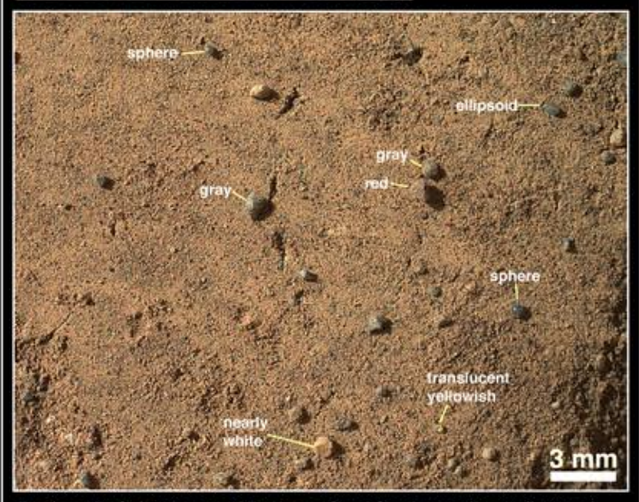
Most Sol 0–100 MAHLI images have scales of 31–110 μm/pixel; some geologic targets were imaged at 21–31 μm/pixel. No opportunities to position the camera close enough to obtain 14–20 μm/pixel high resolution images were available during this initial period.

Sampling Campaign Documentation



Curiosity at Rocknest Sand Shadow during the Rocknest Scooping Campaign. This is a mosaic of MAHLI images acquired on Sol 85.

Candidate Scoop Site Interrogation – Is the Material Suitable for Scooping?

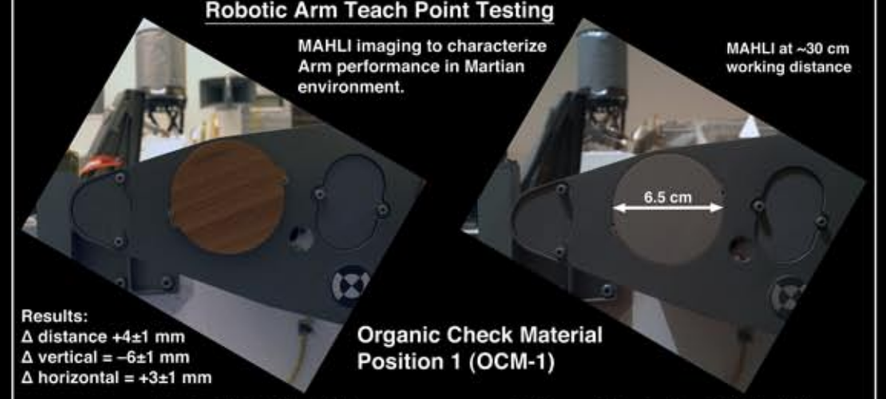


Portion of a Sol 58 image of Rocknest Sand Shadow sediment flattened by the rover's front left wheel. Larger grains (mm-sized) exhibit a variety of colors and shapes. Finer grains are < 150 μm in size, perfect for passing through Curiosity's sample handling system and sieves for delivery to the CheMin mineralogy instrument.

Viewing Sample Portion on Observation Tray

This is a portion of grains sieved to ≤ 150 μm size from the 5th Scoop at the Rocknest Sand Shadow. APXS observed this sample and CheMin and SAM received portions from the same sample. This is a sub-frame of a larger MAHLI image acquired on Sol 95 at 21.2 μm/pixel.

Robotic Arm Teach Point Testing



Results:
Δ distance +4±1 mm
Δ vertical = −6±1 mm
Δ horizontal = +3±1 mm

On Earth, 29 July 2011 — On Mars, 10 September 2012 (Sol 34)

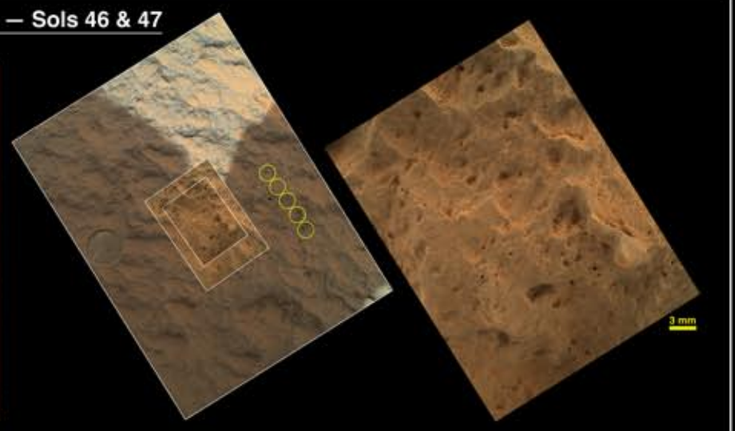
MAHLI Calibration Target – Sol 34

Mastcam-34 Inspections of MAHLI Camera Head

MAHLI camera head inspections, dust cover closed, prior to first-time opening on Mars. Goal was to ensure debris raised during terminal descent would not obstruct dust cover motion.

Rock Campaign — Jake Matijevic — Sols 46 & 47

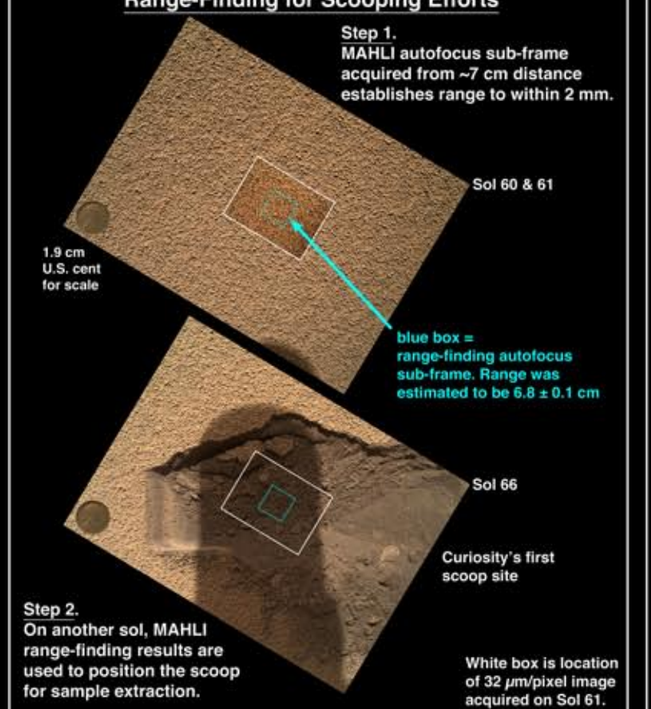
Mastcam-34 view of Jake M. rock on Sol 46 with location of Sol 47 MAHLI images and ChemCam LIBS shots indicated.



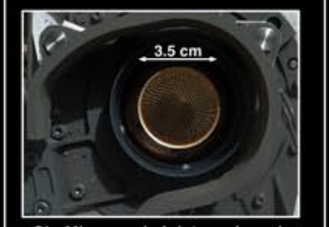
Nested suite of Sol 47 MAHLI images acquired at 102, 32, and 23 μm per pixel with cut-out of 1.9 cm diameter calibration target penny for scale. ChemCam LIBS shots indicated in yellow.

High resolution MAHLI view of dust-coated Jake M. rock surface on Sol 47, acquired at 23 μm/pixel.

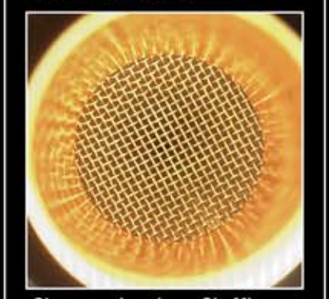
Range-Finding for Scooping Efforts



Sample Delivery Imaging Support

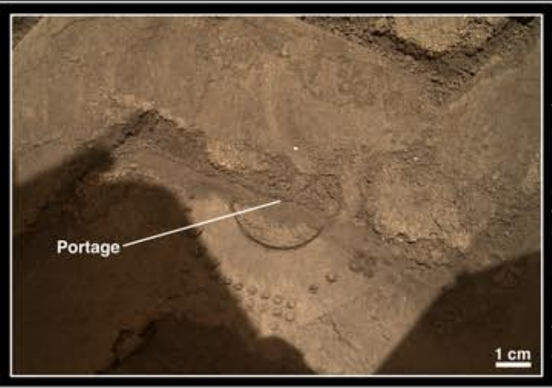


CheMin sample inlet as viewed by MAHLI on Sol 34. This is a focus merge product.



Close-up view down CheMin 3.5 cm diameter inlet after sample delivery; imaged on Sol 94. Mesh permits passage of grains ≤ 150 μm.

APXS Science Support



MAHLI is used routinely to document targets observed by the Alpha Particle X-ray Spectrometer (APXS) instrument.

Shown here is a view of the imprint of the APXS contact sensor on a sandy surface flattened by the rover's left front wheel at the Rocknest Sand Shadow. The APXS target was named Portage.

This is a sub-frame of a MAHLI image acquired on Sol 89.

MAHLI Imaging to Plan Future Contact Science

MAHLI stereo pairs and/or focus merge range map products can be used to plan future contact instrument or tool placement.

During the Rocknest Sand Shadow Campaign, topographic meshes made from MAHLI stereo pairs were ingested into rover planning tools to permit assessment of placement of MAHLI and APXS on targets near the margins of the robotic arm work space. This figure shows an oblique, mouse's-eye view of MAHLI stereo mesh products for rocks Et Then and Burwash.

MAHLI Engineering Support & Science, Sols 0–100

Sol	Activities and Milestones
1	MAHLI first mechanism operation on Mars and first in > 1 year; first color image of landscape from Curiosity (dust cover closed).
10	First Mastcam, MAHLI, MARDI end-to-end checkout after rover flight software update; image of landscape (dust cover closed).
32	Robotic Arm checkout support; MAHLI imaging of cameras on remote sensing mast (dust cover closed).
33	Following Sol 30–32 inspection using Mastcams, dust cover opened for the first time; image of regolith clasts, pointed down from 1.4 m.
34–36	MAHLI support of robotic arm performance in Mars environment; comparison of pre-launch images with those obtained on Mars for various teach points on the rover. MAHLI observation of post-landing cleanliness of MAHLI Calibration Target, APXS Calibration Target and Rover Environmental Monitoring Station (REMS) ultraviolet detectors (including UV LED illumination of the UV sensors). Imaging of rover wheels/undercarriage. First MAHLI focus stack acquired and merged onboard.
44	MAHLI imaging of flag emblem and Presidential signature plaque.
46–47	First contact science; first robotic arm positioning of MAHLI at a rock target (Jake Matijevic); MAHLI support of robotic arm positioning repeatability tests; documentation of APXS and ChemCam laser-induced breakdown spectrometer targets.
54	APXS and MAHLI observation of dark, fine-grained rocks named Bathurst Inlet and Cowles_5.
58	MAHLI observations of wheel-scuffed and undisturbed surfaces of the Rocknest wind drift to assess its suitability for first scooping, sample processing and delivery to CheMin and SAM.
60	Imaging of right-center rover wheel to establish that it is on a firm surface; range-finding and foreign object survey of candidate scooping targets on the Rocknest wind drift.
61	Range-finding confirmation at first scoop location.
65	Image of grains ejected from CHIMRA after its first cleaning activity; images of a small artifact (foreign object).
66	Documentation of first scoop trough and range-finding confirmation at second scoop target.
67	Mosaic of second scoop trough to identify possible foreign objects; re-image candidates for later scoop targets for foreign objects.
69	Additional imaging of a suspected foreign object in second scoop trough; pre-scoop range finding confirmation at third scoop location.
73	Imaging of sieved sand from third scoop on Observation Tray; image of grains ejected from sample processing system (CHIMRA).
74	Imaging of mesh and funnel inside CheMin inlet following sample delivery; pre-scoop range-finding confirmation for fourth scoop; image surface of Rocknest drift on other side of crest.
81	Image grains ejected from sample processing system after fourth scoop; images viewing inside CheMin inlet following sample delivery; imaging and UV LED illumination of REMS ultraviolet sensor.
82	Stereo and range-finding of rocks Burwash and Et_Then for improved future APXS and MAHLI placement at these targets; stereo imaging of third and fourth scoop troughs to examine banding or layering in the wind drift subsurface.
84	Rover self-portrait mosaic and scooping site documentation; additional stereo imaging of scoop troughs and Burwash and Et_Then to support potential future APXS and MAHLI placement.
85	Second rover self-portrait mosaic for stereo with the Sol 84 images; extended coverage to include Aeolis Mons (Mt. Sharp).
86	MAHLI images of sky for flat field characterization; documentation of Et_Then rock in support of APXS placement and for robotic arm positioning repeatability test.
88	Documentation of APXS target, Portage, in wheel scuff on Rocknest sand shadow. Stereo imaging of rock (La_Bine) to support MAHLI stereo mesh development for future robotic arm tool placement.
89	Documentation of APXS target, Portage; range-finding at candidate fifth scoop target.
90	Documentation of APXS target on rock, Et_Then.
93	Document grains on Observation Tray; range-finding confirmation at fifth, final scoop target just before scooping. Pre- and post- sample delivery imaging of SAM sample inlet #1. Pre-sample dumping documentation of area that fifth scoop material might be dumped.
94	Imaging of mesh/funnel inside CheMin inlet after sample delivery.
95	Imaging of sieved sand sample placed on Observation Tray.
96; 98	Pre- and post- sample delivery imaging of SAM sample inlet #1.

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