CURIOSITY'S MARS HAND LENS IMAGER (MAHLI): INITIAL OBSERVATIONS AND ACTIVITIES.

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Introduction: MAHLI (Mars Hand Lens Imager) is a 2-megapixel focusable macro lens color camera on the turret on Curiosity's robotic arm (Fig. 1). The investigation centers on stratigraphy, grain-scale texture, structure, mineralogy, and morphology of geologic materials at Curiosity's Gale robotic 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.

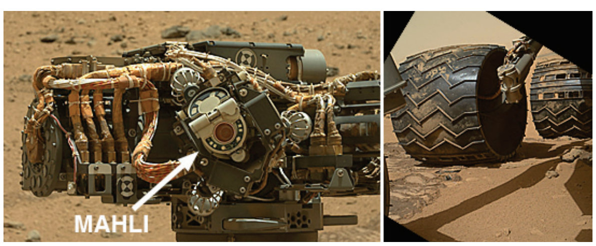

Fig.1. *Left:* MAHLI camera head with dust cover open; sub-frame of a Mastcam-34 image acquired on Sol 85 (1 Nov. 2012). *Right:* Rover right center and rear wheels; sub-frame of a MAHLI image acquired on Sol 60 (6 Oct. 2012) to assess risk of rover wheel slippage during Rocknest scooping activities.

Sol 0–100 Activities: Most MAHLI usage during Sols 0–100 was focused on instrument, rover, and robotic arm engineering check-outs and risk reduction (Table 1), including (1) interrogation of an eolian sand deposit 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; (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) (e.g., Fig. 2); and (5) use of MAHLI autofocus for range-finding to determine locations to position the scoop before each scooping event.

Observations and Results: 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.

Fig. 2. Example of engineering activities that used the MAHLI; this is a terrain visualization product created from MAHLI stereo pair images of rocks Et_Then and Burwash. The data were obtained and processed to assist with robotic arm positioning of MAHLI and APXS and to explore techniques for future MAHLI assistance with placement of Curiosity's robotic arm tools and instruments.

Rocks. Only two rocks, named Jake Matijevic and Bathurst Inlet, were imaged at a resolution higher than the MER MIs. Both were dark gray and mantled with dust and fine/very fine sand (Fig. 3). In both cases, the highest resolution images of these rocks show no obvious, indisputable grains, suggesting that grain sizes (as expressed at the rock surfaces) are < 80 μm. However, owing to the dust and sand obscuration, the co-authors aren't entirely certain about the observables; while it is tempting to report nothing—as was the case for martian valley networks, now known to be real, noticed with uncertainty in Mariner 6 and 7 images—we report here that a few co-authors think they observe some grains of 300–500 µm size in the Bathurst Inlet images; a few others think there are 300–500 µm-sized rhombus-shaped crystals in the rock, Jake Matijevic.

Sand and Dust. Sand and granules (as well as dust), exhibiting a variety of colors, shapes, and other grain attributes, were deposited on rover hardware during terminal descent (Fig. 4). As noted above, sand as well as dust also mantles the rocks observed by MAHLI; in one case the cohesive properties of this material was demonstrated by the presence of a "micro landslide" on a rock named Burwash (Fig. 4). At the Rocknest sand shadow, a variety of coarse to very coarse sand grains of differing color, shape, luster, angularity, and roundness were observed, including glassy spheroids and ellipsoids (possibly formed by impact?) and clear, translucent grains. The fine to very fine sands sieved (≤ 150 µm) and delivered to the rover's observation tray (Fig. 4) also exhibited at least four distinct grain types, including clear, translucent crystal fragments.

Fig. 3. Surface of a dark gray rock named Bathurst Inlet. This is a portion of one of the highest resolution (~21 µm/pixel) MAHLI images of a rock obtained during the first 100 sols of operation on Mars. The rock has a thin mantle of fine to very fine sand, silt, and aggregated dust. A few sand grains (e.g., see arrow) are white and translucent. This sub-frame of MAHLI focus merge product is from Sol 54 (30 Sept. 2012); illumination is from the top/upper right.

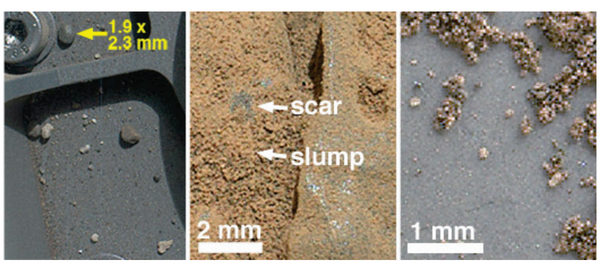

Fig. 4. *Left:* One of MAHLI's first images of sand and granules. These were deposited near the CheMin sample inlet on the rover deck during the landing. The grains exhibit a variety of colors, shapes, angularity, roundness and luster. This is a sub-frame of a Sol 36 (12 Sept. 2012) focus merge product. *Center:* Micro-mass movement (slump) in the dust and very find sand accumulated on a rock named Burwash. This is a sub-frame of MAHLI focus merge product from Sol 82 (29 Oct. 2012). *Right:* Sand, including translucent crystals and crystal fragments, from the Rocknest sand shadow that passed through the CHIMRA 150 µm sieve and were delivered to the Ti Observation Tray (substrate in this image); this is a sub-frame of a MAHLI image from Sol 95 (11 November 2012).

Table 1 – 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.