THE MARS HAND LENS IMAGER (MAHLI) FOR THE 2009 MARS SCIENCE LABORATORY.

K. S. Edgett[1], J. F. Bell III[2], K. E. Herkenhoff[3], E. Heydari[4], L. C. Kah[5], M. E. Minitti[6], T. S. Olson[7], S. K. Rowland[8], J. Schieber[9], R. J. Sullivan[10], R. A. Yingst[11], M. A. Ravine[1], M. A. Caplinger[1], and J. N. Maki[12], [1]Malin Space Science Systems, PO Box 910148, San Diego, CA 92191-0148 USA, [2]Cornell University, Ithaca, NY, [3]US Geological Survey, Flagstaff, AZ, [4]Jackson State University, Jackson, MS, [5]University of Tennessee, Knoxville, TN, [6]Arizona State University, Tempe, AZ, [7]Salish Kootenai College, Pablo, MT, [8]University of Hawai‘i Honolulu, HI, [9]Indiana University, Bloomington, IN, [10]Cornell University, Ithaca, NY, [11]University of Wisconsin, Green Bay, WI, [12]Jet Propulsion Laboratory, Pasadena, CA.

Introduction: The MArs Hand Lens Imager (MAHLI) is a small, RGB-color camera designed to examine geologic material at 12.5–75 µm/pixel resolution at the Mars Science Laboratory (MSL) landing site. MAHLI is a PI-led investigation competitively selected by NASA in December 2004 as part of the science payload for the MSL rover launching in 2009. The instrument is being fabricated by, and will be operated by, Malin Space Science Systems of San Diego, California.

Background: The MAHLI investigation will expand upon the fruits of a revolution that has been underway for just over one year. The first micro-scale images of martian surface materials, acquired by the two Mars Exploration Rover (MER) Microscopic Imagers (MI) [1–3], have changed Mars science forever. MI, alone, settled a 30-year debate regarding whether Mars has sand-sized, windblown sediment [2, 3]. MI also made major contributions that settled debates on whether Mars has waterlain sediments, aqueously-altered rocks, and rock coatings [2–5].

Objectives: The overall science objective of the MSL mission is “to explore and quantitatively assess a local region on Mars as a potential habitat for life, past or present” [6]. In that context, the primary objective of the MAHLI investigation is to characterize and determine the detailed history and processes, particularly as they pertain to habitability, recorded in geologic material at micrometer to centimeter scale at the MSL site. The specific objectives are:

1. Observation of Rocks. Examine rocks (outcrops and clasts ≥ 4 mm) and utilize the results of interaction of rover hardware with rocks to help determine texture, morphology, structure, mineralogy, and stratigraphy. Also, help determine rock type, history/sequence, depositional, diagenetic, and weathering processes.

2. Observation of Fines. Determine the processes that acted on regolith fines (clasts ≤ 4 mm) and individual grains within them by examining physical and mechanical properties, the results of interaction of rover hardware with fines, plus stratigraphy, textures, mineralogy, and depositional processes.

3. Observation of Frost and Ice. If present, characterize frost or ice to determine texture, morphology, thickness, stratigraphic position, and relation to regolith and, if possible, observe changes over time.

4. Facilitate Analytical Laboratory Sampling, Contact Instrument Observations, and other MSL Science. Help MSL science teams identify materials to be collected for, and characterize samples before delivery to, the MSL Analytical Laboratory; document the attributes of surfaces examined by other MSL Contact Instruments; and support other MSL instruments and activities that may require hand lens-scale imaging.

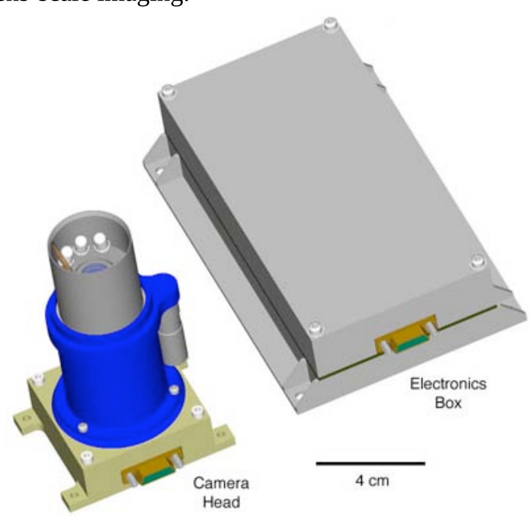

Fig. 1. Rendering of MSL MAHLI camera head and separate electronics box.

Characteristics: Appropriate to Mars, *mahli* means “wind” among some of the languages of people native to southeastern North America (Muskogean languages, *e.g.*, Chickasaw [7]). MAHLI, as proposed in 2004, consists of a small camera head with an integral focus mechanism and lens cover, and a separate box holding the electronics that drive the detector and buffer and process the data (Fig. 1). The total proposed mass for this instrument is 525 g plus 105 g (20%) of reserve. To meet its science objectives, MAHLI will have the following capabilities:

1. Color such as the human eye would see, obtained using a Bayer pattern filter for RGB in a single image.

2. Spatial resolution (12.5 µm/pixel) sufficient to permit characterization of granulometric properties and morphologic elements of particles of very coarse silt size (~50 µm) and larger.

3. A focus mechanism to (a) reduce dependence on exact placement of the Instrument Arm relative to the MER MI, (b) simplify operations because the Instrument Arm does not have to step through focus to acquire images through the depth of field, as it did for MER MI, (c) permit acquisition of images at different resolutions and fields of view, and (d) acquire context for the highest resolution views.

4. White light and ultraviolet (UV) LEDs to illuminate targets, avoid shadowing by targets or rover hardware, permit imaging at night, permit varied incidence angle, and, with UV, help detect carbonate and evaporite minerals.

5. Onboard z-stacking (focal plane image merge) and range/depth map generation from a series of images acquired by stepping through focus, to reduce to two (the z-stacked picture and its depth map) the number of images per target that must be returned to Earth (*i.e.*, MER MI typically returns 3–7 pictures per target to be z-stacked on the ground).

6. A somewhat larger detector array (CCD) than MI (1600 x 1200 vs. 1024 x 1024), providing a larger field of view at MI resolution (30 µm/pixel).

Investigation Concept: The MAHLI investigation is very straightforward and designed for flexibility, adaptability, and simplicity of operations (Figs. 2, 3). The camera will be mounted on the MSL Instrument Arm. Moving the arm will position MAHLI to observe its targets. A 12.5 µm/pixel image is acquired from a distance of about 30 mm. The lowest resolution, 75 µm/pixel, is achieved from about 180 mm distance. The decision to go to a particular working distance/image resolution will be based on the science objective of the image, the accuracy of the Instrument Arm placement, the downlink data rate, and other operational constraints. Once in place, MAHLI automatically focuses the image and steps through focus to capture a series of pictures through the depth of field. The instrument then compiles the best in-focus composite (z-stacking) of these pictures and creates a range/depth map relative to target distance. The data are then losslessly compressed and returned to Earth. Mosaics and stereo pairs can be obtained by moving the Instrument Arm an appropriate distance. Context for the highest resolution MAHLI images can be obtained by placing the camera at a greater distance from the target; context can also be achieved from the highest resolution images of the MSL Mast Camera.

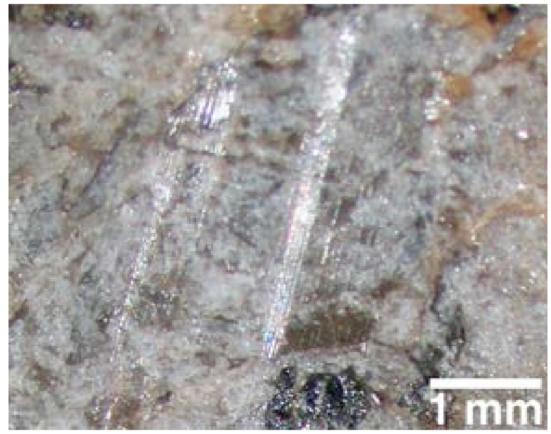

Fig. 2. As with a geologist's hand lens, MAHLI's high resolution will assist in mineral identification. For example, it can show the twinning striations characteristic of plagioclase.

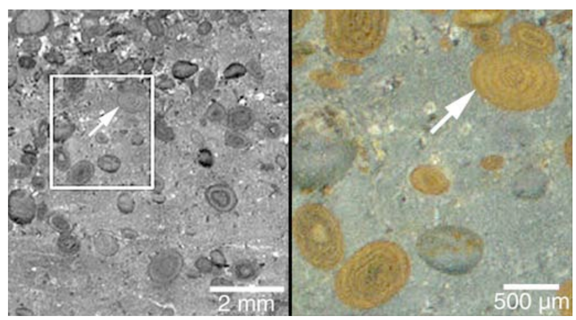

Fig. 3. Example of color and resolution working together, in this case to permit discrimination of different colors (translating to different composition) and concentric zoning (arrow) in goethite/chamosite ooids in a cut (analogous to the MSL abrasion tool) sample of late Devonian Saverton Shale from Iowa. At left is a 30 µm/pixel grayscale view (similar to MER MI); at right, a 12.5 µm/pixel color view of the area outlined by the white box on the left.

References: [1] Herkenhoff, K. E. et al. (2003) *JGR*, *108*(E12), 8065, doi: 10.1029/2003JE002076. [2] Herkenhoff, K. E. et al. (2004) *Science*, *305*, 824-826. [3] Herkenhoff, K. E. et al. (2004) *Science*, *306*, 1727-1730. [4] Squyres, S. W. et al. (2004) *Science*, *306*, 1709-1714. [5] Squyres, S. W. et al. (2004) *Science*, *305*, 794-799. [6] NASA/JPL MSL Proposal Information Package, 14 April 2004. [7] Gordon, M. et al. (2002) *J. Internat. Phonetic Assoc.*, *31*, 287-290.