THE ATHENA MICROSCOPIC IMAGER INVESTIGATION. K. E. Herkenhoff[1], S. W. Squyres[2], J. F. Bell III[2], J. N. Maki[3], H. M. Arneson[2], D. I. Brown[3], S. A. Collins[3], A. Dingizian[3], S. T. Elliot[3], W. Goetz[6], E. C. Hagerott[3], A. G. Hayes[2], M. J. Johnson[2], R. L. Kirk[1], M. B. Madsen[6], R. V. Morris[5], L. M. Scherr[3], M. A. Schwochert[3], L. R. Shiraishi[3], G. H. Smith[4], L. A. Soderblom[1], J. N. Sohl-Dickstein[2], M. V. Wadsworth[3], and the Athena Science Team, [1]USGS Astrogeology Team, Flagstaff, Arizona (kherkenhoff@usgs.gov), [2]Cornell University Dept. of Astronomy, Ithaca, NY, [3]Caltech/JPL, Pasadena, CA, [4]GHS Optics, Pasadena, CA, [5]NASA Johnson Space Center, Code SR, Houston, TX, [6]Niels Bohr Institute for Astronomy, Physics and Geophysics, University of Copenhagen, Denmark.

Introduction: The Athena science payload on the Mars Exploration Rovers (MER) includes the Microscopic Imager (MI) [1]. The MI is a fixed-focus camera mounted on the end of an extendable instrument arm, the Instrument Deployment Device (IDD; see Figure 1).

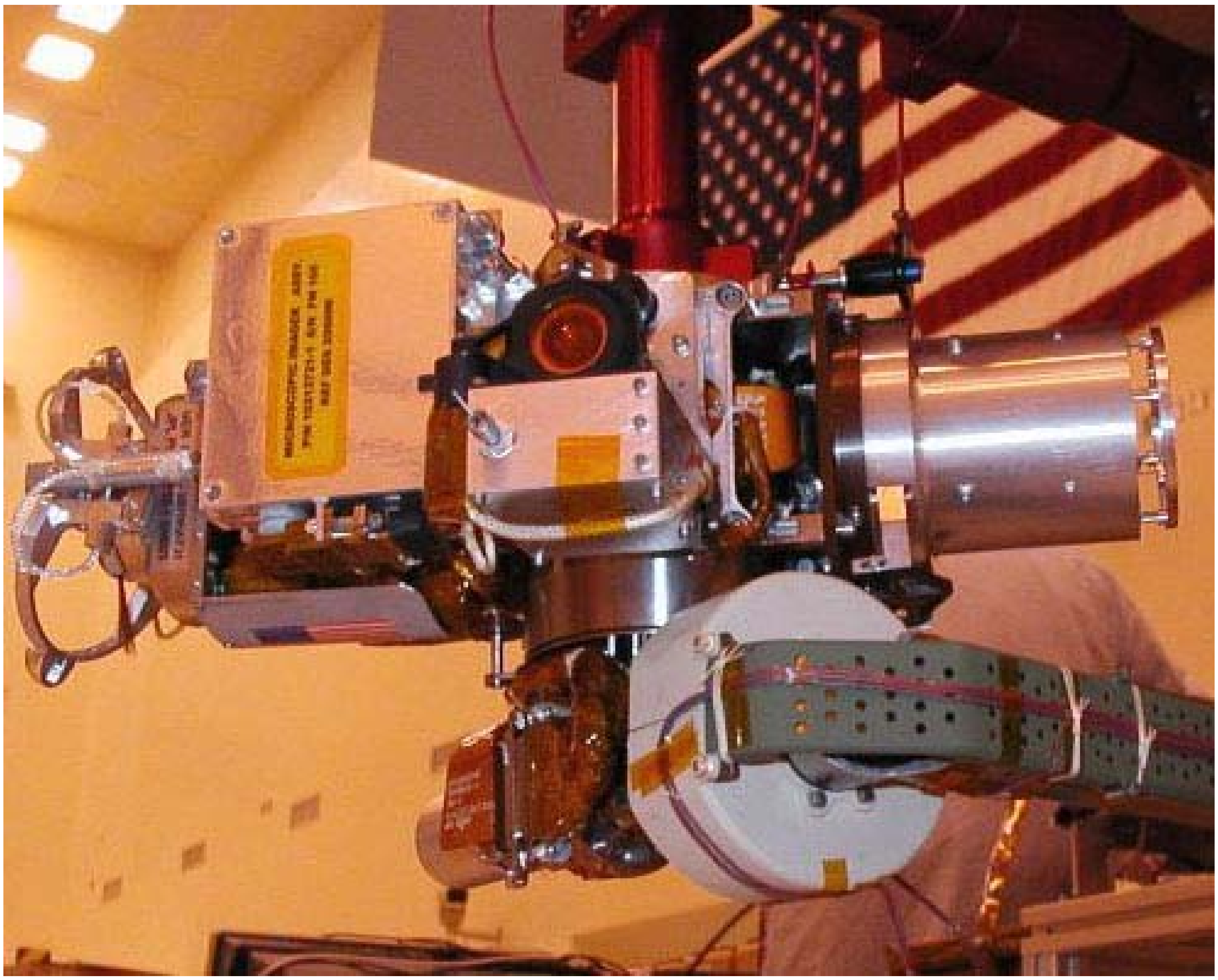

Figure 1. IDD instrument turret during MER 2 testing. RAT at left, MI at center, APXS at right (Mössbauer spectrometer not visible). MI dust cover is shown closed, with contact sensor to lower left.

The MI was designed to acquire images at a spatial resolution of 30 microns/pixel over a broad spectral range (400 - 700 nm; see Table 1). Technically, the "microscopic" imager is not a microscope: it has a fixed magnification of 0.4 and is intended to produce images that simulate a geologist's view through a common hand lens. In photographers' parlance, the system makes use of a "macro" lens. The MI uses the same electronics design as the other MER cameras [2, 3] but has optics that yield a field of view of 31 × 31 mm across a 1024 × 1024 pixel CCD image (Figure 2). The MI acquires images using only solar or skylight illumination of the target surface. A contact sensor is used to place the MI slightly closer to the target surface than its best focus distance (about 66 mm), allowing concave surfaces to be imaged in good focus. Because the MI has a relatively small depth of field (± 3 mm), a single MI image of a rough surface will contain both focused and unfocused areas. Coarse focusing (~ 2 mm precision) will be achieved by moving the IDD away from a rock target after the contact sensor is activated. Multiple images taken at various distances will be acquired to ensure good focus on all parts of rough surfaces. By combining a set of images acquired in this way, a completely focused image can be assembled. Stereoscopic observations can be obtained by moving the MI laterally relative to its boresight. Estimates of the position and orientation of the MI for each acquired image will be stored in the rover computer and returned to Earth with the image data. The MI optics will be protected from the Martian environment by a retractable dust cover. The dust cover includes a Kapton window that is tinted orange to restrict the spectral bandpass to 500-700 nm, allowing color information to be obtained by taking images with the dust cover open and closed. The MI will image the same materials measured by other Athena instruments (including surfaces prepared by the Rock Abrasion Tool), as well as rock and soil targets of opportunity. Subsets of the full image array can be selected and/or pixels can be binned to reduce data volume. Image compression will be used to maximize the information contained in the data returned to Earth. The resulting MI data will place other MER instrument data in context and aid in petrologic and geologic interpretations of rocks and soils on Mars.

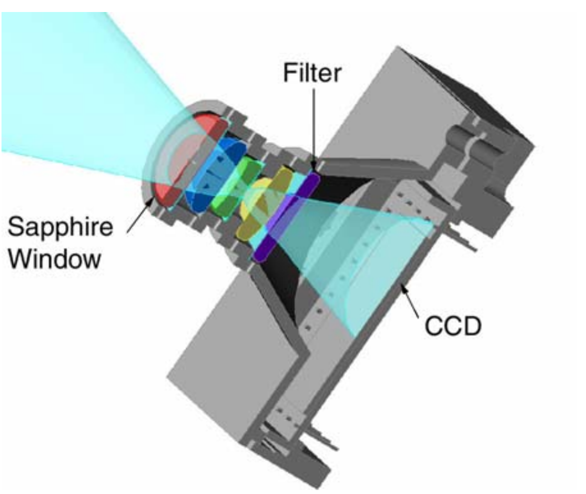

Figure 2. Cutaway diagram of MI optics barrel, showing sapphire window, lenses, and filter.

Table 1. MI performance requirements

Instantaneous Field of View (IFOV) of 30 ± 1.5 micrometers/pixel on-axis
Field of View (FOV) of 1024 x 1024 square pixels
Spectral bandpass of 400-680 nanometers
Effective depth of field of ≥ ±3 millimeters
Optics MTF ≥ 0.35 at 30 lp/mm over spectral bandpass at best focus
Radiometric calibration absolute accuracy of ≤ 20% and relative (pixel-to-pixel) accuracy of ≤ 5%
Signal to Noise Ratio (SNR) ≥ 100 for exposures of ≥ 20% full well over the spectral bandpass within the calibrated operating temperature range
Temperature sensor, accurate to ± 2°C, on the CCD package that can be read out and associated with the image data in telemetry
Working f/# = 15 ± 0.75
Operating temperature range within calibrated specifications = -55 ± 2°C to +5 ± 2°C

Science Objectives: To contribute to the achievement of the science objectives of the MER missions (Crisp *et al*., 2003), the Athena Microscopic Imager will: (1) image fine-scale morphology and reflectance of natural rock and soil surfaces, (2) image fine-scale texture and reflectance of abraded rock surfaces, (3) aid in the interpretation of data gathered by other Athena instruments by imaging areas examined by them at high resolution, and (4) monitor the accumulation of dust on the capture and filter magnets.

A wealth of geologic information can be obtained through studying rocks and soils with microscopes that have resolutions sufficient to enable detailed characterization of coatings, weathering rinds, individual mineral grains, or clasts. Such characterization is particularly important for analyses of aqueous sedimentary rocks. The size, angularity, shape, and sorting of grains reveal much about conditions of transport and deposition. Such information, which can be provided by the Microscopic Imager for sand-size and larger grains, will be extremely useful for understanding past aqueous environments on Mars. A variety of structures may be imaged that could provide diagnostic information about sedimentary environments, both in sedimentary rocks and unconsolidated soils. Across the size range from about 100 μm to 10 cm there are many well-documented sedimentary structures, formed within siliciclastic, carbonate and evaporitic environments, that reveal much about sedimentary processes and sedimentary environment. Examples include stratification (*e.g.,* cross laminations), bedforms (*e.g.,* ripples), chemical precipitation (*e.g.,* crystal fabrics) and dissolution (*e.g.,* stylolites), desiccation features, and sediment fabric. The MI will also be used to study textures and layering in recent sediments such as duneforms and aeolian lag deposits. Observations of the size, shape, color, and sorting of aeolian sediments will be compared with previous theoretical, remote sensing and laboratory studies of windblown material on Mars in order to better understand the origin and evolution of these materials. An example of the type of soil images expected from the MI is shown in Figure 3. A library of images of various terrestrial soil types is being assembled and will be used to aid the interpretation of MI data from Mars.

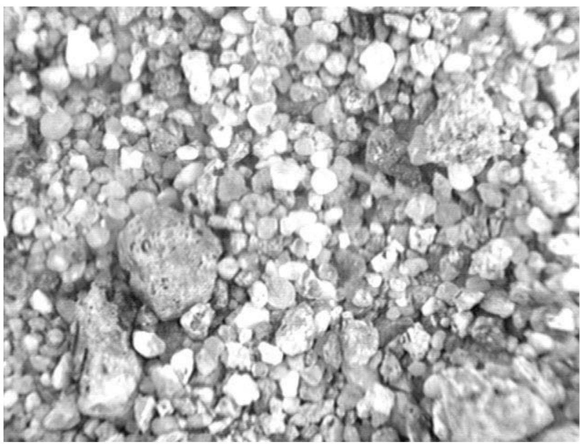

Figure 3. Monochrome version of FIDO Color Microscopic Imager [6] data from May 2001 field test, showing natural soil illuminated by skylight (target in shadow). View is about 13 mm across, 20 microns/pixel, taken at f/10.

Microscopic imaging also provides useful information on volcanic rocks and impact breccias. Vesicularity patterns give an indication of lava volatile content and distribution. Grain size and texture provide information on crystallinity of the magma when emplaced, its depth of origin, and how quickly it cooled. Microscopic imaging can be used to identify small veins of precipitated minerals like the carbonates in the Martian meteorite ALH84001. An example of the type of rock images expected from the MI is shown in Figure 4. In addition to images of natural surfaces, the MI will be used to image surfaces prepared using the Rock Abrasion Tool (RAT). Comparison of microscopic images taken of a rock target before and after abrasion will allow mineralogy and potential weathering processes to be studied.

The MI will also be used to image the filter and capture magnets mounted on the front of the rover [4]. These permanent magnets will be imaged frequently by Pancam and occasionally by MI during the landed mission, as airborne dust slowly accumulates on them. In order to monitor the thickness of the dust layer over time, the glass-bead blasted aluminum surface of the magnets has been marked by three types of tiny impressions (Fig. 4). The surface markings have been designed for MI imaging and are not expected to be visible in Pancam images. This experiment should provide much more precise constraints on the dust layer thickness than previous methods, which were based on the optical contrast between dust-covered and dust-free areas of the magnet surface [5].

Stereoscopic MI data can be obtained by moving the camera laterally using the IDD, allowing the detailed topography of the target to be derived. Such high-resolution topography may help constrain the mineralogy of grains that show cleavage faces. For rocks and soils that exhibit interesting spatial heterogeneity, the IDD can also be used to acquire MI mosaics. The combination of MI and other Athena observations will provide strong constraints on the mineralogy, genesis, and modification of Martian surface materials. Finally, because imaging observations of Mars have not yet been made at the scale expected from the MI, new discoveries and insights are likely.

References:

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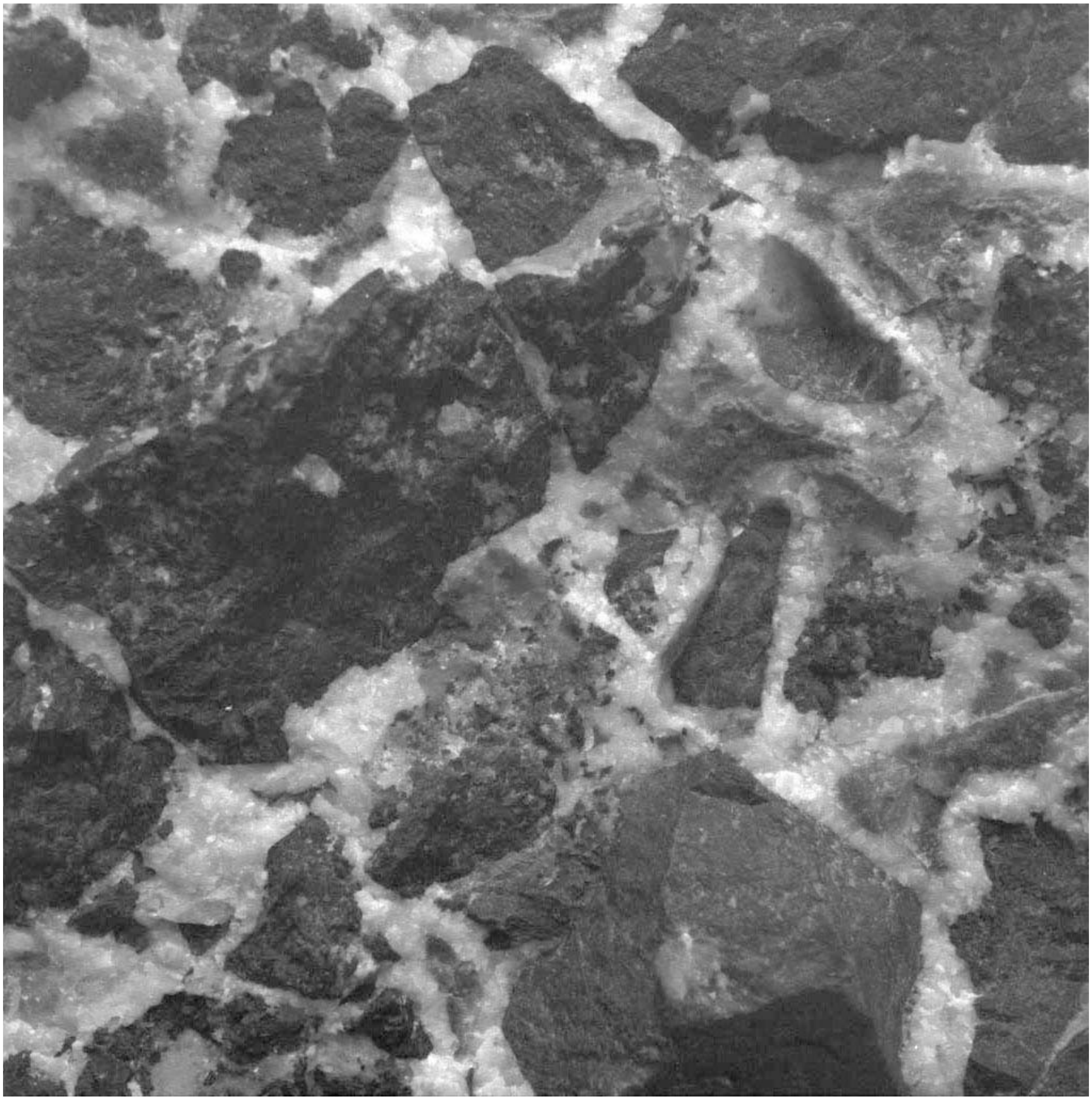

Figure 4. Image of rough side of rock target AREF146, taken by engineering model MI under room lighting. Field of view 31 mm square, 30 microns/pixel.