Dust on the Curiosity Mast Camera Calibration Target. K. M. Kinch[1], M. B. Madsen[1], J. F. Bell III[2], J. R. Johnson[3], W. Goetz[4] and the MSL Science Team. [1]Niels Bohr Institute, Copenhagen University (Juliane Maries Vej 30, DK-2100 Copenhagen, Denmark, kinch@nbi.ku.dk), [2]School of Earth and Space Exploration, Arizona State University, Arizona, USA, [3]Johns Hopkins University Applied Physics Laboratory, Maryland, USA, [4]Max-Planck-Institut für Sonnensystemforschung, Germany.

Introduction: The Mars Science Laboratory (MSL) rover Curiosity[1] landed successfully in Gale Crater[2,3] on Mars on August 6th, 2012 UTC. A crucial part of Curiosity's payload is its mast camera (Mastcam) imager[4], provided by Malin Space Science Systems in San Diego, California. Mastcam is mounted 2 m above the surface on the rover mast and serves the mission as a reconnaissance tool to identify interesting science targets for in-situ instruments and provide local context about such targets. In addition Mastcam is a powerful science instrument in its own right, providing high-resolution morphological information as well as low-resolution visible/near-infrared spectral information about the rover's environment. In order to aid Mastcam in providing high-fidelity reflectance spectra the rover carries the Mastcam calibration target (caltarget). This caltarget is imaged regularly during the mission and accumulation of atmospheric dust can be observed on the caltarget surface. Here we present an overview of the caltarget design, discuss the prospects for monitoring dust deposition and present some early observations of dust on the caltarget.

The Mastcam imager: Mastcam[4] consists of a pair of color CCD cameras. The left eye (M-34) has a field of view of 18.4° x 15° and a 34 mm focal length while the right eye (M-100) is higher resolution with a field of view of 6.3° x 5.1° and a focal length of 100 mm. Each camera eye provides basic color information through standard Bayer RGB color filters bonded on to the CCD. In addition a filter wheel with 8 distinct optical filters is mounted in front of each camera eye[5,6]. In each eye the 0 filter wheel position is a near-infrared cut-off filter, so that this filter position will produce standard Bayer-filter RGB images. Also in both eyes the 7 filter position is a neutral density filter for solar imaging. The remaining six filters in each eye are narrow-band bandpass filters spaced throughout the visible and near-infrared spectral region. Since three of the filters are identical in the two eyes this allows the camera system to acquire 9-point spectra over the wavelength range 445 nm - 1013 nm. This is comparable to the spectral capability of color imagers on the previous missions Mars Pathfinder[7], Mars Exploration Rovers[8] and Phoenix[9].

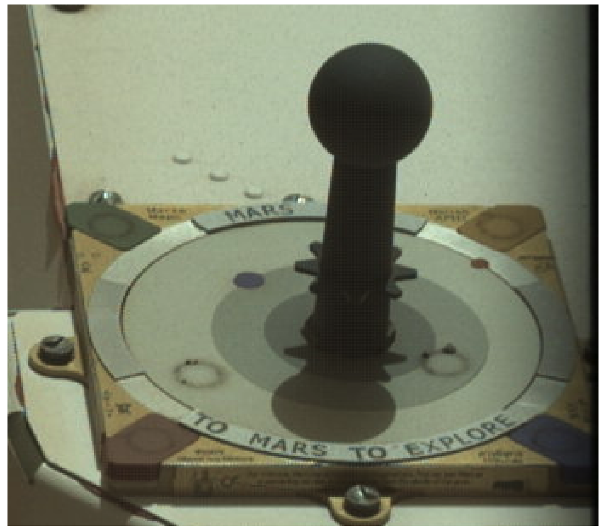

Figure 1: The Mastcam caltarget imaged on sol 3 of Curiosity's mission through the Mastcams L0 filter. The caltarget base is a square 8 cm on a side. Image ID: 0003ML0000140000E1 (shown here is a subframe of the original image product). Image credit: NASA/JPL-Caltech/Malin Space Science Systems

The Mastcam caltarget: The Mastcam caltarget is mounted on the rover deck, roughly 1 m behind the mast and on the same (right) side of the rover. The caltarget (see figures 1 & 2) is a sundial design, optically identical to the Panoramic Camera caltargets on the Mars Exploration Rovers[8]. The caltarget contains 7 spectrally distinct regions: 3 grayscale rings and 4 colored corner chips. The Mastcam caltarget differs from the MER Pancam caltargets in that beneath the reflecting surfaces are mounted six small "sweep magnets". Magnets are mounted underneath the two brightest grayscale rings and underneath each of the 4 corner chips. The magnets are 5 mm tall hollow cylinders made from Sm_2Co_{17} with an outer diameter of 9 mm and an inner diameter of 4 mm. The sweep magnet design is intended to produce an upward-directed magnetic field gradient just above the center of the magnet, which results in an upwards force on magnetic particles (such as martian aeolian dust grains) with the result that the surface above the center of the magnet sees reduced dust deposition. This magnet design was first flown as part of the magnetic properties experiment on the Mars Exploration Rovers[10] and sweep magnets were later integrated into the Surface Stereo Imager caltarget for the Phoenix mission[11].

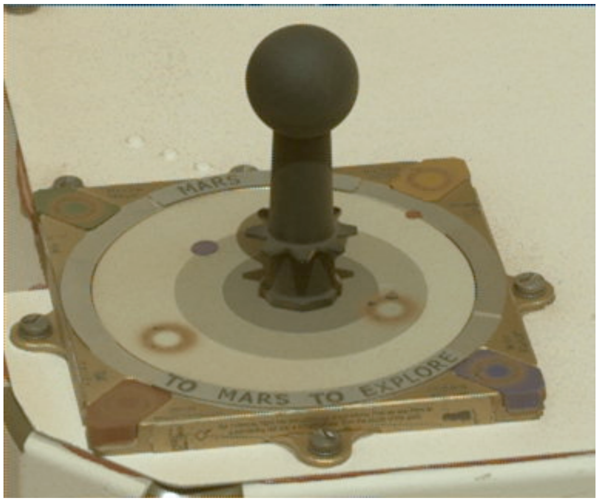

Figure 2: The Mastcam caltarget imaged on sol 72 of Curiosity's mission through the Mastcams L0 filter. The caltarget base is a square 8 cm on a side. Image ID: 0072ML0556000000E1. Image credit: NASA/JPL-Caltech/Malin Space Science Systems

Dust observations: Figure 1 shows a Mastcam image acquired on sol 3 of the mission. Clear rings of black or gray dust are apparent on all 6 sweep magnets as well as what appears to be several larger sand-sized grains or dust agglomerates. Figure 2 is a Mastcam image acquired on sol 72. Here, the dust rings on the magnets are more prominent and appear reddish rather than gray as was the case just after landing. On the Mars Exploration Rovers it was observed that the aeolian dust is separable into a black, magnetite-rich, highly magnetic fraction with larger grain sizes and a fine, bright red, less magnetic fraction[10,12]. We interpret the Mastcam caltarget observations to mean that the material observed on sol 3 was mainly delivered to the caltarget during the landing when significant amounts of dust and sand was lifted by the action of the retrorockets on the surface. The material attracted during the brief landing is dominated by larger and highly magnetite-rich grains. Later, on sol 72, the observed dust is optically dominated by the reddish fine fraction in the aeolian dust that has been delivered gradually during the course of the mission. Figure 3 shows a high-resolution image of parts of the caltarget surface acquired on sol 87 of the mission. In this high-resolution image it is apparent that some dust has been deposited also on the non-magnetic regions of the caltarget.

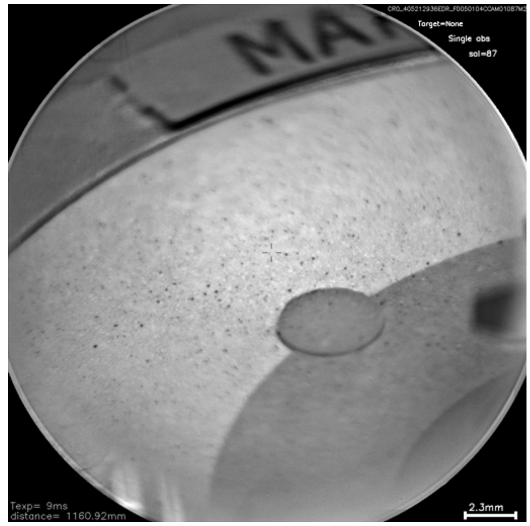

Figure 3: Part of the Mastcam caltarget imaged on sol 87 of Curiosity's mission by ChemCam's Remote Micro-Imager. For scale the small circle in the center of the image is the little blue dot visible just to the left of the caltarget gnomon (central post) in figures 1 & 2. Image ID: CR0_405212936EDR_F0050104CCAM01087M2. Image credit:NASA/JPL-Caltech/LANL/CNES/IRAP/LPGN/CNRS

Future work: Current work focuses on implementing a two-stream radiative transfer model to model the reflectance of dusty caltarget surfaces and derive the optical thickness of dust layers on the Mastcam caltarget as a function of time. Such an analysis was previously performed for the Pancam caltargets on MER[13]. This analysis can can be performed independently for the magnetic rings, the non-magnetic regions and the "clean" central spots of the magnets. and the optical thicknesses of dust layers in the three environments may be compared. Also the extent of dust deposition during the landing may be compared quantitatively to the dust settling rates during later operations.

References: [1] Grotzinger J. P. et al. (2012) *Space Sci. Rev.* DOI: 10.1007/s11214-012-9892-2. [2] Anderson R. B. & Bell J. F. III. (2010) *Mars 5,*76-128. [3] Wray, J. J. (2012) *Int. J. of Astrobiology.* DOI: 10.1017/ S1473550412000328. [4] Malin M. C. et al. (2010) *LPSC LXI,* Abstract # 1123. [5] Bell J. F. III et al (2012) *LPSC LXIII,* Abstract #2541. [6] Bell J. F. III et al This conference. [7] Smith P. et al. (1997) *JGR 102,* E2, 4003. [8] Bell J. F. et al (2006) *JGR 111* E02S03. [9] Smith P. et al. (2008) *JGR 113* E00A18. [10] Madsen M. B. et al. (2009) *JGR 114,* E06S90. [11] Leer et al (2008) *JGR 113,* E00A16. [12] Kinch et al (2006) *Planet. Space Sci. 54,* 28-44. [13] Kinch et al. (2007) *JGR 112,* E06S03