MASTCAM STEREO ANALYSIS AND MOSAICS (MSAM). R. G. Deen (Bob.Deen@jpl.nasa.gov)[1], H. E. Abarca[1], S. S. Algermissen[1], J. N. Maki[1], N. A. Ruoff[1], A. D. Culver[1], S. R. Levoe[1], A. W. Tinio[1], N. T. Toole[1], R. E. Arvidson[2], and K. E. Herkenhoff[3]. [1]JPL/Caltech; [2]Washington Univ., St. Louis; [3]USGS, Flagstaff, AZ.

Introduction: The Mastcam instrument suite on the NASA Mars Science Laboratory (MSL) Curiosity rover consists of two CCD cameras: a 34mm focal length left eye (M34) and a 100mm focal length right eye (M100). Despite the difference in focal length, these cameras are capable of producing high-quality stereo data. Raw data from these cameras have been made available via the NASA Planetary Data System (PDS) [1], and improved radiometric data sets are being produced by Bell *et al* [2]. However, no comprehensive, systematic stereo data sets, or mosaics incorporating Navcam context or stereo, have been made available to the general public.

The authors are rectifying this by producing and archiving in PDS Mastcam stereo, terrain mesh, and mosaic data sets covering the entirety of the MSL mission up to PDS release 17 (sol 1869). This effort, named MSAM, is made possible by the NASA Planetary Data Archiving, Restoration, and Tools (PDART) program.

These data sets will be invaluable for a host of scientific investigations, including geospatial and geomorphological analysis, photometric studies, strike/dip derivation, bedding relationships, mapping, and more. The PDART program does not actually perform these scientific analyses; rather it is aimed at providing well-calibrated data sets for use by the scientific community in their own investigations. This abstract describes the products being created by MSAM.

Stereo Products: All Mastcam stereo pairs (images acquired simultaneously through both cameras using filter 0) will be processed through JPL's Multimission Image Processing Lab (MIPL) stereo pipeline. The differences in focal length between the cameras is handled by the MIPL pipeline via the use of 2-dimensional correlation [3]; the same technique is used to correlate Mastcam stereo data in the operations pipeline.

The products produced are similar to what MIPL (aka OPGS, Operational Product Generation Subsystem) produces and delivers to PDS for the Navcam [4]. Specific image products include:

- Decompanded (8->12 bit expansion)
- De-Bayered (color reconstruction)
- Radiometric correction (non-rigorous; see [2])
- Stereo disparity
- XYZ point clouds
- Surface normal
- Range maps
- Slope maps (degrees of slope from vertical)
- Slope heading (azimuth of slope)
- Range error estimate

In addition, "colorglyphs" (red/blue anaglyphs that provide an impression of color by using red from the left eye and green/blue from the right) will be produced for every image pair for convenient viewing, along with epipolar-aligned color products for use with color stereo display systems.

Improved Camera Models: MSAM is planning on utilizing improvements in geometric camera models being developed by the Mastcam team, assuming they become available before processing begins. Without them, the XYZ accuracy is acceptable for most uses; with them the accuracy will be much improved.

Terrain Meshes: Terrain meshes are a convenient way to visualize data in 3-D. They consist of triangles in 3-D space, with image data attached as textures to each triangle. Meshes will be produced for each stereo pair, in a variant of OBJ format that is compatible with both PDS and popular mesh viewing programs such as MeshLab [5]. Additionally, MeshLab project files will be supplied (as ancillary files) that group meshes from a sequence into a unified whole (these files are not PDS compliant but will be supplied as a convenience).

Mosaics: Several types of mosaics will be produced by MSAM. They are described separately below, but share some common features. MIPL mosaics generally are covered in [4,6].

Mosaics will be made from filter 0 data only, using the rigorous radiometric correction results from Bell *et al* [2], a concurrent PDART task. (The stereo analysis products do not use these results, as radiometric correction has little effect on stereo analysis).

Certain Mastcam frames will be excluded from the mosaics. These include: thumbnails, images that target hardware (i.e. are pointed using a rover hardware frame), calibration target images, images centered above +20 degrees elevation, partial images with a more complete version, and images that have been re-sent at a better (less lossy) compression.

For the Navcam context frames, we exclude images centered above +45 degrees elevation, traverse images, thumbnails, and partial images with a more complete version.

Mosaics (except for stereo mosaics) are grouped by site and drive. Thus there is one of each type of mosaic at every rover location (assuming any Mastcam images were taken there). In areas where the surface has been modified (drill or scoop), additional post-modification mosaics will be included that cover the modified area.

Cylindrical M34/Navcam Context Mosaics: These show M34 images over a left Navcam (left) background, at M34 resolution (the Navcam is upsampled) using a cylindrical projection. The background helps establish context for the Mastcam observations. The mosaics are pointing-corrected [7] to reduce parallax errors.

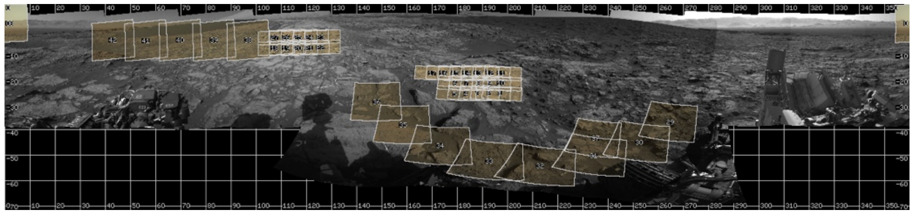

Figure 1: M34 Finder example from Sol 1187. Background grid shows azimuth/elevation.

These mosaics will cover a full 360 degrees in azimuth (when a full Navcam panorama was not acquired, coverage will instead be the union of Mastcam and Navcam). The vertical extent is the union of Mastcam and Navcam, up to a maximum of +20 degrees.

Cylindrical M100/Navcam Context Mosaics: These are similar to the M34 context mosaics, except they are at M100 resolution, and the right Navcam is used as the background (to reduce parallax).

In order to reduce data volume for these very large mosaics, they may be trimmed in azimuth. The Mastcam extent is expanded by 45 degrees in each direction, then the largest gap is trimmed out, if it exceeds 60 degrees. In effect, only gaps > 150 degrees in azimuth will be trimmed. As a special case, "Crater rim extinction" survey frames, often taken at azimuth=0, elevation=1.5 degrees, are excluded from the extent calculation, but are included in the mosaic if they are within the extent.

Cylindrical Mastcam-only mosaics: These are mosaics similar to the above but without the Navcam background. They are trimmed (only the largest azimuth gap is removed) to the Mastcam extent for both M34 and M100. Frames with no neighbors within 30 degrees center-to center (M34) or 10 degrees (M100) are eliminated, as there is little to be gained by mosaicking them with no neighbors or context.

Stereo Mosaics: Epipolar aligned mosaics at M34 resolution using the cylindrical-perspective projection [4,6] will be created for stereo viewing, including both left and right color mosaics, and colorglyphs. These are grouped by sequence ID, so there may be multiple mosaics per rover location. Sequences with only one image are not mosaicked; they can be viewed in stereo using the single-image stereo products.

Orthorectified Mosaics and DEMs: Digital Elevation Models (DEMs) and corresponding coregistered image mosaics will be created using the orthorectified projection [4,6]. Two resolutions will be produced for each rover location:

- 1mm resolution at 10m range (only if there is stereo data < 10m away from the rover)
- 1cm resolution at 75m range (only if there is stereo data >10m away from the rover)

Finder Mosaics: The Mastcam data sets are very large (untrimmed M100 mosaics will typically be on the order of a gigapixel), and often observations are discontiguous and scattered. In order to help users find what images are available, "finder" mosaics will be created for M34, M100, and stereo image coverage at each rover location (Figure 1). Each of these finder mosaics is small (1/4 Navcam resolution), untrimmed (a la M34 context mosaics), and has available Mastcam frames outlined on them, showing coverage and context. Each Mastcam frame has a number on it, which can be used with the accompanying list file to identify the frame, and thus find all the stereo analysis products for the frame. These should be particularly useful to identify stereo singleton frames, which are not mosaicked but are in the stereo image data set.

Data Format: All products (except the MeshLab project files) will be PDS-4 compliant. The image and mosaic products additionally conform to the syntax and semantics of PDS-3. Although they are not technically PDS-3 files, software written to use the Navcam data currently in PDS (described in [4]), or similar data from MER or Phoenix, should be able to read the MSAM data as well. The MIPL tool Marsviewer [8] will also be updated to work with MSAM data. Examples of many of the MSAM products are shown in [9].

Peer Review and Feedback: The MSAM products will go through PDS Peer Review soon after the LPSC 2018 conference. Anyone in the community who would like to be a reviewer should contact the PI (Deen). Additionally, we welcome comments, questions, suggestions, or concerns about this data set.

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