

SUPPORTING LOCATION AND MEASUREMENT FUNCTIONS ON CURIOSITY ROVER MOSAICS IN THE ANALYST’S NOTEBOOK F. Zhou¹, T. Stein², R. E. Arvidson³, and J. Wang⁴, McDonnell Center for the Space Sciences, Department of Earth and Planetary Sciences, Washington University in St. Louis, 1 Brookings Drive, Campus Box 1169, St. Louis, Mo, 63130, ¹chow@wunder.wustl.edu; ²stein@wunder.wustl.edu; ³arvidson@wunder.wustl.edu; ⁴wang@wunder.wustl.edu.

Introduction: The Planetary Data System (PDS) Analyst’s Notebook (AN, <https://an.rsl.wustl.edu/msl>) [1] for the Mars Science Laboratory (MSL) Curiosity rover [2] is an interactive web application containing peer-reviewed, publicly available data from surface operations, supported by documentation that describes context for the observations, processing methodology, and data formats. The Image Viewer tool within the Notebook provides functions to visualize and explore MSL mosaics, including source frame identification, location and distance measurement, and ground location identification. These functions are available in Mars Science Interface (MSLICE) [3], a planning tool restricted to Curiosity rover science team members. Our intent is to make these tools available to the planetary science community for use with archived data.

Background and Methodology: The MSL Camera Software Interface Specification (SIS) document [4] provides details of the methods, algorithms, and models describing how MSL single frame and mosaicked Navigation Camera (Navcam) and Hazard Avoidance Camera (Hazcam) images are generated and processed. Raw Experiment Data Record (EDR) and most higher-order Reduced Data Record (RDR) data products include camera model information [5] within the metadata labels. The metadata are used to reconstruct the geometric setting at the time of imaging and thus to build a mapping between the image domain and the 3D object domain. Navcam image mosaics are generated by Multimission Instrument Processing Laboratory (MIPL) [4], assembled from multiple source frames into a single RDR product.

In addition to the camera model, the mosaic metadata includes the surface model and projection parameters used for mosaic generation. The surface model is a mathematical surface which approximates the actual scene. Most mosaics are created using the flat surface model, a flat plane, with normal direction pointing upwards. Mosaic projection parameters model the transformation between a point on the mosaic surface model and a corresponding pixel on the mosaic image. We implement the mapping between a mosaic and its source frames so that any pixel on the mosaic can be traced back to the corresponding pixel in a particular source frame and vice-versa by following the process of mosaic generation in [4]. A mosaic has multiple source frames, and each source frame may have a derived XYZ RDR product (“XYZ file” in this ab-

stract), a three-band image that provides the site frame coordinates for a given pixel in the source image. From this, we are able to relate image pixel locations to Mars ground coordinates in local, rover, surface, and map reference frames.

The relationship between image pixel locations and Mars ground coordinates is illustrated in Figure 1, where (x_g, y_g, z_g) represent a ground coordinate on the martian terrain surface; (x_m, y_m, z_m) is a coordinate on a mosaic surface model; (i_m, j_m) and (i_s, j_s) represent image pixel coordinates on the mosaic and source frames, respectively. A mosaic pixel coordinate (i_m, j_m) can be converted to a coordinate (x_m, y_m, z_m) on the mosaic surface model, and vice-verse through equations based on mosaic metadata [4]. A ground coordinate (x_g, y_g, z_g) (i.e. values from XYZ file) can be converted to source image pixel (i_s, j_s) using camera model metadata. On the other hand, a ground coordinate (x_g, y_g, z_g) can be derived from a source image pixel (i_s, j_s) by using the value at the same pixel from a XYZ file.

Results of this approach were compared to those obtained by visual inspection of the same features on source frame images. The validation test found a difference of less than 2 cm on the ground between the two methods, an acceptable difference given the precision of data in the XYZ files.

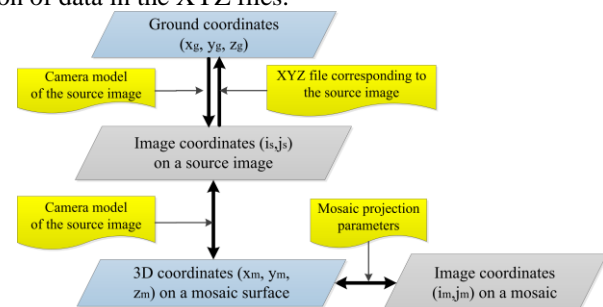


Figure 1. Relationship Diagram between source image pixel (i_s, j_s) , mosaic surface model coordinates (x_m, y_m, z_m) , ground coordinate (x_g, y_g, z_g) and mosaic image pixel (i_m, j_m) .

Use within the Analyst’s Notebook Image Viewer: The AN Image Viewer uses coordinate frame transformation calculations to support location and measurement functions from different frames, including a map projection coordinate system, e.g., Universal Transverse Mercator (UTM).

Source Frame Identification. A user may want to work with one or more source frames that comprise a

given mosaic. Mosaic metadata are used to identify the source frames used, but do not allow specification of their locations on the mosaic. In order to register source images on a mosaic, we calculate the points of intersection between viewing rays from four edges of the source image and the mosaic surface model. Then we project the intersection coordinate (x_m, y_m, z_m) on the mosaic surface model to the image plane of the mosaic to construct the source footprint. Any pixel (i_m, j_m) on a mosaic can be located on its source frame footprint using the point in a polygon algorithm. When a user clicks a point on the mosaic, the source frame(s) are highlighted, as shown in Figure 2.

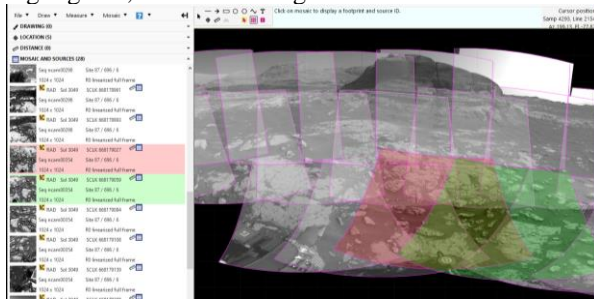


Figure 2. AN Image Viewer screen capture showing a cylindrical mosaic with source footprints visible. The highlighted footprints in green and red identify the two source frames that include coverage of a user-identified location on the mosaic. Corresponding highlights on the left side are direct links to the individual image products.

Location and Measurement Tools. Users may find the position of a point in a mosaic or measure the distance between two selected points. For any pixel on the mosaic, we compute the corresponding coordinate (x_m, y_m, z_m) on the mosaic surface model. Using this coordinate, the image pixel (i_s, j_s) on the source frame is calculated and the coordinate on the ground (x_g, y_g, z_g) of pixel (i_s, j_s) can be read from the XYZ files. In addition, the Image Viewer provides length, distance to rover, and azimuth and elevation angle measurements, as shown in Figure 3. Locations can be shown in different reference frames. Measurement data can be downloaded in an Excel spreadsheet format as well as ESRI shapefiles.

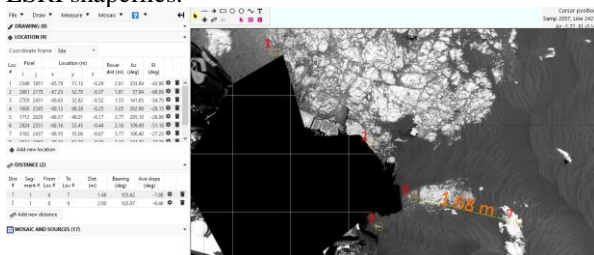


Figure 3. Feature and distance measurements on a vertical mosaic in MSL AN Image Viewer.

Finding a Point Based on a Known Ground Coordinate. A user may want to find the pixel on the mosaic by providing an (x, y) or (x, y, z) ground coordinate. As noted, XYZ files do not exist for mosaic images, and searching each source frame's XYZ file pixel by pixel is time consuming. Instead, we use the camera model and source frame metadata stored in a database to improve performance. To identify a ground coordinate (x_g, y_g, z_g) given by the user, the image pixel coordinate (i_s, j_s) on source frames is obtained by querying the stored metadata. A viewing ray from (i_s, j_s) that intersects the mosaic surface is used to find the (x_m, y_m, z_m) on the mosaic surface mode and the resulting image pixel coordinate (i_m, j_m) on the mosaic. The performance time to find a ground xyz value on a mosaic is less than 1 second even for a mosaic with 76 source frames. If a user does not provide z value, the corresponding (i_s, j_s) is unable to be directly calculated using the camera model. In this case, stored metadata are used to narrow down candidate source frames, which are then searched pixel by pixel to locate the closest match. The performance time is typically two to four seconds. Figure 4 shows the Image Viewer dialog for finding a location on a mosaic using a UTM coordinate and the output result. The output result is automatically converted into site frame.

Find location		Find location result	
Enter location in: <input type="text" value="Map"/>		Desired location	Found location
X	-280680.00 m	X	-56.47 m
Y	8145070.00 m	Y	35.51 m
Z		Z	-5.99 m
		Δ	0.01 m

Buttons:

Figure 4. Find a ground coordinate (x, y) on a mosaic. The Add location button marks the point on the mosaic.

Future Work: Our development is based on previous suggestions from our PDS users, and feedback continues to be sought. (User feedback should be submitted to an@wunder.wustl.edu or by using the online form.) Work continues to incorporate additional features, especially in the areas of related observations and visualization, for example overlay observed targets on mosaics in the Image Viewer.

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References: [1] Stein, T. et al. (2019), 50th LPS, Abstract #1820. [2] Grotzinger, J. et al. (2012) Space Science Reviews, 170, 5-56. [3] Powell, M. et al. (2009), NASA Tech Briefs. [4] Alexander, D. et al. (2018), MSL_CAMERA_SIS. [5] Gennery, D. (2002), JPL Document.