THE NASA MARS 2020 MISSION PERSEVERANCE ROVER MASTCAM-Z DATA ARCHIVE. A.M. Bailey[1] , L.K.Mehall[1], E.Cisneros[1], J.F. Bell III[1], K.N.Paris[1], E.H. Jenson[2], J.N. Maki[3], and the Mastcam-Z science and operations team. [1]Arizona State Univ., Tempe, AZ (ambail10@asu.edu); [2]Malin Space Science Systems, Inc., San Diego, CA; [3]JPL/Caltech Pasadena, CA

Introduction: The Mastcam-Z instrument [1-3] onboard the Mars 2020 Perseverance rover is currently acquiring images in Jezero crater. This instrument is a multispectral, zoomable, and focusable camera pair located on the rover's remote sensing mast (RSM) [Figure 1]. Each camera has an 8-position filter wheel and is capable of acquiring color images using Bayer pattern red, green, and blue (RGB) filters bonded onto the charged-coupled device (CCD) detector; multispectral images using six other narrowband filters (~440 nm to ~1000 nm); or solar images using neutral density filters. The cameras acquire color, multispectral, stereo, and panoramic images of the surface and rover hardware. Mastcam-Z is also capable of taking videos. This makes Mastcam-Z ideal for investigating topographic, morphologic, atmospheric, mineralogic, and physical features of the surface of Mars.

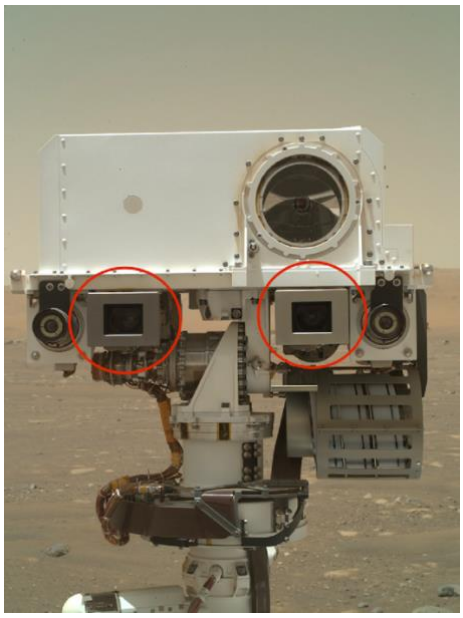

Figure 1: Remote Sensing Mast (RSM) "selfie" acquired using the Mars 2020 Perseverance SHERLOC/WATSON camera located on the turret at the end of the robotic arm. This image shows Mastcam-Z outlined in red mounted on the RSM on Mars. [SI1_0045_0670932474_015ECM_N0031416SRLC07021_000085J] [NASA/JPL-Caltech]

Data Acquisition: Mastcam-Z acquires images in a variety of product types, including: full-frame (1648 x 1200 pixels), subframe, thumbnail, compressed video groups of pictures (GOPs), and focus merges (z-stacks). All of these product types can be stored in the camera Digital Electronics Assembly (DEA). Typically, a full resolution image is written to the DEA as a raw uncompressed image that can be later copied to the rover as a "virtual data product" (VDP) pointer back to the original DEA image. When queued for downlink, the VDPs are processed in the rover's computer into requested data product (DP) format, and then downlinked by way of orbiter passes using the Deep Space Network (DSN) [4]. Once images have been downlinked, they get thoroughly checked for accurate pointing, metadata, saturation, and data dropouts.

Sometimes partial products come down and have to be retransmitted on the next sol (Mars "day"). Reprioritizations can be requested to receive the images sooner if they are needed for tactical decisions on where to drive, sample, etc., and recovered images can be requested in order to acquire an image in a compression or format that is different from how it was originally downlinked, as long as it has been stored in raw format in the DEA. There are four kinds of "level-0" raw data products: (1) color JPEGs (images & thumbnails); (2) Losslessly-compressed images; (3) compressed color videos; and (4) raw 11-bit images [1,5].

Data Products: The Mastcam-Z team at Arizona State University (ASU) generates radiance (RAD) and radiance factor (IOF) calibrated data products "level-1B" for all applicable observations. Mastcam-Z RAD products are calibrated using the required calibration and processing algorithms outlined in Figure 2.

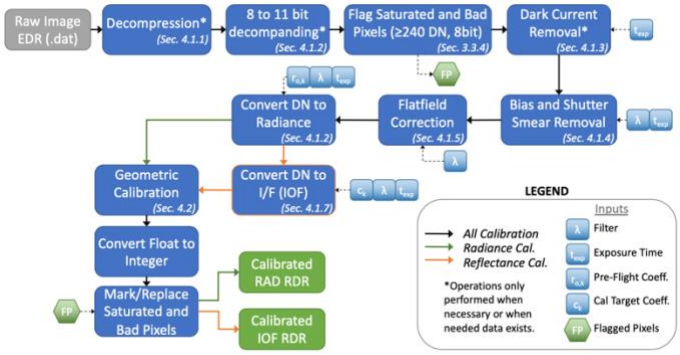

Figure 2: Flowchart of the Mastcam-Z radiometric calibration pipeline [2].

Calibration target (cal target) images are periodically acquired near-in-time to most multispectral

image sequences and used in nominal calibration. Mastcam-Z has a primary and a secondary cal target [Figure 3]. The primary is used to verify and validate preflight calibration while on the surface as well as tactical conversion from radiance to reflectance. The secondary cal target is used to affirm the results of the primary in calibration as well as to monitor dust buildup [4,6].

Data quality information is captured and stored in the attached Object Descriptive Language (ODL) label and is used for calibration efforts and tracking issues within the image products themselves. Images that are missing key metadata among other issues are not calibrated because their products could be misleading and inaccurate.

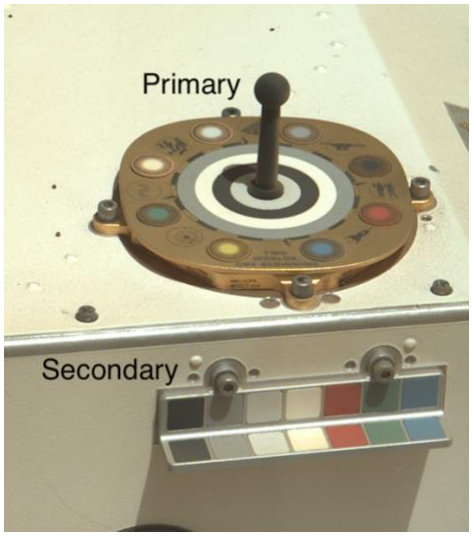

Figure 3: Mastcam-Z primary and secondary calibration targets located on the rover deck. Image taken by the Mastcam-Z left camera. [ZL0_0046_0671018979_320EBY_N0031416ZCAM03011_0480LMJ] [NASA/JPL-Caltech/ASU]

Archive: All Mastcam-Z data products will be available through the Planetary Data System (PDS). The ASU team archives RAD and IOF data products in the form of .IMGs. Derived atmospheric properties like opacity are also archived in the form of an ASCII table. The archive will also include pre-flight calibration data acquired during ATLO testing, as well as cruise data products [7]. All other products, including tactically-generated Mastcam-Z data products not archived by the ASU team will be archived in the PDS by the JPL Mars 2020 Project's Instrument Data Subsystem (IDS). The ASU team acquires the raw and IDS generated experimental data records (EDRs) which go through the Mastcam-Z-team developed RAD and IOF pipelines. Once complete, they get an external Extensible Markup Language (XML) label generated for PDS4-compliant archiving. These products, consisting of the .IMG with attached ODL label and the XML detached label, are then thoroughly vetted through a series of image and label checks. The attached ODL and detached XML labels have individual tools that check the product validity and compliance to PDS4 requirements. All the images are thoroughly vetted by Mastcam-Z personnel and the product data quality is cataloged for the Mastcam-Z science team and public use of the image products. The filenames, label values, and label keywords are all vetted before archiving to ensure high quality products reach the hands of archive users.

The first Mastcam-Z archived images will be released to the public via the PDS (https://pds.nasa.gov/) in August of 2021. This release will include data products for sols 0-89 and are expected to reach an estimated data volume of 31GB.

Acknowledgments: The PDS validate tool for PDS4 XML labels is used for XML label validation https://nasa-pds.github.io/validate/

References: [1] Bell, J.F., *et al. Space Sci Rev* **217,** 24 (2021). https://doi.org/10.1007/s11214-020-00755-x. [2] Hayes, A.G., *et al. Space Sci Rev* **217,** 29 (2021). https://doi.org/10.1007/s11214-021-00795-x. [3] Farley, K.A., et al. Space Sci Rev (2020) 216:142 (2020). [4] Bell, J.F. et al., Mars 2020 Mastcam-Z Investigation Experiment Operations Plan (EOP) v3.1, (2018) JPL D-101346. https://doi.org/10.1007/s11214-020-00762-y. [5] Malin, M.C. et al. (2013). Mars Science Laboratory Project Software Interface Specification (SIS).[6] Kinch, K.M., *et al. Space Sci Rev* **217,** 46 (2021). https://doi.org/10.1007/s11214-021-00828-5. [7] Mehall, L. K., et al., (2019) *4th Planetary Data Workshop* Abstract #7060.

Additional Information: For more information on Mastcam-Z images, publications, and the team, check out https://mastcamz.asu.edu/ .