

MASTCAM-Z IN JEZERO CRATER: OVERVIEW AND STATUS UPDATE. J.N. Maki¹, J.F. Bell III², G.L. Mehall², M.A. Ravine³, M.A. Caplinger³, K.N. Saxton¹, K.M. Kinch⁴, M.B. Madsen⁴, M. Rice⁵, E. Cisneros², B.L. Ehlmann⁶, A. Hayes⁷, B. Horgan⁸, E. Jensen³, J.R. Johnson⁹, K. Paris², A. Winhold², B. Betts¹⁰, M.J. Wolff¹¹, A. Bailey², M. Barrington⁷, E. Cloutis¹², N. Cluff², A. Coates¹³, A. Colaprete¹⁴, P. Corlies⁷, K. Crawford², R. Deen¹, K. Edgett³, S. Fagents¹⁵, S.Z. Fleron⁴, J. Grotzinger⁶, K. Gwinner¹⁶, M.D. Hansen⁴, C. Hardgrove², K. Herkenhoff¹⁷, R. Jaumann¹⁸, M. Lemmon¹¹, L. Mehall², J. I. Núñez⁹, G. Paar¹⁹, M. Caballo-Perucha¹⁹, F. Preusker¹⁶, M.S. Robinson², C. Rojas², N. Schmitz¹⁶, N. Stein⁶, R. Sullivan⁷, C. Tate⁷, A. Vaughan², C. Million²⁰, M. St. Clair²⁰, J. Proton²¹, M. Merusi⁴, ¹JPL/Caltech, Pasadena, CA (Contact: Justin.N.Maki@jpl.nasa.gov); ²Arizona State Univ., Tempe, AZ (Contact: Jim.Bell@asu.edu); ³Malin Space Science Systems, San Diego, CA; ⁴Univ. of Copenhagen, Denmark; ⁵Western Washington Univ., Bellingham, WA; ⁶Caltech, Pasadena, CA; ⁷Cornell Univ., Ithaca, NY; ⁸Purdue Univ., South Bend, IN; ⁹APL/Johns Hopkins Univ., Laurel, MD; ¹⁰The Planetary Society, Pasadena, CA; ¹¹Space Science Inst., Boulder, CO; ¹²Univ. of Winnipeg, Canada; ¹³Univ. College, London, UK; ¹⁴NASA/Ames Research Center, Moffett Field, CA; ¹⁵Univ. of Hawaii, Honolulu, HI; ¹⁶DLR/German Aerospace Center, Berlin; ¹⁷USGS Astrogeology Science Center, Flagstaff, AZ; ¹⁸Free Univ. Berlin, Germany; ¹⁹Joanneum Research, Graz, Austria, ²⁰Million Concepts, Louisville, KY, ²¹Opcode, San Diego CA.

Introduction: Shortly after landing in Jezero crater, Mars, on 18 February 2021, the *Perseverance* rover began sending back high-resolution images from the Mastcam-Z instrument. Mastcam-Z [1] is a high-heritage imaging system that is based on the successful Mastcam investigation on the Mars Science Laboratory (MSL) *Curiosity* rover [2,3]. Mastcam-Z has all of the capabilities of MSL Mastcam, augmented with a 4:1 optical zoom capability that significantly enhances stereoscopic imaging performance for science and rover operations. Each camera has a selectable field of view ranging from ~7.7° to ~31.9° diagonally, with the ability to achieve pixel scales from 67 to 283 $\mu\text{rad}/\text{pix}$ (resolving features ~0.7 mm in size in the near field and ~3.3 cm in size at 100 m) from its position ~2 m above the surface on the Perseverance Remote Sensing Mast.

Mastcam-Z Goals: The goals of the Mastcam-Z investigation are to: (1) Characterize the overall landscape geomorphology, processes, and the nature of the geologic record (mineralogy, texture, structure, and stratigraphy) at the rover field site; (2) Assess current atmospheric and astronomical conditions, events, and surface-atmosphere interactions and processes; and (3) Provide operational support and scientific context for rover navigation, proximity (contact) science, sample selection, extraction, and caching, as well as imaging support for other Perseverance instruments and rover tools.

Landscape/Terrain Observations: After initial checkout and characterization activities, Mastcam-Z acquired images of the Jezero crater floor that show cm-scale textures in the rocks in the immediate vicinity of the landing site (Figure 1). These textured rocks are interpreted as eroded bedrock units of the Crater Floor Fractured Rough [4]. Mastcam-Z images of the more distant terrain show detailed layering, particularly in the remnant buttes located towards the delta front, ~1 km south of the main

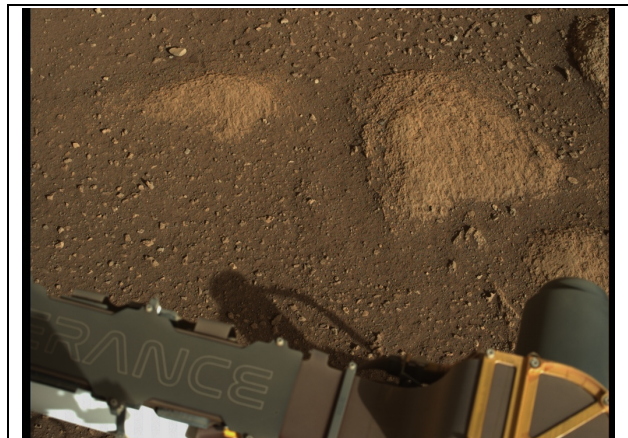


Figure 1. Mastcam-Z image acquired on Sol 2, showing finely textured rocks at the *Perseverance* landing site. Image scale is 155 $\mu\text{m}/\text{pix}$ and grains as small as ~1 mm across can easily be resolved.

western fan deposit in Jezero (Figure 2). Mastcam-Z images of the delta and remnants show layers of five distinct stratigraphic sections not visible from orbit. These structures are believed to be the eroded remnant of an original, extensive lacustrine delta deposit [5].

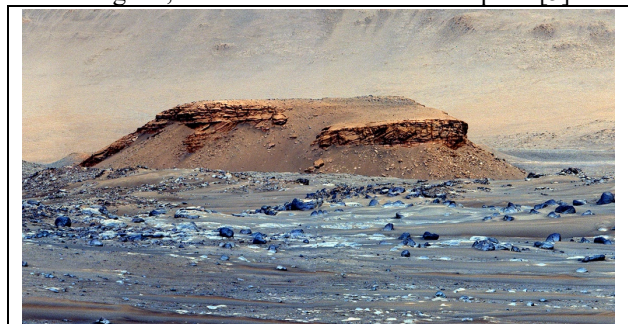


Figure 2. Mastcam-Z image of Kodiak Butte taken in the early morning light on sol 63. The top of the mesa is ~150 m across but the bottom of the feature is not visible below the closer local horizon.

Multispectral Observations: Mastcam-Z multispectral images show a diversity of spectral signatures related to ferric (Fe^{3+}) and ferrous (Fe^{2+}) mineralogy [6]. The layered units in the Séítah region are olivine-bearing,

consistent with orbital observations, while other layered units (e.g., Figure 3) show spectral signatures more consistent with pyroxenes. Some “paver” rocks (e.g., Figure 1), which have low relief and no obvious layering, have spectra consistent with fine-grained, red hematite.

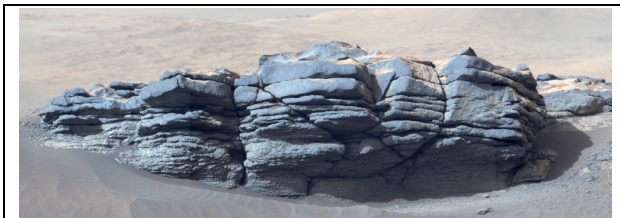


Figure 3. Layering at Artuby. From Mastcam-Z images acquired on Sol 288.

Sample Acquisition Operations: Mastcam-Z images play a critical role in *Perseverance* coring and abrasion activities. Images of the sample workspace provide contextual documentation of the sample locations (Figure 4) and images of the cores within the sample tube (Figure 5) provide operational confirmation of sample acquisition and document the texture and color of the exposed bottom of the core [7].



Figure 4. Mastcam-Z 3D rendering from Sol 297 stereo image reconstruction of the *Issole* outcrop with 5 cm (center) and 10 mm scale bars (upper right, in abrasion patch), showing the *Robine* coring location (left) and *Quartier* abrasion location (right). The abrasion patch is ~ 42 mm in diameter. Visualization and dimensional measurements by PRo3D [8, 9].

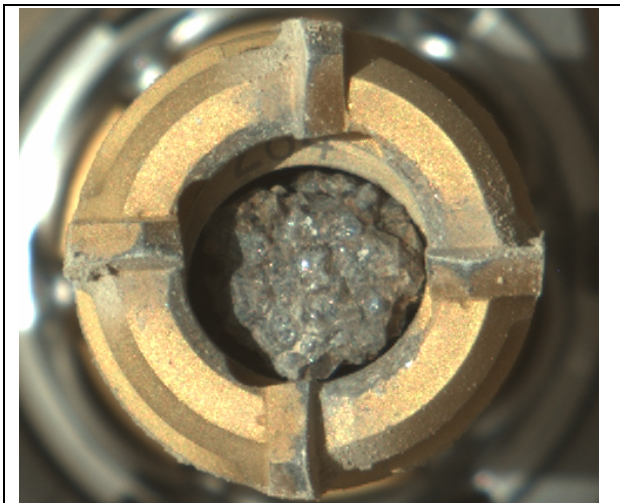


Figure 5. Mastcam-Z image (Sol 271) of the *Coulettes* core within the sample tube. The core diameter is ~13 mm.

Helicopter Operations: Mastcam-Z images and video of the *Ingenuity* helicopter [10] have provided critical documentation of the first powered flight of a vehicle on another planet (Figure 6). These images also show helicopter-induced dust lifting events caused by the helicopter blades. This information can be used to verify near-surface dust lifting models [11].



Figure 6. Mastcam-Z image (Sol 69) of *Ingenuity* flying across the Martian landscape during flight #4.

Atmospheric Observations: Mastcam-Z images of the sun acquired through solar filters at RGB and 880 nm wavelengths enable the direct measurement of dust optical depth. These images show optical depth trends consistent with typical Mars seasonal trends. Morning observations show higher optical depth relative to afternoon observations, consistent with atmospheric water ice particles in the morning.

Summary: As of Sol 300, over 61,000 Mastcam-Z images have been received from Mars. These images are processed and archived in the NASA Planetary Data System (PDS) within 6 months of receipt on Earth [12]. Mastcam-Z continues to function nominally.

References: [1] Bell et al., *Space Sci. Rev.*, doi:10.1007/s11214-020-00755-x, 2020. [2] Malin et al., *Earth & Space Sci.*, 4, 506–539, 2017. [3] Bell et al., *Earth & Space Sci.*, 4, doi:10.1002/2016EA000219, 2017. [4] Stack et al., *Space Sci. Rev.*, doi:10.1007/s11214-020-00739-x, 2020. [5] Mangold et al., *Science* 10.1126/4051 (2021). [6] Rice et al., *LPSC 53*. [7] Maki et al., *LPSC 53*. [8] Barnes, et al., (2018) *Earth & Space Science*, 5(7), 285-307. [9] <https://www.youtube.com/watch?v=67KnMVZoxuU> [10] Balaram, J., et al. *Space Sci Rev* 217, 56 (2021). [11] Rabinovitch et al. 2021, *Aeolian Research* 48, 100653. [12] Bailey et al., *LPSC 53*.