ANTICIPATED INITIAL RESULTS FROM THE NASA MARS 2020 *PERSEVERANCE* ROVER MASTCAM-Z MULTISPECTRAL, STEREOSCOPIC IMAGING INVESTIGATION. J.F. Bell III[1], J.N. Maki[2], G.L. Mehall[1], M.A. Ravine[3], M.A. Caplinger[3], K.N. Saxton[2], K.M. Kinch[4], M.B. Madsen[4], B. Betts[5], E. Cisneros[1], B.L. Ehlmann[6], A. Hayes[7], B. Horgan[8], E. Jensen[3], J.R. Johnson[9], K. Paris[1], M. Rice[10], A. Winhold[1], M.J. Wolff[11], A. Bailey[1], M. Barrington[7], E. Cloutis[12], N. Cluff[1], A. Coates[13], A. Colaprete[14], P. Corlies[7], K. Crawford[1], R. Deen[2], K. Edgett[3], S. Fagents[15], J. Grotzinger[6], K. Gwinner[16], C. Hardgrove[1], K. Herkenhoff[17], R. Jaumann[18], M. Lemmon[11], L. Mehall[1], J.I. Núñez[9], G. Paar[19], M. Caballo-Perucha[19], F. Preusker[18], M.S. Robinson[1], C. Rojas[1], N. Schmitz[18], N. Stein[6], R. Sullivan[7], C. Tate[7], and A. Vaughan[17], [1]Arizona State Univ., Tempe, AZ (Contact: Jim.Bell@asu.edu); [2]JPL/Caltech, Pasadena, CA; [3]Malin Space Science Systems, San Diego, CA; [4]Univ. of Copenhagen, Denmark; [5]The Planetary Society, Pasadena, CA; [6]Caltech, Pasadena, CA; [7]Cornell Univ., Ithaca, NY; [8]Purdue Univ., West Lafayette, IN; [9]APL/Johns Hopkins Univ., Laurel, MD; [10]Western Washington Univ., Bellingham, WA; [11]Space Science Inst., Boulder, CO; [12]Univ. of Winnipeg, Canada; [13]Univ. College, London, UK; [14]NASA/Ames Research Center, Moffett Field, CA; [15]Univ. of Hawaii, Honolulu, HI; [16]DLR/German Aerospace Center, Berlin; [17]USGS Astrogeology Science Center, Flagstaff, AZ; [18]Free Univ. Berlin, Germany; [19]Joanneum Research, Graz, Austria.

Introduction: Mastcam-Z [1] is a high-heritage imaging system aboard NASA's Mars 2020 *Perseverance* rover that is based on the successful Mastcam investigation on the Mars Science Laboratory (MSL) *Curiosity* rover [2,3]. It has all the capabilities of MSL Mastcam, and is augmented by a 4:1 zoom capability that will significantly enhance its stereo imaging performance for science, rover navigation, and *in situ* instrument and tool placement support. The Mastcam-Z camera heads are a matched pair of zoomable, focusable charge-coupled device (CCD) cameras that collect broad-band red/green/blue (RGB) or narrow-band visible/near-infrared (VNIR; ~400-1000 nm) multispectral color data as well as direct solar images using neutral density filters (Table 1). Each camera has a selectable field of view ranging from ~7.7° to ~31.9° diagonally, imaging at pixel scales from 67 to 283 μrad/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 (RSM).

Mastcam-Z Imaging Goals: The goals of the 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.

Mastcam-Z will observe textural, mineralogical, sedimentological, 3-D, structural, photometric, and morphologic details in rocks, outcrops, and regolith at the rover's field site in Jezero crater [4]. Imaging from Mastcam-Z and many of the other cameras onboard the rover [5,6] will permit the science team to constrain rock type (e.g., sedimentary *vs*. igneous) and texture, and to reconstruct a geologic history of the site from stratigraphic and mineralogic evidence in outcrops and regolith. The Mastcam-Z cameras will also document dynamic processes and events via video (*e.g.*, aeolian sand movement, dust devils, cloud motions, and astronomical phenomena) at video rates of 4 frames/sec or faster for subframes, observe the Sun and sky for atmospheric science, and contribute imaging and video data to rover navigation and target selection for investigations by the rover's mobility, coring, and sample caching subsystems as well as other instruments.

Instrument Summary: The Mastcam-Z investigation is led and managed by Arizona State University, working closely with prime subcontractor Malin Space Science Systems (MSSS). The flight hardware consists of 5 elements (Figure 1): two camera heads, mounted on

Table 1. Mastcam-Z Left (L) and Right (R) Filters[a]

Filter Number	λ_{eff} ± HWHM (nm)[b]	
L0/R0 (Red Bayer)	630 ± 43	631 ± 43
L0/R0 (Green Bayer)	544 ± 41	544 ± 42
L0/R0 (Blue Bayer)	480 ± 46	480 ± 46
L1 / R1	800 ± 9	800 ± 9
L2 / R2	754 ± 10	866 ± 10
L3 / R3	677 ± 11	910 ± 12
L4 / R4	605 ± 9	939 ± 12
L5 / R5	528 ± 11	978 ± 10
L6 / R6	442 ± 12	1022 ± 19
L7 / R7[c]	590 ± 88, ND6	880 ± 10, ND5

[a]Red text means new performance compared to MSL/Mastcam.
[b]λ_{eff} is the effective band center wavelength, calculated as the weighted average of the normalized system spectral response (including optics, filter, and CCD) and the solar radiance at the top of the Martian atmosphere. HWHM is the half-width of the bandpass at half-maximum for each filter.
[c]Filters L7 and R7 are for direct imaging of the Sun using Neutral Density (ND) coatings that attenuate the flux by factors of 10^6 and 10^5, respectively. Filter L7 enables 3-color (RGB) Bayer filter color imaging of the Sun at the same λ_{eff} as L0 and R0.
See [7] for details on these derived values.

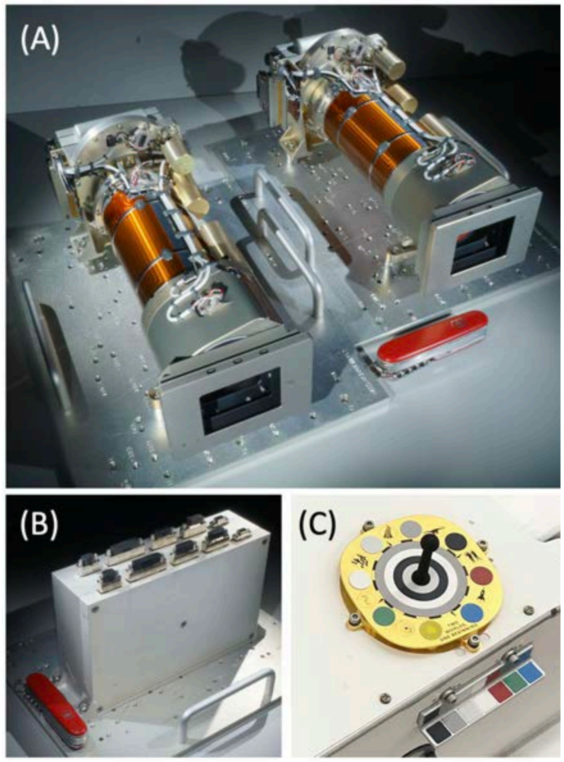

Figure 1. (A) The Mastcam-Z flight cameras. Pocket knife is 89 mm wide, for scale. (B) Flight Digital Electronics Assembly (DEA). (C) Flight primary (top) and secondary (lower) color and grayscale calibration targets [8], mounted on the rover deck. For scale, the primary target is 3.1 x 3.1 inches (8 x 8 cm) across.

the camera plate on the RSM; one Digital Electronics Assembly (DEA) with two electronics cards (one per camera head) mounted into a single housing, located inside the rover chassis, and two passive calibration targets on the rover deck, including a new secondary target designed to improve the calibration by enabling imaging of vertical dust-free surfaces [8]. The Mastcam-Z camera heads each consist of an optomechanical lens assembly (with focus and zoom actuators), a filter wheel (with actuator), and a focal plane assembly and its electronics. Table 2 summarizes the Mastcam-Z instrument characteristics.

Anticipated Initial Images: During the first few months after the scheduled landing of *Perseverance* on Feb. 18, 2021, initial Mastcam-Z imaging observations will verify the health and performance of the cameras and calibration targets relative to pre-launch calibrations and characterizations [7-9], and help to conduct an initial morphological, multispectral, and topographic survey of the landing site near the rover, possibly including the delta top or front and floor units [4]. Additional imaging activities will include assisting the *Ingenuity* helicopter team [10] with the identification of a suitable location for test flights, as well as imaging and video documentation of those flights. Early Mastcam-Z images and panoramas will also help provide guidance to the rover drivers and the science team regarding the initial choice of the traverse path away from the landing site and help identify initial locations for early *in situ* exploration, measurements, and/or sampling.

Table 2. Mastcam-Z Instrument Summary [1]

Focal length	26-110 mm zoom range
Focal ratio	*f*/6.7 at wide zoom; *f*/9.5 at narrow zoom
Pixel Scale (IFOV)	Wide zoom IFOV = 283 μrad/pix (~0.6 mm/pix at 2 m to ~3 cm/pix at 100 m) Narrow zoom IFOV = 67.4 μrad/pix (~0.13 mm/pix at 2 m to ~6.7 mm/pix at 100 m)
Field of View (1600×1200 pix)	25.6°×19.2° (wide) to 6.2°×4.6° (narrow)
Focus Range	0.5 m to ∞ for 26 to ~50 mm focal length 1 m to ∞ for ~50 to 110 mm focal length
SNR	30:1 worst-case narrowband filter >100:1 typical RGB
Filters (Table 1)	Broadband RGB Bayer pattern imaging Multispectral imaging in 11 narrow filters Direct solar imaging in RGB and 880 nm
MTF	> 0.35 at Nyquist (full optical system)
Optics Type	All-refractive, athermalized
Detector	On Semi KAI-2020 CM interline transfer CCD; 1600×1200 photoactive pixels
Pixel pitch	7.4 microns
Command & Data Interfaces	Synchronous LVDS: 8 Mbit/sec (Data) and 2 Mbit/sec (Command) serial link
Digitization	11 bits/pixel; single gain, no offset states
Compression	Lossless ~1.7:1; Lossy JPEG color or grayscale; 11- to 8-bit companding Realtime or deferred
Image memory	256 Mbytes SDRAM 8 Gbyte flash image buffer in each camera
Power	11.8 Watts imaging, per camera 7.5 Watts standby, per camera
Electronics Architecture	Actel FPGA in camera head, Xilinx FPGA in Digital Electronics Assembly (DEA)
Dimensions	11×12×26 cm (each camera head); separation = 24.4 cm; toe-in = 1.15° per camera; 22×12×5 cm (DEA)
Cal Targets (2)	Primary: 10×10×5 cm Secondary: 80×30×16 mm
Mass	Camera Heads: 1.38 kg each; DEA: 1.47 kg; Cal Targets: 103 g and 15 g

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, doi:10.1002/ 2016EA000252, 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] Maki *et al., Space Sci. Rev.*, doi:10.1007/s11214-020-00765-9, 2020. [6] Bhartia *et al., Space Sci. Rev.*, 2020. [7] Hayes, *et al., Space Sci. Rev.*, 2020. [8] Kinch *et al., Space Sci. Rev.*, doi:10.1007/s11214-020-00774-8, 2020. [9] Johnson, J.R. *et al., LPSC 52*, 2021. [10] Balaram *et al.,* AIAA 2018-0023, doi:10.2514/6.2018-0023, 2018.