Initial Results from the Mars 2020 ECAM Imaging System. J. N. Maki[1], D. Gruel[1], C. McKinney[1], M. A. Ravine[2], M. Morales[1], D. Lee[1], R. Willson[1], D. Copley-Woods[1], M. Valvo[1], T. Goodsall[1], J. McGuire[1], R. G. Sellar[1], J. A. Schaffner[2], M. A. Caplinger[2], J. M. Shamah[2], A. E. Johnson[1], H. Ansari[1], K. Singh[1], T. Litwin[1], R. Deen[1], A. Culver[1], N. Ruoff[1], D. Petrizzo[1], D. Kessler[1], C. Basset[1], T. Estlin[1], F. Alibay[1], A. Nelessen[1], S. Algermissen[1], M. Lambert[1], N. R. Williams[1], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, [2] Malin Space Science Systems, San Diego, CA, USA. Justin.N.Maki@jpl.nasa.gov.

Introduction: The Mars 2020 *Perseverance* rover is scheduled to land on Mars on February 18th, 2021. The rover is equipped with a next-generation engineer- ing camera (ECAM) imaging system that represents an upgrade over previous Mars rover missions [1]. These upgrades will improve the operational capabilities of the rover with an emphasis on drive planning, robotic arm operation, instrument operations, sample caching activities, and documentation of key events during entry, descent, and landing (EDL).

The previous generation of Mars engineering cameras, the Navcams and Hazcams, were designed in the early 2000s as part of the Mars Exploration Rover (MER) program [2]. A total of 36 individual MER-style cameras have flown to Mars on five separate NASA spacecraft (3 rovers and 2 landers) [2-7]. Newer technologies and electronics parts obsolescence have brought the MER/MSL camera production to a close, with no additional production runs planned. The Mars 2020 ECAM system builds on the experience and lessons learned from these previous missions and incorporates improved imaging technologies, including color detectors with higher pixel counts. There are a total of 16 cameras in the Perseverance engineering imaging system, including 9 cameras for surface operations and 7 cameras for EDL documentation (3 of the EDL cameras are pointed downward towards Mars during descent).

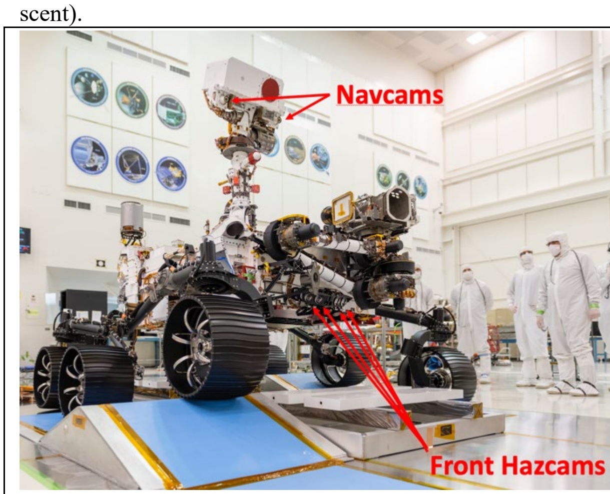

Figure 1. Location of the Mars 2020 Navcams and Front Hazcams. The Cachecam camera is located inside of the rover body.

Navcam, Hazcam, Cachecam: There are 3 types of cameras designed for surface operations: Navigation cameras (Navcams, quantity 2), Hazard Avoidance Cameras (Hazcams, quantity 6), and a Cachecam (quantity 1). The Navcams, mounted on a pan/tilt mast, will acquire color stereo images of the surface with a 96° × 73° field of view (FOV) at 0.33 mrad/pixel. The Hazcams, fixed-mounted to the rover body, will acquire color stereo images of the surface with a 136° × 102° FOV at 0.46 mrad/pixel. The Cachecam, a new camera type, will acquire images of Martian material inside the sample tubes during caching operations at a spatial scale of 12.5 microns/pixel. All three of the camera types use a 5120 x 3840 pixel CMOS detector (CMV-20000). The Navcams, Hazcams, and Cachecam were designed and built at the Jet Propulsion Laboratory (JPL), California Institute of Technology, in Pasadena, CA.

Figure 2. Flight Navcam (left), Flight Hazcam (middle), and flight Cachecam (right). The Cachecam optical assembly includes an illuminator and fold mirror.

EDLCAMs: There are four types of EDLCAM cameras: The Parachute Uplook Cameras (PUCs, quantity 3), the Descent stage Downlook Camera (DDC, quantity 1), the Rover Uplook Camera (RUC, quantity 1), and the Rover Downlook Camera (RDC, quantity 1). The PUC, RDC, and RUC cameras use a 1280 x 1024 pixel ON Semi P1300 detector, and the DDC uses a 2048 x 1536 Sony IMX265 detector. All of these cameras will acquire video during EDL at frame rates ranging from 12 frames/second to 75 frames/second. The rover also carries a microphone, mounted externally on the rover chassis, to capture acoustic signatures during and after EDL. The EDLCAM system is comprised of commercially available camera systems, modified, integrated, and tested at the Jet Propulsion Laboratory (JPL), California Institute of Technology, in Pasadena, CA.

LCAM: The Lander Vision System (LVS) camera (LCAM), mounted to the bottom of the rover chassis and pointed downward, will acquire 90° × 90° FOV images of Mars during the parachute descent phase of EDL as input to an onboard map localization by the LVS. The LCAM uses a 2592 x 2048 pixel ON Semi Python 5000 detector, 2x2 summed to 1024 x 1024 pixels. The LCAM was designed and built at Malin Space Science Systems (MSSS), in San Diego, CA.

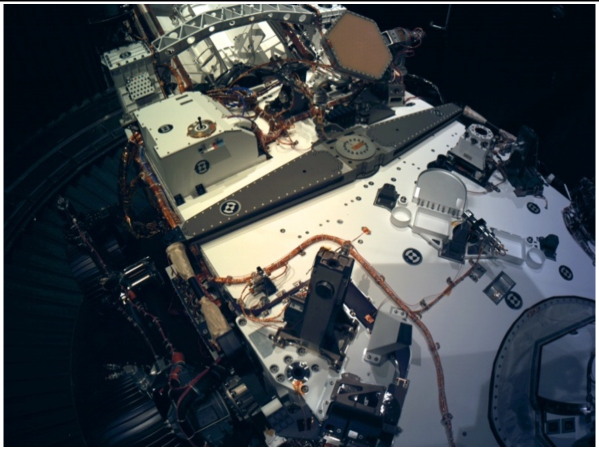

Figure 3. Single frame Navcam image of the Mars 2020 flight rover deck, acquired during system thermal vacuum testing in October 2019.

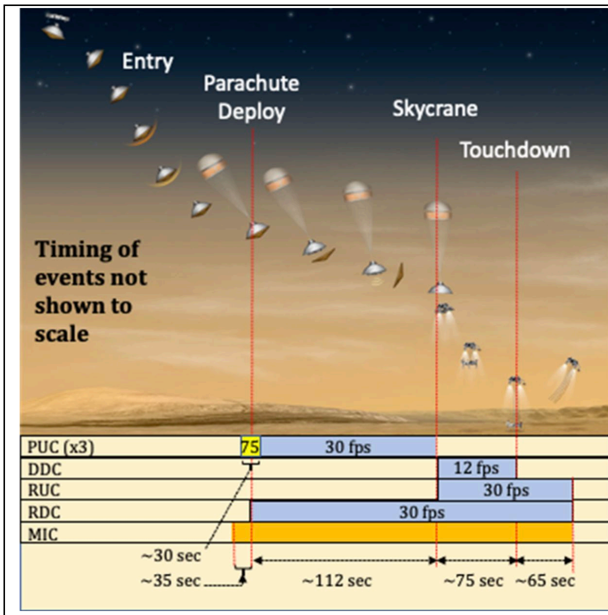

Figure 4. The EDLCAM image acquisition timeline, showing duration and frame rate in frames/second (fps).

Anticipated Data Return: Images from the *Perseverance* Hazcams are expected to be returned to Earth shortly after Mars landing on February 18th, 2021, with EDLCAM image downlink expected in the subsequent days after landing. A 360°, low-resolution Navcam panorama is planned after the remote sensing mast (RSM) is deployed during the commissioning phase of the mission. LCAM images are expected to be downlinked in the weeks and months after landing. Stereo image data from the Hazcam and Navcam imaging system will allow subsequent targeting of the *Perseverance* high-resolution Mastcam-Z imaging system [8], the SuperCam instrument [9], and other science instruments.

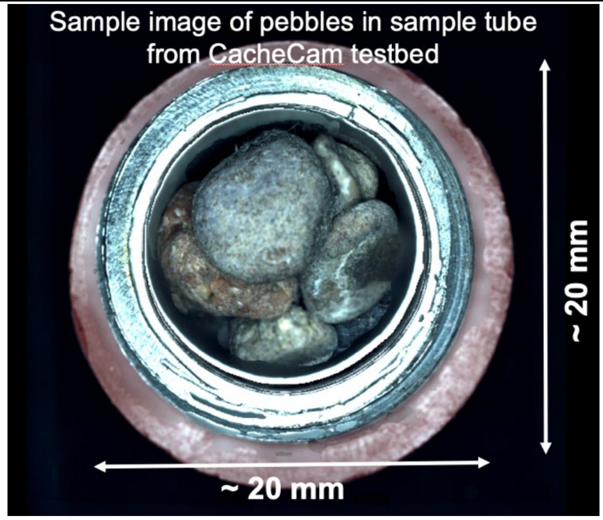

Figure 5. Cachecam testbed example image (acquired from a prototype camera).

References:

[1]. Maki, J.N., et al., The Mars 2020 Engineering Cameras and Microphone on the Perseverance Rover: A Next-Generation Imaging System for Mars Exploration. Space Sci Rev 216, 137 (2020), https://doi.org/10.1007 , [2] Maki, et al (2003), The Mars Exploration Rover Engineering Cameras, J. Geophys. Res., 108(E12), 8071. [3] Maki, et al, (2012), The Mars Science Laboratory engineering cameras, Space Sci. Rev., 170:77-93. [4] Bell et al. (2003), Mars Exploration Rover Athena Panoramic Camera (Pancam) Investigation, J. Geophys. Res., 108(E12), 8063, [5] Herkenhoff et al (2003), Athena Microscopic Imager Investigation, J. Geophys. Res., 108(E12), 8065, [6] Lemmon, et al (2008), The Phoenix Surface Stereo Imager (SSI) Investigation, 39th LPSC XXXIX, No. 1391. [7], Maki et al. (2018), The Color Cameras on the InSight lander, Space Sci. Rev. 214:105, [8] Bell et al., Space Sci. Rev., doi:10.1007/s11214-020-00755-x, 2020., [9] Wiens, R.C., Maurice, S., Robinson, S.H. et al. The SuperCam Instrument Suite on the NASA Mars 2020 Rover: Body Unit and Combined System Tests. Space Sci Rev 217, 4 (2020). https://doi.org/10.1007/s11214-020-00777-5.

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