ENHANCED ENGINEERING CAMERAS (EECAMs) FOR THE MARS 2020 ROVER. J. N. Maki[1], C. M. McKinney[1], R. G. Sellar[1], R. G., Willson[1], D. S. Copley-Woods[1], D. C. Gruel[1], D. L. Nuding[1], M. Valvo[1], T. Goodsall[1], J. McGuire[1], J. Kempenaar[1], T. E. Litwin[1] ([1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, Justin.N.Maki@jpl.nasa.gov).

Introduction: The Mars 2020 Rover will be equipped with a next-generation engineering camera imaging system that represents an upgrade over the previous Mars rover engineering cameras flown on the Mars Exploration Rover (MER) mission [1,2,3] and the Mars Science Laboratory (MSL) rover mission [4]. The previous generation of Navcams and Hazcams, known collectively as the engineering cameras, were designed in the early 2000s as part of the MER development program. A total of 34 individual MER-style cameras have flown to Mars, built in two separate production runs: the original MER run (2003) and a second, build-to-print run for MSL (2008). Newer technologies and electronics parts obsolescence have brought the MER/MSL camera production to a close, with no additional production runs currently scheduled.

The Mars 2020 EECAMs utilize a 20 Megapixel color CMOS sensor, in contrast to the 1 Megapixel grayscale CCD sensor utilized by the MER/MSL cameras. The Mars 2020 Navcams, mounted on a pan/tilt mast, will acquire stereo color panoramas from a height of approximately 2 meters above the Martian surface. The Mars 2020 Hazcams, hard-mounted to the rover body at a height of approximately 0.7 meters above the surface, will acquire color stereo images of the areas immediately in the front and rear of the rover. The Mars 2020 Cachecam, a new camera type, will acquire images of sample materials as they are being processed by the Mars 2020 Sample Caching System. The more capable Mars 2020 EECAMs will help increase the overall efficiency of Mars 2020 rover operations on the surface of Mars. As with the MER/MSL cameras, the Mars 2020 EECAMs are being designed and built by the Instruments Division at the Jet Propulsion Laboratory in Pasadena, CA.

EECAM Instrument Functional Requirements: The Mars 2020 EECAMs inherit the same high-level functional requirements from MER and MSL. The Navcams are required to provide stereo image data for rover traverse planning, targeting of remote sensing instruments, operation of the robotic arm, and the acquisition of panoramas with a 360° field of regard around the rover. The Hazcams are required to provide stereo image data for the onboard detection of navigation hazards during a traverse, terrain context immediately forward and aft of the rover (in particular the areas not viewable by the Navcams) for traverse planning, support for robotic arm operations, support for rover fine positioning, and imaging of the front and rear wheels.

Instrument Description

The EECAMs incorporate proven heritage design principles from MER/MSL: 1) small, ruggedized camera bodies with fixed-focus lenses, 2) a simple camera head with limited processing and storage capabilities; the engineering cameras essentially function as sensor heads only, with image storage and compression functions performed by the spacecraft/rover computer, and 3) cameras mounted together as stereo pairs (the Cachecam, a monoscopic camera, is an exception). The Mars 2020 EECAMs are packaged into a single, compact camera head box (see figure 1).

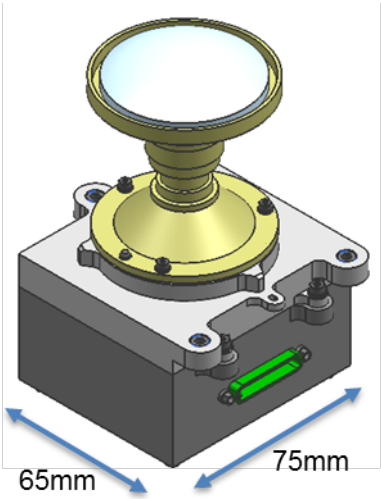

Figure 1. The basic EECAM design consists of a fixed focus lens mounted to a sensor head. Pictured above is the Mars 2020 Navcam camera.

The Mars 2020 EECAMs significantly improve on the MER/MSL designs by adding a CMOSIS CMV-20000, a 20 Megapixel color sensor with a 5120 x 3840 pixel imaging area. The EECAMS lenses have more resolving power than the older MER/MSL designs (as required by the smaller pixel size of the EECAMs), and in the case of the Navcams, also provide a wider field of view. The result of these enhancements is that the Navcam will have more than twice the angular resolution of the MER/MSL Navcam, and the Hazcam will have more than 3 times the angular resolution. Both cameras types will also

produce color images, with better antiblooming capability than the MER/MSL designs. In order to accommodate constraints on downlinked data volume to Earth, the EECAMs have the capability to return images at various reduced resolutions or at full-resolution, depending on the commanded mode.

Table 1. Mars 2020 EECAM Capabilities.
Items in brackets may change, pending final design.

Camera Capabilities	
Sensor Capabilities	
Type	20 MegaPixel CMOS
Optical Format	35 mm
Array Size	5120 x 3840 pixels
Pixel Size and Pitch	6.4 microns
Full well charge	15,000 e^-
Pixel Dark Noise	8 e^- RMS
Pixel Dark Current	125 e^-/s @ 25C
Windowing	Yes, ROI
Shutter	Global
Pixel Quantization	12 bit
Electrical Interface	
Commanding & Data	LVDS
Protocol	MER/MSL/Mars2020 NVMCAM
Power Input	+5 V (+/- 0.5 V)
Power	< [10 W]
Memory	[1 Gbit] SDRAM
Non-Volatile FPGA	MicroSemi Rad-Tolerant [ProASIC3]
Camera System Specifications	
Mass (CBE, no optics)	[< 425 g]
Volume (CBE, no optics)	[75 mm x 85 mm x 55 mm]
Operating Temperature	-55C to +50C
Survival Temperature	-135C to +70C
Mars2020 Optics Configurations	
Navigation Camera (Color)	103° X 77°(H x V), f/12, iFOV ≤ 0.35 mrad
Hazard Camera (Color)	156° X 117°(H x V), f/12, iFOV ≤ 0.54 mrad
Sample Camera (Color)	EFL = [30mm], Focus Distance = 270mm, F/8

The Mars 2020 EECAMs began as a six-month study task in late 2013. After a successful protoype demonstration, the Mars 2020 project approved the new cameras for flight in October 2014. The detailed design is currently underway, with a PDR scheduled for October 2016, a CDR scheduled for April 2017, and delivery to the Mars 2020 project in the fall of 2018. Launch of the Mars 2020 rover mission is scheduled for the summer of 2020.

References:

[1] Maki, J. N., Bell, J., Herkenhoff, K., Squyres, S., Kiely, A., et al (2003) The Mars Exploration Rover Engineering Cameras, J. Geophys. Res., 108(E12), 8071, [2] Bell III, J.F, Squyres, S.W., Herkenhoff, K. E., Maki, J.N., et al. (2003) Mars Exploration Rover Athena Panoramic Camera (Pancam) Investigation, J. Geophys. Res., 108(E12), 8063, [3] Herkenhoff, K., Squyres, S., Bell III, J., Maki, J., et al (2003), Athena Microscopic Imager Investigation, J. Geophys. Res., 108(E12), 8065, [4] Maki, J., D. Thiessen, A. Pourangi, P. Kobzeff, T. Litwin, L. Scherr, S. Elliott, A. Dingizian, and M. Maimone (2012), The Mars Science Laboratory engineering cameras, Space Science Reviews, 170:77-93, [5] Lemmon, et al (2008), The Phoenix Surface Stereo Imager (SSI) Investigation, 39th LPSC XXXIX, No. 1391.