SkyCam: The Mars Environmental Dynamics Analyzer camera on the Mars 2020 rover. M.T. Lemmon[1], M. de la Torre Juarez[2], J. Boland[2], V. Apéstigue Palacio[3], R. López Heredero[3], J. J. Jiménez Martín[3], V. Peinado Gonzalez[4], A. Molina[4], D. R. MacDonald[2], M. C. Helmlinger[2], I. Arruego Rodríguez[2], and J. A. Rodriguez Manfredi[4]. [1]Space Science Institute, College Station, TX, USA (MLemmon@SpaceScience.org), [2]Jet Propulsion Laboratory, Pasadena, California, USA, [3]Instituto Nacional de Técnica Aerospacial (INTA), Torrejón de Ardoz, Madrid, Spain., [4]Centro de Astrobiología (CSIC-INTA), Torrejón de Ardoz, Madrid, Spain.

Introduction: SkyCam is part of the Mars Environmental Dynamics Analyzer (MEDA), a meteorological suite for the Mars 2020 rover with heritage from the Mars Science Laboratory (MSL) Rover Environmental Monitoring Station (REMS) [1]. SkyCam is on the top surface of the rover deck within the Radiation and Dust Sensor (RDS, Fig. 1), which also includes photodiodes and is analogous to, but a significant development from, the REMS Ultraviolet Sensors (UVS) [2]. Sky-Cam is a modified, spare Hazcam [3] from MSL that is mounted within the RDS in an upward-looking geometry. RDS will be used to monitor sky brightness over time in a variety of wavelengths and geometries in order to characterize Martian dust and the solar and thermal radiation environment. SkyCam will image the sky at varying times as part of the dust study, for cloud tracking, and for astronomical imaging.

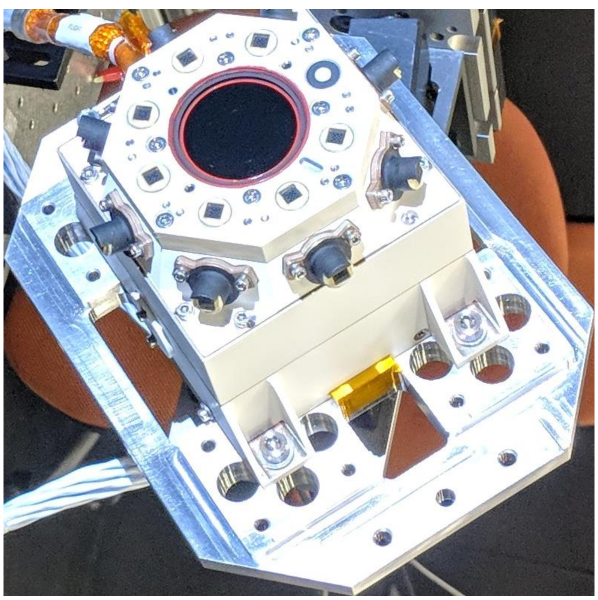

Figure 1. The RDS assembly. The SkyCam window is the dark circle in the center of the top plate.

SkyCam requirements: SkyCam's primary objective is to study the amount and properties of dust. An upward-looking fish-eye camera (field of view at least 120°) was chosen to allow simultaneous measurement of sky radiance over a wide range of scattering angles. A neutral density coating was planned to allow imaging of the Sun in the same exposure as the sky, so that aerosol optical depth could be retrieved from the measured solar flux. A baffle was required so that when the Sun was low in the sky (10-30° to allow conventional plane-parallel radiative transfer models to be used), the images would be uncontaminated by stray light.

In addition to dust studies, SkyCam was intended for measurements of clouds, including the use of time-lapse images to determine wind direction. There were no requirements for night use, but that capability was kept, allowing astronomical imaging to be used to determine night-time cloud and aerosol opacity from stellar (and lunar) fluxes.

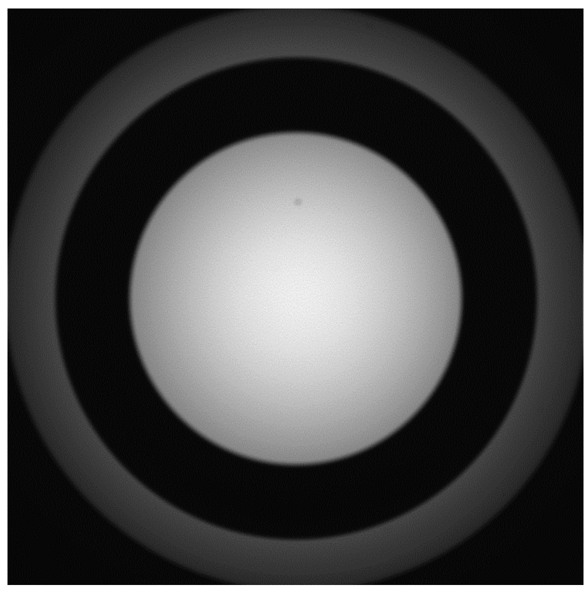

Figure 2. SkyCam flat field image. This image shows the characteristic response fall off of fisheye lenses; a circular region centered on the rover zenith; an annulus of reflective neutral density 5 material for solar flux measurements; an annulus that will show sky light to >60° from zenith; and the circular baffle in the corners.

SkyCam design: A flight-spare Hazcam from MSL was adapted by removing an internal neutral density (ND) coating to increase sensitivity and decrease internal reflections, and adding black coating to select internal surfaces. ND5 coating (10^{-5} extinction) was added to the outer optics in an annulus such that the Sun would spend at least 1 hour within the coated area, twice per Martian day (Fig. 2, 3). The camera is an f/15, fish-eye with a 5.6 mm focal length and 2.1 mrad/pixel, resulting in a 62° minimum radius for the field of view (FOV) over the 1024x1024 pixel Charge-Coupled Device (CCD) array. The spectral range is 591-771 nm with an effective wavelength of 691 nm for grayscale images. The gain is 50 electrons/data number (DN) in the 12-bit digitization, with linearity to 3700 DN. The electronics are the same as MSL Hazcam [3] with a 5.1-s frame transfer time. Binning modes and subframing were not included in flight software, and images will be JPEG compressed.

SkyCam is included in the RDS assembly on the rover deck. Rover hardware will occupy parts of the FOV (Fig. 4). However, most of the area within the baffle is unobstructed, including all of the area interior to the annulus.

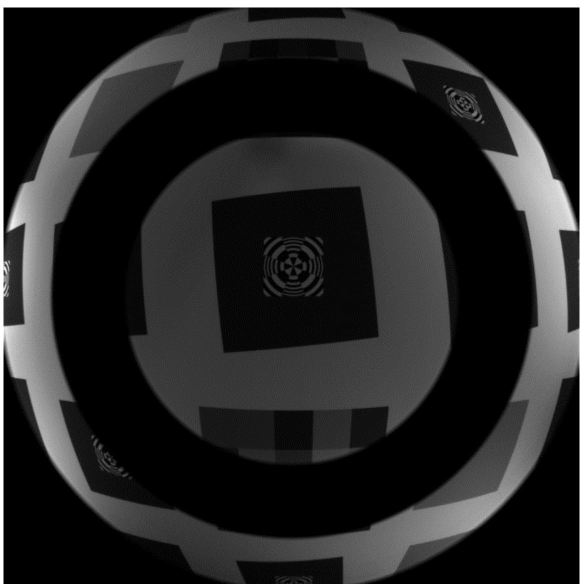

Figure 3. SkyCam image of geometric calibration target.

SkyCam and Mars surface operations: SkyCam will be operated in two modes. Images may be commanded through the rover computer, in the same fashion as the other cameras. When this is done, auto-exposure may be used, and the image is immediately processed with (optional) frame-transfer image subtraction, compression, and thumbnail generation. This mode allows coordination with other instruments.

Additionally, images may be acquired via the MEDA observation table. This mode allows imaging while the rover CPU is asleep so that morning and night images require less energy. In this case, manual exposures must be used and image operations are deferred to a time when the rover CPU is awake.

SkyCam activities will include: imaging timed to have the Sun within the ND5 annulus; imaging timed to have the Sun below the baffle, for studying aerosol properties; repeat images to measure cloud motions; and manual exposure images (up to 334 s) for measuring stellar fluxes at night. Imaging may happen with the Sun in the central part of the FOV, but such images will be affected by significant column bleeding from saturated pixels. Dust accumulation on the window will affect all images. Cross-calibration with Mastcam-Z [4] will be done for both the optical depth measurement (frequently) and for creating sky flat fields from time to time in order to compensate for dust.

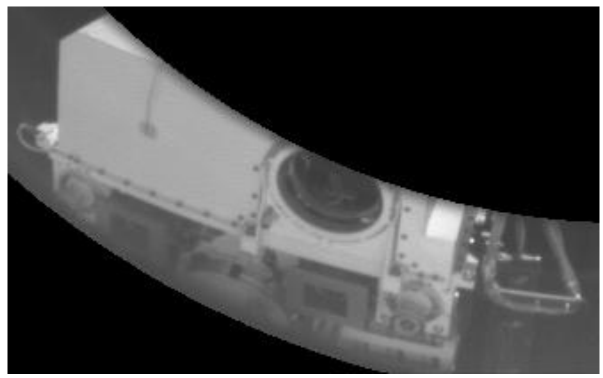

Figure 4. Crop of SkyCam image while mounted on the rover, showing the top of the Remote Sensing Mast.

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References: [1] Gómez-Elvira, J., et al. (2012), Space Sci. Rev., 170, 583-640. [2] Smith, M.D., et al. (2016), Icarus, 280, 234-248. [3] Maki, J., et al. (2012), Space Sci. Rev., 170, 77-93. [4] Bell et al. (2020), LPSC 51 (this issue).