The Panoramic Camera (Pancam) Investigation on the NASA 2003 Mars Exploration Rover Mission.

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Introduction: The Panoramic Camera System (Pancam) is part of the Athena science payload to be launched to Mars in 2003 on NASA's twin Mars Exploration Rover (MER) missions. The Pancam imaging system on each rover consists of two major components: a pair of digital CCD cameras, and the Pancam Mast Assembly (PMA), which provides the azimuth and elevation actuation for the cameras as well as a 1.5 meter high vantage point from which to image. Pancam is a multispectral, stereoscopic, panoramic imaging system, with a field of regard provided by the PMA that extends across 360° of azimuth and from zenith to nadir, providing a complete view of the scene around the rover.

Pancam utilizes two 1024×2048 Mitel frame transfer CCD detector arrays, each having a 1024×1024 active imaging area and 32 optional additional reference pixels per row for offset monitoring. Each array is combined with optics and a small filter wheel to become one "eye" of a multispectral, stereoscopic imaging system. The optics for both cameras consist of identical 3-element symmetrical lenses with an effective focal length of 42 mm and a focal ratio of *f*/20, yielding an IFOV of 0.28 mrad/pixel or a rectangular Field of View (FOV) of 16°×16° per eye. The two eyes are separated by 30 cm horizontally and have a 1° toe-in to provide adequate parallax for stereo imaging. The camera FOVs have been determined relative to the adjacent wide-field stereo Navigation Cameras, and the Mini-TES FOV. The Pancam optical design is optimized for best focus at 3 meters range, and allows Pancam to maintain acceptable focus from infinity to within 1.5 meters of the rover, with a graceful degradation (defocus) at closer ranges. Each eye also contains a small 8-position filter wheel to allow multispectral sky imaging, direct Sun imaging, and surface mineralogic studies in the 400-1100 nm wavelength region. Pancam has been designed to operate within specifications from -55°C to +5°C. The cameras have undergone standard CCD, radiometric, and geometric calibrations both at the component and system (rover) level. An onboard calibration target and fiducial marks provide the ability to validate the radiometric and geometric calibration on Mars. Pancam relies heavily on use of the JPL ICER wavelet compression algorithm to maximize data return within stringent mission downlink limits. All calibration and flight data products will be generated and archived with the NASA Planetary Data System in PDS image format.

The scientific goals of the Pancam investigation are to: (a) obtain monoscopic and stereoscopic images and mosaics to assess the morphology, topography, magnetic properties, and geologic context of the two MER landing sites (to be chosen in spring 2003); (b) obtain multispectral images of selected regions to determine surface color and mineralogic properties; (c) obtain multispectral images over a range of viewing geometries to constrain surface photometric and physical properties; and (d) obtain images of the Martian sky, and Sun to determine dust and aerosol opacity and physical properties. In addition, Pancam also serves a variety of operational functions on the MER mission, including (e) serving as the primary Sun-finding camera for rover navigation; (f) resolving objects on the scale of the rover wheels to distances of ~100 m to help guide tactical rover navigation decisions; (g) providing stereo coverage adequate for the generation of digital terrain models to help guide and refine strategic rover traverse decisions; (h) providing high resolution images and other context information to guide the selection of the most interesting *in situ* sampling targets; and (i) supporting acquisition and release of exciting education and public outreach products.

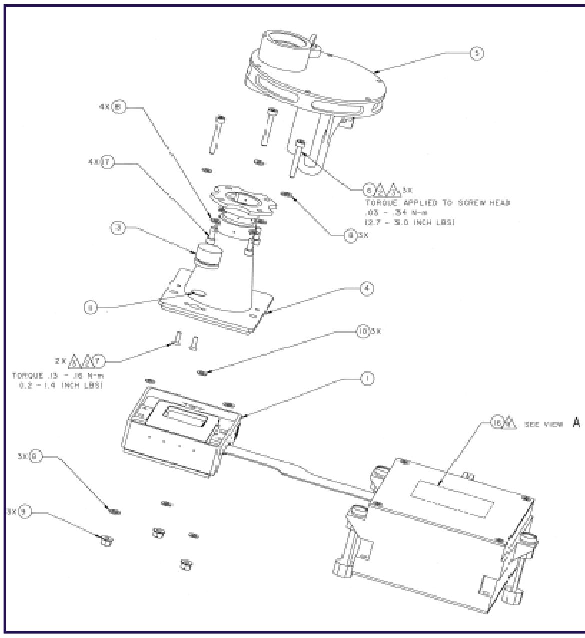

Figure 1. Schematic of the MER Pancam instrument. The instrument consists of a filter wheel, motor and housing (top), optics lens barrel assembly (middle left), CCD housing assembly (lower left), and a separate box containing the FPGA and other electronics (bottom). For scale, the electronics box is ~6.5 cm long.

Table 1. Pancam Instrument Characteristics

Mechanical/Environmental

- Two independent cameras
- 30 cm stereo separation, 1° toe-in
- Mast-mounted, 1.54 meters above surface
- 360° azimuth and ±90° elevation actuation
- Mass of each camera: ~270 g
- Typical power consumption ~3 W per camera
- Operating temp. within specs: -55°C to +5°C
- Onboard calibration target, fiducial marks
- Each camera has an 8-position filter wheel
- Uses the ICER wavelet compression algorithm

Optics

- 3-element Cooke triplet lens design (G. Smith)
- 43 mm focal length, *f*/20 system
- < 0.01% f tanθ geometric distortion
- Optimal focus: 3 m; Focus range: 1.5 m to ∞
- IFOV = 0.28 mrad/pixel; FOV = 16° × 16°
- Equivalent to a 109 mm lens on a 35 mm camera
- Narrowband interference filters (Omega Optical)
- Sapphire window for dust protection
- External sun shade, internal stray light baffles
- Boresight calibrated with Navcams, Mini-TES

CCD

- 1024 × 2048 Mitel frame transfer CCD
- 12 µm square pixels, 100% fill factor
- Opaque Al shield over storage region
- Full well capacity = 200,000 e^-
- System readout noise < 10 e^-
- SNR ≥ 200 in all λ's at 50% full well
- Absolute radiometry ≤ 7%, relative ≤ 1%
- Dark current @ 27°C = 1.5 nA/cm^2
- Dark current spatial nonuniformity < 5%
- Linearity > 99% from 10 to 90% full well
- Flatfield spatial nonuniformity < 1%
- 32 “reference” pixels beyond imaging area
- CCD frame transfer time = 5.2 msec
- CCD readout rate = 200 kpix/sec (5.2 sec)
- Integration time : 0-350 sec, Δ = 5.1 msec
- 4 × 1 hardware (“on chip”) binning option

Calibration Target

- 8 × 8 cm base, 6 cm high post, 60 g mass
- Three rings with 20, 40, 60% reflectivity
- Four colored corners for color calibration
- Vertical post casts shadow across all three rings to calibrate diffuse illumination
- Two mirrored annuli reflect sky color
- Fully illuminated by the Sun from at least 10 a.m. to 2 p.m. local solar time for nominal rover orientations
- Target is embellished with motto, markings, and drawings to be a “Mars Sundial” for E/PO activities

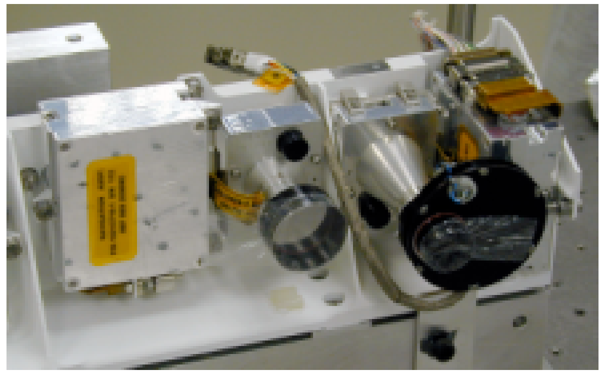

Figure 2. The MER-2 rover left Pancam (far right) and Navcam (center) instruments, as mounted onto the Pancam Mast Assembly camera bar.

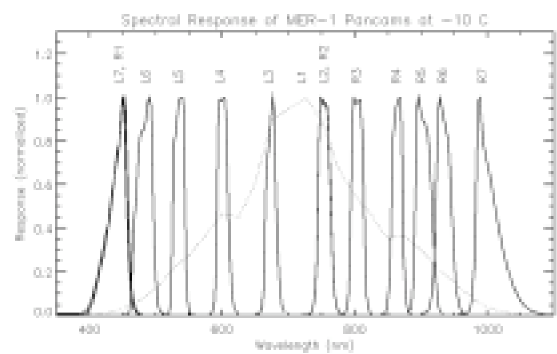

Figure 3. Normalized spectral response profiles of the Pancam multispectral filters. "L" designates left camera, "R" designates right. Solar ND filters not shown.

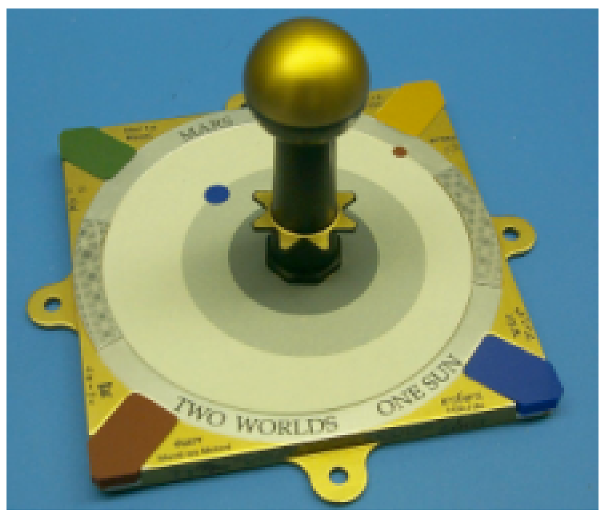

Figure 4. Pancam calibration target. The three gray-scale rings are 20%, 40%, and 60% reflective, and the colored corners contain oxide pigments with distinct spectral characteristics in the visible to near-IR. The base is 8 × 8 cm size and the post is 6 cm high.