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High Resolution Multispectral CCD Imaging from the Mars Exploration Rover Pancam Instruments

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The Mars Exploration Rover (MER) Panoramic Camera (Pancam) instruments are multispectral, stereoscopic CCD cameras that have been acquiring high resolution images from two landing sites on the surface of Mars since January 2004. The Spirit rover was sent to the first MER landing site in Gusev, a 160 km wide impact crater hypothesized to perhaps have once been a crater lake. The Opportunity rover was sent to the second MER landing site in Meridiani Planum, a flat rolling plains terrain containing orbital remote sensing evidence for possibly water-formed crystalline hematite mineral deposits.

Each Pancam instrument is a 1024x2048 pixel frame transfer CCD, with a 1024x1024 pixel active area and 1024x1024 pixel masked storage area for array readout. A 43 mm focal length f/20 Cooke triplet optical system gives each camera an instantaneous field of view of 0.27 mrad, or an effective spatial resolution of about 1 mm/pixel at a distance of around 3 m. The relatively narrow field of view (16 degrees) of each camera means than hundreds of images need to be acquired to build large-scale mosaics and panoramas of the scene. Pancam operations are thus closely tied to the operation and performance of azimuth and elevation actuators on the Pancam Mast Assembly for critical camera pointing activities. Each rover carries two separate cameras, each equipped with an 8-position filter wheel. Thirteen of these 16 available filters (at 11 unique wavelengths) are for narrowband multispectral "geology" studies, 1 filter on each camera is for neutral density solar imaging, and one filter slot is left empty for maximum low-light and night-time imaging sensitivity. The two cameras per rover are separated by 30 cm and toed-in by 1 degree for stereo imaging. A grayscale/color radiometric calibration target is carried on the back of each rover's deck to enable rapid estimates of the radiance factor (I/F) and albedo of imaged scenes. Wavelet-based compression and other processing of the images is often performed onboard the rover

because of limited downlink bandwidth to Earth. Typical SNR is > 200 for most filters and imaging situations on Mars.

As of Spirit sol 1078 and Opportunity sol 1058, the rovers' Pancam instruments had acquired more than 60,000 and 55,000 images, respectively. Approximately 31% and 22% of the images from each rover, respectively, are acquired as part of 11-color "image cubes" used to characterize the multispectral properties of the surface and atmosphere at wavelengths between 430 and 1010 nm. Most of the remainder of the imaging part of the rovers' downlink (which is the vast majority of the overall downlink) has been used for monochrome or limited-filter tactical imaging of targets of interest, or stereo imaging in support of rover driving and/or rover arm instrument in situ chemical, mineralogical, or Microscopic Imager measurements. Approximately 5% of the downlinked bits have been used for calibration observations (bias, dark current, flatfield, calibration target) over the course of the missions.

In this presentation I will highlight the major scientific results at Gusev and Meridiani that have been derived from or enabled by Pancam imaging observations, as well as provide an update on the latest rover imaging and other results. Lessons learned in terms of the design, performance, and remote robotic operation of multispectral CCD imaging system on a planetary surface will also be discussed.