Atmospheric Science with MRO/CRISM: Fun, Fun, Fun.

M. J. Wolff, **R. T. Clancy**, *Space Science Institute, Boulder, CO, USA (wolff@spacescience.org),* **M. D. Smith,** *Goddard Space Flight Center, Greenbelt, MD, USA,* **S. Murchie**, *Applied Physics Laboratory, Lauren, MD, USA*, and the **CRISM Science Team**

Introduction: CRISM (the Compact Reconnaissance Imaging Spectrometer for Mars) is a hyperspectral imager launched on the MRO (Mars Reconnaissance Orbiter) spacecraft on August 12, 2005. CRISM's three major objectives are (1) to map the entire surface using a subset of bands designed to characterize crustal composition and to search for areas that expose rocks diagnostics of past climatic conditions and habitability, (2) to map the mineralogy of key areas with full spectral resolution and high spatial resolution, and (3) to acquire sufficient measurements of the atmosphere to enable separation of its signal from that of the surface and to use the results to characterize atmospheric properties. These objectives are addressed using three major types of observations of the Martian surface and atmosphere.

Instrument: CRISM consists of three subassemblies, a gimbaled Optical Sensor Unit (OSU), a Data Processing Unit (DPU), and a Gimbal Motor Electronics (GME). CRISM's spectral range spans the ultraviolet (UV) to the mid-infrared (MWIR), 362 nm to 3920 nm. The OSU utilizes a Ritchey-Chretien telescope with a 2.12° field-of-view (FOV) to focus light on the entrance slit of a dual spectrometer. Within the spectrometer, light is split by a dichroic filter into VNIR (visible-near-infrared, 362-1053 nm) and IR (infrared, 1002-3920 nm) beams. Each beam is directed into a separate modified Offner spectrometer that focuses a spectrally dispersed image of the slit onto a two dimensional focal plane (FP). The IR FP is a 640 x 480 HgCdTe area array; the VNIR FP is a 640 x 480 silicon photodiode area array. The spectral image is contiguously sampled with a 6.55 nm spectral spacing and an instantaneous field of view of 61.5 mradians. The OSU can be gimbaled to remove along-track smear, allowing long integration times that afford high signal-to-noise ratio (SNR) at high spectral and spatial resolution. The OSU scan motor and angular position encoder are controlled by the separately housed GME. The DPU provides power, command and control, and data editing and compression.

Observation Modes: In multispectral mapping mode, with the gimbal pointed at planet nadir, data are collected at frame rates of 15 or 30 Hz. A commandable subset of wavelengths is saved by the DPU and binned 5:1 or 10:1 cross-track. The combination of frame rates and binning yields pixel footprints of 100 or 200 m. In this mode, nearly the entire planet can be mapped at wavelengths of key mineralogic absorption bands to select regions of interest. In targeted mode, the gimbal is scanned over ±35° to remove most along-track motion, and a region of interest is mapped at full spatial and spectral resolution. Ten additional abbreviated, spatially-binned observations are taken before and after the main hyperspectral image at longer atmospheric path lengths, providing an emission phase function (EPF) of the site for atmospheric study and correction of surface spectra for atmospheric effects. In atmospheric mode, the central observation is eliminated and only the EPF is acquired. Global grids of the resulting lower data volume observations are taken repeatedly throughout the Martian year to measure seasonal variations in atmospheric properties.

Measurement and Analysis Approach: Key properties to be measured include the column abundances of CO2, CO, and H2O gases, the optical depth and scattering behaviors of dust and ice aerosols, and the contribution of $O_2(^1\Delta)$ emission. CRISM will determine these quantities using measurements of local emission phase functions (EPFs). An EPF sequence views the same spot on the surface at a range of different emission angles. The resulting known variation in path length and scattering geometry, while surface illumination remains essentially fixed, allows the retrieval of well-constrained total column abundances of aerosols and gases. Both dust and ice aerosols lead to increased VISIR atmospheric radiance at higher emission angles, corresponding to longer path lengths. However, they are distinguished by both the wavelength dependence of the increased radiance and by the distinct scattering behavior as a function of phase angle (e.g., Clancy et al. 2003). This latter effect leads to an asymmetric emission angle dependence of atmospheric radiance, particularly for ice aerosols. EPF sequences are preferred over limb observations for separating surface and atmospheric contributions because of the inability of the latter to sample the lowest 10-20 km of the atmosphere (due to "thermalization" of the photons by the large slant-path optical depths).

A complete EPF sequence with 11 emission angles covering the range from -70° to +70° will be obtained for each targeted surface observation, to determine associated atmospheric properties and to support the separation of surface and atmospheric signatures. In addition, a global grid of EPF sequences will be taken every ~10° of Ls. This repeated global survey will determine spatial and seasonal variability in CO, H2O, $O_2(^1\Delta)$ emission, and aerosol column abundances, as well as constrain the physical properties of dust and ice aerosols. In addition, such retrievals will form the basis of atmospheric "correction" re-processing for the multispectral survey (initial processing will be done with climatological data based on observations from MGS TES (Smith 2004)).

Analysis of CRISM EPFs will be based upon the approach taken for TES (Clancy et al. 2003) and Viking IRTM (Clancy and Lee 1991). Both TES's and CRISM's EPF measurements are typically obtained at fixed-incidence and moderate-phase angles, in which case surface photometric variations are minimized with respect to atmospheric effects. The key radiative transfer tool will be the discrete ordinates, multiple-scattering algorithm, DISORT (Stamnes et al. 1988). The models shown in Figures 6a through 6c were produced using a version of the DISORT-based code of Clancy et al (2003). Initially, we will use the dust and ice scattering phase functions from upward-looking Pathfinder observations (Tomasko et al. 1999) and TES EPF global analyses (Clancy et al. 2003), with extensions to additional CRISM wavelengths using the indices of refraction published by Wolff and Clancy (2003). These will be augmented with analysis of a small number of EPFs being obtained by OMEGA. Each CRISM EPF observation will be analyzed to retrieve aerosol/gas optical depths and aerosol type. These atmospheric properties are well-constrained by the simultaneous retrieval from the range of EPF angles.