A HIGH RESOLUTION COMPOSITIONAL IMAGER FOR MARS SCIENCE AND FUTURE EXPLORATION N.T. Bridges[1] and S.L. Murchie[1]; [1]Applied Physics Laboratory, 11101 Johns Hopkins Road, Laurel, MD 20723 (nathan.bridges@jhuapl.edu)

Introduction

Orbital geomorphological and compositional measurements enable investigation of the geologic history of planetary surfaces and assessment of the scientific merits and safety of potential sites for landed investigation [1,2]. Increased spatial resolution of orbital measurements of Mars in the last two decades has revolutionized understanding of how hydrological and other processes have shaped the surface, and driven an ongoing exploration program that includes landed assets focused on the search for ancient habitable environments [3,4]. Currently the highest-resolution orbital compositional measurements, by the Mars Reconnaissance Orbiter's Compact Reconnaissance Imaging Spectrometer for Mars (MRO/CRISM) [5], are limited by their 18 m/pixel spatial resolution that can detect outcrops of scientific interest. Analyses using a new approach to enhancing CRISM's spatial resolution [6,7] demonstrate that even the resulting factor of 2-3 improvement shows previously undetected exposures and structure within known outcrops.

Orbital geomorphic and compositional measurements of Mars previously have been acquired by a separate high-resolution imager and lower resolution spectrometer, for example MRO's High Resolution Imaging Science Experiment (HiRISE) [8] and CRISM. HiRISE has a pixel scale of ~30 cm and 3 broad color channels covering the extended visible wavelength range; color images are typically acquired with 2-4-times reduced resolution. CRISM has 6.55-nm bandpasses covering visible to mid-infrared wavelengths (0.36-3.92 μm), allowing it to detect many minerals [4] not evident at visible wavelengths.

Motivation

As decades of terrestrial geologic field experience on Mars analogs shows, and results from the Mars Exploration Rovers (MERs) demonstrate [9,10], mineralogical diversity down to the scale of meters and finer is the norm. This is mirrored by spectral heterogeneity seen at enhanced CRISM spatial resolution [6,7]. Outcrop-scale exposures not seen at nominal CRISM resolution become apparent, including exposures at the Opportunity landing site. Such data have become key in planning MER rover traverses [6]. There is only limited ability to reveal these smaller-scale compositional variations using high-resolution imaging at visible wavelengths, however, because this region of the spectrum conveys mineralogic information mainly on Fe phases (Fig. 1a), whereas coverage of the near-infrared is required to detect many other minerals of interest including carbonates, sulfates, silica, and phyllosilicates (Fig. 1b). Coverage of CRISM's wavelength range at HiRISE color resolution (Fig. 1c) would merge these data types, and become an enabling measurement to further unravel the geology of Mars and to select the best sites for future robotic and human exploration. Here we propose such an investigation.

Conceptual Design

The High-Resolution Compositional imager (HRC) is a framing camera with a filter wheel assembly having bandpasses centered at specific absorptions diagnostic of key minerals, but wide enough for sufficient signal-to-noise (SNR) at high spatial resolution. Two wheels contain 12 spectral filters, whose centers and ~50-nm bandpasses have been simulated by resampling CRISM data (Figs. 1-2). A pixel scale of 2 m (5 μrad) with a field of view of 4x4 km can be achieved in a 400 km orbit using optics derived from the New Horizons Long-Range Reconnaissance Imager (LORRI), equipped with a passively cooled, 2048x2048 pixel Hawaii HgCdTe array. Modeling indicates that a CRISM-derived radiator can cool the detector sufficiently for high-SNR imaging to ≥2.5 μm. Ground motion compensation to limit smear and achieve SNR>200:1 is implemented by gimbaling along-track using hardware and control algorithms adapted from CRISM. A standard sequence acquires images in all 12 filters, plus two additional 770-nm frames before and after for stereo (Fig. 3). Acquisition of stereo images allows registration of color images onto a terrain model derived from a stereo pair having the same illumination. Besides providing compositional measurements at nearly ten times higher spatial resolution than CRISM, this approach would vastly expand the number of digital terrain models available at scientifically interesting locations and potential landing sites.

Science Objectives

With properly selected spectral bandpasses, the HRC will detect diagnostic igneous and alteration phases including ferric minerals, olivine and pyroxene, Al- and Fe/Mg-phyllosilicates, hydrated sulfates, carbonates, silica, and H_2O and CO_2 ices (Fig. 1-2). Its primary science objectives are: 1) Detect and characterize mineralogic signatures of water-bearing and potential life-forming environments; 2) Determine compositional stratigraphy of the Martian crust; and 3) Characterize the distribution of ices in the polar deposits.

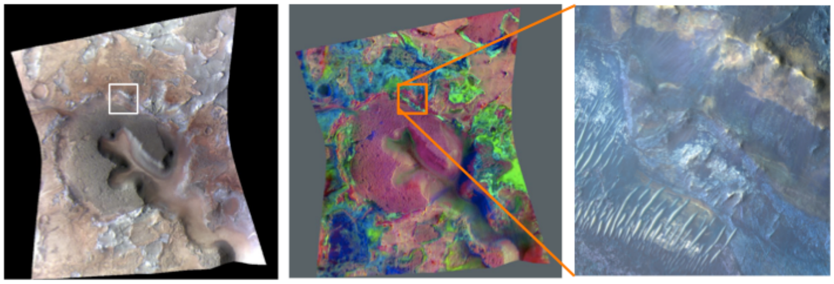

Fig. 1. (a) CRISM visible wavelengths show variations in Fe mineralogy (CRISM image FTR00003E12). (b) 12 50-nm multispectral bands convolved from CRISM IR data distinguish key minerals (clay – pink, carbonate – green, olivine – blue, basalt – red). (c) HiRISE color image approximates spatial resolution of the HRC (HiRISE image PSP_002888_2025).

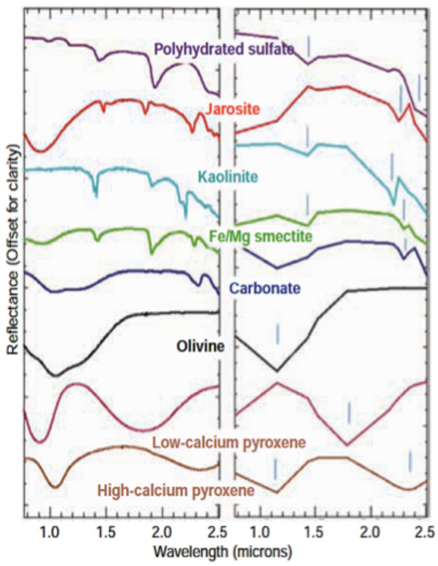

Fig. 2: Spectra from a variety of CRISM images (left) demonstrate how key mineral phases would be discriminated using 12 bandpasses (right).

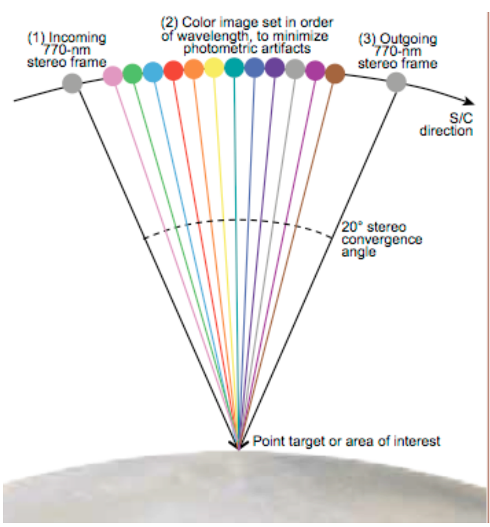

Fig. 3: Typical imaging sequence including color and a bracketing stereo pair.

Relevance to Future Robotic Missions

A mission to collect Martian samples from key environments for subsequent Earth return was the highest priority Flagship mission of the 2013-22 Decadal Survey. High-resolution compositional data can enhance site selection for sample return by qualifying additional sites to the 6-7 reference sites identified so far, and by supporting traverse planning at the selected locations. New detections of aqueous minerals in enhanced-resolution CRISM images implies that there may be additional sites, not yet recognized, that combine both igneous and sedimentary materials within a safe landing ellipse. The HRC's meters-scale resolution, capable of detecting compositions of individual outcrops, will support precise planning of rover traverses and sample collection sites, saving months of landed reconnaissance.

This instrument concept is also applicable to future Mars lander and rover investigations. Traditionally, surface packages contain independent instruments for imaging and compositional analysis. Recent examples include Pancam and Mini-TES on MER, and Mastcam and ChemCam on MSL. A mast-mounted VIS-IR imager would, with one instrument, provide imaging and compositional information, thereby playing a critical role in sample selection and geologic investigation.

Use for Human Exploration

Human exploration of Mars will focus on scientific investigation, resource utilization, and setting up infrastructure for subsequent missions. The science aspects are similar to those for MSR in that pre-flight assessment of the location, context, and relative abundance of geologic materials will provide critical input for site selection and planning of astronaut field campaigns. Similarly, understanding mineralogy will be crucial for filling strategic knowledge gaps. With its ability to map out key mineralogies at high spatial resolution, HRC and similar follow-on instruments will be crucial for identifying potential astronaut landing sites on Mars, thereby playing a supporting role in human exploration.

References: [1] Golombek, M.P. et al. (2005), *Nature, 436*, doi:10.1038/nature03600. [2] Arvidson, R. et al. (2008), *J. Geophys. Res., 113*, doi:10.1029/2007JE003021. [3] McEwen, A.S. et al. (2010), *Icarus, 205*, doi:10.1016/j.icarus.2009.04.023. [4] Murchie, S.L. et al. (2009), *J. Geophys. Res., 114*, doi:10.1029/2009JE003344. [5] Murchie, S. et al. (2007), *J. Geophys. Res., 112*, doi:10.1029/2006JE002682. [6] Arvidson, R.E. (2011), *AGU Fall Meeting,* abstract P22A-03. [7] Fraeman, A. et al. (2012) Lunar Planet. Sci. 43, abstract #2123. [8] McEwen, A.S. et al. (2007), *J. Geophys. Res., 112*, E05S02, doi:10.1029/2005JE002605. [9] Grotzinger, J.P. et al. (2005), *Earth Plan. Sci. Lett., 240*, 11-72 [10] Ruff, S.W. et al. (2011), *J. Geophys. Res., 116*, doi:10.1029/2010JE003767.