HiSCI EXPERIMENT ON *EXOMARS TRACE GAS ORBITER*.

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Introduction:

The High-resolution Stereo Color Imager (HiSCI) has been chosen for the payload of the *ExoMars Trace Gas Orbiter (TGO)* an ESA/NASA joint mission scheduled to arrive at Mars in 2016. There are 3 major HiSCI partners: (1) the telescope will be built in Switzerland overseen by the University of Bern; (2) the overall design, electronics, and integration will be from Ball Aerospace in Colorado; and (3) operations will be at the University of Arizona.

The chief objective of *TGO* is to search for and map the spatial and temporal distribution of disequilibrium trace gases of possible biological importance, such as methane, with high-resolution spectrometers [1]. Once localized, a key question is: What is the nature of the source regions? Spectra obtained in both occultation and nadir modes combined with atmospheric monitoring and modeling will make it possible to determine source locations to ~100 km. HiSCI will then image candidate features within these source regions at 2 m px^{-1}, in color and in stereo, over an 8.5-km swath width. If no sources are identified or confirmed, HiSCI will nevertheless lead to many new results on active and ancient Martian processes.

Many viable hypotheses exist for the origin(s) and release of Martian atmospheric trace gases such as methane; all involve active surface processes. Dust deposition homogenizes surface colors over time, but other active processes create spatial and temporal color variability. To identify color anomalies and hence active locations, color imaging at high spatial resolution and high signal to noise ratio (SNR) is essential. Topographic data at similar resolution are also needed to understand physical processes and to orthorectify images for reliable change detection.

The HiSCI Experiment:

HiSCI will acquire the best-ever color and stereo images over significant areas of Mars. HiSCI will exceed by >20X the color and stereo coverage of Mars per year by the High Resolution Imaging Science Experiment (HiRISE) on *MRO*, and will image at significantly better resolution and SNR than the extensive coverage by the *MRO* Context Camera (CTX) and Mars Express High Resolution Stereo Camera (HRSC) (Figure 1).

HiSCI may be the only high-resolution orbital imaging available during the joint Mars landed missions of 2018 and beyond. *TGO* results could lead to surprising new high-priority locations for future surface exploration. It is highly unlikely that already fully certified landing sites will fortuitously lie next to such locations. HiRISE has acquired >18,000 images to identify meter-scale hazards, but only ~2,000 stereo pairs, many of which are compromised by changing illumination angles. HiSCI will provide the 6 m (~1 m vertical) scale topographic data needed to complete certification of new candidate landing sites with HiRISE sampling of meter-scale hazards.

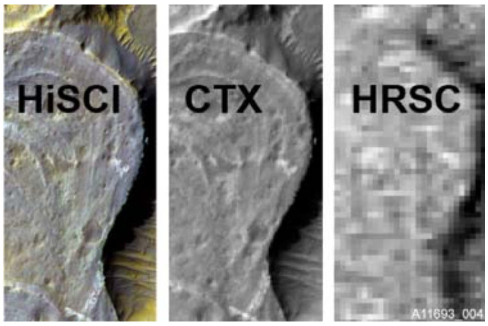

Figure 1. HiSCI (HiRISE reduced to 2 m/pixel), CTX (5.5 m/pixel), and HRSC (12.5 m/pixel) images of fluvial landforms in Eberswalde delta.

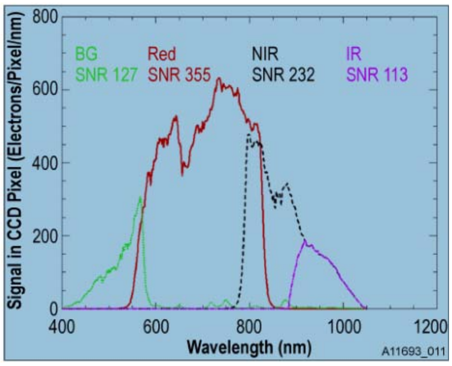

Figure 2. HiSCI filters and expected SNR over a dark region at 45° phase angle.

How HiSCI Works:

High SNR is essential to mapping subtle color differences through a dusty atmosphere (Figure 2). A modest-size high-resolution camera can achieve high SNR via time delay integration (TDI), which in turn requires orienting the pixel columns parallel to image motion to prevent smear. *TGO* plans a yaw strategy to keep the sun off spectrometer radiators, so HiSCI must have a yaw rotation drive (YaRD) to align the TDI columns with image motion. HiSCI also will use the YaRD to acquire along track stereo imaging. The benefit of along-track stereo is that it ensures identical illumination angles for optimal stereo correlations. The telescope will point 10° away from nadir in the direction of TDI motion. A stereo pair is acquired by first rotating the telescope to point ahead 10° to image, then rotating it 180° to point 10° behind for the second stereo view. The build-to-print CCDs feature bidirectional TDI, essential to HiSCI stereo. The 10° look angle increases the pixel scale and atmospheric path length by only 1.5%, yet provides a slightly larger than 20° stereo convergence angle (accounting for planetary curvature). The proper yaw orientation for TDI is not precisely parallel to the groundtrack because Mars rotates, and this offset also ensures excellent overlap between the 2 stereo images (maximum mismatch is 3% of the swath width near the equator).

Figure 3 Top: CRISM map at ~18m/px of pyroxene (green) and phyllosilicate (red). Bottom: Corresponding HiRISE image re-sampled to HiSCI resolution revealing folded pyroxene-rich and phyllosilicate-bearing beds, and phyllosilicate-bearing blocks at bottom right. Scene is ~0.6 km across.

Synergy with CRISM:

HiSCI will provide the best color imaging ever acquired from Mars orbit. HiRISE has revealed spectacular small-scale color diversity, but suffers from a very narrow color swath width. *MRO*'s Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) provides high-SNR data in 545 wavelengths, but at no better than 18 m/pixel scale. HiSCI will have excellent stray light rejection and essentially identical photometric angles and path lengths for each color band. Co-analysis of HiSCI and CRISM data will be an important part of the HiSCI investigation (Figure 3). The 2 m/pixel color imaging improves mapping and interpretation of mineral units identified by CRISM (Figure 3), and Digital Terrain Models (DTMs) will enable stratigraphic measurements.

Science Objectives:

HiSCI has 3 main objectives: (1) to better understand active or potentially active processes (mostly on the surface), (2) to map regions known to release trace gases, and (3) to complete the certification of new candidate landing sites. For active processes we will focus on better understanding of:

- Seasonal processes (frost, gullies, aeolian changes)
- Shallow subsurface ice and related processes
- Impact processes
- Tectonics, mass wasting and hydrothermal processes
- Volcanic processes
- Fluvial processes
- Mineralogy and stratigraphy
- Clouds

Note that *TGO* will have an inclined orbit (74°±10°) so HiSCI cannot image polar deposits, but will observe at all times of day to better understand seasonal processes.

Expected Data Volume and Imaging Modes:

The minimum HiSCI data rate will be 2.9 Gb/day (2 Tb over a Mars year), but we expect this to increase now that *TGO* plans to use Ka-band downlink. The degree of binning, image length, and compression are commanded for each HiSCI image so there is substantial flexibility to match the allocated downlink rate. We will use 2x2 or 4x4 pixel binning when the SNR of surface features is otherwise too low, such as when imaging near the terminator or when the atmosphere is especially dusty. HiSCI will image in color but not stereo over many regions.

Image Products:

We will produce a set of data products similar to those from HiRISE, including hundreds of DTMs produced at US and European centers. HiSCI will continue the new standard set by HiRISE for rapid release of high-level data products to NASA's Planetary Data System (PDS), and to ESA's Planetary Science Archive (PSA). We will release image products as soon as is practical, typically 1 month after acquisition rather than the required 6 months. There will be a website similar to http://hirise.lpl.arizona.edu and a mirror website at the University of Bern. We also plan an extensive public outreach program including color flyover movies from HiSCI stereo.

References:

[1] JIDT (2009). Final Report from the 2016 Mars Orbiter Bus Joint Instrument Definition Team, November 2009.