HIGH-RESOLUTION MULTI-COLOR PUSHBROOM IMAGERS FOR MARS SURFACE CHARACTERIZATION AND LANDING SAFETY. J. W. Bergstrom[1], R. Dissly[1], W. A. Delamere[2], A. McEwen[3], L. Keszthelyi[4], [1]Ball Aerospace & Technologies Corp., P.O. Box 1062, Boulder, CO 80306 (jbergstr@ball.com), [2]Delamere Space Systems, [3]LPL, U of Arizona, [4]U.S. Geological Survey Astrogeology Center.

Introduction: Multi-color high resolution imaging from Mars orbit is critical to understanding surface characteristics, in particular morphology, active processes and to a lesser extent composition. It is also essential for safe landing site selection. In addition, high resolution orbital images aid in navigation of landed assets [1]. Future imagers should capitalize on these capabilities, demonstrated by the HiRISE camera during more than six years in Mars orbit.

Measurement Requirements: Key high resolution imaging requirements are driven both from science and safety considerations, and are outlined in other abstracts to this workshop [1, 2]. These include: a combination of high resolution (~0.3 m/pixel) with high SNR (>50) for identification of features at scales relevant to planning safe surface operations for both robotic and human exploration, broadband color imaging for change detection and for interpolation of low spatial resolution spectroscopy products to finer spatial resolution [3], and stereo coverage for the creation of Digital Terrain Models over as much of the Mars surface as possible. To date, only ~1.5% of Mars has been covered by HiRISE (at <1m/pixel image scale or GSD).

Key Instrument Features: State-of-the-art pushbroom imaging can satisfy all of these measurement requirements. Specific instrument features include:

Time delay integration (TDI) is an enabling technology built into the CCD detectors of pushbroom imagers to greatly enhance the signal-to-noise ratio for small pixels. However, it does drive requirements on the instrument and/or spacecraft design. The TDI columns must be lined up with the ground track and the field of view angular rates must be controlled during an imaging sequence. If the spacecraft is not designed to properly orient or stabilize the imager, additional instrument mechanisms can be added to compensate.

Stereo image pairs taken within a single orbital pass have the advantage of identical lighting conditions, greatly facilitating the post-processing. A key enabling technology for this concept of operations is the use of bi-directional TDI in the CCD detectors.

Color. Several broadband interference filters can be incorporated into the FPA housing (e.g., HiRISE) or the multispectral CCD modules (e.g., HiSCI). Full color across the imaging swath is possible at high resolution in a compact design.

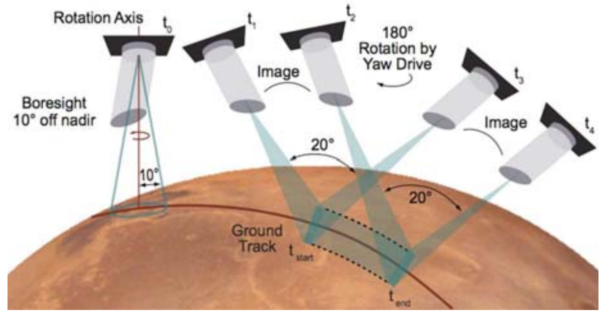


Figure 1 - Concept of operations for collection of a stereo image pair in a single orbital pass, used by the HiSCI instrument.

Jitter Correction. The longer effective integration times afforded by TDI operation leads to smearing and registration errors in the image due to spacecraft pointing errors. Having multiple (color) arrays of detectors provides a means to correct at certain frequencies [4].

HiRISE: The HiRISE camera has proven to be a very successful high performance imager in a very mass-efficient implementation. During the MRO mission HiRISE has completed more than 25,000 observations. It is the first orbital camera to resolve all boulders large enough to constitute a serious hazard for landing on Mars (Figure 2).

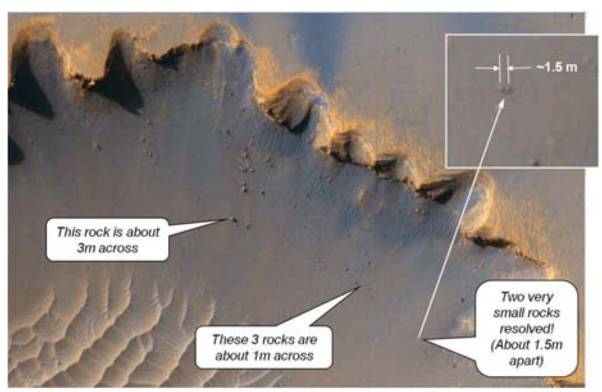


Figure 2 - Victoria Crater image demonstrates HiRISE ability to resolve 1-m hazards [5].

By taking images on different orbits, HiRISE is able to collect stereo data that can be converted into 1 m/post digital elevation maps (DEMs). Both of these capabilities are the result of a combination of very small ground sampling distance and high SNR [1].

HiSCI: The High resolution Stereo Color Imager (HiSCI) is currently being designed for the ExoMars Trace Gas Orbiter (TGO) mission to provide 2 m/pixel images in four colors with a full swath width of 8.5 km [6]. HiSCI is designed to 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 HiRISE on *MRO*, and will image at significantly better resolution and SNR than previous or current imagers.

A key feature of HiSCI is its ability to align the TDI array from an arbitrary yaw orientation and collect stereo image pairs within an orbital pass using a single instrument mechanism along with bi-directional TDI capability.

HiSCI also utilizes the JPEG 2000 compression standard, which is incorporated in the focal plane electronics. It also needs less than half the resources (mass & power) required for HiRISE.

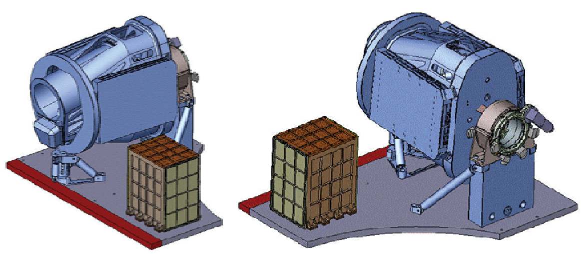
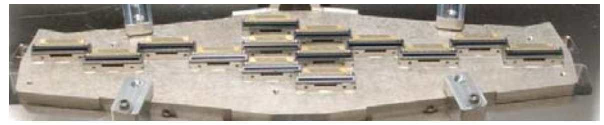
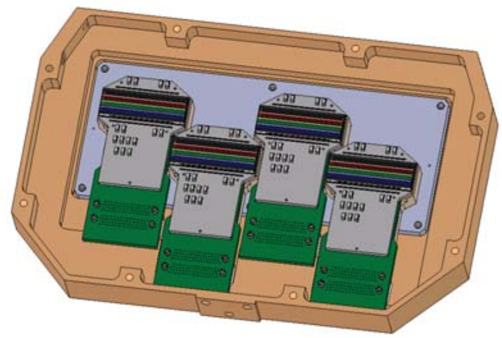


Figure 3 – The HiSCI instrument design is a joint effort between Univ. of Arizona, Ball Aerospace and Univ. of Bern (Switzerland). The yaw rotation mechanism can be seen attached to the mount of the right-side image.

Flexibility Through Modularity: Building on HiRISE heritage, Ball Aerospace has developed a standard modular focal plane architecture for high resolution pan and multi-color imaging. In many cases this allows tailoring of the camera design without the high expense of custom CCDs, FPA packaging and focal plane electronics. The HiSCI design is one such application of these modular components.



(a)



(b)

Figure 4 – (a) The HiRISE focal plane has three colors, but only in the central 1.2 km of the 6 km swath width. Each module includes a single color filter. (b) The HiSCI focal plane has four colors in each module, which extends the color coverage over the full 8.5 km swath width. Images not to scale.

Future Cameras: To meet the orbital measurements requirements for future high resolution imaging, future imagers can leverage to design features of both HiRISE and HiSCI for a low risk development approach. With a build-to-print telescope and multi-color full width CCD modules, all desired requirements could be met. Further improvements over current HiRISE capabilities are possible, including a GSD of 20 cm/pixel (from a 300 km orbit) and a larger number of color bands. Ultimately the design is limited by cost and flight system resource constraints, such as mass, power, pointing capability and particularly the downlink capacity.

References:

[1] Keszthelyi L. et al. (2012 submitted) *CAME Workshop*. [2] McEwen A. et al. (2012 submitted) *CAME Workshop*. [3] Delamere W. A. et al. (2010) *Icarus* 205, 37-52. [4] McEwen A. et al. (2010) *Icarus* 205, 2-37. [5] Ebben T. et al. (2007) *SPIE,* 6690-11. [6] McEwen A. et al. (2011) LPSC 2270.