ADVANCED ORBITAL IMAGING FOR FUTURE MARS SCIENCE AND EXPLORATION.

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Introduction: A substantial effort has been completed by the Mars science and exploration community to analyze strategic knowledge gaps (SKGs) associated with human missions to Mars and how to address these gaps[1]. **Table 1** lists areas of overlap between these Human Exploration and Operations (HEO) knowledge gaps and science objectives that can be addressed through orbital imaging. The 2012 workshop on Concepts and Appoaches for Mars Exploration (CAME) solicited ideas for measurements and related instrumentation to fill in the SKGs. Several ideas presented for orbital imaging will be discussed here. In particular, we consider requirements that can be met with straightforward extensions of the original HiRISE camera on Mars Reconnaissance Orbiter (MRO).

Table 1 Science Goals & Objectives, HEO Strategic Knowledge Gaps (SKG) and Gap Filling Activities (GFA) [1].

MEPAG Goals / Science Objectives	HEO-SKG	HEO-GFA
Determine if life ever arose on Mars	B5 Forward Contamination	B5-1 Identify and map special regions
Surface geology/chemistry Prepare for human exploration	B7 Landing Site & Hazards	B7-2 Landing site selection
Surface geology/chemistry Processes and history of climate Evolution of the surface and interior	D1 Water Resources	D1-4 Hydrated mineral occurrences D1-6 Shallow water ice occurrences
Prepare for human exploration	A4 Technology: to/from Mars System	A4-1 Autonomous rendezvous and docking demo. A4-2 Optical Comm. Tech. demo.

Science Requirements:

Composition. Several of the MEPAG goals require surface compositional information. The (cross-track) coverage for HiRISE color detectors (Blue-Green and IR) is only 1/5th of the broadband Red coverage. As a minimum requirement, these color detector arrays should be extended to full swath width.

A high (spatial) resolution *compositional imager* has been described [2]; they suggested 12 spectral bands centered at specific absorption features of key minerals. Spectral measurements are required in the 1-2.5µm wavelength range with ~50-nm passbands.

Key requirements or improvements for *stereo mapping* [3]: HiRISE-scale imaging with 3-4 pixels/m is required to resolve meter scale hazards for landers and rovers. Lower resolution (1-5 m/pixel) stereo for context is also desirable for >10 m landing site slopes. Producing fewer, larger images reduces the effort to generate stereo images; however, enlarging the HiRISE cross-track FOV substantially from 1.15° would likely require a major optical system redesign and would not be warranted. Push-broom cameras are susceptible to jitter, but multiple overlapping detectors facilitate jitter correction [4]. Images with SNR>100, free from compression artifacts, enable use of automatic stereo image matching. Along track stereo (single-pass) maintains lighting conditions, thus simplifying stereo image matching and the creation of digital terrain models (DTM).

The potential for near-surface water activity in Recurring Slope Lineae (RSL) [5] creates focused opportunities to search for extant life. RSL occur on steep, rocky slopes on which landing is dangerous, but several concepts for surface exploration of RSL were presented in 2012 (http://www.lpi.usra.edu/meetings/marsconcepts2012/). Another challenge is that RSL sites will require additional expenses for planetary protection [6]. For these reasons, it is important to learn as much as possible about RSL from orbital observations such as extended MRO. There is also a need for an orbiter to search for evidence of water over a range of local times (especially ~8-10 AM when surface brines are most stable [7-8]) during the seasons when the RSL are active [9-10].

Science Requirements Implementation:

Composition. A straightforward design improvement on HiRISE would be to increase the number of color detector modules to encompass the full swath width of the Red detectors. The original telescope optical design is compatible with this modest increase in focal plane area.

A multi-spectral imager in the short-wave IR (SWIR) wavelength region would be a natural extension of HiRISE through incorporation of a vis/SWIR focal plane. The Ball-built Operational Land Imager (OLI) has been providing Earth imagery from 0.4 to 2.5 µm for approximately one year on Landsat 8. OLI uses a pushbroom FPA with 9 spectral bands. Radiometric modeling predicts SNR values ≥ 50 in all bands using a HiRISE-derived telescope and OLI heritage detector modules (3 m/pixel at 300 km) with filters updated for Mars observation.

Implementing *along-track stereo imaging* for an instrument the size of HiRISE (50-cm aperture) is challenging. The smaller (14-cm aperture) High Resolution Stereo Color Imager (HiSCI) for Mars [11], which was being designed by Ball and The Univ. of Bern, Switzerland, was going to use a Ball-provided rotation actuator and flex capsule to rotate the entire telescope and focal plane subsystem. That is not feasible for the half-meter aperture telescope of HiRISE. Assuming that the focal plane has bi-directional read out, a large 2-position "flip" mirror located at the telescope entrance could be used to "look ahead" and "look back" in order to image the same region from two directions.

Technology Demonstration Requirements:

*Autonomous rendezvous and docking.*Visible imaging of targets for rendezvous and docking notionally requires a narrow FOV (~0.5-1.5°) camera for long range acquisition and wide FOV (~30-45°) for proximity operations, eg., [12].

Optical communication technology. Optical communication will be required to provide the increased downlink bandwidth planned for future missions. A notional requirement of 100 Mbit/s, which is ~16X higher than MRO, has been assumed.

Technology Demonstration Implementation:

Autonomous rendezvous and docking.

The MRO OpNav camera (FOV=1.4°x1.4°, 50µrad/pixel) has been baselined previously [13-14]. It has been suggested that adding a framing detector chip to the HiRISE focal plane could facilitate detection and tracking of the orbiting sample container for the Mars Sample Return mission. However, the pixel scale (1 µrad/pixel) of HiRISE is not compatible with this application. Modifications to the HiRISE optics and pushbroom focal plane subsystem to incorporate this function would not be practical. A small dedicated imager would be more resource efficient.

Optical communication technology. A conceptual design (see Figure 1) was completed to show the synergism between optical communication and high resolution imaging. A link budget for this design achieves 100 Mbit/s data rate with 2.5 dB link margin.

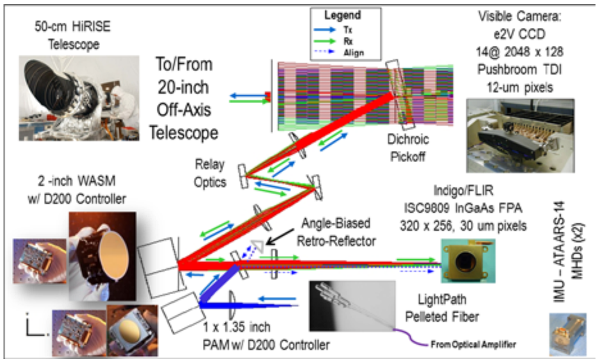

Figure 1 Dual-use of the HiRISE telescope provides high resolution imaging and transmit optics for a high data rate downlink from Mars.

Conclusions and Recommendations: While it may be desirable to achieve 5-10 cm/pixel images [15], HiRISE resolution (25-32 cm/pixel) appears adequate for the majority of current high-resolution imaging requirements from Mars orbit. Instead, we recommend a modest enhancement of the HiRISE-class camera by extending the existing Blue-Green and IR detector arrays to full-swath-width. If desired, a 3rd NIR multispectral color channel could be added with limited impact. The option to add up to nine SWIR (1-2.5µm) bandpass channels would be a substantial science upgrade.

References:

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