MISSION SCIENCE/OPERATIONS SUPPORT AND TRAINING FOR SPACECRAFT PAYLOADS: BUILDING THE NEXT GENERATION OF PLANETARY MISSION PROFESSIONALS. L. L. Tornabene[1], K. Block[2], E. Pilles[1], N. Baugh[2], A. S. McEwen[2], C. Hansen[3], A. Espinoza[2], G. R. Osinski[1], A. Bina[1*], M. Bourassa[1], R. Capitan[1*], C. Caudill[1], K. Hansen[1*], E. Harrington[1*], S. Hibbard[1], R. Hopkins[1], J. Kissi-Ameyaw[1*], Z. Morse[1], J. Newman[1], I. Pritchard[1*], E. Silber[1*], S. Simpson[1], G. Tolometti[1], and A. Werynski[1*], [1]CPSX, Dept. of Earth Sci., Western University, London, Canada (ltornabe@uwo.ca; *denotes that they were once affiliated with CPSX WesternU, but have since moved on), [2]LPL, Univ. of Arizona, Tucson, AZ, [3]PSI, Tucson, AZ.

Introduction: The Centre for Planetary Science and Exploration (CPSX) at Western University (WesternU) has successfully provided mission operations support for the High Resolution Imaging Science Experiment (HiRISE) payload aboard the Mars Reconnaissance Orbiter (MRO) [1] and training over the last 4 years involving 17 individuals. These 17 Highly-Qualified Personnel (**HQP**) included undergraduate students, graduate students, postdoctoral fellows, and staff from the geology, astronomy & physics, engineering, and geography departments at WesternU ranging from no mission experience to some basic mission support experience. These HQP electively participated in teams of 2-3 trainees under a CPSX and WesternU-based HiRISE science team member (Livio L. Tornabene) spread over 8 two-week image-planning "cycles" in conjunction with an international science/operations team spanning North America and Europe; thus, the HQP were provided unique and invaluable mission science/operations experience to help prepare them as the next generation of spacecraft (s/c) and planetary science professionals, all the while completing vital MRO-HiRISE operational tasks and support.

Background: The HiRISE mission operations team uses a hand-off operations approach wherein science guidance for each two-week planning cycle rotates between a large, international and widely-distributed group of Co-Investigators (**Co-Is**) and science team members, while mission operations engineering is provided by a smaller, fixed team based at the University of Arizona in Tucson.

Two-week cycles are essentially planned cooperatively between a Co-I of the Pay Period (**CIPP**) or science team member (and in some cases their affiliates), who provides part-time science support, and an Operations Engineer who provides full-time technical and operations support. The science team member provides the scientific focus for each imaging cycle: prioritization of imaging opportunities (*a.k.a.*, target suggestions), guidance on imaging modes (*e.g.*, pixel-binning or image spatial resolution preferences), and ensuring the acquired images are able to satisfy the science objectives of the original target suggestion. The Operations Engineer creates s/c image sequence and command files, balances data volume, manages temperature constraints, and is responsible for the commands and ultimate safety of the instrument and quality of the data returned during the planning cycle.

HiRISE Planning Process and Responsibilities: The HiRISE planning process incorporates inflexible deadlines across multiple weeks (~5 weeks in total including execution); participation is a significant time commitment requiring weekend-work and availability. CIPPs use specialized software built on JMARS (Java Mission-planning and Analysis for Remote Sensing) [2] called HiPlan. HiPlan provides both planning tools and a Geographical Information System (GIS) package that incorporates all public- and team released datasets for Mars, to maximize the science return of planned HiRISE images.

It is the principal responsibility of the CIPP to set an overall science emphasis for each cycle, determine a carefully curated, oversubscribed list of targets appropriate for that science emphasis and the current seasonal constraints, and then assign relative priorities to each target in the list. Precisely targeting surface coordinates requires the MRO s/c to roll off nadir. The motion of the s/c places an inherent time and space limit on each instruments desired surface target on an orbit-by-orbit basis, so the instruments must "compete" for roll opportunities on each orbit. In order to equitably allocate s/c rolls and timeline in a given two-week planning cycle among each of the MRO instruments, each team submits an oversubscribed (~2-4x the requests), prioritized list of candidate targets. These targets are then scheduled in a round-robin process by MRO support staff at NASA/JPL.

Once the round robin process has been completed and all rolled and s/c interactive images for each science team are scheduled, the CIPP makes recommendations for coordination or "ride-along" opportunities (*i.e.*, acquisition of HiRISE image where another MRO instrument is taking the lead on observing the surface). Additionally, CIPPs provide guidance for individual imaging decisions such as binning and length based on seasonality, lighting, and atmospheric conditions, prepare and give presentations describing the planning cycle and emphasis to the science team, and respond to any issues as needed.

CPSX HQP trainees are involved in all aspects of the role of the CIPP and perform the same duties under the guidance of the advising HiRISE science team member based at WesternU (Tornabene).

Results: Tornabene and seventeen HQP trainees, have supported a total of 8 cycles returning ~1600 images (**Fig. 1)** that include targets requested by both the science team and public (both science and the lay communities).

1599 images across 8 two-week planning cycles to date…
Of these:
39 candidate future landing site images
1427 coordinated science observations with other MRO instruments
258 stereo images
41 potential new impact site confirmation images
…totaling 339.89 GB of image data

Fig. 1. HiRISE image statistics (as of submission) based on the science/operational support of the CPSX WesternU-based team over the last 4 years.

HQPs gained valuable experience and skills. These include general skills, such as:

- Working on a team,
- Working towards firm/critical deadlines,
- Troubleshooting and problem solving,
- Leadership skills,
- Communication and Public Speaking: Presentation of information to a greater team,
- CPSX and HIRSE Education and Public Outreach (EPO) through Social Media and science communication (engaging the public through web-released image captions, Twitter, Facebook, Open Houses, public presentations and News – TV, radio, podcasts, newspapers/magazines);

And specific skills, such as:

- Hands-on real-time science/operations mission experience
- Learning of MRO/HiRISE specific science/operations information
- Mars geology and geography
- GIS and Remote sensing experience
- Basics of orbital mechanics and
- Basics of s/c payload operation
- Basics of imaging systems (*i.e.*, "cameras")

Key Factors that Contributed to Success: *1. Since its early days of planning, HiRISE operations has been structured around a remote science team.* Operations procedures, software information, image planning details, and cycle planning deadlines are maintained online. A HiRISE team-maintained wiki supplements training information, and materials are accessible by remote team members off the University of Arizona campus. This wide dissemination and accessibility of information are key to the success of a remote science team.

2. Guidance to trainees is provided by experienced science and operations team members. Although HiRISE has well-established, thoroughly vetted operations procedures on the wiki, it takes experienced personnel who can be flexible and responsive to handle the myriad issues that may arise during each planning cycle. Many of these challenges may require modifying, deviating or creating new procedures – sometimes on the fly, and while maintaining firm deadlines. A science team member (Dr. Tornabene) and the partnering Operations Engineer, with their extensive HiRISE and other spacecraft experience, have been critical to the success of science/operations support and training at CPSX.

3. Time is allowed for cohort training, and group formal and informal shadowing of more experienced peers. Less experienced participants shadow experienced team members while building their capacity and familiarity with the HiRISE planning process, with the goal of providing leadership in the future. Over the last 4 years, the CPSX WesternU-based support of HiRISE mission operations culminated in one HQP trainee (Pilles) building sufficient experience to where he was able to successfully perform the CIPP role (via HiRISE science team member Tornabene) for the 8th HiRISE imaging cycle supported from CPSX WesternU.

4. Institutional support provides critical scaffolding for success. The WesternU-based team has a dedicated "Mission Control" space in which to work with necessary tools, such as: a dedicated work station, multiple screens for imagery and planning software, a speaker phone for use in HiRISE team telecons and communication with the science operations team, a printer and office supplies at their disposal.

Conclusions: The experienced group of spacecraft science and operations professionals at WesternU CPSX and The University of Arizona have worked together to provide training and experience to 17 undergraduate students, graduate students, and postdoctoral fellows for mission operation support for HiRISE aboard Mars Reconnaissance Orbiter. This unique, mutually beneficial arrangement has provided valuable spacecraft for the participants, and critical science operations input for the HiRISE team.

References: [1] McEwen, A. M et al. (2007) *JGR, 112,* E05S02. [2] Christensen P.R. et al. (2009) *AGU Fall Mtg 2009,* abstract #IN22A-06.

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