THE FUTURE OF MRO/HIRISE. A. S. McEwen[1] and the HiRISE Science and Operations Team [1]LPL, University of Arizona (mcewen@lpl.arizona.edu).

Introduction: The High Resolution Imaging Science Experiment (HiRISE) [1-2] on the Mars Reconnaisance Orbiter (MRO) [3-4] has been orbiting Mars since 2006. The nominal mission ended in 2010, but MRO has continued science and relay operations, now in its 4th extended mission. Both the spacecraft and instrument have experienced a variety of anomalies and degradation over time, although the performance of both has been exceptional well past their originally planned lifetimes. This presentation describes the accomplishments to date of HiRISE and prospects for the future, with perhaps another decade of imaging.

HiRISE obtains the highest-resolution orbital images acquired of Mars, ranging from 25-35 cm/pixel scale depending on MRO's altitude and the off-nadir look angle. To acquire such images with a high signal:noise ratio (SNR), HiRISE uses time delay integration (TDI), imaging each patch of ground up to 128 times and summing the signal. High SNR is essential because about half of the image brightness comes from scattering by the dusty air, so images with 150:1 SNR at the top of the atmosphere have SNR ~75 for surface features. Producing sharp images over such a small instantaneous field of view (1 microradian/pixel) and with 128 TDI lines requires very stable pointing from the spacecraft.

HiRISE has 14 CCD detectors: 10 with a broadband (RED) filter that cover the ~5-6 km wide image swath, plus 2 with blue-green (BG) and 2 with near-infrared (NIR) filters, producing 3-color imaging in a narrow central swath of each image. Electronics for one of the RED CCDs failed in 2011; fortunately on the edge of the swath, so subsequent images are just 10% narrower rather than having a gap.

HiRISE Accomplishments: As of 1/1/18, HiRISE has returned over 52,000 large (~giga-pixel) images of Mars, covering a total of 2.92% of the martian surface if all coverage was unique. Given frequent repeat coverage for stereo imaging and change detection, the unique coverage is about 2% of Mars.

HiRISE data have been used to find the best landing sites for multiple landers and rovers: Phoenix (2008), MSL (2013), Schiaprelli (2016), InSight (2018), Mars2020 (2020), and ExoMars rover (2020). With sharp pixels at ~30 cm scale, HiRISE images identify 1 meter scale hazards such as boulders.

Over 5,400 stereo pairs have been acquired, with over 500 full-resolution digital terrain models (DTMs) produced and archived with the PDS (https://www.uahirise.org/dtm/). Many researchers in the community are now producing HiRISE DTMs, and we can help with PDS archival of any full-resolution, high-quality DTMs.

More than 1,300 peer-reviewed publications with "HiRISE" and "Mars" are found by NASA ADS full-text search (Fig. 1). A good sample of HiRISE-based studies can be seen by searching for "HiRISE" in LPSC abstracts; in 2017, there were 181 abstracts. Most publications do not include HiRISE team members as authors, so much of the community may be unaware of changes over time.

HiRISE image anomalies: There have been a number of anomalies that affect image quality.

Loss of CCDs. RED9 was lost in 2011, narrowing the swath width. Fortunately there have been no further failures to date, but this remains a distinct possibility in the future.

Flipouts. Soon after launch we discovered bit flips in some image channels. This problem has grown worse and affected more and more image channels (each CCD has 2 readout channels). The bit flips, when severe, create negative values that get encoded as zeroes, so the returned images may be useless. Fortunately we can mitigate this problem by warming the focal plane electronics (FPE) prior to Mars imaging, and we have been raising the minimum FPE temperature to start imaging by about 1.5°C/year. Concurrently we must either raise the uppermost Allowable Flight Temperature (AFT) for the FPE, or acquire shorter images that ensure we do not exceed the AFT (which triggers powering off the instrument). We now believe we can raise the AFT substantially above the initial very conservative limit, but given the uncertainty in how this will affect the electronics, we prefer to raise it slowly and also limit image length. Hence, although early images had up to 120,000 lines at full resolution (no pixel binning), the maximum now is near 50,000 lines (or ~150,000 2x2 binned lines).

In spite of warming the FPE, there is noise due to bit flips in some images, especially IR10 (both channels) and channel 1 of CCDs RED0, 1, and 3. These images will sometimes have columns with all zeros, and minor bit-flip noise throughout the image. IR10 channel 1 has always been the worst, and frequently is so bad that we do not process the data into higher-level products.

Image blur. Starting in early 2017, we began to see some blurred images (Fig. 2). This can be difficult to recognize because the surface of Mars is often smoothed by aeolian processes, but comparison to earlier images over the same location makes it clear when an image is blurred. Through 2017 the percentage of blurred images has increased, to about 40% of full-resolution images at the end of 2017. We do not understand the cause of this blurring, which is under investigation, but it seems most likely to be high-frequency pointing jitter. Maintaining pointing accuracy to within 1 microradian was recognized to be a major challenge during the development of MRO and the spacecraft has done an excellent job for more than 12 years since launch. Hopefully this problem will be understood and we can then realize some mitigation. If the problem continues to worsen over time, we may decide that it is no longer useful to acquire bin-1 (full resolution) images. We already use 2x2 binning for more than half of our images because it produces a higher SNR and we can cover four times as much area for the same data volume.

MRO orbit expectations: MRO has been in a sun-synchromnous (nearly polar) orbit near 3 PM Local Mean Solar Time (LMST), which is close to ideal for imaging the surface because the illumination angle accentuates topography while still providing ample signal for high SNR. However, MRO's batteries are gradually losing capacity. To keep MRO functioning for another decade, a number of changes are being made to prolong battery life, including a plan to move to a later LMST (near 4:30 PM) after the Mars2020 rover landing (Feb. 2021). This later time of day reduces the duration of eclipses, when the solar arrays are not illuminated and battery power must be used.

The change to 4:30 PM LMST will provide disadvantages and advantages to HiRISE science. First, it complicates change detection because we cannot re-image with similar lighting conditions. Second, it limits the latitude range of useful imaging within each season, reducing the seasonal range for monitoring polar processes. Third, it means that stereo pairs must be completed more rapidly to avoid large changes in shadow lengths and positions, although this may have an operational mitigation. Advantages are that relatively flat equatorial regions are better imaged later in the day to accentuate subtle topography, and some early morning imaging is possible at high latitudes.

Future HiRISE images: Expect more binned images for two main reasons: (1) the later LMST provides lower brightness levels, reducing SNR, mitigated by pixel binning; and (2) the image blurring, if it continues, will mean we do not gain much or any resolution advantage from bin-1 imaging. Hopefully the image blur will not worsen to the point where bin-2 images are significantly degraded. However, we can cover four times as much of Mars with bin-2 images compared to full-resolution, and ~0.6 cm/pixel remains better than any other orbital imaging of Mars. Many science objectives will benefit from the greater coverage. Landing site reconnaissance and small-scale change detection will be degraded but still useful.

HiWISH: Go to https://uahirise.org/hiwish to help us choose where to image.

HiRISE-2? HiRISE-class imaging is highly recommended in a study of the next Mars orbiter (https://mepag.jpl.nasa.gov/reports.cfm). Extending the high-resolution mapping and monitoring has great scientific value and is essential for landing sites. Advances in detector and electronics technologies since 2002 would lead to significantly improved images.

References: [1] McEwen, A.S. et al. (2007) JGR, 112, E05S02. [2] McEwen, A.S. et al. (2010) Icarus, 205, 2-37. [3] Zurek, R.W., Smrekar, S.E. (2007) JGR 112, E05S01. [4] Graf, J.E. et al. (2007) Acta Astronautica 61, 44-51.

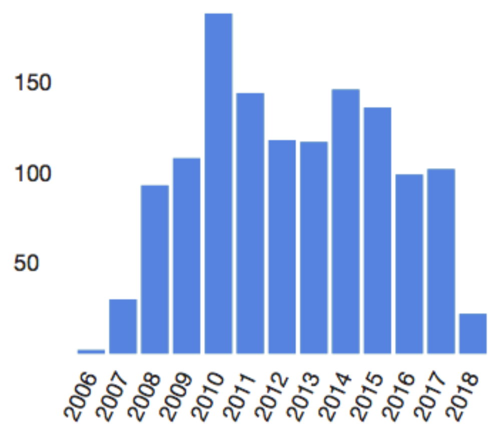

Figure 1: Numbers of peer-reviewed journal publications as of 1/1/18 with "HiRISE" and "Mars".

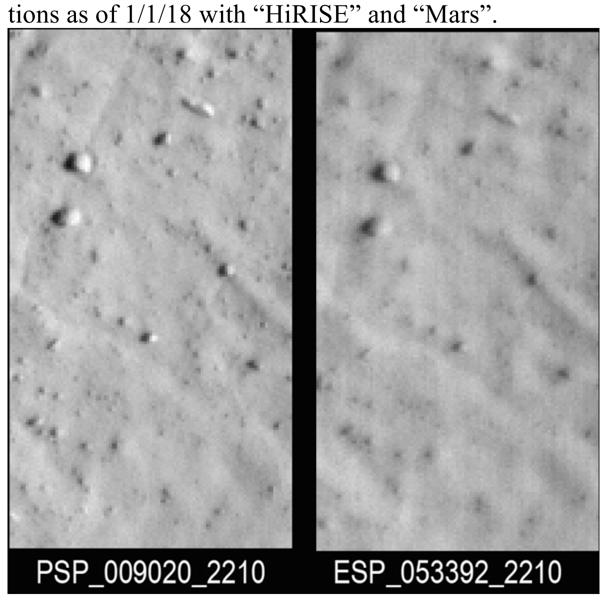

Figure 2: Comparison of bin-1 images covering the same patch of ground under very similar photometric angles, but showing blur in the more recent image (ESP_053392_2210, acquired 12/16/2017).