THE HIGH-RESOLUTION IMAGING SCIENCE EXPERIMENT (HIRISE) IN THE MRO EXTENDED SCIENCE PHASES (2009–2022), A. McEwen[1], S. Byrne[1], C. Hansen[2], and the HiRISE team. [1]Lunar and Planetary Lab, University of Arizona, Tucson, AZ 85721, USA, [2]Planetary Science Institute, Tucson, AZ, USA.

Introduction: The Mars Reconnaissance Orbiter (MRO) has been orbiting Mars since 2006 and has acquired more than 77,000 HiRISE images with sub-meter resolution, contributing to over 1,800 peer-reviewed publications (Fig. 1). This abstract and poster summarizes a paper submitted to the MRO special issue of Icarus [1]. The paper provides information useful to the HiRISE data user community, updating the information [2] about the Primary Science Phase (PSP) of MRO. There are 12 major sections to the paper:

1. Introduction
2. Science Publications and Team
3. Operations History
4. Summary of HiRISE Archived Dataset
5. Special Data Products and Analysis Tools
6. Imaging for Lander and Rover Missions
7. Science Planning and Uplink Tools and Techniques
8. Instrument Issues and Anomalies
9. Calibrations
10. Citizen Science and Machine Learning
11. Education and Public Outreach
12. The Future of Very High-Resolution Orbital Imaging of Mars

We continue to invite all interested people to suggest HiRISE targets on Mars via HiWish, and to explore the easy-to-use publicly available images.

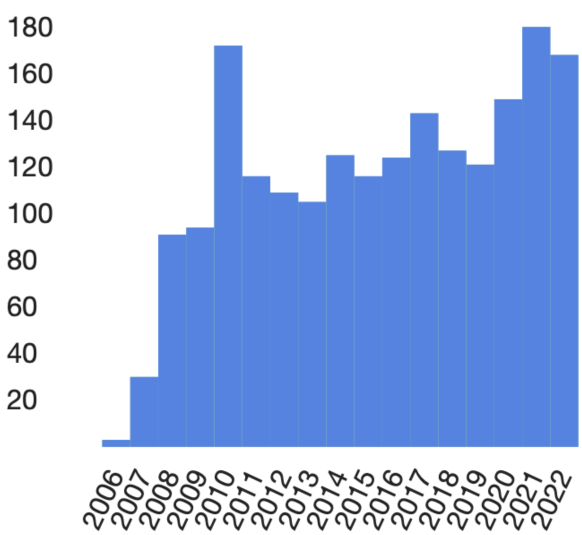

Figure 1. Number of search results on NASA's ADS at https://ui.adsabs.harvard.edu/ for all peer-reviewed articles that contain the text Mars and HiRISE.

Science Highlights:

- Many current and candidate landing and traverse sites have been mapped in color and stereo, leading to regional geologic studies and that enabled safe landings and complement surface results and traverse planning for rovers (see [1] for references).
- New impact craters have constrained current impact rates and assisted interpretation of seismic signals [3-4].
- New craters also show that shallow water ice is present at lower latitudes than previously known, plus mid-latitude scarps have revealed thick bodies of massive ice [5-6]
- Mapping of shallow valleys, alluvial fans, channels, and deltas have shown that water flowed on Mars relatively recently, within the past 2 billion years [7-9].
- Mapping of sediments and ancient bedrock with HiRISE stereo-derived topography combined with mineralogic information from MRO's CRISM has revealed that minerals containing water are widespread on early Mars and formed more recently than previously known, again within the past 2 billion years [10-11].
- Pristine gullies on Mars have been shown by HiRISE to be forming at a high rate today from the action of carbon dioxide frost, rather than being remnants of a recent wetter climate [12-13].
- Recurring Slope Lineae, a new phenomenon discovered by HiRISE [14], look like water seeps but are probably strange dry flows of dust and sand, showing that Mars today is very different than Earth [15-16].
- Sand dunes and other wind-driven bedforms are now known to be actively migrating across much of Mars [12]. Another class of widespread bright ripple features are much less active, indicating that they were formed under different conditions than present day Mars [17-18].
- Some polar landforms like "spiders" or furrows are also actively forming on Mars today from seasonal processes involving carbon dioxide ice and gas [19-20].
- HiRISE has revealed the remarkable diversity of volcanic landforms and processes on Mars, including mud volcanism [21-22], flood lavas [23]

and distinguishing aqueous from volcanic geomorphology [24-25].

- Sedimentary rocks have been studied in detail [26], revealing periodicities in the layering that may relate to orbital cycles [27].
- The north- and south-polar layered deposits and their outliers have periodic climate signals in the topography of their exposures stretching back millions of years [28-30].
- Accumulation and erosion of the residual polar ice caps can be tied to the current climate and its variability from year to year [31-32].
- The recognition of many glacial and periglacial landforms on Mars [33-35] and the story they tell us about Mars recent climate and hydrosphere has been instrumental in understanding the distribution of shallow ground ice which will underpin future human exploration [36].

Changes Since the PSP: There have been many changes to science planning, data processing, and analysis tools since the initial Primary Science Phase in 2006–2008. These changes affect the data used or requested by the community and how they should interpret the data. There have also been a variety of complications to the dataset over the years, such as gaps in monitoring due to spacecraft and instrument issues and special events like the arrival of new landers or rovers on Mars or global dust events.

Instrument Performance: The HiRISE optics have performed well except for a period when small optical elements became too cold, blurring some images. The focal plane system has had 13 rather than 14 operational detectors since 2011; fortunately, the failed unit was at the edge of the swath width, reducing image width by 10% rather than creating gaps. An unusual problem with the digital numbers (bit flips) as part of analog-to-digital conversion of the signal has continued to worsen over time, but mitigation steps so far have preserved full-resolution imaging over the full swath width (about 5 km on Mars). In a few more years we expect that full-resolution imaging will be narrowed to a subset of the detectors and there will be more 2x2 binned data.

The Future of Very High-Resolution Orbital Imaging of Mars: The Mars Exploration Program has relied on HiRISE for characterization of landing sites. HiRISE contributes to the analysis of science potential, along with many other remote-sensing experiments, and uniquely contributes to characterization of landing site safety. DTMs from HiRISE stereo coverage are used for detailed landing simulations, terrain relative navigation and boulder counts, slopes, and topography are used to assess small-scale hazards. However, the full resolution of HiRISE is essential to many of these data products. For example, too many boulders are unresolved in bin2 images to fit a size-frequency distribution down to the scale relevant to landers [37]. In future years, HiRISE may lose full-resolution capability, or at least have a narrower swath at full resolution, due to bit flips worsening over time. These points are especially relevant given that HiRISE is the only Mars orbital imager that is operating or planned and capable of meeting the data requirements for sufficiently characterizing landing sites.

We discuss some of the many lessons learned (or received) relevant to future very high-resolution imaging of planetary surfaces.

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