The Future of MRO/HiRISE

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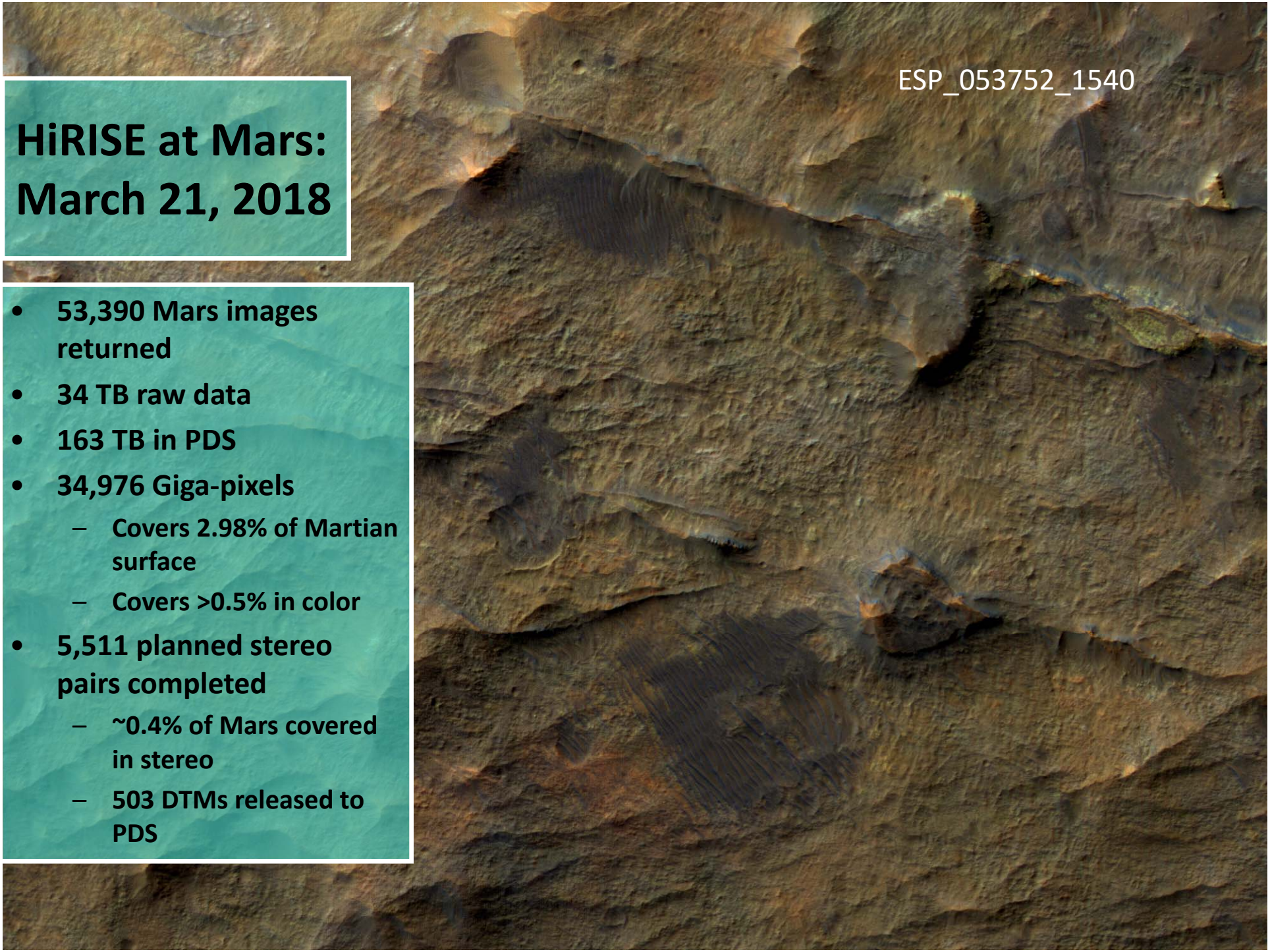
(these slides composed Alfred's poster at MEPAG Meeting 36)

Image width ~1.1 km
Enhanced IR-shifted colors

One Minute Summary:

- MRO and the HiRISE camera have been orbiting Mars >12 years
  - Designed for 5 years
  - Increasing hardware issues
- MRO has developed a plan to continue operations for another 10 years
  - Success depends on unpredictable future issues
- The HiRISE camera also has issues, but continues to acquire very high-quality images
  - We had a scare with image blur—now understood and fixable
  - Image bit flips are annoying, but are being mitigated
  - One of 14 detector electronics unit failed in 2011; more could fail in the future
- MRO will be moving to a later time of day
  - Necessary to prolong the lifetime of the batteries
  - Expect local mean solar time (LMST) ~4:30 PM by 2022
    - HiRISE will acquire more 2x2 binned images for adequate signal:noise
    - There will still be many opportunities for high-quality full-resolution images
- MRO funding keeps getting cut with each mission extension
  - Science team cannot be adequately supported
  - Exploration at Mars is no longer a high NASA priority
  - We need the full Mars community to help enter good targets via HiWish
    - https://www.uahirise.org/hiwish/

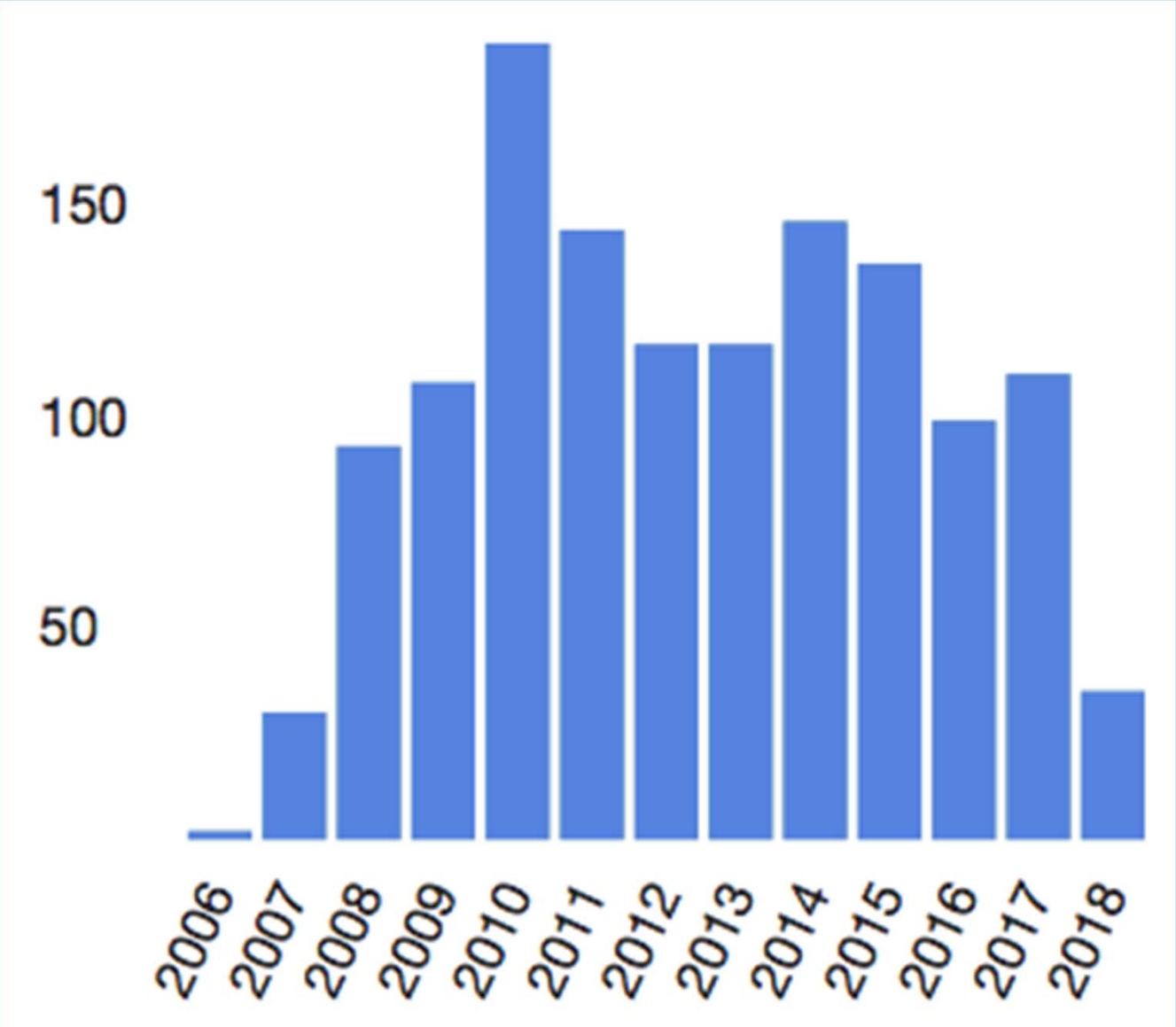
HiRISE at Mars: March 21, 2018

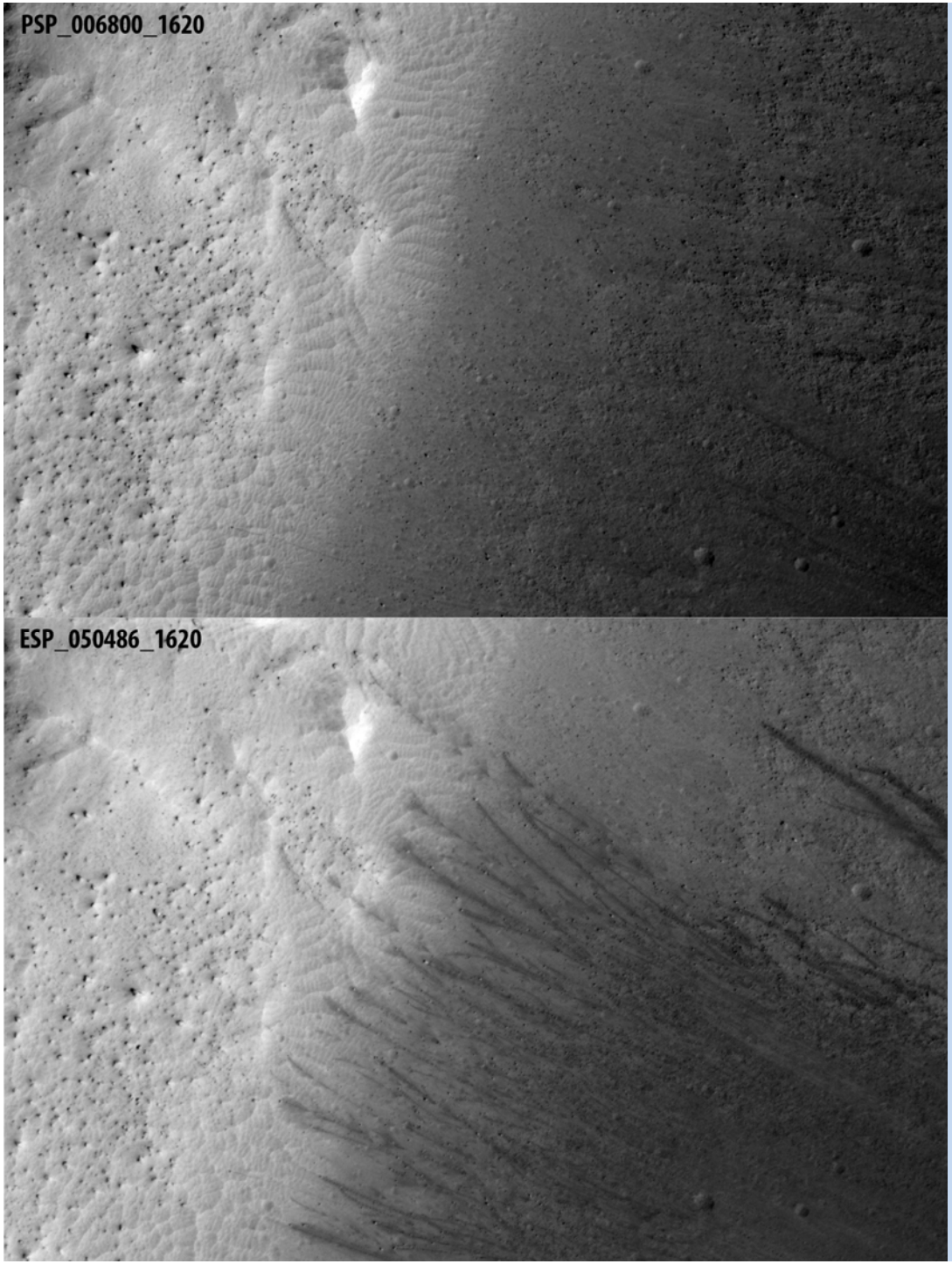


- 53,390 Mars images returned
- 34 TB raw data
- 163 TB in PDS
- 34,976 Giga-pixels
  - Covers 2.98% of Martian surface
  - Covers >0.5% in color
- 5,511 planned stereo pairs completed
  - ~0.4% of Mars covered in stereo
  - 503 DTMs released to PDS

1,335 refereed HiRISE publications

From NASA ADS full-text search on “HiRISE” and “Mars” from 2006-2018.
There are 171 LPSC abstracts containing “HiRISE” in 2018.



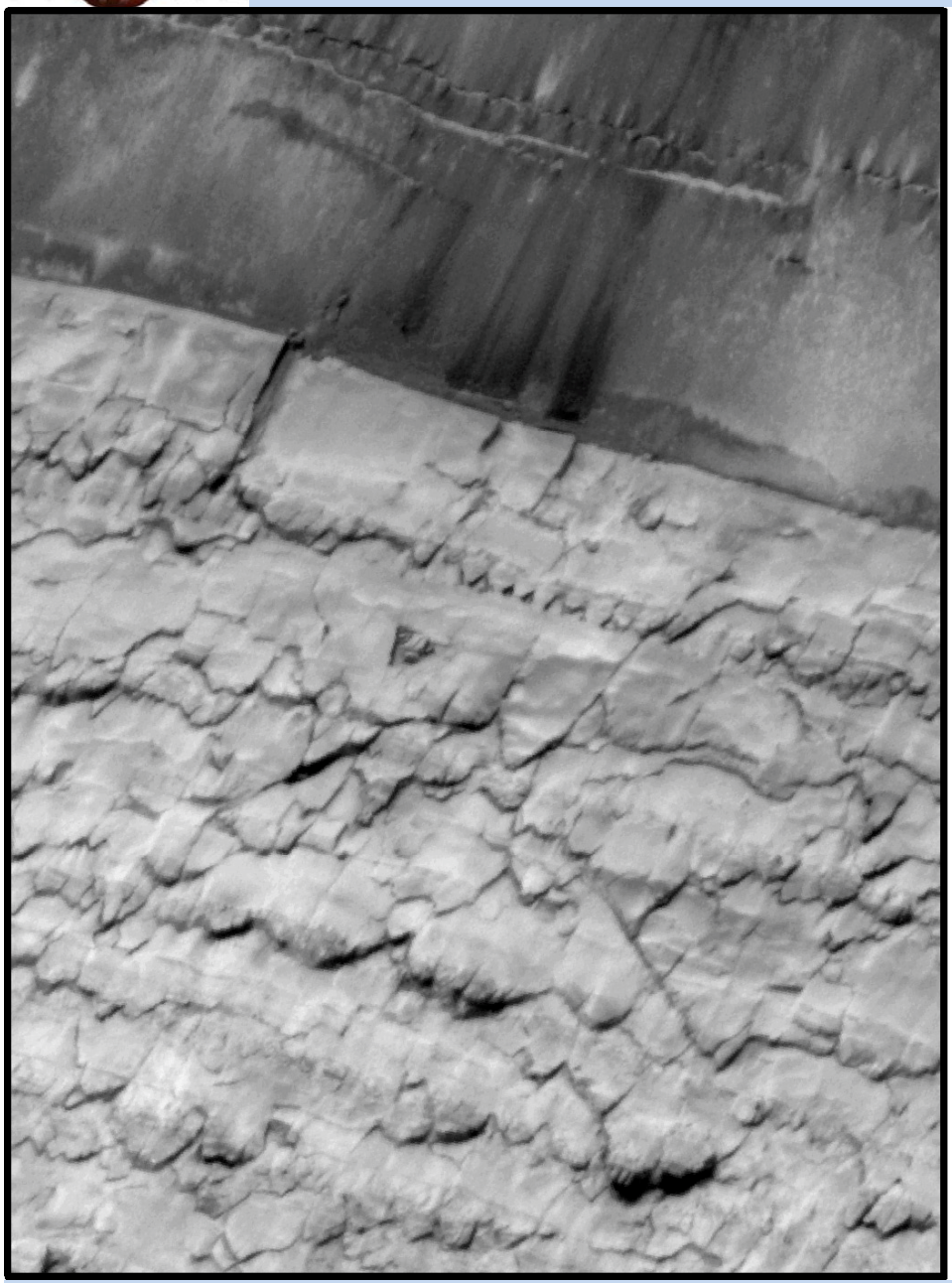


New Change Detection Campaign

- Find opportunities for near-exact match images (illumination and emission angles) before move to later LMST
- Team members request ~30/cycle, ~20 acquired

Left: Boulder tracks at distal end of avalanche in Gratteri Crater.

Failure of North Polar cliff section in late-summer or winter of MY 30



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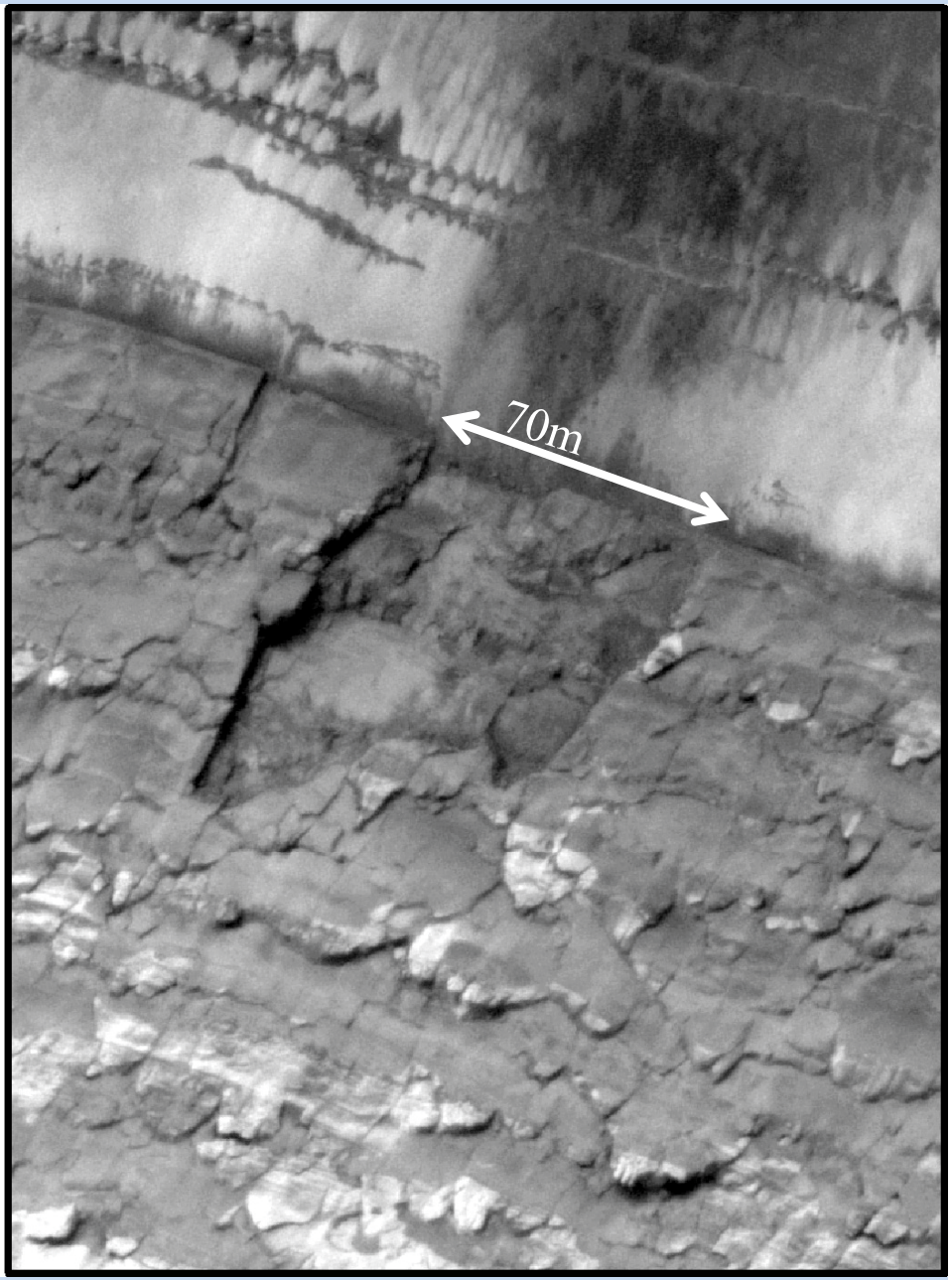

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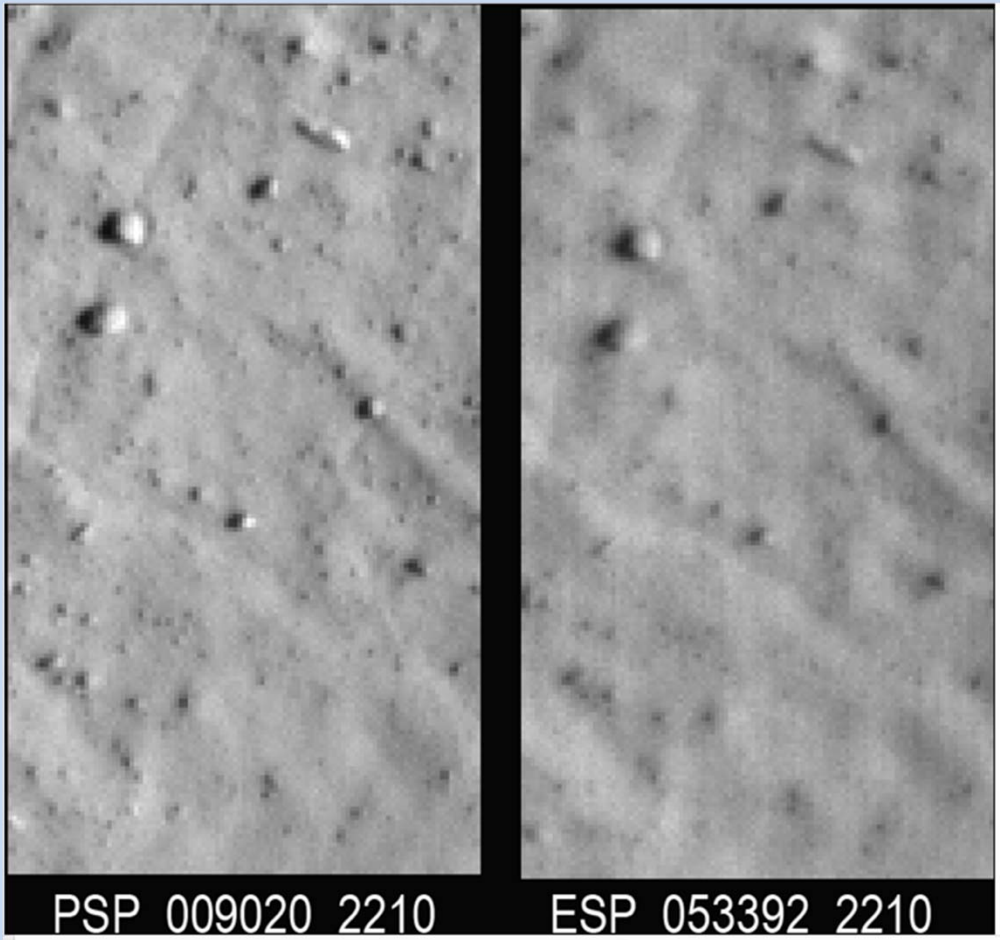
Important Instrument Issues

- ADC Bit-flip noise
  - Managed by raising electronics temperatures
- CPMM13 (RED9) stopped responding to commands Aug 2011
  - Narrowed RED swath width by 10%
- Image blur:
  - Temporary problem
  - Now understood
  - Will be prevented in future

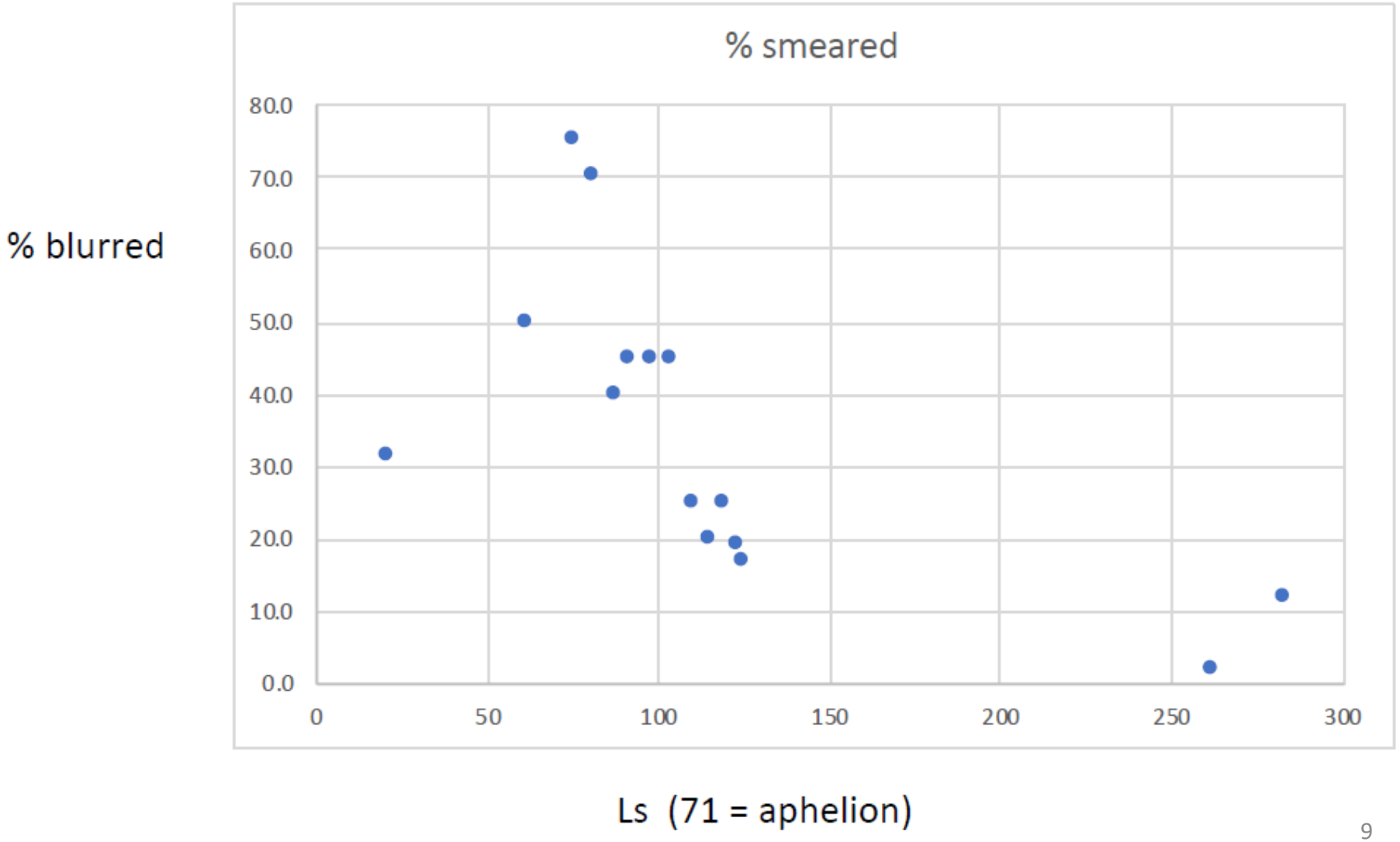


The Rise and Fall of Blurred HiRISE images

- To preserve lifetime of IMUs, MRO has developed an all-stellar (AS) mode that uses only star tracker data for the attitude control system (ACS).
- All-stellar demo with imaging Oct 17-21, 2017
  - HiRISE targeted previously acquired bin-1 images of boulder fields with near exact matching illumination and emission angles, and found that 75% of these and other bin-1 image pairs were more blurry than the earlier images.
    - Blur magnitudes range from ~0.3 to 1.5 pixels
- Upon learning that ACS control parameters were changed on April 19 in preparation for AS, we checked more image pairs and found a significant increase in blurring after April 19.
- On Nov 11 the original ACS control parameters were restored, and the blurring was reduced from ~70% to ~45%.
- On Jan 29 to Feb 1, 2018, AS 4.1 executed, but only 20% of images were blurred! Blur actually a seasonal trend.
- This is a temperature-focus issue, not all stellar!

Aphelion and Blurring

Blur peaked right at aphelion—coldest time of year



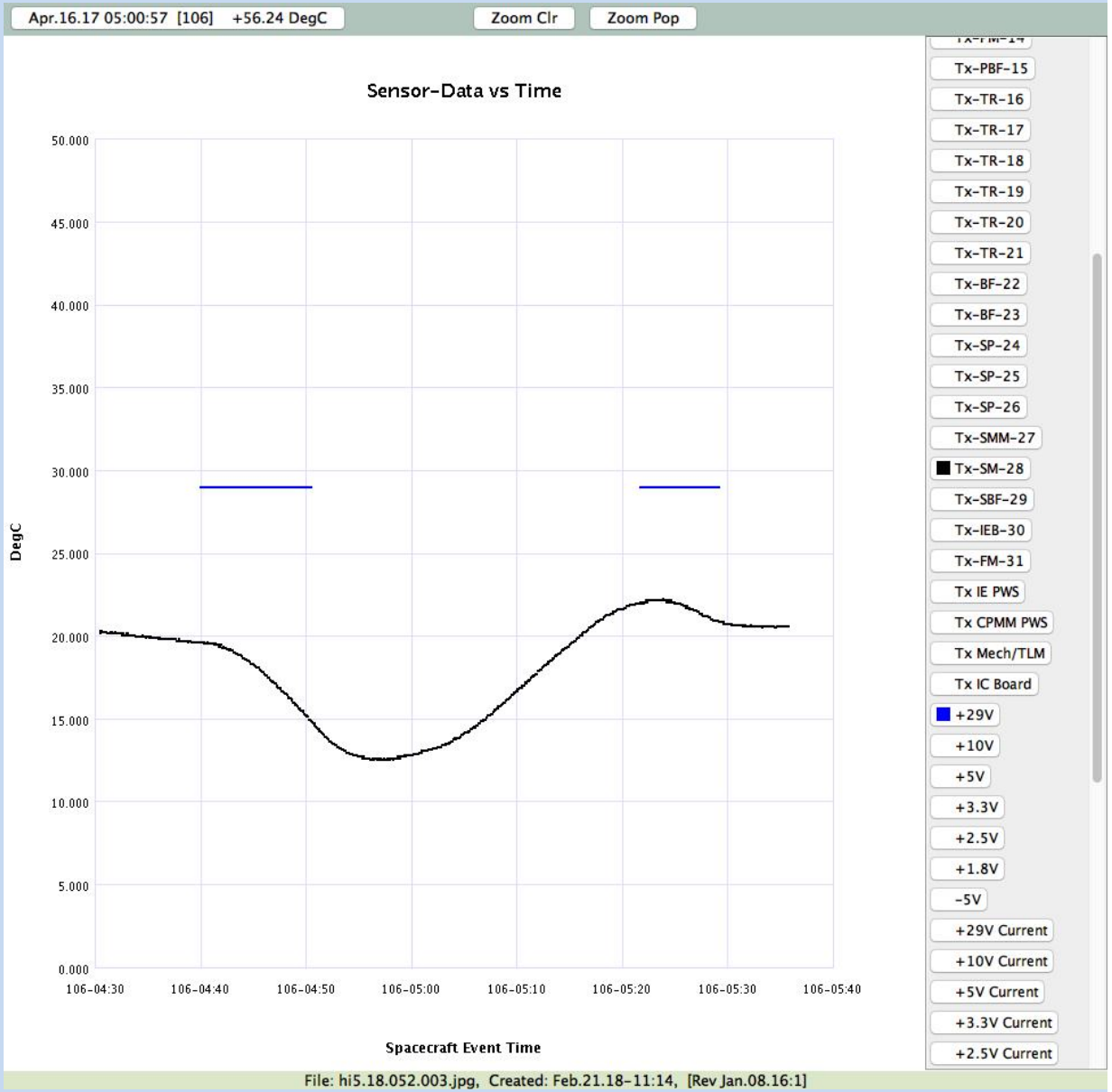
We made this problem worse by moving warmup images out of eclipse, to extend MRO battery lifetime

Example of warmup followed by science image prior to moving warmups out of eclipse

Black is secondary mirror temperature.

Blue is +29V power supply. Plotted to illustrate when HiRISE is imaging.

Secondary mirror temperature recovers to setpoint before science image starts.



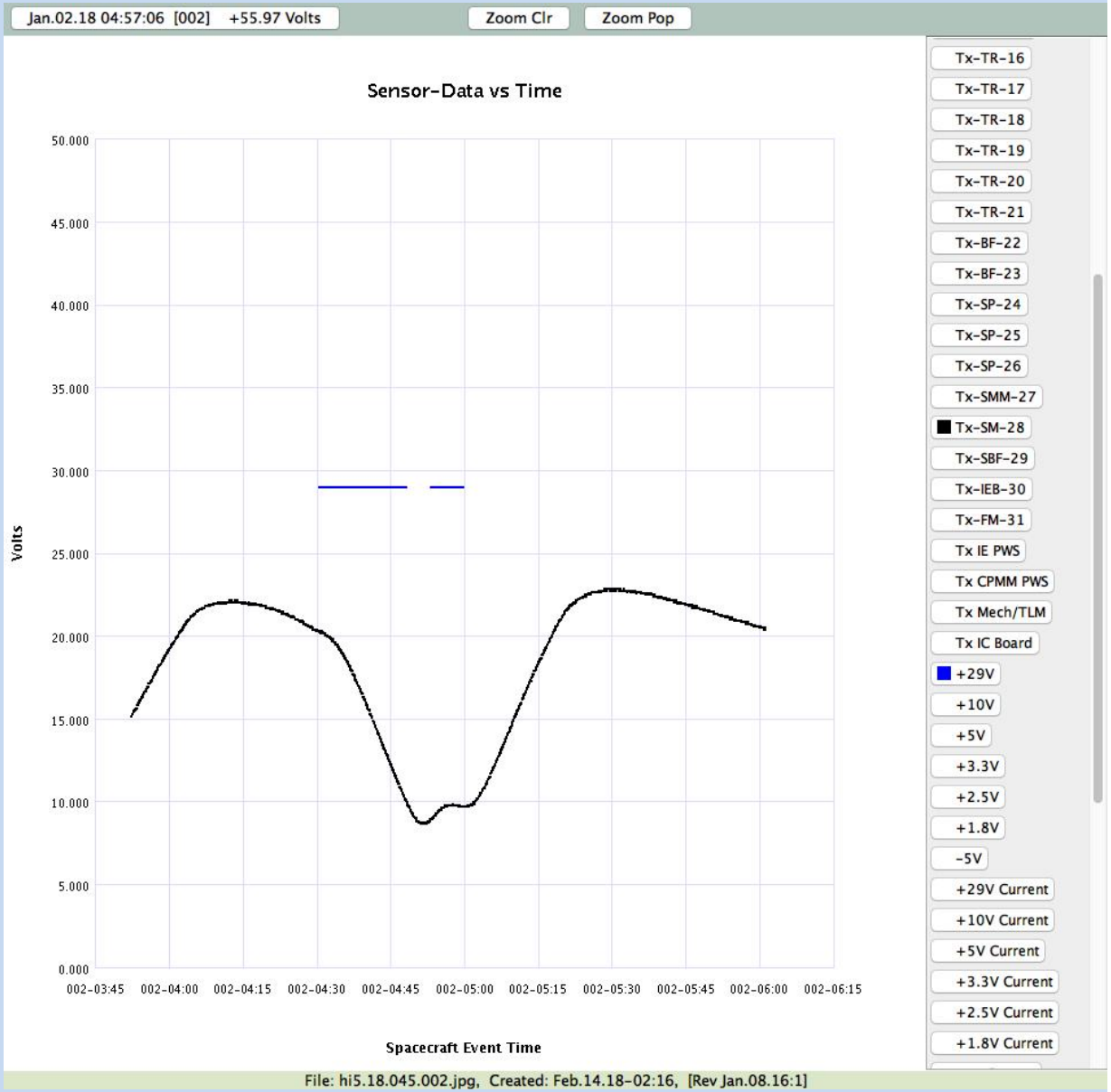
Example of warmup followed by science image after warmups moved out of eclipse

Black is secondary mirror temperature.

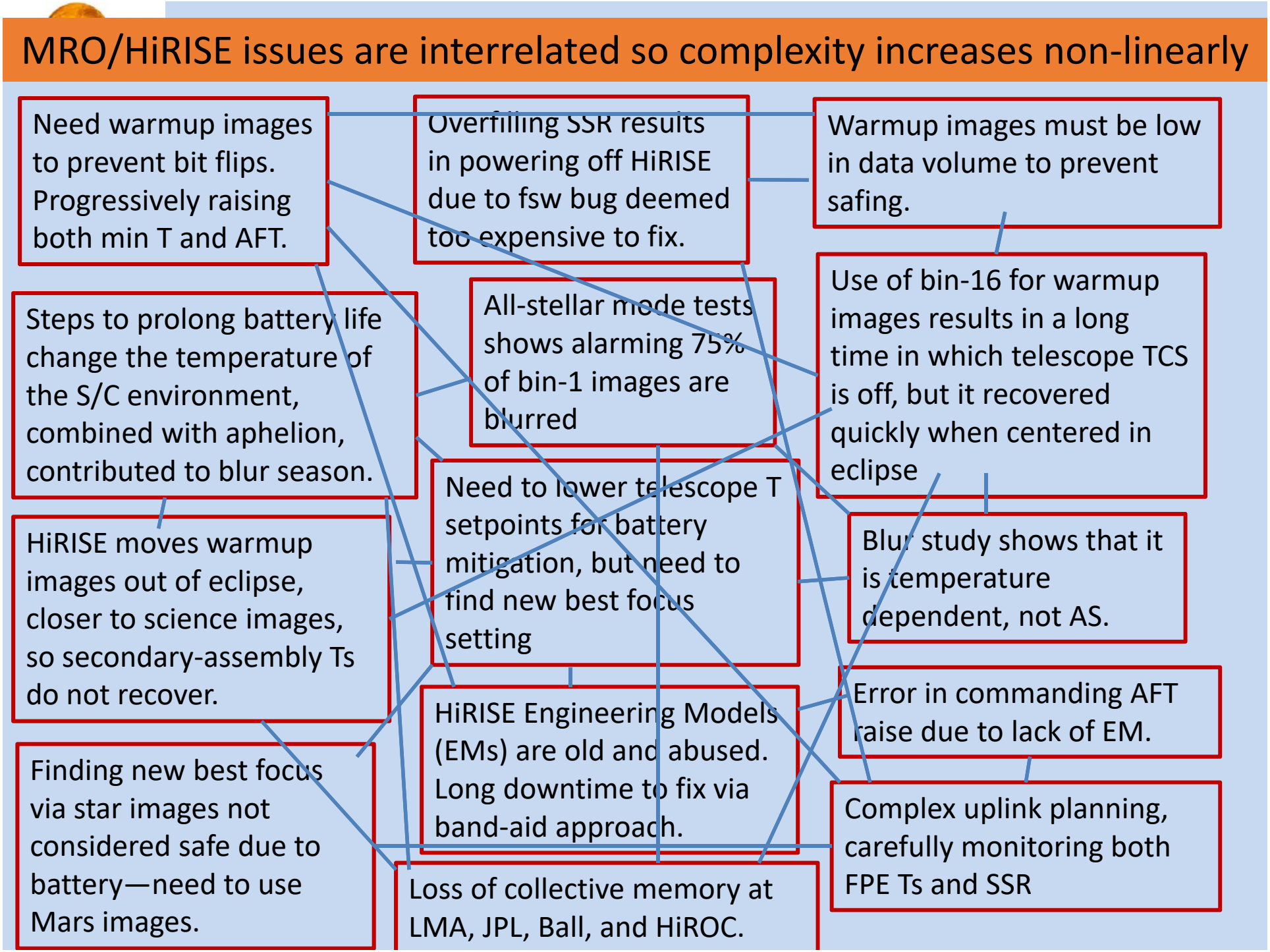
Blue is +29V power supply. Plotted to illustrate when HiRISE is imaging.

Secondary mirror temperature does not recover to setpoint before science image starts.

This isn't the whole explanation, but clearly we need to control optics temperatures during warmup imaging to solve blur problem.

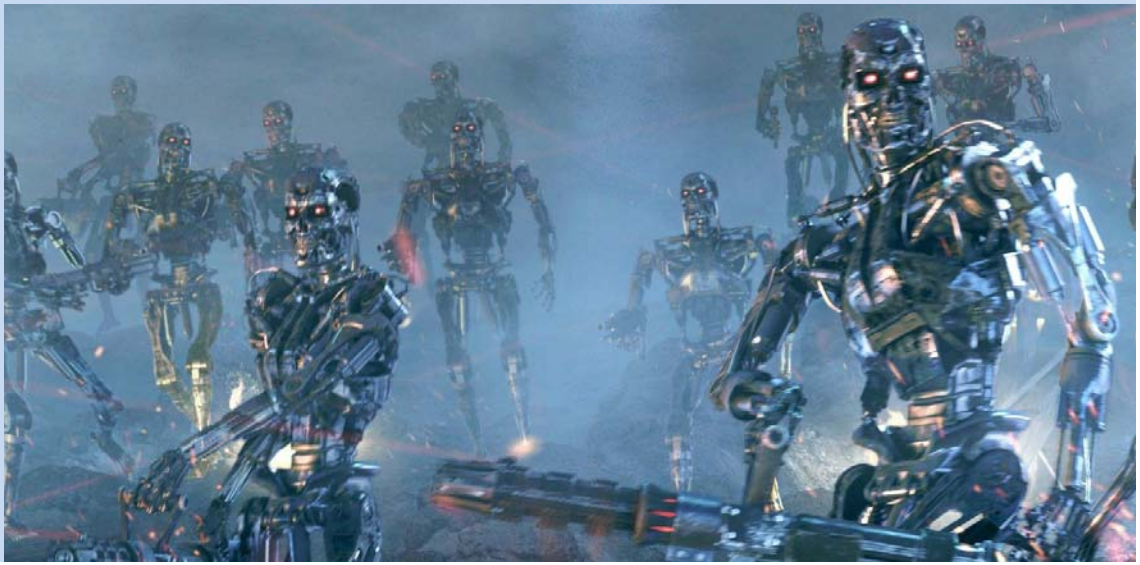


MRO/HiRISE issues are interrelated so complexity increases non-linearly



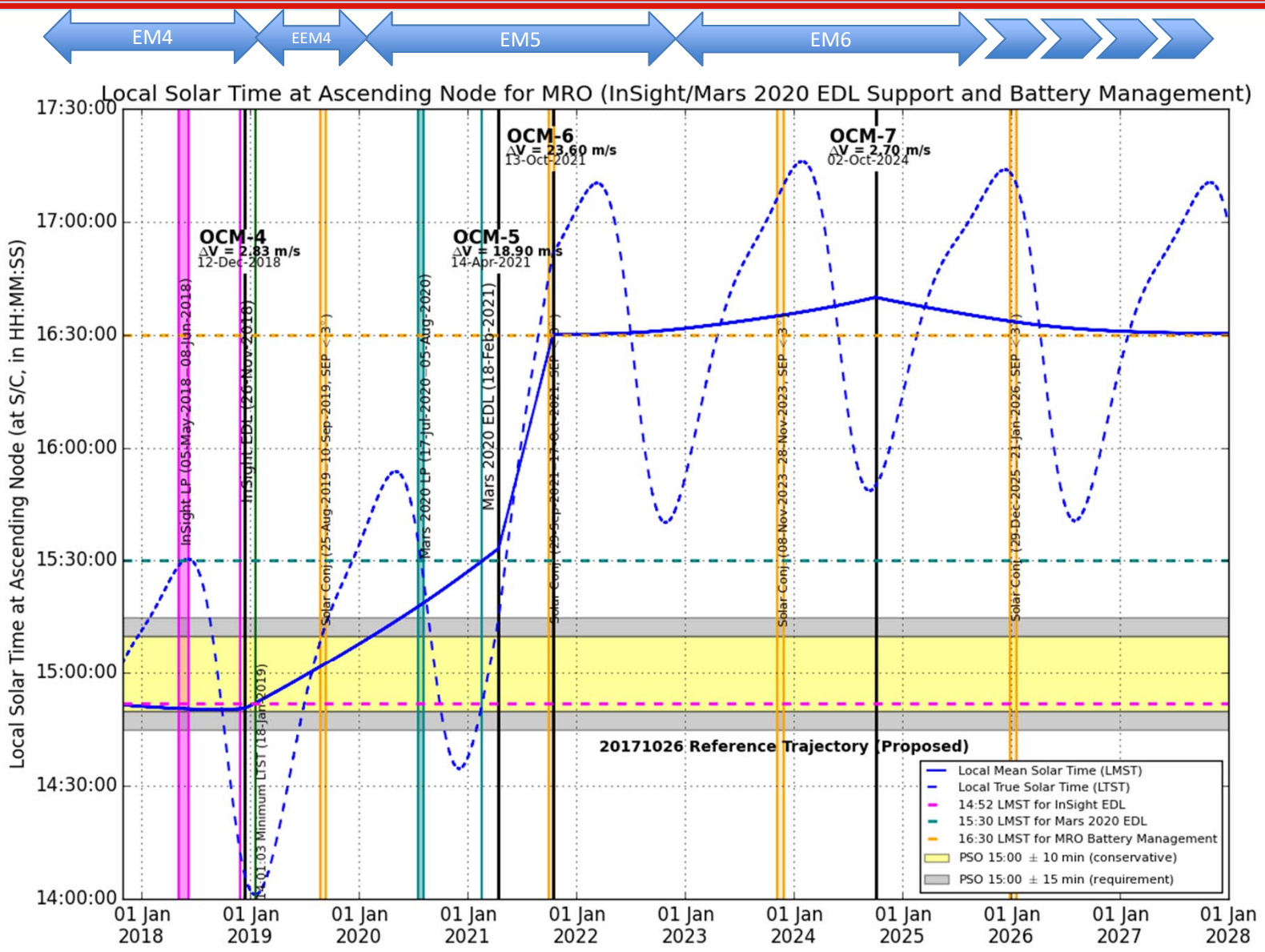
What will the Future be like?

- MRO working on 10-year survival plan, to support Mars Sample Return
  - Planning does not guarantee success
  - Relay from landers and rovers is top priority
- Expect continued “graceful” degradation of HiRISE instrument
  - Bit flips increase noise, even when major flips are mitigated
  - Lower telescope temperature setpoints (for battery lifetime) may blur images a little
  - 4:30 PM LMST: lower-sun illumination will decrease signal
    - Need new stereo rules with longer shadows—must complete faster
  - **Expect more binned images**
  - Another CPMM may fail
- Expect little to no science team support

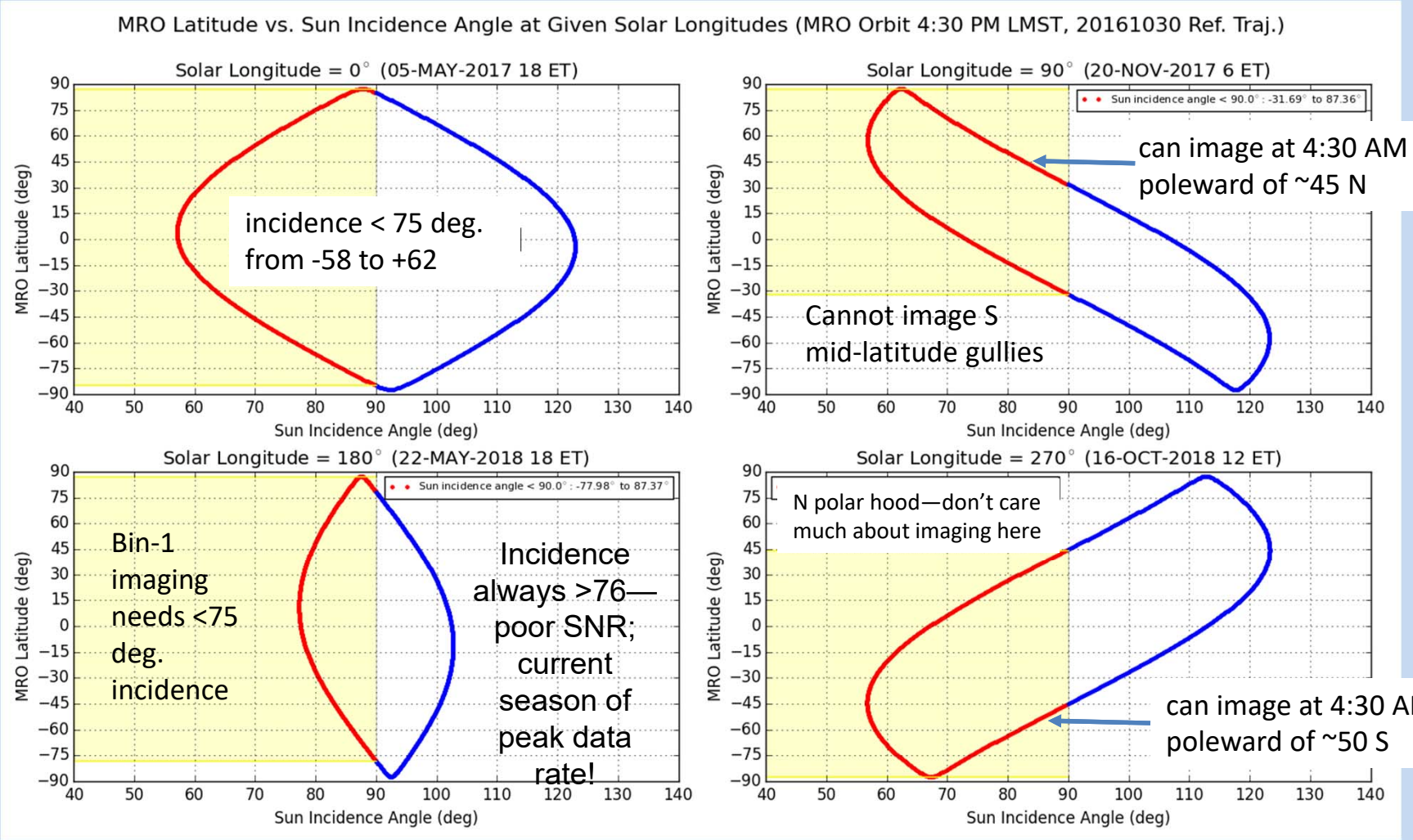


MRO Reference LST for InSight & Mars 2020 EDL Support

2017-10-26 MRO Reference Trajectory (subject to change)



Sun Incidence Angle Profile – 4:30 PM LMST



Season of peak data rate is migrating to later Ls

Detriments of 4:30 PM LMST

- Poorer SNR for most images
  - Requires more 2X2 and 4X4 binning
  - Loss of full resolution capabilities at some latitudes/seasons
- Less time to complete stereo imaging due to longer shadows
  - Need new operational procedures
- Impact on existing monitoring series that require similar illumination conditions to identify subtle changes over multiple years
- Loss of early/late season polar monitoring
  - Loss of monitoring for winter gully activity in shadows
- Ls 180 is especially bad (all incidence angles > 76 degrees)
  - Occurs at current peak data rate

Benefit of 4:30 PM LMST

- Low-sun/high incidence images of flat terrain in the equatorial regions
  - Left: image acquired at 72° incidence – not ever possible for latitudes -30 - +30 in current orbit
  - Equatorial latitude region includes most candidate landing sites, and young fluvial and volcanic features in Elysium Planitia
  - Low-sun images have longer shadows that emphasize subtle terrain and assist in identification and measurement of small-scale landing/roving hazards like boulders

HiRISE
hirise.lpl.arizona.edu

HiWish: You can target the HiRISE images of your favorite places on Mars!

- **Image suggestion site: /uahirise.org/hiwish**
- **Over 6,000 public suggestions have been acquired!**
- **We especially like targets from the science community, and acquire them relatively rapidly (depending on location)**
- **Some science users:**
  - **Edwin Kite, Ken Edgett, Matt Balme, Alan Howard, Alexis Rodriguez, Caleb Fassett, Devon Burr, Jay Dickson, John Carter, Rebecca Williams, Samantha Peel, Jacob Bleacher, Bethany Ehlmann, David Crown, Jennifer Buz, Jim Skinner, Mary Bourke, Christy Caudill, Glen Cushing, Wes Watters, Petr Broz**

HiRISE: The People's Camera

NASA and/or MEP are ignoring 2016 National Academies study

- Extending Science—NASA's Space Science Mission Extensions and the Senior Review Process
  - http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_169078

- **Finding:** After the first few years of extended operations, most missions have implemented all (or almost all) practical steps to reduce costs. Further budget cuts often then result in disproportionate cuts to project-funded science activities, increasing risks that science will be diminished or not performed at all.

- **Recommendation: Given the demonstrated science return from extended missions, NASA should continue to recognize their scientific importance and, subject to assessments and recommendations from the Senior Reviews, ensure that, after the first two Senior Reviews, both operations and science for high-performing missions are funded at roughly constant levels, including adjustments for inflation.**