Mars 2020 Robust Rock Detection and Analysis Method

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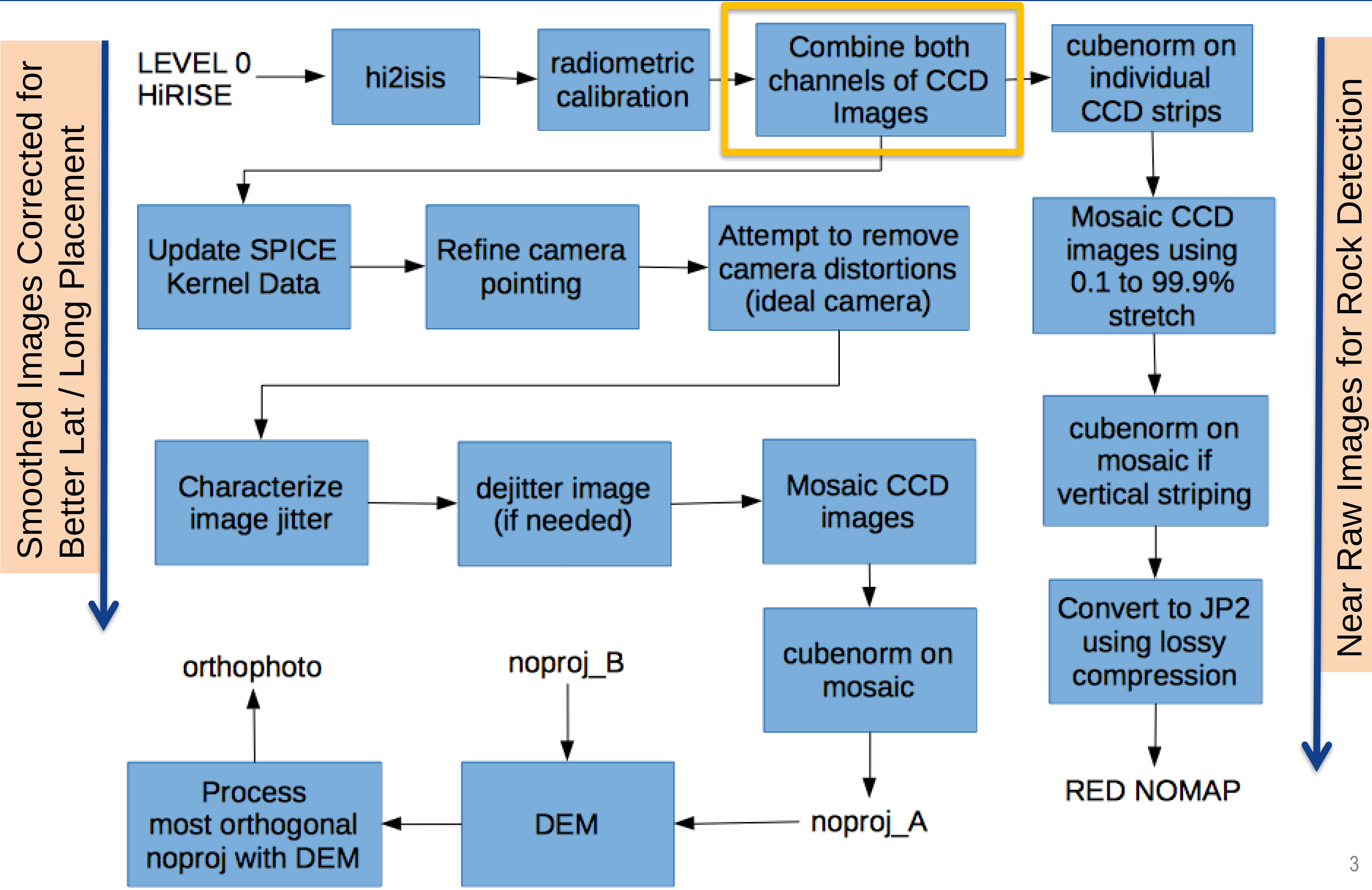
Version 2

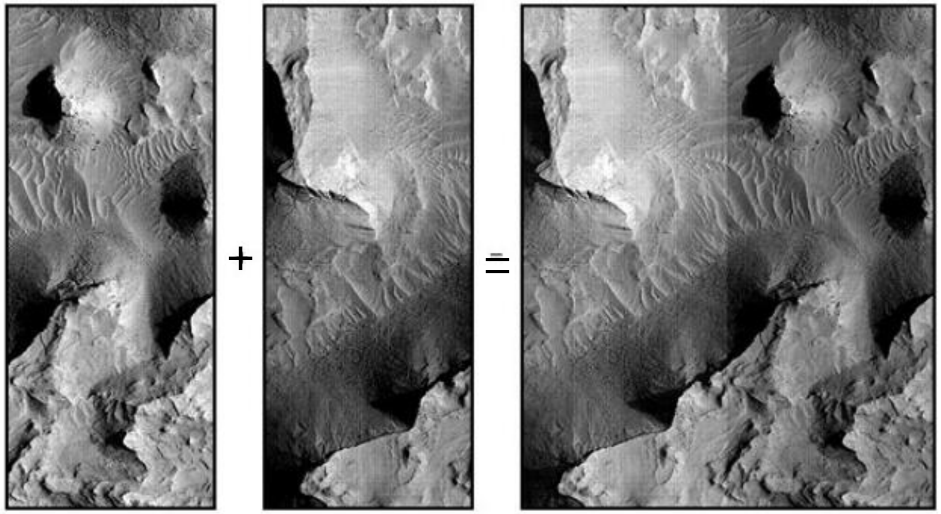
Presentation Outline

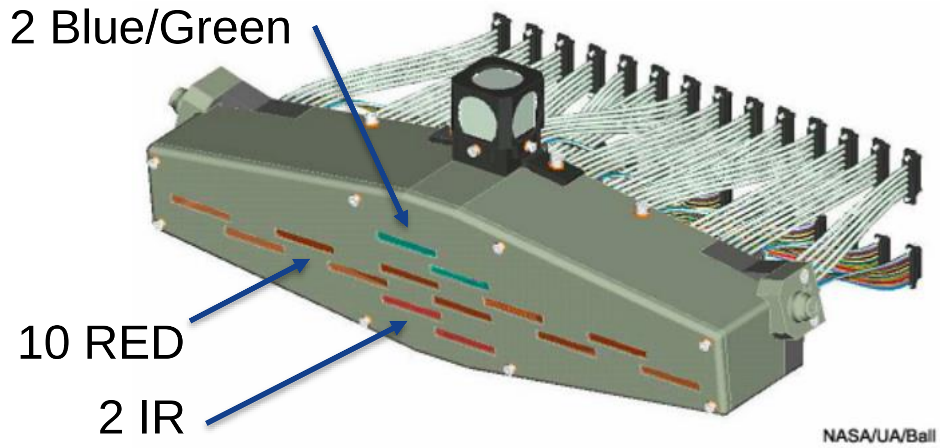
- Mars 2020 has a unique use case
  - Statistical treatment of hazards for ellipse placement (typical for MSL, InSight, MER, Pathfinder, etc)
  - Landing day guidance decisions for landing (Mars 2020 only)
  - Accurate rock placement and knowledge required
- Images used for rock detection
- Update of process to map results to lat / long domain
- Highlighting an important rock detection parameter
- Outlining the current manual approach
  - What needs to be extended for our use case?
- Plan to address these concerns

Images Created for Rock Detection



Combine Channels for CCD Sensors





HiRISE Instrument
Note slightly overlapping sensors

The output image from one of the 10 RED charge-coupled devices (CCD). Each CCD has two channels that are stitched together into one image.

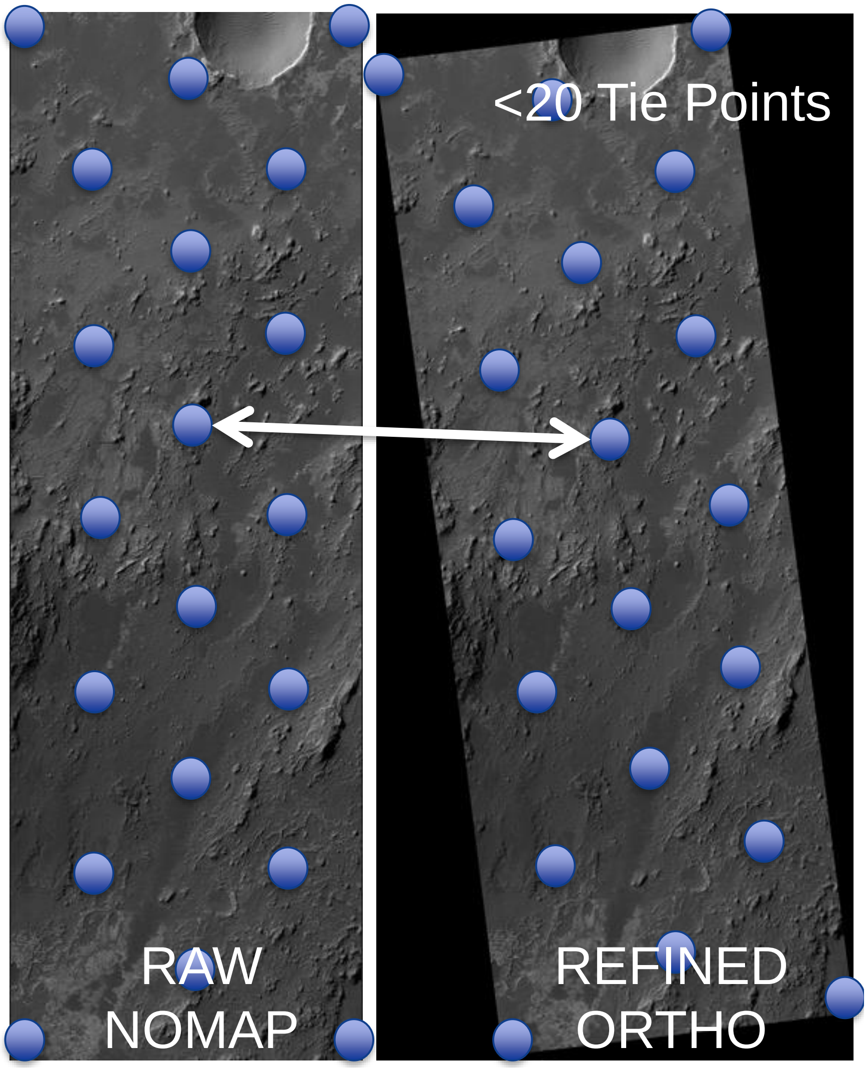
Most information and coverage on the red wavelength; RED is used for rock detection

10 RED CCD image strips make 1 HiRISE image

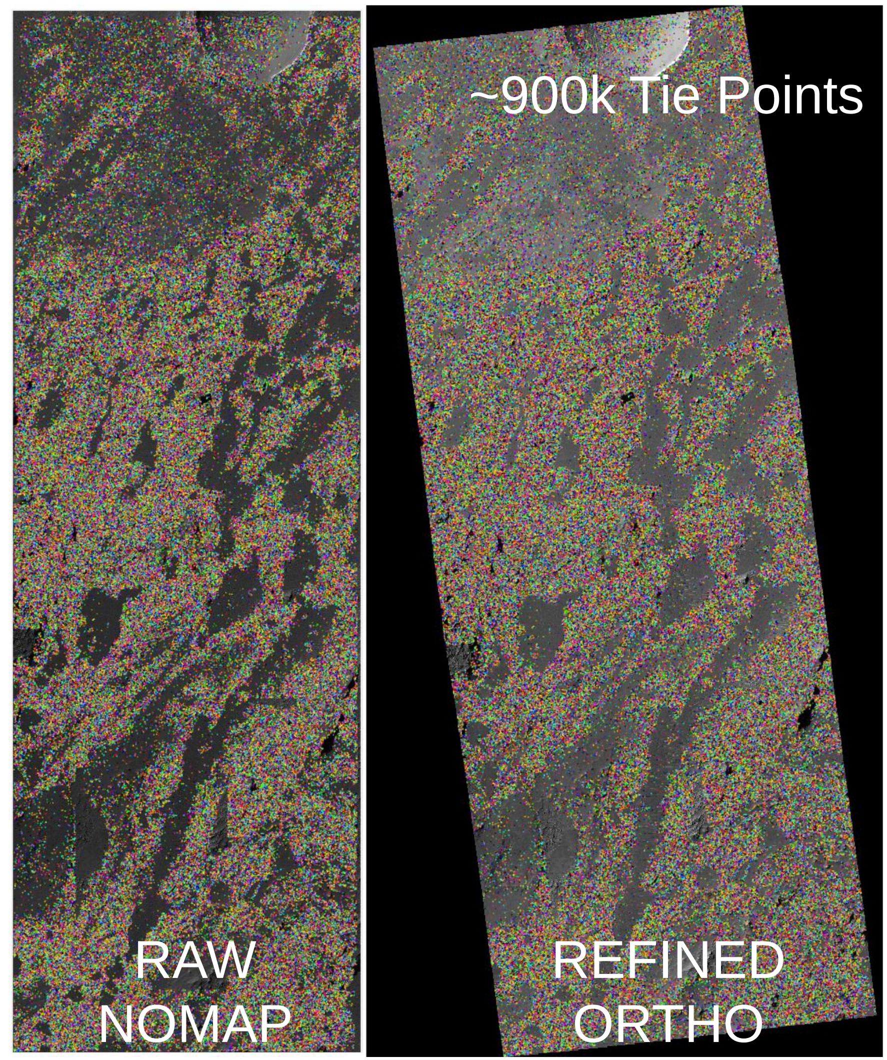
Advanced Mapping of Rock Results into Lat / Long Space

THEN: 1-2 days human marking
<10m rock mapping accuracy

NOW: <2 hour automated SIFT marking
<1m rock mapping accuracy



Discontinuities at the 10 HiRISE sensor boundaries as NOMAP uses very basic CCD image stitching



Most Important Rock Analysis Parameter: Gamma Correction of NOMAP Image

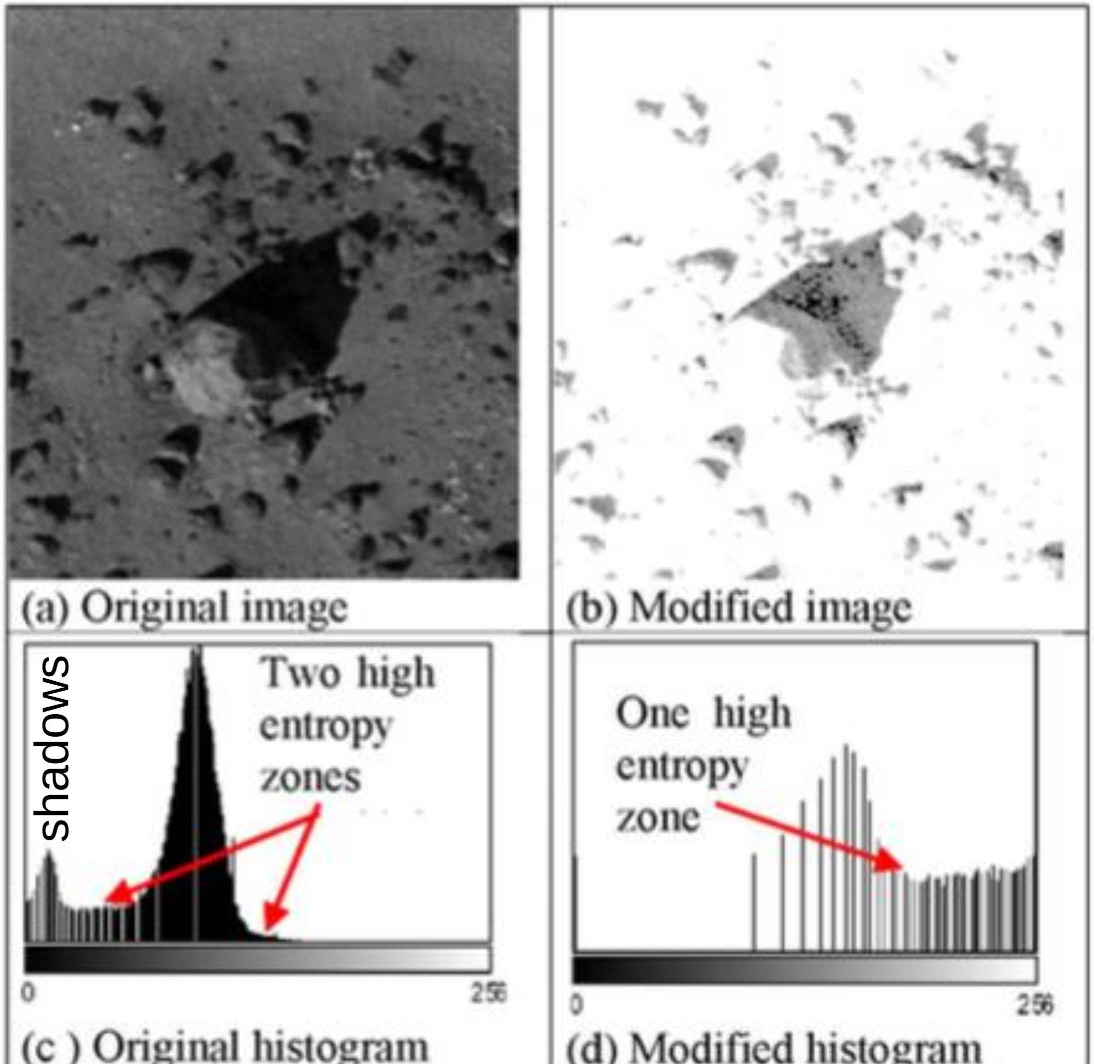


Figure 5. gMET histogram modification.

$$C(\gamma) = I + 255\left(\frac{I}{255}\right)^{\frac{1}{\gamma}}$$

$$C(0) = I$$
$$C(1) = 2I$$
$$C(\gamma_1) > C(\gamma_2), if\ \gamma_1 > \gamma_2$$

Gamma correction helps separate shadows from illuminated background via histograms.

Small shadows are washed out at higher values of gamma while strong large shadows remain.

Reference: A. Huertas, et al. (2006) IEEE Aerospace, paper #1434

Current Process for Human Operator

- Pick *one* set of 7 parameters for the rock detection that balance false negative (didn't find a rock) with false positive rock detections
  - Real rocks are not detected to avoid false detections elsewhere
  - Typically gamma and filtering criteria are manipulated
- Concern with the standard approach for Mars 2020
  - We are missing rocks that we are clearly able to see in the image
- Changes in process for Mars 2020
  - Ellipse is small enough (~3 NOMAPs) to use geologists to mark observed rocks within the ellipse
  - Run parameter sweeps to find diameter that should be used for the human marked rocks
  - Use machine learning to extrapolate marked terrain into areas not marked by humans

Mars 2020 Rock Detection Process

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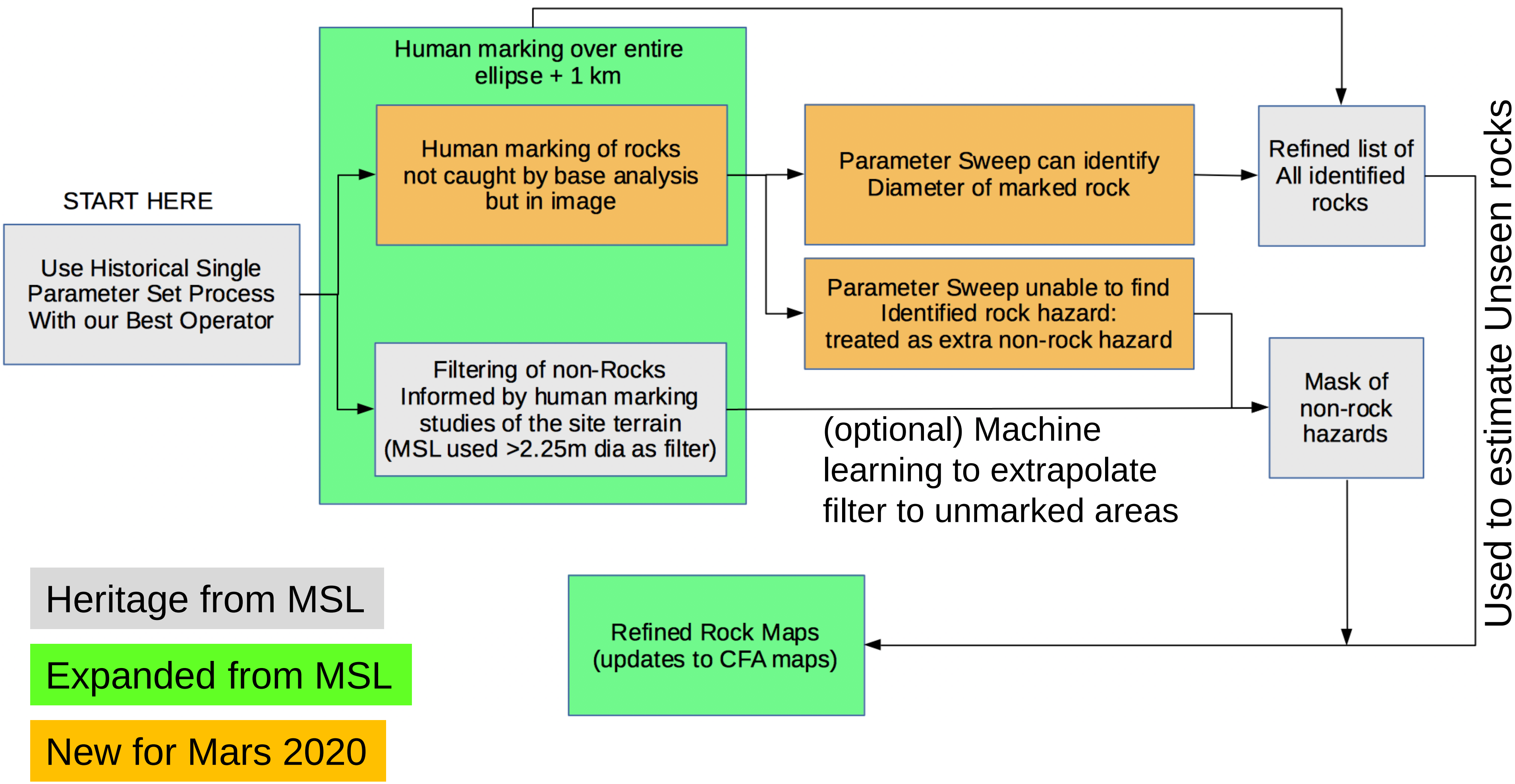


Use human marking (with standard rock measurement) to address missed rock fields

Conclusions

- Current process of human selection of parameters for rock detection needs to balance between false negatives (missed rock fields) and false positives (non-rocks detected as rocks).
  - Use human marking of missed rocks to handle missed rock fields
  - Use human marking to confirm a filter for non-rock detection (currently using the simple >2.25m diameter MSL filter)
- Parameter sweeps will be used to measure the diameter of human located rocks
- Comprehensive human marking possible due to the size of our ellipse
  - Size on the order of 12 x 8km
  - A large ellipse could use parameter sweeps as an initial guess and human marking as a training set for a machine learning filter to remove non-rocks
- Process now adequate to capture the knowledge required for guidance decisions on the day of landing

BACK UP

Improving CFA Accuracy: Combining Rock Analysis Results (Future Work)

- Complexity of combining rock results can notably increase fidelity
- Earth-based Mars analog testing at Mars Hill
  - 136 reference rocks, 7 images of same area with 7 different sun incidence angles between 30-70 deg
  - 85% chance of detecting >=5 pixel rocks (Huertas, et al. "Real-time hazard detection for landers." *Proc. NASA Science Tech Conf., Adelphi, MD*. 2007)
- Combining results increases our likelihood of seeing every rock >=1.5m
  - Rocks between 1.5 – 2.25m diameter used to create the CFA estimates
  - CFA curve used to estimate the risk of unseen rocks <1.5m diameter

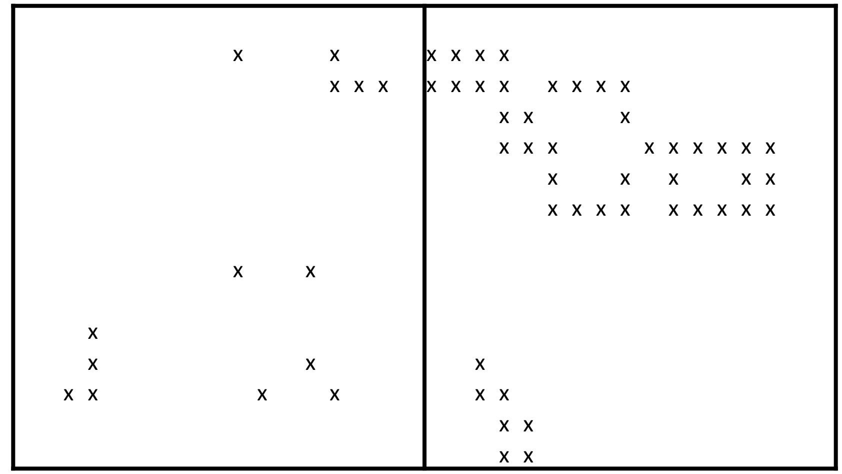
Binomial Confidence Interval	Base chance of seeing all rocks >=1.5m dia (%)	Chance of two combined results seeing all rocks >=1.5m dia (%)
99%-tile	92	99
50%-tile	85	98
1%-tile	77	95

Improving CFA Resolution: Moving the Analysis Support Window (in Practice)

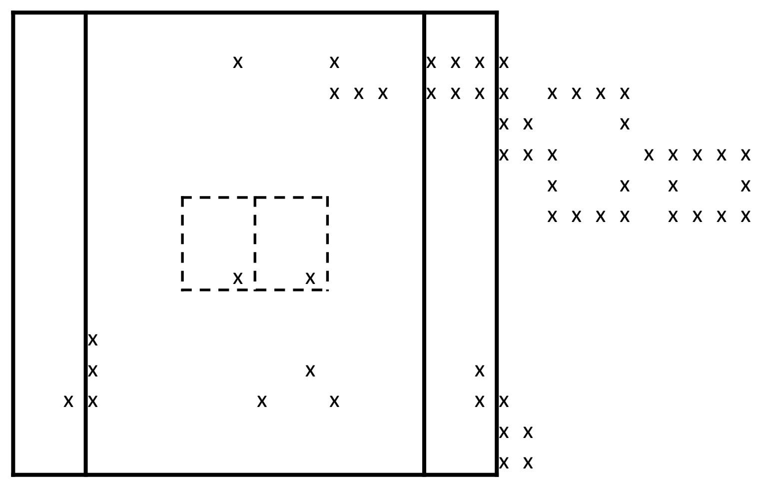
- Example shows ‘x’ as rocks
- The MSL approach
  - averages rock contribution into 150x150m bins
  - rock rich bins may still have clear areas that could be used for landing
- The M2020 Approach
  - Still uses the same statistical mechanics as the MSL version
  - the smaller bin in the center of the support tile is assigned the value calculated from the support tile
  - the support tile exists to have a large enough area for a meaningful statistical sample of rocks

A rolling average approach was shown to enable higher location resolution rock maps

MSL Approach



M2020 Approach



CFA Map Resolution Examples (150 vs 30m)

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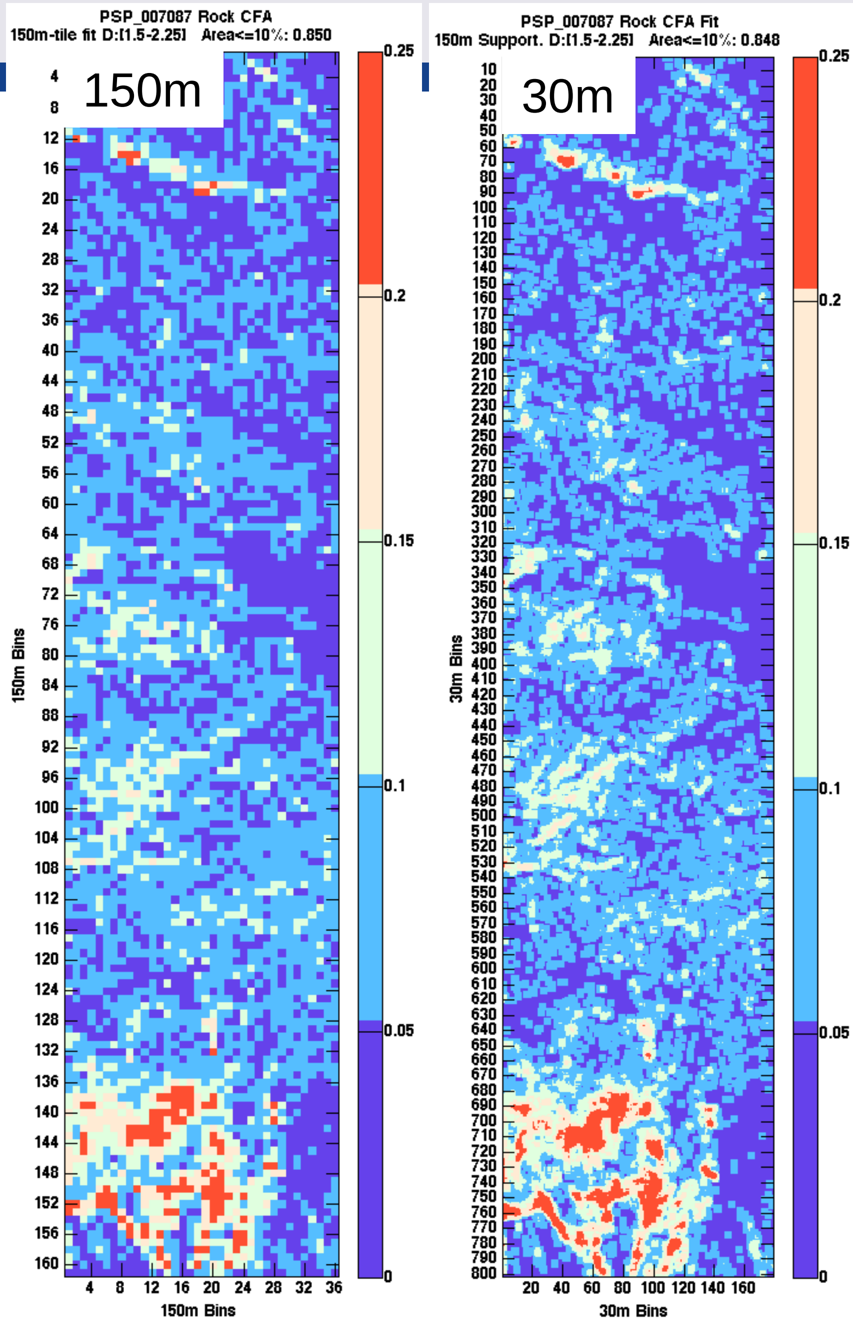
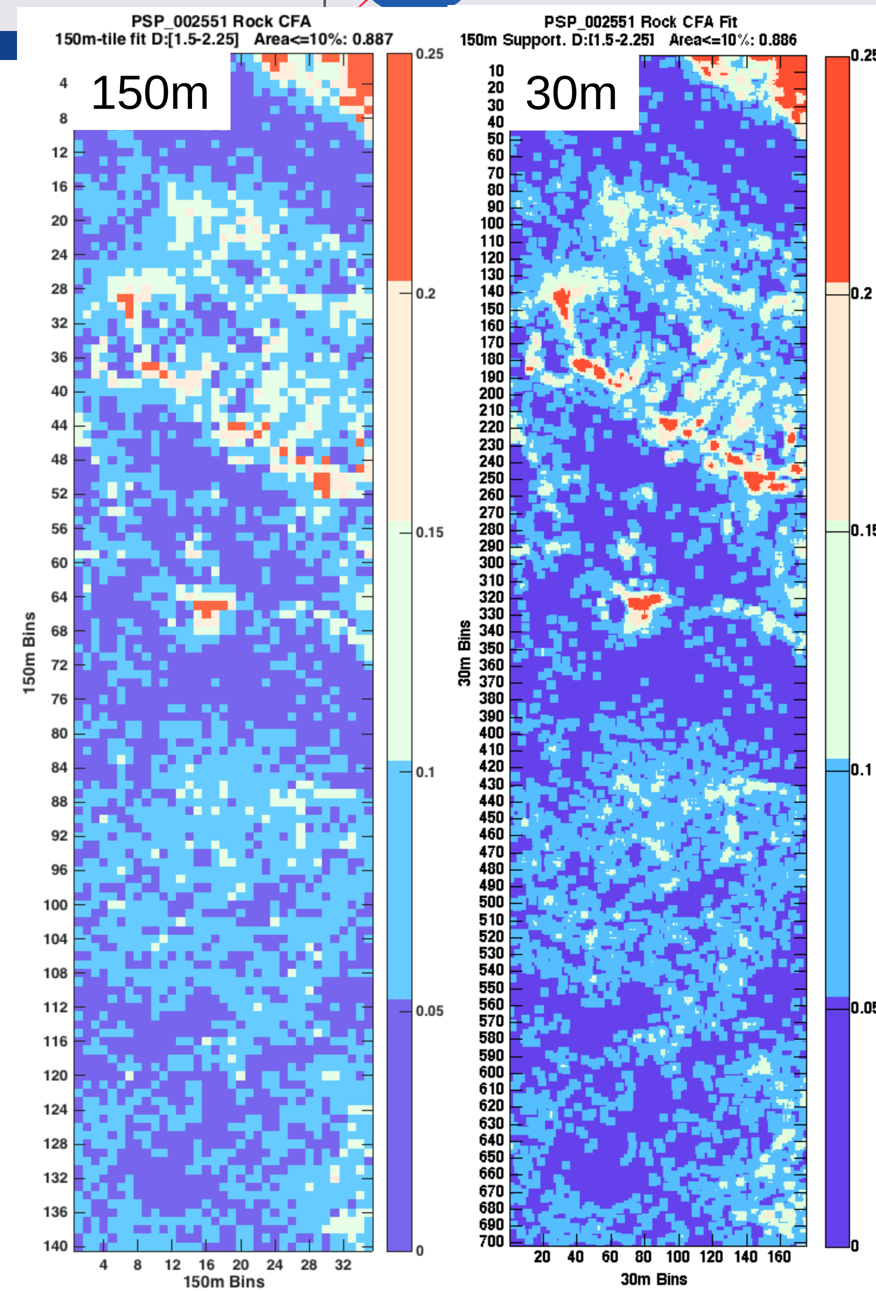
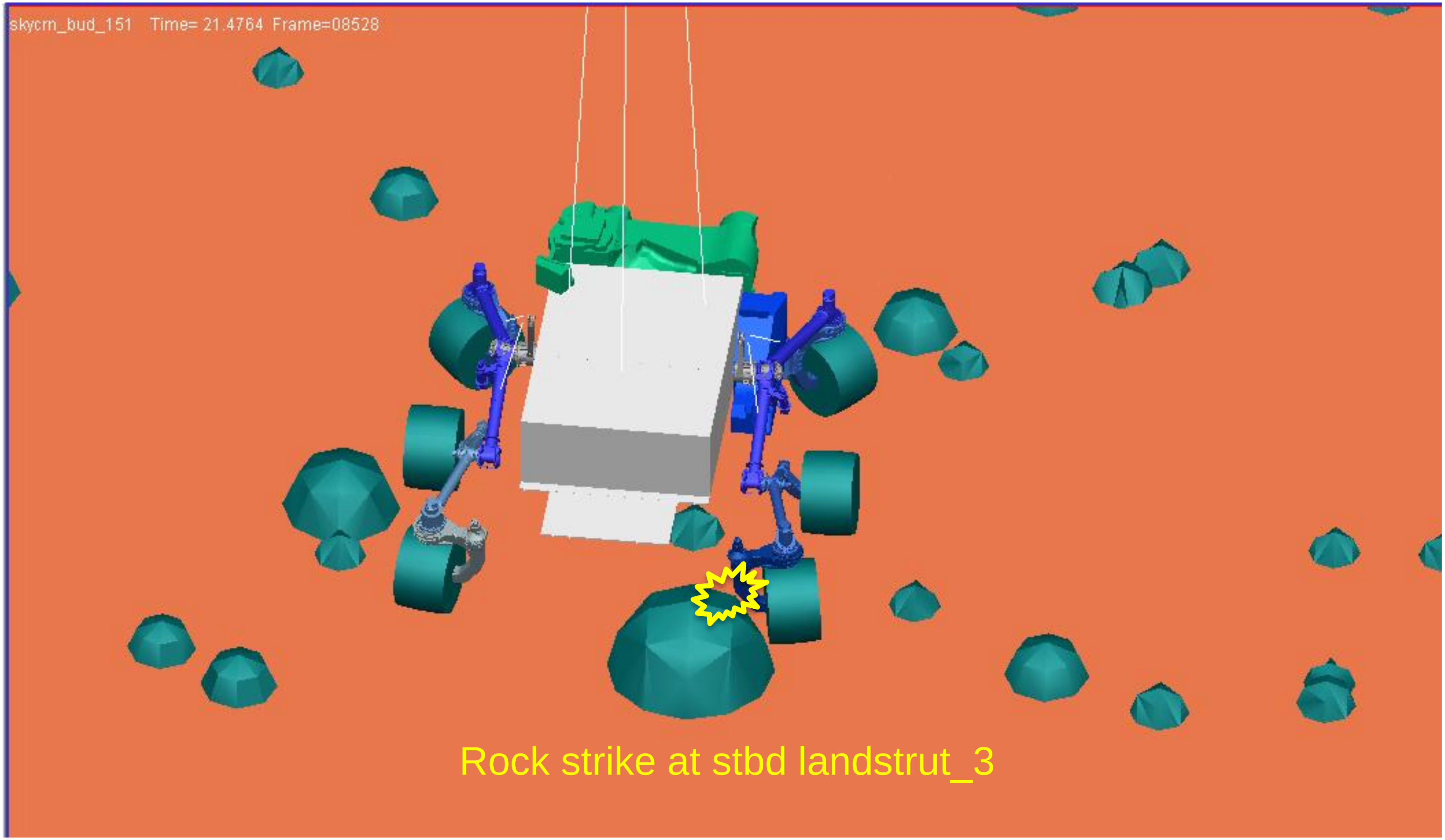




Example of Rock-based Failure from ADAMS Monte Carlo



We can use HiRISE NOMAP images to accurately determine the size of objects on Mars

- Earth analog testing to verify technique to determine rock diameters from shadows in images
  - Crane-based tests at different resolutions: Mars Yard
  - Helicopter-based tests over Mars analog: Mars Hill
  - *Matthies, L., A. Huertas, Y. Cheng, and A. Johnson, Landing hazard detection with stereo vision and shadow analysis, AIAA 2007-2835, May 2007.*
- Mars testing using HiRISE NOMAP images for shadow detection
  - Comparing against objects of known sizes (Landers / Rovers) using orbital data
  - Size of rocks check after landing based on ground-based images
  - *Golombek, M. P., et al. (2008), Size-frequency distributions of rocks on the northern plains of Mars with special reference to Phoenix landing surfaces, J. Geophys. Res., 113, E00A09, 2008.*

Golombek Rock Abundance Curves

- CFA percentage is simply where the curve crosses the y-axis
- Same curves developed from Viking and Earth data have shown good predictive performance
- Used for Pathfinder, MER, MSL, M2020
- The way to estimate CFA has evolved (HiRISE now available) but the underlying rock abundance relationship is still the same