# Can (and will) the data be processed? Technology development to address science questions

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# Outline

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- Instrument Calibration and Sensor Model Development
- Algorithms & Tools Lag Instrument Development - Examples
- Need for Geometric Stability
- Lack of global shape models of sufficient resolution
- (*Need to control data)
- (*Standards issues)
- Future Needs
- Summary

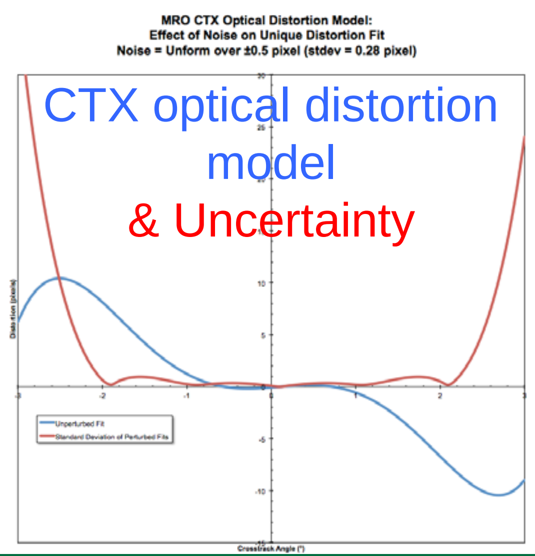
* See abstract & backup

# Introduction

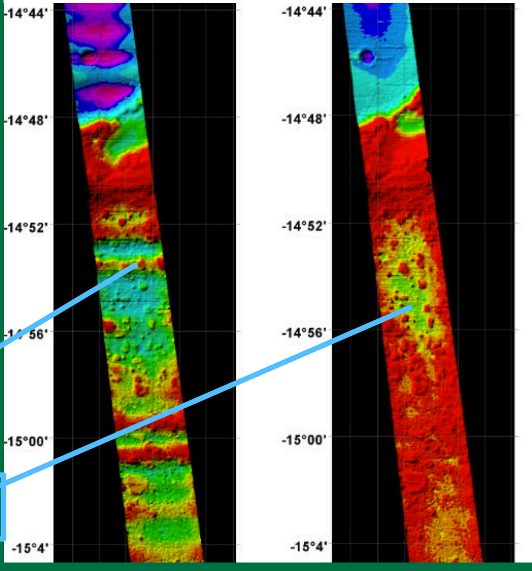
- Meeting objectives addressed:
  - Technology needed to address science questions
  - Lessons learned and vision for what is needed for the next generation of instruments
- Our concern is with technology needs *beyond* the initial design and construction of an instrument
  - Processing of data into high level products—often *not* trivial
  - Needed to support scientific research *and* subsequent mission operations
  - Should be considered by e.g. mission, NASA, before development
- We have raised these issues in a series of abstracts and papers, since 2007
  - The problems have not yet been solved
  - They will be more severe for future instruments and missions

# Instrument Calibration and Sensor Model Development

- Standards are needed for documenting instrument calibration
  - Geometric is our main concern—see Saleh et al poster, this meeting—but radiometric calibration is equally important
  - "Checklist" to ensure adequate cal data have been collected
  - Help users understand and use the data
  - Ensure that data can be processed in "go to" software systems such as  JPL VICAR or USGS ISIS and packages that rely on these such as ARC IRG Stereo Pipeline
- History teaches:  don't skimp on calibration based on intended use!
  - Users will always press data to the limits of resolution and accuracy
  - Unexpected and *critical* uses will arise, e.g. landing site certification
  - Examples
    - Lunar Orbiter, Apollo Pan, MGS MOC NA were not geometrically calibrated
    - MRO CTX only calibrated over center of field of view
  - Reasonable choices at the time but limiting later on




MOC DTM
Spirit landing site

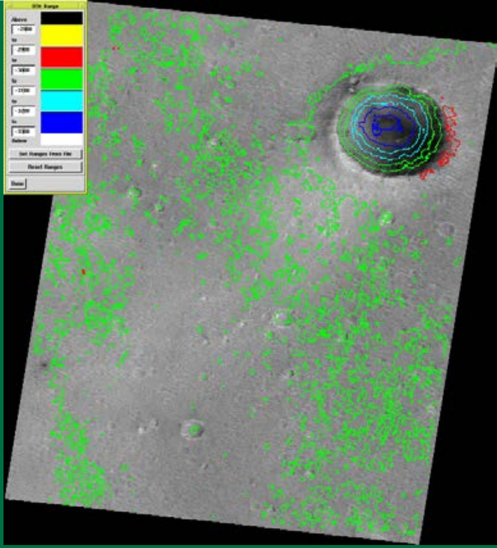



Ripples caused by jitter

Central trough caused by optical distortion

# Algorithms & Tools Lag Instrument Development (1/3)

- First planetary pushbroom line scanning camera (MGS MOC) launched in 1996
- Development of methods/software to project, control, and use the images was not considered or supported until long after data were in hand
  - First MOC DEMs in 2001
  - Line scanners (HiRISE, CTX, HRSC, someday LROC NAC) now critical for landing site mapping and certification
  - First large scale control and mosaics in 2011! (LROC NAC, n and s poles; THEMIS IR)



First MOC-NA DTM, sw of Mars Pathfinder landing site 10 m grid, 100 m contours

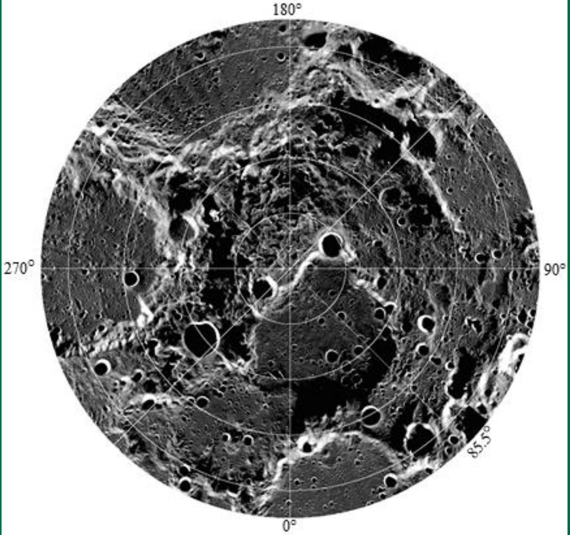
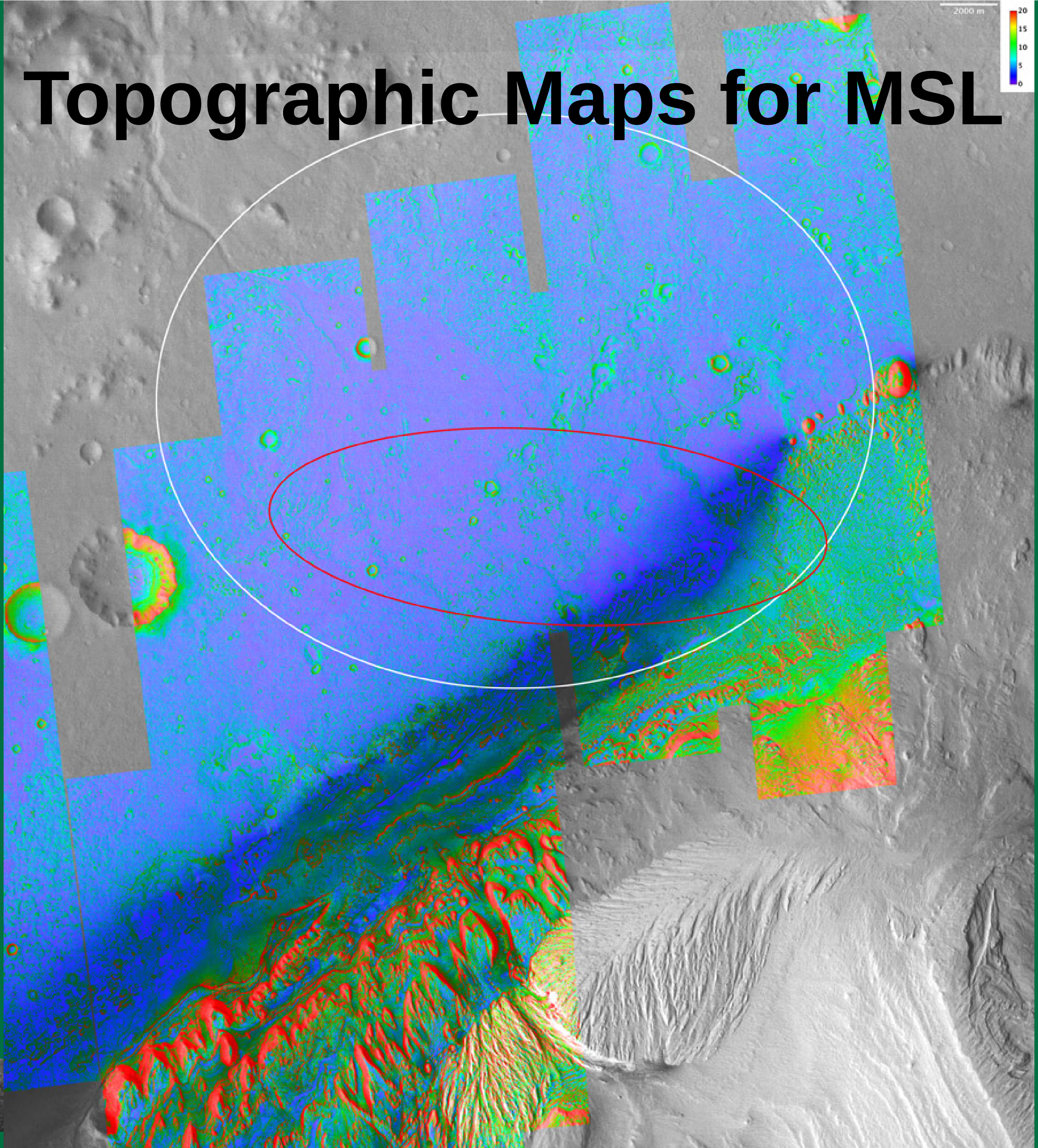



Figure 1. North Pole mosaic

Lunar north pole controlled mosaic – from 3,682 LROC NAC images; 2.1M measures on 340,142 points – 1 meter resolution!

# Topographic Maps for MSL

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# Algorithms & Tools Lag Instrument Development (2/3)

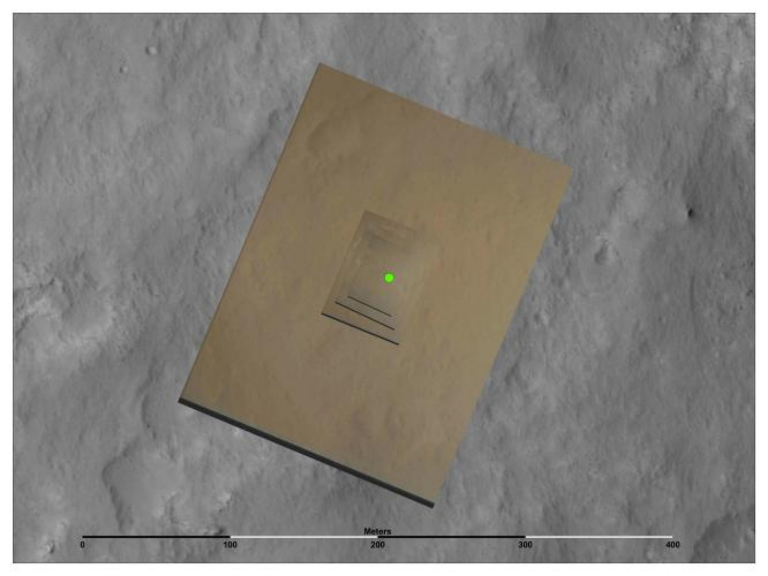

LOLA model compared to (WAC) GLD100 model (Scholten et al., 2011). Herschel crater at lower center.

(Courtesy: Trent Hare)

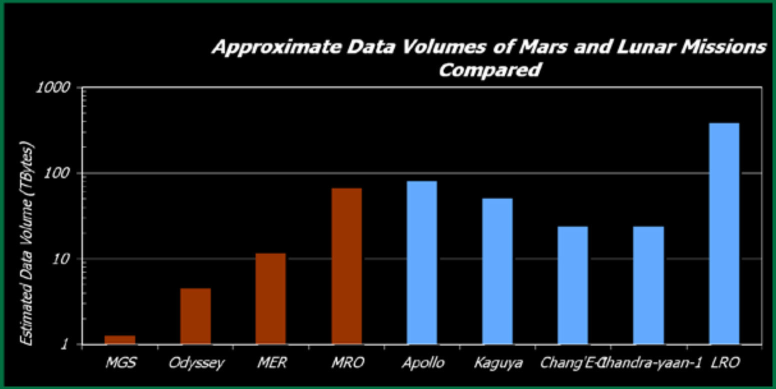
- Push frame (THEMIS VIS, MARCI, LROC WAC) – getting very good mosaics/DEMs now (WAC) but still no way to control images
  - Example below: offset between LOLA and WAC DEMs
  - Improvements still underway, but…
  - Biggest concern is uncertainty at any given location not well quantified (below few pixel level)

# Algorithms & Tools Lag Instrument Development (3/3)

- Other needs:
  - Geodetic control of orbital, descent, and landed images ➔
  - Tie pointing algorithms not keeping up with volume, variety of images ➔
  - Tying images to DEMs not yet automated
  - New methods combining stereo + photoclinometry not yet rigorously compared to each other and conventional stereo
  - Better understanding, use of coordinate system and mapping standards
  - Combination of images and lidar needed for Moon, Mars, Mercury, asteroids but rigorous methods not yet developed




Curiosity landing site (MARDI over HiRISE)

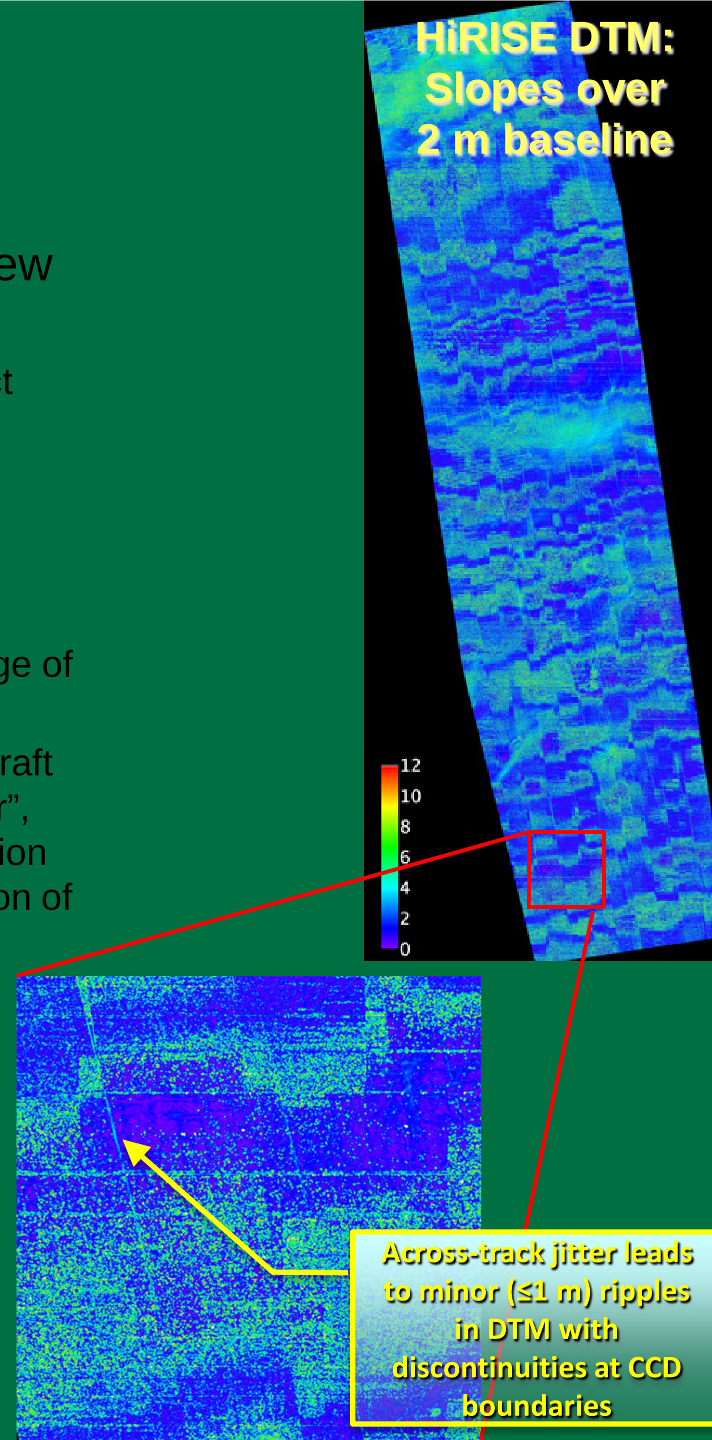



Mars and lunar data volumes in **LOG** Tbytes

# Need for Geometric Stability

- Fully photogrammetric cameras desirable, but few flown—Apollo Metric is the main exception
  - ARC-USGS DEM/mosaic of Apollo zone, current product (released 2011, ~30 years after data collected)
- Issue has become use of line scanner cameras (e.g. MOC, THEMIS IR, HRSC, HiRISE, CTX, LROC NAC)
  - Depends on accurate and highly time-resolved knowledge of spacecraft position and orientation
  - Problematic due to unmeasured and unmodeled spacecraft motions (particularly at high frequencies) known as “jitter”, leaving the actual geometric knowledge of image collection uncertain (at best) and often poor relative to the resolution of the camera
  - Still issues recognizing and addressing these problems
  - Some existing stereo data may not be useable (for full res DEMs)
  - Big issue is still handing large number of images – i.e. eventual global LROC NAC coverage at 2 m/pixel

**Stereo matching becomes “noisy” where images are out of alignment along-track because of jitter**

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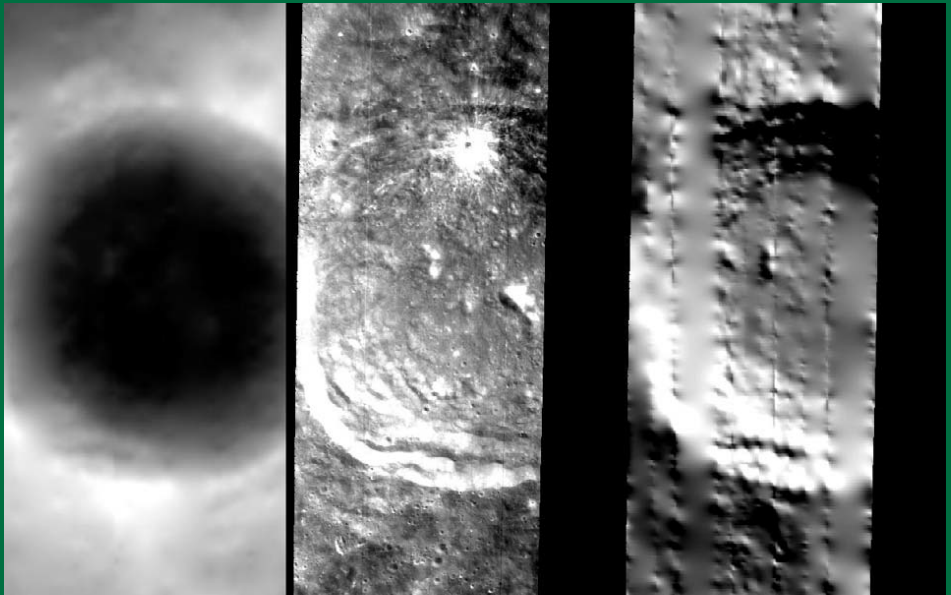
# Lack of global shape models of sufficient (i.e. image) resolution

- E.g. models of far less resolution than LROC NAC (50-200 cm) or HiRISE (30 cm)
- Critical issue for calibrating color and multispectral data —> for mineral resources and eventual ISRU
- Is the topo information sufficient to do processing? How will the required data be obtained?



$M^3$ hyperspectral image (center) compared with LOLA DTM (left) and LOLA-derived photometric correction (right)

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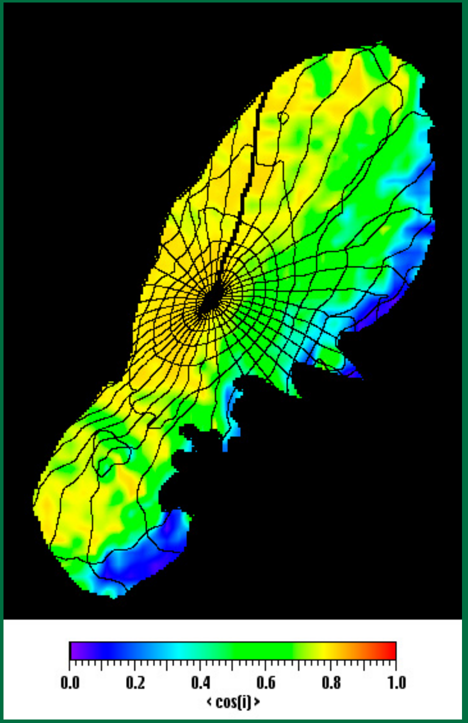
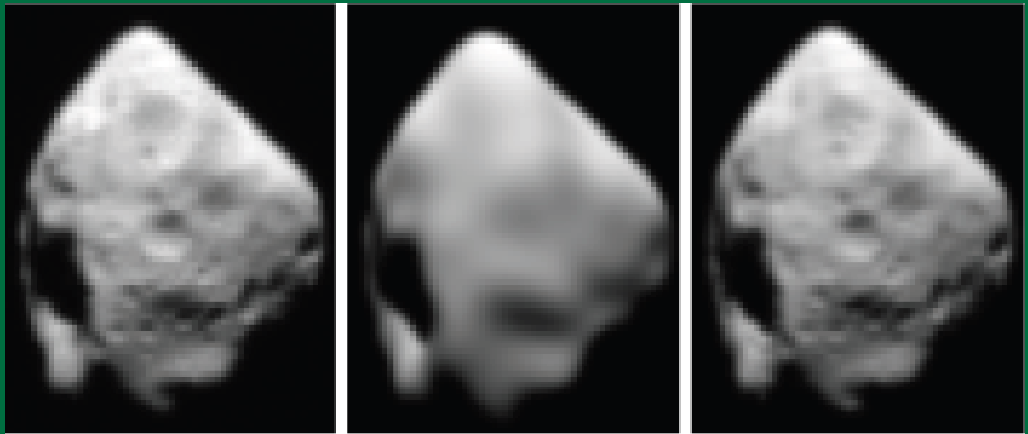
# Future Needs

- True 3D mapping (highly irregular bodies, landscapes around rovers)
- Images and lidar together
  - Various papers, this meeting
    - Degnan; Dissly et al.; Abshire et al.
  - OSIRIS-REx
- Combination stereo and photoclinometry, with validated accuracy information
- Real-time, near real-time mapping
  - On-board capability for crewed missions?




19P/Borrelly nucleus thermal model—shape from stereo



Steins—shape model refinement by multi-image shape from shading

# Related issues

- Planning and funding actually needed to do data processing
  - As recommended by Decadal Survey
  - Large efforts not really possible currently under R&A programs
  - Should be part of future mission planning/funding
- What products should be done? Who decides?
  - NASA Cartography panel used to make such recommendations, but no longer
  - Analysis Groups, PSS, NAC, other? should consider this issue

# Summary

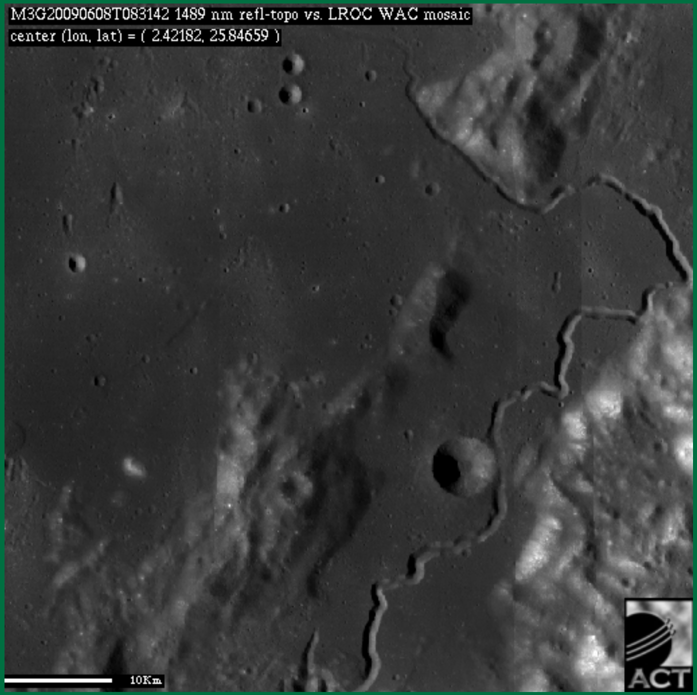
- Need to be able to *process* the data into useful, full resolution, controlled scientific products
  - Should not be forgotten during instrument and mission development – consider alternatives
- Need to improve on present-day cartographic processing capabilities—for existing as well as future datasets
- Tradeoffs of sensor types (e.g., line scanner camera vs. framing camera) need to be considered in terms of data acquisition (spacecraft stability) and the complexity/cost of data processing, and not merely in terms of performance (resolution, SNR, etc.) and the up-front cost of building the instrument.
- There is always a need for a topography (shape) model for the registration and orthoprojection of any instrument data

# Backup

# Need to control data

- Only way to register data in a common frame
- Yields KNOWN level of accuracy
- Uses: geology, mineralogy (and ISRU), site selection, landing and landed operations
- Other benefits: seam removal, proper orthometric projection of data; registration of multispectral data, proper photometric correction, change detection
- Might have been able to discover non-linear rotation of Titan sooner (internal ocean) and might still be able to verify structure of Enceladus, but data still not yet controlled

iPhone map without proper control and/or topographic base




Current $M^3$ vs. WAC GLD100 DEM

Apollo 15 and Hadley Rille site

(Courtesy: M^3 Team, ACT)

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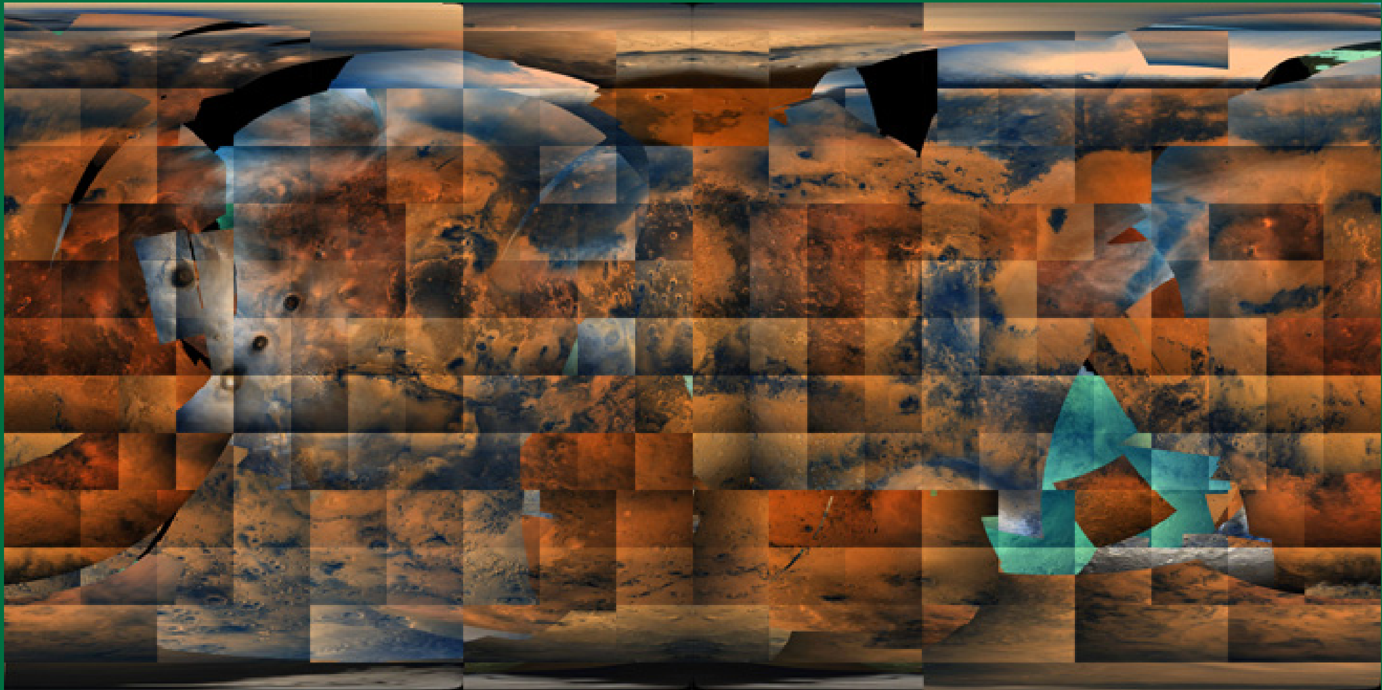
# Standards issues

- Cartographic standards help to avoid confusion in processing and use of datasets
- Need to be considered and understood by missions and instruments early on
- Would also help to standardize product formats (further) so as to make usage and understanding easier.



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# Current Processing Needs

- Faster, more robust tie pointing
- Control of push frame camera images
- Use of coordinate system, mapping, and format standards
- Comparison of different DEM generation methods


"Who cares if it's crap? It's digitally enhanced."