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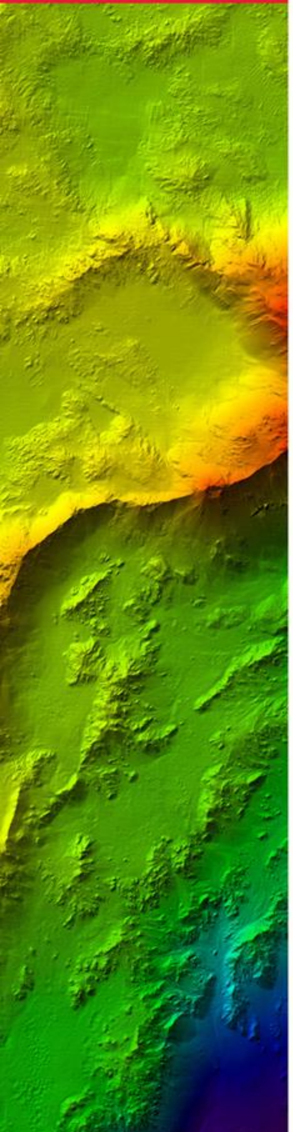
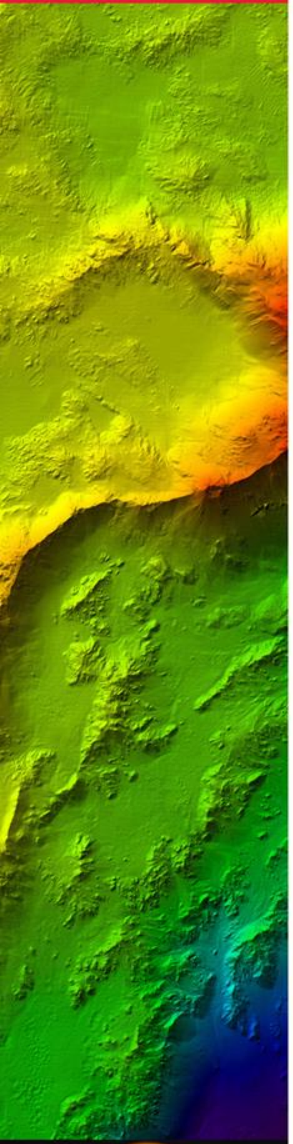


HiRISE

Photogrammetric Processing of Planetary Stereo Images Using SOCET SET®

July 27 - 29, 2015



Photogrammetric Processing of HiRISE Stereo Images

Robin Fergason & Randy Kirk

Project Chiefs

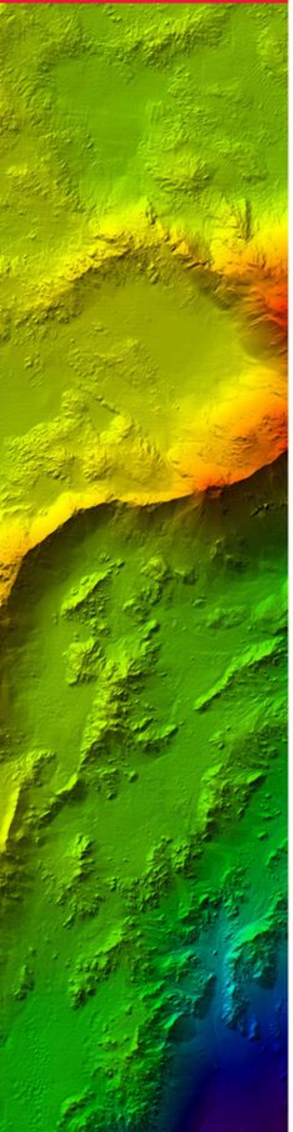
Presenters

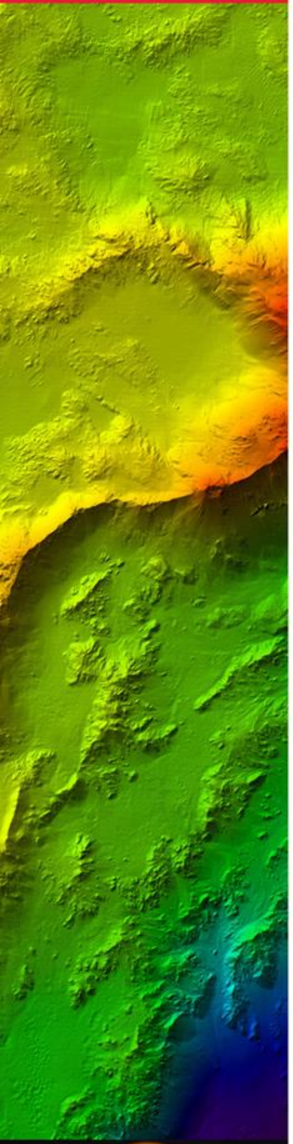
Robin Fergason, Ph.D. Research Geophysicist
Donna Galuszka, Cartographer
Bonnie Redding, Cartographic Tecnician

USGS Flagstaff Science Campus, Building 6: Astrogeology

Daily Schedule

- Begin daily at 8:00 am
- Lunch break: 11:30 am – 1:00 pm
  - Lunch is on your own
  - Can eat off campus or bring a lunch
- Afternoon session: 1:00 – 5:00 pm
- Short breaks in the morning and afternoon

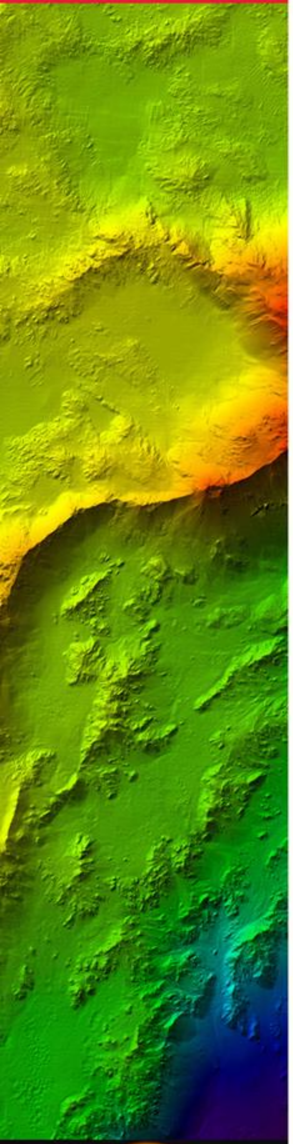




HiRISE

Intended Audience

- Workshop is intended to serve those actively working in the planetary science field
  - Both scientists and engineers
  - Funding provided by NASA
  - Demonstrations and training aimed at HiRISE, however other cameras follow the same general steps
- Guest Facility Users
  - Receive initial training
  - Return at a later date to do processing here
  - Will not need distributed files and software



Outline

- "Photogrammetry 101"— a quick introduction to cartography and stereo topographic mapping
- HiRISE overview
- Review ISIS and SOCET SET software versions
- ISIS <-> SOCET SET workflow
- ISIS3 HiRISE processing steps
- SOCET SET import procedures for HiRISE
- SOCET SET processing steps
- SOCET SET export procedures (ISIS3)
- Future work

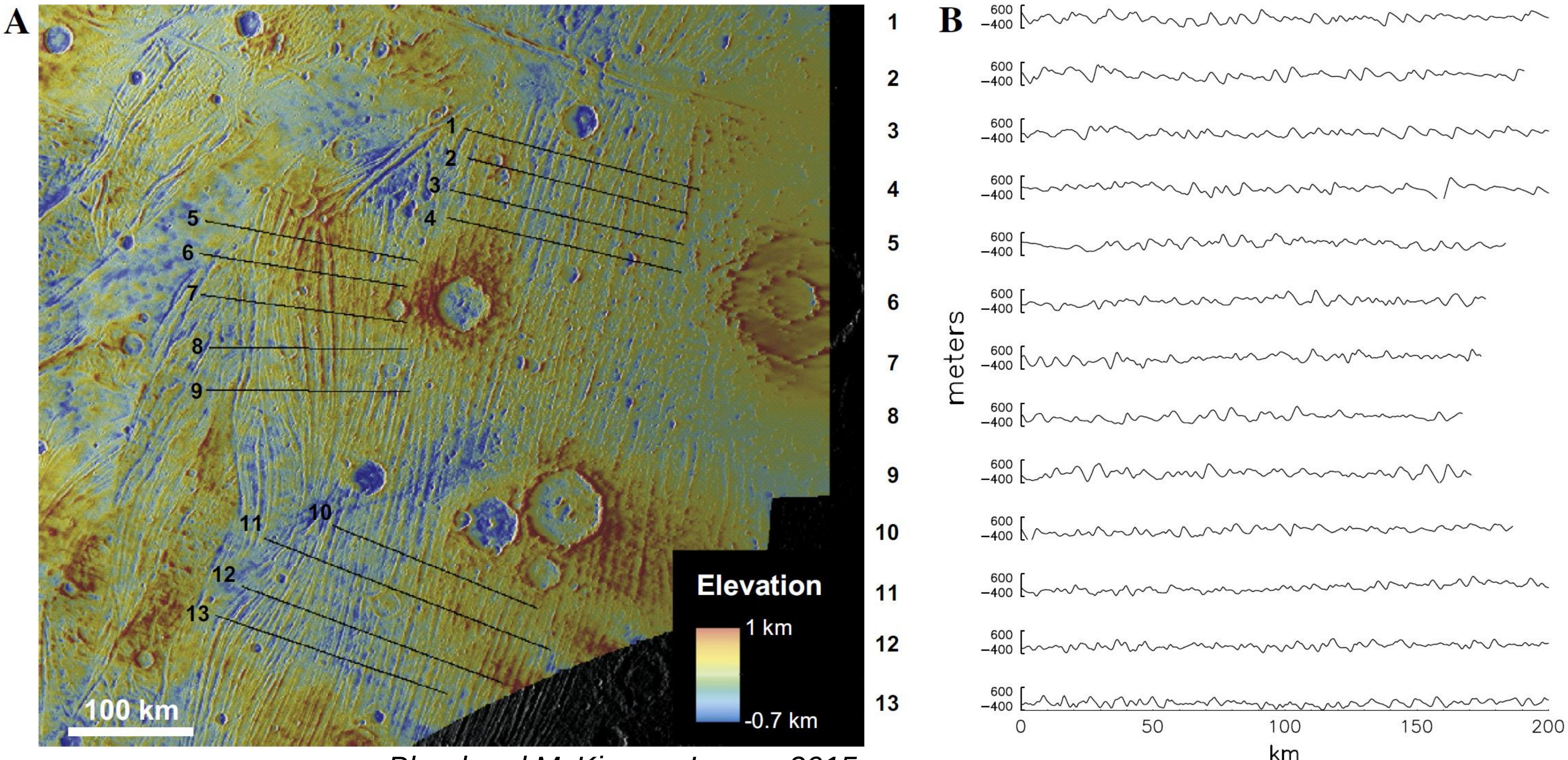
What is Cartography?

car•tog•ra•phy *n.* the study and practice of making maps

- Products of planetary cartography:
  - Unit maps, such as geochemical, geomorphic, albedo, and thermal maps
  - Geologic maps – integrating many different, registered data sets, to interpret a body's surface
  - Elevation, slope, and slope aspect maps (e.g., DEMs)
  - Nomenclature
- Often closely integrated with Geographical Information Systems (GIS)

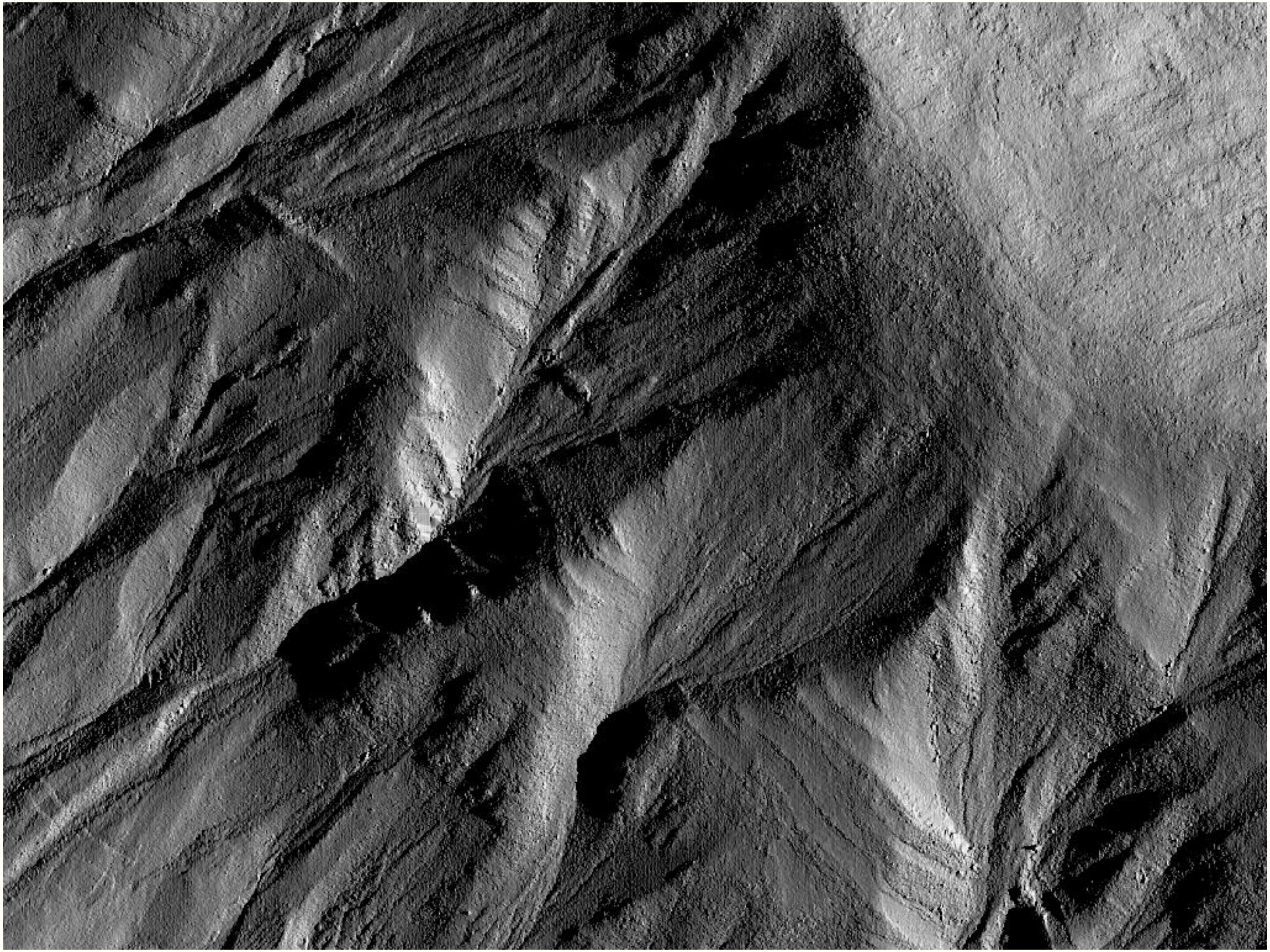
Local and Global Strain History

Voyager image, Bubastis Sulci, Ganymede



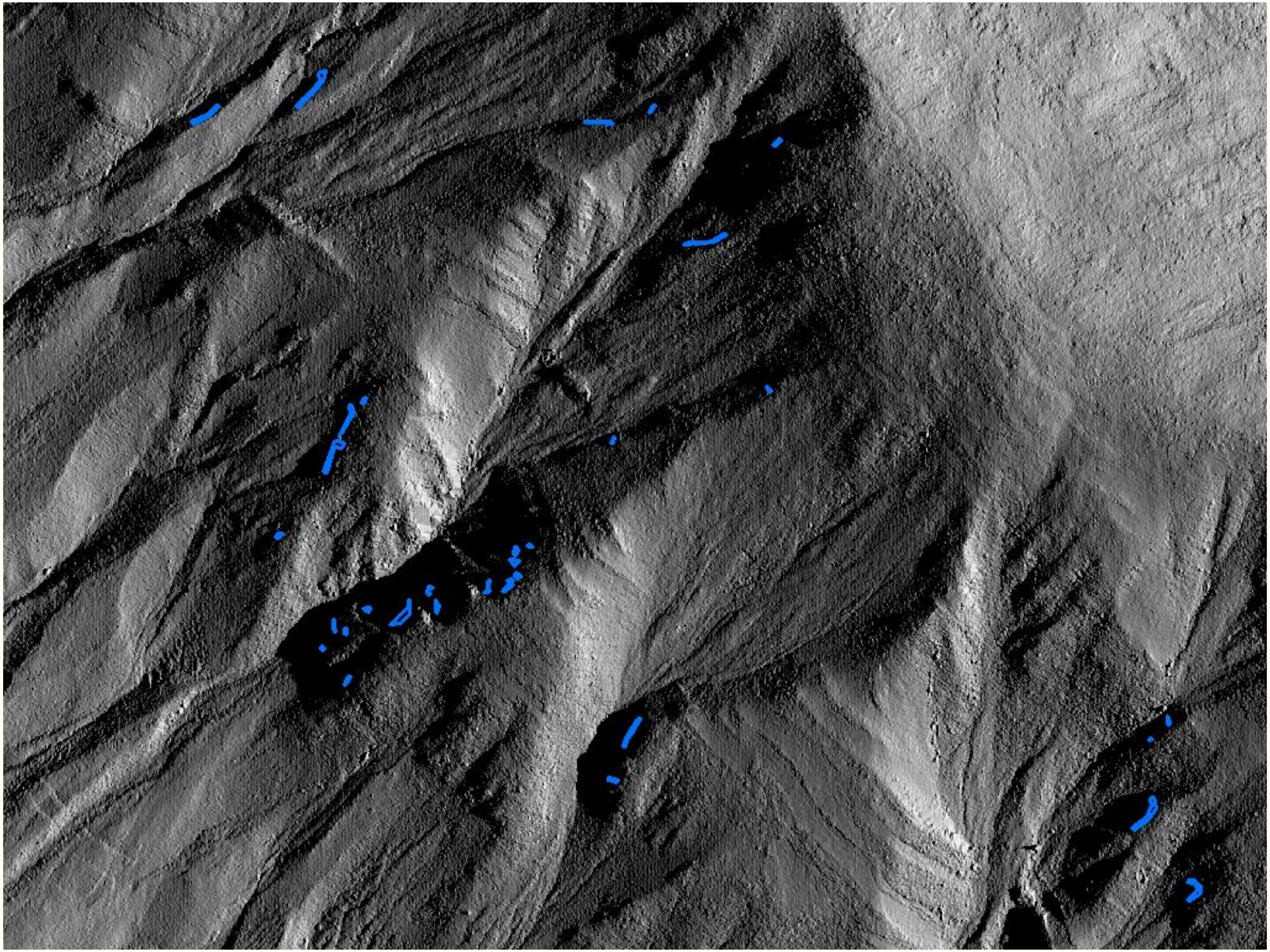
Bland and McKinnon, Icarus, 2015

HiRISE DEM; Palikir crater, Mars, L_S=290



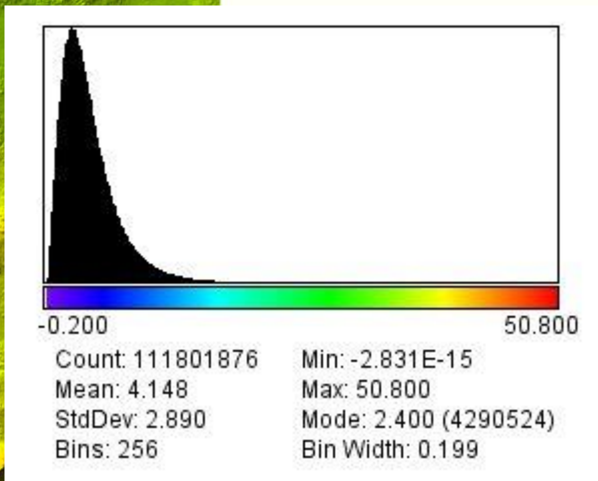
Dundas et al., LPSC, Abs. 2327, 2015

HiRISE DEM; Palikir crater, Mars, L_S=290

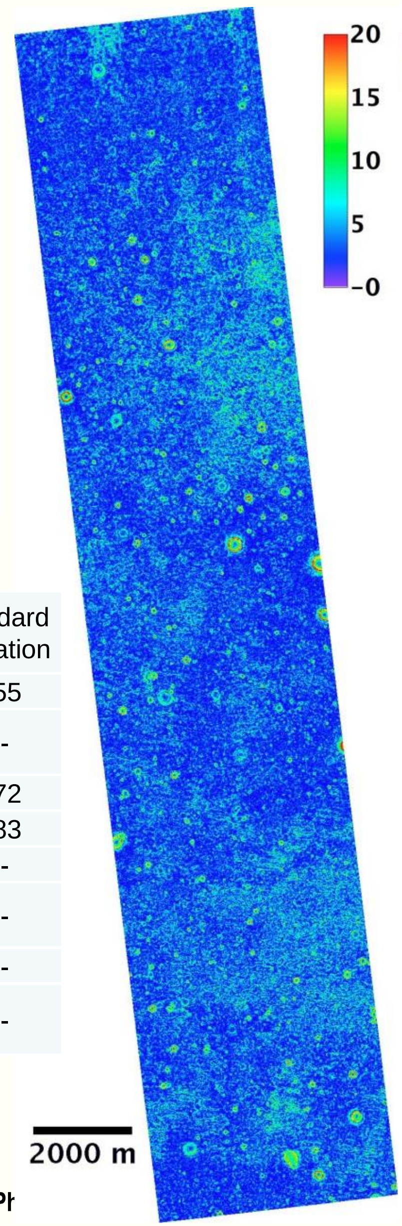


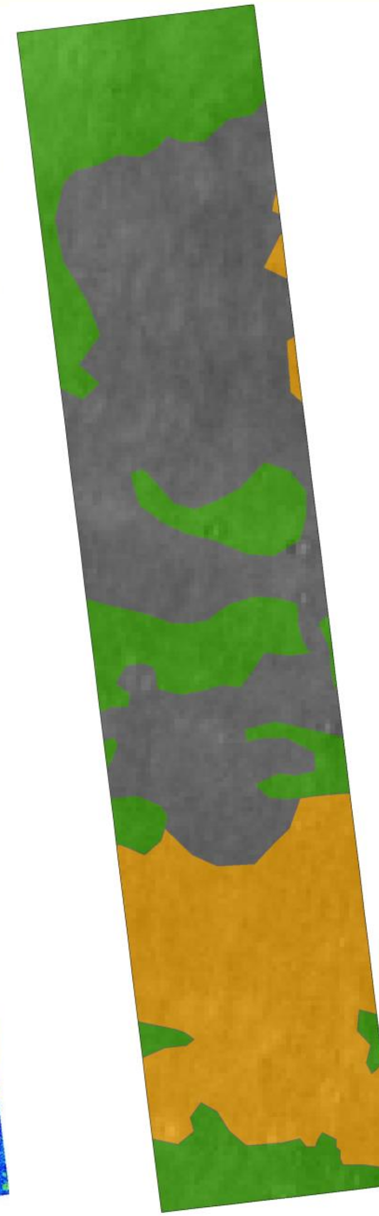
Dundas et al., LPSC, Abs. 2327, 2015

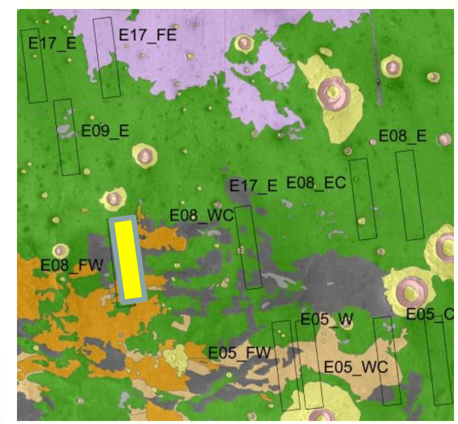
InSight Ellipse 8



	Terrain Type	Unit Mask	Mean Slope	Standard Deviation
E08_FW	Smooth Terrain	1	3.85	2.55
	Crater Ejecta Terrain	2	---	---
	Dark Terrain	3	4.22	2.72
	Etched Terrain	4	4.41	2.83
	Ridged Terrain	5	---	---
	Dense Crater Swarms	6	---	---
	Crater Rim Terrain	7	---	---
	Gradational Etched Terrain	8	---	---







Pl

CET SET®

What Matters in Cartography?

Establishing the coordinate system in which features can be located

Geodesy – Size, shape, spin of body; prime meridian, “sea level”, latitude and longitude; orbit and gravity modeling; global network of landmarks for reference

Determining the locations of features

Photogrammetry – Calculate real-world positions based on measurements in images

Portraying locations and spatial relations between features

GIS – Manage spatial databases

Scientific Visualization – Effective portrayal of data

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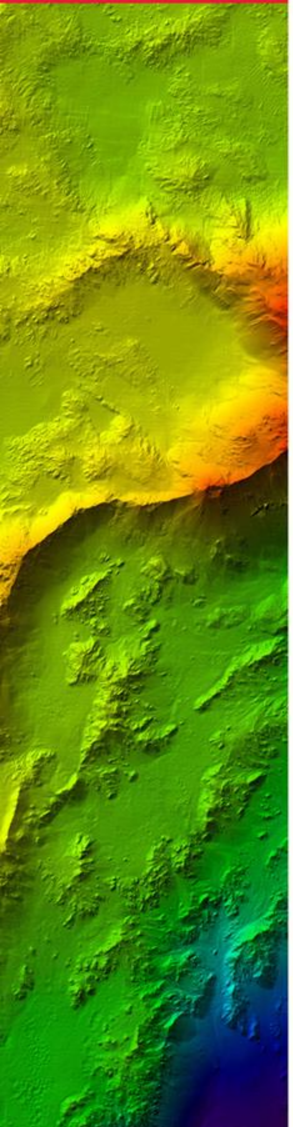


HiRISE

Photogrammetry 101

- Input Data
  - “Match”, “Pass”, or “Tie” point
  - Ground control points (known)
- Types of Calculations
  - Intersection
  - Bundle Adjustment
  - Orthorectification
- Complications Due to Different Sensors
  - Framing cameras (GLL SSI, CSS ISS, Clem UVVIS)
  - Line scanners (MGS MOC, MRO HIRISE, LRO LROC)
  - Pixel scanners (GLL NIMS, CSS VIMS)
  - Altimeters (MGS MOLA, LRO LOLA)

Photogrammetry 101

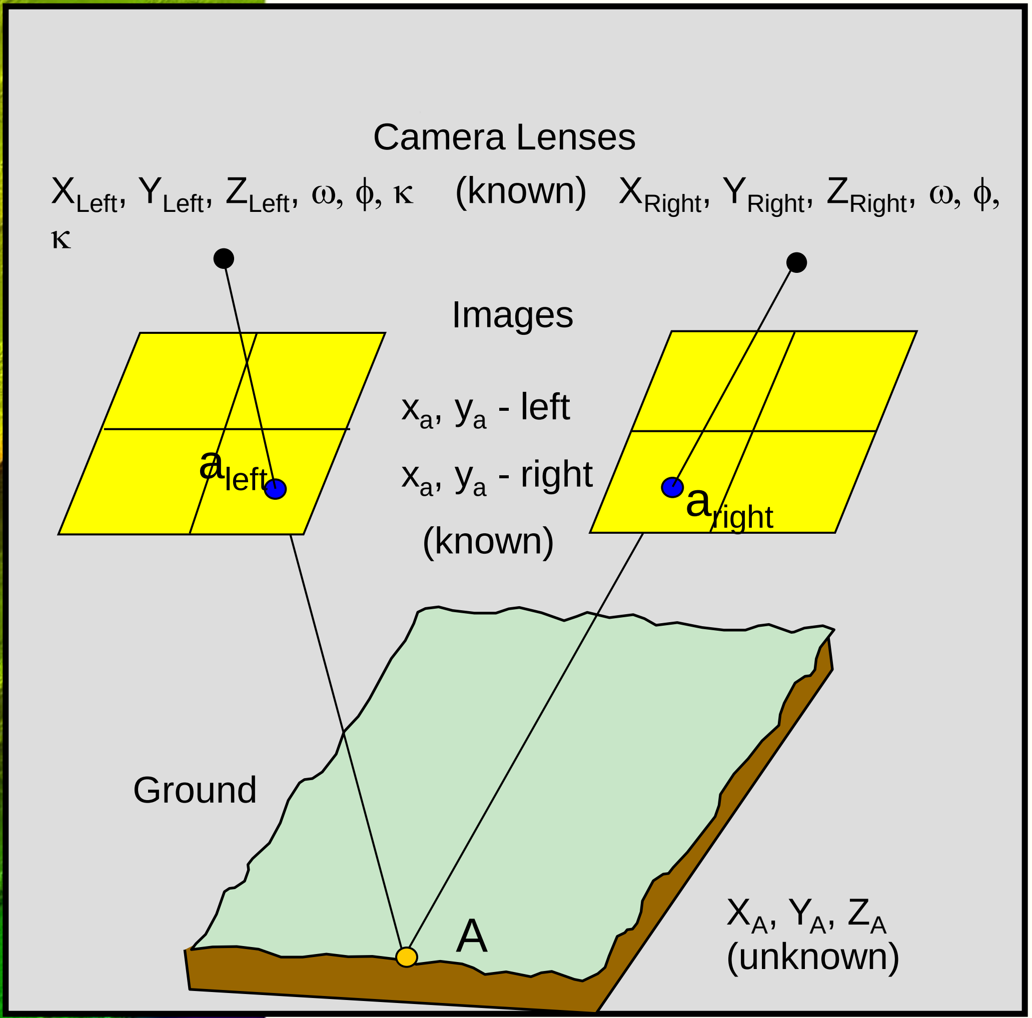


Image Credit: BAE Systems® Training Material

- The camera lens, image point, and ground point, must form a straight line (co-linear)
- The location of a ground point can be found using two overlapping images and by intersecting the lines through the same point on both images up to the camera lenses

Omega, Phi, Kappa

- These values are used to determine the rotation of the camera in 3 directions
  - **Omega** represents the rotation of the camera about the X axis
  - **Phi** represents the rotation of the camera about the Y axis
- **Kappa** represents the rotation of the camera about the Z axis
  - This value can be determined by estimating the flight direction
  - The angle from the ground easting to the camera X axis with positive angles generated in a counter or anti-clockwise direction

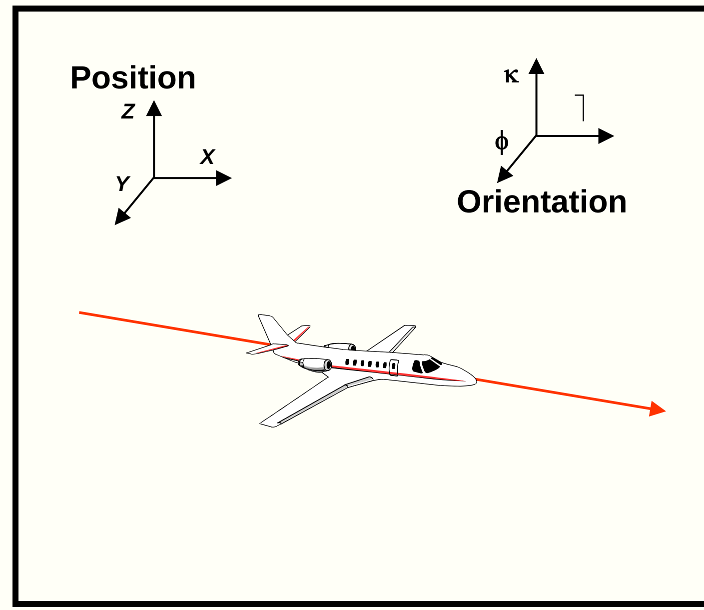


Image and Content Credit: BAE Systems® Training Material

History of Photogrammetry

Image credit: USGS

Image credit: USGS Astrogeology

History of Photogrammetry

Analytic Stereo Analysis

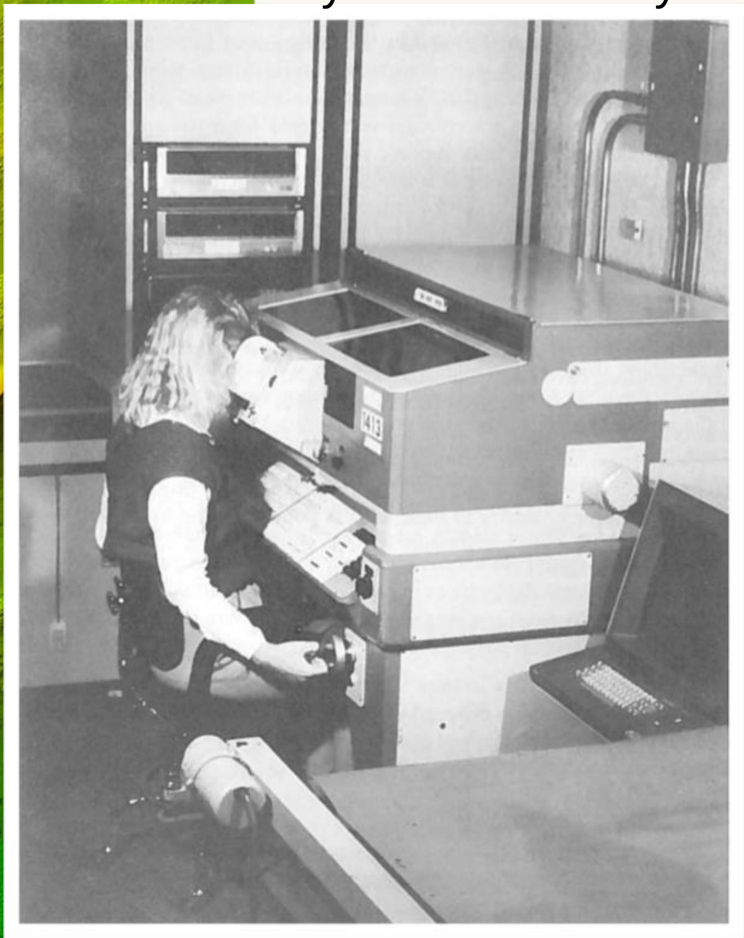
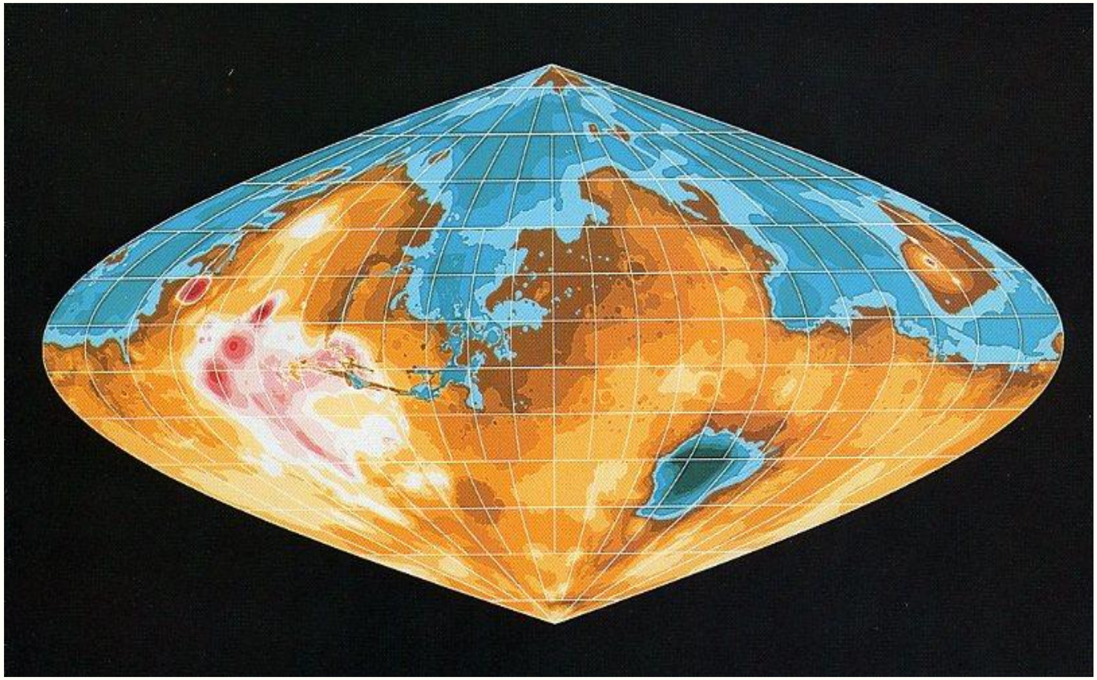


Image credit: USGS Astrogeology

USGS Viking Orbiter Global DTM



Wu et al., 1986

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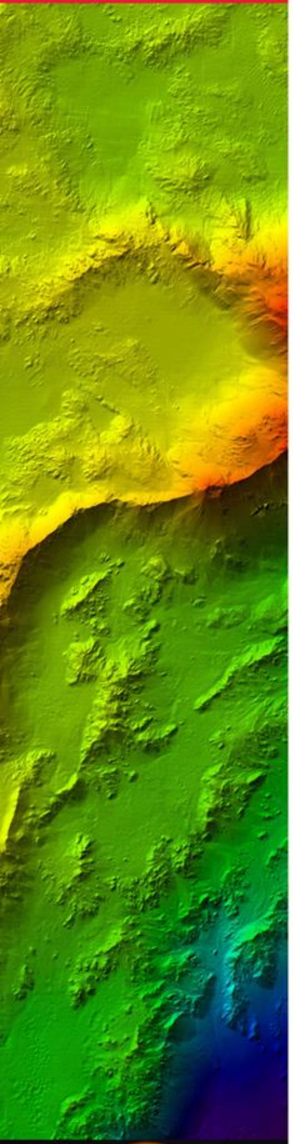

HiRISE

History of Photogrammetry

Typical HiRISE Pair

Image credit: NASA/JPL/UofA

Image credit: USGS Astrogeology

For a long HiRISE image, there can actually be more posts than in the Viking Orbiter Global DEM

HiRiSE DEM contains almost 100% real data – no interpolation

We’ve come a long way!

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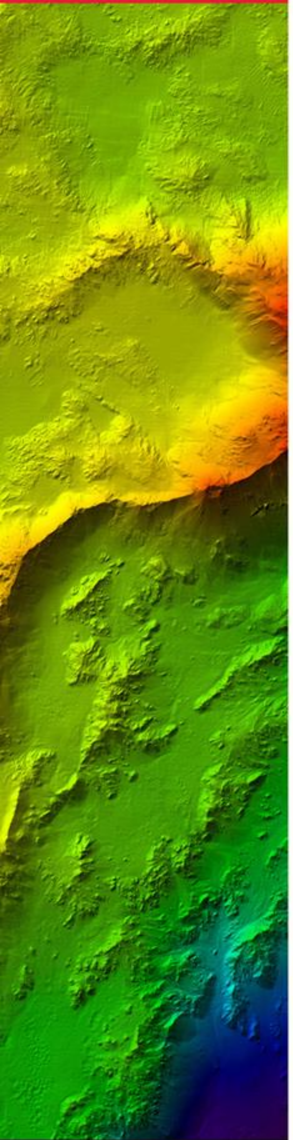
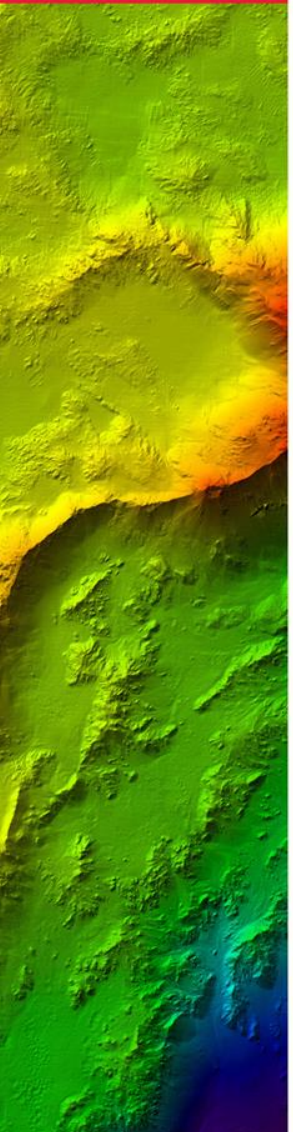


HiRISE

Selected Planetary Imagers

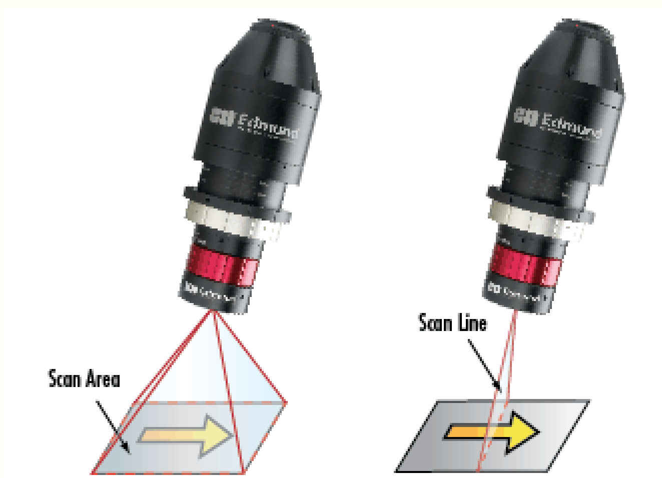
Target	Mission	Instrument	Res	Image Size	Sensor Model	Remarks
Moon	Lunar Orbiter	High Res	1-60 m	31000x8000	Frame	Film scanned on s/c
		Med Res	8-500 m	9000x8000	“	“
	Apollo	Mapping	20 m	9000x9000	“	Film returned
		Panoramic	≥ 1 m	9000x90000	Panoramic	“
	Clementine	UVVIS	100-300 m	384x288	Frame	Polar maps made
Venus	Magellan	SAR	75 m	250x250000	Custom	18% of planet in stereo
Mars	Viking Orbiter	VIS	8-1000 m	1156x1204	Frame	Vidicon, pre-correct dist’n
	MGS	MOC NA	≥ 1.5 m	2048x many k	Pushbroom	Limited stereo
		MOC WA	≥ 250 m	3456x many k	“	Fisheye, pre-correct dist’n
	Odyssey	THEMIS VIS	≥ 18 m	1024x200	Frame	Nadir only, so far
		THEMIS IR	100 m	320x many k	Pushbroom	“
	Mars Express	HRSC	≥ 10 m	5184x many k	“	9-line stereo + color
		SRC	≥ 2.5 m	1024x1024	Frame	Stereo with MOC NA
	MRO	HiRISE	≥ 0.3 m	20000x60000	Pushbroom	Extensive stereo
Landers	Viking Lander	Panoramic	≥ 2 mm	≤9000x2500	Custom Req’d	2 cams for stereo, fixed
	MPF	IMP	≥ 1 mm	256x248	Frame	2 cams for stereo, rotating
	MER	Pancam	≥ 0.3 mm	1024x1024	“	“
		MI	0.03 mm	1024x1024	“	Microscope w/stereo
Asteroid	NEAR	MSI	2-10 m	244x537	“	Complex image coverage
Comets	DS 1	MICAS	≥ 50 m	60x150	“	2 stereopairs
	Stardust	ONC	≥ 14 m	150x150	“	~10 stereopairs
Titan	Cassini	RADAR	300-1400 m	400x25000	Custom	Limited stereo planned
	Huygens	DISR	≥ 10 m	≤130x256	Frame	3 cameras on spinning probe, some stereo

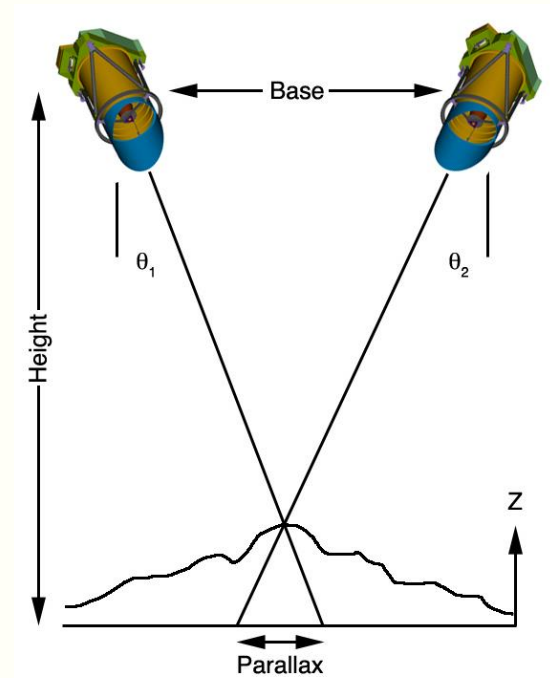


HiRISE

Stereo and Single-Line Pushbroom Scanners

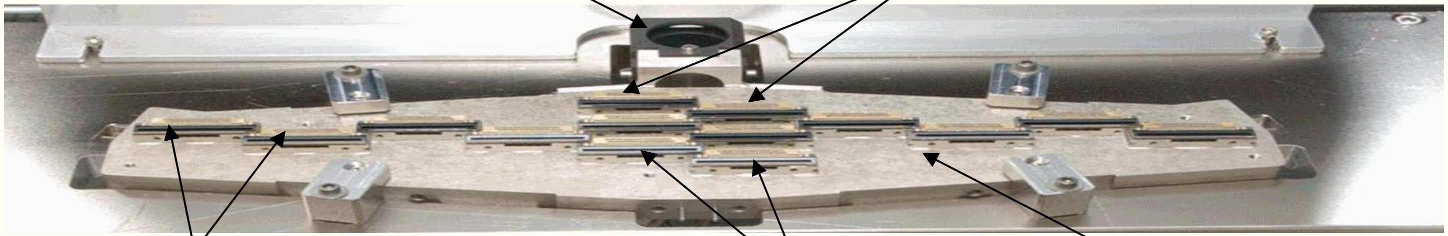
Pushbroom/Line scan
Rather than a single frame acquired, a “line” of data is acquired and images can vary in length.

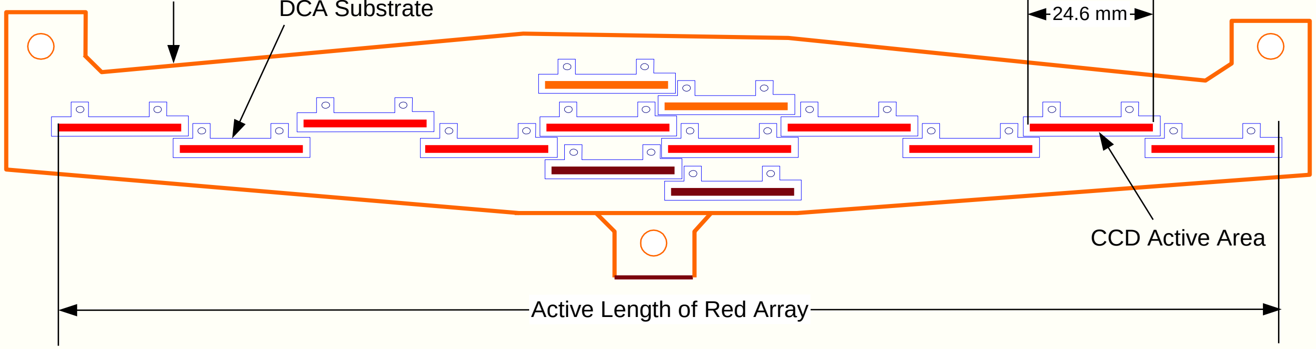




MRO HiRISE
3 sets of detectors for color, but stereo angle is negligible. Obtain stereo pairs by repeat imaging on separate orbits.

HiRISE Instrument

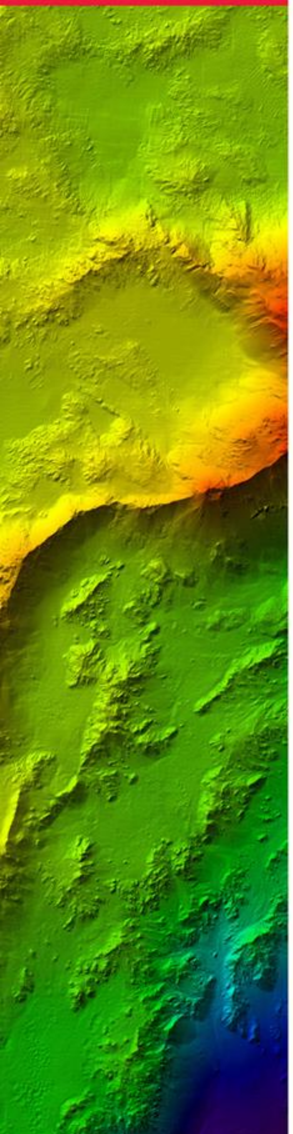




14 CCDs (2048 x 128 pixels):
- 10 CCDs Form Red Channel (20,000 pixels)
- 2 CCDs Form Blue-Green Channel (4000 pixels)
- 2 CCDs Form NIR Channel (4000 pixels)

Noproj: needed for undistorted DTMs

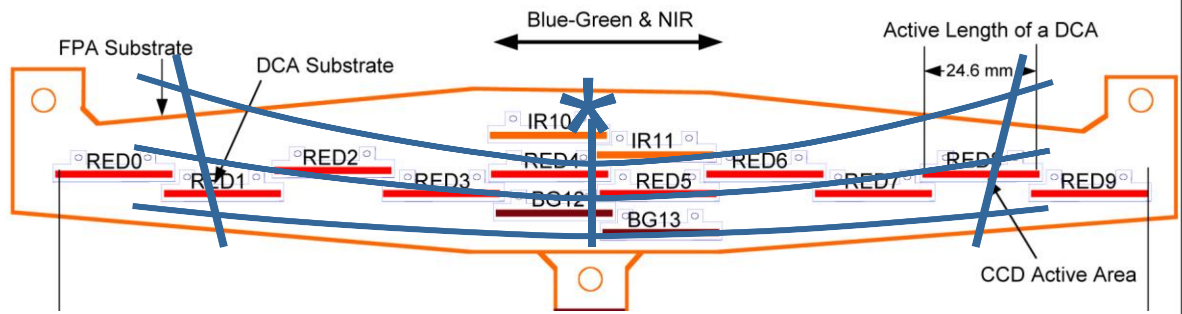
- Required for HiRISE and Viking
- Removes camera (lens) distortions in a level 1 cube
  - Creates an undistorted version of the level 1 cube based on an idealized camera
  - Maintains level 1 image geometry
    - Image statistics at any pixel



Noproj: needed for undistorted DTMs

- Additionally for HiRISE
  - Adjusts all CCDs to the same line in the focal plane so we can mosaic to create a single undistorted image
  - Jitter distortions can also be removed by resampling from jittery to smooth CK blob
    - Not yet in HiRISE pipeline…but soon

Noproj – HiRISE Focal Plane



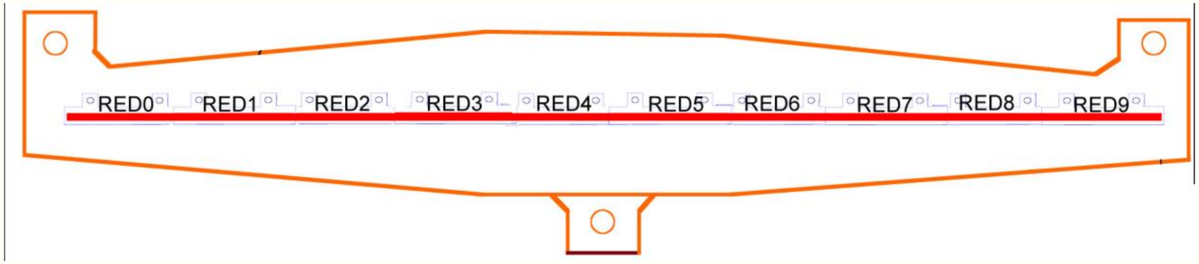
Optical distortion of lines on Mars' surface.
Curvature highly magnified.

Figure 2.1.b - Focal Plane Array

Figure from:
HiRISE_EDR_SIS_2006_13_17

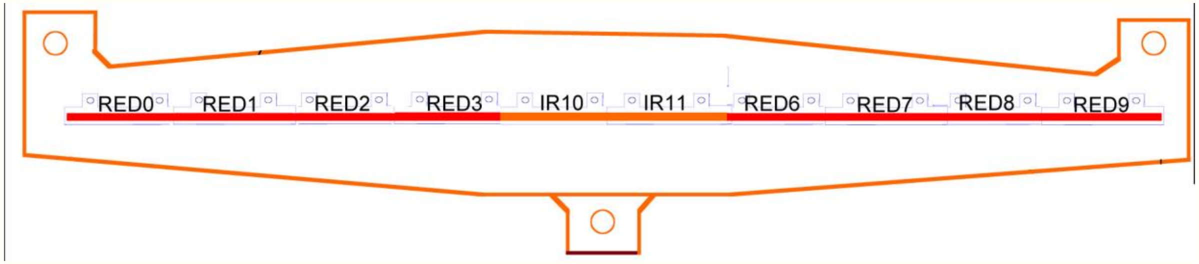
* Boresight

Noproj – HiRISE Undistorted ('idealized') Focal Plane



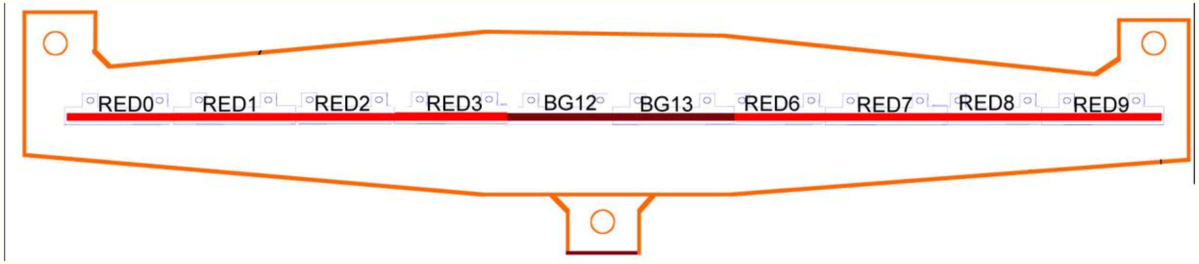
All RED CCDs are aligned

Noproj – HiRISE Undistorted ('idealized') Focal Plane



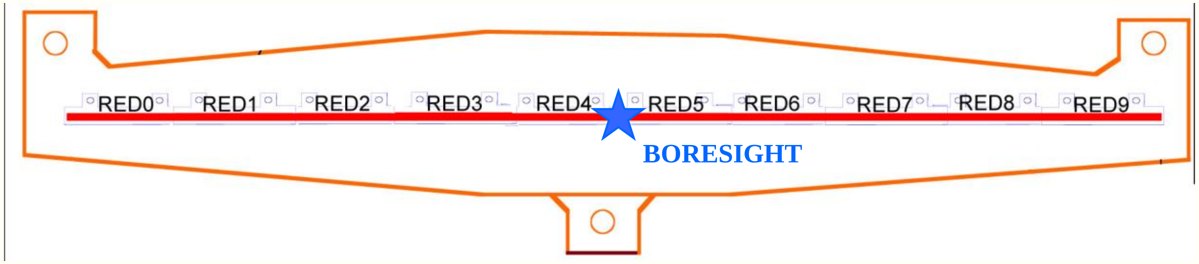
IR CCDs overlay RED4 and RED5

Noproj – HiRISE Undistorted ('idealized') Focal Plane



BG CCDs overlay RED4, RED5, IR10 & IR11

Noproj – HiRISE Undistorted ('idealized') Focal Plane

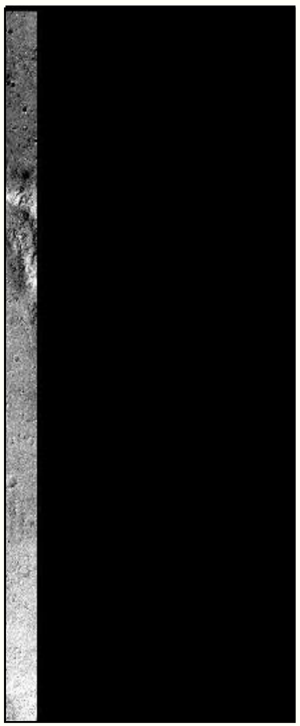


Boresight is centered on the focal plane

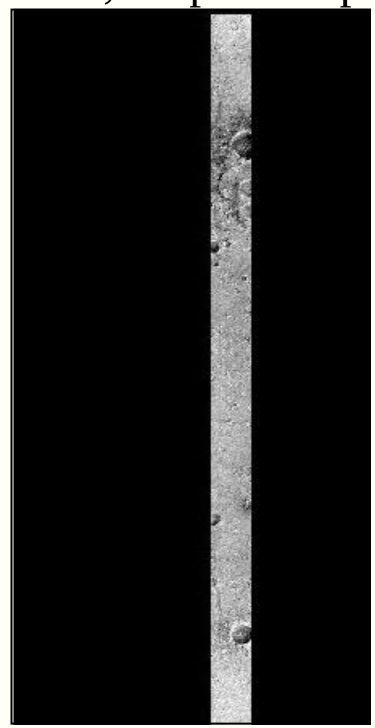
Noproj – HiRISE Undistorted ('idealized') Focal Plane

Sample NOPROJ results for PSP_001777_1650

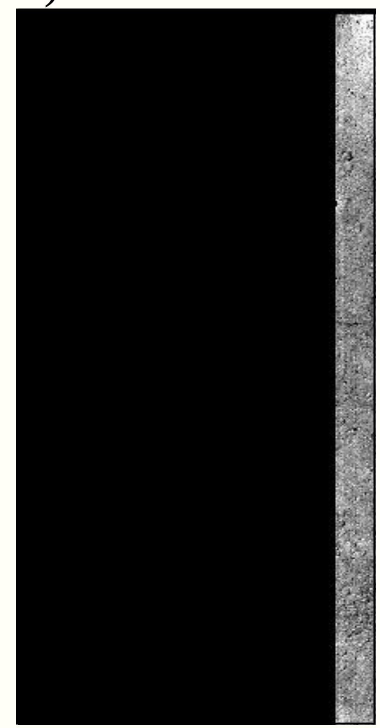
(Summation=1; output samples=20,000)



RED0

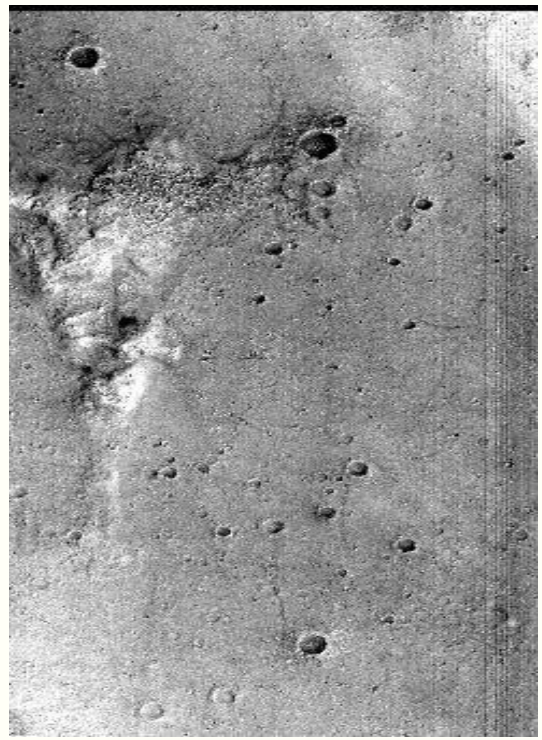


RED5



RED9

Noproj – HiRISE Undistorted ('idealized') Focal Plane



PSP_001777_1640
Undistorted mosaic