NASA AISR Program PI Meeting

Integration of Orbital, Descent and Ground Imagery for Topographic Capability Analysis in Mars Landed Missions

March 2006 – September 2009

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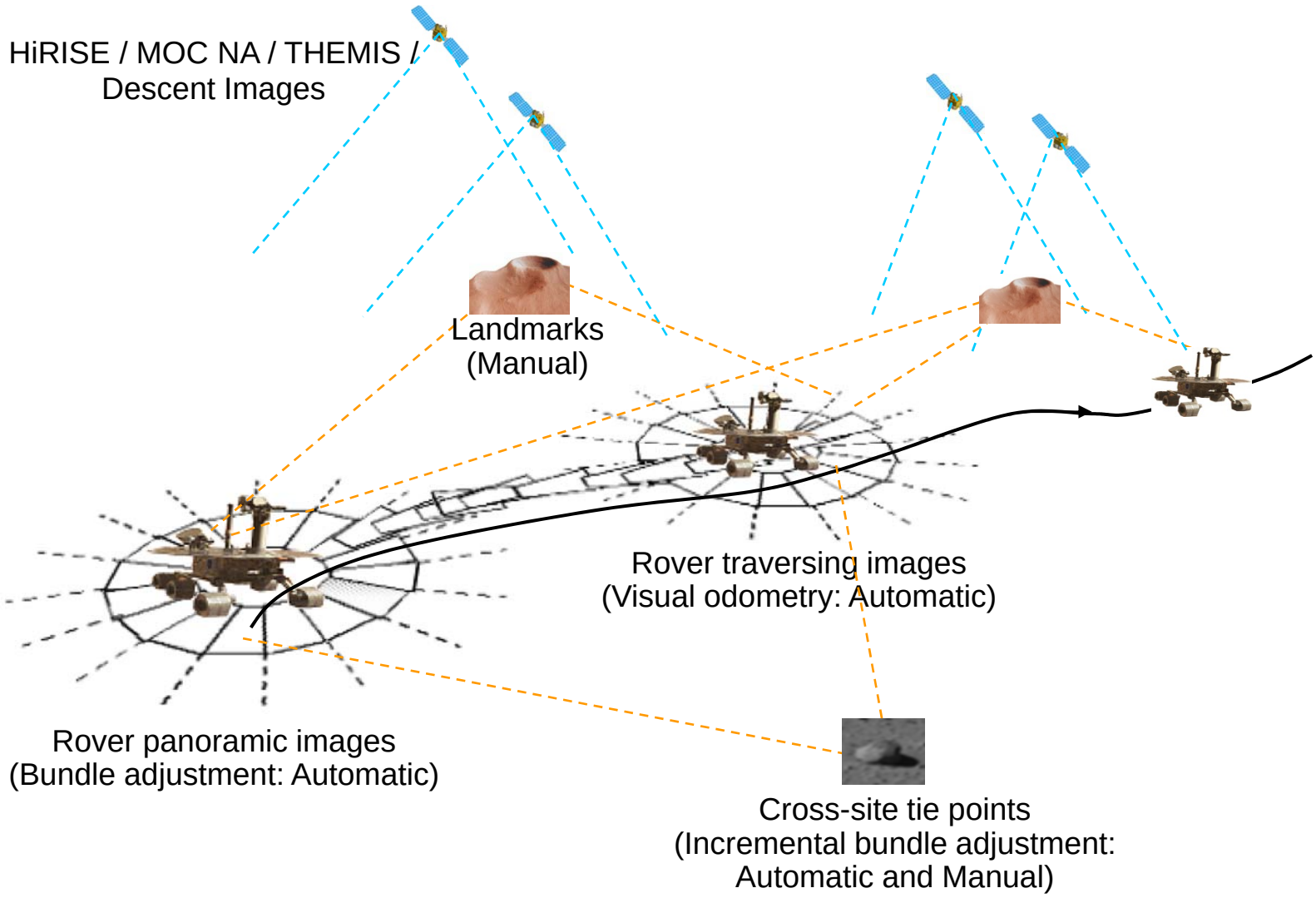
October 14th-16th, 2009, Moffett Field, CA

Contents

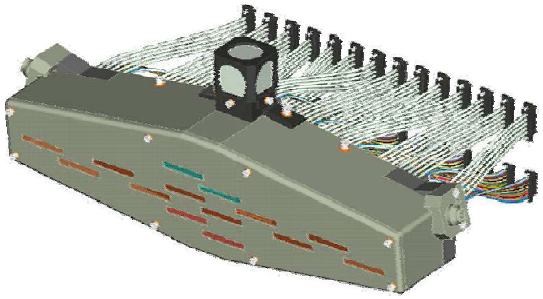
- Overview of image network.
- Rigorous photogrammetric modeling of high-resolution orbital imaging sensor (e.g., HiRISE).
- Topographic mapping (orbital and ground).
- Integration of orbital and ground images.
- Applications: MER mission support.
- Future work: autonomous rover localization and navigation.

Image Network

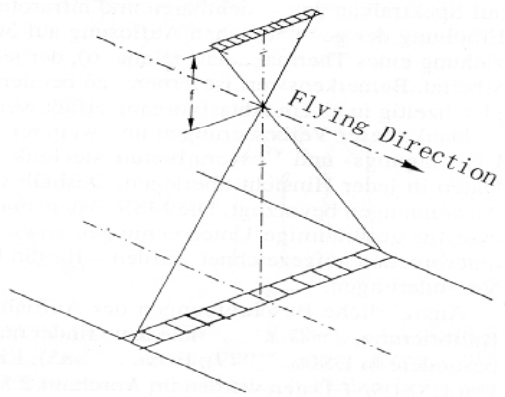


Rigorous HiRISE Geometric and Bundle Adjustment Model

MRO over Mars
(Image credit: NASA)



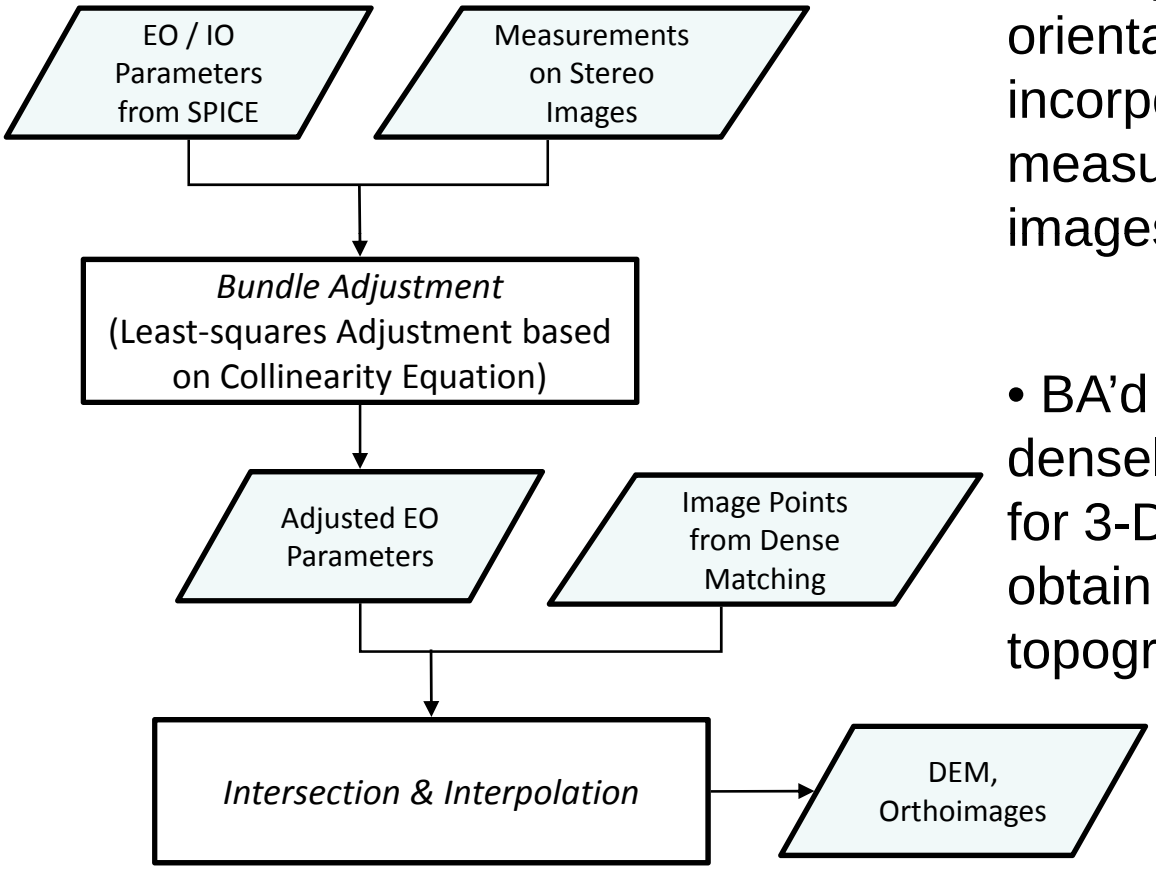
HiRISE Sensor



Pushbroom Geometric Model of HiRISE

- HiRISE: a push-broom imaging sensor with 14 CCDs (10 red, 2 blue-green and 2 NIR).
- Each CCD: 2048 pixels in the across-track direction, 128 pixels in the along-track direction.
- Generates images with up to 20,264 across-track observation pixels.
- Push-broom-geometry-based bundle adjustment model.

Photogrammetric Data Processing



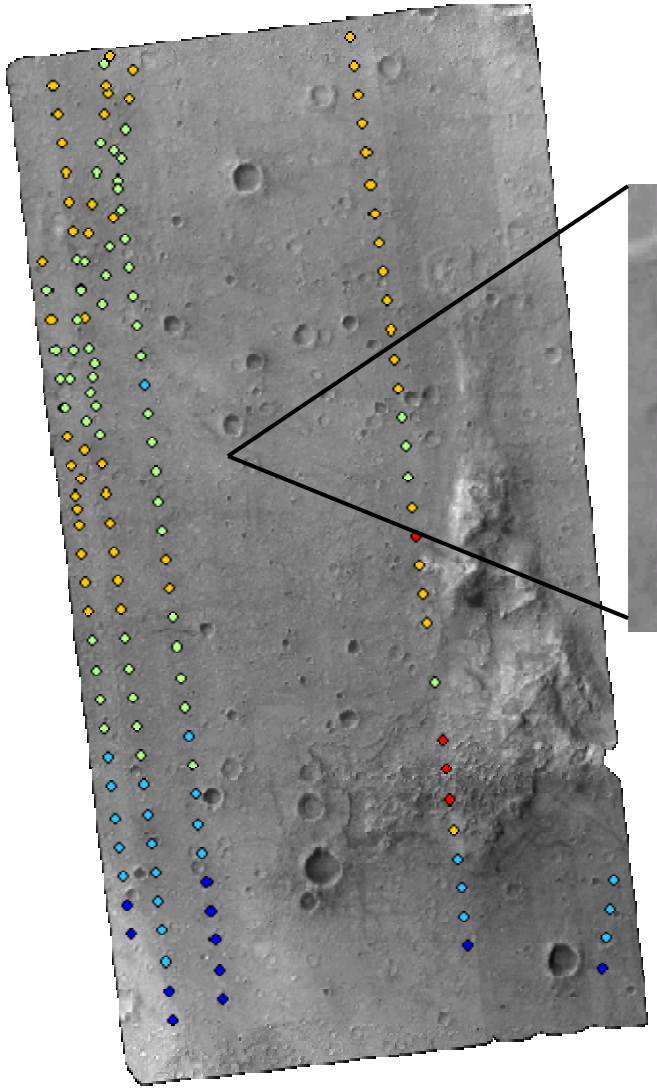
Flowchart of OSU Orbital Mapper Software

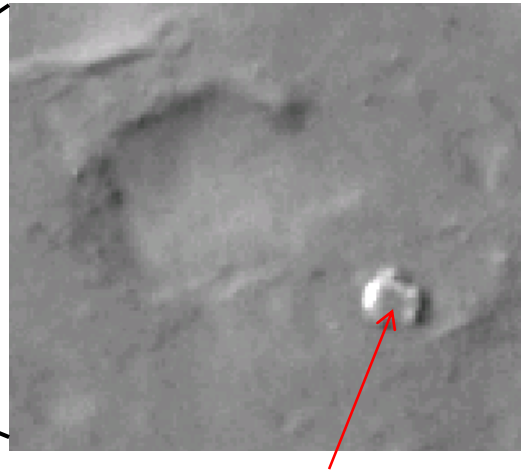
- Bundle adjustment (BA) for the adjustment of initial exterior orientation (EO) parameters incorporating interest point measurements from stereo images.

- BA'd EO parameters and densely matched stereo points for 3-D spatial intersection to obtain highly accurate topographic information.

Orbital-Ground Correspondence for BA using MOLA and Ground Control Points

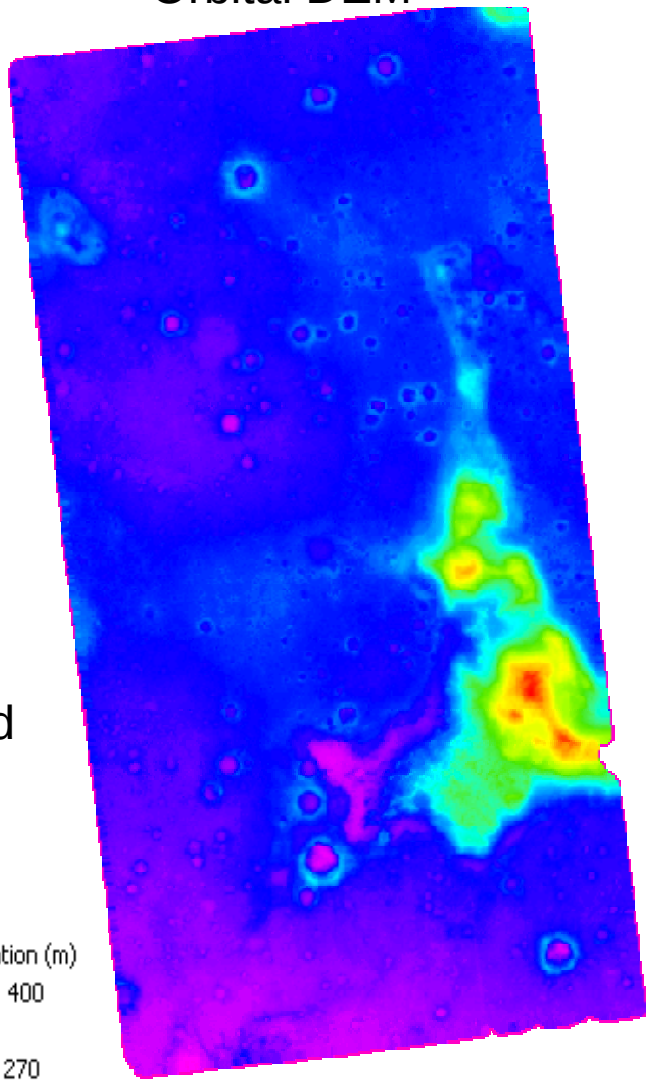
MOLA altimetry data (points) used as vertical control



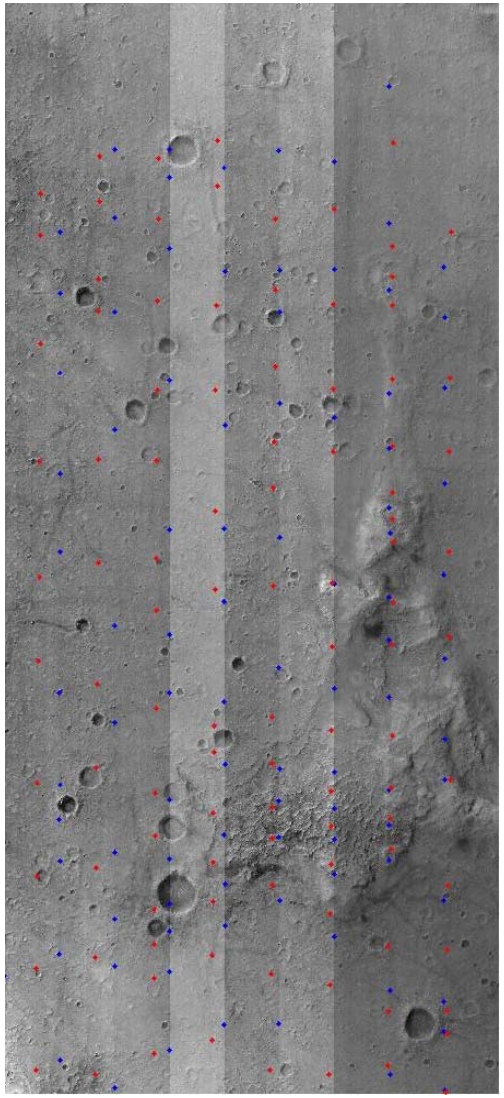


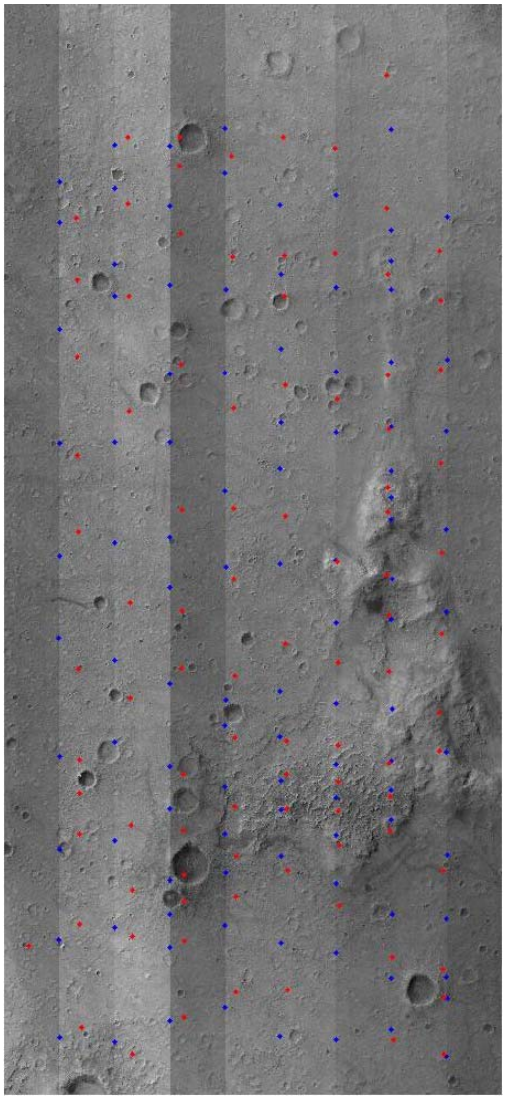
MER landing site used as horizontal control

Orbital DEM



HiRISE Stereo Images of Spirit Landing Site

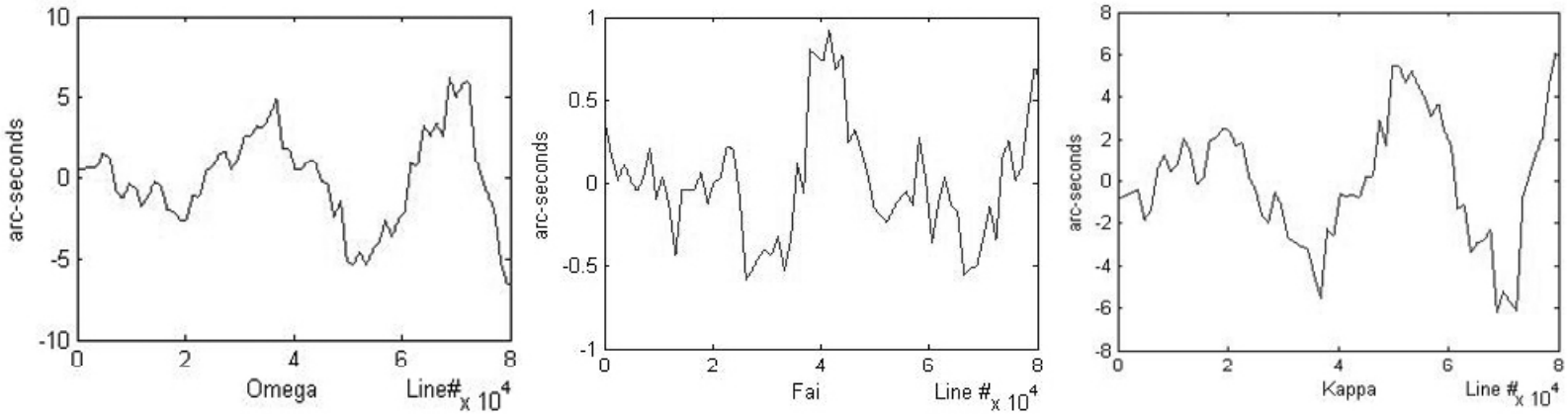




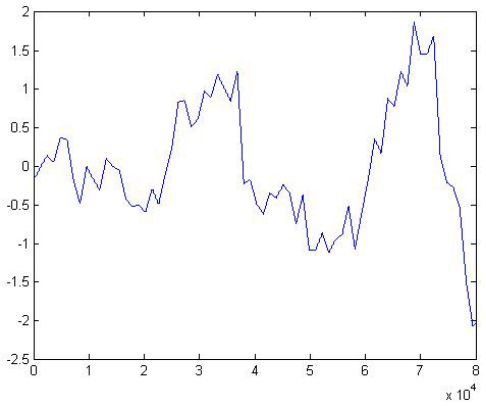
- Study Area
  - 14.6° S latitude
  - 175.5° E longitude
  - Columbia Hills
  - Entire Spirit traverse
- PSP_001777_1650 (left)
  - Dec 12, 2006
  - 40,000 rows
  - 26.3 cm/pixel
- PSP_001513_1655 (right)
  - Nov 22, 2006
  - 40,000 rows cropped from 80,000 rows
  - 27.1 cm/pixel

Orbital Jitter and Modeling Rotation Angles

- Jitter: small motions of the spacecraft around its nominal pointing.
- Third-order polynomial fitting.
- Jitter filtering: subtracting the best-fit polynomial from the raw data.



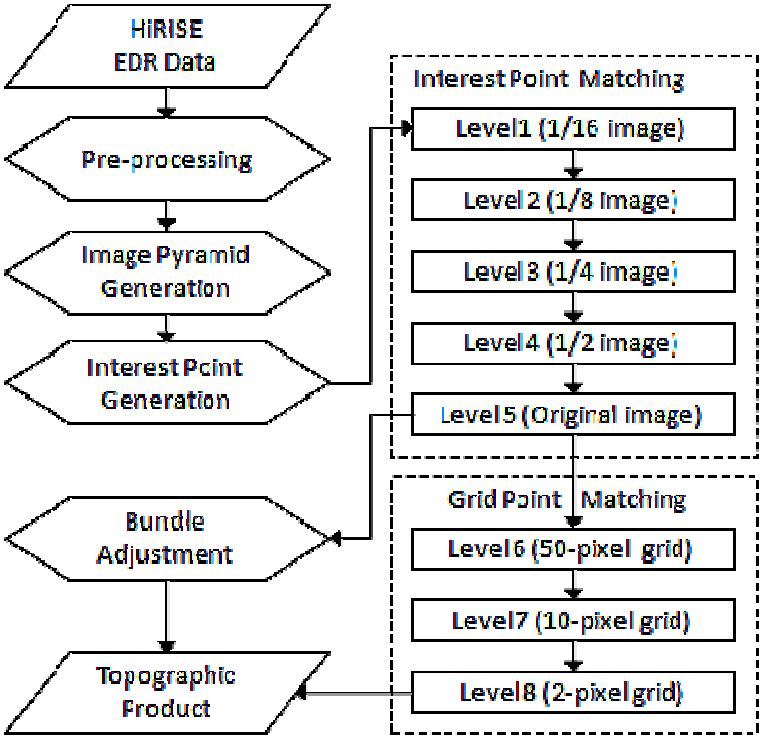
Jitter extracted from HiRISE image (PSP_001513_1655)

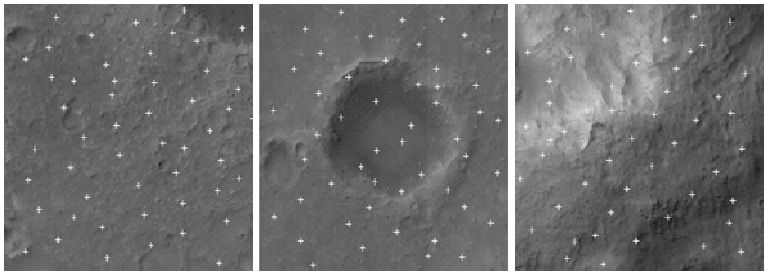


- The topographic effect of orbital jitter.
- Jitter trajectory projected onto the Martian surface is about 2~3 m along the 20-km swath.

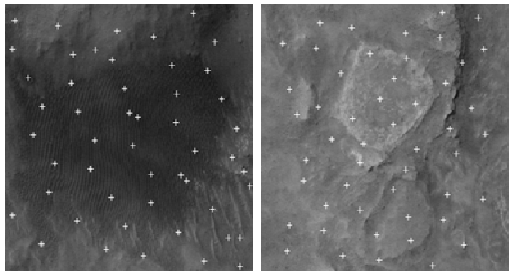
Topographic effect of Jitter

Hierarchical Stereo Matching and Verification of Matching Results





I. Level Terrain II. Crater III. Summit

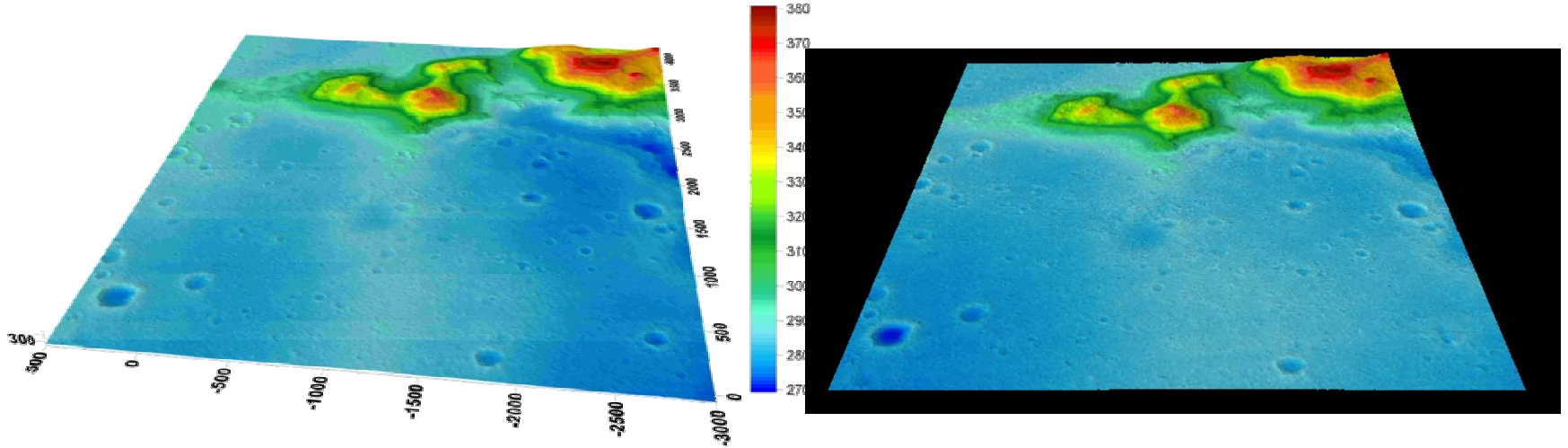


IV. Hill V. Level/Ridge

Check points manually selected on different terrain types

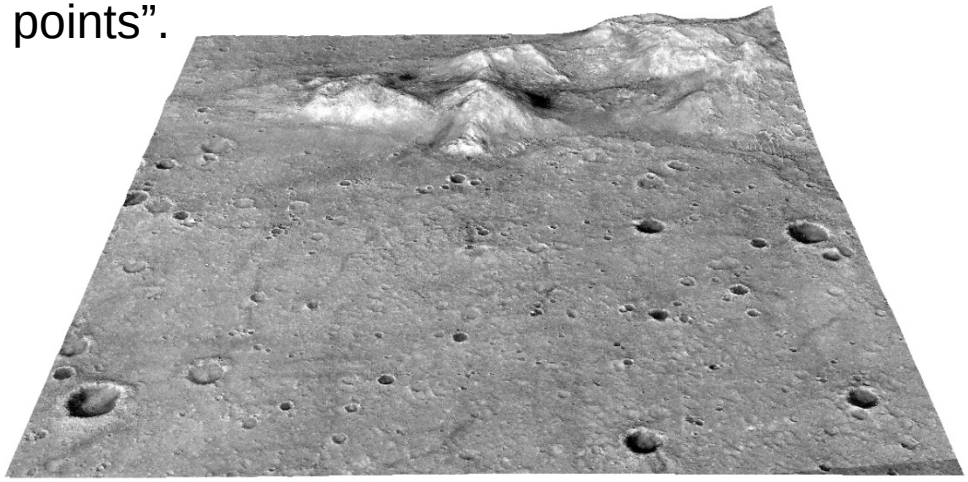
Site ID	Terrain Type	Number of Check Points	Residuals (pixel)		
			Mean	Standard Deviation	Maximum
I	Level	50	0.06	0.24	1
II	Crater	50	0.04	0.20	1
III	Summit	50	0.10	0.30	1
IV	Hill	50	0.09	0.30	1.41
V	Level/Ridge	50	0.11	0.33	1.41

Seamless DEM and Orthophoto

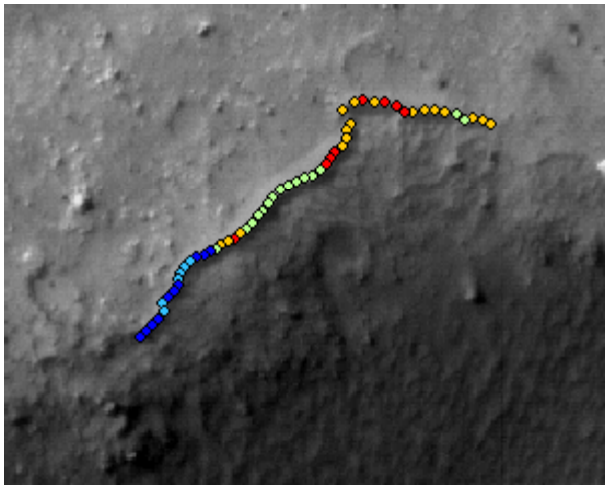


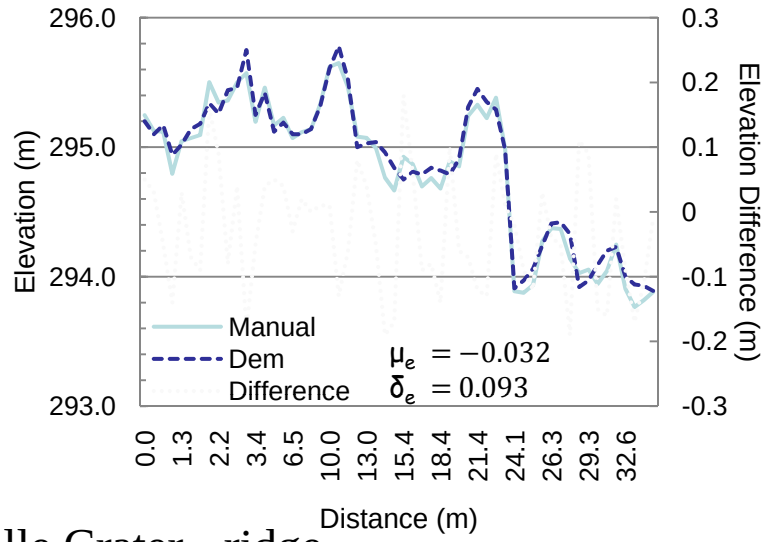
Comparison of the two DEM surfaces:

Inconsistencies between different swaths are removed by a bundle adjustment incorporating “stitch points”.

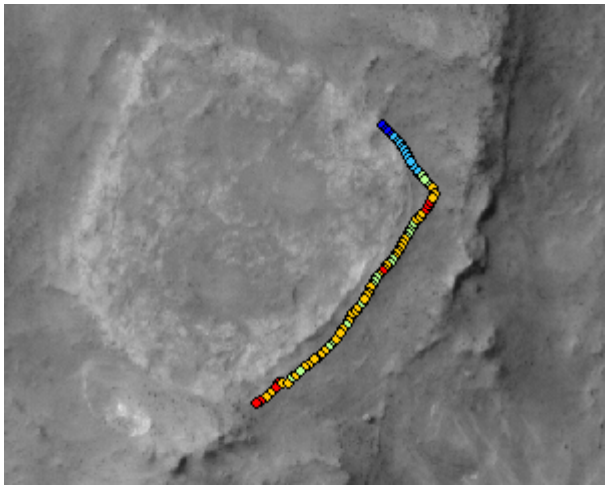


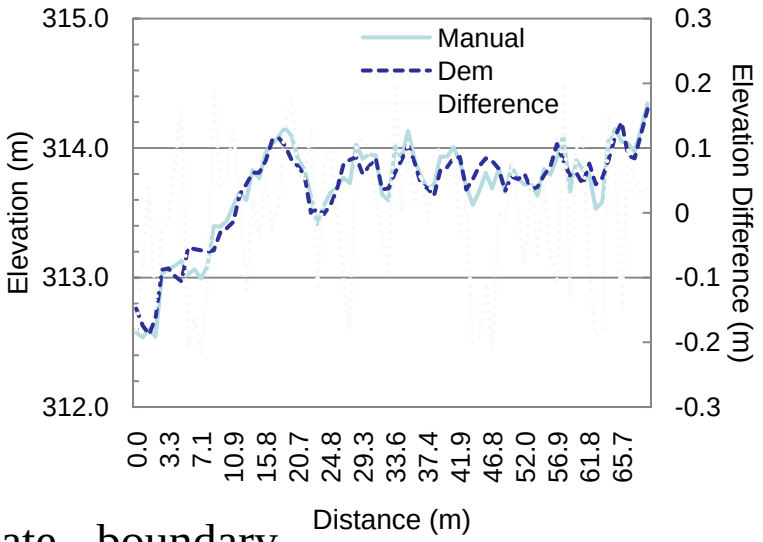
Verification of DEM Results using Manually Matched Topographic Features





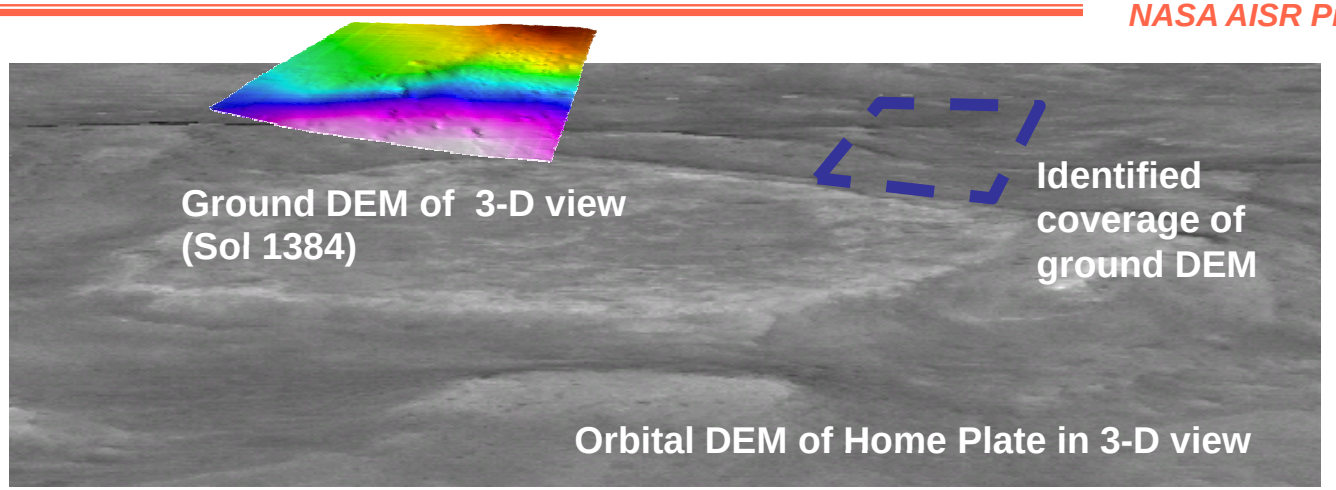
Bonneville Crater - ridge

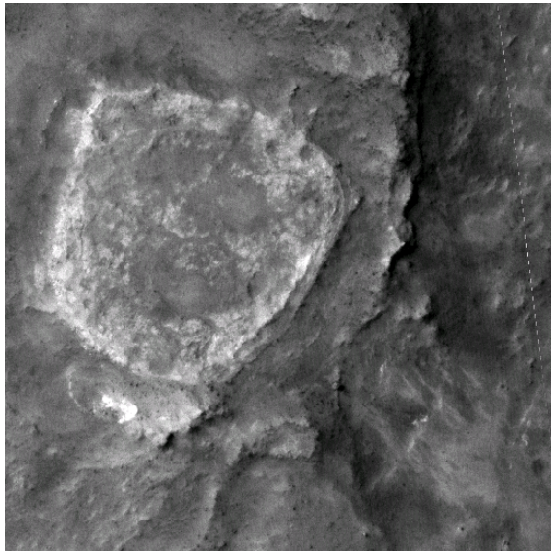




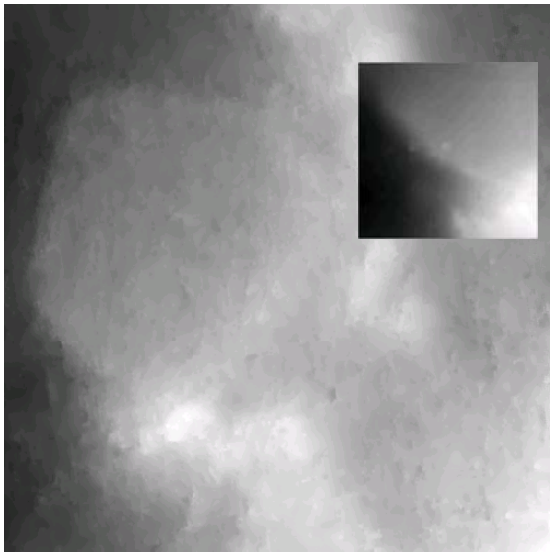
Home Plate - boundary

Terrain Matching for Rover Localization (Sol 1384)





25-cm resolution
HiRISE orthophoto



Matching result
(orbital and ground DEM)

Extraction of Rocks from Orbital Images

Find “dark” pixels
(compared to local average)

⇩

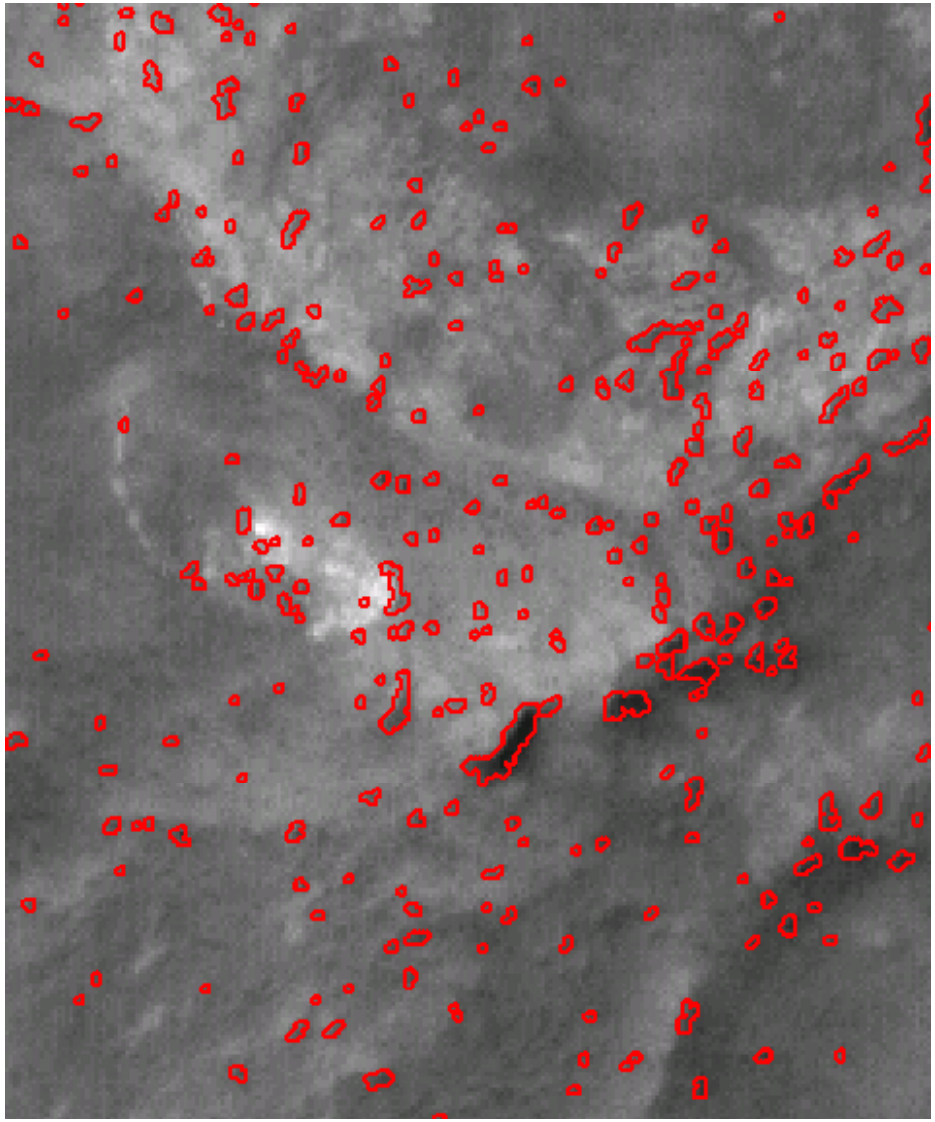
Group “dark” pixels

⇩

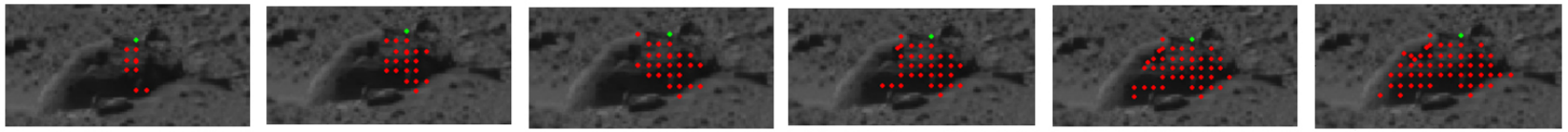
Find dark regions
(having less than 8 pixels)

⇩

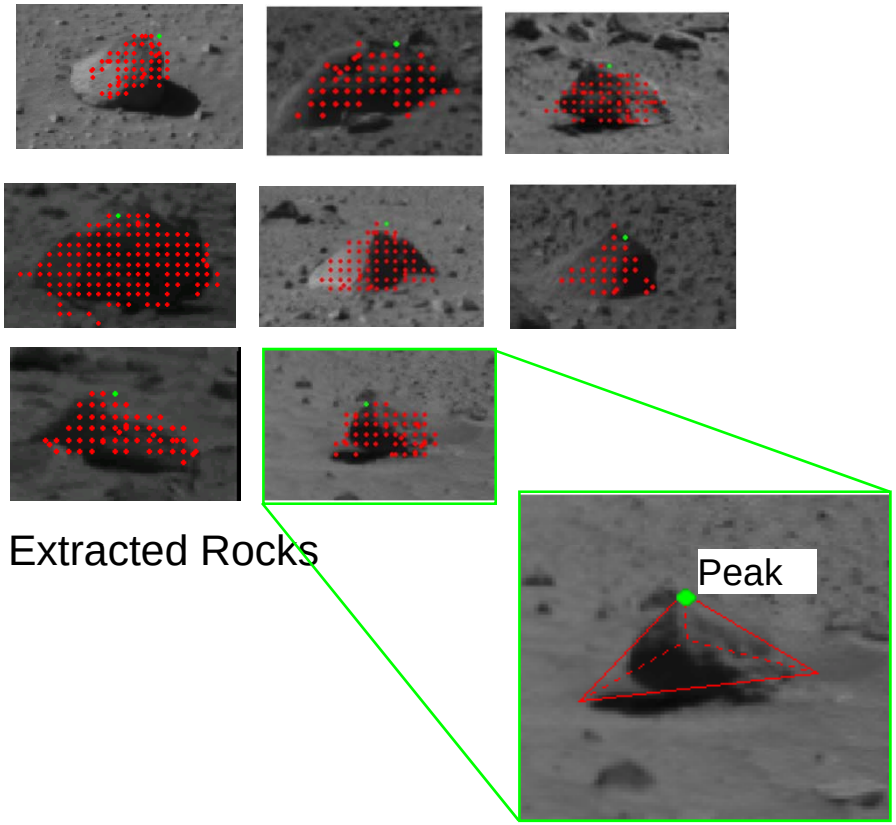
Calculate center coordinates
of these dark regions



Rock Extraction and Modeling

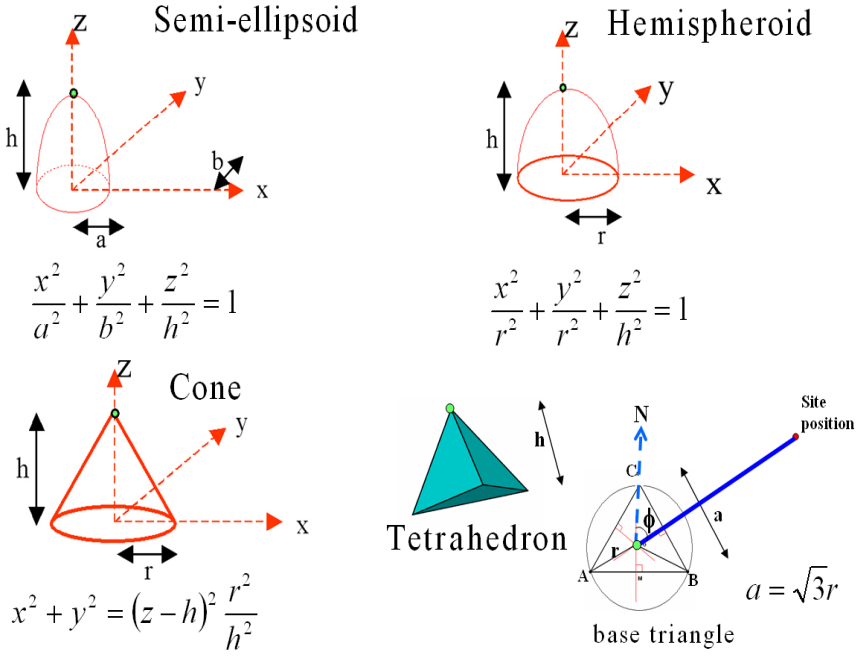


Rock Extraction Process (green points: rock peaks; red points: rock surface points)



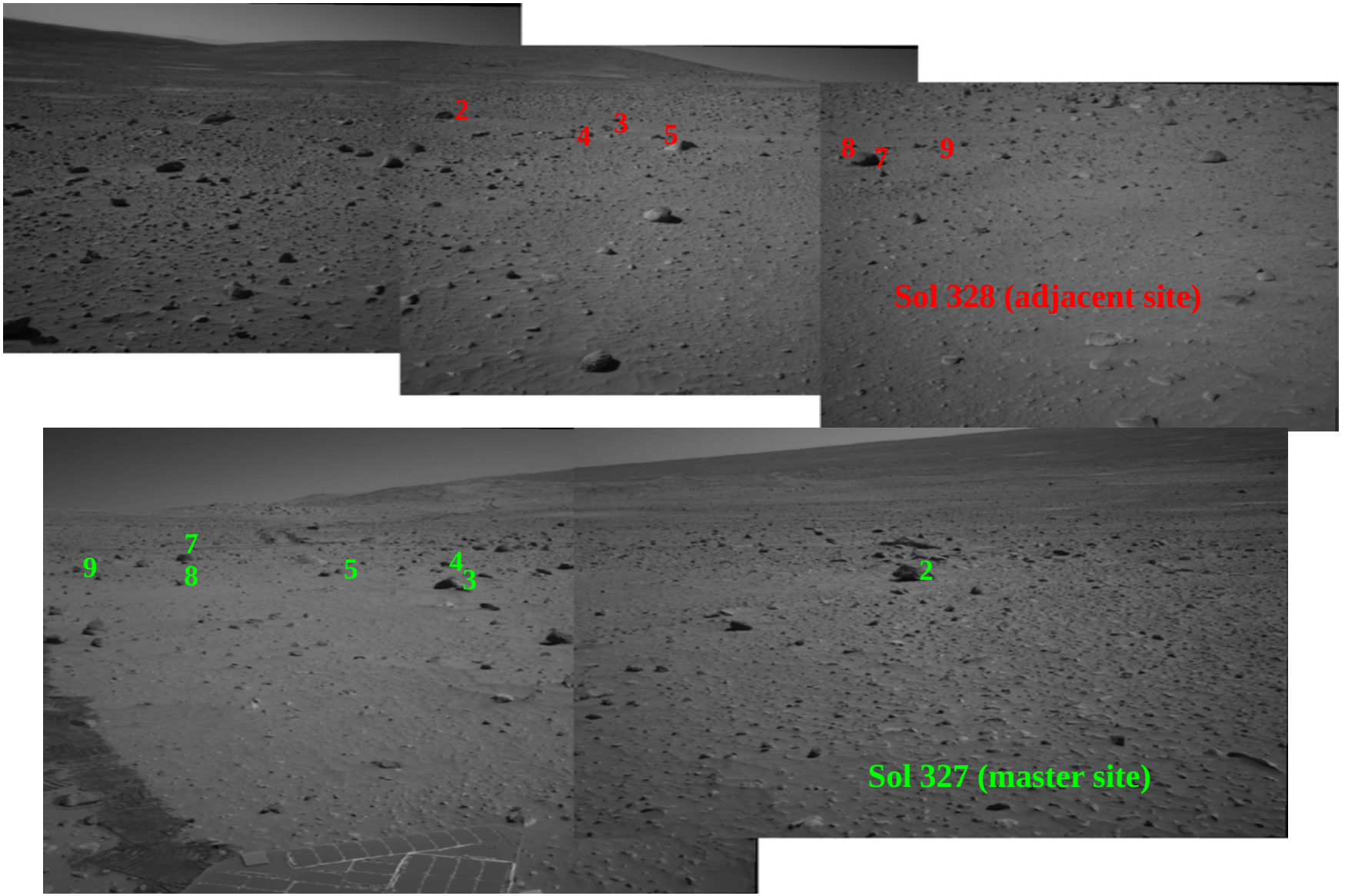
Extracted Rocks

Modeled Rock

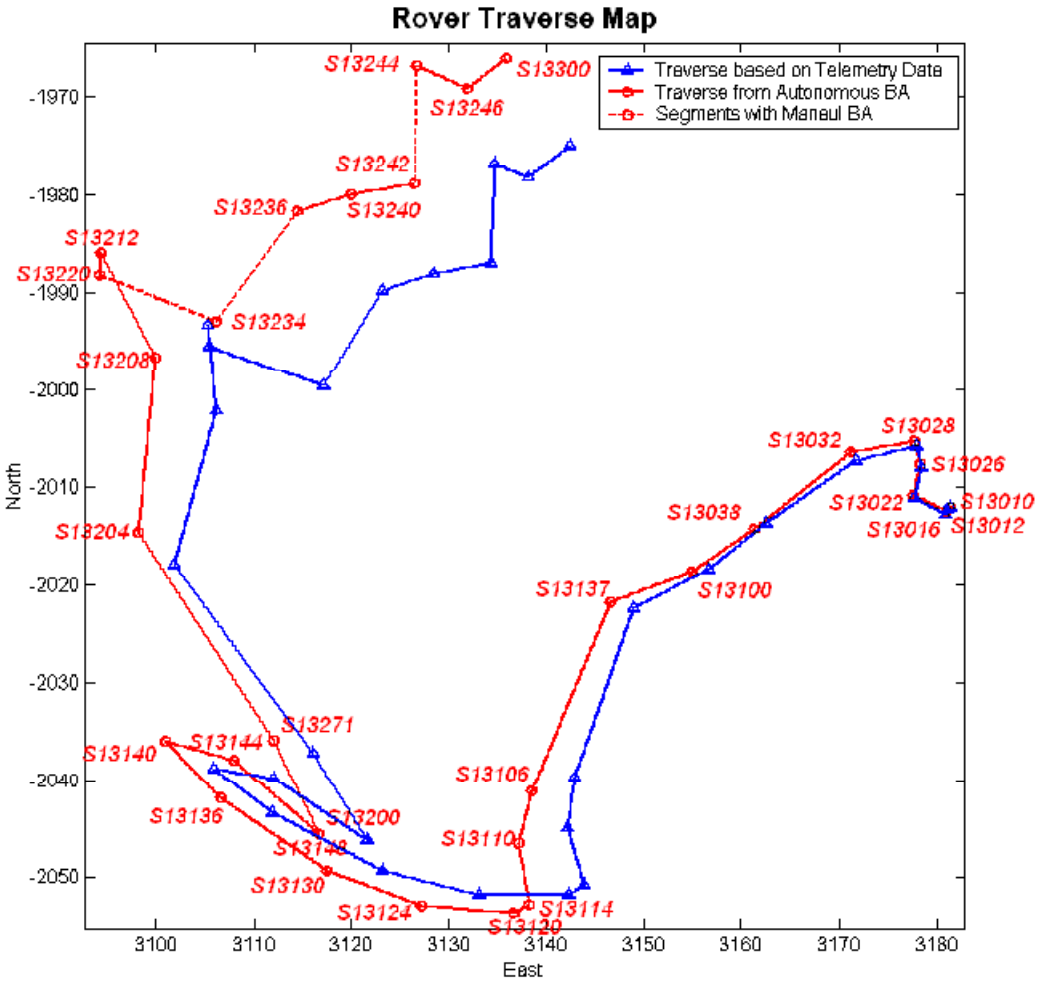


Rock Models

Automatic Cross-Site Tie-Point Selection for Bundle Adjustment



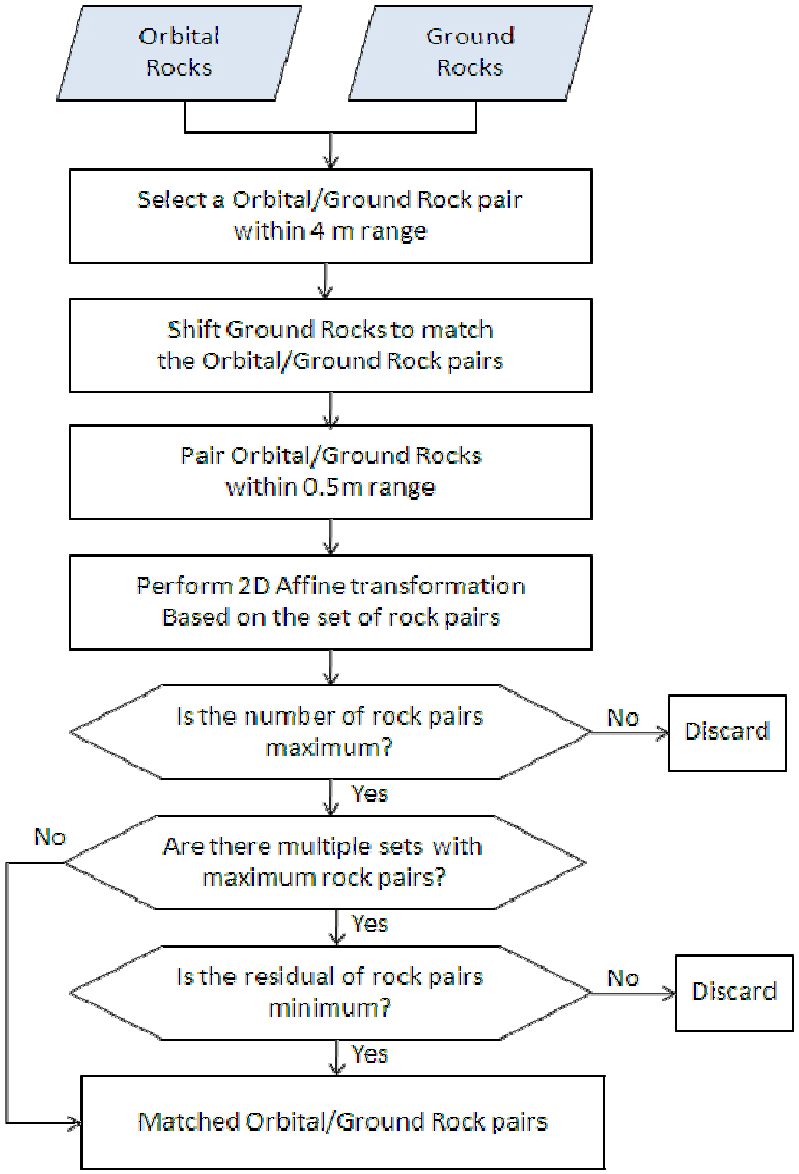
Automatic Cross-Site Tie-Point Selection for MER Operations

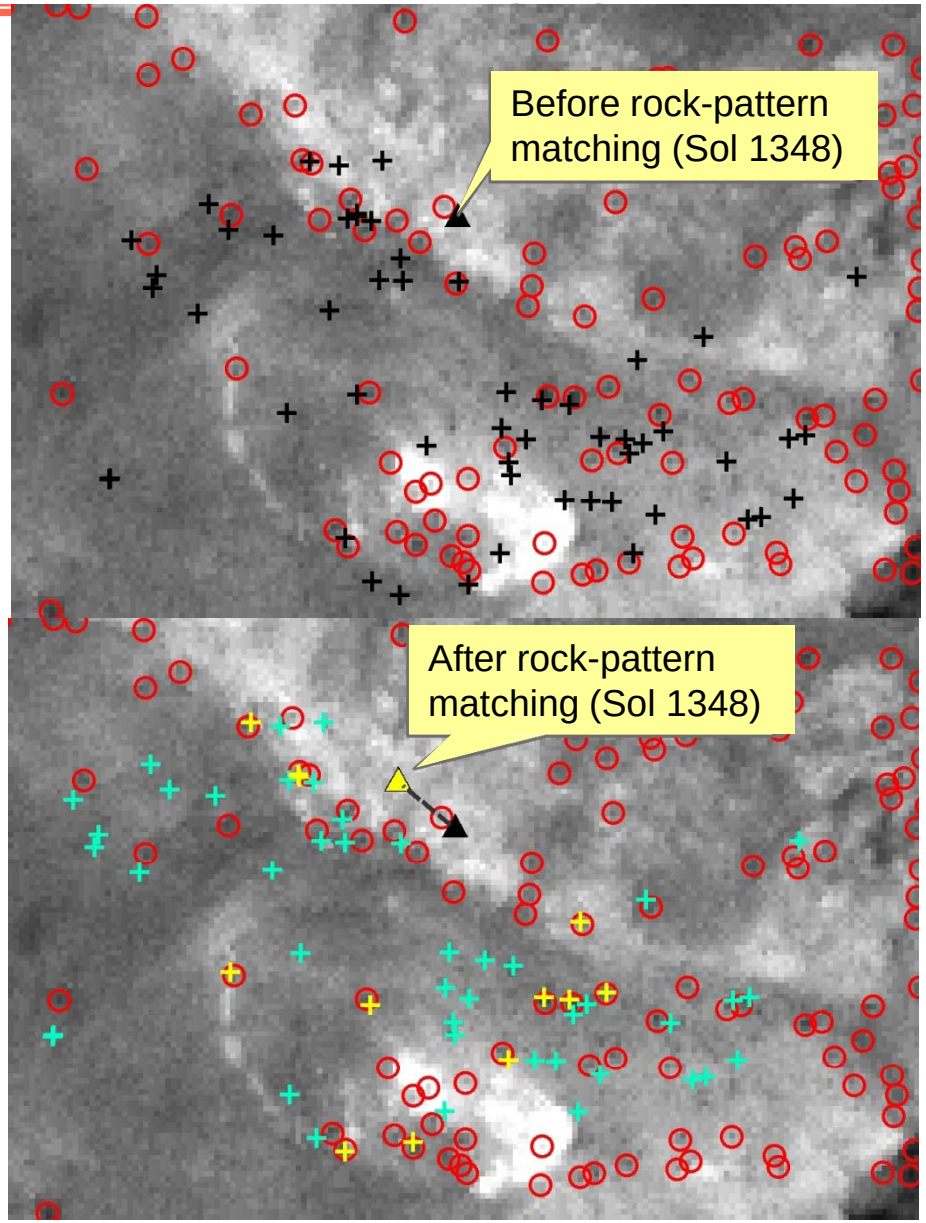


Results from Home Plate area of MER-A site

- Autonomous BA (on Earth) for Spirit rover localization to support MER operations since August 2007.
- Automatic selection of cross-site tie points at 71% of the 38 total segments.
- Position correction: 11.03 m out of a total traverse of 270.92 m.

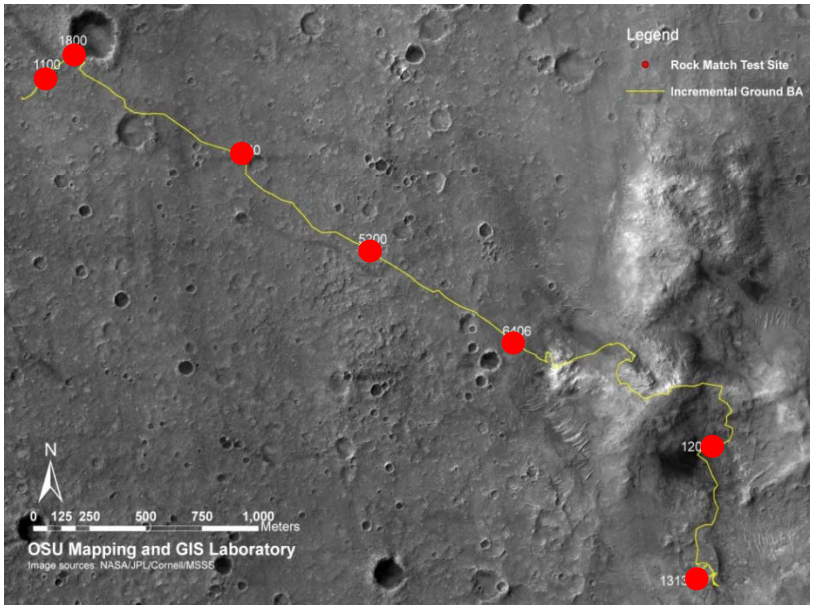
Orbital-Ground Rock-Pattern Matching





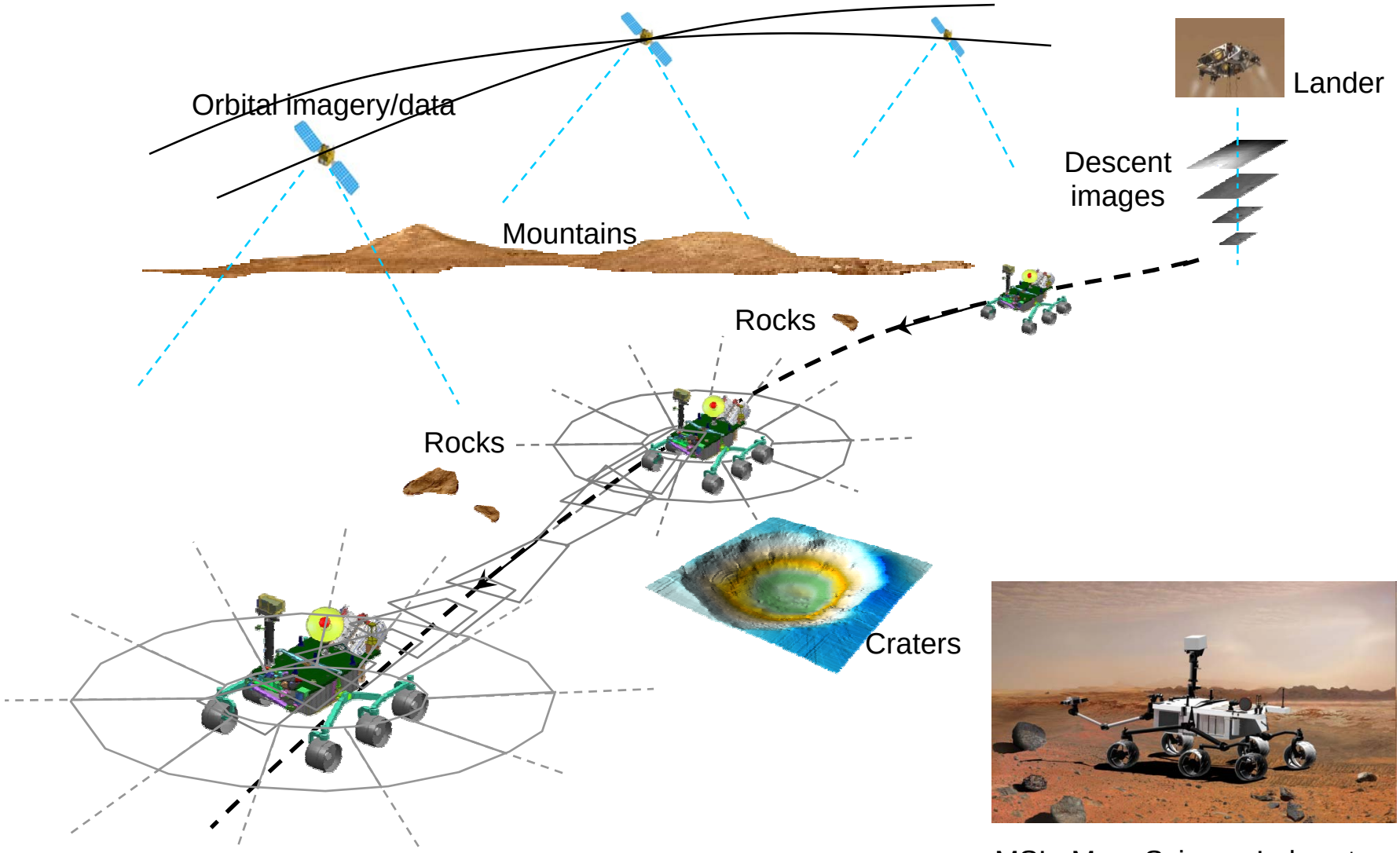
Rock Matching: Results

Sites of rock matching verification along the Spirit rover traverse



Sol	51	67	118	132	152	697	1348
Distance from the origin	159.7 m	309.6 m	1299.5 m	2037.3 m	2802.4 m	4660.2 m	5832.7 m
Number of ground rocks	20	36	23	12	14	26	54
Number of matched ground rocks	10	13	5	6	6	8	10
Percent matched	**50.0 %**	**36.1 %**	**21.7 %**	**50.0 %**	**42.9 %**	**30.8 %**	**18.5 %**

Future Work: Autonomous Rover Localization and Navigation for MSL



MSL: Mars Science Laboratory

Presentation by

Ron Li

Principal Investigator

"Integration of Orbital, Descent and Ground Imagery for Topographic Capability Analysis in Mars Landed Missions"

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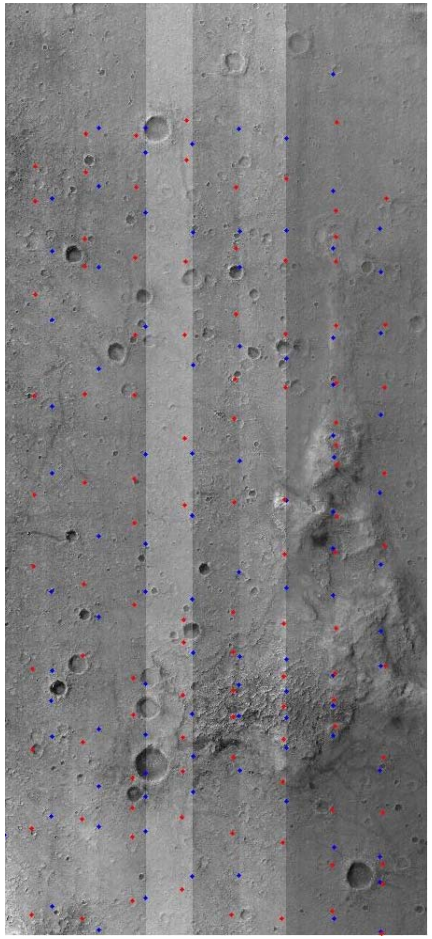
Distribution of "Stitch Points"



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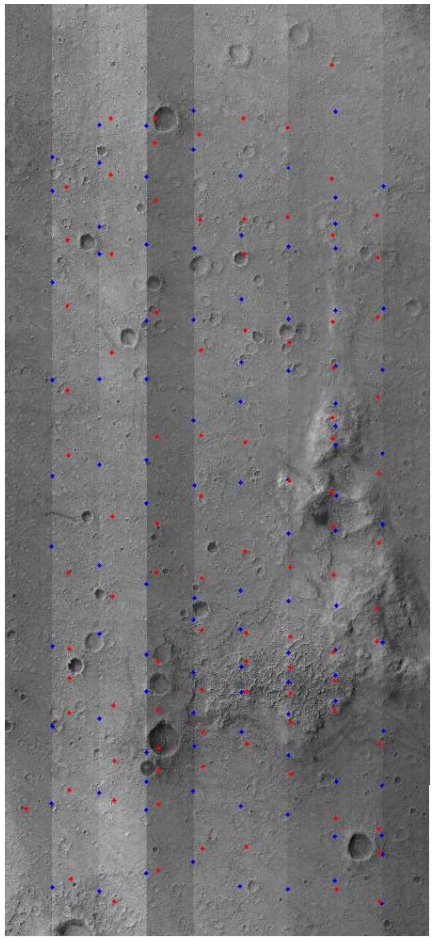
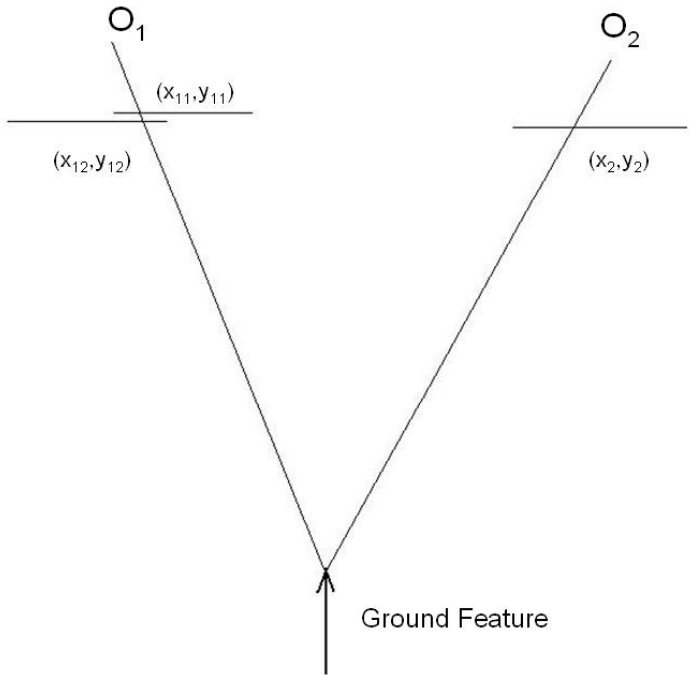
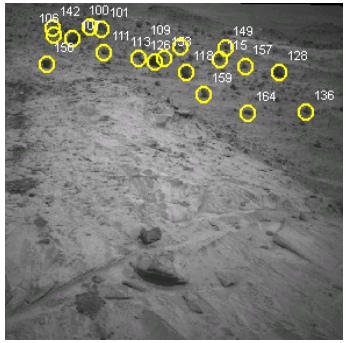


PSP_001513_1655

- Inconsistencies between different swaths of the same HiRISE image mosaic.
- "Stitch points" for resolving inconsistencies between overlapping CCDs in one orbit.



"Stitch points" selected on stereo images



3-D point cloud from intra/inter stereo matching

Is the distance from the 3-D point to the rover within a middle range?

Discard

Identify local rock peak points based on elevation

Select candidate rock points (CRP) from the area surrounding the local peak points

Is the individual CRP darker than the threshold?

Discard

Group candidate rock points based on proximity

Is the number of CRPs in the group less than 10?

Discard

The height and width of the rock within a threshold?

Discard

Rock Points

Finding Winter Haven at Von Braun