Mars Applied Information Systems Research Program

Investigators’ Workshop

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

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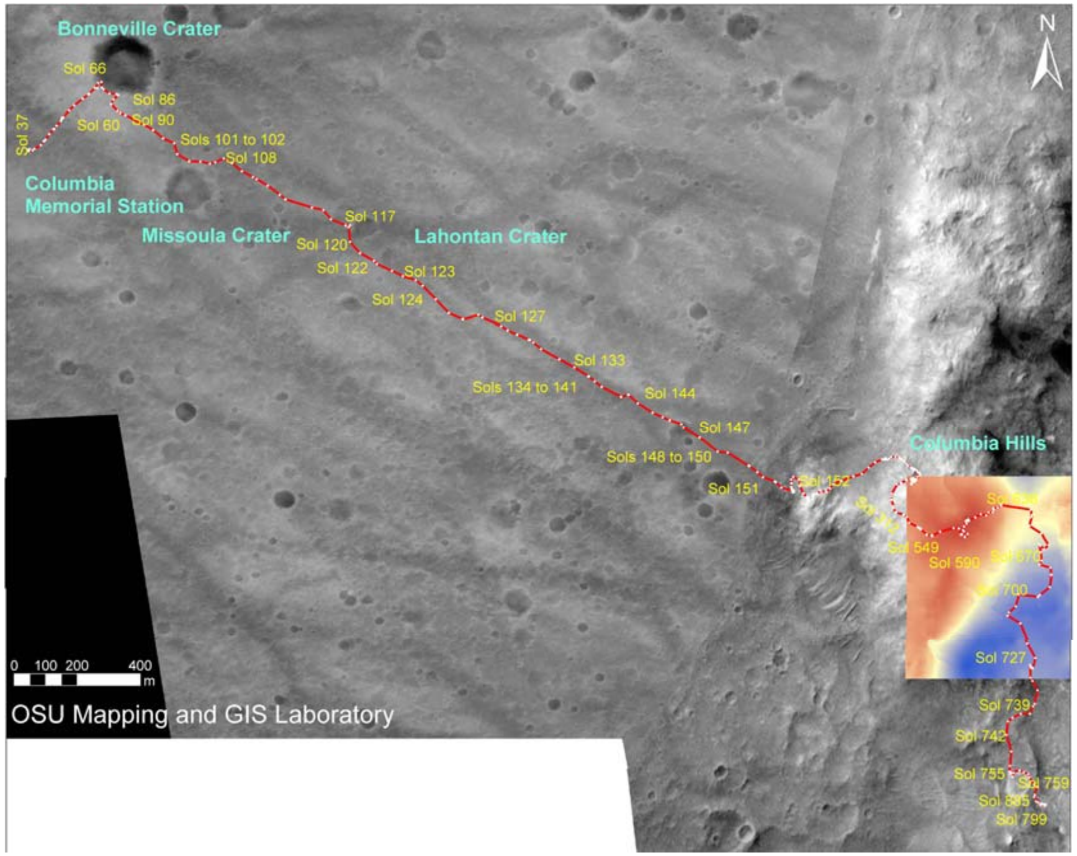
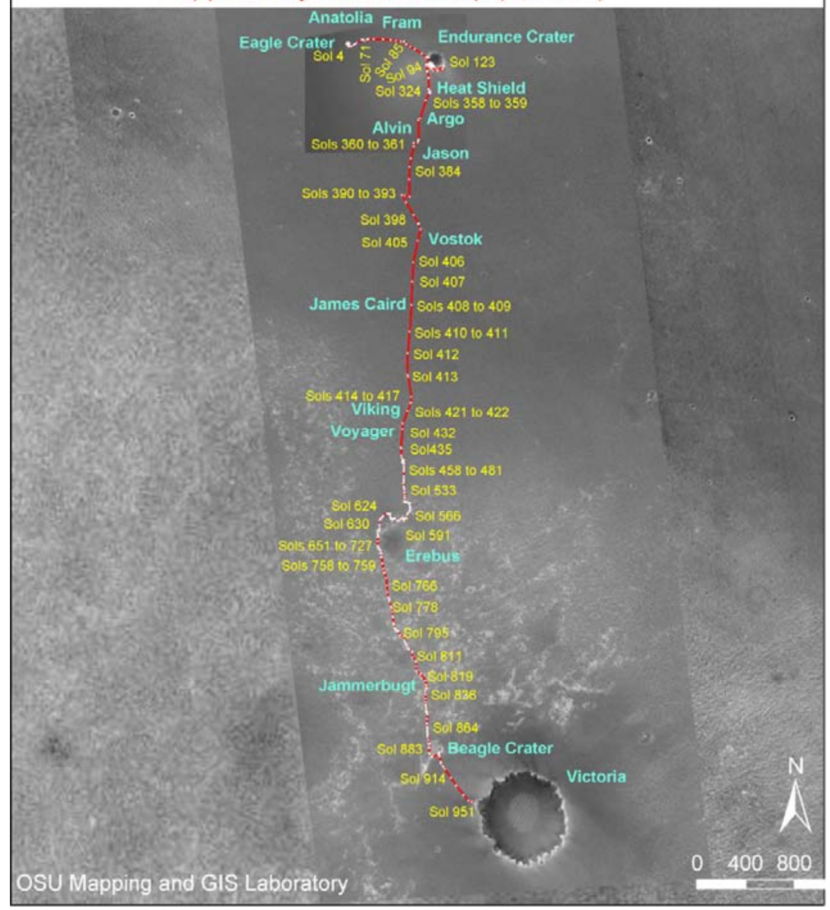
Background - Mars Exploration Rover Localization and Topographic Mapping

NASA Applied Information Systems Research Program (AISRP)

Spirit Traverse Map (Sol 885)



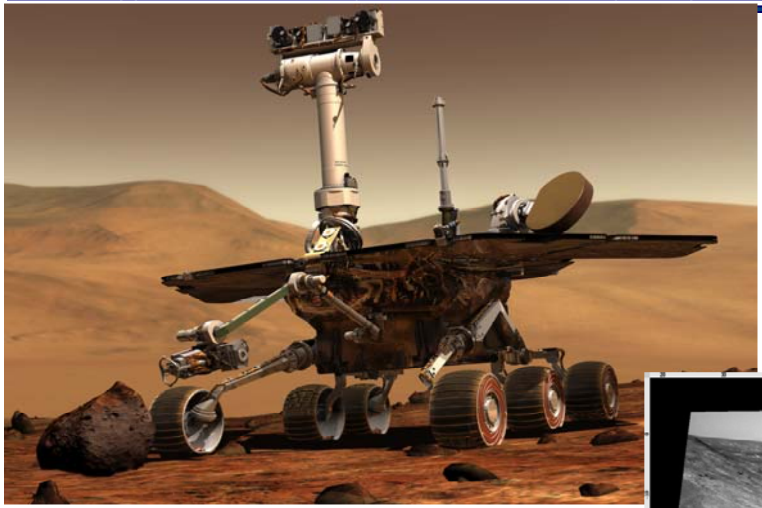
Opportunity Traverse Map (Sol 951)

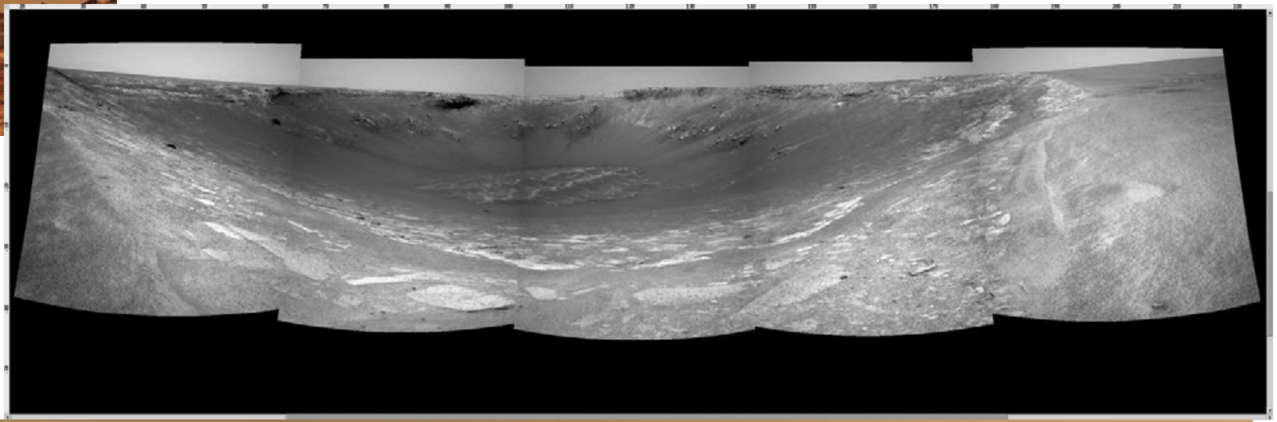


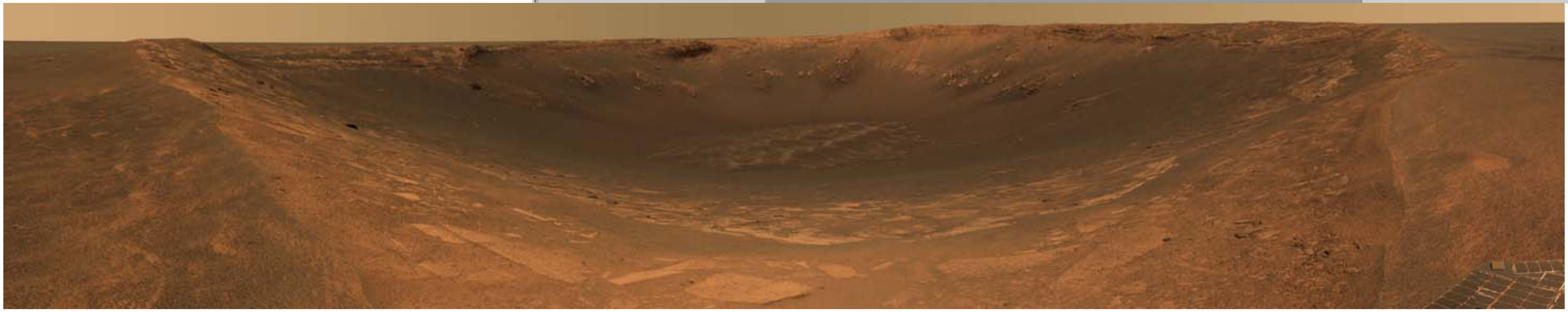
Spirit, Sol 885, overall traverse distance 6.16 km.

Opportunity, Sol 951, overall traverse distance 8.95 km.

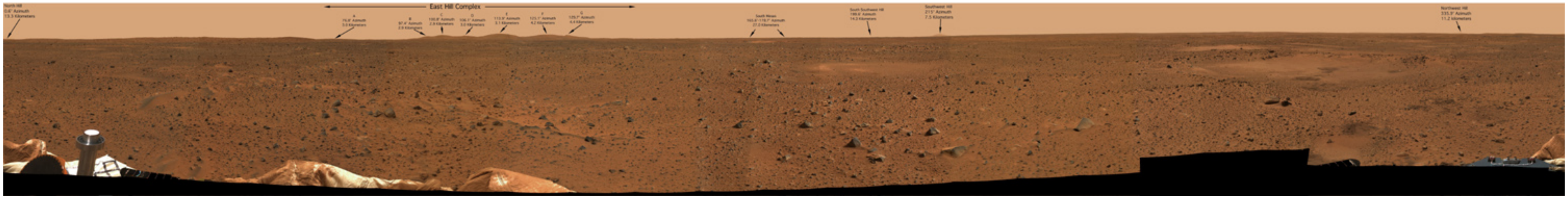
Mars Exploration Rover (MER) Navcam and Pancam Panoramas

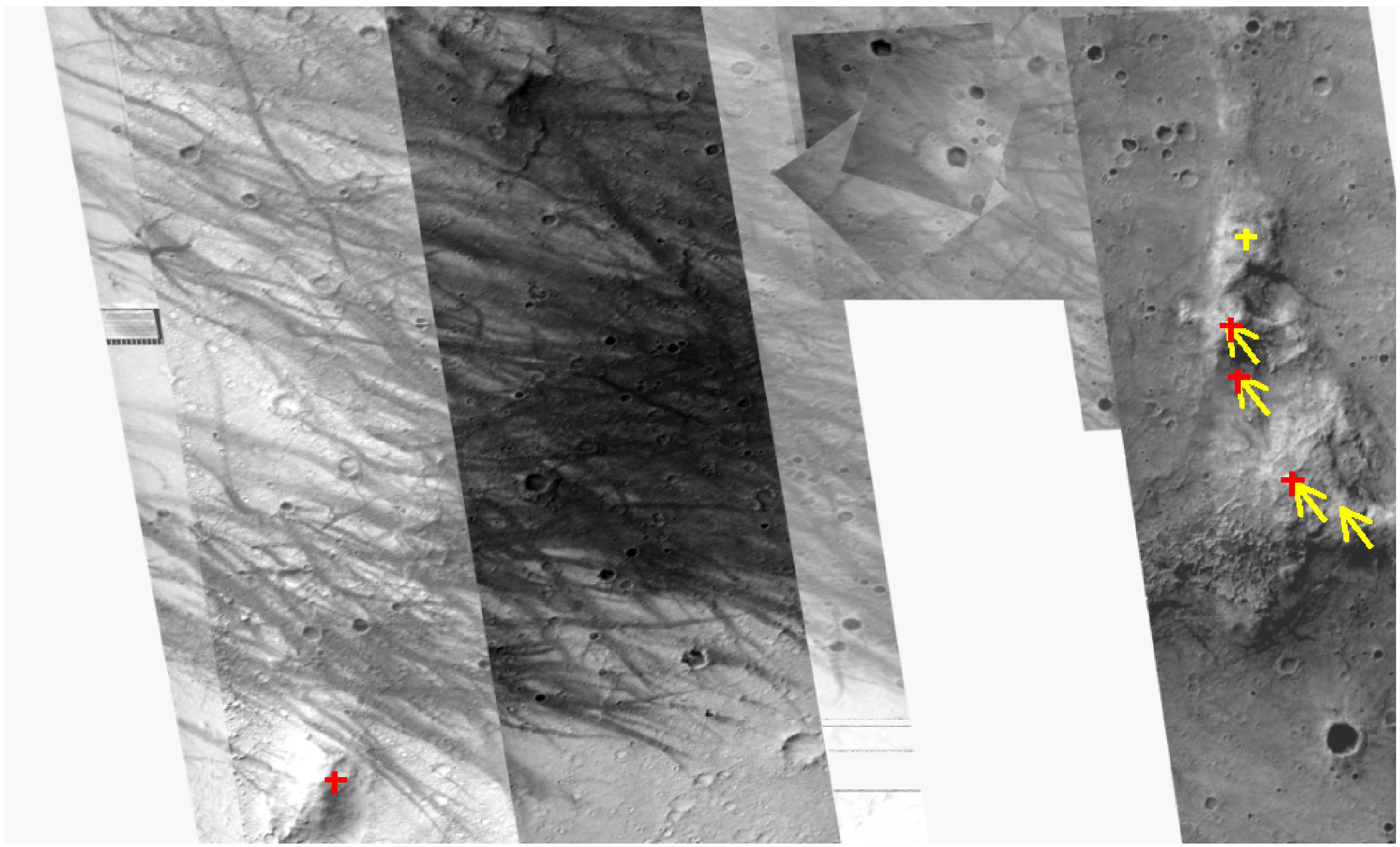




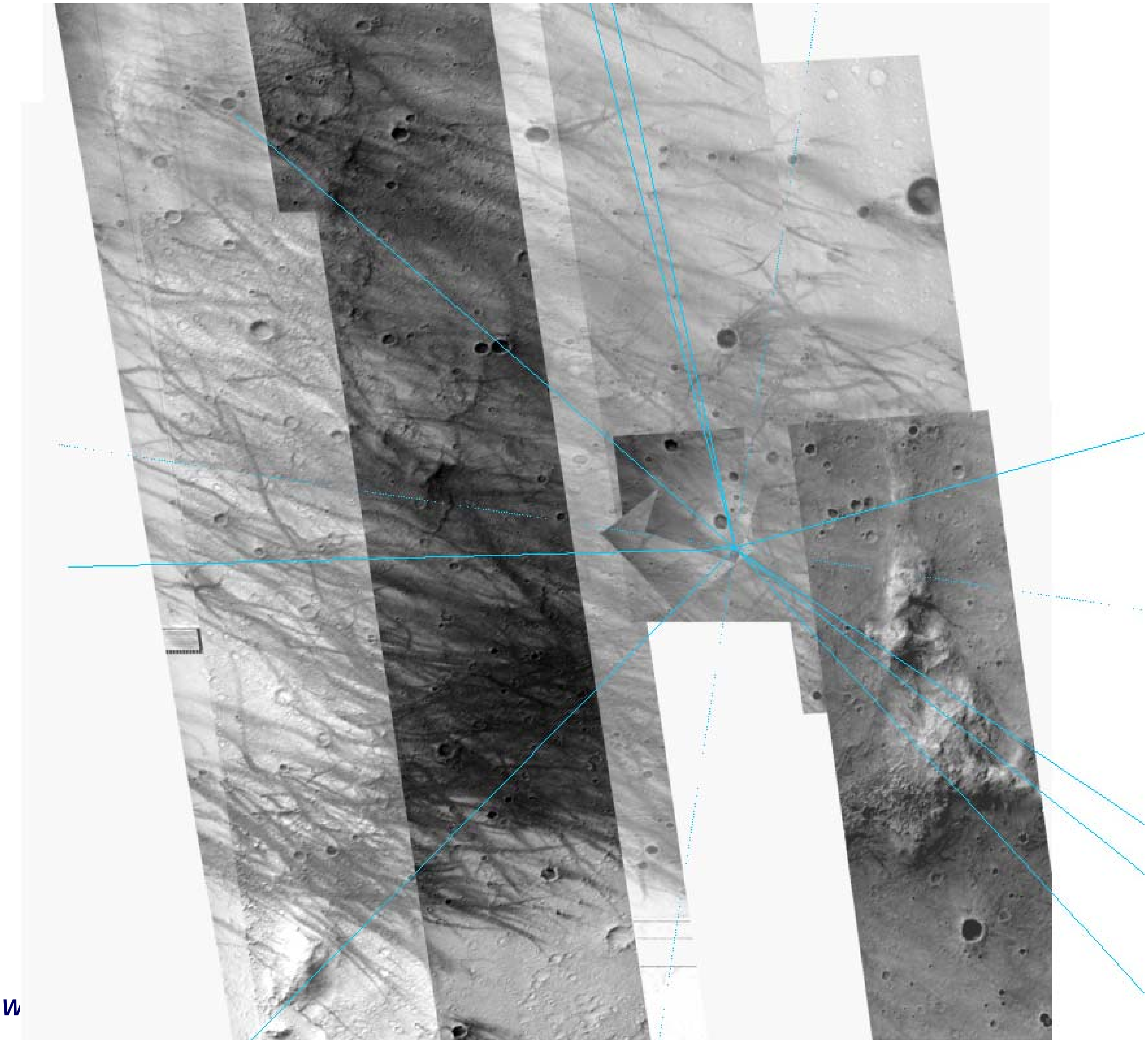


Lander Localization by Orbital-Ground Comparison



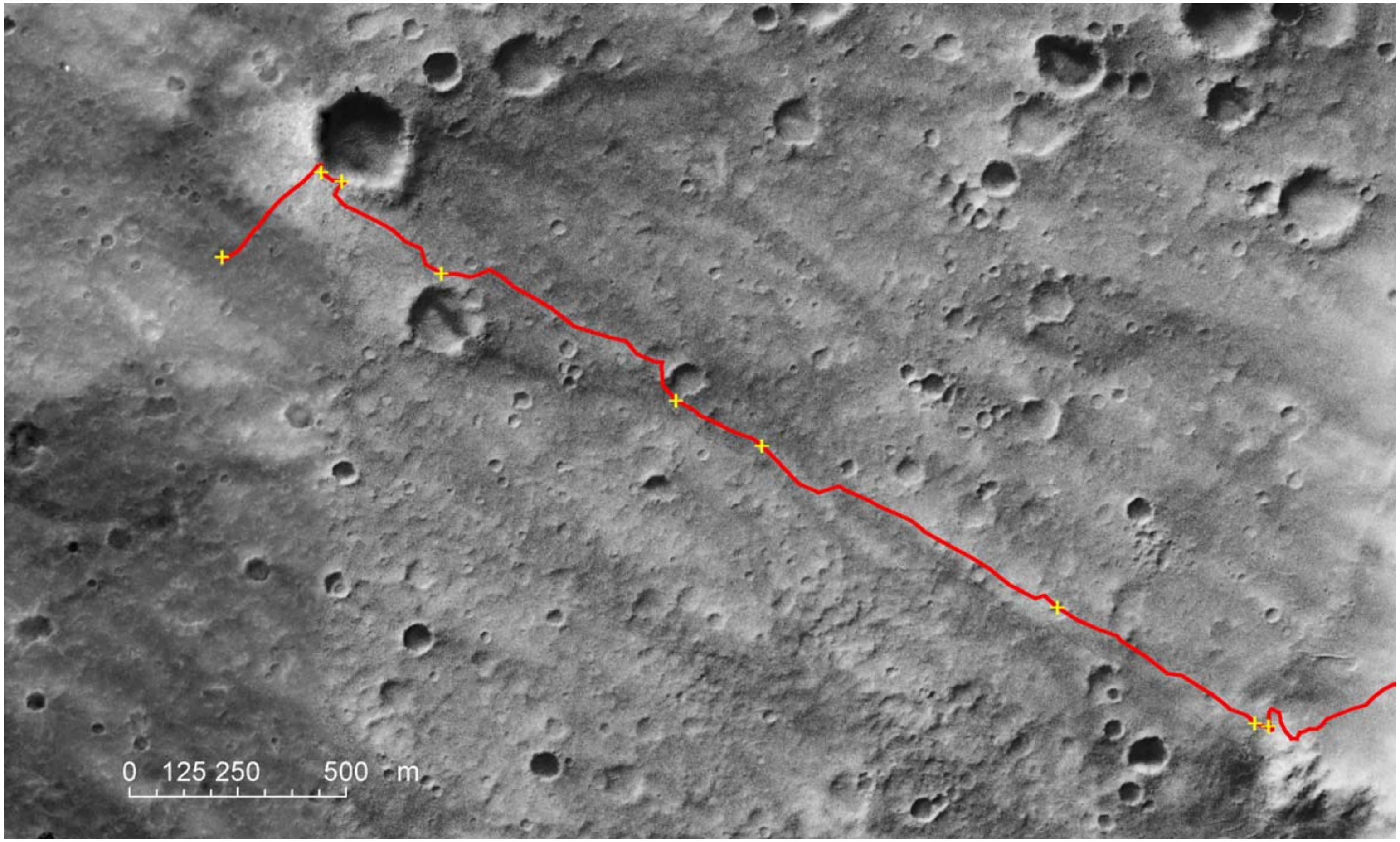


Lander Localization by Orbital-Ground Comparison



Bundle-adjusted Rover Traverse and the Actual Rover Track on the MOC NA Mosaic

1 m resolution mosaic



The shape and scale of the bundle-adjusted traverse and the track on the MOC NA mosaic match well. However, there is a relative rotation difference of 1.3 degrees.

Goals and objectives of the AISRP Project

- **Goal**
  - to develop advanced geo-information technology to integrate orbital, descent and ground imagery for topographic capability analysis in Mars landed missions.
- **Objectives**
  - Investigate how to integrate the orbital, descent and ground imagery within a true 3D integrated geometric model,
  - Estimate the precision of topographic features mapped on the Martian surface, and
  - Develop innovative applied information methods to register orbital, descent and ground imagery through distinctive landmarks, and to develop methods for automatic mapping of large terrain features such as major craters, hollows, and hills.

Relevance to NASA and Applications to NASA Missions and Programs

- **The integration of Mars orbital, descent and ground imagery has the potential to achieve the best possible accuracy for integrated Mars topographic mapping capability analysis. This research directly contributes to the high priority area of AISR program "to increase science return from data" by integrating three types of imagery and deriving topographic products and rover localization data that are far better than those that can be derived from a single type of imagery.**
- **This high accurate mapping capability will be very valuable for planetary scientists in their studies, in regional geology, crater mechanics and modeling, cross-site geological processes, etc. It will be very helpful for rover mobility analysis and rover navigation strategy development for future landed missions. The developed methods can also be used in future missions for landing-site selection.**

Overview of the Proposed Approach

- **The basis for topographic capability analysis of orbital, descent and ground imagery is rigorous modeling of the imaging geometry.**
  - Model the orbital images (MOC NA and HRSC) with a generic linear scanning sensor model (each scan line has one set of exterior orientation parameters).
  - Modeling descent images and ground images with the frame camera model (one image has one set of exterior orientation parameters).
- **Bundles of both sensor models are based on the collinearity equations:**

$$x_p = -f \frac{m_{11}(X_P - X_O) + m_{12}(Y_P - Y_O) + m_{13}(Z_P - Z_O)}{m_{31}(X_P - X_O) + m_{32}(Y_P - Y_O) + m_{33}(Z_P - Z_O)}$$

$$y_p = -f \frac{m_{21}(X_P - X_O) + m_{22}(Y_P - Y_O) + m_{23}(Z_P - Z_O)}{m_{31}(X_P - X_O) + m_{32}(Y_P - Y_O) + m_{33}(Z_P - Z_O)}$$

Overview of the Proposed Approach

- **An image network will be built by linking the orbital, descent and ground images using tie points and landmarks selected.**
- **The integrated image network connects image exposure centers, selected image tie points between overlapped images, and their corresponding ground locations. It presents a much stronger geometry than any individual type of images.**
- **We will develop an extended bundle adjustment method to adjust the positions and orientations of all three types of images in the integrated image network to achieve the best possible accuracy.**

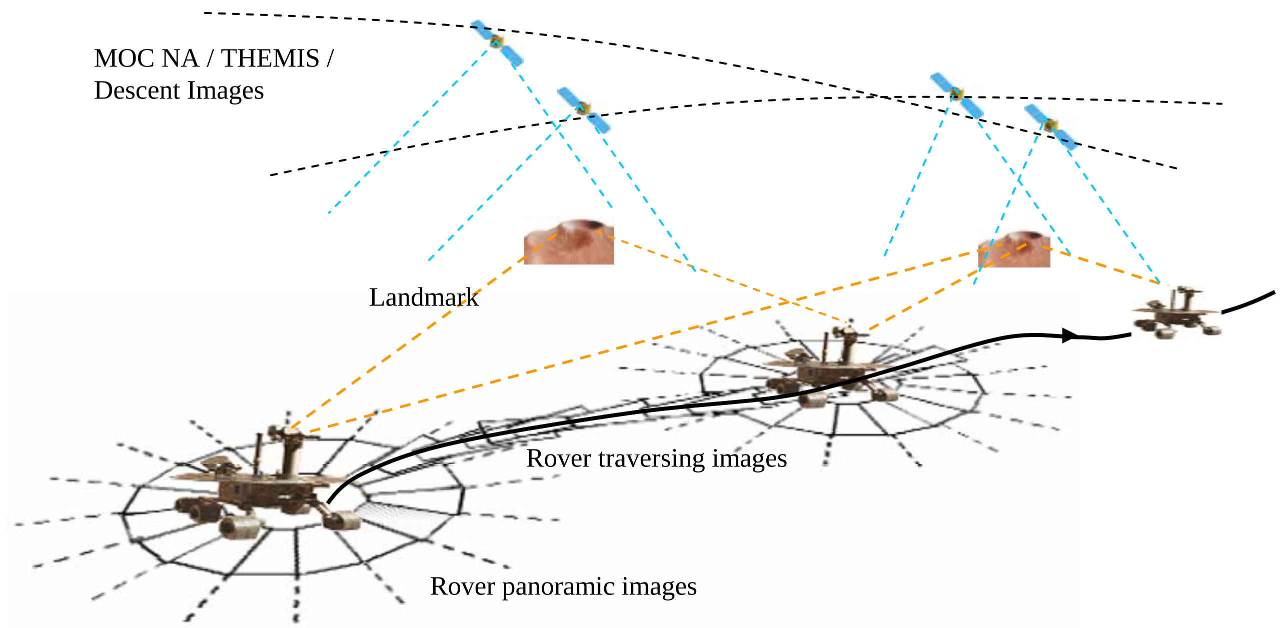
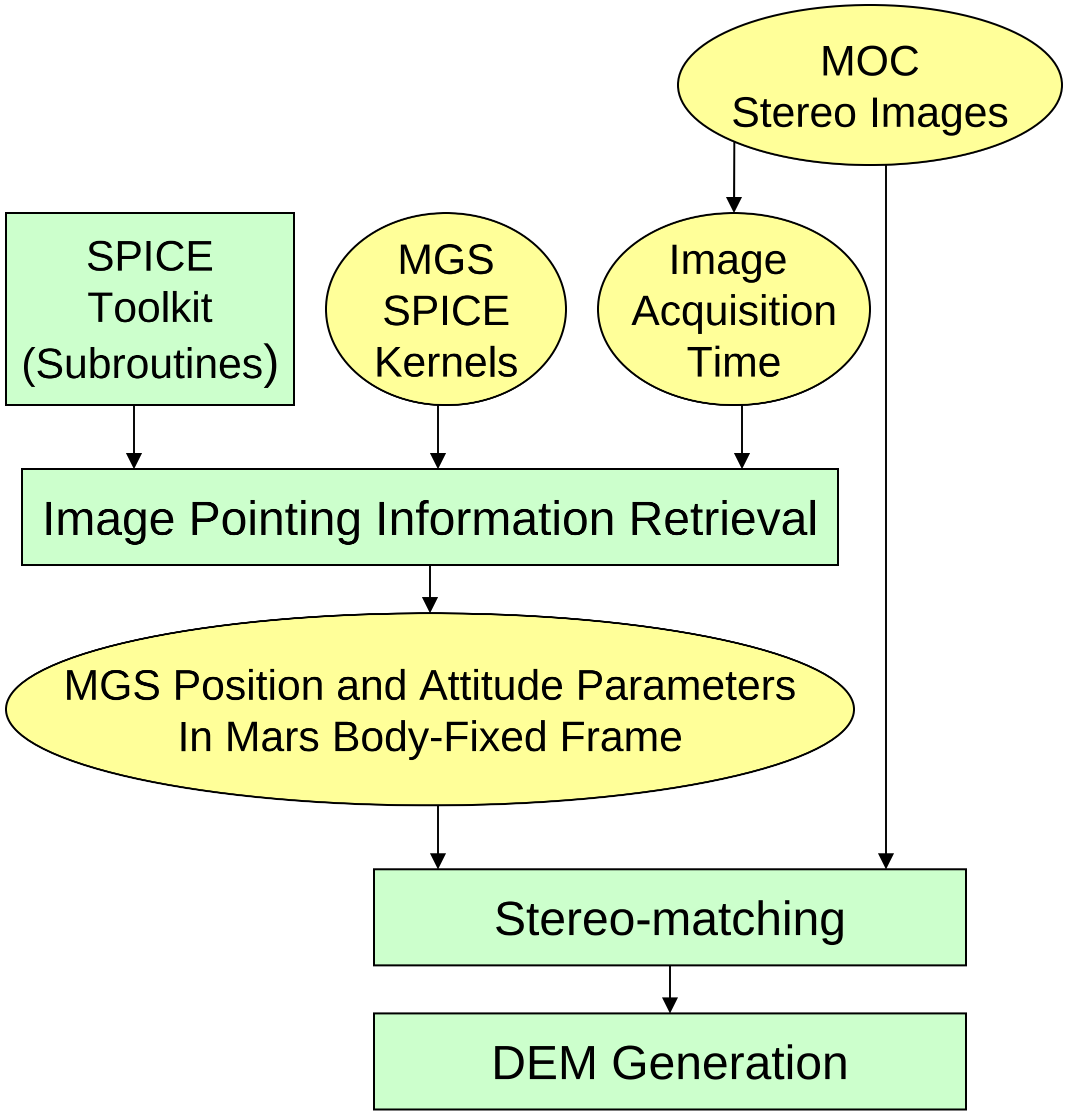


Diagram for Orbital (MOC NA) Data Processing



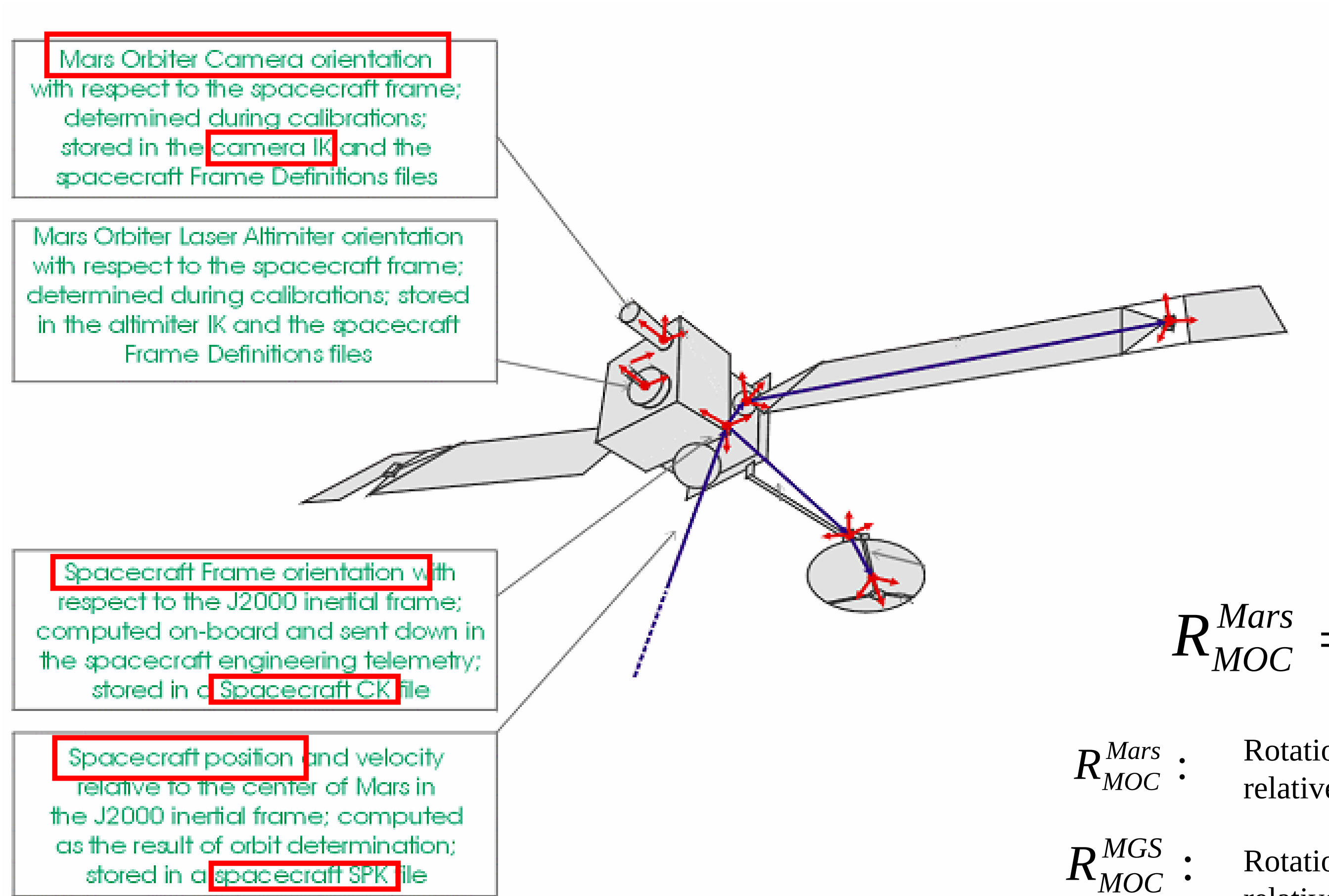
Understanding SPICE

Logical View	Physical View	Content
S Spacecraft	SPK	Space vehicle or target body trajectory (ephemeris)
P Planet	SPK, PcK	Target body size, shape and orientation
I Instrument	IK	Instrument field-of-view size, shape and orientation
C Camera-matrix	CK	Orientation of space vehicle or any articulating structure on it
E Events	EK (ESP ESQ ENB)	Events information: - Science Plan (ESP) - Sequence of events (ESQ) - Experimenter's Notebook (ENB)
	Others: FK	Reference frame specifications
	Others: LSK	Leapseconds tabulation
	Others: SCLK	Spacecraft clock coefficients
S Software	SPICE Toolkit	FORTRAN, C and IDL libraries, plus a few utilities and example programs

(blue) = time varying data (SPK, CK, EK, SCLK)

(green) = "fixed" data (PcK, IK, FK, LSK)

Applying SPICE to an Orbiter (MGS)



CK IK

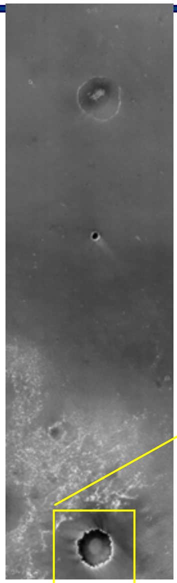
$$R_{MOC}^{Mars} = R_{MGS}^{Mars} R_{MOC}^{MGS}$$

R_{MOC}^{Mars} : Rotation matrix of MOC scan line relative to the Mars-body fixed frame

R_{MOC}^{MGS} : Rotation matrix of MOC scan line relative to the MGS

R_{MGS}^{Mars} : Rotation matrix of MGS relative to the Mars-body fixed frame

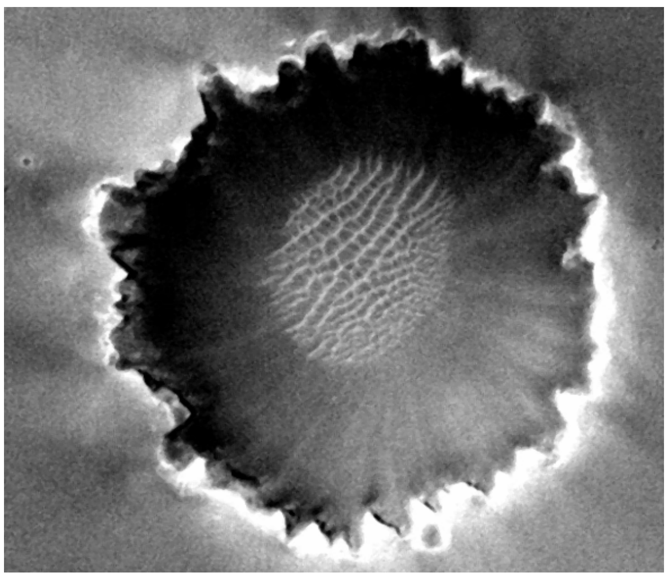
MOC NA Stereo Images Used for Victoria Crater DTM Generation



R1400021

1.77m/pixel

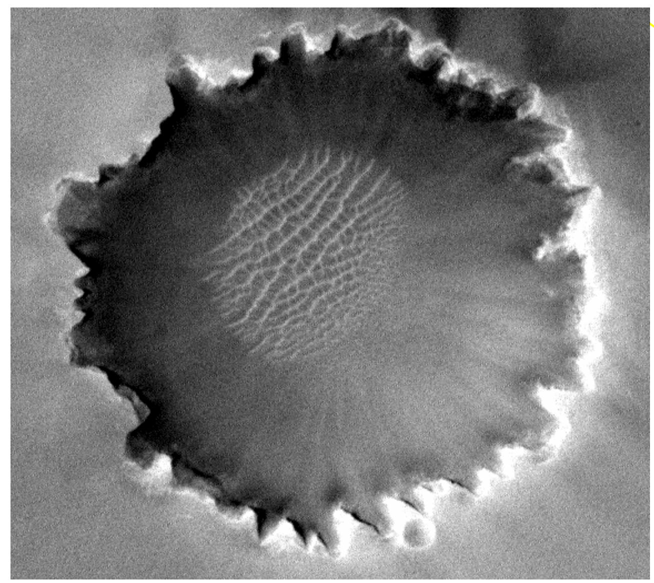
2004-02-01

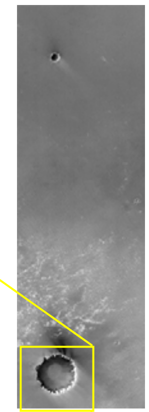


S0500863

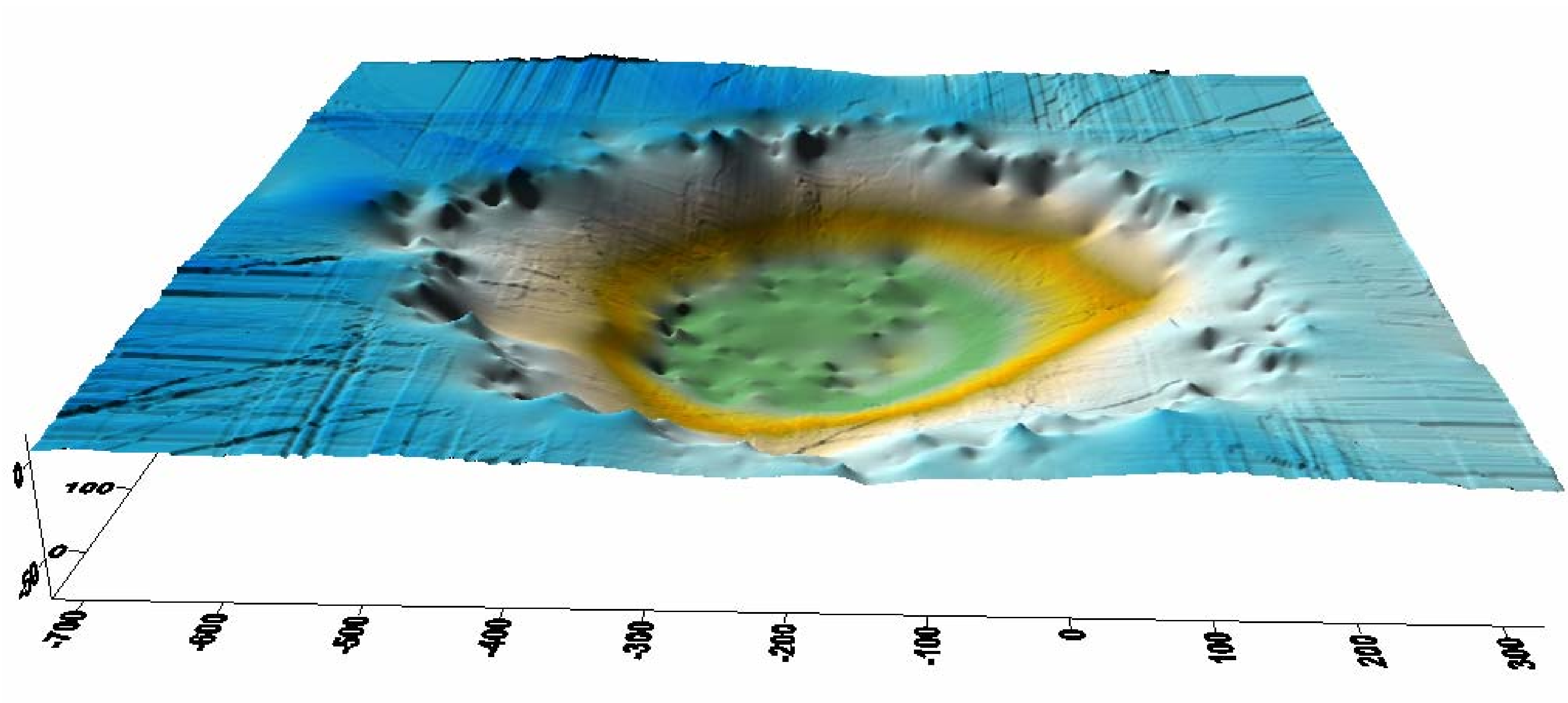
1.57m/pixel

2005-04-16

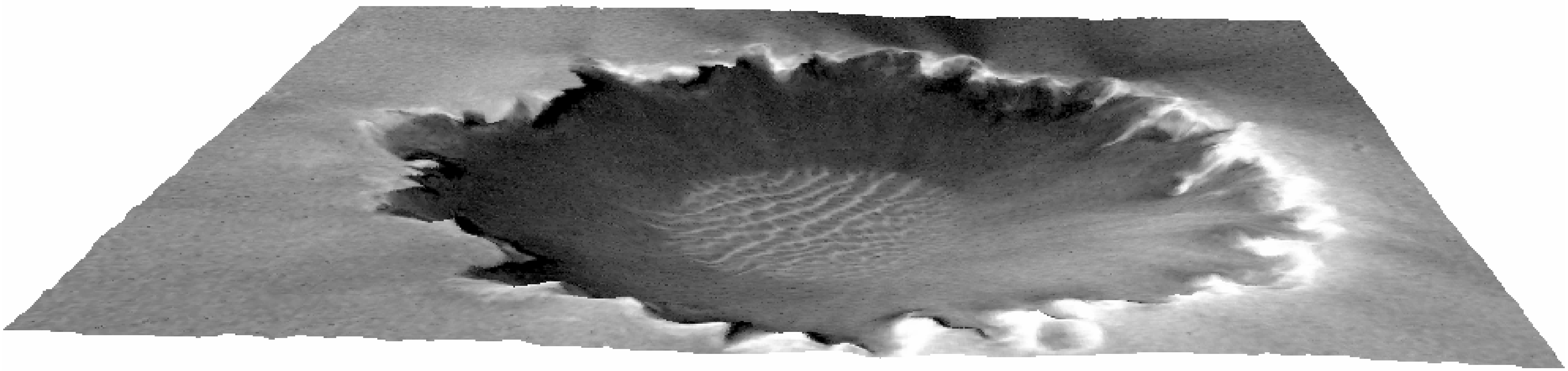




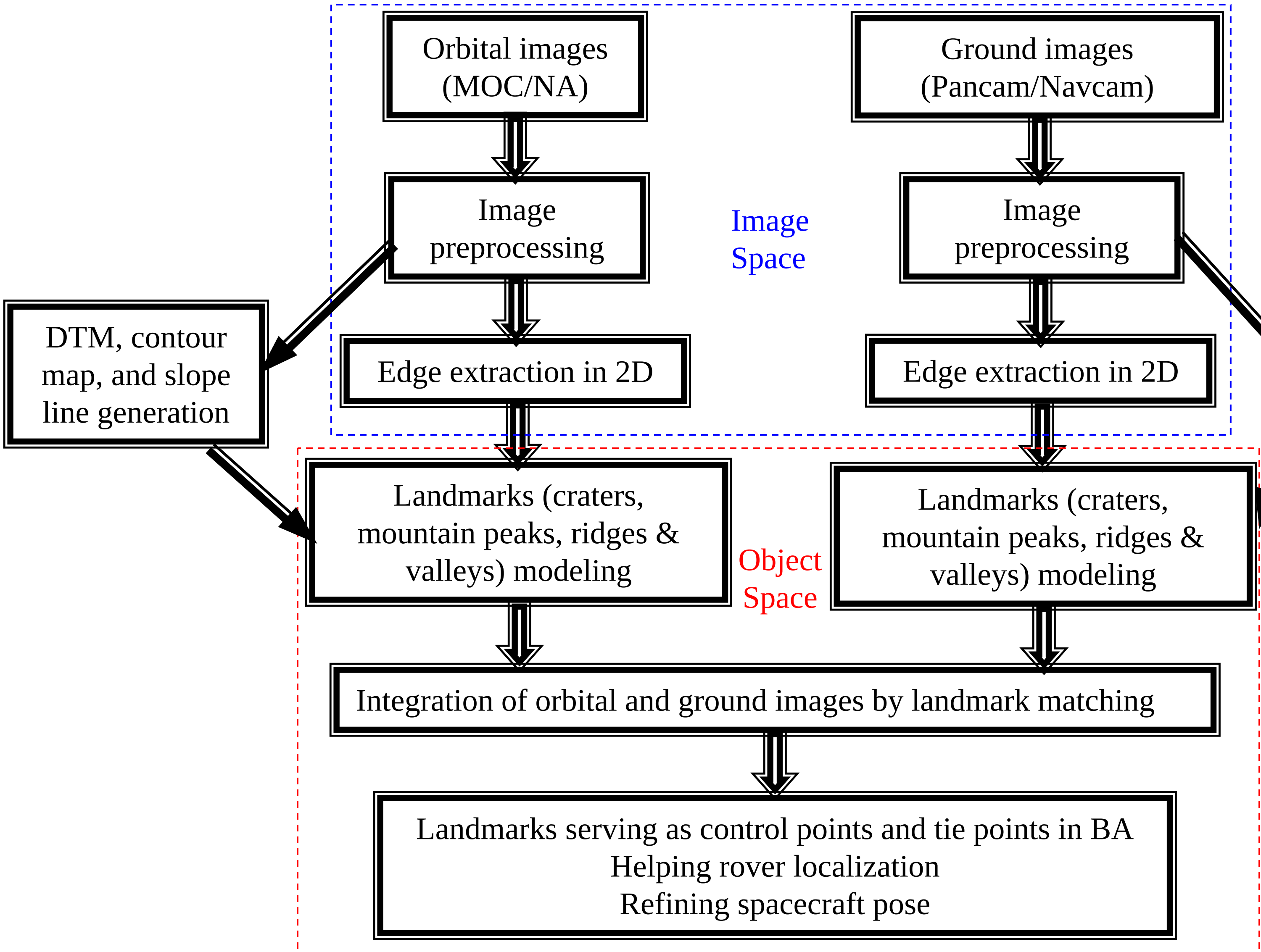
Victoria Crater DTM



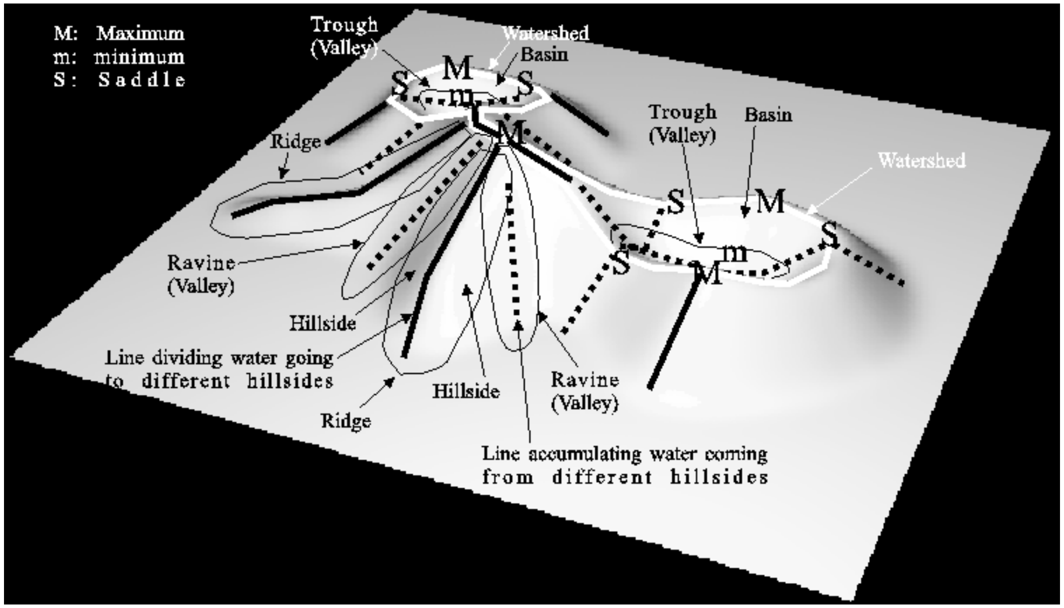
MOC Image of Victoria Crater Draped on DTM



Procedure of Orbital-Ground Integration



Landmark Definition: Mountain



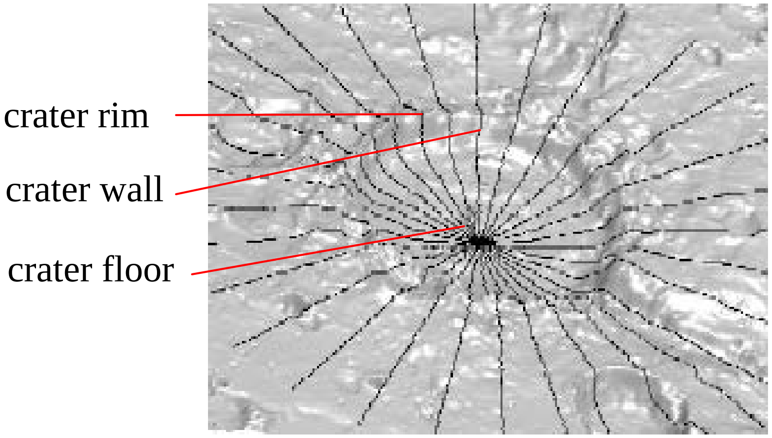
- A mountain is a landform that extends above the surrounding terrain in a limited area
  - Regions with spatial complexity
  - Areas of high relief
  - Distinct changes in terrain slope
- Shape of a mountain can be described by the combinations of features listed in the following table

***The figure and some definitions are adopted from http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/LOPEZ/node2.html and other web pages.**

Feature	Characteristics	Data structure
Peak	the summit of a mountain	points
Ridge	a geological feature with a continuous elevation crest for some distance	poly-line
Valley	a low-lying area of land, surrounded by higher areas such as mountains or hills	polygon
Watershed	a watercourse dividing a mountain into closed regions called basin districts	poly-line

Landmark Definition : Crater

- A crater is a bowl-shaped depression formed by the impact of e.g. a meteorite
  - Area within the crater rim being topographically lower than the area outside it
  - Having localized rotational symmetry
  - With different size, height, and orientation



- Shape of a crater can be described by the combinations of features listed in the following table

Feature	Characteristics	Data structure
Crater rim	the outset part of the crater, often associated with the steepest gradients in the Martian landscape	polygon (circle)
Crater wall	with slope smaller than that of the crater rim, and bigger than that of the crater floor, and having the layered nature	
Crater floor	a low-lying area of a crater	