

**LOCALIZATION, LOCALIZATION, LOCALIZATION.** T. Parker<sup>1</sup>, M. Malin<sup>2</sup>, M. Golombek<sup>1</sup>, T. Duxbury<sup>1</sup>, A. Johnson<sup>1</sup>, J. Guinn<sup>1</sup>, T. McElrath<sup>1</sup>, R. Kirk<sup>3</sup>, B. Archinal<sup>3</sup>, L. Soderblom<sup>3</sup>, R. Li, and the MER Navigation Team and Athena Science Team. <sup>1</sup>Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109, <sup>2</sup>Malin Space Science Systems, San Diego, CA 92191, <sup>3</sup>U.S. Geological Survey, Flagstaff, AZ 86001, <sup>4</sup>Ohio State University, Columbus, OH 43210.

**Introduction:** Localization of the two Mars Exploration Rovers involved three independent approaches to place the landers with respect to the surface of Mars and to refine the location of those points on the surface with the Mars control net: 1) track the spacecraft through entry, descent, and landing, then refine the final roll stop position by radio tracking and comparison to images taken during descent; 2) locate features on the horizon imaged by the two rovers and compare them to the MOC and THEMIS VIS images, and the DIMES images on the two MER landers; and 3) “check” and refine locations by acquisition of MOC 1.5 meter and 50 cm/pixel images.

**Spirit:** The navigation team determined the location of the lander by fitting direct-to-earth (DTE) two-way X-band Doppler from 01/05 02:50 to 01/08 08:15 and two passes of UHF two-way Doppler between MER-A and Mars Odyssey. As reported by the navigation team, Spirit is located in inertial space, translated to the MOLA IAU 2000 frame at:

14.571892°S  
175.47848E°

This location was reported by Joe Guinn at the Jan. 13, 2004 MER press conference. This is the location that should be used for any application that is based on inertial space (i.e., the location of the lander for Odyssey or MGS passes, any DSN application, etc.).

With respect to surface features in the present MOLA IAU 2000 cartographic reference frame, the Spirit lander is located at:

14.5692°S  
175.4729°E

This location was reported by Tim Parker at the Jan. 13, 2004 MER press conference and was derived by careful correlation of about a dozen hills and craters in both the lander panorama and the DIMES descent and MOC images (Fig 1). This is where the lander is located in any map based on the MOLA IAU 2000 cartographic reference frame. This is the location that should be used for any application that is in reference to a map or the location of the lander with respect to other surface features. These two locations are separated by about 300 m.

The Mars Global Surveyor (MGS) Mars Orbiter Camera (MOC) acquired an image of Spirit on 19 January 2004. The Spirit/Columbia Memorial Station is clearly seen as a bright feature in the image (Fig. 2), as are the parachute and backshell from which Spirit was detached during the landing on 4 January 2004. Also evident is a dark scar on the rim of a crater to the northeast of the lander; this dark marking was not pre-

sent prior to landing, and is believed to have been caused by the impact of Spirit's heatshield. The lander is white because the data received from Mars were saturated at this location--that is, the lander was so much brighter than the surrounding terrain that the camera saw it as a white object.

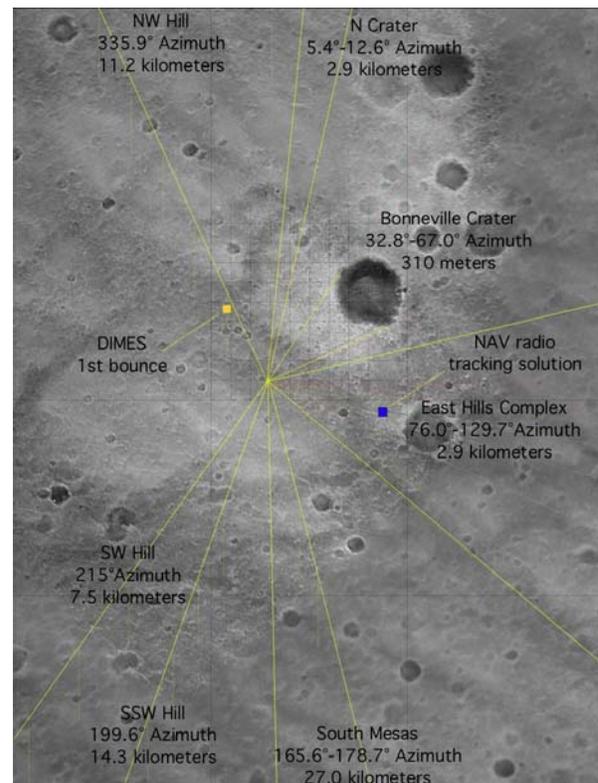


Figure 1: High resolution DIMES and MOC mosaic of area around the Spirit lander. Blue square shows the location of the navigation solution described in the text. Yellow square shows the first bounce point from the DIMES EDL reconstruction. Lines show azimuths to crater rims and hills clearly visible from the Spirit lander.

**Opportunity:** The navigation team determined the location of the Opportunity lander by fitting direct-to-earth (DTE) two-way X-band Doppler and two passes of UHF two-way Doppler between MER-B and Mars Odyssey. As reported by the navigation team, Spirit is located in inertial space, translated to the MOLA IAU 2000 frame at:

1.948282°S  
354.47417°E

This is the location (Fig 2) that should be used for any application that is based on inertial space (i.e., the location of the lander for Odyssey or MGS passes, any DSN application, etc.).

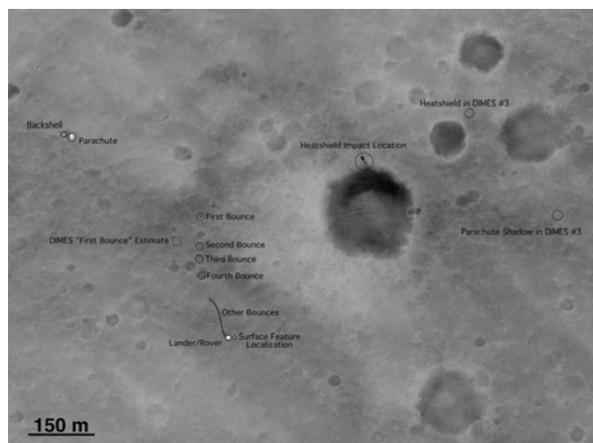


Figure 2: MOC "cPROTO" (Pitch and Roll Only Targeted Observation with planetary motion compensation) image of the Spirit landing site taken on January 19<sup>th</sup>, 16 days after the landing. Key spacecraft hardware and features are annotated and described in the text.

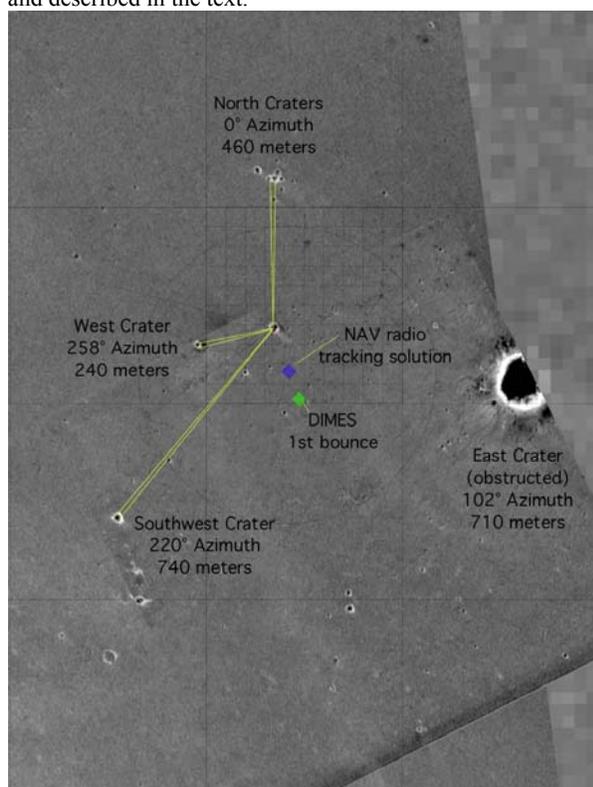


Figure 3: High resolution DIMES and MOC mosaic of area around the Opportunity lander. Blue diamond shows the location of the navigation solution described in the text. Green diamond shows the first bounce point from the DIMES EDL reconstruction. Yellow vectors show the azimuth and distance to crater rims clearly visible from the landing location of Opportunity inside the 20 m diameter crater.

Analysis of the DIMES images and EDL bounces indicates the lander bounced about 230 m north-northwest into the crater from its initial impact point (Fig. 3). This agrees with the first bounce mark into the crater from the south-southeast direction. The to-

pographic map of the crater derived from stereo images shows the best match in shape with this crater (versus other craters nearby) as well. This is where the lander is located in any map based on the MOLA IAU 2000 cartographic reference frame. This is the location that should be used for any application that is in reference to a map or the location of the lander with respect to other surface features.

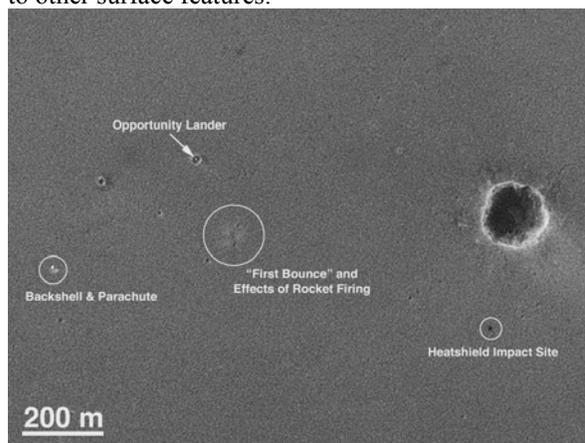


Figure 4: MOC ROTO image (Roll-Only Targeted Observation) was taken on February 1<sup>st</sup>, just 7 days after landing. Key spacecraft hardware and features are annotated and described in the text.

A MOC ROTO image (Fig 4) was acquired by rolling the MGS spacecraft approximately 22.7° off-nadir toward the west. The picture shows the location of the Opportunity lander within a 20 meter (~66 ft.) diameter crater on the dark plains of Meridiani. At the time the picture was taken, the rover had already driven off the lander. The image also shows several features related to the landing of Opportunity, which occurred on 25 January 2004. Just left of center is the location of the first bounce as Opportunity's airbags hit the ground. Just before the airbagged lander was released, rockets fired and disrupted the surface at that location. After the lander was released, the backshell and parachute drifted westward and landed at the site indicated. Meanwhile, the heatshield, which was ejected before the rockets fired and airbags inflated, impacted to the southwest of the "first bounce" location. The lander itself ended up in a nearby crater, within which the rover has been operating for just over two weeks. The image is illuminated from the left/lower left; north is up; and the 200 meter scale bar is about 656 feet long. Note that the large crater on the right-center side of the image, and the crater in which the Opportunity lander sits, both have a wind streak, somewhat brighter than the general Meridiani plains, pointing toward the lower right (southeast). These wind streaks indicate that the dominant winds blow through the region from the northwest (upper left).