LOCALIZATION AND 'CONTEXTUALIZATION' OF CURIOSITY IN GALE CRATER, AND OTHER LANDED MARS MISSIONS.

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Introduction: Localization is a process by which tactical updates are made to a mobile lander's position on a planetary surface, and is used to aid in traverse and science investigation planning and very high-resolution map compilation. "Contextualization" is hereby defined as placement of localization information into a local, regional, and global context, by accurately localizing a landed vehicle, then placing the data acquired by that lander into context with orbiter data so that its geologic context can be better characterized and understood.

Curiosity Landing Site Localization: The Curiosity landing was the first Mars mission to benefit from the selection of a science-driven descent camera (both MER rovers employed engineering descent imagers). Initial data downlinked after the landing focused on rover health and Entry-Descent-Landing (EDL) performance. Front and rear Hazcam images were also downloaded, along with a number of MARDI thumbnail images. The Hazcam images were used primarily to determine the rover's orientation by triangulation to the horizon. The landing site location was identified by the MARDI PI (Malin) based on the MARDI thumbnails on Sol 1. By Sol 3, the first 360° Navcam panorama had been downlinked, and the location of Bradbury Landing was determined to be at -4.589467° latitude, 137.441633° longitude (MOLA 2000, E longitude), based on a controlled photomosaic of CTX and HiRISE images compiled prior to EDL [1].

MARDI EDL images are being compiled into two mosaics that will provide color coverage of the landing site and science target regions imaged during EDL. These mosaics will be incorporated into the landing site base map [1] in two ways. 1) All images prior to ~#490 are lower in spatial resolution than HiRISE. This mosaic will be georeferenced to the HiRISE base map and used to colorize the HiRISE data; 2) All images after ~#490 are higher in spatial resolution than the HiRISE base map and will be georeferenced to and overlain onto the HiRISE, with each successively higher resolution MARDI image over the previous image. The result will be georeferenced to the HiRISE base mosaic.

Fig 1: Portion of mosaic of MARDI EDL images. MARDI imaged the landing site and science target regions in color.

When is localization done?

After each drive for which Navcam stereo data has been acquired post-drive and terrain meshes have been processed and incorporated into MSLICE (Curiosity) or Maestro (Opportunity) as orthographic (overhead) projections. In most cases, these updates are available in time for planning the next sol's activities.

The Localization Scientists (Parker and Calef) maintain a location map of the entire Curiosity traverse from Bradbury Landing to the current location. Parker also maintains a similar map of Opportunity's traverse across Meridiani Planum.

"Contextualization" of Curiosity and other lander observations: The traverse maps for Curiosity, Opportunity, and Spirit, are the first step in placing each vehicle in a local and regional geologic context. During the Viking and Pathfinder missions, the highest resolution images available to the science teams were acquired by the Viking Orbiters during the late 70s and early 80s. MOC and Themis VIS was available for landing site selection for the MER rovers, and HiRISE images became available for planning during the third year of the MER mission. HiRISE images were also available for final site selection and localization of Phoenix. HiRISE mosaics were acquired beginning well in advance of the MSL landing, and have been used for daily science planning since landing.

The "resolution gap" between orbiter and ground-based images available during surface operations is much smaller for Curiosity, MER, and Phoenix than it was for Pathfinder and Viking Landers 1 and 2. Yet, it is still desirable to "bridge" that gap by placing the ground panoramas and DEMs into context with the orbiter images and DEMs now available. This work involves georeferencing orthorectified Navcam, Mastcam, and Pancam panoramas and DEMs (MSL and MER), which can be produced at centimeter-scale postings, to HiRISE orthorectified images and DEMs (1 meter-postings). A perspective view of a Curiosity Navcam panorama and DEM with 1cm-posting to HiRISE image and DEM with 1m-posting is shown in Fig 2. Preliminary results suggest that Navcam-based DEMs are reliable to a distance of about 50 meters for Curiosity and 20-30 meters for Opportunity and Spirit. It should be noted that the limit isn't due to image resolution, but to the typically-shallow viewing angle. When images are taken from a topographic vantage point, the viewing geometry will be more favorable for DEM generation using close range photogrammetry.

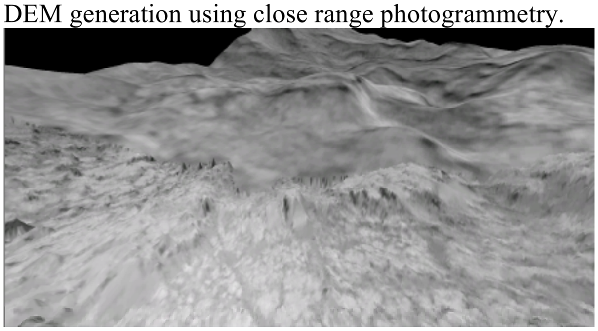

Fig 2: Perspective view of Curiosity Navcam panorama and DEM georeferenced to HiRISE image and DEM. Note individual rocks and small ledges are resolved at 1cm-posting.

As of this writing, work is under way to generate similar DEMs from Mastcam stereo observations (both from single-pointing L-R stereo and long baseline stereo).

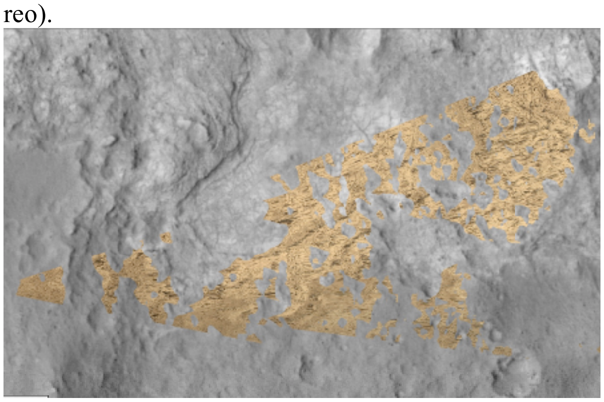

Figure 3: Mastcam 100mm pan of Glenelg projected onto HiRISE DEM, with additional georeferencing in ArcMap.

Another method of "contextualizing" ground-based observations is to project monoscopic panoramas onto the HiRISE 1 m post DEM (Navcam, Mastcam, and Pancam) Fig 3 shows a portion of a Mastcam 100mm pan of the Glenelg region projected onto the DEM.

Additional georeferencing was required in Arcmap because projecting the high-frequency topographic details in the Mastcam pan onto the comparatively low-frequency HiRISE DEM introduced distortions into the orthorectified mosaic (primarily range disparities where the projected image intersected the DEM). As noted above, we find that the best results are achieved when projecting onto a slope facing the vehicle, or from an elevated viewpoint. Even at several hundred meters distance, correlation between the ground view and the HiRISE map is possible. Mastcam 34mm images have a comparable IOF to HiRISE at about 1 km distance. The 100mm camera is comparable to HiRISE at about 3 km. This suggests that from the right vantage point (e.g., climbing Mt. Sharp) Curiosity could, in effect, provide its own very high resolution orthographic image and topography maps.

Contextualizing Opportunity observations: Opportunity has amassed several hundred Navcam and Pancam stereo panoramas since it landed in Eagle Crater 9 years ago. In several locations along its traverse, sites where these data were acquired are close enough together to provide overlapping coverage, primarily from Navcam. The most recent such example – Matijevic Hill – was imaged deliberately in this manner, in part to allow compilation of a Navcam-scale orthorectified image and DEM map that could be georeferenced to the HiRISE image and DEM. Figure 4 is a sample from the Matijevic "Walkabout". Incorporating the Navcam DEMs into this map gives the science team the ability to determine the extent of structures laterally beyond the edges of a single rover location and help unravel the stratigraphic record of the Endeavour Crater rim area.

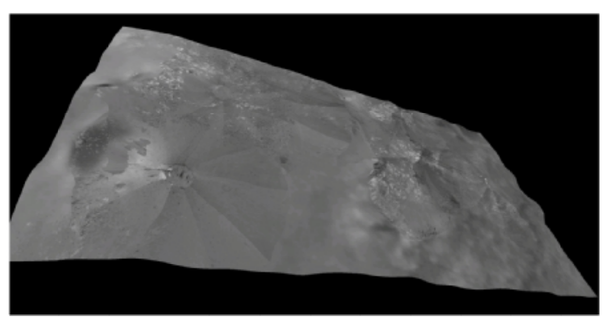

Figure 4: Perspective view of a portion of Matijevic Hill, looking north. Opportunity Navcam panoramas georeferenced to HiRISE image and DEM.

Reference: [1] Parker et al. (2012) *LPS* 43, 2535.