MERCATOR - USING HIGH RESOLUTION TOPOGRAPHY FOR NAVIGATION. E. E. Palmer[1], R. W. Gaskell[1] and M. V. Sykes, [1]Planetary Science Institute (1700 E. Fort Lowell, Suite 106, Tucson, AZ 85716, epalmer@psi.edu).

Introduction: Autonomous navigation has been a focus of robotic missions for years, [1,2,3,4] and is labor intensive. Mercator is a project to use a high-resolution topographic digital elevation model (DEM) to determine the location of surface-based assets, such as landers, rovers and even astronauts. It works using a panoramic image from a surface asset and comparing it to synthetic horizon images generated from the high resolution DEM.

This technique of position determination is software based, thus, it can be applied to almost most any surface mission. It has two data sources: high-resolution imagery taken from orbit and panoramas taken from the ground. These two data products are usually available for missions in which a lander or rover has landed on airless bodies.

Previously, we reported results for a test region on the Moon, Tsiolkovsky crater [5]. Here we report on a “ground truth” experiment we are conducting on Earth in which we test the entire process, from data collection, DEM creation and panorama testing. We use a test site near Sonoita, Arizona, which allows for easy access. Located at 31°43.644’N 110°35.203’W, it is a high-desert region with significant erosional terrain, chosen for limited vegetation and a variety of terrain types. There are mountains on the horizon, but local topography obstructs most of them, minimizing their contribution to local horizon profiles.

Method: There are two major steps to conduct the Mercator method of position determination: building the DEM and testing panoramas.

Building a DEM. Missions that land on the surface of airless bodies have significant imagery taken of its surface from orbit. Using stereophotoclinometry (SPC), we can solve for the slopes and the surface reflectance of the surface at a resolution on the order of the images themselves. These calculations can then be used to extract a DEM and albedo maps, which was done for numerous missions [6,7,8].

For our ground truth test we contracted with Cooper Aerial Surveys Co. to collect panchromatic imagery of a 100 km^2 test region at 20 cm resolution with a 60% down-track overlap and a 30% cross-track overlap. This was conducted on 29 November 2012 by aircraft with a Wild RC30 camera. The survey consisted of two flights, one at 17,000 mean sea-level (MSL) in which there were two passes, one running north-south and the other running east-west, and generated 36 nadir images. To provide an extended viewing and illumination geometry, a second flight was flown four hours later at an altitude of 11,000 MSL, providing 50 images and a higher resolution.

To simulate the highly varied, and sometimes spotty, coverage of orbital missions, we are sequestering every second image, which removes most of the stereo coverage, and places the bulk of the DEM determination to non-successive images taken in different orientations, altitudes and time. Future work will evaluate the improvement of the DEM when the stereo images are added.

Testing Panoramas. Testing panoramas require both a real panorama taken in the field and a large set of synthetic panoramas generated from the DEM. We generate synthetic panoramas with the FORTRAN program “panorama.” This reads in DEM files and outputs images of what would be seen by an observer on the ground. This has been done using a DEM of the Moon [5] and Vesta [8]. Once a high quality DEM is derived for the Earth data set, we will generate the synthetic testing panoramas.

Observed panoramas were taken in the field on 3 January 2013 from 39 waypoints using a Canon T1 camera with an 18mm lens on a tripod. Each panorama was made from nine images and stitched together via photoshop. Because the testing site had vegetation and clouds, we will trace the horizon profile by hand. Then, they can be compared with the synthetic panoramic horizon profiles.

Discussion: The previous work based on lunar data used the same DEM for the “observed” and “synthetic” horizon profiles, one being distinguished from the other by the introduction of systematic error [5]. That work showed that position matching is possible, and the best solution was the correct solution, except within craters.

These current Earth-based data not only have independent panoramas, but they properly simulates real-world operations -- orbital assets take high resolution images, then ground assets take panoramic images.

Initial evaluation of the data shows that they are sufficient and will provide a good test; however, there are some complications. First, while the area did not have many large trees, there were still a few present. While they lacked leaves, they still cast shadows. Unlike rocks or boulders that have deterministic brightness for any illumination condition, trees and shrubs change their shadow depending on a breeze. They also can cast partial shadows (i.e. limbs can produce shadows but are sub-pixel and result in grey pixels).

Future Work. The DEM of the testing region is only a preliminary DEM. We will continue to refine the model by continuing the processing until a solution converges. We will generate a 2 meter resolution DEM on the entire test region, 100 km^2. Additionally, we will generate a 20cm DEM for specific sub-regions to test the improvement in location determination.

Additionally, we have held back half of the collected data. Once the DEM has fully converged on a solution, we will introduce the second half of the data and update the DEM with this new data set. We will do analysis of the change in the DEM, which will be an indication of the effectiveness of SPC to reduce error depending on the redundancy of the data.

Finally, it is not uncommon to have several "close matches" using the horizon matching algorithm [5]. Typically, the best match is the correct answer; however to improve the solution, we will evaluate the effect of moving a small distance and integrating the results. For this test, we took a panorama from a well determined location, then moved 5, 10 and 15 meters taking additional panoramas. We will evaluate the correlation among these locations to see if two or more panoramas improve accuracy.

References:

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Acknowledgements: This project is funded by NASA's LASER program. It is a joint venture between Raytheon Missile Systems and the Planetary Science Institute.

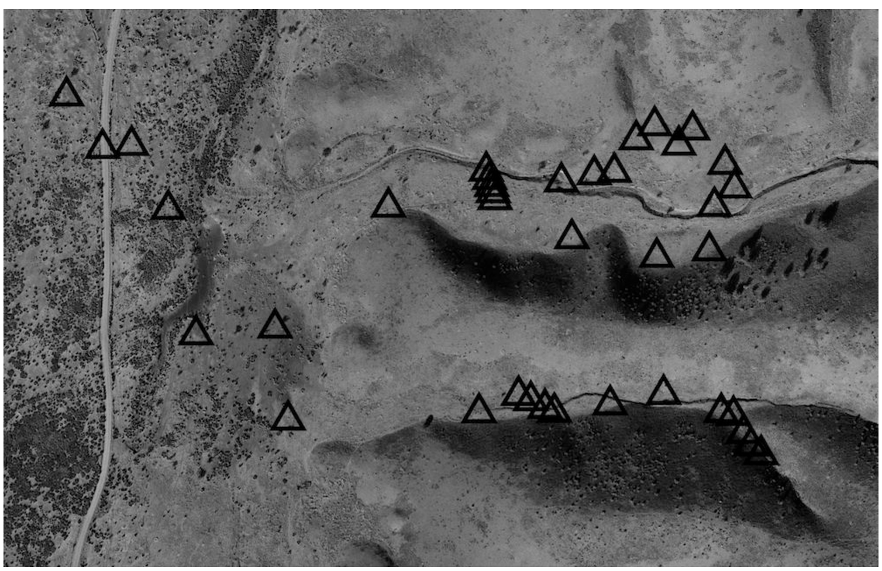

Figure 1. This is a 1 km region of the 10x10km target region. The source imagery has a resolution of 20cm per pixel. The black triangles are locations where we took panoramic images.

Figure 2. This is a panorma taken from one of the locations. It was a series of nine images and stiched together with a cylinderical projection. While vegetation is minimal, it does cause some problems that must be removed by hand.