THE NEAR SHOEMAKER LANDING ON EROS.

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Introduction: The NEAR Shoemaker spacecraft landed on asteroid 433 Eros on 12 February 2001 at 19:44:16 UTC [1]. Radio tracking was able to determine its final location in body-fixed x and y directions quite accurately from Doppler data. NEAR imaging data has been analyzed with stereophotoclinometry [2] (SPC) to construct very accurate topography of Eros' surface. By tying images taken during the landing sequence to the topography, a solution for the spacecraft's trajectory was obtained until 7 minutes before landing. NEAR Laser Ranging (NLR) data [3] was used to refine this solution. The trajectory is being extrapolated to the landing location by modeling the spacecraft dynamics, using a gravity field from the Eros global topography model (GTM) [4] and modeling accelerations during the last three maneuvers, EMM-3, 4 and 5. Our effort to more precisely determine the final trajectory and landing location of NEAR will provide better context information for interpreting the geology at the landing site, and might provide new data on any density heterogenities that might be present with interior of Eros.

Imaging Data: During the last 37 minutes, 67 images of the surface were taken. The last 10 formed five isolated overlapping pairs, but the remaining images form a continuous mosaic with many images prior to 13 minutes from landing containing surface features identifiable in earlier lower resolution frames. So far, over 32000 images have been used in the topography construction.

Topography: With SPC Eros has been mapped globally to a resolution of 6 m and at higher resolution where data is available. Imaging data covering a small surface patch is extracted and a slope/albedo solution is obtained by minimizing the brightness residuals. The slopes are then integrated to produce a topography/albedo "maplet", with constraints coming from limbs and overlapping maplet topography. The central point of each maplet constitutes a control point. Its location in each image is determined by correlating illuminated maplet topography with imaging data. The ensemble of maplets is used to construct the GTM and high-resolution topography maps (HRTM) such as the 513x513x3m map in Fig. 1.

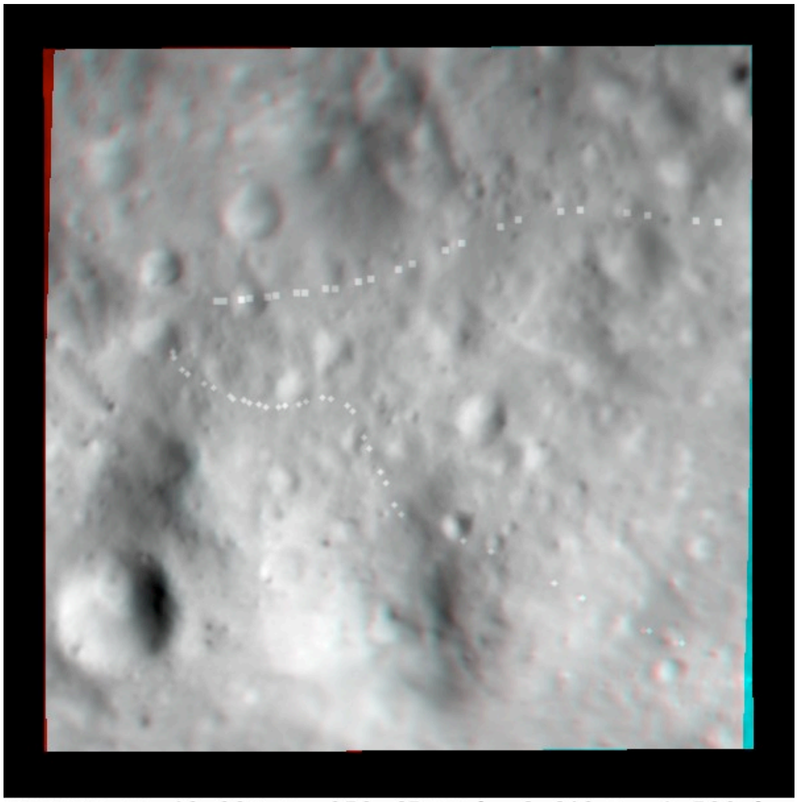
LIDAR: If the spacecraft position and orientation are known, the distance from the spacecraft in the direction of the NLR boresight to a point on an HRTM should match the range measurement at the corresponding time. Observed residuals over sequences of images suggest that they are primarily due to orbit errors, and their magnitudes are consistent with estimates of these errors. During the landing, however, the SPK errors were very large and a combination of SPC results from imaging and NLR ranges had to be used to determine the trajectory.

Geometry: The ensemble of control points is used to estimate their body-fixed locations and the spacecraft position and orientation at each image time. The solution is constrained by the nominal values from the SPICE SPK and CK files with appropriate weights. Formal uncertainties in our solutions for s/c orientation and position are about 60 μrad and 5 m, and the uncertainty in body-fixed control point locations is about 2 m. The nominal spacecraft locations were deweighted for the landing sequence. The solution was constrained by the NLR ranges at each imaging time.

Current Status: The trajectory solution extends to about 7 minutes befre landing. We have attempted to fit this trajectory with the known gravitational accelerations and by solving for accelerations during the EMM-3 and EMM-4 burns, taking into account the 17 second timing shift discussed in [1]. The solution, and its extrapolation to six of the remaining ten images, are shown in Fig 1. The upper points represent the ground track of the spacecraft at imaging times while the lower ones represent corresponding NLR surface points. The final image shown was 207 seconds before landing. The final four images have not been plotted. They took place during the EMM-5 burn and we are not yet happy with our models of the burns.

Fig. 2 shows the overlap between the last two images plotted. The mis-alignment in the prediction amounted to less than a meter. Since the images were shuttered 20 seconds apart, the velocity error is about 5 cm/s. We hope to use velocity estimates from image overlaps in the fit, along with better burn modeling, to determine precisely NEAR Shomaker's landing site.

References: [1] Antreasian P. G. et al. (2001) AAS/AIAA Astrodynamics Spec. Conf. Paper AAS 01-372. [2] Gaskell R. W. (2008) *Meteoritics & Planet. Sci.* 43, 1049-1062. [3] Smith D. E. (2002) NASA Planetary Data System, NEAR-A-NLR-5-CDR-EROS/ORBIT-V1.0. [4] Gaskell R. W. (2008) NASA Planetary Data System, NEAR-A-MSI-5-EROSSHAPE-V1.0.



XXXXXY Lt=42.23S Ln=273.65W Rd= 6.642 Sz=1.539 km

Figure 1. Spacecraft ground track and NLR intercepts on 3m/px HRTM

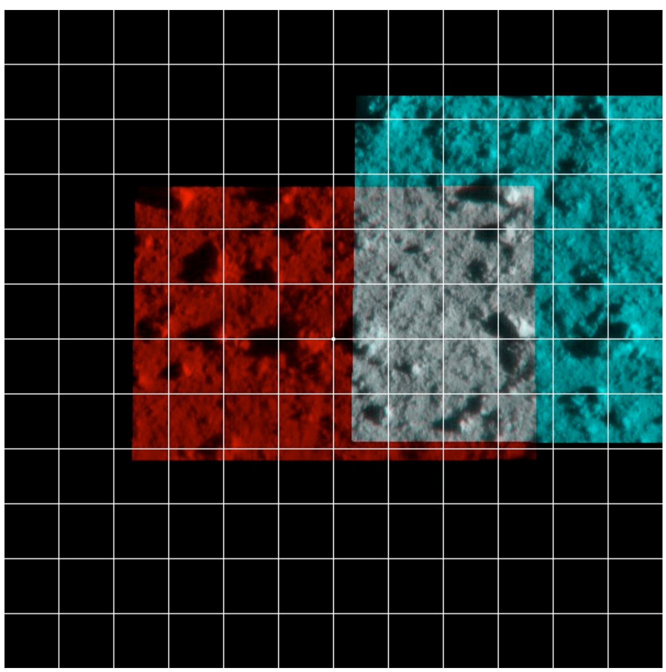


Figure 2. Overlap of NEAR images M0157417048 and M0157417068