THE NEAR LASER RANGING EXPERIMENT;

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Summary. The primary objective of the NEAR Laser Ranging investigation is to obtain high integrity profiles and grids of topography for use in geophysical and geological studies of asteroid 433 Eros. The resolution, surface coverage, and absolute accuracy that will characterize these data will enable detailed analysis of the structure, morphology and evolution of this near-Earth asteroid. Asteroidial radii will be produced in a well-defined reference frame so that topographic data can be readily compared to information from other NEAR sensors, which will further increase the value of these data.

Instrument. The principal component of the NEAR Laser Ranger (NLR) laser is a Q-switched, neodymium-doped yttrium aluminum garnet (Nd:YAG) laser oscillator which is pumped by a multi-bar laser array. Each bar contains numerous AlGaAs (aluminum, gallium arsenide) laser diodes. The laser will emit pulses with a wavelength of 1.064 μm and a beam divergence of ~200 μrad at rate of 0.125, 1, 2 and 8 Hz. The laser was designed and built by the McDonnell Douglas Space Systems Division, St.Louis, and has heritage to the Clementine [1, 2] and MOLA [3] lasers The instrument also includes a silicon avalanche photodiode detector and a 480 MHz oscillator. The total range accuracy of the instrument will be no worse than 6 m. The total weight of the instrument is < 5kg and data rates vary from 6.4 to 51 bits per second..

The instrument provides a measure of the slant range of the spacecraft to the asteroid surface by measuring the round trip time of flight of individual laser pulses. By correcting for the position of the spacecraft with respect to the center of the asteroid via calculation of the spacecraft orbit from the X-band Doppler tracking data, the range data can be transformed into a discrete set of planetary radii referenced to the asteroid center of mass. The altimetric and tracking data from NEAR will be reduced in the same reference frame in order to maximize the accuracy of both the topography and gravity data sets.

Along-track Resolution. The size of the laser footprint on the surface of Eros will depend on the spacecraft altitude. Given the spacecraft orbits of 35 km or 50 km from center of Eros, the laser beam divergence of 200 μrad and approximate semi-major and minor axes of Eros of 18 and 8 km, the spot size on the surface will vary from about ~4-9 m. For a nominal spacecraft velocity of ~5 m s^{-1}, the along track resolution will be comparable to the spot size for a 99% probability of successful ranging.

Topographic Coverage and Scientific Questions. In the current NEAR mission scenario [4], Phase 3 of the mission consists of 42 days of mapping in a 35-km orbit followed by Phase 4 which consists of ~120 days of mapping in a 50-km orbit. We have simulated the distribution of NEAR ground tracks for 3 days in the 50-km orbit and for 2 days in the 35-km orbit. Results indicate that the 50-km orbit yields ground tracks that have a spacing of ~11^o at the equator, but have large gaps between sets of ground tracks, the spacing in the 35-km orbit case is ~62^o uniformly over the asteroid. Thus the 35-km orbit is preferable if the objective is to make a global map in the shortest period of time that can be subsequently filled in to the desired level.

For geophysical problems such as determining the internal density structure of the asteroid, it is desirable to have topographic information at the same resolution as gravity. It is reasonable to expect a gravitational field at Eros up to degree and order 15 [5, 6], which corresponds to a half wavelength resolution of 3 km. Our simulations indicate that the topographic resolution will exceed the gravity resolution in about 1 month.

Higher resolution coverage will be desired to address interesting geological questions such as understanding the origin of grooves, if they exist on Eros, from measurements of their widths and depths [7]. The shapes of impact craters, the morphology of the surface and its relationship to regolith thickness will also be addressed. For the anticipated NEAR mission scenario, the topographic resolution of Eros will improve considerably with time for about the first 6 months of the mission, after which continued mapping will not yield a significantly denser grid.

Data Corrections. In order to produce topographic profiles and gridded topography from spacecraft to surface ranges, a number of corrections need be made. Here we focus on effects that are expected to induce meter-scale or larger errors in topographic height. The largest correction is generally associated with uncertainty in the knowledge of the spacecraft orbit [3]. The orbital accuracy the NEAR spacecraft around Eros should be recoverable at approximately the 5-10-m level with respect to the asteroid center of mass [5, 6]. For comparison the topography of Venus is known to many tens of meters [8], the Moon is now known to ~100 m [2], and Mars in places has errors in excess of 3 km [3]. Another correction arises from the fact that spacecraft motions will cause the instrument to deviate slightly (generally up to several milliradians) from nadir-pointing. To correct for this effect requires spacecraft orientation information from the SPICE kernals. Also, because the NLR will make use of a leading edge detector, spreading of the laser pulse generally necessitate a "time walk" correction [9]. For the expected range of laser spot size and a judicious estimate of footprint-scale surface roughness of, the pulse will be spread by at most by a factor of 3 or 4, which corresponds to a 1-2 m correction. In addition, effects of possible changes in surface albedo will add errors of 1-2 m (RMS). However if we rss the various sources of error discussed here we estimate that the topographic field will be globally accurate to approximately 10 meters with respect to the center of mass.

Data Products. Data products will include profiles and global and regional grids of topography referenced to the asteroid center of mass. We will also derive a global reference surface and produce a spherical harmonic expansion of the topography at a level commensurate or better with the resolution of the gravity data.

Time Varying Topography. Finally, we feel some consideration should be given to the possibility that Eros is a highly complex body, possibly composed of more than one object. Thus we plan to compute independent topography models of Eros for subsets of the data (~monthly) to test this hypothesis.

Synergy with Other Data Sets. The NLR will be bore-sighted with the Multi-spectral Imager [10], and inflight alignment will be possible as the MSI will be capable of imaging a laser spot on Eros' dark side when the laser fires in burst (8 Hz) mode. It will thus be possible to directly correlate elevations with surface features, which considerably enhances both geological analysis and geodetic positioning on the surface. In addition, all topographic data sets will be produced in an areocentric, center of mass reference frame and will be easily comparable to data from the other NEAR sensors. In summary, the NEAR laser ranging investigation will make significant contributions to the shape, internal structure and evolution of 433 Eros in particular and near Earth asteroids in general, and will facilitate interpretation from other NEAR spectral and geophysical sensors.

References. [1] Nozette S. et al. (1994) *Science, 266,* 1833. [2] Zuber M.T. et al. (1994) *Science, 266,* 1839. [3] Zuber M.T. et al. (1992) *JGR, 97,* 7781. [4] Cheng, A.F. (1995) *LPSC XXVI,* this volume. [5] Yeomans D.K. et al. (1995) *LPSC XXVI,* this volume. [6] Smith D.E. et al. (1995) *LPSC XXVI,* this volume. [7] Thomas P. (1979) *Icarus, 40,*223. [8] Ford, P.G. and Pettengill G.H. (1992) *JGR, 97,* 13,103. [9] Harding D.J. et al. (1994) *IEEE Trans. Geosci. Remote Sensing.* [10] Veverka J. et al., *LPSC XXVI,* this volume.