LASER ALTIMETER OBSERVATIONS FROM MESSENGER'S FIRST MERCURY FLYBY. Maria T. Zuber[1], David E. Smith[2], Sean C. Solomon[3], Roger J. Phillips[4], James W. Head[5], Jürgen Oberst[6], Stanton J. Peale[7], Catherine L. Johnson[8], Gregory A. Neumann[2], Frank G. Lemoine[2], Xiaoli Sun[2], Olivier Barnouin-Jha[9], and John K. Harmon[10]. [1]Department of Earth, Atmospheric and Planetary Sciences, MIT, Cambridge, MA 02139-4307 (zuber@mit.edu); [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771; [3]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015; [4]Southwest Research Institute, Boulder, CO 80302; [5]Department of Geological Sciences, Brown University, Providence, RI 02912; [6]DLR, Berlin, Germany; [7]Department of Physics, University of California, Santa Barbara, CA 93106; [8]Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada; [9]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723-6099; [10]NAIC, Arecibo Observatory, Arecibo, Puerto Rico 00612.

Introduction: The MErcury Surface, Space ENvironment, Geochemistry, and Ranging (MESSENGER) mission [1, 2, 3] includes three flybys of Mercury during its cruise phase prior to orbit insertion. During the first MESSENGER flyby on January 14, 2008, the Mercury Laser Altimeter (MLA) [4] will range to Mercury's surface and is expected to collect a long ($>10^3$ km) topographic profile in the equatorial region of the planet, largely within the hemisphere of Mercury not imaged by Mariner 10.

The Mercury Laser Altimeter: The MLA [4] is a time-of-flight laser rangefinder that will use direct pulse detection and pulse edge timing to determine precisely the range from the MESSENGER spacecraft to the surface of Mercury. MLA's laser transmitter emits 5-ns-long pulses at an 8-Hz rate with 20 mJ of energy at a wavelength of 1064 nm. Return echoes are collected by an array of four refractive telescopes that are detected using a single silicon avalanche photodiode detector (SiAPD) and three matched low-pass electronic filters. The timing of laser pulses is measured using a combination of crystal-oscillator-based counters and high-resolution time-of-flight application-specific integrated circuits (ASICs).

During MESSENGER's orbital mission phase, the MLA will contribute to the geophysics [5] and geology [6] objectives of the mission by measuring the topography of the planet's northern hemisphere; the southern hemisphere will be out of range due to MESSENGER's elliptical orbit. To maximize the amount of surface mapped by the MLA, the instrument's tracking algorithm was designed to maintain lock on the surface over a rapidly changing spacecraft range [4]. This performance attribute will be beneficial in MESSENGER's Mercury flybys.

MLA is designed to perform range timing measurements up to 1800 km from Mercury's surface, but because of signal-to-noise considerations, the instrument will range most effectively at distances <800 km. Since the single-pulse signal link margin is close to 0 dB for altitudes above 800 km (*e.g.*, Figure 1), the MLA data acquisition scheme allows collection of up to fifteen and downlink of up to ten returns per shot in order to allow the use of correlation techniques to process the range signals on the ground. Measurement of both the outgoing pulse energy and received pulse shape estimated from leading- and trailing-edge threshold crossings enable a measurement of the reflectivity of the target.

In May 2005 the MLA was operated successfully at 24 Gm from Earth as part of the first two-way laser ranging link at interplanetary distance [7], and in June 2007 the instrument ranged successfully to the clouds of Venus [8], executing the instrument's science-mode tracking algorithm for the first time. If all proceeds as planned, MESSENGER's first Mercury flyby will represent the first time that the MLA will range to a solid planetary surface.

First Mercury Flyby: MESSENGER's first flyby of Mercury will occur approximately in the equatorial plane, mostly within the hemisphere of Mercury not imaged by Mariner 10 [9]. Figure 2 shows the approximate altitude and location of the flyby. MLA will begin ranging to the surface about 1 minute before closest approach and will continue until the altitude reaches 1800 km, about 10 minutes later. The spacecraft will spend ~6 minutes within 800 km of the planet, where a near-continuous profile is expected over a distance of ~2200 km. At MESSENGER's closest approach distance of ~193 km, the spacecraft velocity of ~5.8 km/s will lead to laser-illuminated spots of ~15 m diameter on the surface spaced ~725 m apart. The profile will fall approximately in the region within which Earth-based radar profiles have been obtained [11], increasing the topographic knowledge of the equatorial region and allowing comparisons of these independent data sets. The MLA profile should provide new quantitative constraints on, for example, the geometry of impact craters, topography of tectonic structures, topography and roughness of geological units [cf. 6], and possible flexure of plains units [5].

References: [1] Solomon S. C. et al. (2001) *Planet. Space Sci., 39,* 1445-1465. [2] Santo A. G. et al. (2001) *Planet. Space Sci., 39,* 1481-1500. [3] Solomon S. C.

et al. (2007) *Space Sci. Rev., 131,* 3-39. [4] Cavanaugh J. F. et al. (2007) *Space Sci. Rev., 131,* 451-480. [5] Zuber M. T. et al. (2007) *Space Sci. Rev., 131,* 105-132. [6] Head J. W. (2007) *Space Sci. Rev., 131,* 41-84. [7] Smith D. E. et al. (2006) *Science, 311,* 53. [8] Smith D. E. et al. (2007) *Eos Trans. AGU, 88,* Fall Meeting suppl., P41B-04. [9] McAdams J. V. et al. (2007) *Space Sci. Rev.,* 219-246. [10] Head J. W. et al. (2008) *Lunar Planet. Sci*., this issue. [11] Harmon J. K. et al. (1986) *J. Geophys. Res., 91,* 385-401.

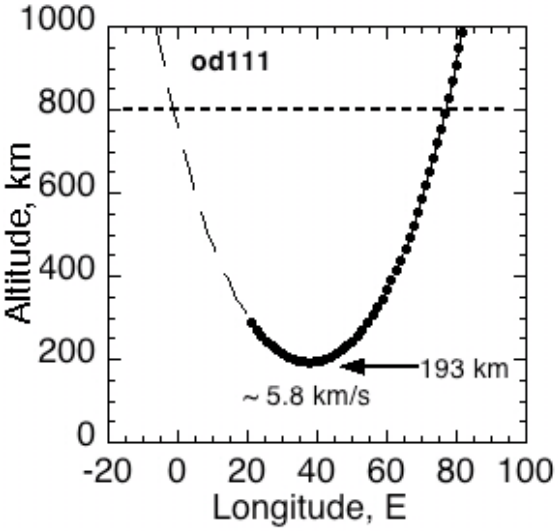

Figure 1. MESSENGER spacecraft altitude during the first Mercury flyby using a recent predicted trajectory (od111). The spacecraft velocity and altitude at closest approach are noted. The altitude line is dotted where the MLA is in science mode and collecting altimetric ranges. The short-dashed horizontal line corresponds to the altitude (800 km) above the surface at which the MLA has a single-pulse positive link margin. Note that MLA's range to the surface will often be larger than the altitude of the spacecraft due to the requirement [2] to keep the spacecraft sunshade between the spacecraft and Sun. This mission design constraint will necessitate that MLA obtain many off-nadir observations of Mercury's surface.

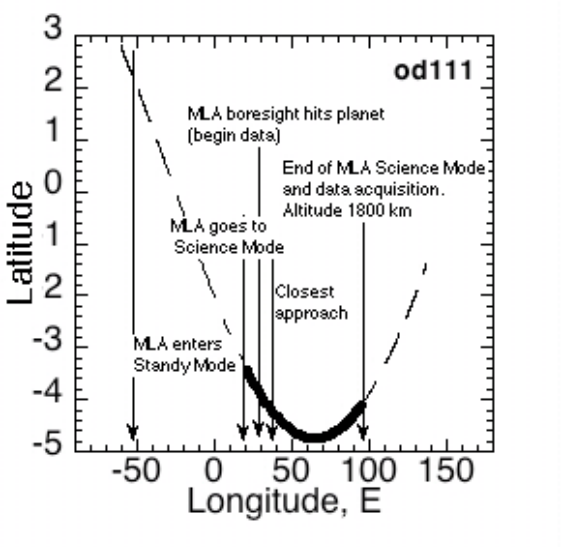

Figure 2. Expected groundtrack of MESSENGER during the first Mercury flyby along with significant events in the operation of the MLA.