PLANET SCANNERS – NEXT-GENERATION ORBITAL LIDAR INSTRUMENTATION FOR TOPOGRAPHIC MAPPING AND MONITORING. D. A. Paige, [1]Dept. Of Earth, Planetary, and Space Sciences, University of California, Los Angeles, dap@moon.ucla.edu.

Introduction: Accurately determining and monitoring temporal changes the shapes of planetary bodies is fundamental to understanding interior structure, geology and the distribution and behavior of volatiles. Today, planetary topography from orbit is determined using multiple complementary approaches that include radar altimetry, laser altimetry, and photogrammetry. On Earth, advances in airborne scanning lidar technology has made it possible to obtain dense, accurate, spatially continuous topographic mapping data over wide areas in a single pass. Here, we investigate the application new laser and detector technologies to create the next generation "planet scanner" instruments that can provide similar data from orbit.

Lidar Science: Laser altimeters have been successfully flown on orbital missions to Mercury, Earth, the Moon and Mars [1-5]. By measuring the time of flight of a laser pulse from the spacecraft to the surface and back, they provide definitive surface elevation data when combined with accurate reconstructions of the position of the orbiter relative to the planet's center of mass. Such measurements can be used to define global figure as well as geomorphology and topographic roughness. Repeat spatial coverage has enabled temporal monitoring of the topography of the Earth and Mars to quantify changes in the distribution of surface ices [6-7]. Moon and Mercury laser altimeters have also been used as reflectometers to perform active laser measurements of the surface reflectivity [8-9]. The results of these measurements provide uniform albedo maps at zero phase angle that are independent of solar illumination angle, and can be used to map the distribution of surface volatiles in shadowed regions [10-11]. By measuring multiple reflections per footprint, lidar data can also be used to characterize cloud height distributions, surface slopes and roughness, as well as vegetation cover [12-13].

Next-Generation Lidar Science: Laser and detector technologies are evolving very rapidly, and one can foresee a number of exciting scientific applications for the next generation of lidar instruments. Wide area coverage will enable the complete and uniform topographic mapping of planetary surfaces – a goal that has not yet been fully accomplished even for the Earth or the Moon. For planets such as the Earth and Mars with temporally varying topography, wide area repeat coverage will enable detailed characterization and monitoring of changes over time. For icy moons in the outer solar system that experience eccentricity-driven tidal flexure, topographic monitoring will enable accurate characterization of diurnal changes in global figure to constrain the properties and thicknesses of ice shells and subsurface oceans [14-15]. Multi-spectral lidar measurements will also enable the mapping and characterization of surface volatiles and organics in the permanently shadowed regions of airless bodies such as Mercury and the Moon.

Measurement Requirements: Table 1 outlines key parameters relevant to future orbital lidar measurements for a range of planetary bodies of interest, including anticipated science goals, orbital altitudes, desired ranging accuracies, return waveform point densities, and time resolutions for repeat coverage. Because of the range of science goals and orbital configurations, there will not be a "one size fits all" planet scanner instrument, but rather a family of instruments whose capabilities are tailored to fit mission requirements.

Trade Studies: We have developed a physics-based lidar performance and orbital mission modeling tool to conduct systems-level trade studies for a range of future lidar mission scenarios. The model results provide optimized estimates of the aperture, volume, mass, energy, lifetime and data resources required to

Table 1. Measurement requirements for topographic mapping and monitoring of solar system bodies

Solar System Body	Orbital Altitude (km)	Ranging Accuracy (m)	Data Points Per Pixel	Time Resolution for Repeat Coverage	Key LIDAR Science Goals
Mercury	600	1	1	n/a	Topographic mapping, surface volatiles
Moon	50	0.5	1	n/a	Topographic mapping, surface volatiles
Earth	600	0.05	100	30 days	Topographic mapping, monitoring of ice, water, land surface, vegetation, and global change
Mars	300	0.2	10	60 days	Topographic mapping, monitoring of clouds and seasonal frost
Europa	200	1	1	1 day	Topographic mapping and monitoring of tidal flexure
Enceladus	200	1	1	8 hours	Topographic mapping and monitoring of tidal flexure
Small Bodies	30	0.1	1	30 days	Topographic mapping

achieve a given set of measurement objectives through the application of a range of lidar laser and detector technologies. Instrument configurations that have been investigated include single laser/detector systems scanned using a rotating mirror, and multiple fiber-optic fed laser/detector systems that require no moving parts. Trade study results for a range of mission scenarios will be presented at the conference.

References: [1] Cavanaugh, J. F. et al., Space Sci. Rev DOI 10.1007/s11214-007-9273-4 (2007). [2] Abshire, J. B. et al., Gephys. Res. Lett, 43, L21S02 (2005). [3] Cook, A. C., J. Geophys. Res. 106, 12,023-12,033 (2000). [4] Smith, D. E. et al., Space Sci. Rev 150, 209-241, (2010). [5] Neumann, G. A., J. Geophys. Res., 106, 23,753-23,769, (2001). [6] Zwally, H. J. et al., J. Geodynamics 34, 405-445, (2002). [7] Aharonson, O. et al., J. Geophys. Res. 109, DOI 10.1029/2003JE002223, (2004). [8] Neumann, G. A. et al., Science 339, 296-300 (2013). [9] Lucey, P. G. et al., J. Geophs. Res. 119, 1655-1679 (2014). [10] Paige et al., Science DOI 10.1126/science.1231106, (2013). [11] Fisher, E. A. et al., LPSC 47, #2574 (2016). [12] Neuman, G. a. et al., J. Geophys. Res. 108, DOI 10.1029/2002JE001849 (2003). [13] Lefsky, M. a. et al., Geophs. Res. Lett. 32, DOI 10.1029/2005GL023971 (2005). [14] Moore and Schubert, Icarus 147, 317-319, (2000). [15] Spencer, J. R. et al., Saturn from Cassini-Huygens, 683-724, (2009).