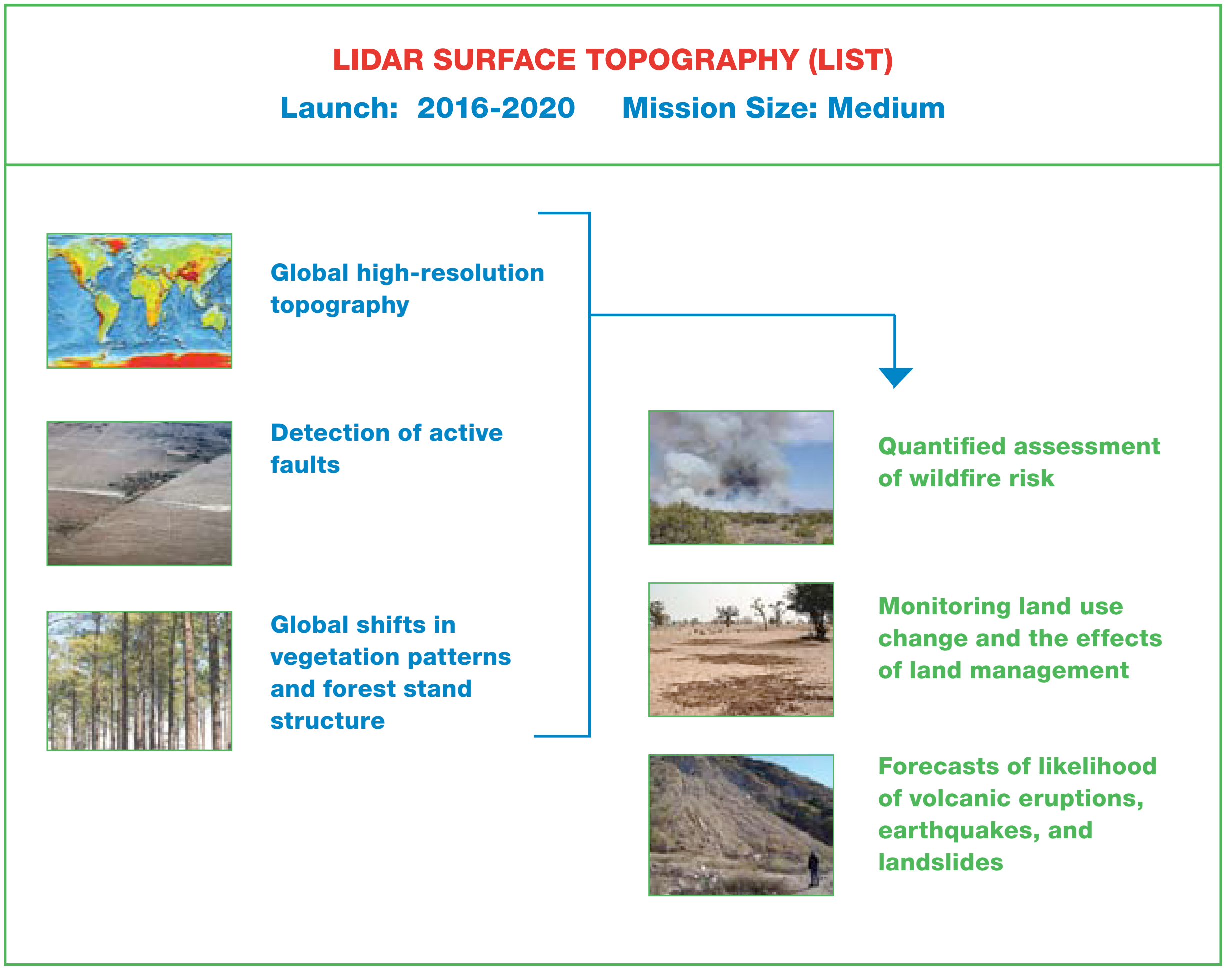

LIDAR SURFACE TOPOGRAPHY (LIST) MISSION

Predicting the location and timing of landslides, floods, tsunami runup, pyroclastic flows, and mudflows depends on precise topographic data. Global topographic data are available at a resolution of only 30-90 m and a precision of only about 10 m in the vertical, which is inadequate for these purposes. The proposed 5-m global topographic survey at decimeter precision would permit mapping of landslide and flood hazards on a scale small enough to be useful for site-specific land-use decisions. High-resolution topographic data would also advance the science on which such risk assessments are based. Precise topographic measurements would aid in finding active faults (including "blind" faults) and thus contribute to better earthquake hazard assessments. Time series of high-precision topographic data would aid in mapping the loss of topsoil worldwide; in detecting incipient hazards from volcanic eruptions, pyroclastic flows, and mudflows; and in determining the slip distribution in large earthquakes. The proposed lidar mapping mission would also yield global data on forest-stand structure and thus allow quantitative assessment of wildfire risk to an unprecedented level.

Background: Earth's surface is dynamic in the literal sense: it is continually being shaped by the interplay of uplift, erosion, and deposition as modulated by hydrological and biological processes. Surface topography influences air currents and precipitation patterns and controls how water and soil are distributed across the landscape. As a result, topography regulates the spatial patterns of soil depth, soil moisture, and vegetation. And it influences how natural hazards—such as landslides, floods, and earthquakes—are distributed across the landscape. High-resolution topographic data can be analyzed to understand the tectonic forces shaping Earth's surface and the geologic structures through which the forces are expressed. Time series of high-precision topography can be used to observe the reshaping of Earth's surface by landslides, flooding, erosion, large earthquakes, and tsunamis. Until recently, the coarse resolution of topographic mapping has been a major impediment to understanding the forces and dynamic processes that shape Earth's surface.

Small areas can be surveyed at high resolution by using airborne lidar, but airborne surveys of large areas are impractical. Space-based global coverage at 5-m resolution would facilitate comprehensive studies of Earth's surface across diverse tectonic, climatic, and biotic settings, even in areas that are otherwise inaccessible for geographic, economic, or political reasons. Lidar can also be used to measure the height of vegetation, enabling global studies of forest-stand structure and land-cover dynamics. Periodic repeat surveys (on time scales of months to years) would permit large-scale measurements of erosion and deposition fluxes. More frequent repeat surveys could be targeted where topography is changing rapidly (because of, for example, storms, volcanic eruptions, or earthquakes) or where topographic time series would be particularly helpful in detecting incipient natural hazards.

Science Objectives: High-resolution topographic data and high-precision measurements of topographic change are needed to understand the coupling between climate, tectonics, erosion, and topography; to estimate the geomorphic transport laws that shape Earth's surface; to calibrate and test models of landform evolution; to predict and detect erosional response to climate change; to quantify global shifts in vegetation patterns and forest-stand structure in response to climate shifts and human land-use; to infer changes in groundwater aquifers; to measure changes in volumes of glaciers and ice sheets; to quantitatively map topsoil losses; and to assess the risk of landslides, floods, tsunami runup, volcanic eruptions, and earthquakes. At present, global coverage is at a horizontal resolution of, at best, 30 m and a vertical precision of 10 m. The threshold for major advances is at about 5-m horizontal resolution and 10-cm vertical precision.

Mission and Payload: Earlier-generation space-borne laser systems (such as the shuttle laser altimeters and ICESat) were generally single-beam systems that collected profiles of the surface along the spacecraft ground track, but emerging technology will enable spatial elevation mapping. Three approaches could enable spatial mapping of Earth's surface from an orbital platform. The first uses a single laser beam and a scanning mechanism with kilohertz ranging rates to spatially map the surface, as demonstrated by the Goddard Space Flight Center airborne Laser Vegetation Imaging Sensor. The second uses a single laser and splits the beam into numerous parts with a diffractive optical element; separate detectors are used to measure elevation in each backscattered beam. That approach is being implemented in the design of the lunar orbiter laser altimeter to be flown on the Lunar Reconnaissance Orbiter to be launched in 2008. The third approach uses a single laser beam to illuminate a broad swath of surface and a pixilated detector in which each pixel makes a time-of-flight measurement. An example that uses that approach is the Lincoln Laboratory JIGSAW airborne system; analysis has shown that 5-m mapping of the Moon could be achieved in 2 years with an adaptation of this system. Further study will be required to determine the optimal technological approach for the LIST mission. In any case, megabit to gigabit data rates will need to be managed during mapping operations.

Cloud cover will limit the coverage available in each pass, so multiple passes will be required for complete coverage. A relatively long mission lifetime may be needed to achieve the desired spatial density and coverage, and repeated measurements over several years would facilitate detecting surface changes, such as topsoil losses to erosion.

The mission will obtain global coverage from LEO. Global repeat coverage will be achieved on scales of months to years, with more frequent repeat coverage of areas of special interest.

Cost: About $300 million.

Schedule: 2017-2019.

Further Discussion: See in Chapter 8 the section "Mission to Measure High-Resolution (5-m) Topography of the Land Surface," in Chapter 9 the section "Ice Sheet and Sea Ice Volume," and in Chapter 11 the section "Sea Ice Thickness, Glacier Surface Elevation, and Glacier Velocity."

Related Responses to Committee's RFI: 57 and 111.

Supporting Documents:

NASA (National Aeronautics and Space Administration). 2002. *Living on a Restless Planet*. Solid Earth Science Working Group Report. Jet Propulsion Laboratory, Pasadena, Calif. Available at http://solidearth.jpl.nasa.gov/seswg.html.

NRC (National Research Council). 2003. *Living on an Active Earth: Perspectives on Earthquake Science*. The National Academies Press, Washington, D.C.

NRC. 2004. *Review of NASA's Solid-Earth Science Strategy*. The National Academies Press, Washington, D.C.