

Principles of Airborne Laser Altimeter Terrain Mapping

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Detailed topographic maps of very high accuracy are produced by airborne laser altimeter terrain mapping. The unique capabilities of this new technique yield more comprehensive and precise topographic information than traditional methods. Airborne laser altimeter data can be used to accurately measure the topography of the ground, even where overlying vegetation is quite dense. The data can also be used to determine the height and density of the overlying vegetation, and to characterize the location, shape, and height of buildings and other man-made structures.

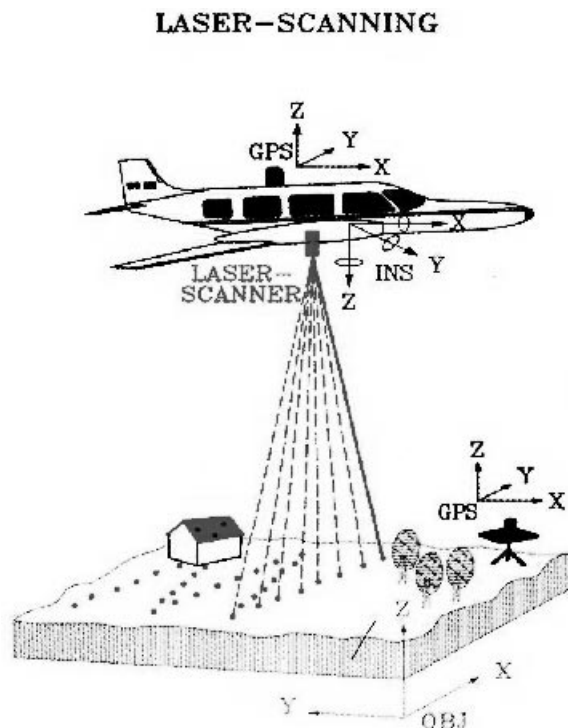


Figure 1 (adapted from Flood and Gutelius, 1997).

The method relies on measuring the distance from an airplane, or helicopter, to the Earth's surface by precisely timing the round-trip travel time of a brief pulse of laser light (Figure 1). The travel-time is measured from the time the laser pulse is fired to the time laser light is reflected back from the surface. The reflected laser light is received using a small telescope that focuses any collected laser light onto a detector. The travel-time is converted to distance from the plane to the surface based on the speed of light. Typically a laser transmitter is used that produces a near-infrared laser pulse that is invisible to humans. The laser light reaching the ground surface is completely safe. It can not cause any eye damage to a person who might be looking up at the plane as it flies overhead.

Laser transmitters are used that fire thousands of pulses per second. By scanning the laser pulses across the terrain using a rotating mirror, a dense set of distances to the surface is measured (Figure 1) along a narrow corridor. The distance measurements are converted to map coordinates and elevations for each laser pulse by combining the distance data with information on the position of the airplane at the time the laser pulse was fired and the direction in which the pulse was fired. The airplane position along its entire flight path is determined using the Global Positioning System (GPS), applying a technique known as a differential kinematic solution. The direction of the laser pulse is established using an Inertial Navigation System (INS), that measures the orientation of the airplane, and measurements of the orientation of the scan mirror. Combining all this information on distance, position, and

direction yields what is known as a geolocated laser return. A large area is mapped by flying many parallel lines, guided by GPS, so that the narrow corridors of data overlap along the edges. The data from all the corridors is then assembled together to provide coverage of a large area.

Early versions of laser altimeters measured the distance to the first feature reflecting the laser pulse. In areas of dense vegetation that is usually the top of the vegetation canopy (Figure 2). More recent laser altimeter systems measure multiple returns for each laser pulse. Typical systems produce a laser pulse that is several feet in diameter. If this several foot wide laser pulse reflects off of more than one feature, distances to the multiple features can be measured. For example, if parts of the laser pulse reflects off of off tree branches or foliage at several levels and the remainder of that laser pulse reflects off of the ground, the elevation of the branches, foliage and ground can be measured. This capability is very important when trying to map ground topography beneath vegetation. The ‘last returns’ for each pulse are those from the lowest features and thus are more likely to be reflections from the ground. Sophisticated algorithms are used to identify the laser returns that are from the ground.

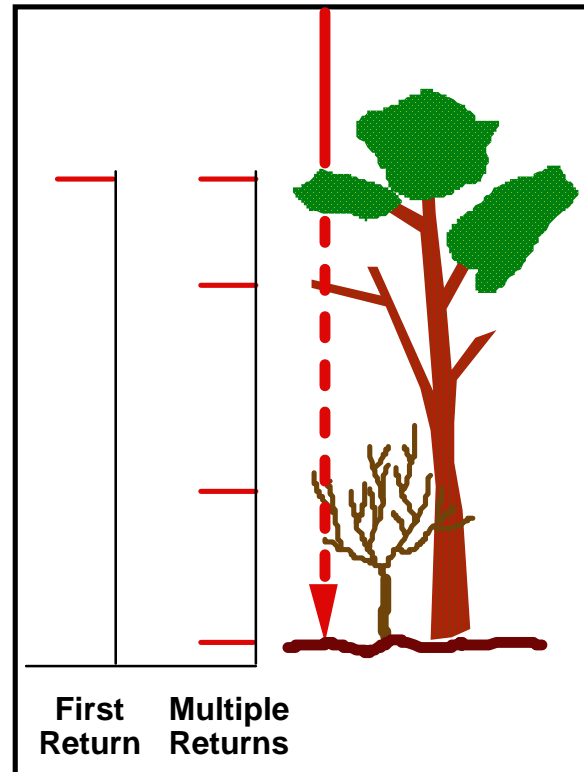


Figure 2.

Once the ground returns are identified, they are used to produce what is known as a digital elevation model (DEM) that describes the ground topography using a regularly spaced grid of elevation values. The returns identified as being from vegetation above the ground are used to measure the height and density of the vegetation. In urban areas, a similar separation is done to identify returns from the ground versus those from buildings and structures. The resulting data products have important applications in many areas. These include geologic hazard assessment, hydrologic modeling, riparian zone and flood plain mapping, assessment of stream quality for salmon spawning, characterization of forest habitat and timber quality, urban planning, and transportation corridor mapping.