**Title:** High-Resolution Measurements of Surface Topography with Airborne Laser Altimetry and the Global Positioning System

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**Discipline:** Land

We have recently developed and are now operating an airborne lidar system that measures laser pulse time-of-flight and the distortion of the pulse waveform upon reflection from Earth surface terrain features. This instrument is combined with Global Positioning System (GPS) receivers and a two-axis gyroscope for accurate recovery of aircraft position and pointing attitude. The laser altimeter system is mounted on a high-altitude aircraft platform and operated in a repetitively-pulsed mode for measurements of surface elevation profiles at nadir. The laser transmitter makes use of recently developed short-pulse diode-pumped solid-state laser technology in Q-switched Nd:YAG operating at its fundamental wavelength of 1064 nm. A reflector telescope and silicon avalanche photodiode are the basis of the optical receiver. A high-speed time-interval-unit and a separate high-bandwidth waveform digitizer under microcomputer control are used to process the backscattered pulses for measurements of terrain.

Accurate recovery of the surface topography to the 10 cm level and understanding of the laser waveform data require 3-axis position knowledge and 2-axis pointing knowledge for the aircraft platform. These data are primarily provided by an on-board Global Positioning System (GPS) receiver and roll and pitch gyroscope sensors. Aircraft position in three-dimensions is measured to sub-meter accuracy by use of differential Global Positioning System receivers. An eight-channel, single frequency GPS receiver is located inside the aircraft and operated to provide one-half of the required aircraft position data set. Differential GPS position recovery results by utilizing a second, ground-based receiver, identical to the airborne unit. The ground-station is usually located at the airbase operations center or in the remote target area at a survey marker or other geodetic reference point. Aircraft roll and pitch attitude are obtained to the resolution of ~ 1.5 mrad by orthogonal-mounted 12-bit gyroscopes and the associated synchro/resolver electronics.

The lidar system, position-determination sensors, and pointing-attitude sensors are packaged into a relatively compact and low-power interface to a NASA turbojet research aircraft, a T-39 Sabreliner, that is based at Wallops Flight Facility (WFF), Wallops Island, Virginia. Laser altimeter measurements are typically acquired along the nadir track of the WFF T-39 aircraft. Data acquisition is possible over the entire operational envelope of the T-39 aircraft. This extends under clear atmospheric conditions from approximately 150 m to 12.5 km altitude. The laser divergence slightly overfills the receiver field-of-view of 2.5 mrad. Thus, the laser footprint on the surface is 2.5 m diameter per kilometer of altitude. At an aircraft speed of 100 m/sec, typical for the T-39 during straight & level VFR data acquisition, the 55 Hz ranging rate of the laser altimeter will produce contiguous data at altitudes of 730 m or above. This is the standard operational mode and can accommodate data runs from a single pulse to 5 minutes of data (16,500 pulses covering 30 km of horizontal distance).

This airborne lidar instrument was developed during the period 1986-1990 under sponsorship of the Land Processes Program of NASA Headquarters for topographic profiling studies of dynamic geology. It has been employed to date in five airborne topography campaigns in the Western U.S. from which data sets are now becoming available. The airborne instrumentation described here has been developed to provide the capability for ranging and waveform studies of Earth surface topography at high resolution as a precursor to the development and application of spacecraft instruments and as a means to acquire local-scale geological data. Both this airborne instrument and the spacecraft instruments are designed with laser pulse timing and waveform capability for geodetic quality (~ 10 cm) topography data.