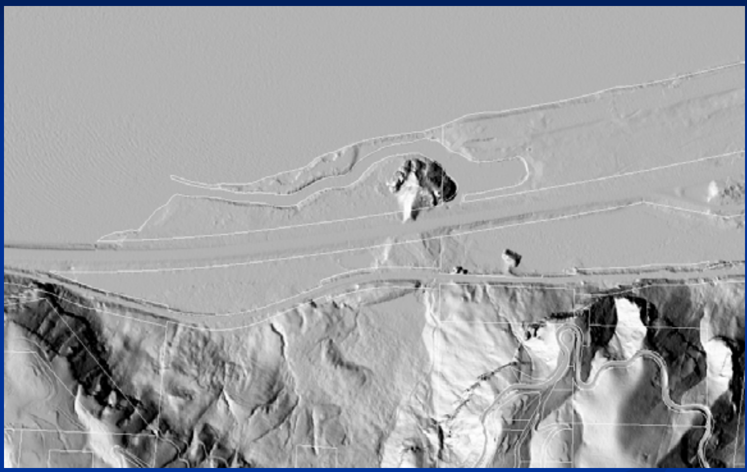
# LIDAR
## an Introduction and Overview



Rooster Rock State Park & Crown Point. Oregon DOGAMI Lidar Project

Presented by Keith Marcoe
GEOG581, Fall 2007. Portland State University.

## What is Lidar?

- Light Detection And Ranging
- Active form of remote sensing: information is obtained from a signal which is sent from a transmitter, reflected by a target, and detected by a receiver back at the source.
- Airborne and Space Lidar Systems. Most are currently airborne.
- 3 types of information can be obtained:
  - a) **Range to target** (Topographic Lidar, or Laser Altimetry)
  - b) **Chemical properties of target** (Differential Absorption Lidar)
  - c) **Velocity of target** (Doppler Lidar)
- Focus on Laser Altimetry. Most active area today.

## Lidar History

- 60s and 70s - First laser remote sensing instruments (lunar laser ranging, satellite laser ranging, oceanographic and atmospheric research)
- 80s - First laser altimetry systems (NASA Atmospheric and Oceanographic Lidar (AOL) and Airborne Topographic Mapper (ATM))
- 1995 - First commercial airborne Lidar systems developed.
- Last 10 years - Significant development of commercial and non-commercial systems
  1994 - SHOALS (US Army Corps of Engineers)
  1996 - Mars Orbiter Laser Altimer (NASA MOLA-2)
  1997 - Shuttle Laser Altimeter (NASA SLA)
  Early 2000s - North Carolina achieves statewide Lidar coverage (used for updating FEMA flood insurance maps)

  Statewide and regional consortiums being developed for the management and distribution of large volumes of Lidar data
- Currently 2 predominate issues - Standardization of data formats
  Standardization of processing techniques to extract useful information

## Comparison of Lidar and Radar

| Lidar | Radar |
|---|---|
| Uses optical signals (Near IR, visible). Wavelengths ≈ 1 um | Uses microwave signals. Wavelengths ≈ 1 cm. (Approx 100,000 times longer than Near IR) |
| Shorter wavelengths allow detection of smaller objects (cloud particles, aerosols) | Target size limited by longer wavelength |
| Focused beam and high frequency permit high spatial resolution (< 1m horizontal) | Beam width and antenna length limit spatial resolution (10s of meters). Synthetic aperture techniques reduce antenna length requirements. |
| Nadir looking sensor | Side looking sensor. |
| Limited to clear atmospheric conditions, daytime or nighttime coverage. | Can operate in presence of clouds. Daytime or nighttime coverage. |

## Topographic Lidar Operating Principles

Distinguish between **Pulsed** and **CW** Lidar systems.

- **Pulsed system**: Transmitted signal consists of a series of laser pulses, 10,000 to 150,000 pulses/second (10 - 150 kHz pulse rate).
  Range to target calculated from time to receive pulse:
  Range = c*t / 2

- **CW system**: Transmits sinusoidal signal of known wavelength
  Range calculated from number of full waveforms and the phase difference between transmitted and received signal.
  Much less common technique compared to pulsed system.

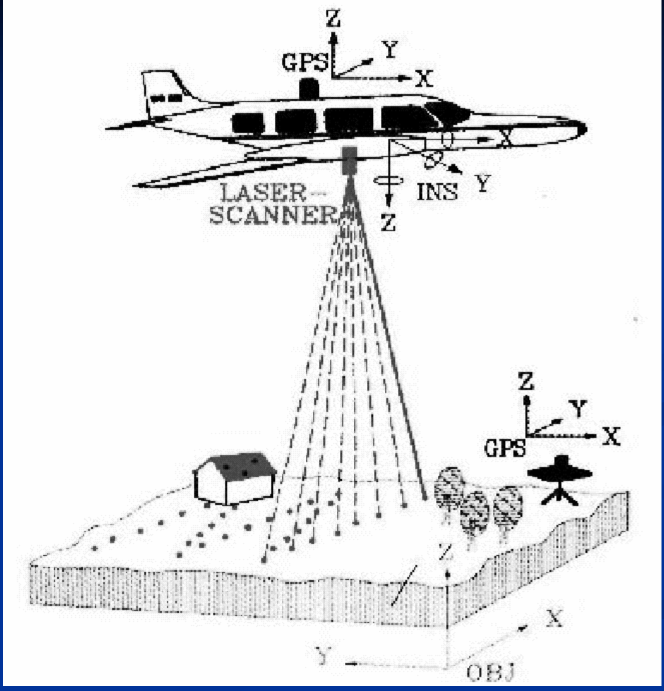
## Pulsed System Operation

- Wavelengths utilized: **1.0 - 1.5 μm** (terrestrial studies)
  **0.50 - 0.55 μm** (bathymetric studies)

- Combination of scanning mirror and moving platform produces a 2D field of range measurements.

- Additionally recorded information: Angle from nadir of measurement
  GPS horizontal and vertical positions ( 1 Hz)
  Aircraft Inertial Measurements (pitch, roll, yaw) (50 Hz)

- On board processing: Slant distance calculated from range measurement + angle from nadir for each returned pulse
  Slant distance corrected using IMU measurements
  GPS data integrated to provide a georeferenced elevation value for each returned pulse.
  **GPS measurements are crucial to vertical accuracy.**




- **Pulsed systems are one of two types**:
  - **Small footprint**: Ground unit = 5 - 30 cm
    Useful for detailed local mapping, edge detection, detailed vegetation canopy studies
  - **Large footprint**: Ground unit = 10 - 25 m
    Larger swath width
    Useful for larger scale studies of canopy response
- Footprint size is a function of **IFOV**
  **Sensor altitude**
  **Viewing angle from nadir**

## Spatial Resolution Considerations for Pulsed System

- Achievable point density is a function of:
  - **IFOV of instrument**
  - **Altitude of platform**
  - **Number of points collected**
    - platform speed
    - scan speed and scan angle (swath width)
    - altitude of platform
    - pulse frequency
- For a given set of operating conditions, pulse frequency becomes the primary figure of merit.
- Pulse repetition frequencies have increased from about 5 kHz in 1995 to 150 kHz presently, reducing spatial grid resolutions to < 0.5 meters

**Typical Lidar Performance Characteristics** (pulsed small footprint system, 2001)

| Specification | Typical Value |
|---|---|
| Wavelength | 1000-1500 nm |
| Pulse Rep. Rate | 140 kHz |
| Pulse Width | 10 nsec |
| Scan Angle | 40° - 75° |
| Scan Rate | 25 - 40 Hz |
| Swath Width | Up to 0.7 * altitude |
| Z accuracy RMSE | Approx 15 cm |
| X,Y accuracy RMSE | 10 - 100 cm |
| Footprint | 0.25 - 2 m (from1000m) |
| Resolution | 0.75 meters |
| GPS frequency | 1 Hz |
| IMS Frequency | 50 Hz |
| Operating Altitude | 500 - 2000 m |

## Post-Processing of Topographic Lidar Data

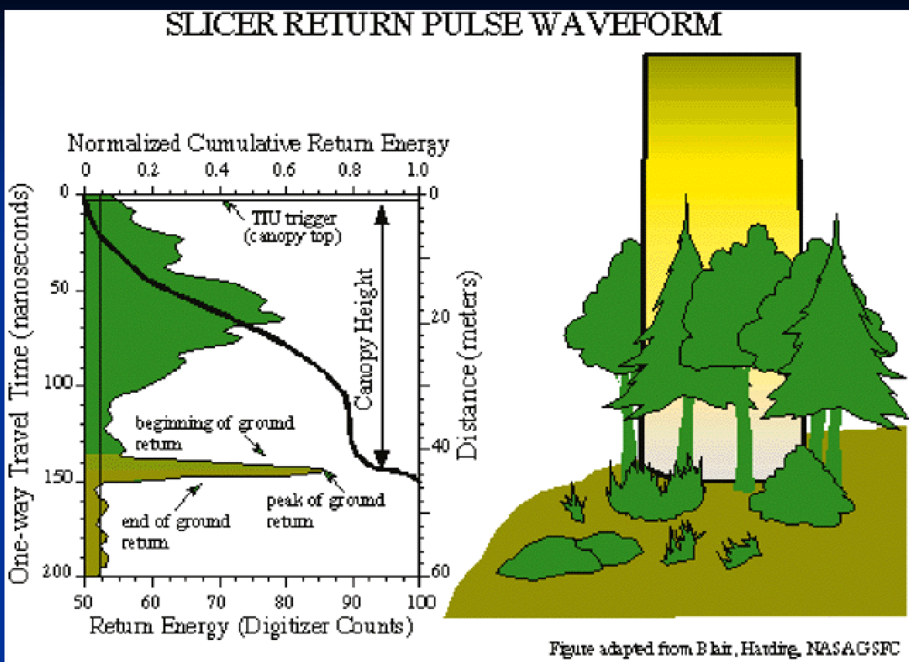
- Near IR pulses capable of reflection off of multiple surfaces
- Profile of received signal depends on nature of target surface:

  **Vegetation** - first return (crown)
  intermediate returns (underlying branches/leaves)
  last/ground return (earth surface)

  **Buildings** - single return (first = last)

  **Bare Earth** - single return (first = last)

- Older Systems - Detected single (first) return from each pulse.
  Elevation profile is a Digital Surface Model (DSM).
- Newer Systems - Capable of detecting multiple returns from each pulse (Waveform Capture).
  Dataset is unfiltered point cloud.
  Post Processing needed to distinguish between first, intermediate, and last returns.




From Flood, 2001

## Post Processing Techniques

- Filtering Last Returns from point cloud to generate **Bare Earth DEM. Capable of producing bare earth DEMs in areas with moderately dense vegetation cover.**
- First Return - Last Return to determine **Canopy Height**
- Filtering First and Intermediate returns to estimate **vegetation biomass, tree densities, individual tree structure information**
- Separate First Return signals at abrupt edges to delineate **Building Features** (small footprint systems)
- Several Filtering Methods are currently being developed. Most combine automated algorithms with manual correction.

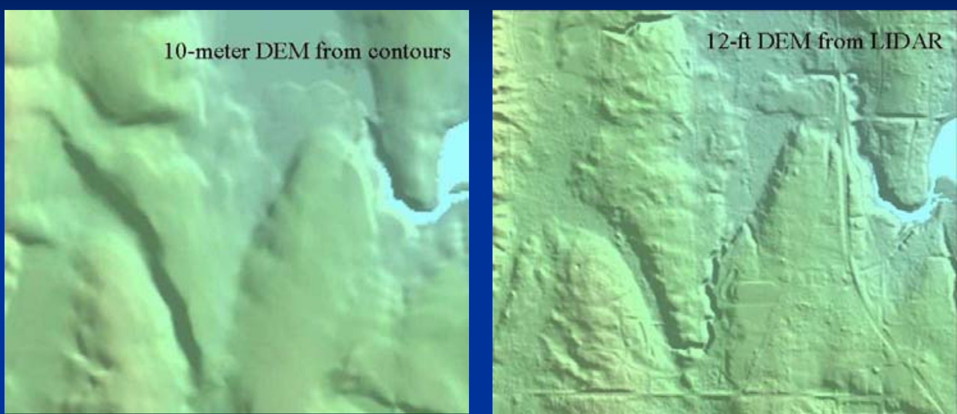
## Lidar Applications

- Update digital elevation models (NED)
- Glacial Monitoring
- Detecting Faults and measuring uplift
- Forest Inventory
- Shoreline and Beach Volume Changes
- Bathymetric Surveying (SHOALS)
- Landslide Risk Analysis
- Habitat Mapping
- Subsidence Issues
- Telecom Planning
- Urban Development

## Free Lidar Sources

- Puget Sound LIDAR Consortium
- OR  Dept. of Geology and Mineral Industries (DOGAMI).  Portland DEMs.
- Louisiana State University
- Red River Basin Decision Information Network
- NOAA Coastal Services Center
- USGS Center For Lidar Information Coordination and Knowledge (CLICK)
- USACE Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX)
- North Carolina Floodplain Mapping Program

## Comparison of Lidar versus standard USGS 10m DEM

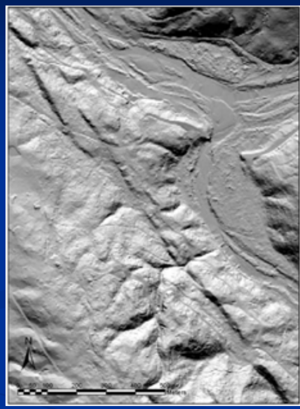



Bainbridge Island, WA.  From Puget Sound Lidar Consortium

## San Andreas Fault Detection Using Lidar

Aerial Photo

First Return DSM

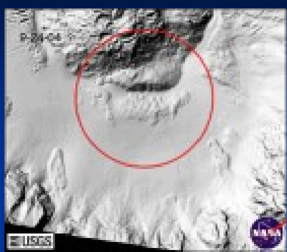


Last Return DEM showing fault

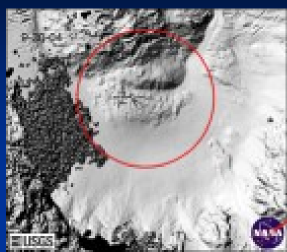
**http://quake.usgs.gov/research/geology/lidar/example1.html**

## Dome Formation, Mt. St. Helens

09_03_2004

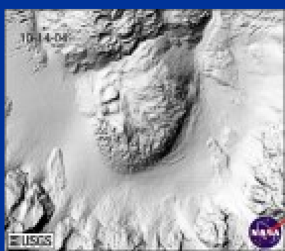


09_24_2004

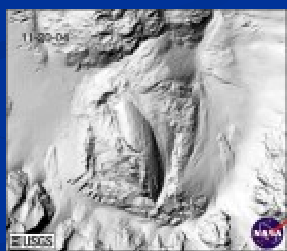


09_30_2004

10_04_2004



10_14_2004



11_20_2004

**from USGS Cascades Volcano Observatory**

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NASA Tutorial: http://www.ghcc.msfc.nasa.gov/sparcle/sparcle_tutorial_morelidar.html

NOAA Coastal Services Center: http://www.csc.noaa.gov/crs/rs_apps/sensors/lidar.htm