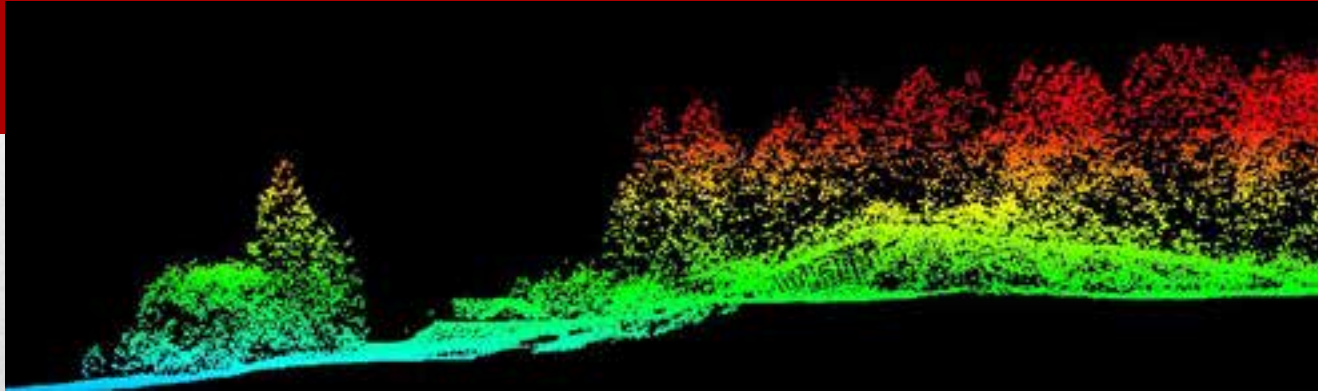


# A Practical Introduction To LiDAR & Forestry



**Behron LLC**

**May 2012**



# What happened to Ron?

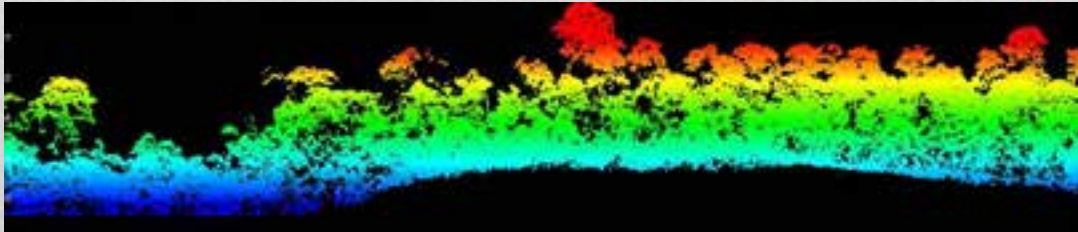
## Ski Joring



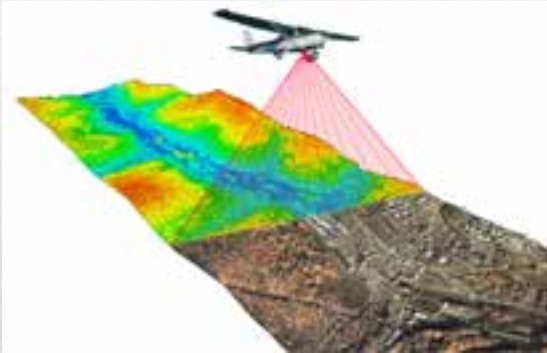
# Behron LLC

## Ron Behrendt

- **Founded in 2005**
- **Provides LiDAR-centric consulting services**
- **Focused on Forestry & Utility applications**
- **Applied technology via ArcGIS**
- **Esri business partner**



# Introduction to LiDAR & Forestry



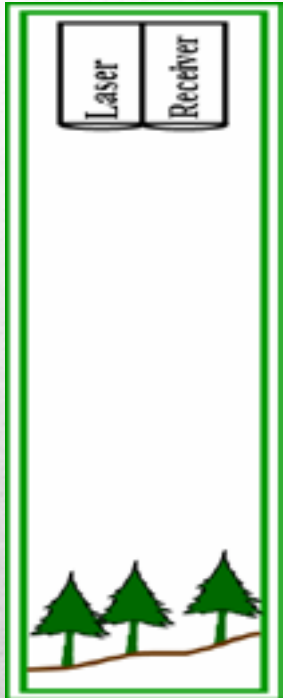
- **LiDAR technology**
  - **Common acquisition deliverables**
  - **Applied to forestry**
  - **Futures**
-

# Different Types of LiDAR

- **Atmospheric LiDAR**
- **Bathymetric: Senses up to 50 meters deep **BUT** requires clear water!**
- **Terrestrial: Tripod mounted or mobile**
- **Airborne Laser Scanner (ALS)**



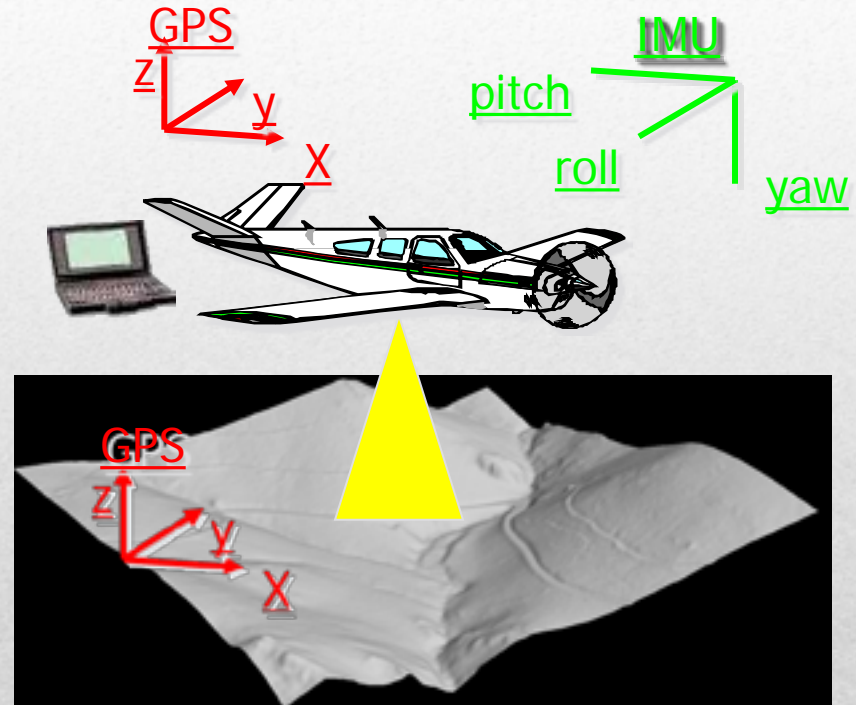
# LiDAR Technology - Introduction



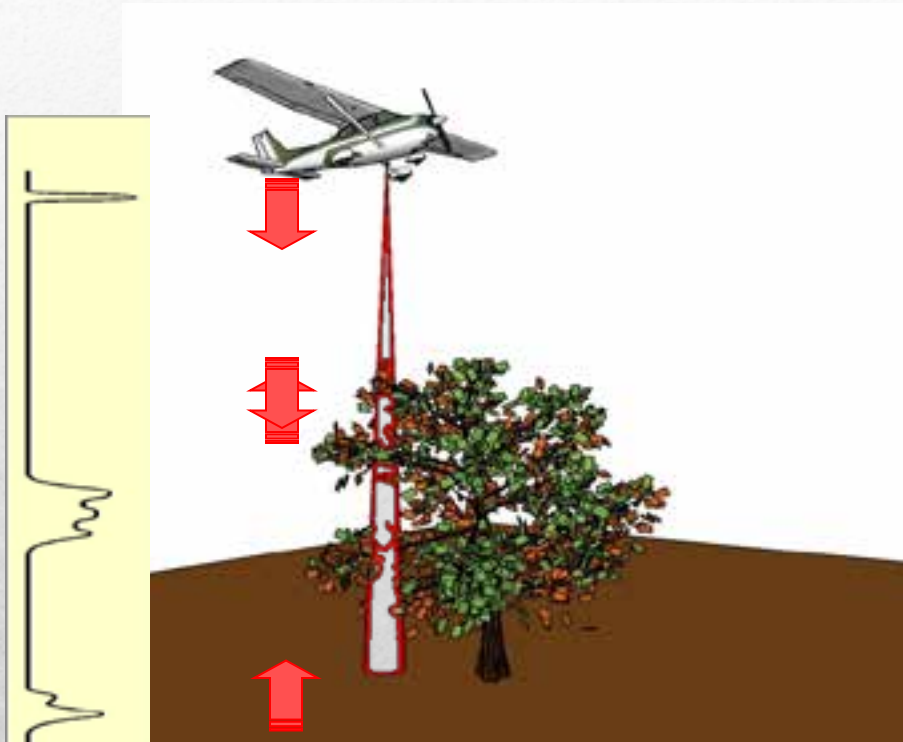
- **LiDAR -- Light Detection And Ranging**
  - similar in concept to Radar & Sonar
- Measures distances (through laser pulses) that strike and reflect off of features on the surface of the earth
- Converts scanning angle and distance-from-sensor information into georeferenced data points
- Current sensors can collect hundreds of thousands of positions each second ('point clouds')

# Airborne LiDAR System Components

- Scanning laser emitter-receiver unit
- Differentially-corrected GPS in the plane
- Inertial measurement unit (IMU)
- Computer to control the system and store data



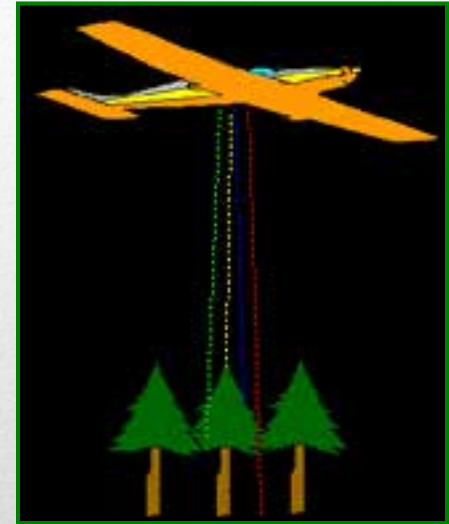
# LiDAR Technology





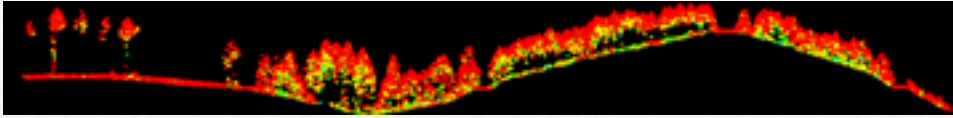
# LiDAR Data Characteristics

- A **“Return”** is a portion of the LiDAR pulse that is reflected back to the sensor
- Most laser systems can record several returns or “multiple returns” for each pulse
  - Multiple returns occur when the laser beam is only partially blocked
  - The remaining laser energy continues downward until it is reflected back by the next feature
- Up to 4 returns per pulse, but typically only receive 2-3 returns

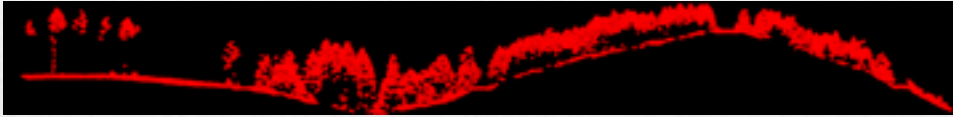


— — —	<u>1<sup>st</sup> Return (Canopy Ht)</u>
— — —	<u>Intermediate Return</u>
— — —	<u>Intermediate Return</u>
— — —	<u>Last Return (Ground)</u>

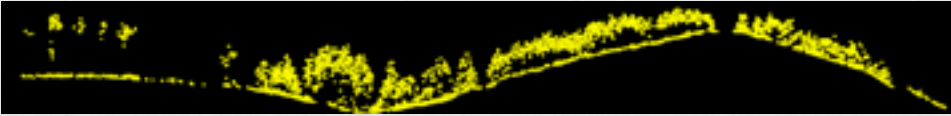
# LiDAR Data Characteristics



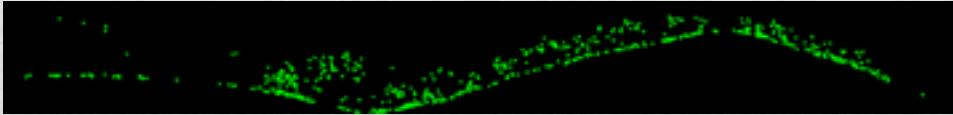
All returns (100%)



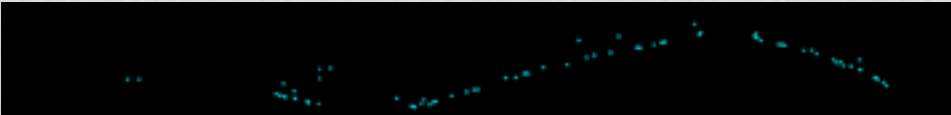
1<sup>st</sup> returns (69%)



2<sup>nd</sup> returns (26%)



3<sup>rd</sup> returns (4%)



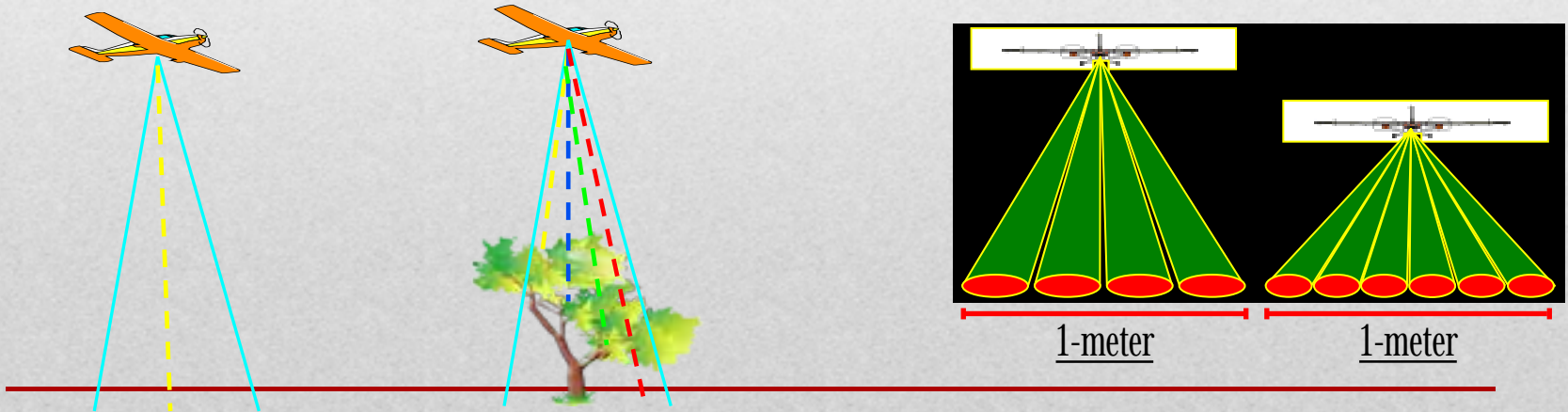
4<sup>th</sup> returns (<0.1%)



# LiDAR Data Characteristics

## LiDAR Data Resolution (PPM)

- The only consistent measure of LiDAR data resolution (when considering the full point cloud) is the number of pulses per unit area or **Pulse Density** (pulses/m<sup>2</sup>).
- Return density can vary depending on the target being scanned.

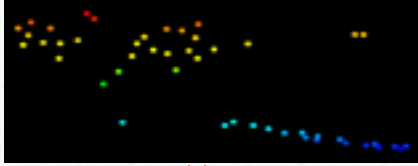


# LiDAR Data Characteristics

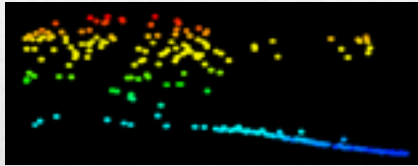
**LiDAR Data Resolution (PPM) is dependent on:**

- **Laser scan rate (more pulses @ same speed à higher resolution)**
  - **Flying height and speed (higher or faster à lower resolution)**
  - **Side-lap coverage (e.g. 50% side-lap will result in 2x resolution)**
-

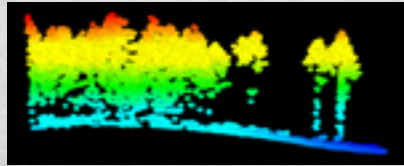
# LiDAR – Pulse Density & Products



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- **Low** Pulse Density ( $\leq 1$  Pulse/m<sup>2</sup>)
    - Product: Moderate Resolution Topographic Products ( $\geq 2$  meter Grid)
  - **Moderate** Pulse Density (1-3 Pulses/m<sup>2</sup>)
    - Products: Stand Level Vegetation Metrics (e.g. canopy height, canopy cover) and High Resolution Topographic Products
  - **High** Pulse Density ( $\geq 3$  Pulses/m<sup>2</sup>)
    - Products: Forest Structure
-

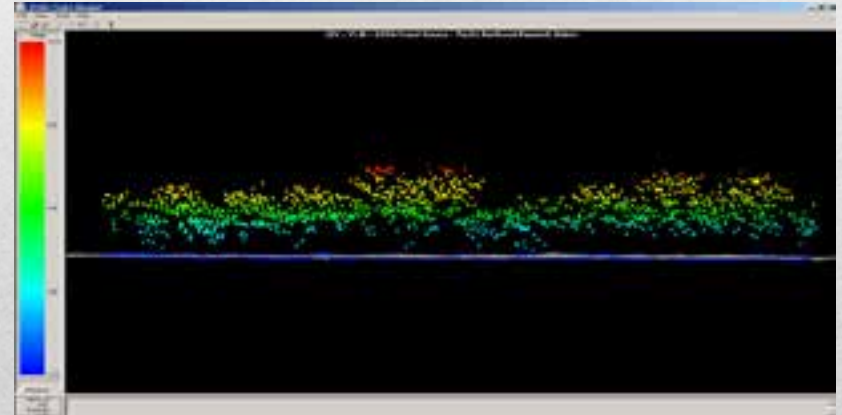
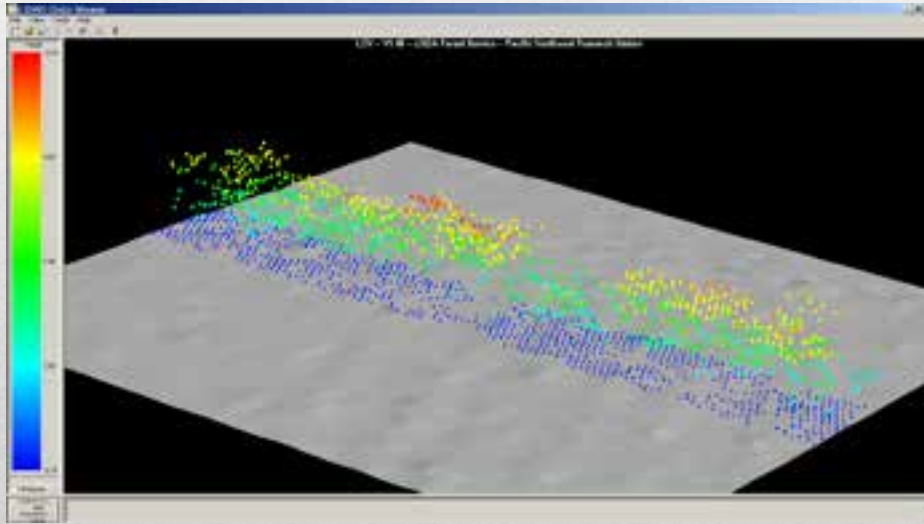
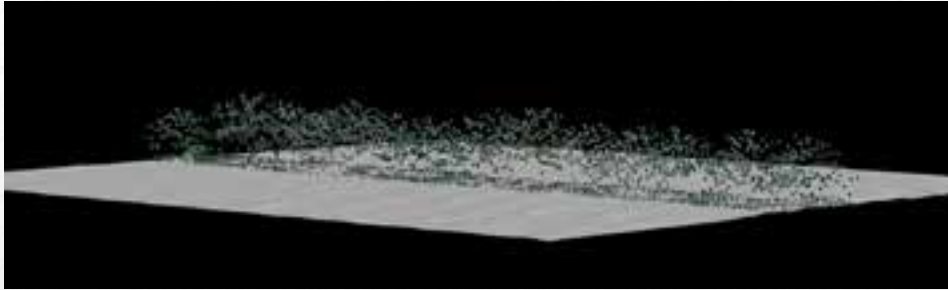
# LiDAR Data Characteristics

**Spatial accuracies depend on:**

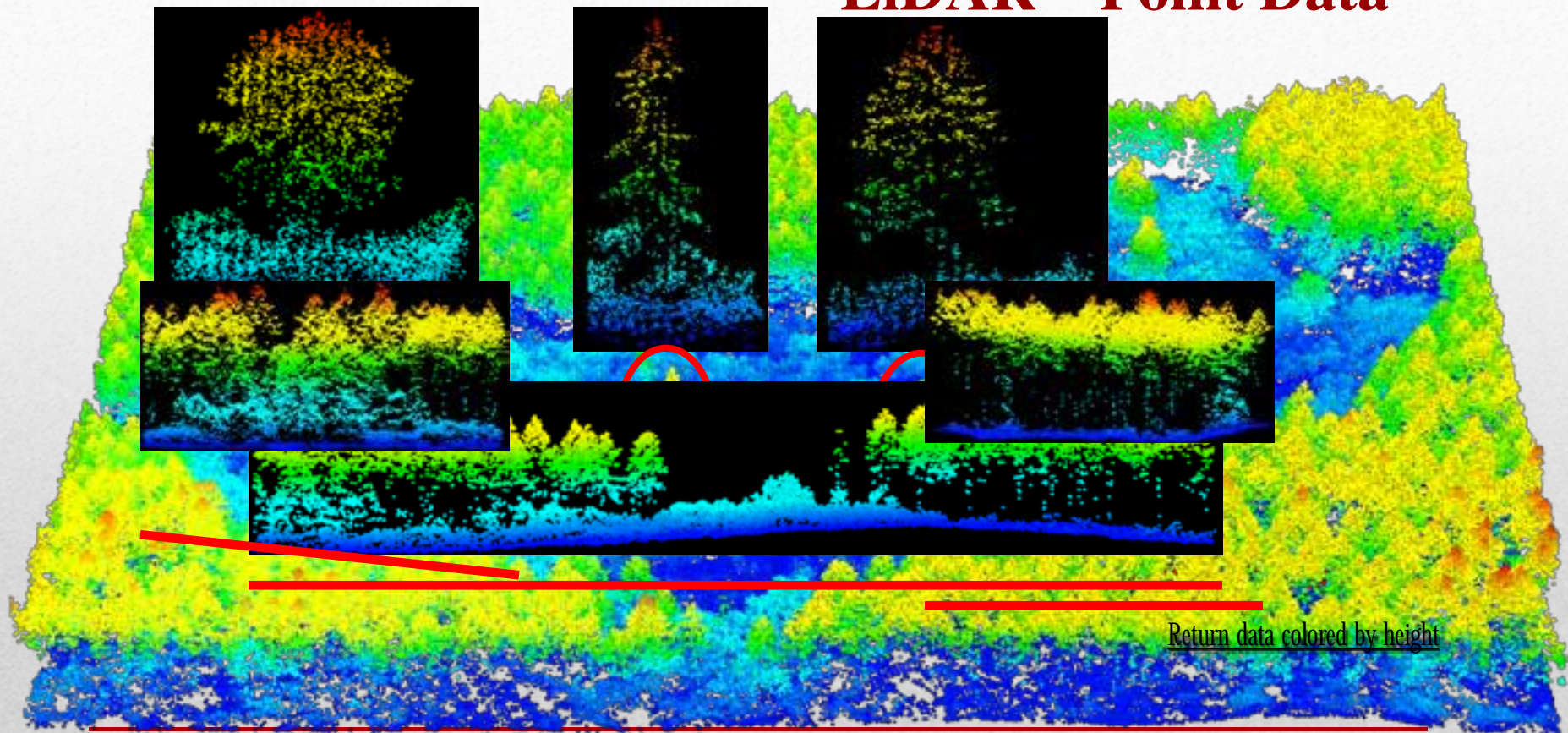
- **Slope (flat vs. steep)**
  - **Ground cover (pavement vs. trees)**
  - **Acquisition altitude**
  - **Quality of instruments**
  - **Capabilities of provider**
  - **Best case: +/- 5cm vertical**
-

# LiDAR – Point Data

- True 3D Data!



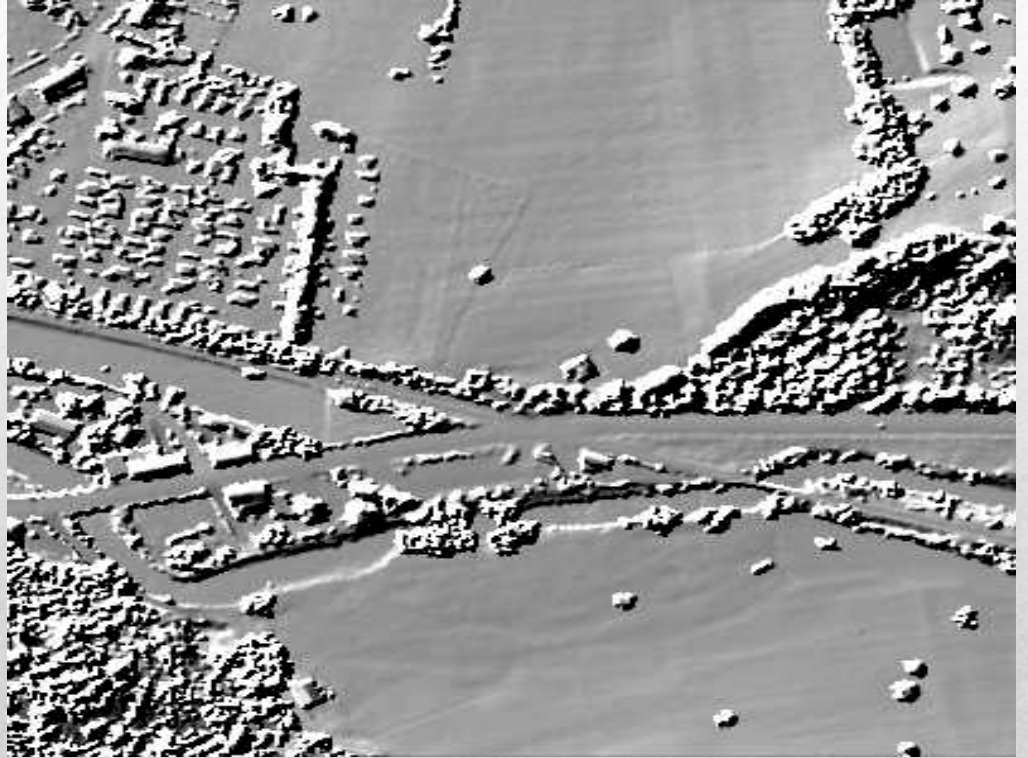
# LiDAR – Point Data





## LiDAR – Deliverables

- **Digital Surface Model (DSM)** is an elevation model which accurately describes the earth's surface including vegetation, buildings and objects.

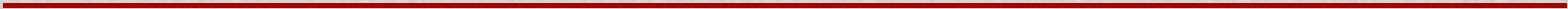
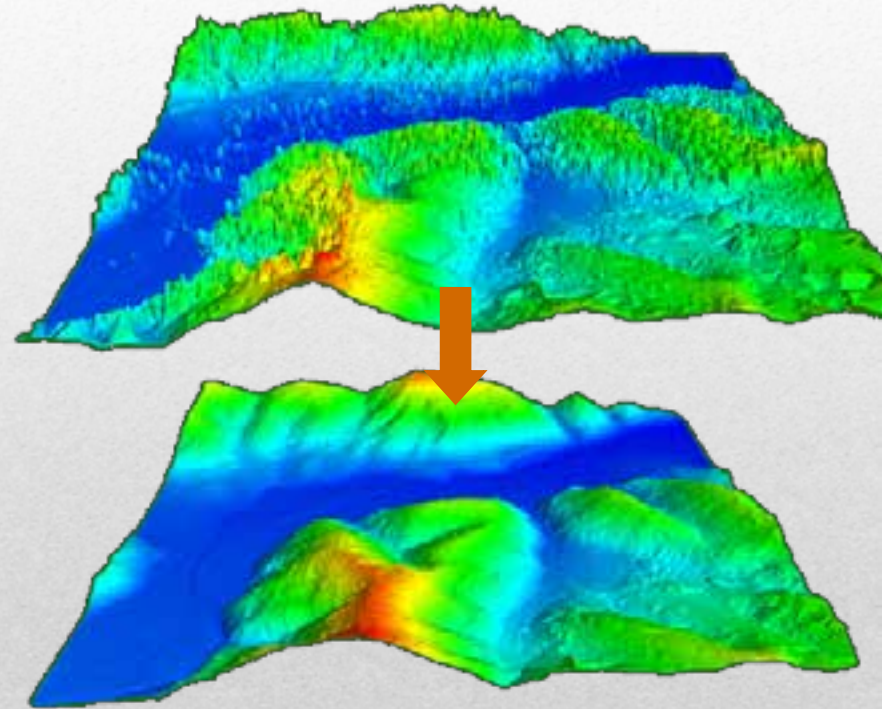
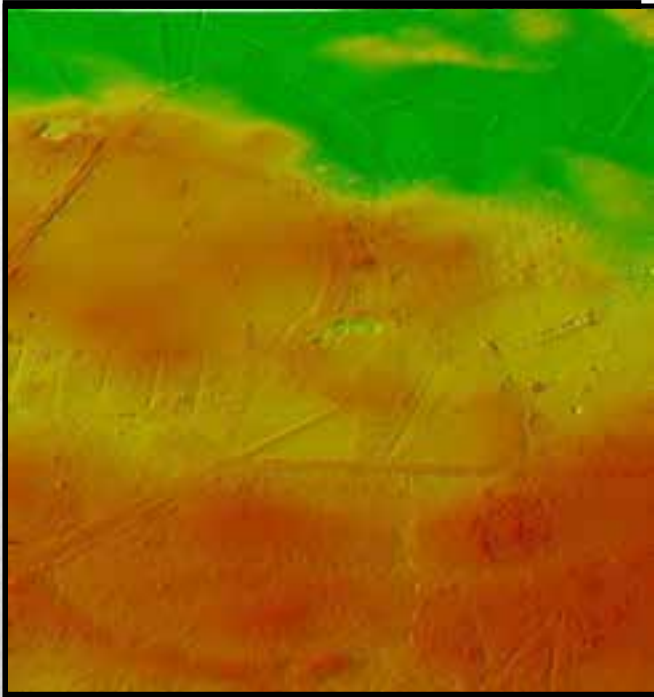


**Digital Terrain Model (DTM) is an elevation model which depicts the terrain surface without buildings and vegetation, commonly referred to as “bare earth”.**

## **LiDAR – Deliverables**

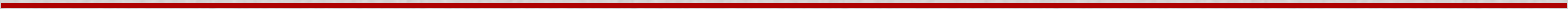
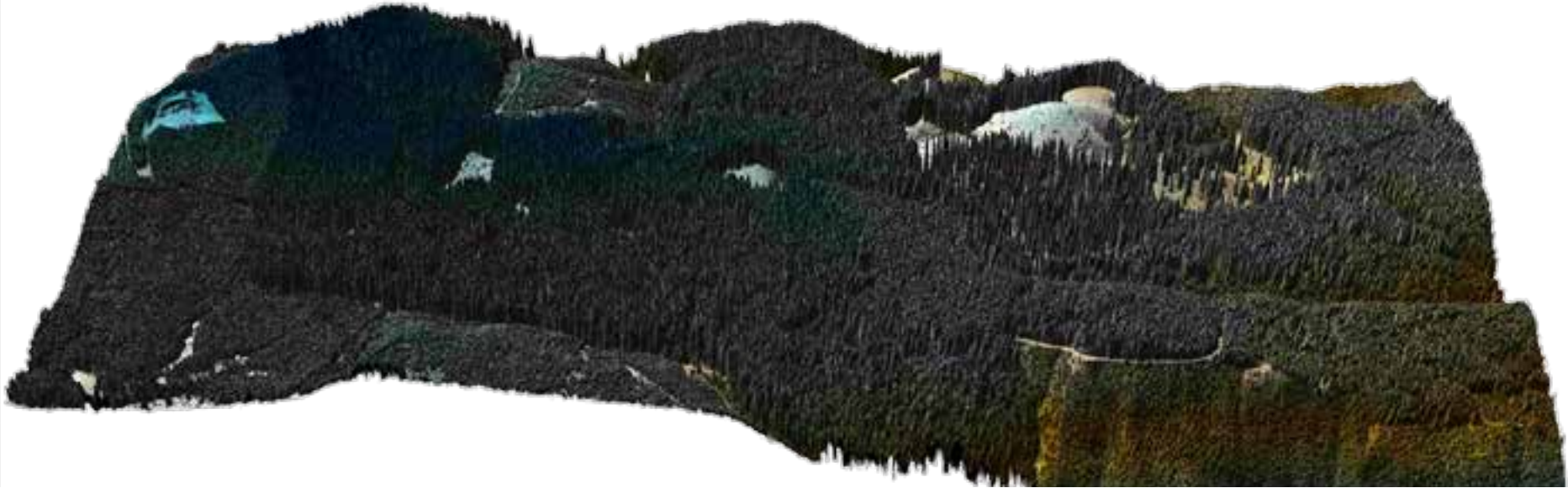


# LiDAR – Deliverables

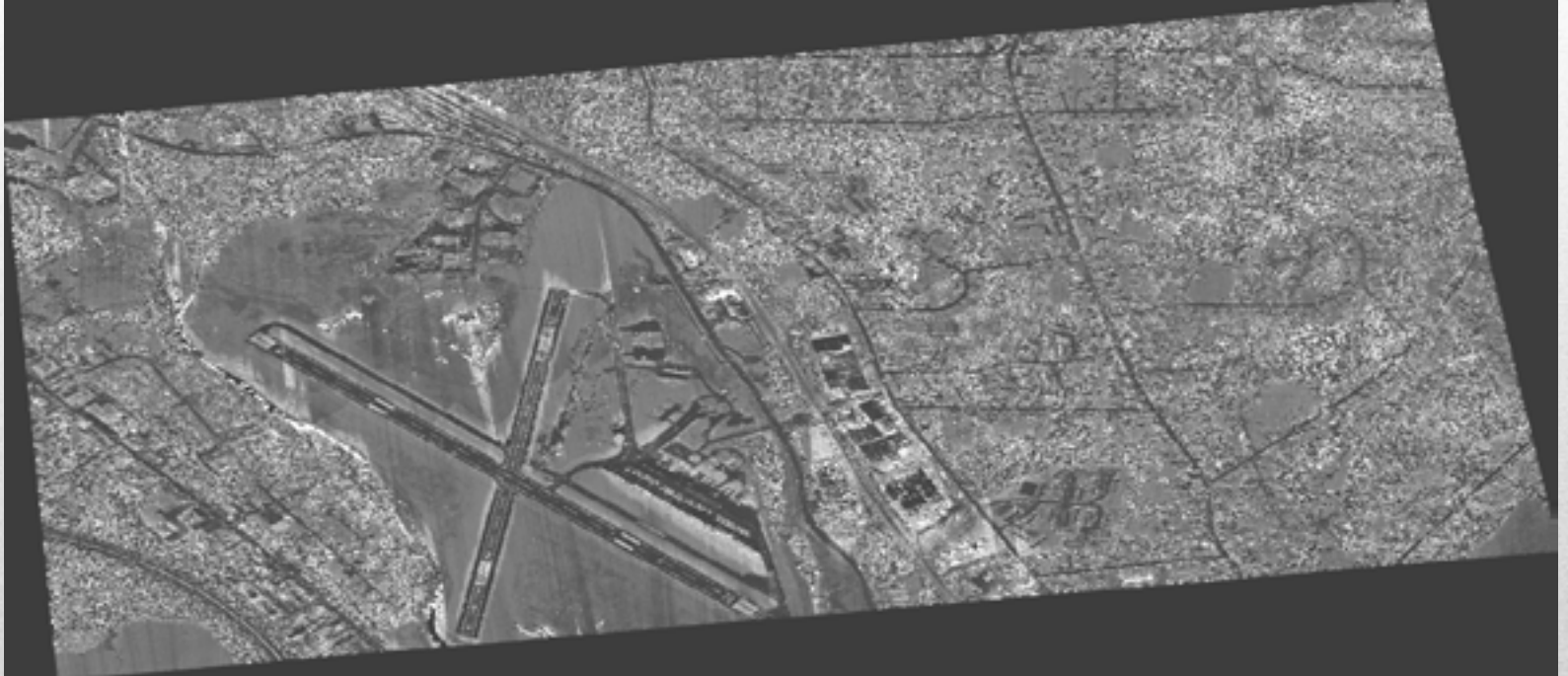


DSM & DTM

**LiDAR – Deliverables**



# LiDAR – Intensity Image



# LiDAR – Intensity Image



# LiDAR Point Classification

- Each point can be classified allowing software such as ArcGIS to filter on class and “sort” the point cloud.
- Most common: Ground/non ground

Table 17: ASPRS Standard LIDAR Point Classes (Point Data Record Formats 6-10)

Classification Value	Meaning
0	Created, never classified
1	Unclassified <sup>3</sup>
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Reserved
9	Water
10	Rail
11	Road Surface
12	Reserved
13	Wire – Guard (Shield)
14	Wire – Conductor (Phase)
15	Transmission Tower
16	Wire-structure Connector (e.g. Insulator)
17	Bridge Deck
18	High Noise
19-83	Reserved
64-255	User definable

# LiDAR Point Cloud Storage

## The .las File Format

- **Public format allowing the exchange of LIDAR data**
  - **Developed by the American Society for Photogrammetry and Remote Sensing (ASPRS)**
  - **Contains LiDAR specific information (vs. ASCII)**
    - **Point return number**
    - **Point classification**
    - **RGB**
    - **Intensity**
-



# LiDAR Capabilities Applied to Forestry

- **High accuracy terrain data, even in areas of relatively dense vegetation**
- **With multiple return LiDAR, analysis of forest structure is possible**
- **Ability to distinguish between the top of the canopy and the ground.**
- **Apply topographical information (i.e. slope) to road & stream vectors.**
- **Measurement on a tree by tree basis feasible if desired (micro vs. macro scale)**



# LiDAR Data & Forestry

## One Flight, Numerous Layers

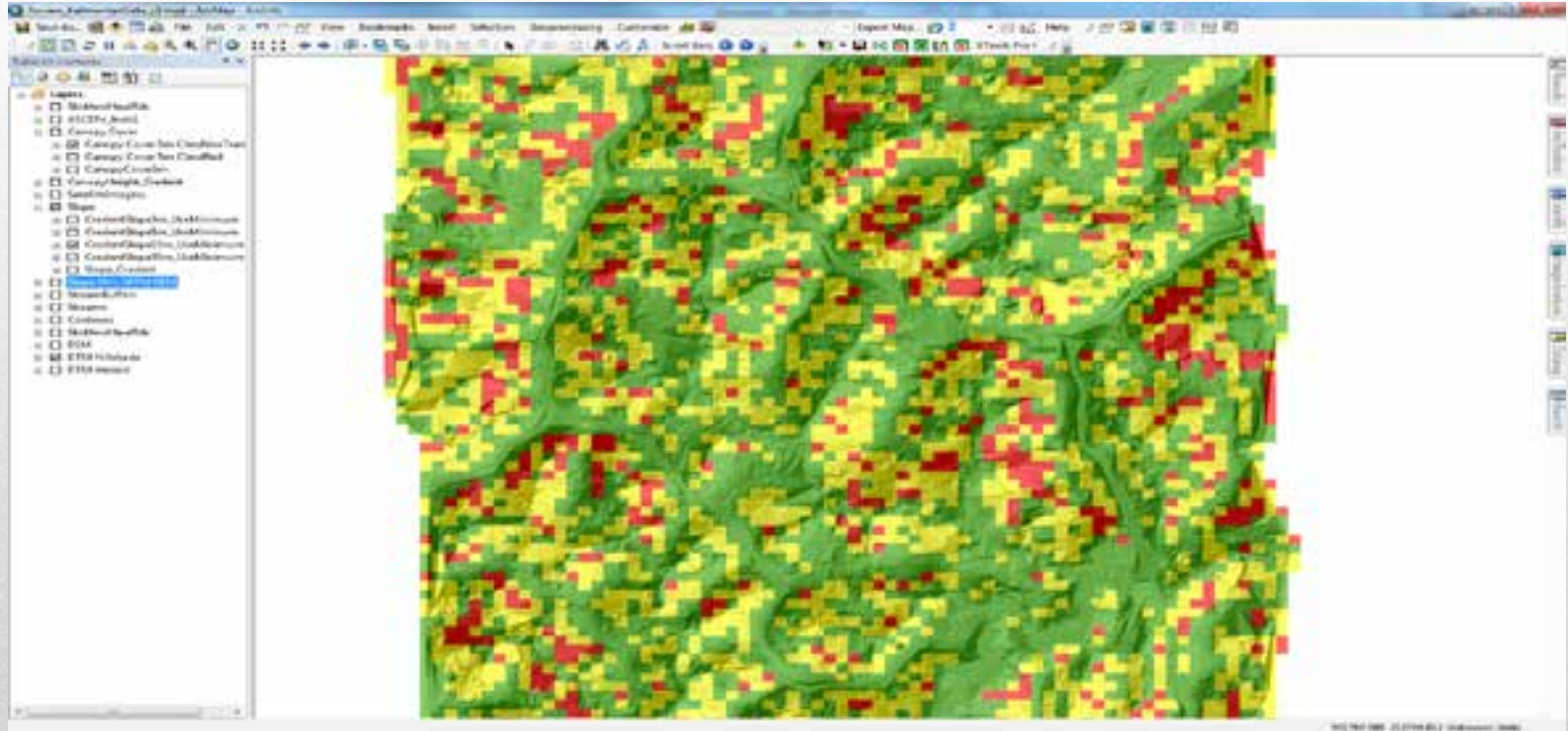
- GIS layers “created” from LiDAR data
  - Canopy height
  - Canopy cover
  - Canopy density (mid-story)
  - Slope maps
  - Hydrological maps in 3D
    - stream location, direction & slope
  - Roads (existing & historical) in 3D
  - Cultural features (i.e. buildings)
- Imagery often collected simultaneously
  - Colour and/or Colour Infrared Imagery



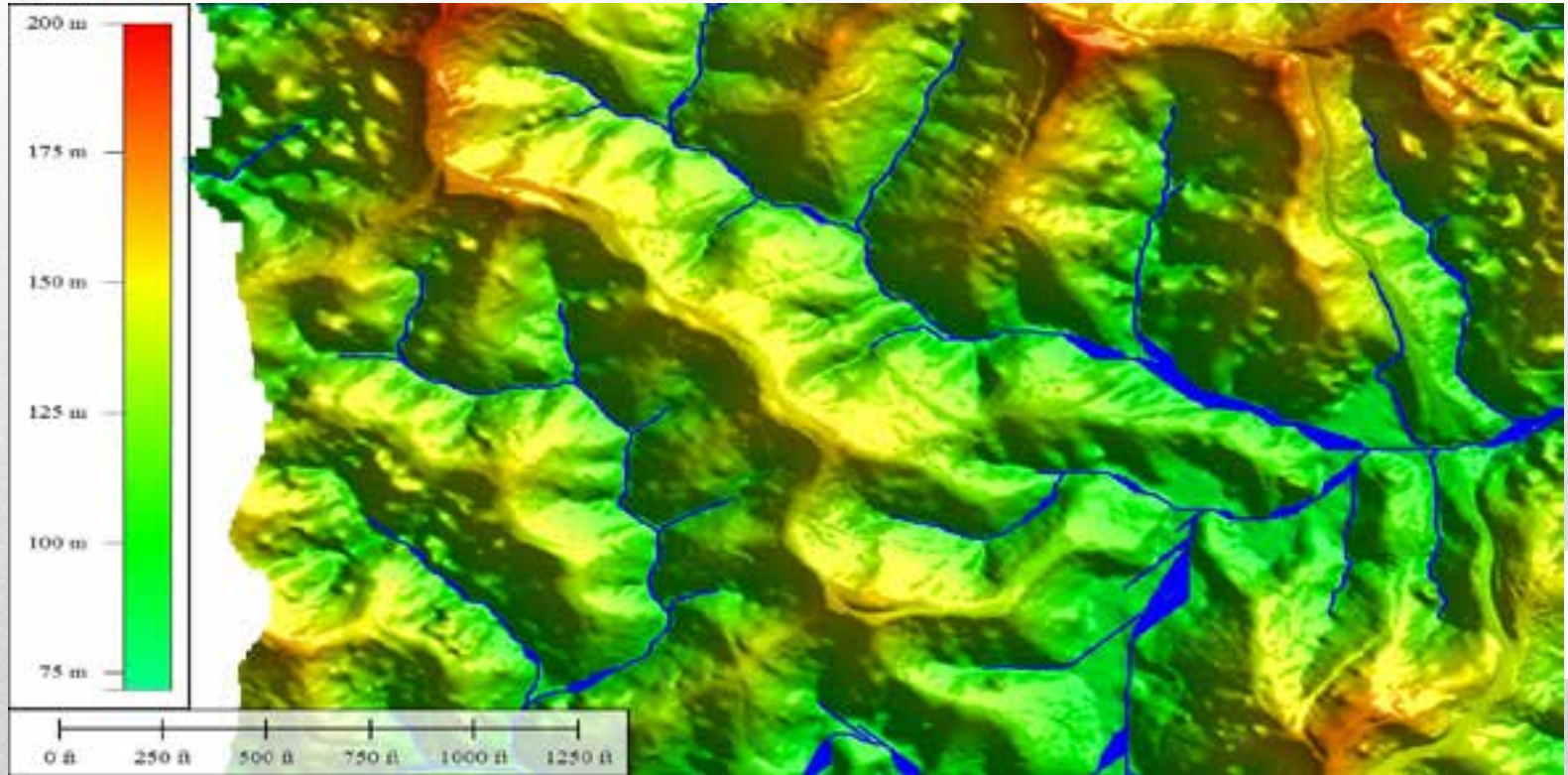
# LiDAR Applications for Forestry

- **Baseline examination**
  - **Topographical analysis**
  - **3D viewshed analysis**
  - **Quantify forest stand characteristics**
    - **Biomass estimates**
    - **Fire fuel modeling**
  - **Landslide analysis**
  - **Change over time**
-

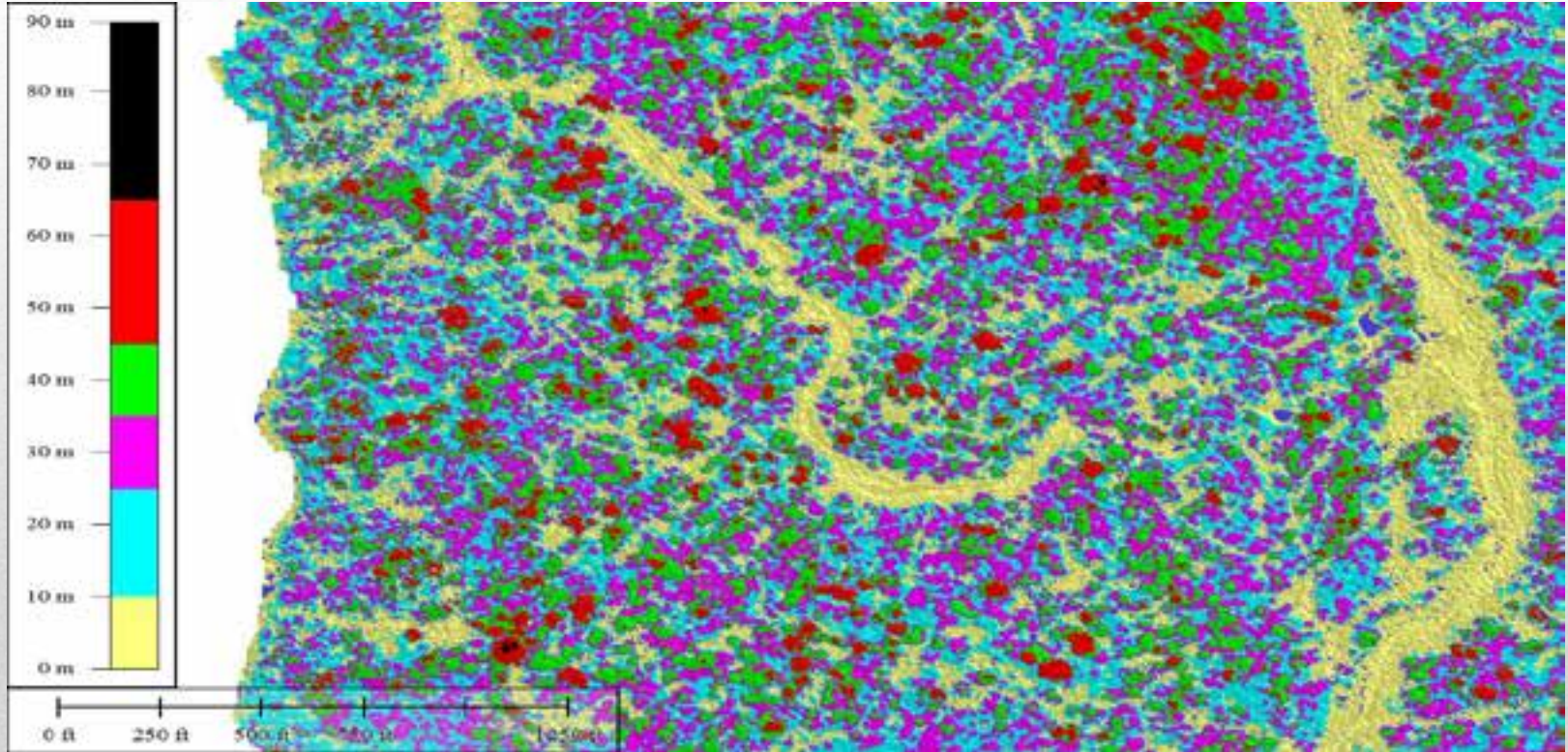
# Slope Map



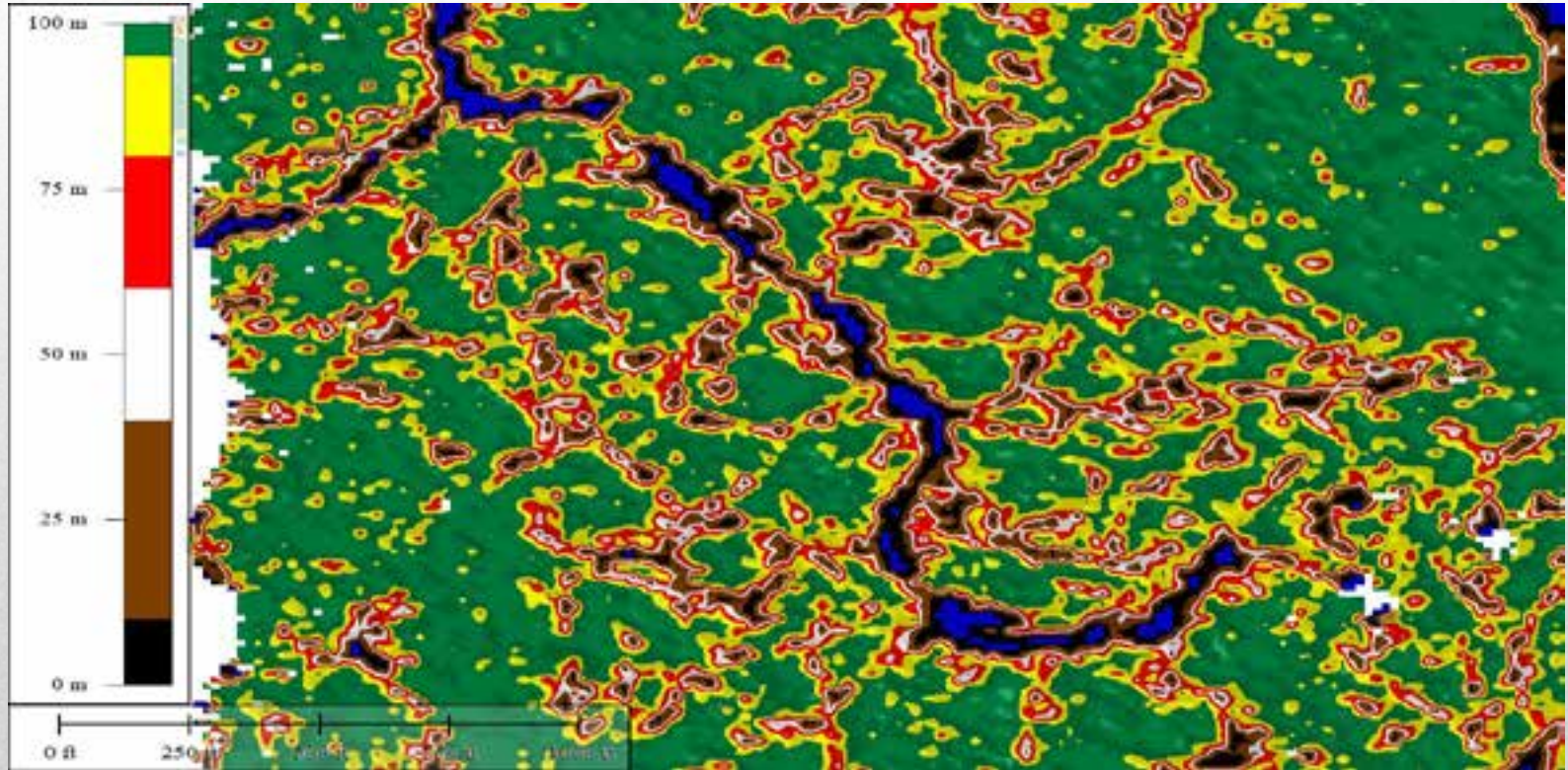
# Hydro Flow Map



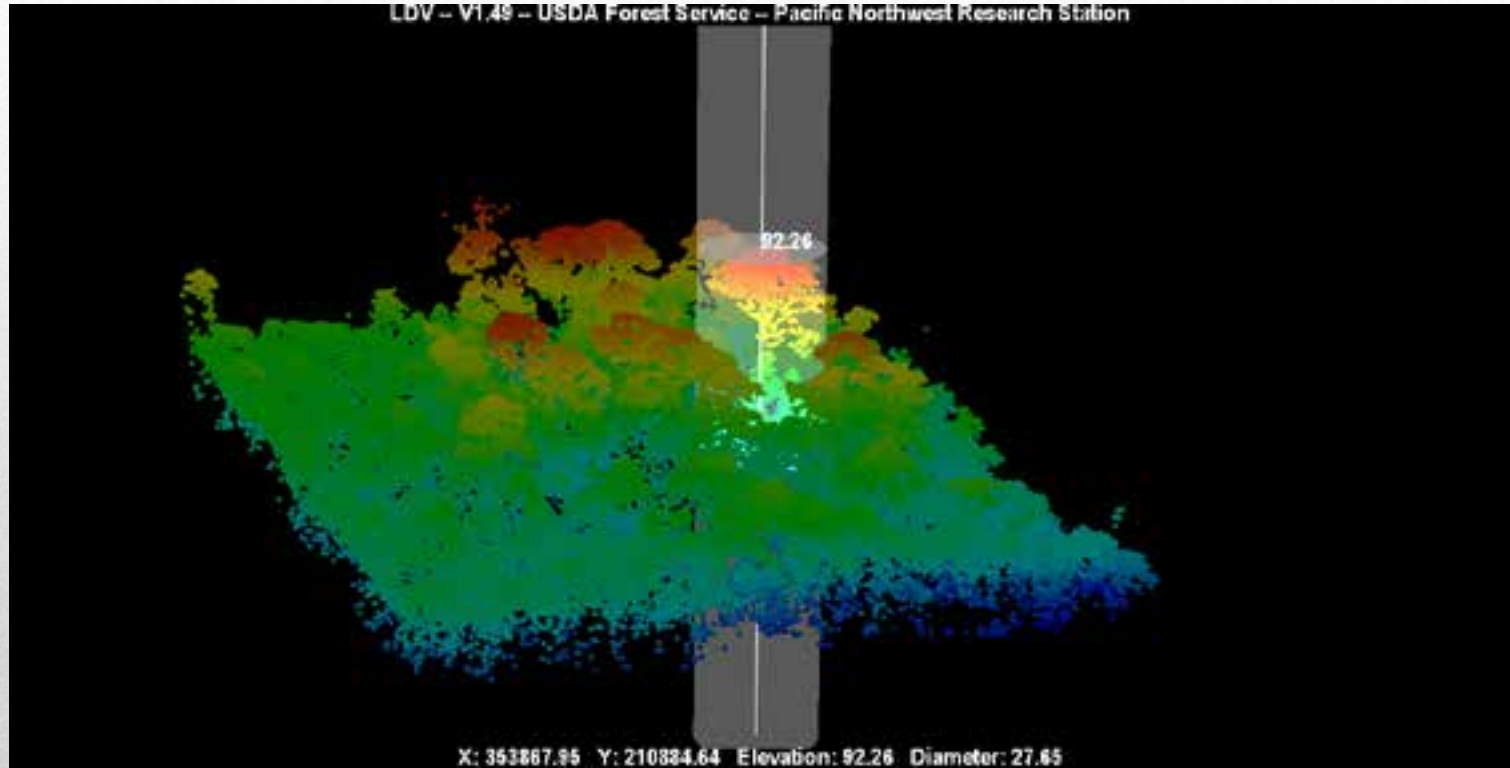
# Canopy Height Map



# Canopy Cover Map



# Inventory Individual Trees





# LiDAR – Procurement Considerations

- **What will the LiDAR be used for?**
    - **Pulse density**
    - **Spatial accuracy**
    - **Laser sensor scan angle**
    - **Point cloud classification**
    - **Flight line overlap (i.e. 50%)**
  - **Deliverables?**
  - **Combine with high resolution imagery? Fused?**
-

# Futures

- **Existing LiDAR Technology**
    - **Faster pulse rates**
    - **Multiple sensors in one box**
  - **New LiDAR Technologies**
  - **Better Feature Extraction Software**
    - **More automation**
    - **Improved results**
  - **Change Detection (PC to PC)**
-

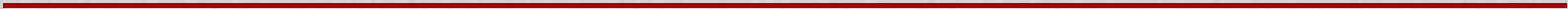
# **LiDAR For Forestry - Summary**

- **Airborne LIDAR is a tool that provides Foresters with:**
    - **Highly accurate topographical data**
    - **Forest stand information including canopy height, density and percentage of closure**
    - **3D visualization of the ground and land cover**
    - **A source accurate GIS information, even in remote areas**
    - **A quantifiable and repeatable data source**
  - **One flight = Many GIS data layers**
  - **Often combined with high resolution imagery**
-

# Acknowledgements

- **U.S.D.A. Forest Service Pacific Northwest Research Station**
    - **Bob McGaughey and Steve Reutebuch**
  - **U.S.D.A. Forest Service Remote Sensing Applications Center (RSAC)**  
**<http://fsweb.rsac.fs.fed.us>**
    - **Brent Mitchell**
  - **Optech Incorporated**
  - **Credent Technology (ASIA) PTE LTD**
    - **(<http://www.credent-asia.com>)**
-

# Questions ?



**Thank You!**

