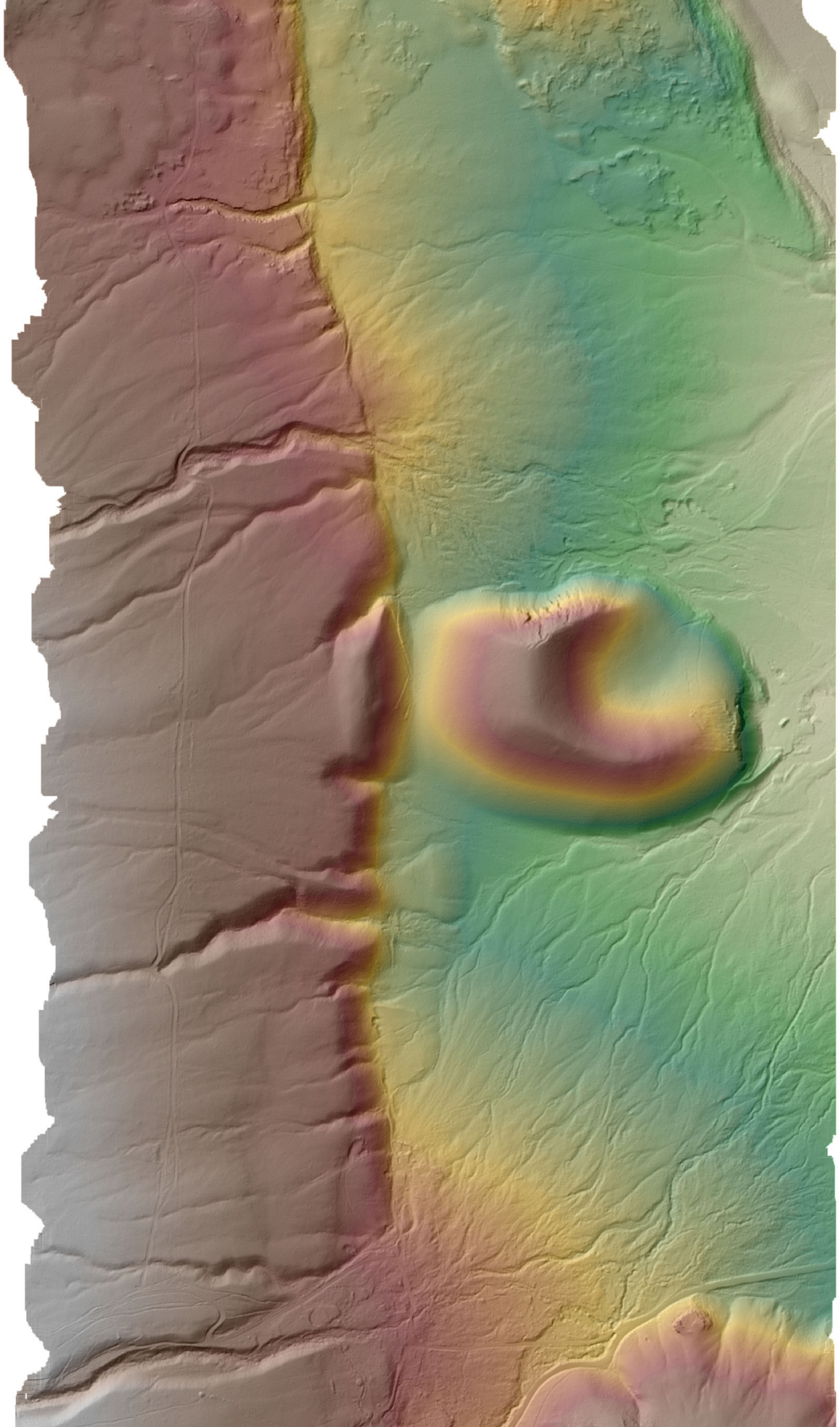


INTRODUCTION TO LIDAR

Christopher Crosby

UNAVCO, Boulder, CO

OpenTopography

(with content adapted from Ralph Hagerud; Ian Madin, DOGAMI; Jason Stoker, USGS; Tristan Goulden, NEON; Quantum Spatial)

Light Detection and Ranging (LIDAR)

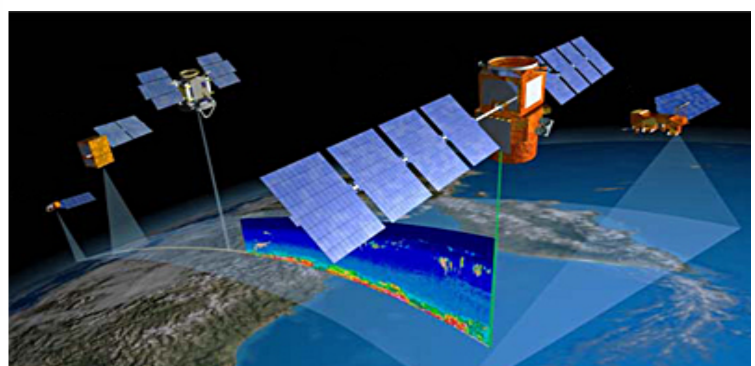
- Accurate distance measurements with a laser rangefinder
- Distance is calculated by measuring the two-way travel time of a laser pulse.
- Near IR (1550nm) or green (532nm)

Modified from Ian Madin, DOGAMI

UNAVCO

LIDAR PLATFORMS

BUSINESS WIRE COMMERCIAL PHOTO



J. Stoker, USGS

Terminology

Similar technology, different platforms:

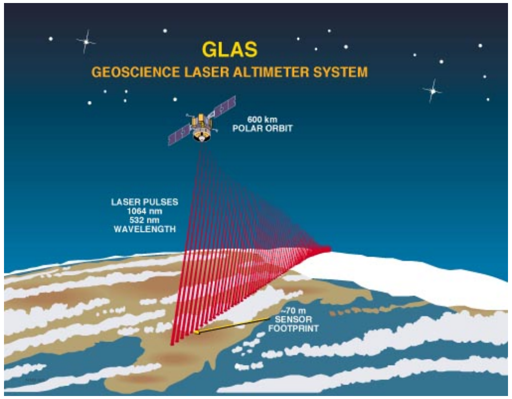
Terrestrial Laser Scanning (TLS)

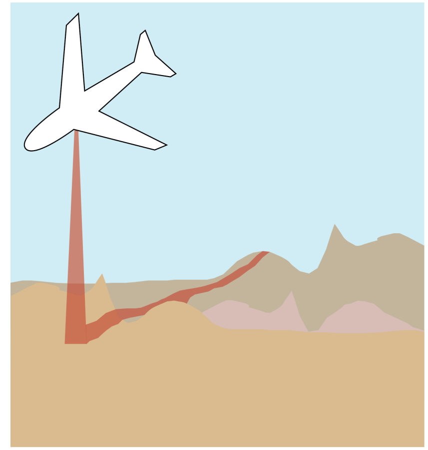
- Also called ground based lidar or T-lidar.

Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

Laser scanning from airborne platform = Airborne Laser Scanning (ALS).

LIDAR PLATFORMS



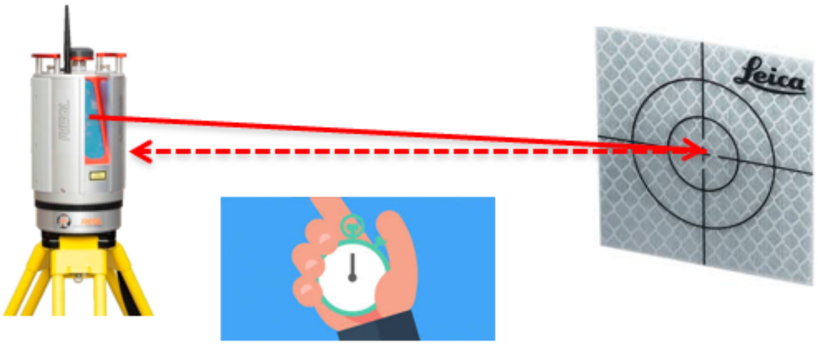


System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1–10 cm
Vertical Accuracy	15cm to 10m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1–10 cm Depends on range, which is few meters to 2 km or more

Time of flight

Time it takes for emitted pulse to reflect off object and return to scanner.

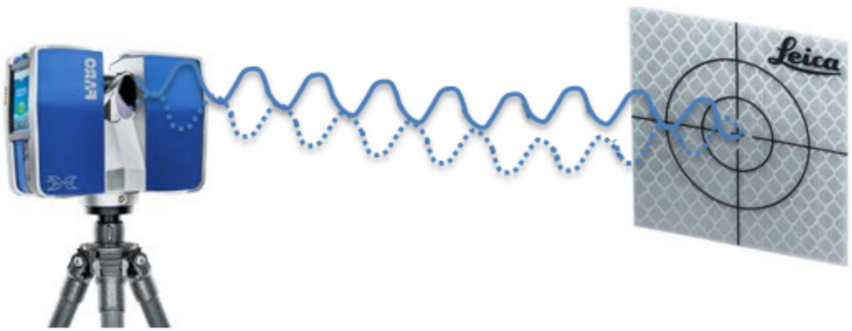
$$Distance = \frac{Speed\ of\ Light\ x\ Time\ of\ Flight}{2}$$



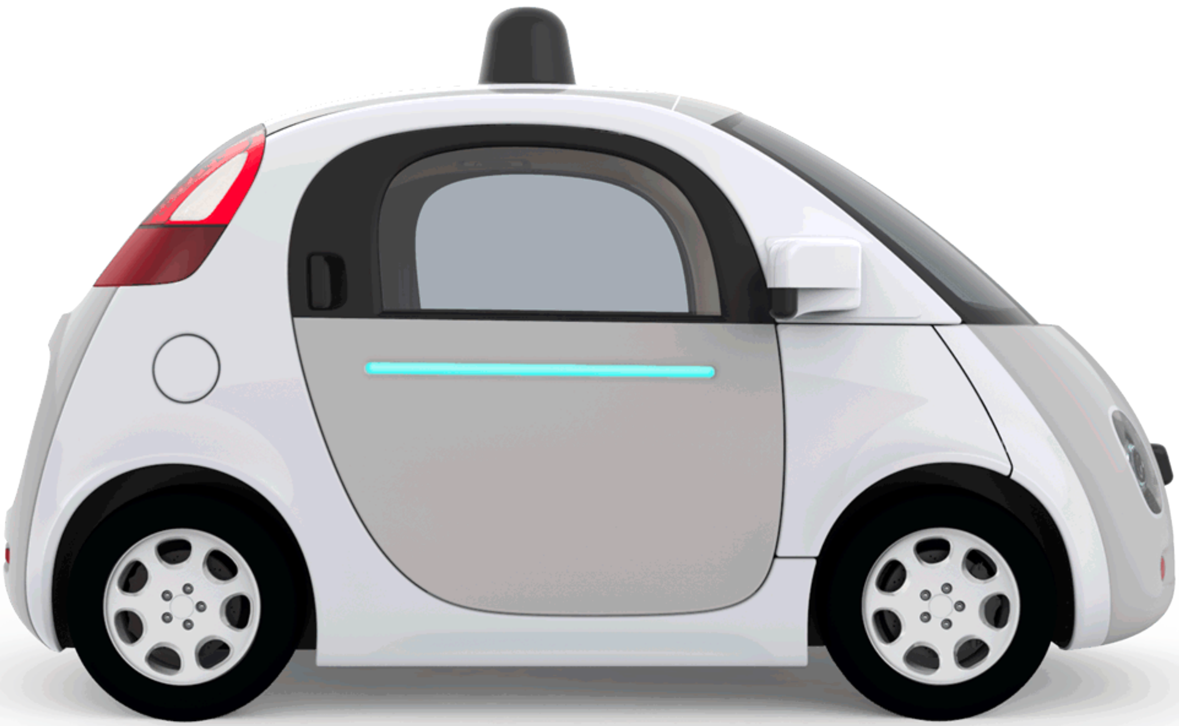
Phase Shift

Distance is calculated along a sinusoidally modulated laser pulse.

$$Time\ of\ Flight = \frac{Phase\ Shift}{2\pi\ x\ Modulation\ Frequency}$$



Lidar & Autonomous Vehicles



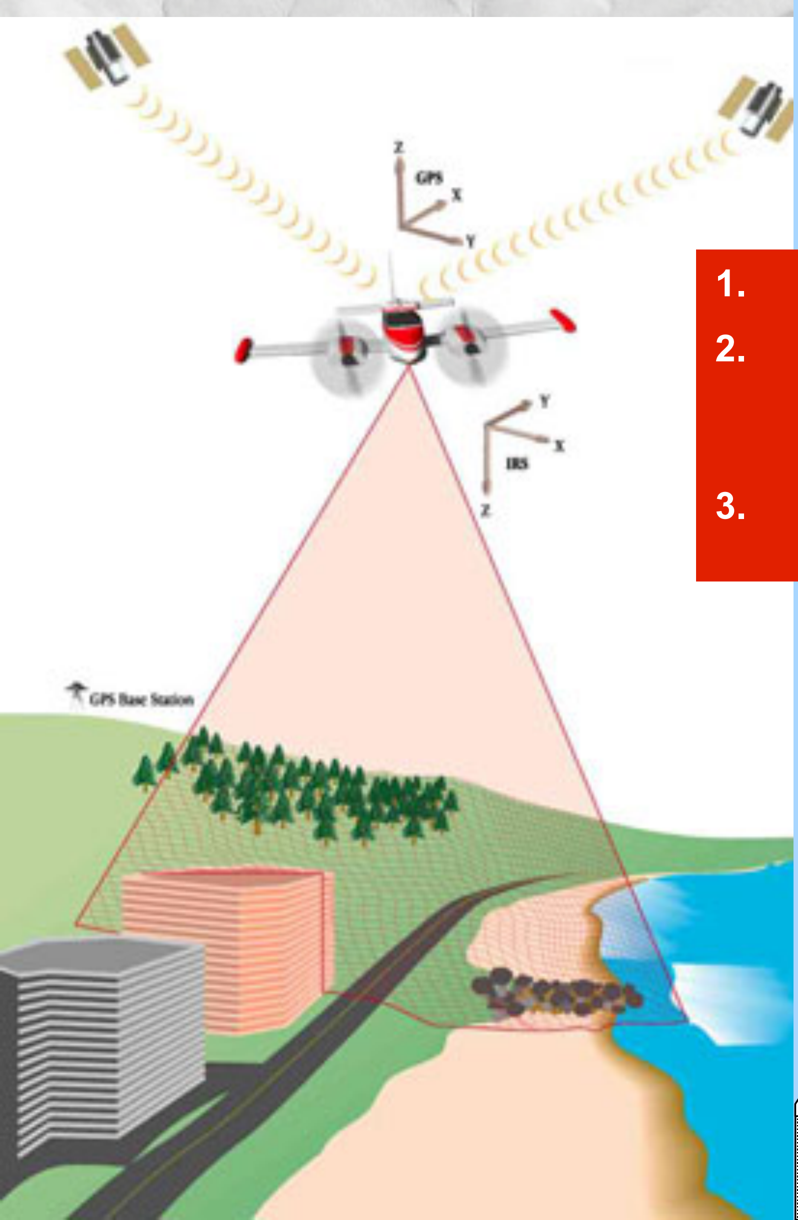
LIDAR & AUTONOMOUS VEHICLES

Sight Lines, ScanLAB: https://vimeo.com/145248208

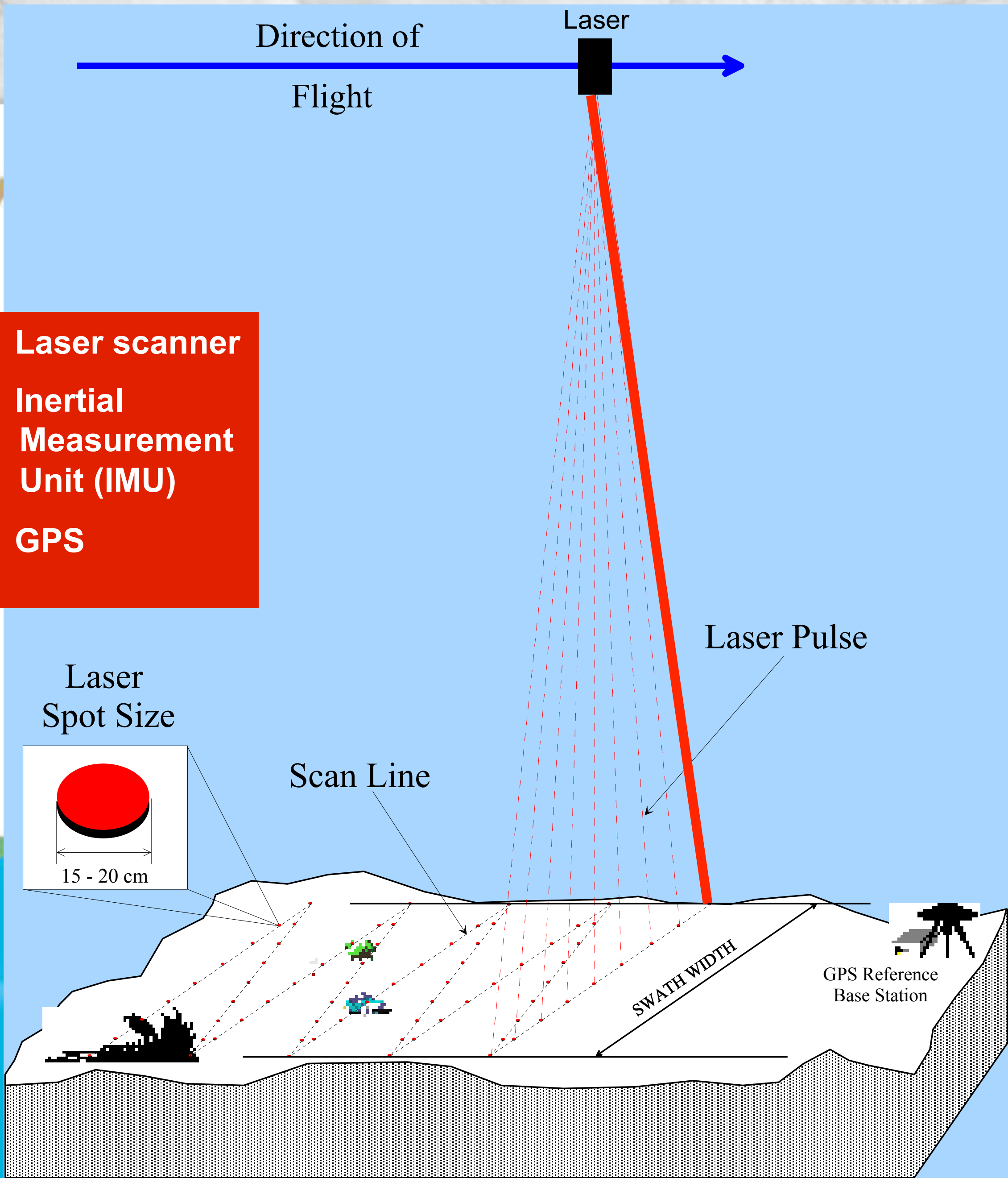
LIDAR DATA COLLECTION

Ian Madin, DOGAMI

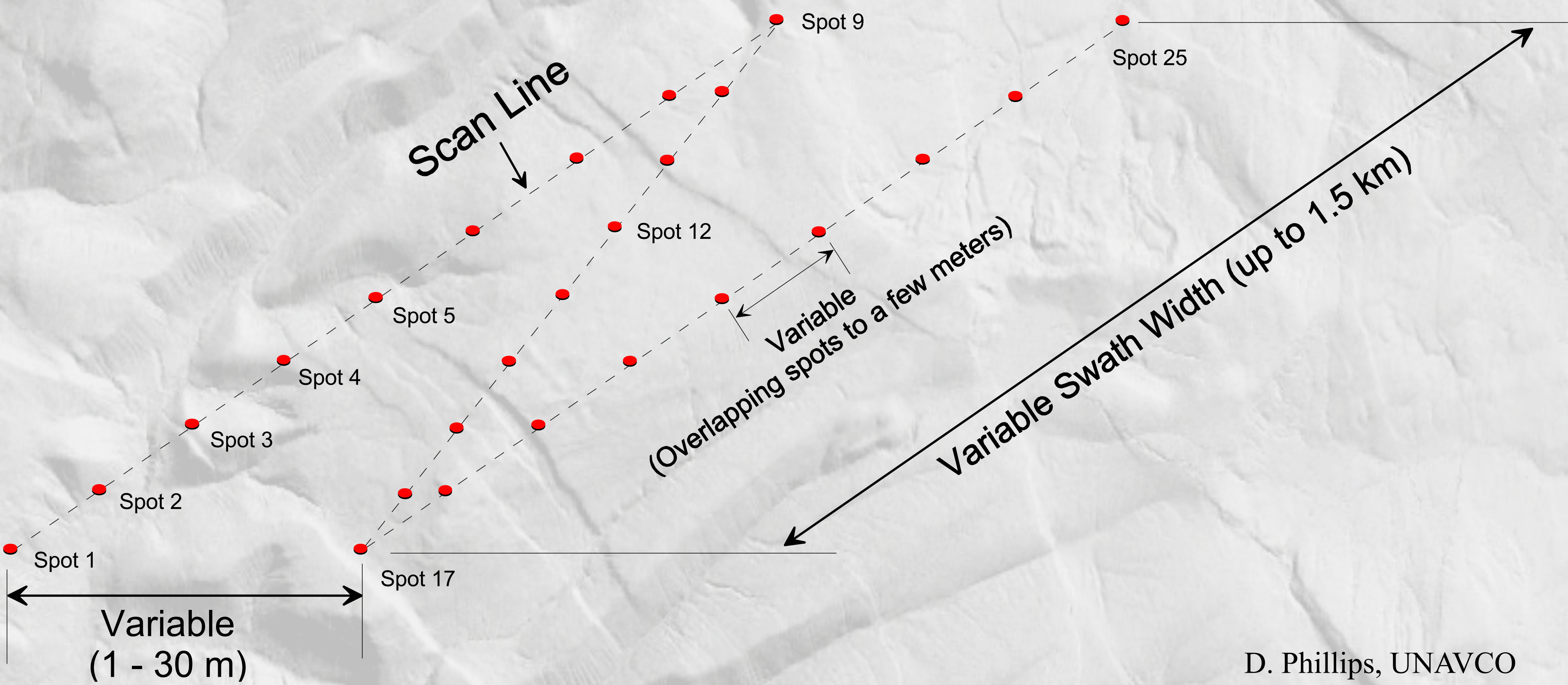
LIDAR DATA COLLECTION



1. Laser scanner
2. Inertial Measurement Unit (IMU)
3. GPS



Surface Point Spacing



D. Phillips, UNAVCO

Scan line spacing, swath width, spot size and overlap can all be defined as necessary to achieve target data to specification

Typical Lidar Data Collection Parameters

Aircraft: - Cessna 337 Skymaster
- One pilot, one operator in plane
- GPS ground crew (2 to 10+ people)

Scanner:	Optech near-IR
PRF:	33-900 KHz
Pulse width:	10 ns
Flying:	600 – 1,000m AGL, 120mph
Swath overlap:	50% nominal
Ground truthing:	GPS (campaign & CORS)

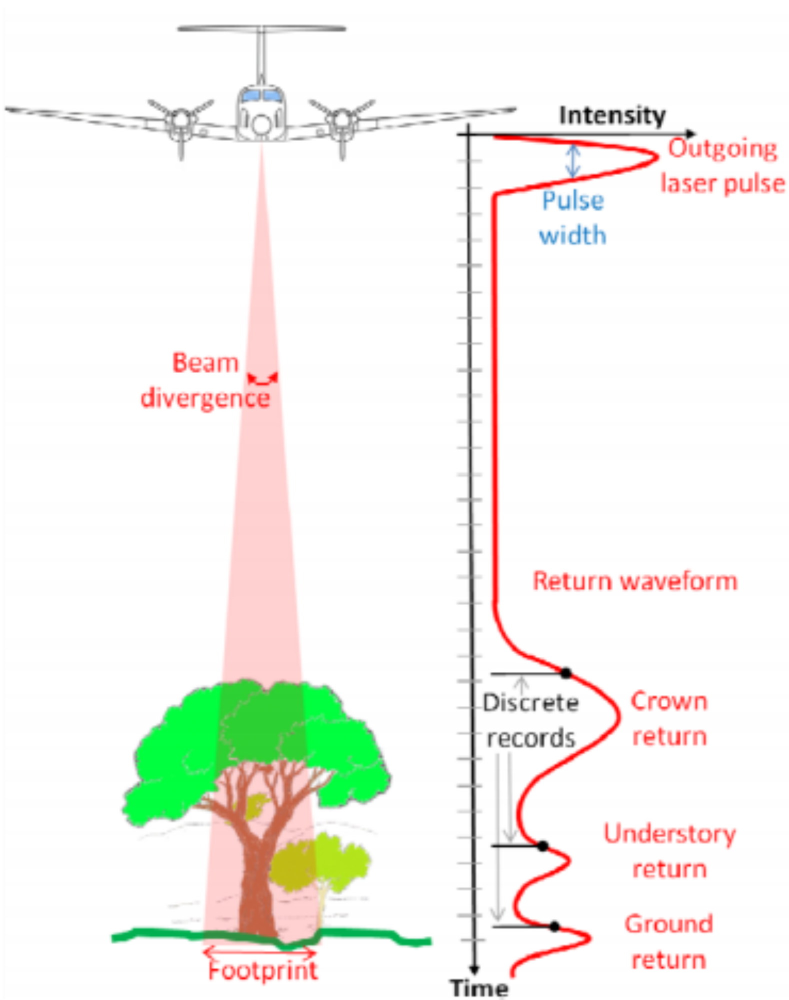
Pulse spacing: sub-meter

Nominal Accuracy (on open hard and flat surface)

- Vertical: 3 – 6 cm.
- Horizontal: 20 – 30 cm.

NCALM
The National Center for Airborne Laser Mapping

DISCRETE PULSE AND FULL WAVEFORM LIDAR



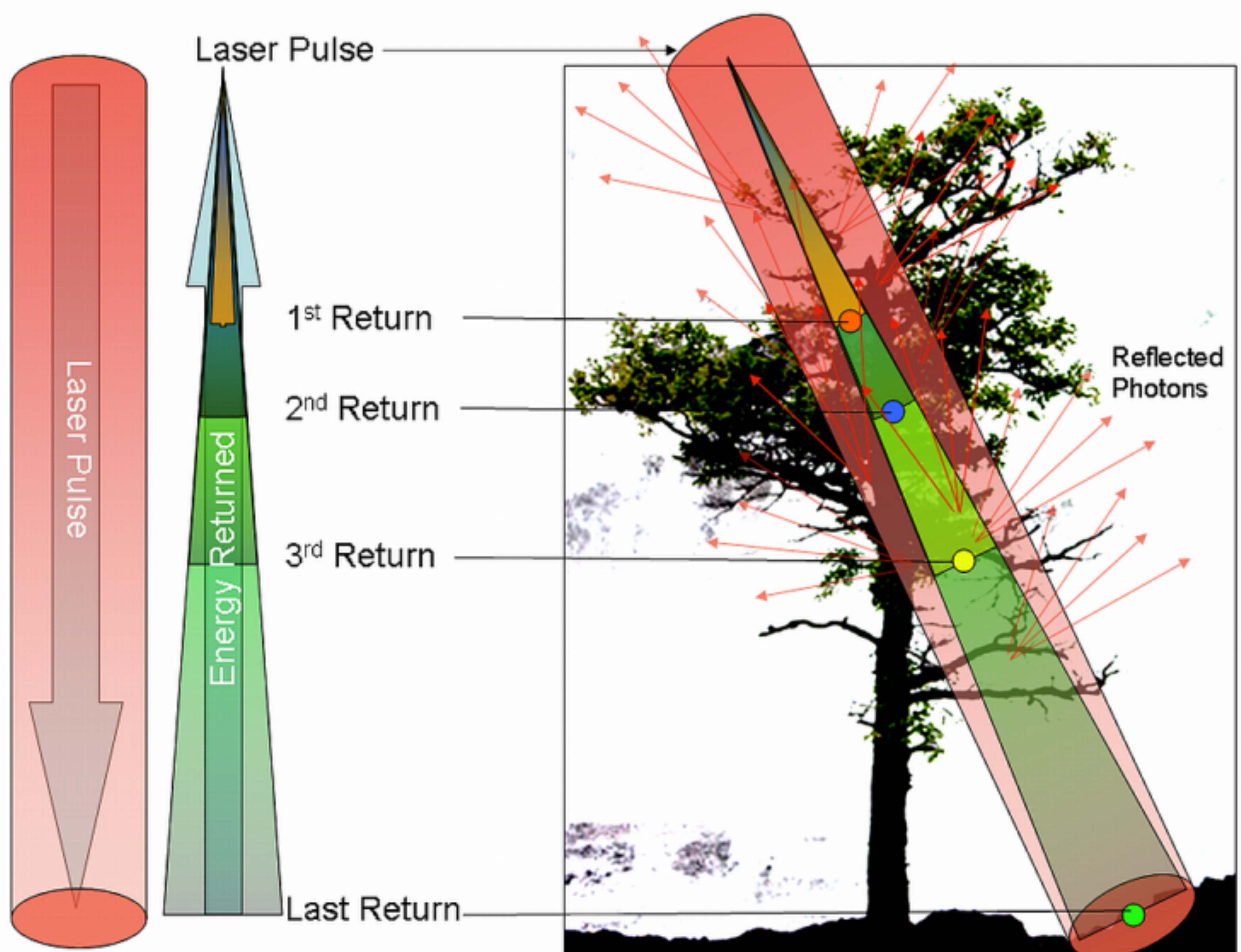
Discrete pulse = binary yes or no return. Only location of return is saved.

Full waveform = digitized backscatter waveform. Saves the full return energy signature

Data size / processing time vs. enhanced information

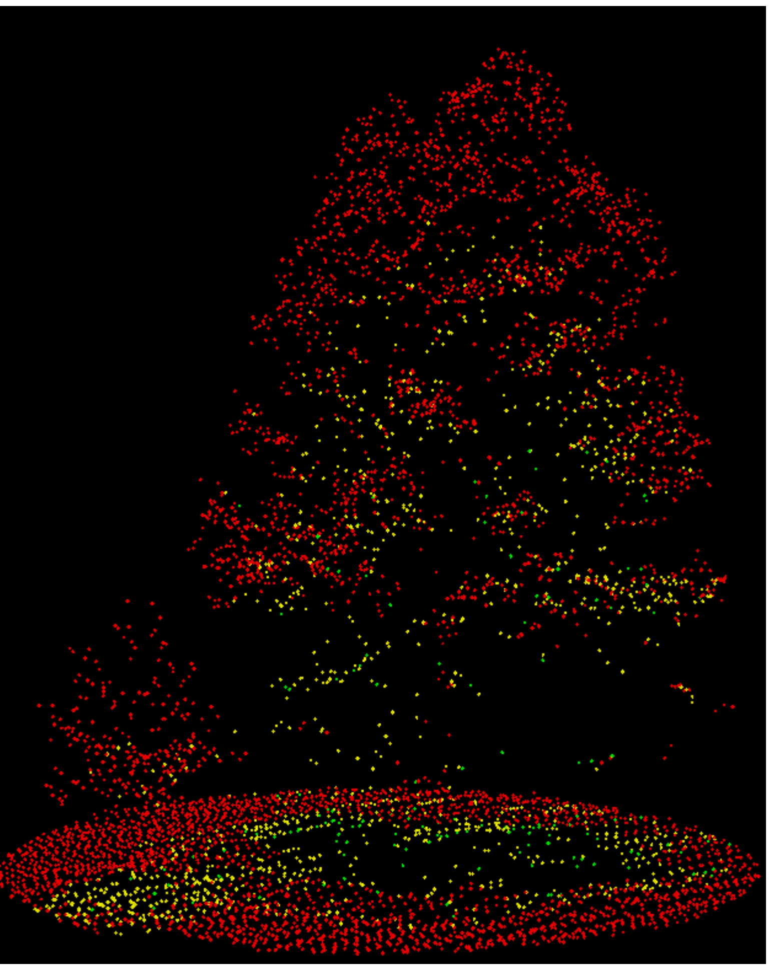
T. Goulden, NEON

DISCRETE PULSE AND FULL WAVEFORM LIDAR



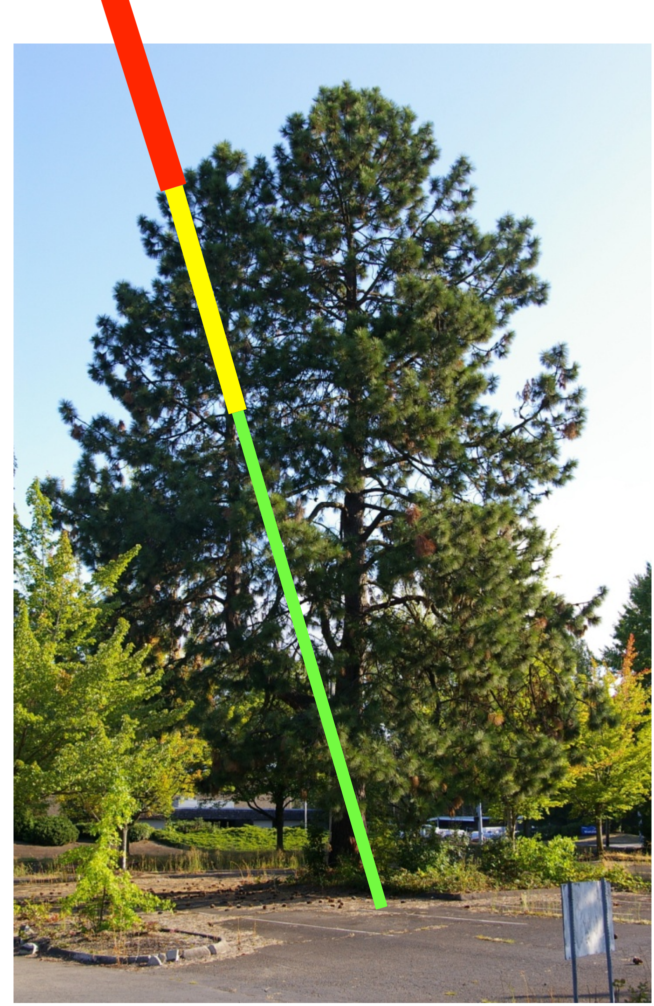
LIDAR RETURN STRUCTURE

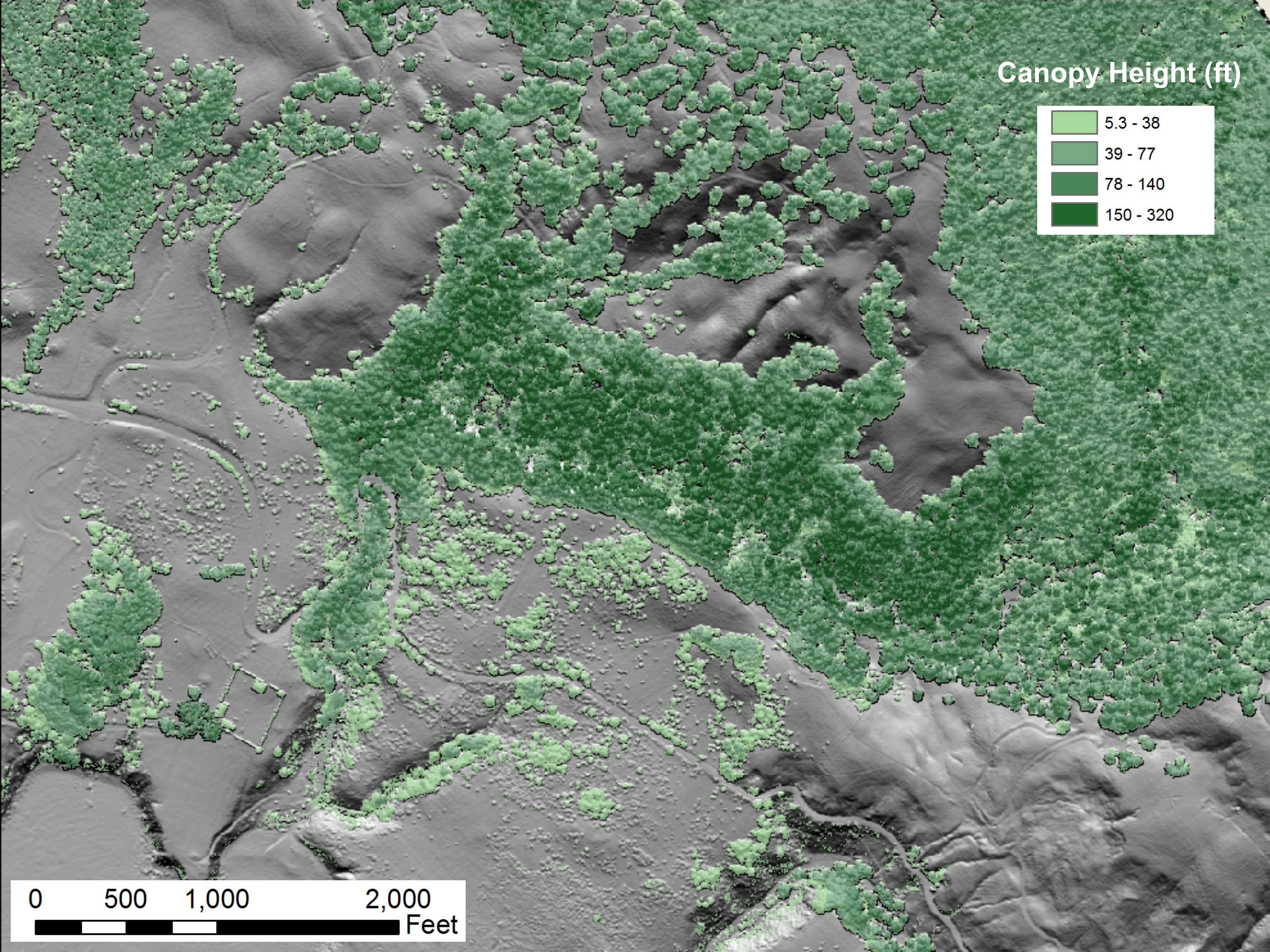
Ian Madin, DOGAMI



- Left = point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

- Red= 1st
- Yellow = 2nd
- Green = 3rd





Canopy Height (ft)
5.3 - 38
39 - 77
78 - 140
150 - 320
0
500
1,000
2,000
Feet

Lidar Data Quality

Not all lidar is created equal – huge range in quality, resolution, accuracy of data publicly available.

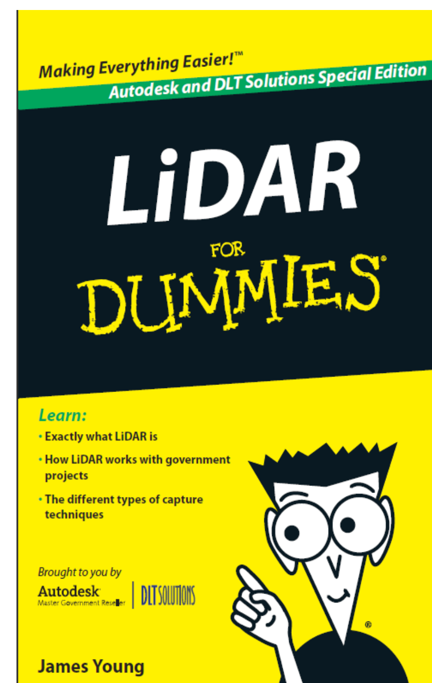
Typical metric is pulse density / shot (“post”) spacing:

- Describes sampling density of data and potential grid resolution.
- Shot density highly heterogeneous.
- Ground point density typically far lower than total pulse density

Evaluate lidar data quality by:

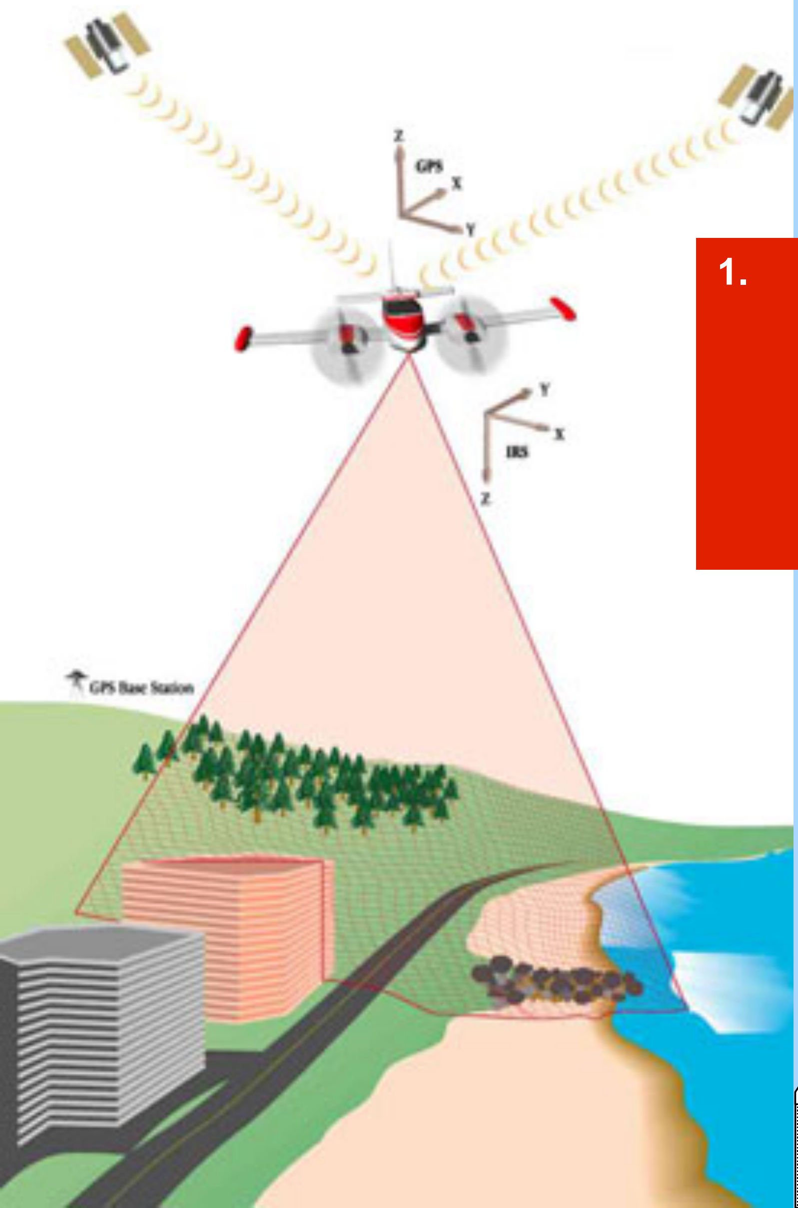
- Testing against ground control
- Looking at big images
- Quantifying swath to swath reproducibility

Read the metadata & survey report



Modified from R. Hagerud, USGS

LIDAR DATA COLLECTION



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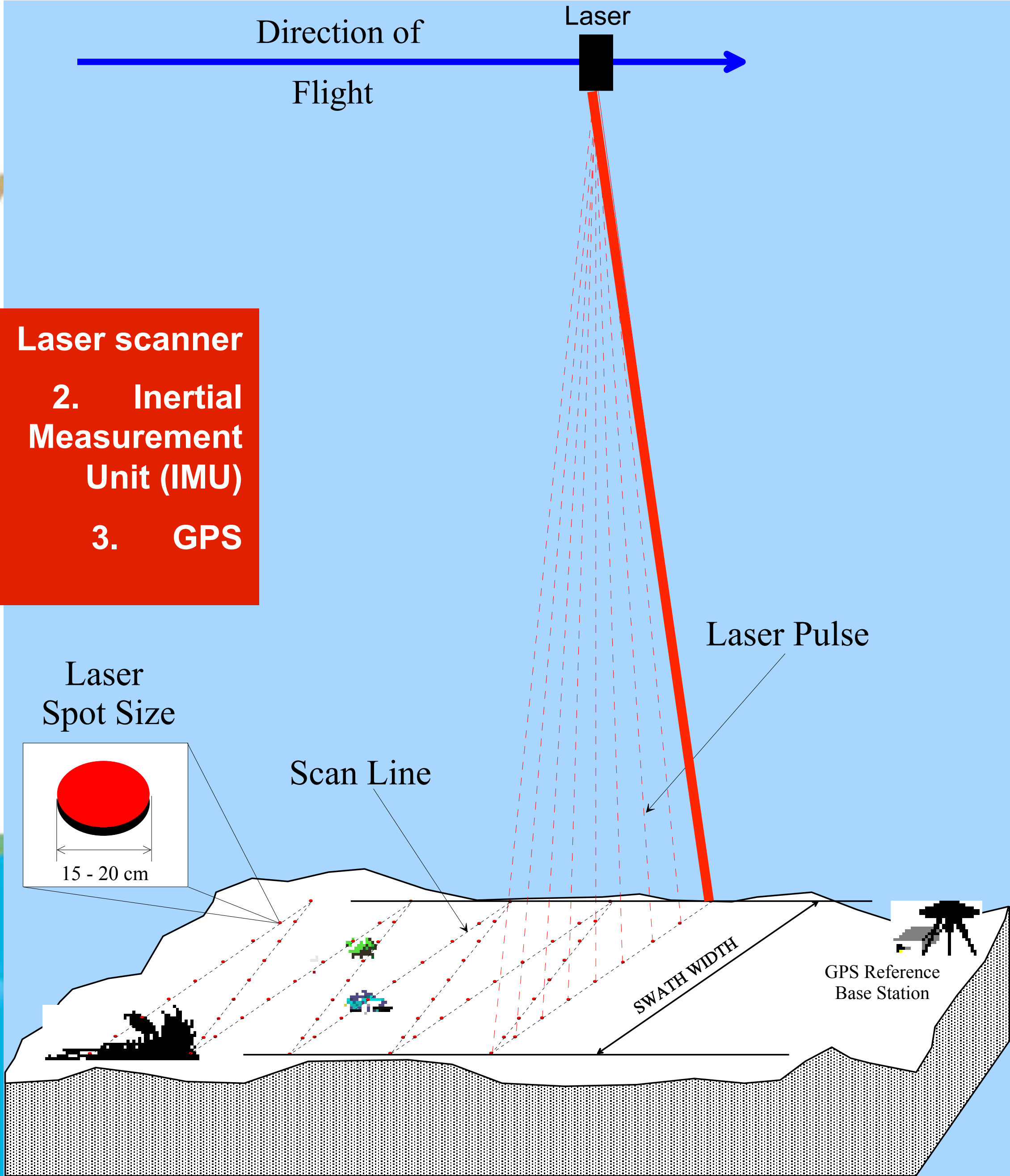


Lidar Data Error Sources

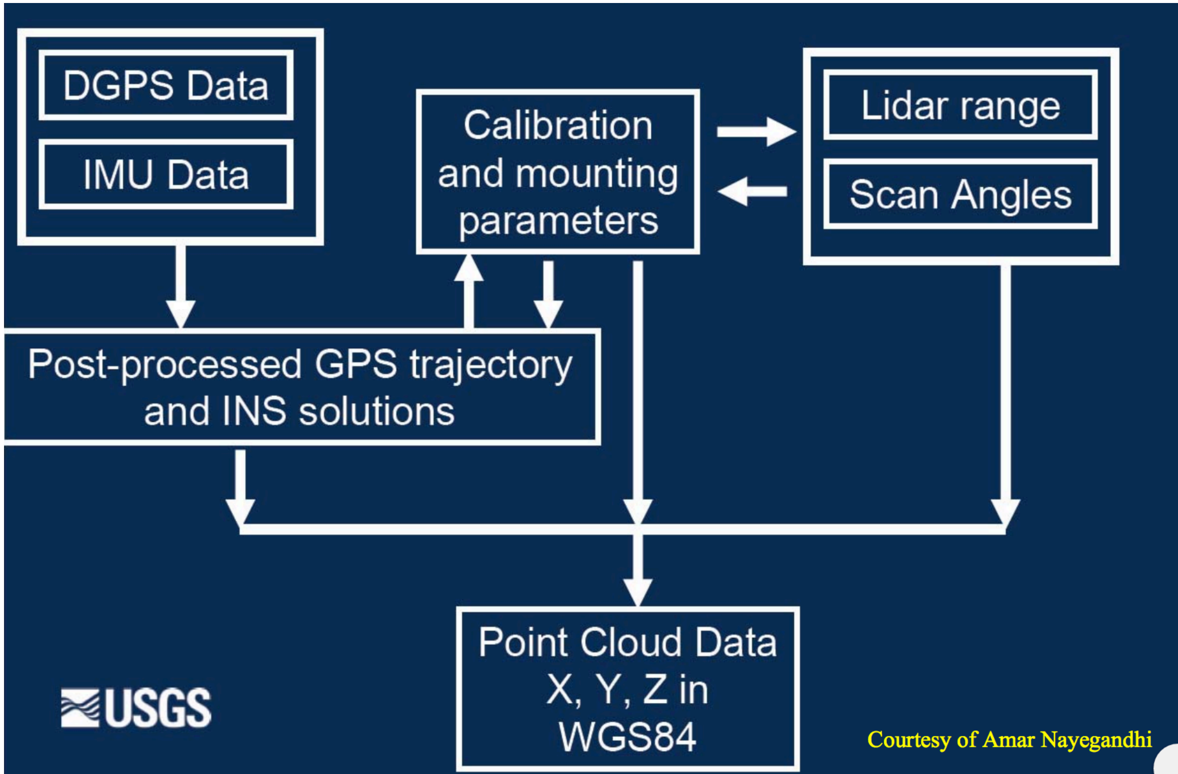
Two majors sources of uncertainty

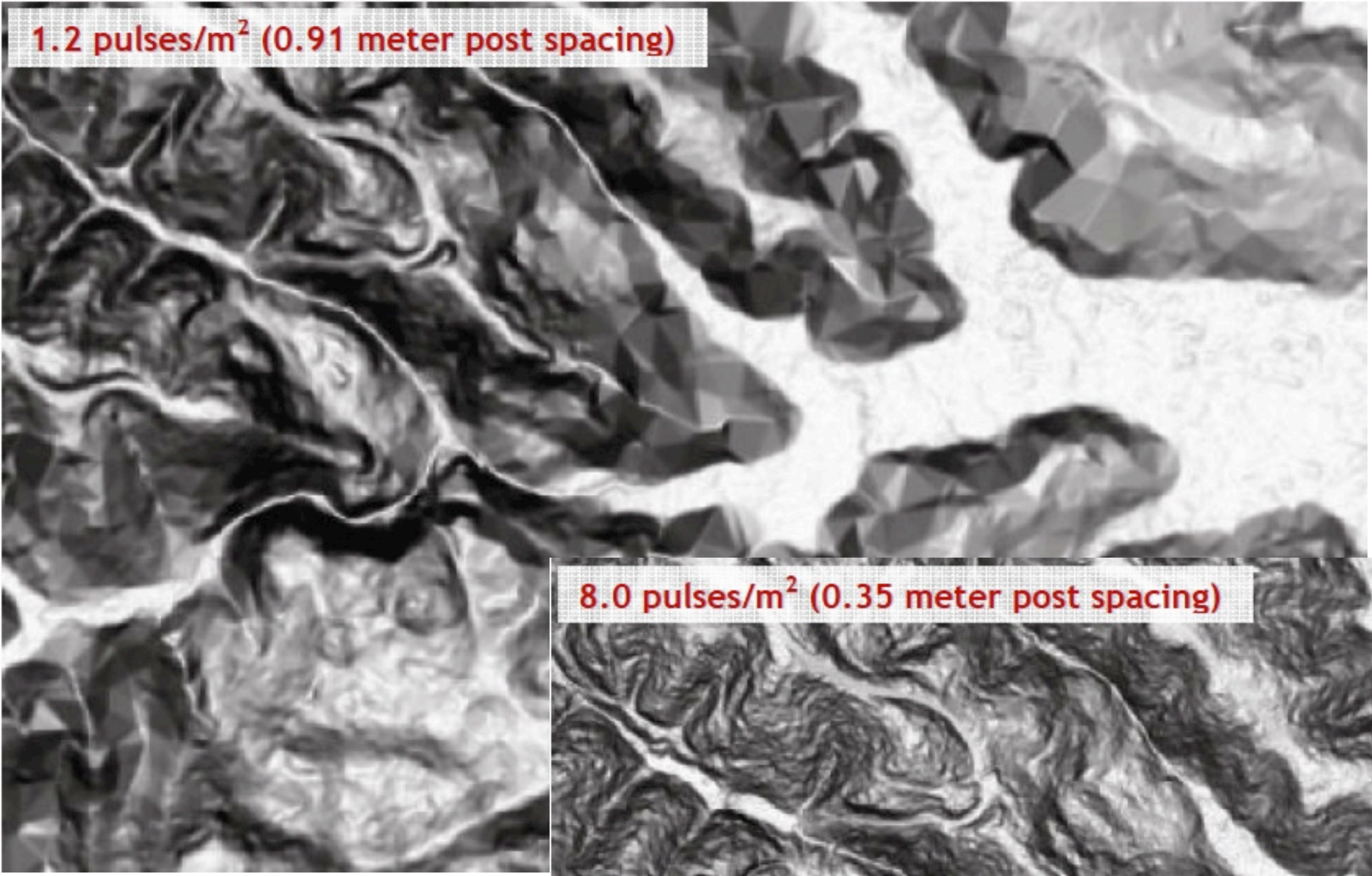
- Geolocation (GPS, INS, ranging) uncertainty
- Processing uncertainty

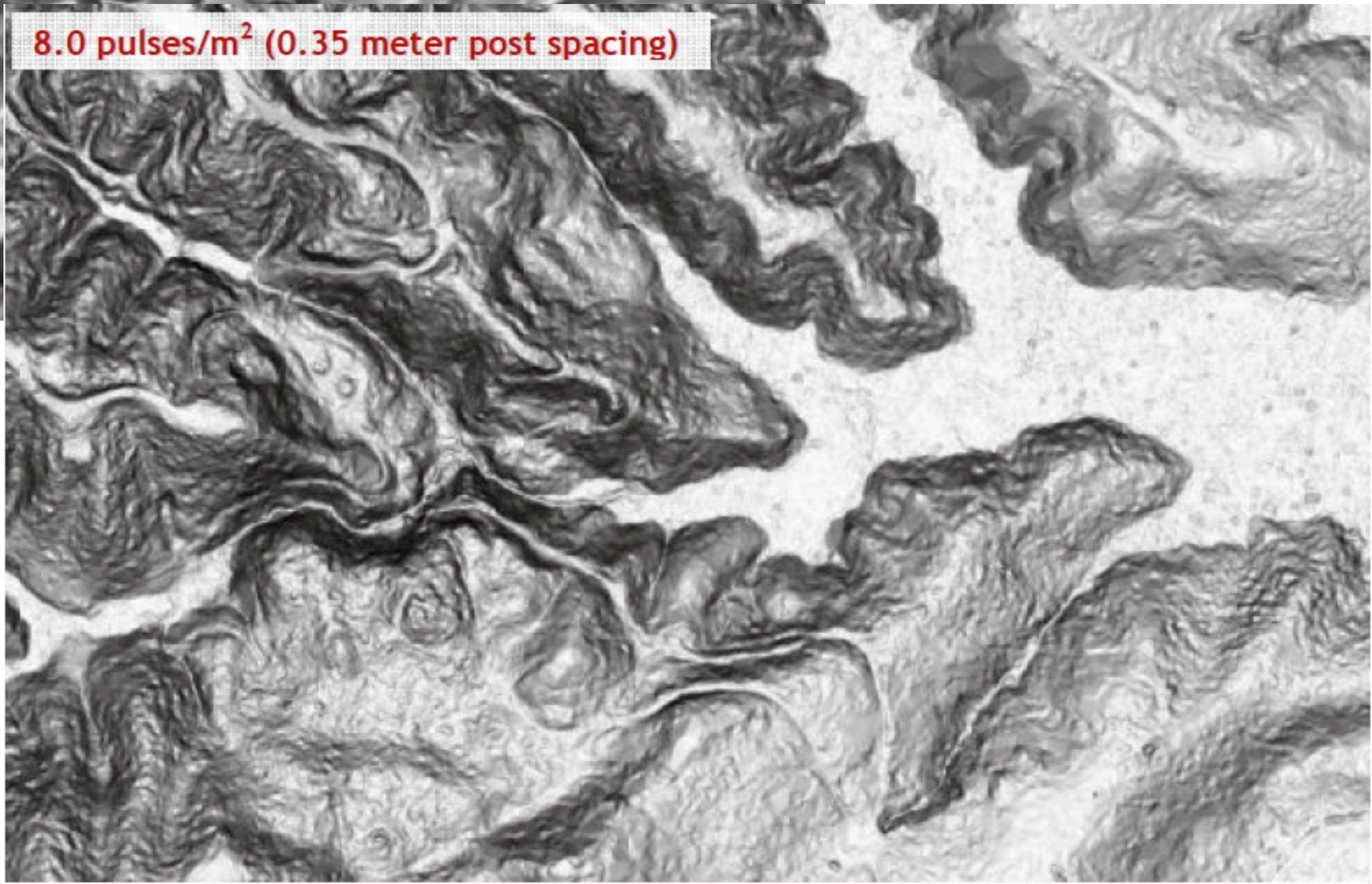
Vegetation and terrain conditions affect uncertainty

Error budget =

+/- 5 to 15 cm (vertical)

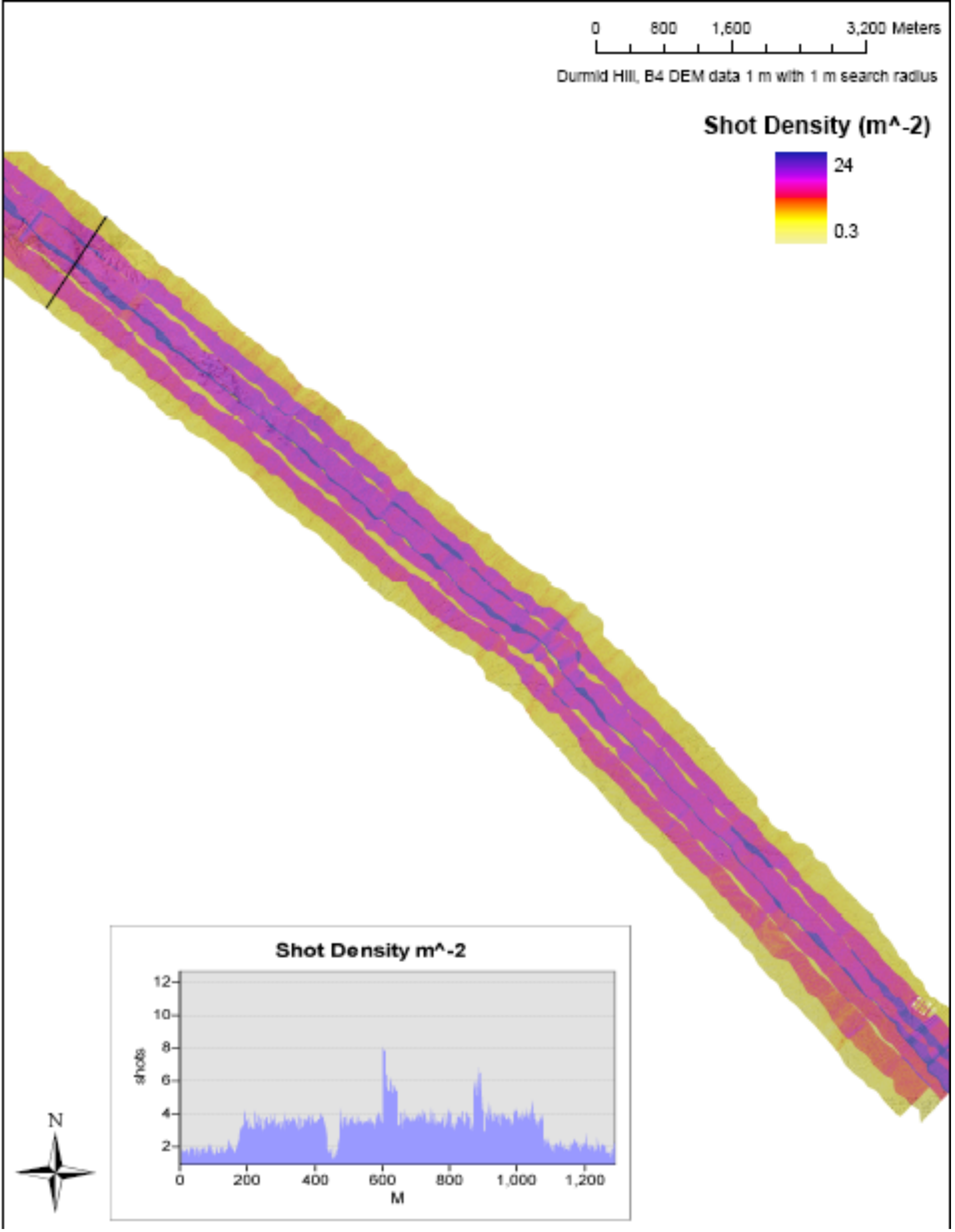


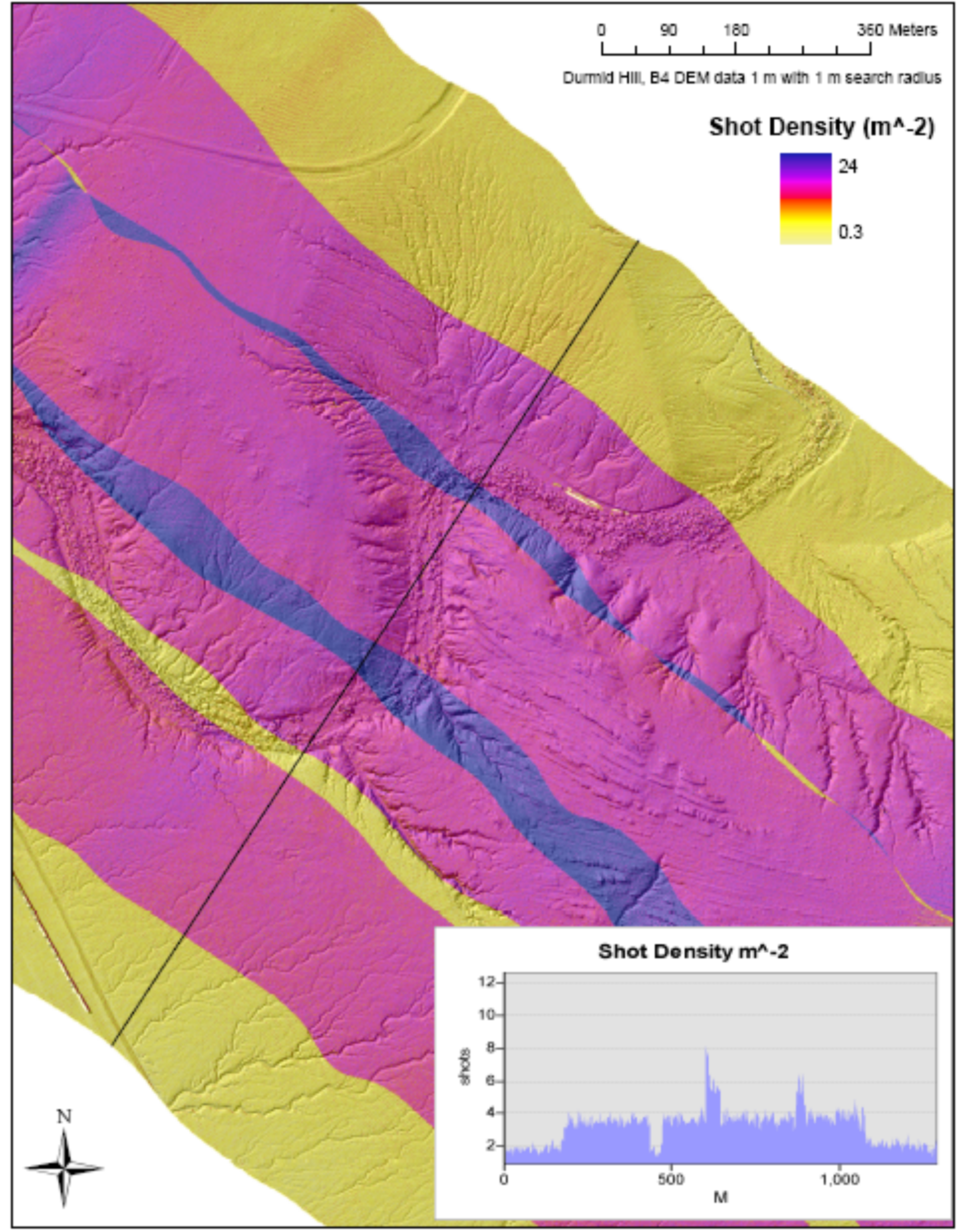




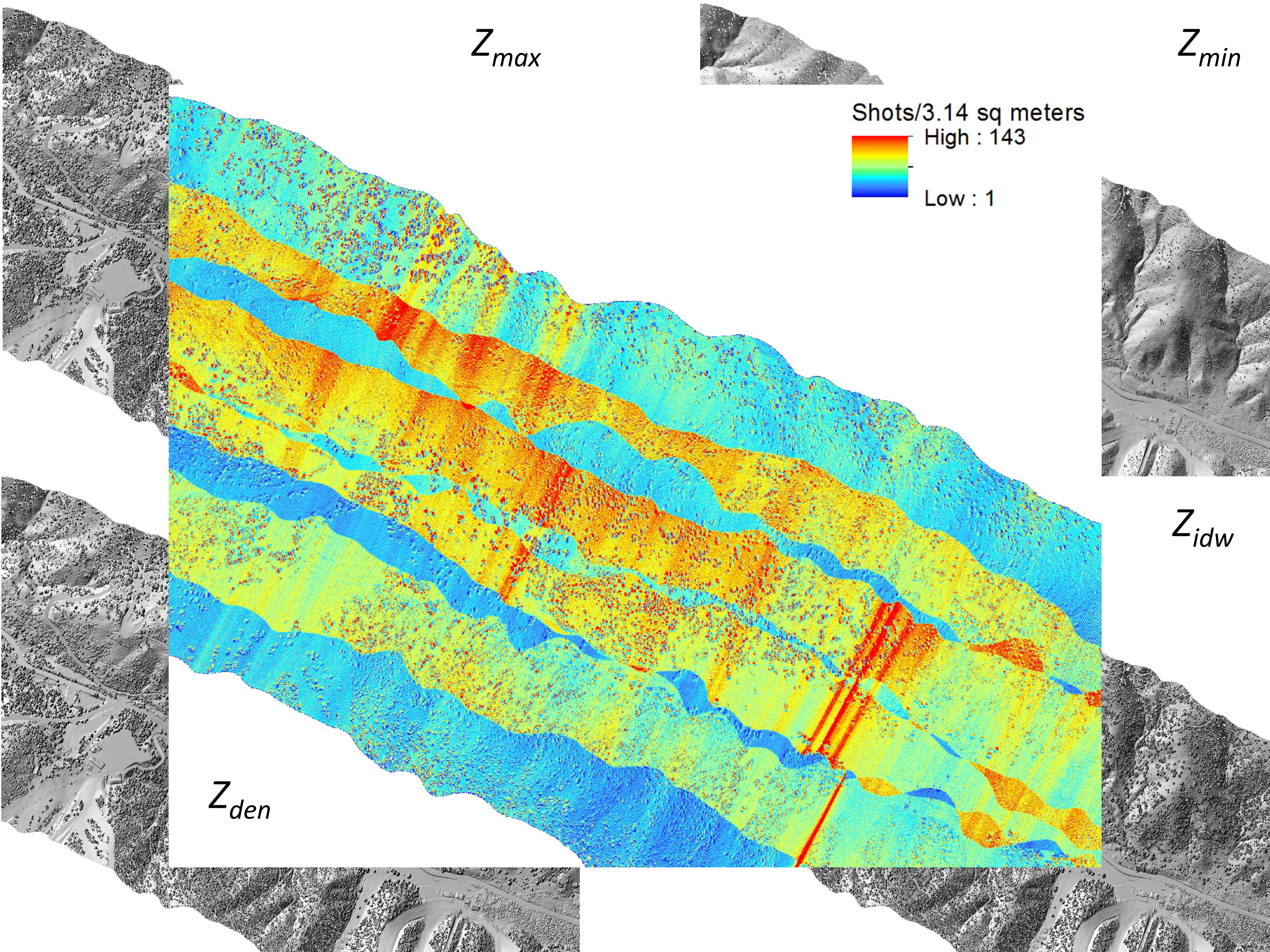
In the PNW: 14% of points classified as ground

Minimum LiDAR Considerations in the Pacific Northwest
Watershed Sciences, Inc.
http://www.oregongeology.org/sub/projects/olc/minimum-lidar-data-density.pdf



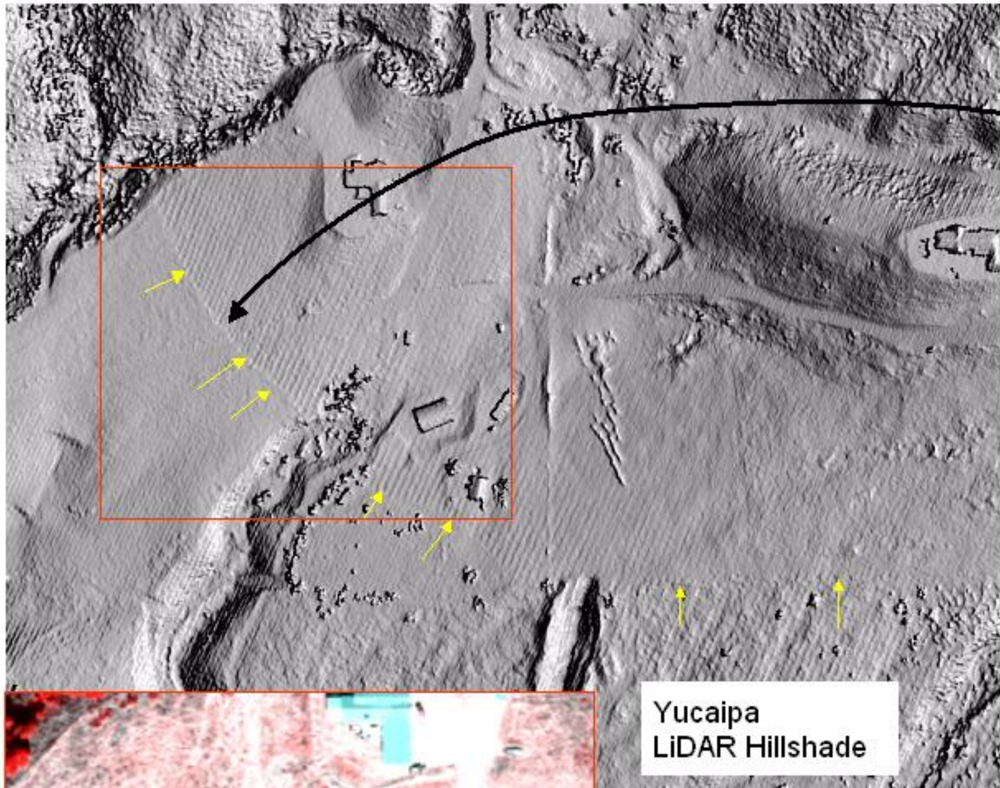


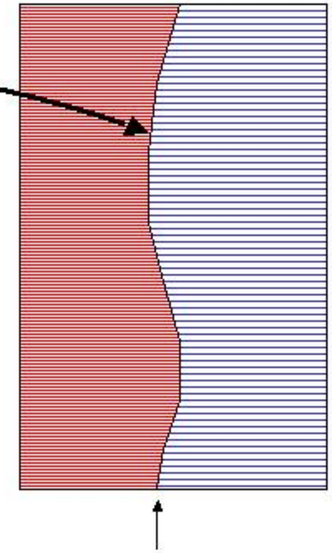
Heterogeneity of surface sampling: B4 shot density maps and profiles



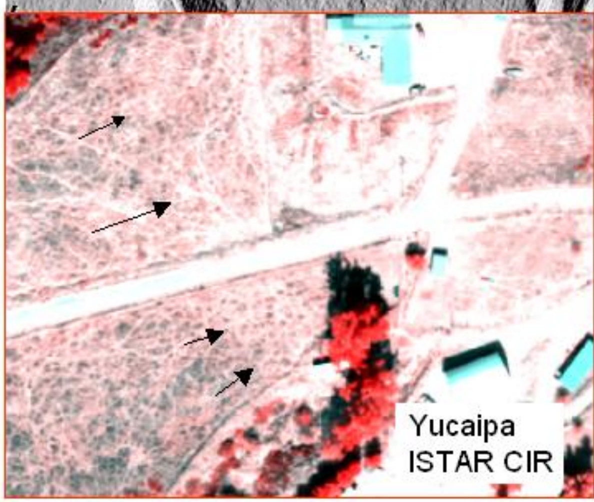
Z_{max}
Z_{min}
Shots/3.14 sq meters
High : 143
Low : 1
Z_{idw}
Z_{den}

LIDAR ARTIFACTS





"Seam line" between swaths where the corduroy artifacts will not line up due to Vertical Swath Offset.



Red Arrows – features *attributed* to artifacts   Green Arrows – "natural" features (aligned drainages, scarplets)

Ante Perez, CGS

LIDAR ARTIFACTS

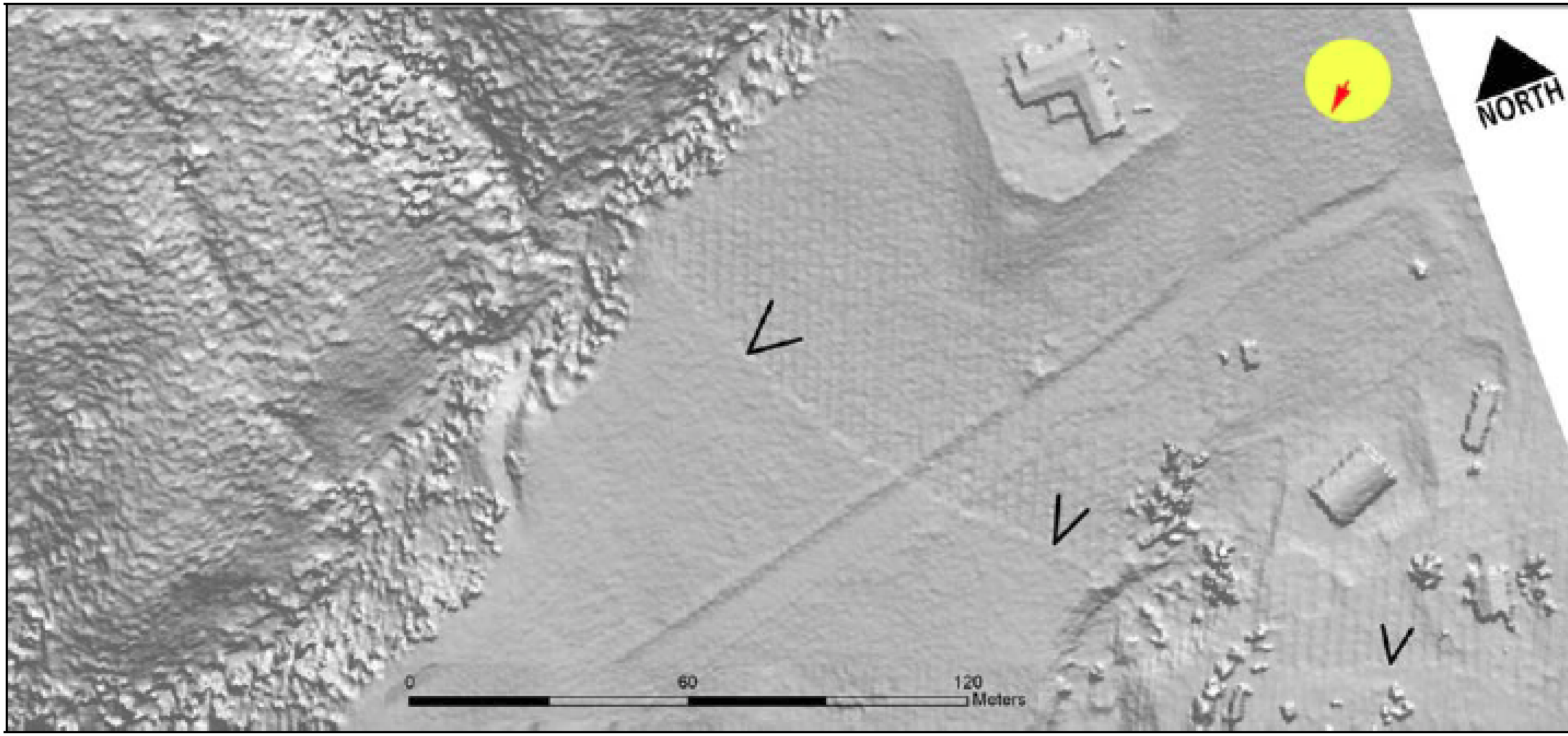
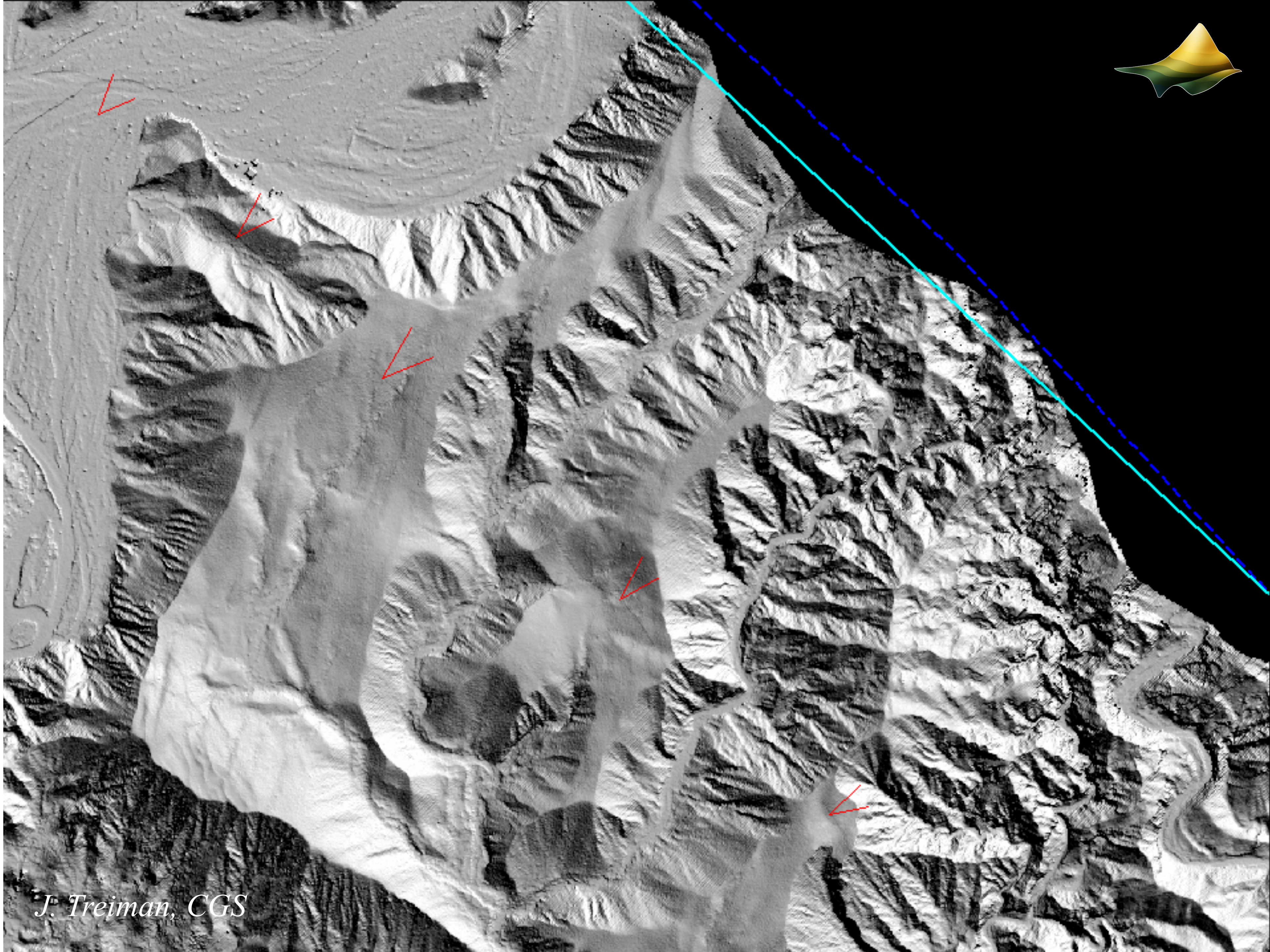


Figure 7a. LiDAR artifact (arrows) in the Yucaipa study area. The artifact appears as a linear highlight suggestive of an east-facing scarp. However, the evident "corduroy" texture on one side versus the other alerts one to the likelihood that this is an artifact. Indeed, it corresponds to the overlap margin between LiDAR swaths.

Treiman, Perez, & Bryant, 2010, USGS Award No. 08HQGR0096 Final Tech. Report


J. Treiman, CGS

LIDAR DATA DELIVERABLES

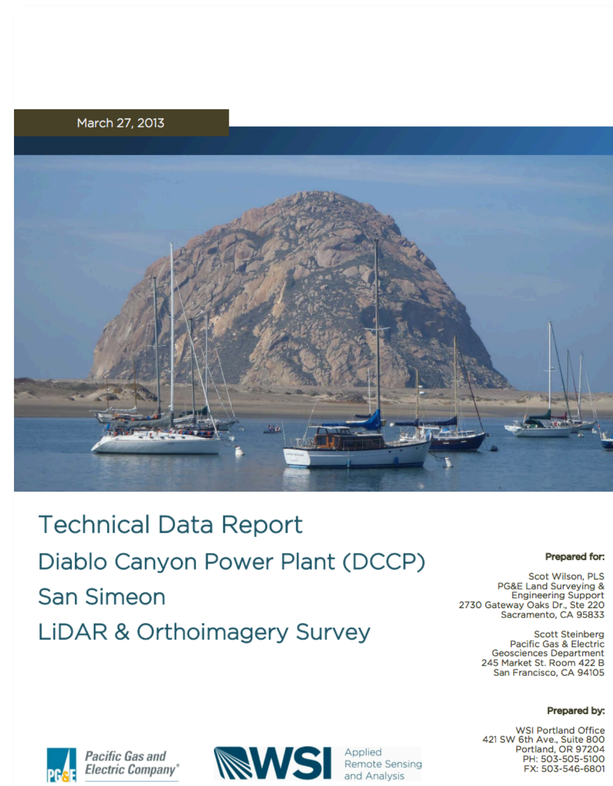
Classified point cloud

- Ground, vegetation, buildings, water, blunders etc.
- Intensity, return number & number of returns, GPS time, RGB…
- Tiled or swath LAS/LAZ

Raster data derivatives

- DTM (“bare earth”), DSM (“highest hit”)
- Hillshades of DTM, DSM; intensity; RGB
- Tiled GeoTIFF, IMG, Arc Binary

Metadata & survey report


March 27, 2013

Technical Data Report
Diablo Canyon Power Plant (DCCP)
San Simeon
LiDAR & Orthoimagery Survey

Prepared for:
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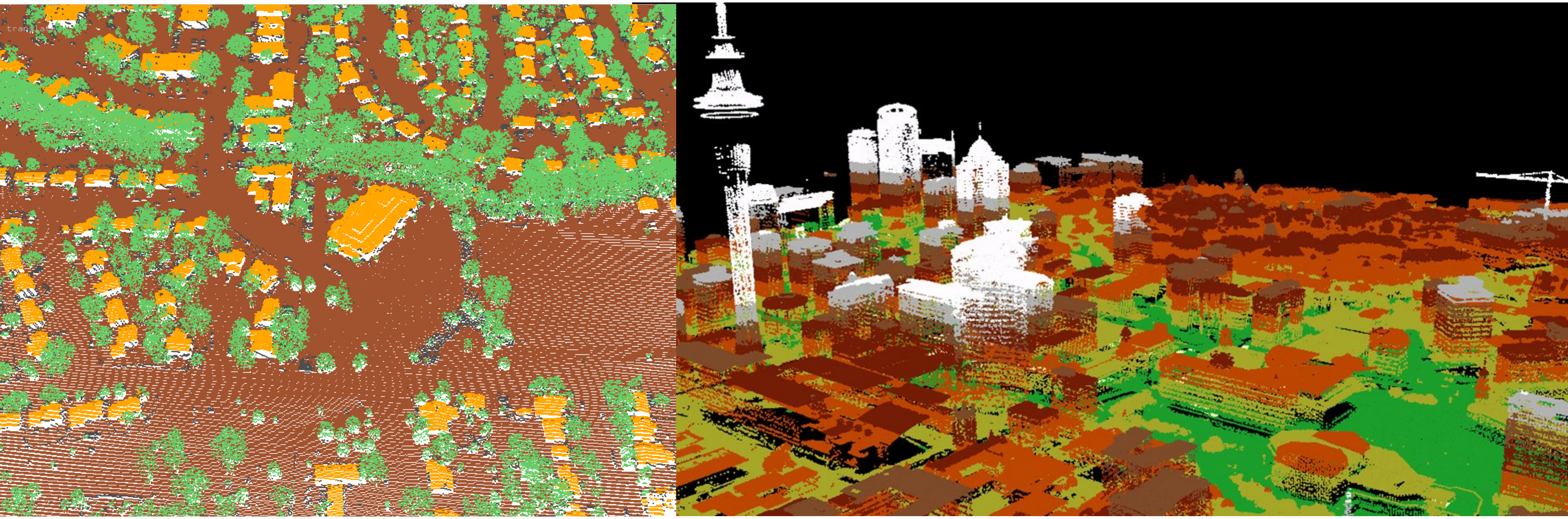
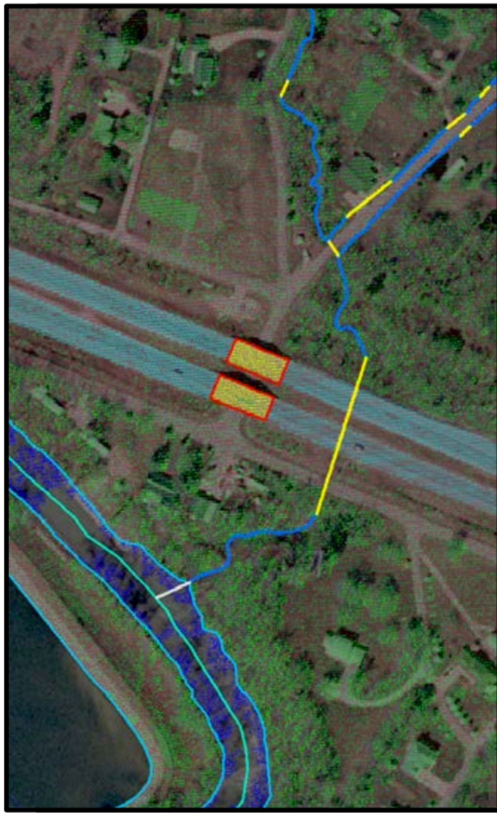
Pacific Gas and Electric Company
WSI Applied Remote Sensing and Analysis

Lidar data deliverables

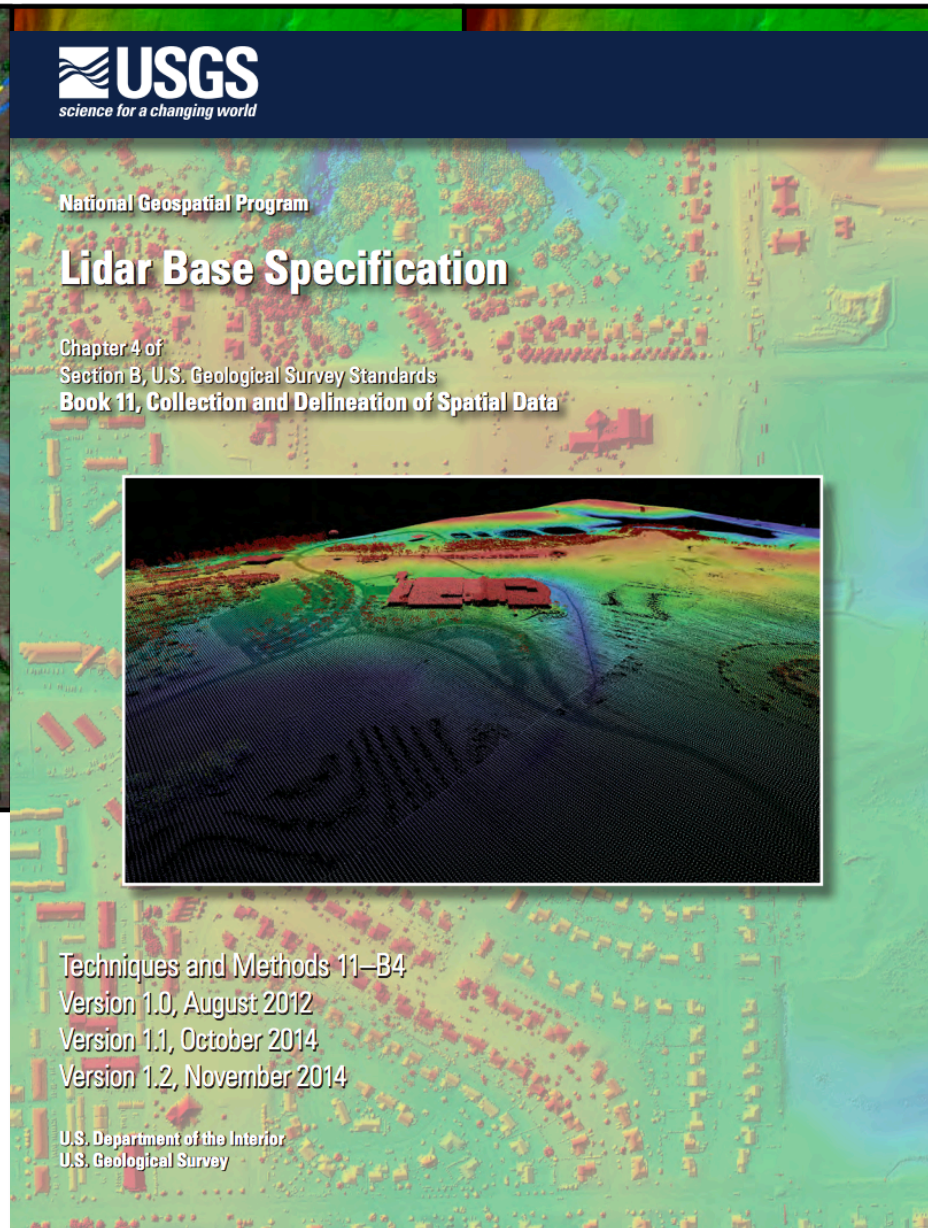
A ***point cloud*** is the fundamental lidar dataset – discrete x,y,z points with attributes (Intensity, return number & number of returns, classification, gps time, RGB…):



LIDAR DATA DELIVERABLES



LPC and Breaklines



USGS
science for a changing world

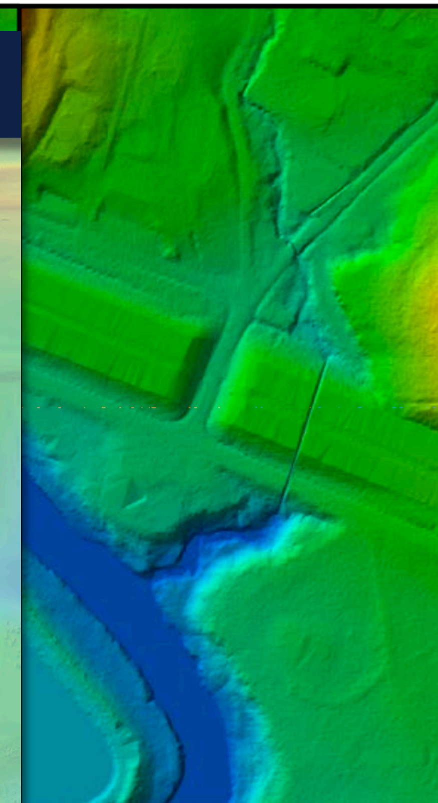
National Geospatial Program

Lidar Base Specification

Chapter 4 of
Section B, U.S. Geological Survey Standards
Book 11, Collection and Delineation of Spatial Data

Techniques and Methods 11–B4
Version 1.0, August 2012
Version 1.1, October 2014
Version 1.2, November 2014

U.S. Department of the Interior
U.S. Geological Survey



Hydro enforced DEM

J. Stoker, USGS

THANKS!

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@OpenTopography

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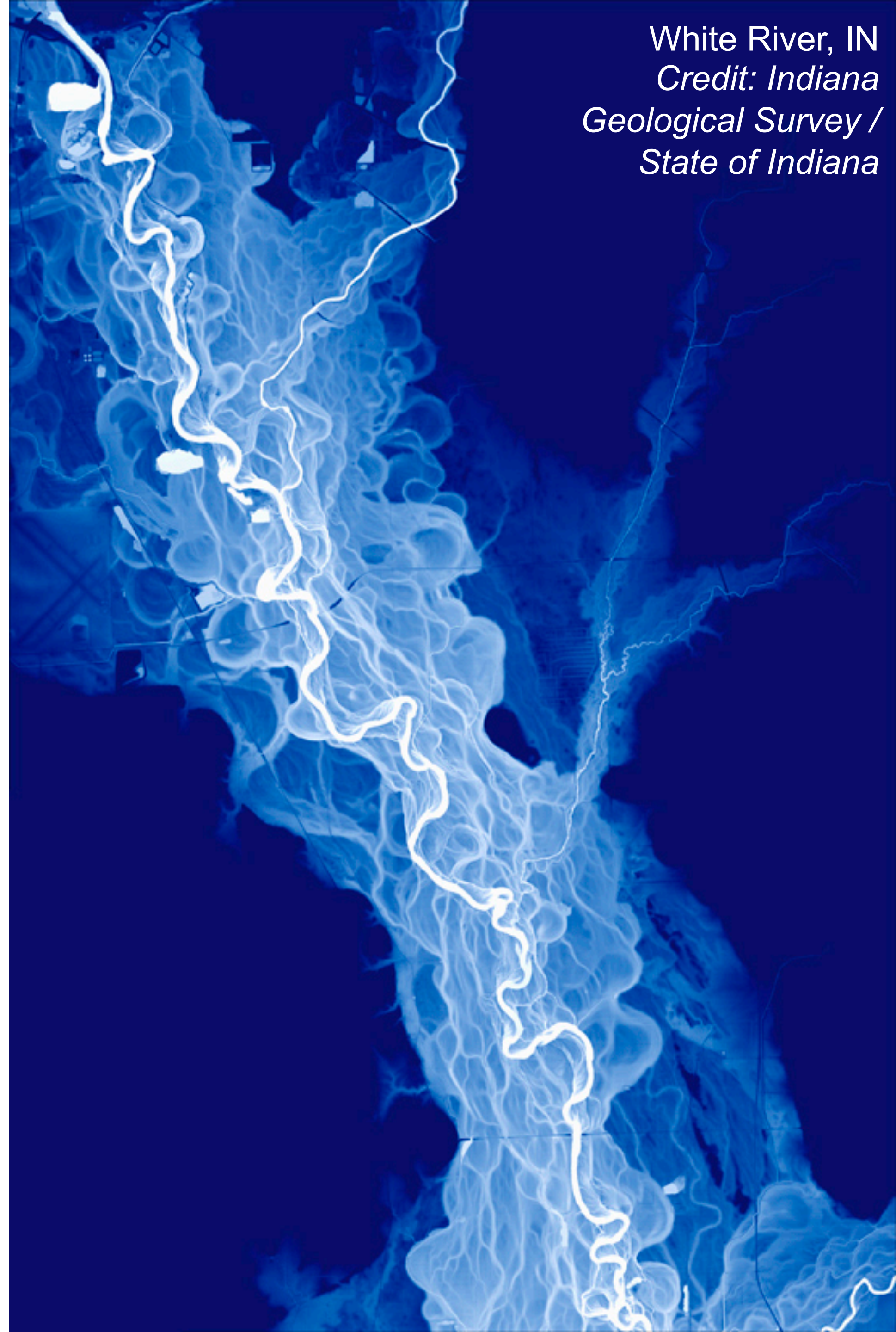
@OpenTopogaphy

info@opentopography.org

I ♥ LIDAR

WWW.OPENTOPOGRAPHY.ORG



White River, IN
Credit: Indiana Geological Survey / State of Indiana