Introduction to Lidar

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UNAVCO / OpenTopography

(with content adapted from NCALM, David Phillips (UNVACO), Ian Madin (DOGAMI), and Dave Harding (NASA))

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OpenTopography

UNAVCO

LIDAR / LiDAR / lidar / ALSM… = light detection and ranging

• Billions of of accurate distance measurements with a laser rangefinder

• Distance is calculated by measuring the time that a laser pulse takes to travel to and from an object.

Ian Madin, DOGAMI

Light Detection And Ranging (LiDAR)

Same technology, different platforms:

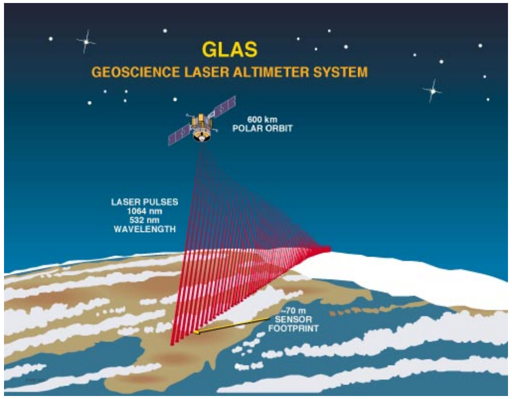
Terrestrial Laser Scanning (TLS)

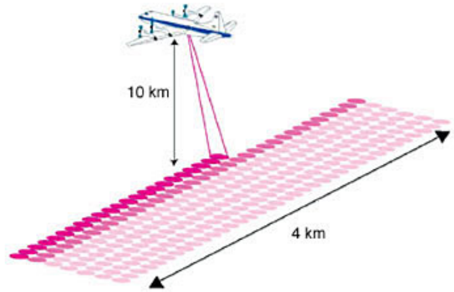
- Also called ground based LiDAR or T-LiDAR.

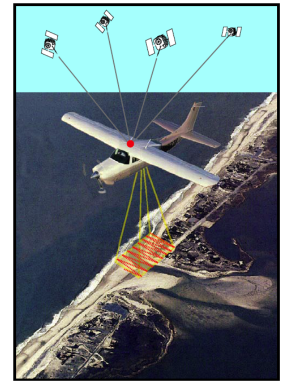
Laser scanning moving ground based platform = Mobile Laser Scanning (MLS).

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

Light Detection And Ranging (LiDAR)

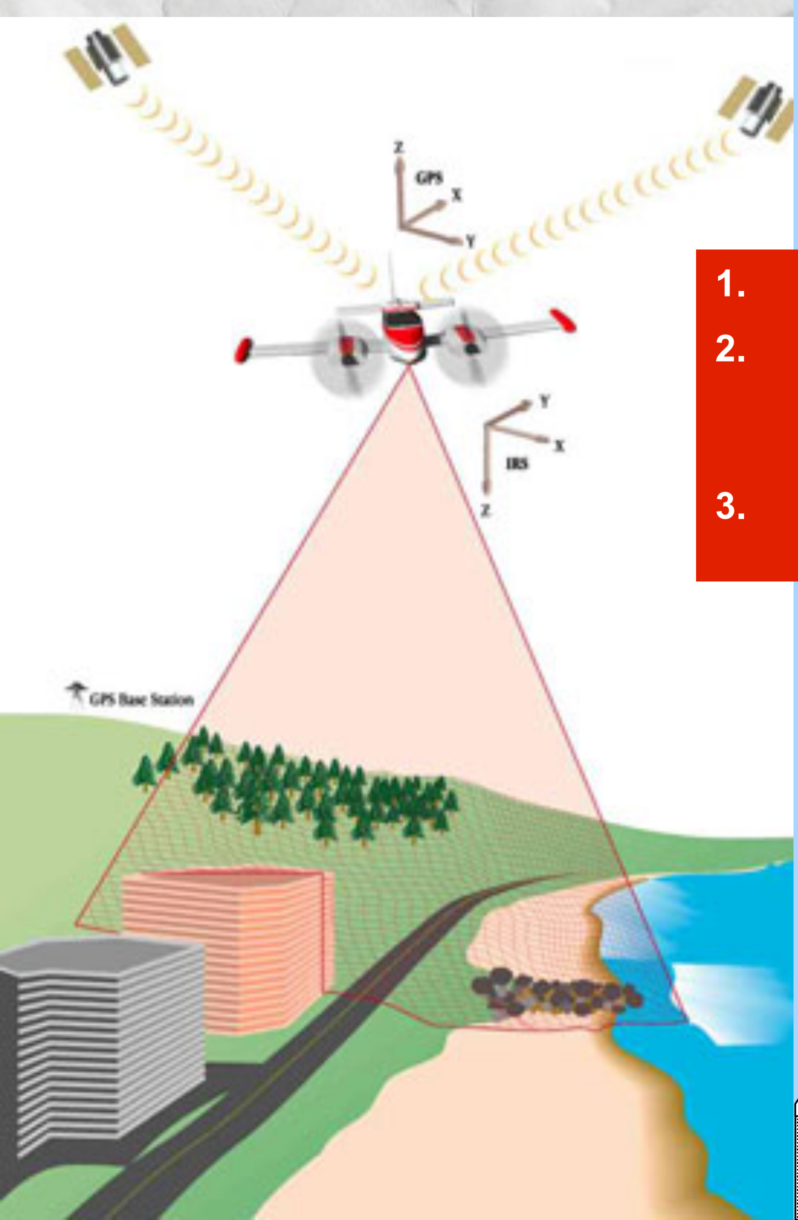




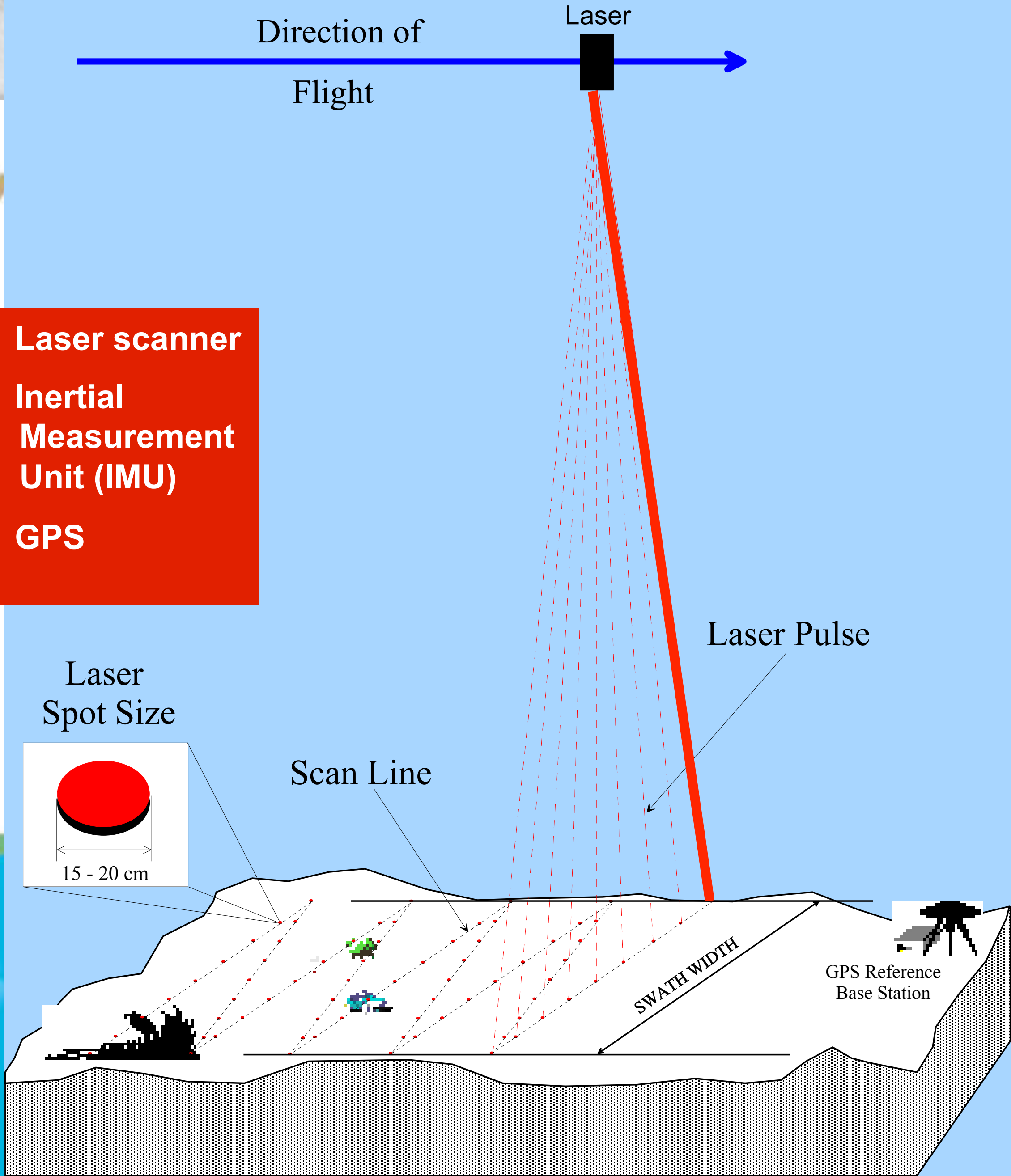


System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1-10 cm
Vertical Accuracy	15 cm to 10 m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1- 10 cm Depends on range which is few meters to 2 km or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

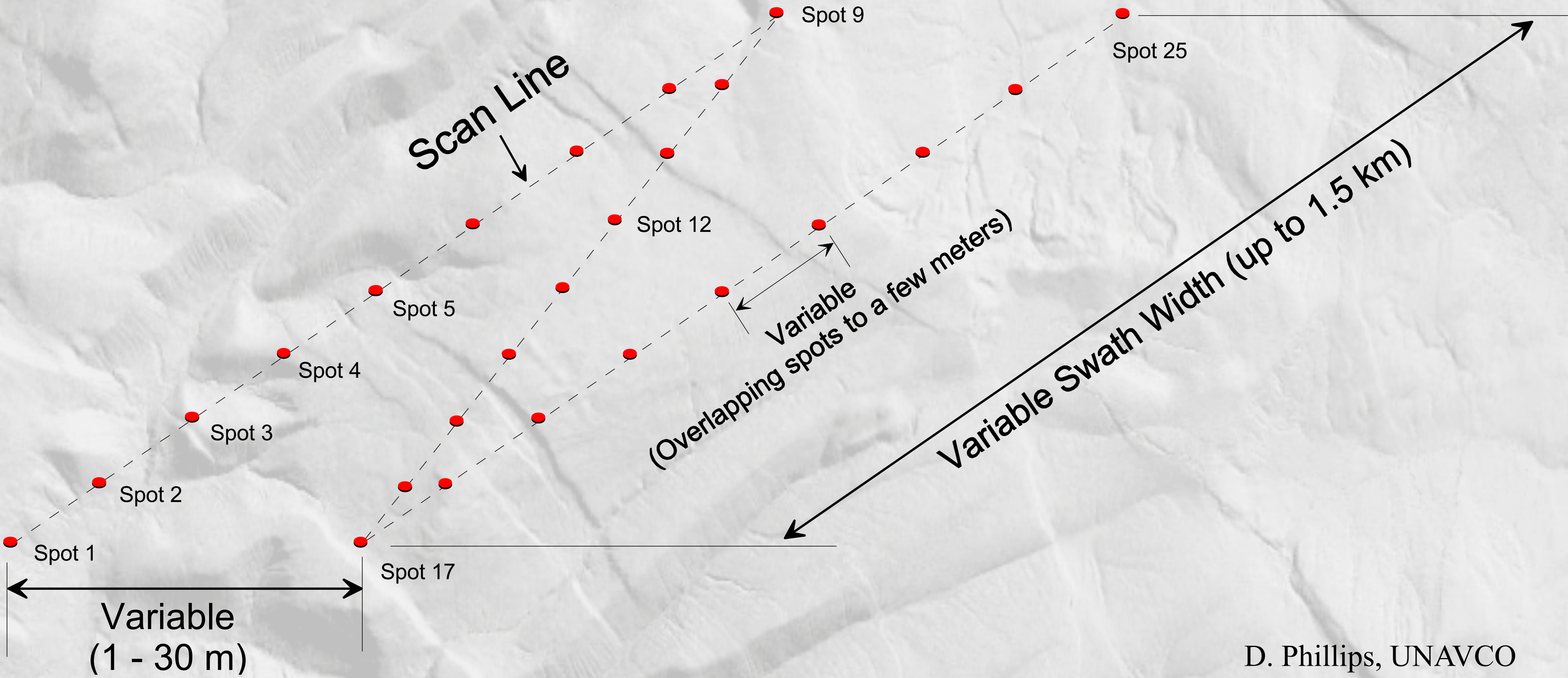
Lidar data collection



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



Surface Point Spacing

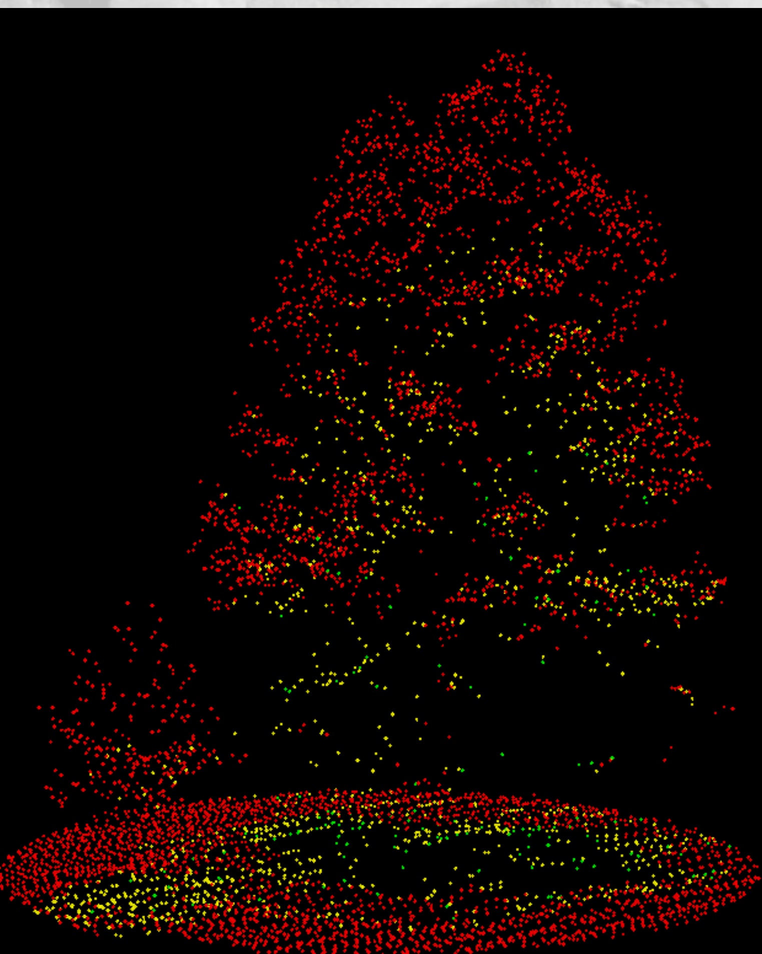


D. Phillips, UNAVCO

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

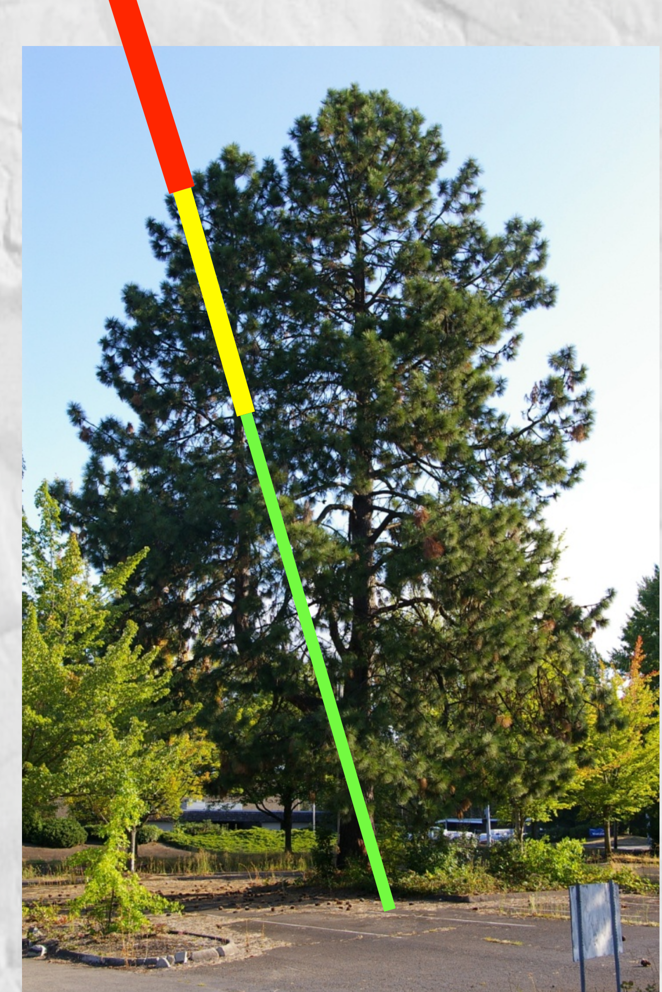
Each laser pulse can produce multiple consecutive measurements from reflections off several surfaces in its path

Ian Madin, DOGAMI

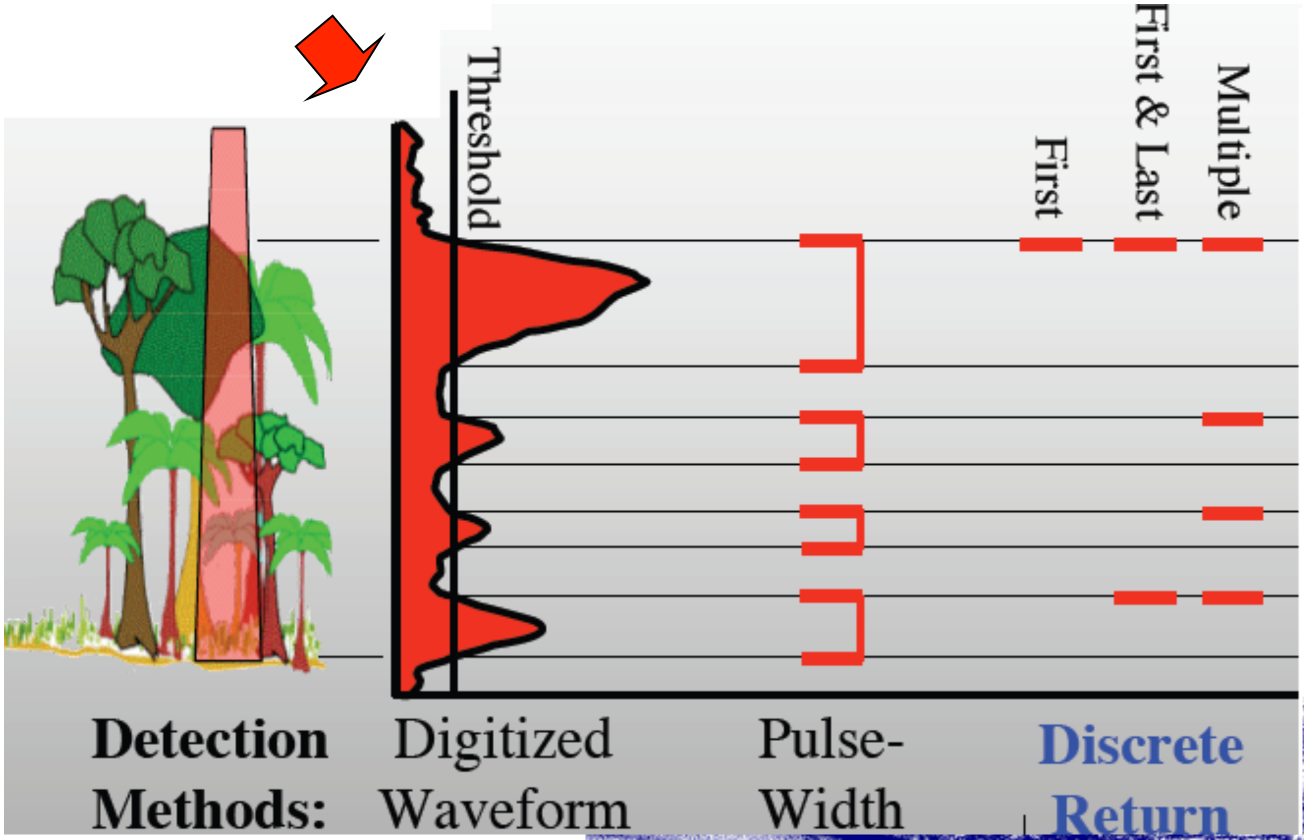


- Left = point cloud view of the tree in the photo on the right. Each point is colored by which return it was from a particular pulse:

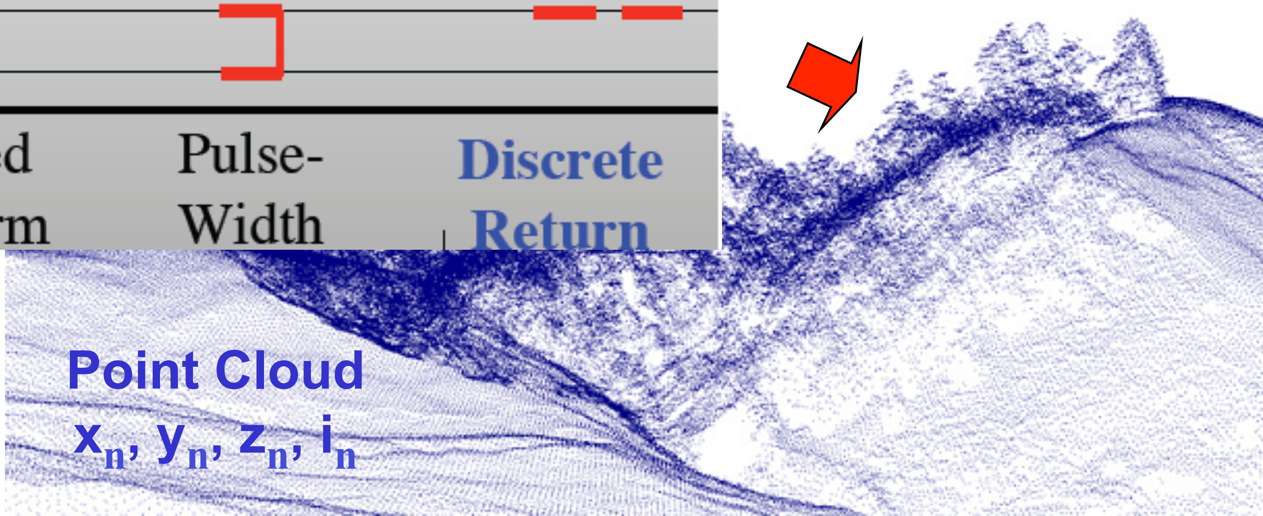
- Red= 1st
- Yellow = 2nd
- Green = 3rd



Lidar = Geodesy and signal processing



D. Harding, NASA



Typical Lidar Data Collection Parameters

- Aircraft: Cessna 337 Skymaster
- Personnel
    - One pilot, one operator in plane
    - GPS ground crew (2 to 10+ people)
- Scanner: Optech near-IR (Gemini)
- PRF: 33-125 KHz
- Flying height: 600 – 1,000m AGL
- Flying speed: 120 mph
- Swath overlap: 50% nominal
- Ground truthing: GPS (campaign & CORS)
- Navigation solution: KARS
- Point 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

Lidar Acquisition Considerations

- Target identification and prioritization
- Defining collection scheme and data product requirements
  - Tradeoffs concerning resolution vs. coverage
  - GPS ground control requirements
  - End use: geomorphology, geodesy, etc.
  - Cost
- Seasonal constraints - “Leaf off”, snow, heat, etc.
- Data volume…lots of TB’s
- Standard data products?
- Distribution scheme?

3. Processing

- GPS data processing and trajectory generation
  - Kinematic software (KARS, TRACK, etc.)

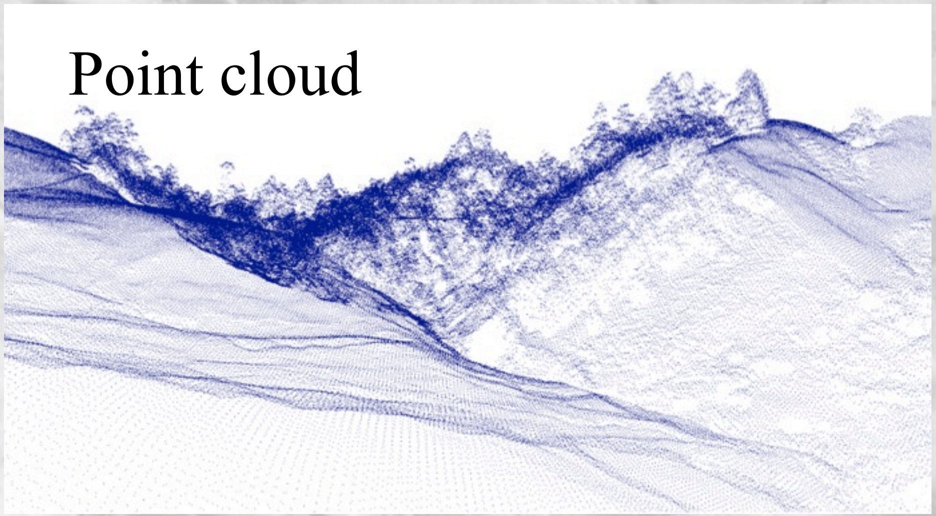
- LiDAR range processing and XYZ point cloud generation
  - Proprietary software (Terascan, Optech…)

- Point cloud classification:
  - Typically completed with proprietary software (Terascan).
  - Limited open source / free software available to “do it yourself”.
  - Not fully automated – significant manual intervention necessary.

5. Data Delivery

- Data typically arrives on HD from vendor.

- Deliverables:
  - Point cloud (ascii or LAS)
  - Bare earth and first return DEMs
  - Data mosaics at lower resolution (e.g. 1 m vs 0.5 m)
  - Metadata (XML, machine readable if lucky)
  - Report of the survey – PDF, human readable



Deliverables - DEMs

- **DEM Data**:
  - Bare earth and first return DEMs in tiles (1 km x 1 km, USGS ¼ quad)
  - Hillshades of above DEMs
  - Mosaics at lower resolution
  - Intensity images
- **File Formats**:
  - No standards
  - Common: Arc ESRI binary grid, ERDAS .IMG, GeoTiff, ascii grids, Surfer .grd, etc.

Deliverables – Point Cloud

- **X,Y,Z + attributes**:
  - Attributes: GPS time, Intensity / RGB, return #, classification (ground, vegetation, other), swath ID
  - All return files:
    - Organized into tiles (1 km x 1 km, subset of USGS ¼ quad) or by swath

- **File Formats**:
  - ASCII (.txt, .xyz)
    - Easily parsed (linux – painful on Windows), portable, HUGE, need to move to another format for on-the-fly analysis.

```
x,y,z,gpstime,intensity,classification,flight_line
560149.82,4108410.91,-14.54,331709.549800,5,2,9
560149.54,4108410.78,-14.04,331709.549800,5,1,9
```

Deliverables – Point Cloud II

File Formats:

- LAS (.las)
  - Standard format (at v. 1.3) defined by ASPRS (American Society for Photography and Remote Sensing).
  - Binary – smaller, easily parsed and indexed with correct libraries (libLAS)
  - Standard…
  - Robust header
    - Scanner info, processing software, spatial coordinates, bounding box, # of points in file
  - Requires software that can read and write LAS
  - More restrictive in terms of what attributes you can add
  - LAS vs. fully populated LAS – still need to output all the attribution
  - Version 1.3 supports waveforms (*kinda…*)

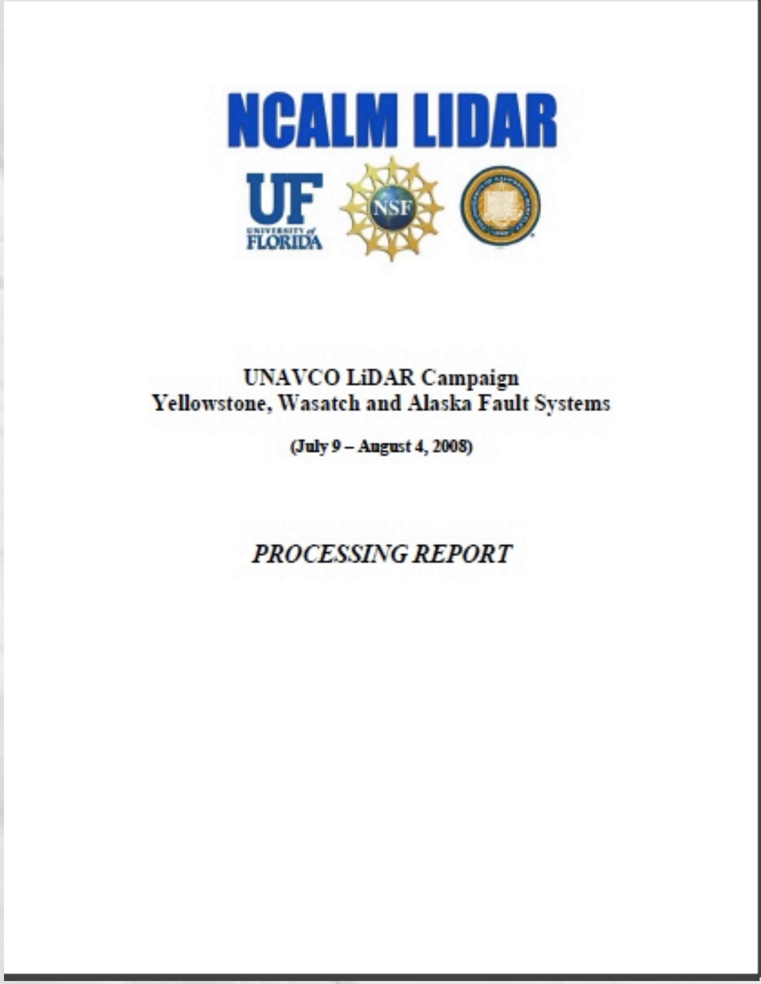
Item	Format	Size	Required
X	long	4 bytes	*
Y	long	4 bytes	*
Z	long	4 bytes	*
Intensity	unsigned short	2 bytes	
Return Number	3 bits	3 bits	*
Number of Returns (given pulse)	3 bits	3 bits	*
Scan Direction Flag	1 bit	1 bit	*
Edge of Flight Line	1 bit	1 bit	*
Classification	unsigned char	1 byte	
Scan Angle Rank (-90 to +90) – Left side	char	1 byte	*
File Marker	unsigned char	1 byte	
User Bit Field	unsigned short	2 bytes	

ASPRS Standard LIDAR Point Classes

Classification Value (bits 0:4)	***Meaning***
0	Created, never classified
1	Unclassified[1]
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	*Reserved for ASPRS Definition*
11	*Reserved for ASPRS Definition*
12	Overlap Points[2]
13-31	*Reserved for ASPRS Definition*

Deliverables – Metadata

- **Report of the Survey**:
  - PDF format (human readable)
    - Data provider, area surveyed, when surveyed, instrument used, processing software and methods, spatial coordinates and datums, know issues, etc.
    - Spatial reference framework
    - Data provider's report on data quality
    - Naming, formats, spatial organization of data files

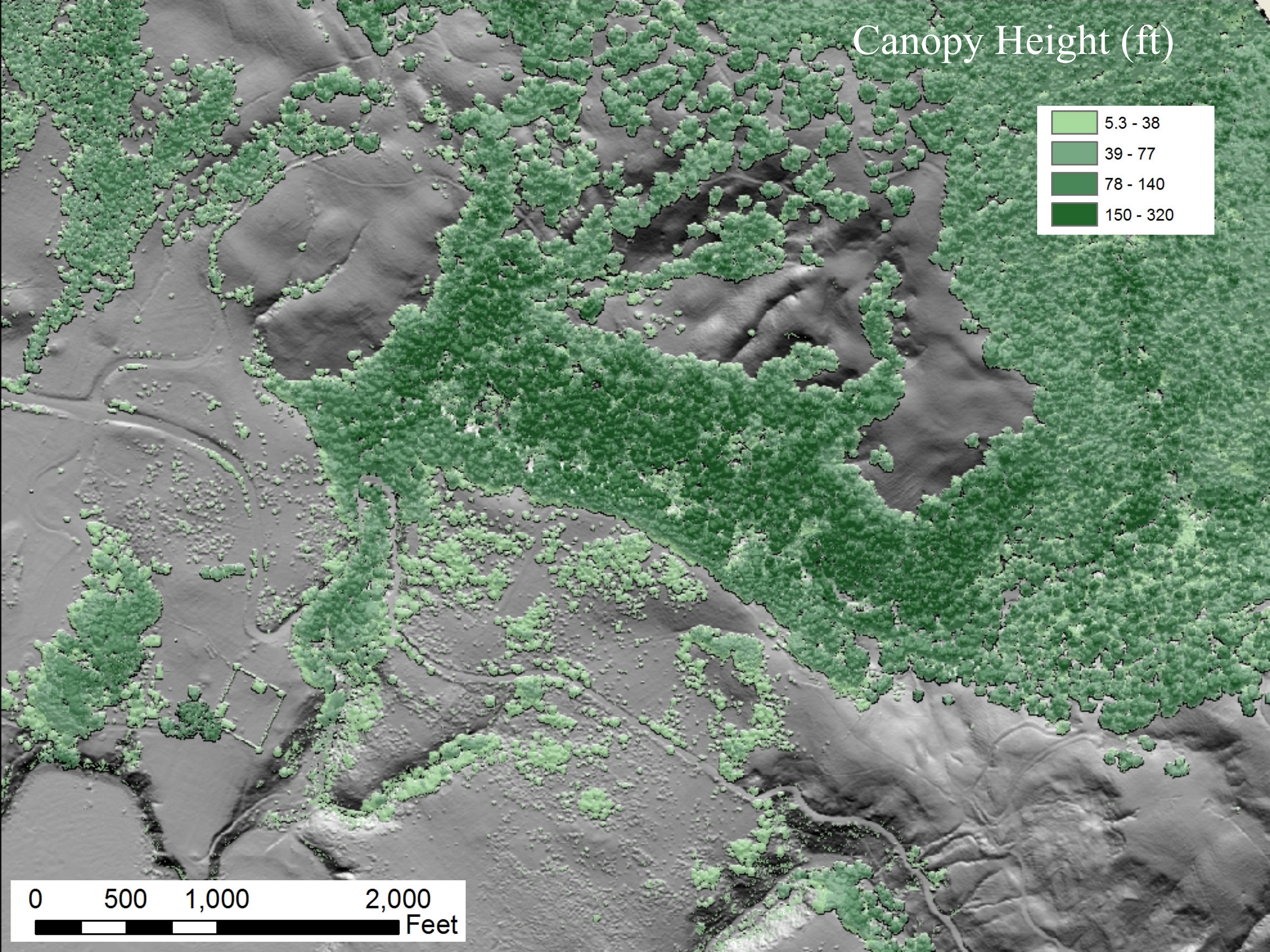

NCALM LIDAR

UNAVCO LiDAR Campaign
Yellowstone, Wasatch and Alaska Fault Systems

(July 9 – August 4, 2008)

PROCESSING REPORT

- **FGDC (or similar) metadata**:
  - XML (machine readable)
  - Ideally populated by vendor and client
  - Not delivered by NCALM…



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

What is ground?

Three assumptions:

Can be used to guide automated processing approaches

1. **Ground is smooth**
   - **despiking, iterative linear interpretation algorithms**

2. Ground is continuous (single-valued)
   - No-multiples algorithm

3. Ground is lowest surface in vicinity
   - Block-minimum algorithms

Modified from: R. Hagerud, USGS

Ground is smooth $\Rightarrow$ despike algorithm

Approach:

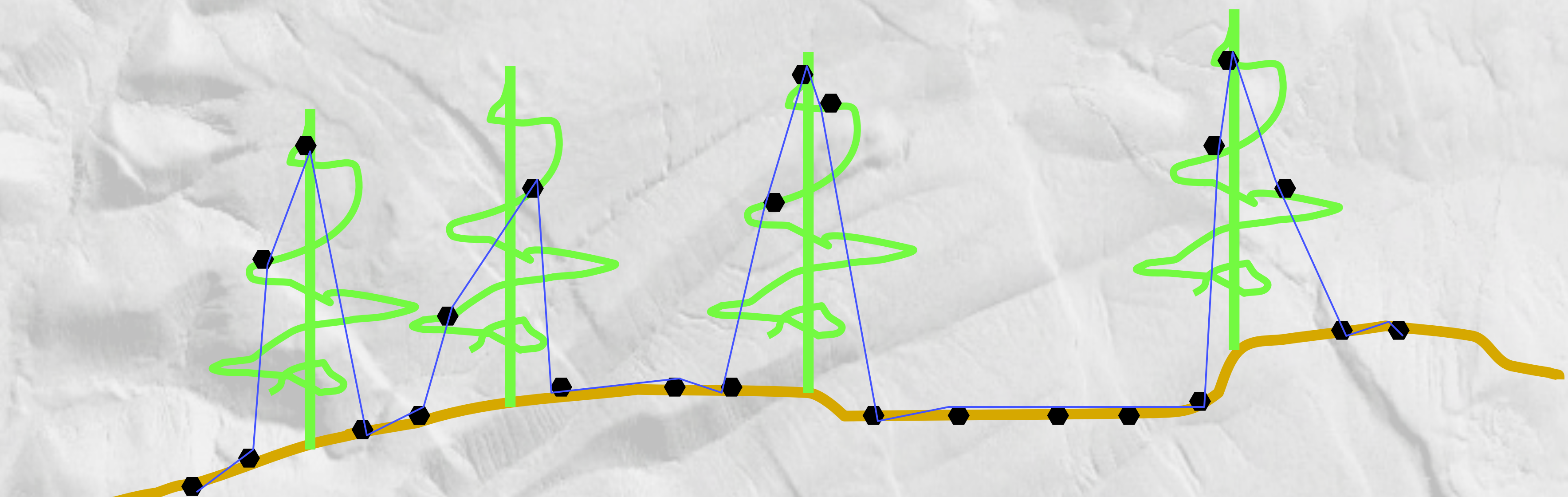
1. flag all points as ground

2. repeat:
   - build TIN (triangulated irregular network) of ground points
   - identify points that define strong positive curvatures
   - flag identified points as not-ground

3. until no or few points are flagged

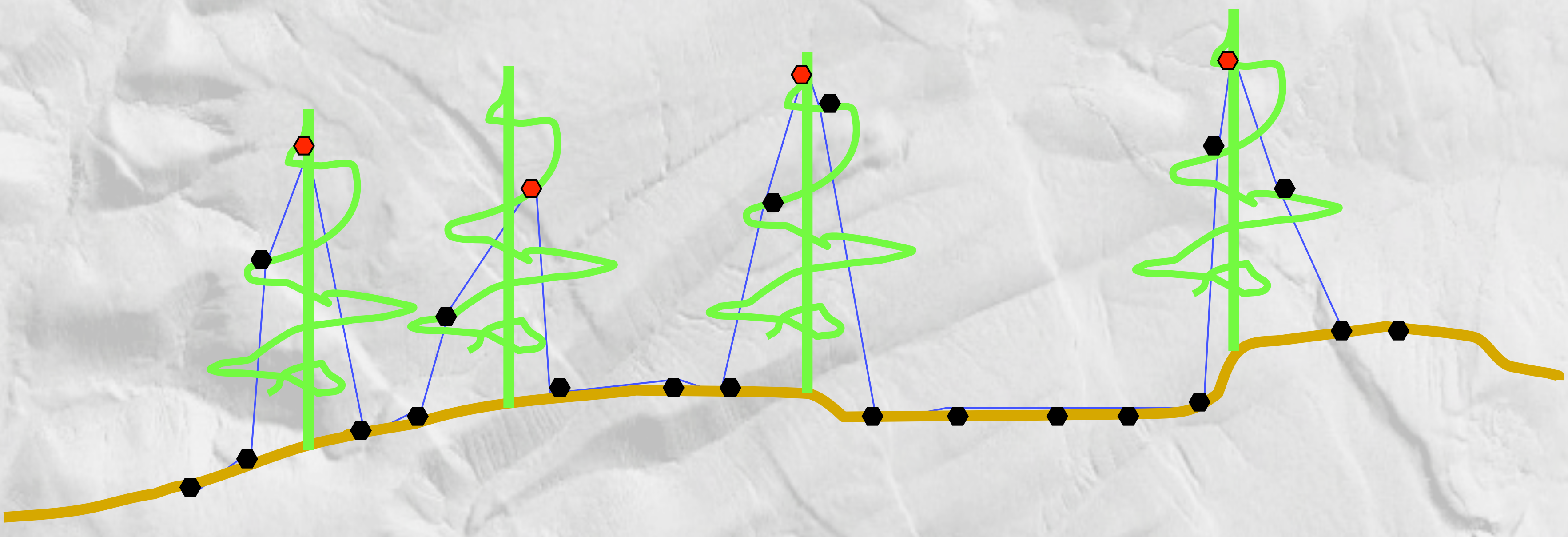
R. Hagerud, USGS

Start with mixed ground and canopy returns (e.g. last-return data), build TIN



R. Hagerud, USGS

Flag points that define spikes
(strong convexities)

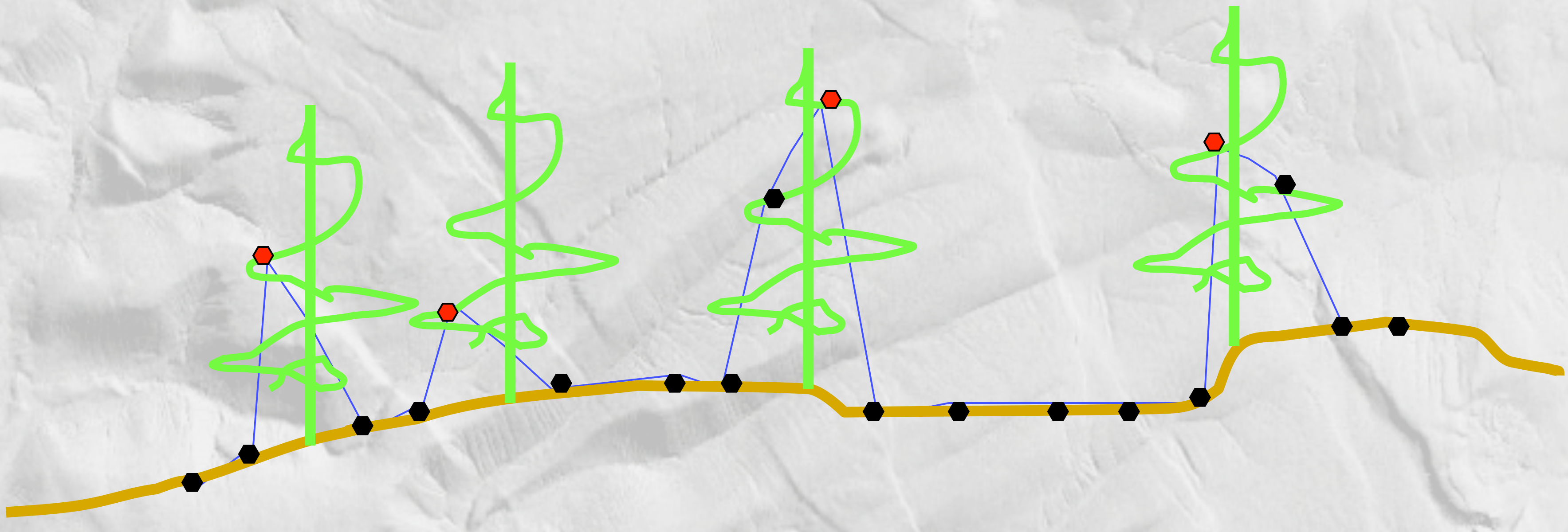


R. Hagerud, USGS

Rebuild TIN

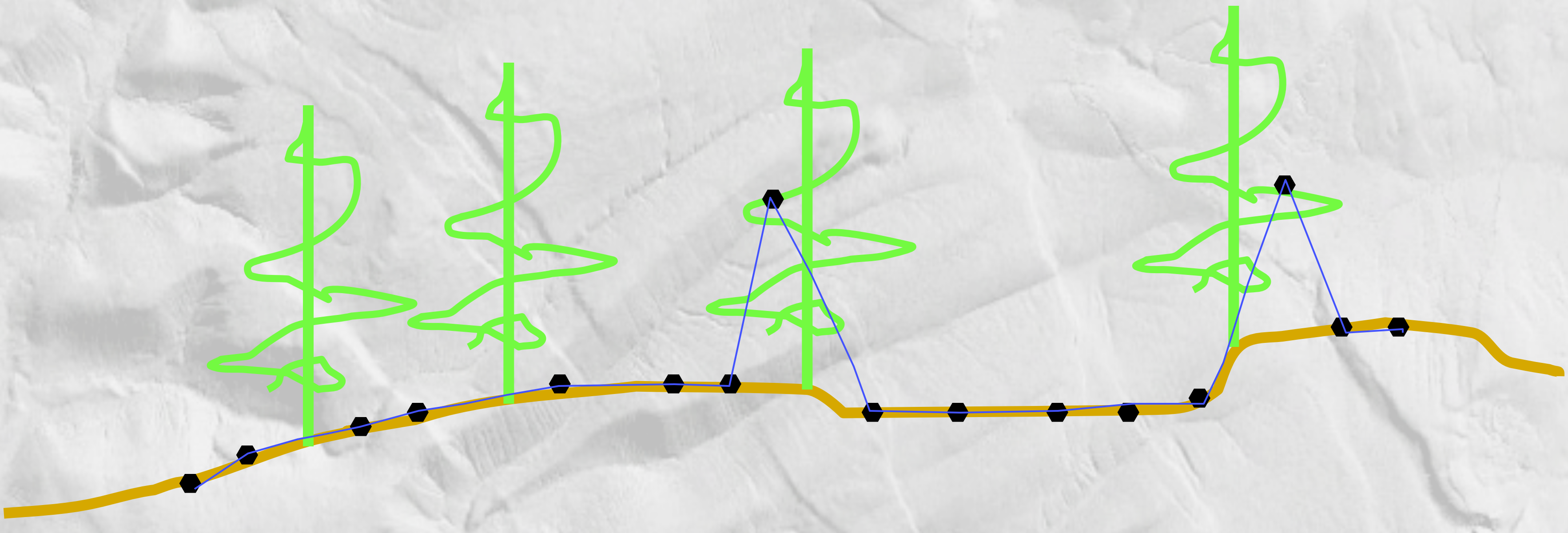
R. Hagerud, USGS

Flag points that define spikes (strong convexities)



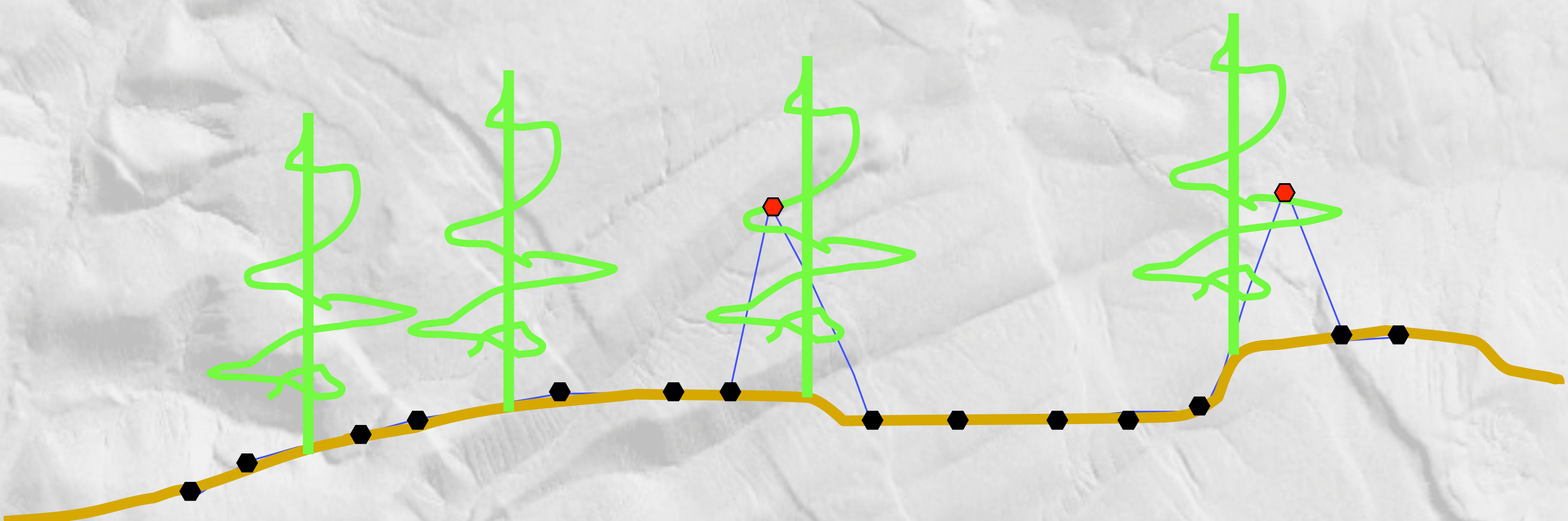
R. Hagerud, USGS

Rebuild TIN



R. Hagerud, USGS

Flag points that define spikes (strong convexities)



R. Hagerud, USGS

Rebuild TIN

R. Hagerud, USGS

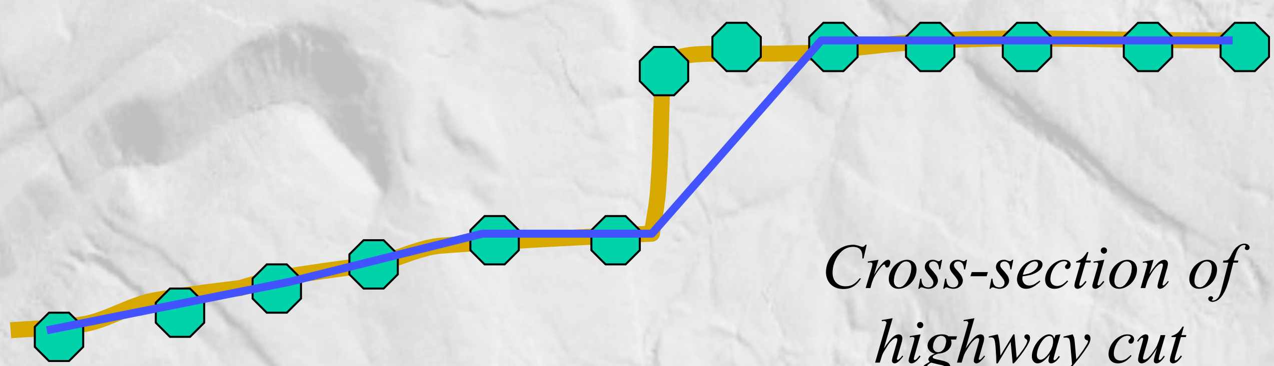
Despike algorithm

Benefits:

- It works
- It's automatic
  - Cheap(!)
  - All assumptions explicit
- It can preserve breaklines
- It appears to retain more ground points than other algorithms

R. Hagerud, USGS

Despike algorithm



Cross-section of highway cut

Problems:

- Removes some corners
- Sensitive to negative blunders
- Computationally intensive
- Makes rough surfaces
  - Real? Measurement error? Misclassified vegetation?

R. Hagerud, USGS

In the real world…

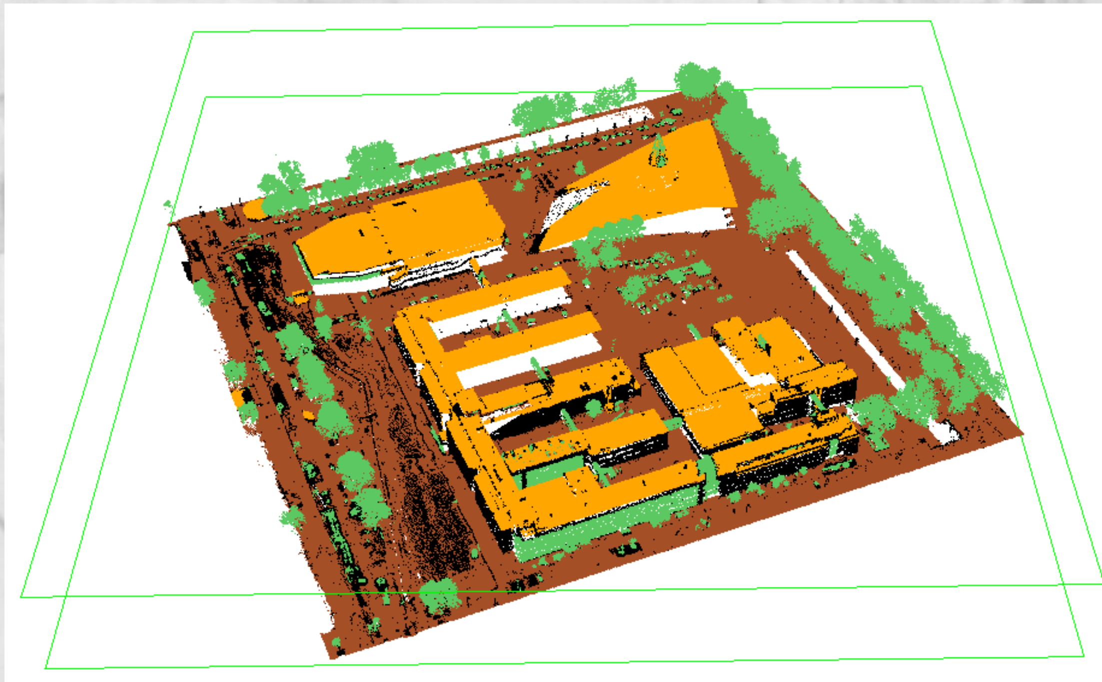
- Almost all return classification is done with proprietary codes (Terascan the standard)

- Successful classification uses a mix of
  - Sophisticated code
  - Skilled human
    - To adjust code parameters
    - To identify and remedy problems

- Let somebody else do it! - *then carefully check their work*

- We have no useful metrics for accuracy of return classification

Do it yourself:



Open Source - Automated:

- LASTools –
  lasground.exe &
  lasclassify.exe

- MCC-lidar
  (Evans & Hudak, 2007)
  http://sourceforge.net/apps/trac/mcclidar/

- BCAL lidar tools (requires ENVI): http://bcal.geology.isu.edu/tools-2/envi-tools

More discussion: http://www.opentopography.org/index.php/blog/detail/tools_for_lidar_point_cloud_filtering_classification#comments

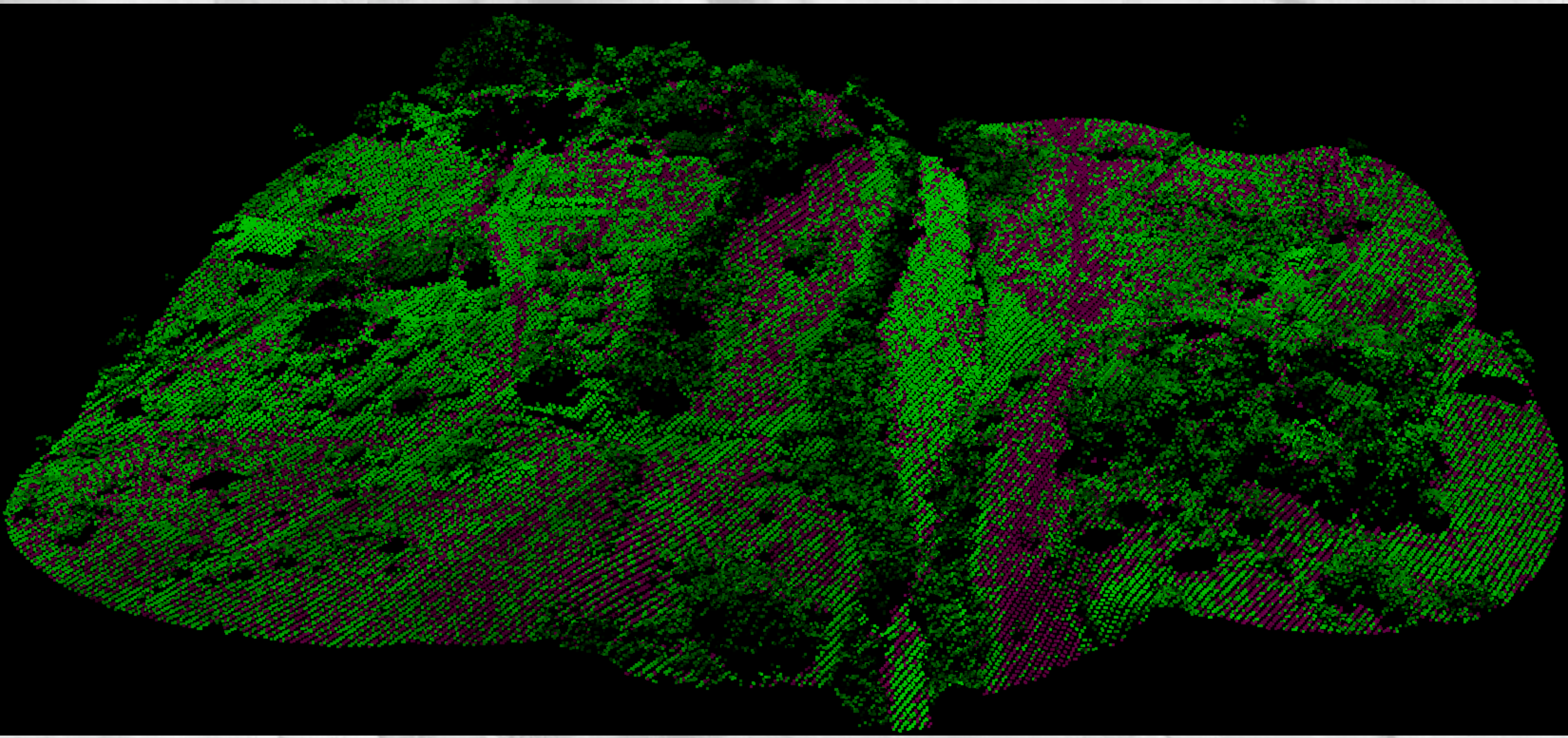
Open Source - Manual:

- LidarViewer (KeckCAVES)

R. Hagerud, USGS

When Automatic Classification Goes Wrong:

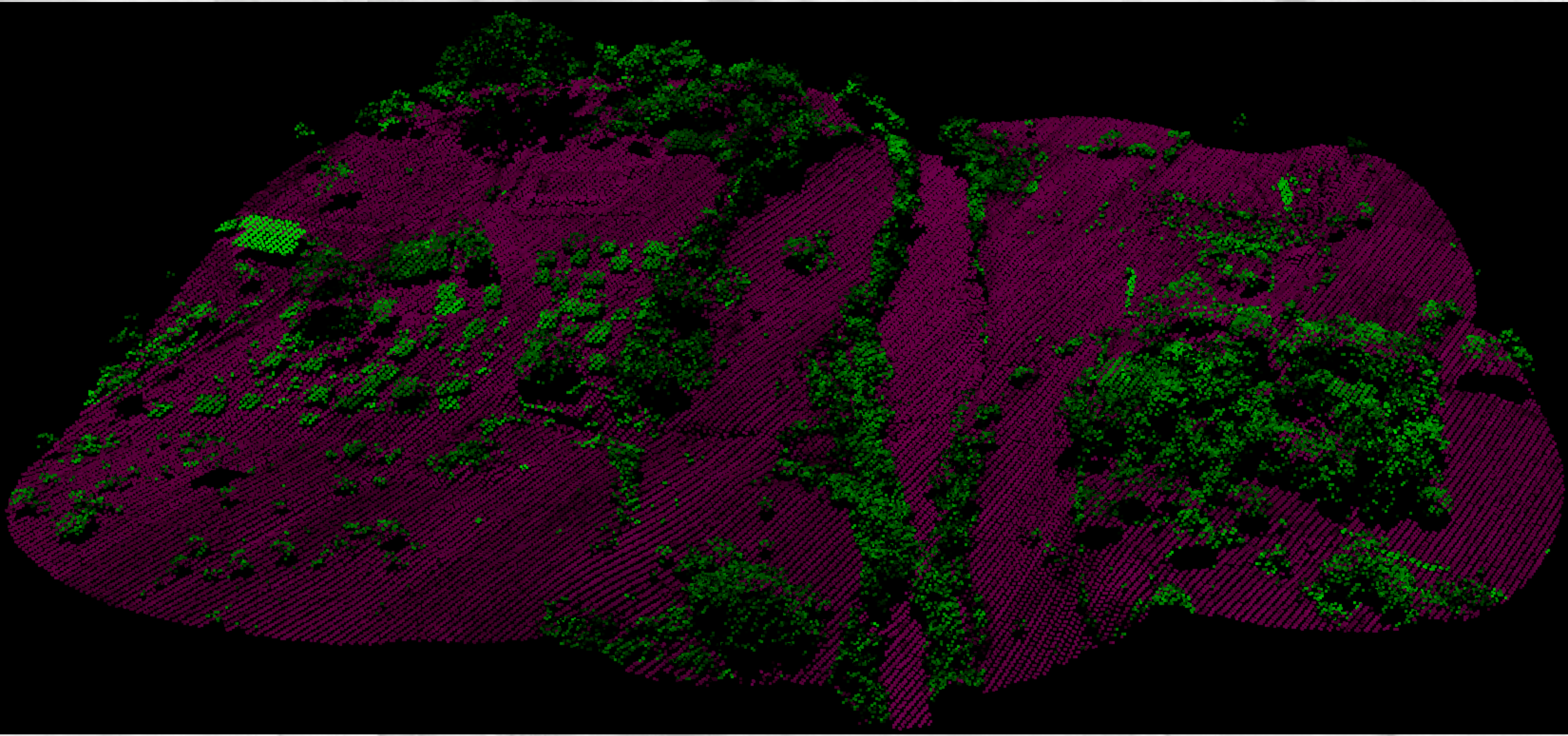
Dumay Slip-Rate Site, Enriquillo Fault, Haiti



This data set was processed quickly for assessing urban area, not faults

Manual Classification in 3D Cave

Dumay Slip-Rate Site, Enriquillo Fault, Haiti



Manual classification practical for small areas using a 3D environment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