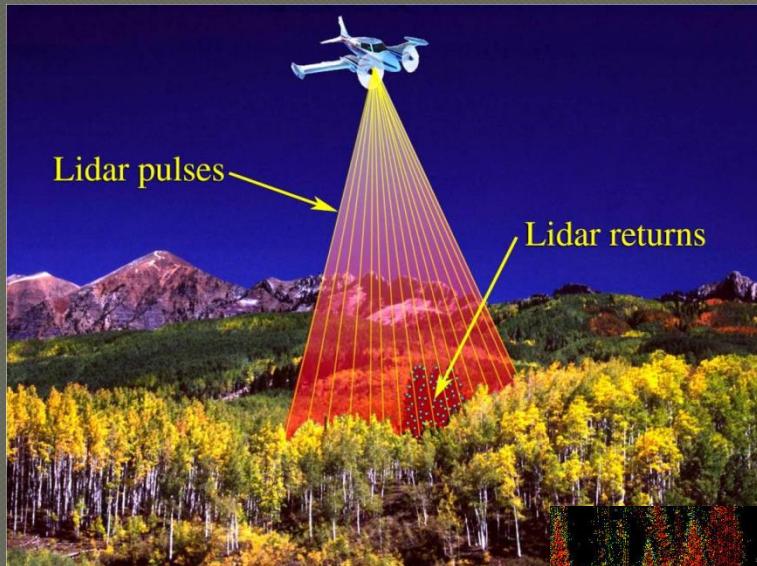
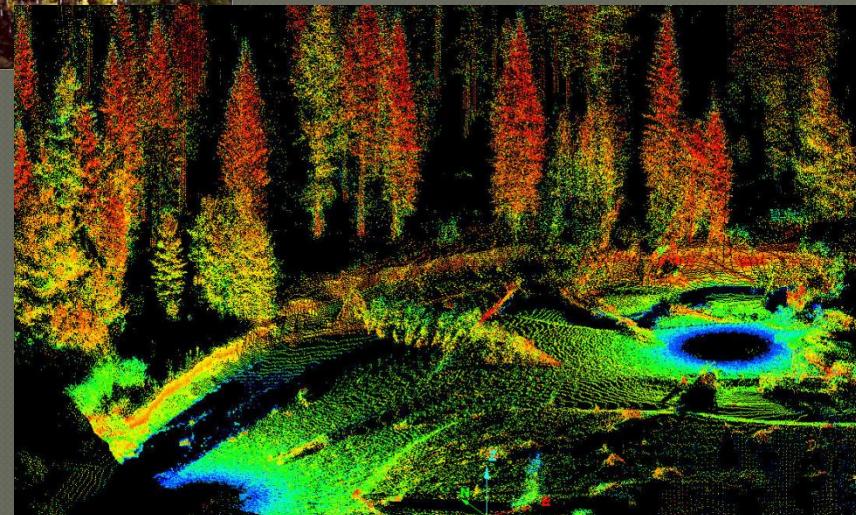


Light Detection and Ranging



Bjarne Fog
Geography section, IGN



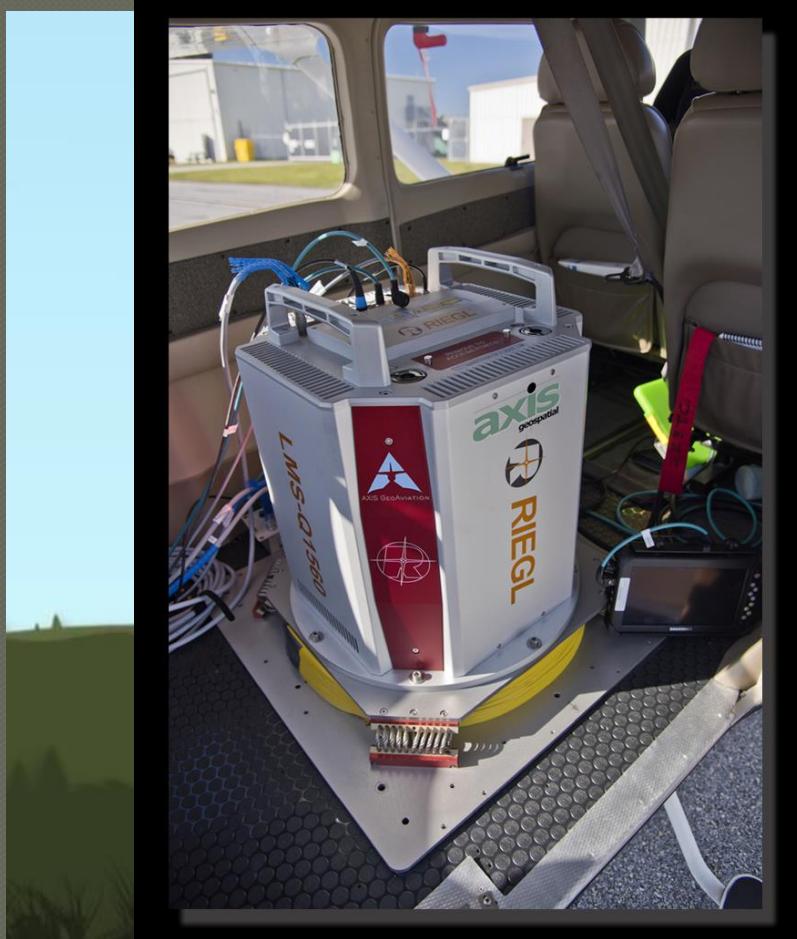
LiDAR

- What is LiDAR?
- Data acquisition
- Data editing, manipulation, classification
- Lidar products covering Denmark
- DEM, DSM and point cloud
- Other platforms

What is LiDAR?

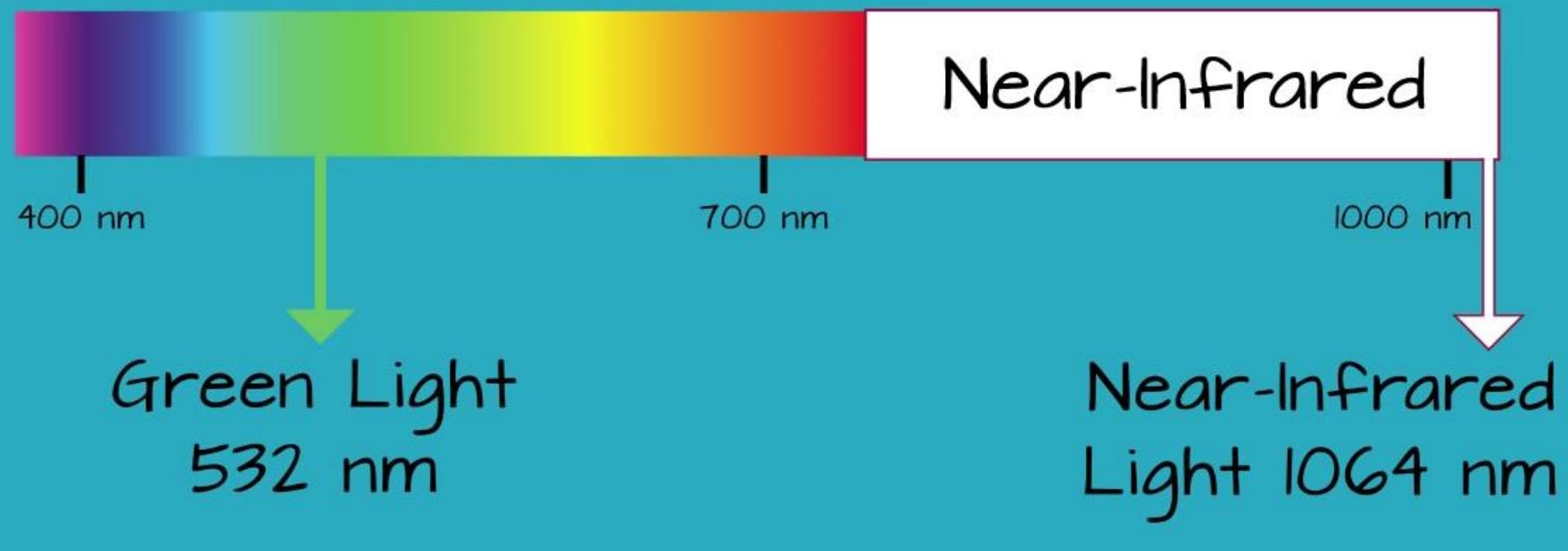
- LIDAR, which stands for *Light Detection and Ranging*, is a **remote sensing** method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system—generate precise, three-dimensional information about the shape of the Earth and its surface characteristics. (NOAA)

Laser sensor



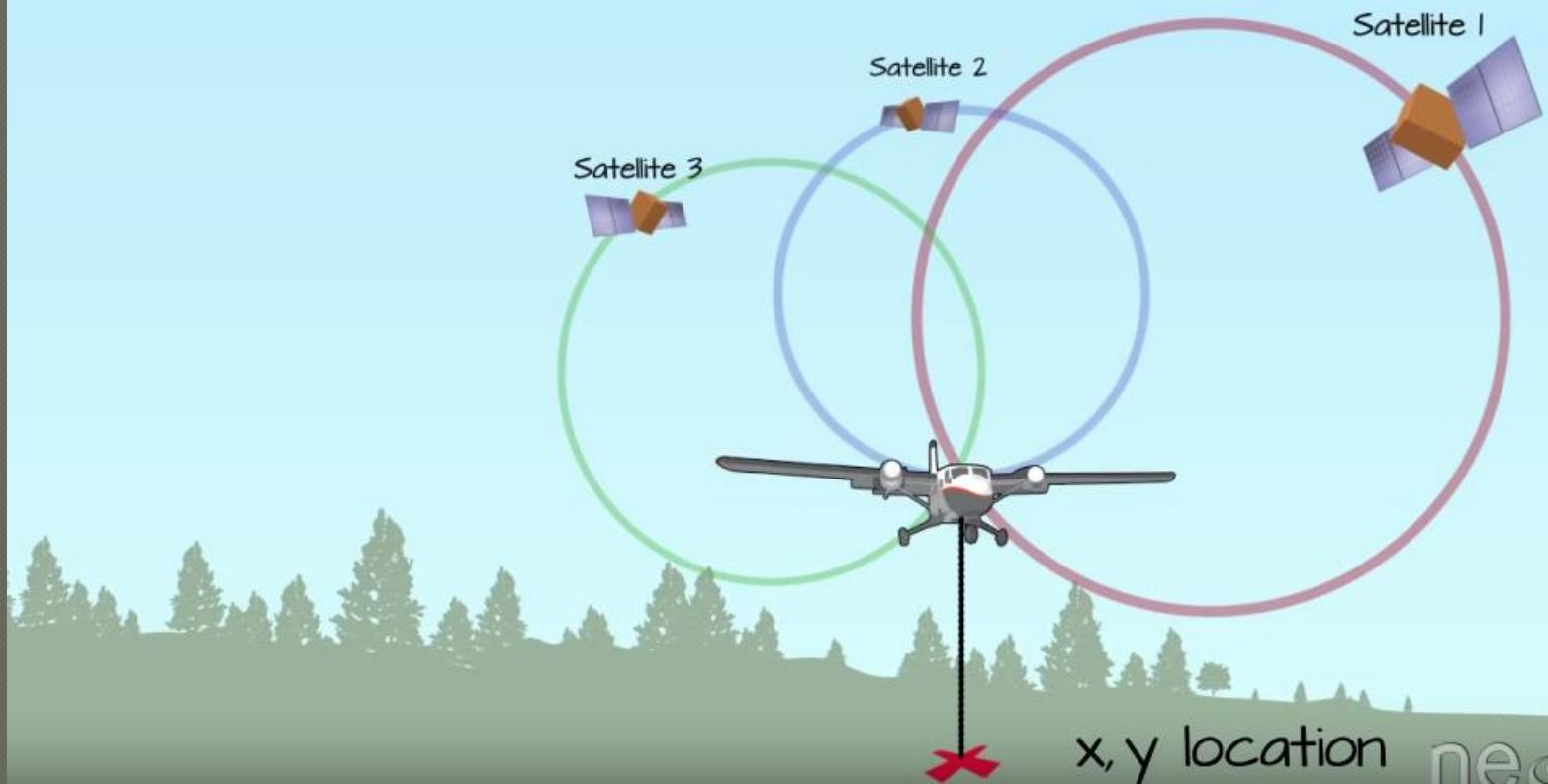
The beam of Light

Electromagnetic Spectrum



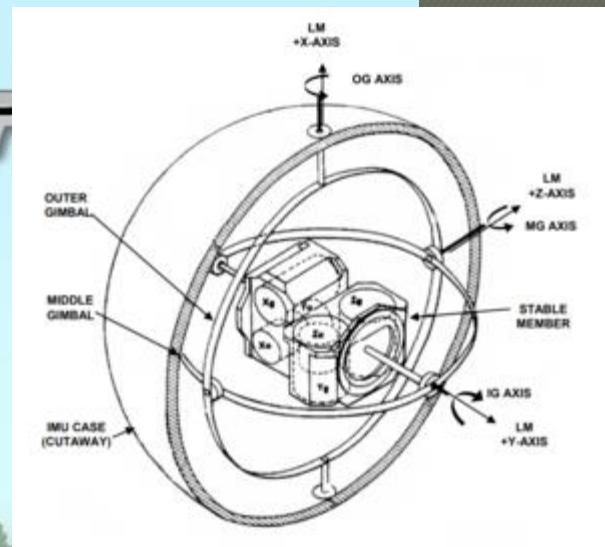
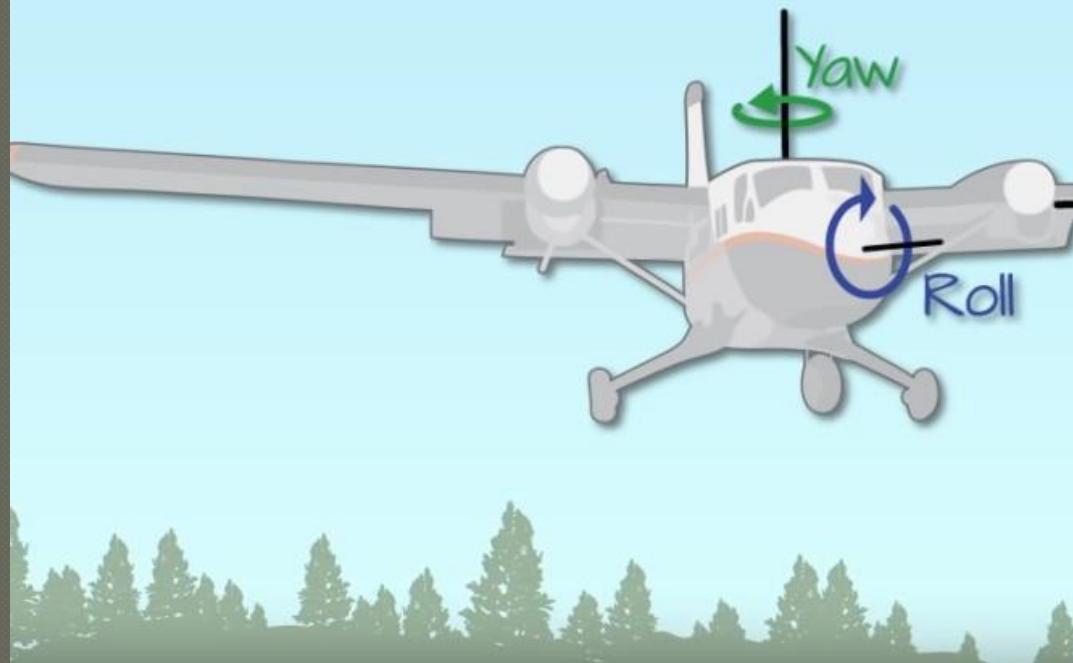
GPS/GNSS

Global Positioning System
-Tracks planes x,y,z position



IMU

Inertial Measurement Unit (IMU)
-Tracks Plane Position



Computer

Computer
-Records Data



neon

How is the height measured?

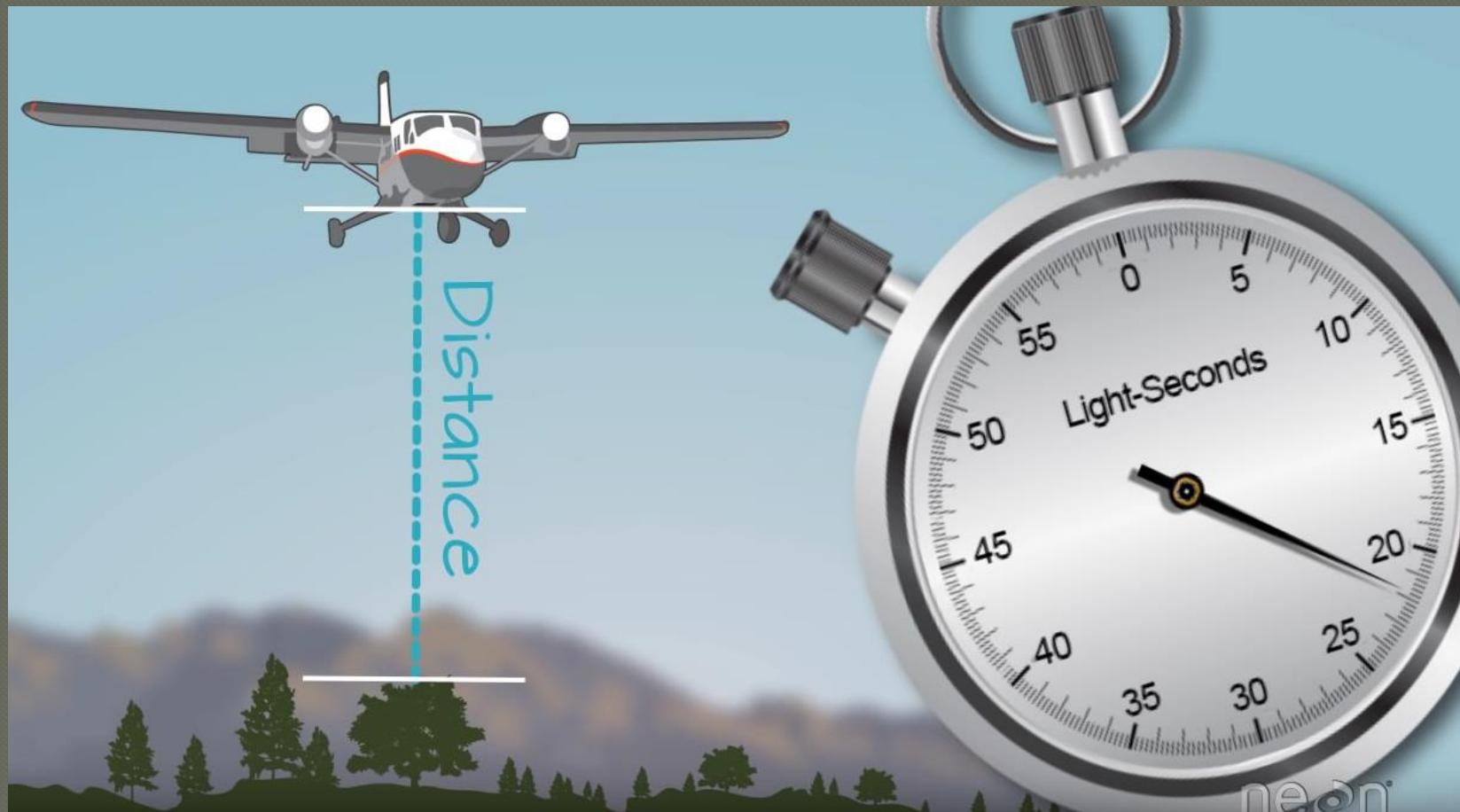
pulse + return = height??

How is the height measured?

Laser + GPS + IMU + Computer



Distance = time x speed of light



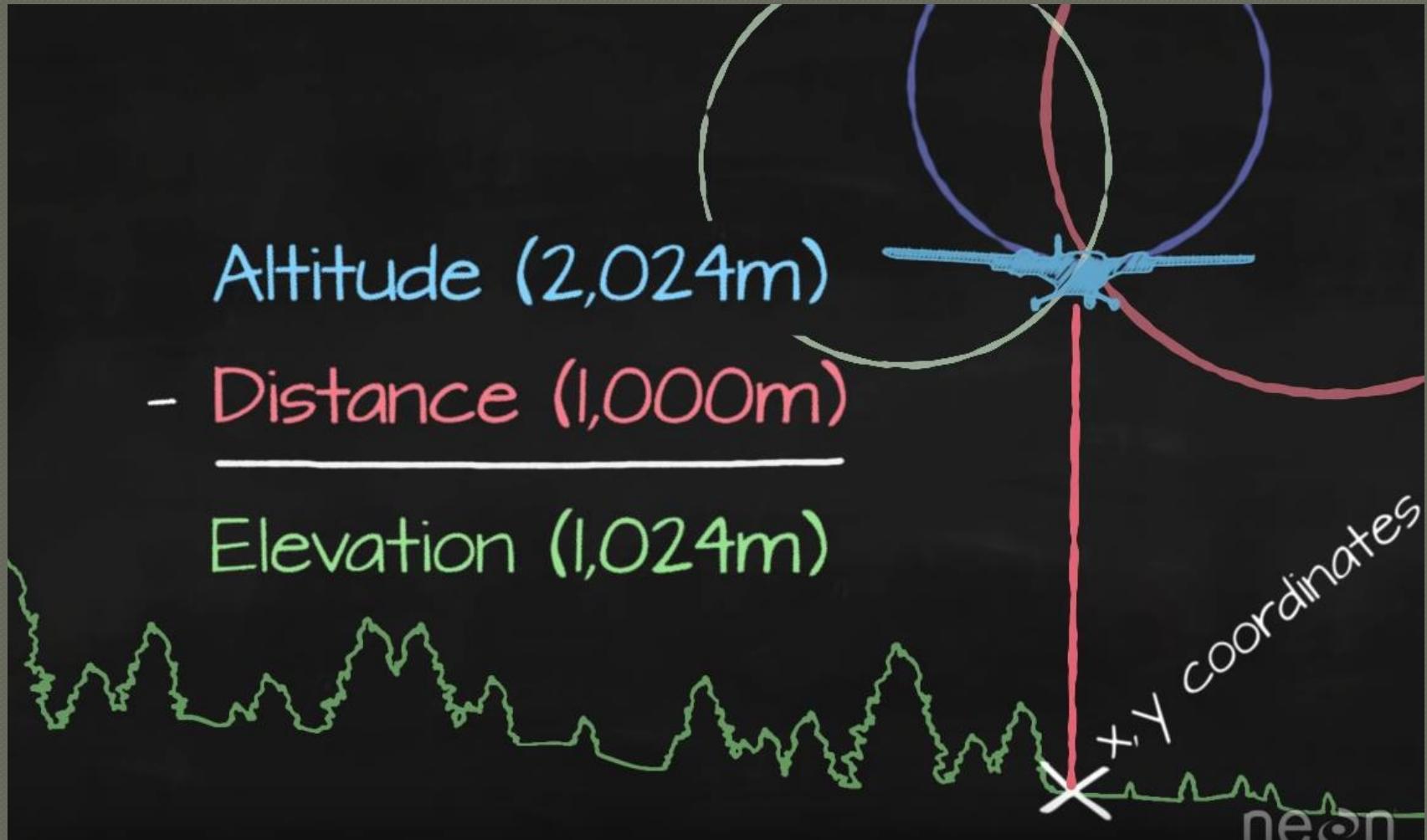
Distance

$$\frac{(\text{travel time}) * (\text{speed of light})}{2} = \text{Distance}$$

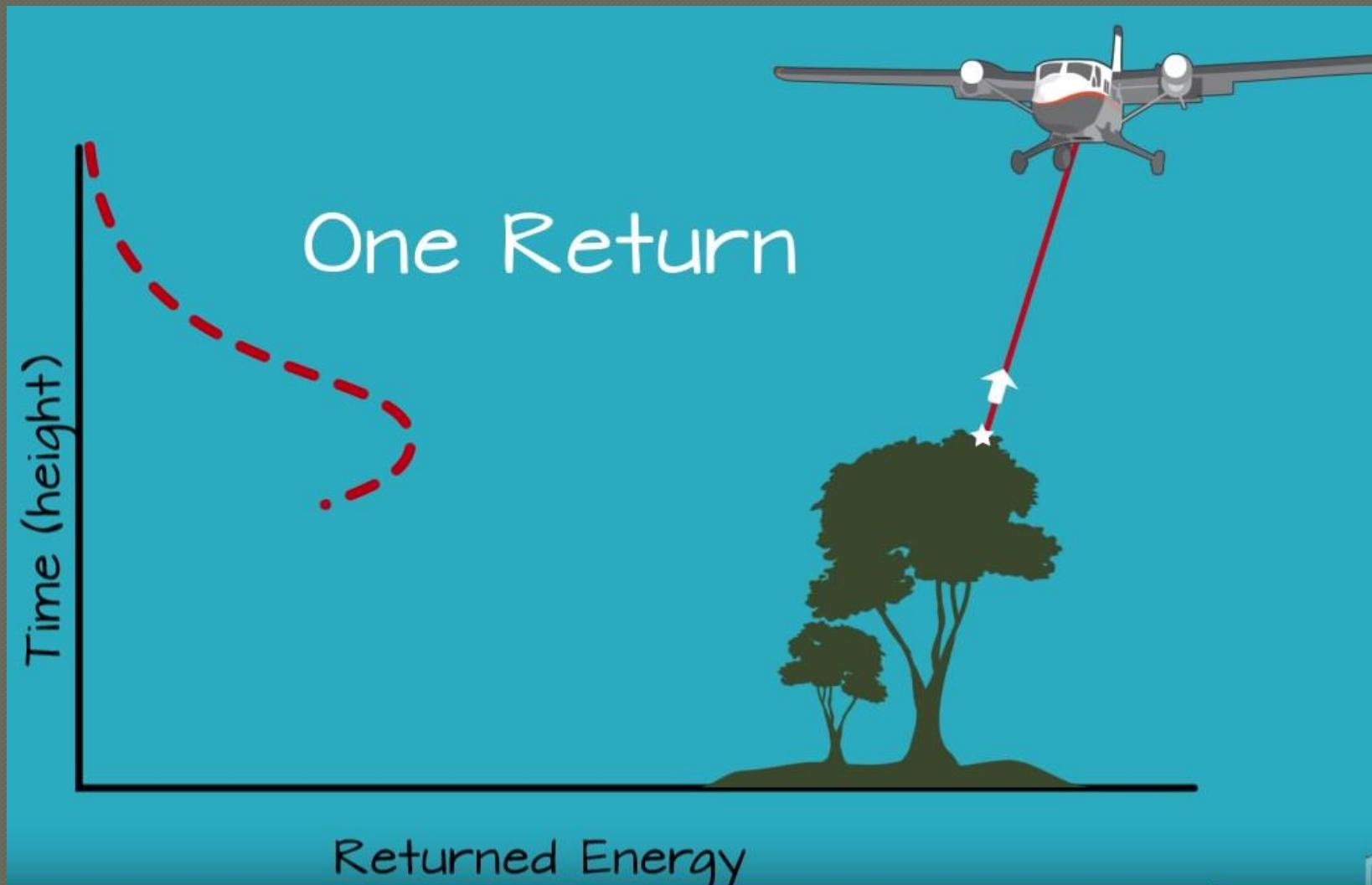


neon

Elevation



Surface (trees)

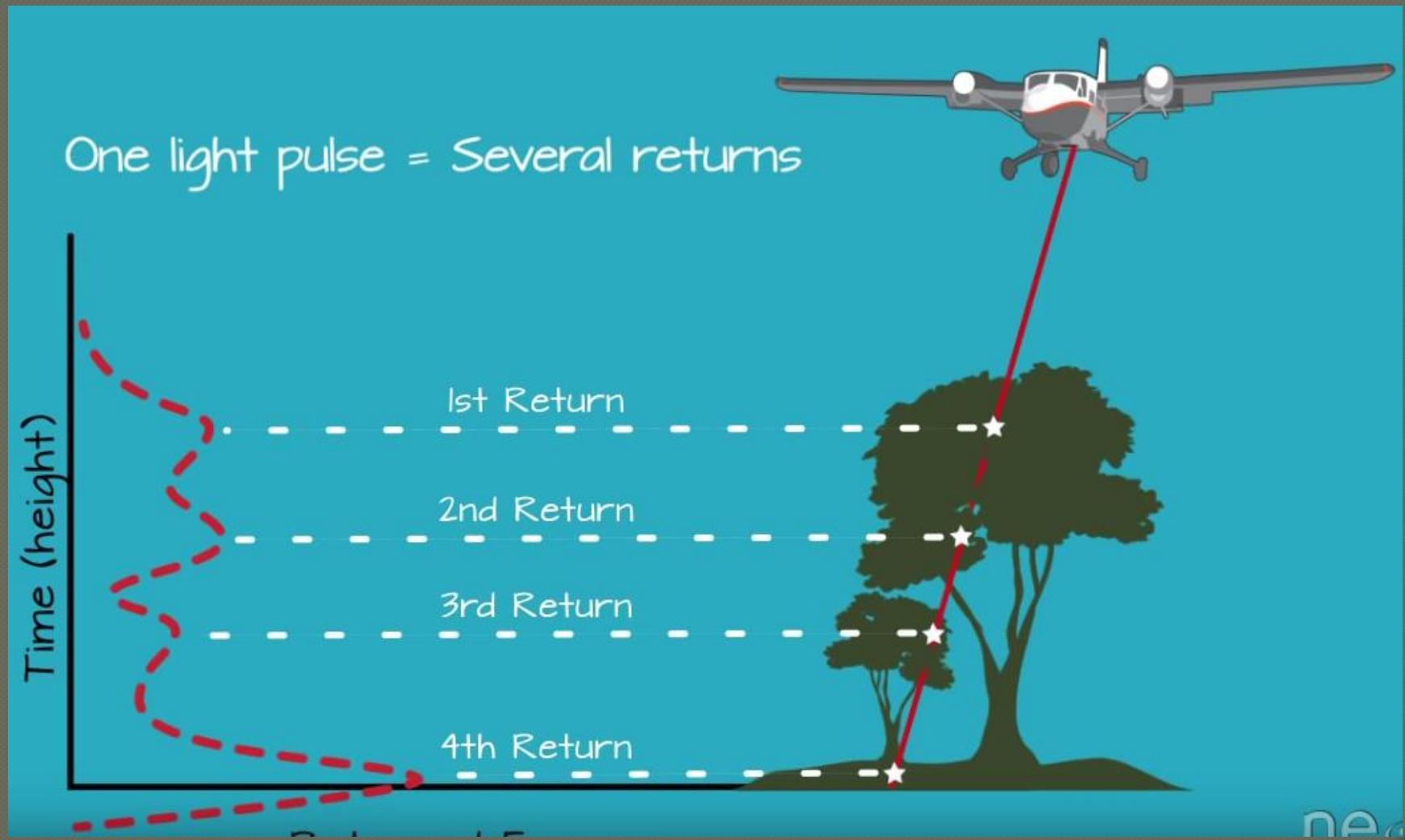


Radiation in a forest

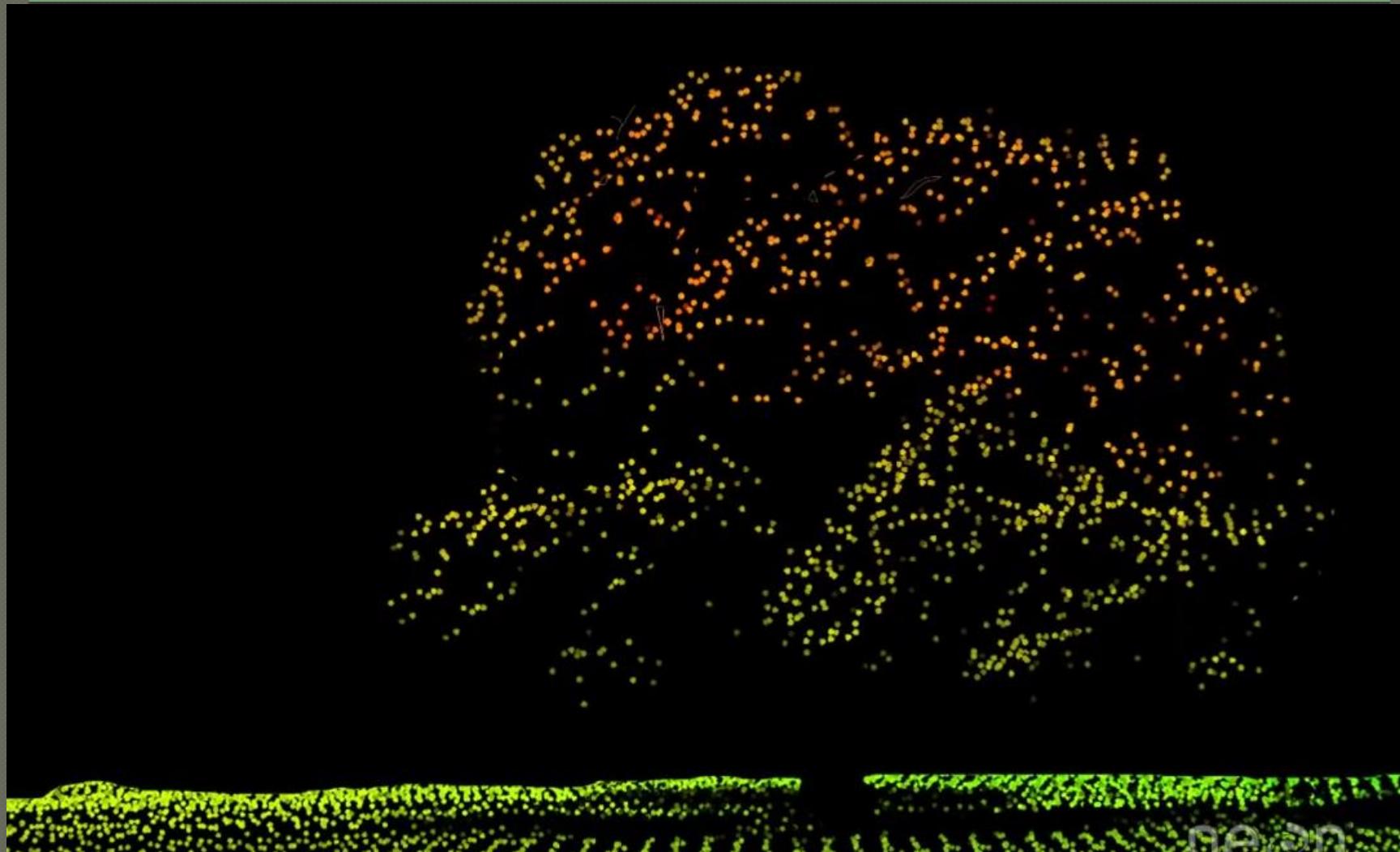


nebor

Returned energy

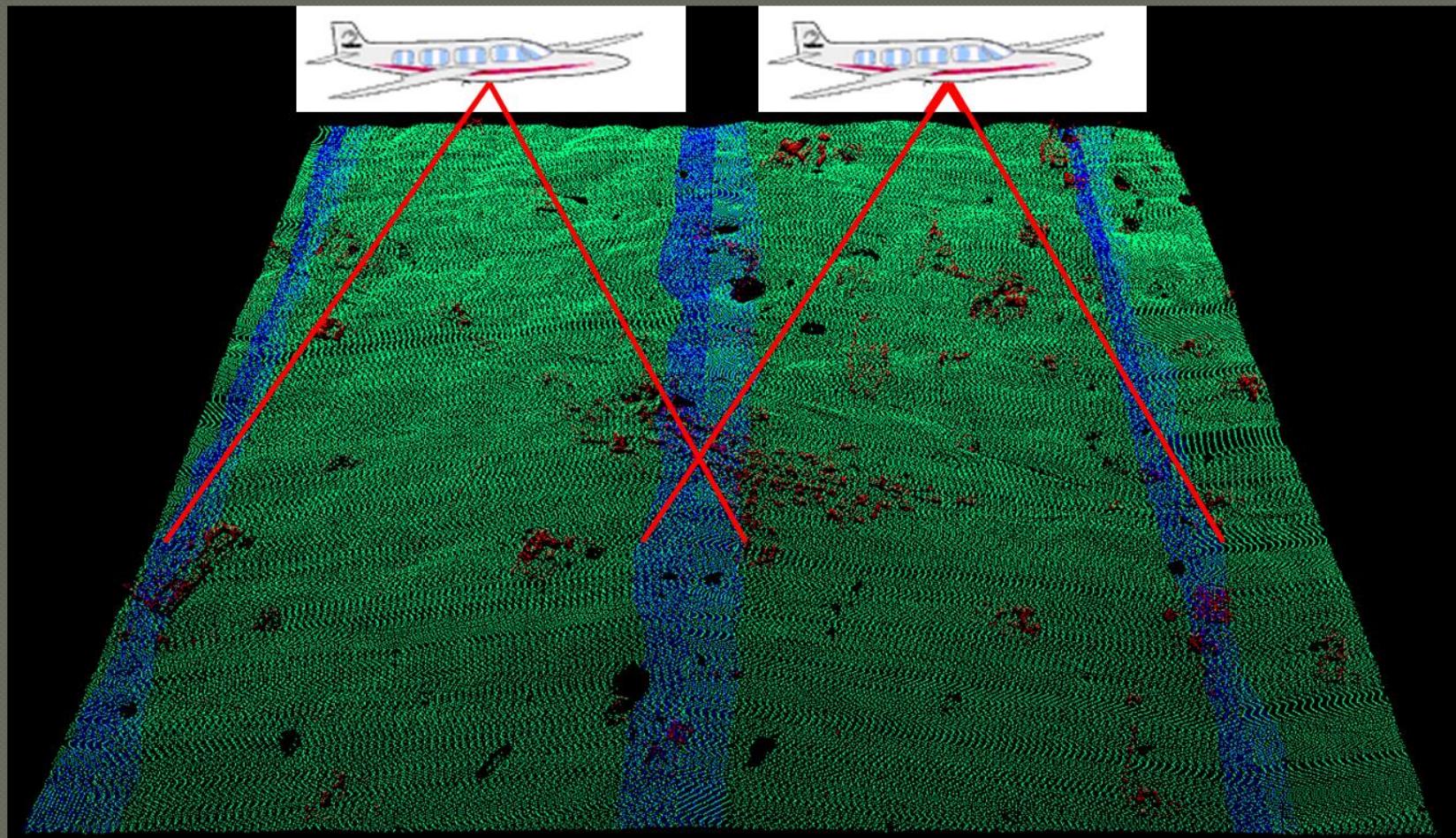


Point cloud (returns)

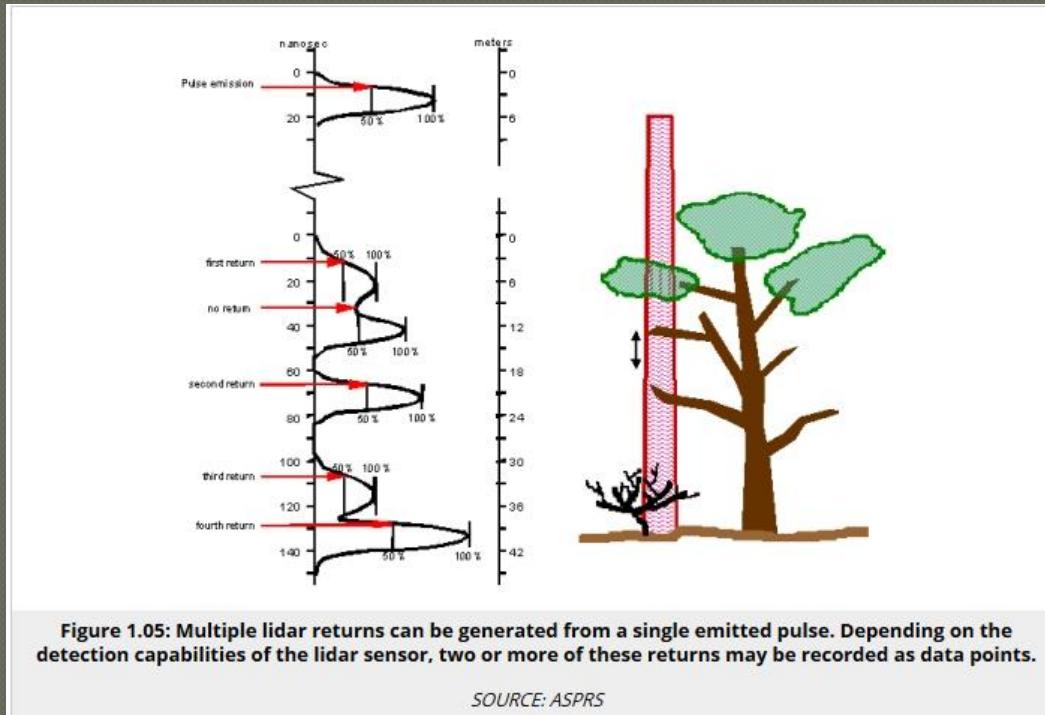


ne an

Data acquisition



Data acquisition (discrete)



Table

P6161_640

OBJECTID *	SHAPE *	Class	Return	Intensity	Z	NumReturns	ScanDir	Edge	ScanRank	UserData	PointSrcID	GPSTime	Red	Green	Blue	Synthetic	Key	Withheld
1582	Point	2	1	126	10.04	1	0	0	10	2	46139	1080673619.178621	0	0	0	0	0	0
1583	Point	2	1	190	10.05	1	0	0	10	2	46139	1080673619.178624	0	0	0	0	0	0
1584	Point	2	2	140	10.05	1	0	0	10	2	46139	1080673619.178627	0	0	0	0	0	0
1585	Point	7	2	7	8.3	2	0	0	10	2	46139	1080673619.178627	0	0	0	0	0	0
1586	Point	2	1	156	10.06	1	0	0	10	2	46139	1080673619.178629	0	0	0	0	0	0
1587	Point	2	1	146	10.06	1	0	0	10	2	46139	1080673619.178632	0	0	0	0	0	0
1588	Point	2	1	164	10.04	1	0	0	10	2	46139	1080673619.178635	0	0	0	0	0	0
1589	Point	2	1	158	10.06	1	0	0	10	2	46139	1080673619.178638	0	0	0	0	0	0
1590	Point	2	1	154	10.02	1	0	0	10	2	46139	1080673619.185753	0	0	0	0	0	0
1591	Point	2	1	132	10.01	1	0	0	10	2	46139	1080673619.185756	0	0	0	0	0	0

Data acquisition multiple returns

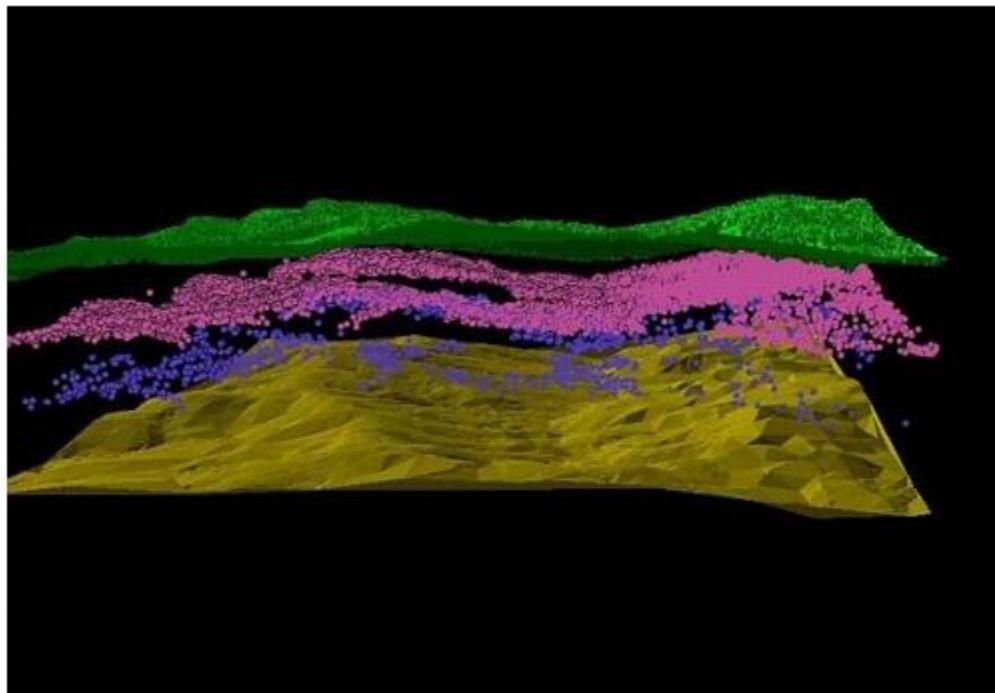
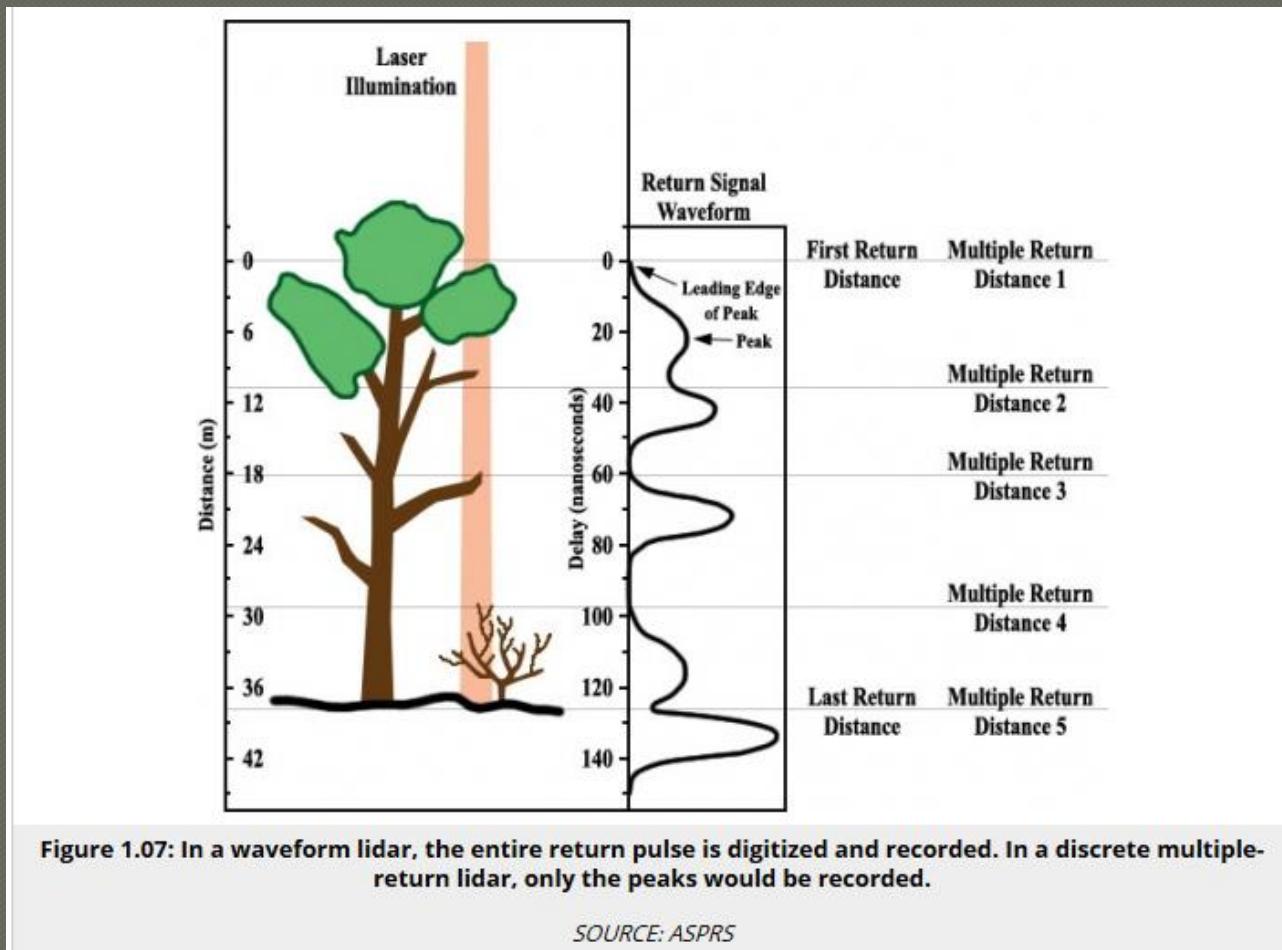


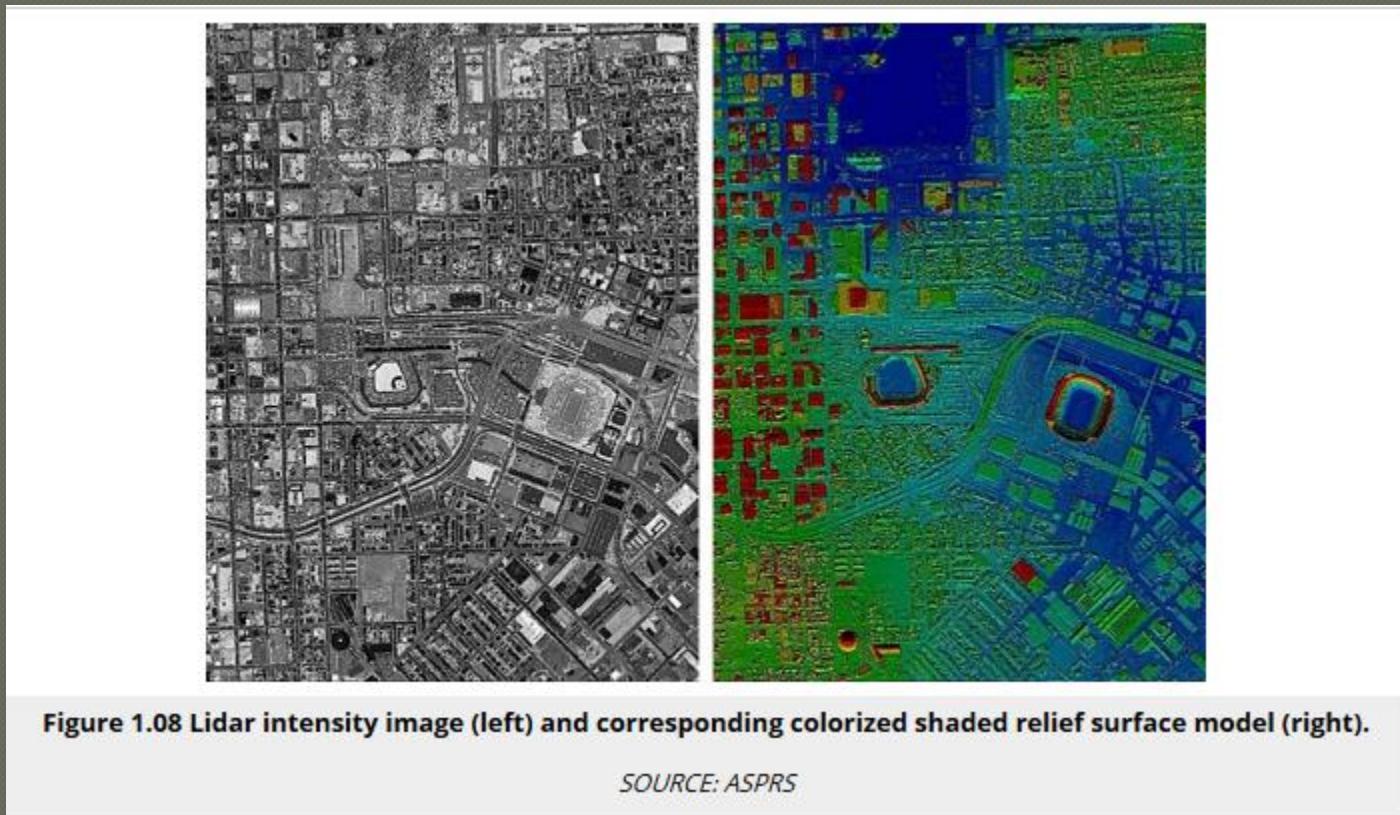
Figure 1.06: Visualization of multiple lidar returns in a forest canopy, showing first returns from the top of canopy, second returns from forest understory, and third returns near or on the ground. The bare earth surface produced from post-processing is also shown.

SOURCE: ASPRS

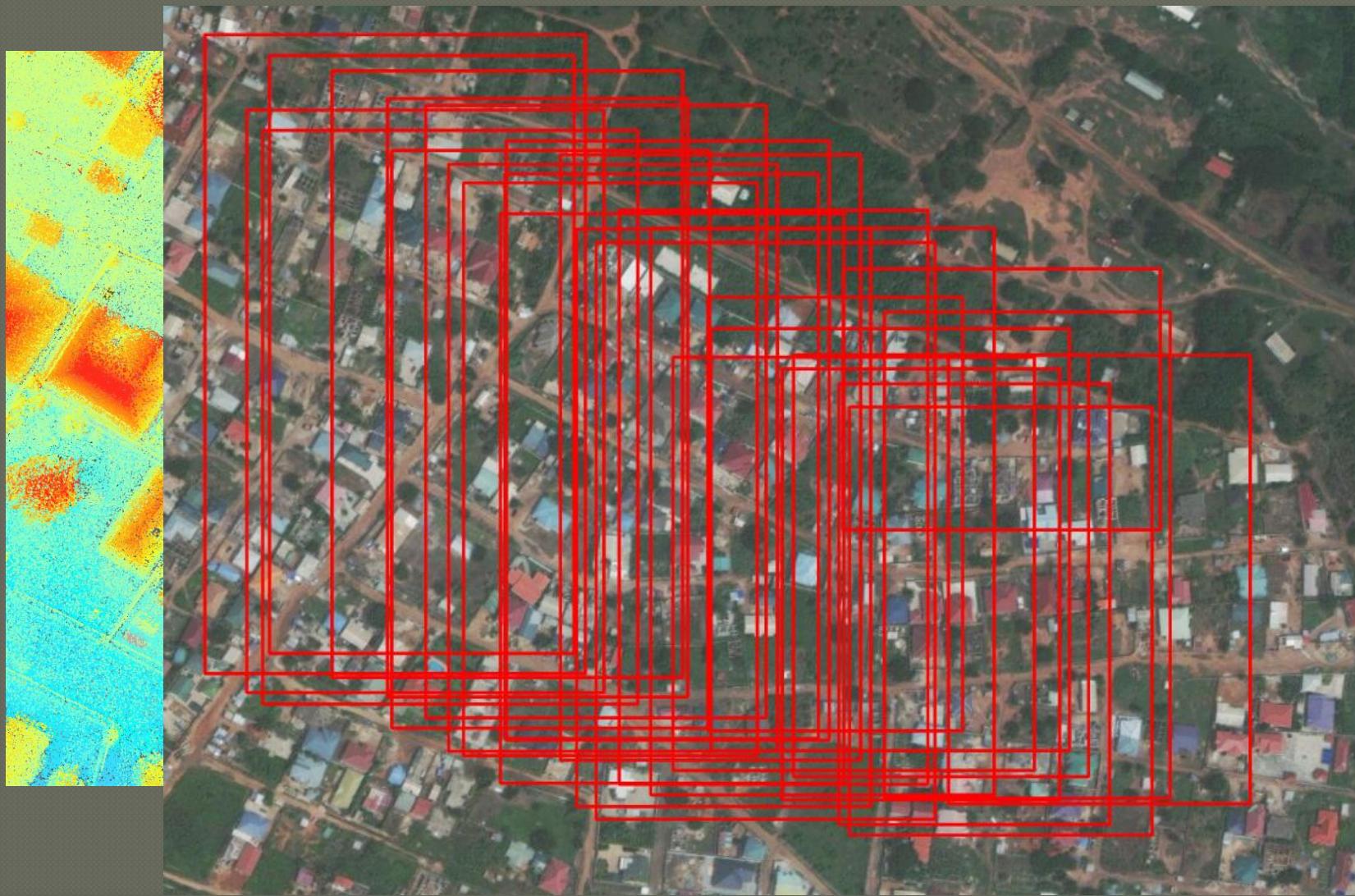
Data acquisition (Full waveform)



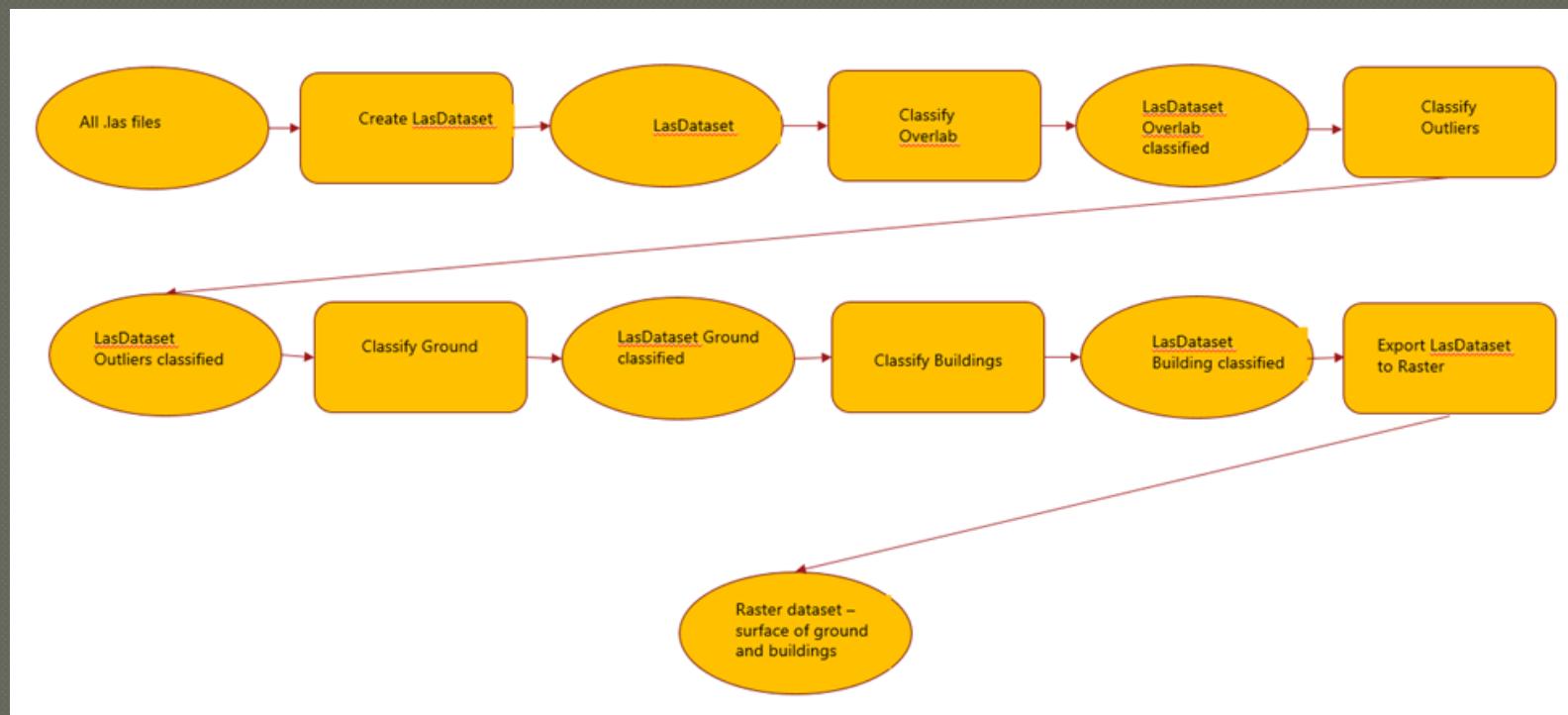
Data acquisition (Intensity)



Point cloud - .las files



Automatic filtering in ArcGIS Pro



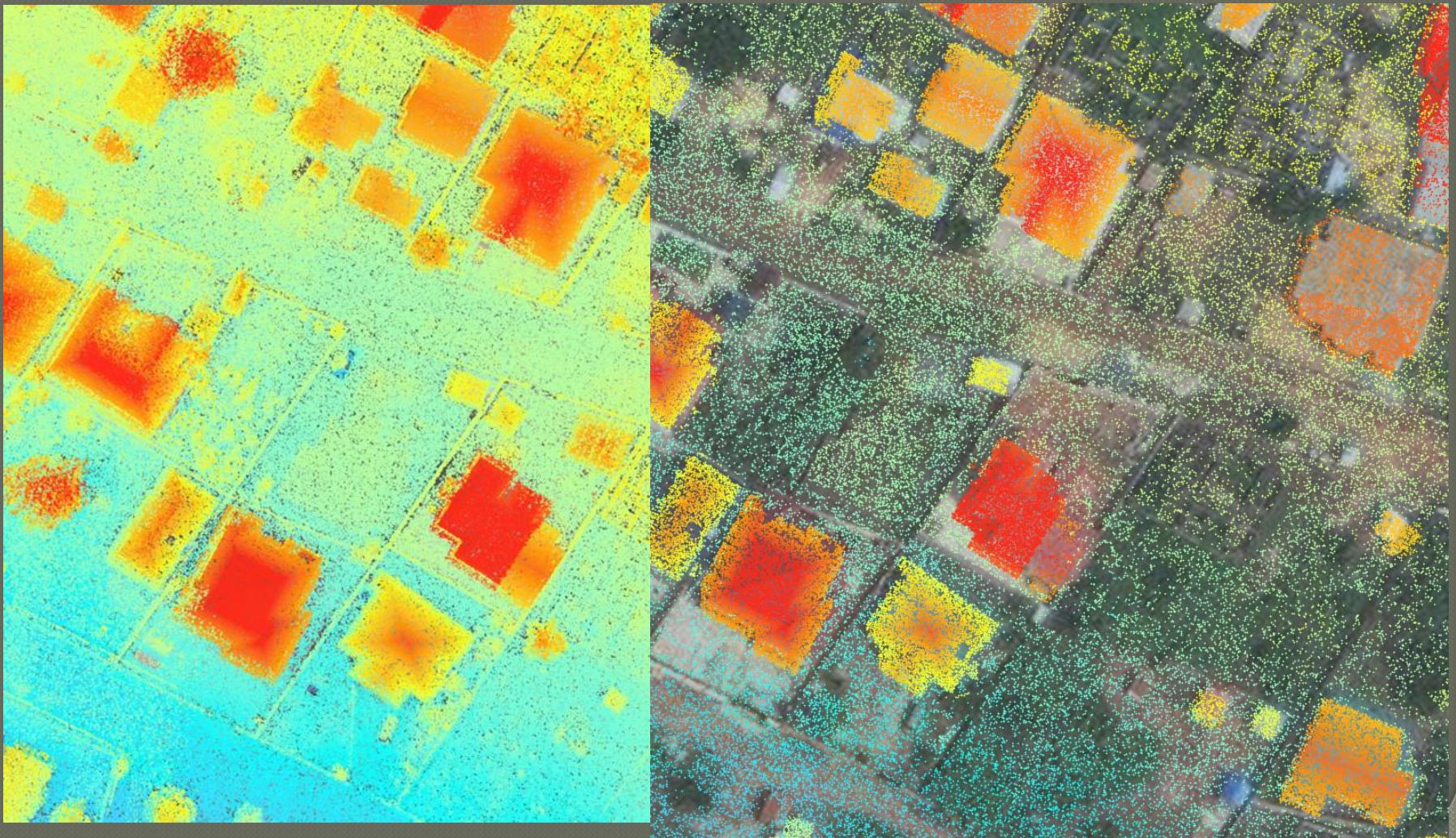
Classification

ASPRS Standard LIDAR Point Classes	
Classification Value	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

Figure 5.01: LAS Standard Classification Scheme.

Source: ASPRS

Result of classification



DSM – ground and buildings



Manual edits

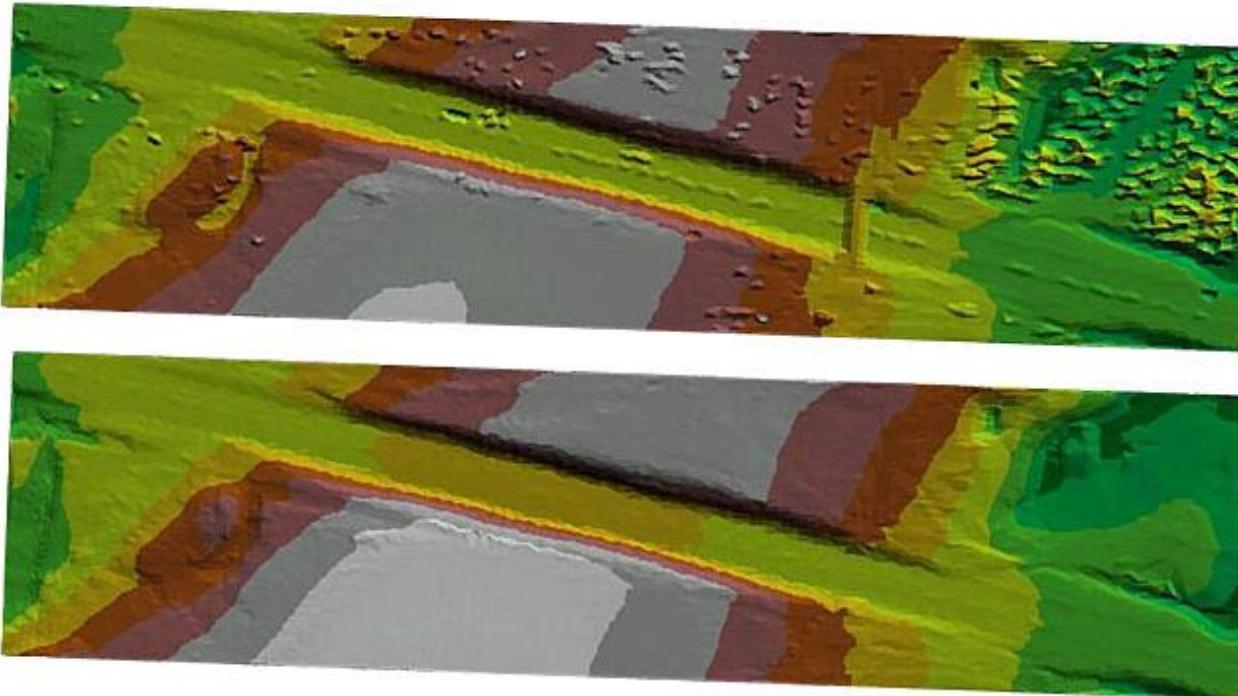
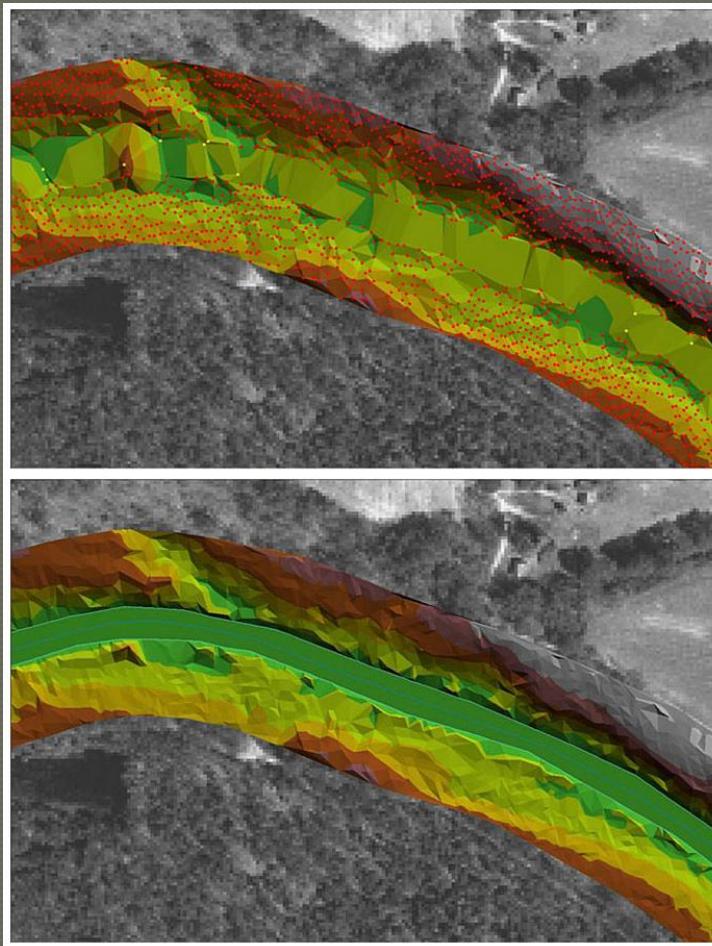


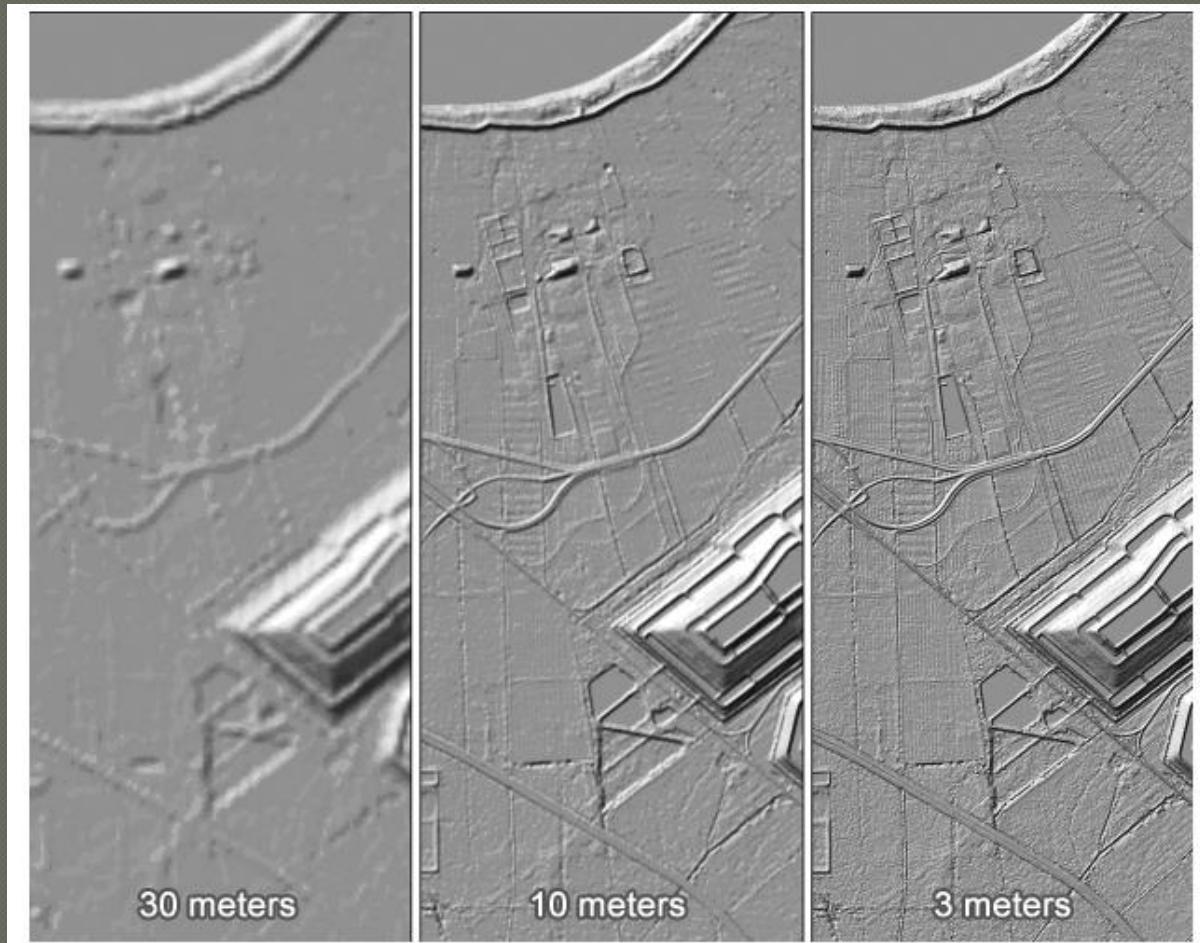
Figure 5.05: Automated filtering along this road feature (top) removes most, but not all of the vegetation. In addition, the bridge overpass is put into the ground class, which is contrary to standard practice for topographic mapping. A human editor correctly removes the bridge deck, residual vegetation, and bits of cars traveling along the roadway from the ground class (bottom).

Source: Fugro EarthData

Hydrological enforcement

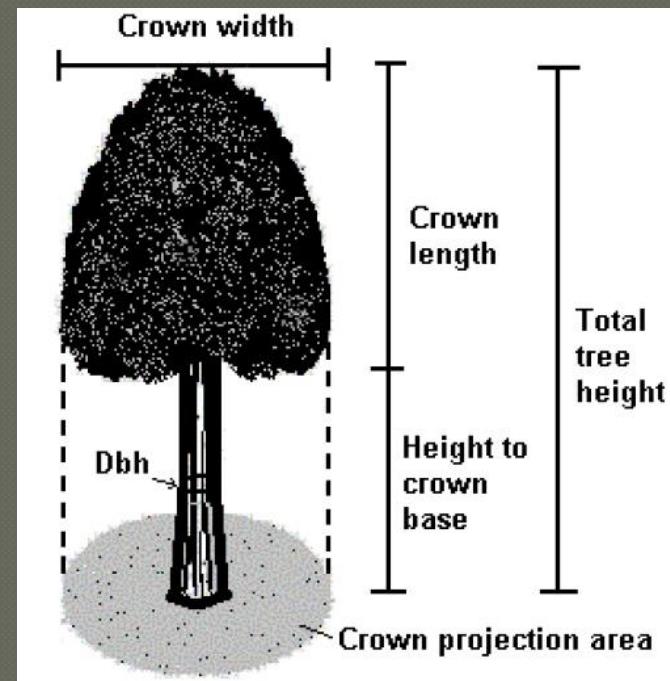


DEM (terrain)



Applications

- DTM
- Floodings
- Climate adaptation
- DSM
- Forest monitoring
- 3D city models



Denmarks DEM 2024

- 4 points/m² (0.45)
 - Horizontal accuracy 0.15 m (0.7)
 - Vertical accuracy 5 cm (7)
 - RGB colour orthophoto
 - Full waveform
 - Partial update every year
-
- <https://dataforsyningen.dk>

Data formats

◎ Point cloud

- .las
 - The LAS file format is a public file format for the interchange of 3-dimensional point cloud data between data users.
- .laz
 - The LAZ file is a compression of a number of LAS files

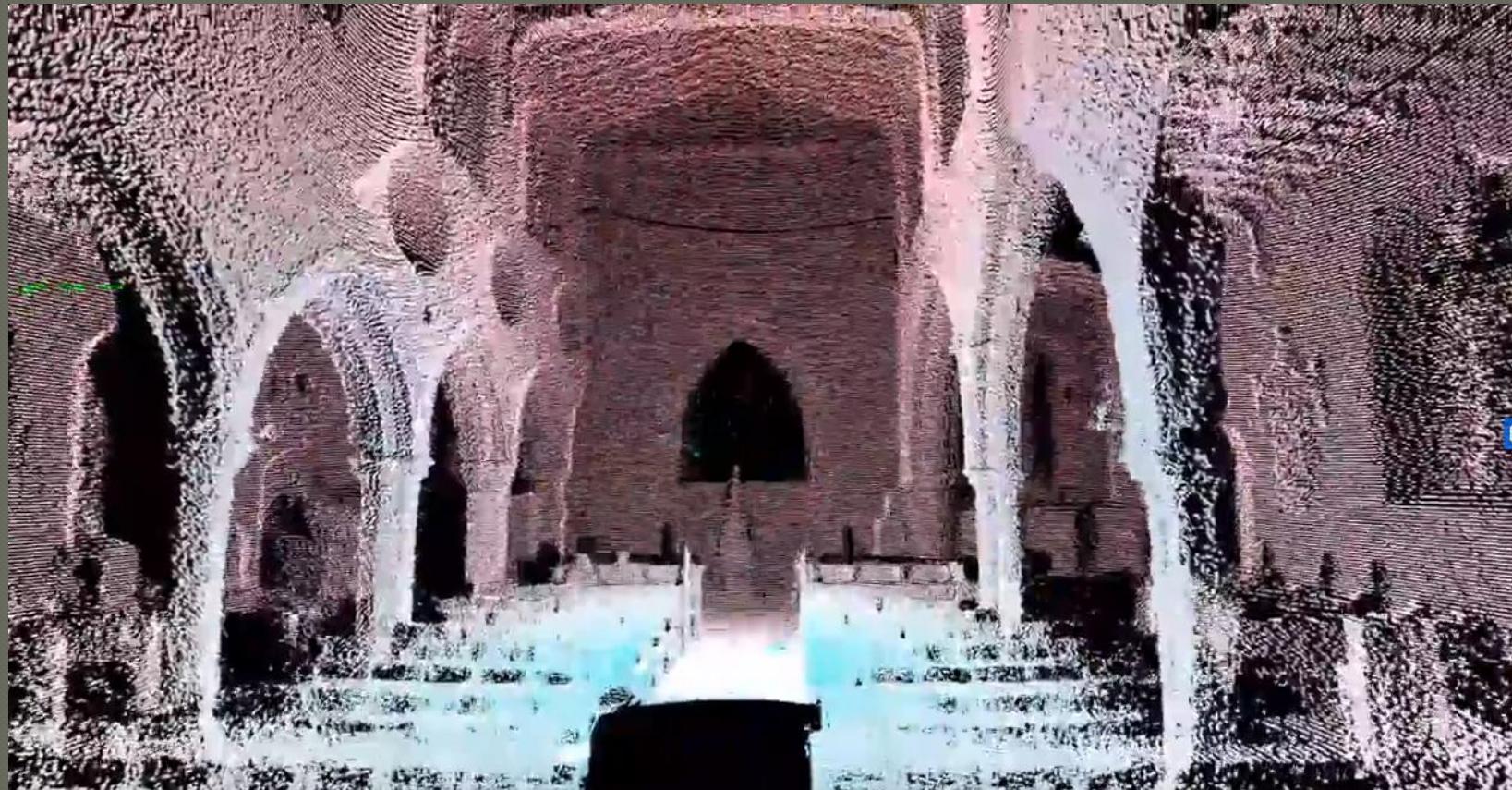
◎ DEM and DSM

- Raster
 - ESRI grid file, tiff, jpeg

Indoor LiDAR scanning

Scanning the interior of a church

<https://www.youtube.com/watch?v=qUbFzMzKFPU>



Other platforms

iPhone 12

- Range up 5 m
- Internal processesing

IceSat-2 (Ice, cloud and ele

- 6 transects
- 10.000 pulses per second
- Measurements every 0.75 meter along the satellite's

