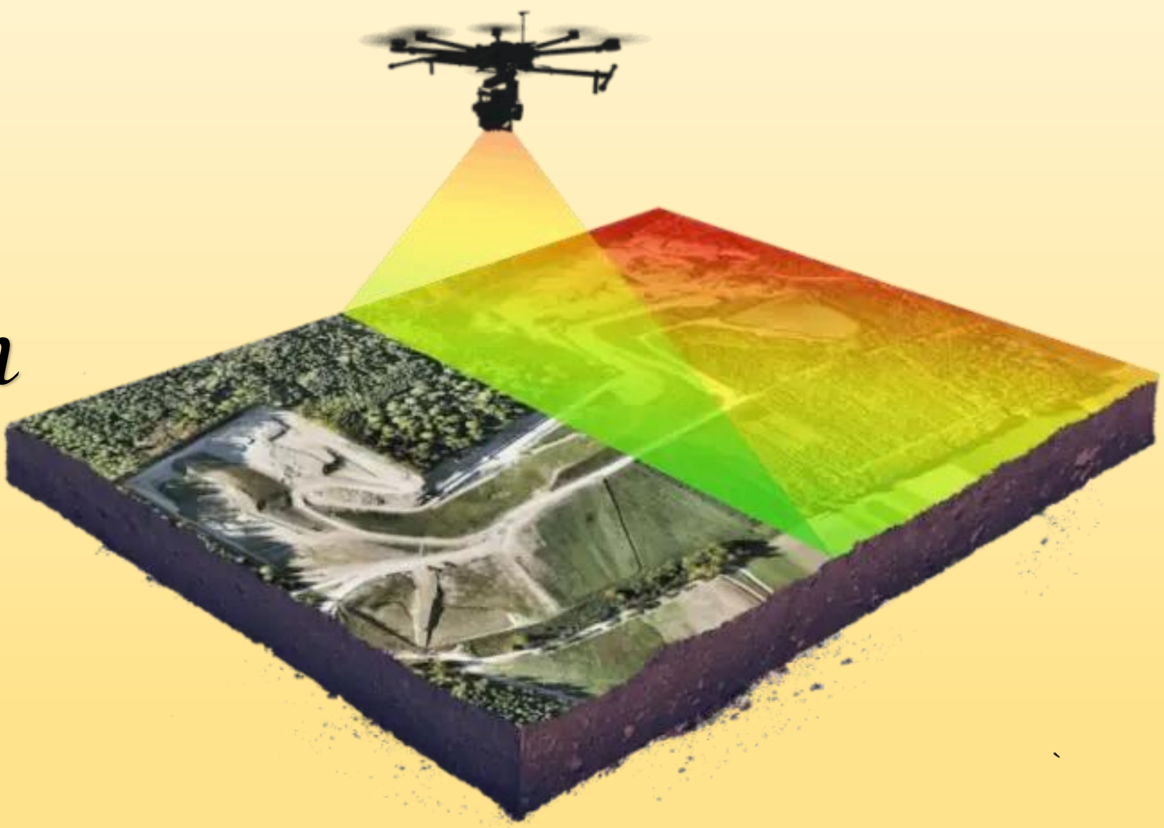
L *Light*

I

D *Detection*

A *And*

R *Ranging*



LASERS

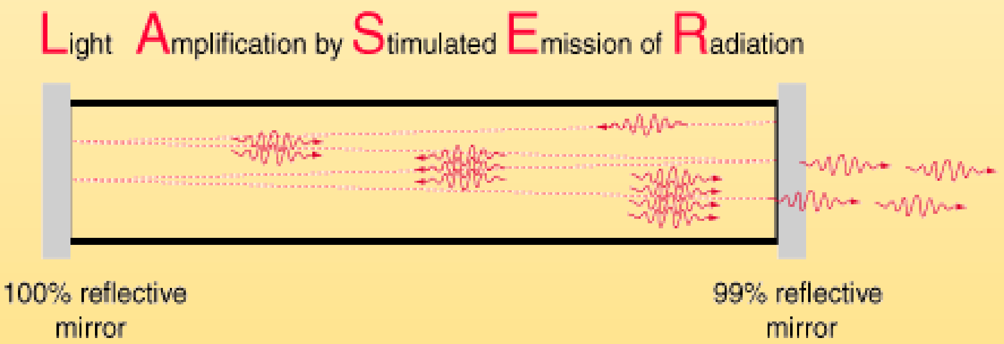
L Light

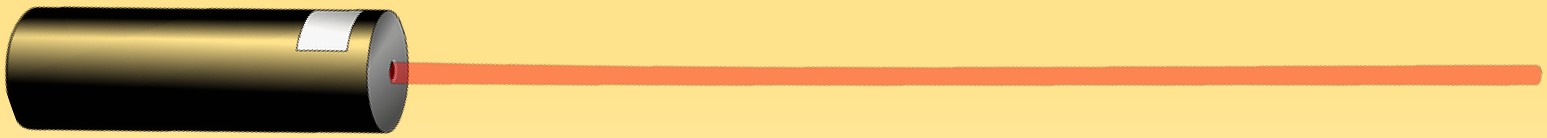
A Amplification By

S Stimulated

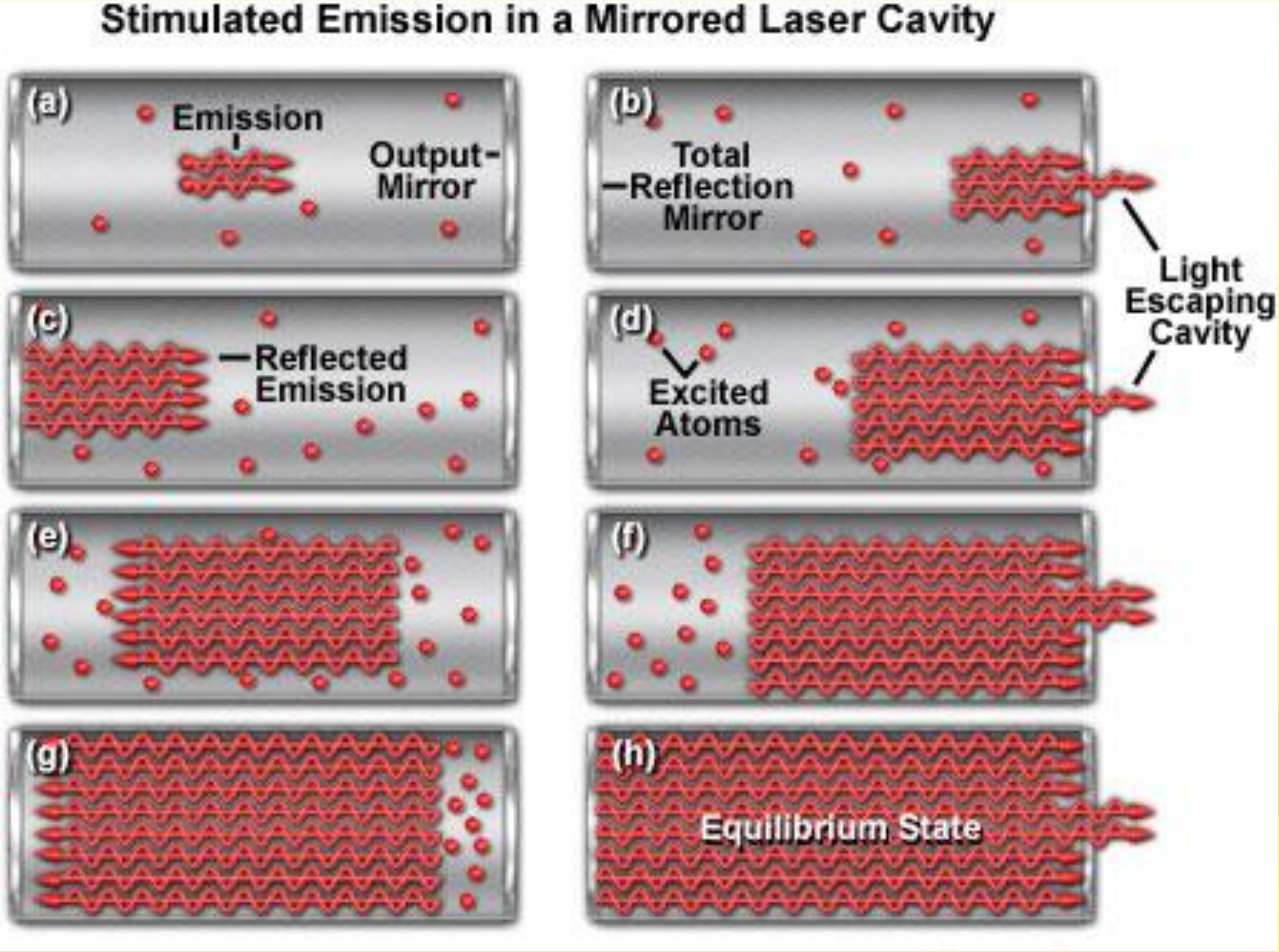
E Emission Of

R Radiation



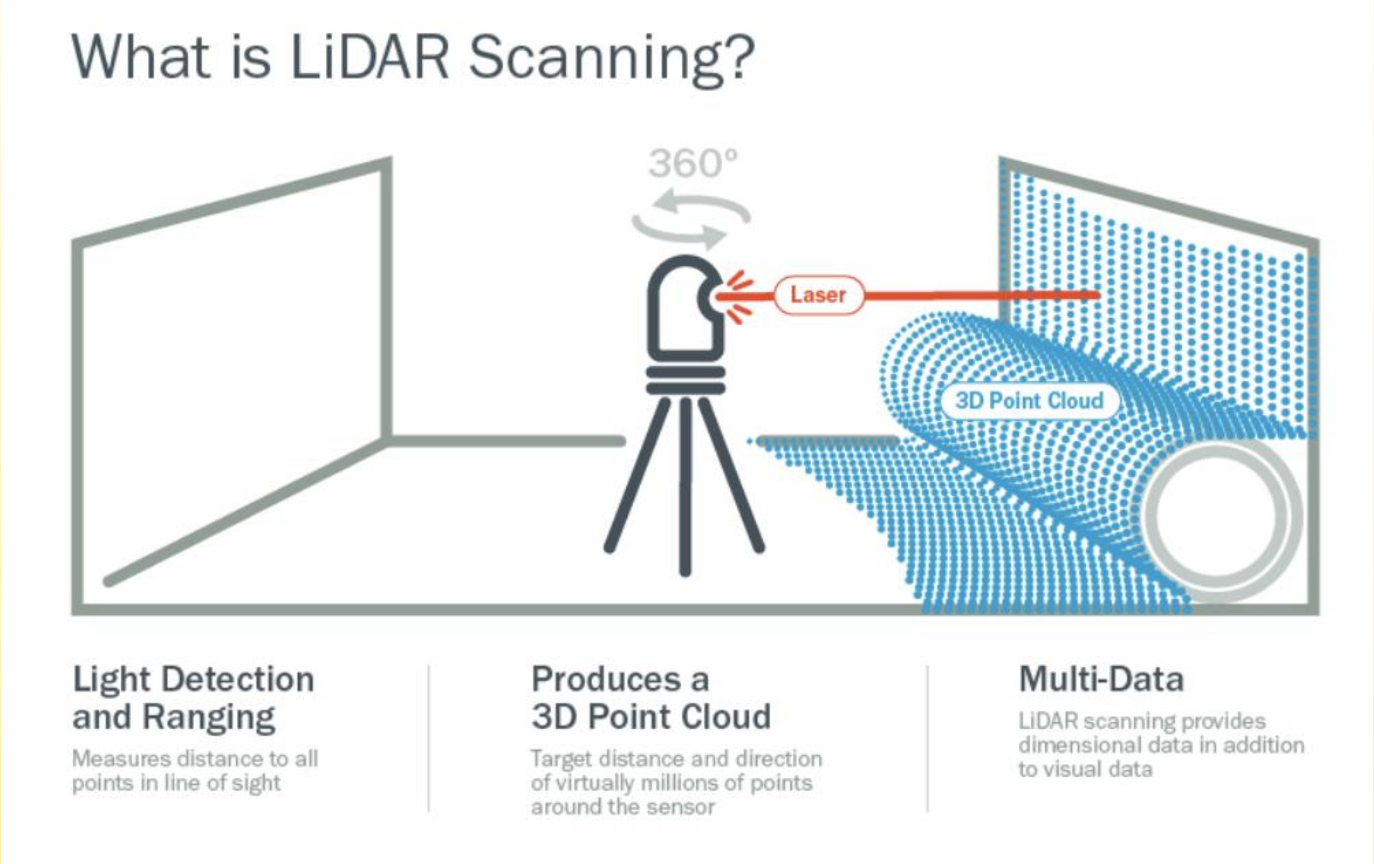


LASER



Stimulated Emission in a Mirrored Laser Cavity
(a)
Emission
Output Mirror
(b)
Total Reflection Mirror
Light Escaping Cavity
(c)
Reflected Emission
(d)
Excited Atoms
(e)
(f)
(g)
(h)
Equilibrium State

LIGHT DETECTION AND RANGING (LIDAR)



LIDAR (Light Detection and Ranging) is a remote sensing technology that uses laser pulses to measure distances and create precise, high-resolution 3D maps of objects and environments. It works similarly to radar but uses light waves (lasers) instead of radio waves.

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)

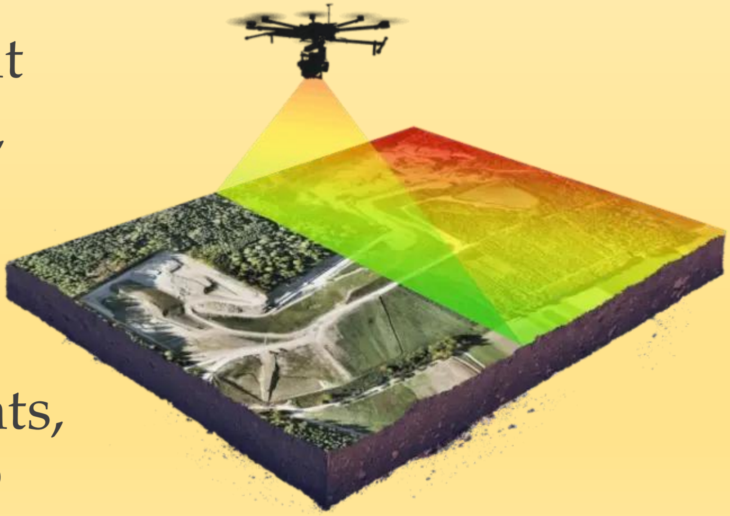
LIGHT DETECTION AND RANGING (LIDAR)

How LIDAR Works:

1.**Laser Emission**: A LIDAR system emits rapid laser pulses toward a target.

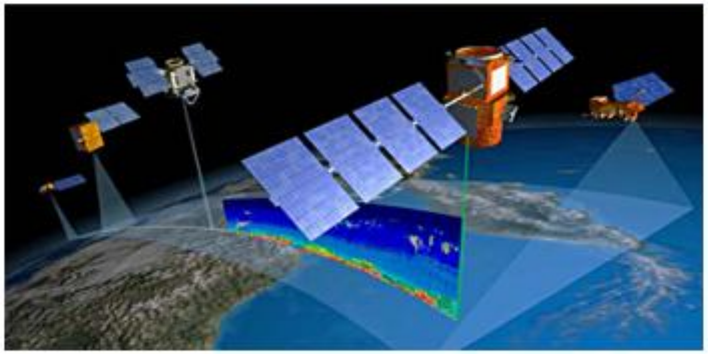
2.**Reflection Detection**: The light reflects off objects and returns to the sensor.

3. **Time-of-Flight Calculation**: The system calculates distance by measuring the time it takes for the light to return (Time of Flight, ToF).



4. **3D Mapping**: By scanning multiple points, LIDAR builds a detailed **point cloud** (a 3D representation of the environment).

LIDAR PLATFORMS



LIDAR PLATFORMS

Similar technology, different platforms:

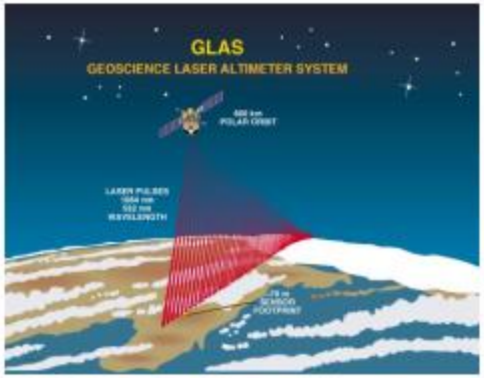
Terrestrial Laser Scanning (TLS)

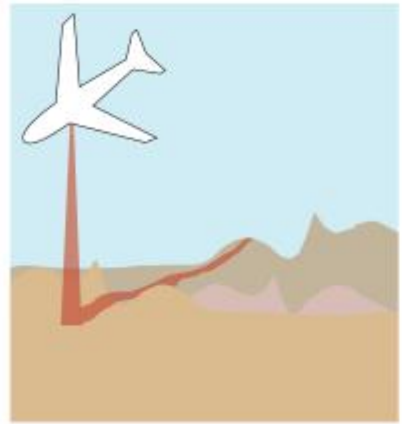
- Also called ground based lidar or T-lidar.

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

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

LIDAR PLATFORMS





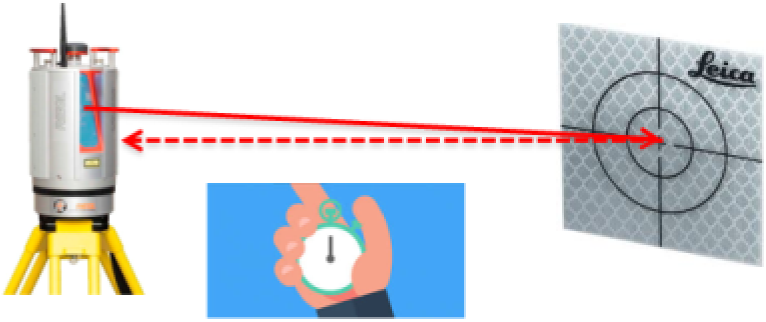
System:	Spaceborne (e.g. GLAS)	High Altitude (e.g. LVIS)	Airborne (ALS)	Terrestrial (TLS)
Altitude:	600 km	10 km	1 km	1 m
Footprint:	60 m	15 m	25 cm	1–10 cm
Vertical Accuracy	15cm to 10m depends on slope	50/100 cm bare ground/ vegetation	20 cm	1–10 cm Depends on range, which is few meters to 2 km or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

HOW IS RANGE MEASURED?

Time of flight

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

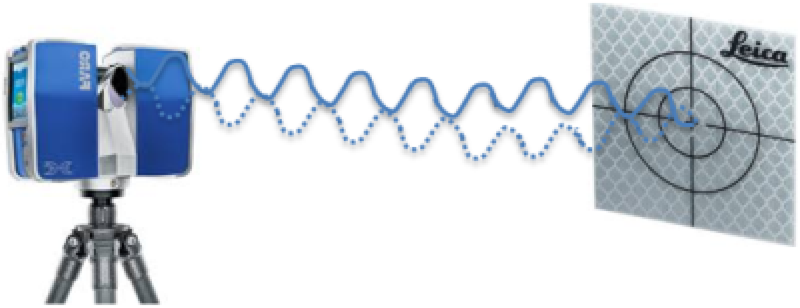
$$Distance = \frac{Speed\ of\ Light\ x\ Time\ of\ Flight}{2}$$

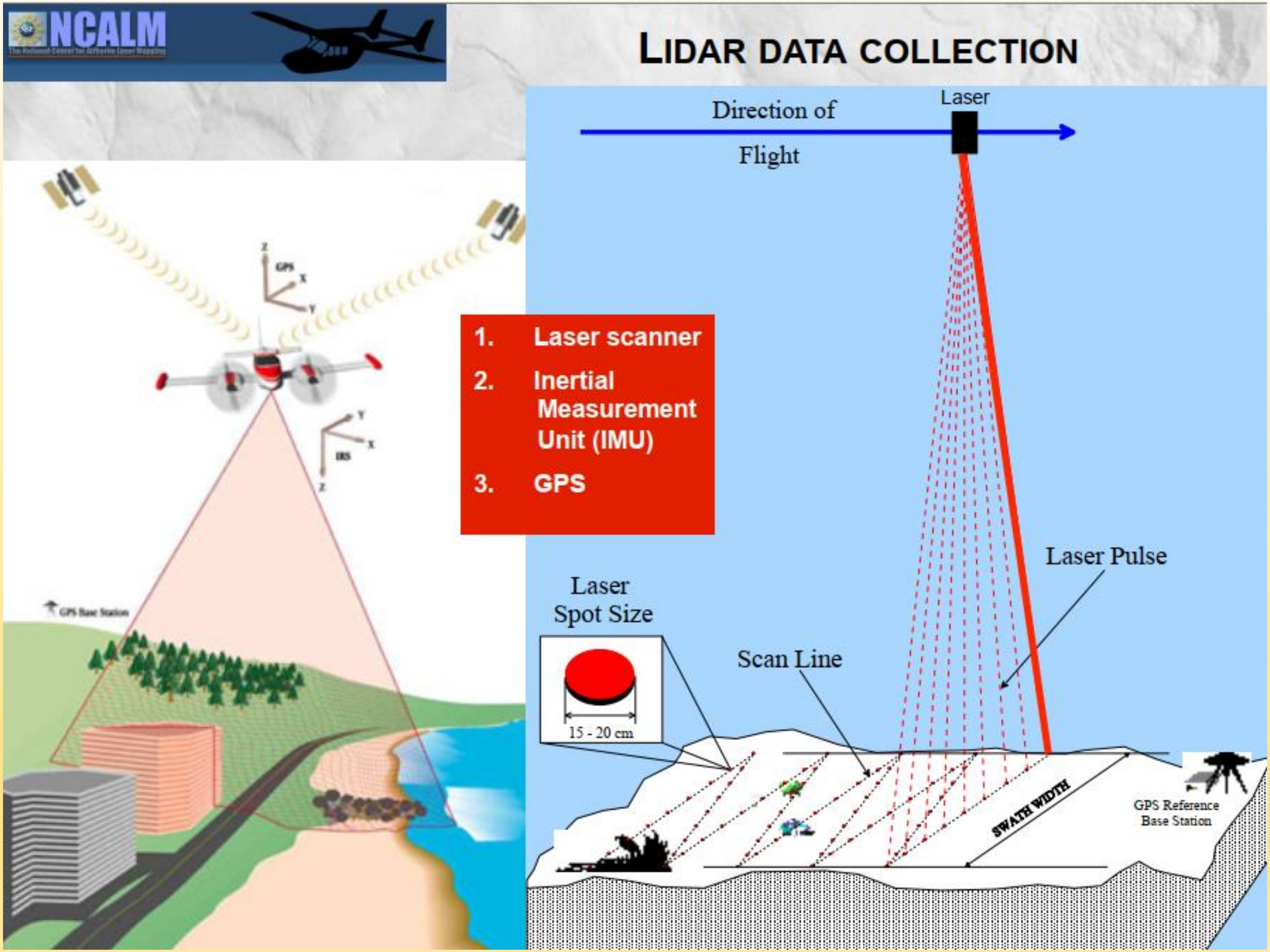


Phase Shift

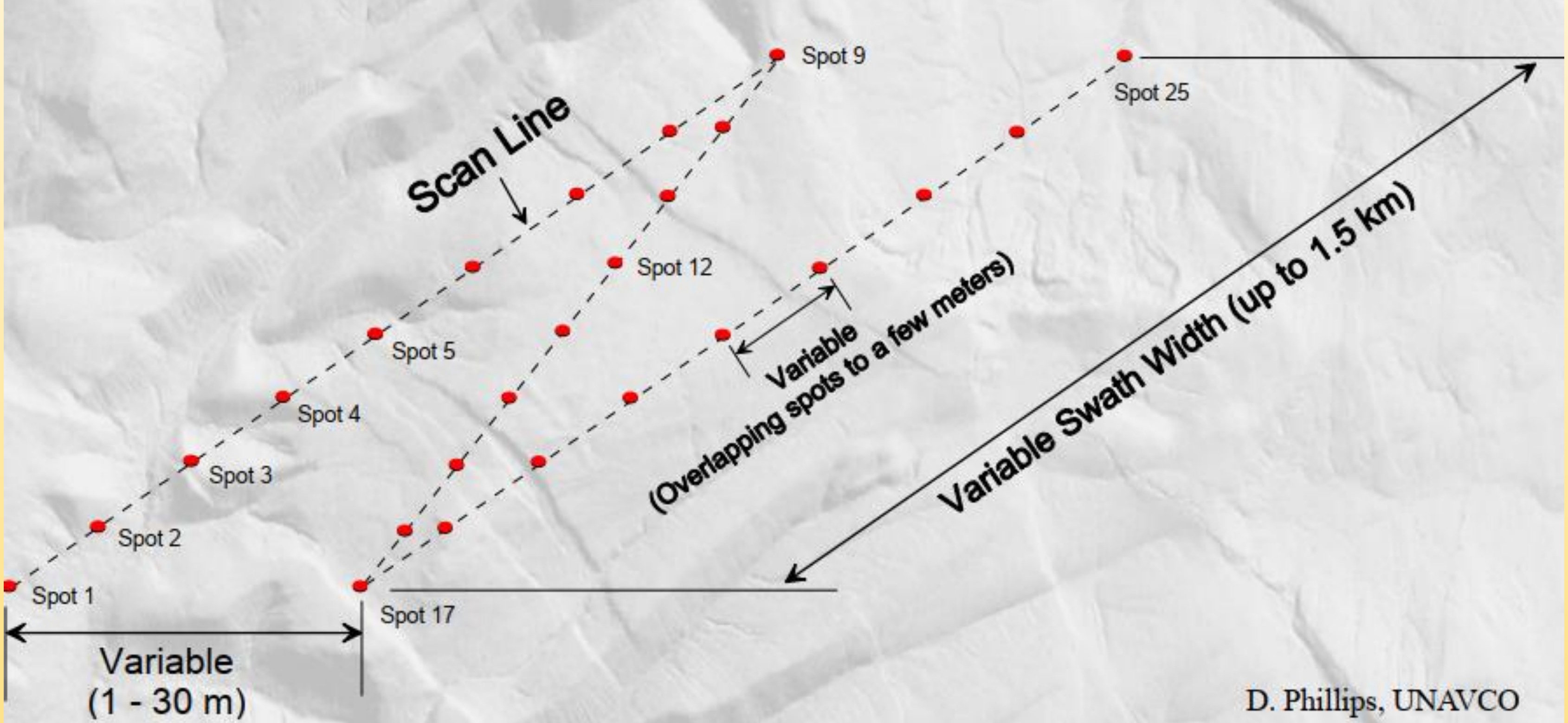
Distance is calculated along a sinusoidally modulated laser pulse.

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



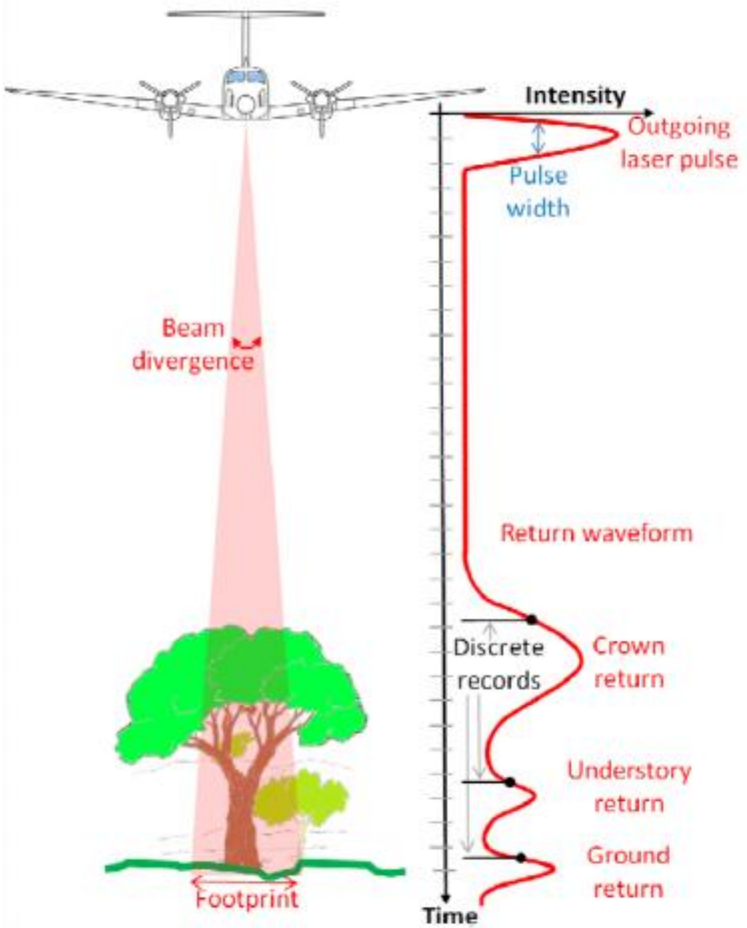

NCALM
LIDAR DATA COLLECTION
Direction of
Flight
Laser
1. Laser scanner
2. Inertial Measurement Unit (IMU)
3. GPS
Laser Pulse
Laser
Spot Size
15 - 20 cm
Scan Line
SWATH WIDTH
GPS Reference
Base Station

Surface Point Spacing



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

DISCRETE PULSE AND FULL WAVEFORM LIDAR

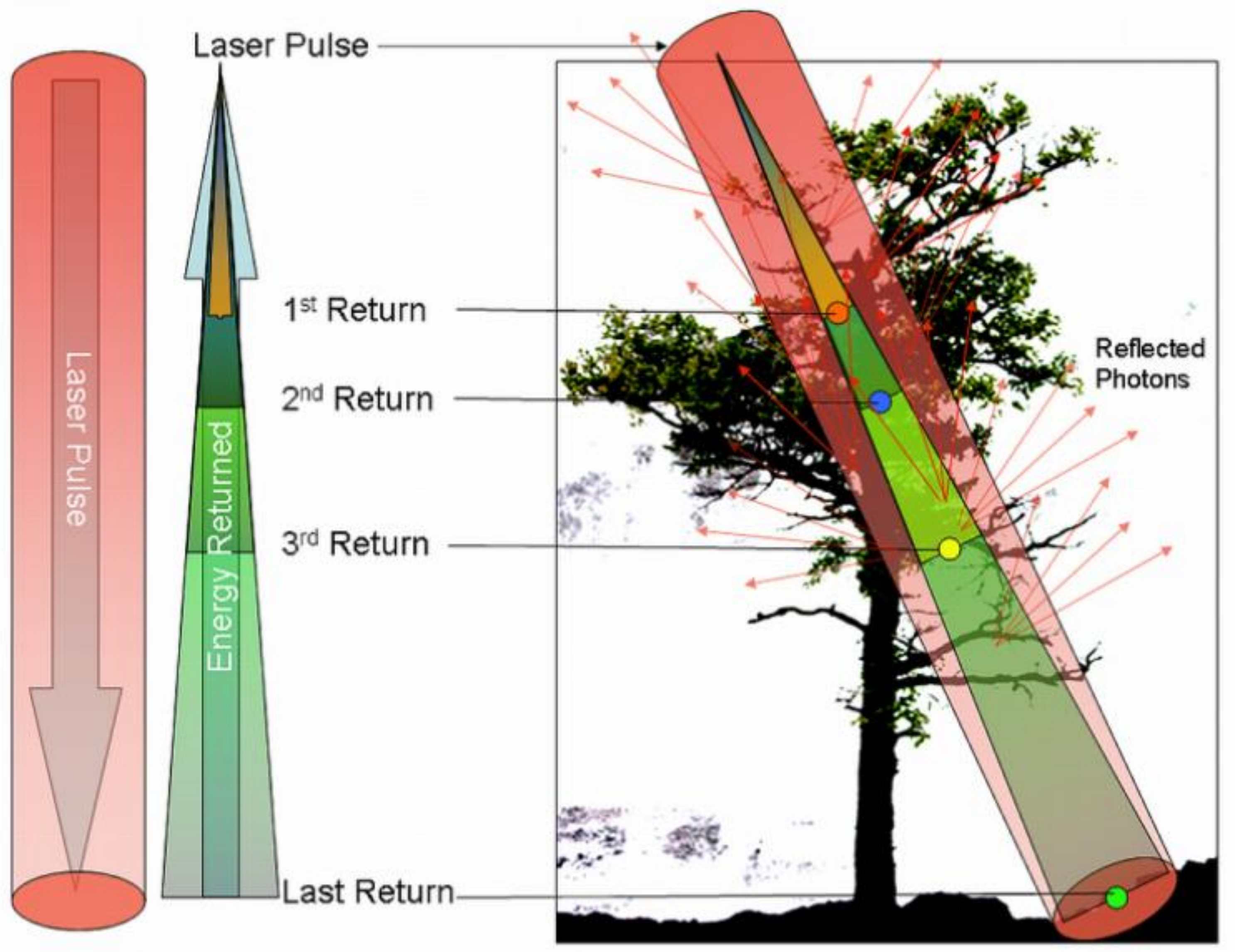


Discrete pulse = binary yes or no return. Only location of return is saved.

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

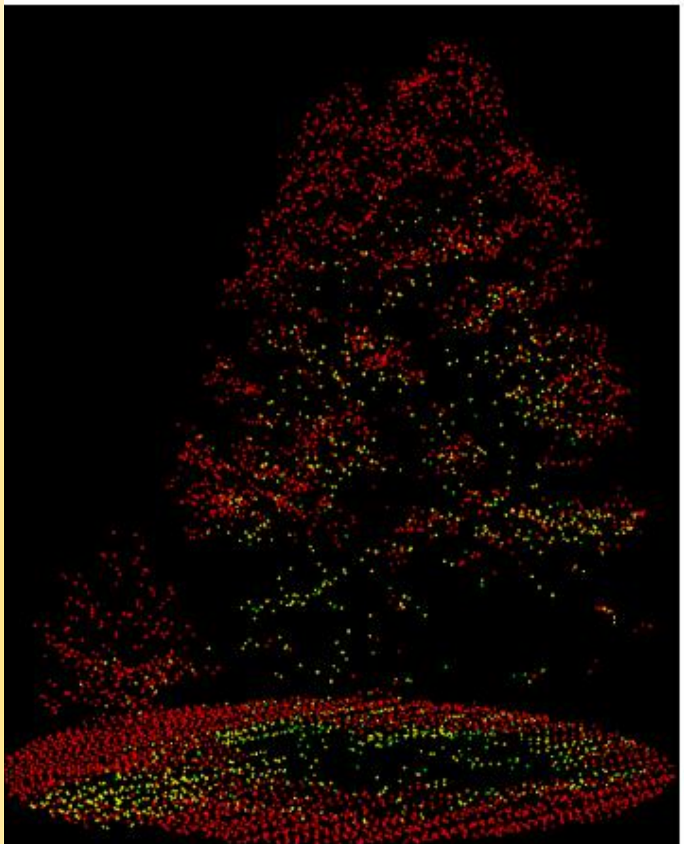
Data size / processing time vs. enhanced information

DISCRETE PULSE AND FULL WAVEFORM LIDAR



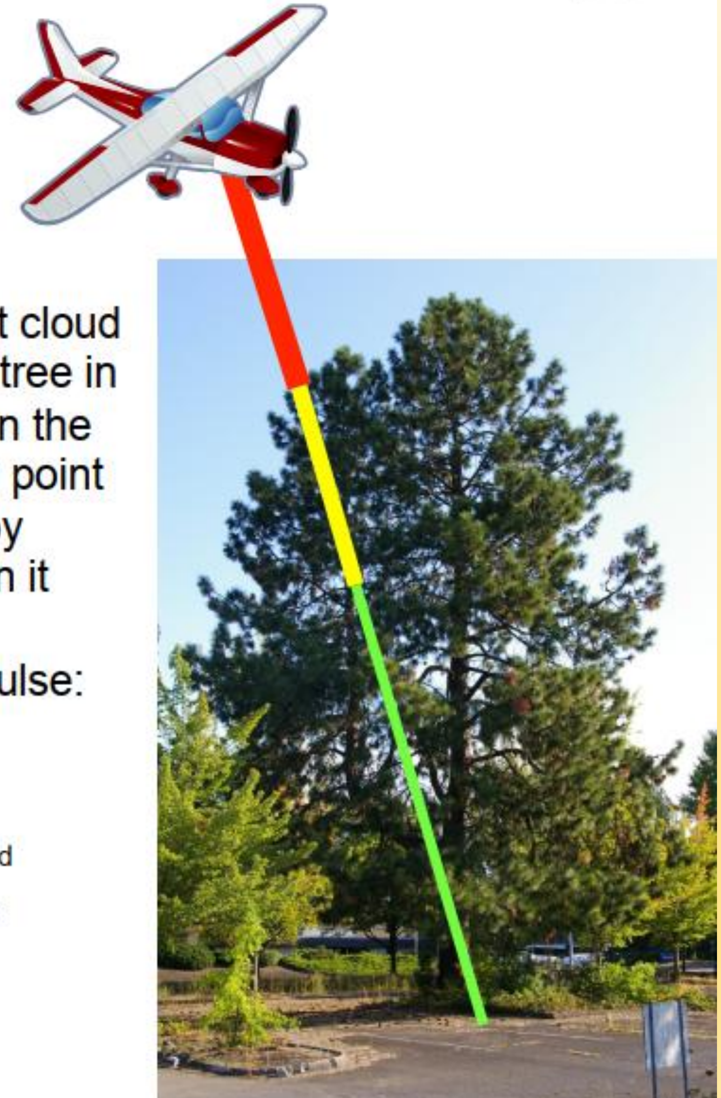
LIDAR RETURN STRUCTURE

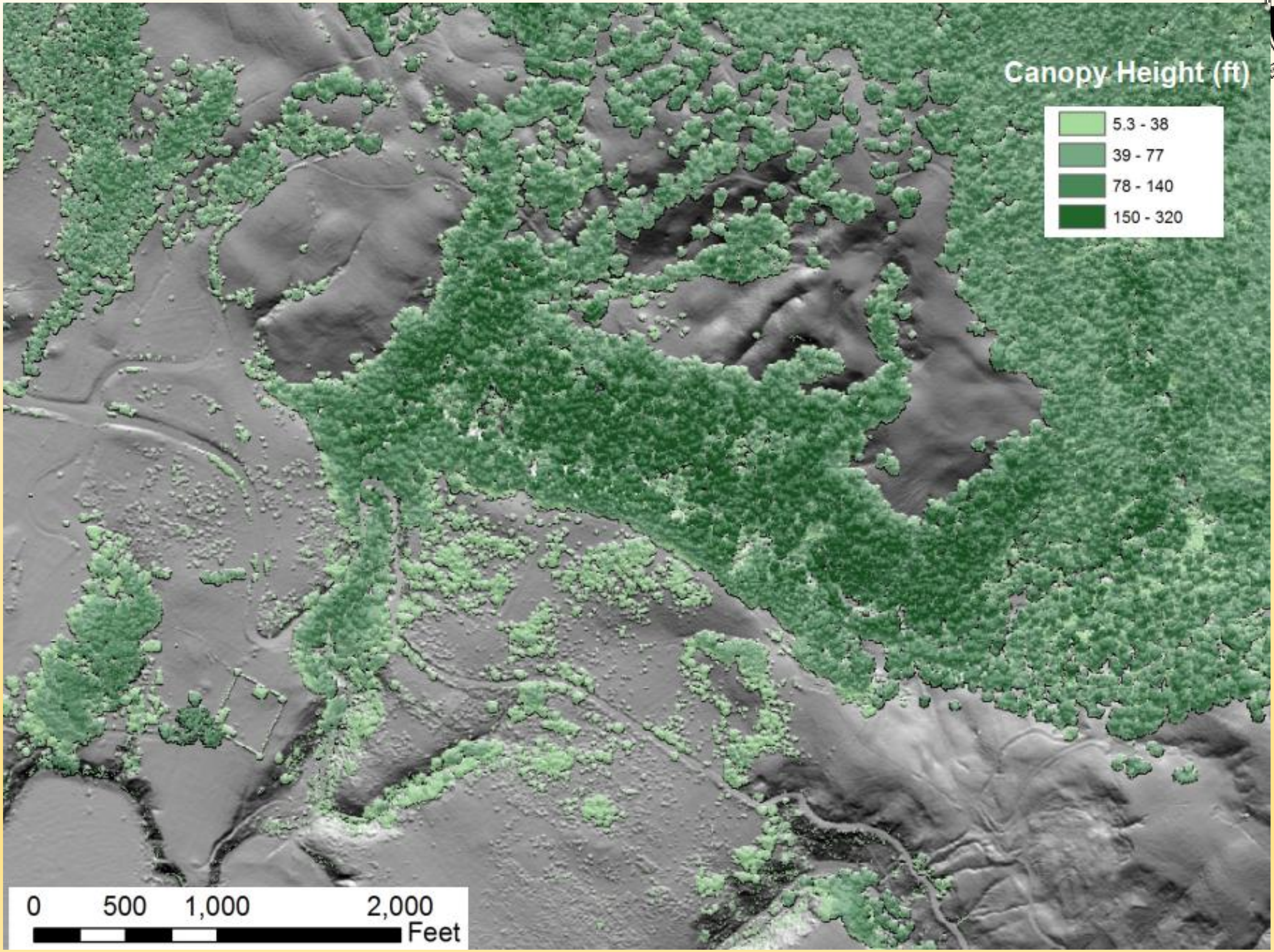
Ian Madin, DOGAMI



- 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

Feature	LIDAR	RADAR	Camera
Medium	Light	Radio Waves	Visible Light
Resolution	Very High	Moderate	High (but depends on lighting)
Weather Resistance	Poor (affected by fog/rain)	Good (works in most conditions)	Poor (low light, glare issues)
Cost	High	Moderate	Low

Advantages of LIDAR:

✓ High accuracy (centimeter-level precision).
✓ Works day and night (unlike cameras).
✓ Can penetrate vegetation (useful for forest mapping).

Disadvantages of LIDAR:

✕ Expensive compared to other sensors (like cameras or radar).
✕ Affected by weather conditions (fog, rain can scatter laser beams).
✕ Large datasets require significant processing power.

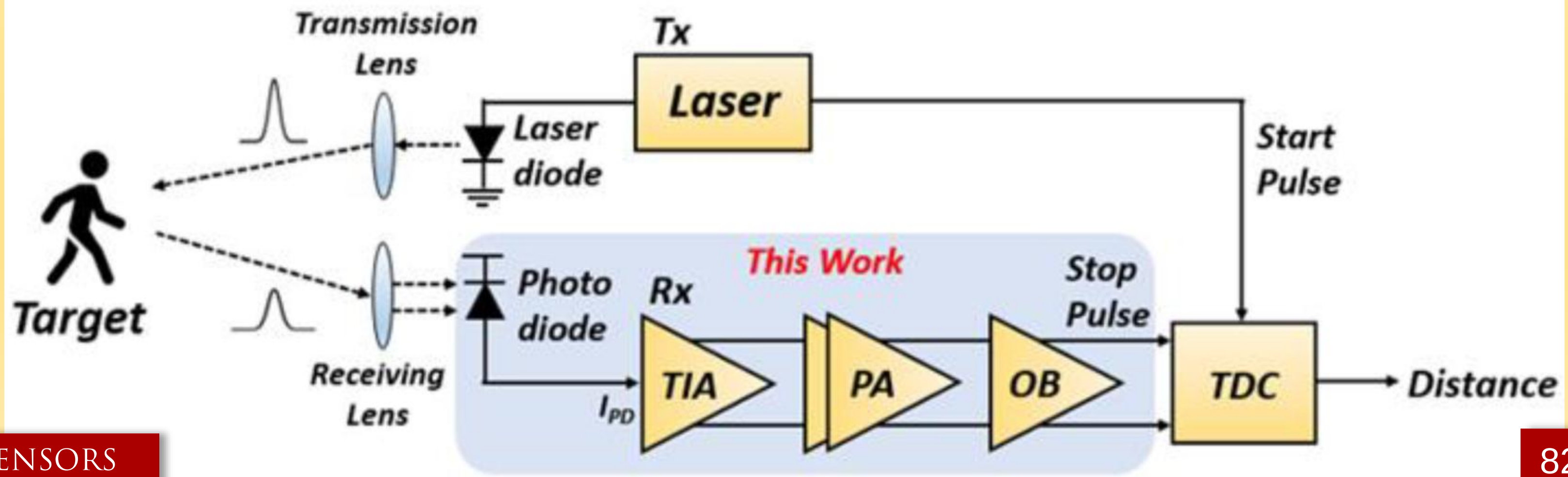
Role of Photo Sensors in LIDAR

LIDAR works by emitting laser pulses and measuring their return time (Time-of-Flight, ToF).

The **photo sensor's work** is to:

- **Detect reflected laser light** (often weak due to scattering and distance).
- **Convert light into an electrical signal** for processing.
- **Filter out noise** (ambient light, other light sources).

Without high-quality photo sensors, LIDAR would struggle to accurately measure distances or create detailed 3D maps.



Types of Photo Sensors Used in LIDAR

Different LIDAR systems use various photo sensors based on sensitivity, speed, and application:

A. Avalanche Photodiodes (APDs)

•**Most common in LIDAR** (especially automotive and long-range systems).

•**Highly sensitive** (amplifies weak signals via avalanche effect).

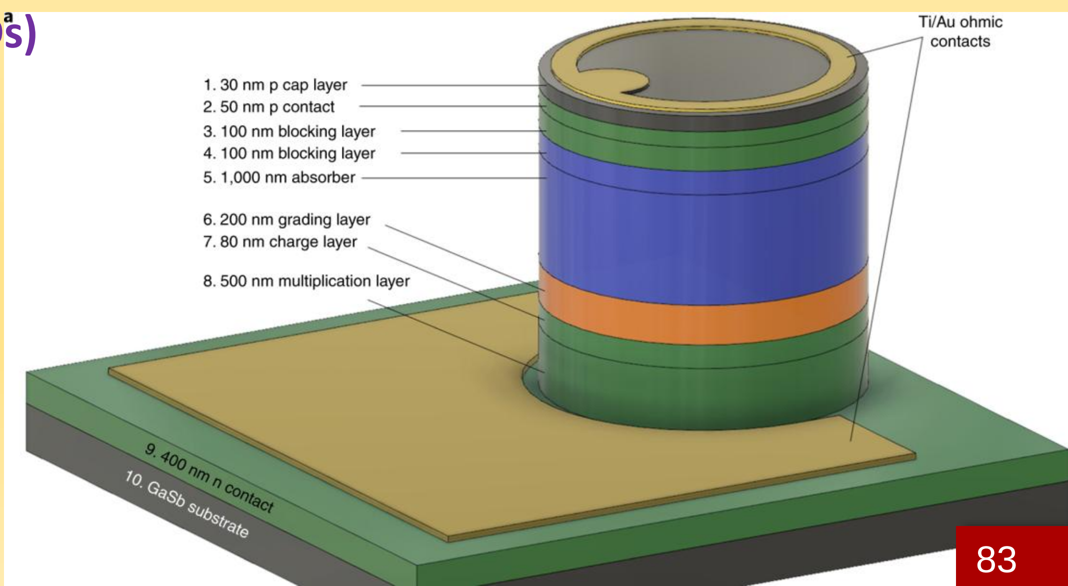
•**Fast response time** (nanosecond-level detection).

•**Works best with near-infrared (NIR) lasers** (905nm, 1550nm).

B. Single-Photon Avalanche Diodes (SPADs)

C. Silicon Photomultipliers (SiPMs)

D. PIN Photodiodes



Future of LIDAR:

- **Solid-State LIDAR**: Cheaper, more compact sensors for mass adoption.
- **Quantum LIDAR**: Emerging tech for even higher precision.
- **AI Integration**: Better real-time processing for autonomous systems.