Airborne Lidar

How Does it Work ?

An overview of the technology behind the data

Underlying physics:

- the speed of light is very high but finite
- light moves in a straight line

Measurement principle (basic):

- a laser is used to send out a very short pulse of light
- a telescope is used to observe the reflection of the pulse by distant objects
- a very accurate stopwatch is used to measure the time between those two events
- the measured time is directly proportional to the distance

Measurement principle (advanced):

- very accurately measure location and orientation of laser source

- vary direction of outgoing laser pulse between shots

- record all measurements

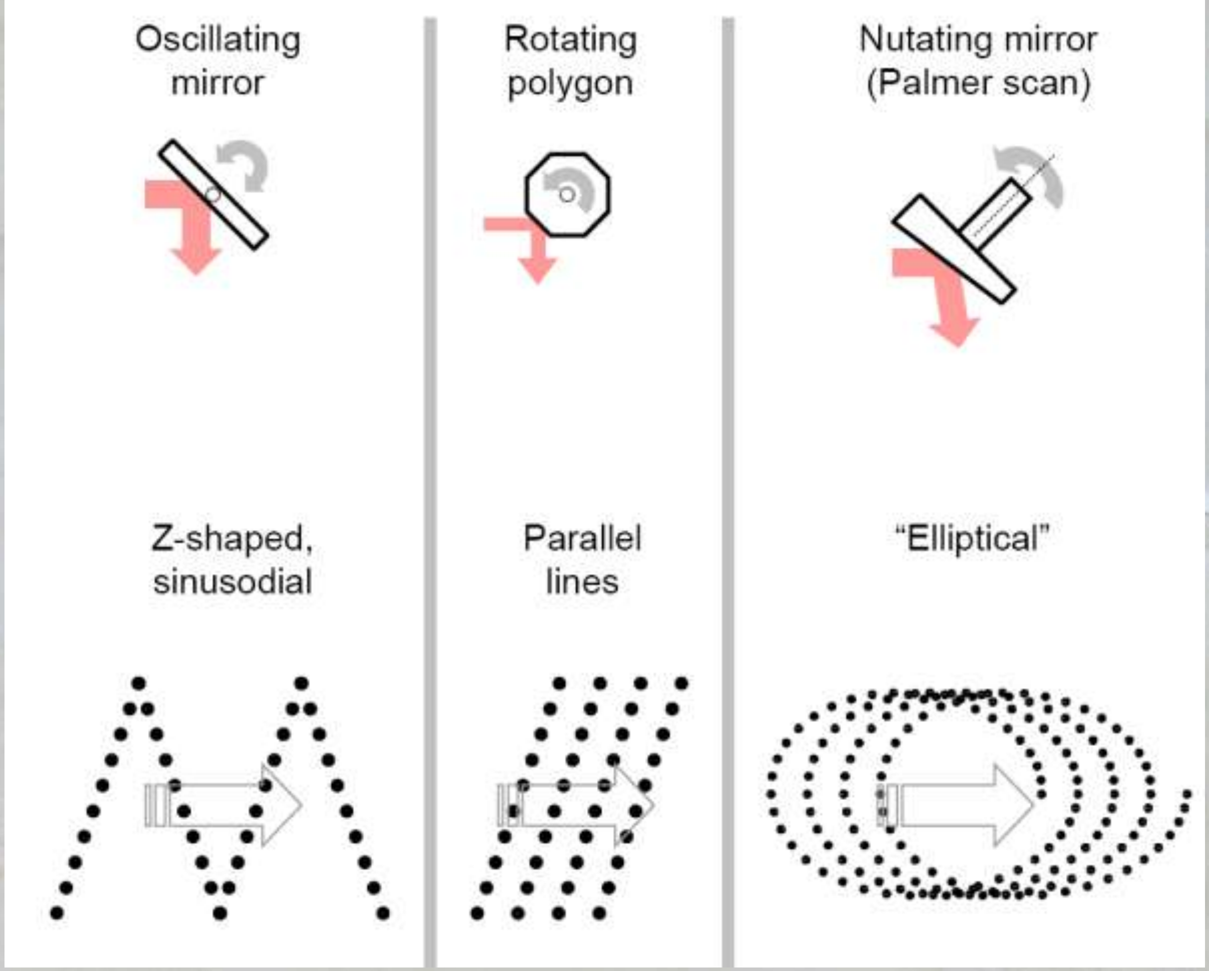
- repeat the above as fast as you can ...

Voilà, you’ve got a laser scanner ...

Scanning Mechanisms

Mechanism

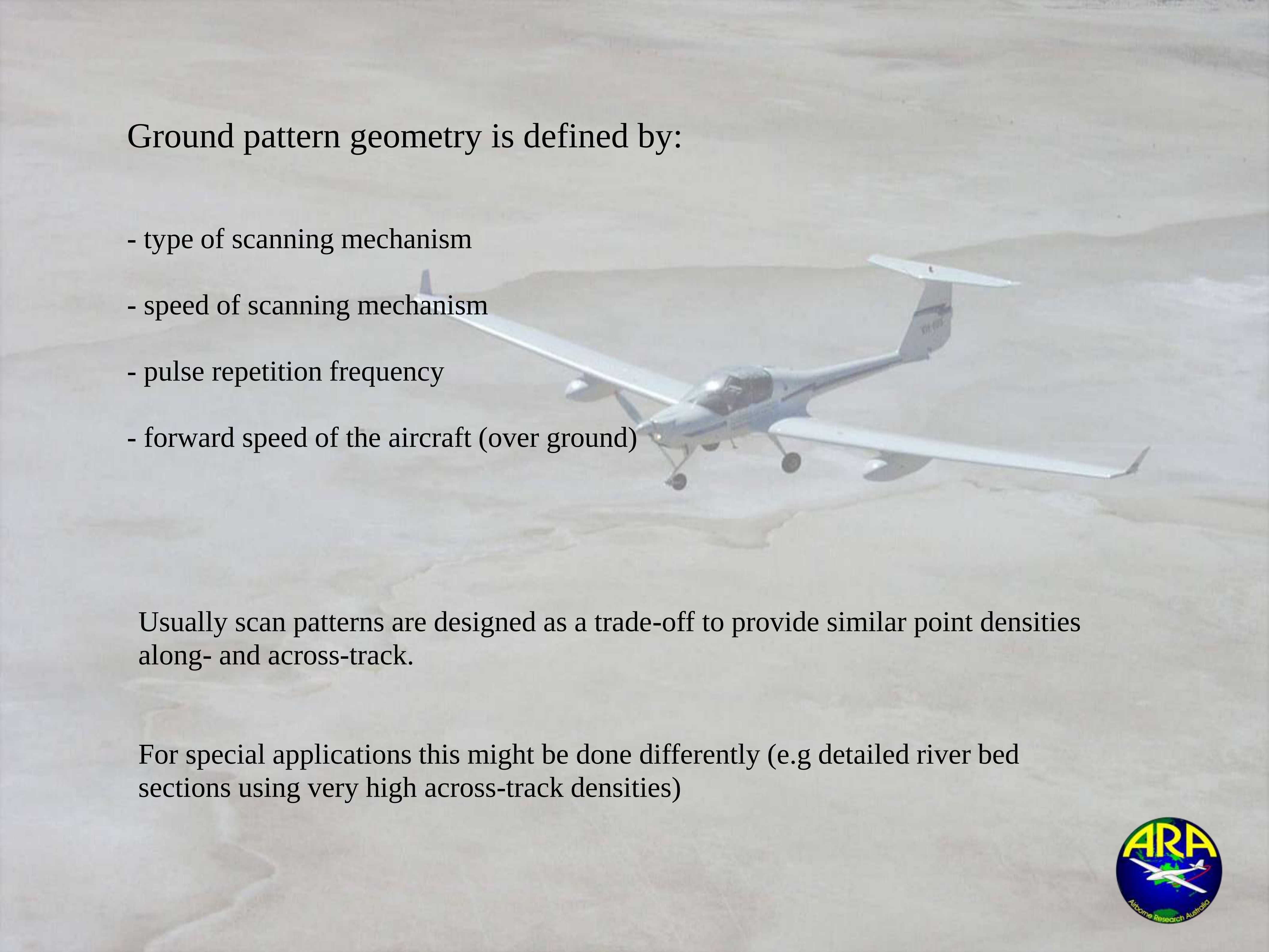
Ground pattern



Q560
Q680iS
VUX

VQ820G

Modified from Nikolaos 2006



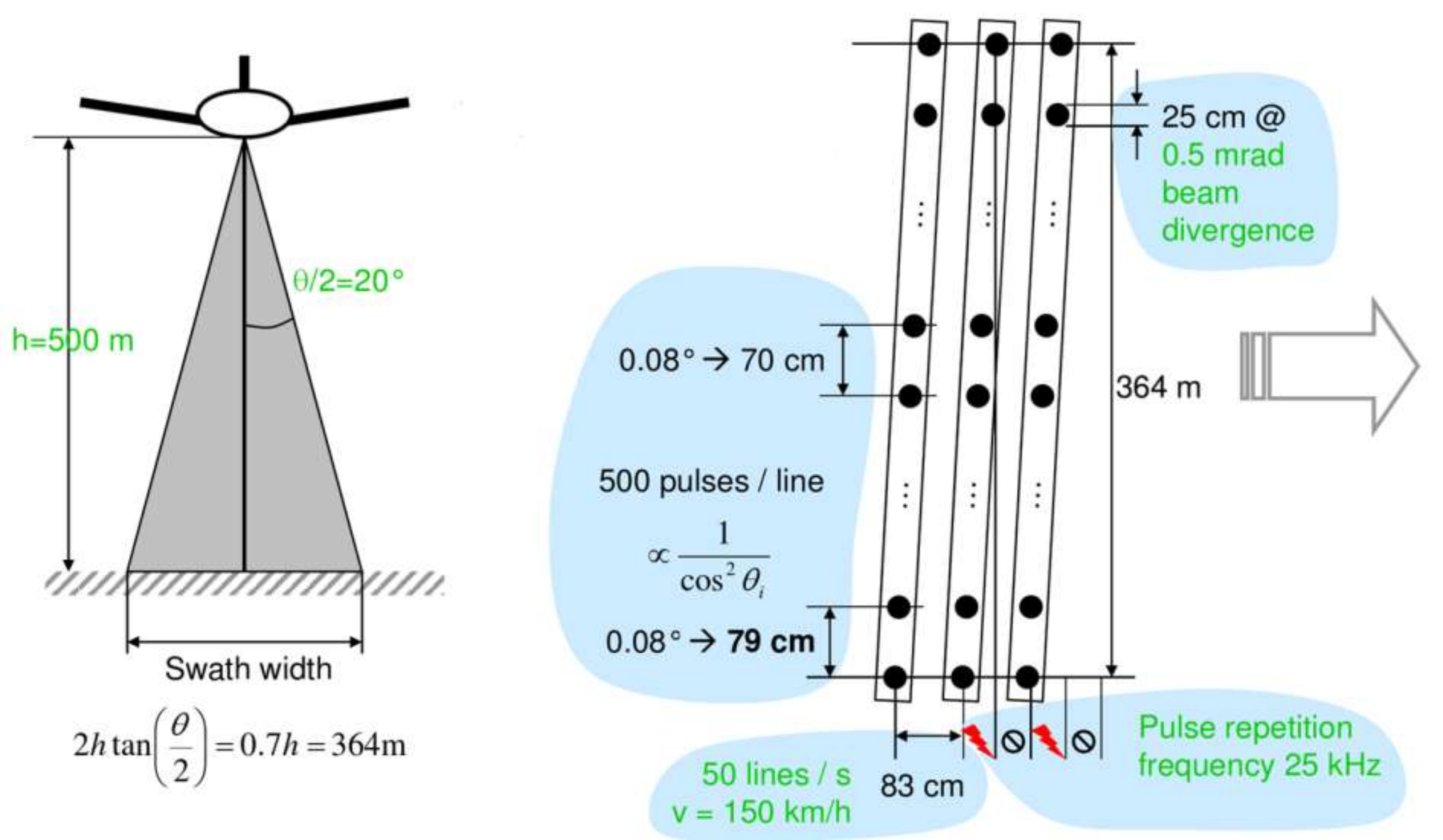
Ground pattern geometry is defined by:

- type of scanning mechanism
- speed of scanning mechanism
- pulse repetition frequency
- forward speed of the aircraft (over ground)

Usually scan patterns are designed as a trade-off to provide similar point densities along- and across-track.

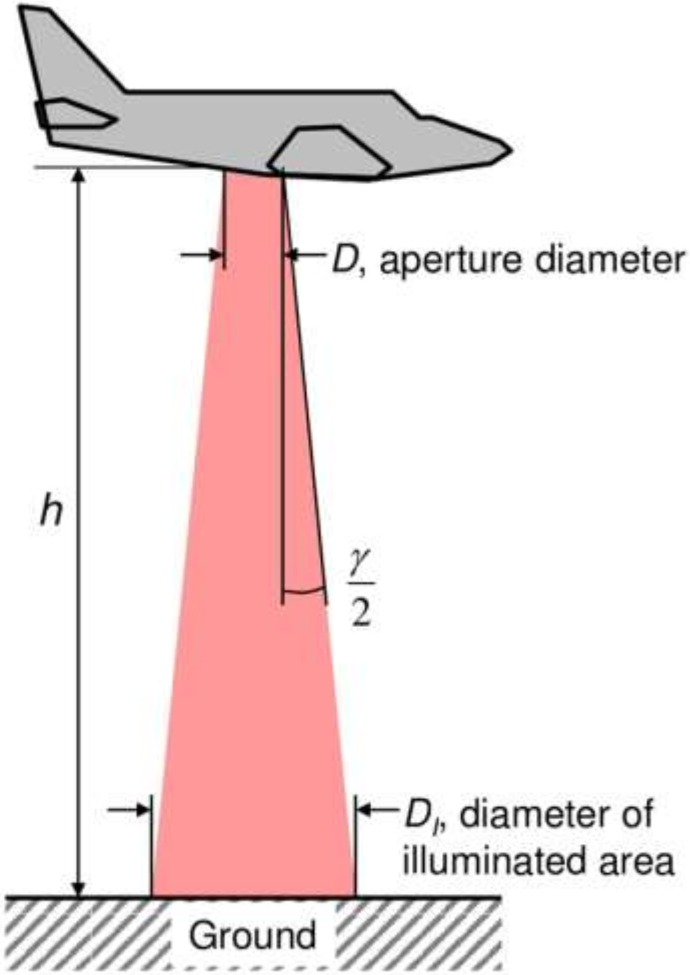
For special applications this might be done differently (e.g detailed river bed sections using very high across-track densities)

Scan pattern example



Modified from Baltsavias 2008

Laser footprint



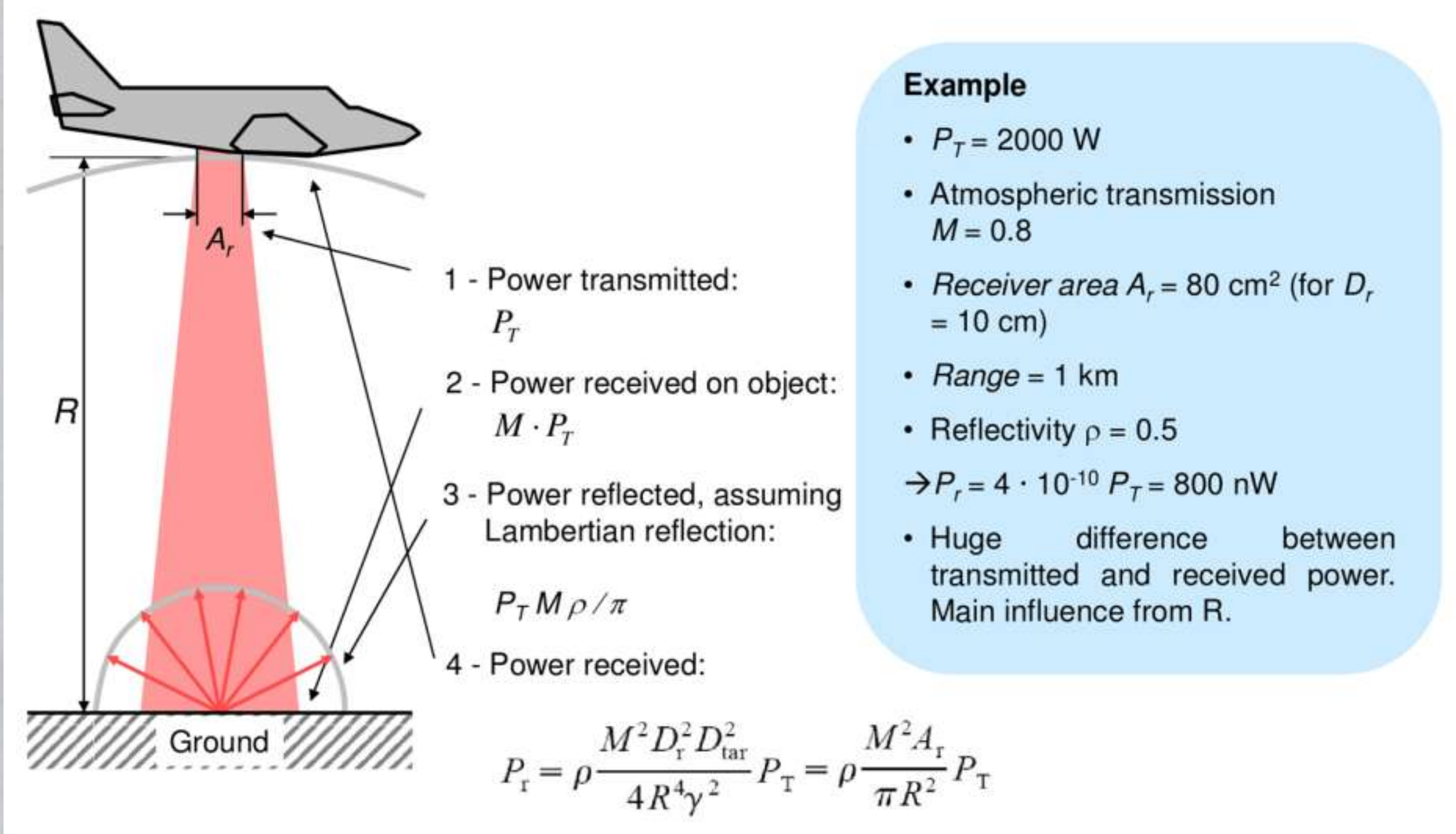
- Laser beam widens with distance
- Beam divergence γ
- Theoretical limit by diffraction $\gamma \geq 2.44 \frac{\lambda}{D}$
- Example:
  λ = 1064 nm, D = 10 cm → 0.026 mrad
- Typical values for ALS:
  γ = 0.15 – 1 mrad
- Ground laser beam diameter (assuming a circle)

$$\begin{aligned} D_l &= D + 2h\tan(\gamma/2) \\ &\approx 2h\tan(\gamma/2) \\ &\approx h\gamma \end{aligned}$$

- Example:
  γ = 1 mrad
  → 1 m diameter @ h = 1 km flying height

Modified from Baltsavias 2008

Pulse energy



1 - Power transmitted:
P_T

2 - Power received on object:
$M \cdot P_T$

3 - Power reflected, assuming Lambertian reflection:

$P_T M \rho / \pi$

4 - Power received:

$$P_r = \rho \frac{M^2 D_r^2 D_{tar}^2}{4 R^4 \gamma^2} P_T = \rho \frac{M^2 A_r}{\pi R^2} P_T$$

Example

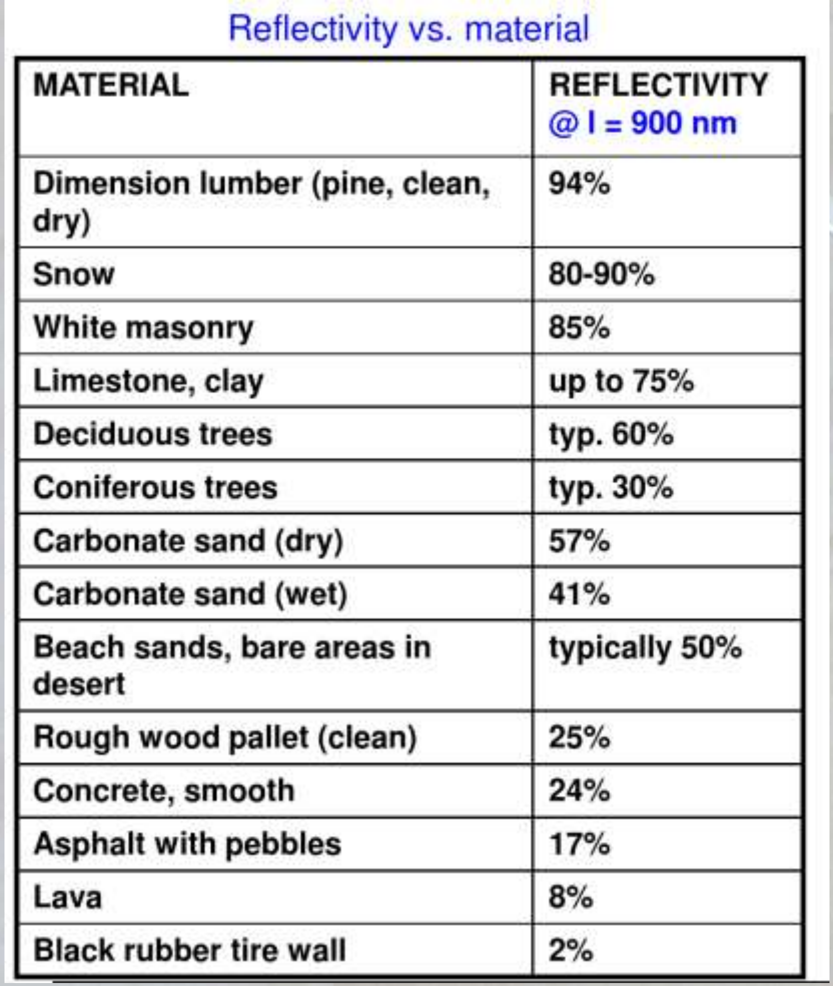
- P_T = 2000 W
- Atmospheric transmission $M = 0.8$
- *Receiver area* A_r = 80 cm^2 (for D_r = 10 cm)
- *Range* = 1 km
- Reflectivity $\rho = 0.5$

→$P_r = 4 \cdot 10^{-10}\ P_T$ = 800 nW

- Huge difference between transmitted and received power. Main influence from R.

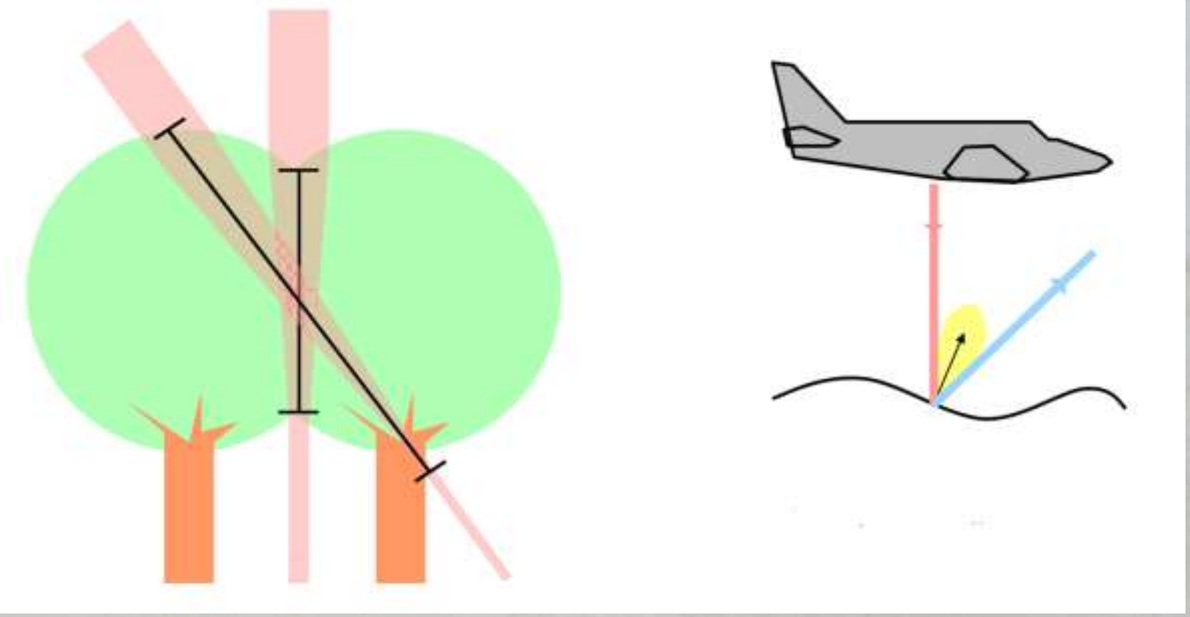
Modified from Baltsavias 2008

Other influences



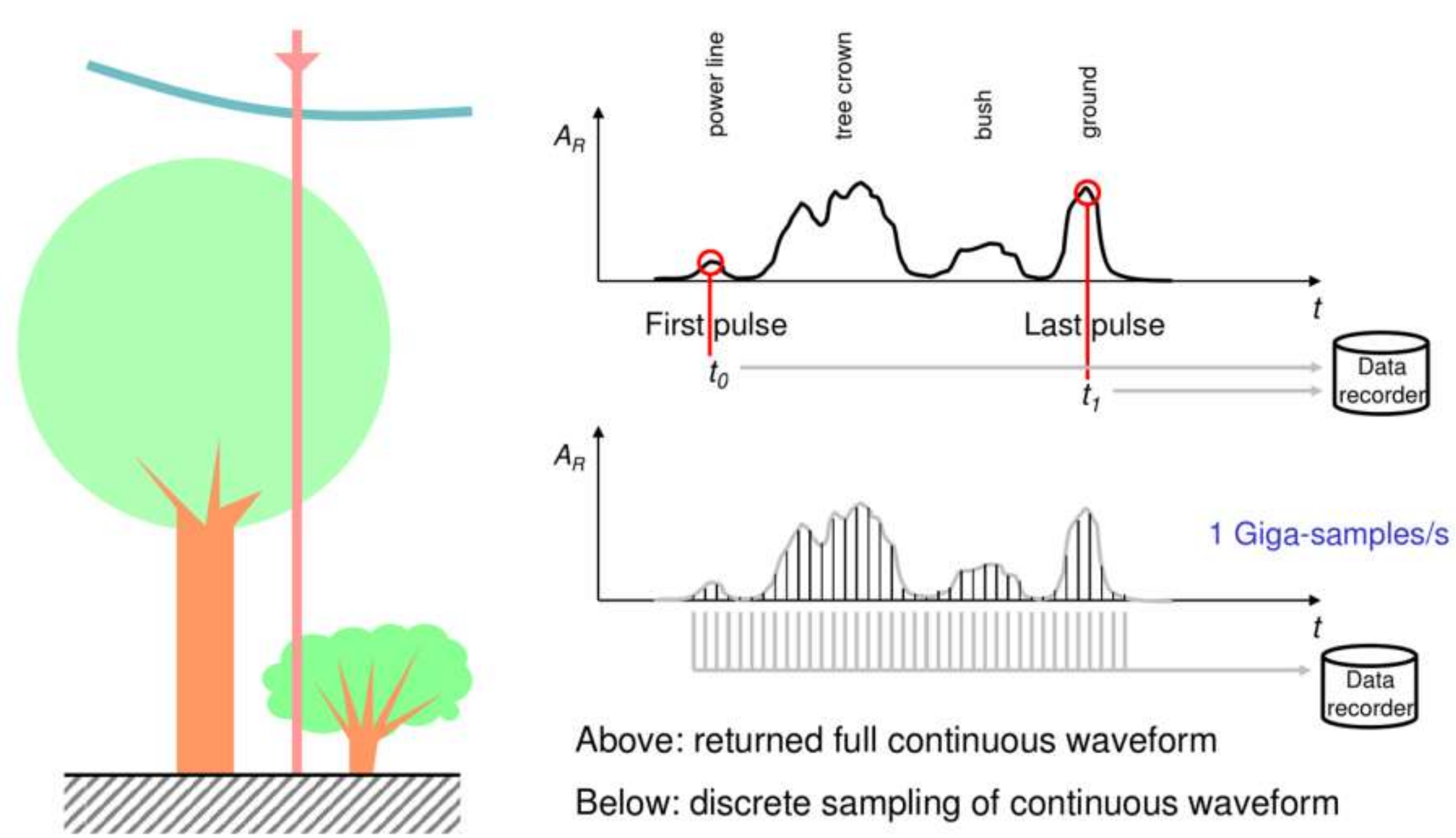
Reflectivity vs. material

MATERIAL	REFLECTIVITY @ l = 900 nm
Dimension lumber (pine, clean, dry)	94%
Snow	80-90%
White masonry	85%
Limestone, clay	up to 75%
Deciduous trees	typ. 60%
Coniferous trees	typ. 30%
Carbonate sand (dry)	57%
Carbonate sand (wet)	41%
Beach sands, bare areas in desert	typically 50%
Rough wood pallet (clean)	25%
Concrete, smooth	24%
Asphalt with pebbles	17%
Lava	8%
Black rubber tire wall	2%



Modified from Baltsavias 2008

Full waveform Lidar



Above: returned full continuous waveform

Below: discrete sampling of continuous waveform

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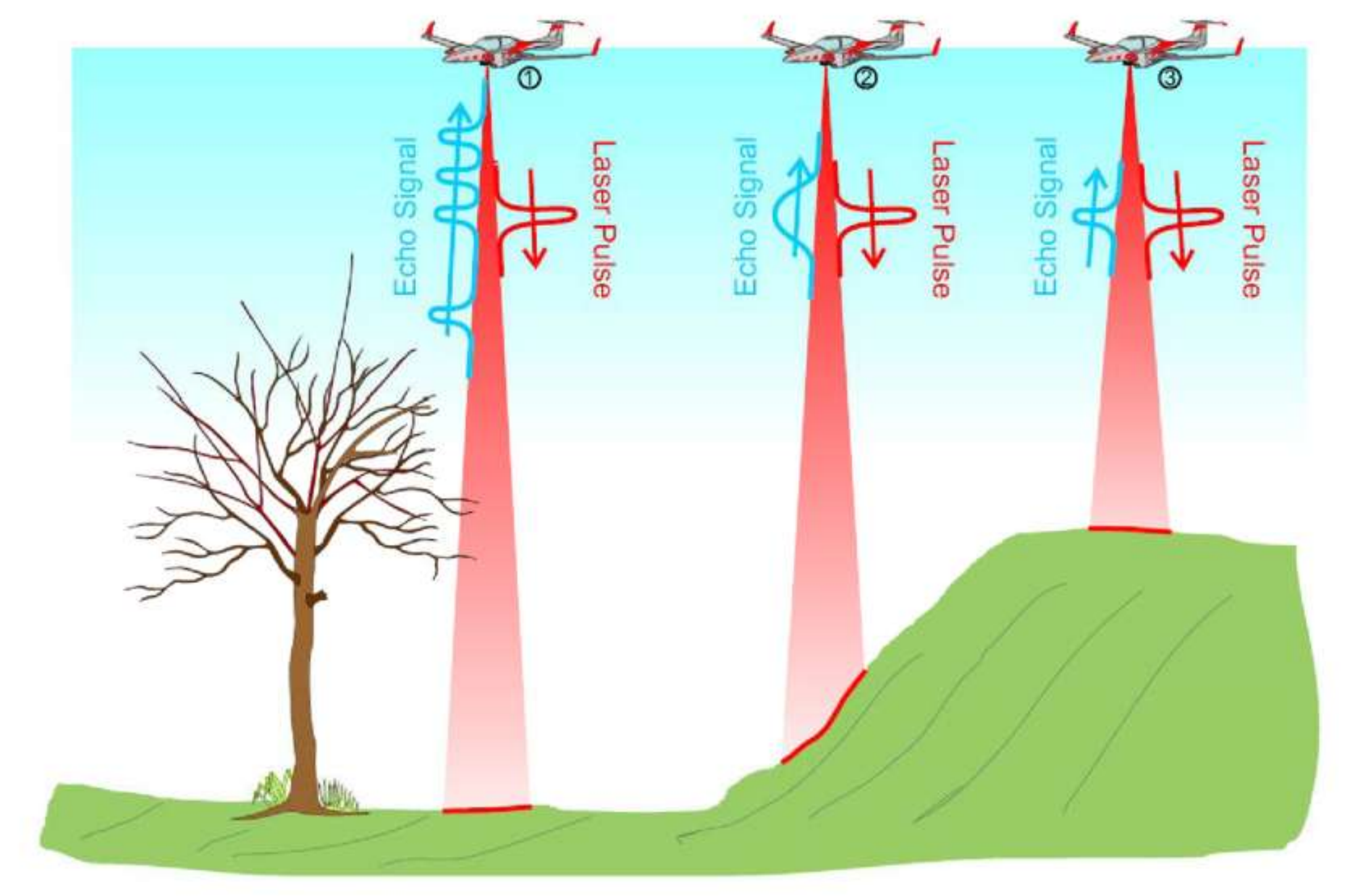
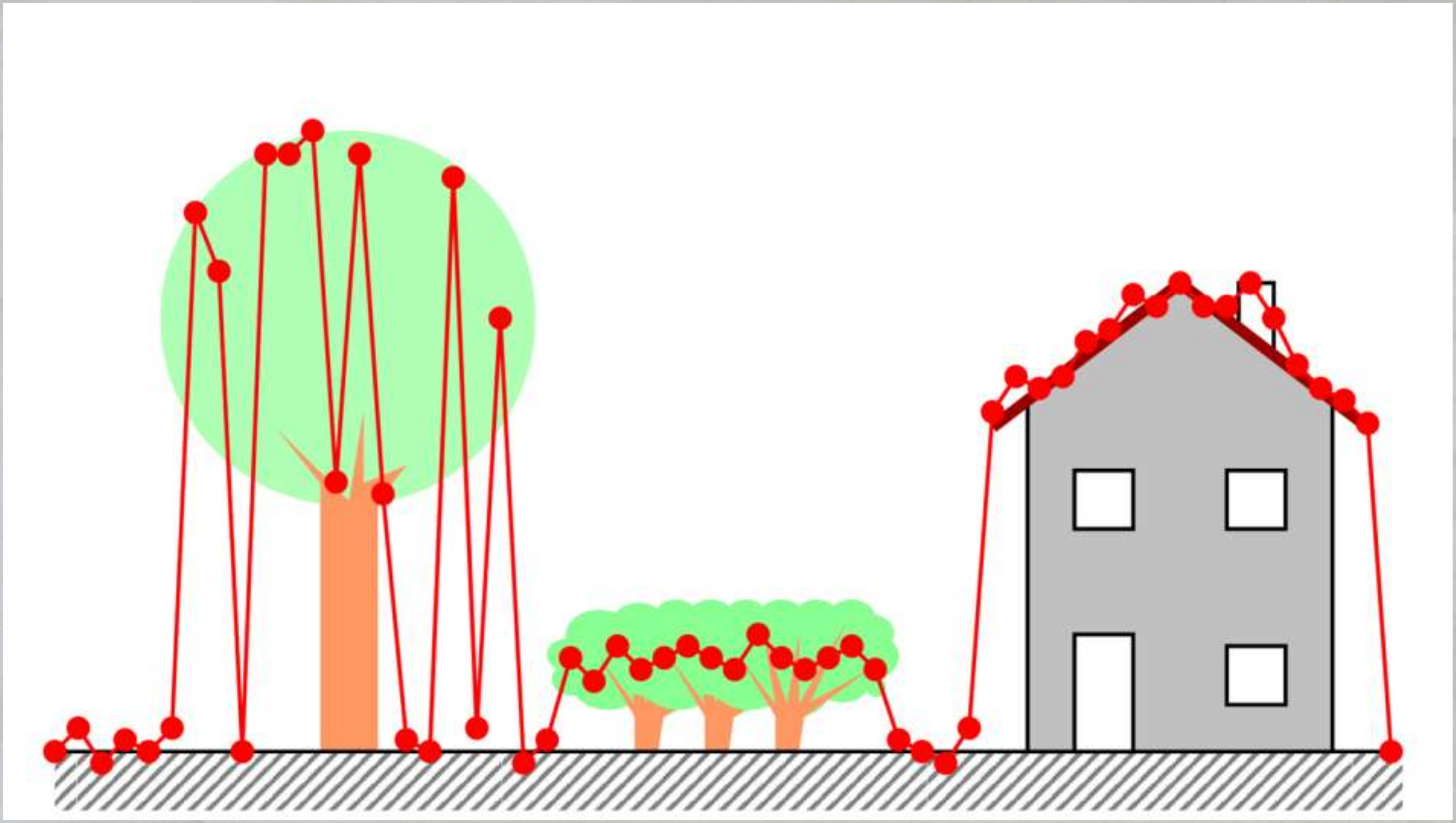


From Riegl Q680iS manual



Now the only thing left to do is to make some sense of all those points ...

Modified from Baltsavias 2008