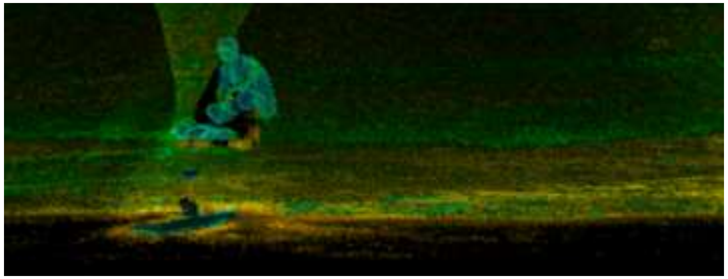
# Applications of laser scanning

Juha Hyyppä



# Centre of Excellence in Laser Scanning Research:
# **"Together what is otherwise impossible"**


Hardware-driven approach

Pulsed time-of-flight laser radar

*Juha Kostamovaara*
*Univ. Oulu*

Mobile and ubiquitous Laser Scanning

*Juha Hyyppä*
*FGI*

Laser scanning for precision forestry

*Markus Holopainen*
*Univ. Helsinki*

Laser scanning for built environment

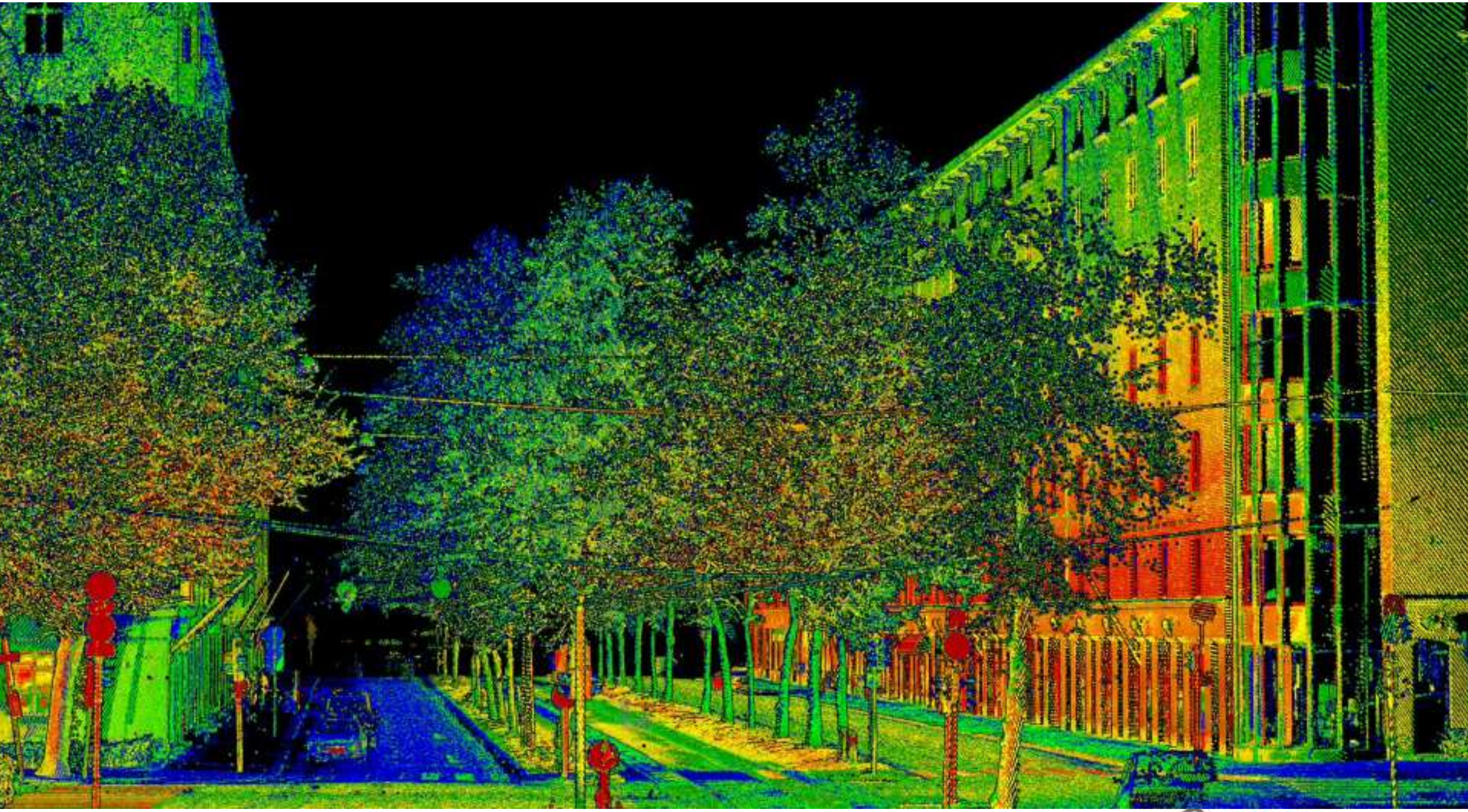
*Hannu Hyyppä*
*Aalto Univ.*

**International benchmarking studies**

# CoE-LaSR Vision

- "**Laser scanning is omnipresent and affecting positively the life of every citizen in modern information society by early 2020s**"
- In the next two decades, new MLS and PLS systems are making LS more ubiquitous in the same sense as the first personal computing was followed by ubiquitous computing. Even autonomous robots using point-cloud-generating perception sensors may be added to the ecosystem during this timeframe. **What can be said for certain is that during the 2020s and 2030s, there will be a great number of laser scanners omnipresent in everyday life. Mobile Laser Scanning is one of the main techniques to create local virtual reality**.
- **We are in the middle of disruptive technologies, multidisciplinary work**

# Development of new sensors and test their feasibility for various applications



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# General Principles in Laser Scanning

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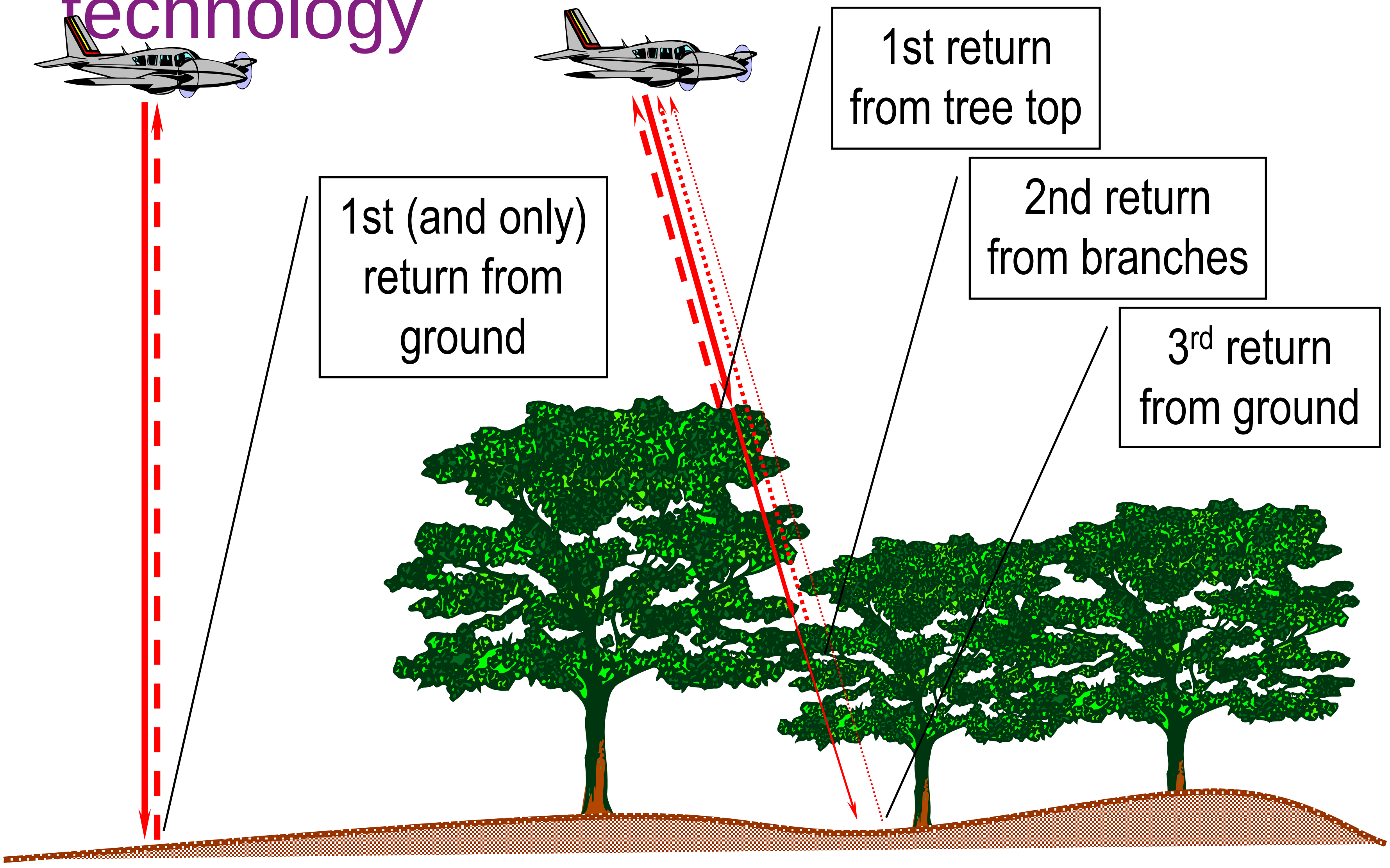
# Fundamentals of multiple discrete return technology

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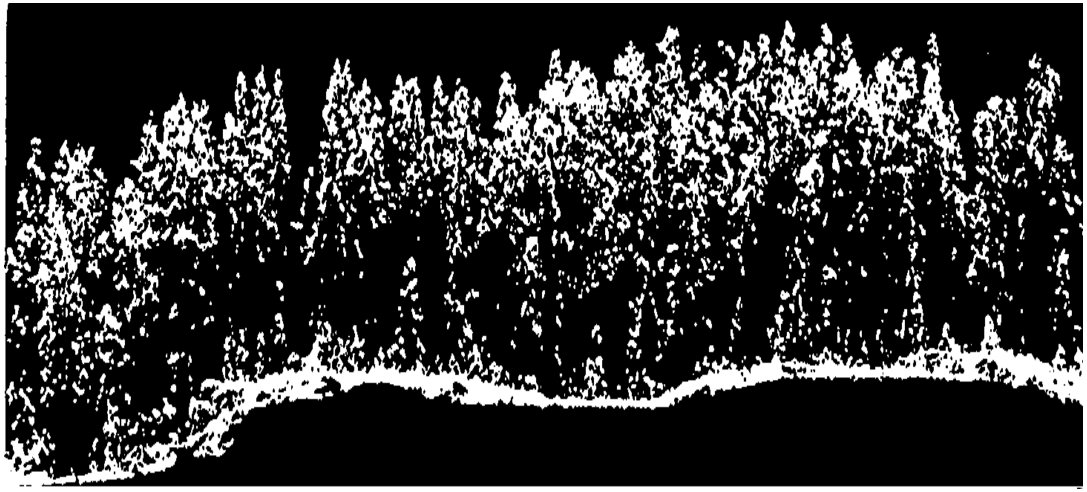
# ALS Output

Output: x,y,z, intensity !



C. Hannu Hyyppä, Petri Rönnholm

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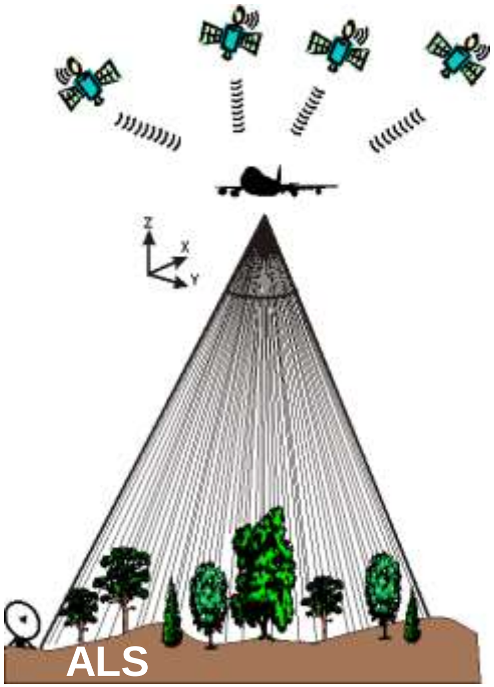
# Various Platforms for LS




Airborne Laser Scanning


Terrestrial Laser Scanning


Mobile Laser Scanning

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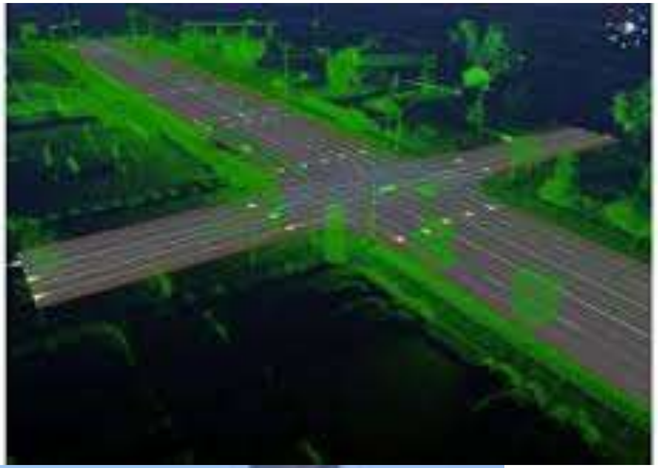
# HERE & Google





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# Characteristics of LS

## Airborne Laser Scanning

- Point density 0.5-40 pts/$m^2$
- Homogenous point density
- Elevation accuracy 5-30 cm
- Planimetric accuracy 20-80 cm
- Few hundred m to several km
- Transfer costs
- Cost-effective for areas larger than 50$km^2$
- Multitemporal ALS applications studied relatively little (Murakami et al. 1999, Yu et al. 2004)
- Reference book Shan and Toth (2009), Vosselman and Maas (2009)

## Airborne mini-UAV scanning

- New research area (idea in Zhao et al., 2006, first demo for mapping Jaakkola et al. 2010)
- Point density 10-several hundred pts/$m^2$
- Elevation accuracy 5-30 cm
- Altitude tens of m
- Usable for research and multitemporal studies
- Presently commercial applications
- Reduces $CO_2$ consumption of research

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# Characteristics of LS

## Mobile laser scanning

- Point density in the range of 100 to several thousands pts/$m^2$
- More homogeneous (TLS) point density
- Point accuracy of few centimeters (egg) when collected with good GNSS coverage
- Applicable range of few tens of m
- Viewing angle different from ALS
- Higher variation in the range data (e.g. round traffic poles are not round in the data)
- Vast data sets when data collection is done continuously
- Need for automatic and interactive algorithms

## Terrestrial Laser Scanning

- Point density in the range of 10000 pts/$m^2$ at the 10 m distance
- Distance accuracy of few mm to 1-2 cm
- Operational scanning range from 1 to several hundred m
- Feasible for small areas less than few tens of m distance
- Processing time challenging: image processing technigues applied
- Small variation in data, e.g. Distance variation low -> surface normal etc can be calculated
- Reference book: Vosselman and Maas (2009)

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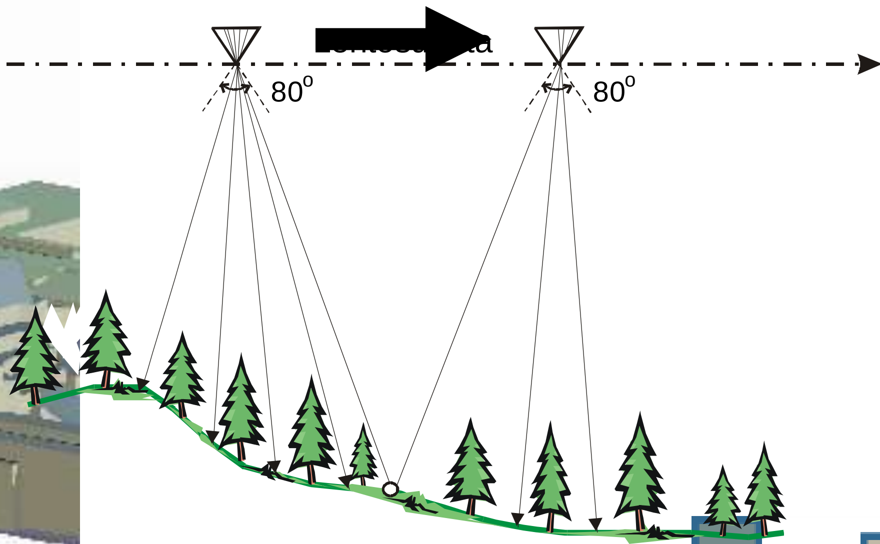
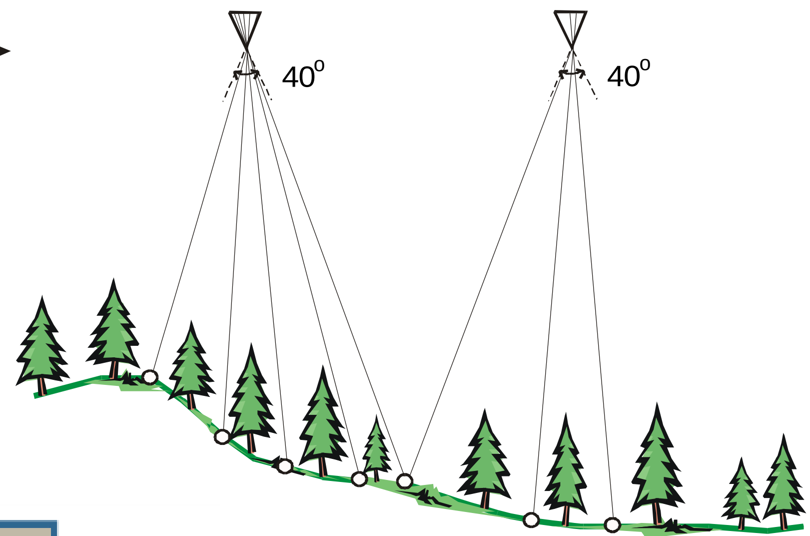
# Compared to Photogrammetry

Photogrammetry




Laser scanning



# Image taken with a camera

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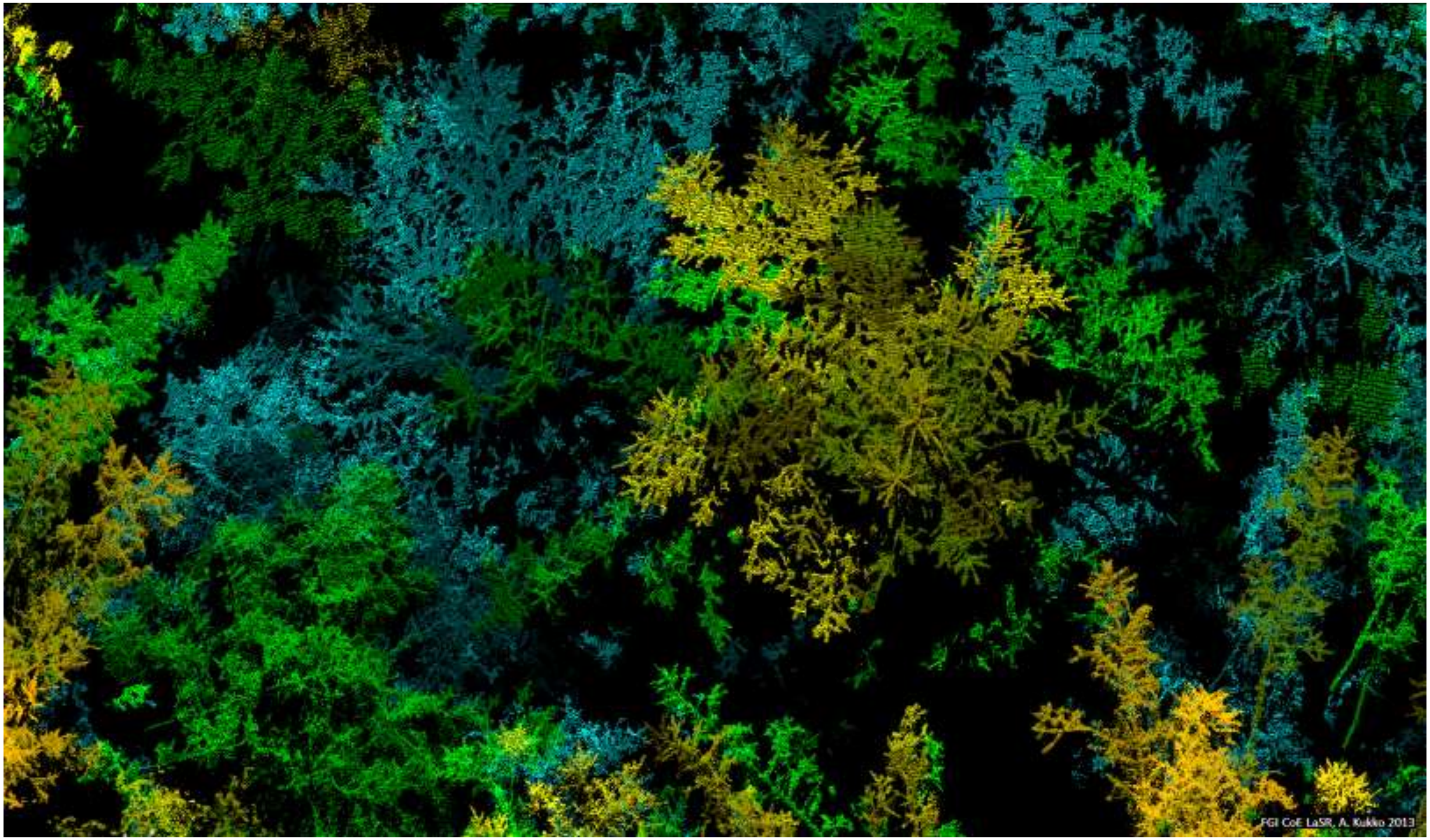
# With LS same area

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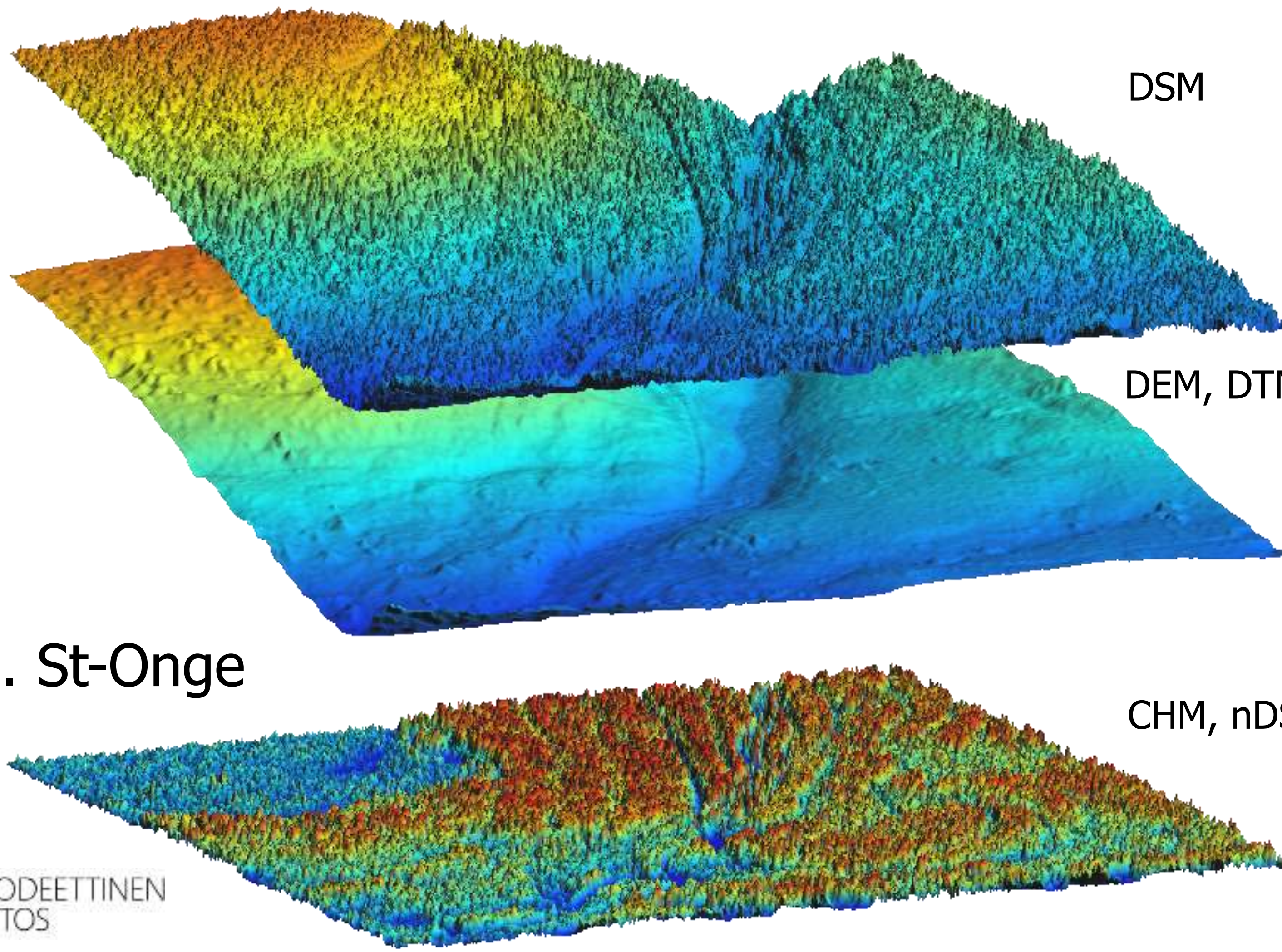
# DTM, DSM, nDSM




c. St-Onge

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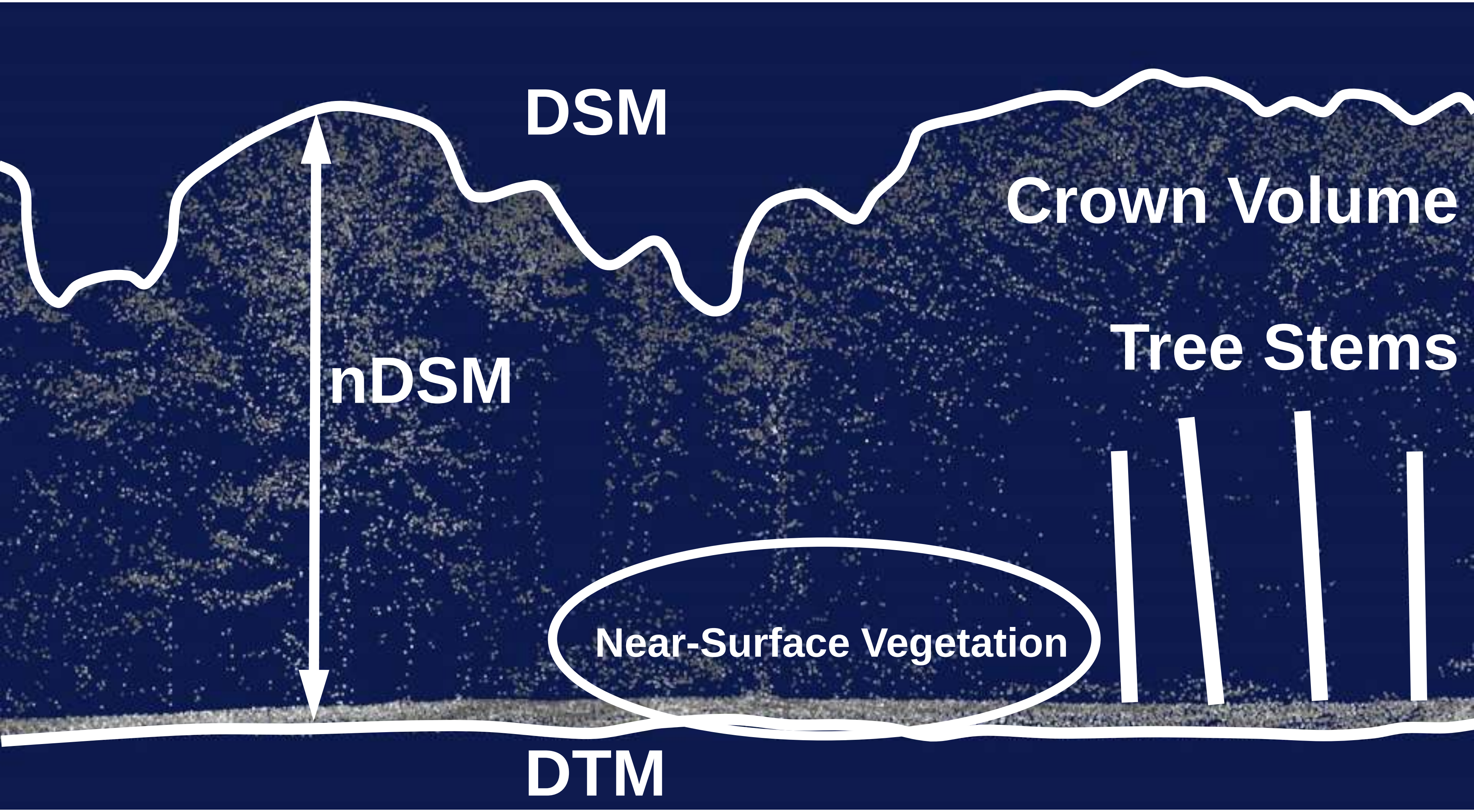
# Interpreting ALS Point Clouds

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# Autonomous Driving Information Systems

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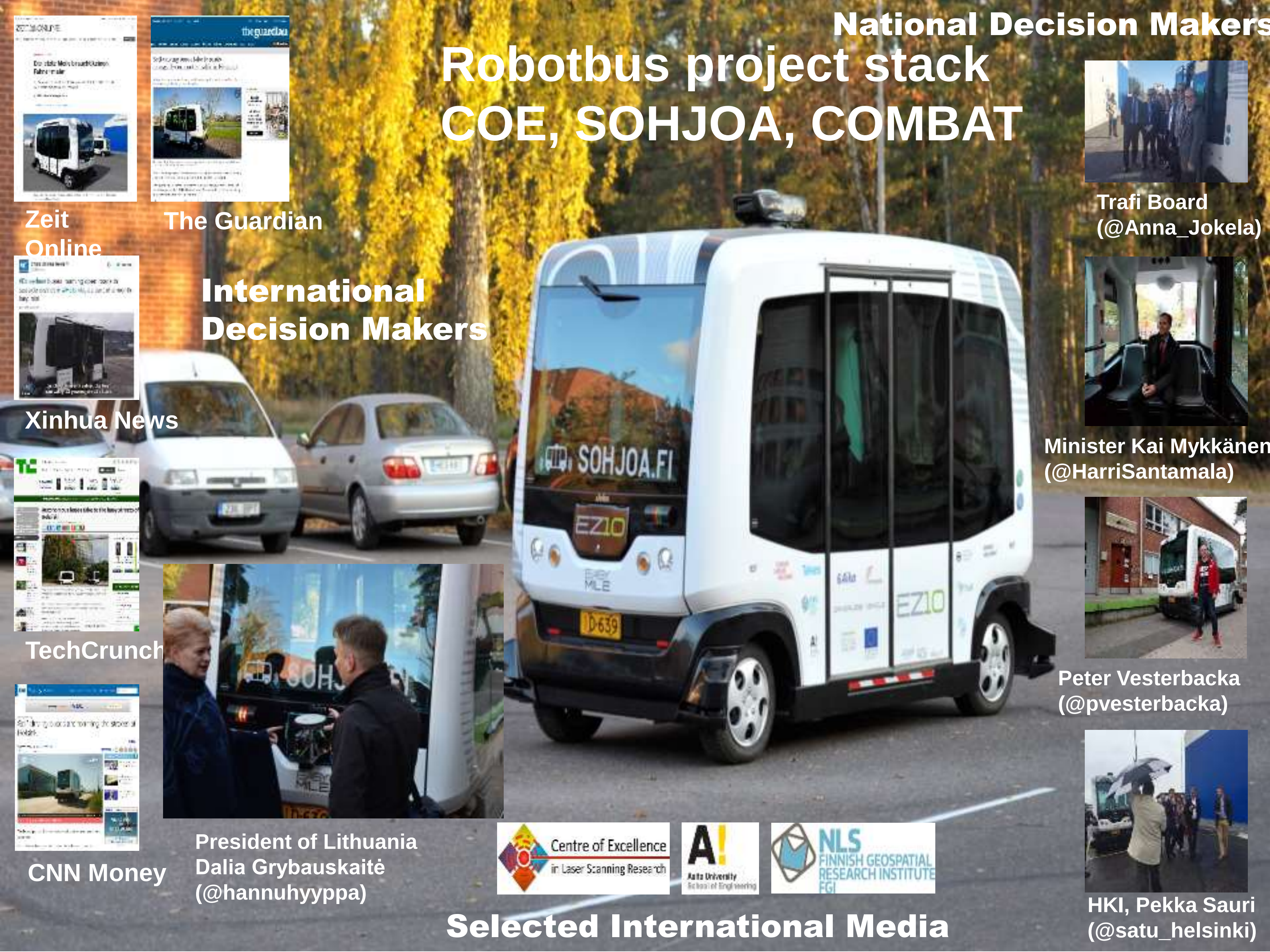
Robotbus project stack
COE, SOHJOA, COMBAT
National Decision Makers
International Decision Makers
Selected International Media
Zeit Online
The Guardian
Xinhua News
TechCrunch
CNN Money
President of Lithuania
Dalia Grybauskaitė
(@hannuhyyppa)
Trafi Board
(@Anna_Jokela)
Minister Kai Mykkänen
(@HarriSantamala)
Peter Vesterbacka
(@pvesterbacka)
HKI, Pekka Sauri
(@satu_helsinki)
SOHJOA.FI
EZ10
Centre of Excellence in Laser Scanning Research
Aalto University School of Engineering
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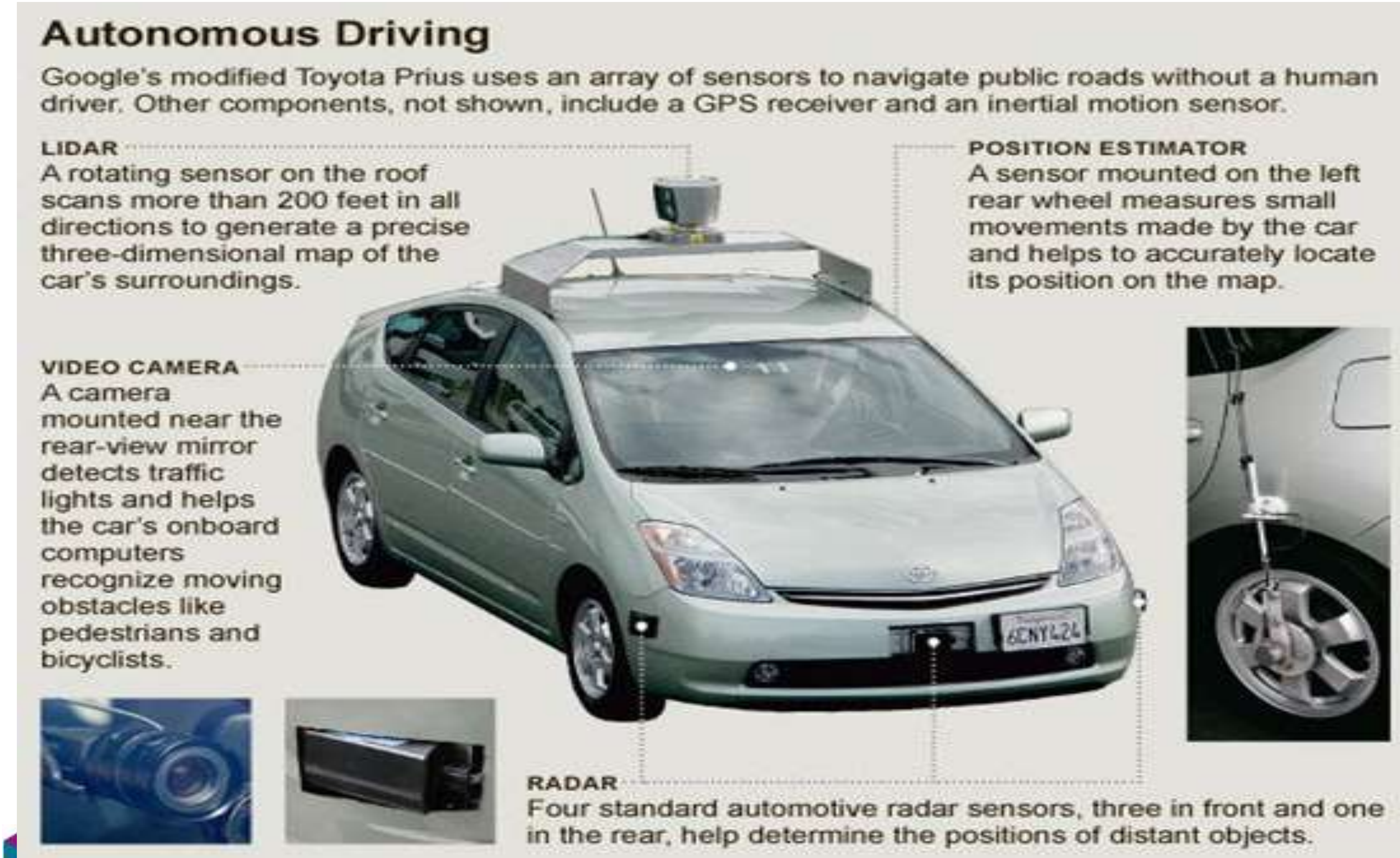
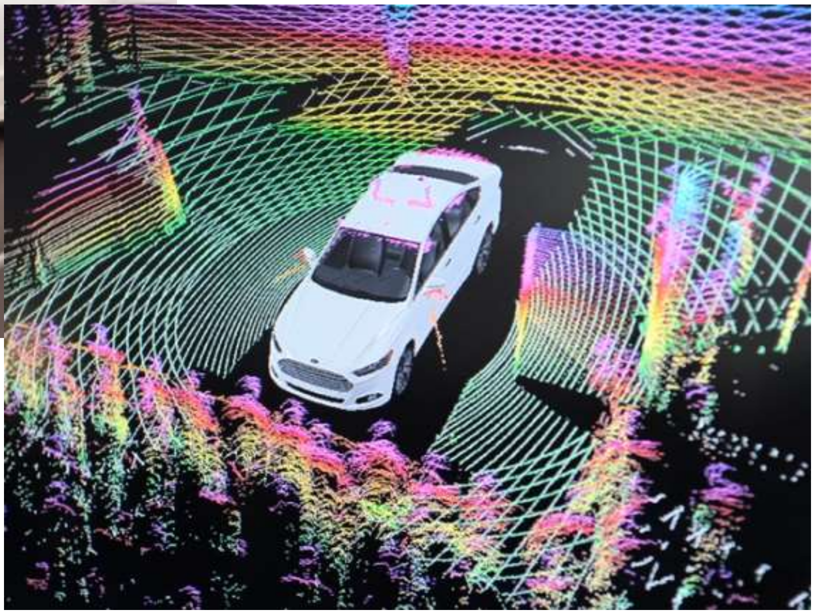
# Oman konenäkölaitteen kiinnitys


# Autonomous driving



# Real implementations



# New autonomous vision sensor solutions

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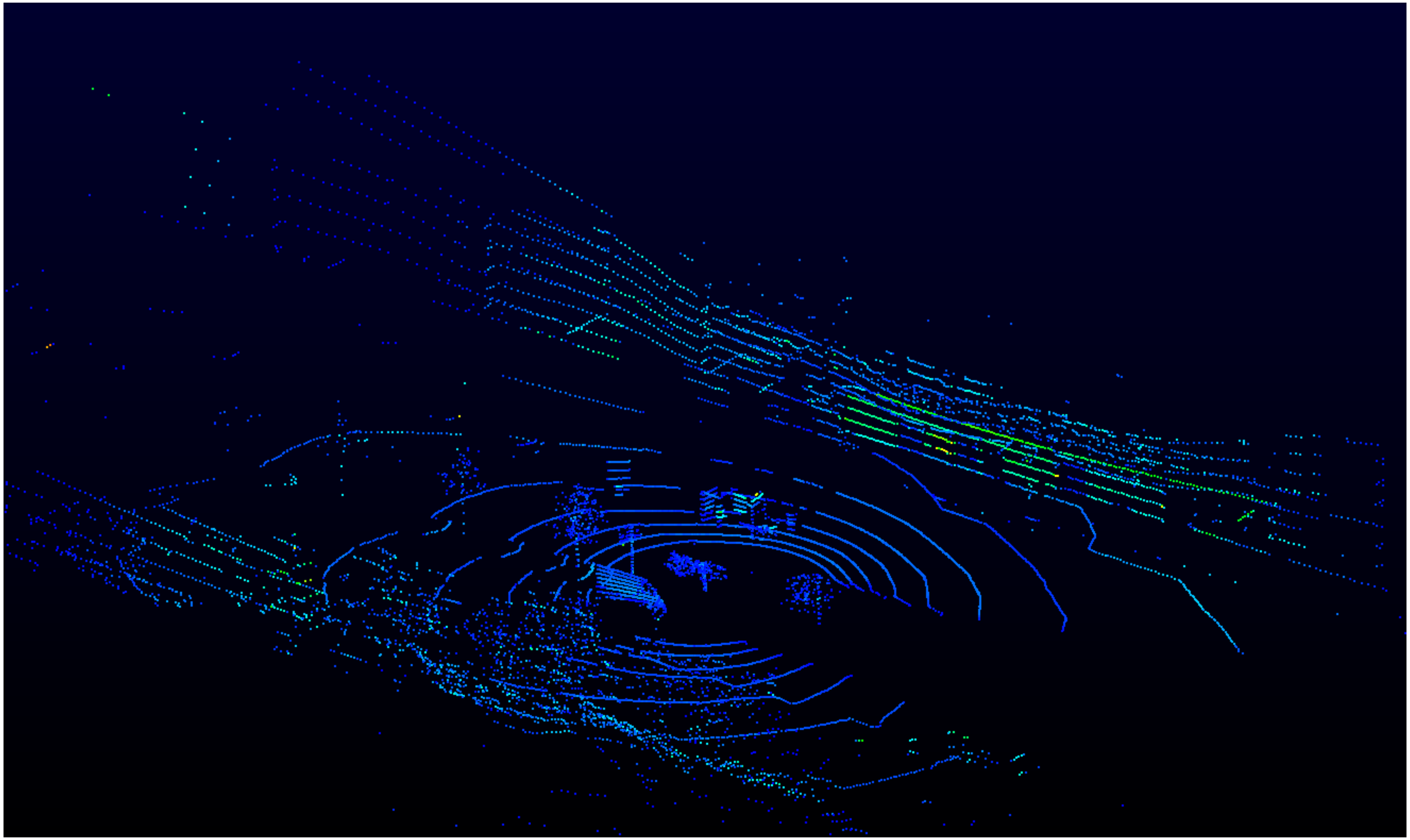

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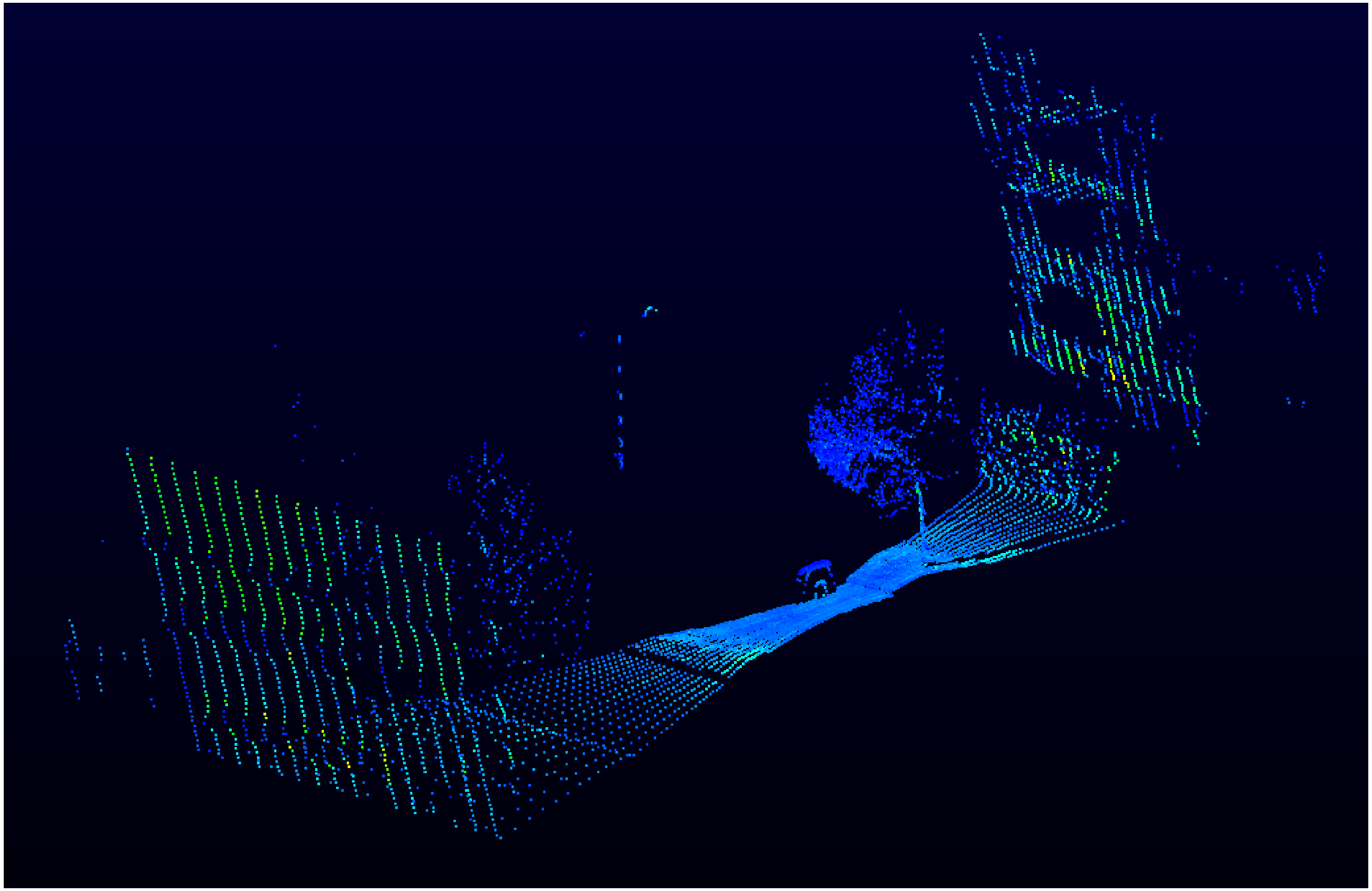

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# Car parkings


**Figure.** a) Part of the street Espoonlahdenkatu as recorded on the reference video during data acquisition Drive 1. b) Raster representation of the car-based laser scanner data. The pixel value of each 0.3 m × 0.3 m cell corresponds to the number of laser points inside the cell. Parked cars appear as L shaped clusters of bright pixels.

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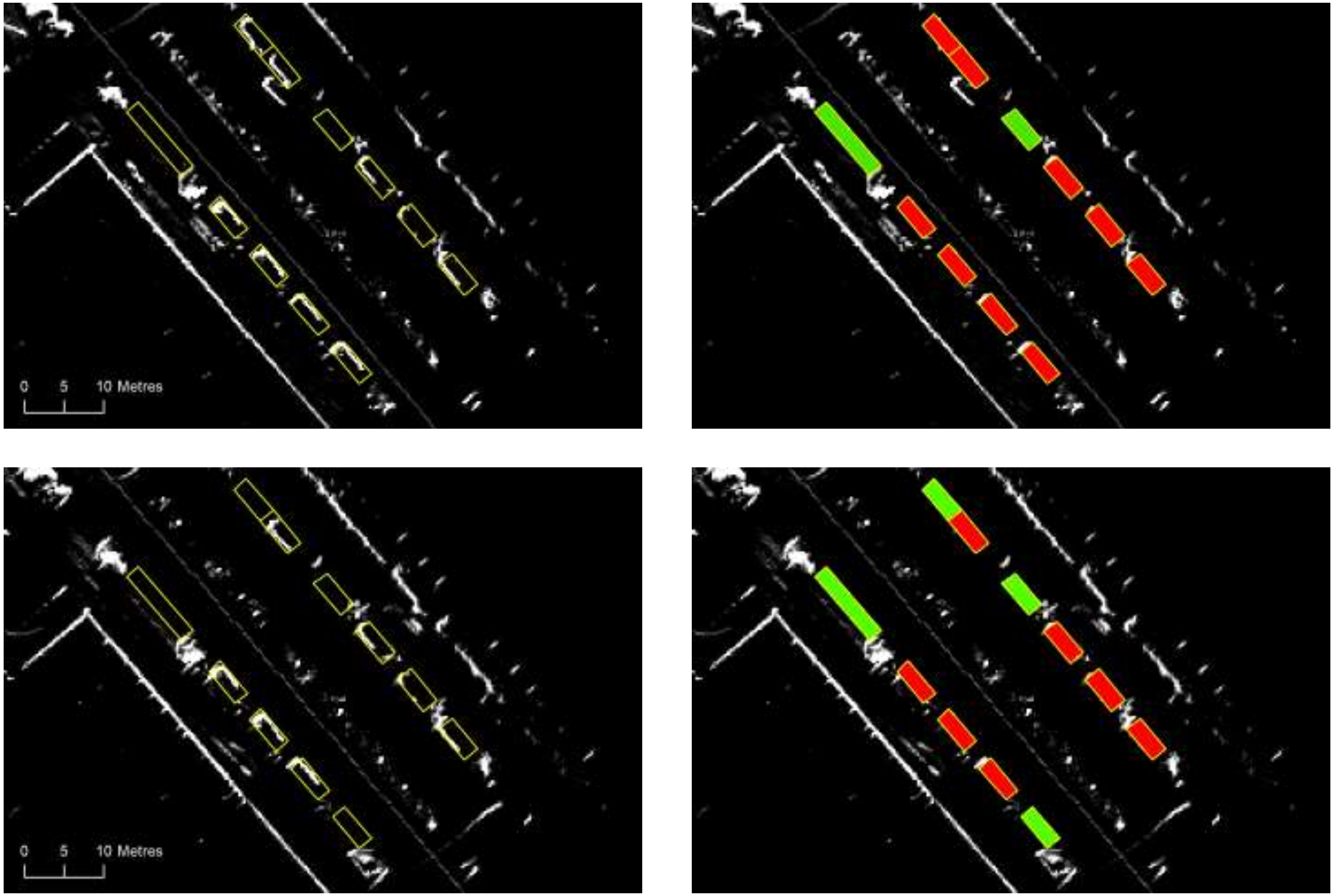
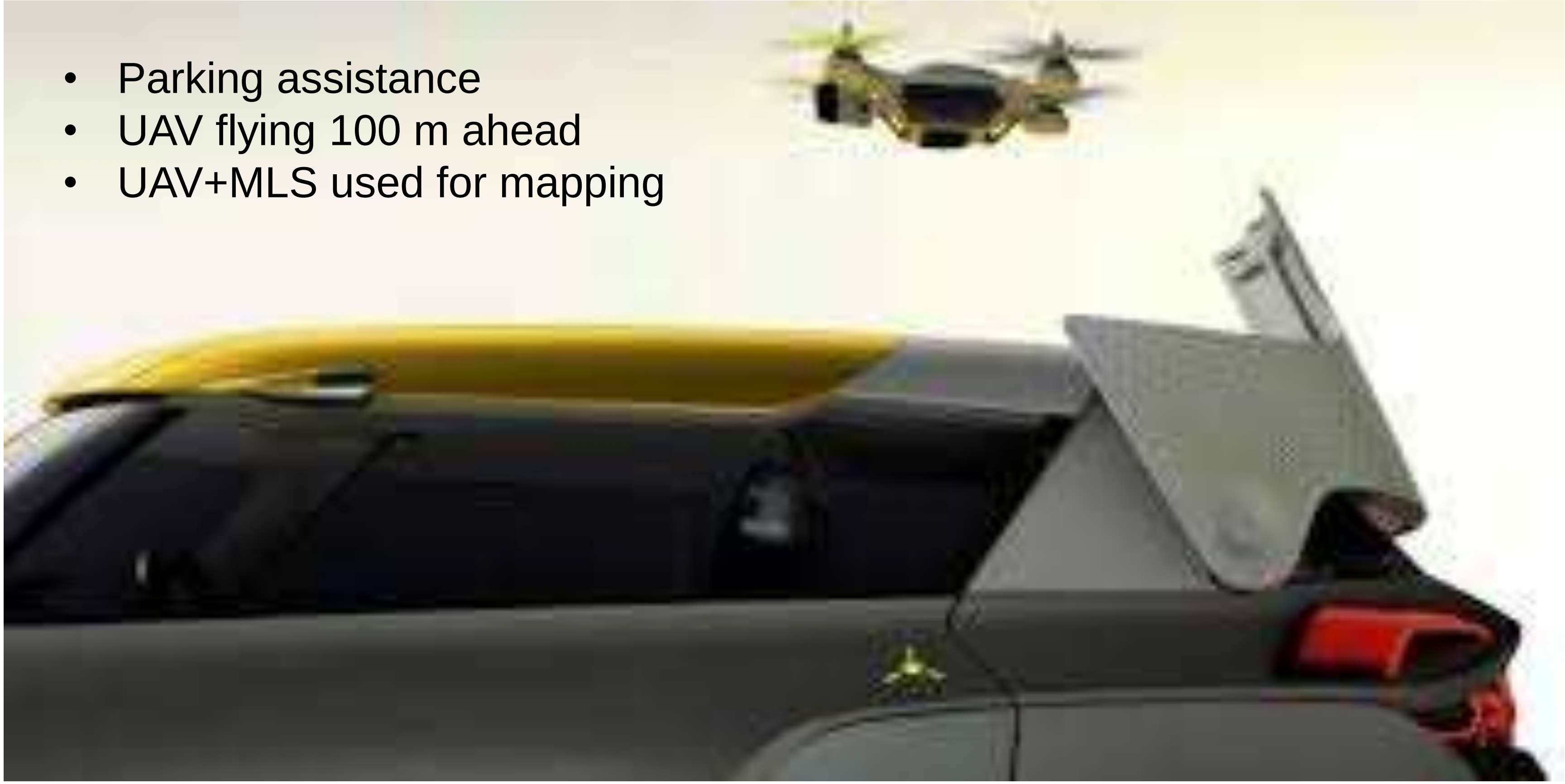


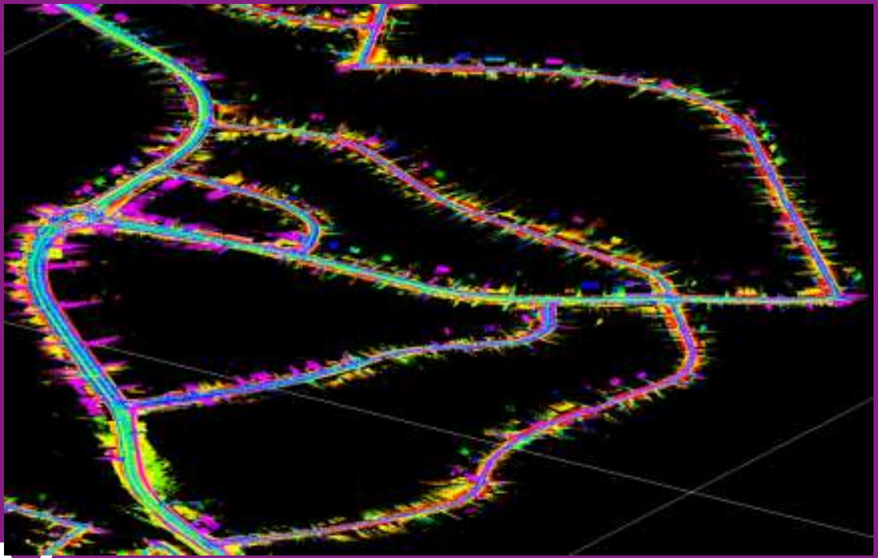

**Figure x.** Data (left) and classification results (right) for Drives 1 (upper row) and 2 (lower row). Parking places classified as free are shown in green and parking places classified as occupied are shown in red. Digitized boundaries of the parking places are shown in yellow.

# UAV and MLS linkage

- Parking assistance
- UAV flying 100 m ahead
- UAV+MLS used for mapping



# Road Inventory



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# Inventory and modeling of Roadside




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# Highway data at Ring III, Luoma


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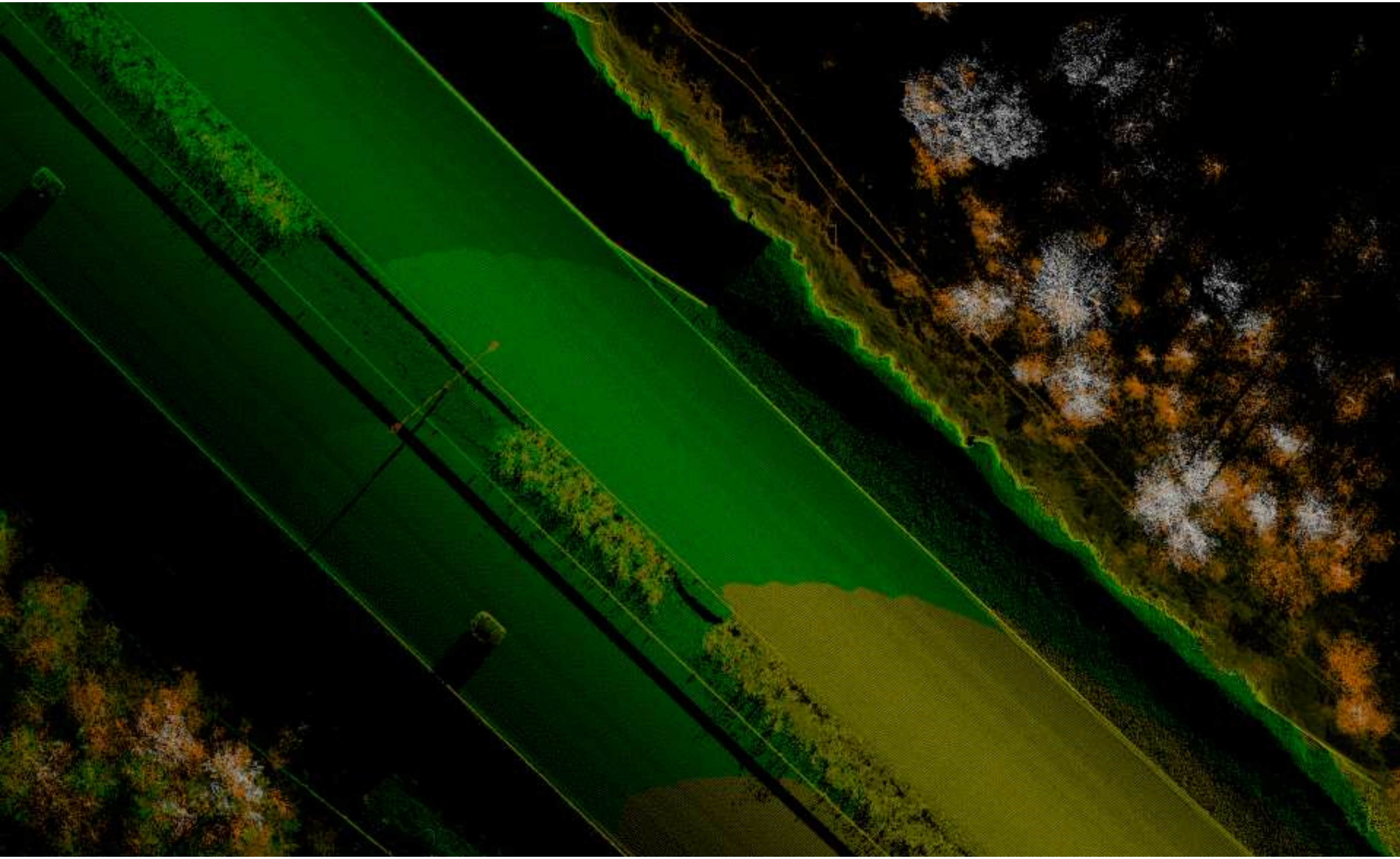
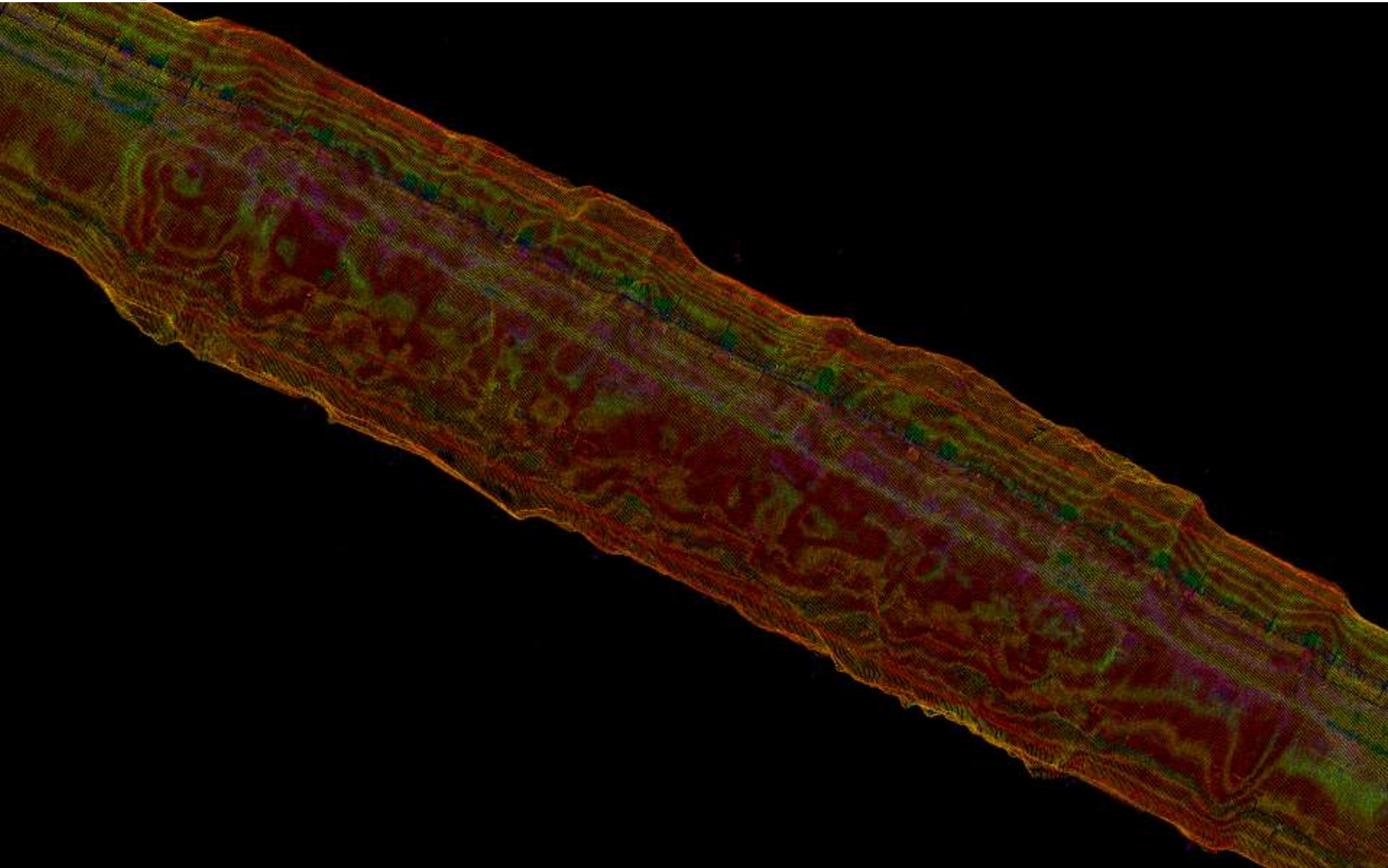
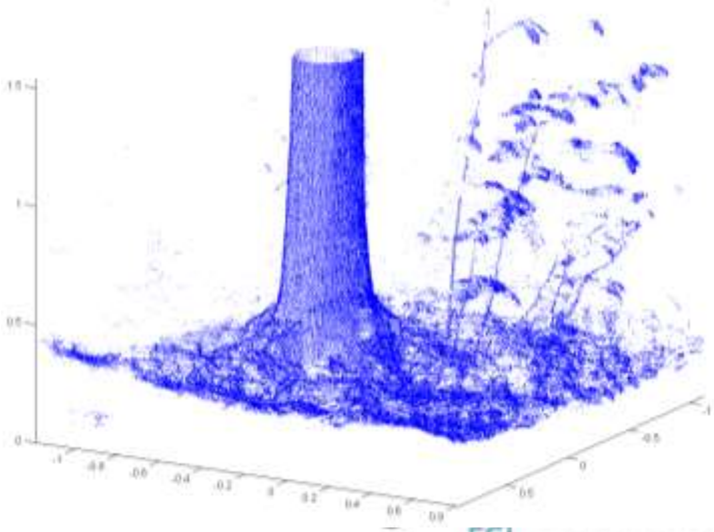


# Speeds of 60, 80 and 100 km/h

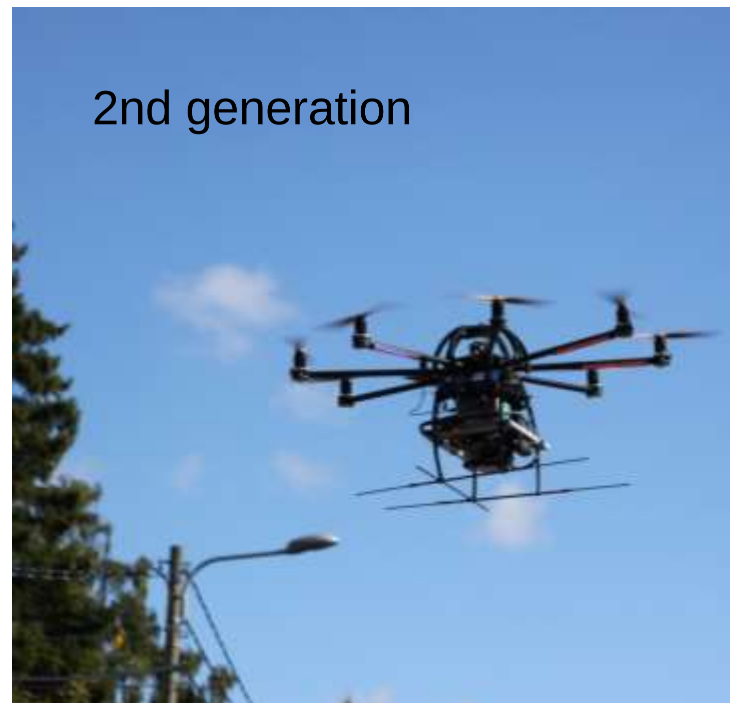


# Mini-UAV Laser Scanning



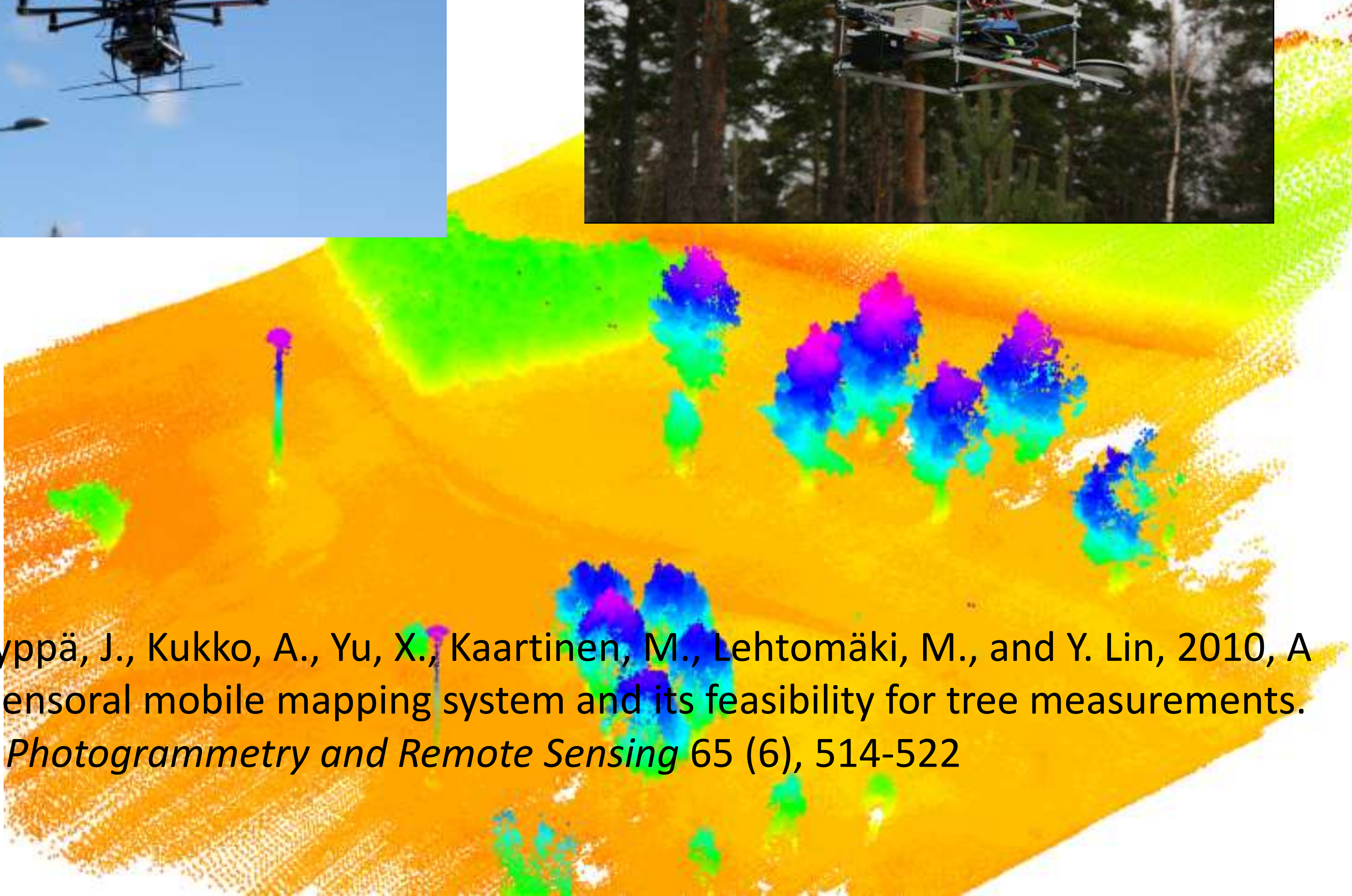
# FGI Sensei – first mini-UAV LS (2009)

- NovAtel SPAN-CPT
- Ibeo Lux/Sick LMS151
- AVT Pike F-421C
- Specim V10H
- Flir Photon 320



2nd generation

# World’s first mini-UAV Laser Scanner SENSEI



Jaakkola, A., Hyyppä, J., Kukko, A., Yu, X., Kaartinen, M., Lehtomäki, M., and Y. Lin, 2010, A low-cost multi-sensoral mobile mapping system and its feasibility for tree measurements. *ISPRS journal of Photogrammetry and Remote Sensing* 65 (6), 514-522

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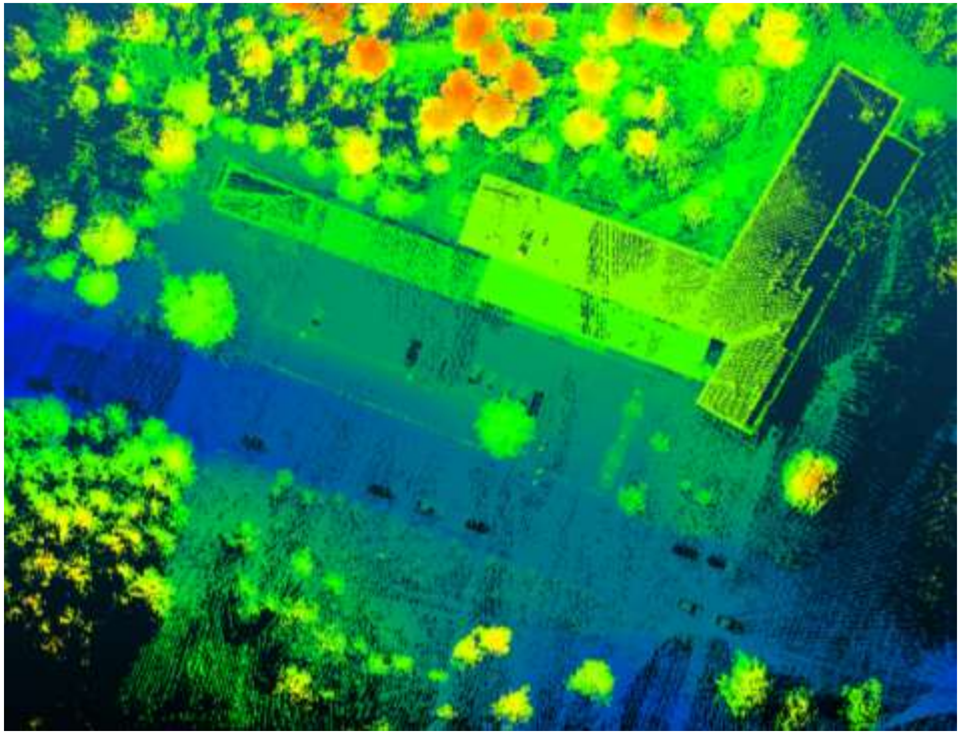
# 3rd gen UAV LS

- Lighter
- Higher PRF
- Better range accuracy
- Better planimetric accuracy



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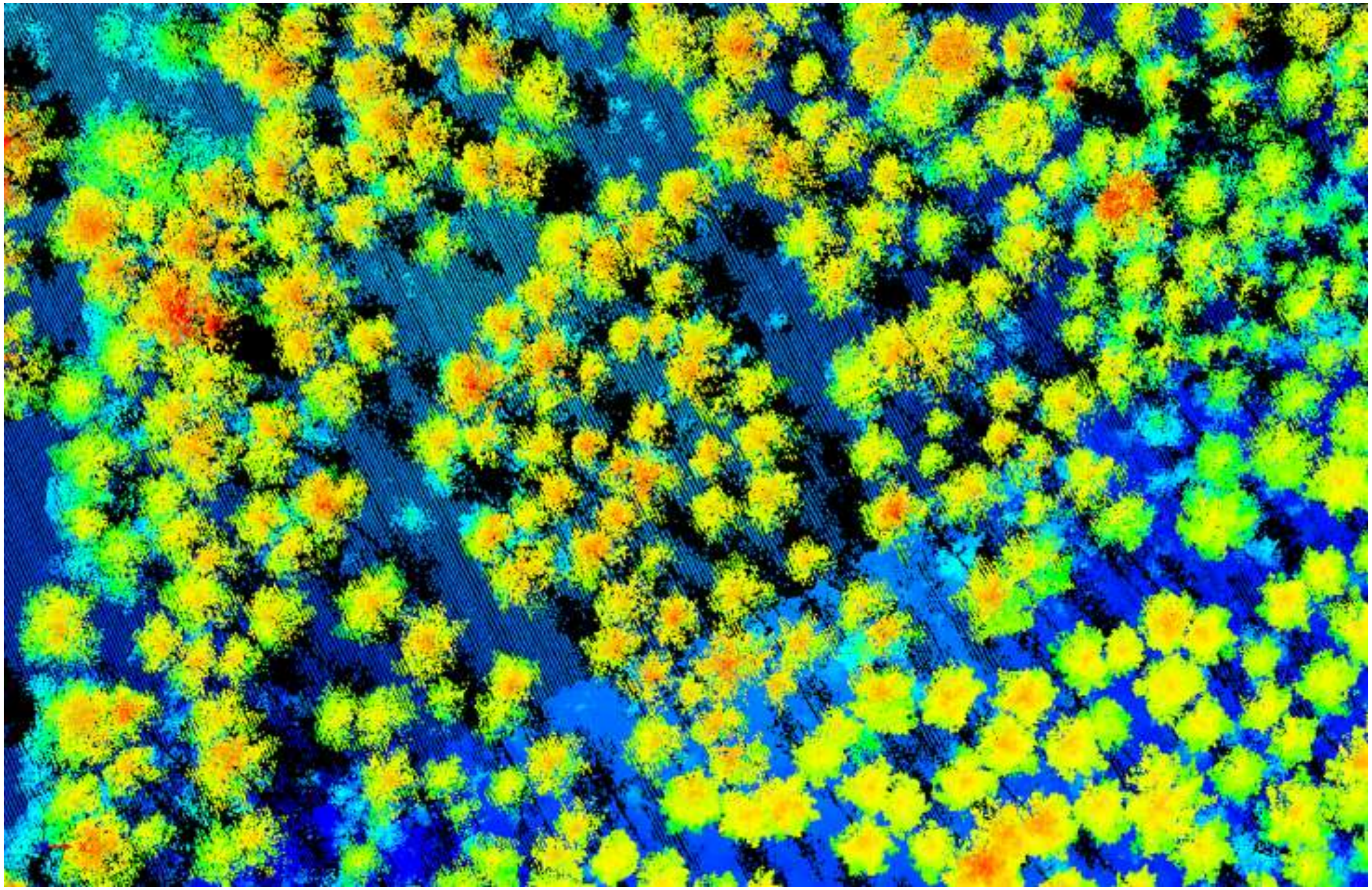
# Applications and Impact

- Ecological for measurements (no transfer cost/pollution of large planes)
- Effective for Change-detection and multitemporal surveys (data also obtained when needed)
- Simulates ALS, but also for reference data collection
- Costs are going down
- New UAV applications
  - Powerline measurements
    - Operational pilot in September 2014 (first in the world)



# Change based national mapping: LS every 2-5 years

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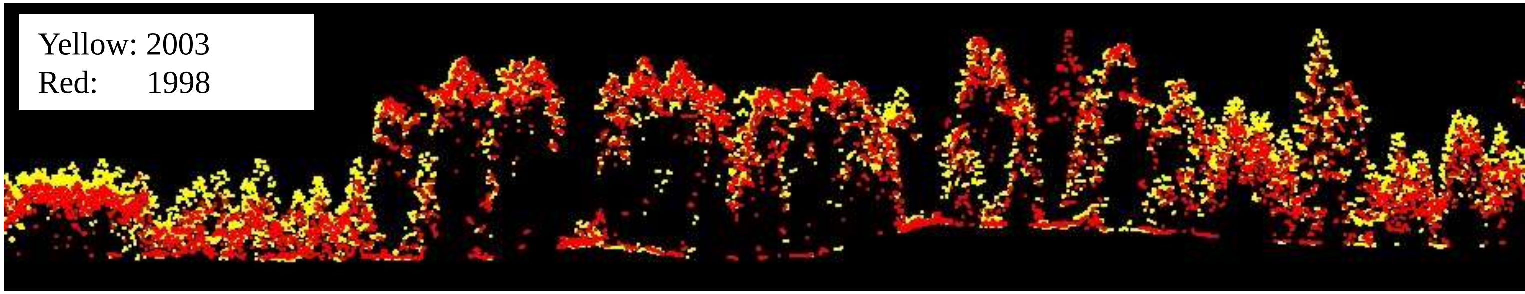
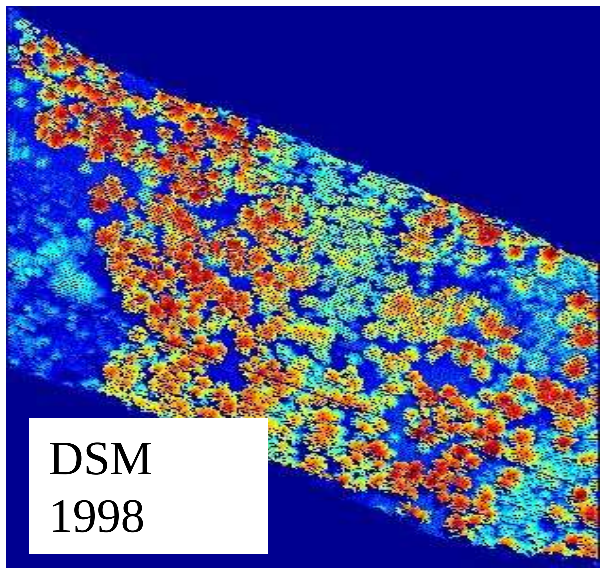
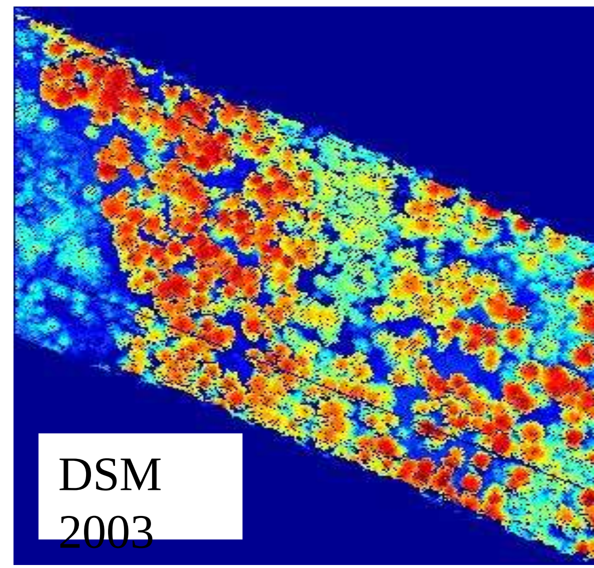
# Change Based Mapping




Hyyppä, J., Yu, X., Rönnholm, P., Kaartinen, H., and H. Hyyppä, 2003. Factors affecting laser-derived object-oriented forest height growth estimation, *The Photogrammetric Journal of Finland,* Vol. 18(2), 16-31.

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**Courtesy to Xiaowei Yu, FGI**

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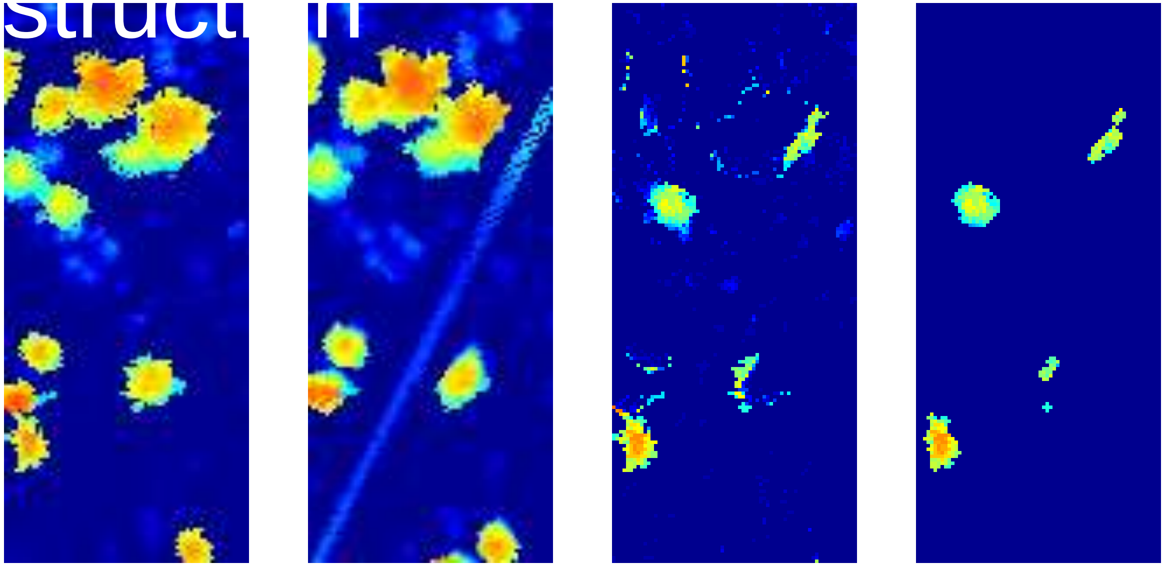
# This change monitoring capacity would cost in Finland 1€/person per year



Yu, X., Hyyppä, J., Kaartinen, H., and M. Maltamo, 2004. Automatic detection of harvested trees and determination of forest growth using airborne laser scanning. *Remote Sensing of Environment*, Vol. 90, 451-462

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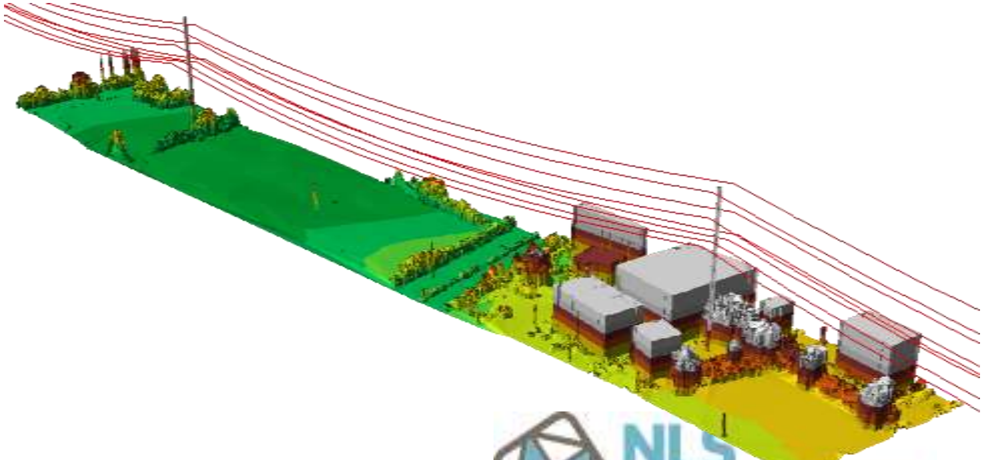
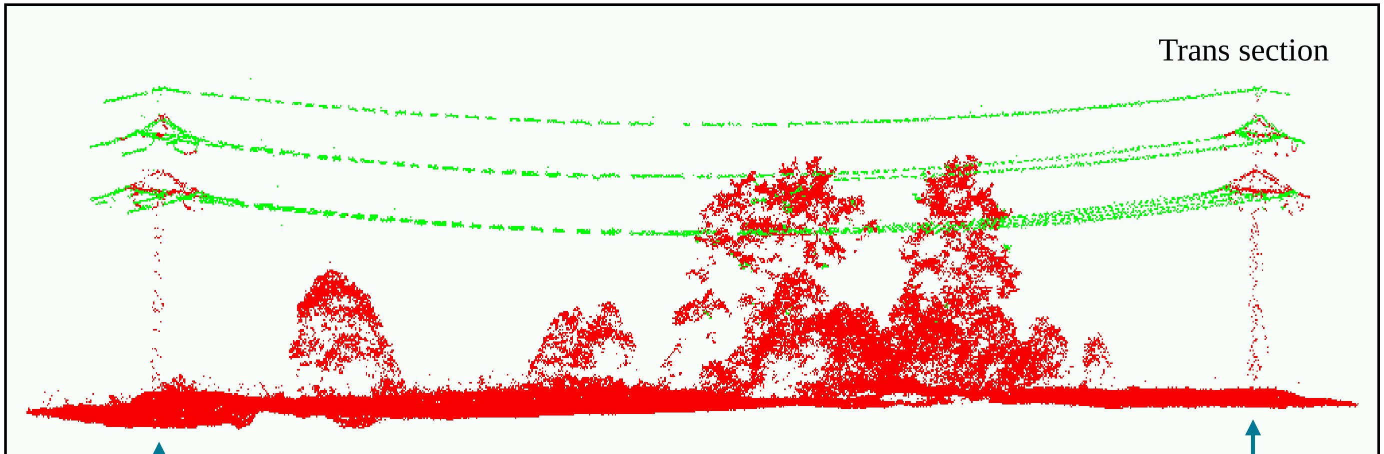
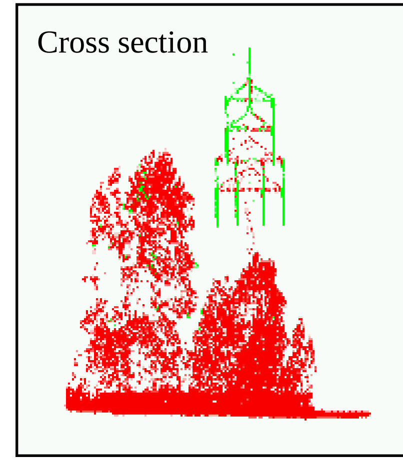
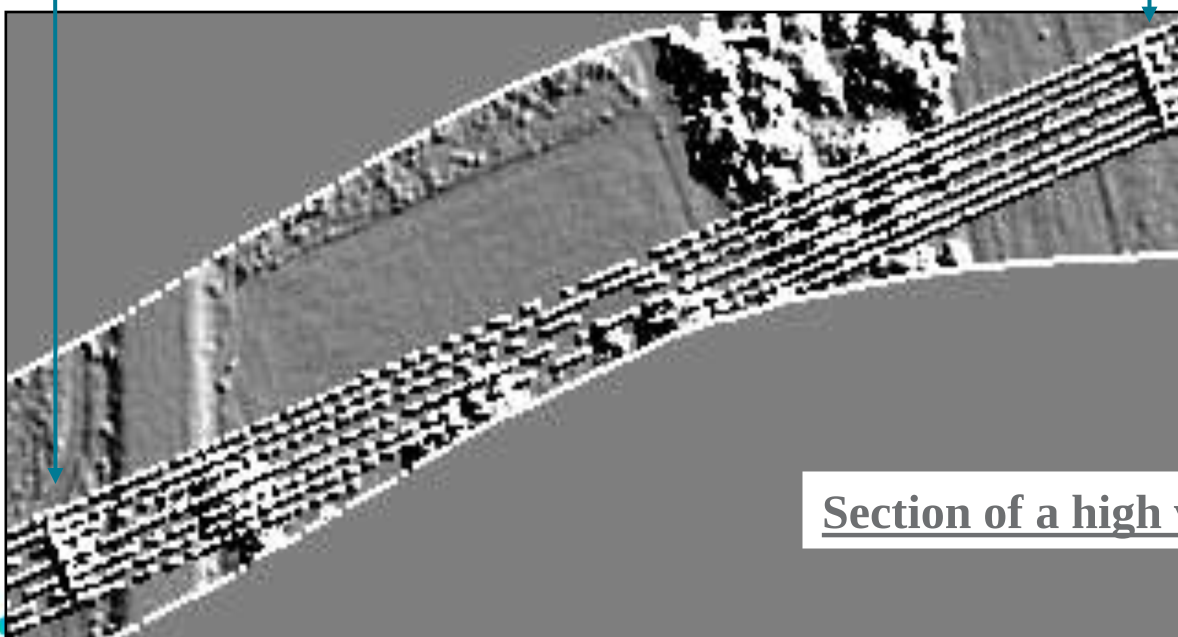
# UAV for Trees near Power lines



# **I**ntegrated **H**elicopter **C**orridor **M**apping

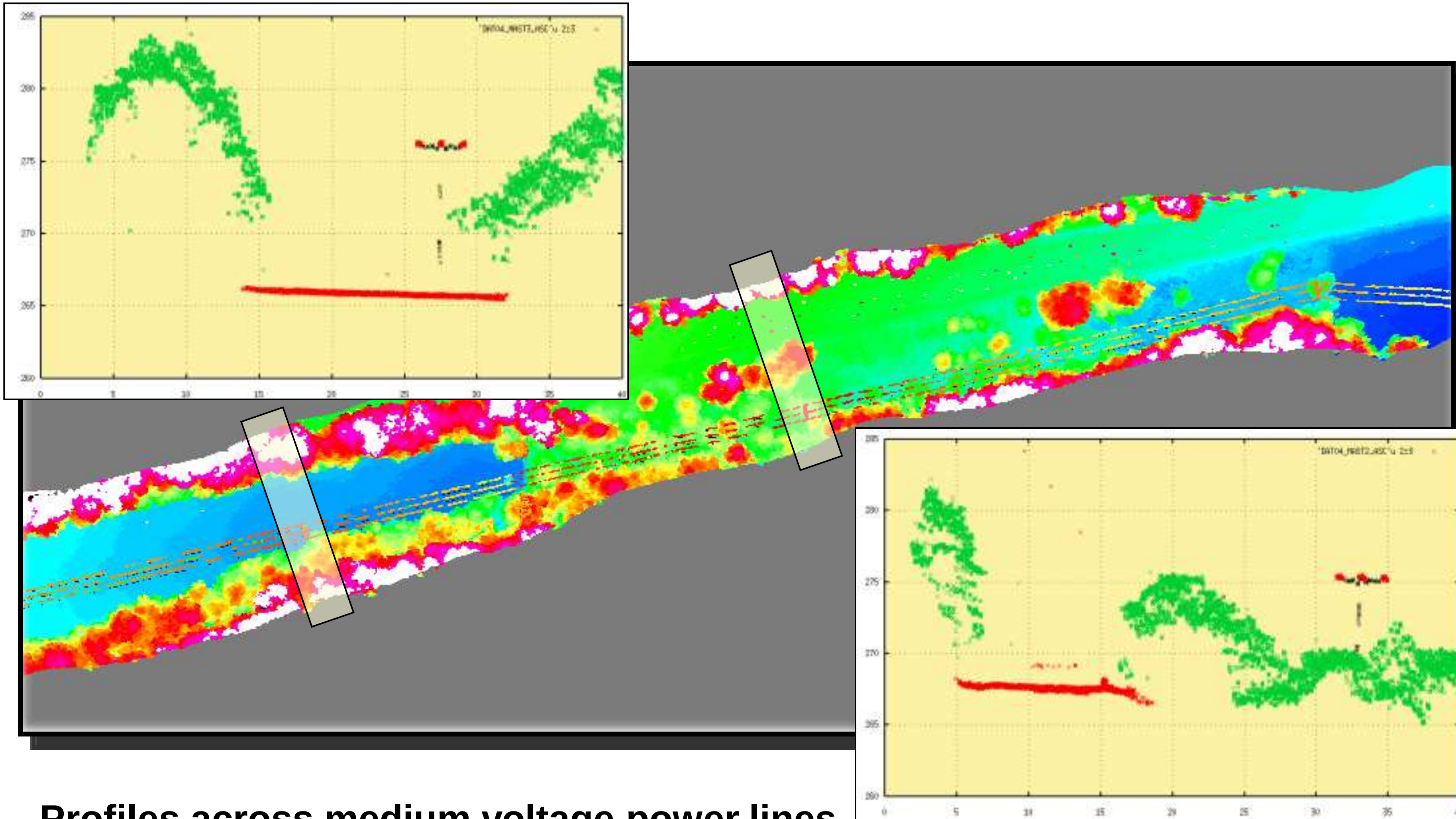


Digital Surface Model DSM,
0,5 m resolution

**Section of a high voltage power line**



# Profiles across medium voltage power lines

Pseudo-colour presentation of DSM raw data, 0.1 m grid

27 May 2014 Last updated at 23:52 GMT

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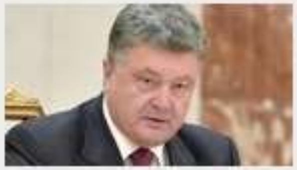
# Tree-mapping drone start-up has sky-high ambitions

By Mark Bosworth
BBC World Service, Helsinki


## Top Stories



'Russian
deployed

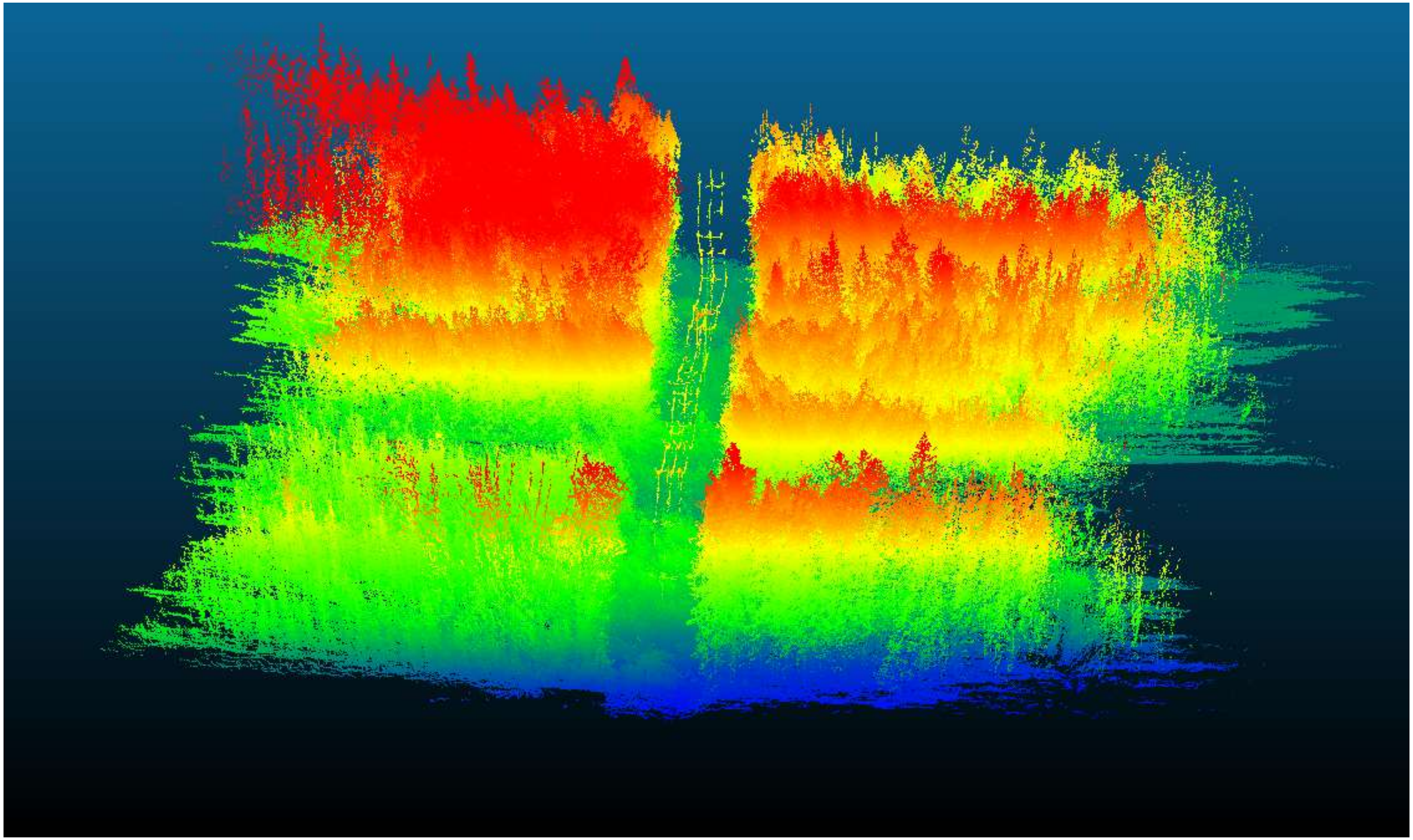
IS 'kills dozens of Syrian soldiers

Ebola spreads to Nigeria oil hub

Missing plane search area refine

France urges special Libya supp

# World’s first mini-UAV-LS operational corridor mapping, Sept 2014



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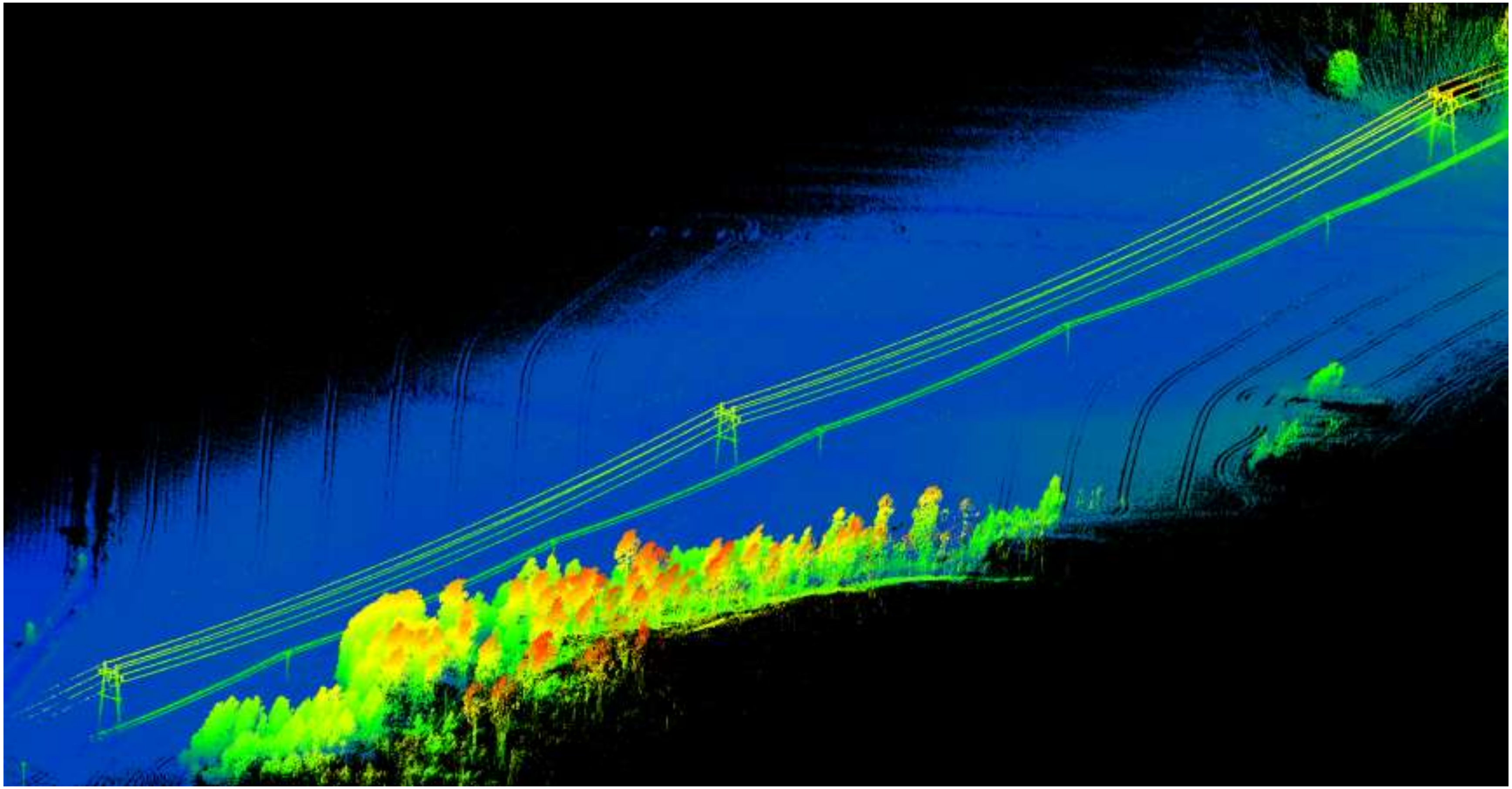

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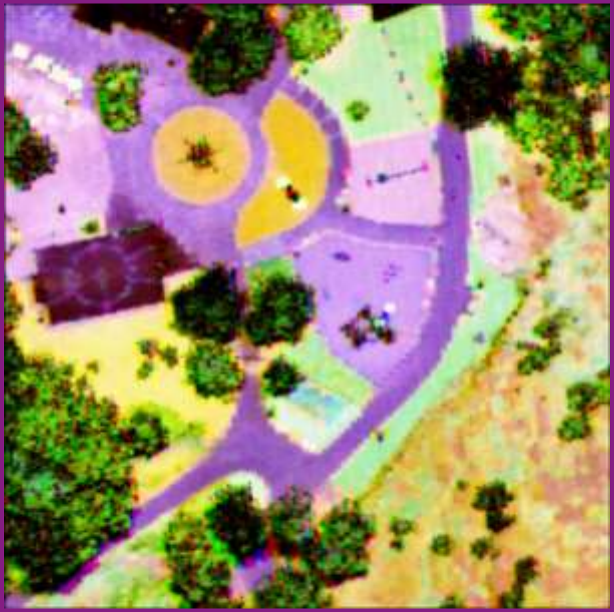
# Multispectral LS



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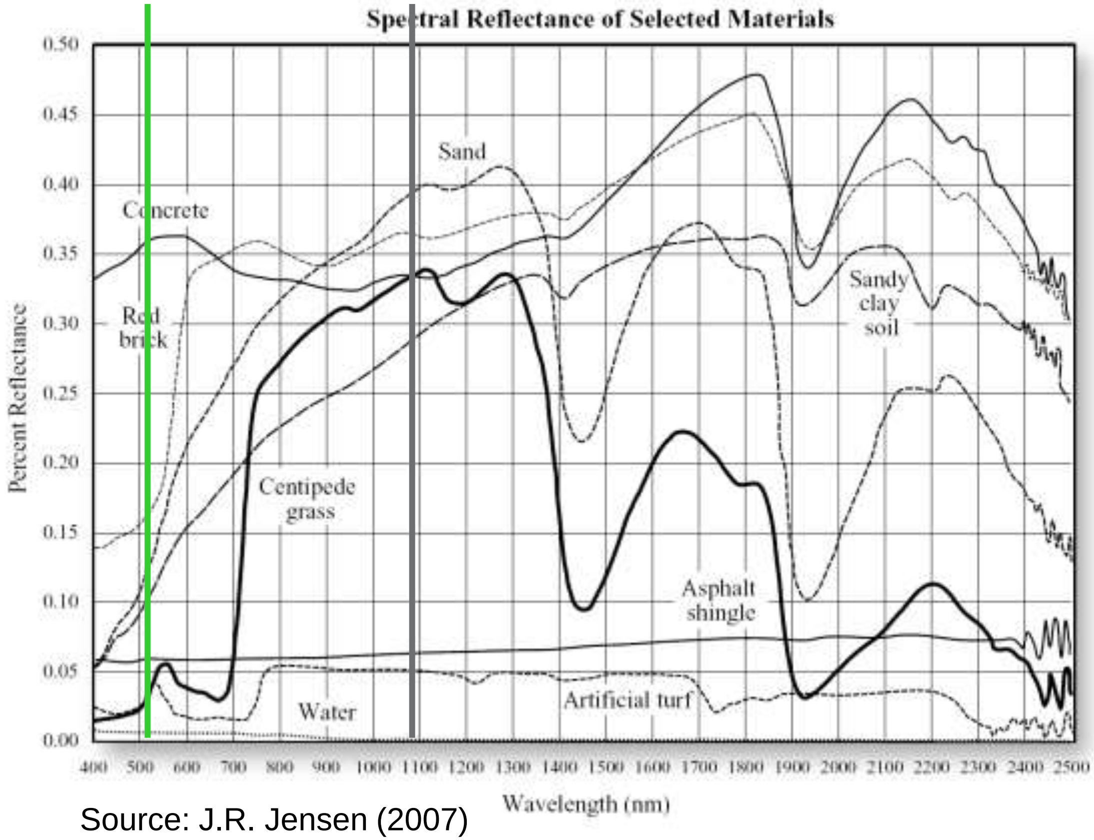
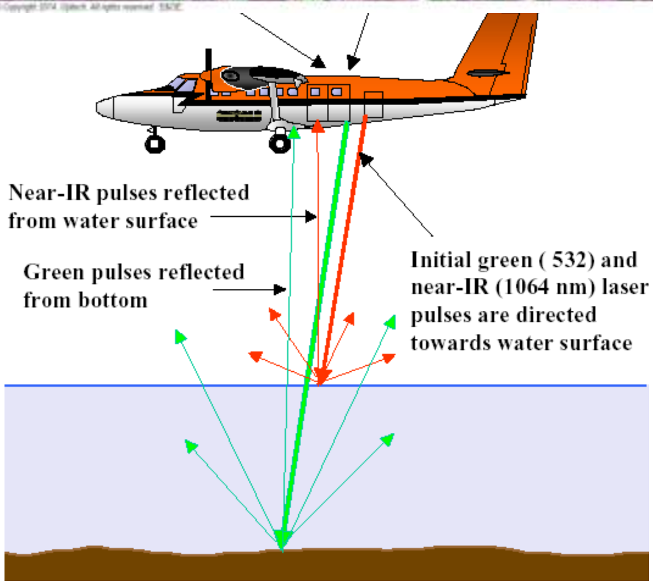
# Multispectral ALS

- Distinguish echoes from different materials




Source: J.R. Jensen (2007)


Source: http://www.optech.on.ca

# Optech Titan

- 3 wavelengths for imaging and classification
- Radiometrically consistent image – night or day
- Green laser for shallow water bathymetry
- 3x300=900 kHz: very dense point cloud
- Full waveform digitizer
- 80 Mp RGB/CIR camera
- Gyrostabilized mount

# Multispectral LS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