Terrestrial Laser Scanning

5. Lecture

Airborne laser scanning

Ing. Tomáš Křemen, Ph.D.

Presentation was supported by 105 1052201A003 FCE CTU in Prague Internal Project

Contents

- Airborne laser scanning (ALS)
- Wobbling of laser beam
- Errors of measurement
- Example of applications

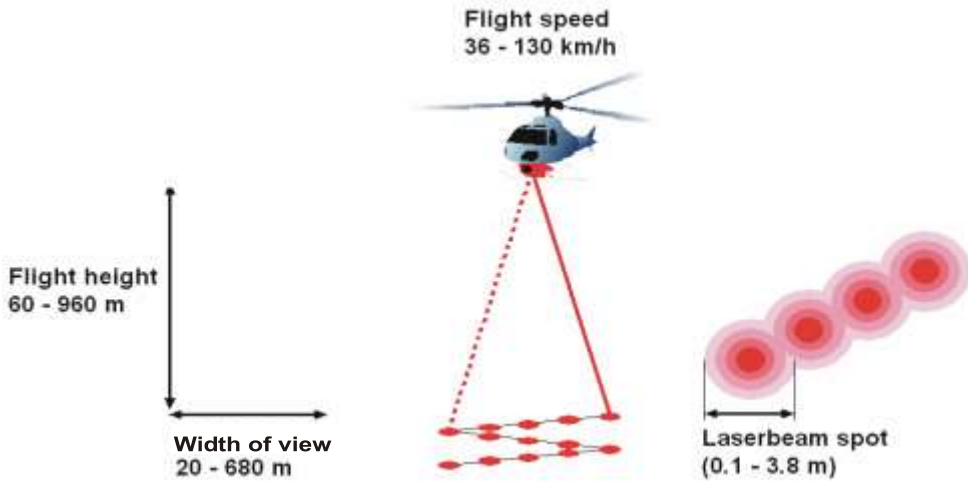
Airborne laser scanning

- ALS – airborne laser scanning
- An airborne laser scanning system consists of a scanner, an INS unit (Inertial Navigation System), a GNSS unit, a control unit and additional units (cameras, etc.)

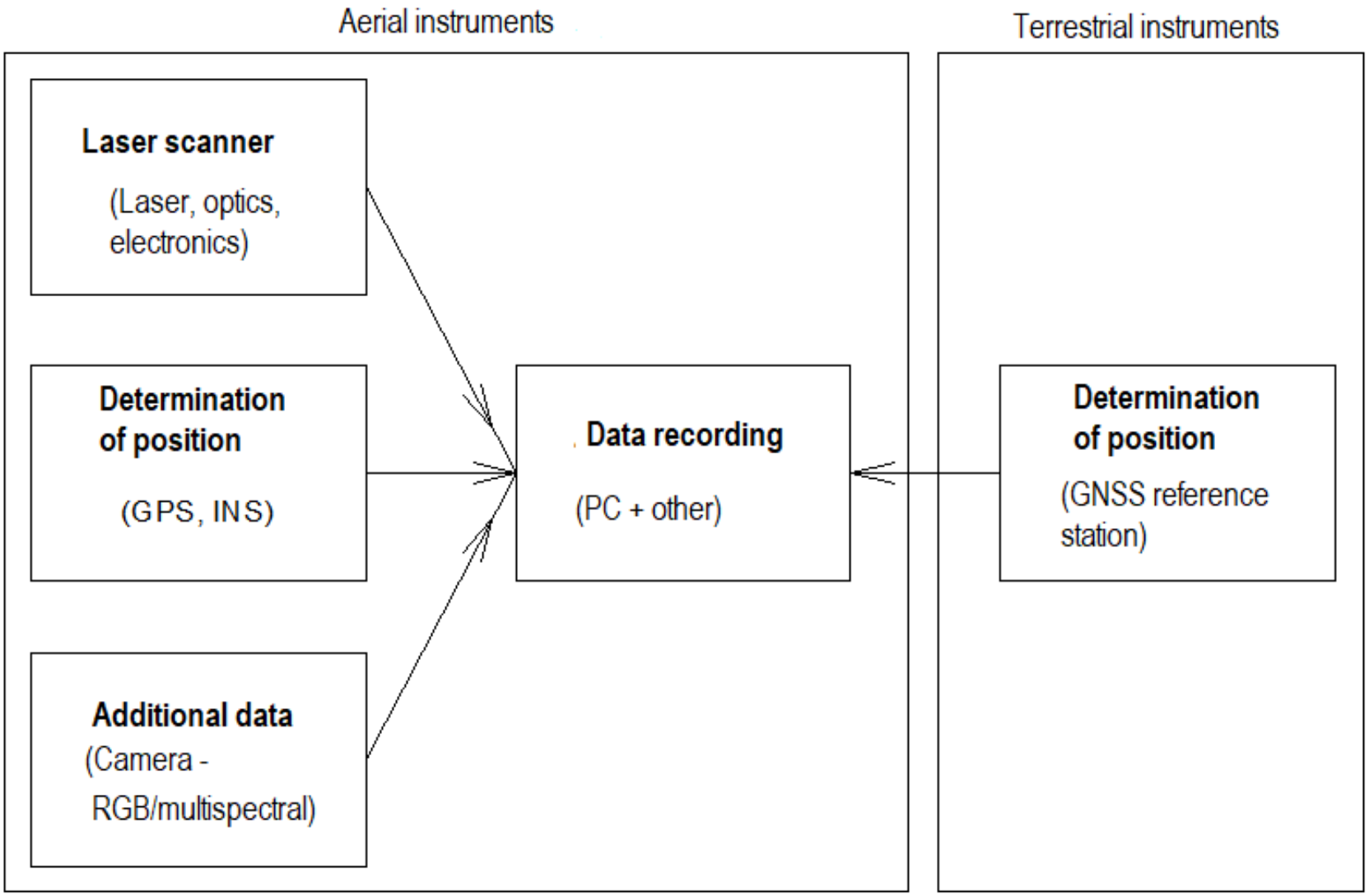
www.riegl.com

Airborne laser scanning

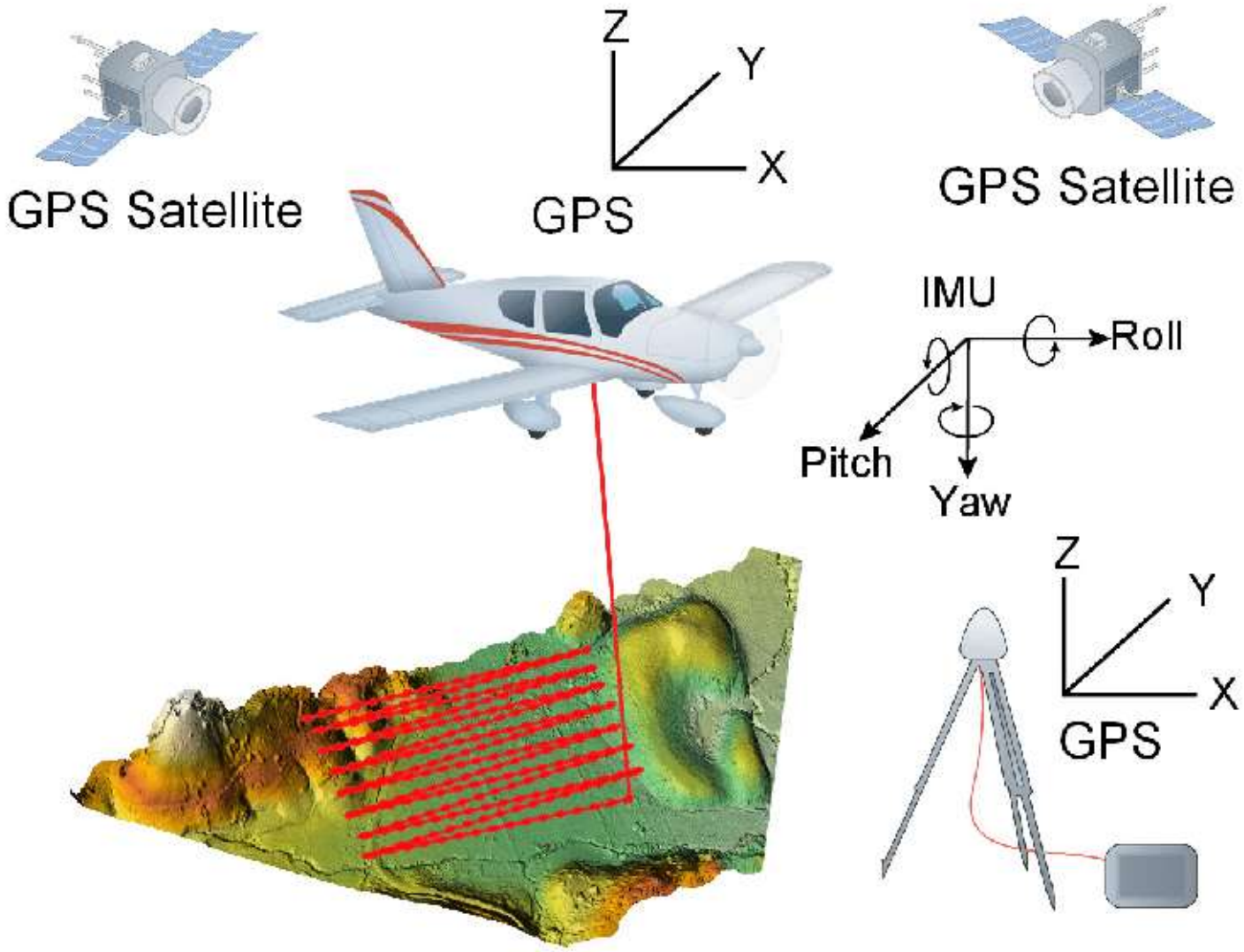
- The scanner only scans in "line", the additional dimension is provided by the movement of the airborne platform
- the constant, erratic and rapid movement of the scanner adds the need for continuous positioning and orientation (attitude), each point has an attitude
- The attitude data (position and spatial orientation) is recorded by GNSS and INS units



Airborne laser scanning- scheme

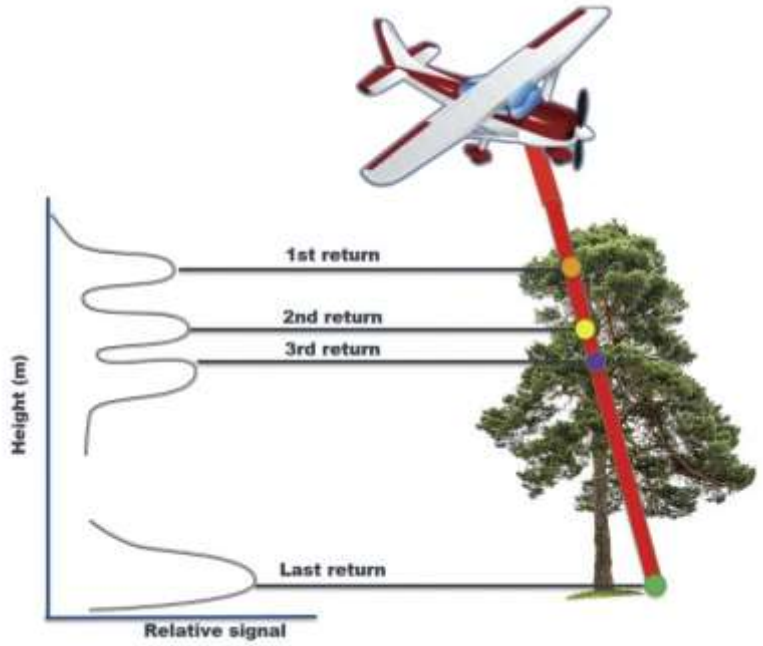


Airborne laser scanning- scheme



Airborne laser scanning

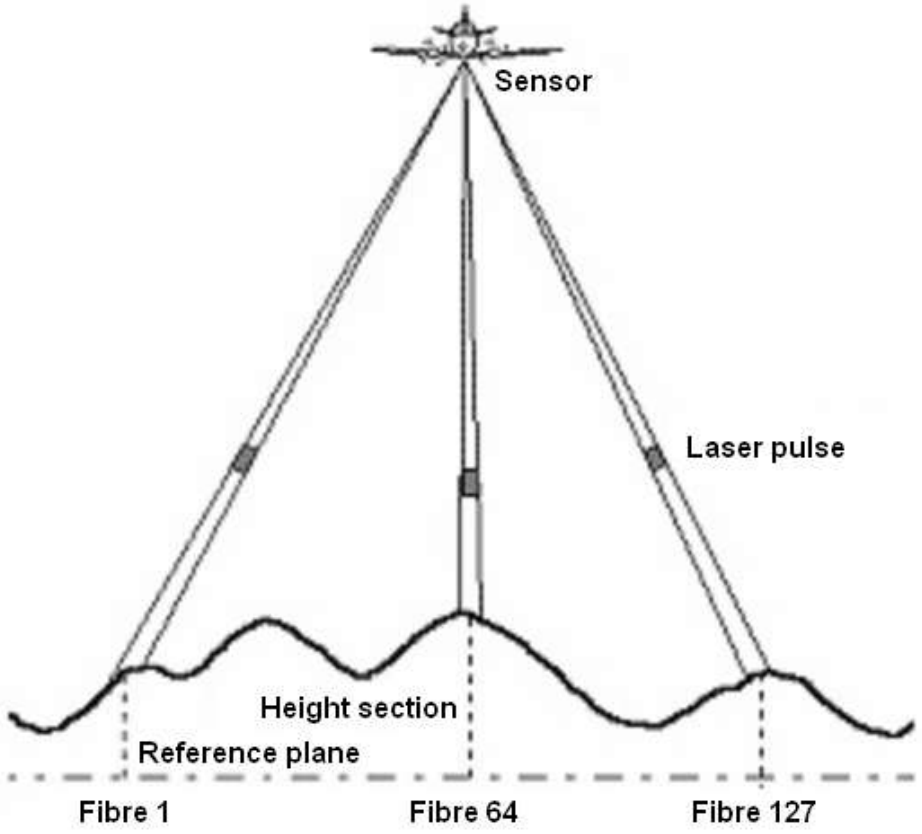
- Scanner
  - High-speed laser pulse rangefinder (sometimes in combination with phase measurement), passive reflection, measurement speeds in the hundreds of thousands of points per second
  - For most airborne scanners, echo (reflection serial number) can be recorded, from 2 to 14 or more reflections, depending on type and manufacturer



https://www.newport.com/n/lidar

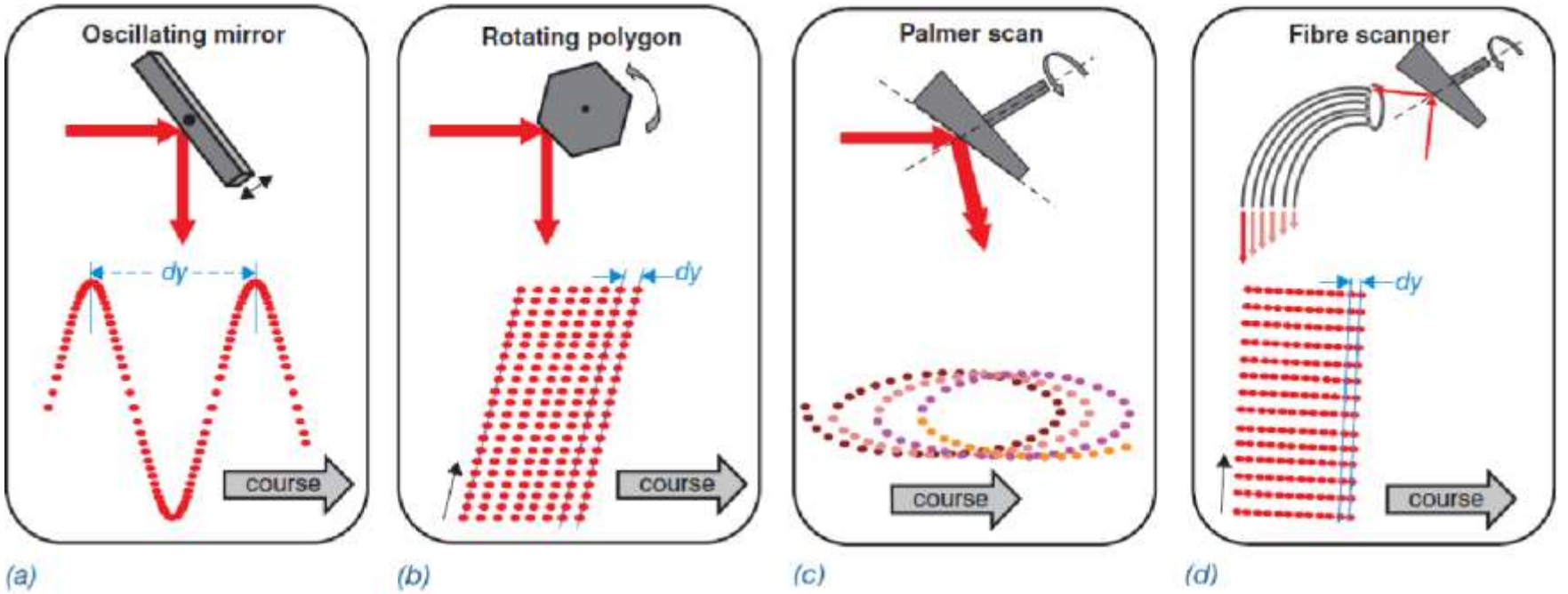
Airborne laser scanning- measuring

- The scanning angle varies depending on the scanning system. It ranges from 14° to 60°
- Beam footprint size diameter from 0.1 m to several meters, depending on the system (beam divergence) and flight height.



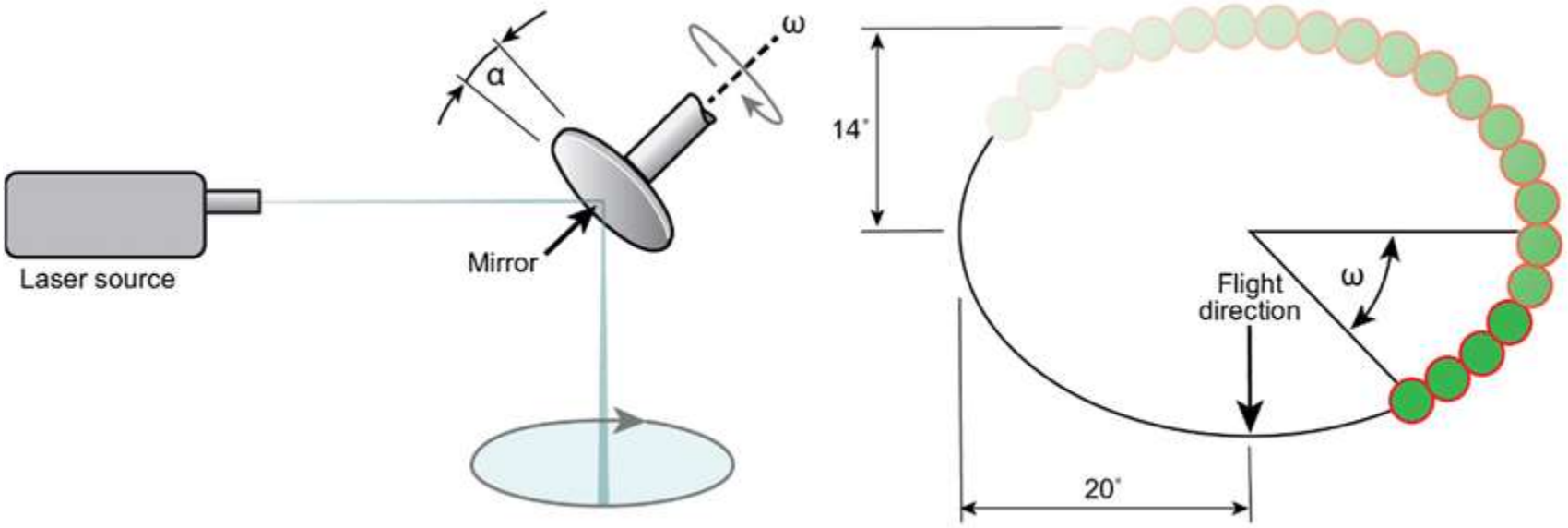
Airborne laser scanning– wobbling of laser beam

- Wobbling of laser beam can be performed by a) oscillating mirror (sawtooth lines of points), b) rotating polygon (parallel lines of points oblique to the direction of flight), c) specially rotating mirror (Palmer scanner, elliptical lines of points), d) optical fibers (parallel lines of points perpendicular to the direction of flight)



Airborne laser scanning

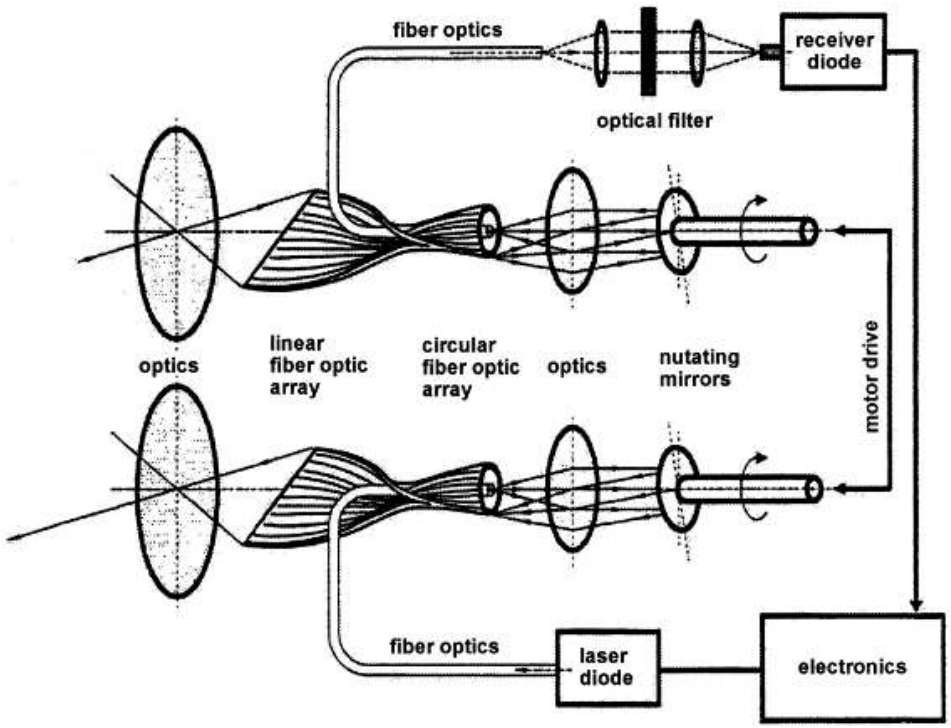
- Palmer scanner

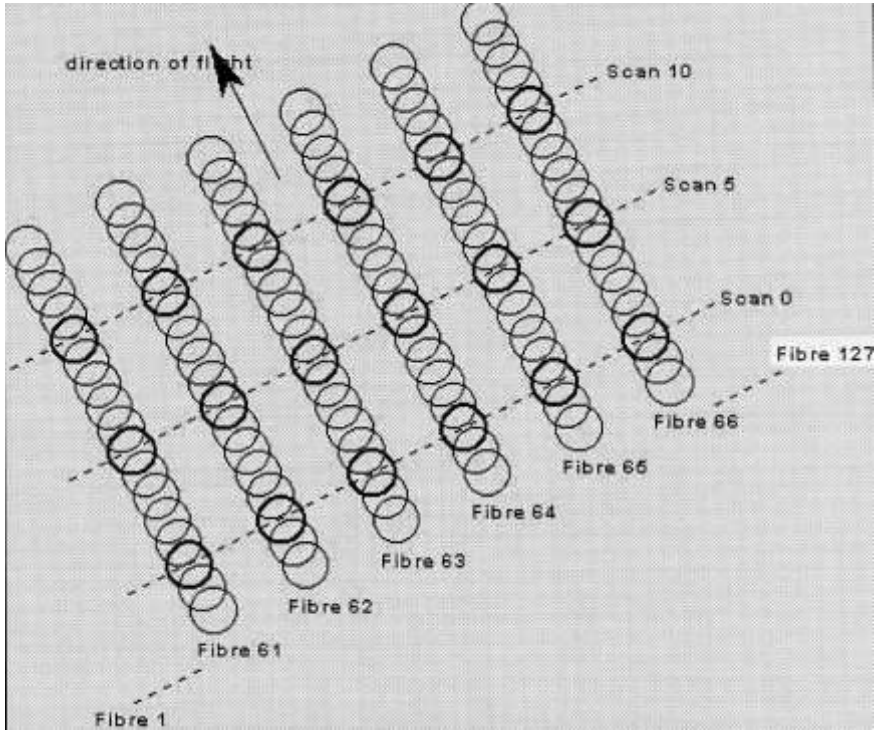


Citation:
Saylam, Kutalmis & Averett, Aaron & Costard, Lucie & Wolaver, Brad & Robertson, Sarah. (2020). Multi-Sensor Approach to Improve Bathymetric Lidar Mapping of Semi-Arid Groundwater-Dependent Streams: Devils River, Texas. Remote Sensing. 12. 2491. 10.3390/rs12152491.

Airborne laser scanning

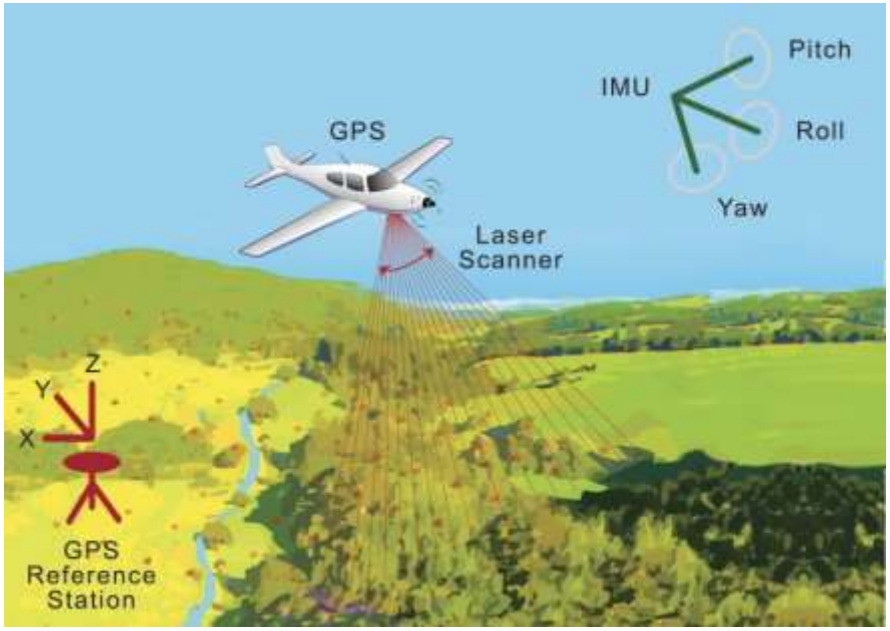
- Scanner with optical fibers





Airborne laser scanning

The airborne LiDAR system is comprised of three major time-synchronized components: a laser scanner unit, a GPS, and an IMU. The laser scanner is composed of a laser range finder unit, which is based on time-of-flight distance measurement techniques, and a beam deflection device that creates the desired scanning pattern. The GPS provides the absolute position of the sensor platform (plat), and the IMU records the angular attitude of the platform (including roll, pitch, and yaw/heading). This enables the system to generate the aircraft's absolute position (X, Y, Z) at any given time. The position is synchronized using the detector's recording system for each recorded reflection. The required recording speeds and the amount of collected data require strong, real-time computation capabilities on board the aircraft.



https://www.newport.com/n/lidar

Airborne laser scanning – Airborne platforms

- Airplane × helicopter, UAV
  - for the determination of the digital terrain model and measurement of flat areas, the laser system is usually installed in the airplane, for the measurement of objects where greater accuracy and density of points is required, it is necessary to install the system in a helicopter or UAV.
- Airplane:
  - usually flies at an altitude of 200 to 1,600 metres at a speed of around 200 km/h. The spacing of the laser tracks is therefore about 0.4 m in the longitudinal direction and 2 m in the lateral direction (Toposys). The absolute accuracy of the measured points is between 0.1 and 0.3 m.
- Helicopter/UAV:
  - offers the possibility to fly significantly slower than an airplane and even at a very low altitude. The density of points can therefore be several times higher.
  - The density of the points together with the accuracy of around 2 cm allows for use even in engineering surveying.

Airborne laser scanning– errors of measurement

Callibration:

- it is a very complex system; it is necessary to regularly calibrate individual components and the whole system.
- pre-flight (mainly setting the individual components of the system to the correct functional state),
- post-flight (mainly determining the spatial relationships of the individual components, or the possibility of detecting and correcting systematic scanner errors).

- "External" measurement errors:

  - GNSS errors,

  - INS errors.

Airborne laser scanning– errors of measurement

Laser error

- sending a pulse at the wrong time.

Detector error

- detection of weak reflection (noise),
- detecting too strong a reflection (saturation, measuring shorter lengths),

Mirror errors

- Mirror angle determination error,
- torsion of an oscillating mirror (twisting of the axis due to momentum = inertia of the mirror).

Clock error

- Error in the measurement of time by the system clock, which usually has an upward tendency, can be mathematically modelled and introduced into the calculation,
- a time delay in the control unit resulting in a systematic error in position.

Airborne laser scanning– errors of measurement

Integration errors

- Control and monitoring unit errors, especially failure to ensure that all measurements must be referenced to the same timeline, as each component usually has its own clock.

Influence of the atmosphere

- the path of the beam is not a straight line, but is a spatial curve, i.e. a longer distance is measured than the correct distance,
- the effect of atmospheric refraction is

  the smallest in the perpendicular direction

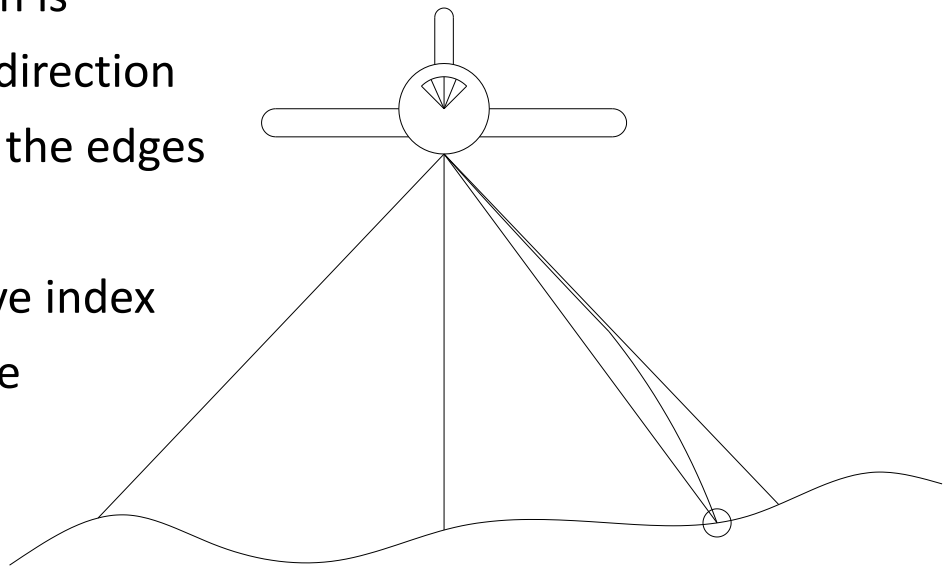
  towards the Earth, the greatest at the edges

  of the scan strip (spherical

  temperature distribution, refractive index

  is most dependent on temperature

  of the atmosphere),
- suppressed by models.



Airborne laser scanning– processing

- The data obtained from the scanner is very opaque (including 2 or more reflections) and contains errors or noise. Therefore, it is necessary to automatically preprocess them. If clouds are millions of points in size for ground scanners, they can be more than an order of magnitude larger for airborne scanning.
- Depending on the complexity, preprocessing is divided into Filtration and Classification.

Filtration

- finding the points of one surface. This is done e.g. with knowledge of the approximate course of the terrain or with respect to surrounding points.
- morphological filters,
- slope comparison filters,
- region growing filter,
- linear prediction.

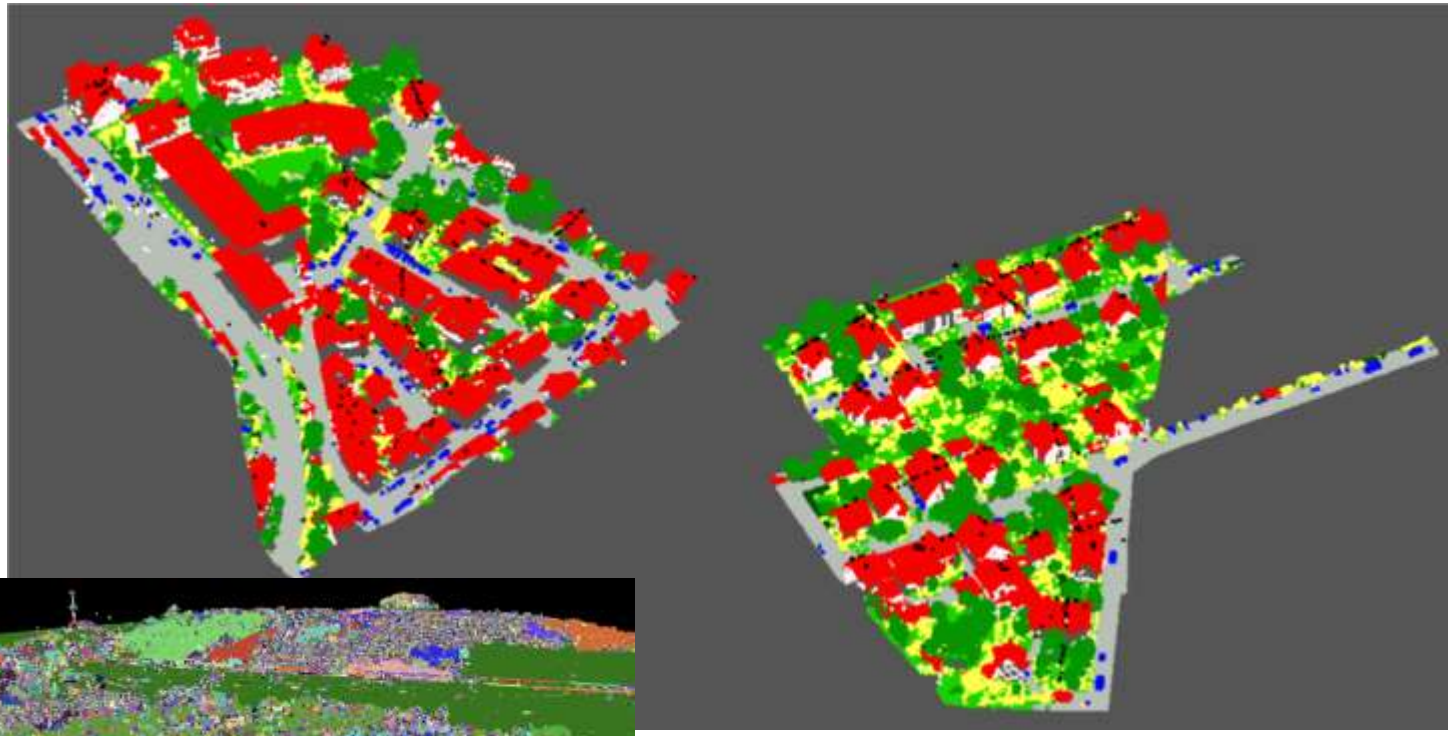
Airborne laser scanning– processing

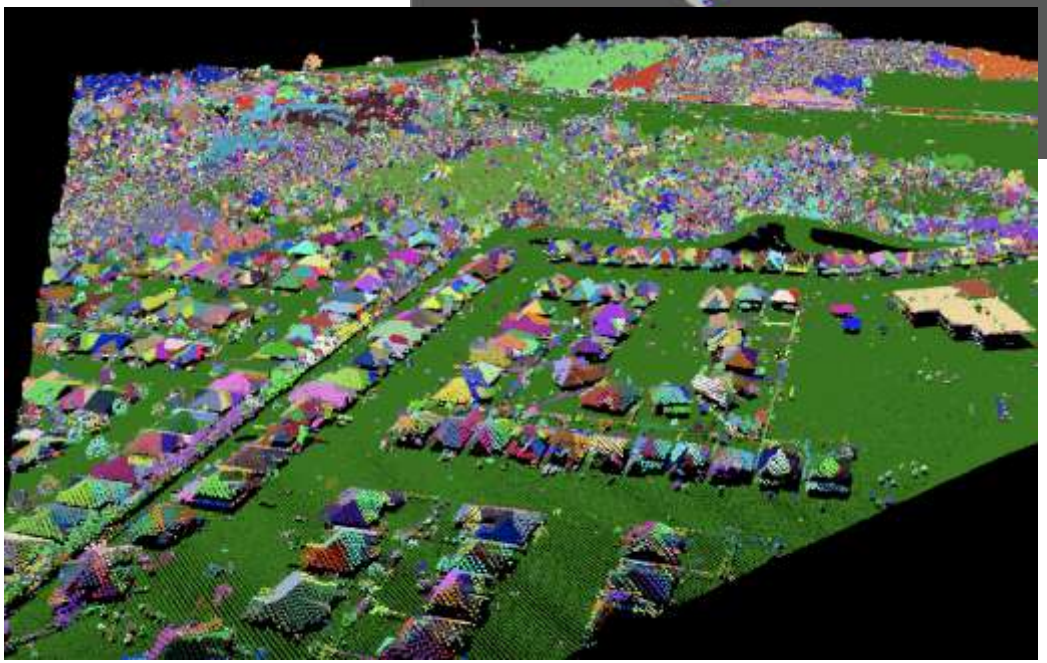
Classification and segmentation

- For larger works it is advisable to perform automatic classification, i.e. to divide the points into classes according to the type of object on which they lie. This is often done based on the height ratios of surrounding points, signal intensity or additional values from e.g. a camera or RGB scanner. Classification is performed in multiple cycles, where points of one class are selected in one cycle. The next cycle takes place without the already classified points. Usually the following classes are used:
- terrain,
- buildings,
- vegetation,
- bugs,
- then e.g. points under terrain, low vegetation, high vegetation,
- roads, elevation lines, terrain skeleton points + others according to the purpose of processing.
- Segmentation is the division of the cloud into individual elements

Airborne laser scanning– processing

Classification



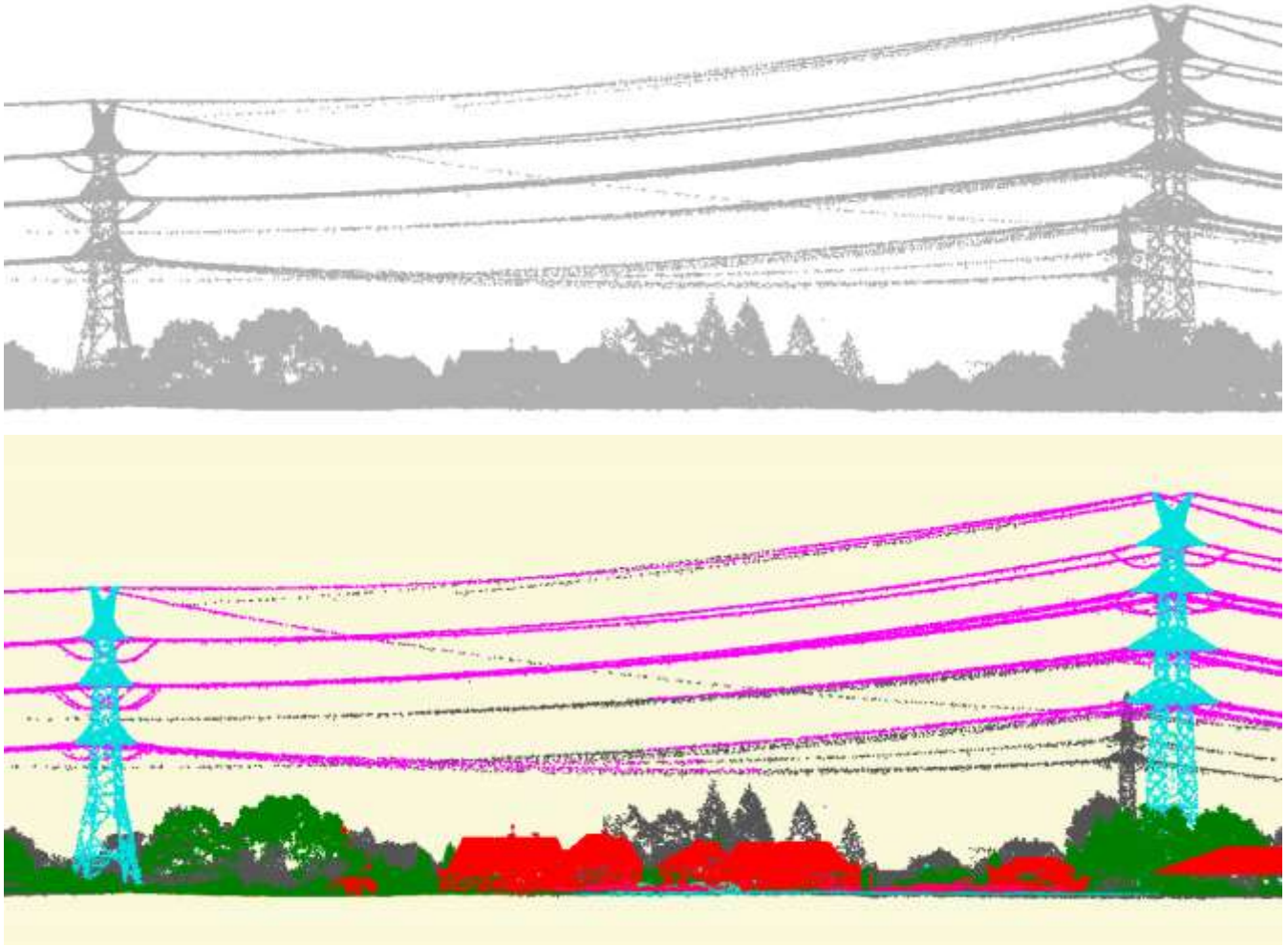


Airborne laser scanning– processing

- Classification - example of unclassified and classified data

Visible classes:

- Buildings
- Vegetation
- Columns
- Power lines



Airborne laser scanning– applications

ALS has applications in a wide range of areas

- DMT, DMP creation
- Vegetation mapping
- Coastal mapping and coastal bedform mapping
- Mapping of linear structures - roads, power lines
- And more

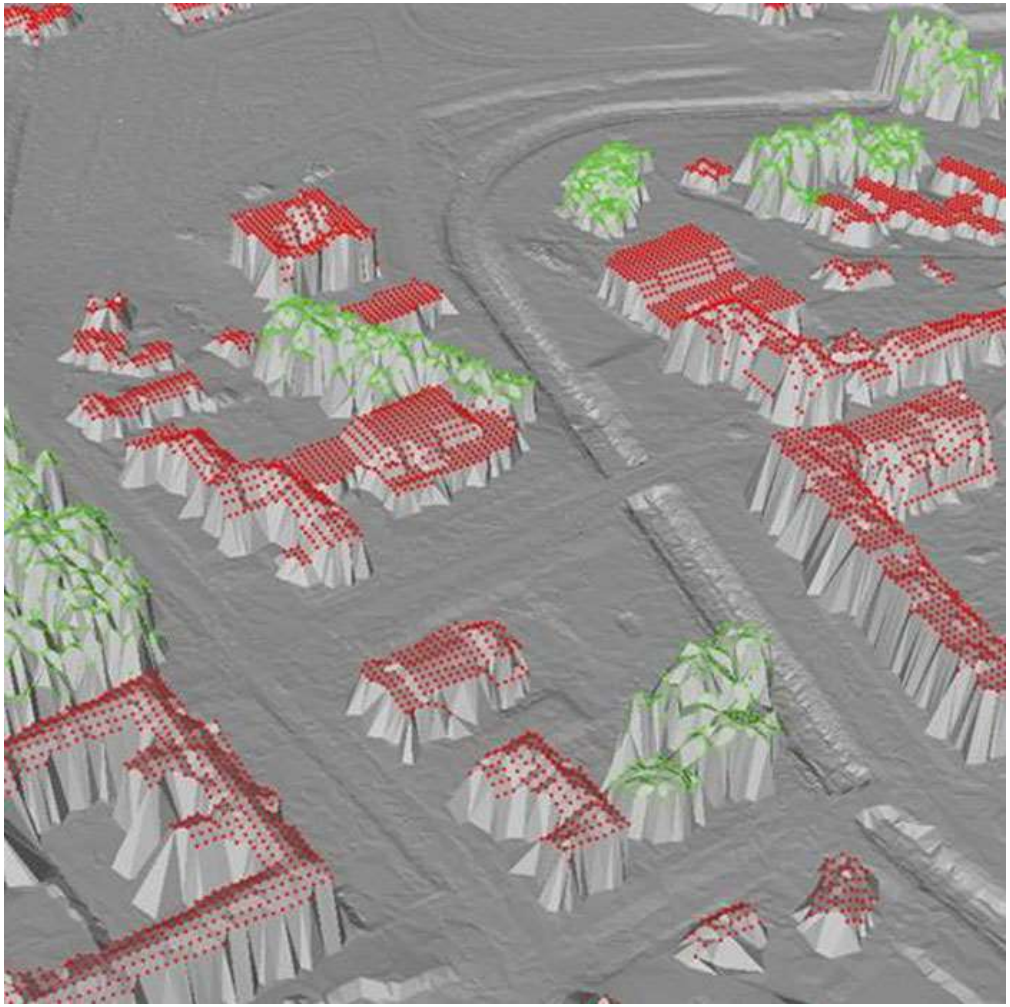
Airborne laser scanning– applications

Creation of DTM (Digital Terrain Model) and DSM (Digital Surface Model)

- Scanning of Czechia
- DMR 5G. Digital Terrain Model of the Czech Republic of the 5th generation (DMR 5G) - digital representation of the natural or man-made land surface in the form of heights of discrete points in a triangular irregular network (TIN) of points with a full mean height error of 0.18 m in exposed terrain and 0.3 m in forested terrain
- Digital Surface Model of the Czech Republic of the 1st generation (DMP 1G)- representation of the territory including buildings and vegetation cover in the form of an irregular network of height points (TIN) with a full mean error of 0.4 m for precisely defined objects (buildings) and 0.7 m for objects not precisely defined (forests and other elements of vegetation cover).

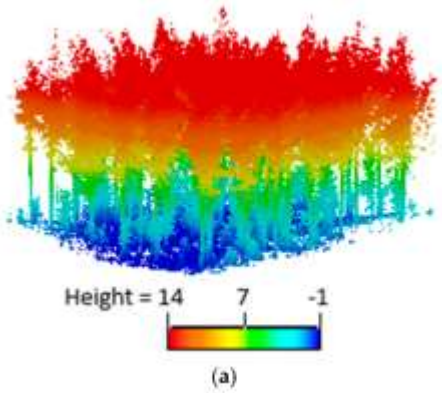
Airborne laser scanning– applications

DMP 1G

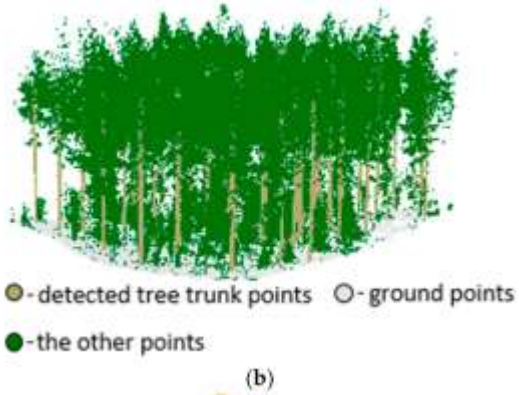


Airborne laser scanning– applications

- Vegetation mapping - determining the number of trees



(a)

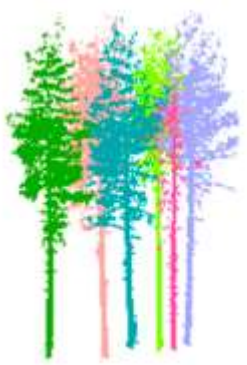


(b)

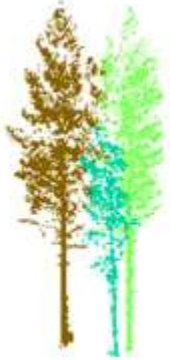

(c)

(d)


(a)


(b)


(c)

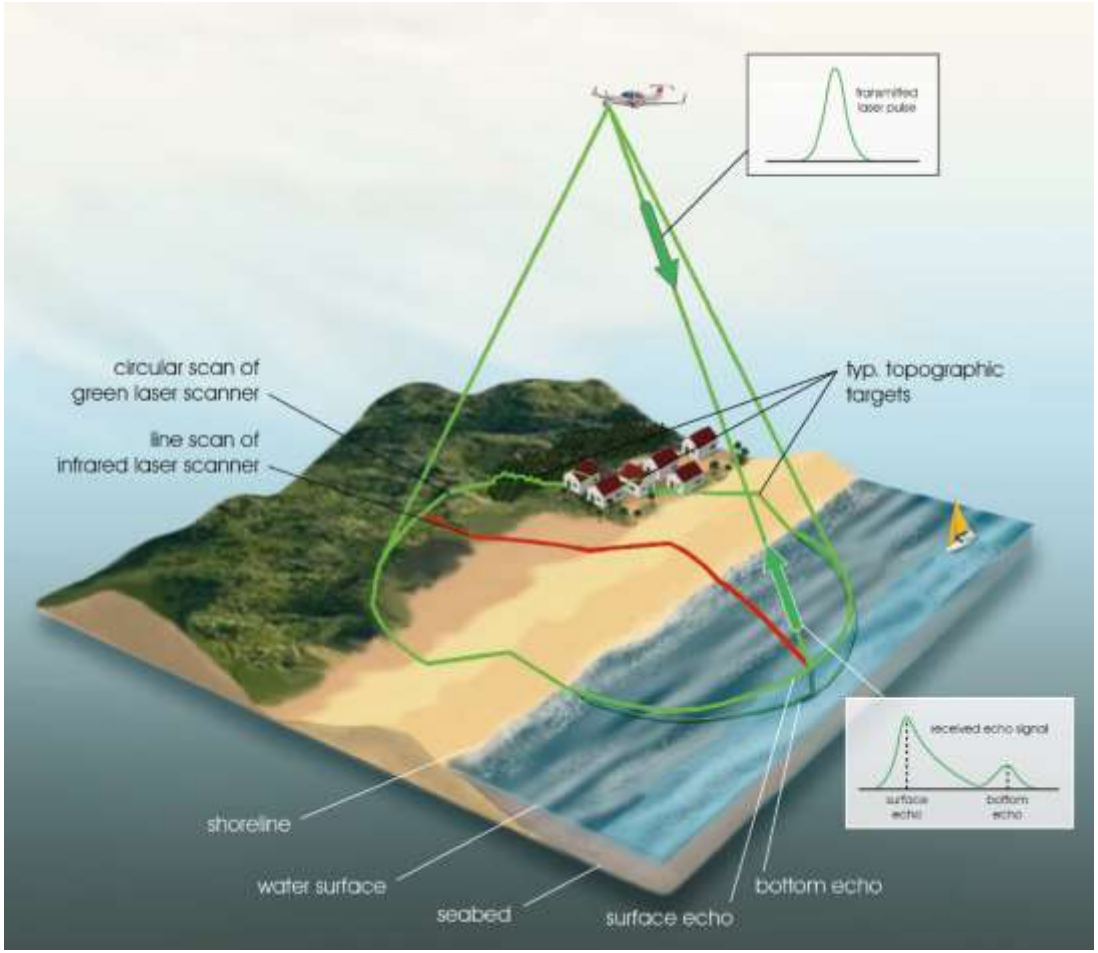

(d)


(e)

Airborne laser scanning– applications

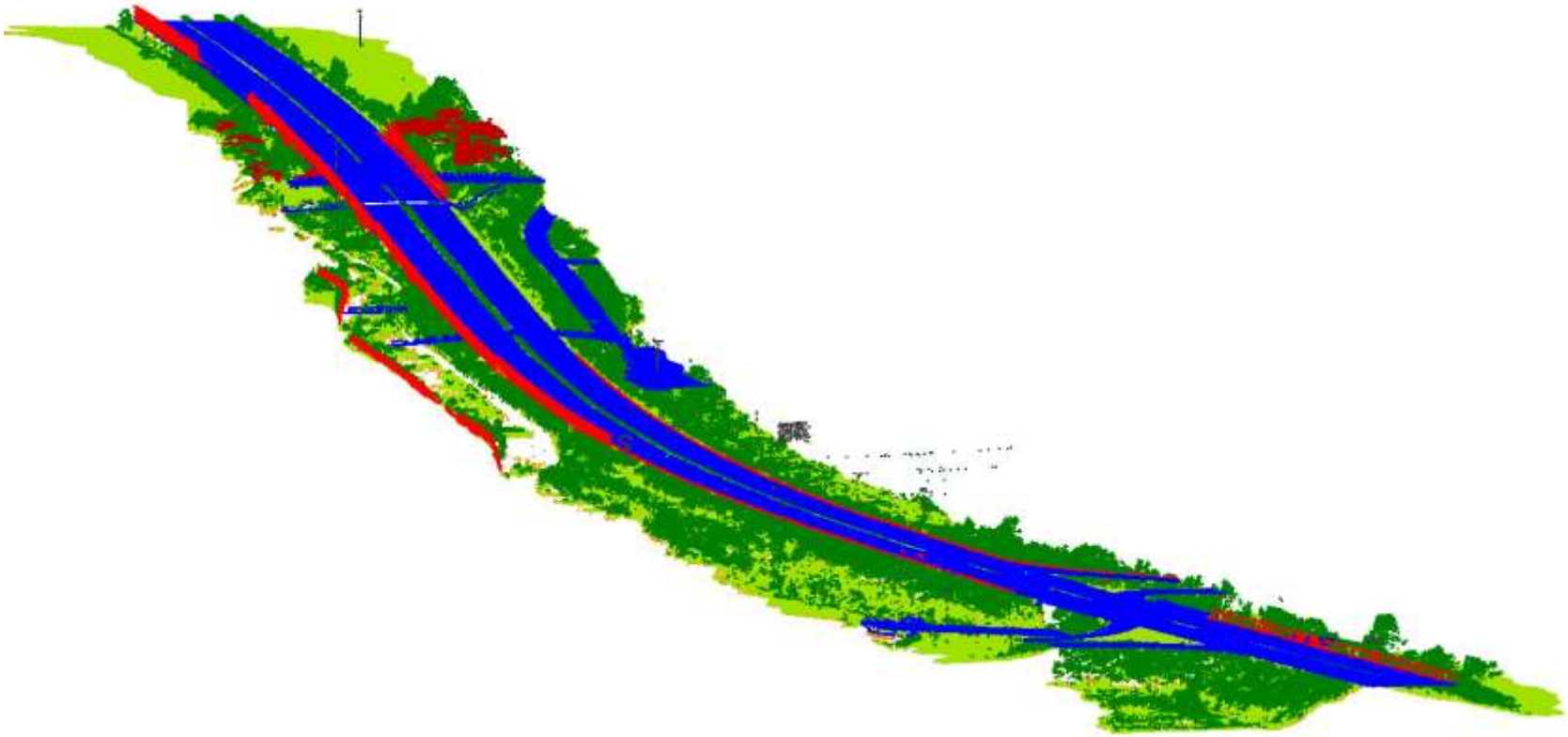
- Mapping of the coastline and the seabed of coastal waters

- Riegl VQ-880-GII



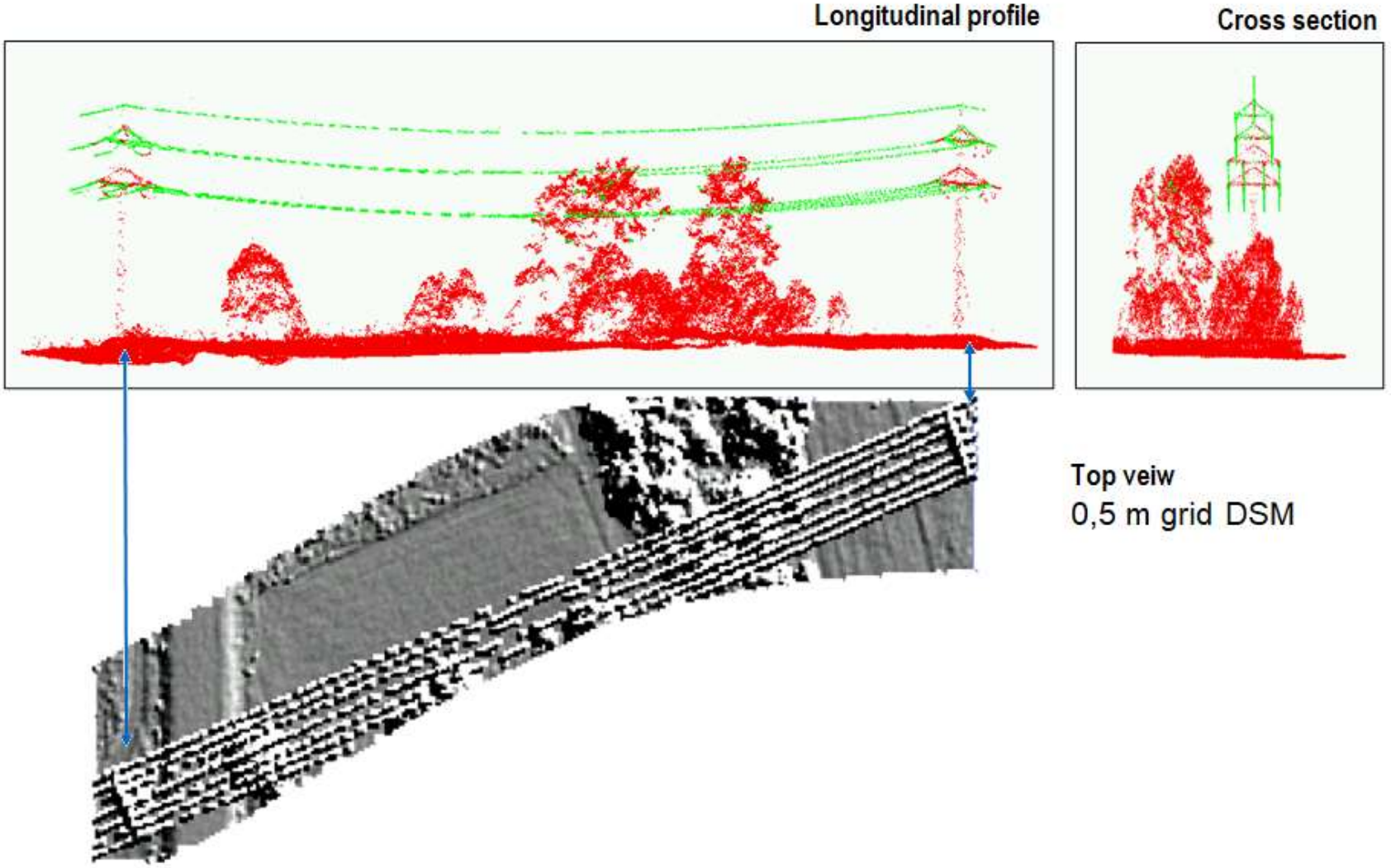
Airborne laser scanning– applications

- Mapping of linear structures - roads
- View of the classified point cloud of a section of highway. The data was acquired with FLIMAP, scan density is about 14 points per m^2.



Airborne laser scanning– applications

- Mapping of linear structures - part of high voltage power lines



Thank you for your attention!