The SPL 100 in Europe

Simon Musäus

Sr. Vicepresident Mapping

COWI

This is the COWI Group today

2018 net turnover: EurM **831**

Approx. **7,200** employees

World-class competencies within **engineering, economics and environmental science**

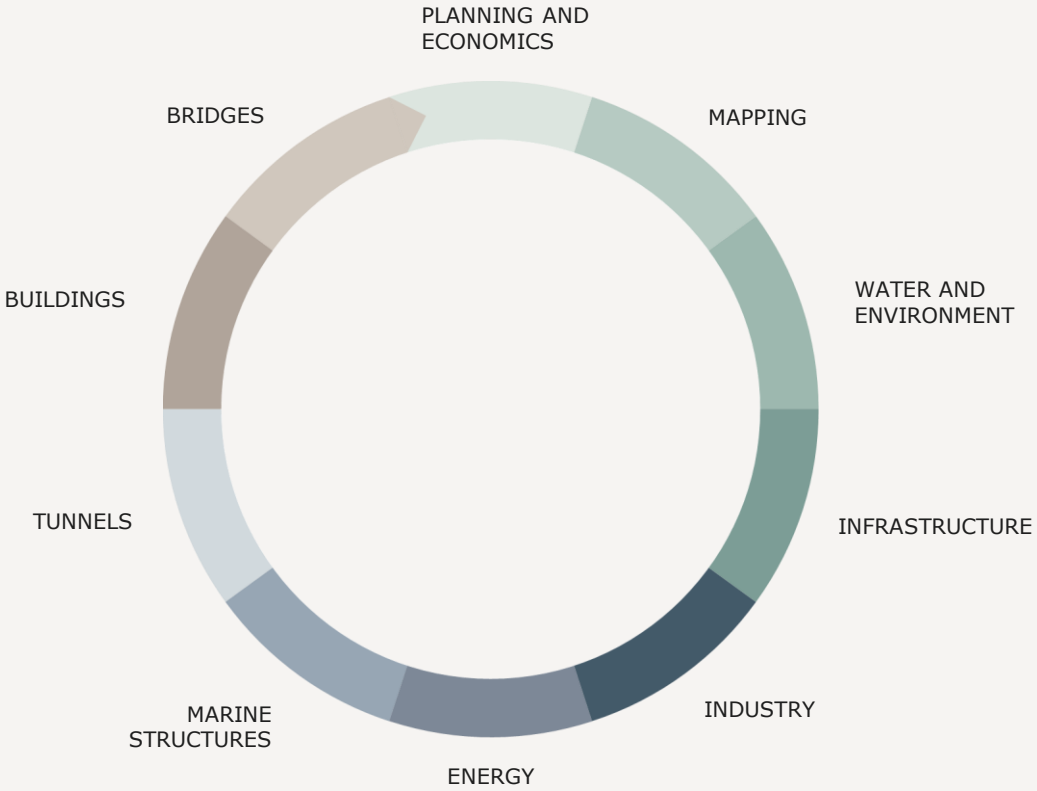
At any given time, **12,000** ongoing projects

88 years of history

COWI

Services

Delivering 360° solutions



COWI

World-class knowledge combined with worldwide presence

BAHRAIN
1 office

BELGIUM
1 office

CANADA
3 offices

CHINA
1 office

DENMARK
9 offices

GERMANY
1 office

HONG KONG
1 office

INDIA
3 offices

LITHUANIA
1 office

MOZAMBIQUE
1 office

NORWAY
17 offices

OMAN
1 office

POLAND
2 offices

QATAR
1 office

SOUTH KOREA
1 office

SWEDEN
13 offices

TANZANIA
1 office

TURKEY
1 office

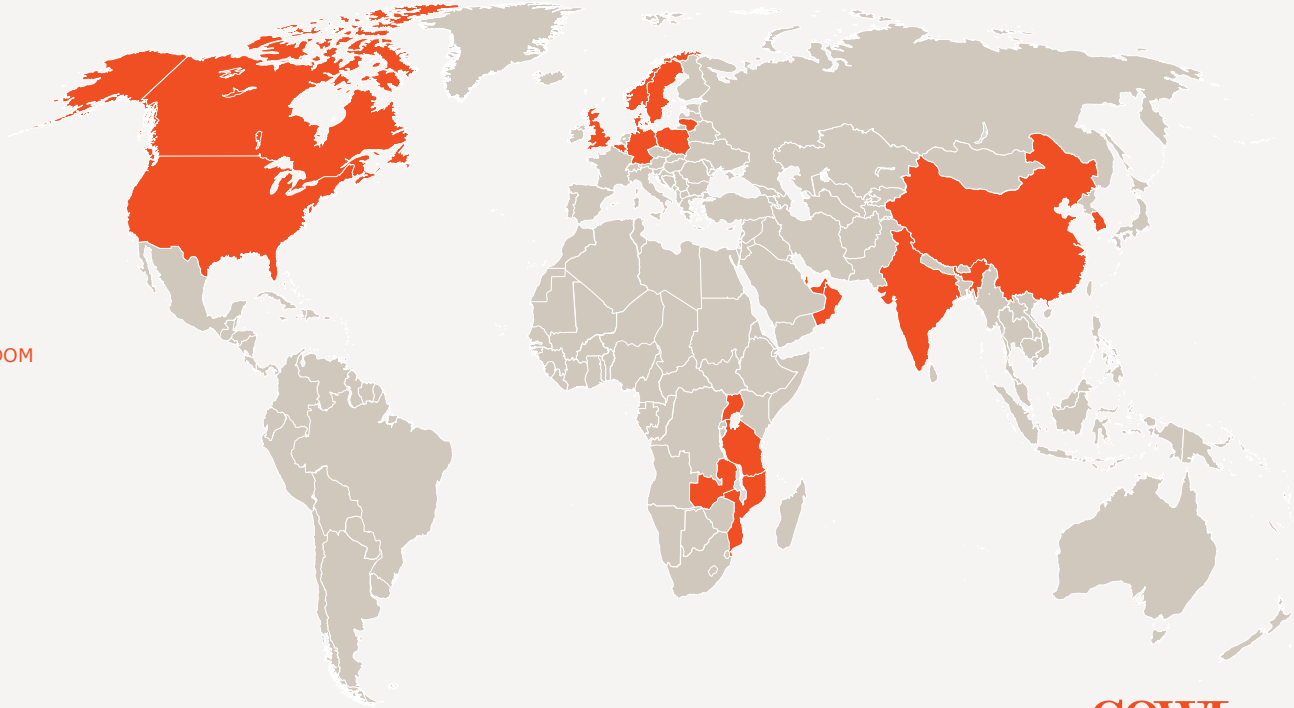
UAE
2 offices

UGANDA
1 office

UNITED KINGDOM
7 offices

USA
9 offices

ZAMBIA
1 office



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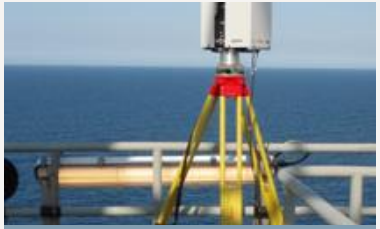
Geographical Information – Products and Services

Aerial Imagery

LIDAR
Digital Terrain Models
GIS-Datasets

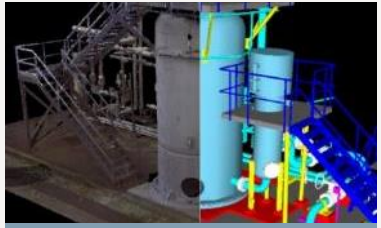
Thermography

Oblique imagery and
Panoramic View



Surveying and
As-Built Documentation

Infrastructure Inspection
Automated solutions



3D Models, BIM
Asset DB
Software solutions

Vegetationsmanagement
Risk Analysis

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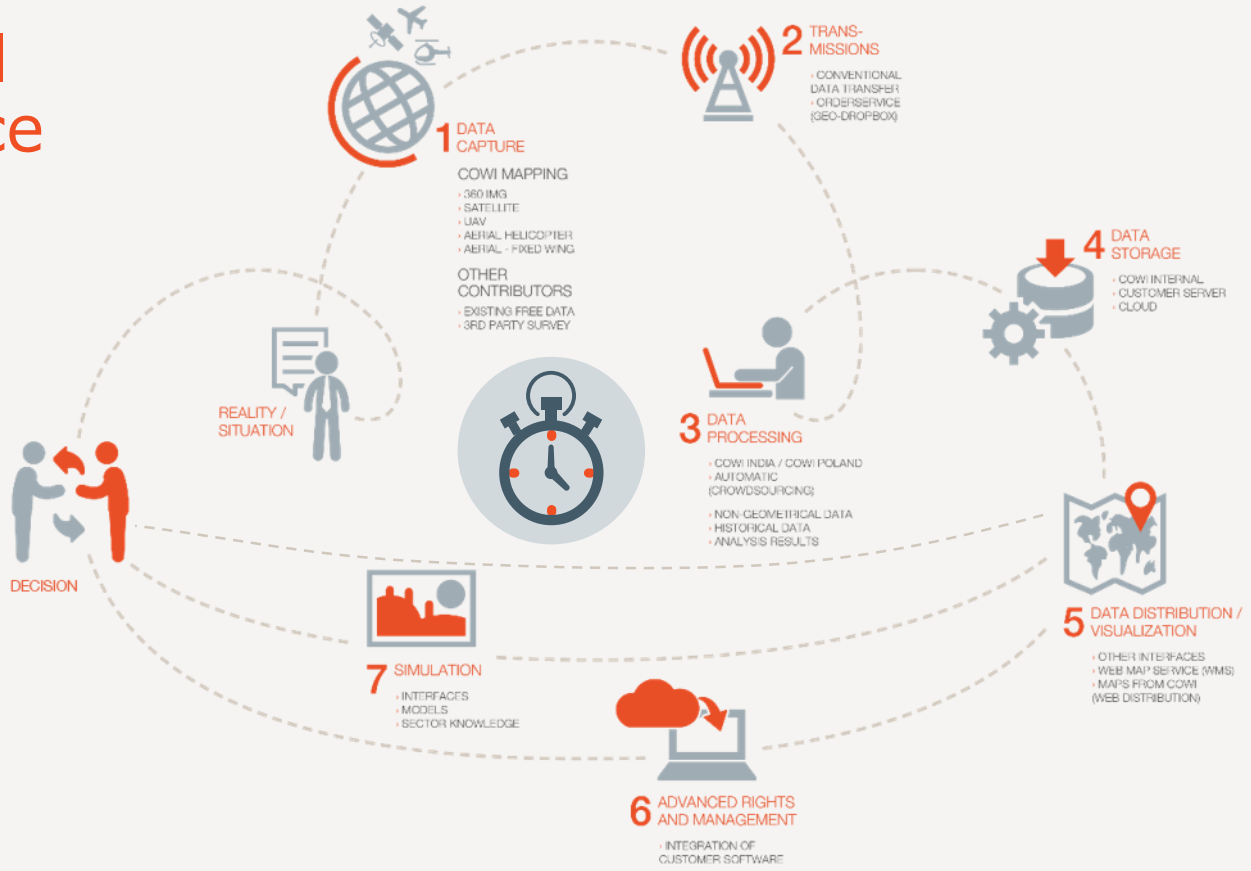
Geospatial Intelligence Lifecycle



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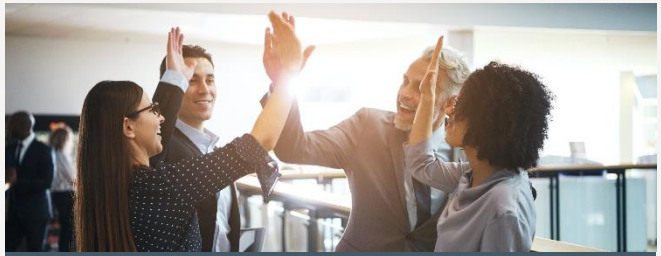
COWI Mapping in Numbers today



OUR COLLEAGUES

400 Specialists

11 Locations

12 Nationalities

4 Continents

>750,000 Hours/year

OUR CARTOGRAPHY

3 Aircraft (2 pressurized)

2 Large Format Cameras Leica DMC-3

3 Large Format Cameras Vexcel UC

2 LiDaR ALS80 HP

1 Oblique Camera RCD 30 Penta

1 DigiTherm

Hexagon Content Program

up to 10 ADS100 HP / DMC3

up to 2 SPL 100 Photon Scanner

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What's flying @COWI 2019?

















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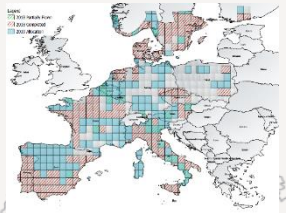
360° Solutions

Exciting projects

110,000 KM PANORAMIC ROAD IMAGE



EUROPEAN ORTHOPHOTO (HXIP)

FIRST DIGITAL ORTHOPHOTO FOR CADASTER IN INDIA

3D MODEL OF 8000 KM RAILWAY

1200 KM AERIAL RAILROAD SURVEY

2300 KM RAILROAD SURVEY

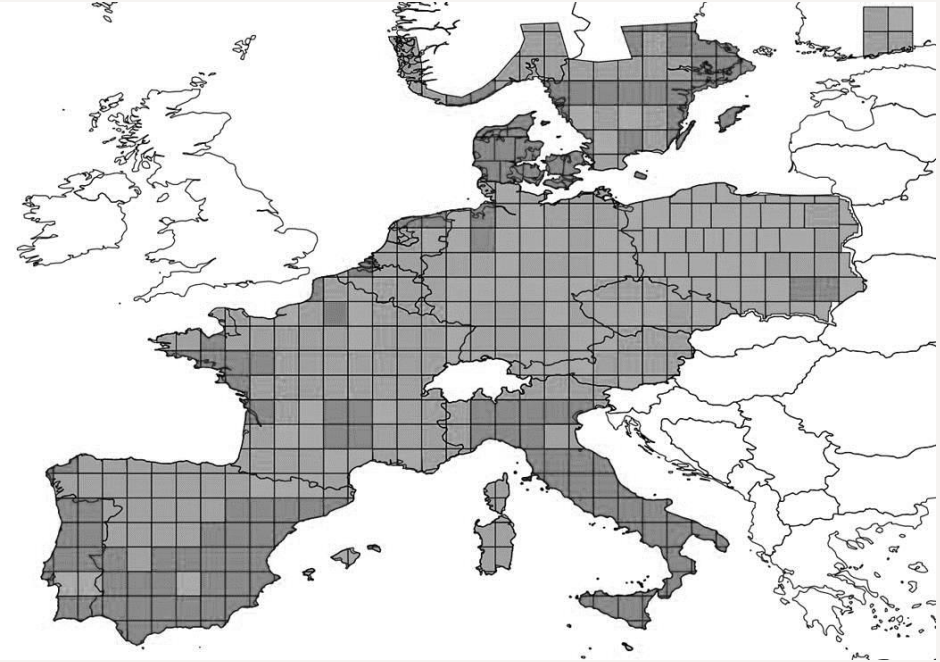
600,000 KM² AERIAL ORTHOPHOTO AND VECTORMAP

3D CITY MODEL DUBAI

COWI

The Hexagon Image Program (HxIP)

- Covering greater Europe and USA & Canada
- RGB & NIR
- 30 cm ortho
- 80 cm DSM
- WMS access or off-line delivery
- Metadata
- Update every 3-4 years
- High Value Areas, 150 cities in Europe every 2 years



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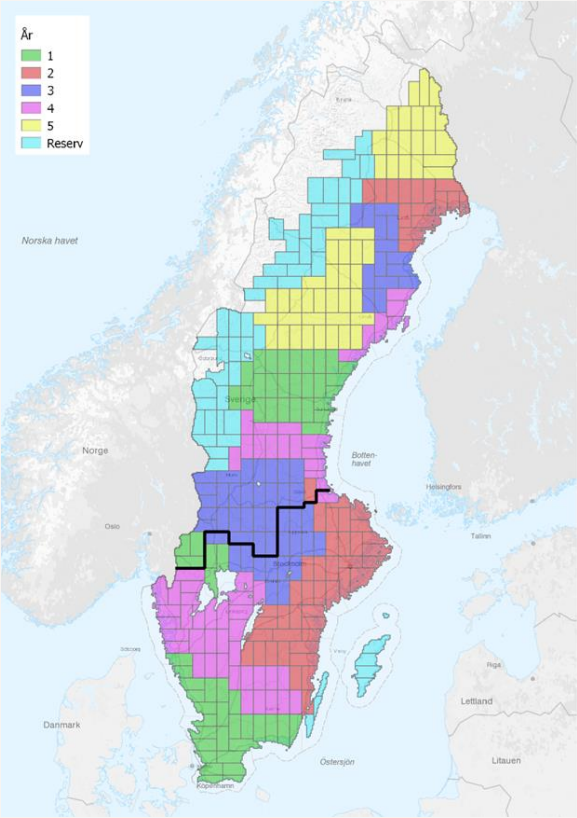
Swedish National Height Model

- Nation wide Lidar program -> update Height model, Forrestry calculations and environmental studies
- Client: Landmateriet
- 5 year program 2018 - 2022
- 1 to 2 pts per sq/m
- COWI sole contractor:
  - Local office, Security clearance
  - 2x Leica ALS80
  - Production LAS, DTM, classification



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Geodata – Serving Nations

- Hexagon Content Program Europe since 2015
- ORBIS Networkrail UK 2015-2016
- Swiss Rail SBB – Tree Risk Analysis, 2016/2017
- Worldwide Railway 3D, since 2010
- Denmark Orthophoto/Vector since 1996
- Norway/Sweden National Cartography since 2008
- Sweden NHM 2009-2013, 2018 onwards
- Finland NHM 2009-2013+2014-15
- Ordnance Survey Great Britain since 2001
- Switzerland, National Building Model 2014-2017
- Street Imagery (DDG) Denmark since 2014

SPL 100 – Single Photon Lidar

COWI

Mid 2017: ACL Group

ACL

Collaboration between Aerodata, COWI and Leica Geosystems

Purpose

Assessment of laser scanning with new Single Photon technology in Europe. Seek collaboration with National Mapping agencies

How?

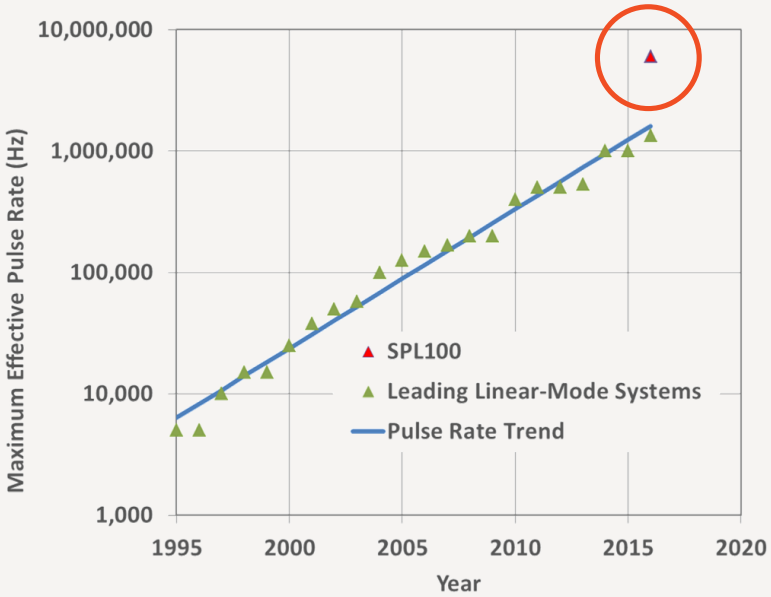
Implementing a number of test projects in Europe to gain experience and feedback on:

- Technology / Performance
- Production / Workflow and handling of large amounts of data
- Market / Adaptation to local / national conditions

Single Photon LiDAR

The logical next step for large area LiDAR terrain mapping

- Large-area mapping driven by cost per data point
  - Dictates high effective pulse rates
  - Ability to fly high enough to cover wide swaths, while maintaining high pulse rates
- Current technology has allowed a doubling of pulse rate roughly every two years
- SPL100 breaks pulse rate barriers a 6.0 mhz effective pulse rate



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(Test) Projects and examples

2017-18

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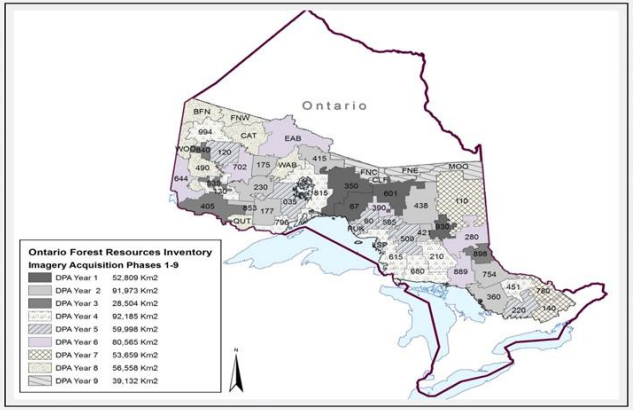
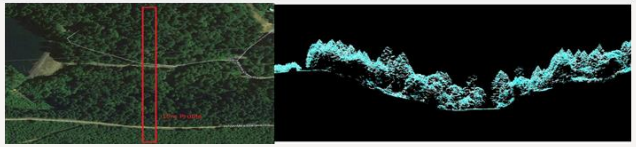
Canadian project : Ontario Ministry of Natural Resources (OMNR) Forest Resource Inventory (FRI) Program

- Province of Ontario Canada - North West Geomatics Ltd., 9 Year Forest Resource Inventory Program (FRI): 2017 – 2025
- Leica SPL100 lidar to integrate precision bare earth DTM for enhanced accuracy and added functionality to FRI processes
- Area coverage between 450-550,000 sq km Lidar point cloud with classification product deliverables >25 pts/m²
- Acquisition window (imagery and lidar) ~ June 1 – September 15th each year





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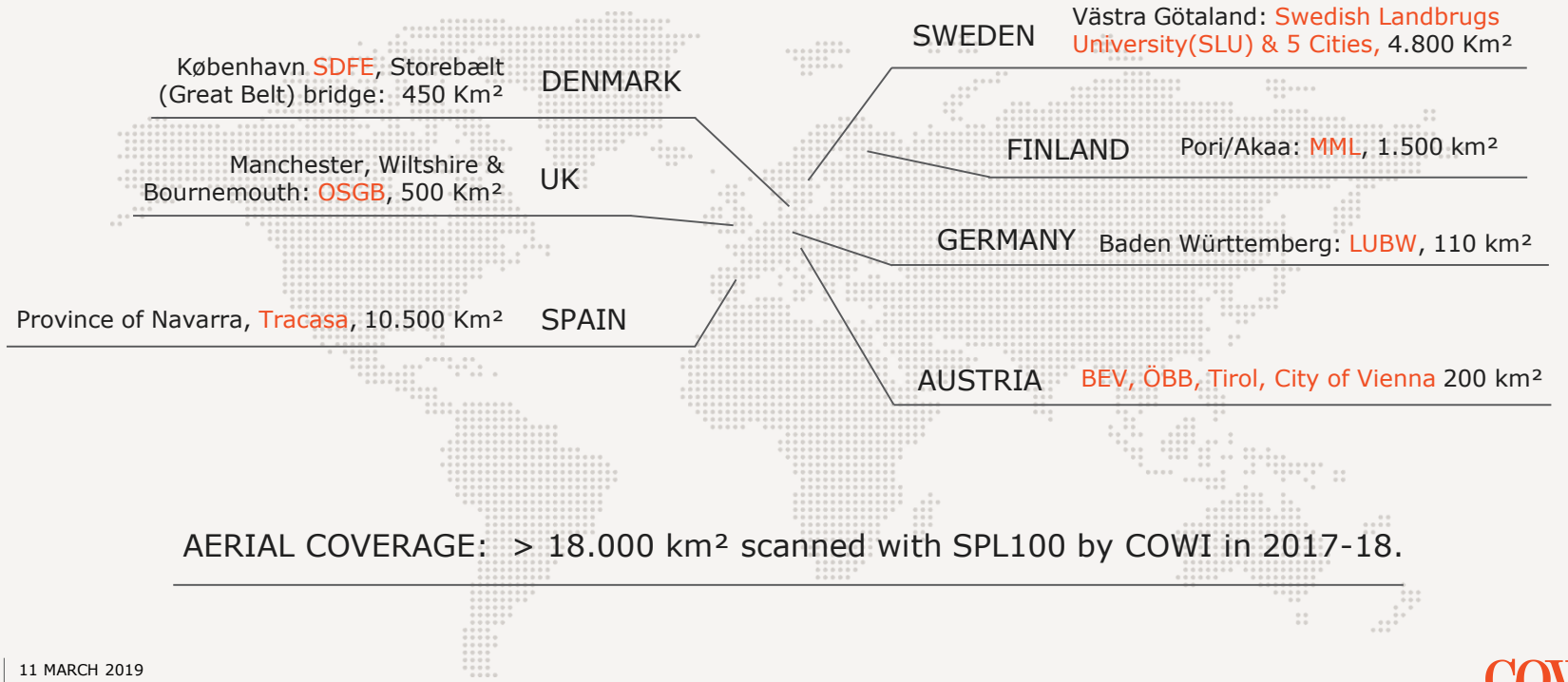
COWI (pilot) projects in 2017-18:



AERIAL COVERAGE: > 18.000 km² scanned with SPL100 by COWI in 2017-18.

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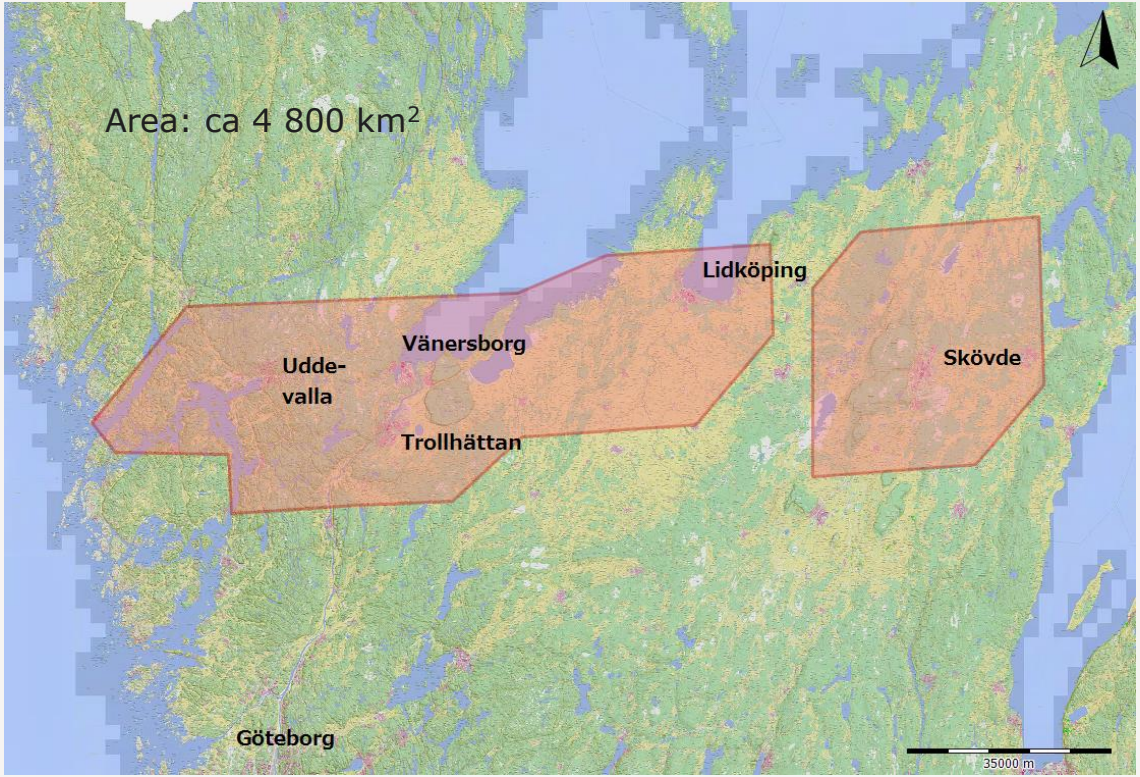
Flight info

SPL Projects	Planned point density single line pts/m²	Minimum sidelap %	Flying height AGL m	Planned speed knot	Swath width m
Denmark					
High point density	30	50	2435	115	1300
Standard Pont density	10	20	4212	160	2256
UK					
Wiltshire	15	20	3750	150	2009
Manchester	30	50	2054	140	1100
Bournmouth	30	50	2054	140	1100
Sweden					
Standard point density	10	18	4212	160	2256
High Pointdensity	30	-	1980	140	1000
Austria					
Tirol	25	60	2290	150	1225
Oberösterreich	15	50	3750	150	2009
Wien	15	60	3750	150	2009
Germany					
Argen	15	50	3810	115	2400
Schussen	25	50	2590	115	1388

Closer look @ Swedish Västra Götaland – SLU & 5 Cities



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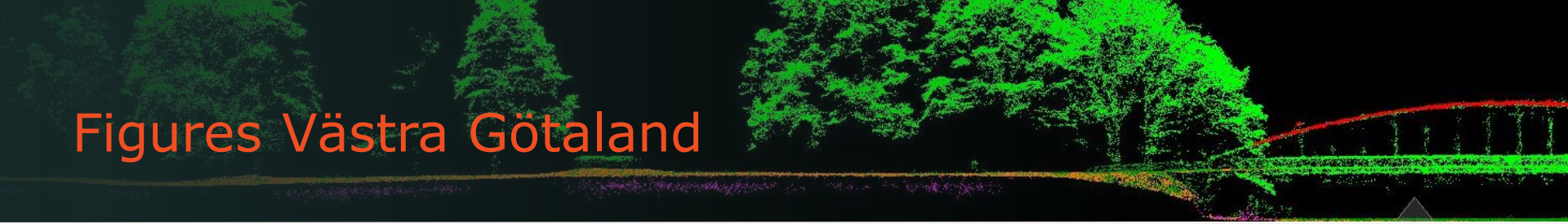
Testproject Sweden: points of interest

SLU – Sveriges Landbrugs University	Skövde kommun | Lidköpings kommun | Vänersborgs kommun Trollhättans kommun | Uddevalla kommun
Evaluation of SPL data over SLU's test area. Focus on forest applications; What are the pros and cons of conventional laser scanning	Evaluation of SPL data over SLU's test area. Focus on forest applications; What are the pros and cons of conventional laser scanning

COWI



Figures Västra Götaland

Density	Pulse rate	Elevation	Scanningsperiod
Full coverage of about 10 points / m², add lines 35 pts/ m²	4.5 MHz	4 500 m/2 700 m	Oktober – November 2017

Imagery (RGB)	Classification	Intensity	Colored point cloud
Yes	Ground / Water	Yes	RGB, where images are available

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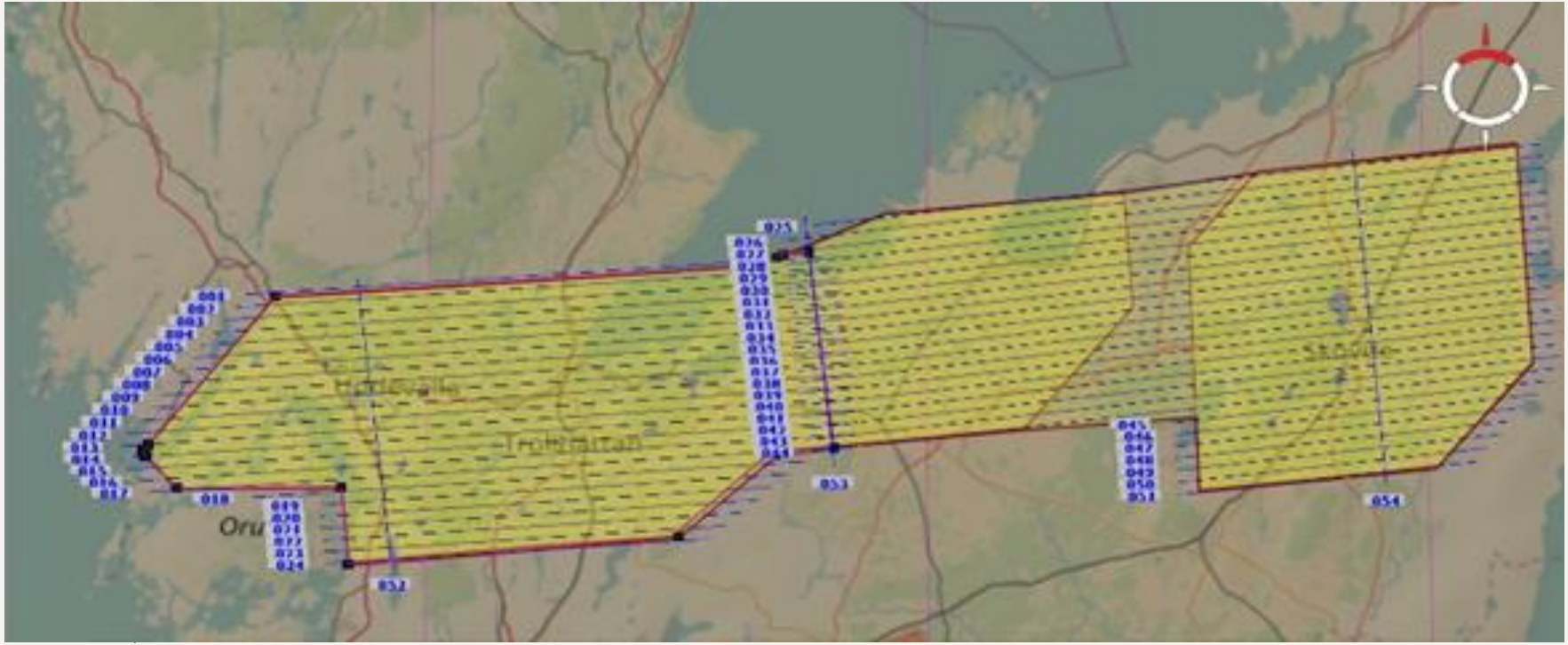
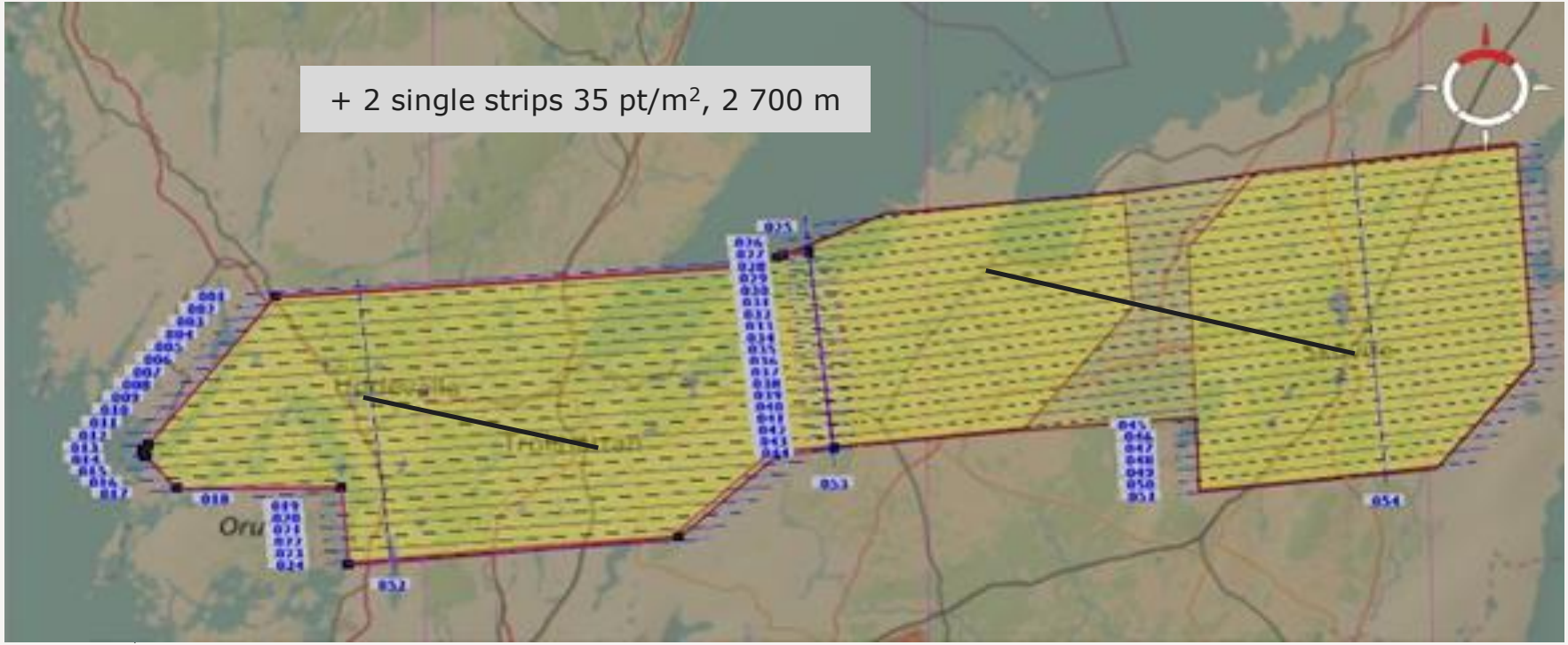
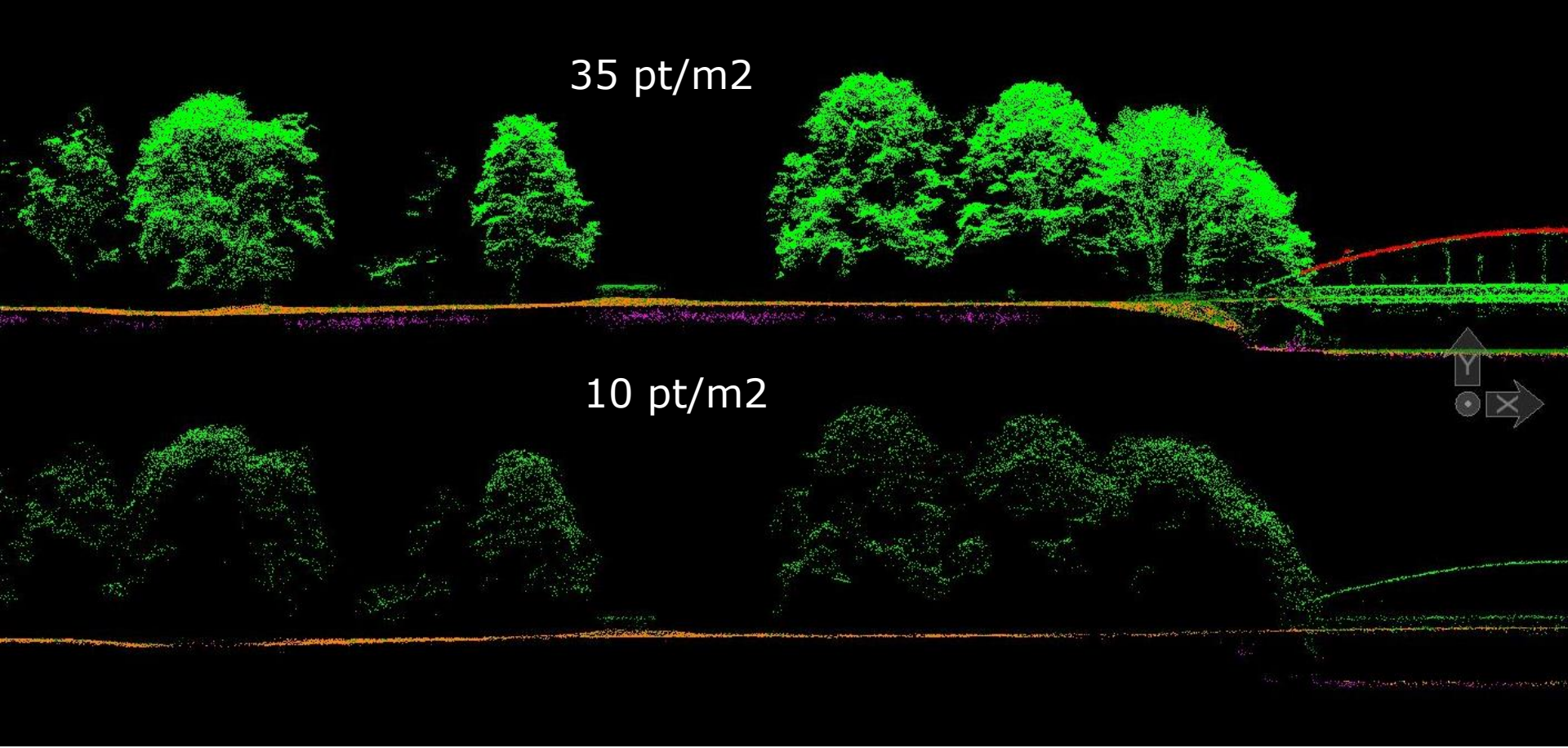
Testprojekt Västra Götaland



Testprojekt Västra Götaland





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Feed-back from SLU ON THE TESTDATA SWEDEN:

Conclusions in scientific article:

1

Forest variables can be estimated with estimation accuracies **similar or slightly higher** using a single photon lidar system operated from high altitude **(3800 m)**, compared to estimates from a conventional system, with the same pointdensity but operated from low altitude **(400m).**

2

An advantage of the SPL100 system appears to be a **better ability to penetrate dense canopies**.

3

The high flight altitude, speed and point density enable **efficient areal coverage**

4

Future research should investigate methods for minimizing the negative influence of solar noise and noise filtering in forest environments.

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Feed-back from SLU ON THE TESTDATA SWEDEN:

Other statement in the article:

> **The systems' capability….makes the SPL100 a revolution in the field of lidar technology.**

Kilde: "Forest Variable Estimation Using a High Altitude Single Photon Lidar System": André Wästlund, Johan Holmgreen, Eva Lindberg and Håkan Olsson.

Link: https://www.mdpi.com/2072-4292/10/9/1422

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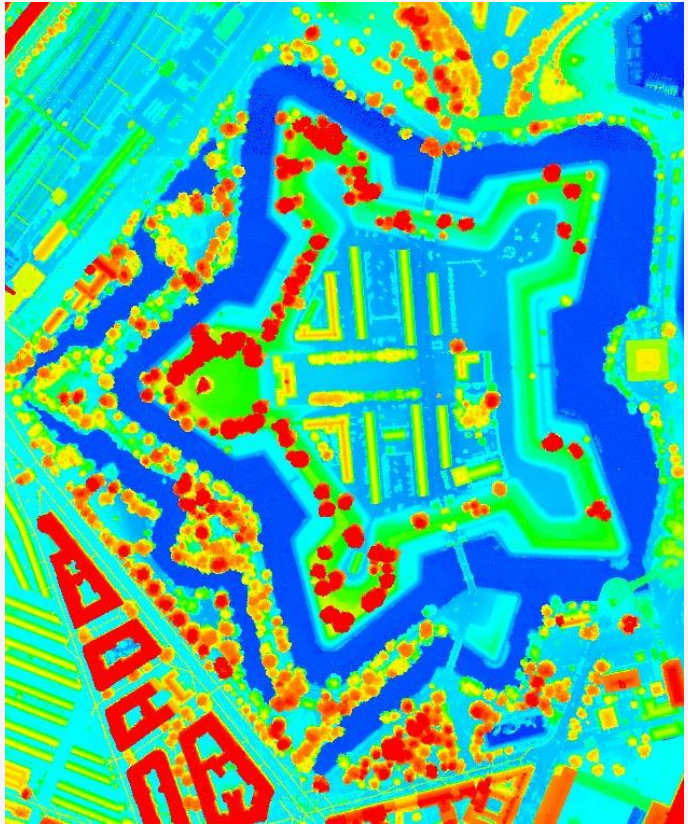
Colour from last year’s Summer Orthophoto

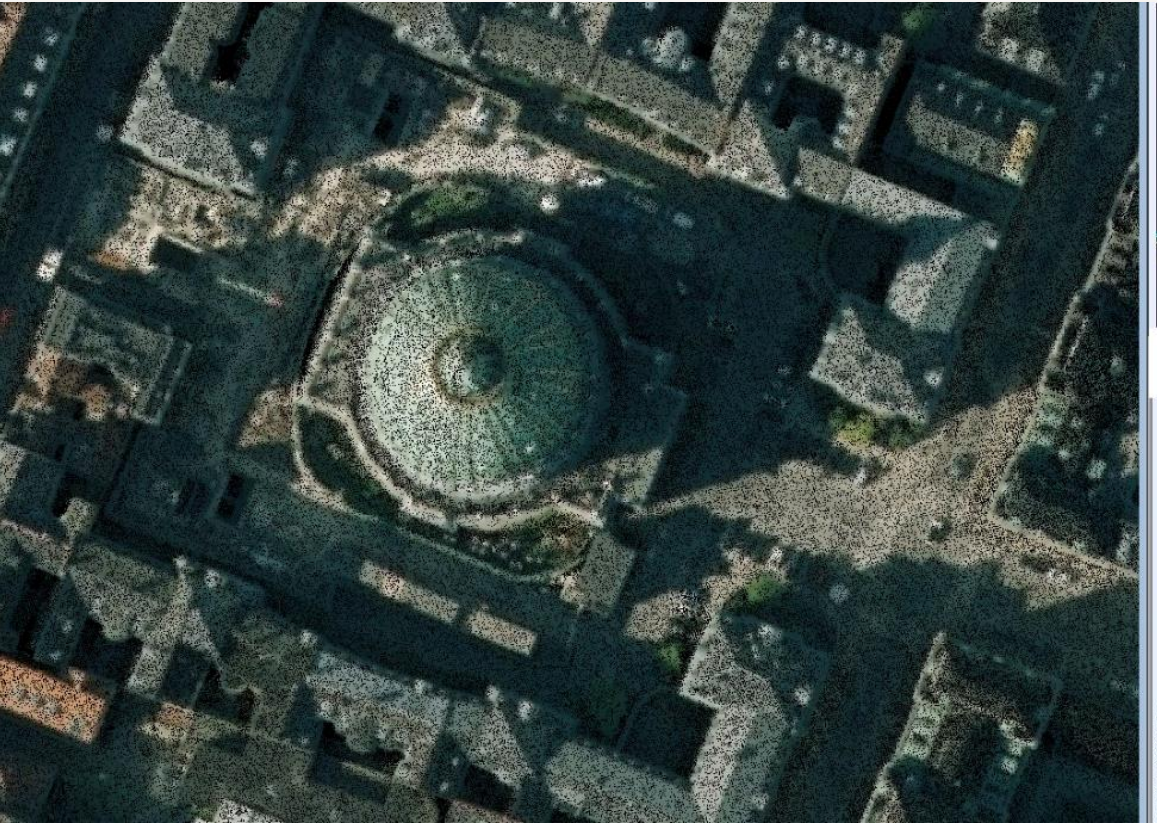
København

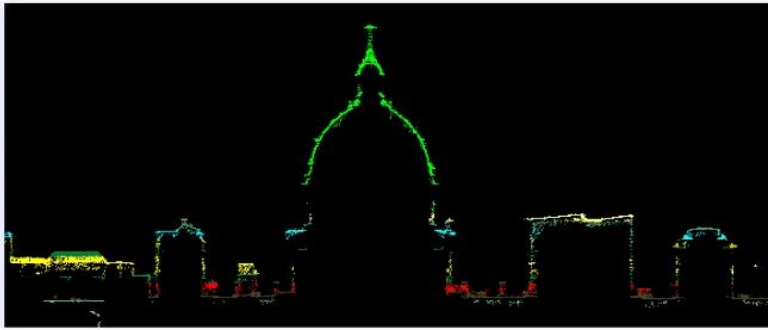


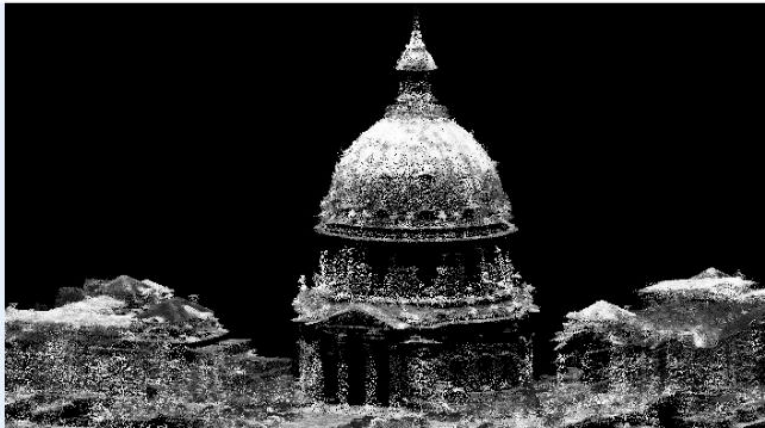
Details

København

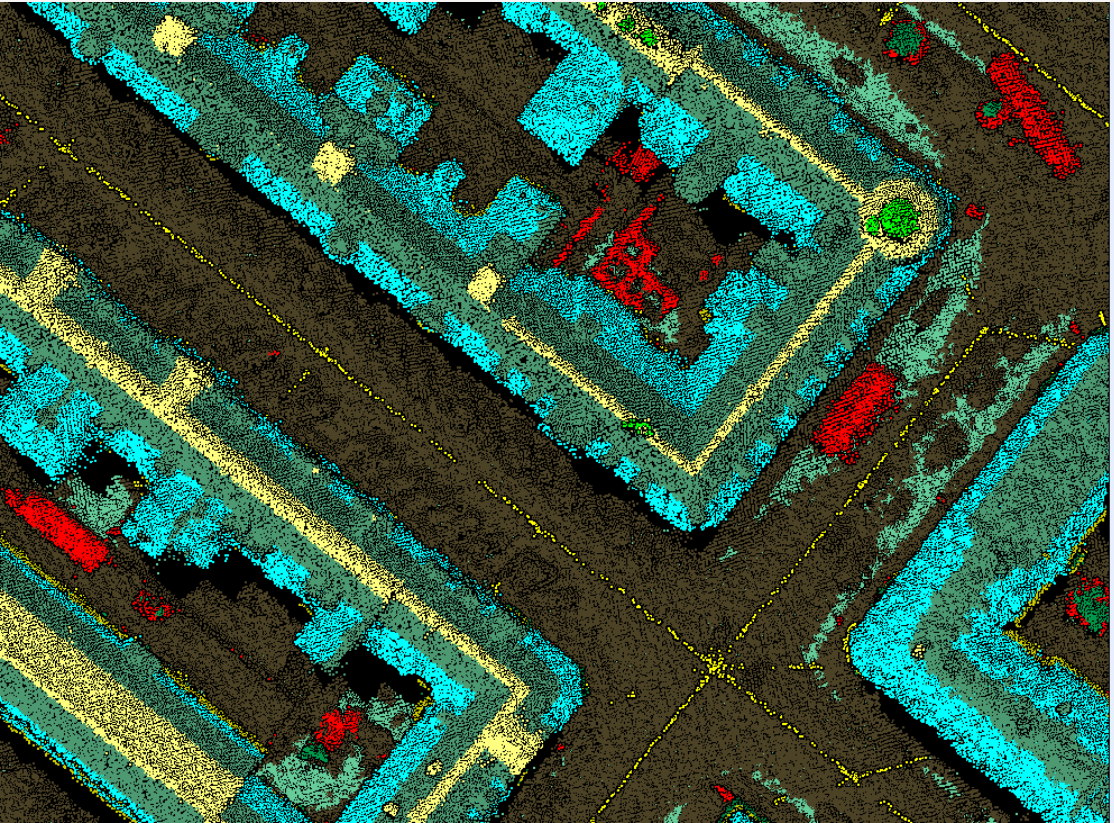
København

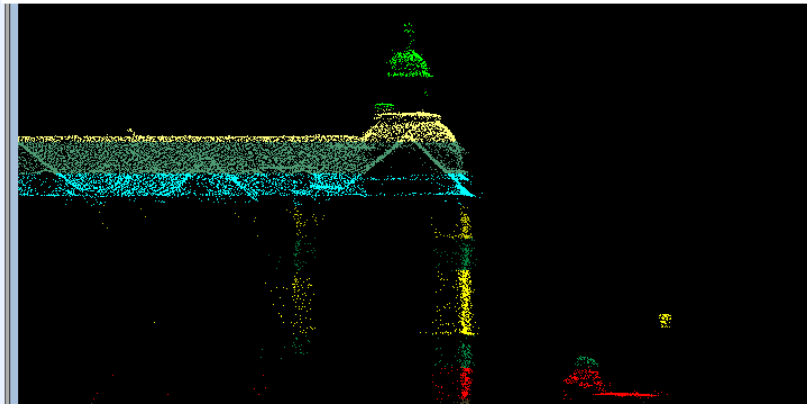




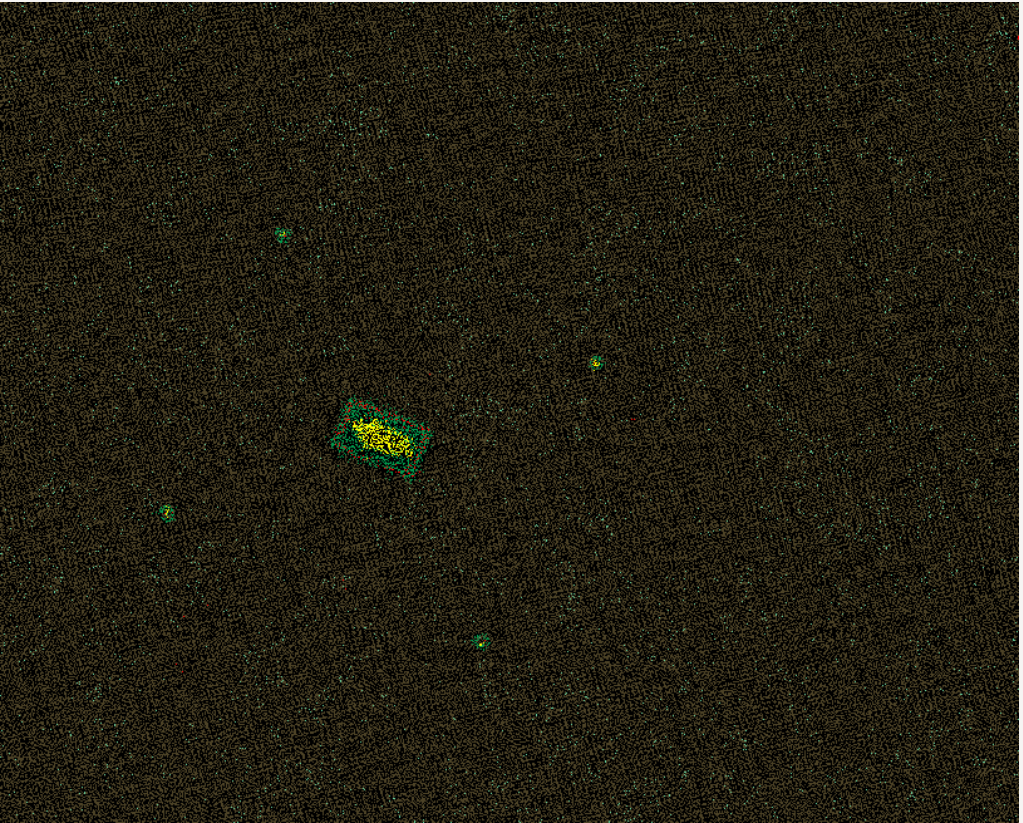


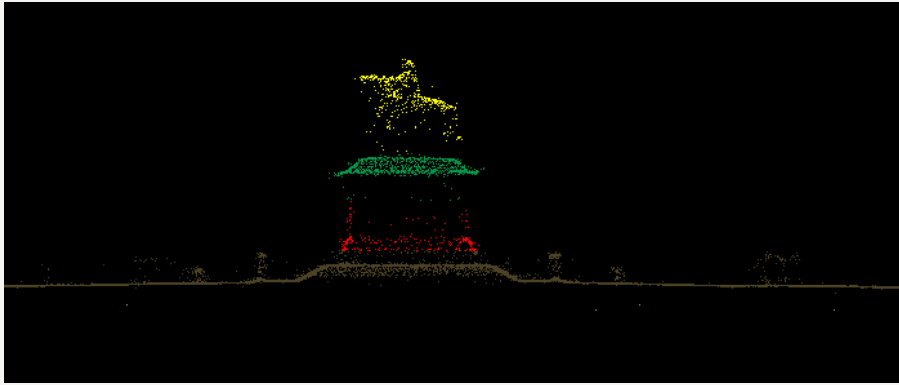
København

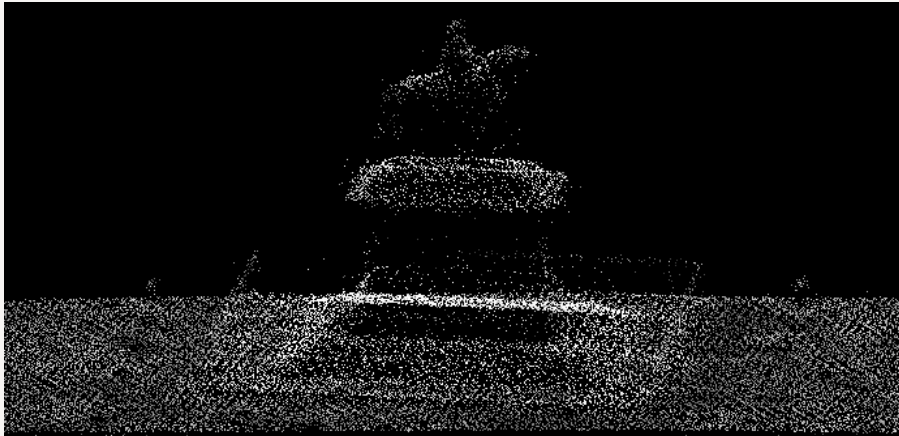




København

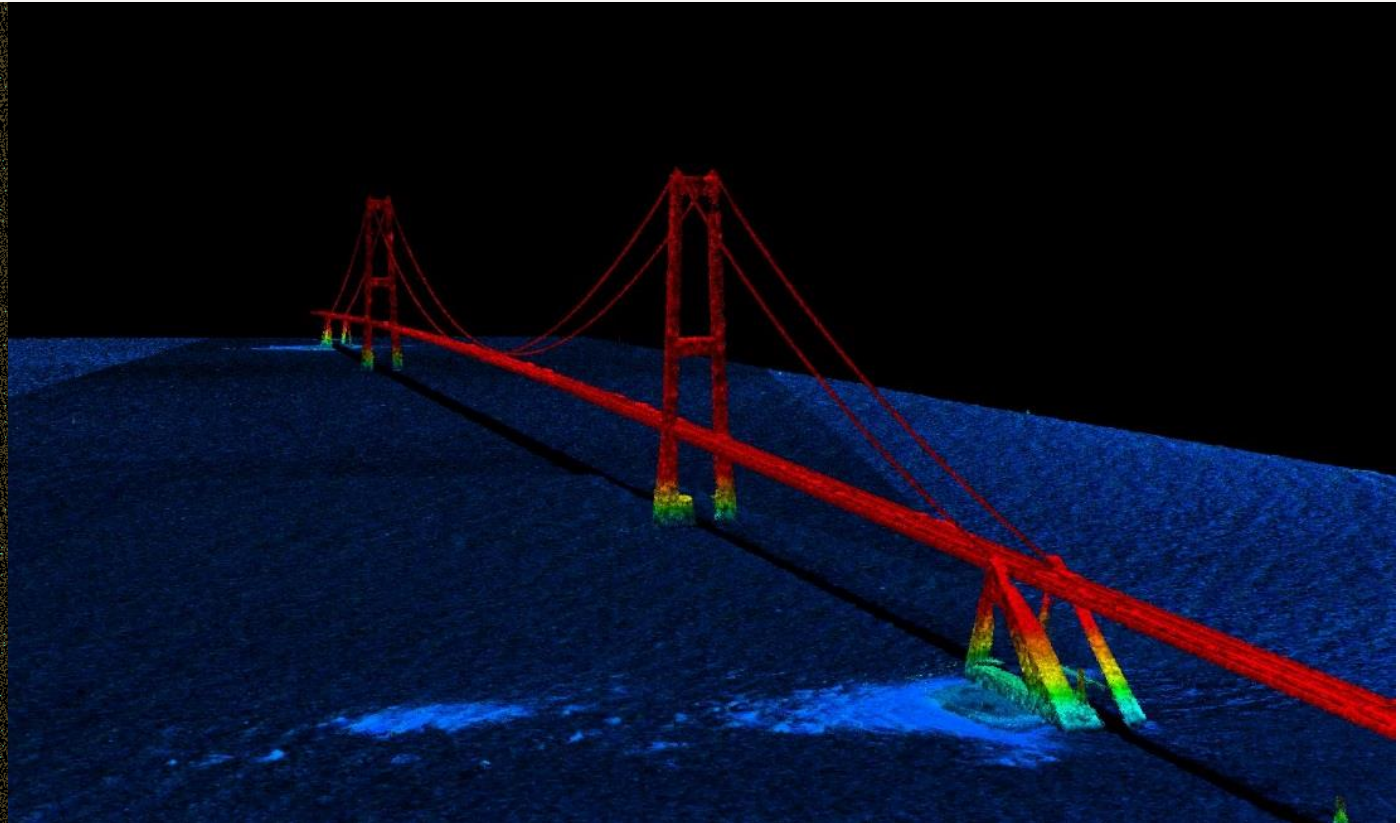


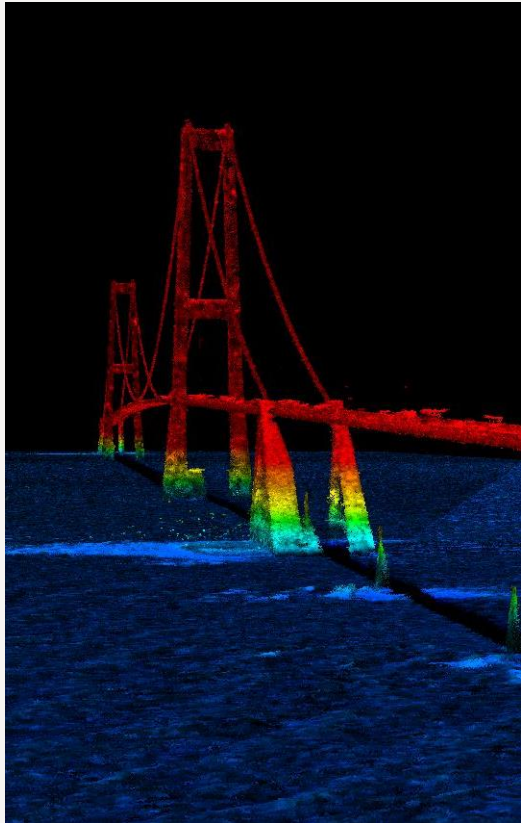




Do we get sufficient information/data for further modelling?

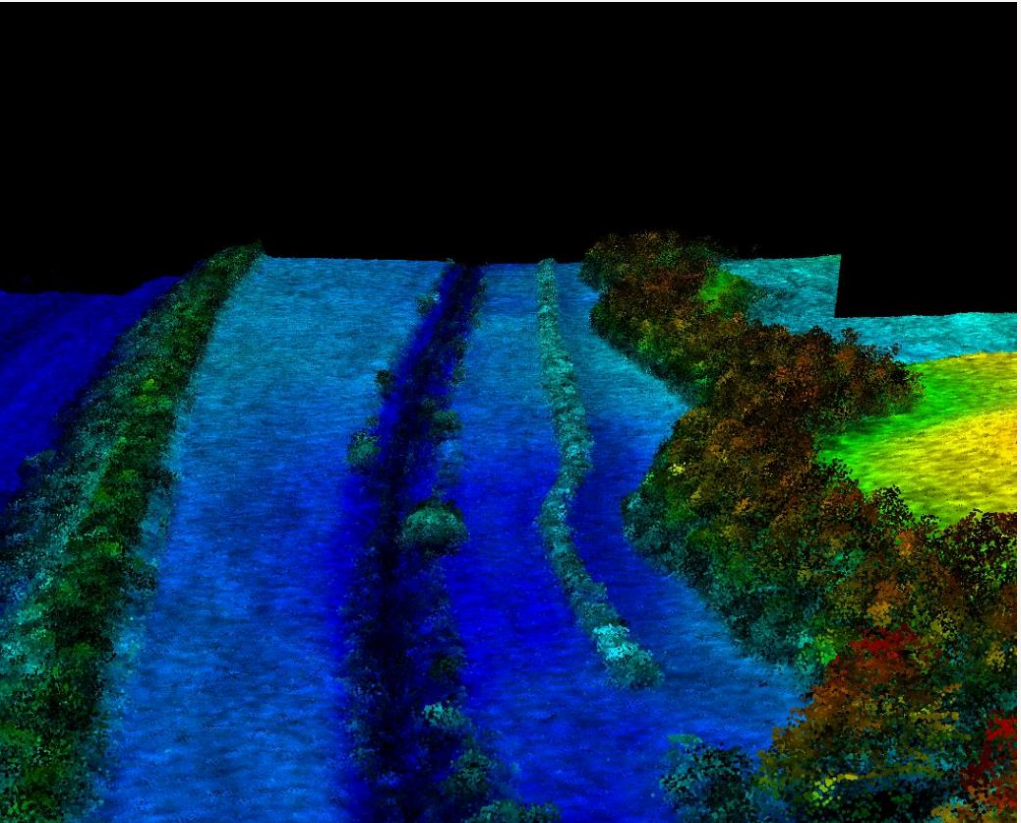
Great Belt Bridge – 40pt/m

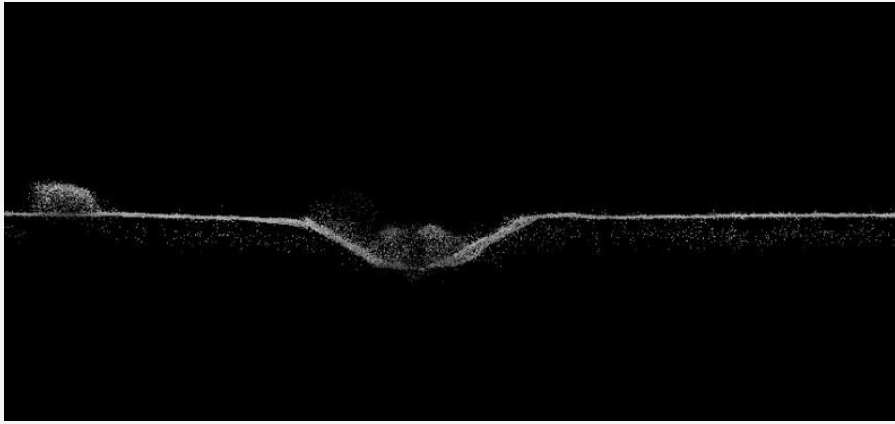


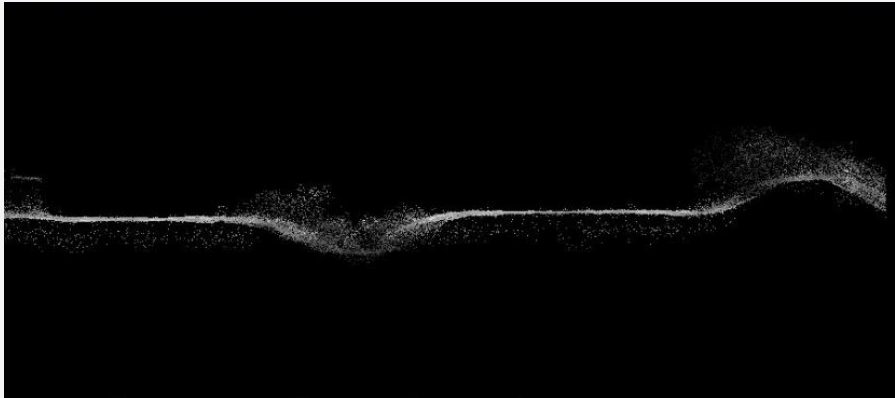


Can ditches and streams be surveyed through vegetation and water?

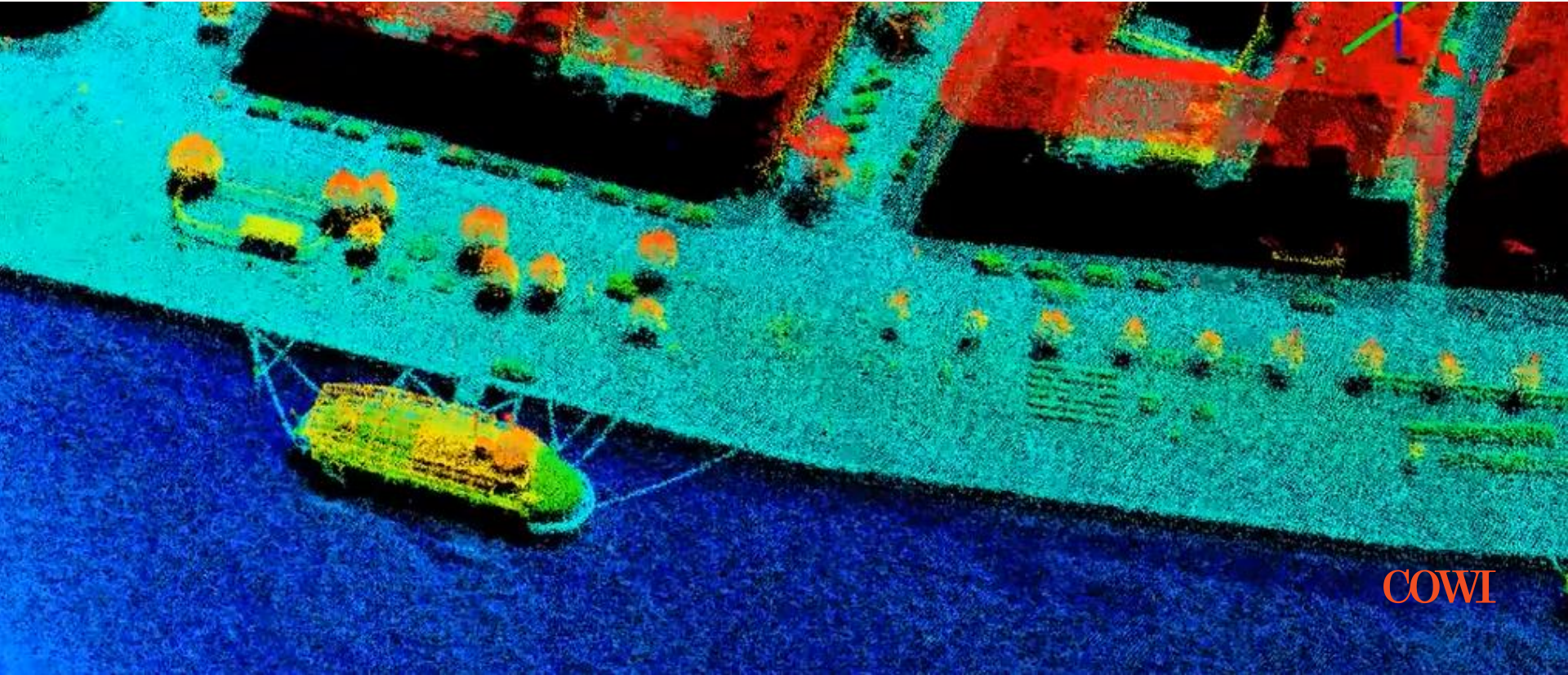
Ditches and streams

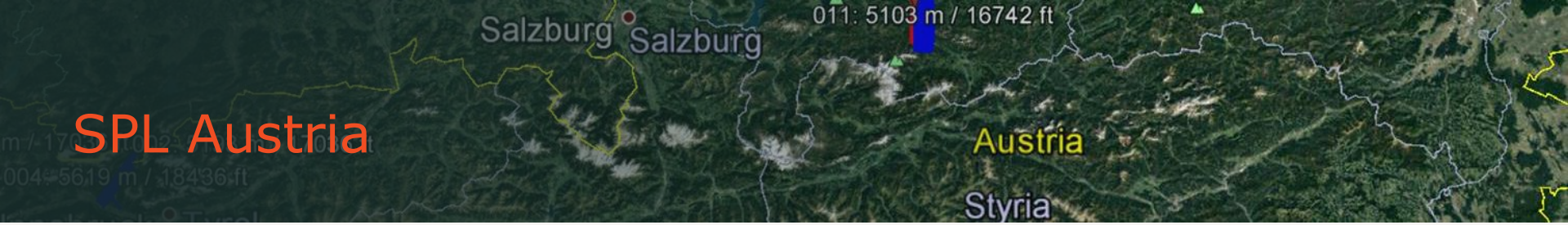






House boat in Nyhavn





SPL Austria

SPL scanning of areas in Austria for ÖBB & **City of Vienna**

Spec: **10** ppm2 normal res. & **40** ppm2 high res.

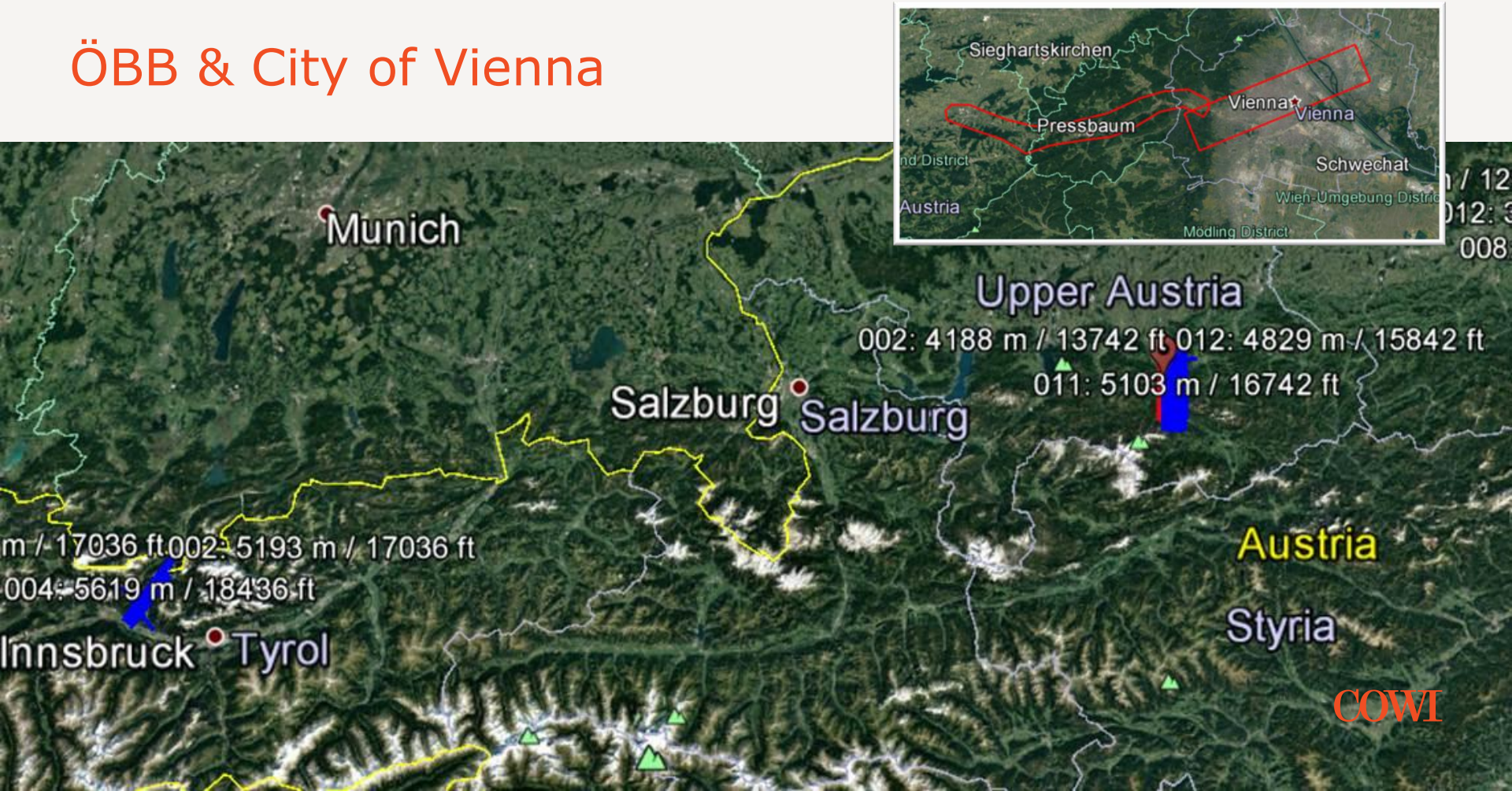
Approx. **450** Km²

Scanned **10%** Nov. **2017** - snow stopped acquisition

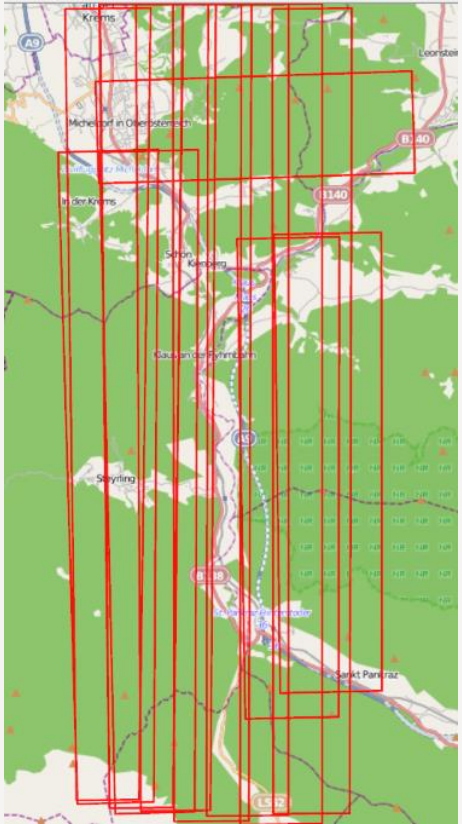
Remaining **90%** scanned late summer **2018**

Point cloud, Classification and colorization to be processed **by COWI**

ÖBB & City of Vienna

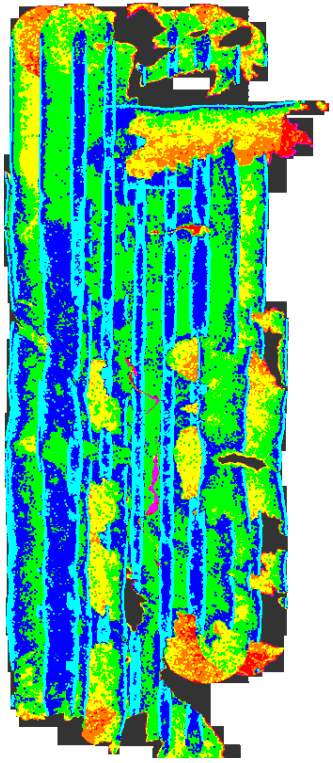


Oberösterreich



Oberösterreich

MATCHING

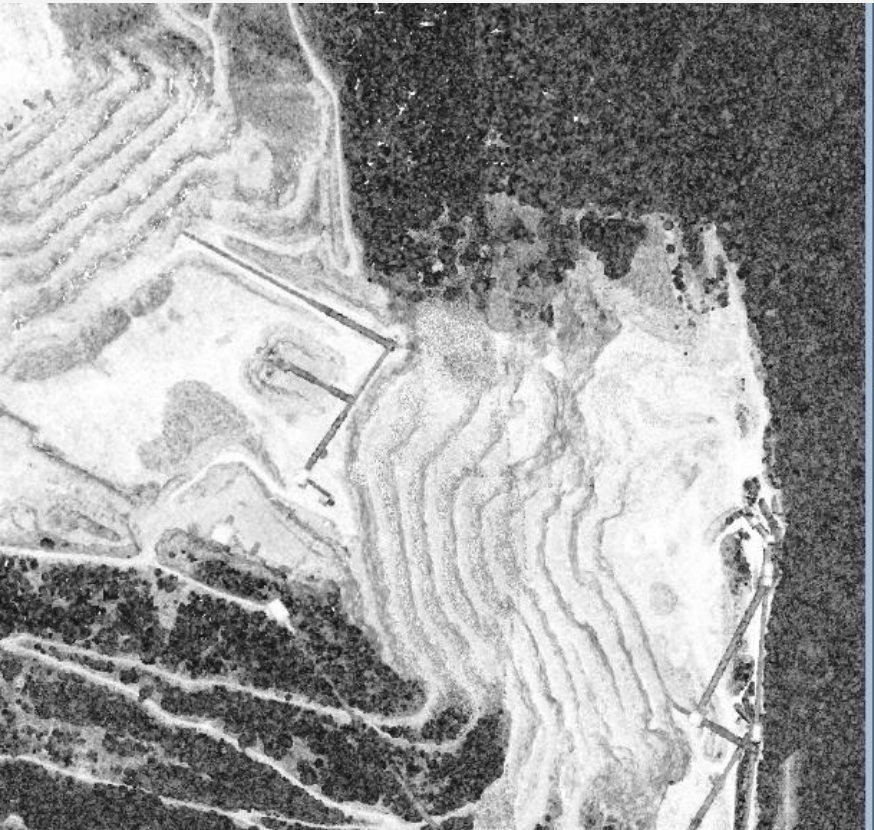


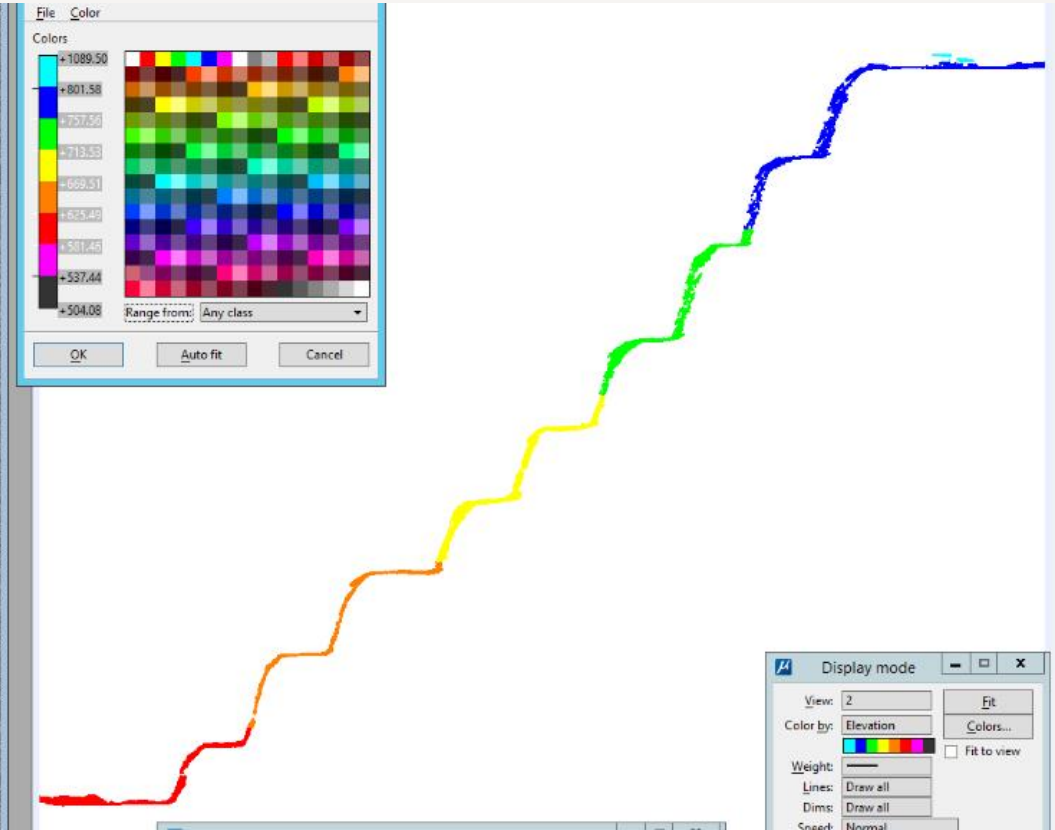
Range	Color
> 0,2	Magenta
0,15 to 0,2	Red
0,1 to 0,15	Orange
0,05 to 0,1	Yellow
0 to 0,05	Green

COWI

Details HT masts and lines, excavation & vegetation interference

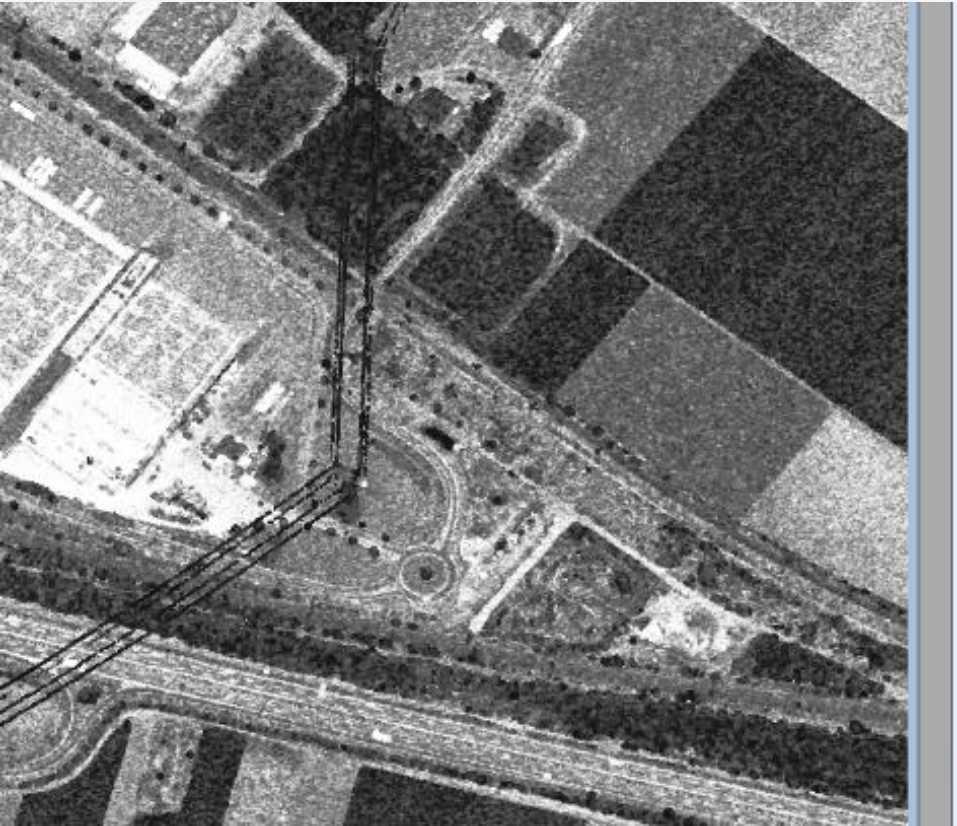
Oberösterreich

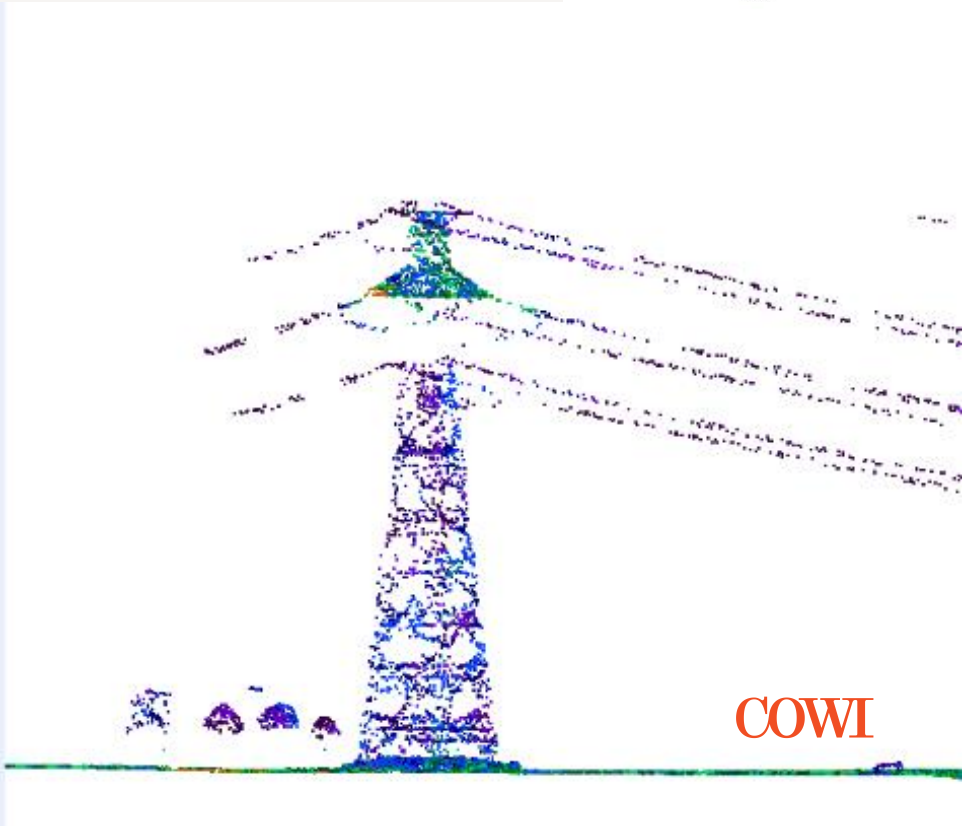




Details HT masts and lines, excavation & vegetation interference

Oberösterreich



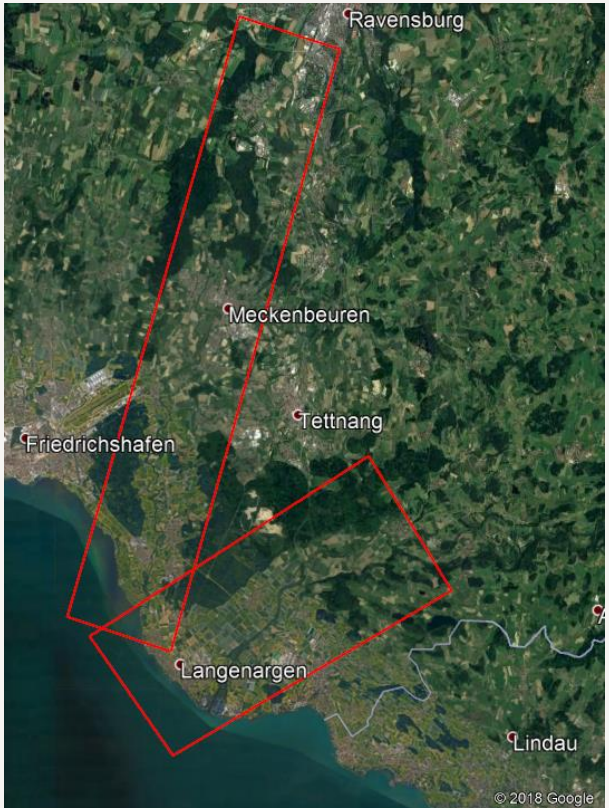


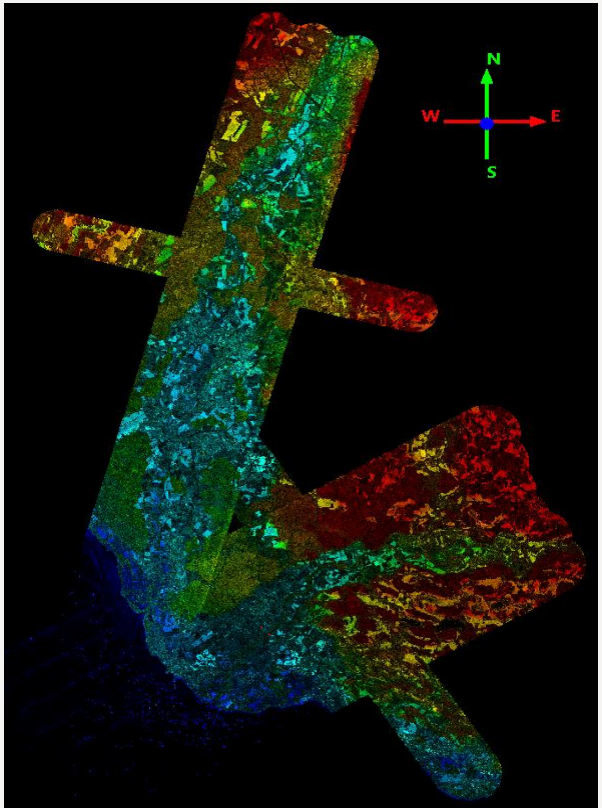
Pilotproject SPL100 – LUBW

PROJECT GOAL:

- Single-Photon-Lidar SPL100 Data for comparison with the bathymetric Lidar from 2014 and other Lidar data of LGL BW
- Acquisition with different point densities
- SPL Raw-data handling
- Automatic classification in three classes
- Manual classification in 13 classes
- Generation of a Digital Terrain Model (DGM)
- Generation of a Digital Surface Model (DOM)

SPL Schussen/Argen - LUBW





Argen 15pt @ 3810 m AGL

Schussen: 25pt/m² @ 2590 m AGL

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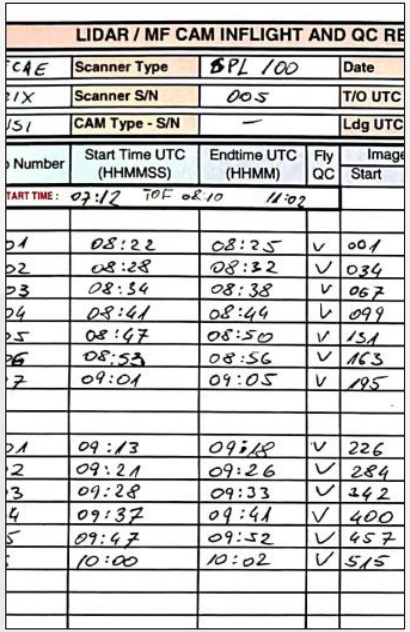
Data acquisition

FLIGHT PLAN:

SPL projekt	Planned point density [pt./M²]	Min. Sidelap [%]	Height AGL [m]	Planned speed [knots]	Swath [m]	Strips
Argen	15	50	3810	115	2400	6+1
Schussen	25	50	2590	115	1388	5+1



LIDAR / MF CAM INFLIGHT AND QC RE

CAE	Scanner Type	SPL 100	Date
IX	Scanner S/N	005	T/O UTC
151	CAM Type - S/N	—	Ldg UTC

Number	Start Time UTC (HHMMSS)	Endtime UTC (HHMM)	Fly QC	Image Start
TART TIME:	07:12 TOF 08:10	11:02		
01	08:22	08:25	V	001
02	08:28	08:32	V	034
03	08:34	08:38	V	067
04	08:41	08:44	V	099
05	08:47	08:50	V	131
06	08:53	08:56	V	163
07	09:01	09:05	V	195
01	09:13	09:18	V	226
02	09:21	09:26	V	284
03	09:28	09:33	V	342
04	09:37	09:41	V	400
05	09:47	09:52	V	457
	10:00	10:02	V	515

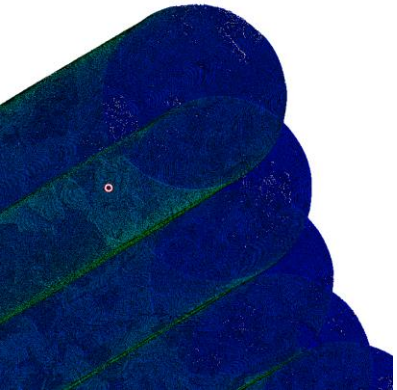
ACQUISITION:

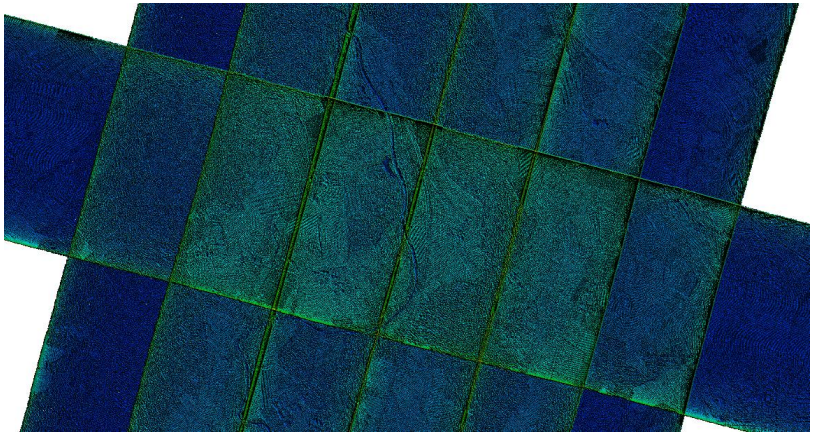
- Saturday, 4. August 2018
- Excellent weather (sunshine, no clouds, light wind)
- Argen (47 km²) 10:22 – 11:05
  Schussen (63km²) 11:13 – 12:02

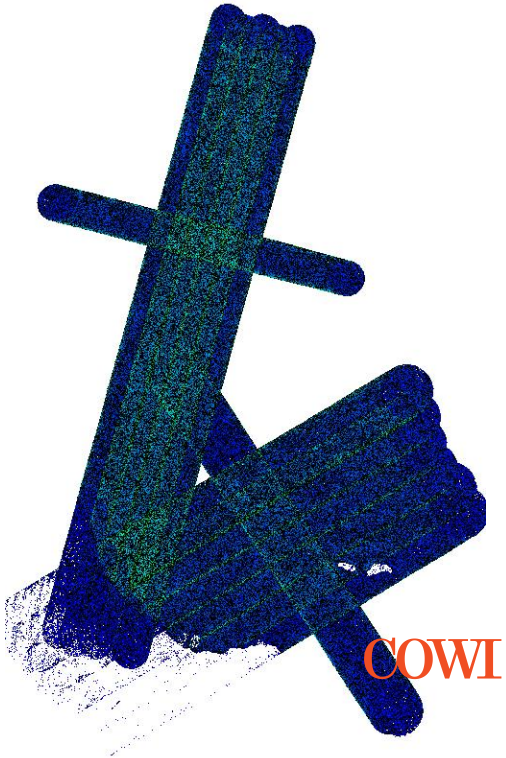
Quality check – point density

Area	Number measurements	Average point density
Schussen (25ppm)	27	50.15 ppm
Argen (15ppm)	27	24.73 ppm
Overlap	11	91.27 ppm

Margins of the lines (300-500 ppm)

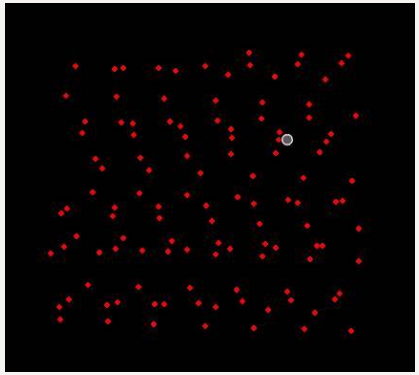




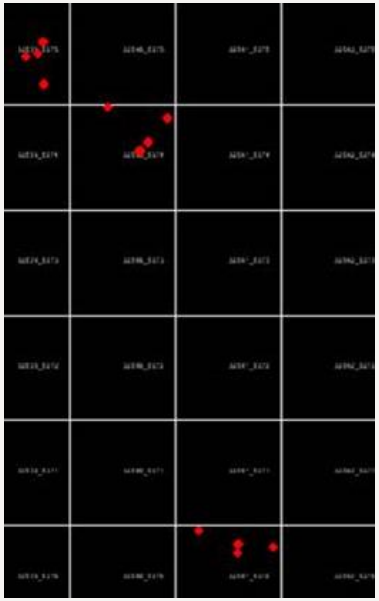


Quality checks – Control surfaces

- Control surfaces (LiDAR2015) by LUBW
- 3238 points / 17 areas



Average dz	-0.021
Minimum dz	-0.250
Maximum dz	+0.120
Root mean square	0.067
Std deviation	0.064



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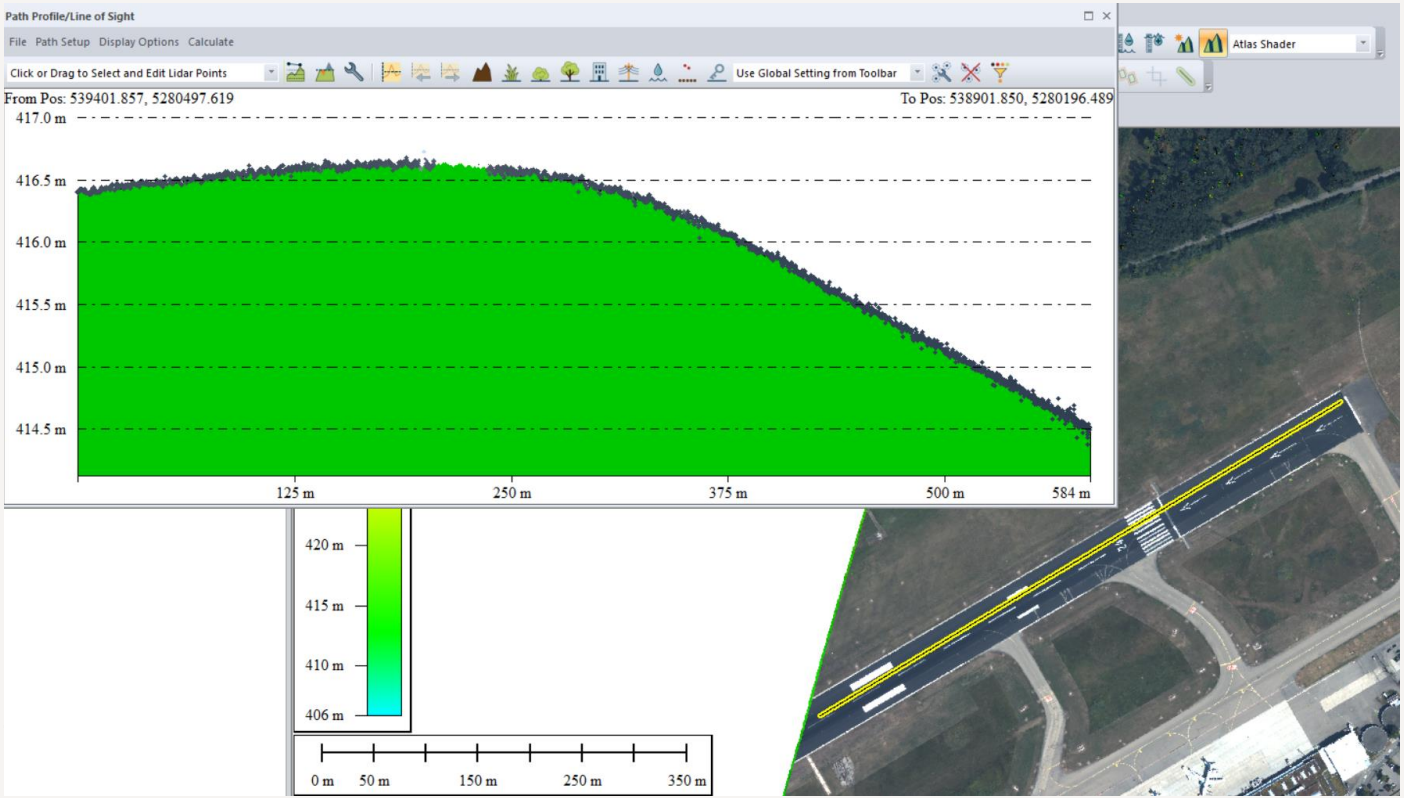
Profillinie entlang der Landebahn Flughafen Friedrichshafen (25ppm Streifenrand, keine 50% Überlappung) mit DGM



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Conclusions

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Some recurring questions

QUESTION: “Is the point distribution as regular as with other systems?”

- The SPL delivers economically much more pts/m² to choose from.
- Example 8 pts/m² : Riegl VQ1560i 1450 m AGL/1000 m swath vs. SPL100: 3750 m AGL/2000 m swath
- If the SPL flies the same swath of 1000 m, the density increases to >30 pts/m²

QUESTION: “Isn’t the signal/noise ratio very high?”

- SPL records single photon events and averages less than linear systems. Filtration happens in the processing software and not on-board. More control for the processor!
- The final results are not noisy!

QUESTION: “Isn’t the processing very resource consuming?”

- Right! So not everyone can operate it
- But processing power increases with Moore’s law and we have a grip on it.

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Conclusion

- 2-3 time more area per hour compared to the next better system
  - >450 km²/hr at 8 pts/m² ! Other systems reach about 150 -250 km²/hr
    - → Use of short time or ATC windows for meaningful acquisition
    - → Very large areas in short time

- Can be flown around the clock, multiple sessions with LiDAR per day if the weather permits
    - → Great resource utilization
    - → Very large areas in short time

- SPL can pass low clouds, ground fog
- Extended acquisition window (spring/fall, mornings/afternoon)
    - → Detailed DTM around shorelines

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Conclusion

- Due to the rotating beam, there are fewer areas with "shadows"
  → very efficient in urban areas

- System was still under development
  - Range gate issues were still existing during the first projects but are now resolved
  - Leica/Sigma followed closely

- Very resource intensive – needs up to 20 times more processing resources
  → Requires specialized cluster setup for the operator

- Point distribution required careful planning
  → We earned the experience only over time

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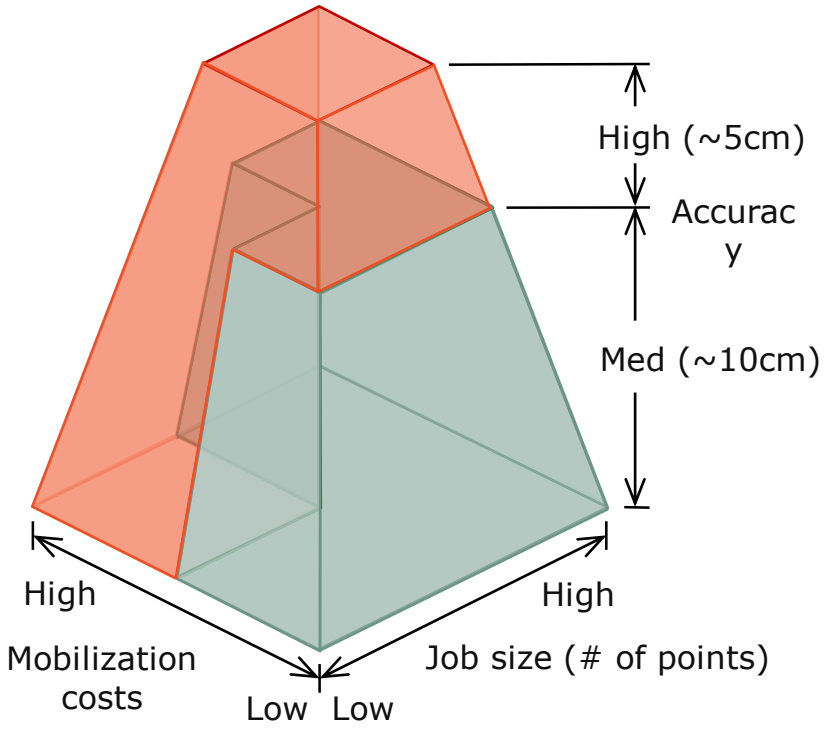
Application

- Large areas (> 3000 km²)
- High point densities (>8 pts/m²)
- Acquisition windows short
- Standard accuracies (5-10 cm RMSE)
- Combination with small waterways and shorelines
- High humidity/ground fog/water on fields



Orange = can be satisfied by linear-mode systems

Green = can be satisfied single-photon technology

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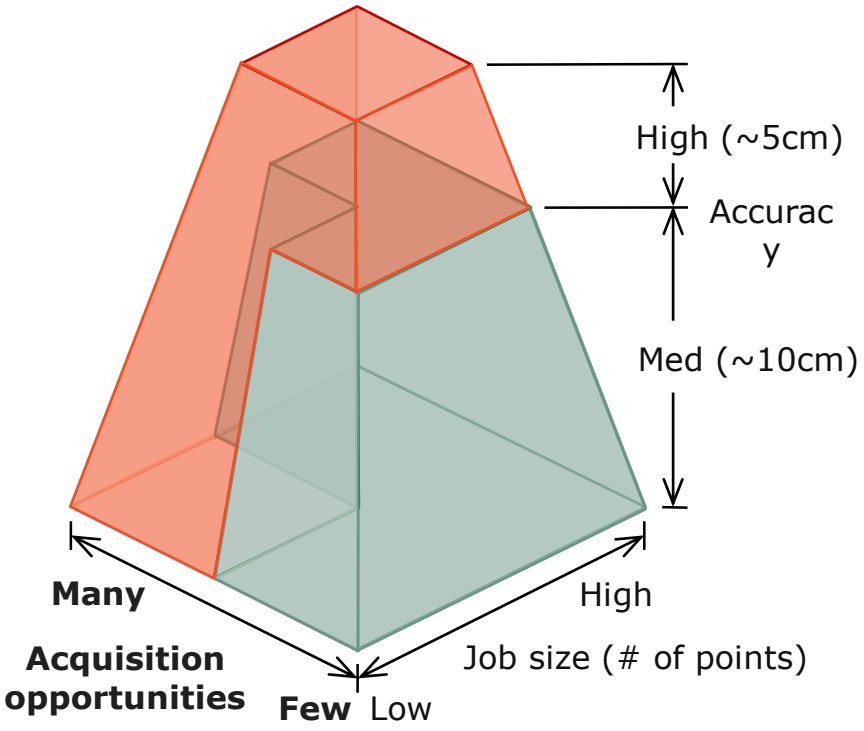

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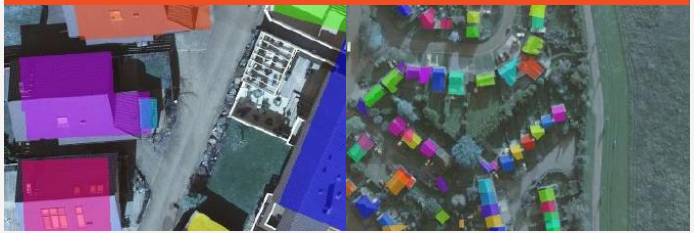
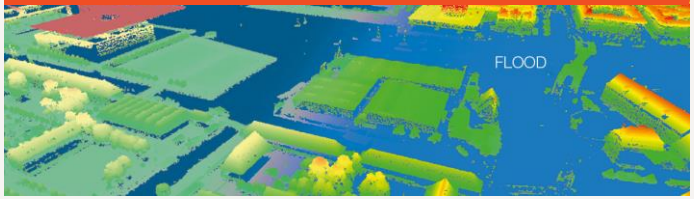
Core fields for application

Automated Mapping

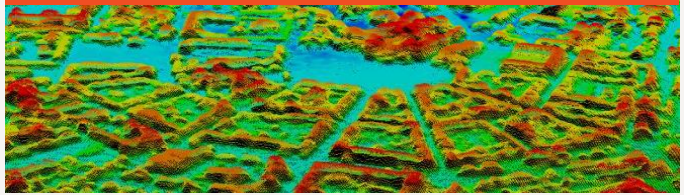


Regional Elevation Models

Flood Modeling



3D Models for Solar,5G, Vegetation, Agriculture, Infrastructure



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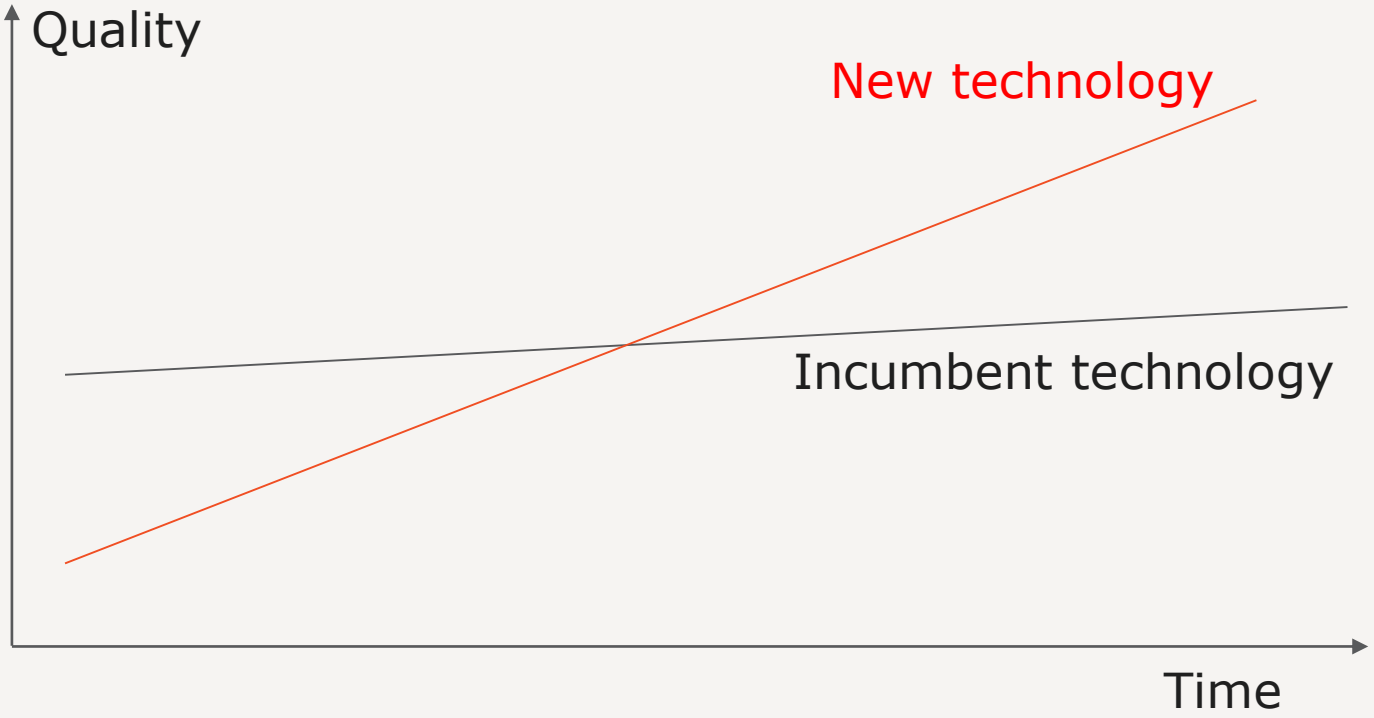
3D Elevation Program

Home

To respond to growing needs for high-quality elevation data, the 3D Elevation Program (3DEP) is systematically collecting 3D elevation data during an 8-year period in the form of light detection and ranging (lidar) data over the conterminous United States, Hawaii, and the U.S. territories.



Tushman, M., Reilly, C., HBS

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THANK YOU!

Dr. Simon Musäus

SIMU@ COWI.com

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