The SPL 100 in Europe

Simon Musäus
Sr. Vicepresident Mapping
Group overview

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**
Delivering 360° solutions
World-class knowledge combined with worldwide presence
Geographical Information – Products and Services

- Aerial Imagery
- LIDAR Digital Terrain Models GIS-Datasets
- Surveying and As-Built Documentation
- Infrastructure Inspection Automated solutions
- Thermography
- 3D Models, BIM Asset DB Software solutions
- Oblique imagery and Panoramic View
- Vegetations management Risk Analysis
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
What's flying @COWI 2019?
Exciting projects

3D MODEL OF 8000 KM RAILWAY

110,000 KM PANORAMIC ROAD IMAGE

EUROPEAN ORTHOPHOTO (HXIP)

FIRST DIGITAL ORTHOPHOTO FOR CADASTER IN INDIA

3D CITY MODEL DUBAI

2300 KM RAILROAD SURVEY

600,000 KM² AERIAL ORTHOPHOTO AND VECTORMAP

1200 KM AERIAL RAILROAD SURVEY

11 MARCH 2019
EUROSDR, BARCELONA 2019
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
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
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
<table>
<thead>
<tr>
<th>ACL</th>
<th>Purpose</th>
<th>How?</th>
</tr>
</thead>
</table>
| Collaboration between Aerodata, COWI and Leica Geosystems | Assessment of laser scanning with new Single Photon technology in Europe. Seek collaboration with National Mapping agencies | 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
(Test) Projects and examples

2017-18
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
COWI (pilot) projects in 2017-18:

AERIAL COVERAGE: > 18,000 km² scanned with SPL100 by COWI in 2017-18.

SWEDEN
Västra Götaland: Swedish Landbrugs University (SLU) & 5 Cities, 4,800 km²

DENMARK
København SDFE, Storebælt (Great Belt) bridge: 450 km²

UK
Manchester, Wiltshire & Bournemouth: OSGB, 500 km²

FINLAND
Pori/Akaa: MML, 1,500 km²

GERMANY
Baden Württemberg: LUBW, 110 km²

FINLAND
Pori/Akaa: MML, 1,500 km²

AUSTRIA
BEV: ÖBB, Tirol, City of Vienna 200 km²

SPAIN
Province of Navarra, Tracasa, 10,500 km²
## SPL Projects

<table>
<thead>
<tr>
<th>Country</th>
<th>Planned point density single line pts/m²</th>
<th>Minimum sidelap %</th>
<th>Flying height AGL m</th>
<th>Planned speed knot</th>
<th>Swath width m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Denmark</strong></td>
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<tr>
<td>High point density</td>
<td>30</td>
<td>50</td>
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<td>115</td>
<td>1300</td>
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<tr>
<td>Standard Point density</td>
<td>10</td>
<td>20</td>
<td>4212</td>
<td>160</td>
<td>2256</td>
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<tr>
<td><strong>UK</strong></td>
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<tr>
<td>Wiltshire</td>
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<td>20</td>
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<td>150</td>
<td>2009</td>
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<tr>
<td>Manchester</td>
<td>30</td>
<td>50</td>
<td>2054</td>
<td>140</td>
<td>1100</td>
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<tr>
<td>Bournemouth</td>
<td>30</td>
<td>50</td>
<td>2054</td>
<td>140</td>
<td>1100</td>
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<td><strong>Sweden</strong></td>
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<td>-</td>
<td>1980</td>
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<td>1000</td>
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<td><strong>Austria</strong></td>
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<td>Tirol</td>
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<td>60</td>
<td>2290</td>
<td>150</td>
<td>1225</td>
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<tr>
<td>Oberösterreich</td>
<td>15</td>
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<td>3750</td>
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<td><strong>Germany</strong></td>
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<tr>
<td>Argen</td>
<td>15</td>
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<td>3810</td>
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<td>2400</td>
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<tr>
<td>Schussen</td>
<td>25</td>
<td>50</td>
<td>2590</td>
<td>115</td>
<td>1388</td>
</tr>
</tbody>
</table>
Closer look @ Swedish Västra Götaland – SLU & 5 Cities
**Testproject Sweden: points of interest**

<table>
<thead>
<tr>
<th>SLU – Sveriges Landbrugs University</th>
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<tr>
<td>Evaluation of SPL data over SLU's test area. Focus on forest applications; What are the pros and cons of conventional laser scanning</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Skövde kommun</th>
<th>Lidköpings kommun</th>
<th>Vänersborgs kommun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trollhättans kommun</td>
<td>Uddevalla kommun</td>
<td></td>
</tr>
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<td>Evaluation of SPL data over SLU's test area. Focus on forest applications; What are the pros and cons of conventional laser scanning</td>
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</table>
**Density**

Full coverage of about 10 points / m², add lines 35 pts/ m²

**Pulse rate**

4.5 MHz

**Elevation**

4 500 m/2 700 m

**Scannings period**

Oktober – November 2017

**Imagery (RGB)**

Yes

**Classification**

Ground / Water

**Intensity**

Yes

**Colored point cloud**

RGB, where images are available
Testprojekt Västra Götaland
Testprojekt Västra Götaland

+ 2 single strips 35 pt/m², 2 700 m
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 point density but operated from low altitude (400 m).

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.
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."


Link: [https://www.mdpi.com/2072-4292/10/9/1422](https://www.mdpi.com/2072-4292/10/9/1422)
Colour from last year’s Summer Orthophoto

København
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
Oberösterreich
Oberösterreich
Details HT masts and lines, excavation & vegetation interference

Oberösterreich
Details HT masts and lines, excavation & vegetation interference

Oberösterreich
Pilot project 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
Data acquisition

FLIGHT PLAN:

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

ACQUISITION:

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

<table>
<thead>
<tr>
<th>Area</th>
<th>Number measurements</th>
<th>Average point density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schussen (25ppm)</td>
<td>27</td>
<td>50.15 ppm</td>
</tr>
<tr>
<td>Argen (15ppm)</td>
<td>27</td>
<td>24.73 ppm</td>
</tr>
<tr>
<td>Overlap</td>
<td>11</td>
<td>91.27 ppm</td>
</tr>
</tbody>
</table>

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

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

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

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

- 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

- 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!

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

Accuracy
High (~5cm)
Med (~10cm)

Job size (# of points)
High

Mobilization costs
Low
Application

- Large areas (> 3000 km²)
- High point densities (>8 pts/m²)
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Core fields for application

Automated Mapping

Regional Elevation Models

Flood Modeling

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

Time

New technology

Incumbent technology

Tushman, M., Reilly, C., HBS
THANK YOU!

Dr. Simon Musäus
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