15 years practical expierence in airborne laser bathymetry -

Project examples for continued sensor development and survey demands on data processing

Ramona Baran, Ursula Riegl,
Frank Steinbacher & Martin Pfennigbauer

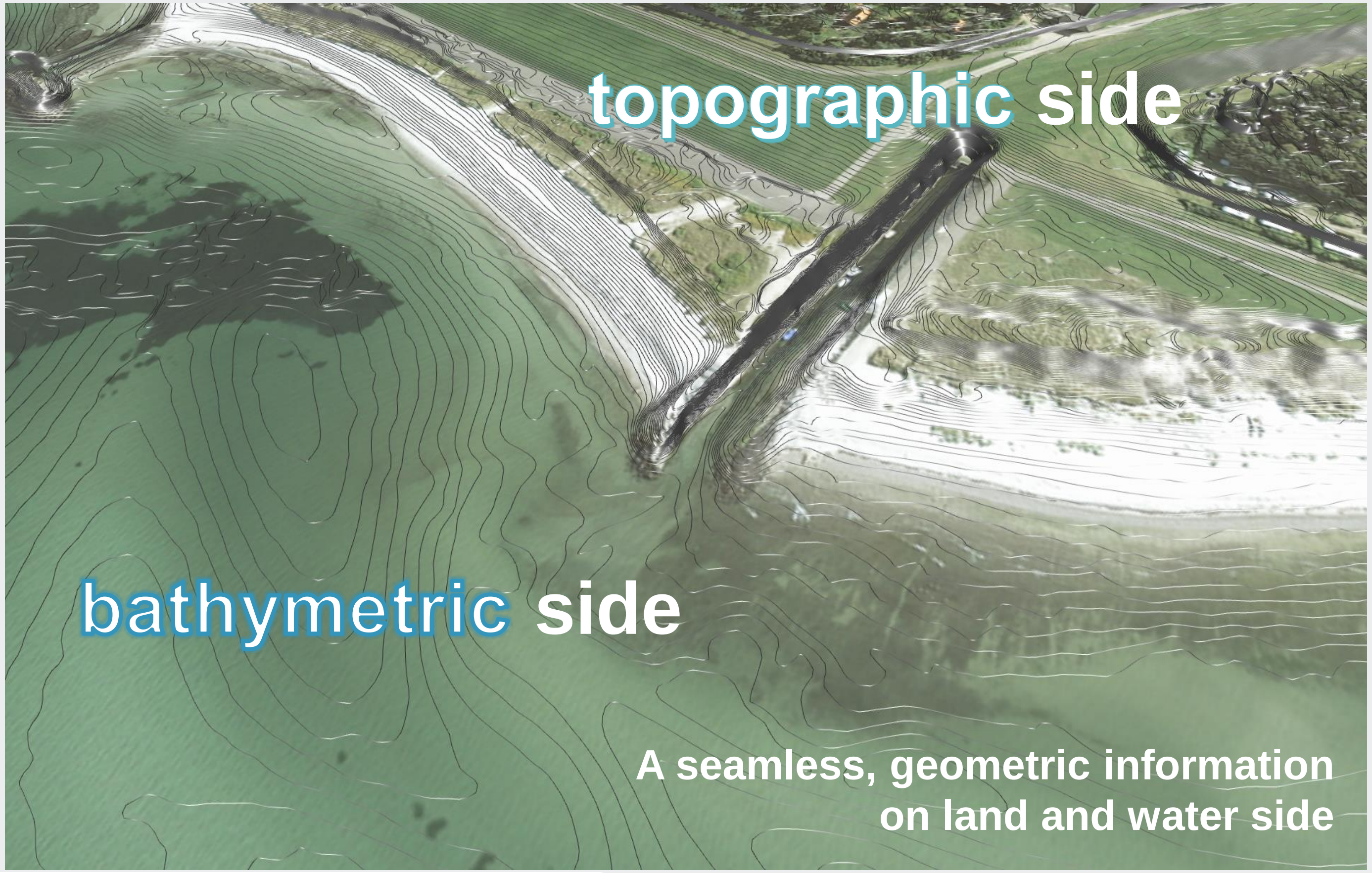
Warnemünde, 07.11.2024

HYDRO 2024
Hydrographic Conference

RIEGL® AHM

What is topobathymetry?

Airborne Hydro Mapping



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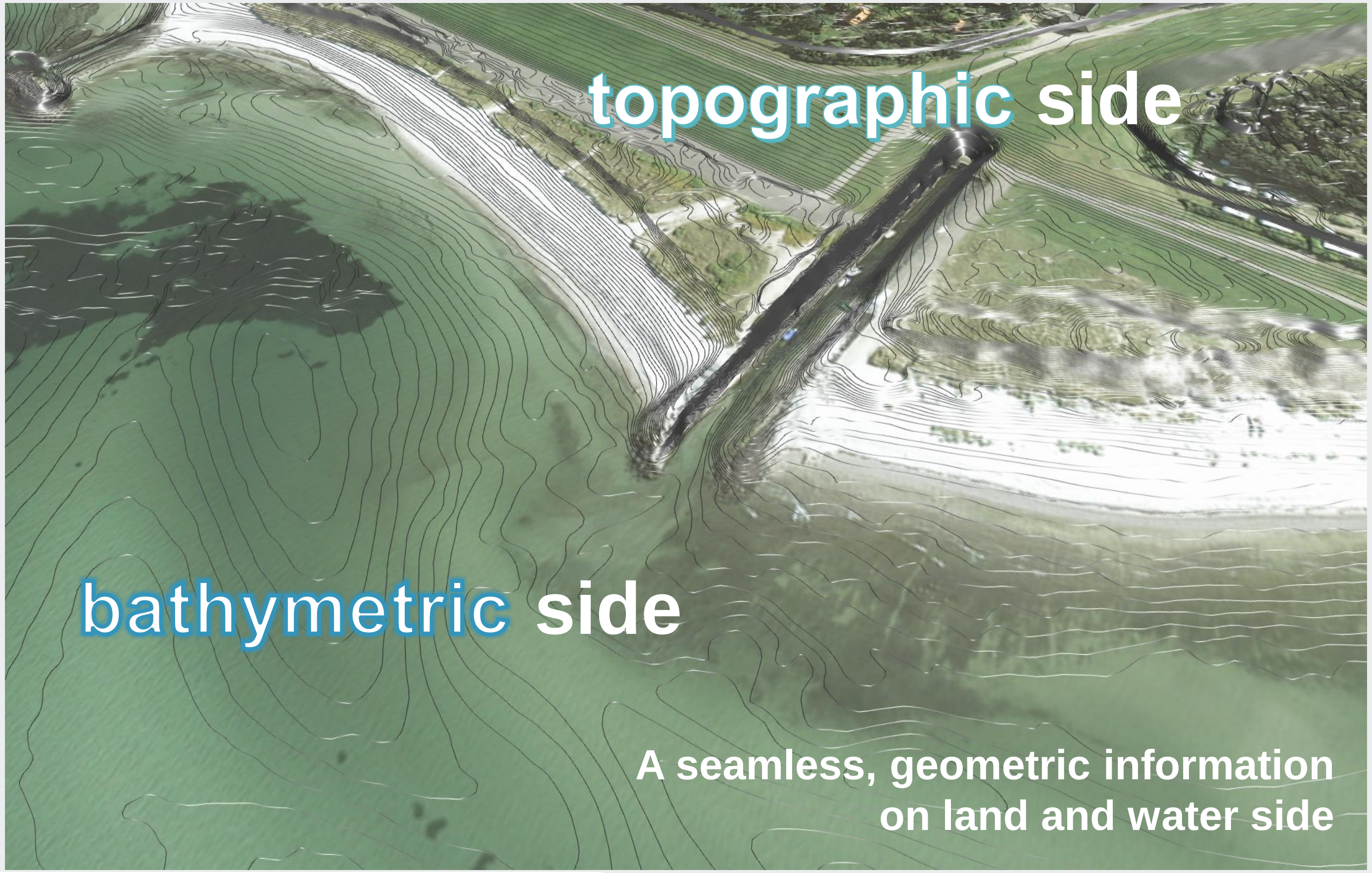
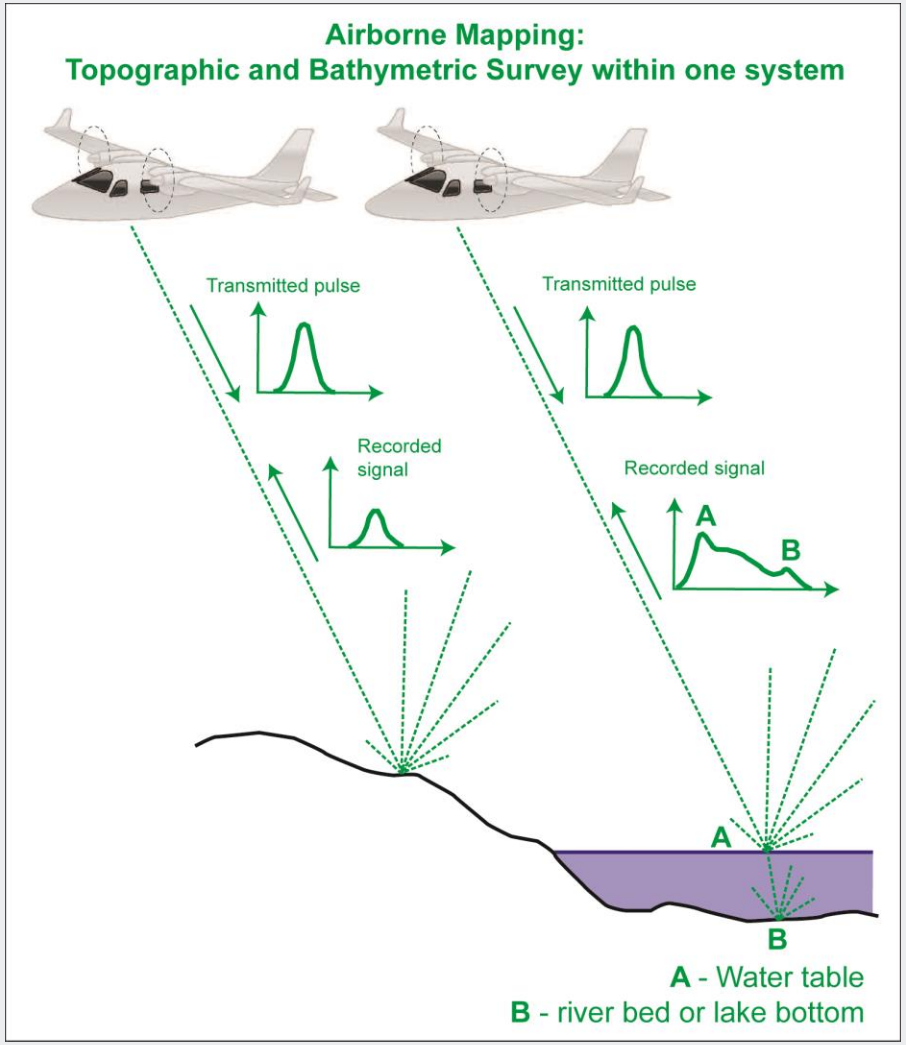
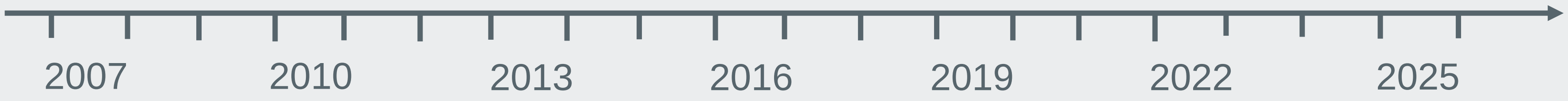
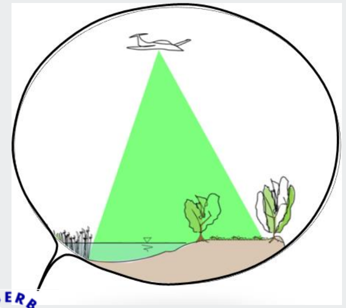




Time line



Kick-off times … 2007-2010: Airborne Hydromapping

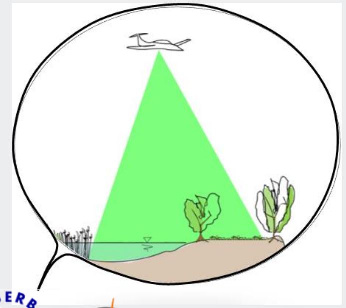


2007 2010 2013 2016 2019 2022 2025

Main driver: **EUropean Water Framework Directive**

27 countries → 500 million people → 1 aim:
Sustainable and ecological utilization of water by developing and implementing of extensive river basin management plans as well as comprehensive risk assessments of different river basin units. Mandatory update every 6 years.

Kick-off times … 2007-2010: Airborne Hydromapping



Demands from hydraulic engineering

Data required for different kinds of numerical models and their calibration (hydraulic/sediment transport/groundwater …)

- riverbed changes due to sediment transport
- continuous and close to reality modeling of river structures and riparian areas
- water management and habitat mapping
- documentation of renaturation and technical measures on water bodies
- database for civil authorities
- flood management and planning
- Indication of water quality

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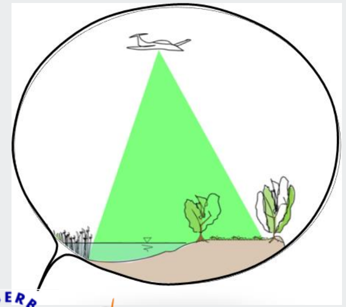

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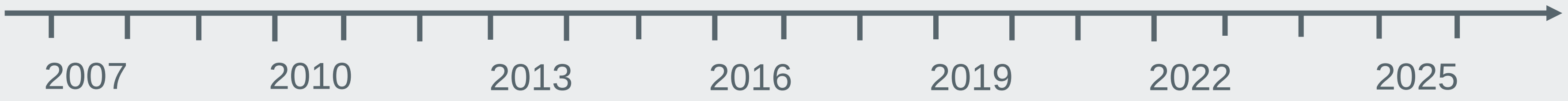
Factors driving system parameters

- wavelength given by transmittance
- focus on minimum depth capturing for shallow water (25 m in clear water)
- eye safety guarantee during operation
- high resolution for numeric models & water engineering purposes
- high ranging accuracy for water engineering purposes
- turbidity/sediment transport: indication of differing turbidity and sediment transport
- compact system layout for integration in small airborne survey platforms (aircraft/helicopter)
- selection of suitable laser technology
- optimization of opto-mechanical sensor technology
- full-waveform signal recording

Kick-off times … 2007-2010: Airborne Hydromapping



RIEGL LASER MEASUREMENT SYSTEMS
FFG

Airborne Hydromapping

Austrian FFG-funded research project betweeen academic & economic partners

→ Joined development of compact topobathymetric LiDAR system dedicated for airborne surveys

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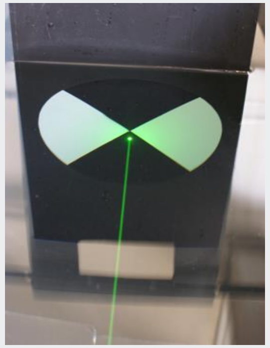

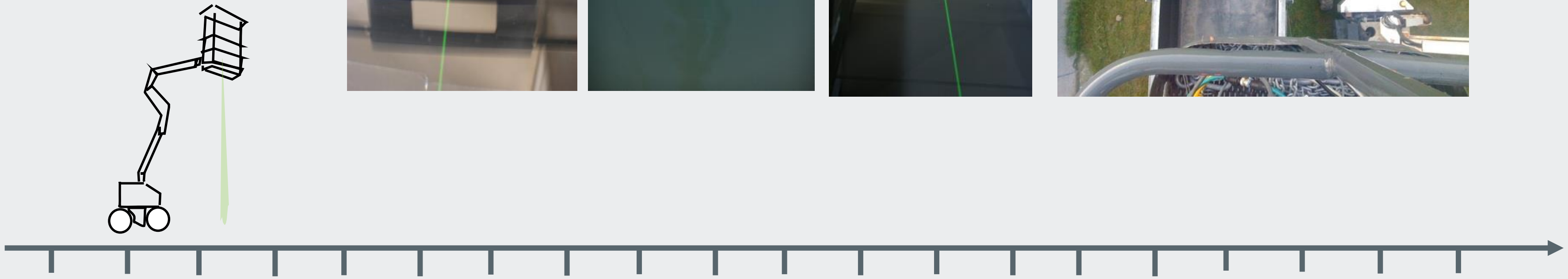

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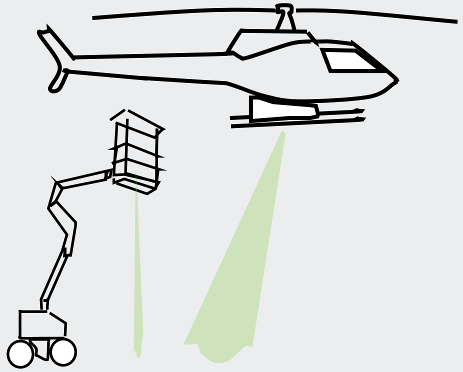

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FFG
WASSERBAU INNSBRUCK
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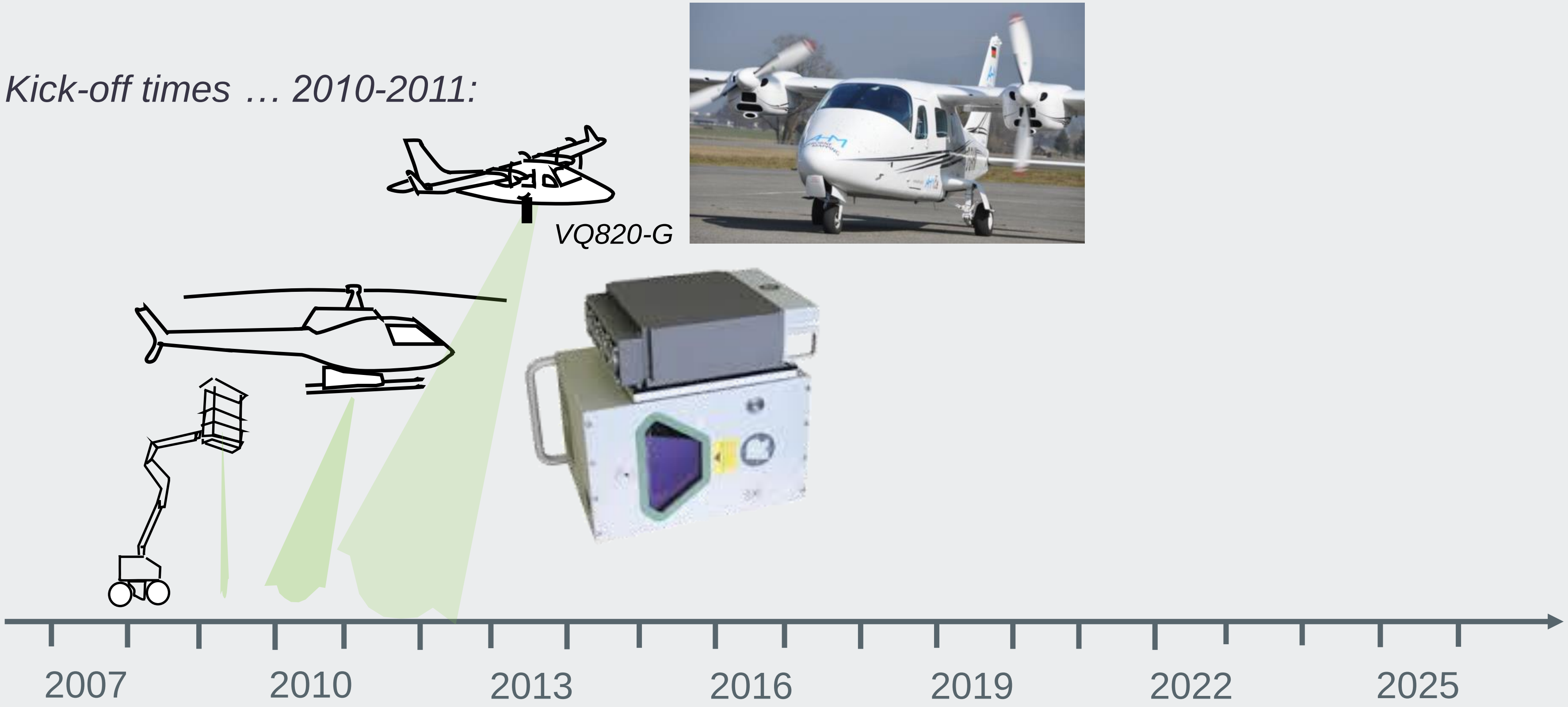
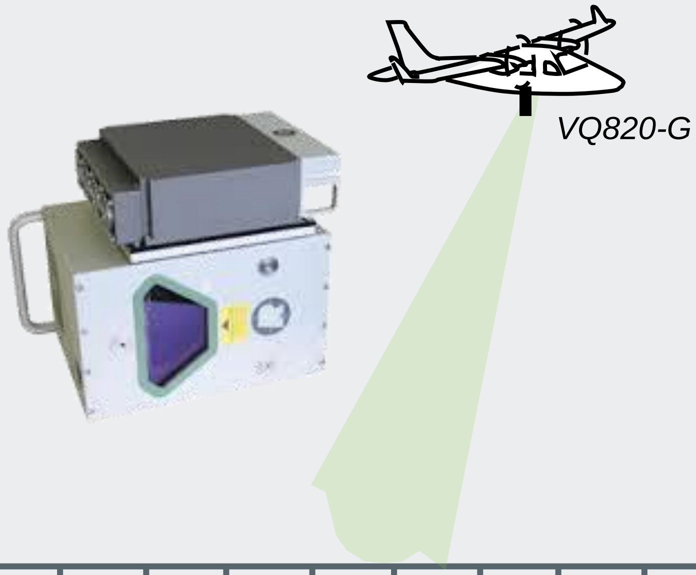
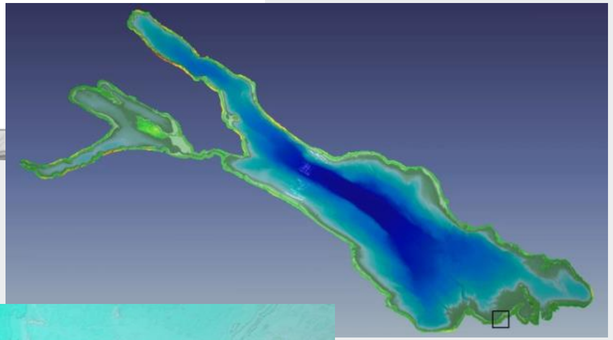


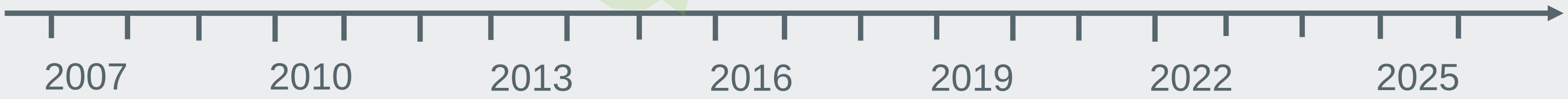
Foundation of AHM GmbH as academic spin-off of Innsbruck University
Tecnam P2006T

Launch of topobathymetric LiDAR sensor production with VQ820-G

Proofing by practice – 2012-2016:

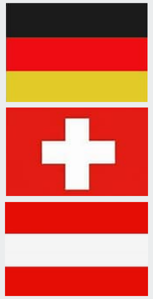


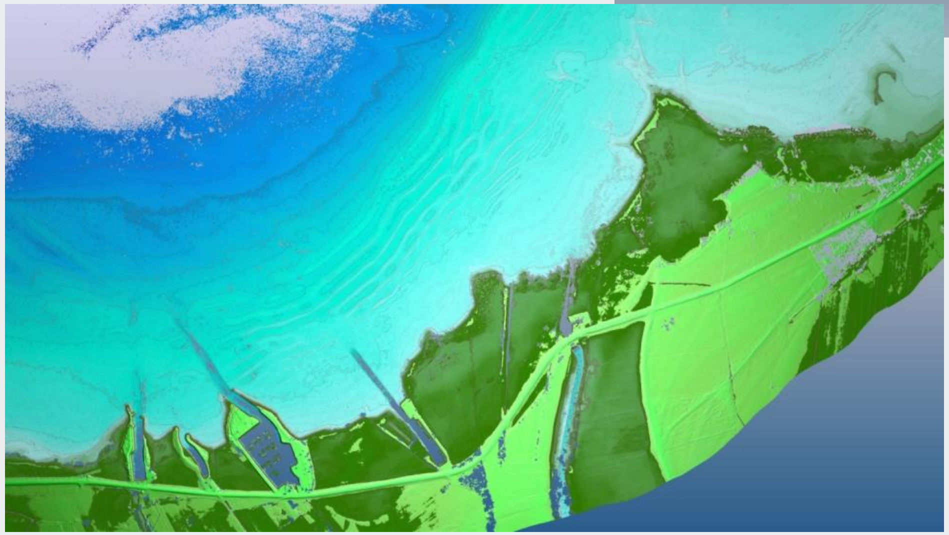




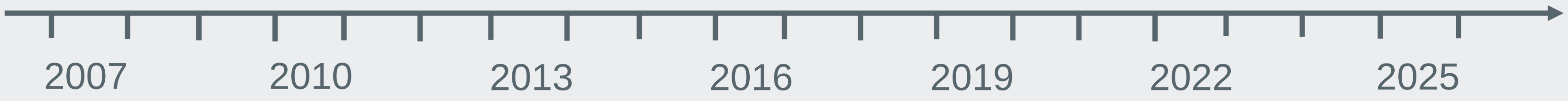
Lake Constance: IGKB - Tiefenschärfe

- Shoreline length 273 km
- Waterdepth down to 10 m





Research to practice – 2012-2016:



Alpine Airborne Hydromapping

Austrian FFG-funded research project between academic & economic partners

→ Close knowledge transfer from scientific institutions & sensor manufacturer to economic applicants of technology

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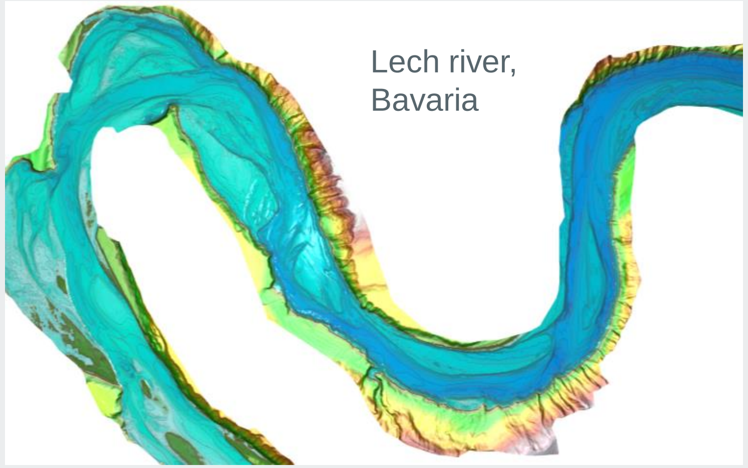

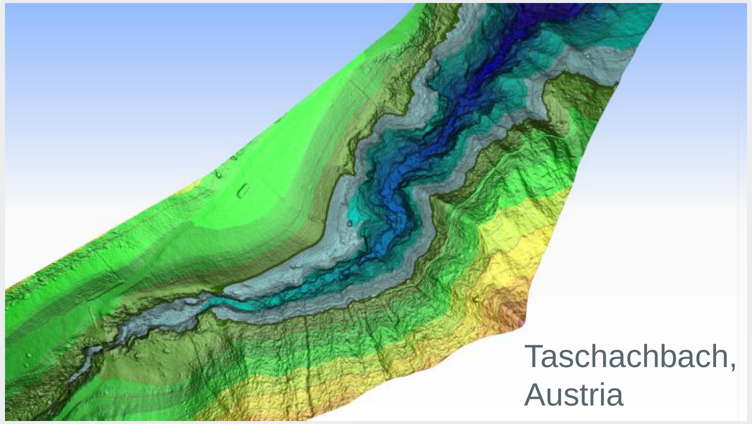

Alpine & pre-Alpine test sites
for data – acquisition/processing/evaluation

2007 2010 2013 2016 2019 2022 2025

Alpine Airborne Hydromapping

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Research to practice – 2012-2016:

Topobathymetry 2.0

RIEGL LASER MEASUREMENT SYSTEMS 2nd sensor generation with VQ880-G
→ two wavelengths
→ completely integrated system including IMU & camera

RIEGL LASER MEASUREMENT SYSTEMS Hardware / Software Development

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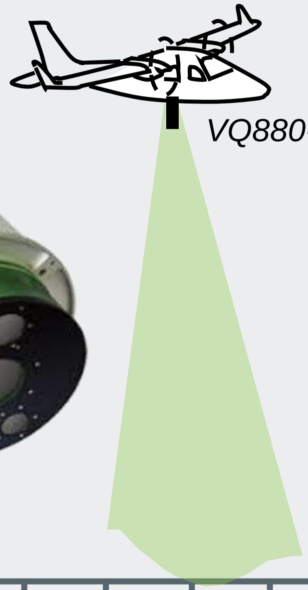
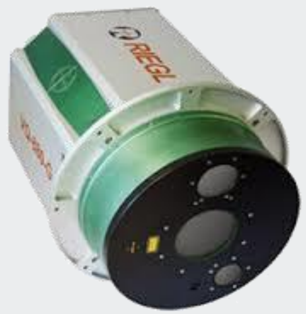
Research to practice – 2012-2016:



VQ880-G



Topobathymetry 2.0

RIEGL LASER MEASUREMENT SYSTEMS 2nd sensor generation with VQ880-G

AHM Sensor upgrade to VQ880-G

2007 2010 2013 2016 2019 2022 2025

RIEGL LASER MEASUREMENT SYSTEMS — Hardware / Software Development

AHM — Data Acquisition / Software Development

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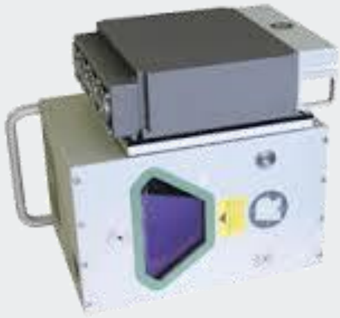
Latest developments – 2016-2024:

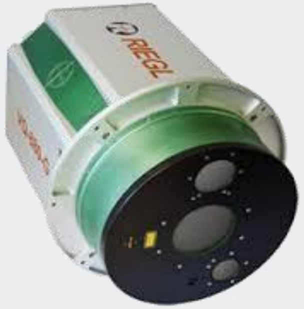
2007 2010 2013 2016 2019 2022 2025

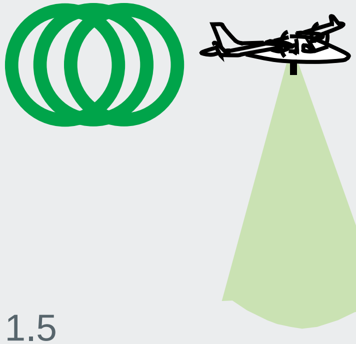
Tecnam
P2006T

Tecnam
P2012 SMP

Topobathymetry 2.0 in practice





	VQ820-G	**VQ880-G**
Altitude	600 m (eye safety)	600 m (eye safety)
Wavelength	532 nm	532 nm
Beam divergence	fix (1 mrad)	variable (0.7-1.1 mrad)
Pulse repetition rate	256 kHz	up to 550 kHz
Scan angle	20° backward	20° forward & backward
Scan pattern		
Secchi depth	1	1.5
Online waveform	yes	yes
Full waveform	(yes)	yes

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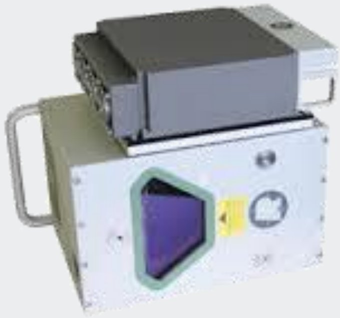

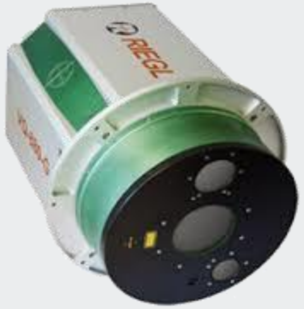

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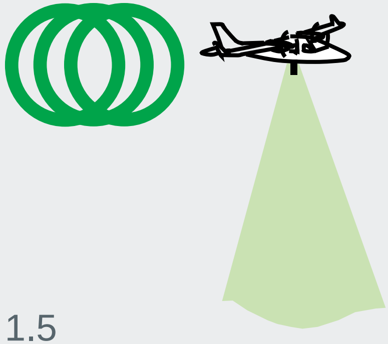
Scan pattern		
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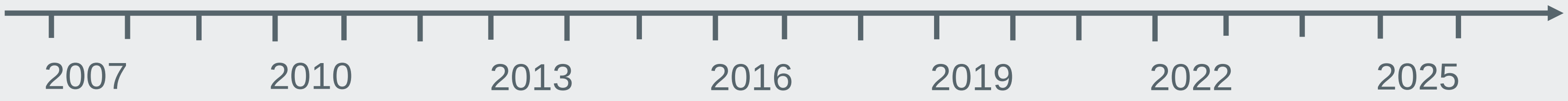
Full waveform	(yes)	yes Trigger

Latest developments – 2016-2024:



Data Acquisition / **Software Development**

KomVISH HYDROVISH

Latest developments – 2016-2024:

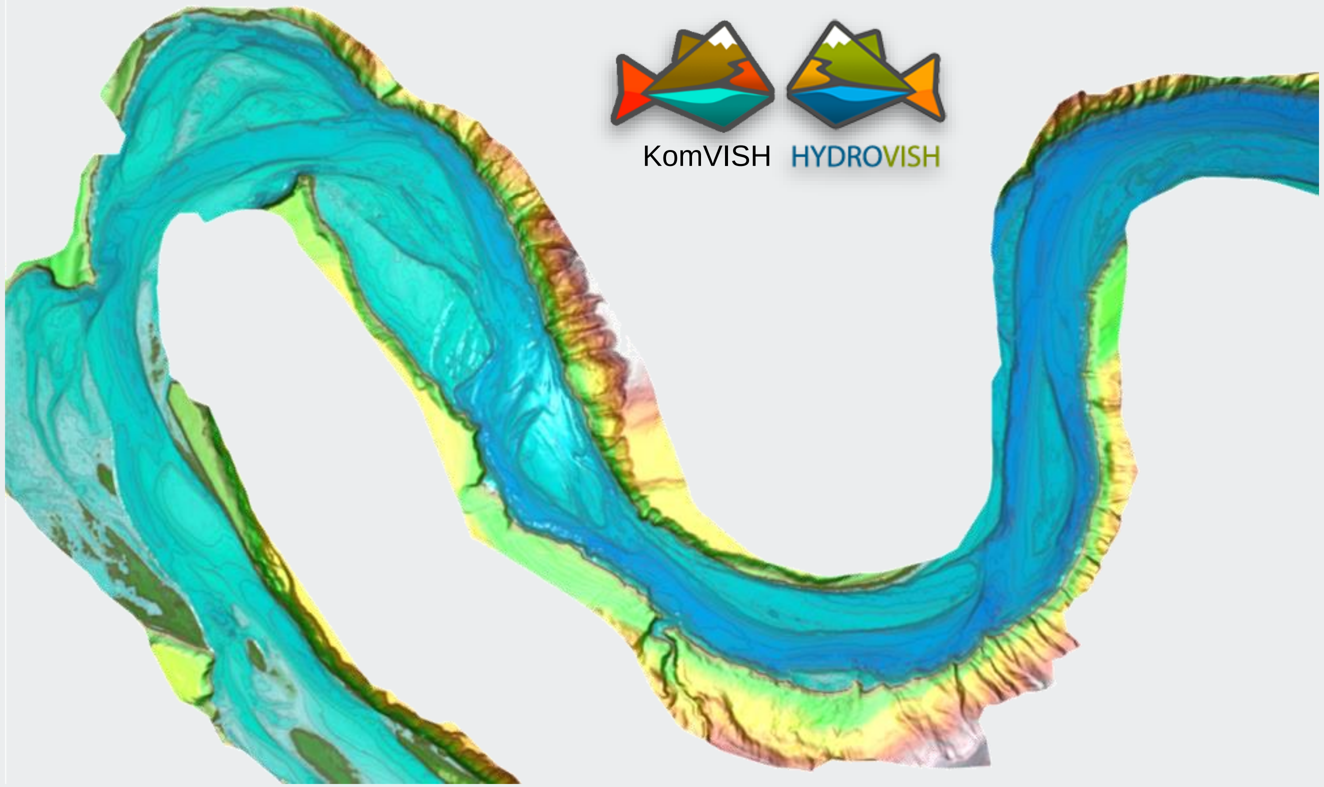
HydroVISH

Data visualisation, -processing & -modelling (filtering, strip adjustment, classification, refraction, FWF analysis, DTM, profiles, contour lines, hydraulic meshes …)

Data merging (LiDAR, MBES, RGB, hydraulics, LoD ...)

3D-geodata Viewer KomVISH as interface to 2D-GIS (ArcGIS Pro & Kominfo)

Handling 3D-geomass data (e.g. LiDAR & DSM-data Bavaria)

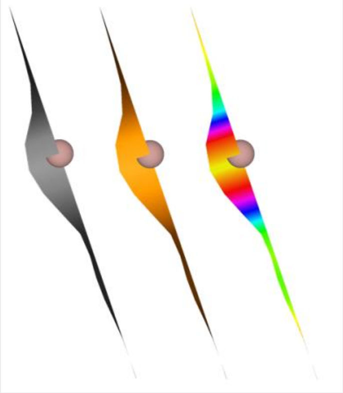


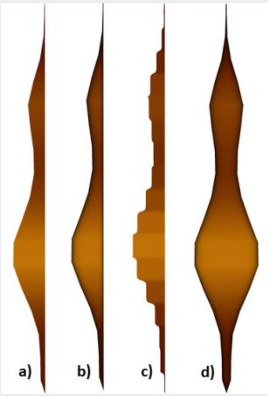
Latest developments – 2016-2024:

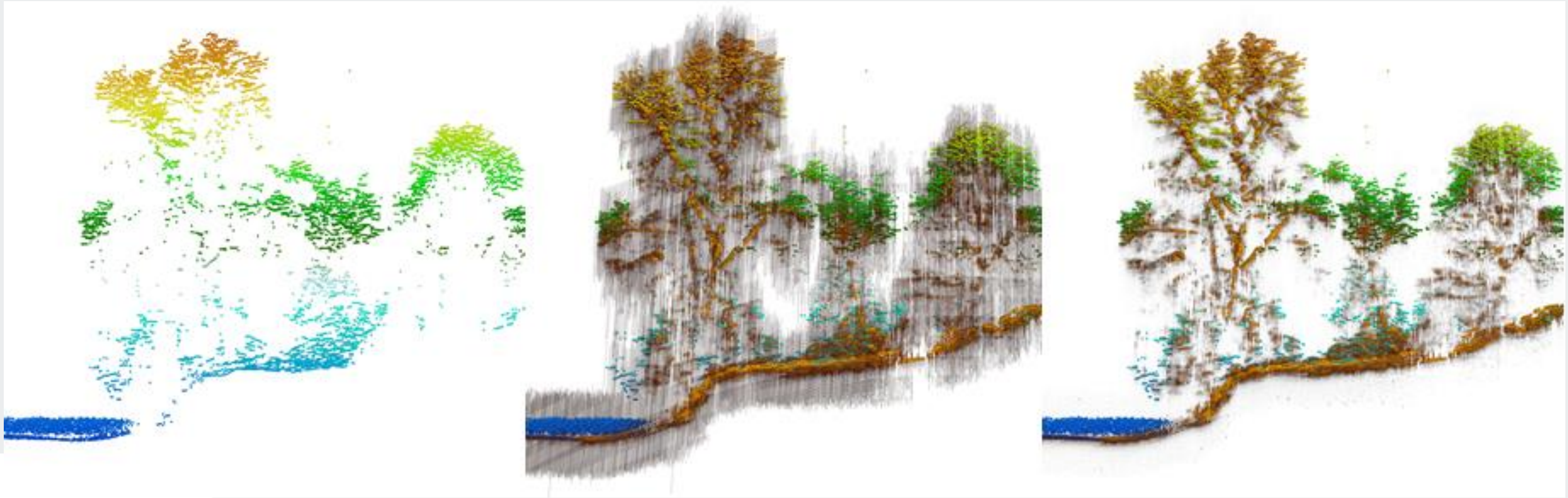
HydroVISH

Flexible real-time visualisation of full waveform & point data
for evaluation of data quality related penetration depth
and aerial waterground coverage

→ **Support of FWF analysis**





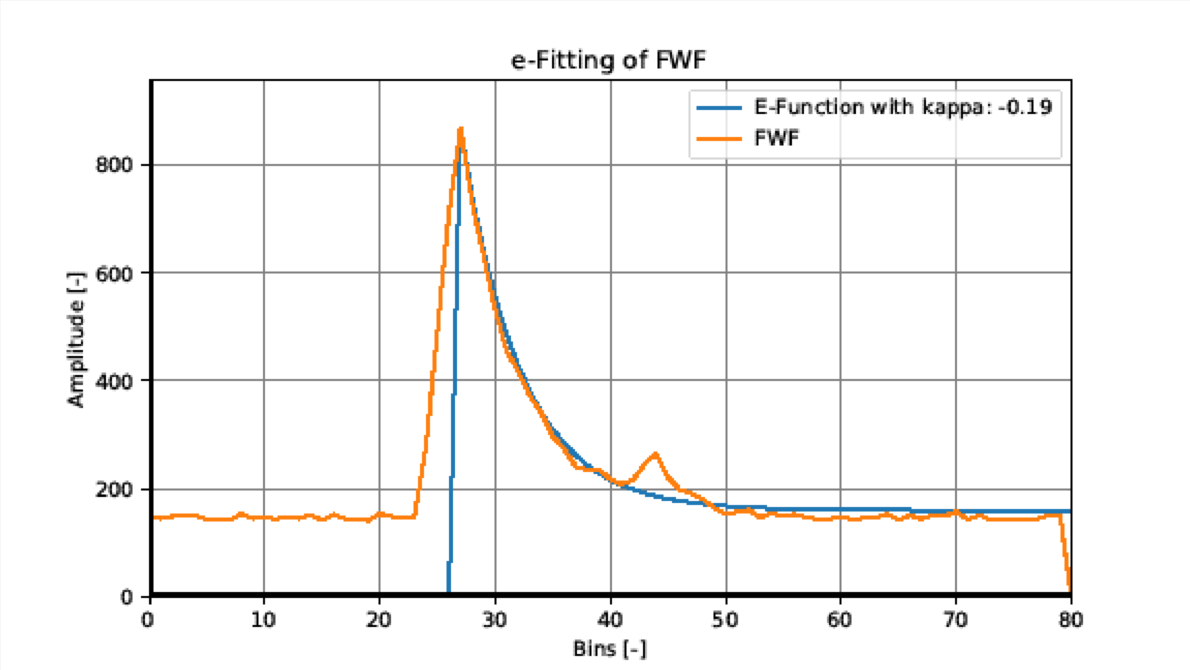


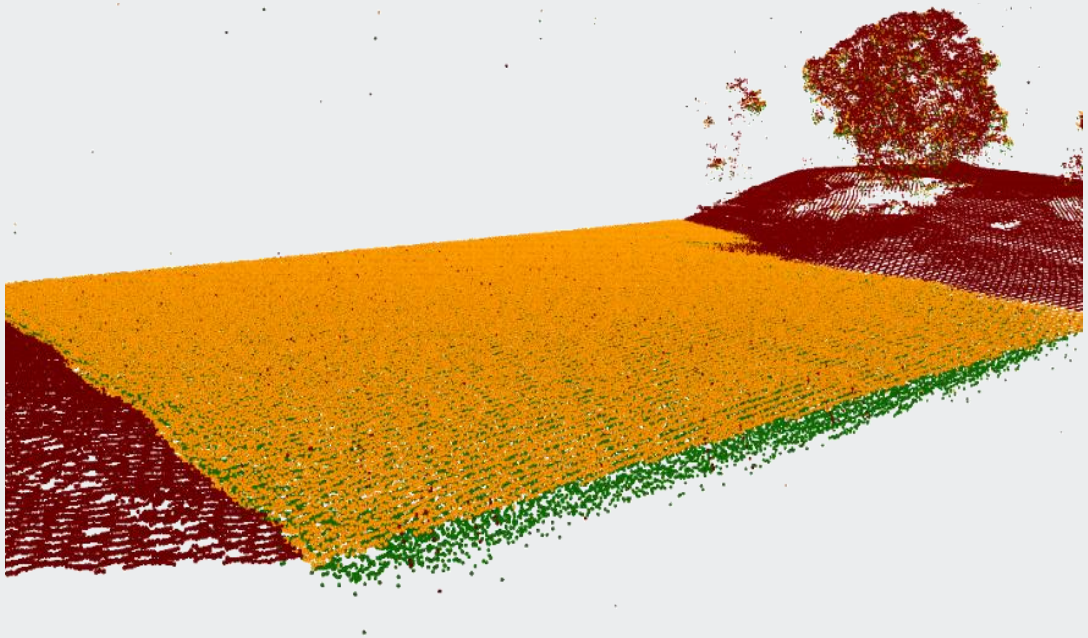
Latest developments – 2016-2024:

HydroVISH

Pre-classification of waterbody based on FWF by e-function fitting

→ **Support of point classification**





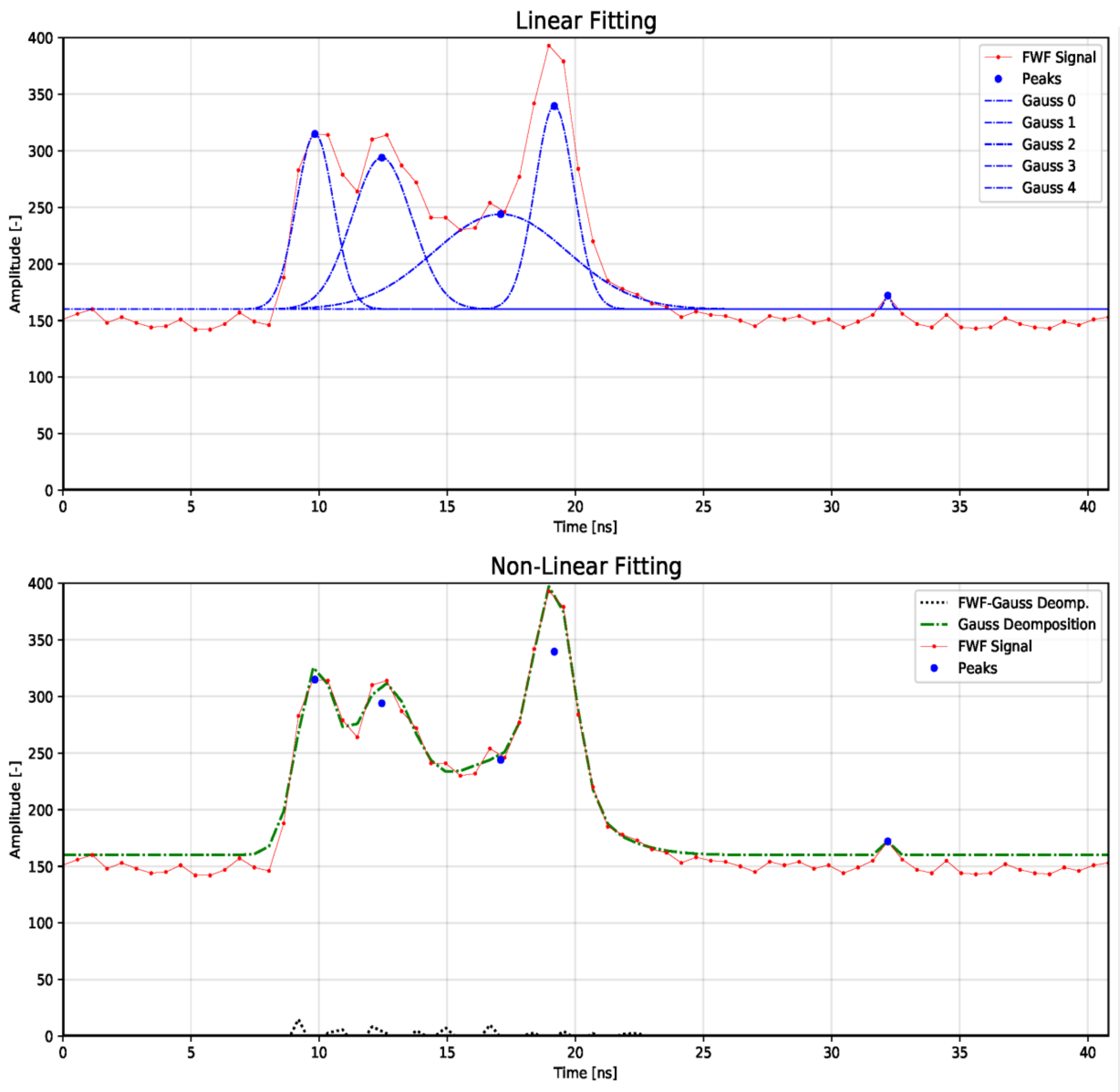
Latest developments – 2016-2024:

HydroVISH

Flexible FWF analysis related

Signal decomposition:

Implemented: Gaussian decomposition



Latest developments – 2016-2024:

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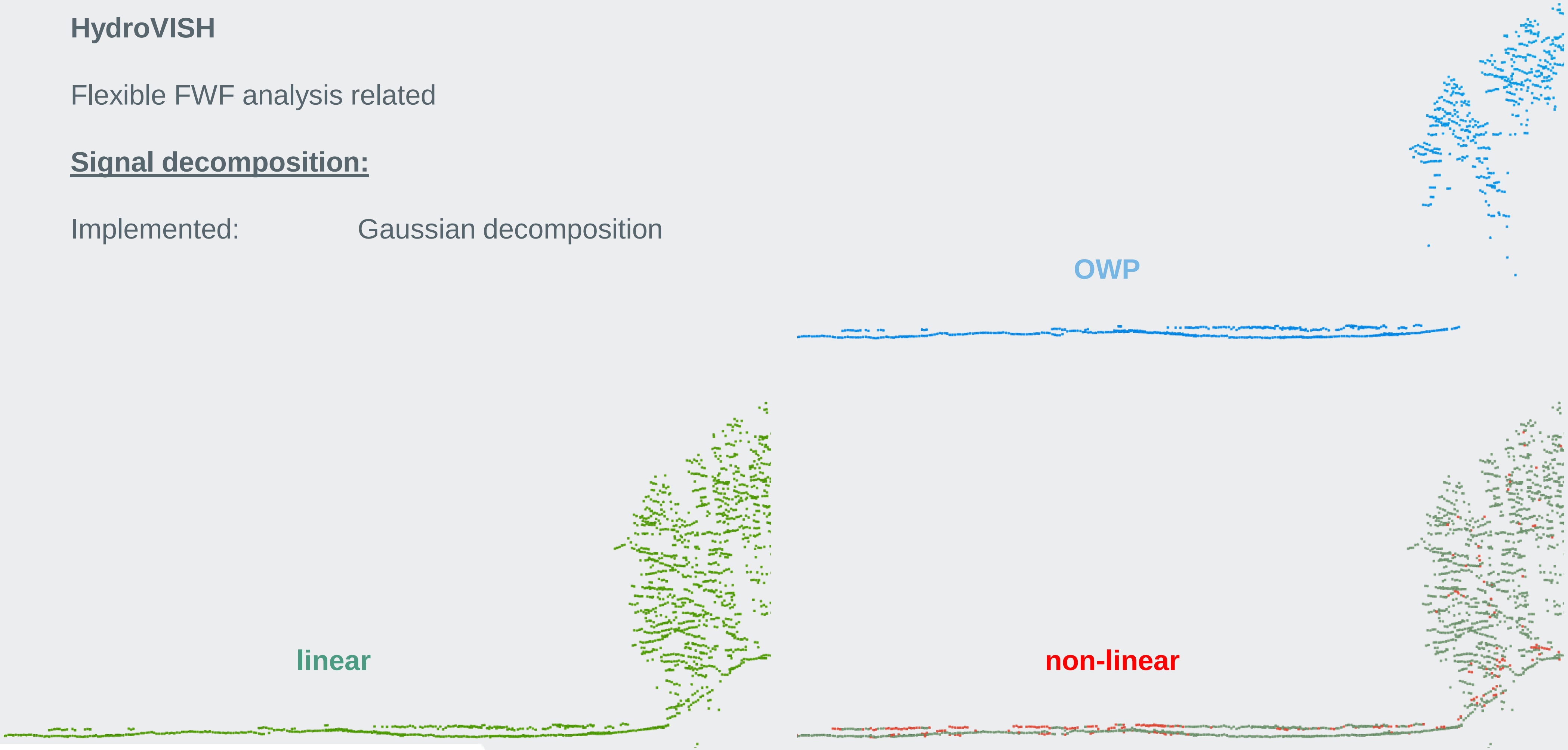


Latest developments – 2016-2024:

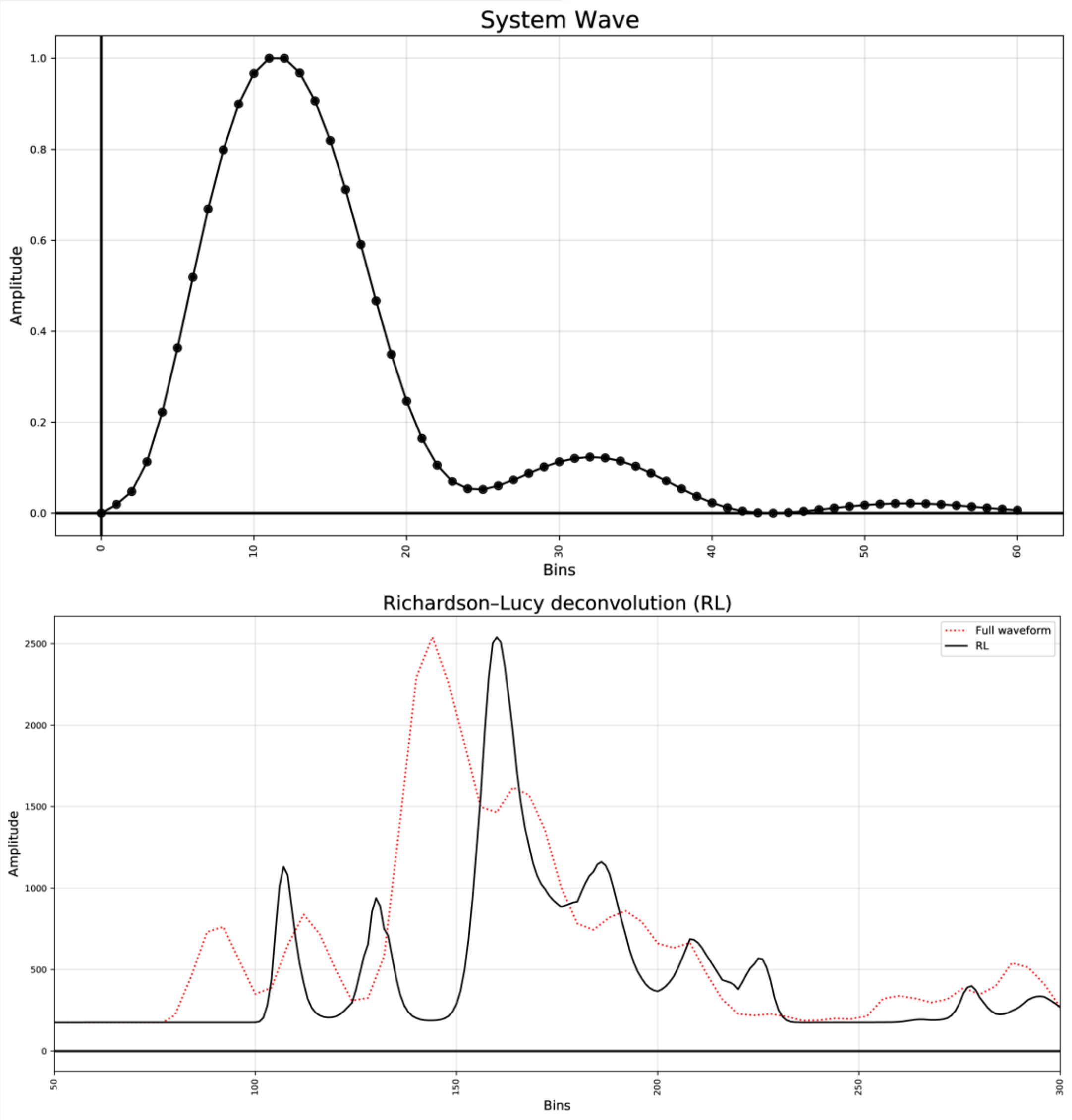
HydroVISH

Flexible FWF analysis related

<u>Deconvolution</u>

Using known system wave

Implemented: Richardson-Lucy



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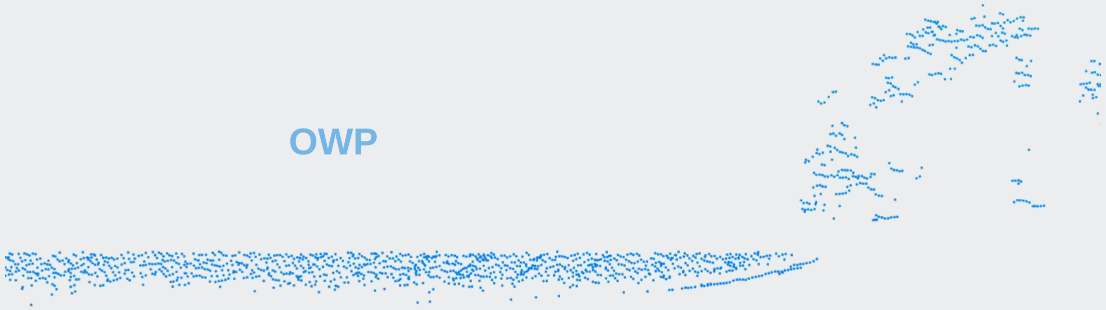


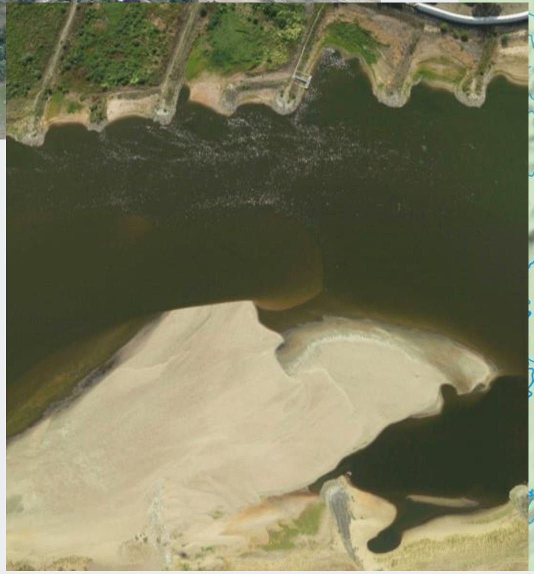
AHM

Latest developments – 2016-2024:

Elbe – August 2018

600 km river survey at extreme low water stage

Secchi depth 1.2-1.5 m → penetration depth down to 2.5 m



WSV.de
Wasserstraßen- und Schifffahrtsverwaltung des Bundes

RIEGL®

Latest developments – 2016-2024:

Elbe – August 2018

Scientifically supported FWF analysis and evaluation of results for three ca. 5 km long river section:

Classified waterground point density
Aerial waterground coverage

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Wasserstraßen- und Schifffahrtsverwaltung des Bundes

TU WIEN

RIEGL

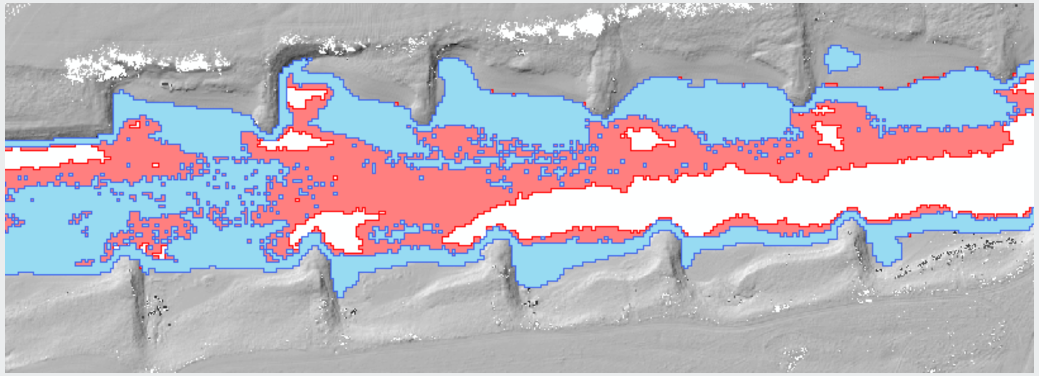
Latest developments – 2016-2024:

Elbe – August 2018

Best statistics for Richardson Lucy deconvolution & hybrid approach

Results very similar, as for hybrid approach at low amplitudes of waterbody Richardson Lucy deconvolution is applied

High amplitudes: Gaussian decomposition with one iteration → Suppression of implausible FWF points from implausible FWF peak detection



Perimeter	Method	Mean (points/m²)	Median (points/m²)	Total number water ground points
TS1 Hamburg	FWF - linearGauss	33.383	24	5‘384‘882
	FWF - GaussZerlegung	35.077	25	5‘421‘125
	FWF - RL-Entfaltung	38.087	28	6‘902‘709
	FWF - Hybrid	37.332	28	6‘475‘765
	OWP	35.085	26	5‘088‘627
TS2 Magdeburg	FWF - linearGauss	38.951	30	10‘736‘365
	FWF - GaussZerlegung	35.812	25	9‘660‘734
	FWF - RL-Entfaltung	43.384	34	12‘886‘671
	FWF - Hybrid	42.695	33	12‘301‘374
	OWP	40.102	31	8‘931‘249
TS3 Elster	FWF - linearGauss	54.454	51	25‘214‘902
	FWF - GaussZerlegung	51.382	47	23‘595‘085
	FWF - RL-Entfaltung	61.002	56	28‘646‘848
	FWF - Hybrid	60.853	56	28‘329‘504
	FWF - Stapelung	69.450	65	32‘133‘627
	OWP	46.936	40	12‘642‘703

Perimeter	Method	Number of 2x2 m-raster cells	Water ground area (m²)	Gain in FWF- to OWP-water ground (%)
TS1 Hamburg	FWF - linearGauss	49‘727	198‘908	+10.66
	FWF - GaussZerlegung	48‘337	193‘348	+7.57
	FWF - RL-Entfaltung	53‘616	214‘464	+19.32
	FWF - Hybrid	51‘673	206‘692	+14.99
	OWP	44‘935	179‘740	
TS2 Magdeburg	FWF - linearGauss	82‘061	328‘244	+18.63
	FWF - GaussZerlegung	81‘077	324‘308	+17.21
	FWF - RL-Entfaltung	86‘226	344‘904	+24.65
	FWF - Hybrid	83‘893	335‘572	+21.28
	OWP	69‘175	276‘700	
TS3 Elster	FWF - linearGauss	122‘442	489‘768	+53.19
	FWF - GaussZerlegung	121‘933	487‘732	+52.55
	FWF - RL-Entfaltung	123‘950	495‘800	+55.08
	FWF - Hybrid	122‘911	491‘644	+53.78
	FWF - Stapelung	122‘394	489‘576	+53.13
	OWP	79‘928	319‘712	

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Latest developments – 2016-2024:

Topobathymetry 2.0

RIEGL LASER MEASUREMENT SYSTEMS Bridging gaps: UAV with VQ840-G

→ First compact ALB-scanner for lower flight levels
→ Integration on smaller drones, or crewed helicopters/aircrafts
→ very detailed survey of complex environments & feature detection within water column
→ 2x Secchi depth & pulse repetition rate up to 200 kHz

2007 2010 2013 2016 2019 2022 2025

RIEGL LASER MEASUREMENT SYSTEMS Hardware / Software Development

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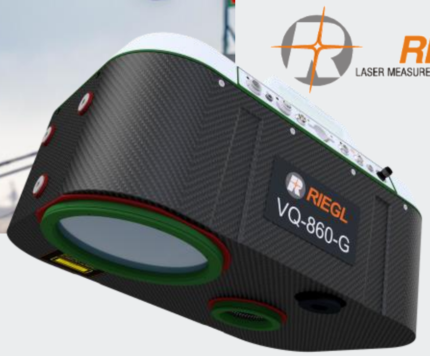
Future – 2025 & beyond:



Topobathymetry 3.0 – green at ALL

RIEGL LASER MEASUREMENT SYSTEMS VQ860-G

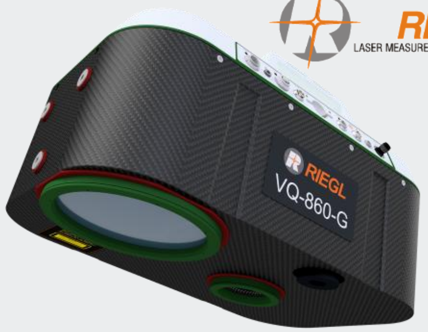
→ Compact high performance ALB-scanner for increased water depth penetration
→ enhanced productivity due to larger operational envelope up to 300 m flight altitude
  → 2.5x Secchi depth
  → pulse repetition rate up to 100 kHz

2007 2010 2013 2016 2019 2022 2025

RIEGL LASER MEASUREMENT SYSTEMS — Hardware / Software Development

Future – 2025 & beyond:

Topobathymetry 3.0 – green at ALL



RIEGL LASER MEASUREMENT SYSTEMS VQ860-G

AHM eVTOL Ehang 216

2007 2010 2013 2016 2019 2022 2025

RIEGL LASER MEASUREMENT SYSTEMS — Hardware / Software Development

AHM — Data Acquisition / Software Development

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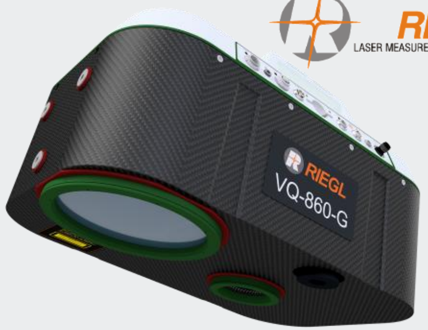
Future – 2025 & beyond:

Topobathymetry 3.0 – green at ALL

RIEGL LASER MEASUREMENT SYSTEMS VQ860-G

AHM eVTOL Ehang 216



2007 2010 2013 2016 2019 2022 2025

E-Formica EF-12EV, 420 kWh movable charging & start/landing platform for eVTOL

eloaded
STREAMING ENERGY

https://www.ehang.com

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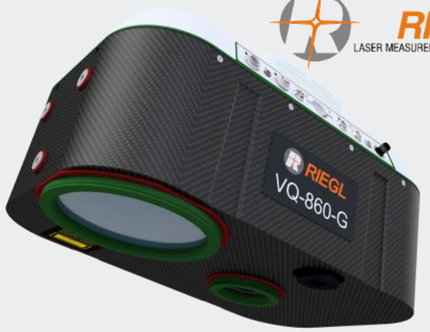
Future – 2025 & beyond:

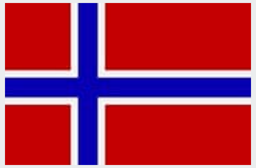
Topobathymetry 3.0 – green at ALL



RIEGL LASER MEASUREMENT SYSTEMS VQ860-G

AHM eVTOL Ehang 216

→ Potential pilot application in



2007 2010 2013 2016 2019 2022 2025

https://www.ehang.com

E-Formica EF-12EV, 420 kWh movable charging & start/landing platform for eVTOL

eloaded STREAMING ENERGY

Thank you for your attention!

Any questions?

HYDRO 2024 Hydrographic Conference