True Autonomy in Offshore Wind Operations & Maintenance

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The Offshore Wind Market

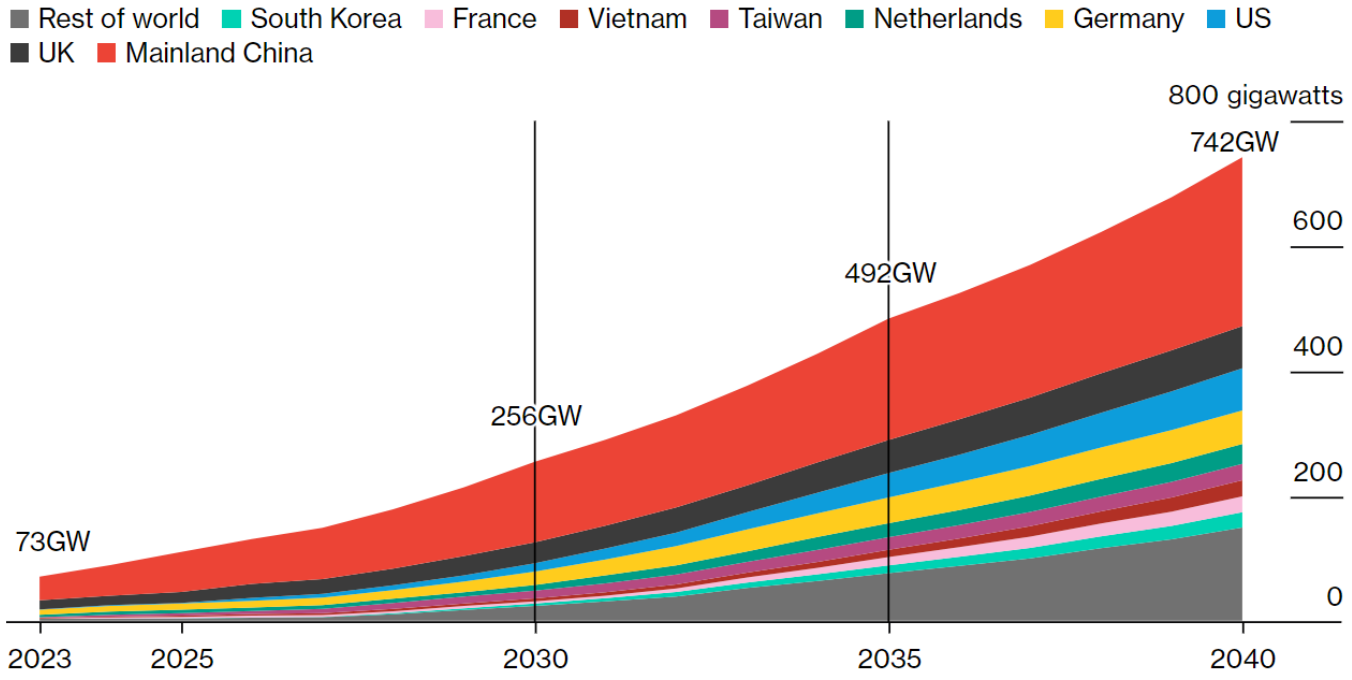
Growth and Opportunities for Hydrographic Services

Global Offshore Wind Market

- Global CAGR: 15-20%
- Global capacity (2023): 73 GW
- Projections (2033): 400 GW

Offshore Wind Installations to Grow 10-Fold Through 2040

Outlook for global cumulative offshore wind installations, by market



Source: BloombergNEF
Note: Rest of the world = Australia, Belgium, Brazil, Colombia, Denmark, Estonia, Finland, Greece, Ireland, India, Italy, Japan, Latvia, Lithuania, Norway, Poland, Portugal, Spain, Sweden.

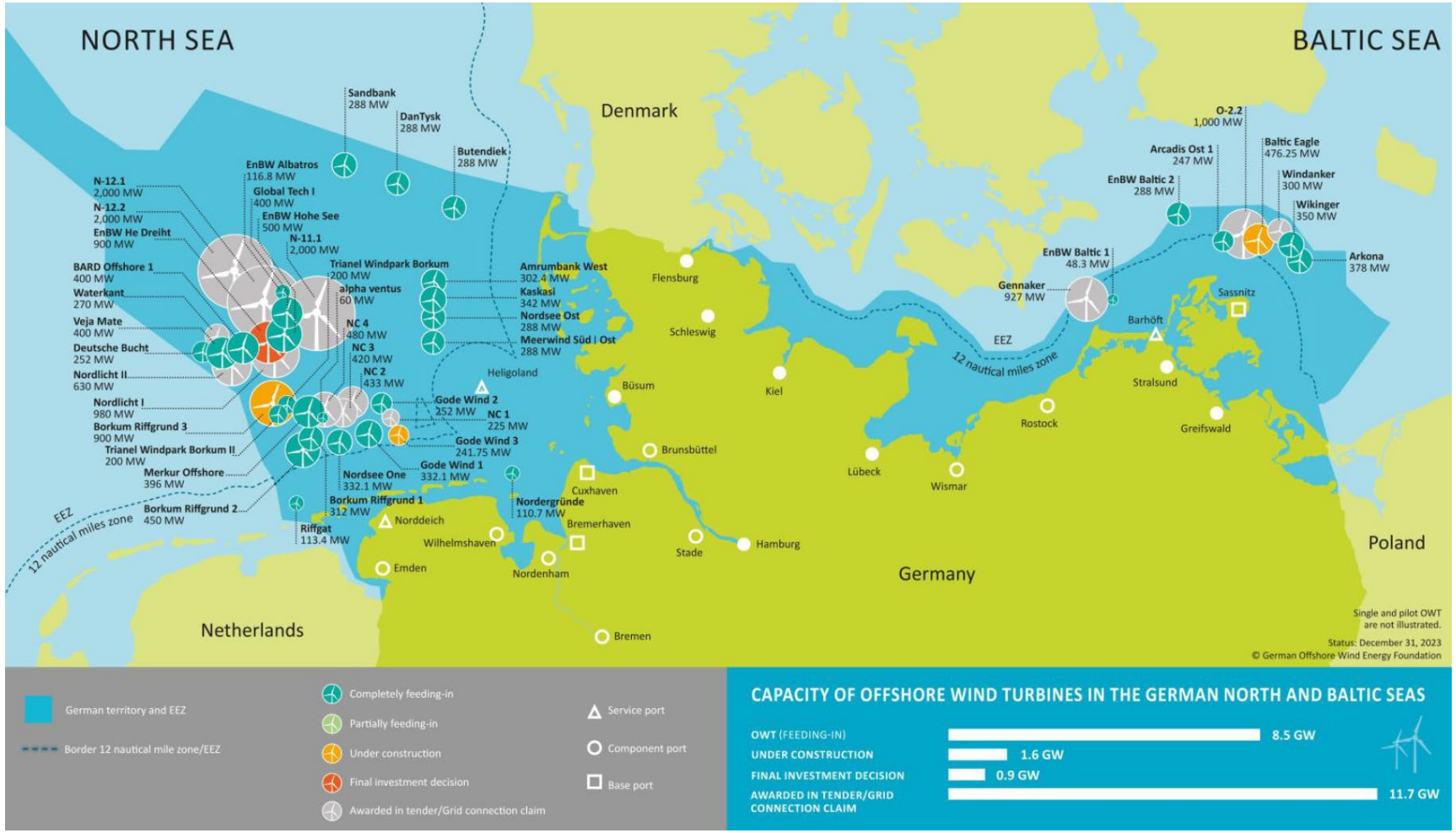
BloombergNEF

Germany’s Offshore Wind Market

- OWT: 1,566
- Total capacity: 8.5 GW

→ (31.12.2023)

- Germany’s target:
  - at least 30 GW by 2030
  - and 40 GW by 2040,
- Economic Impact:
  - Significant contribution to economy
  - Important for Germanys energy security



Offshore Wind Operations & Maintenance

Key Objective:

To maximize energy production

Ensure safety

Minimize downtime and repair costs through regular, proactive maintenance

O&M Challenges in Offshore Wind:

Environmental Conditions: Offshore turbines face harsh conditions, including high winds, saltwater corrosion, and strong currents

Accessibility: Remote locations make access difficult, requiring specialized vessels and weather-dependent scheduling

Costs: O&M costs can constitute up to 25-30% of the total lifecycle costs of an offshore wind farm, making efficiency crucial for cost-effectiveness

Key Components of Offshore Wind O&M:

Foundation and Structural Maintenance

Electrical Systems Maintenance

Turbine Maintenance

Essential Hydrographic Tasks

Annual survey and inspection of
25 % (100 %) of the

- Foundations of the Wind Turbine Generators
- Foundations of the Offshore Substations
- Inter-Array Cables
- Cathodic Protection
- Cable Protection Systems

Traditional Survey Methods

Challenges and Limitations

Conventional methods of generating and analyzing marine data involving **crewed vessels** and **human data analysts**, are notably costly leaving the full potential of such data largely untapped.

Challenges and limitations

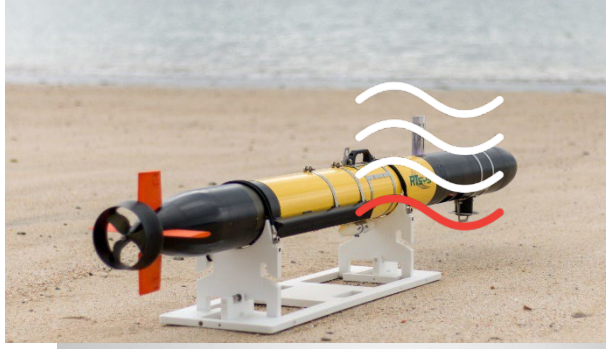
- High Operational Costs:
  - Fuel and Crew Expenses: Large vessels are costly to operate due to high fuel consumption and the need for skilled personnel.
  - Weather Delays: Surveys are often postponed in poor weather, adding costly standby charges.
- Environmental Impact:
  - High Emissions: Large survey vessels produce significant emissions, counter to the renewable energy mission of offshore wind.
- Crew Safety Risks:
  - Offshore work in harsh, remote environments presents safety hazards for crew members, particularly in bad weather or turbulent seas.
- Operational Inflexibility:
  - Mobilization Time: Large vessels require extended planning and setup time, reducing responsiveness for urgent or ad-hoc surveys.

The shift towards True Autonomy

Subsea Europe Services simplifies marine data acquisition and analysis

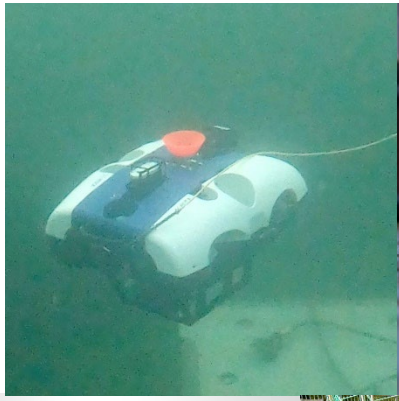
We deliver integrated survey solutions and software applications that merge autonomous high-quality data collection with enriched analytical capabilities, adding significant value for our customers.

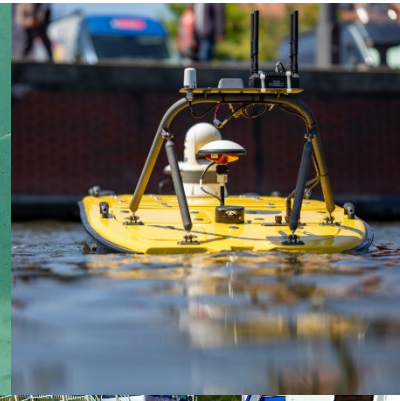
Subsea Europe Services in a Nutshell



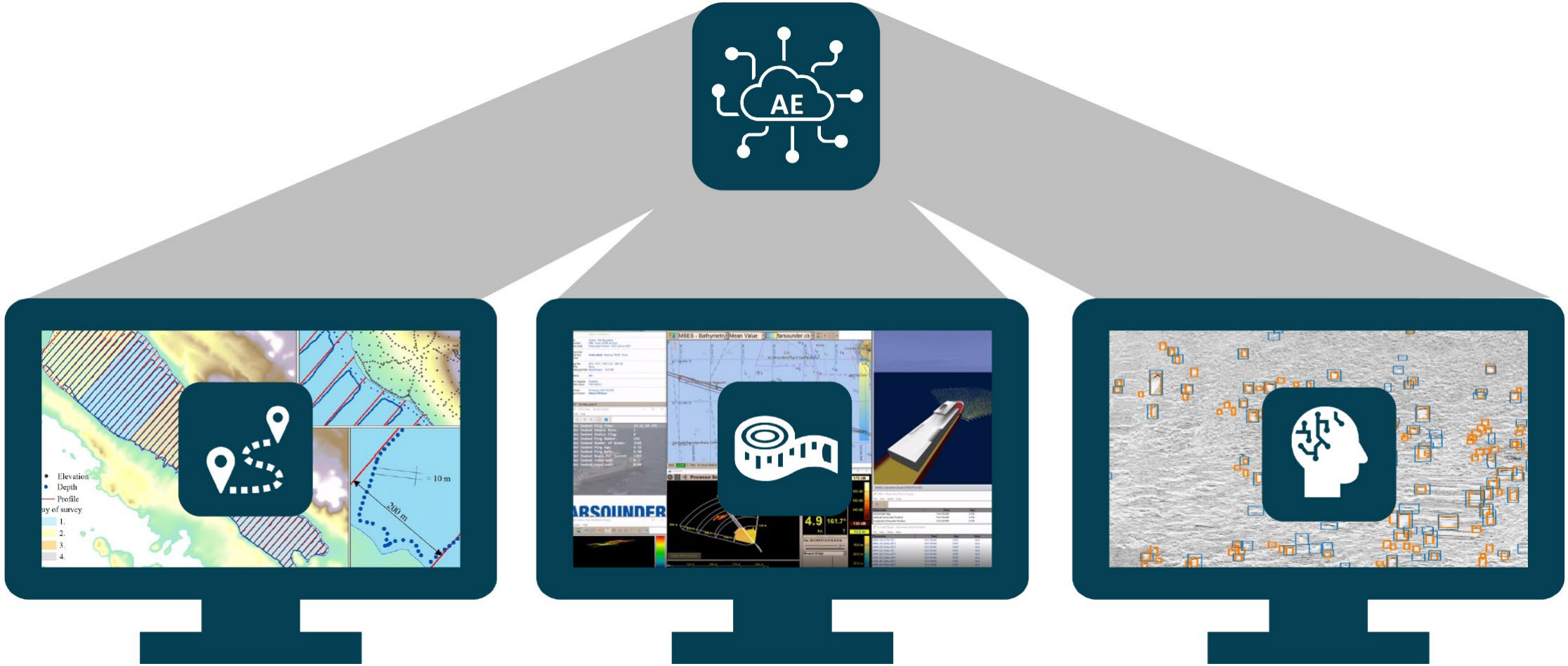
Subsea Europe Services' mission is to **simplify marine data acquisition and analysis** by delivering integrated survey solutions and software applications that merge autonomous high-quality data collection with enriched analytical capabilities, adding **significant value for our customers**.

- Established in January 2020
- 28 Employees and growing
- Logistics hub in Halstenbek
- R&D and Test Center in Rostock
- Rental, Sales & Services for
  - Hydrographic Survey Equipment
  - Integrated Systems (AUV, HAUV and USV)
- Extended Services:
  - Survey and Inspection as a Service
  - Maritime Security as a Service





The Autonomy Suite

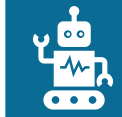


Autonomous Planner

Autonomous Operator

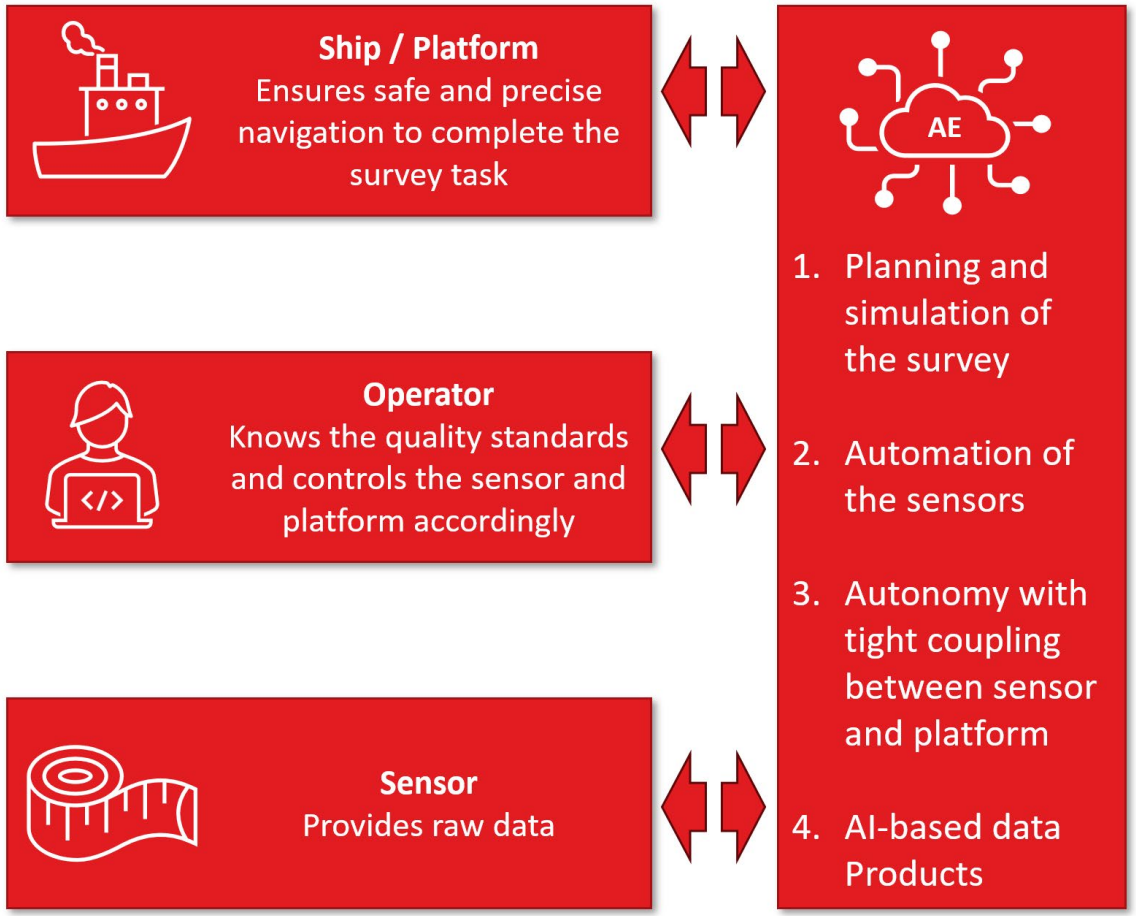
Autonomous Analyst

Survey Autonomy Level

	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
	No Automation	**Driver Assistance**	**Partial Automation**	**Conditional automation**	**High Automation**	**Full Automation**
Car 	Driver controls everything.	Most functions controlled by driver but some can be done automatically by the car.	At least 2 critical functions are automated (like cruise control & line centering), but the driver must be ready to take control.	Drivers still necessary, but not required to monitor the situation all the time.	Vehicle performs safety-critical driving functions for the entire trip, human override is still an option.	Vehicle performs all driving tasks under all conditions. No human attention or interaction required!
Ship 	Same a car	Same a car	Same a car	Same a car	Same a car	Same a car
Sensor 	Surveyor controls everything	Most functions controlled by surveyor but some can be done automatically by the sensor.	At least 2 critical functions are automated (like range and gate track), but the surveyor must be ready to take control	Sensor performs critical functions automated (range, gate, swath, power). Surveyor still necessary, but not required to monitor sensor all the time.	Sensor performs all functions automated, human override is still an option.	Sensor performs all survey tasks under all conditions. No human attention or interaction required!
Survey System 	Captain and Surveyor control everything.	Most functions controlled by captain and surveyor but some can be done automatically by ship and sensor (independently).	At least 2 critical functions are automated for both, ship and sensor (still independently).	Survey System (ship + sensor) are loosely coupled and perform critical functions as an coupled system.	Survey System (ship + sensor) are tightly coupled and perform all functions as an integrated system, human override is still an option.	Survey System (ship + sensor) are tightly coupled and perform all functions as an integrated system. No human attention or interaction required!

The Autonomy Engine

The Autonomy Engine breaks down the silos between safe and efficient navigation, high-quality data acquisition, and extraction of high-value information. This is what we call **True Autonomy.**

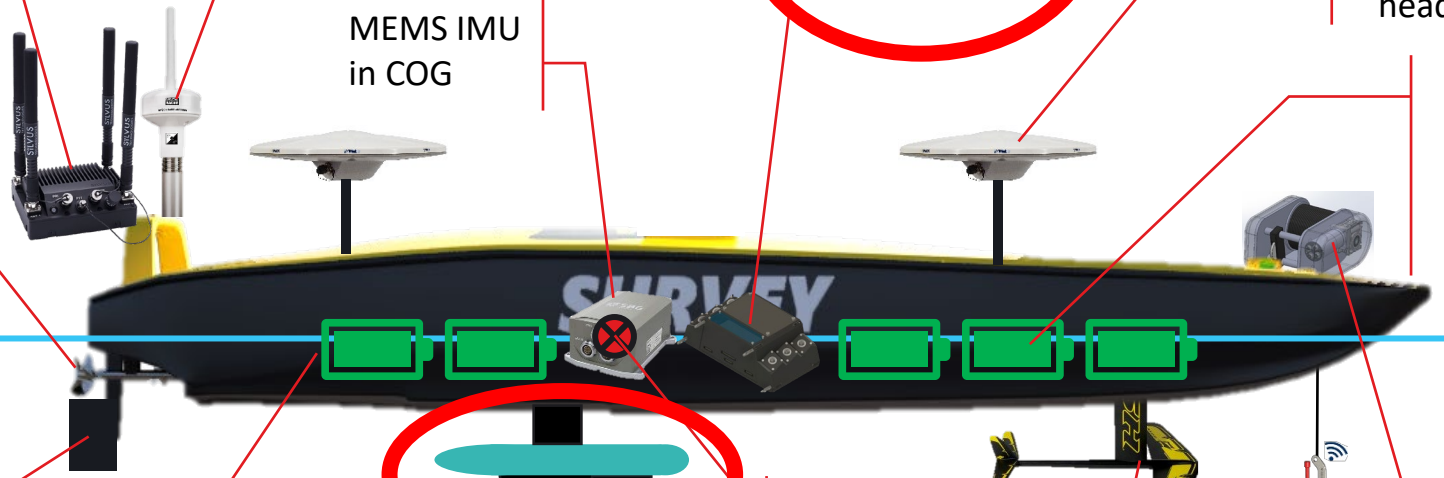


Our Hardware and Software Stack

USV – MANTAS T12

- 3.6 meter uncrewed surface vehicle of the "X-Class" (originally for military use)
- All-electric drive with replaceable batteries
- Extremely low CO2 footprint when surveying sensitive areas (offshore wind, renaturation, etc.)
- Sensor connection via our own "Autonomy Engine"
- Suitable for deployment with davit or deck crane from any "Vessel of Opportunity" (mothership) or from land
- Application, recovery and operation up to Hs 1.5 m

USV – MANTAS T12



High-speed MIMO radio, LOS and 2 x 4G (no 5G for reasons!)

AIS Transceiver

MEMS IMU in COG

C-SPINE Sensor Interface

Dual antenna system with 2 m baseline for robust heading

High propulsion battery capacity for min. 6 hours of survey time with payload at 4 knots

2 redundant drive trains for survey speeds up to 10 knots

Large rudder for more control on survey lines (line keeping with less energy consumption)

COG at water line

Electric winch for sound velocity profiler (SVP)

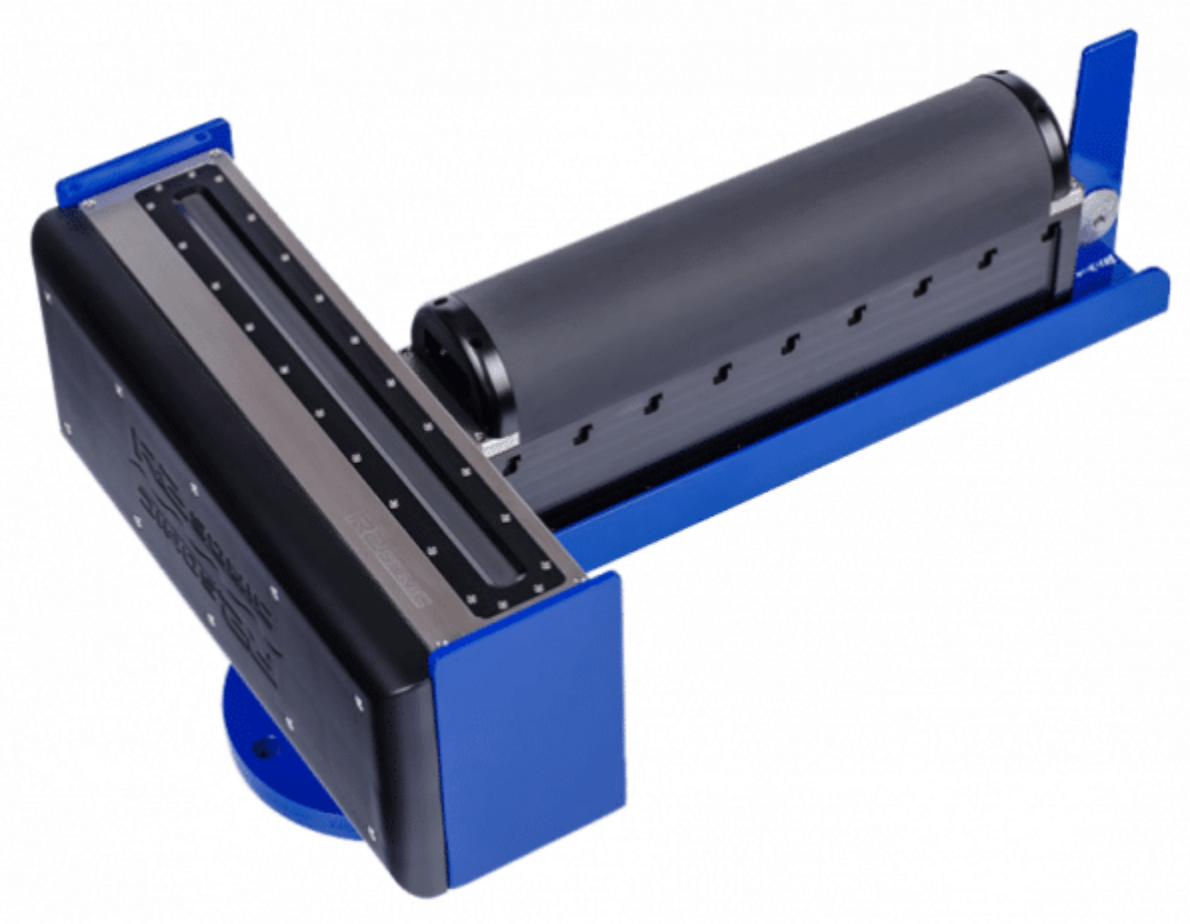
High payload battery capacity for min. 6 hours of survey time with payload

Acoustic centre of sensor payload at COG

Small hydrofoil to dampen roll and pitch induced by small waves

Solution – R2Sonic Sonic 2026v

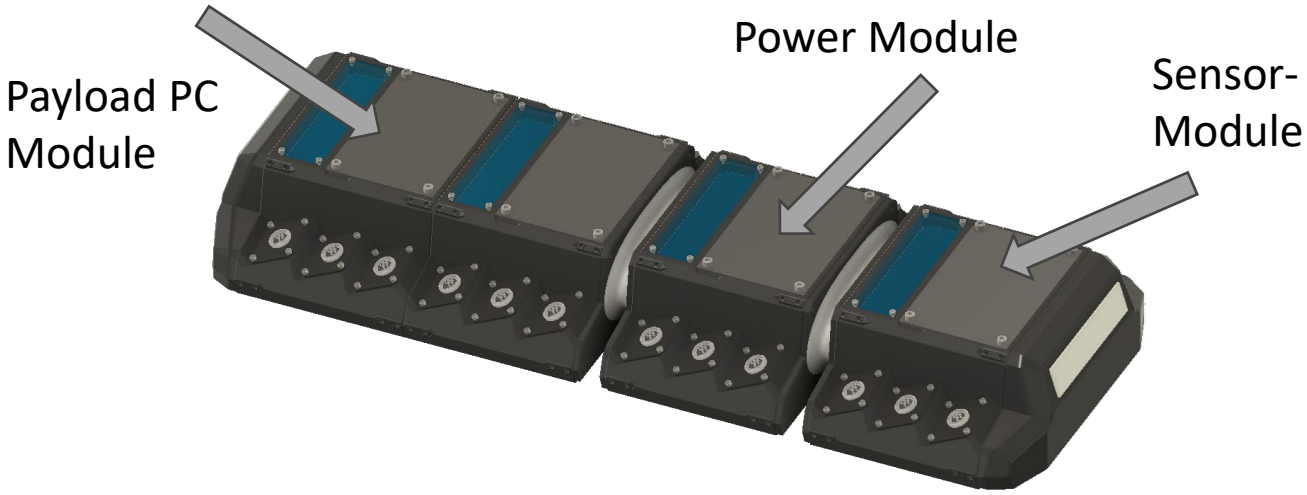
- Roll and Pitch stabilized beams
- Tightly-coupled IMU in Sonar Head
  - Roll & Pitch 0.015° Heading 0.03° with baseline >2m
  - Heave 5cm or 5% real-time, 2cm or 2% with delayed-heave
  - Position Horizontal: 1cm + 0.5 ppm, Vertical: 1.5cm + 1 ppm
- Beamwidth 0.45° x 0.45° at 450kHz
- Up to 1024 soundings per ping



SES Hardware Developments

C-CASTER

- Modular Sound Velocity Profiler winch
- For uncrewed an crewed vessels
- Control via REST API (Web server)
- Highly modular (swappable Gear, Drum, Motor)
- Modular Payload: rope + SVP; 360°camera+ tether, rope + SideScanSonar



C-SPINE

SMART **P**ORTABLE **IN**TERCONNECTED **E**NCLOSURES

- System integration within minutes
- Plug and Play and Payload swap while mission
- Auto set of IP-settings, sonar-settings..

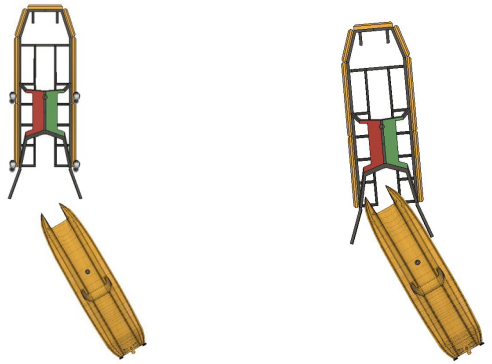
Advantage: Customer does not have to carry out system integration
→ Mobilization costs fall rapidly (less connectors, less cables, …)

SES Hardware Developments

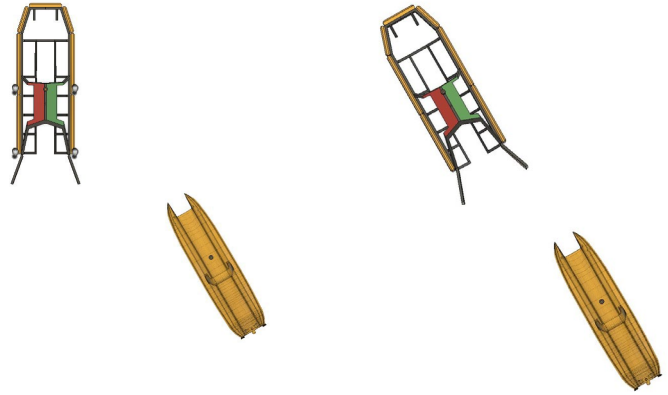
C-LARS

- C-LARS system offers a fully autonomous launch and recovery solution
- USV and C-LARS equipped with positioning system (IMU+GPS)
- C-LARS and USV receive each positioning data
- C-LARS equipped with thrusters to align to USVs driving vector

C-LARS traditional Recovery

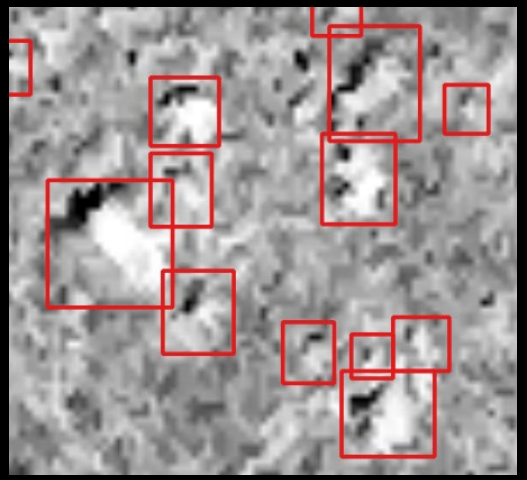


C-LARS Recovery self-alignment by Vector

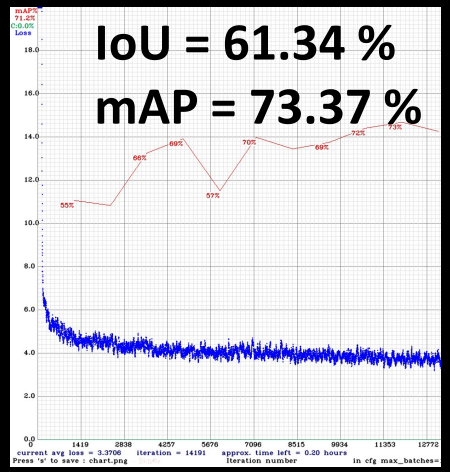


Autonomous Analysis (counting stones)

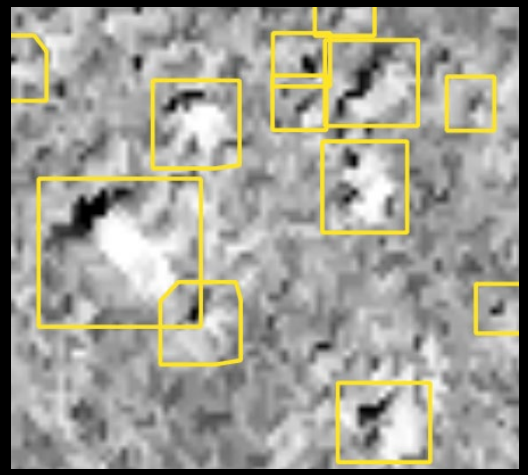
Model training with annotations of boulders and empty examples without boulders



Running of trained model



Output: Boulder detections (geodata) with confidence



Project partner:

Leibniz Institute for Baltic Sea Research Warnemünde

BSH Bundesamt für Seeschifffahrt und Hydrographie

→ 14 seconds instead of 14 days…

Just Stones?...

Our Methodology

The Mothership Approach

Mothership Approach

Resident Presence in the Wind Park:

By residing within the wind farm, the mothership enables constant monitoring and rapid response without needing to return to shore. This presence reduces the need for frequent mobilization of large vessels, which are costly and weather-dependent.

Support for Autonomous Operations:

The mothership provides recharging, data processing, and maintenance for the USVs, allowing them to operate autonomously for extended periods. It may also house remote monitoring systems, spare parts, and maintenance teams, increasing operational resilience.

Advantages of the Mothership Concept:

- **Cost Efficiency**: Minimizes the need for repeated trips from shore, which are expensive and time-consuming.
- **Operational Flexibility**: The resident presence allows continuous operations, monitoring, and quick adaptations to changing conditions.
- **Environmental Benefits**: Reduces fuel consumption and emissions by avoiding multiple long-range vessel trips.
- **Enhanced Safety**: Limits human exposure to offshore conditions by enabling remote and autonomous tasks.

The Mothership Approach - Prerequisites

Capable Technology

- Platform (USV) capable of handling higher sea-states in an OWP
- Sensor payload capable of handling small platforms with a lot of movement
- Communication devices capable of handling long distances between Mothership and USV

“True Autonomy”

- Autonomy of Platform and Sensor Payload must have a high autonomy level
- Platform and Sensor Payload must be tightly coupled
- Data must flow from Platform to Cloud and back with very little latency

Residence in OWP

- Survey and Inspection Systems must be resident in OWP to achieve maximum savings
- Residence can be achieved by using existing vessels, such as SOV and CTV
- Minimum-manning must be as low as possible

Selected Campaigns

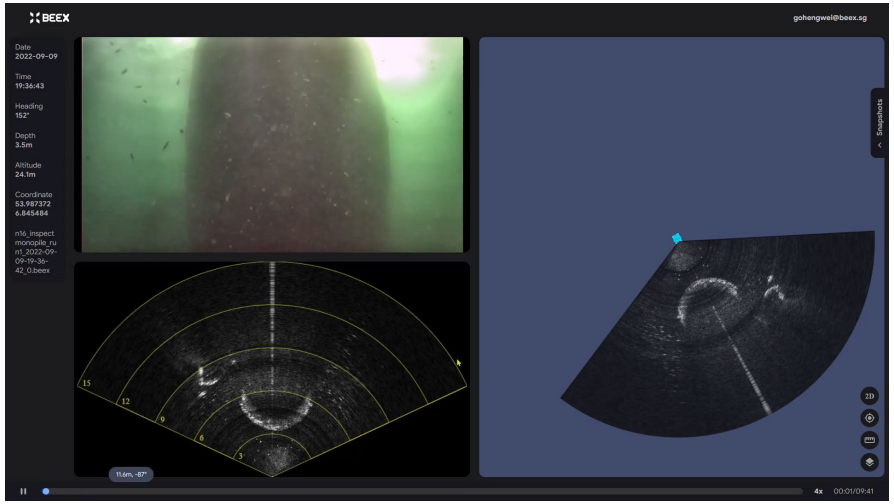
Combined survey and inspection at the OWP Deutsche Bucht – July 2023

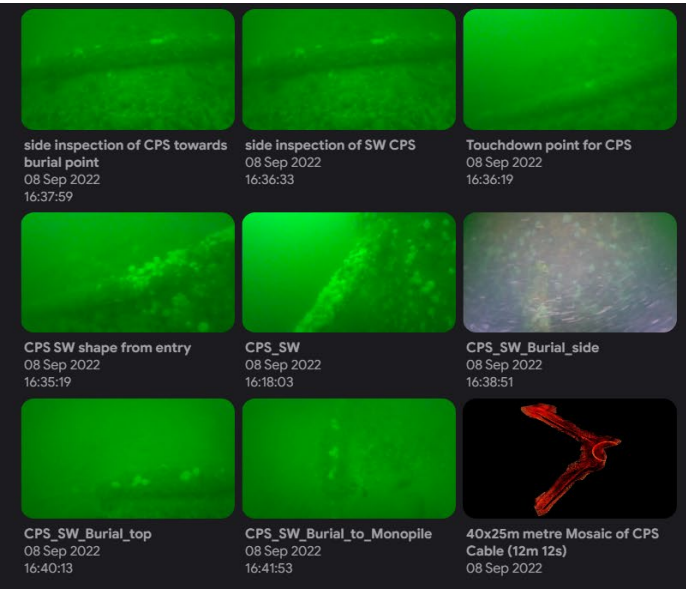
World's first combined survey and inspection of an OWP from a mother ship

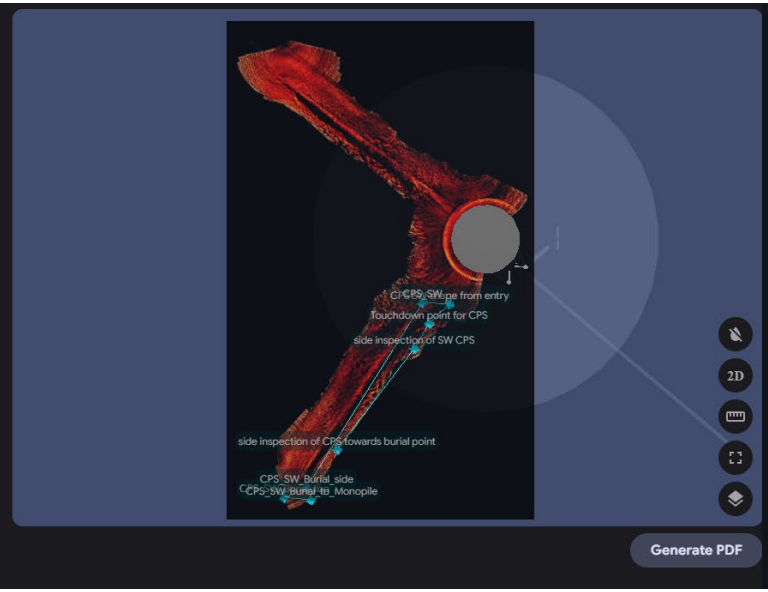
- ✓ Results were accepted by the BSH
- ✓ The systems were "resident" in the OWP for 14 days and did not interfere with regular operation
- ✓ Customer (Northland Power) and all companies involved (Esvagt, Vestas) are convinced of the mothership concept

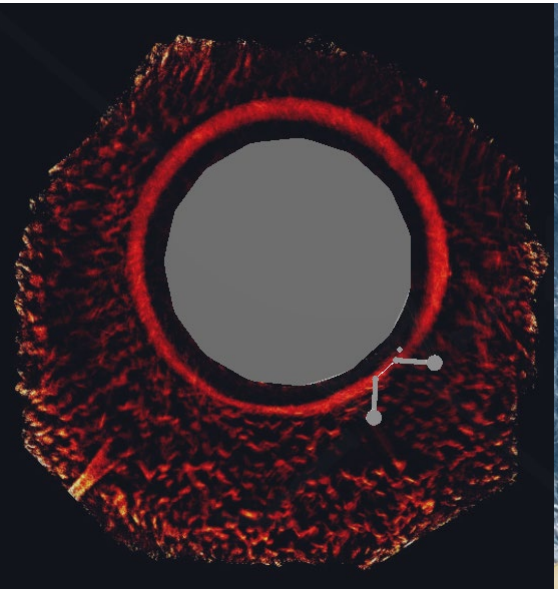
Offshore Wind Farm – Monopile Inspection

- Fully autonomous monopile inspection and CP assessment
- 3D surveys and 2D mosaic for scour protection
- Cloud-based automated reporting and geo-referenced analysis

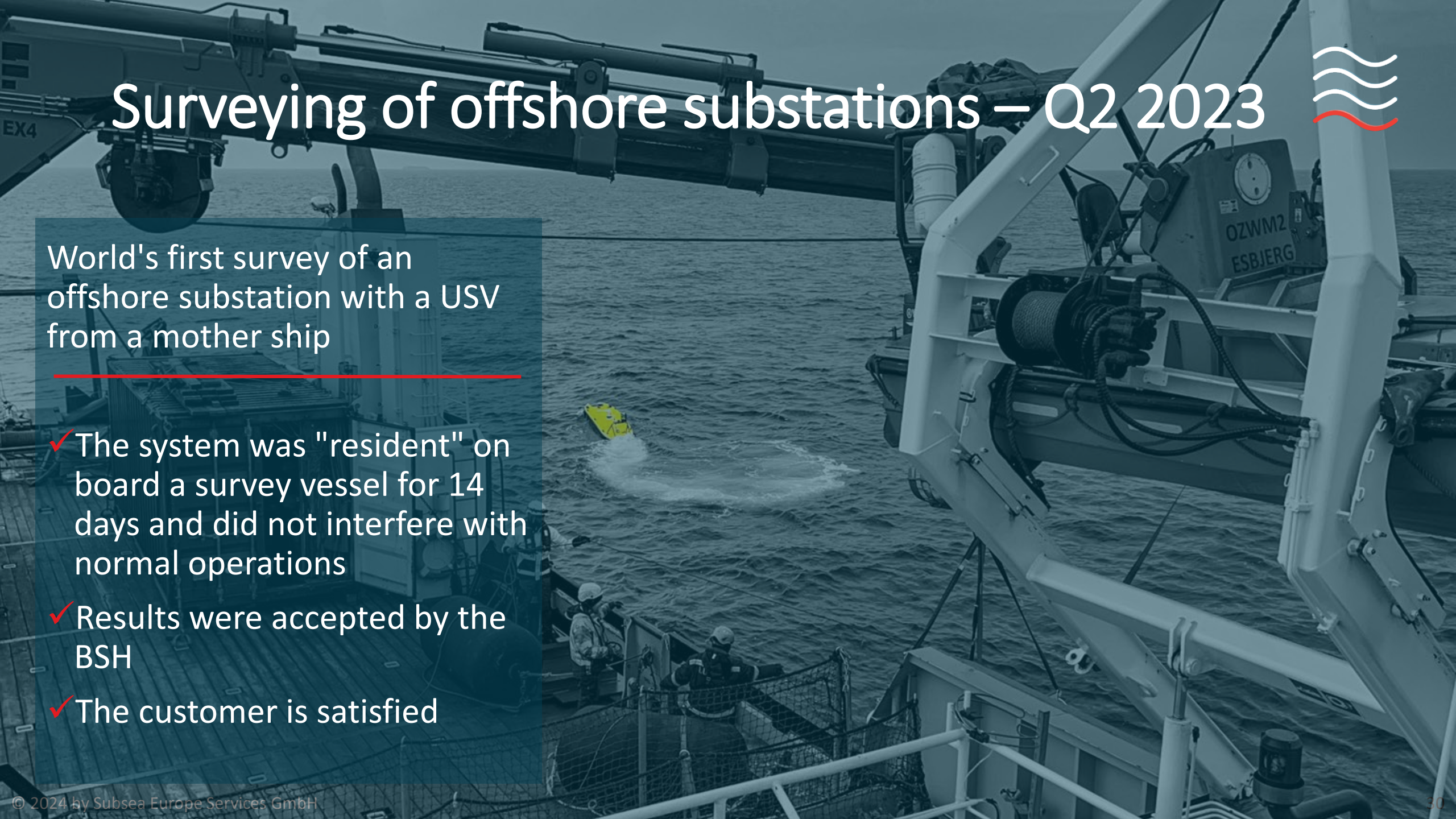








Surveying of offshore substations – Q2 2023



World's first survey of an offshore substation with a USV from a mother ship

- ✓The system was "resident" on board a survey vessel for 14 days and did not interfere with normal operations
- ✓Results were accepted by the BSH
- ✓The customer is satisfied

Autonomous survey in coastal areas – Q4 2022

Successful shallow water operation of the MANTAS T12 USV from the beach

- ✓ More than 80 kilometers of track measured in very shallow water within 3 days
- ✓ The risk to personnel has been significantly reduced through the use of uncrewed systems
- ✓ The deployment and recovery of the system, completely independent of a supply vessel, resulted in significant time and cost savings for the project
- ✓ Very good visibility throughout the supply chain

Conclusion

- Automation is the key to reducing costs, improving efficiency, and ensuring safety in offshore wind operations
- True autonomy in bathymetric surveys and the adoption of cutting-edge technologies are set to revolutionize offshore wind O&M
- The Mothership Concept and resident autonomous systems enable rapid response, lower costs and minimize the environmental impact
- As offshore wind parks continue to expand in size and complexity, we are dedicated to evolving our autonomous systems to meet these needs and support a future powered by clean, efficient energy

References

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Subsea Europe Services

SIMPLIFY MARINE DATA ACQUISITION AND ANALYSIS

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