Environmental Risk Assessment of an Underwater Acoustic Mobile Network

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This work is part of the MarTERA UNDINA Project

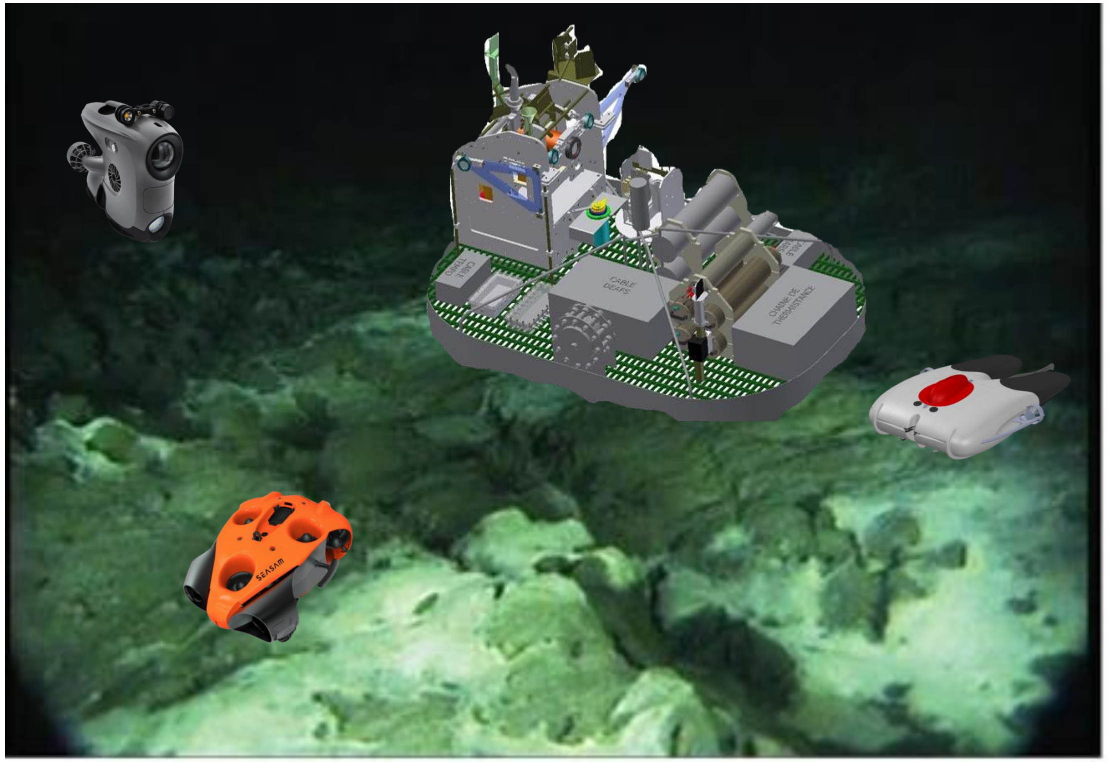
Agenda

- Context and study motivation
- Method
- Results
- Conclusions

Context and motivation

Scientific and industrial use cases

Scientific use case: resident network to visual mapping of time and space dynamics of bacterial mats from warm and cold seeps



Background figure source: Feseker, T., Boetius, A., Wenzhöfer, F. *et al.* Eruption of a deep-sea mud volcano triggers rapid sediment movement. *Nat Commun* **5,** 5385 (2014). https://doi.org/10.1038/ncomms6385

Industrial use case: Resident networks of drones for IMR operations in offshore infrastructures

- In offshore wind farms
- 80% of cost of offshore wind is **maintenance cost**
- **Y. Pettilot of ORCA Research predicts 10s of 1000s of wind turbines to inspect and maintain!!**
- **Small autonomous surface vehicles performing subsea inspection reduce fuel consumption by 95%**
- **And remove the additional support needed for human occupancy**

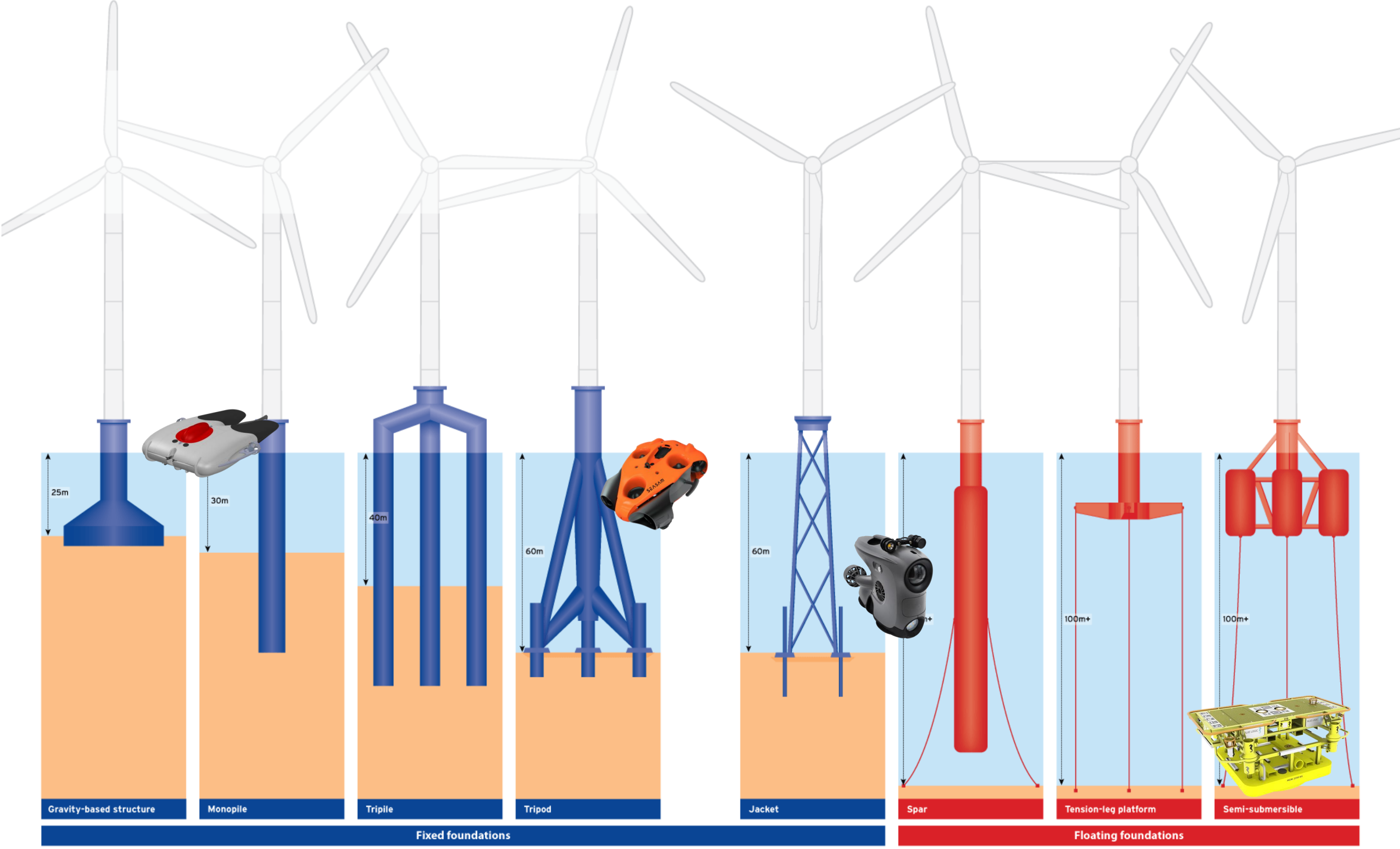


Figure source: https://www.windpowermonthly.com/article/1210054/foundations-types-depth-limits-alternative-solutions

Why do we need an environmental risk assessment?

Figure source: EU project JONAS European Marine Board - https://www.jonasproject.eu/

Classes	Main species off the coasts of Trondheim, Finistere and Baltic sea
Low Freq (LF)	Minke Whale (Balaenoptera acutorostrata) Blue whale (Balaenoptera musculus) Fin whale (Balaenoptera physalus) Humpback whale (Megaptera novaeangliae)
High Freq. (HF)	Bottlenose dolphin (Tursiops truncatus) Short-beaked common dolphin (Delphinus delphis) Risso's dolphin (Grampus griseus) Striped dolphin (Stenella coeruleoalba) Long-finned pilot whale (Globicephala melas) Killer whale (Orcinus Orca)
Very High Freq. (VHF)	Harbour porpoise (Phocoena phocoena)
Phocids (PCW)	Grey seal (Halichoerus grypus) Harbour seal (Phoca vitulina) Ringed seal (Pusa hispida) Harp seal (Pagophilus groenlandicus)

1. **National Marine Fisheries Service. (2018).** Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59.
2. **Southall, B. L., Finneran, J. J., Reichmuth, C., Nachtigall, P. E., Ketten,D,R., Bowles, Ann. E., Ellison, W. T., Nowacek, D. P., Tyack, Peter.L. (2019).** Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals 2019, 45(2), 125-232, DOI 10.1578/AM.45.2.2019.125.

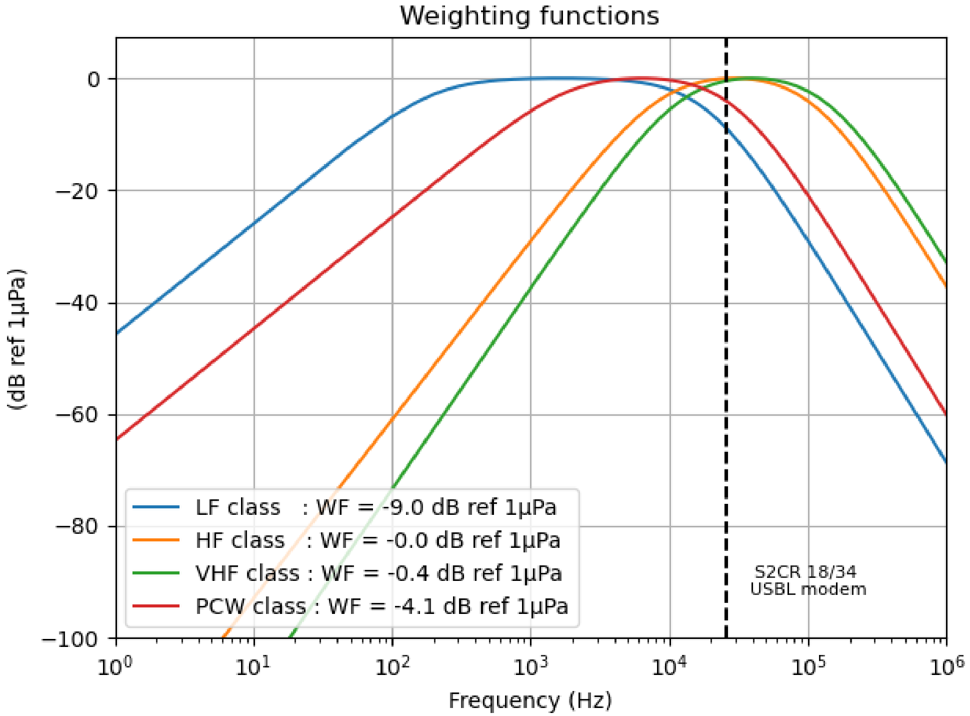
Method from[1,2]

Environmental acoustic risk assessment

Compute the Sound Exposure Level (SEL) at i-th emission at a distance from source R_i

Source Level (dB re. 1 µPa @ 1m)

$$SEL_i(T_i, R_i) = SL + WF + 10\log_{10}(T_{i,pkt}) - TL(R_i)$$



$$T_{i,pkt} = T_{header} + T_{pos} + T_{data}$$

$$TL(R_i) = 15\log_{10}(R_i) + \alpha R_i$$

transmission losses over the distance R_i (m) between the source and the animal

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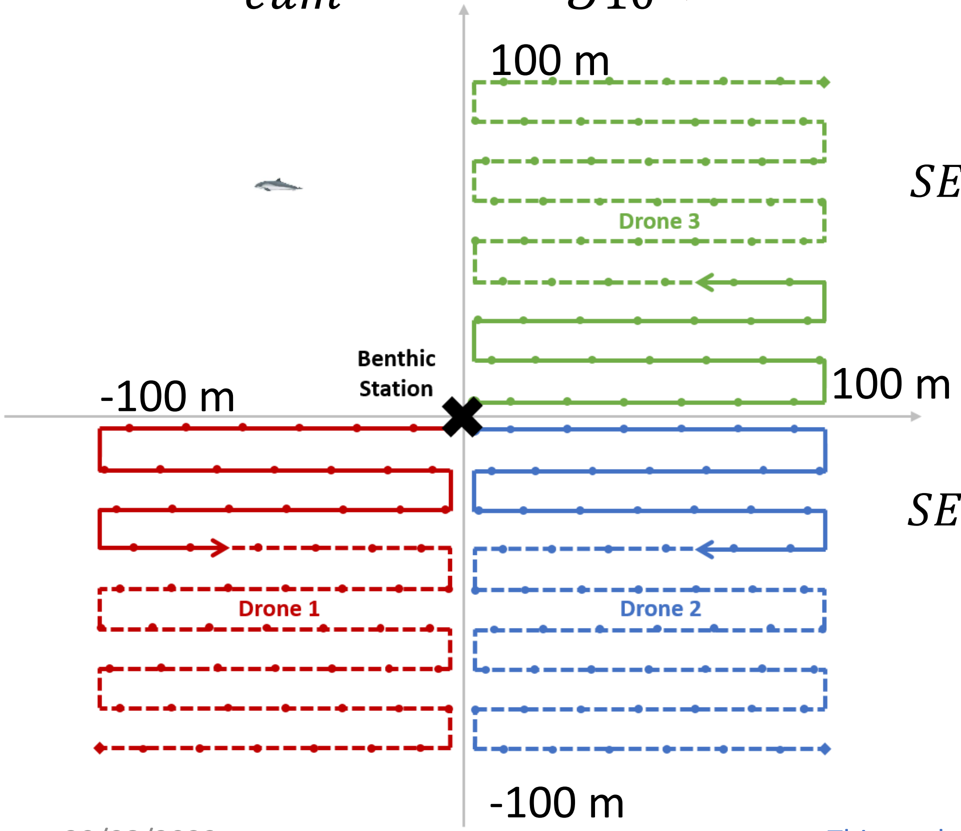
Compute the cumulative Sound Exposure Level SEL_{cum}(dB ref. 1μPa²s) over 24 hours period

$$SEL_{cum} = 10\,log_{10}\left(10^{\frac{SEL_{BS}}{10}} + 10^{\frac{SEL_{drone1}}{10}} + 10^{\frac{SEL_{drone2}}{10}} + 10^{\frac{SEL_{drone3}}{10}}\right)$$



$$SEL_{BS} = SL + WF + 10\,log_{10}\left(T_{pkt}\right) - TL\left(R_0\right) + 10\,log_{10}\left(N_{BS}\right)$$

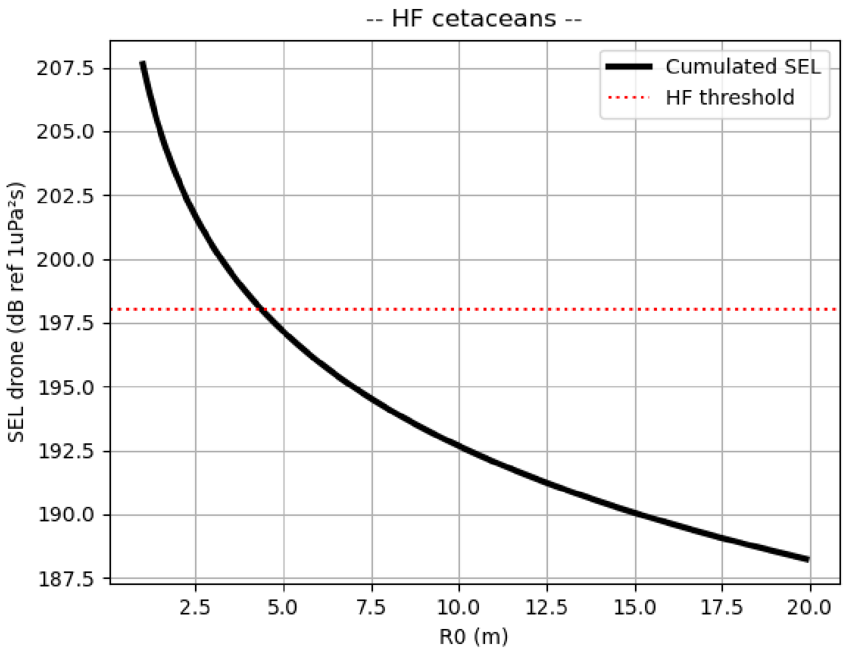
$$SEL_{drone} = \sum_i 10^{\frac{SEL_i\left(T_{i,pkt}\,R_i\right)}{10}}$$

Compute the impact radius for PTS and TTS

PTS and TTS represents a permanent shift of 6 dB only on permanent/temporary auditory sensitivity
(that is very conservative, for example, for humans, we talk about slight deafness for shifts between 20 and 40 dB)

$$SEL_{cum} \approx SL + WF + 10\,log_{10}\left((N_{BS} + N_{Drones}) \times T_{pkt}\right) - TL(R_0)$$
$$\Gamma_{PTS(TTS)} \approx SL + WF + 10\,log_{10}\left((N_{BS} + N_{Drones}) \times T_{pkt}\right) - TL(R_{impact})$$

Marine mammal class	Permanent threshold shift Γ_{PTS} (dB ref. 1µPa²s)	Temporary threshold shift Γ_{TTS} (dB ref. 1µPa²s)
LF	199	179
HF	198	178
VHF	173	153
PCW	201	181



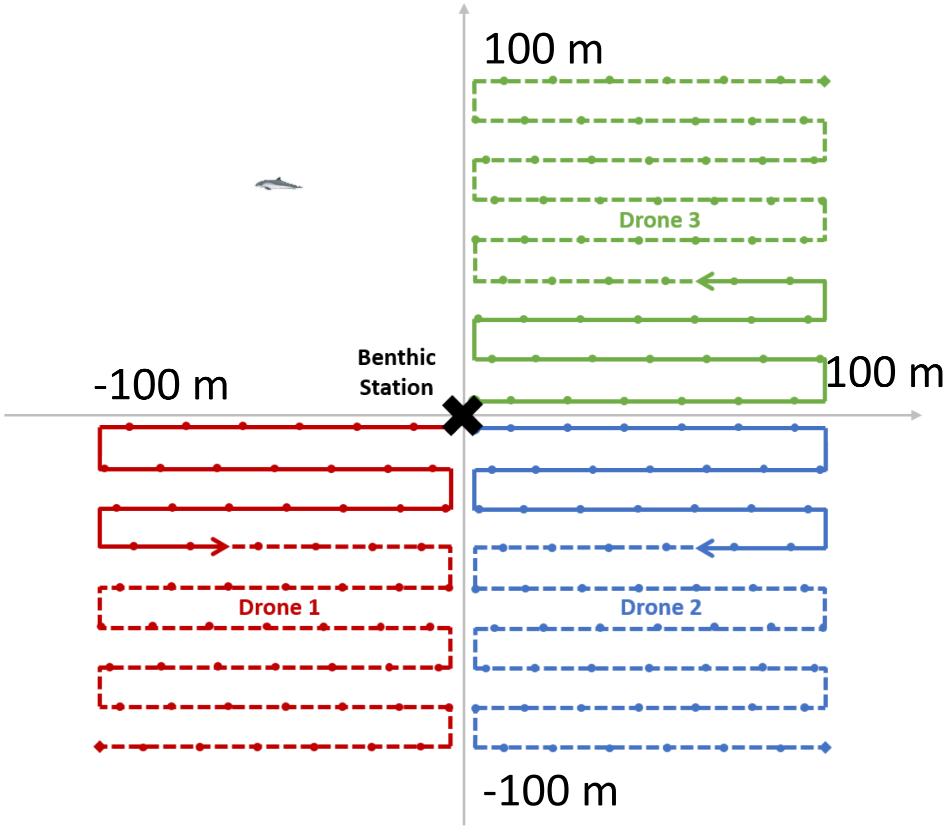
Results

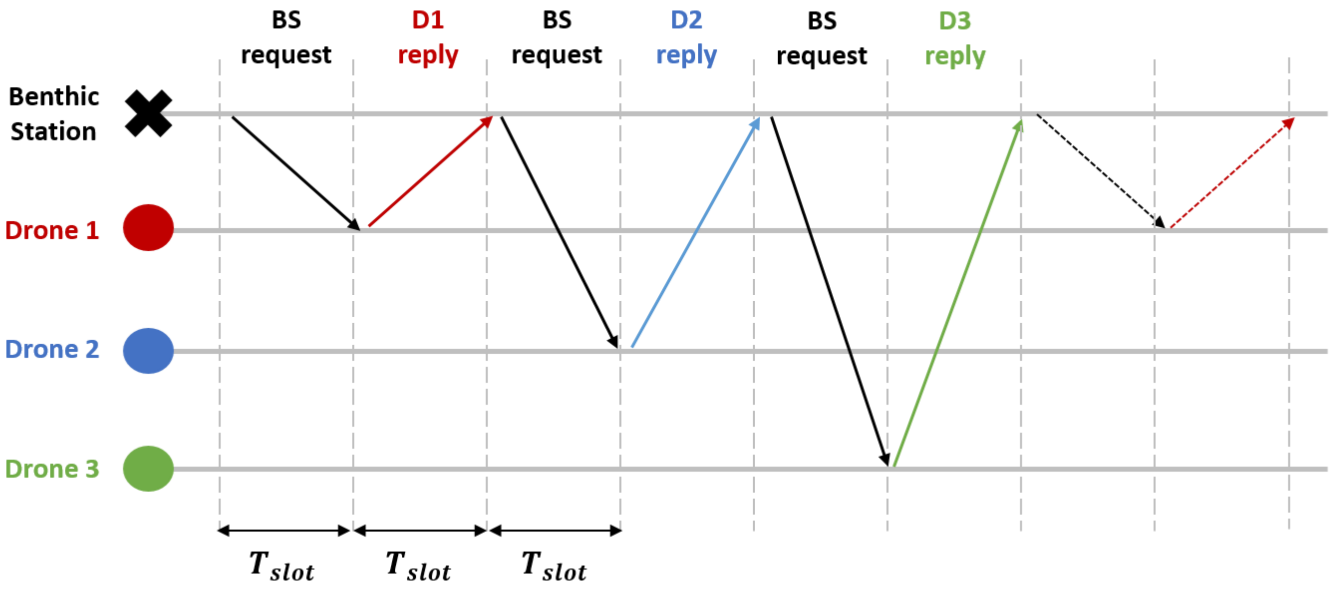
Cumulative sound exposure level

Impact radius for Permanent Threshold Shift (PTS)

Impact radius for Temporary Threshold Shift (TTS)

Considered scenario of mobile underwater acoustic network





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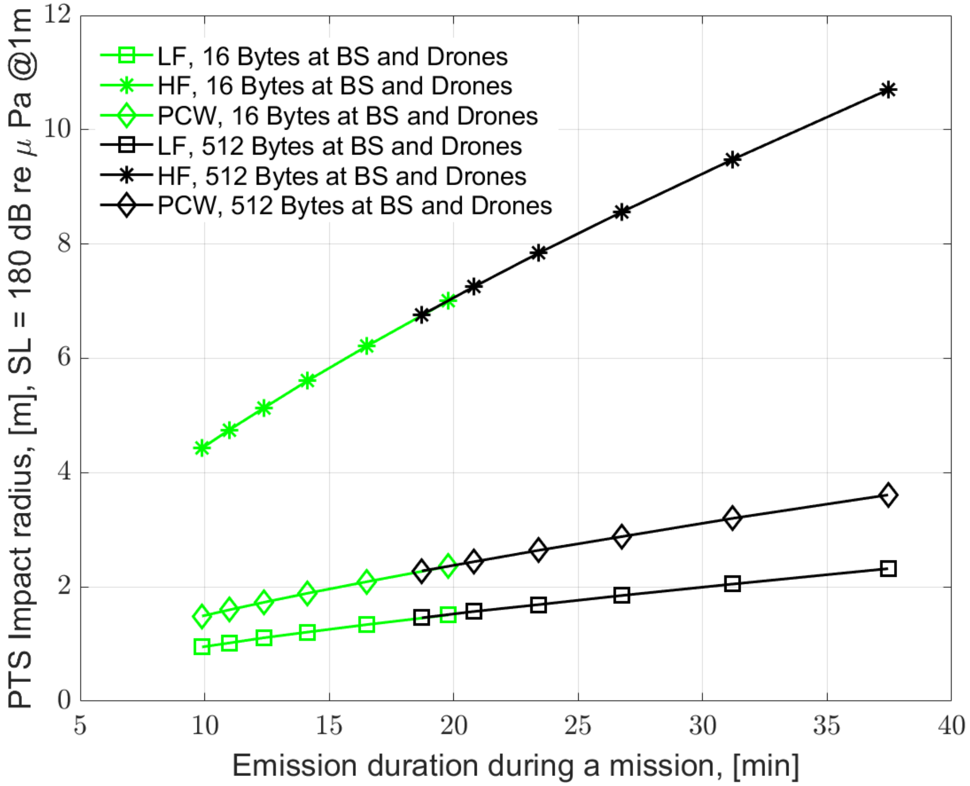
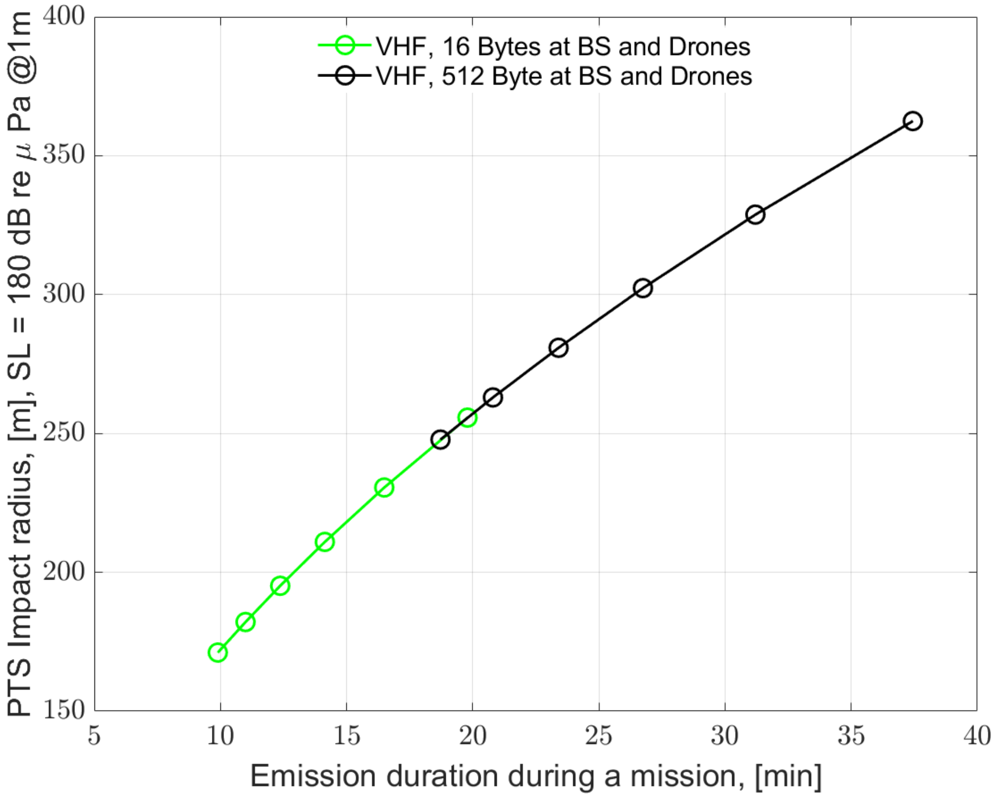
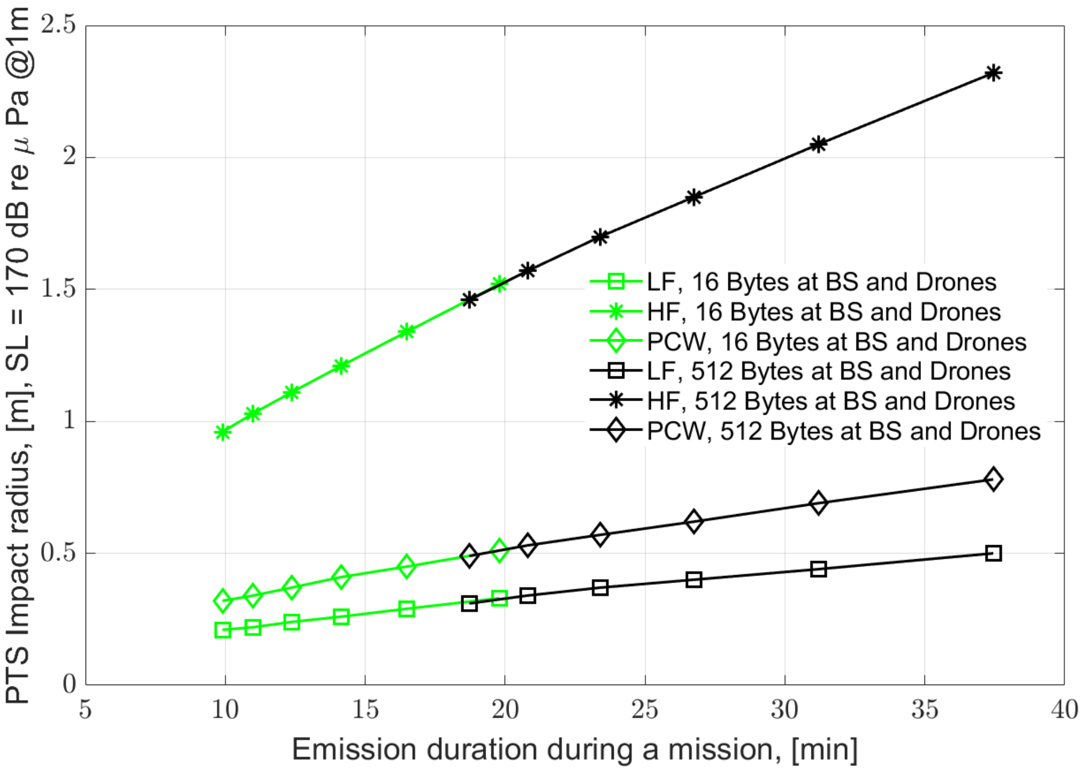
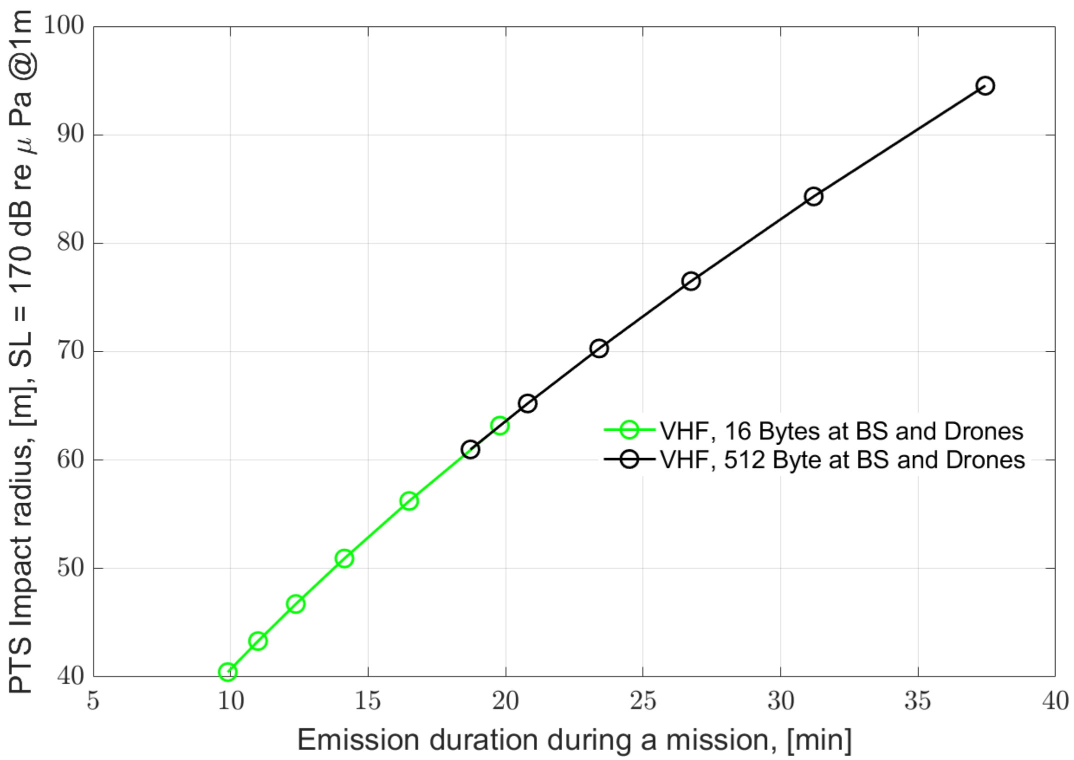
Derived impact radius for PTS with SL 180 dB ref. 1µPa @1m



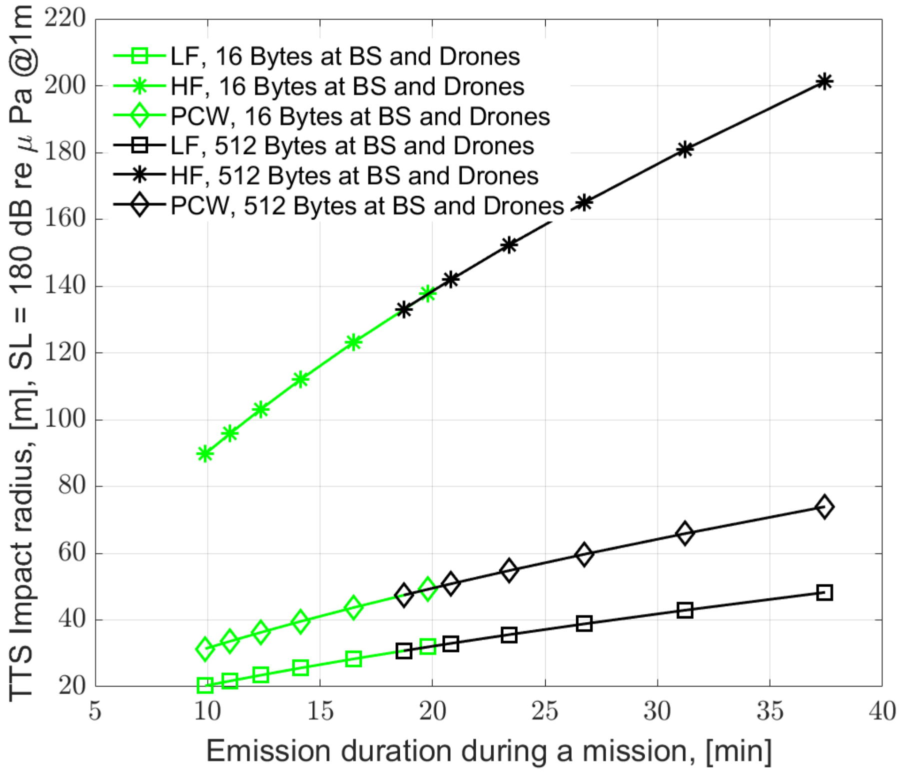


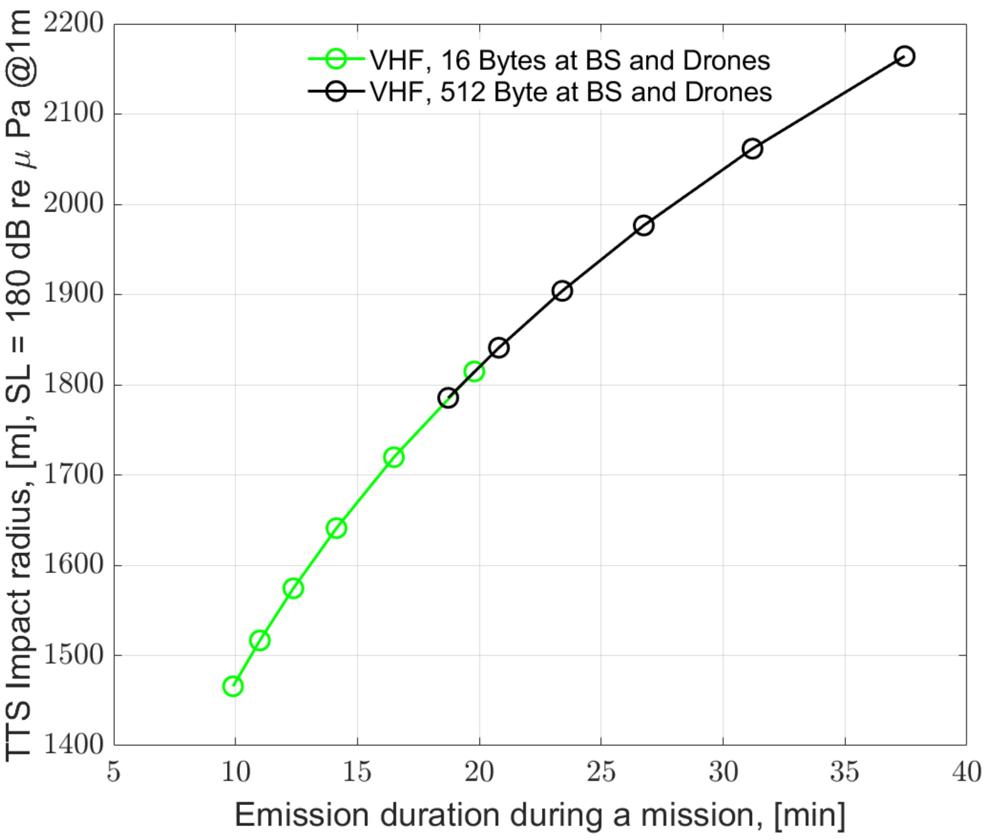
Derived impact radius for PTS with SL 170 dB ref. 1µPa @1m





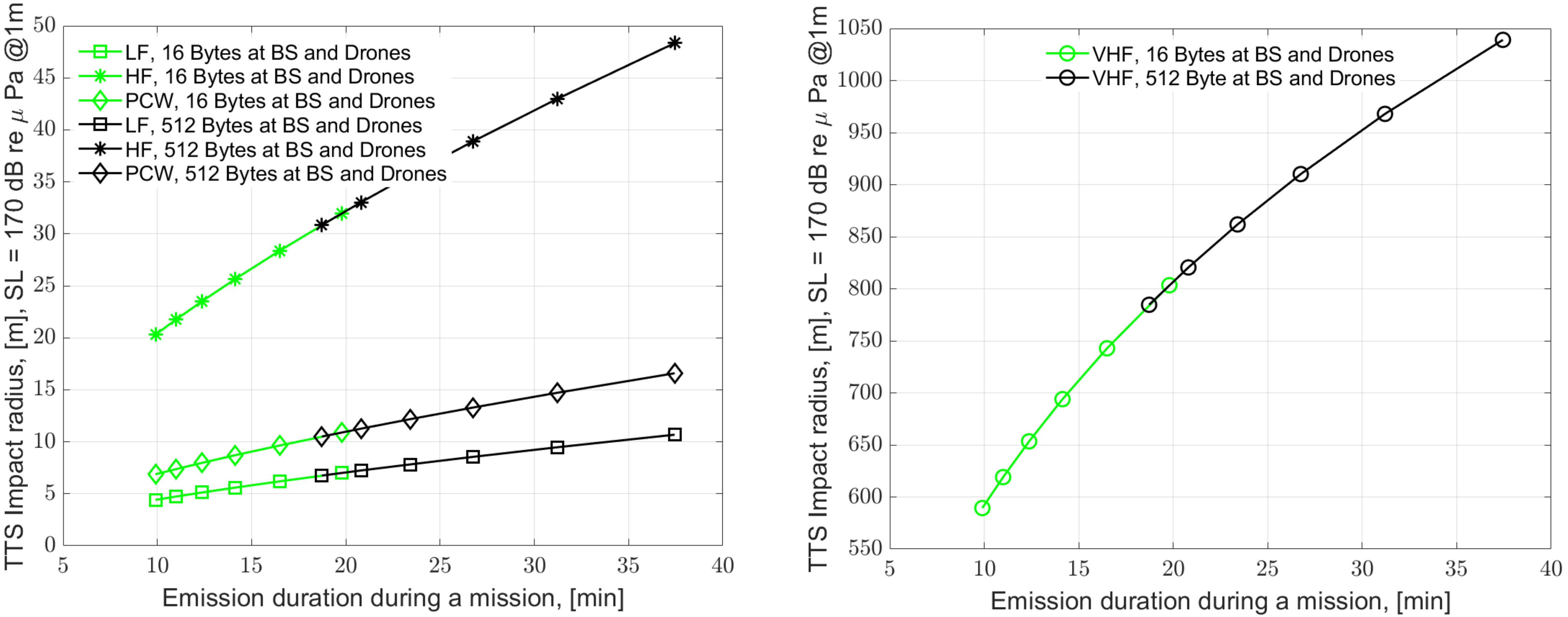
Derived impact radius for TTS with SL 180 dB ref. 1µPa @1m





This work is part of the MarTERA UNDINA Project

Derived impact radius for TTS with SL 170 dB ref. 1μPa @1m



Conclusions

And further work on this topic

Conclusions

- Results
  - VHF and HF cetaceans are most likely more affected, however harbor porpoises are ‘shy’ animals so they tend to move away from any annoying noise
- Possible solutions
  - Reduce the SL as much as possible (170 db re uPa@1m)
  - Use other communications systems to transmit large data loads underwater and use acoustics mainly for positioning and control messages
  - Scare the animals before the experiments
- Limiting assumptions and study improvements
  - Hypothesis that the animal does not escape the noise and remains in the area and stationary throughout the mission
  - Hypothesis that the drones are collocated in the vicinity of the benthic station (to invert the equation)
  - Specific to the 3 experimental areas hydro acoustic propagation conditions are not taken into account
  - Validate through Passive Acoustic Monitoring the presented analycal results

Partners

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NTNU
Norwegian University of Science and Technology

Fathom Robotics

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Thank you!

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Forskningsrådet

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Bundesministerium für Wirtschaft und Klimaschutz

through the

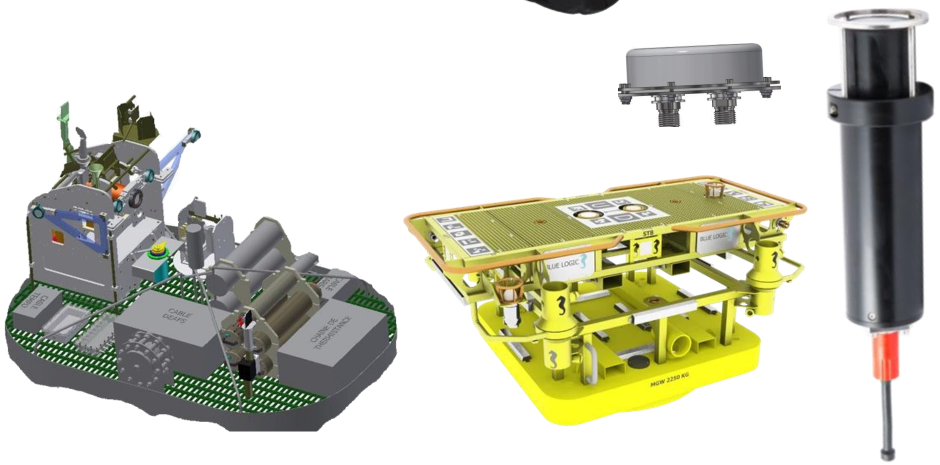
MarTERA ERA-NET COFUND

UNDINA stands for:

UNderwater robotics with multi-moDal communIcation and Network-Aided positioning system

UNDINA aims to develop

- A communication, networking and positioning system
  - specifically designed for resource constrained AUVs
    - easy maneuverability
    - low weight, small dimensions
    - low associated operational costs
  - reliable, scalable, compact, plug-and-play



Technical specifications of comms and positioning system

Optical

Connection :	10 Mbit/s
Interface :	Ethernet / Serial
Power :	12 – 36V (2-17W)
Range :	50 m
Directivity :	120 deg
Propagation speed :	2.25 10^8 m/s
Size :	Ø 60mm, L 100mm
Connector :	Subconn eth
Interference :	solar radiation, other artificial light sources

Acoustic

Connection :	13.9 Kbit/s
Interface :	Ethernet / Serial
Power :	12 V- 24V
Range :	3500 m
Directivity :	Omnidirectional
Propagation speed :	1.5 10^3 m/s
Size :	Ø 170 mm, L 315mm
Connector :	Subconn eth
Interference :	in band ambient and anthropogenic noise sources

Magnetic Inductive

Connection :	500 Mbit/s
Charging :	3A@16.8VDC (50W)
Interface :	Ethernet / Serial
Range :	0.004 m
Directivity :	Omnidirectional
Propagation speed :	2.25 10^8 m/s
Size :	Ø 60mm, L 20 mm
Connector :	Subconn eth
Interference :	EM fields in the platforms

Technical specifications of mobile platforms

SEASAM

Manufacturer : Notilo Plus
Max depth: 100 m
Max current: 1 knot
Camera system : yes fixed
Video tagging: yes
AI support for image: yes
Weight: approx. 10kg in air
Cabled/autonomous : ethernet
tethered 150 m

Blueye X3

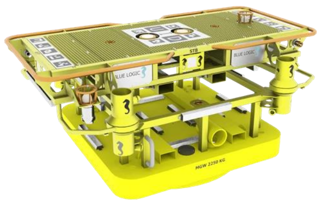
Manufacturer : Blueye Robotics
Max depth: 300 m
Max current: 1 knot
Camera system : yes tilting
Video tagging: yes
AI support for image: yes
Weight: approx. 10kg in air
Cabled/autonomous : ethernet
tethered 300 m

Poggy

Manufacturer : EvoLogics
Max depth: 70 m
Max current:-
Camera system : no
Video tagging: no
AI support for image: no
Weight: approx. 50 kg in air
Cabled/autonomous : autonomuos

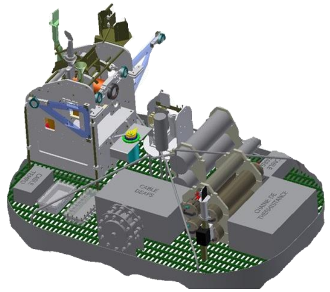
Technical specifications of benthic platforms

NTNU – Ocean Lab



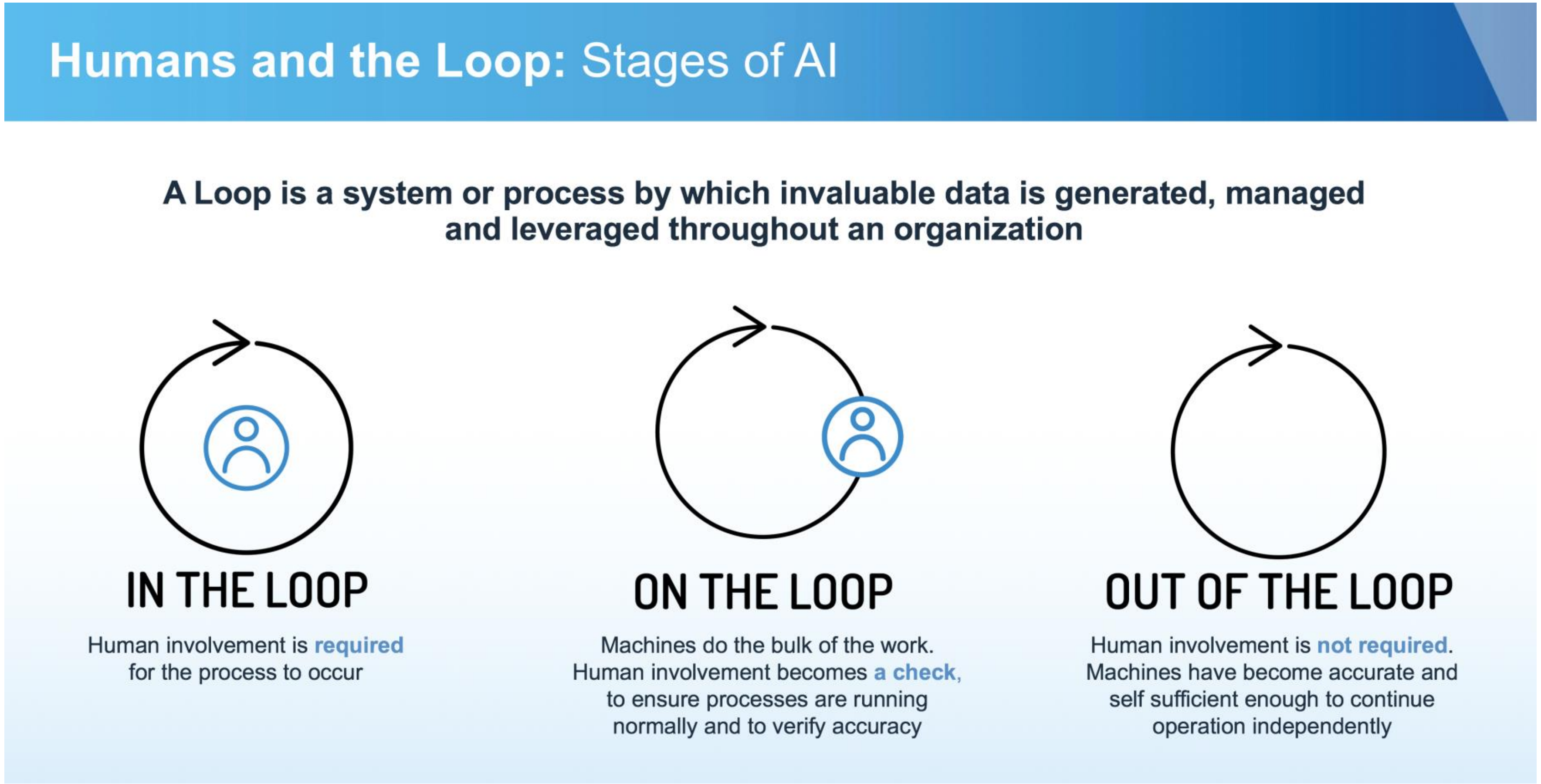
Operator : NTNU
Deployment depth in UNDINA: 90 m
Power and ethernet cabled to control room
Deployed at Trondheimfjord (NO)
With possibility to have a recharging docking cage for the drone

IFREMER standalone observatory



Operator : IFREMER
Deployment depth in UNDINA: 30 m
Battery Powered and autonomous
Deployed at Brest roadsted (FR)
With possibility to have a recharging docking cage for the drone

AI development in UNDINA: humans and the loop



Source: https://www.datacenterdynamics.com/en/opinions/path-ai-connected-government/

IN THE LOOP

Inspection data transferred from mobile to BS connected to END USER

Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

END USER detects maybe a default

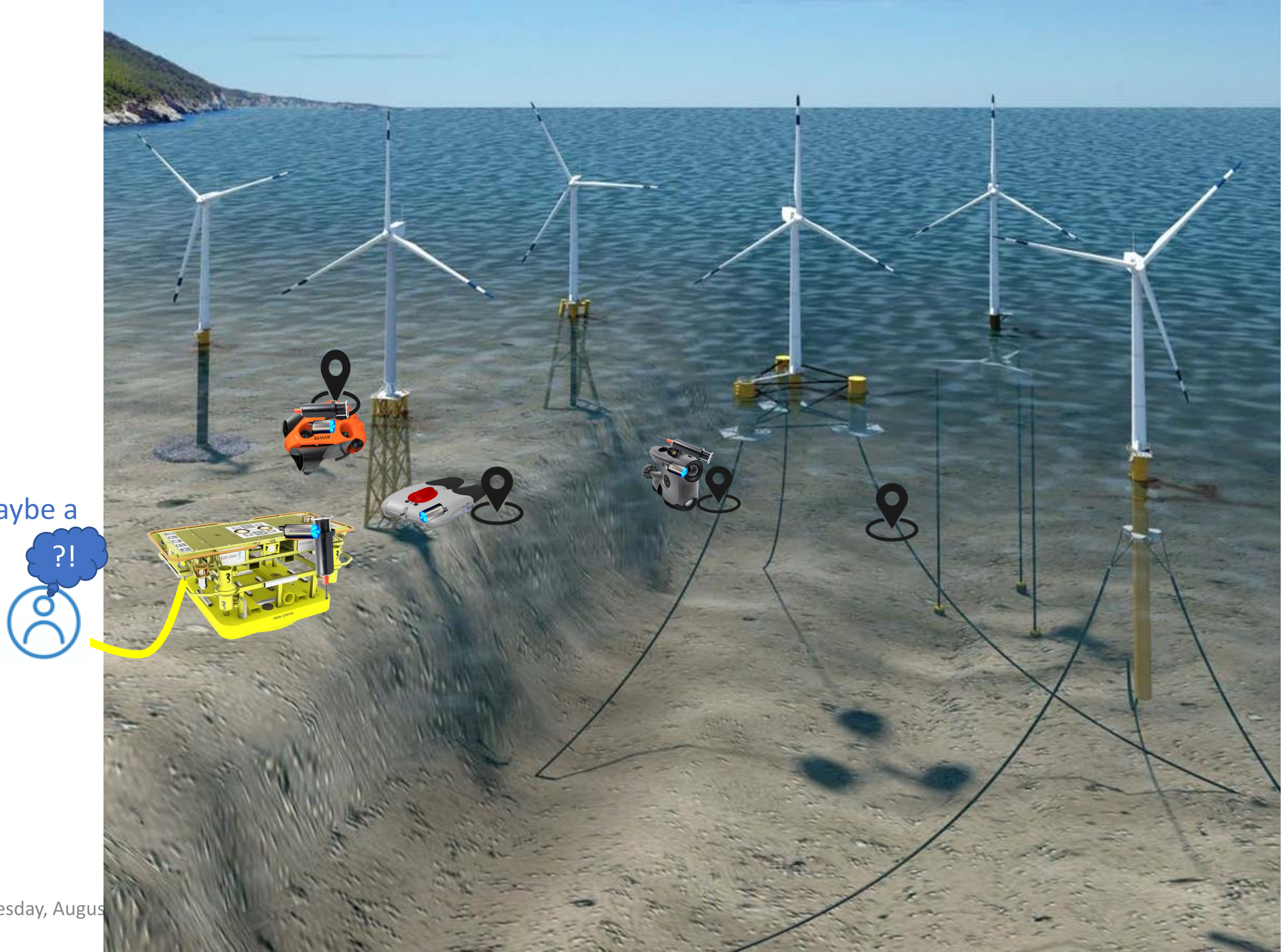


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

END USER commands the mobile to return to x,y,z point

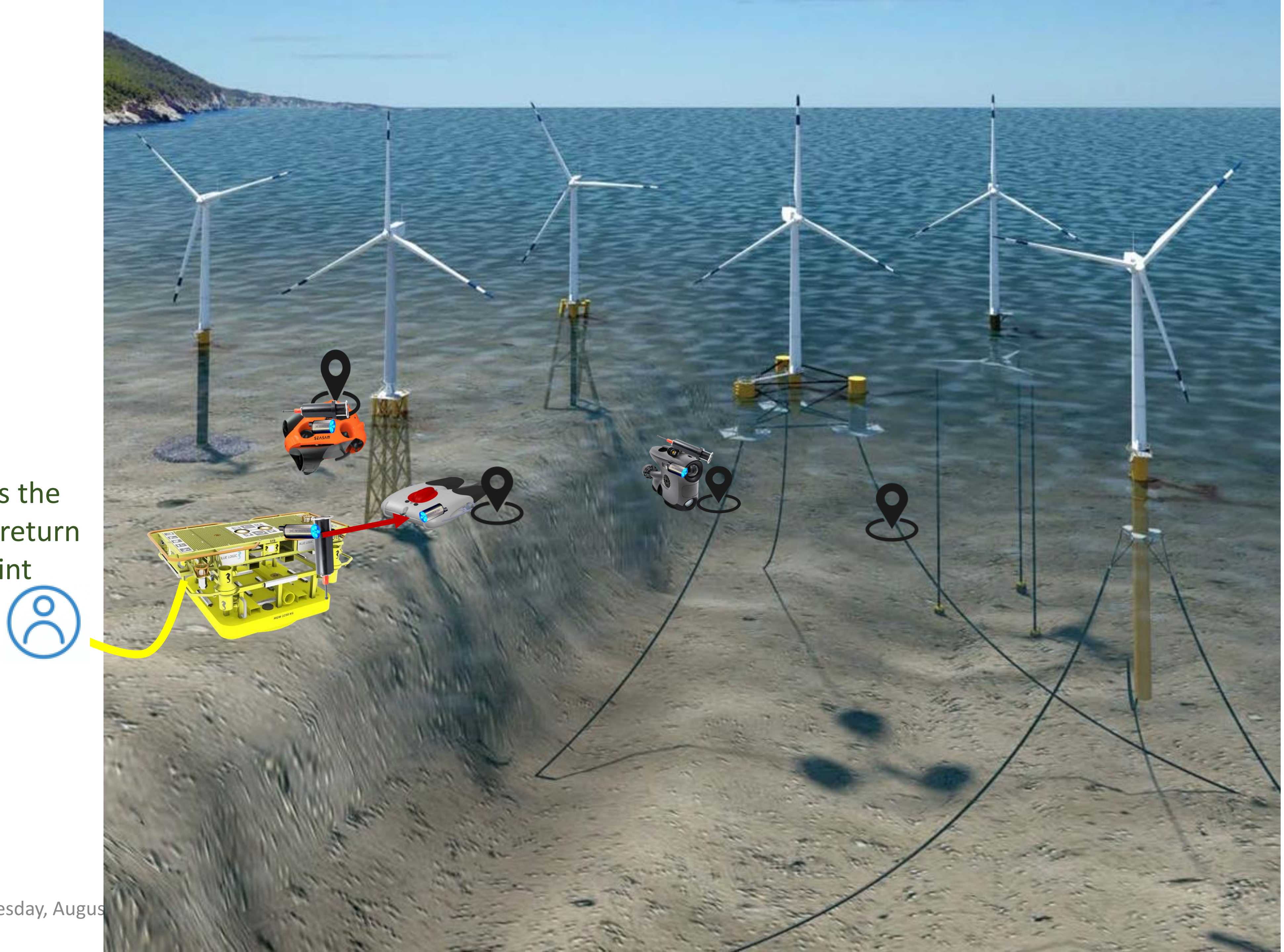


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

MOBILE returns and inspects more closely xyz point

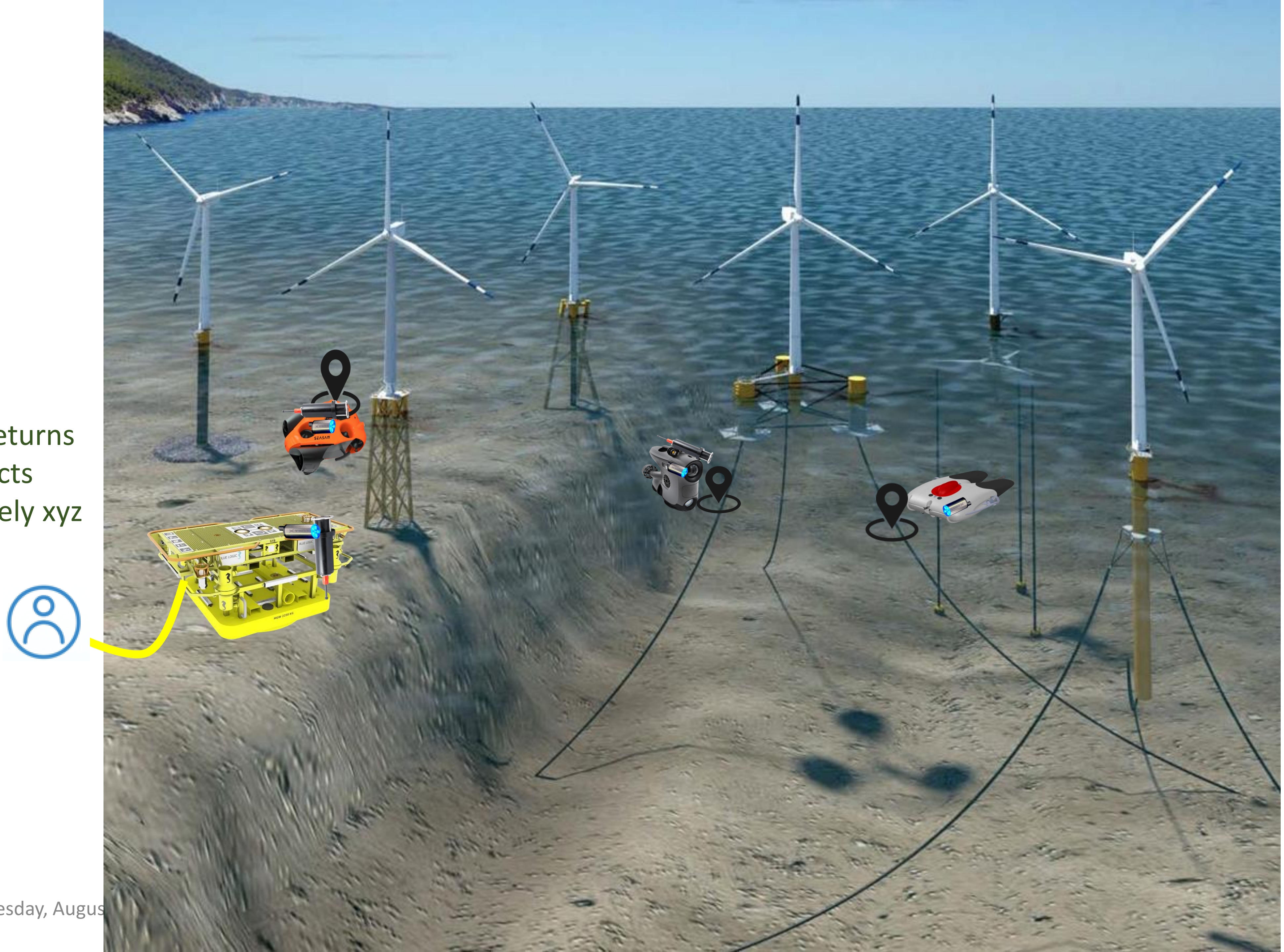
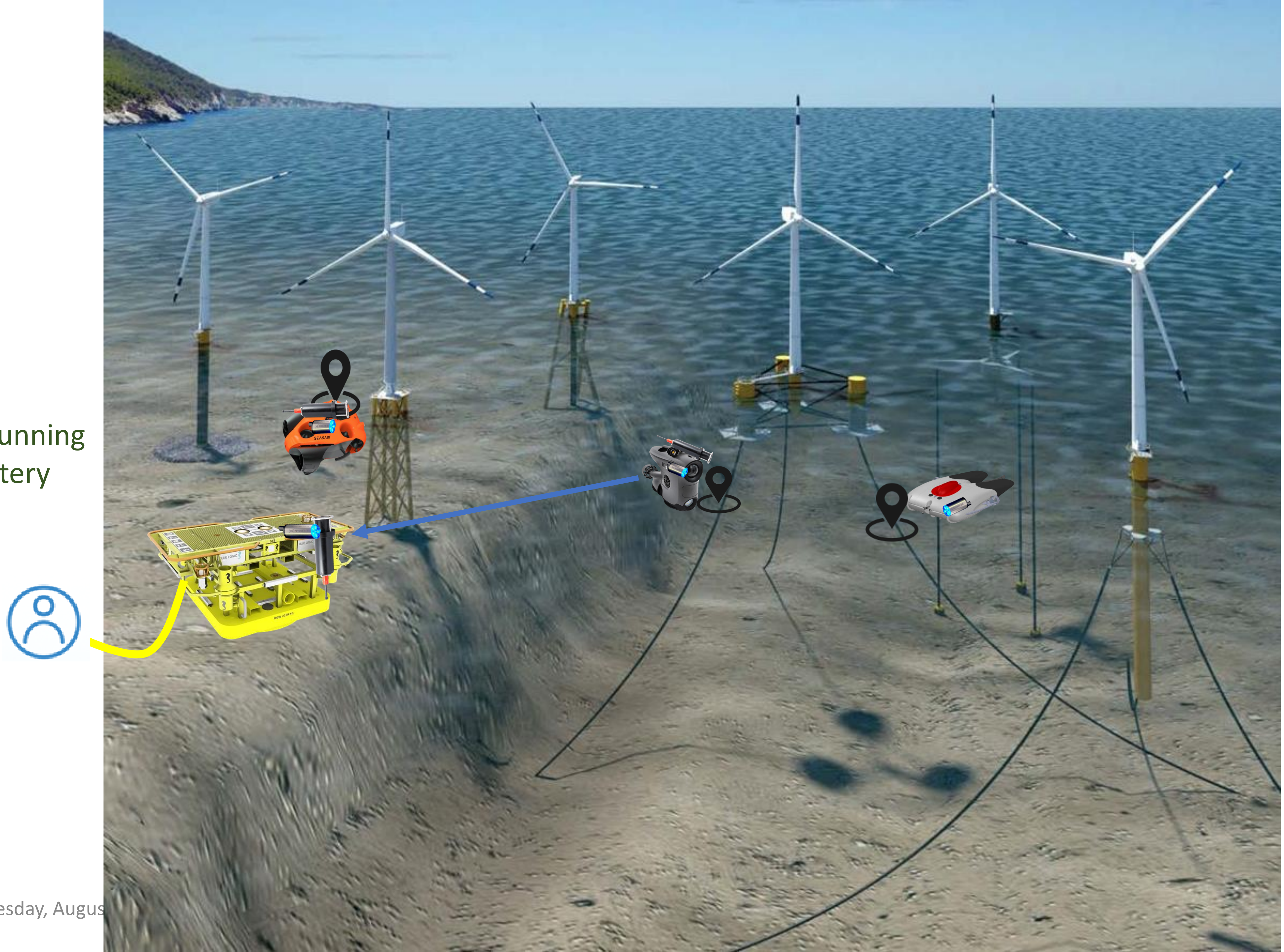


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

Drone is running out of battery



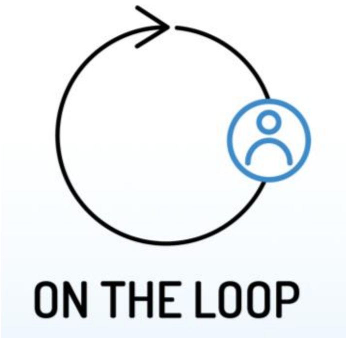


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

END USER sends 'ok docking station available' to mobile

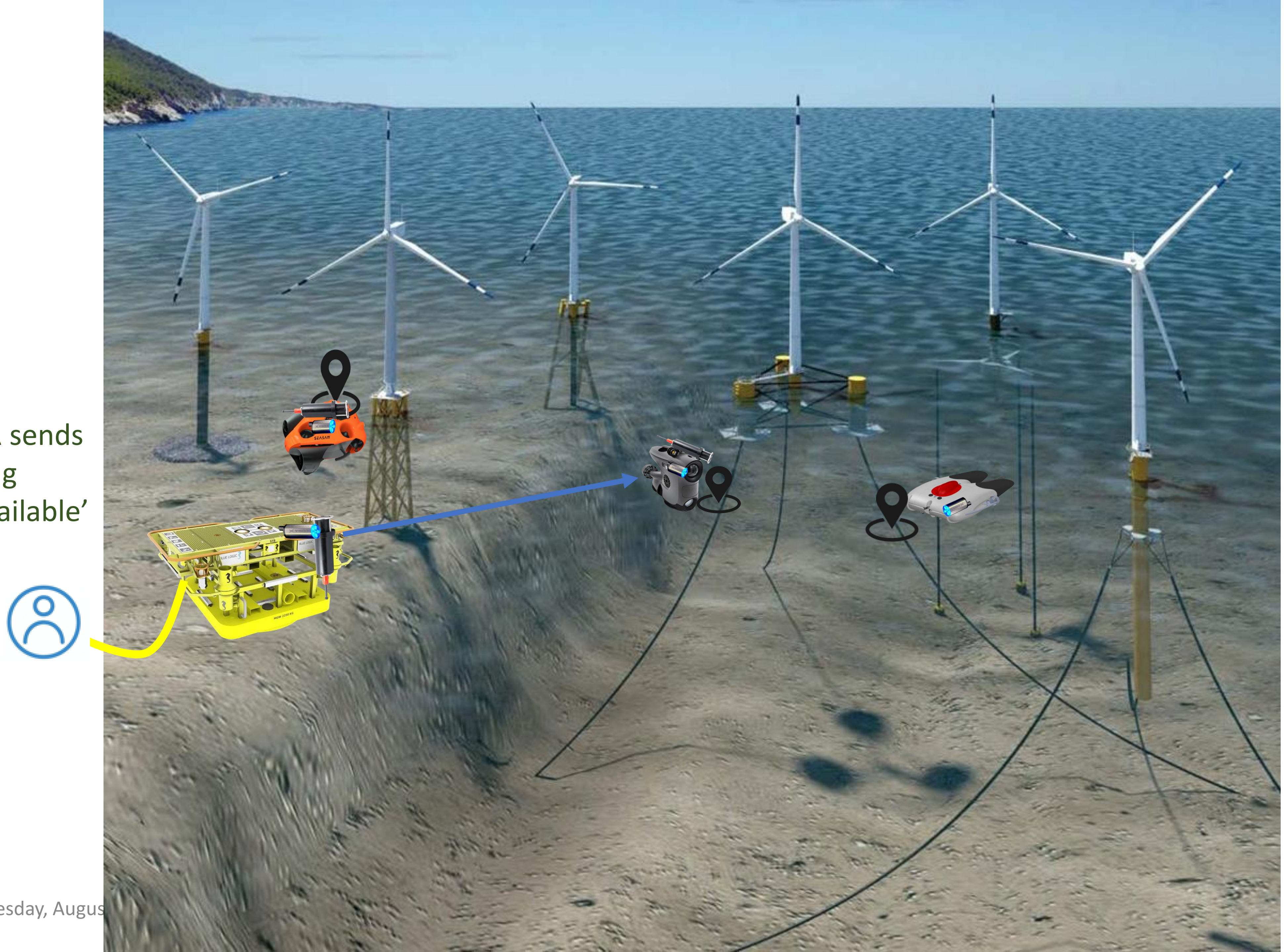


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

Mobile docks and recharges

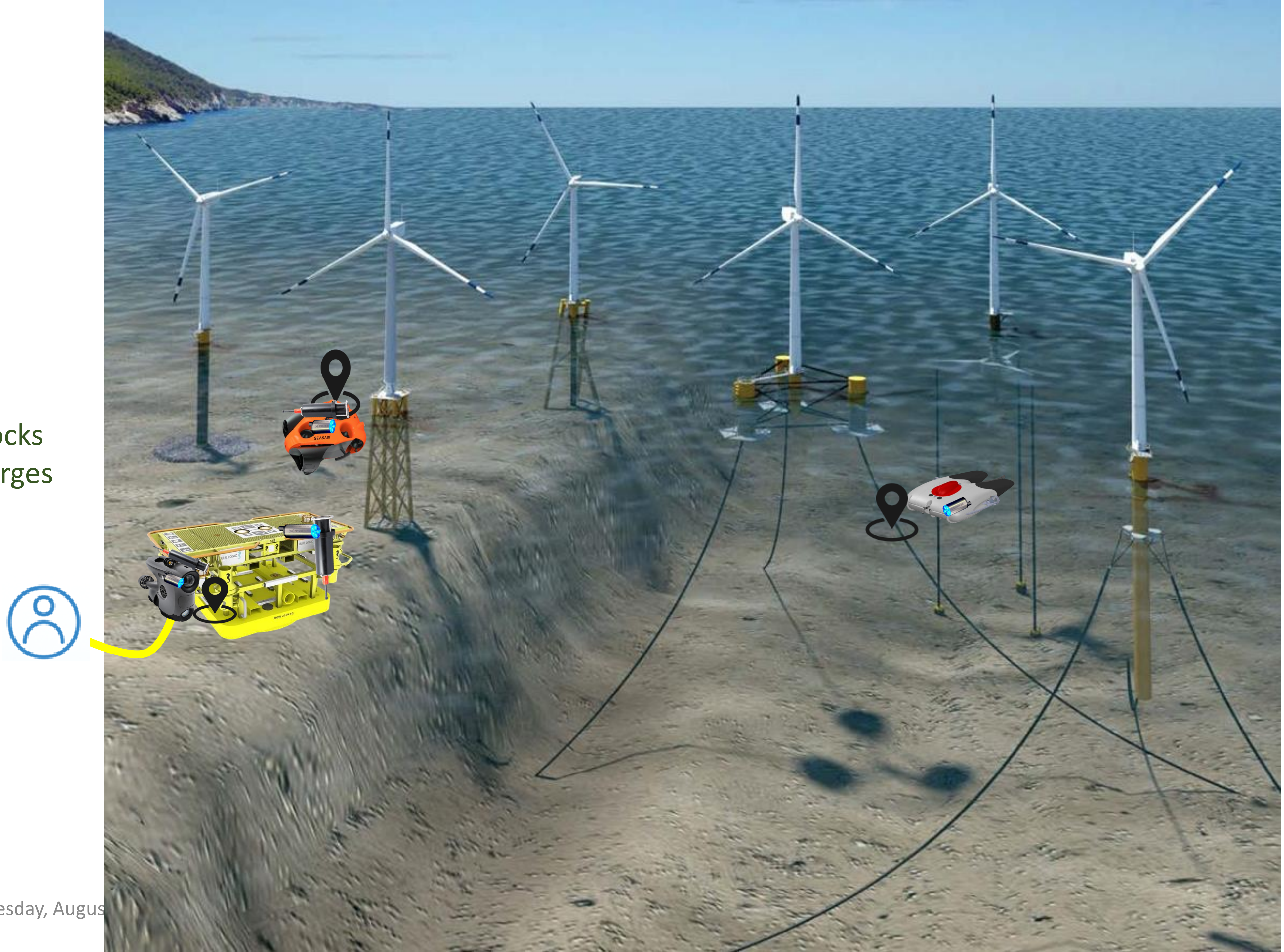


Image Source credit: NREL, 2014-2015 Offshore Wind Technologies Market Report

DATA muling from an autonomous system