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ADVANCES IN AUTONOMOUS SYSTEMS: ANTI-SUBMARINE WARFARE AND CRITICAL UNDERSEA INFRASTRUCTURE SECURITY

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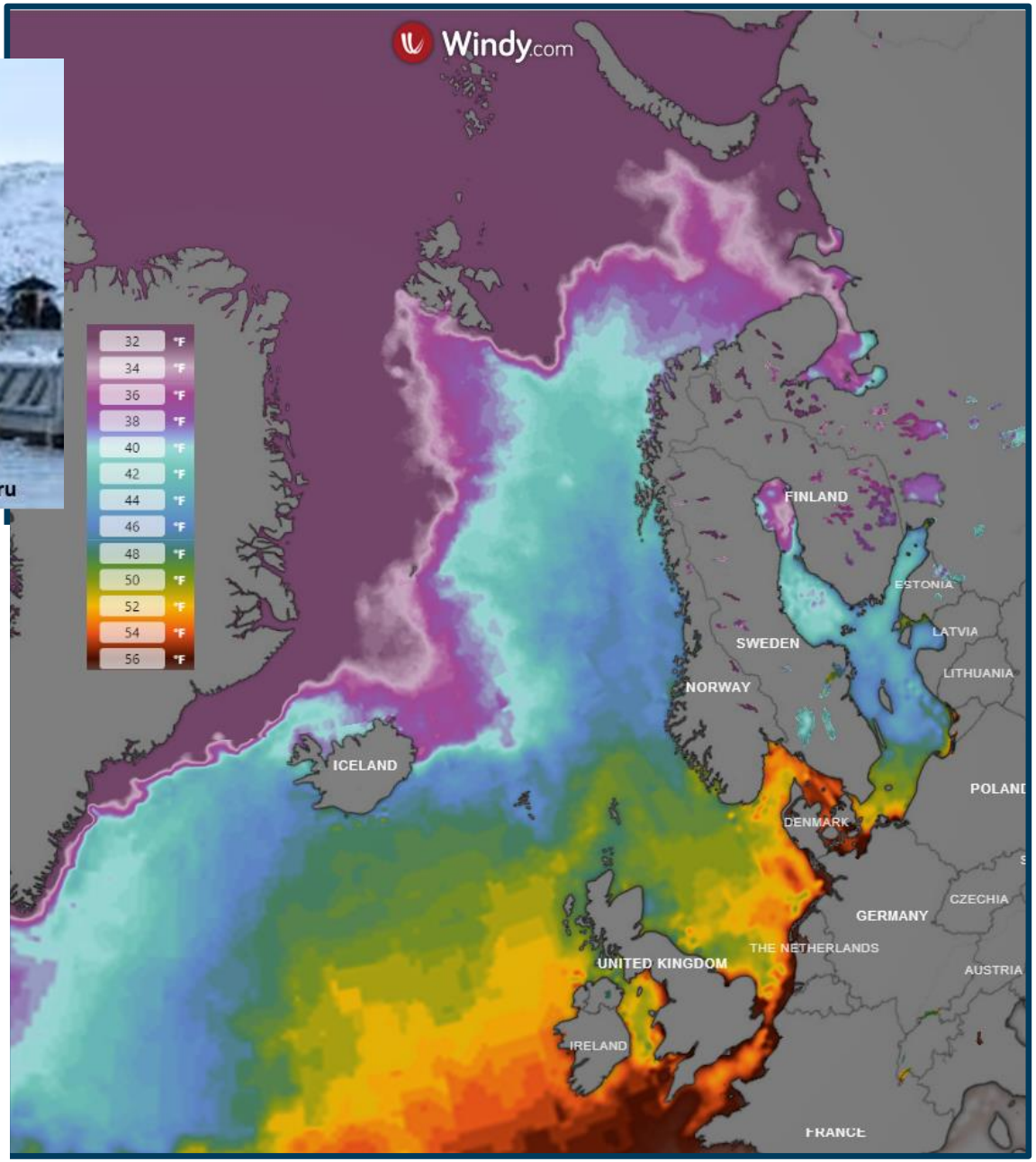
The Need for Undersea Persistent Surveillance

Adversary Undersea Assets Operates over Vast Areas

Norwegian Sea –
1.4 million sq. km

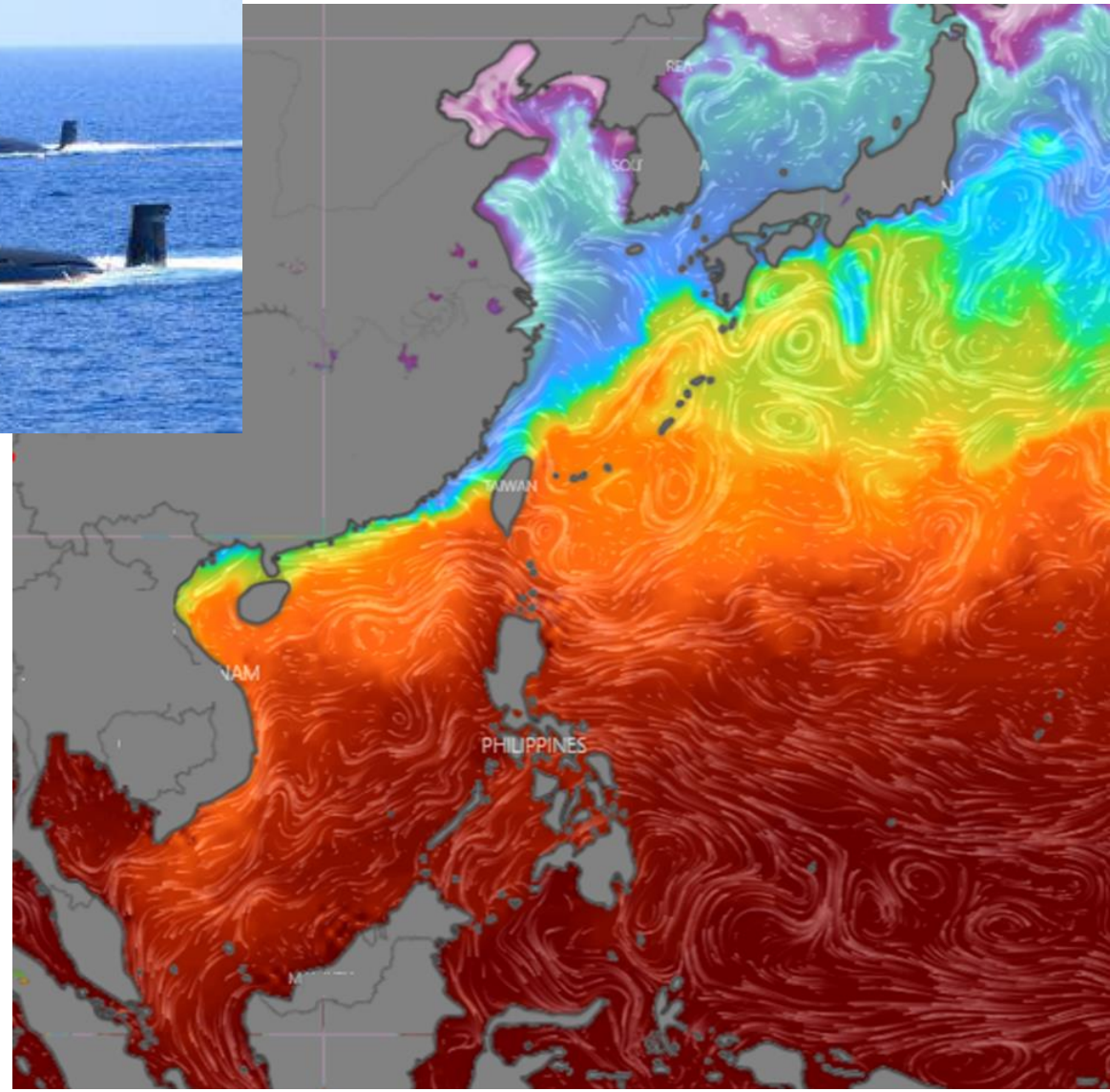
GIUK Gap
Greenland to Iceland –
~ 320km
Iceland to Scotland
~ 800km



Operational Area – Indo-Pacific

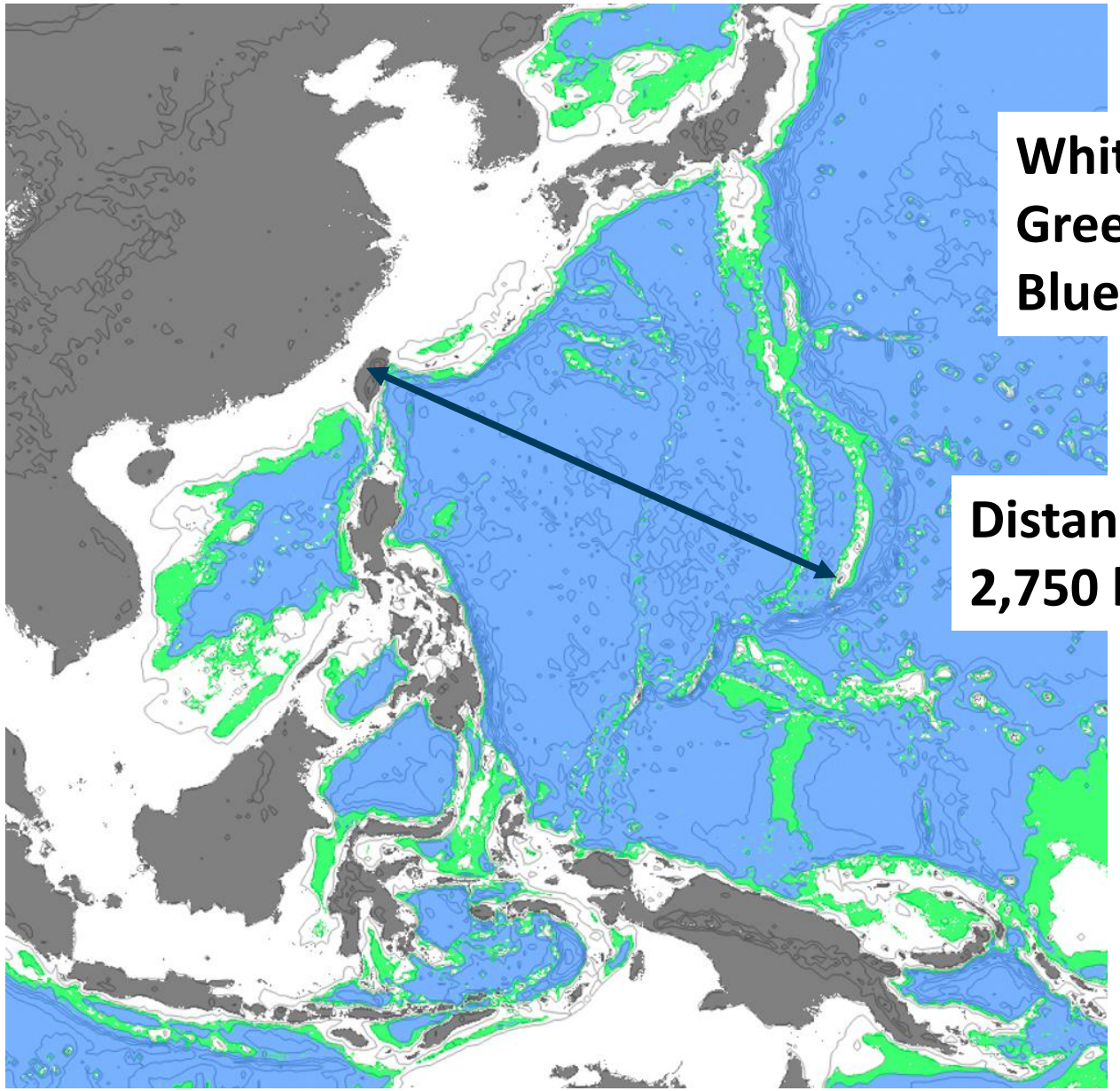
South China Sea – 3.5 million sq. km

Strong currents and thermal differences north to south



Bathymetric Reality within Second Island Chain

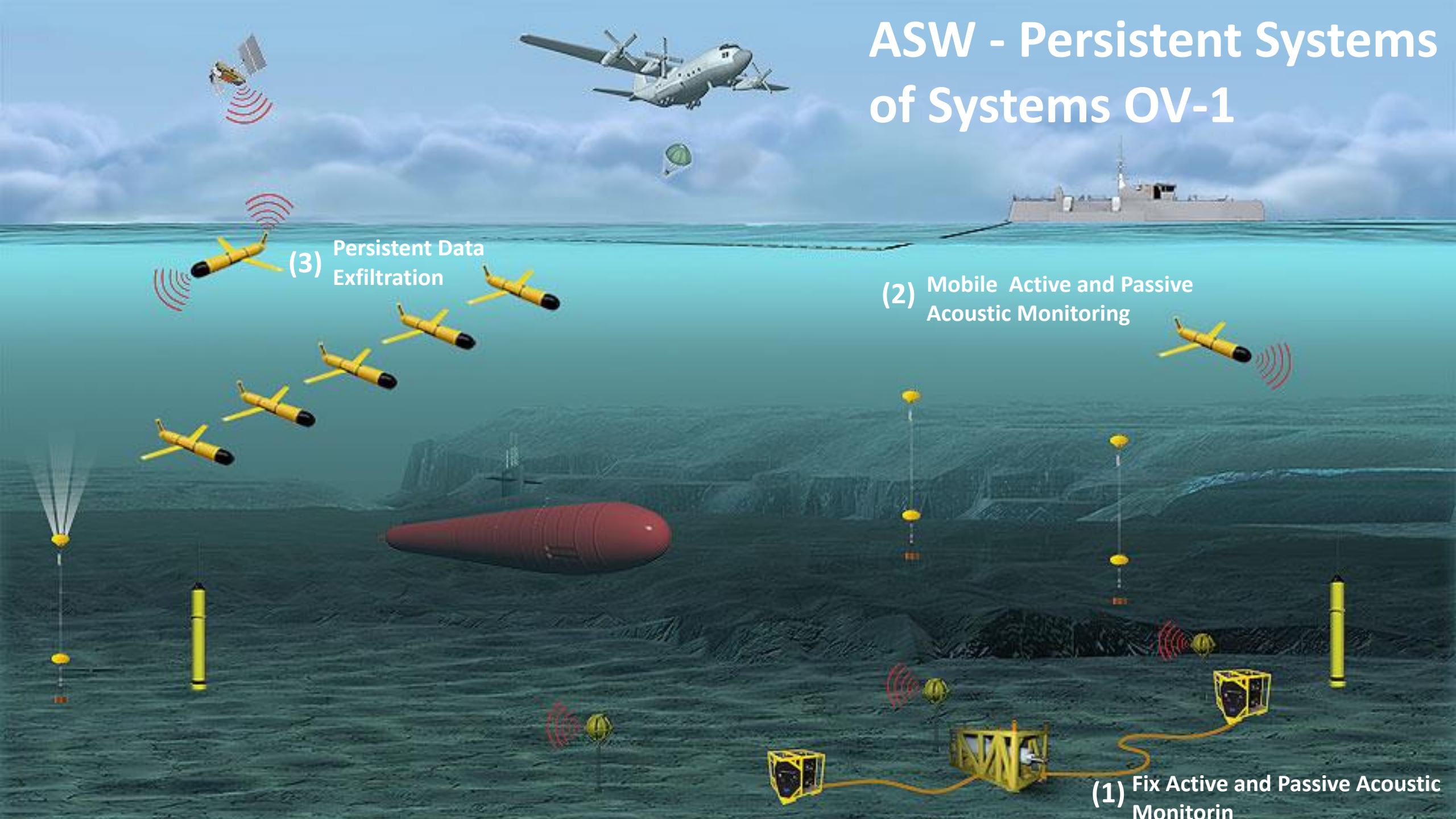
- Need to be able to operate in shallow and deep water
- Need scale, and reach



White: 0 to 2000 m
Green: 2000 to 3000 m
Blue: 3000 m

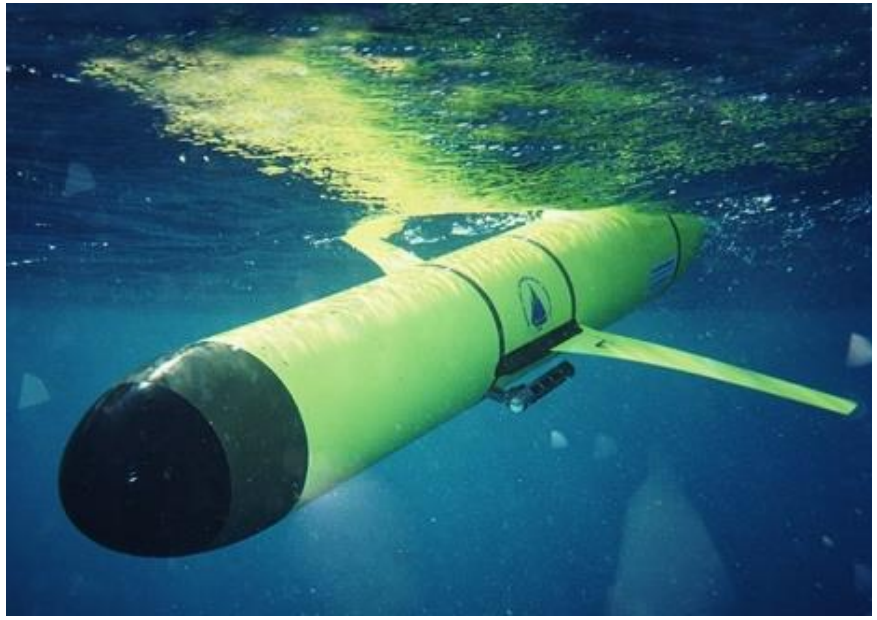
Distance - Guam to Taiwan
2,750 km

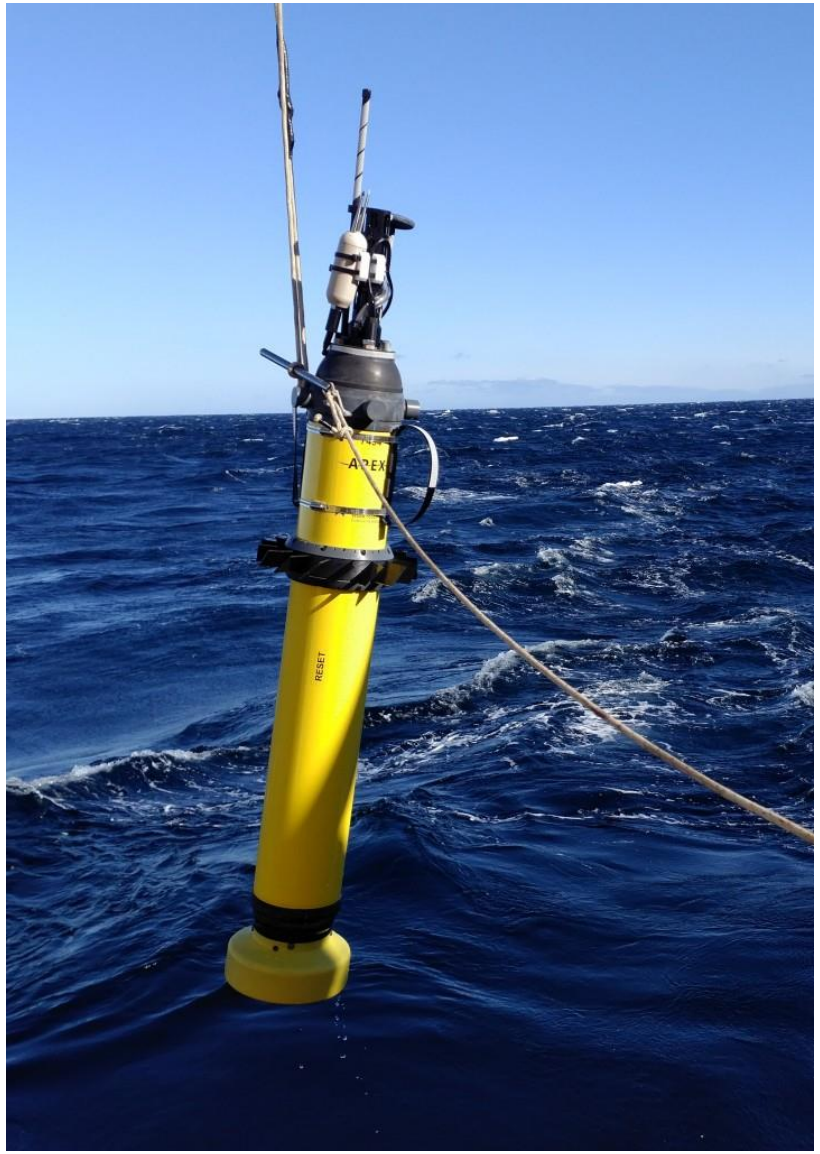
ASW - Persistent Systems of Systems OV-1



Water Column Sensor Platforms (REA)

- Underwater gliders can maintain a presence for month to a year
- Profiling floats (lagrangian drifters) provide multiyear oceanographic and environmental acoustic information





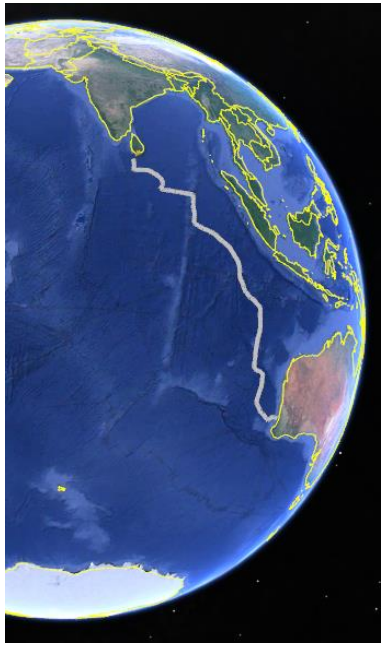
Unmanned Systems at Scale

- U.S. Navy has deployed over 100 underwater gliders during a single operation
- Minimal staffing required – Oversight/ manage by exception
- Over 1200 gliders delivered

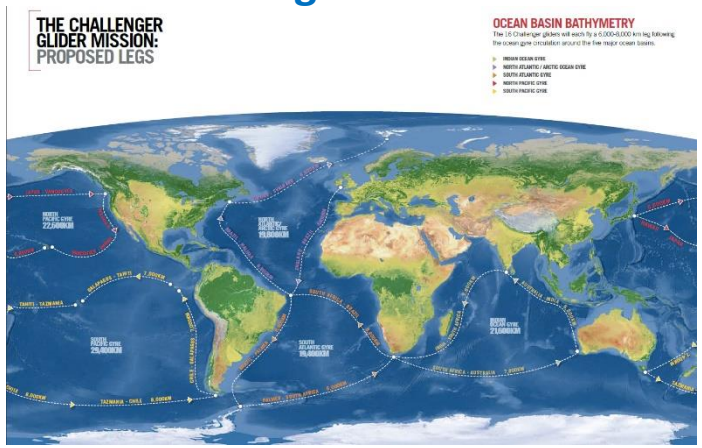
"The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement."

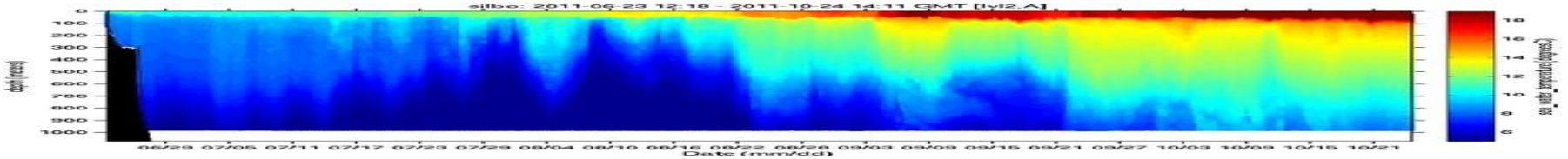
Photo by Rebecca Eckhoff
Courtesy of DVIDS

Trans-Oceanic Crossings – How Persistent Are the Systems?



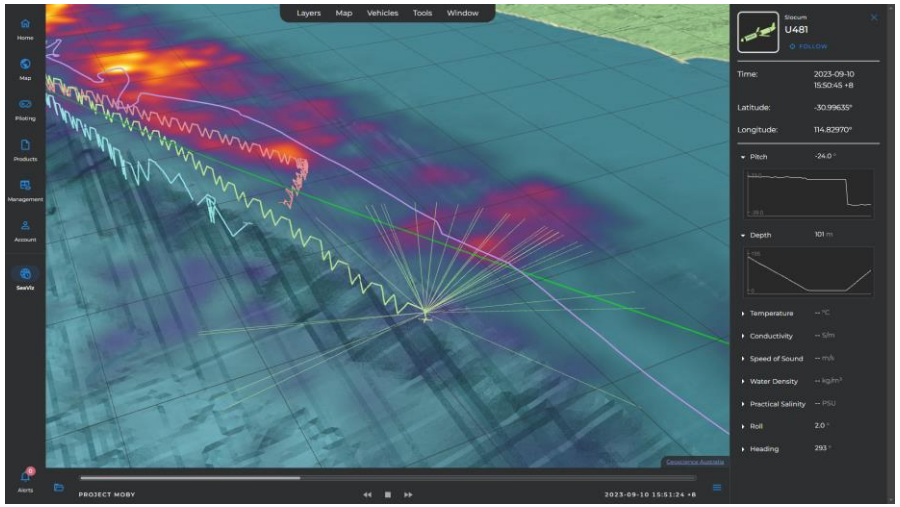
Challenger Mission

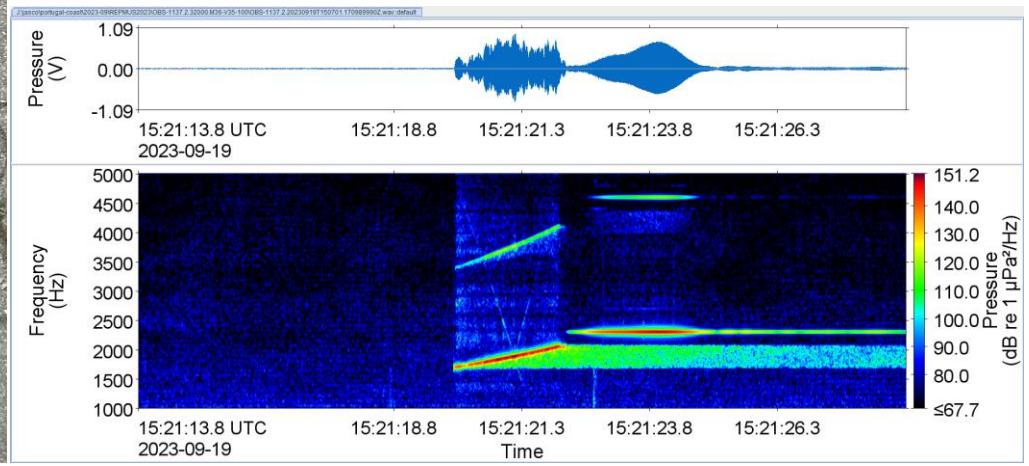




Passive Acoustic Sensors

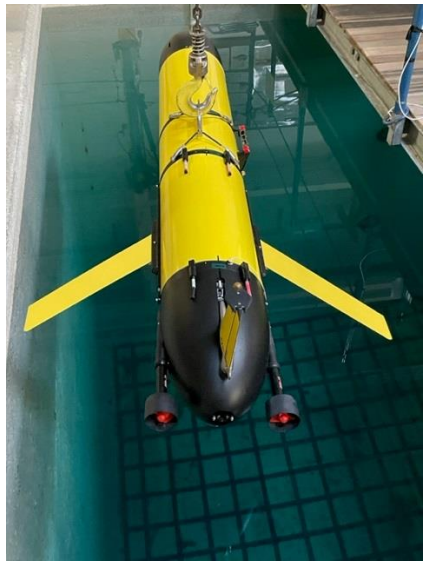
Slocum glider with a JASCO OceanObserver Spatial Array





Slocum Sentinel glider – Expanding the Operational Envelope

- Depth rating: 1000 m
- External Diameter: 33cm (13 inches)
- Length: 2.57m (8.4 feet)
- Energy: 3.6 times a standard Slocum G3
  - 23 kWh
- Endurance: Up to 2+ years

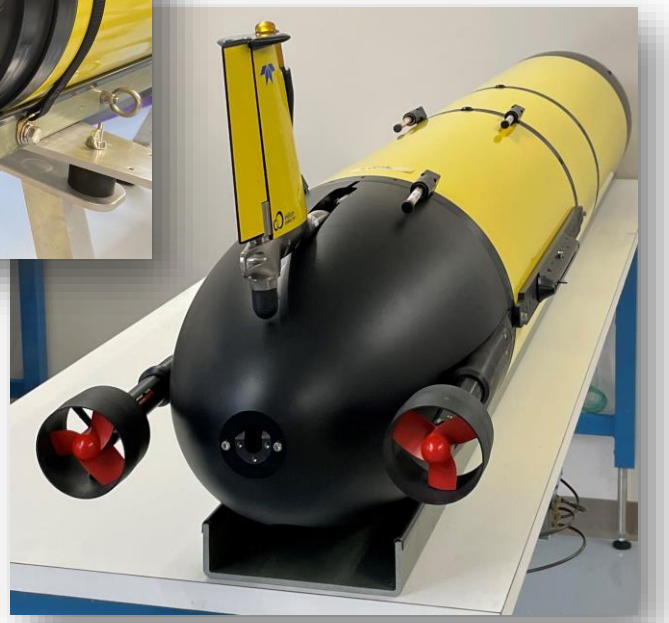


Slocum Sentinel glider – Faster and More Capable

Operations over greater distances and more diverse operational areas

Largest Ever Buoyancy Engine
- **4 Liters Ballast Drive (+/- 2L)**
- **Average Glide speed: 1 knot**

2 x Integrated Thrusters
- **Burst speed to handle difficult water conditions**
- **Included on every Slocum Sentinel Glider**

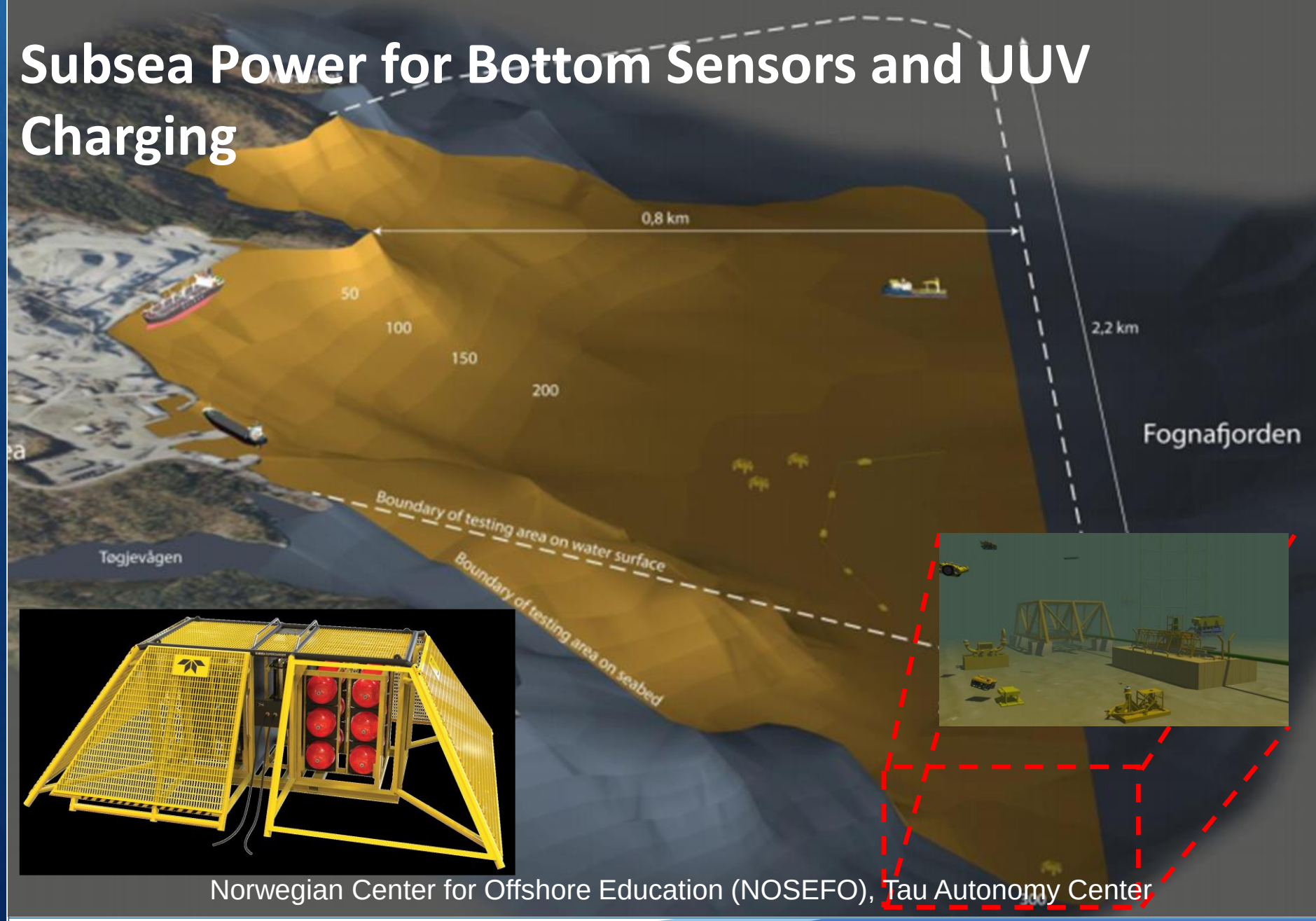


- Operations in areas with greater changes in density
- Operations in areas with higher currents
- Data gathering over larger operational areas
- Faster boat-free transit to remote areas of operation

Achieving Persistence for UUVs

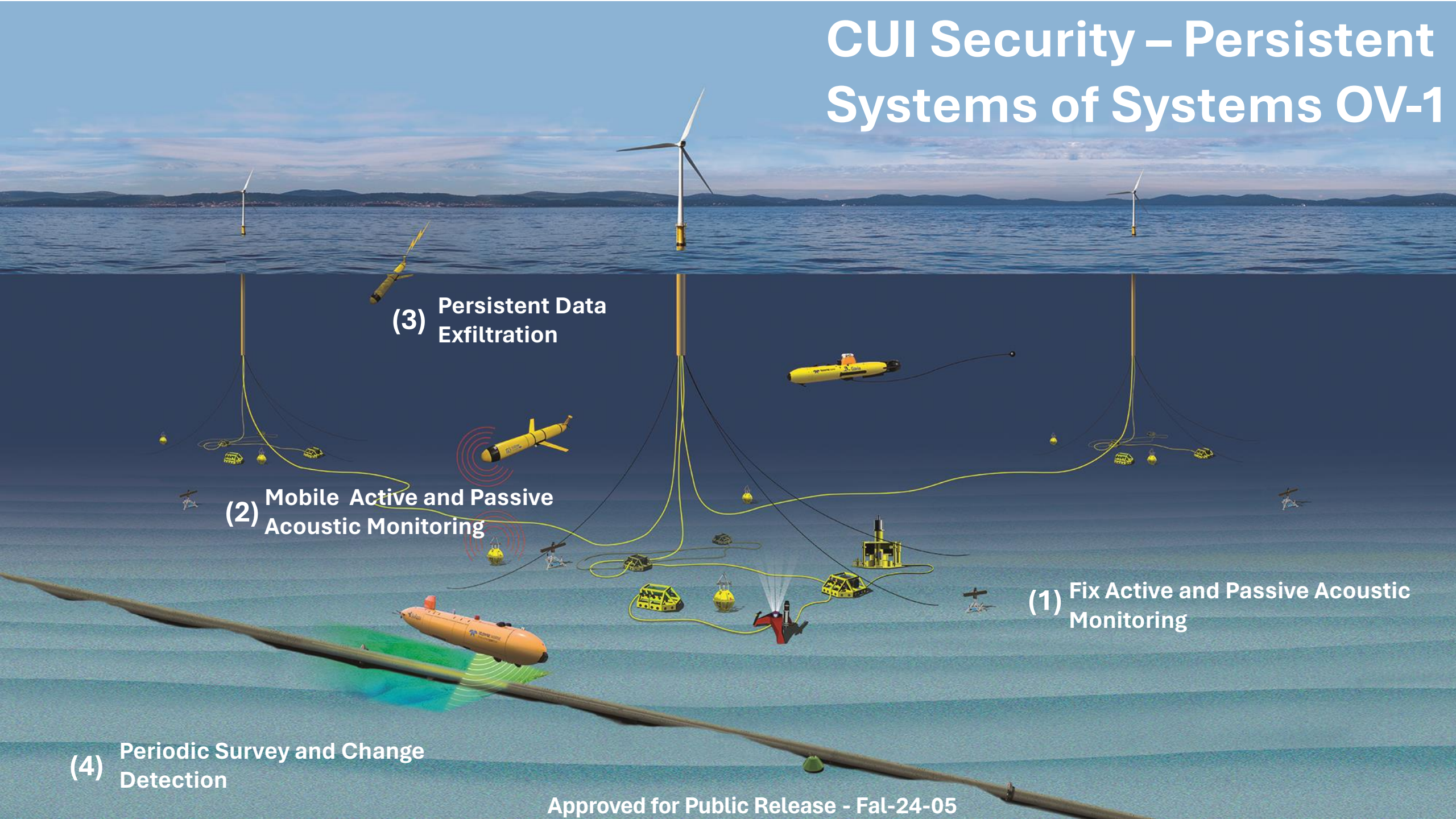
- Teledyne Energy Systems, Inc. Subsea Supercharger
- Leverages existing fuel cell technology
- >1.0 MWh of energy storage
- Uncrewed system docking and charging
- 40-foot container version can supply about 5 MWh
  - That is about 200 Osprey UUV surveys

Subsea Power for Bottom Sensors and UUV Charging



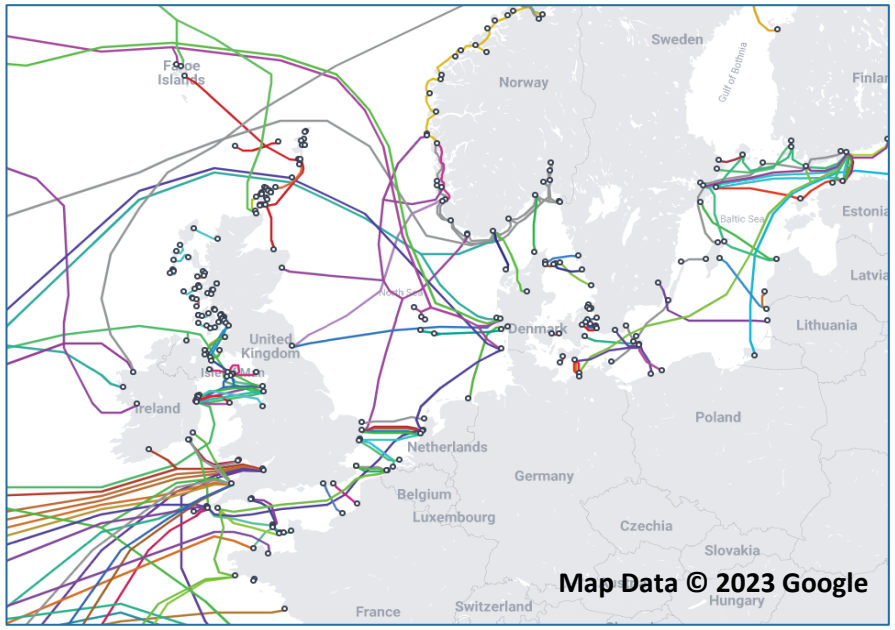
Norwegian Center for Offshore Education (NOSEFO), Tau Autonomy Center

CUI Security – Persistent Systems of Systems OV-1



Critical Undersea Infrastructure (CUI) Risk

- Surface and subsurface maritime infrastructure is vulnerable to both state and non-state actor threats
- Significant spatial extent
  - Complex to monitor results in an asymmetric threat

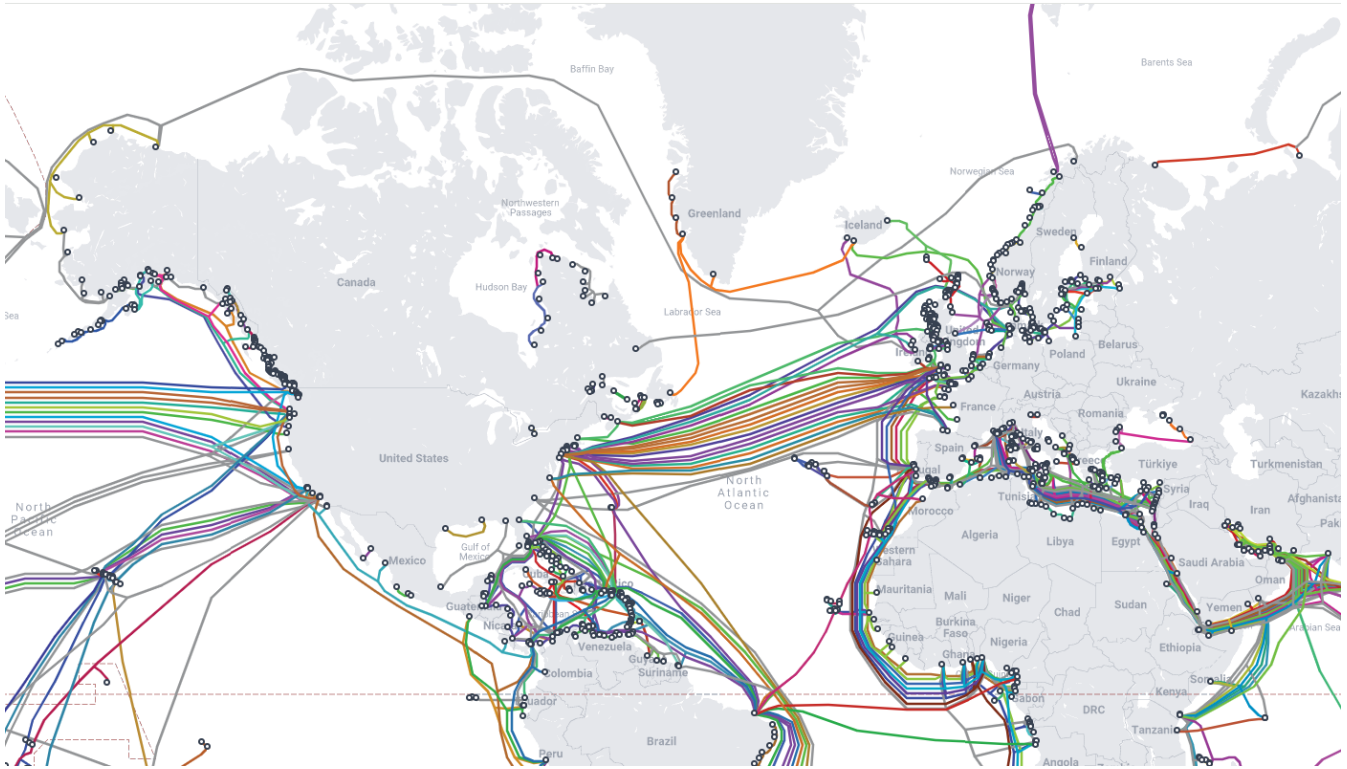


Critical Undersea Infrastructure (CUI) Risk - Windfarms

- European offshore wind power projections
  - Up to 100 million homes by 2030
- Windfarm design does not account for the emerging subsea threat
  - Would the topology change if subsea security is a high priority?

Critical Undersea Infrastructure (CUI) Risk – Telecommunication Cables

- More than 1.4 million kilometers of subsea telecommunication cable worldwide
- Baltic Sea Submarine Cable is over 1000 km in length
  - Damaged last fall
  - The system design does not account for the emerging subsea threat
- In February 2024 at subsea telecom cable (Europe India Gateway (EIG)) was damaged, likely by a non-state actor



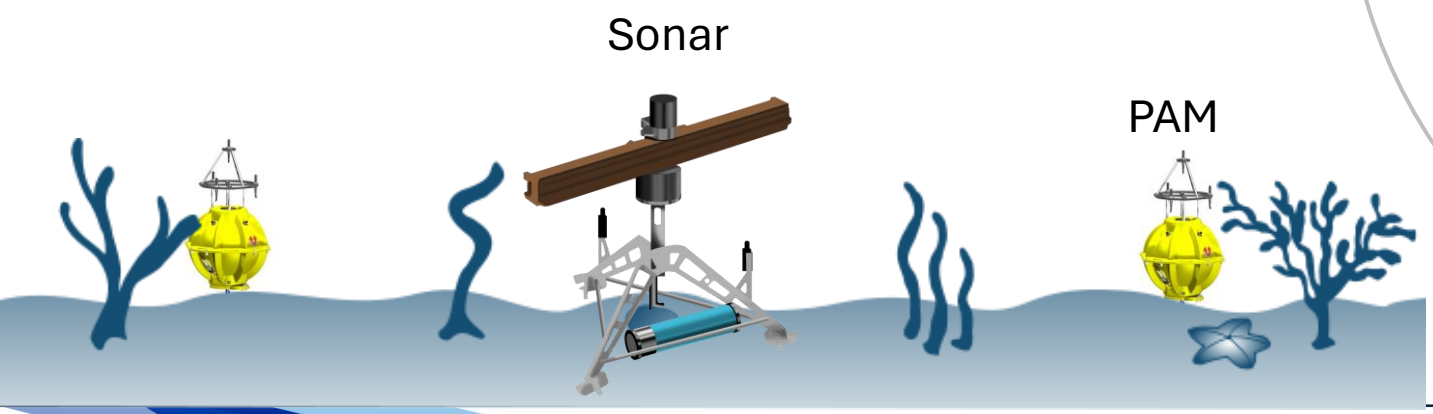
https://www2.telegeography.com/

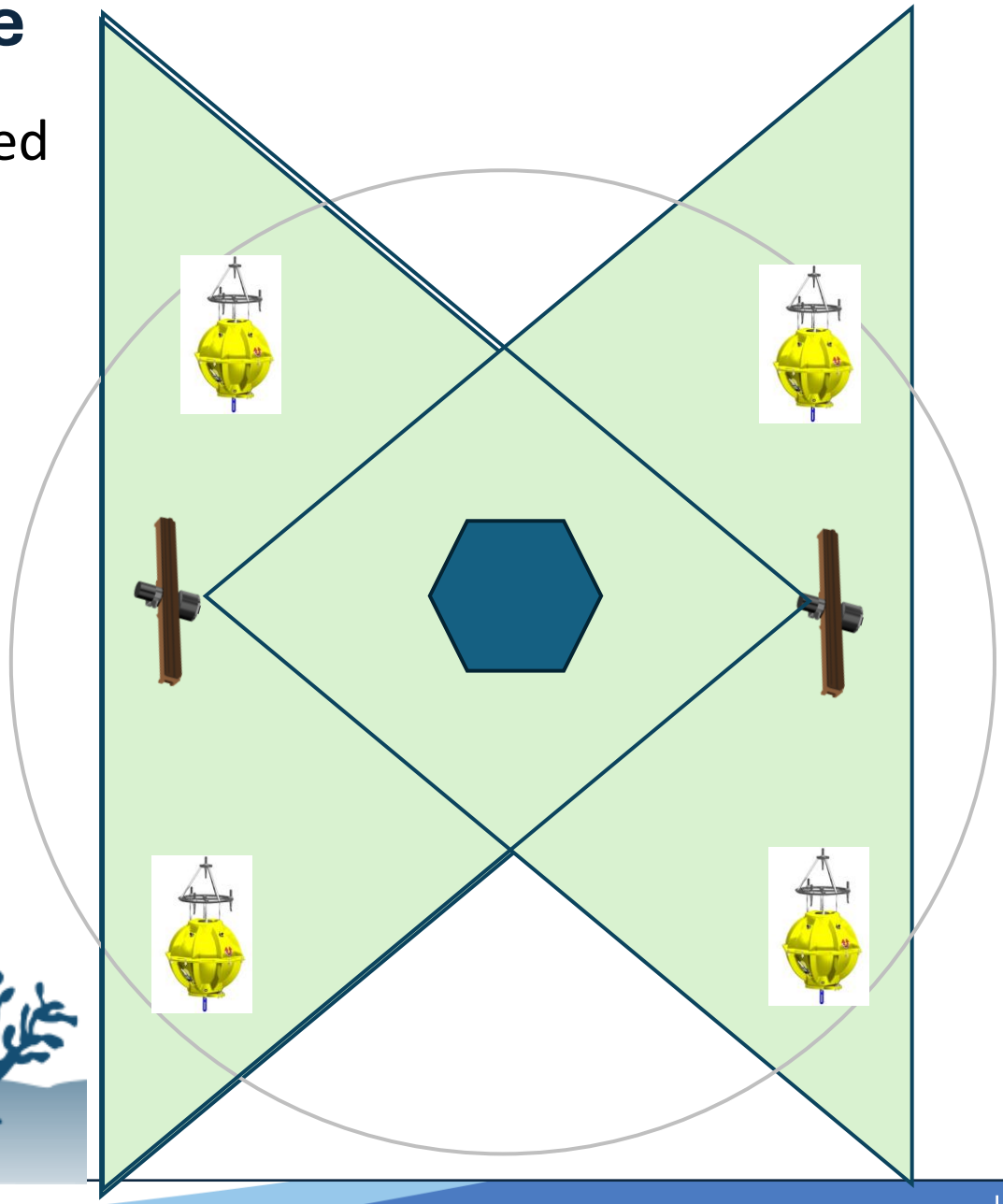
CUI Security Approaches

- Protection of subsea infrastructure can be achieved by continuous monitoring
  - Multiple subsea sensing modalities are required
    - For example – subsea acoustic threat detection
  - Very expensive for wind farms and pipelines
  - Exploit Distributed Acoustic Sensing (DAS) for fiber optic cables
- Periodic or threat-based monitoring
  - Survey and change detection cued by other intelligence
- Design for resiliency

Asset monitoring – Passive & Active

- Passive Acoustic Monitoring (PAM) array placed at the bottom to act as cue sensor
- Bottom mounted multibeam sonar to image/track threat in water column
- Acoustic or wired communication for target data exfiltration



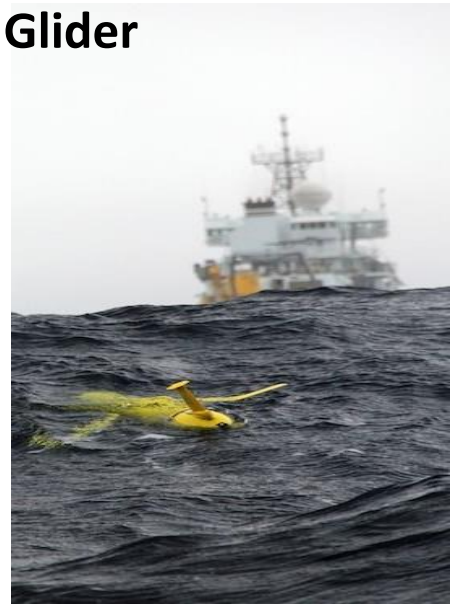


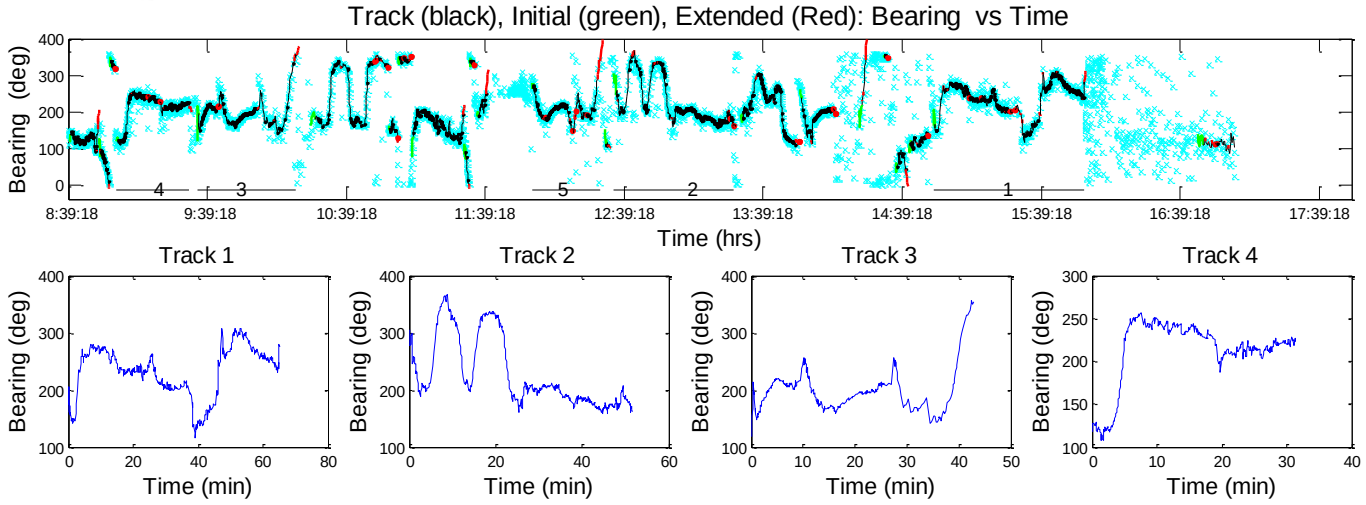
Continuous Passive Monitoring

- Seafloor compact passive bearing detector (PBD) – Passive Acoustic Monitoring (PAM) system
- Acoustic exfiltration of events and tracks

Passive bearing detector (PBD) establishes bearing to broadband acoustic source

Persistent Data Exfiltration via Underwater Glider





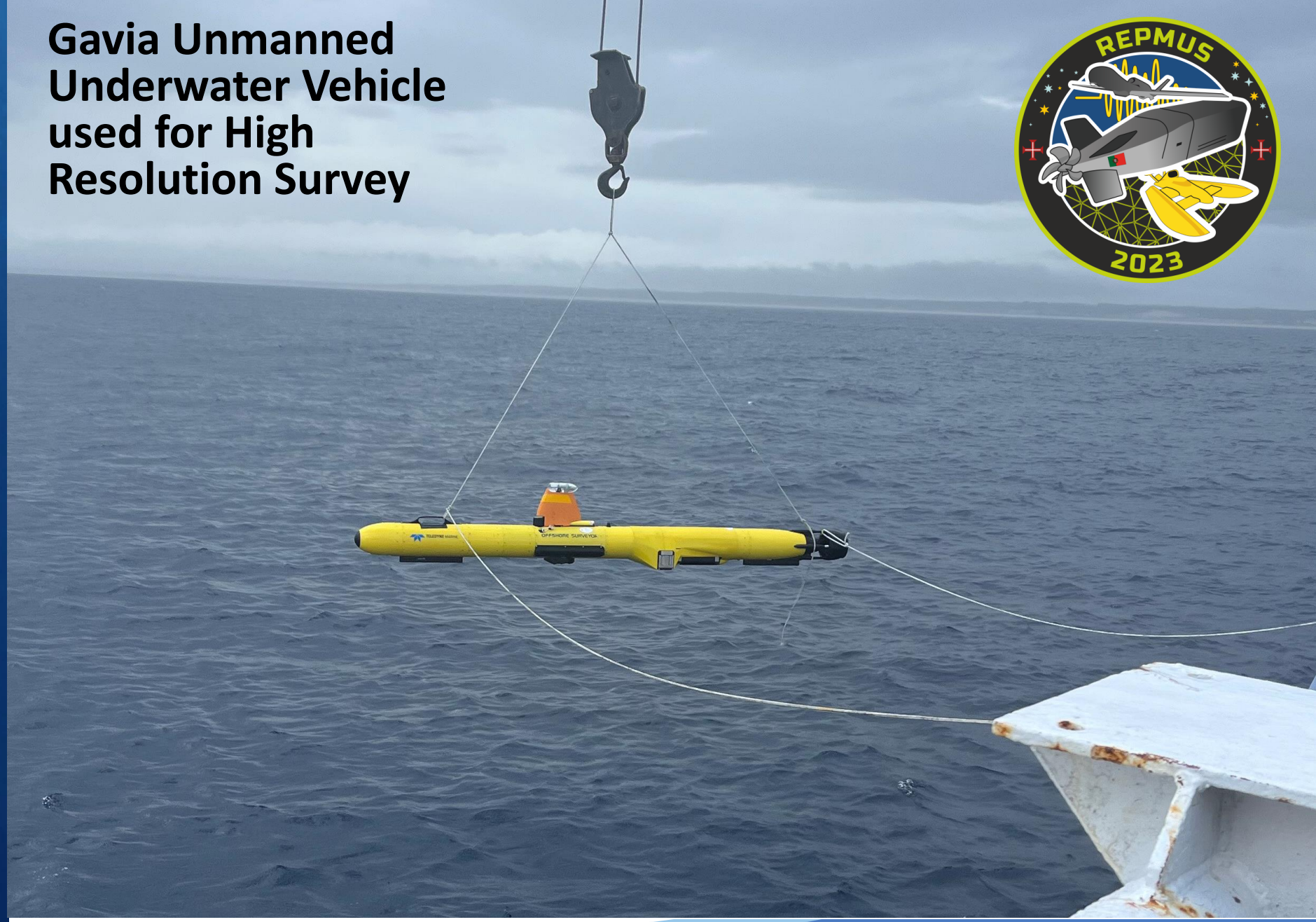
Tracks of a subsea target passing in the vicinity of the PBD

Active Acoustic Sensor – Bottom Mounted

- Leverage ship mounted mine hunting multibeam sonar
- Triple frequency band for high flexibility
  - Better resolution at close ranges
- Images and track targets in the water column
  - UUVs
  - Divers

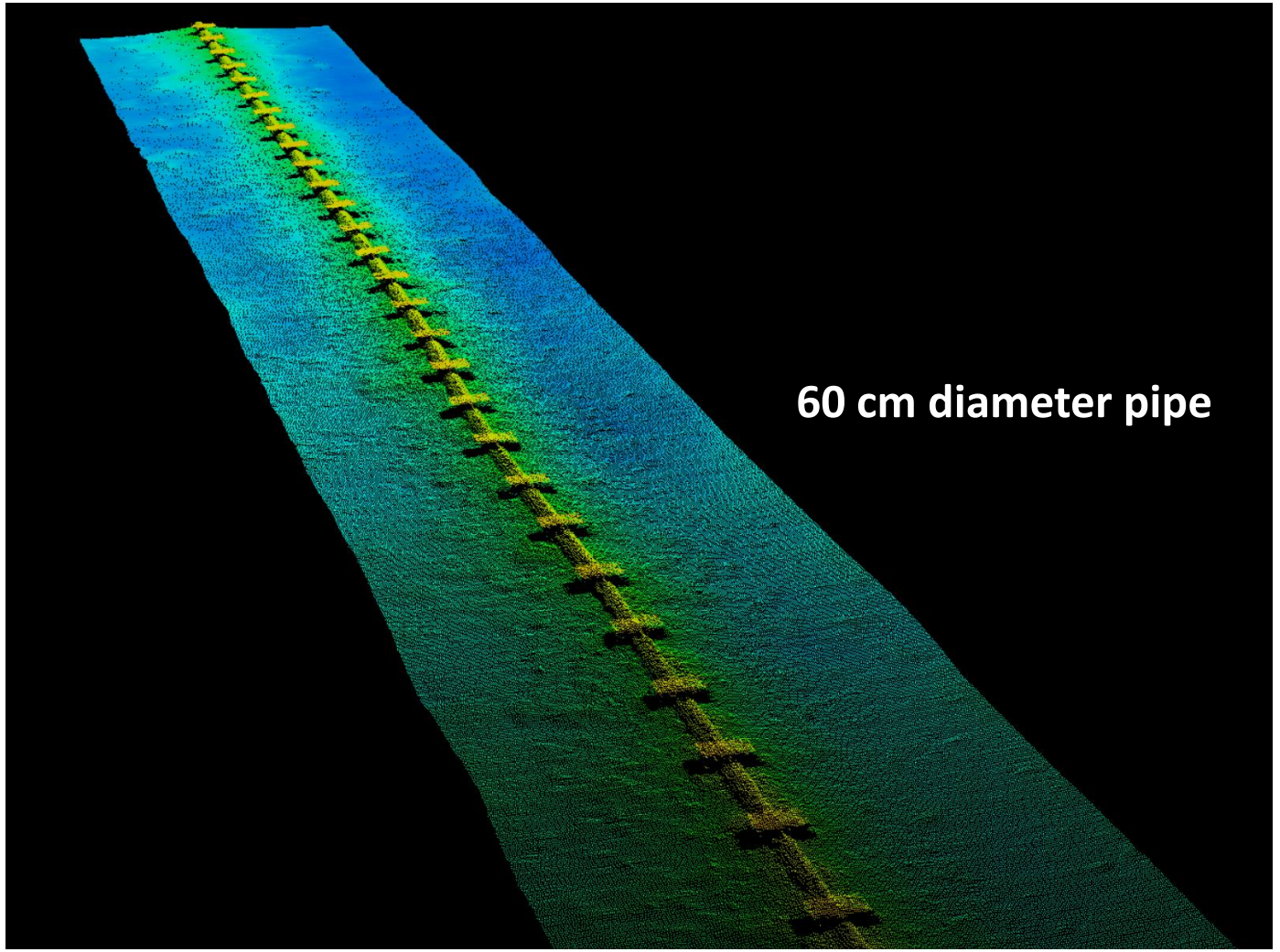
Periodic Monitoring

- Establish baseline survey of undersea infrastructure
- Periodic resurvey to ensure accurate baseline
- Threat driven survey and change detection to find potential deployment of



Multibeam UUV Survey of Pipeline using RESON T-20 Module

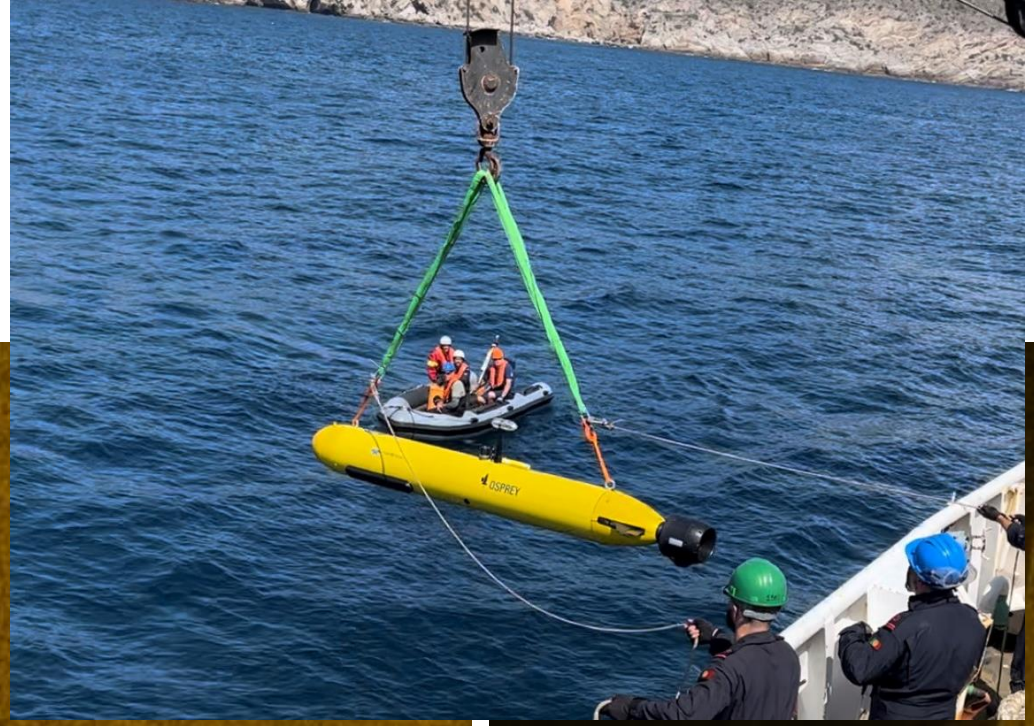
- High resolution bathymetry to establish baseline
  - Small UUV with true multibeam
- Pipe tracking to optimize survey time
- Change detection can be achieved automatically by comparison of point cloud
  - Baseline survey versus threat response survey

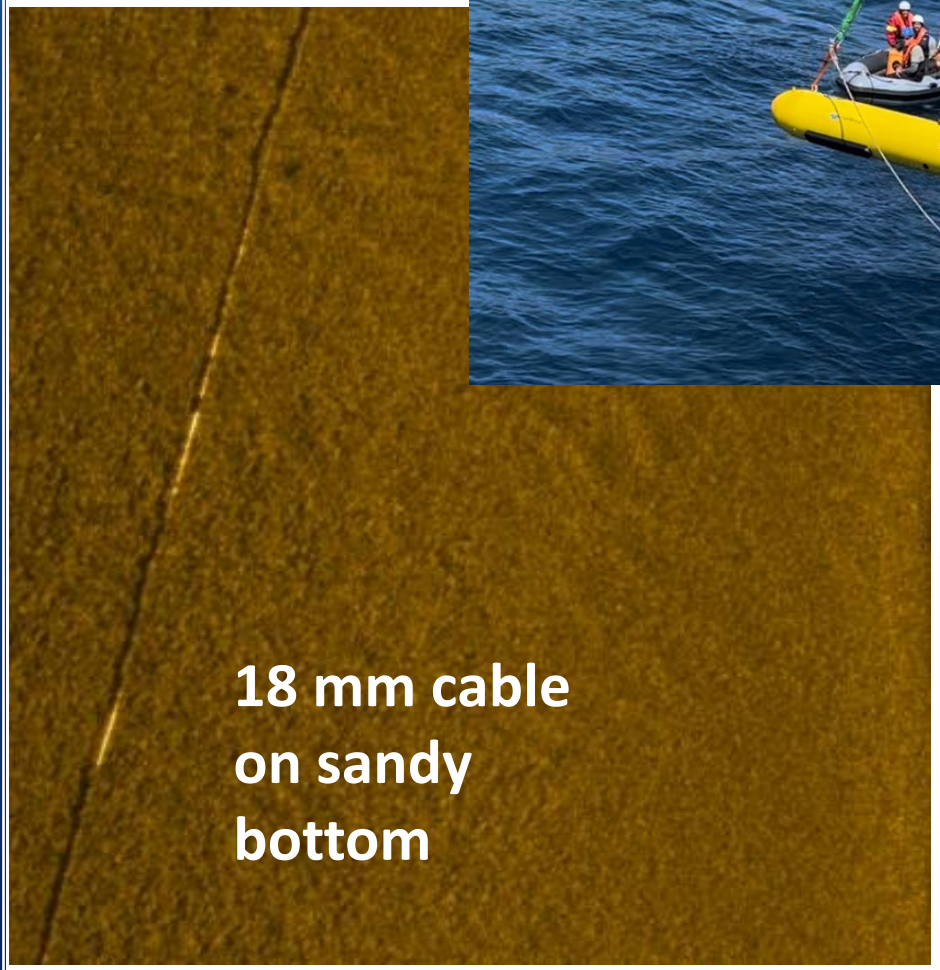


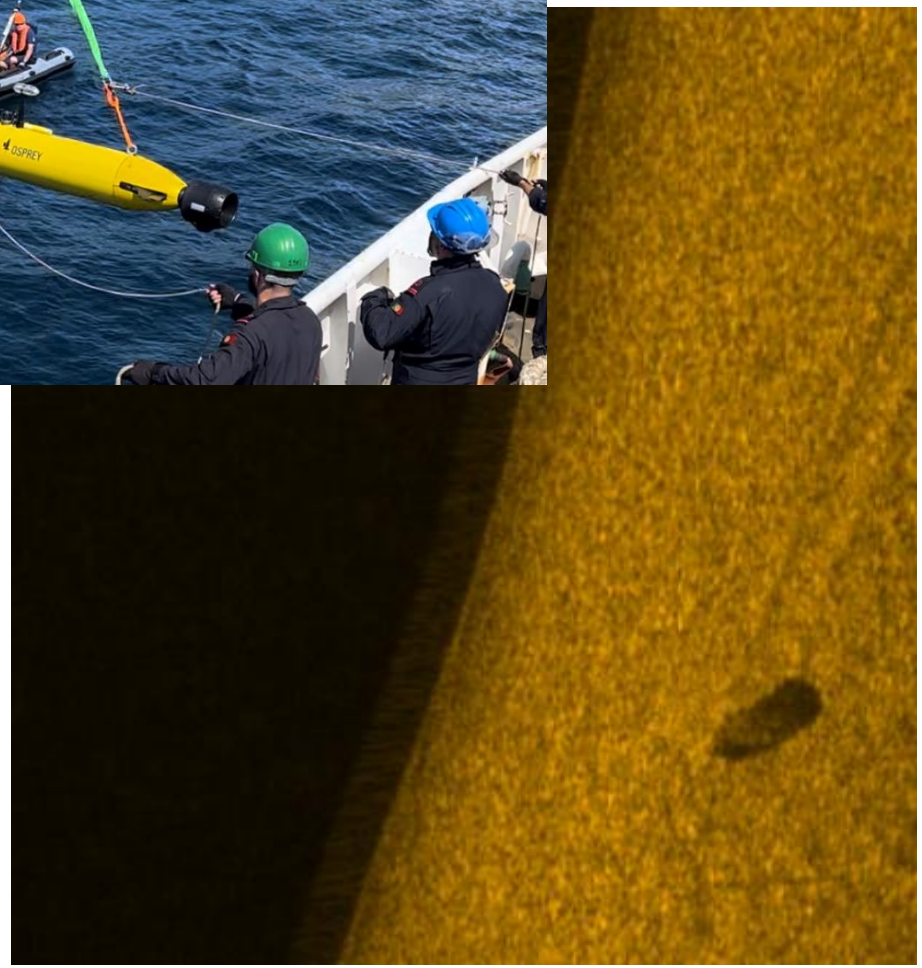
CUI Experiment September 2023

Osprey SSS results

- Cable (L)
- Cable anchor (R)



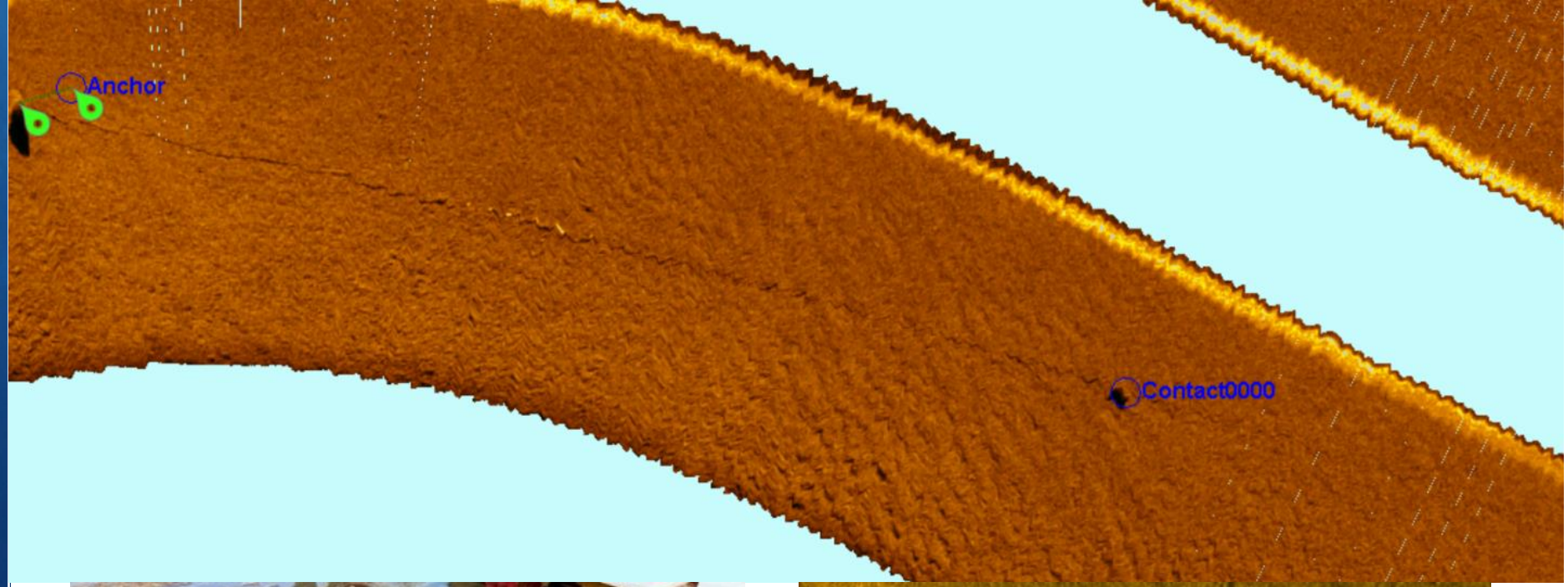


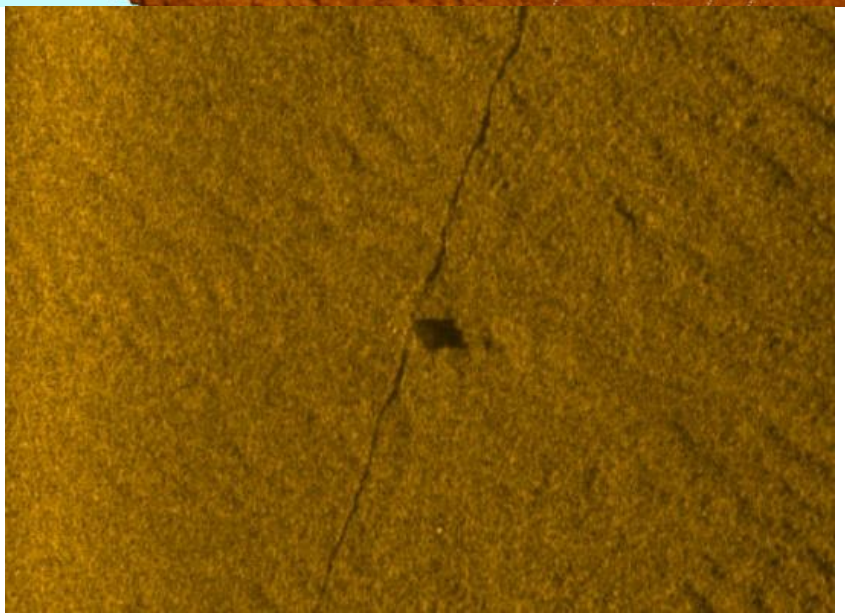


CUI Experiment September 2023

Osprey SSS results

- Cable and potential target
- Resurvey after treat target removed





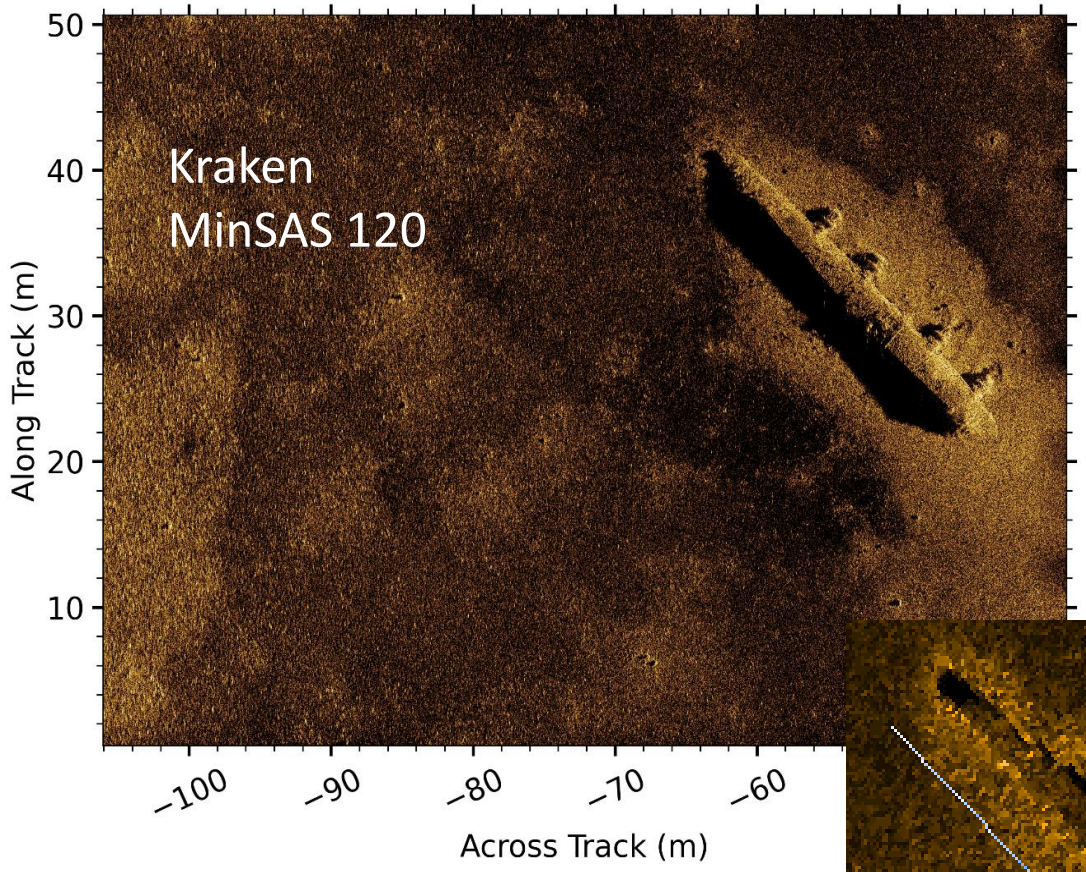
REPMUS 24 Deep CUI Experiment

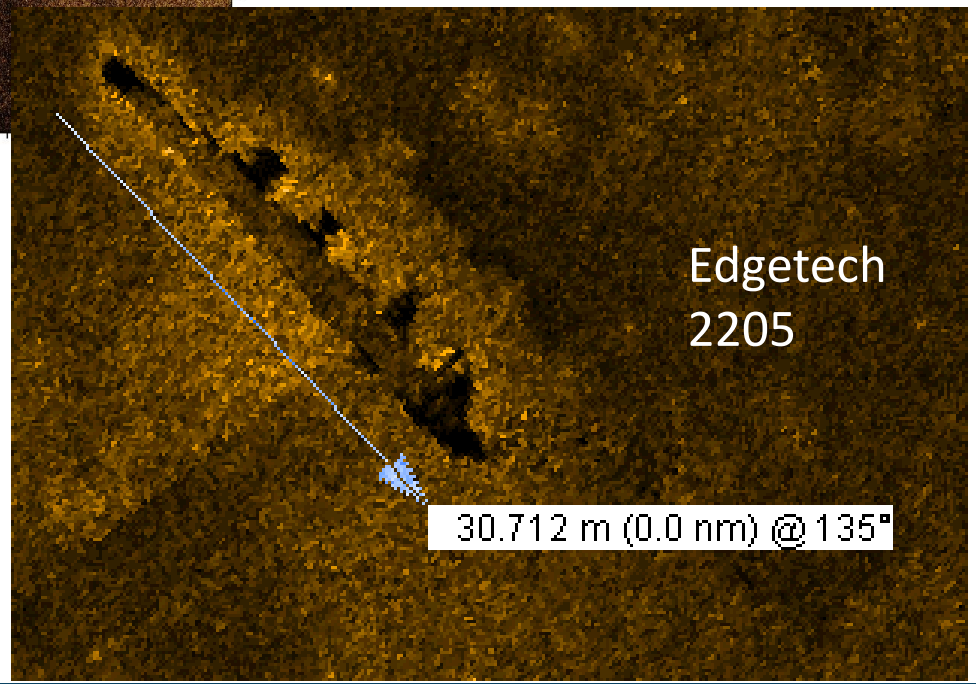
Teledyne Gavia with Kraken minSAS

200mm diameter modular expeditionary UUV rated to 1000 meters

Synthetic Aperture Sonar Versus Sides Scan Sonar

High resolution subsea imagery





Critical Undersea Infrastructure (CUI) Security Path Forward

- Persistent bottom mounted and water column sensors are high TRL
- UUVs are proven for other survey missions
- But an integrated system of systems is still in nascent stage