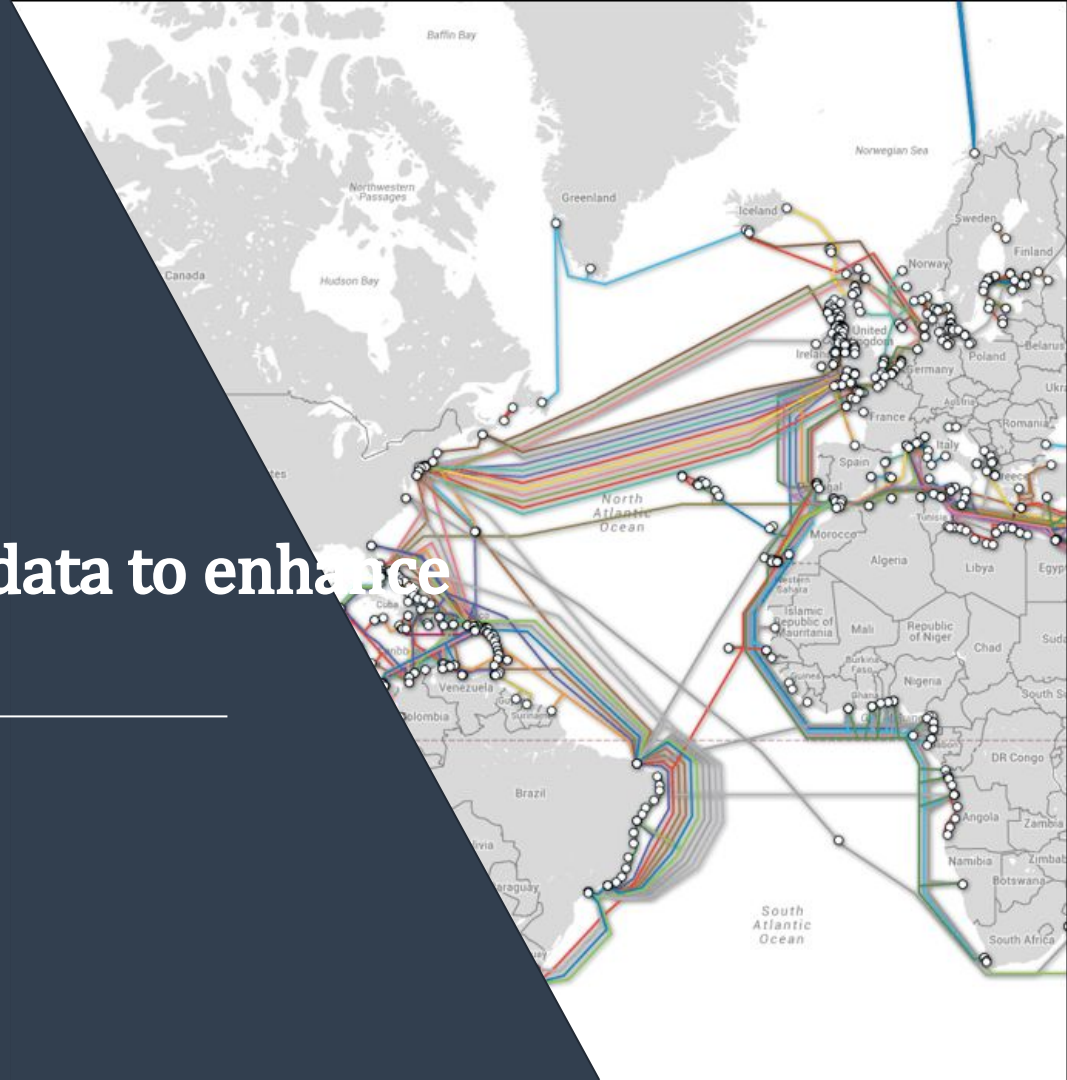


Multi-Sensor Data Fusion

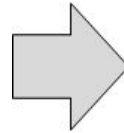
Integration of space-based data to enhance maritime operations

CDR (j.g.) Patrick O'Keeffe

Centre of Excellence for Operations
in Confined and Shallow Waters (COE CSW)



Who am I?



Institut für
Sicherheitspolitik
an der Universität Kiel

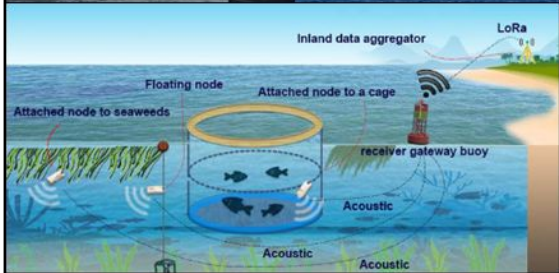
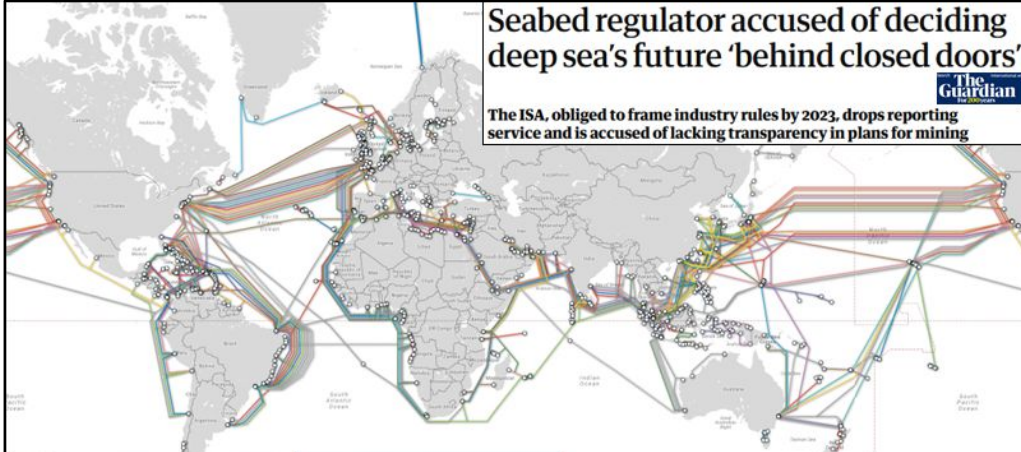


Global Trends & Challenges

Seabed regulator accused of deciding deep sea's future 'behind closed doors'

The ISA, obliged to frame industry rules by 2023, drops reporting service and is accused of lacking transparency in plans for mining

The Guardian



CMRRE Reprint Series

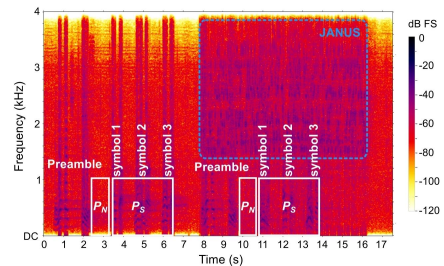
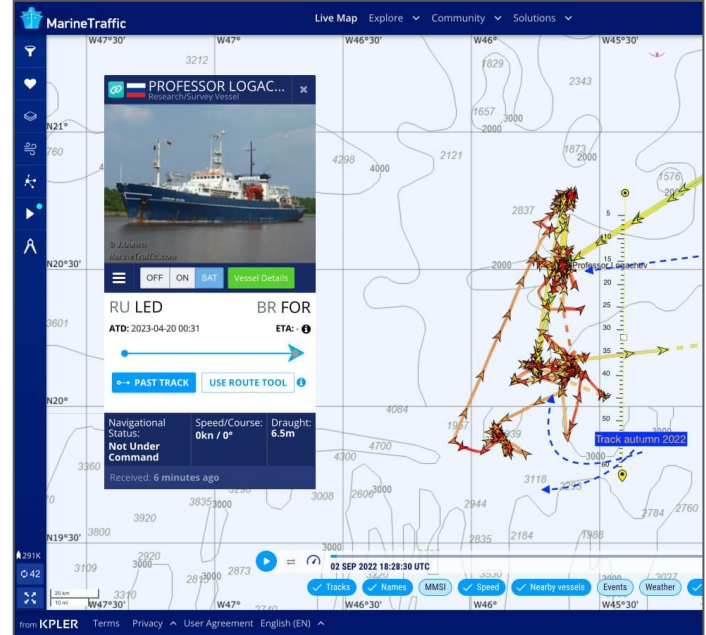


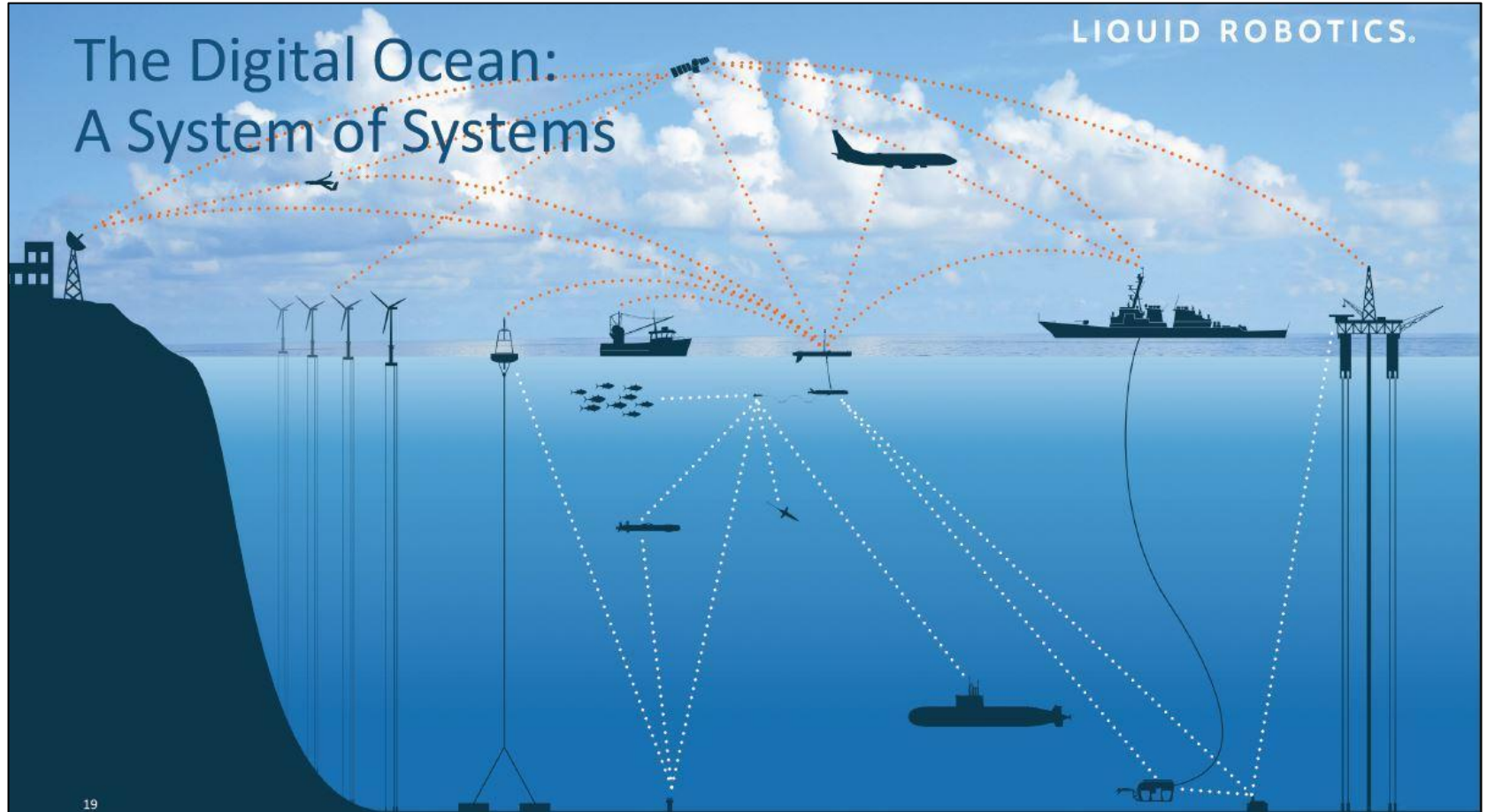
Fig. 2: Illustration, over acquired data, of the signal portions used to calculate noise, signal and interference power during a sequence of clean and interfered voice recordings



Twitter, @aunsson, 17 MAY 23, 18:28

LIQUID ROBOTICS.

The Digital Ocean: A System of Systems



Florence Parly

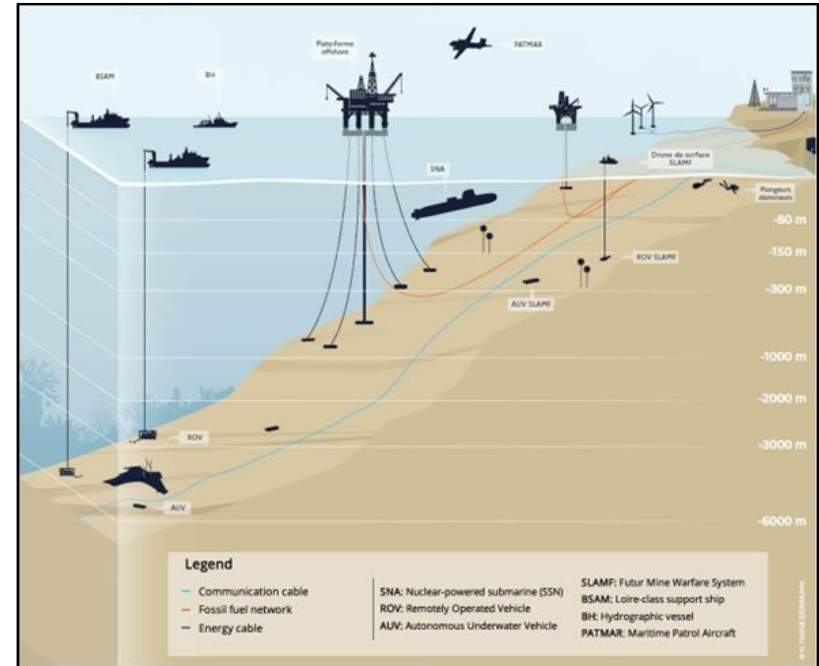
FRA Minister of Defence (JAN 2022)

“The goal of the new strategy is to equip the French military with the **ability to reach depths of 6,000 meters**”

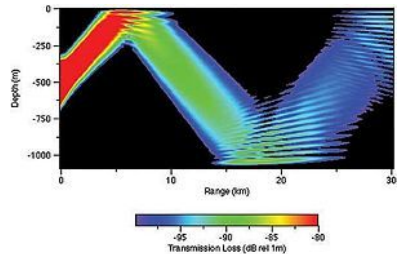
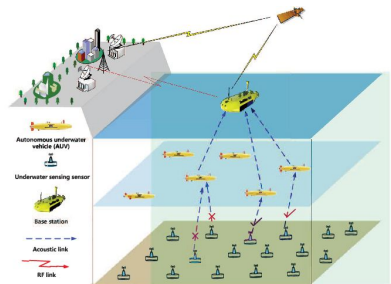
“This makes it possible to cover 97 percent of the seabed and effectively **protect our interests**, including sub-marine cables”

“Today, the emergence of drones and remotely operated robots – driven by the needs of industry [and] capable of carrying out operations that meet military objectives at a depth of several thousand meters – are **transforming the seabed into a new space for strategic competition**”

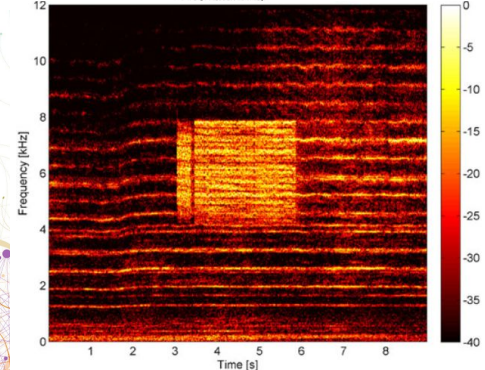
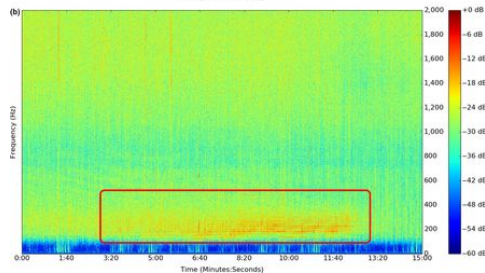
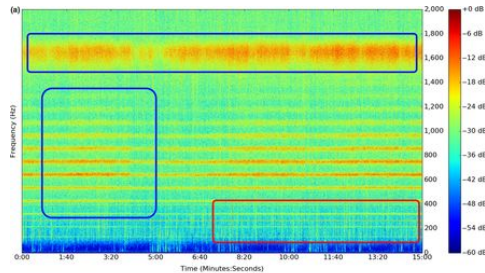
“One thing is certain: We know space much better than we know the seabed. We now know about space, cyber and artificial intelligence; every frontier of our technological knowledge has been pushed back. But there is still one left: **the seabed. This is the last frontier.**”



DISTRIBUTED



MULTI-SPECTRAL

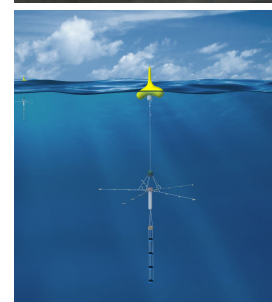


AND

MULTISTATISTICS



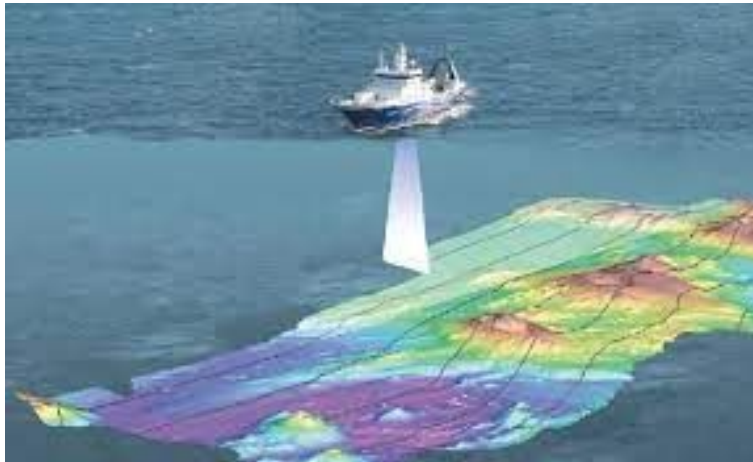
SENSING



Amount of Data is Growing

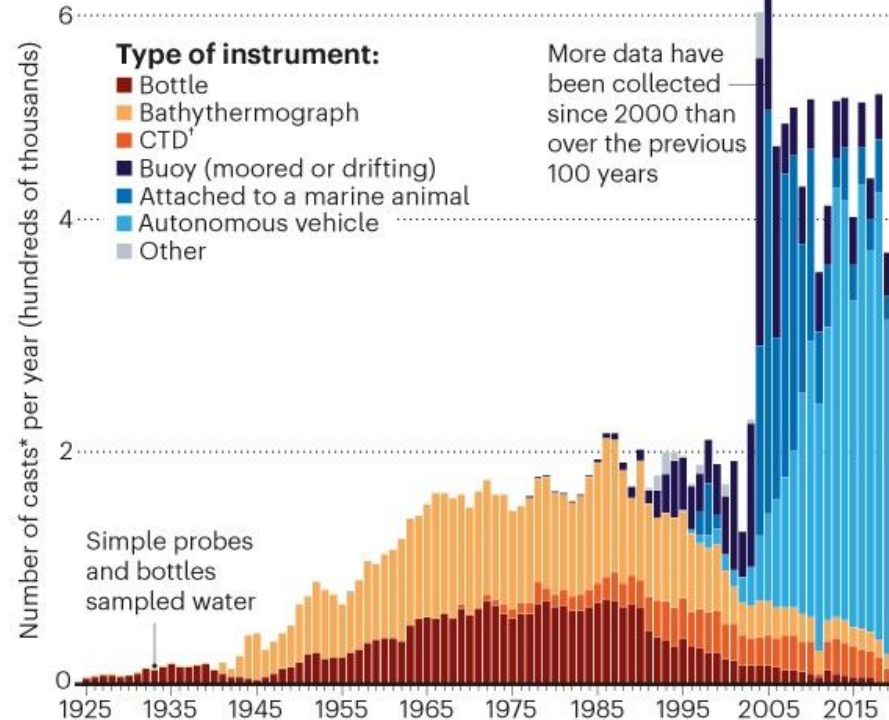
“Modern equipment used for seabed mapping activities may generate more than 100 GB of data per hour” (2016)

Hydrographic processing considerations in the “Big Data” age



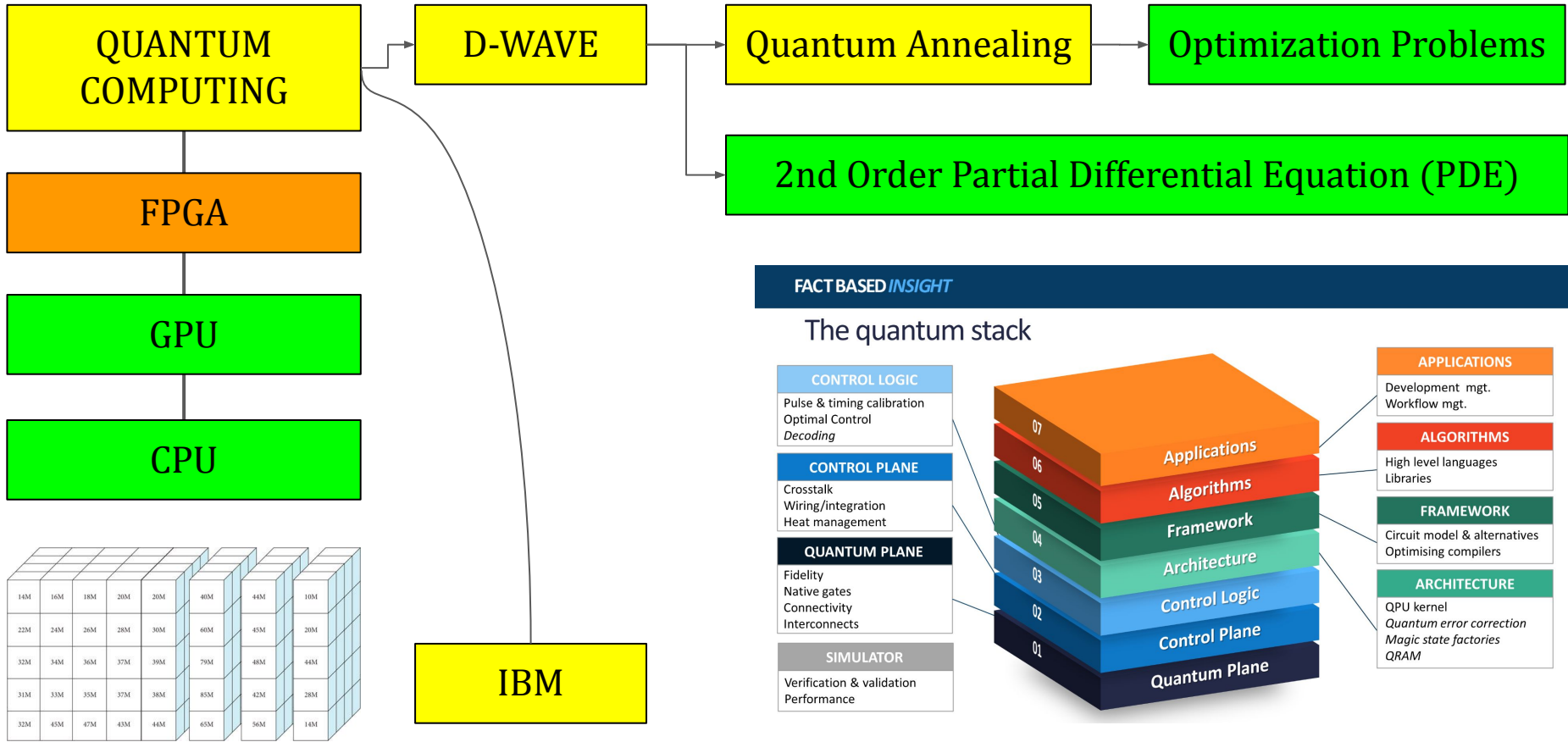
DATA TSUNAMI

The rapid growth in ocean information in the past decade has not been accompanied by a rethink of how data are collected, shared and accessed. Historical data-management methods prevent a comprehensive understanding of the impact of human activities on the ocean.



*A cast is a set of measurements for a single variable, such as temperature or salinity at different depths.
¹CTD, high-resolution sensor of conductivity, temperature and depth.

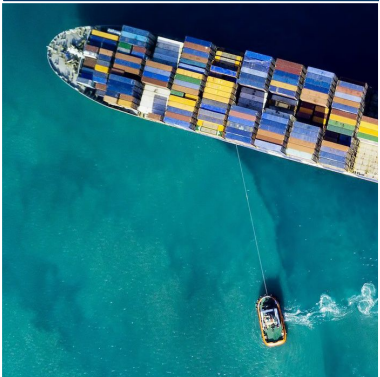
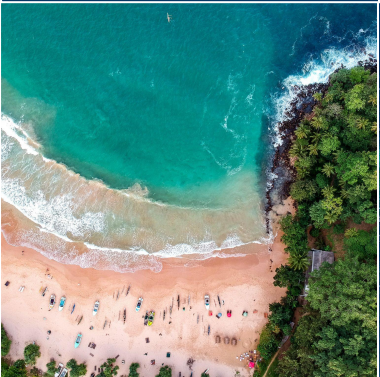
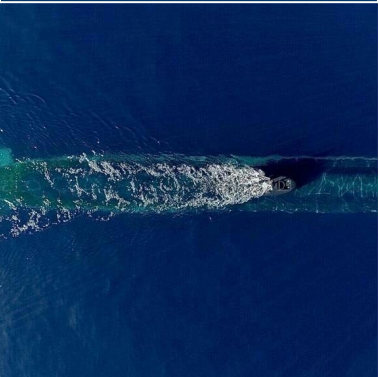

Big Data ⇒ Advanced Computing



Space Systems for Maritime Operations



Space Systems for Maritime Operations

Maritime Situational Awareness (MSA)	Rapid Environmental Assessment (REA)	Anti-Submarine Warfare (ASW)	Post Mission Analysis
			



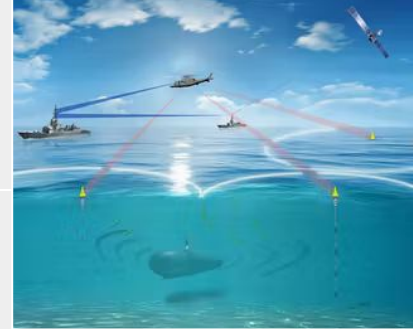
Space Systems for Maritime Operations

VISION	To increase situational awareness from the seabed to the surface	MISSION	Combining multiple space-based data sources and underwater acoustic analysis with unmanned maritime systems to provide individual workflows for various mission types
GOALS	Establishment of a Multi-Sensor Data Fusion Cell (MSDFC)	VALUES	Unclassified for as long as possible
	To support detection, monitoring and identification of objects in any given area of interest		Shareable with partners

Situation - Challenge - Solution

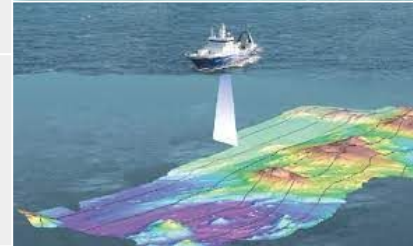
Situation

Underwater Situational Awareness
requires a sophisticated
Surface Situational Awareness

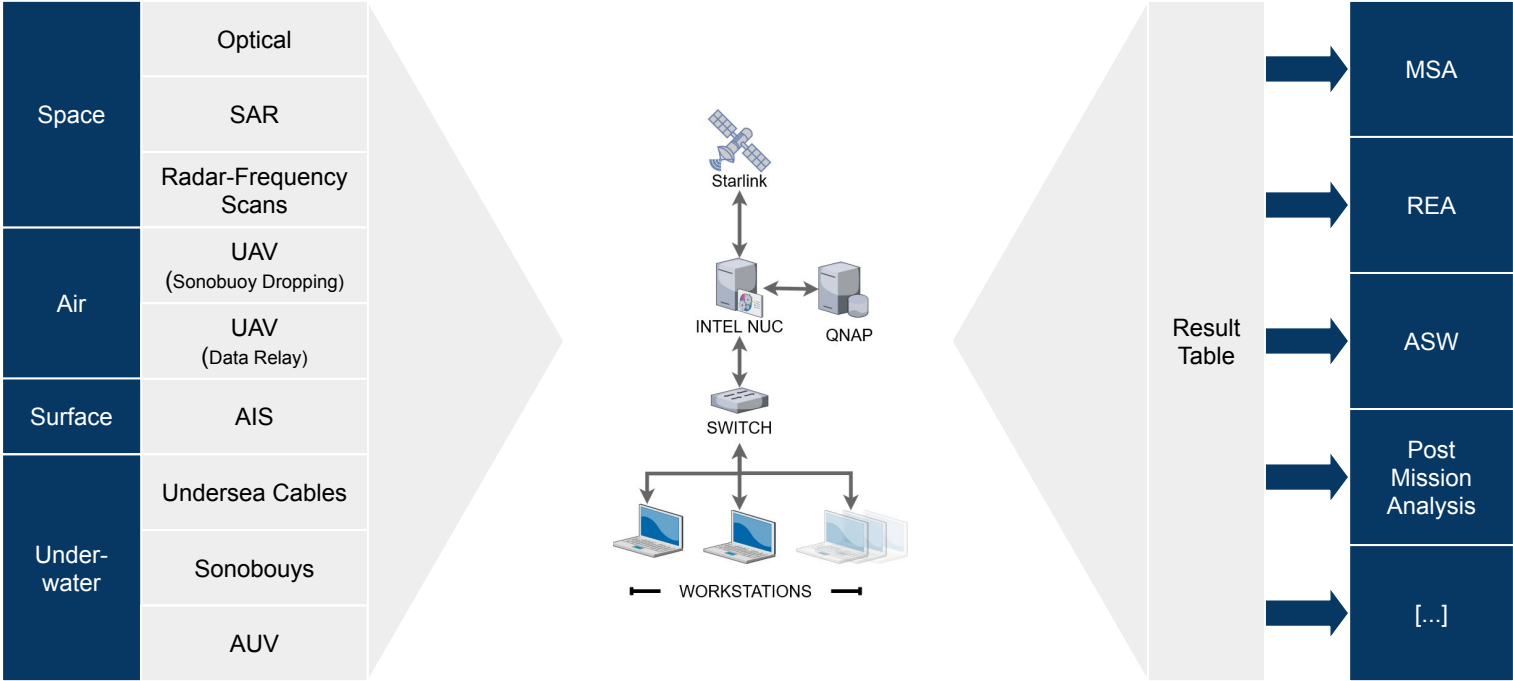


Challenge

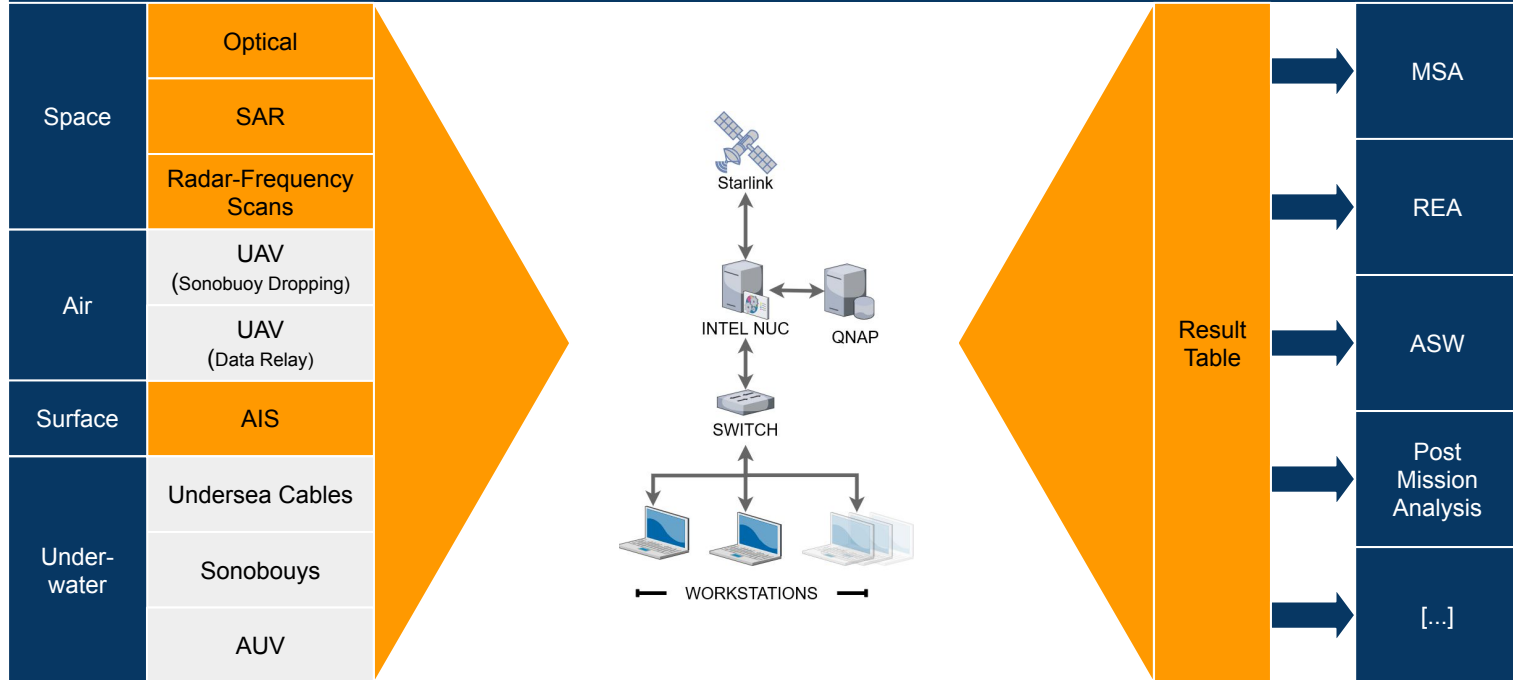
Multiple Data Sources for
Surface and Underwater Awareness
are available but not yet integrated



Multi-Sensor Data Fusion Cell (MSDFC) Blueprint



Multi-Sensor Data Fusion Cell (MSDFC) Blueprint



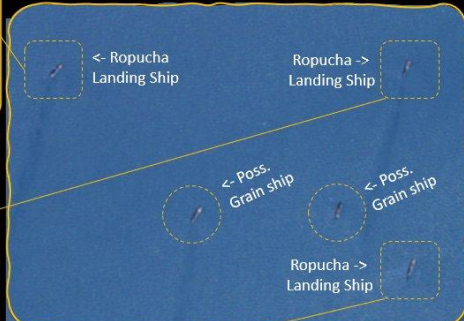
Expectations Management



Russian Warships And Grain Ships Off Crimea. June 13

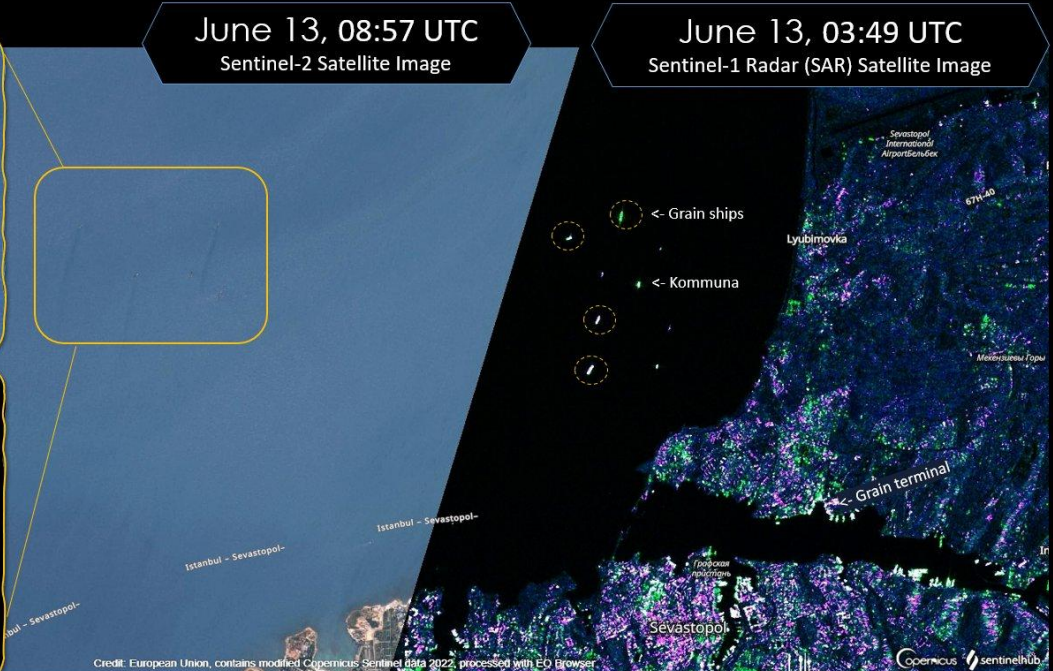
H I Sutton Twitter: @CovertShores, Website: www.hisutton.com

Warships



June 13, 08:57 UTC
Sentinel-2 Satellite Image

June 13, 03:49 UTC
Sentinel-1 Radar (SAR) Satellite Image



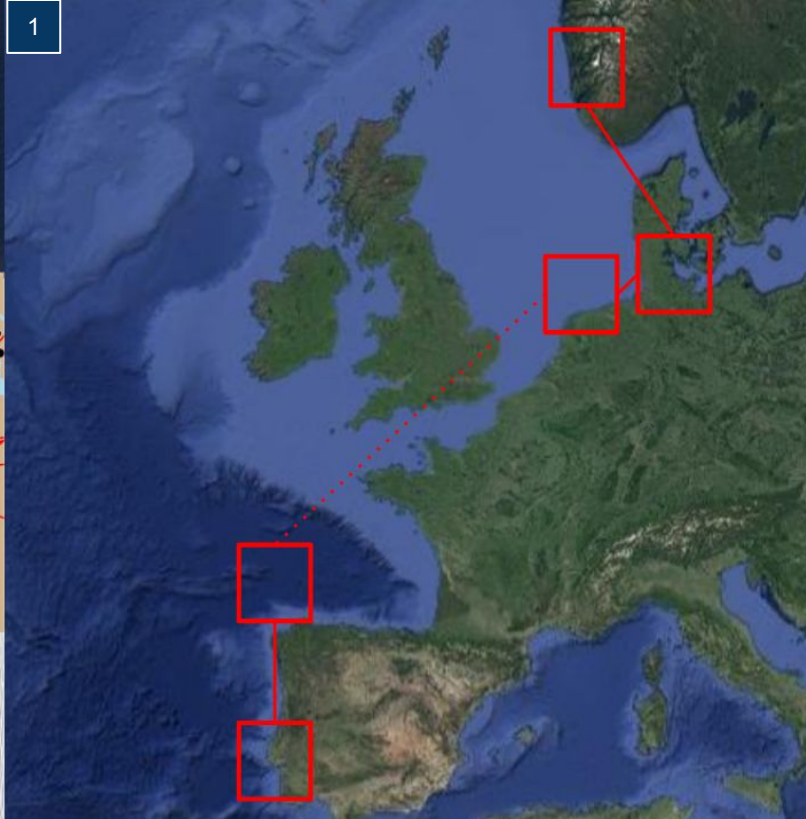
Credit: European Union, contains modified Copernicus Sentinel data 2022, processed with EO Browser

Example: Manual Tracking of the FGS Planet (From Norway to REPMUS 22)

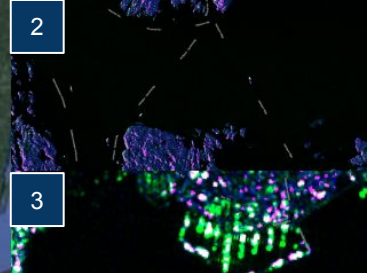
6



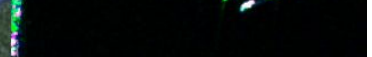
1



2



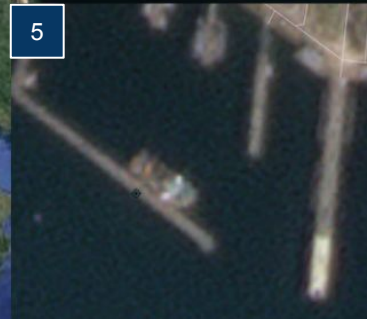
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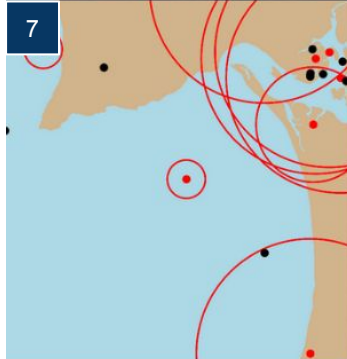
4



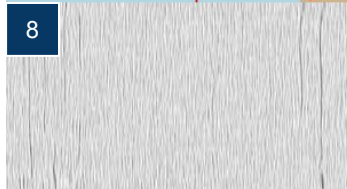
5



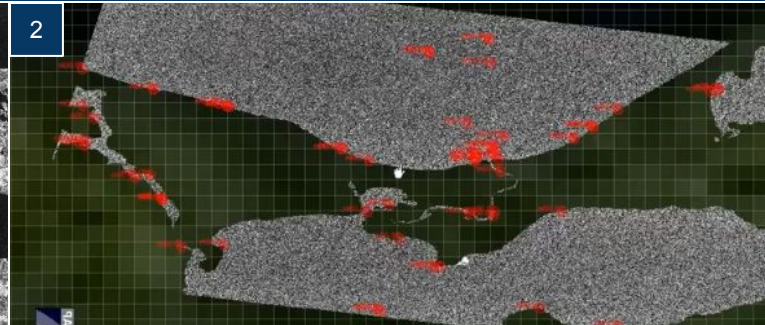
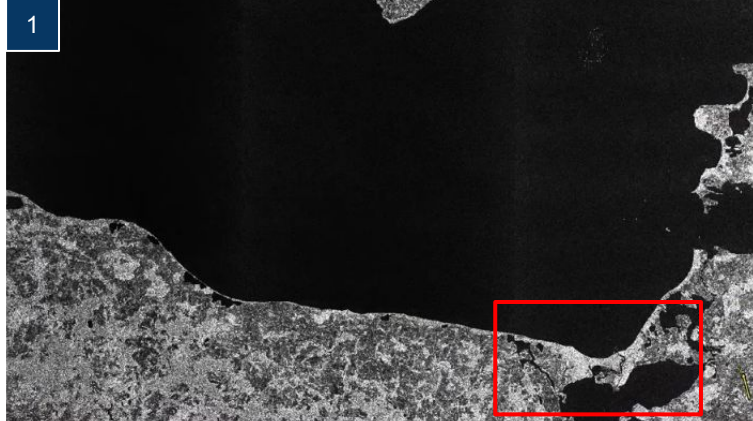
7



8

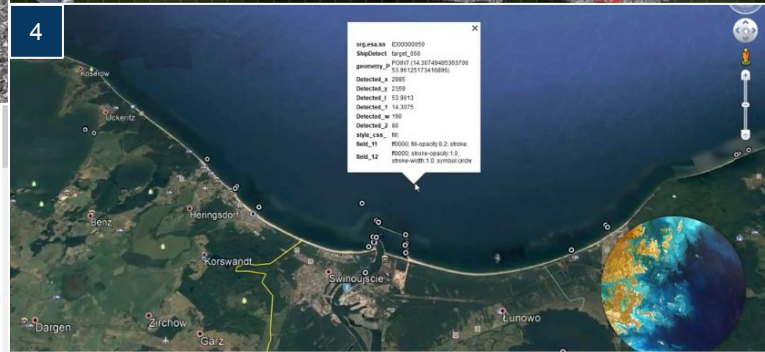


Example: Automatic Surface Contact Detection with Sentinel-1



3

```
uitGeometry-geometry 1
sa_stop geometry:13982020708.53.42 ShipDetections:String geometry:Point Detected_x:Integer Detected_y:Integer
ced_lat:Double Detected_lon:Double Detected_width:Double Detected_length:Double style_name:String
000000 target_000 POINT (14.1458816846245 53.741615218554544) 1465 197 53.741615218554544 14.1458816846245
50.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
-----00001 target_001 POINT (14.23017481248338 53.76157462010659) 2054 306 53.76157462010659 14.23017481248338
70.0 10.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
7 ID00000002 target_002 POINT (14.40142737410637 53.75916404064205) 3155 68 53.75916404064205 14.40142737410637
30.0 30.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
8 ID00000003 target_003 POINT (14.404509228343368 53.76062173380038) 3178 80 53.76062173380038 14.404509228343368
60.0 90.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
9 ID00000004 target_004 POINT (14.344121259394493 53.80573045443902) 2885 640 53.80573045443902 14.344121259394493
60.0 50.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
10 ID00000005 target_005 POINT (14.34680044155996 53.8062487774186) 2819 635 53.8062487774186 14.34680044155996
50.0 50.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
11 ID00000006 target_006 POINT (14.57011786183038 53.82684548157896) 4397 623 53.82684548157896 14.57011786183038
50.0 10.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
12 ID00000007 target_007 POINT (14.61582613917317 53.82830725405746) 4688 501 53.82830725405746 14.61582613917317
20.0 20.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
13 ID00000008 target_008 POINT (14.381856034141057 53.837108753810786) 3196 932 53.837108753810786 14.381856034141057
30.0 70.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
14 ID00000009 target_009 POINT (14.280255467443654 53.86149923787452) 2594 1319 53.86149923787452 14.280255467443654
60.0 60.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
15 ID00000010 target_010 POINT (14.3059698978603 53.8639819670048) 2765 1314 53.8639819670048 14.3059698978603
40.0 20.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
16 ID00000011 target_011 POINT (14.415735256026242 53.86578646491912) 3476 1198 53.86578646491912 14.415735256026242
60.0 40.0 fill:#ff0000 fill-opacity:0.2 stroke:#ff0000 stroke-opacity:1.0 stroke-width:1.0 symbol:circle
```



Example: BlueWhale (IAI / Atlas)



Manual Mode ⇒ Automatic Systems

The screenshot displays the MarineTraffic interface with a central map showing satellite tracks. The tracks are labeled with timestamps and coordinates. Two inset panels provide detailed views of specific satellite passes.

Top Left Panel: Sentinel-1 AWS-IW-VVVH

- Visualize
- 2022-08-29
- 18:22:13 UTC

Top Right Panel: Sentinel-2 L2A

- Visualize
- 2022-08-30
- 11:37:44 UTC
- 97.2%
- 29UNR

Map Data Points:

- 50.12272°, -8.39133°
- 11:40:44 UTC
50,3601 N
8,0089 W
- 18:28:17 UTC
49,2391 N
8,3812 W
- 18:22:50 UTC
49,2229 N
8,3902 W
- 18:21:28 UTC
49,2196 N
8,3936 W

Inset 1 (Bottom Left): Shows a satellite pass with a distance of 4-5 km.

Inset 2 (Bottom Right): Shows a satellite pass with a distance of 4-5 km.

Map Labels: Cork, Plymouth, Vyazma, St. Davids, Penzance, Laval, Angers, Saumur, Cholet.

Map Controls: 50 km, 30 mi, 308K, 539", 2022 18:22:39 UTC, Names, MMSI, Speed, Nearby vessels, Events, Weather.

**Thank you very much
for your attention!**

Questions?

CDR (j.g.) Patrick O'Keeffe

Centre of Excellence for Operations
in Confined and Shallow Waters (COE CSW)

