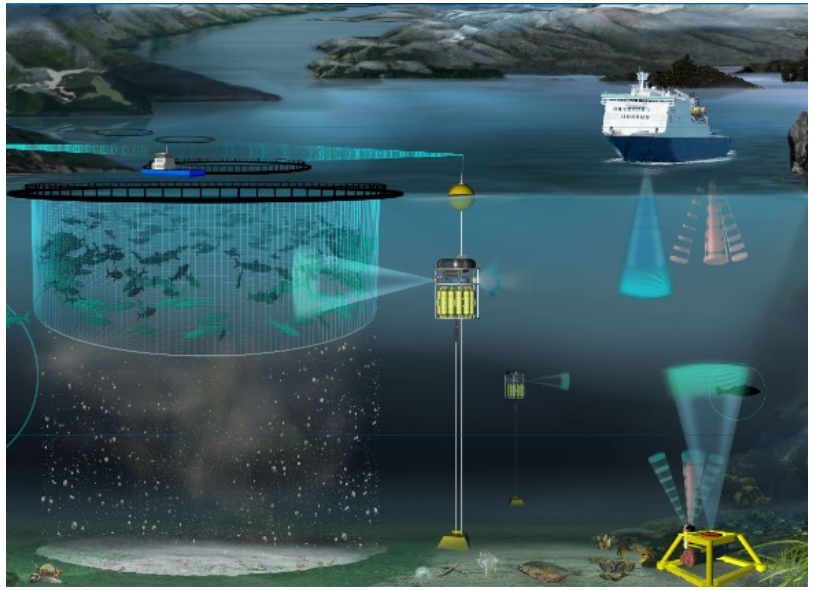
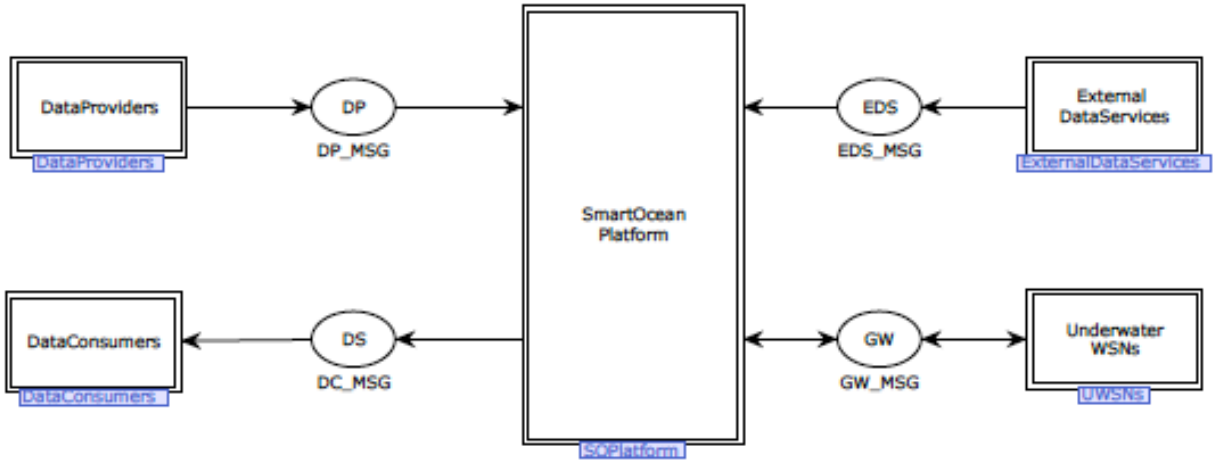
Towards a Formal and Exectuable Software Architecture Specification of the Smart Ocean Data Service Platform





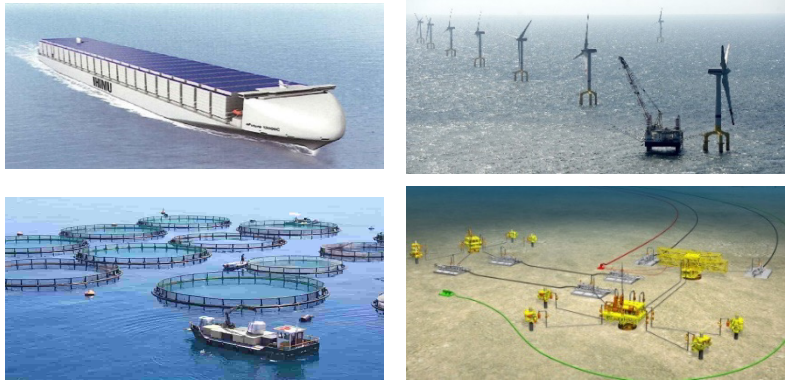
R. Heldal, L.M. Kristensen, K. Lima, T. Oyetoyan and N.T. Nguyen
Software Engineering Research Group
Western Norway University of Applied Sciences

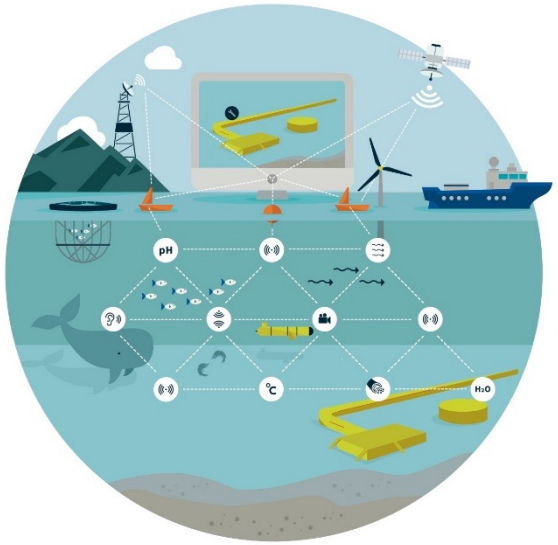
SFI SMART OCEAN

Smart Ocean

Flexible and cost-effective monitoring for management of a healthy and productive ocean

- **Centre for research-based innovation (2020-2028) funded by industry partners and NFR (~20 MEUR)**





Western Norway University of Applied Sciences

NORCE

KONGSBERG

UNIVERSITAS BERGENSIS

HAVFORSKNINGS INSTITUTTET

AANDERAA a xylem brand

FFI Forsvarets forskningsinstitutt
Norwegian Defence Research Establishment

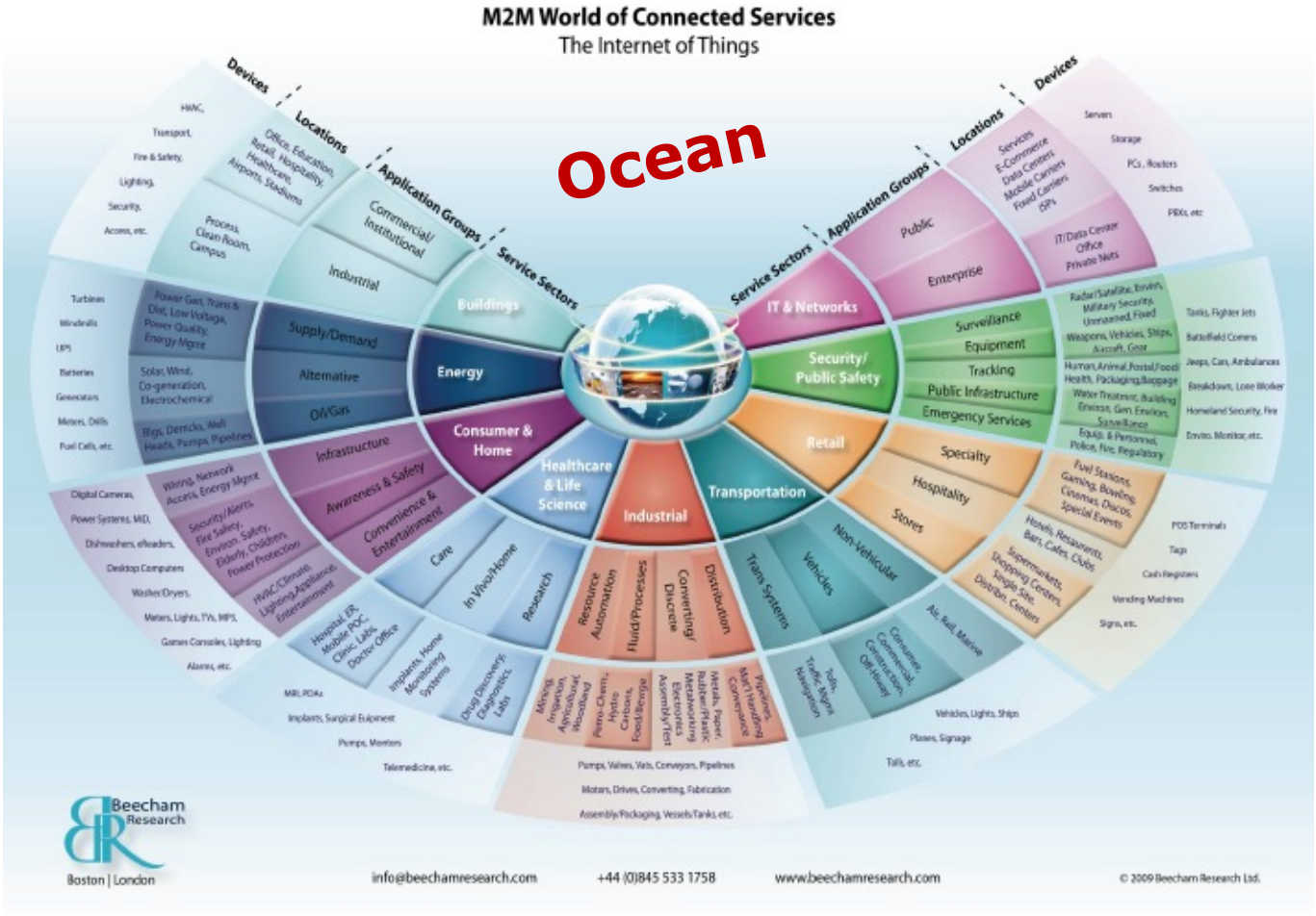
bouvet

Objective

- **Create a wireless observation system for multi-parameter monitoring of underwater environments and installations**

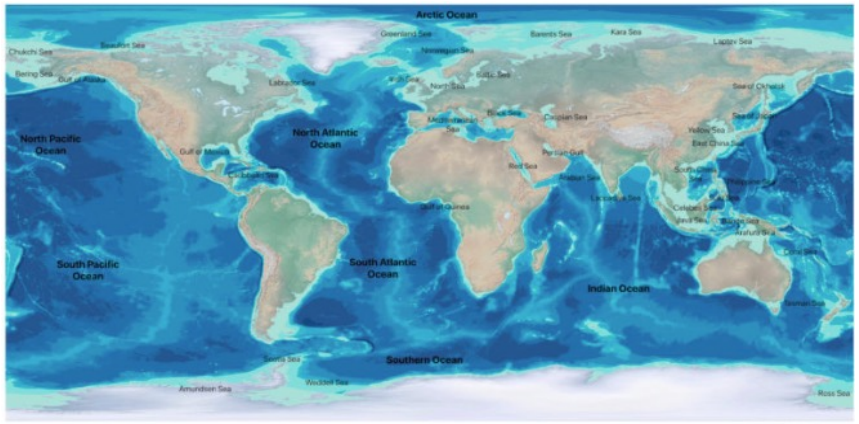
Smart systems are becoming pervasive

IoT, sensors, data-driven applications and analytics



- **Improved management**
- **Monitoring**
- **Auditing and reporting**
- **Situation awareness**
- **Decision support**
- **Efficient operation**
- **Cost-effectiveness**
- **Competitive services**
- **…**

Why Smart Ocean?



The ocean is of key importance

- critical for climate and ecosystems, food- and energy production, transportation,…
- the ocean industries have potential to double their economic growth in the next ten years*

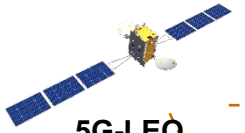
Aim is to develop enabling technology for

- fact-based ocean management via ocean monitoring, sensor systems, and data services
- supporting sustainable industrial operation and ocean research

*The Ocean Economy in 2030, OECD Publishing

What is Smart Ocean?

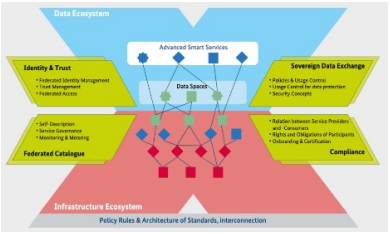
Underwater IoT and cloud computing services – but with new fundamental challenges

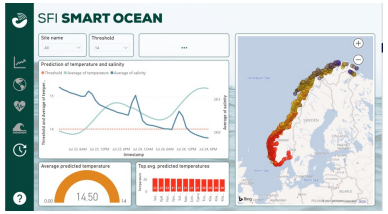


5G-LEO

Data service platform

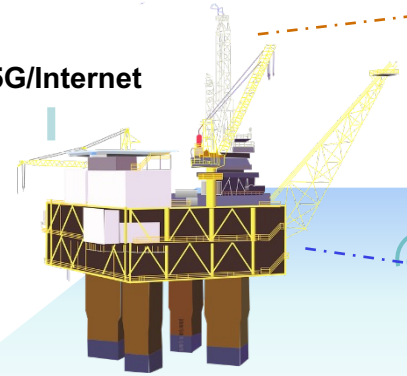
Data spaces [share, find, access data]





Data-driven applications [compose]

5G/Internet



Data buoy

Smart sensors, edge computing, and application-driven on-demand data

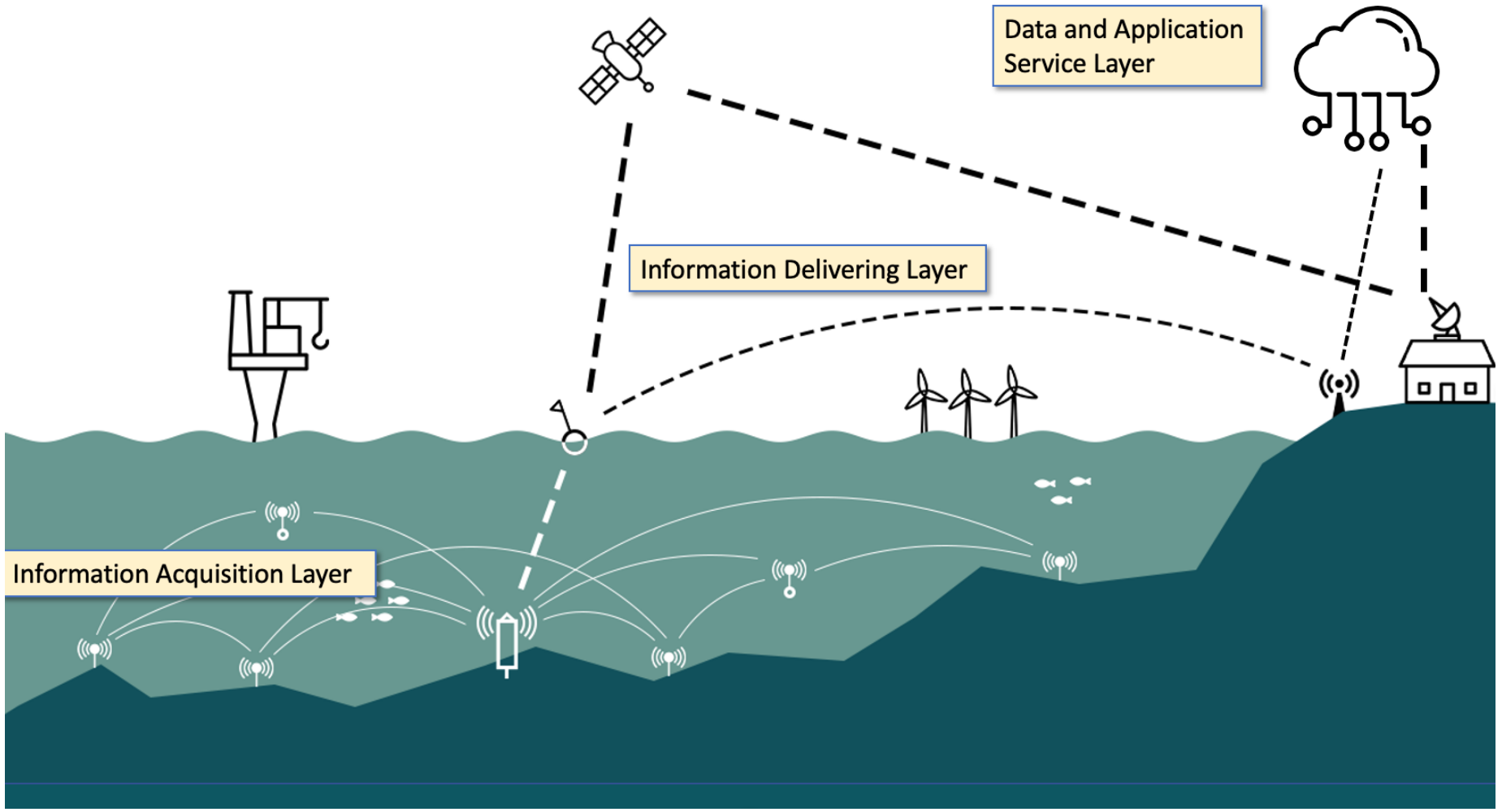
Sensor network gateway

Sensor nodes and hubs

Underwater IoT challenges

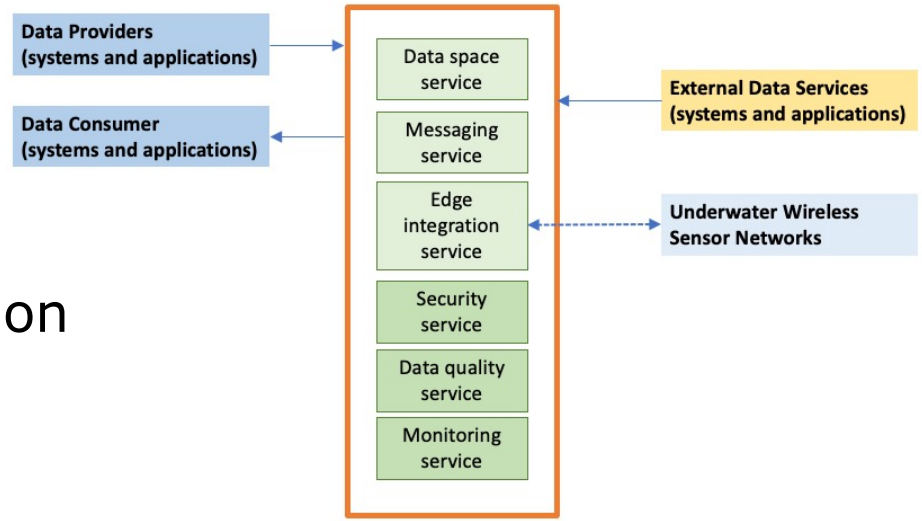
- Very limited infrastructure
- Large geographical areas
- High deployment and maintainance costs
- Cabling not generally feasible
- Limited power sources (battery)
- Very low communication bandwidth (acoustic communication)

High-level system architecture



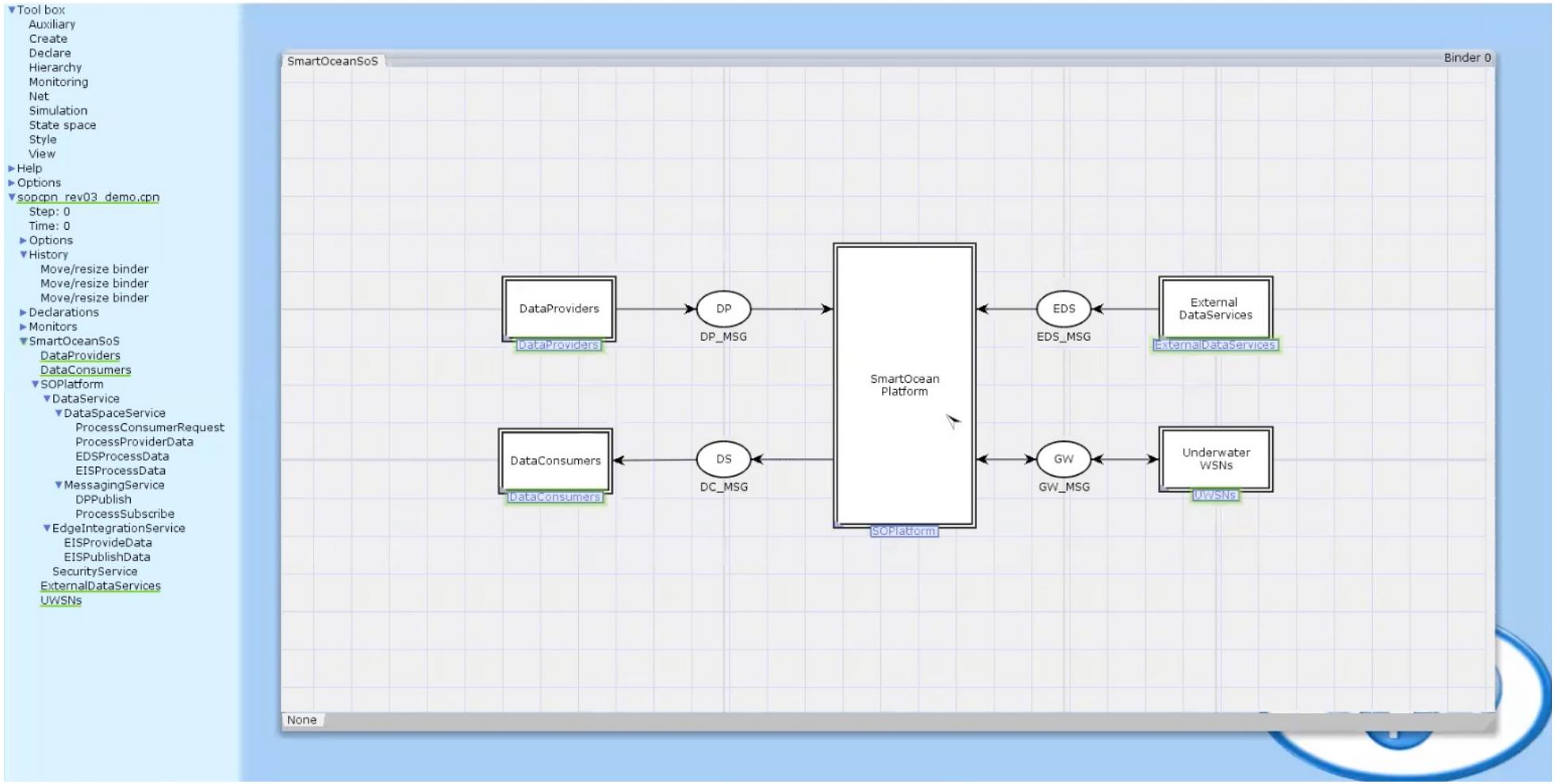
Data and application services

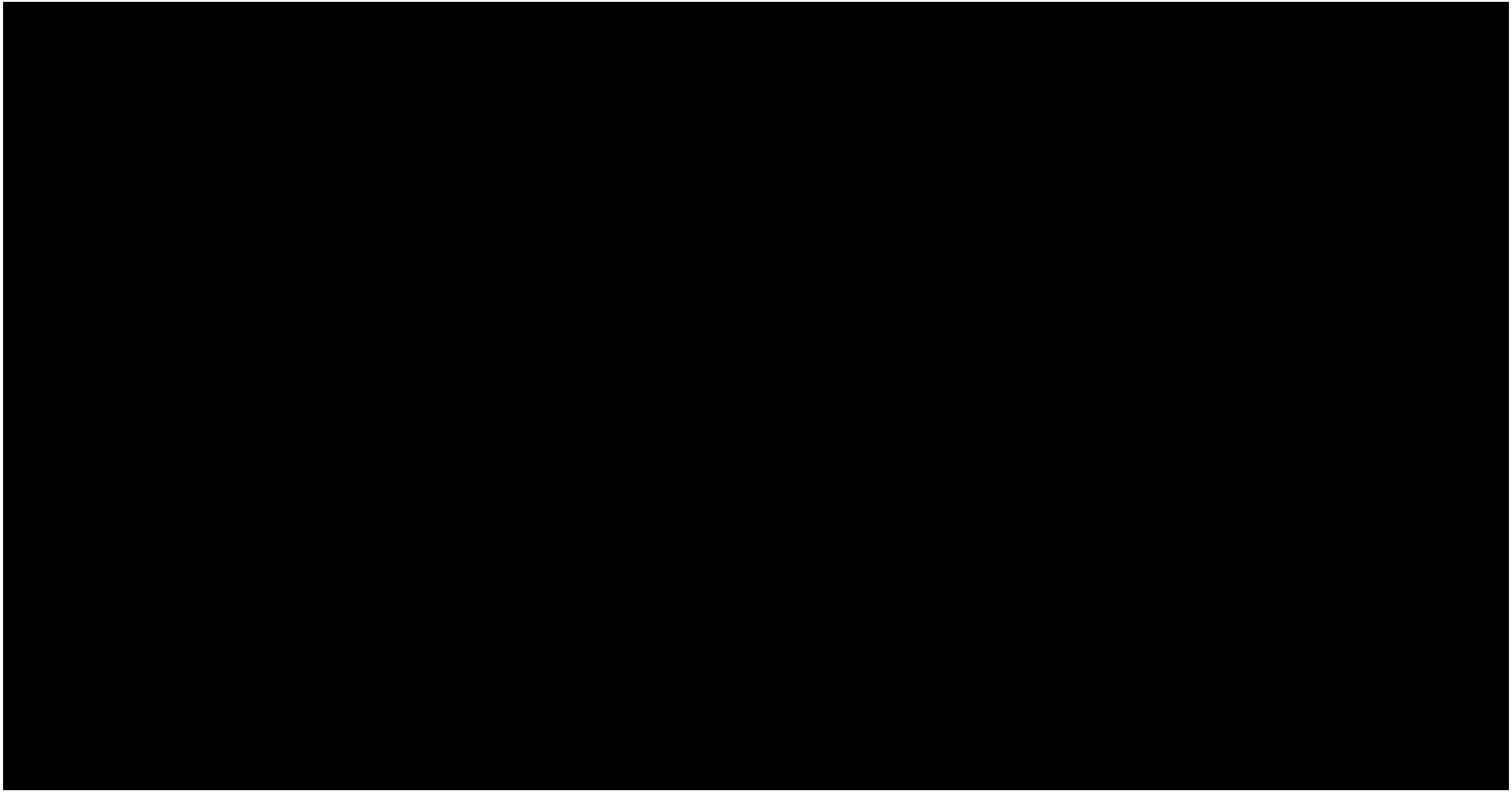
- **A core element of the smart ocean digital systems-of-systems ecosystem is the smart ocean data service platform**
- **Providing cloud-based integration services for data-driven software systems and applications**
- **Coloured Petri Net (CPN) modelling has been applied during development of the platform**
  - Capture the system-of-systems arhitecture
  - Specify services and their interaction
  - Formalisation and conceptualisation
  - Facilitate design discussions aided by simulation
  - …



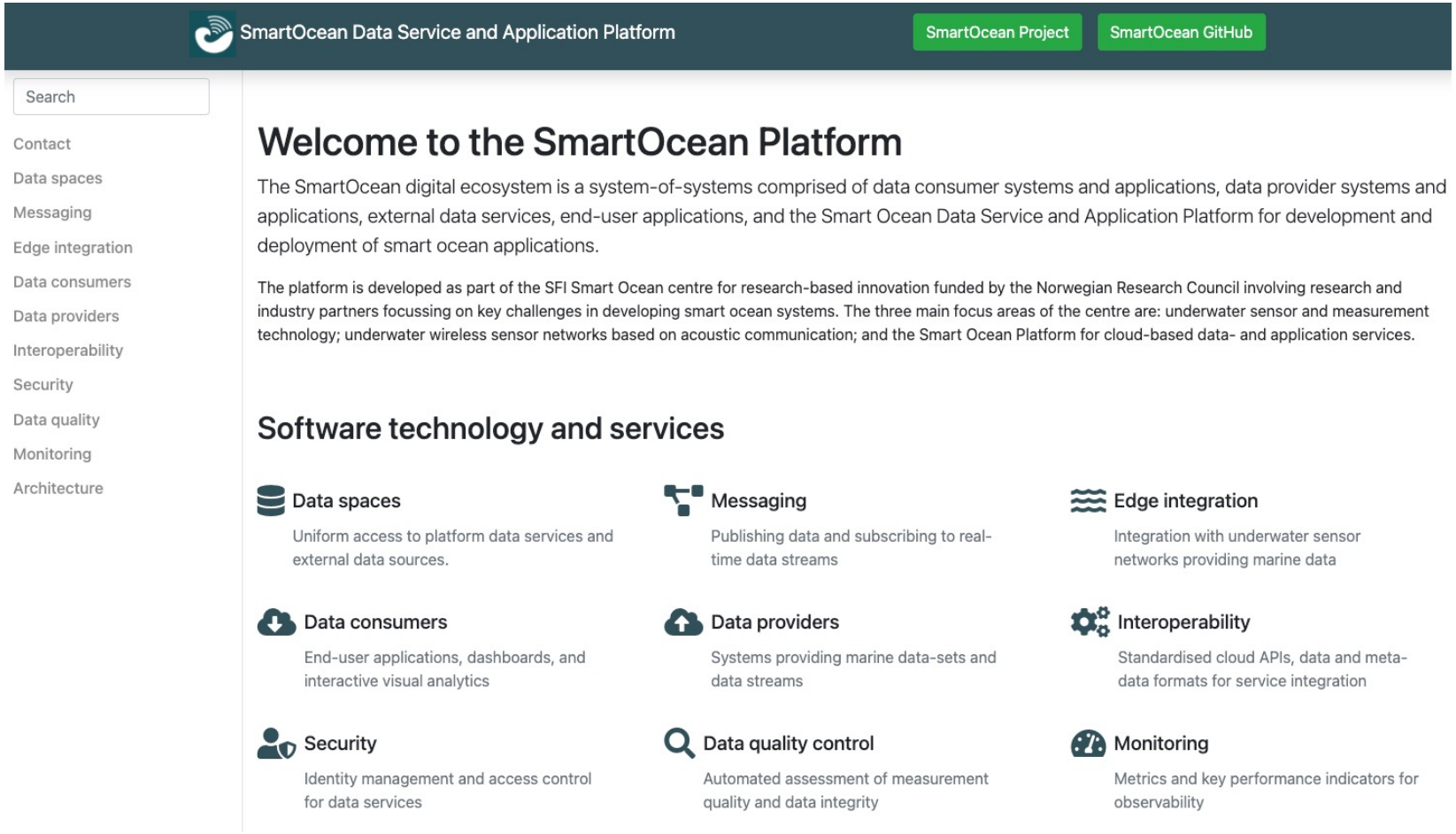
Smart Ocean Platform

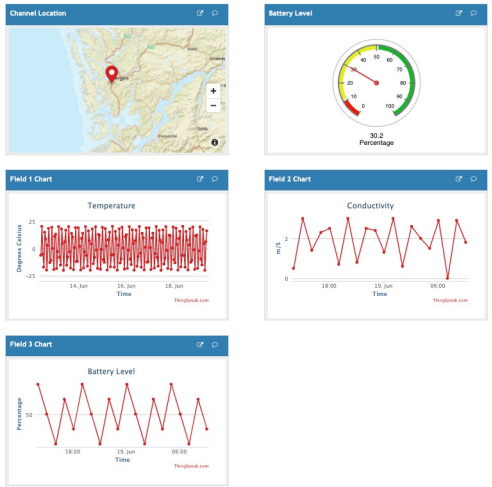
CPN model demonstration

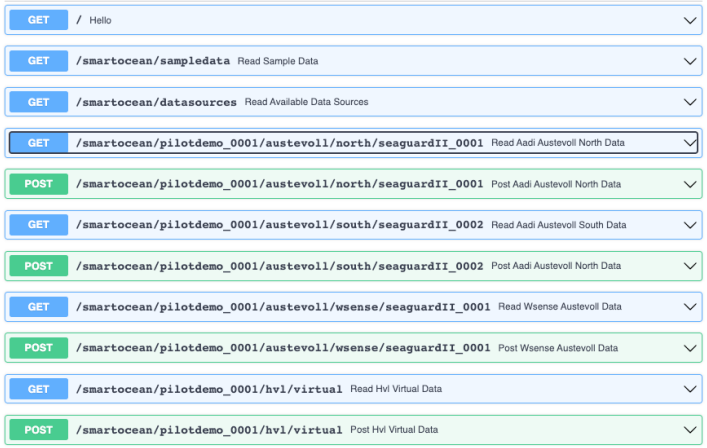




Platform implementation

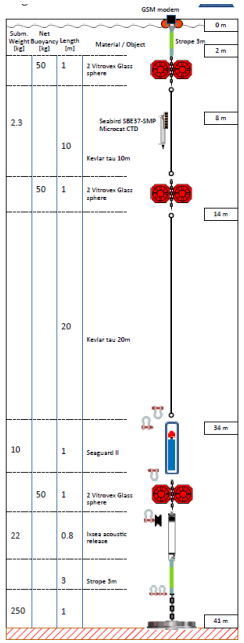






Platform deployment

- **Sensor nodes have been deployed at the Austevoll research facility of the Norwegian Institute of Marine Research**



- **Sensor data is transmitted from the underwater sensor hubs into the smartocean data service cloud platform**

Status and future work

- **CPN modelling and simulation have been used during design and implementation of the Smart Ocean platform**
  - Facilitated design, conceptualisation, and implementation discussions
  - Specification of systems-of-systems and software architecture
  - Abstract modelling of service endpoints (APIs) and the service interaction

- **The CPN model serve as a basis for further development of the data services and the Smart Ocean platform**
  - Meta-data, data source and API discovery
  - Sensor hubs, node control and configuration
  - Edge computing and edge-cloud distributed intelligence
  - Extended to cover underwater sensor network protocols
  - …