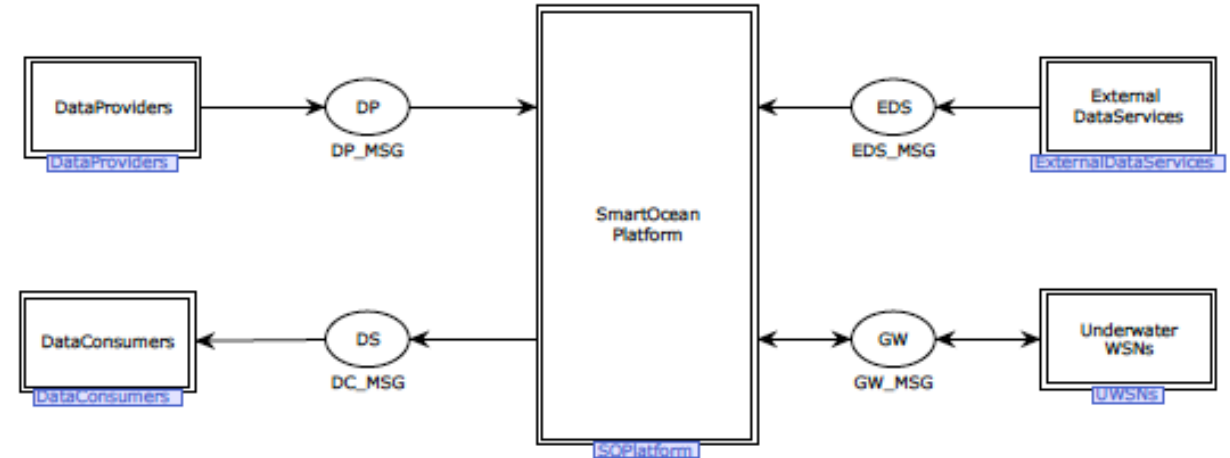
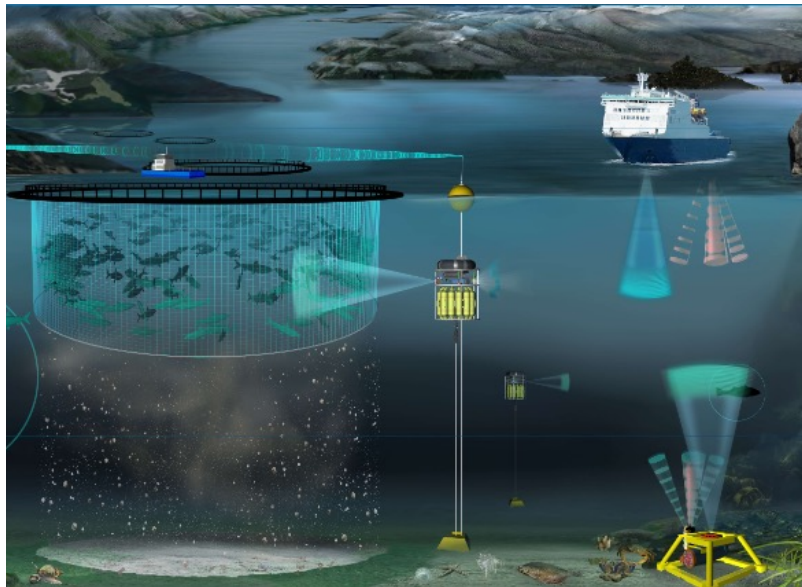


Towards a Formal and Executable Software Architecture Specification of the Smart Ocean Data Service Platform

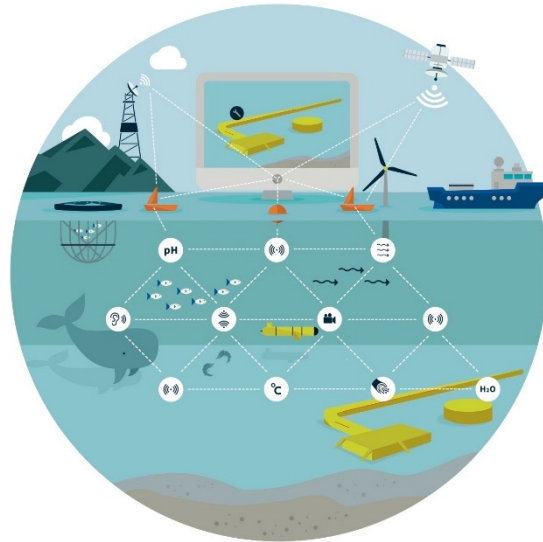
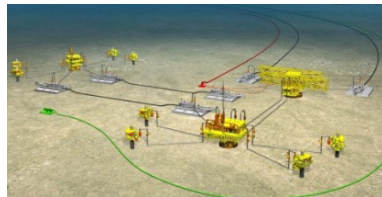


R. Heldal, **L.M. Kristensen**, K. Lima, T. Oyetoyan and N.T. Nguyen
Software Engineering Research Group
Western Norway University of Applied Sciences

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)**



KONGSBERG



a xylem brand



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
- ...

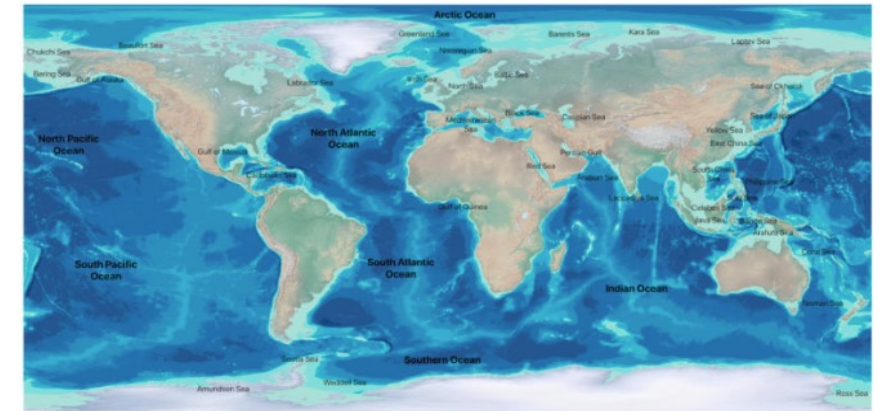
Why Smart Ocean?

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*

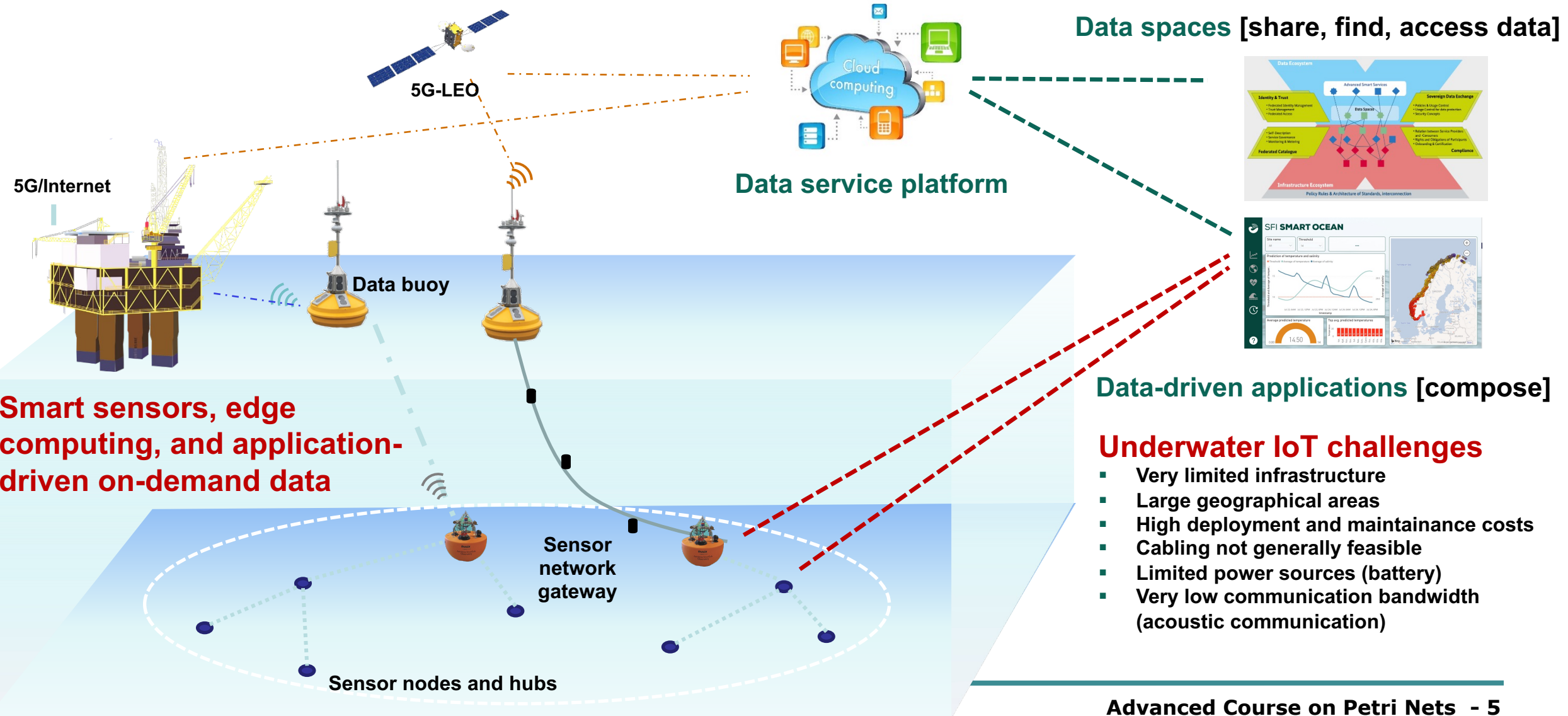
Aim is to develop enabling technology for

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

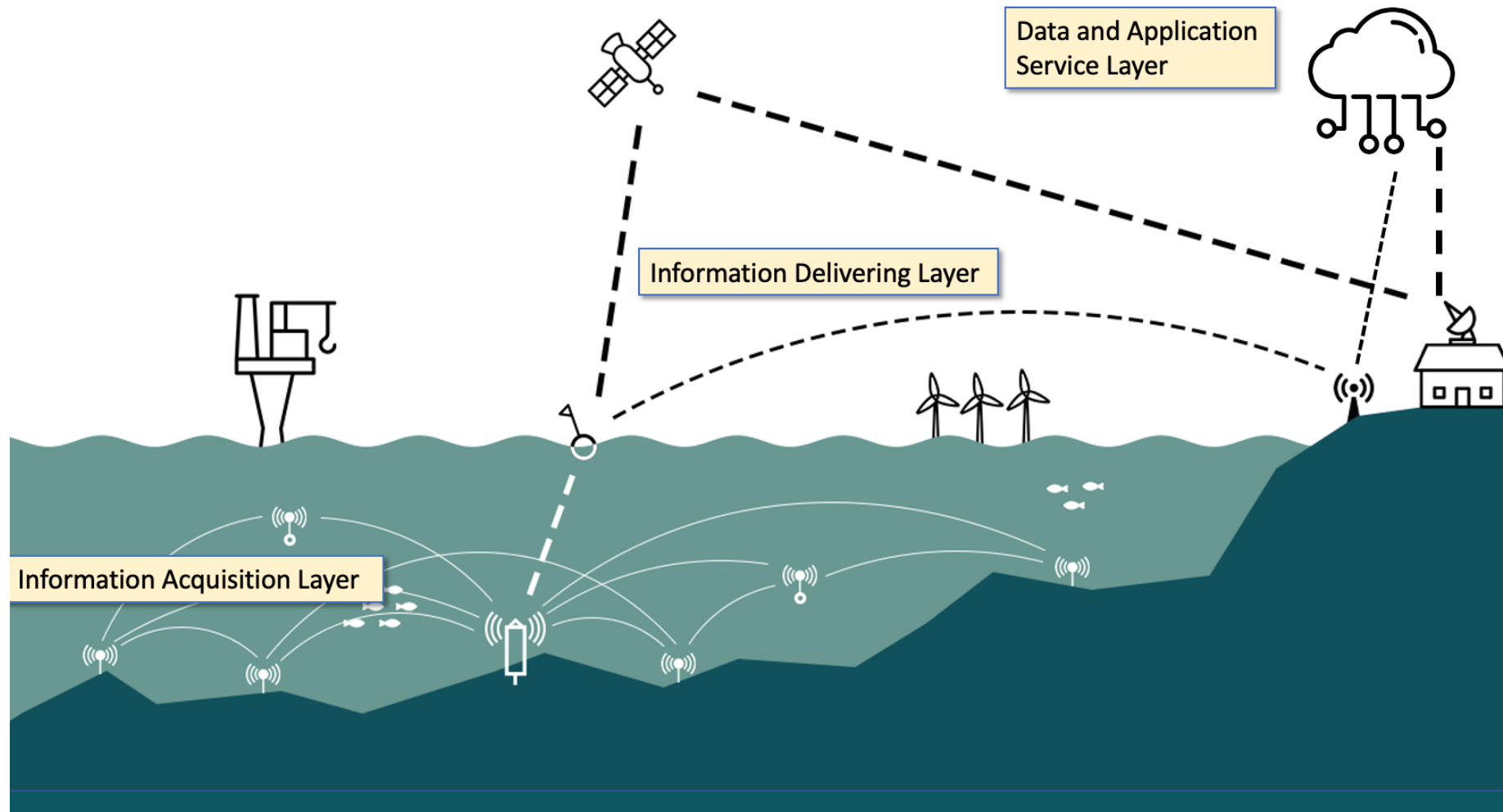


What is Smart Ocean?

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

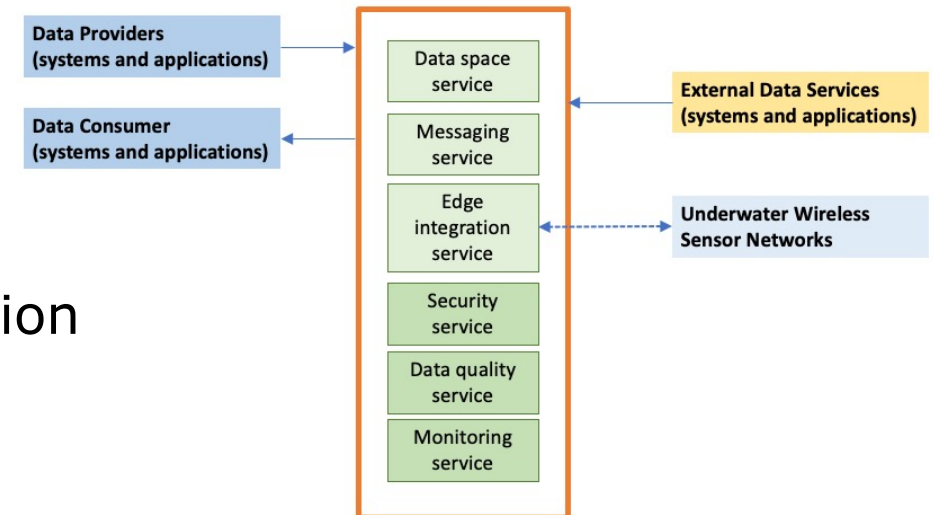


High-level system architecture



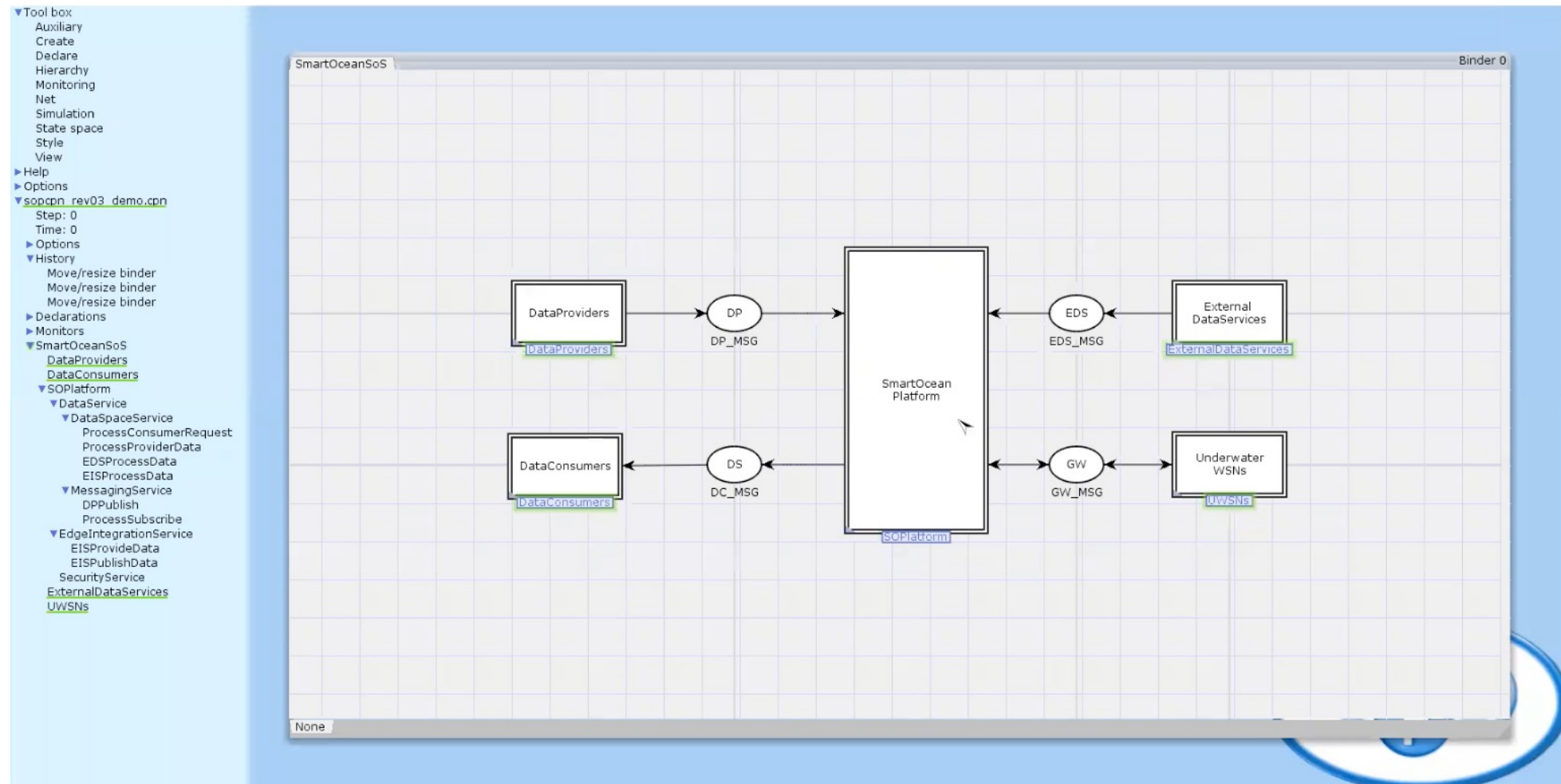
Data and application services

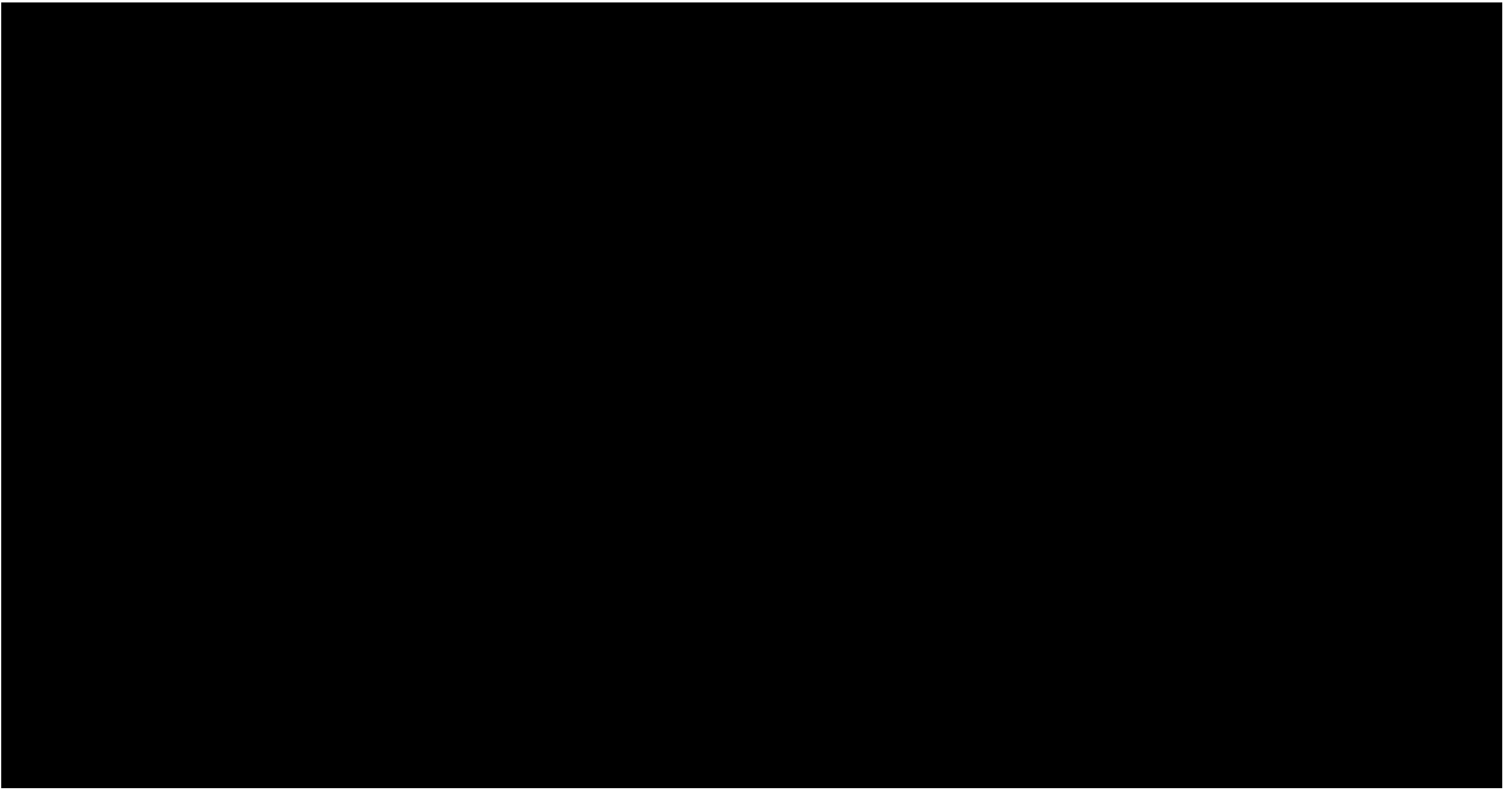
- A core element of the smart ocean digital systems-of-systems ecosystem is the **smart ocean data service platform**
- Providing cloud-based integration services for data-driven software systems and applications
- **Coloured Petri Net (CPN) modelling has been applied during development of the platform**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




Smart Ocean Platform

CPN model demonstration





Platform implementation

 SmartOcean Data Service and Application Platform

SmartOcean ProjectSmartOcean GitHub

Search

Contact

Data spaces

Messaging

Edge integration

Data consumers

Data providers

Interoperability

Security

Data quality

Monitoring


Architecture

Welcome to the SmartOcean Platform

The SmartOcean digital ecosystem is a system-of-systems comprised of data consumer systems and applications, data provider systems and applications, external data services, end-user applications, and the Smart Ocean Data Service and Application Platform for development and deployment of smart ocean applications.


The platform is developed as part of the SFI Smart Ocean centre for research-based innovation funded by the Norwegian Research Council involving research and industry partners focussing on key challenges in developing smart ocean systems. The three main focus areas of the centre are: underwater sensor and measurement technology; underwater wireless sensor networks based on acoustic communication; and the Smart Ocean Platform for cloud-based data- and application services.

Software technology and services




Data spaces

Uniform access to platform data services and external data sources.




Messaging

Publishing data and subscribing to real-time data streams




Edge integration

Integration with underwater sensor networks providing marine data




Data consumers

End-user applications, dashboards, and interactive visual analytics




Data providers

Systems providing marine data-sets and data streams




Interoperability

Standardised cloud APIs, data and meta-data formats for service integration




Security

Identity management and access control for data services



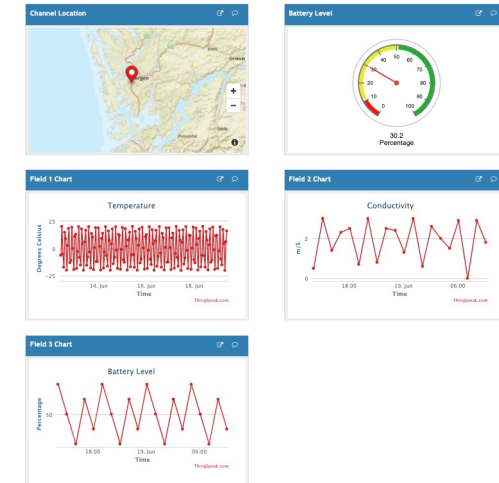
Data quality control

Automated assessment of measurement quality and data integrity



Monitoring

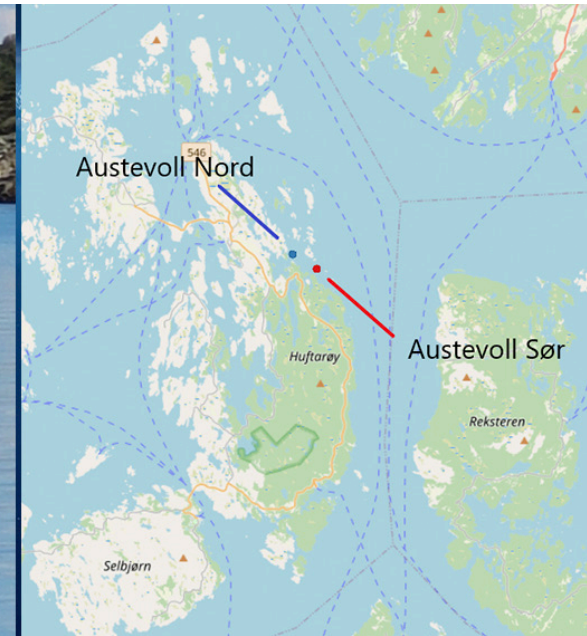
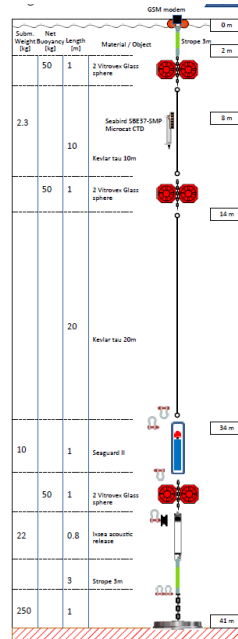
Metrics and key performance indicators for observability



GET	/ Hello	
GET	/smartocean/sampledata	Read Sample Data
GET	/smartocean/datasources	Read Available Data Sources
GET	/smartocean/pilotdemo_0001/austevoll/north/seaguardII_0001	Read Aadi Austevoll North Data
POST	/smartocean/pilotdemo_0001/austevoll/north/seaguardII_0001	Post Aadi Austevoll North Data
GET	/smartocean/pilotdemo_0001/austevoll/south/seaguardII_0002	Read Aadi Austevoll South Data
POST	/smartocean/pilotdemo_0001/austevoll/south/seaguardII_0002	Post Aadi Austevoll South Data
GET	/smartocean/pilotdemo_0001/austevoll/wsense/seaguardII_0001	Read Wsense Austevoll Data
POST	/smartocean/pilotdemo_0001/austevoll/wsense/seaguardII_0001	Post Wsense Austevoll Data
GET	/smartocean/pilotdemo_0001/hv1/virtual	Read Hvi Virtual Data
POST	/smartocean/pilotdemo_0001/hv1/virtual	Post Hvi Virtual Data

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
 - ...