

A Public API Supporting Autonomous Navigation

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SINTEF Ocean AS

2nd International Conference on Maritime Autonomous Surface Ship - ICMASS

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OFFSHORE INDUSTRIES

Agenda

- The Hull-to-Hull (H2H) project
- H2H Conceptual and Domain Model
- H2H Interfaces
- Open API Initiatives and Open API Specification
- H2H REST and WebSocket API
- Signal K open source project as a candidate for H2H public framework
- Summing up

Hull to hull Objective

The overall objective of the project is to address the need of the maritime community to safely navigate in close proximity of other vessels and objects.

Hull to hull supports both traditional navigation as well as autonomous vessels



Hull-to-Hull (H2H) Project



- Funding from the European GNSS Agency (GSA) under the European Union's Horizon 2020 R&I programme grant agreement No. 775998



- 3 years project started 01.11.2017
- 5 Partners



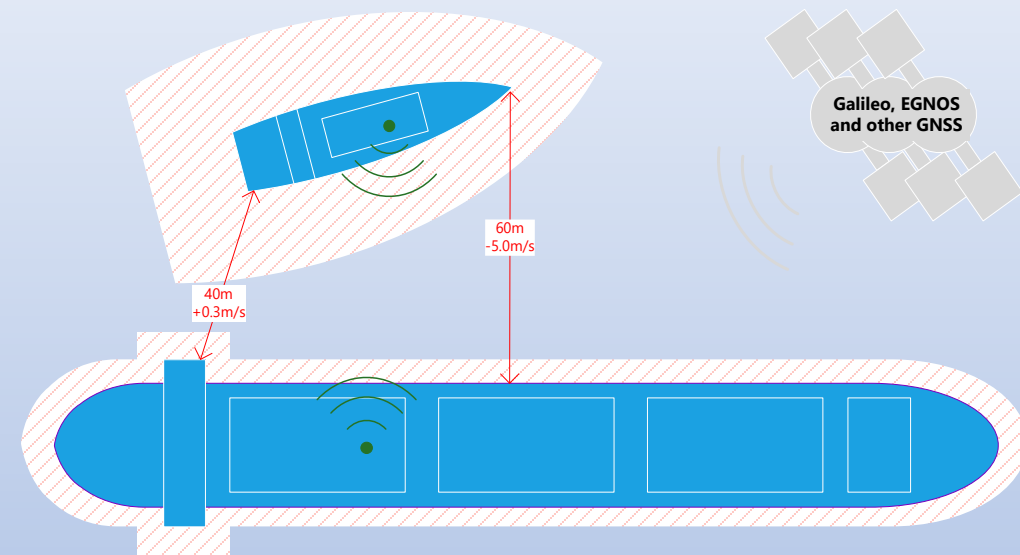
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Basic Concept

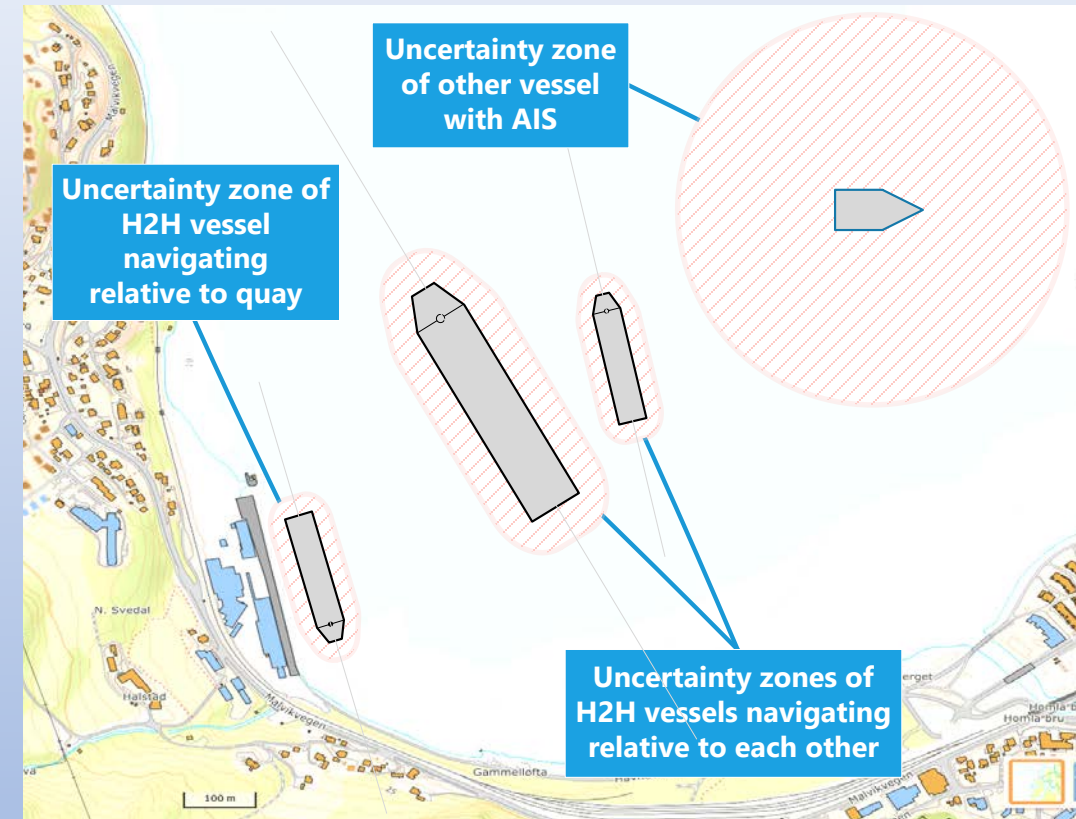


- **Hull-to-hull positioning** based on 3D models and position measurements
- **Vessel to vessel data exchange:**
 - 3D vessel models
 - Sensor measurement, e.g. position, orientation.
- **Open concept** with **standardized** data exchange
- **Uncertainty zones** for own vessel as well as neighbouring objects indicate position accuracy



More on uncertainty zone

- Represents the **uncertainty in the outer boundary** of the geometry of vessels and objects of interest
- In maritime domain we define the uncertainty zone to represent a probability of **95% or 2σ**
- Represented as:
 - For a 3D object it is a **volume** around the object
 - For a 2D object it is an **area** around the object
 - For a single point (e.g. non-H2H vessel with no geometry data) it is a **circular area**

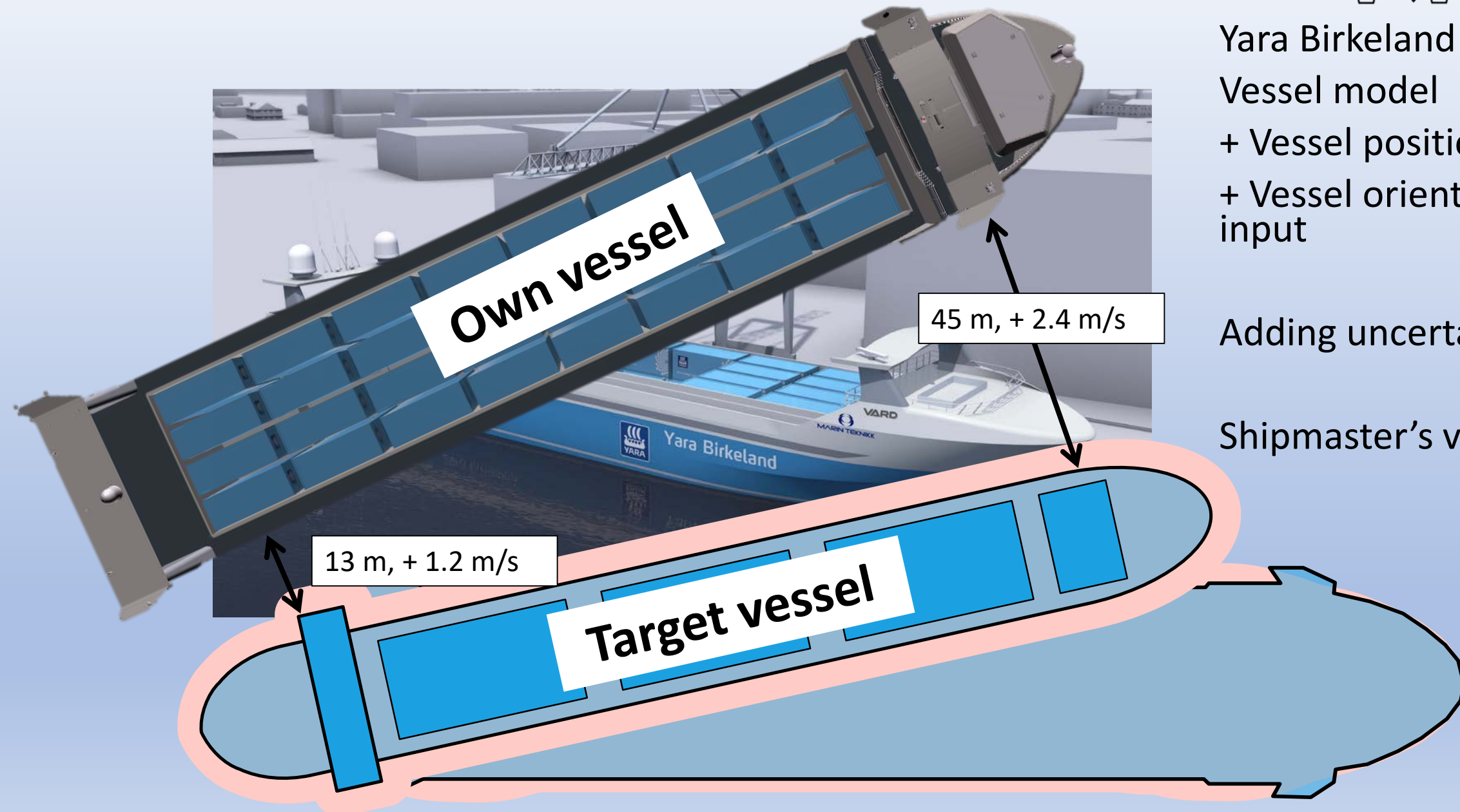




Yara Birkeland top view
Vessel model
+ Vessel position input
+ Vessel orientation
input

Adding uncertainty zone

Shipmaster's view

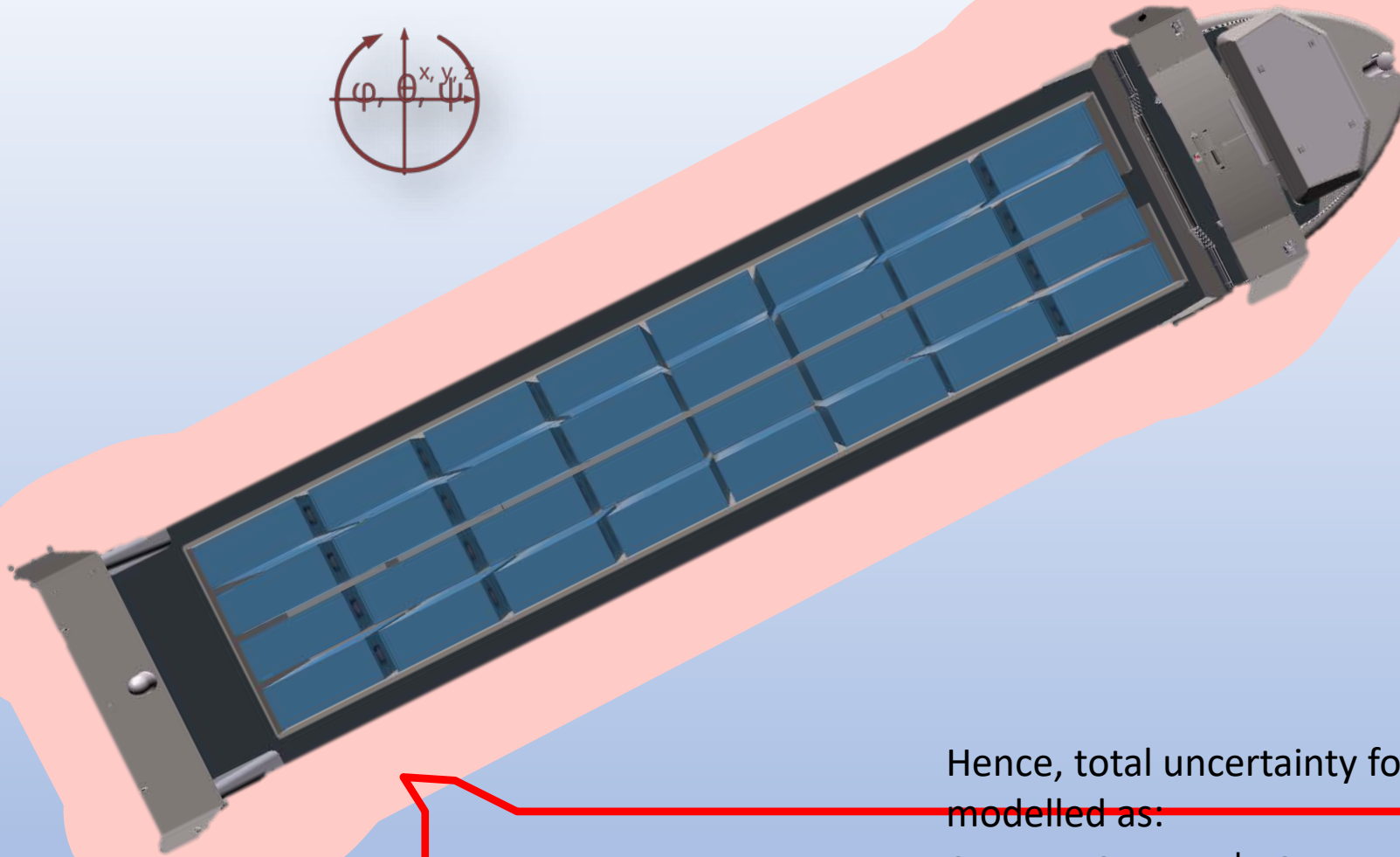


Own vessel

45 m, + 2.4 m/s

13 m, + 1.2 m/s

Target vessel



Uncertainty zone shall encompass actual hull with 95% probability

Contributions to uncertainty:

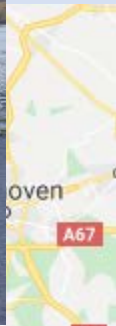
- Sensor errors:
 - measurement error, ε_{sensor}
 - installation error, $\varepsilon_{installation}$
- Geometrical model error, $\varepsilon_{3Dmodel}$

Hence, total uncertainty for an arbitrary point on the hull can be modelled as:

$$\varepsilon_{hull} = \varepsilon_{sensor} + \varepsilon_{installation} + \varepsilon_{3Dmodel}$$

3 pilot demonstrations

- Simultaneous operation in Norway
- Inland waterways in Belgium
- Auto-mooring in Belgium



Cogge, 1:8 scale model of a barge



Ocean Space Drone 1 and 2

H2H Conceptual model



Stakeholders (users)

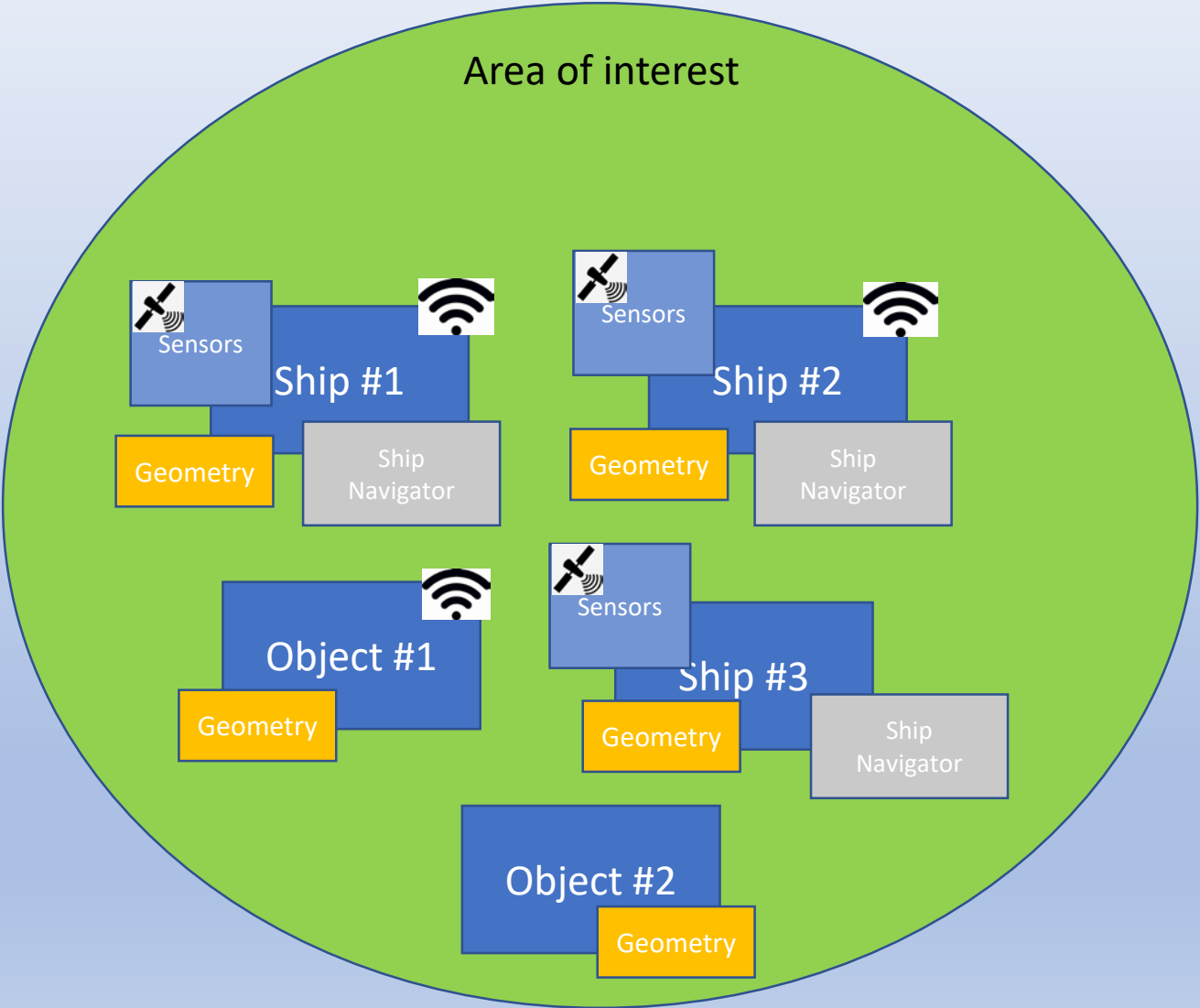
Navigator



Shore control centre

VTS

- AIS
- Terrestrial
 - Satellite



- Sensors
- GNSS
 - IMU
 - Pos sensor
 - (AIS)

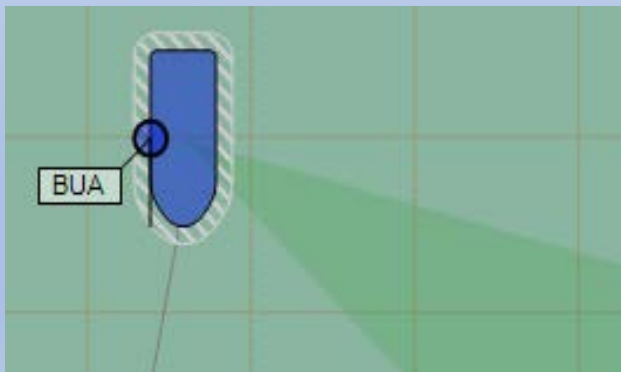
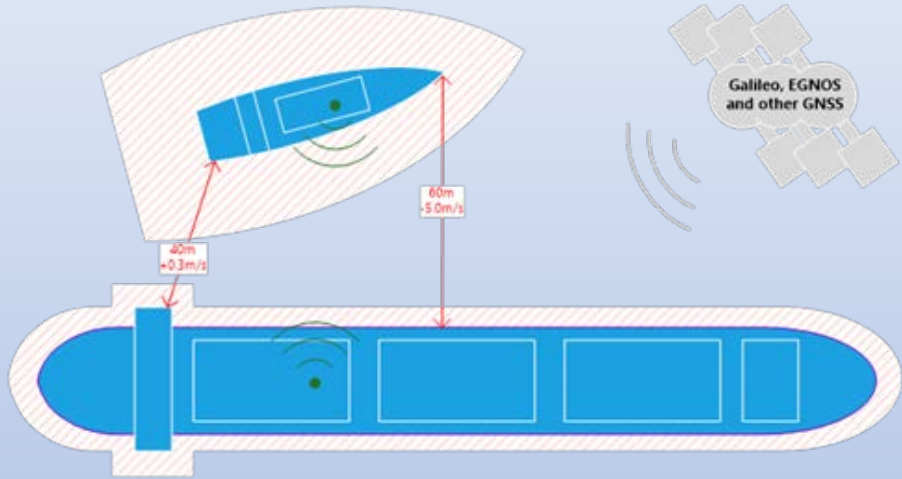


- Wireless
- WiFi
 - Satellite
 - MBR

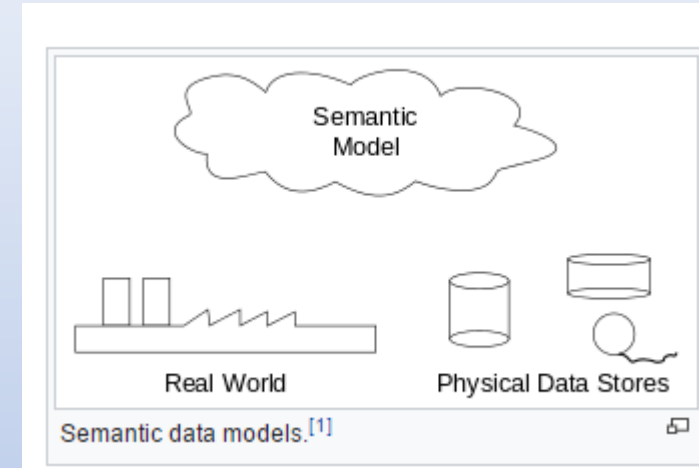


= Satellite

Domain and semantic data model



- Operation
- Objects (movable, fixed)
- Sensors
- Communications
- Geometries
- Uncertainty zone
- Operational zone
- Meta data (configuration)

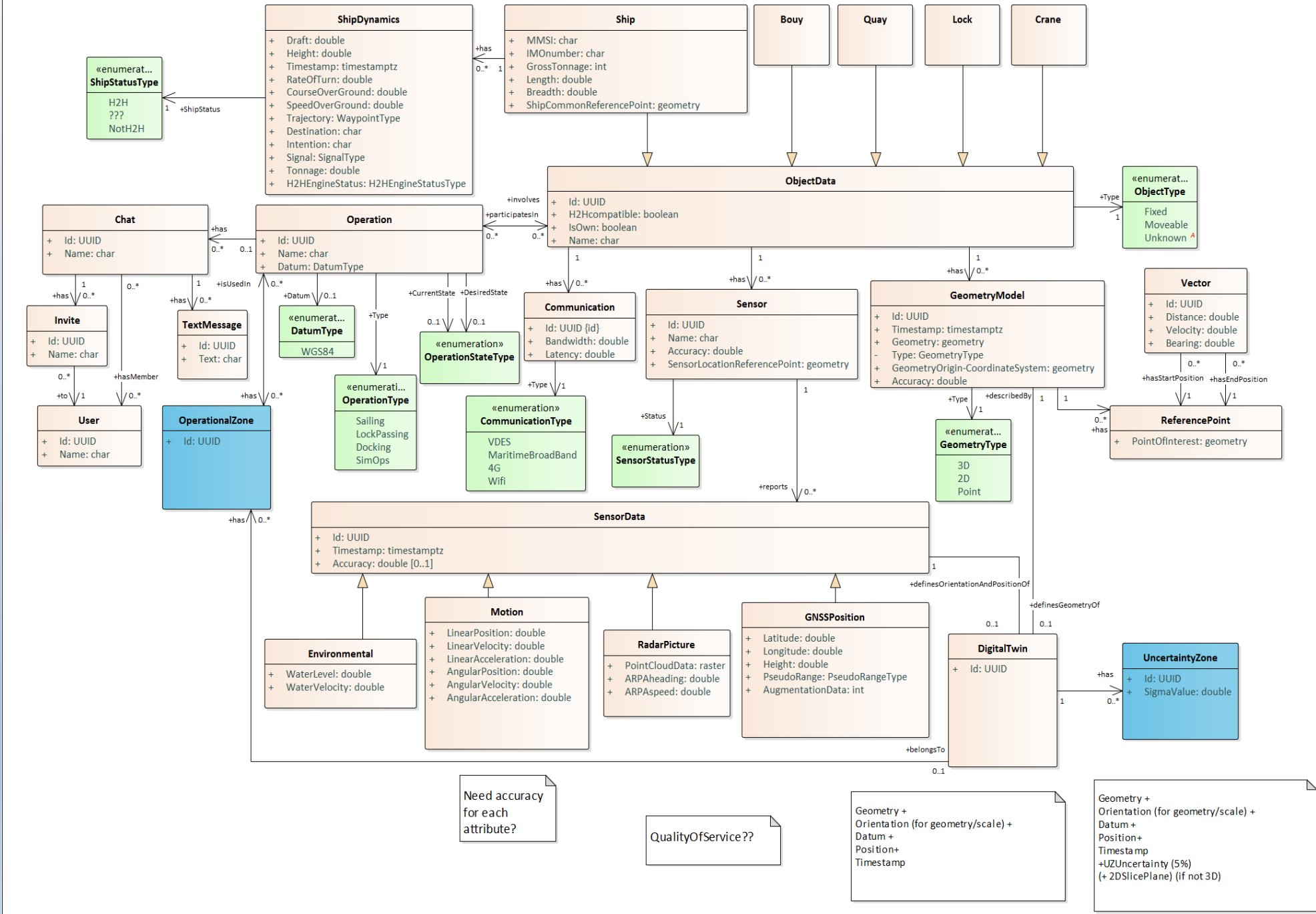


It is a [conceptual data model](#) in which semantic information is included. This means that the model describes the meaning of its instances. Such a semantic [data model](#) is an abstraction that defines how the stored [symbols](#) (the instance data) relate to the real world.^[1]

Digital representation of the H2H concept

Part 1 Data Engine-Engine

1. An object is either ship, bouy, quay, lock or crane.
2. ShipDynamics: Ship properties that may change during the voyage
3. Each object has some Communications, some Sensors and some GeometryModels
4. Each sensor has an accuracy, a reference point related to a geometry model and a set of sensor data.
5. DigitalTwin is the combination of a geometry model and a set of sensor data at a certain timestamp.
6. UncertaintyZone and OperationalZone are related to a DigitalTwin
7. OperationalZone can be related directly to an operation (no digital twin needed)
8. Blue: E2A, otherwise E2E



Need accuracy for each attribute?

QualityOfService??

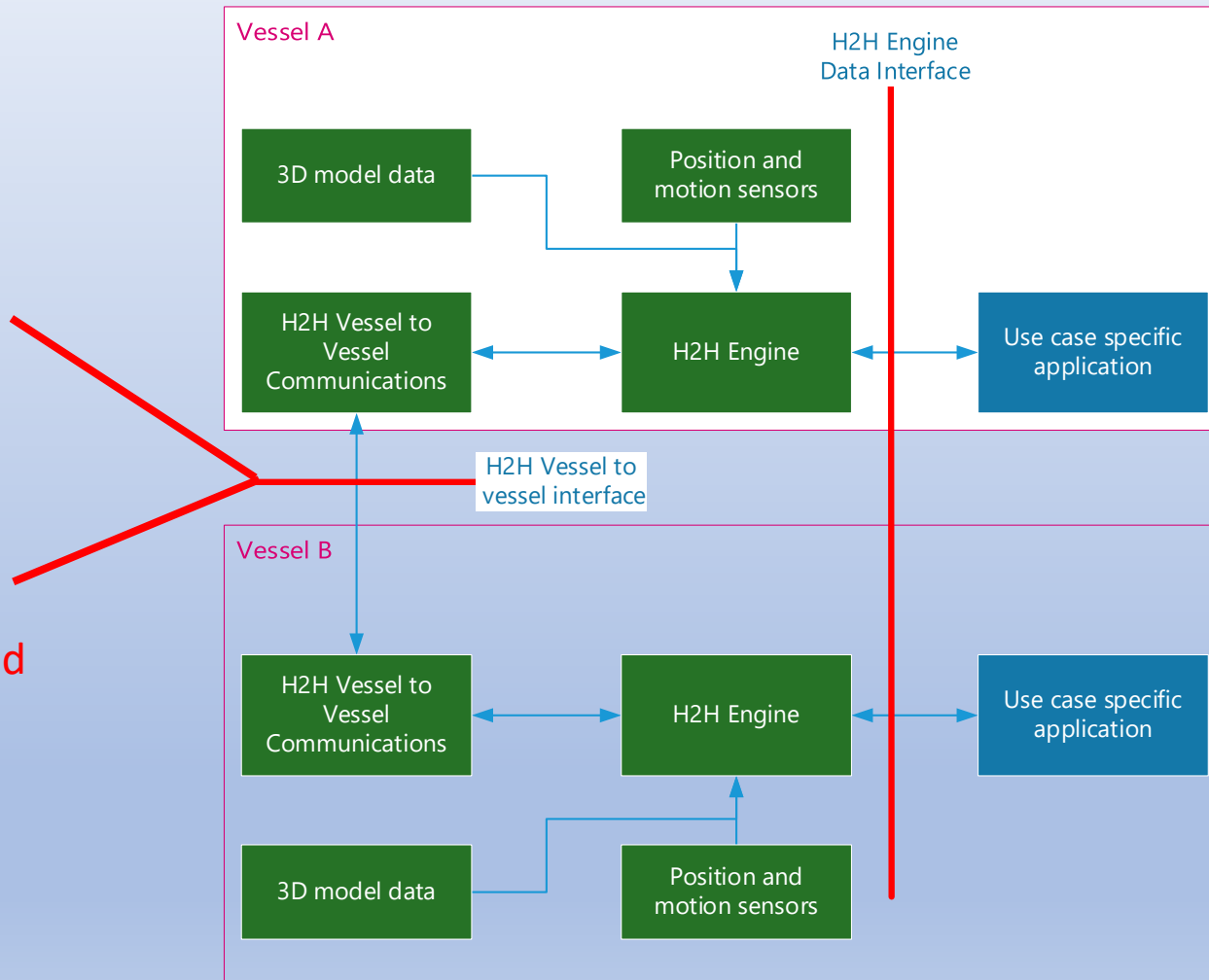
Geometry + Orientation (for geometry/scale) + Datum + Position + Timestamp

Geometry + Orientation (for geometry/scale) + Datum + Position + Timestamp +UZUncertainty (5%) (+ 2DSlicePlane) (if not 3D)

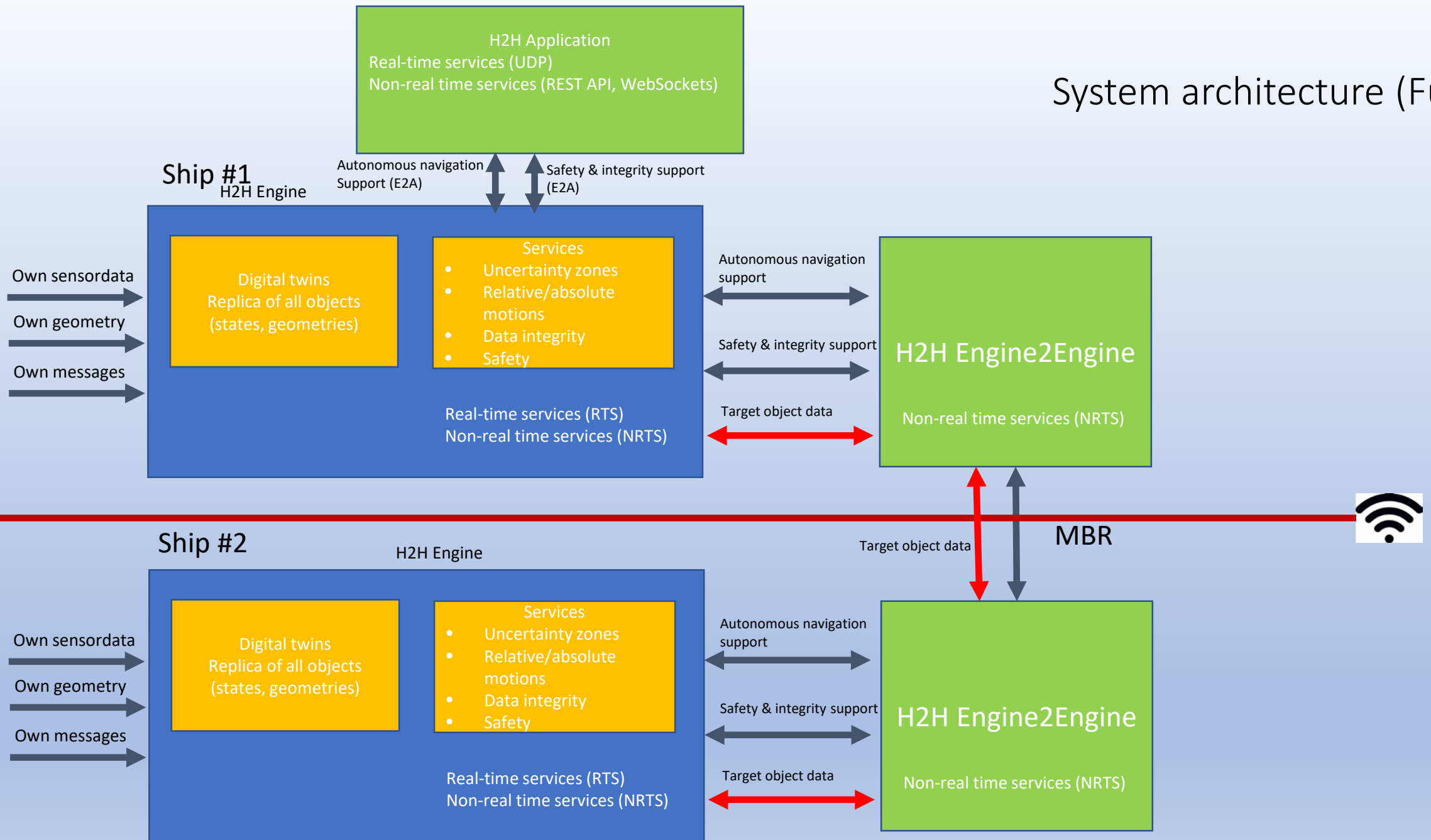
H2H Vessel-to-vessel interface



- 3D models
- Position measurements
- Auxiliary data
- Supports **safe and secure communication**



System architecture (Full)



Typical own ship network topology

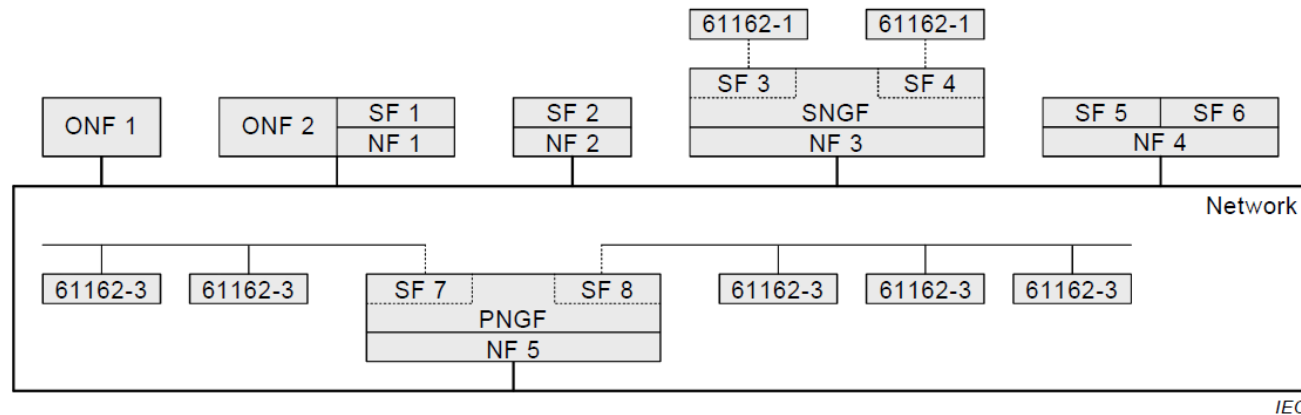
IEC FDIS 61162-450

TITLE:

Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 450: Multiple talkers and multiple listeners – Ethernet interconnection

IEC FDIS 61162-450 © IEC 2018

– 15 –



Key

- SF system function block
- NF network function block
- SNGF serial to network gateway function block
- ONF other network function block
- PNGF PGN to network gateway function block

Figure 1 – Network topology example

61162-1 = NMEA 0183

61162-3 = NMEA 2000

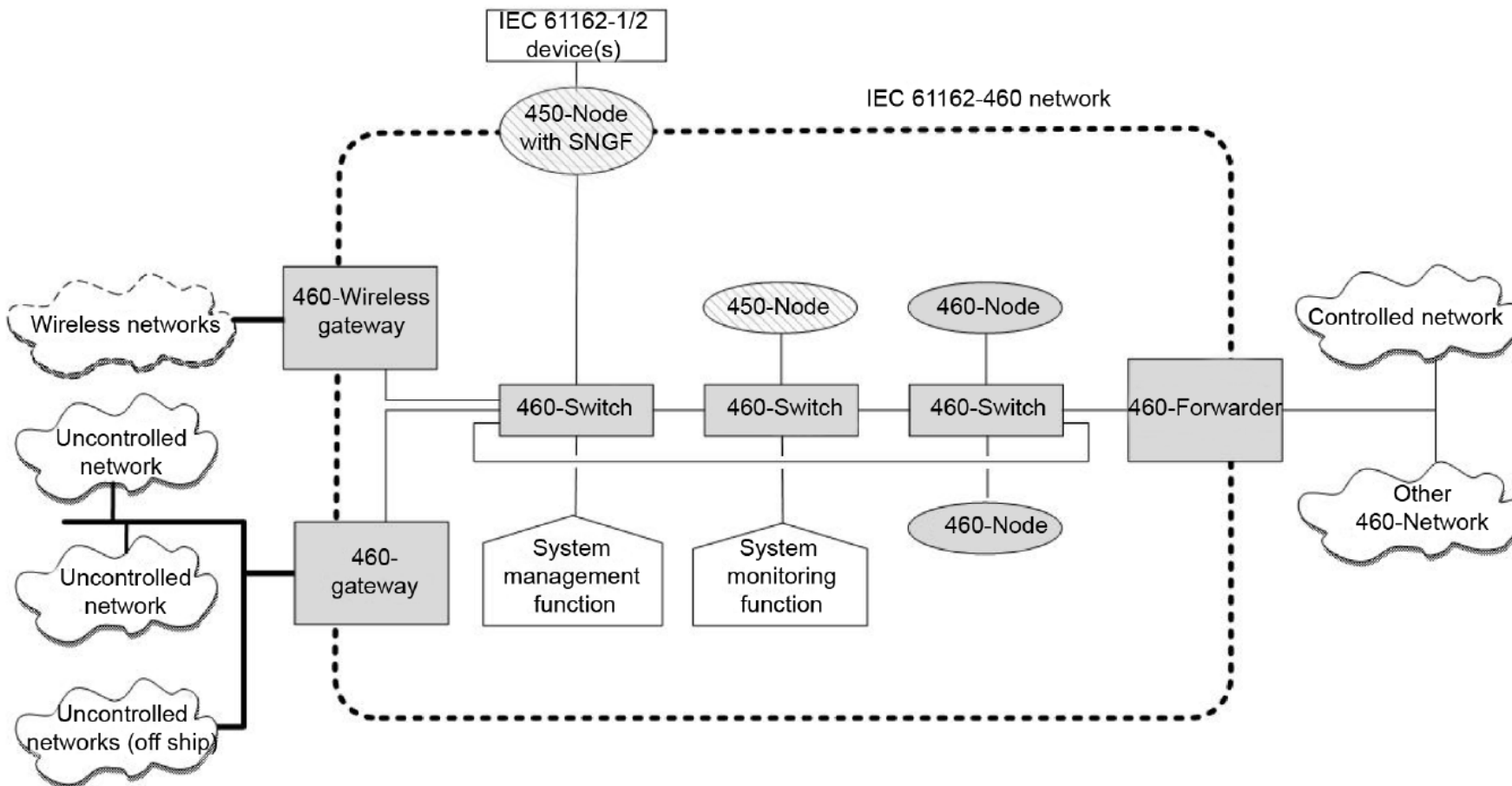
SF2, NF2 = GNSS

IEC FDIS 61162-460



TITLE:

Maritime navigation and radiocommunication equipment and systems – Digital interfaces – Part 460: Multiple talkers and multiple listeners – Ethernet interconnection – Safety and security



H2H Own ship network topology

IEC FDIS 61162-450 © IEC 2018

- 15 -

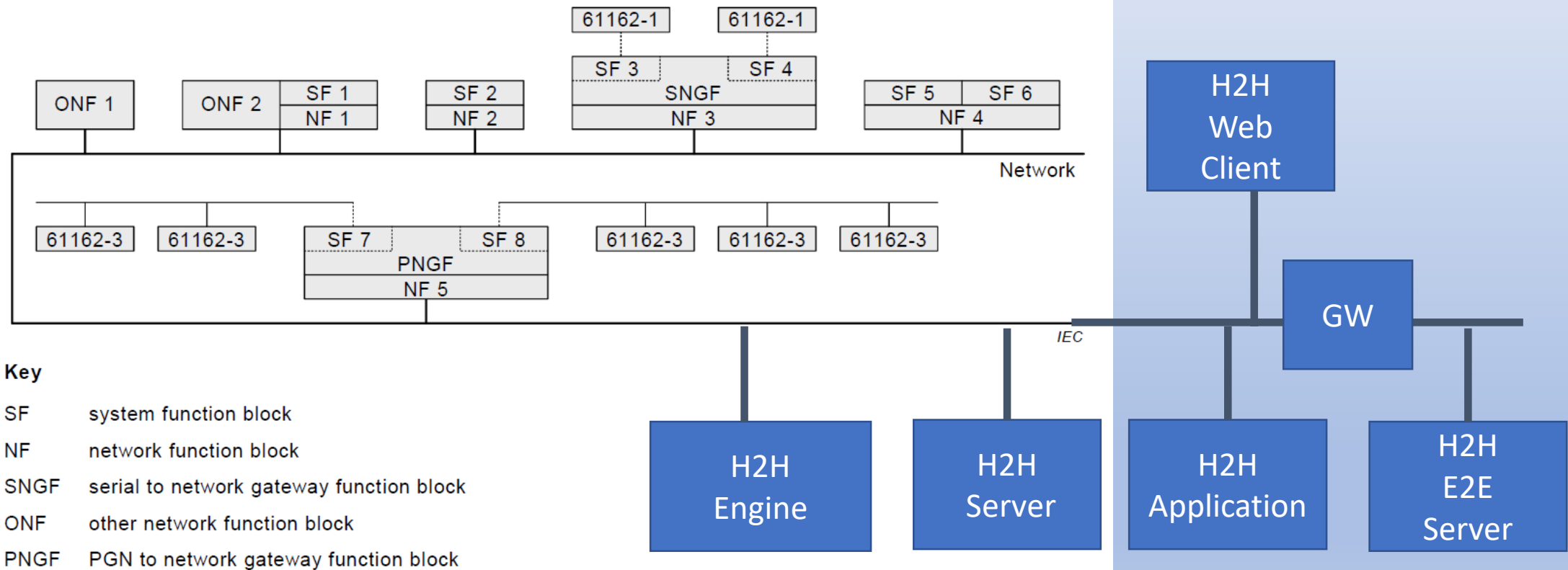


Figure 1 – Network topology example



Open API Initiatives

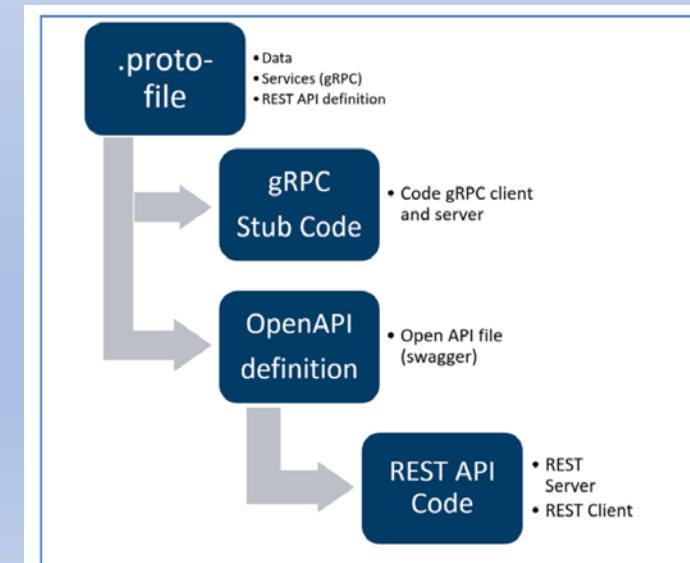
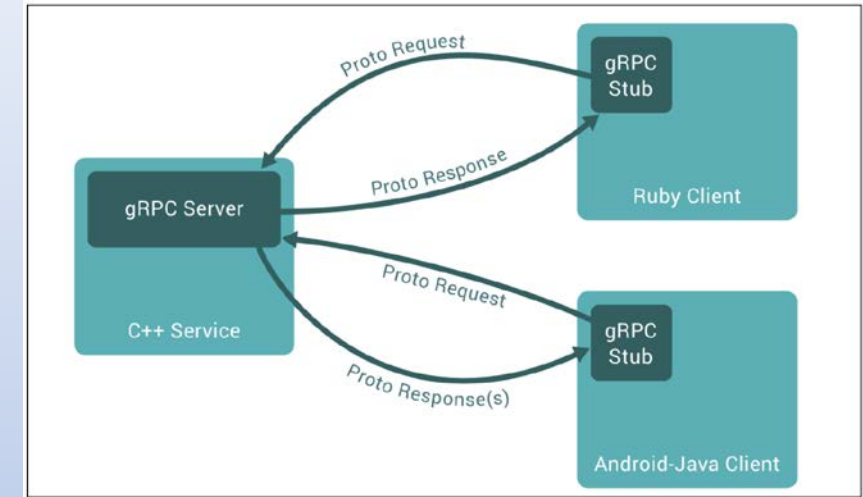
- *"The Open API initiative (OAI) focused on creating, evolving and promoting a vendor neutral description format. APIs form the connecting glue between modern applications. Nearly every application uses APIs to connect with corporate data sources, third party data services or other applications. Creating an open description format for API services that is vendor neutral, portable and open is critical to accelerating the vision of a truly connected world"*
- *Two different technologies*
 - *REST API*
 - *Remote Procedure Calls (RPC)*

REST API

- *REST* (Representational State Transfer) is a software architecture style used for creating web services (REST APIs) that provide interoperability between internet applications
- HTTP/1.x protocol
- End-to-end data communication (TCP/IP)
- Swagger (<https://swagger.io>) offers tools for using Open API specification file
- Automatic generation of code for server and client side in different programming languages

Remote Procedure Calls (RPC)

- User defined code can be executed in a different address space (computer or network)
- Data shared on network
- gRPC
 - Google Protocol Buffer to optimize payload
 - Generates code stubs in different languages
 - HTTP/2 (allows streaming both ways)



Relevant standards

Data model/communications standards

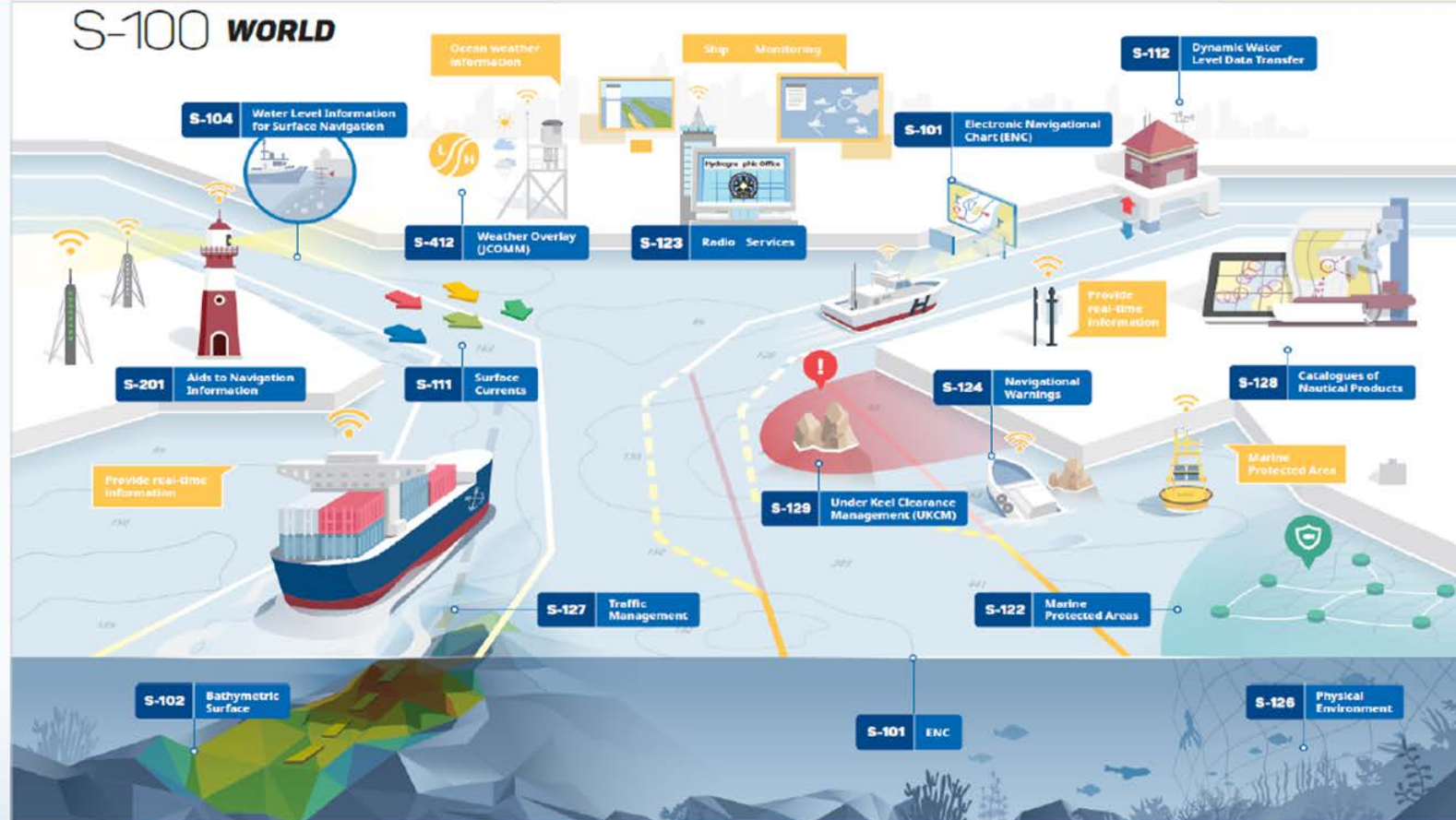
- S-100
- STEP/ISO-10303
- ISO-28005
- RTCM 10403.1
- IEC 62940
- IEC 61108
- Inland AIS
- Inland ENC (Inland ECDIS Standard 2.3)
- IEC 61162-1/2/3/450/460 (NMEA 0183/2000)

Safety standards

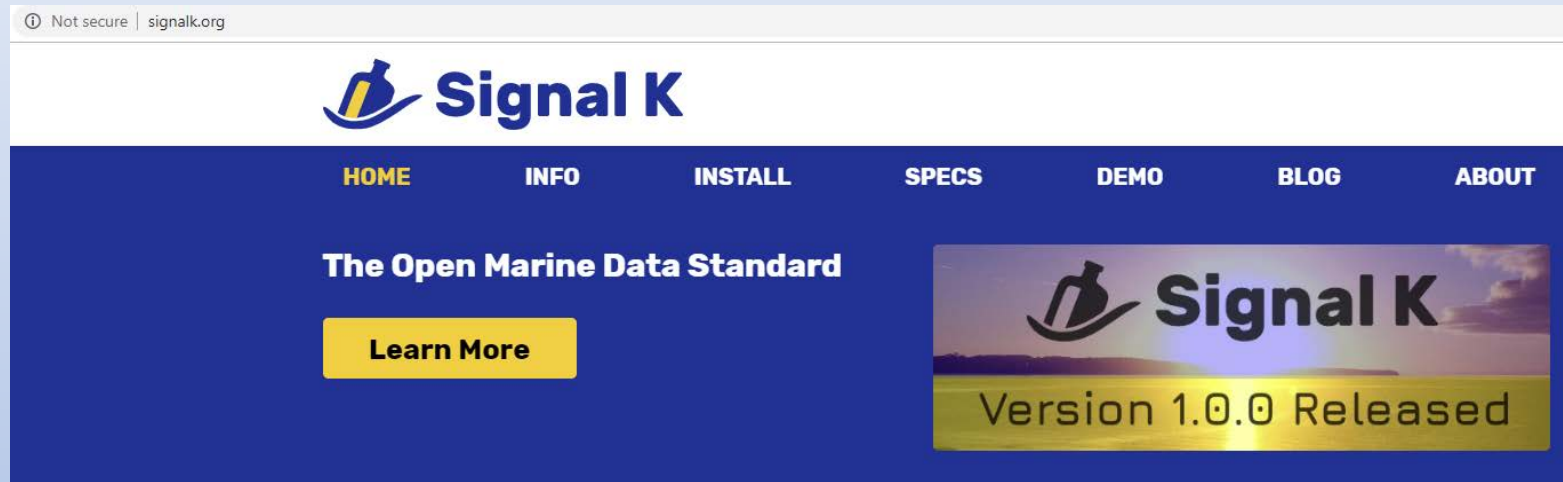
- EN 50159
- IEC 61508
- IEC 61784

S-100 Framework

S-100 Universal Hydrographic Data Model

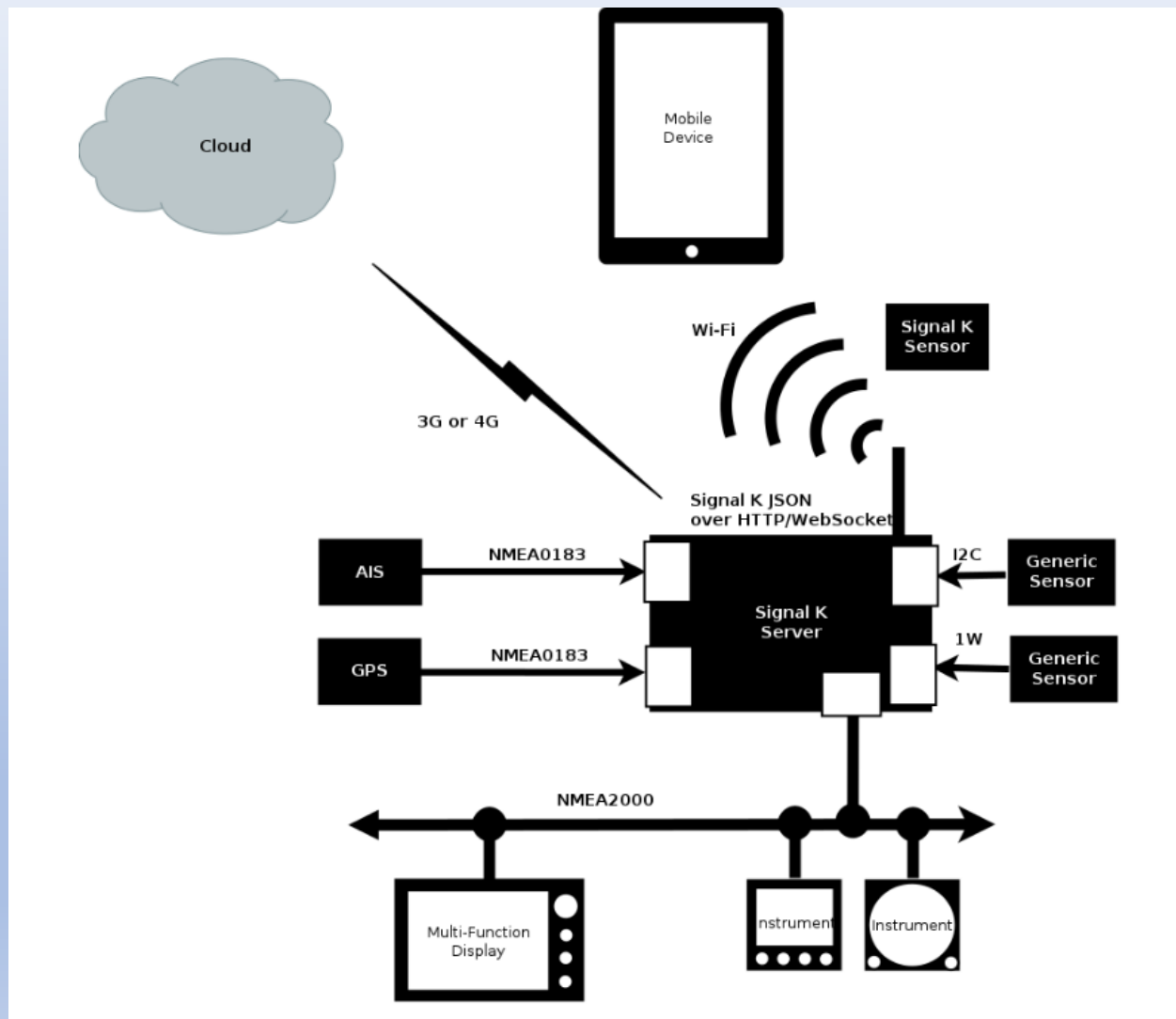


Open source project for Marine Data Exchange



- Open source project on GitHub
- Used by smaller yachts, fishing vessels
- Sharing data on WiFi, cellphones, tables and Internet

Signal K (<https://signalk.org/>)



"The Open Marine Data Standard"

Signal K JSON over HTTP/WebSocket

```
{
  "vessels": {
    "urn:mrn:signalk:uuid:705f5f1a-efaf-44aa-9cb8-a0fd6305567c": {
      "navigation": {
        "position": {
          "value": {
            "altitude": 0.0,
            "latitude": 37.81479,
            "longitude": -122.44880152
          },
          "source": {
            "label": "ttyUSB0",
            "type": "NMEA0183",
            "talker": "GP",
            "sentence": "PRMC"
          },
          "timestamp": "2017-05-16T05:15:58.007Z"
        }
      }
    }
  }
}
```

Signal K server



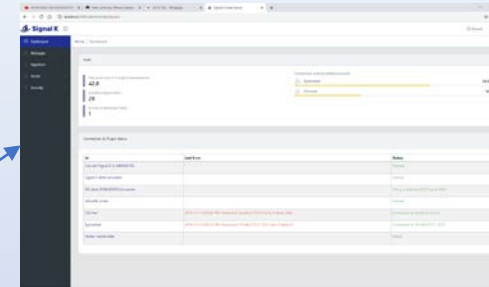
- Inputs
 - NMEA0183 (also AIS messages), NMEA 2000, onboard sensors..
- Transport protocols:
 - HTTP, WebSocket, TCP, UDP, Serial connections
 - Security supported: SSL/TSK (https, wss)
- REST API based on Signal K project
 - signalk/authenticate
 - signalk /v1/api
 - signalk /v1/stream

```
localhost:3000/signalk/v1/api/
{"vessels":{"urn:mrn:signalk:uuid:44a5dd33-711f-4412-8f31-da61d6095a3b":{"uuid":"urn:mrn:signalk:uuid:44a5dd33-711f-4412-8f31-da61d6095a3b","name":"tes
{"value":5},"sensors":{"gps":{"fromBow":{"value":10},"fromCenter":{"value":10}},"navigation":{"headingTrue":{"meta":{"units":"rad","description":"The
magneticVariation"},"value":3.7227872953539274,"$source":"Chrome.II","timestamp":"2019-11-05T20:26:09.637Z","sentence":"HDT"},"headingMagnetic":{"meta
magneticDeviation"},"value":3.7227872953539274,"$source":"Chrome.II","timestamp":"2019-11-05T20:26:09.636Z","sentence":"VHM"},"speedThroughWater":{"me
water"},"value":2.98377853366834,"$source":"Chrome.II","timestamp":"2019-11-05T20:26:09.636Z","sentence":"VHM"},"position":{"meta":{"description":"The
{"longitude":138.53783333333334,"latitude":-35.12583333333333},"$source":"Chrome.GP","timestamp":"2019-11-05T20:26:09.000Z","sentence":"GLL"},"datetime
05T20:26:09.632Z","$source":"Chrome.GP","timestamp":"2019-11-05T20:26:09.639Z","sentence":"ZDA"},"courseOverGroundTrue":{"meta":{"units":"rad","descrip
05T20:26:09.000Z","sentence":"RMC"},"speedOverGround":{"meta":{"units":"m/s","description":"Vessel speed over ground. If converting from AIS 'HIGH' val
notifications"},"value":5.813223694905559,"$source":"Chrome.GP","timestamp":"2019-11-05T20:26:09.000Z","sentence":"RMC"},"magneticVariation":{"meta":{"
the magnetic heading to derive the true heading. Easterly variations are positive and Westerly variations are negative (in Radians)."},"value":0,"$sour
{"meta":{"units":"s","description":"Seconds since the 1st Jan 1970 that the variation calculation was made"},"value":1572985569,"$source":"Chrome.GP","
{"units":"m/s","description":"Wind speed over water (as calculated from speedApparent and vessel's speed through water)","value":40.02378791713738,"$s
{"units":"rad","description":"True wind angle based on speed through water, negative to port"},"value":0.21293016879192644,"$source":"Chrome.WI","times
{"units":"m/s","description":"Apparent wind speed"},"value":34.67356433952519,"$source":"Chrome.WI","timestamp":"2019-11-05T20:26:09.642Z","sentence":"
port"},"value":2.712241658218473,"$source":"Chrome.WI","timestamp":"2019-11-05T20:26:09.642Z","sentence":"MW"},"water":{"temperature":{"meta":{"units
05T20:26:09.642Z","sentence":"MTW"},"depth":{"belowTransducer":{"meta":{"units":"m","description":"Depth below Transducer"},"value":51.3,"$source":"CH
{"units":"m","description":"Depth transducer is below the water surface"},"value":1,"$source":"Chrome.SD","timestamp":"2019-11-05T20:26:09.642Z","sente
surface"},"value":51.3,"$source":"Chrome.SD","timestamp":"2019-11-05T20:26:09.643Z","sentence":"DBS"},"belowKeel":{"meta":{"units":"m","description":"D
05T20:26:09.643Z","sentence":"DBK"}}},"urn:mrn:imo:mmsi:257143740":{"mmsi":"257143740","name":"VALOEYTIIND","design":{"draft":{"meta":{"description":"T
05T20:20:31.971Z","sentence":"VDM"},"aisShipType":{"meta":{"description":"The ais ship type see http://www.bosunsmate.org/ais/message5.php"},"value":{"
05T20:20:31.971Z","sentence":"VDM"},"navigation":{"destination":{"commonName":{"meta":{"description":"Common name of the Destination, eg 'Fiji', also
05T20:20:31.971Z","sentence":"VDM"},"speedOverGround":{"meta":{"units":"m/s","description":"Vessel speed over ground. If converting from AIS 'HIGH' us
```

Signal K Example

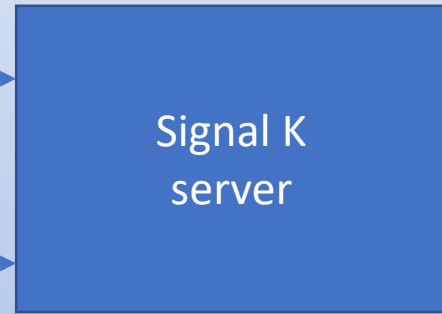


REST API
WebSocket



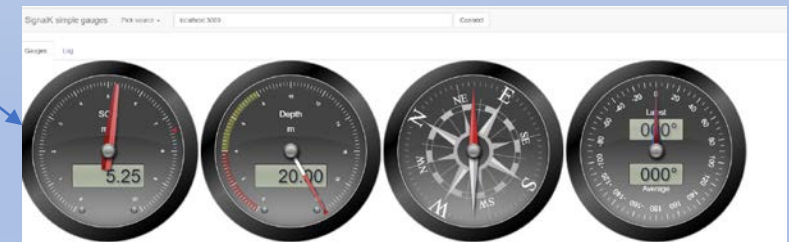
Kystverket AIS port

NMEA simulator
(own data)

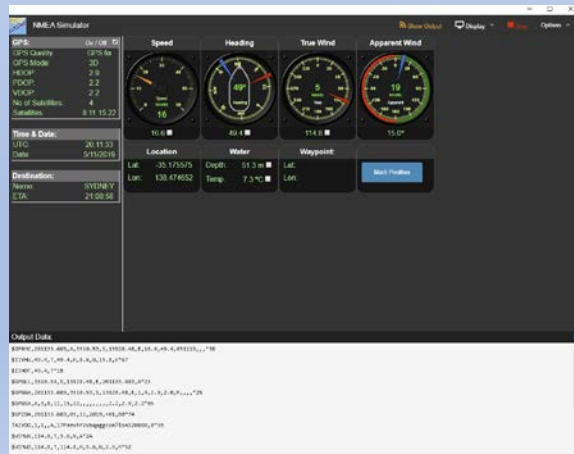


JSON

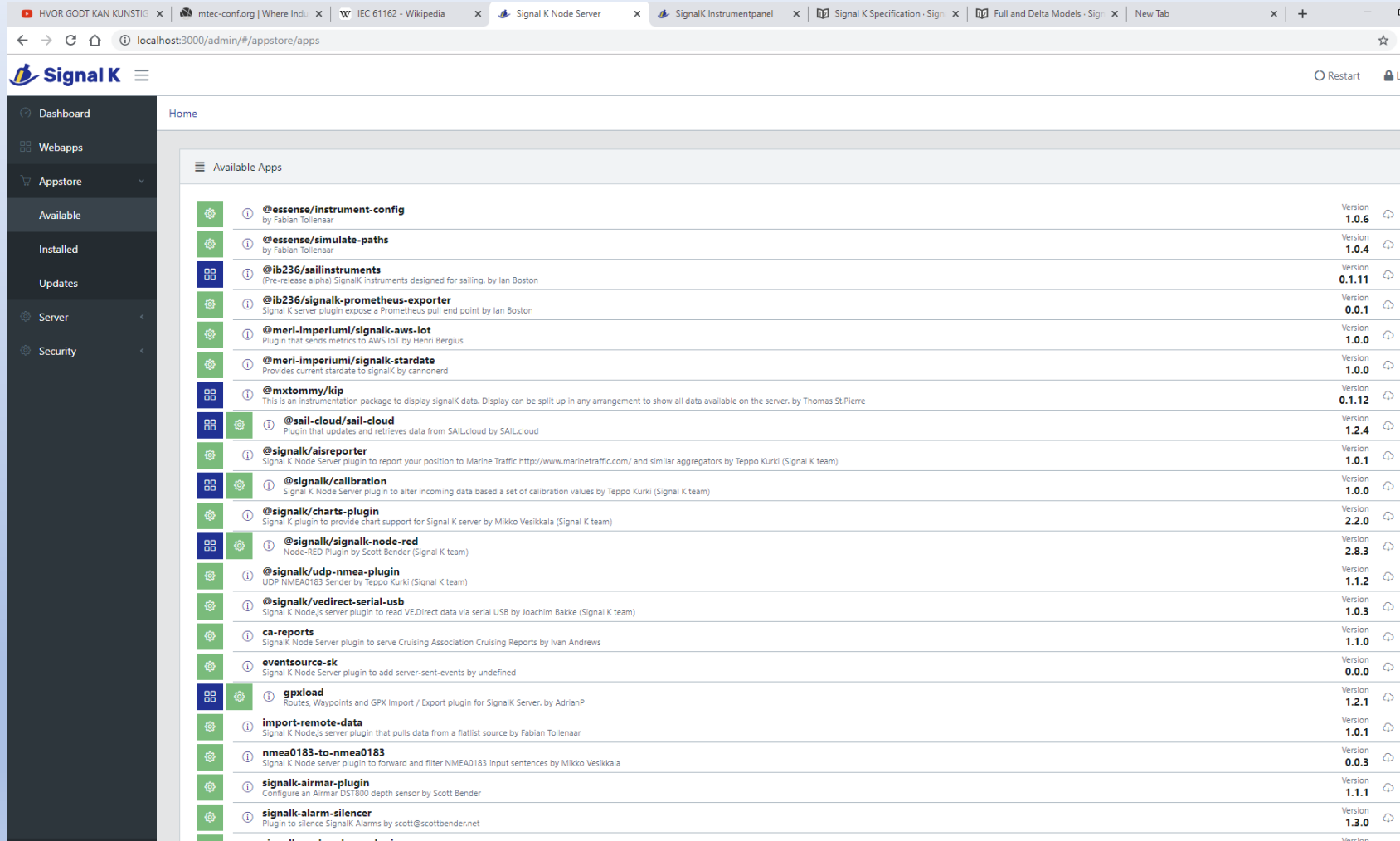
```
{  
  "vessels": [  
    {  
      "urn:nris:signalk:uid:705f5f1e-efef-44ea-9cb0-ef06305567c": {  
        "navigation": {  
          "position": {  
            "value": {  
              "altitude": 0.0,  
              "latitude": 57.81478,  
              "longitude": -122.04888132  
            }  
          },  
          "source": {  
            "label": "styUSB0",  
            "type": "NMEA0183",  
            "talker": "GP",  
            "sentence": "PRNC"  
          },  
          "timestamp": "2017-05-16T05:15:50.007Z"  
        }  
      }  
    ]  
  }  
}
```



Influx database



Signal K Example



The screenshot shows the Signal K Admin interface at localhost:3000/admin/#/appstore/apps. The left sidebar contains navigation options: Dashboard, Webapps, Appstore, Available, Installed, Updates, Server, and Security. The main content area is titled 'Available Apps' and lists various plugins and their versions.

App Name	Version
@essense/instrument-config	1.0.6
@essense/simulate-paths	1.0.4
@ib236/sailinstruments	0.1.11
@ib236/signalk-prometheus-exporter	0.0.1
@meri-imperiumi/signalk-aws-iot	1.0.0
@meri-imperiumi/signalk-stardate	1.0.0
@mxtommy/kip	0.1.12
@sail-cloud/sail-cloud	1.2.4
@signalk/aisreporter	1.0.1
@signalk/calibration	1.0.0
@signalk/charts-plugin	2.2.0
@signalk/signalk-node-red	2.8.3
@signalk/udp-nmea-plugin	1.1.2
@signalk/vedirect-serial-usb	1.0.3
ca-reports	1.1.0
eventsourcesk	0.0.0
gpxload	1.2.1
import-remote-data	1.0.1
nmea0183-to-nmea0183	0.0.3
signalk-airmar-plugin	1.1.1
signalk-alarm-silencer	1.3.0
signalk-anchoralarm-plugin	

Plugins Apps

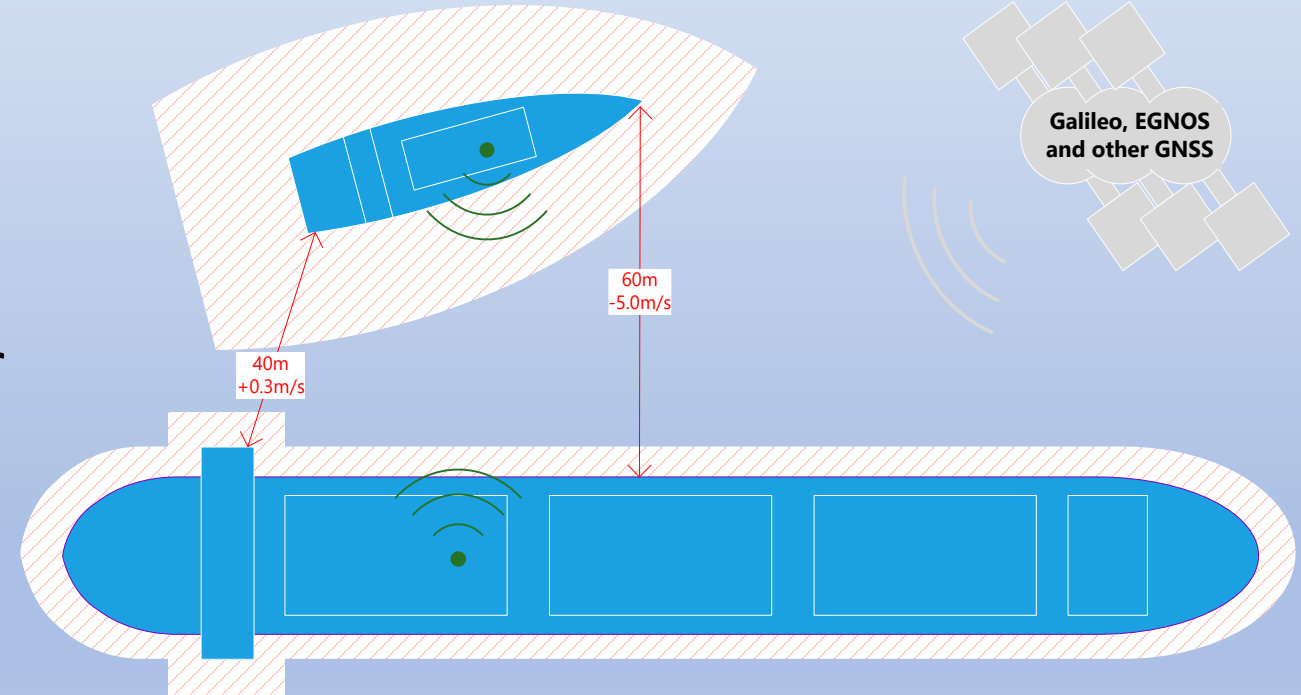


What is missing to comply with the H2H requirements?

- Implement H2H data model
 - Geometry data (object geometry)
 - Uncertainty zones
 - Operational zones
 - Relative distances and velocities between objects
- New APIs
 - RTCM interface
 - H2H Engine interface
 - H2H Application interface (S-100 compatible)

Summary

- Signal K is a candidate for open maritime data API
- Uses maritime standards as far as possible (IEC 61162-series)
- JSON messages for data exchange to 3rd party applications and plugins
- Must append new data models for geometries, relative distances and velocities for safe navigation
- Encryption possible with secure http and ws





HULL TO HULL

Public information

The screenshot shows the Hull to Hull website. At the top, there is a navigation menu with links for Home, Work packages, Schedule/timeline, News & activities, Publications & Downloads, and Partners. Below the menu is a large image of an autonomous ship with the word 'AUTONOMOUS' written on its side. Below the image is a Facebook icon and a heading: 'Using EGNOS and Galileo to support Autonomous Maritime Operations'. At the bottom of the screenshot is a timeline diagram with three years:

- Year 1**:
 - Concept definition
 - Gap analysis
 - User requirements
- Year 2**:
 - Technology adaption
 - Safe communication
 - Standardisation
- Year 3**:
 - H2H pilot demonstrations

This is a flyer for the Hull-to-Hull project, Year 1. It features a timeline with three years and a large image of a ship. The text includes project objectives, a list of partners (NTNU, SINTEF, Inovent, etc.), and a description of the project's goals and activities.

1st year flyer

This is a flyer for the Hull-to-Hull project, Year 2. It features a timeline with three years and a large image of a ship. The text includes project objectives, a list of partners, and a description of the project's goals and activities.

2nd year flyer

<https://www.sintef.no/projectweb/hull-to-hull/>



HULL TO HULL

HORIZON 2020