UNCERTAINTY ZONES

DYNAMIC DATA EXCHANGE FOR AUTONOMOUS FUNCTIONS

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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.

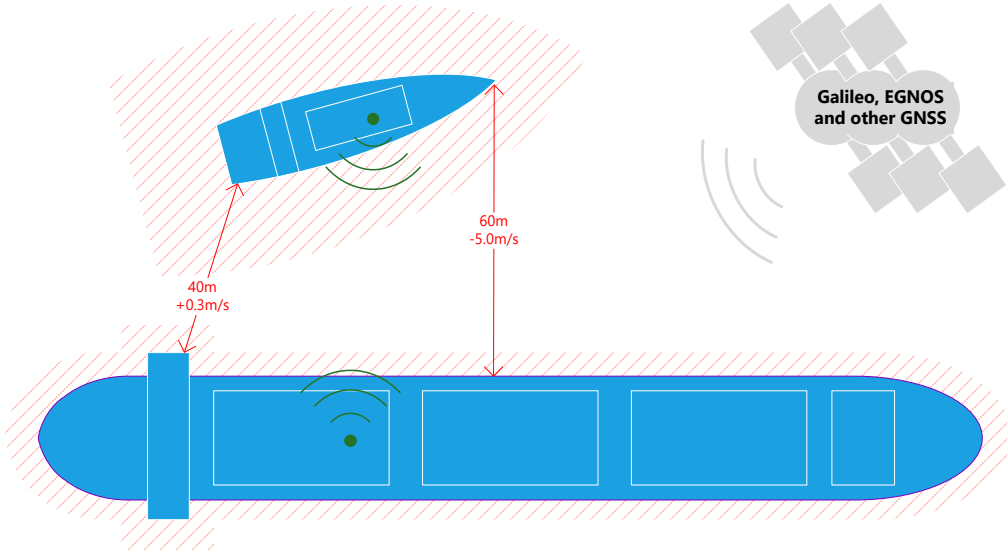
Hull to hull supports both traditional navigation as well as autonomous vessels

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

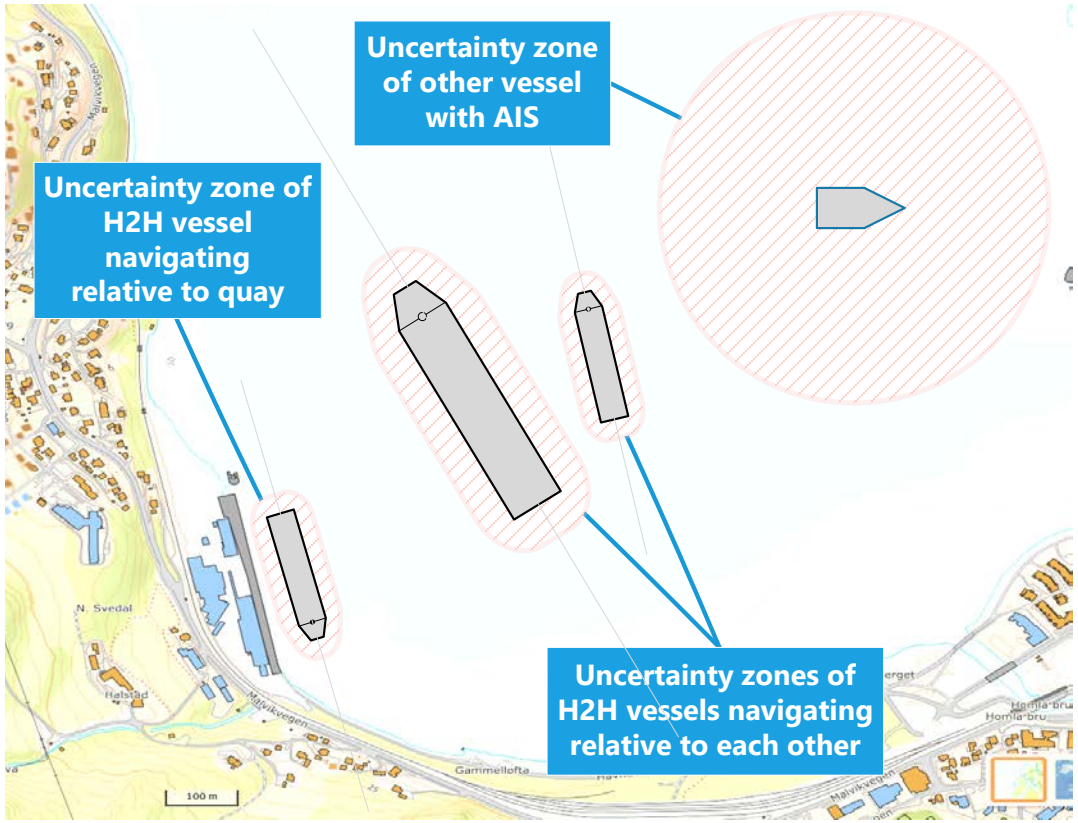
Basic Concept

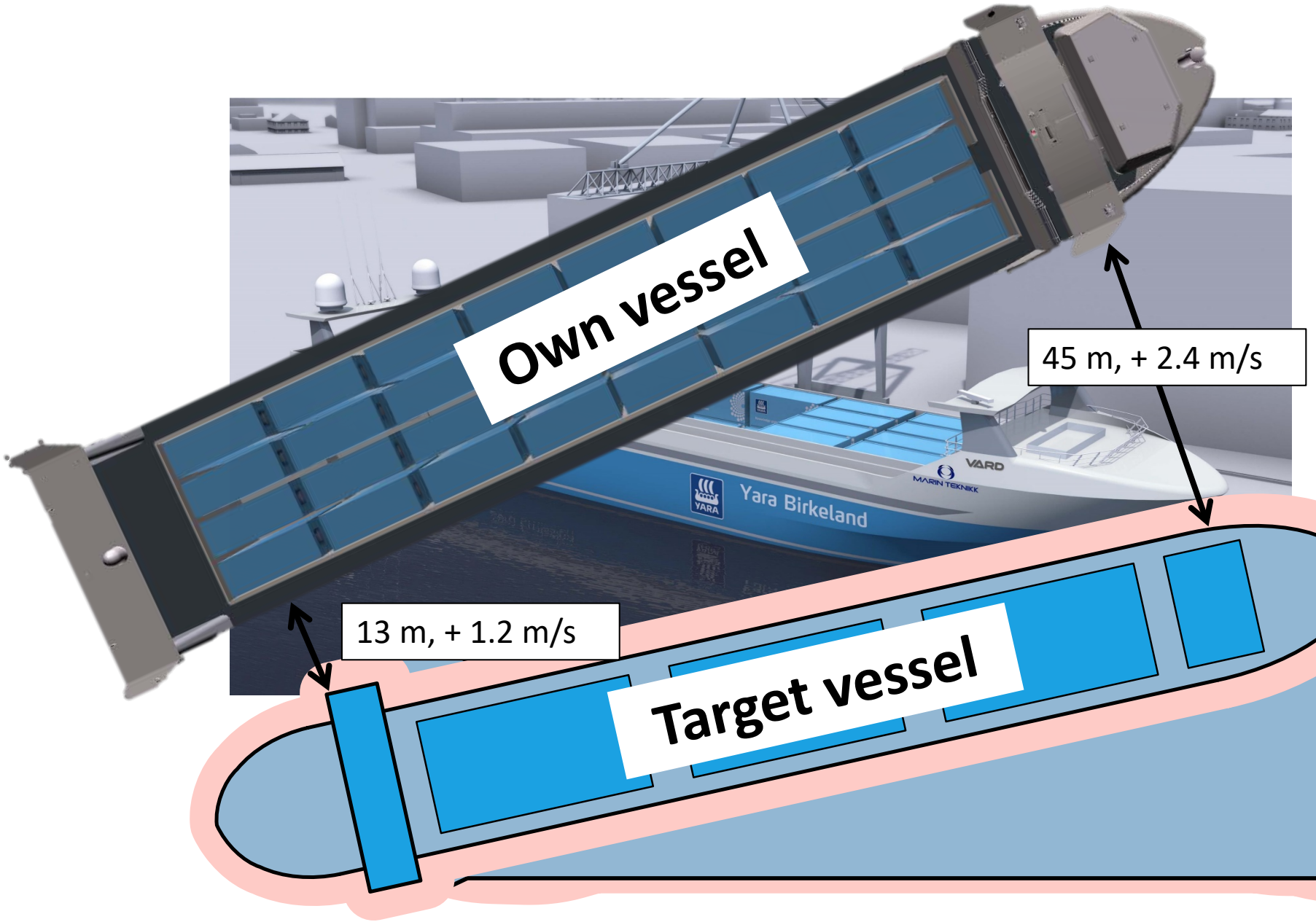
- Hull-to-hull positioning based on 3D models and position measurements
- Vessel to vessel data exchange:
  - 3D vessel models
  - Sensor measurement, e.g. position, orientation.
- Open concept with standardized data exchange
- Uncertainty zones for own vessel as well as neighbouring objects indicate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

hipmaster's view

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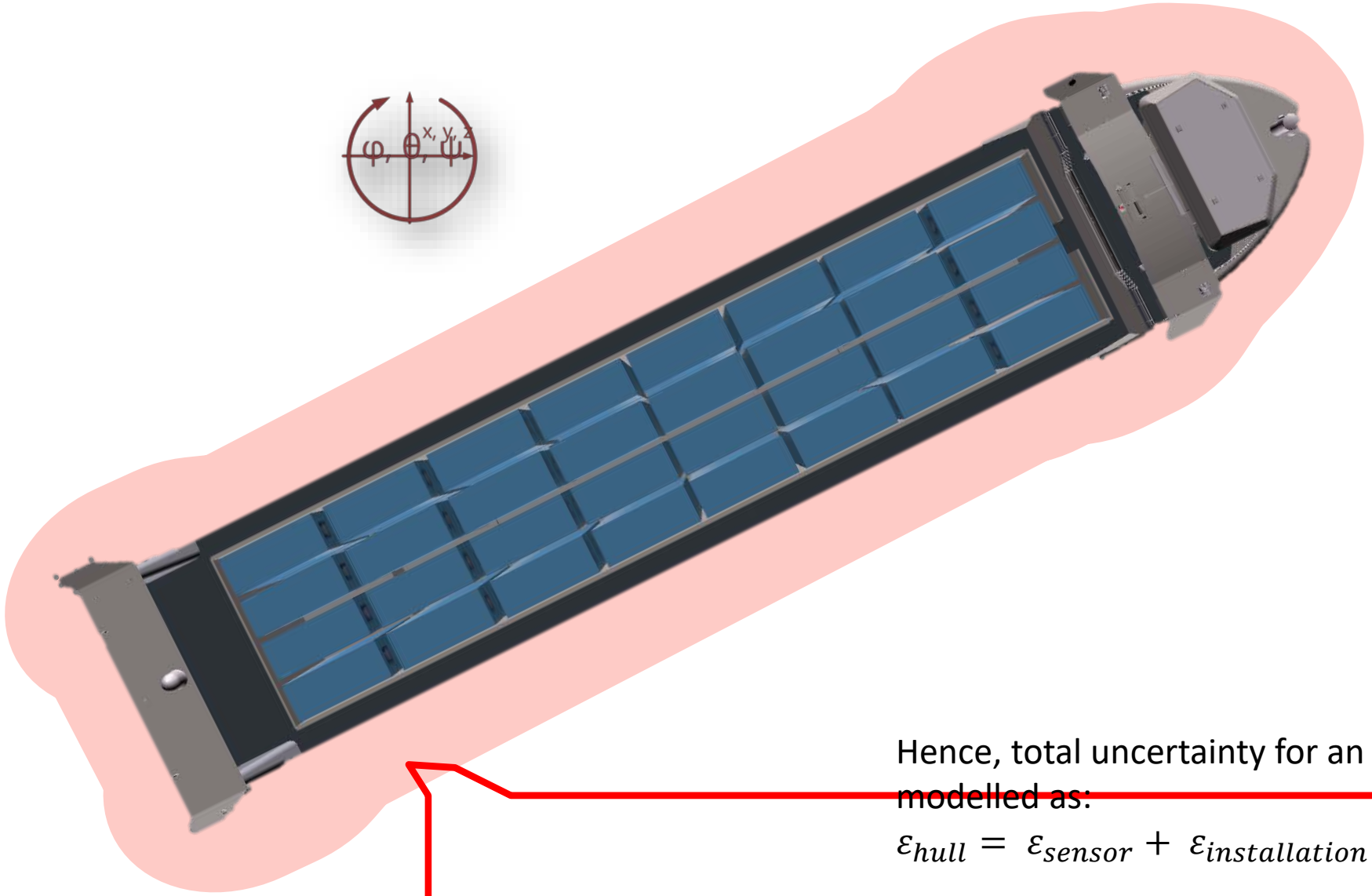

Uncertainty zone shall encompass actual hull with 95% probability

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:

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

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3 pilot demonstrations

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

Zulu 04, Barge from BLL

Ocean Space Drone 1 and 2

Cogge, 1:8 scale model of a barge

HULL TO HULL

H2H Conceptual model

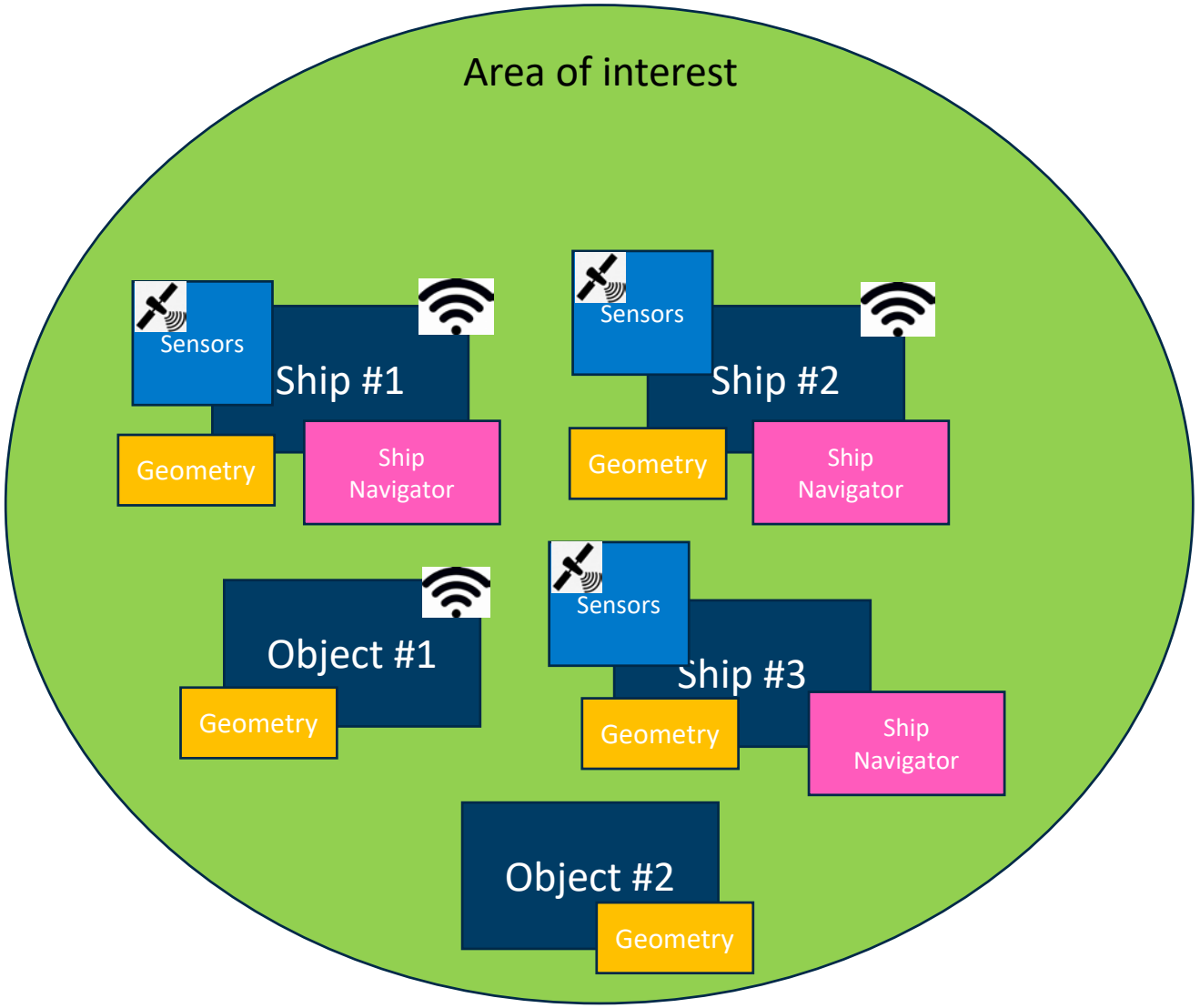
Stakeholders (users)

Navigator

Shore control centre

VTS

AIS
- Terrestial
- Satelite



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

Wireless
- WiFi
- Satelite
- MBR

= Satelite

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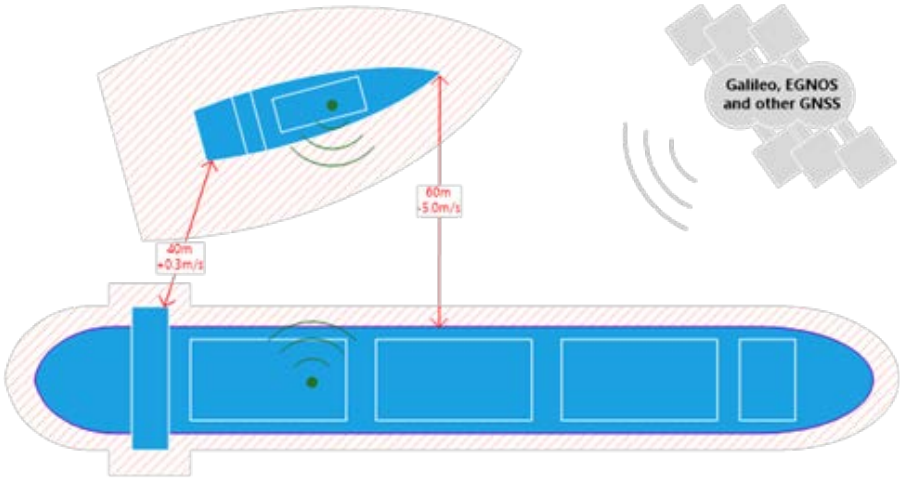
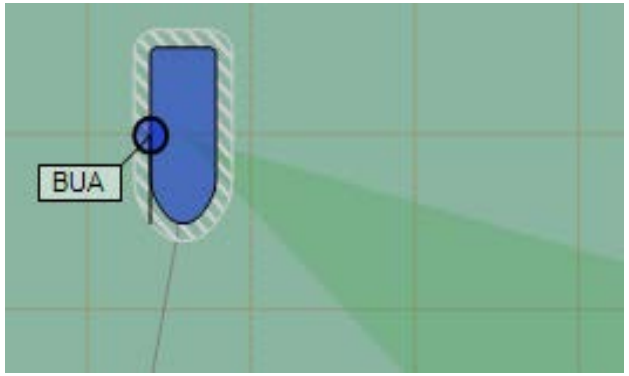
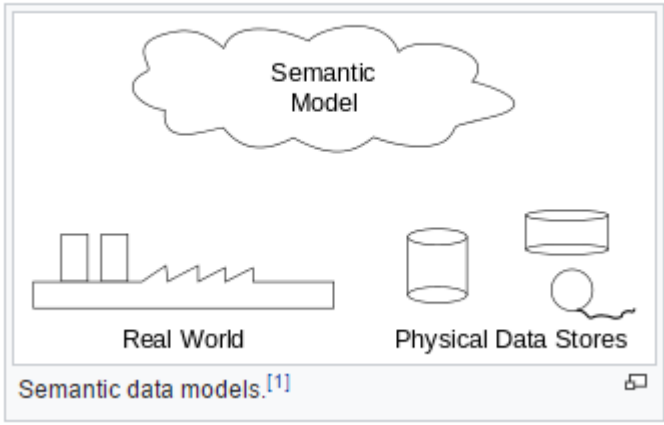
Domain and semantic data model





- 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

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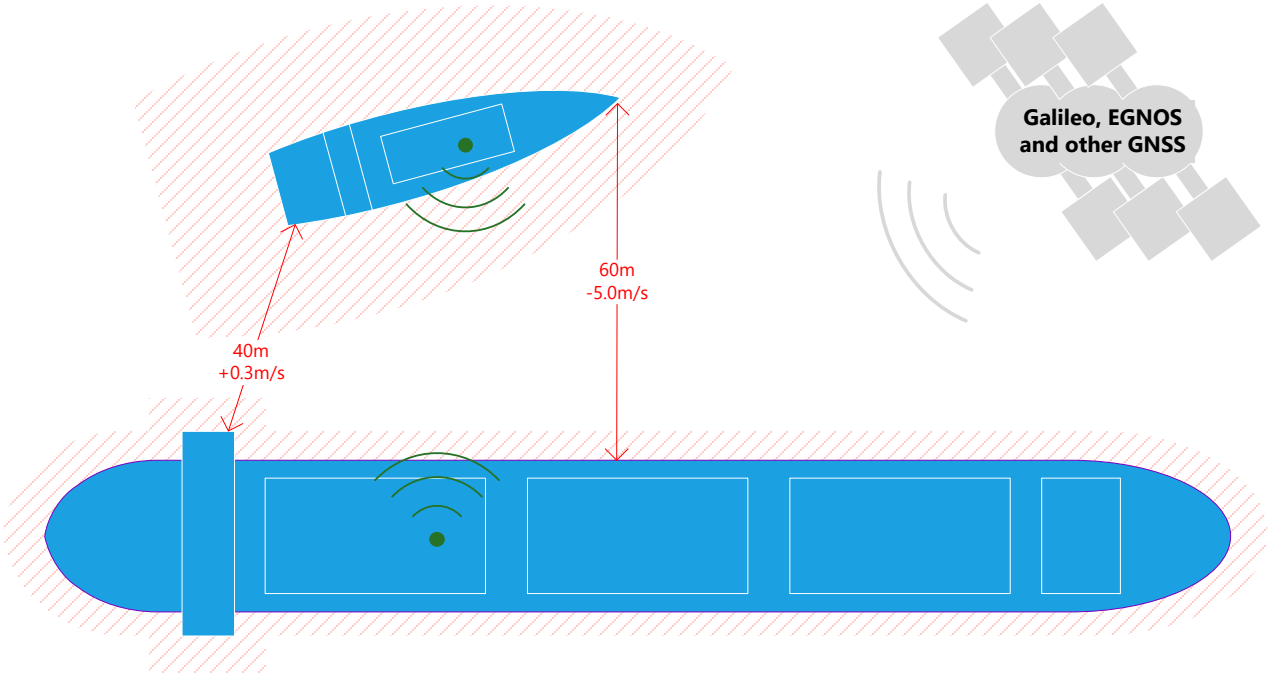
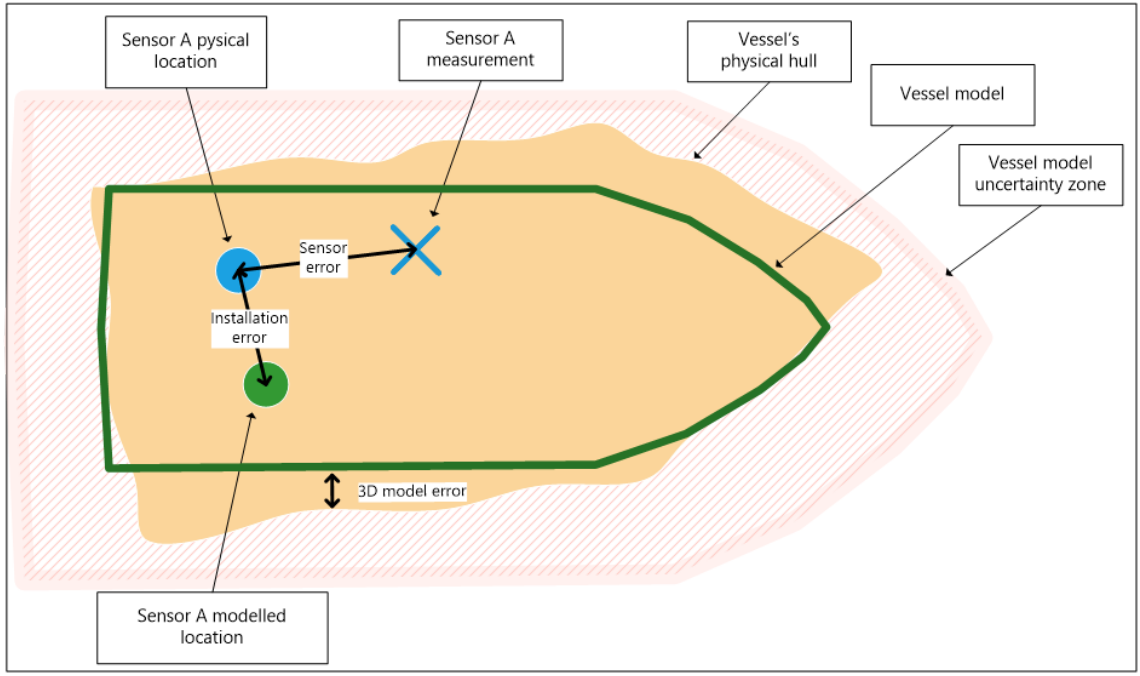
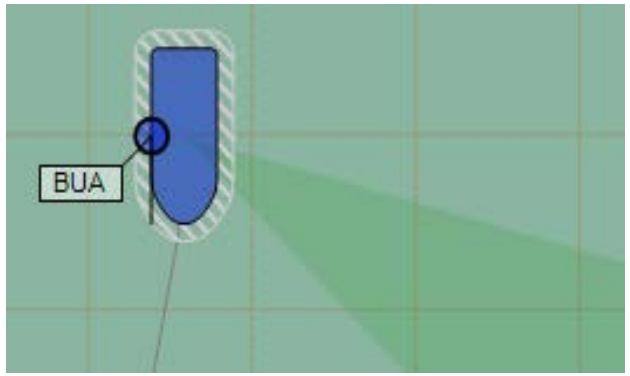
Object geometry and accuracy







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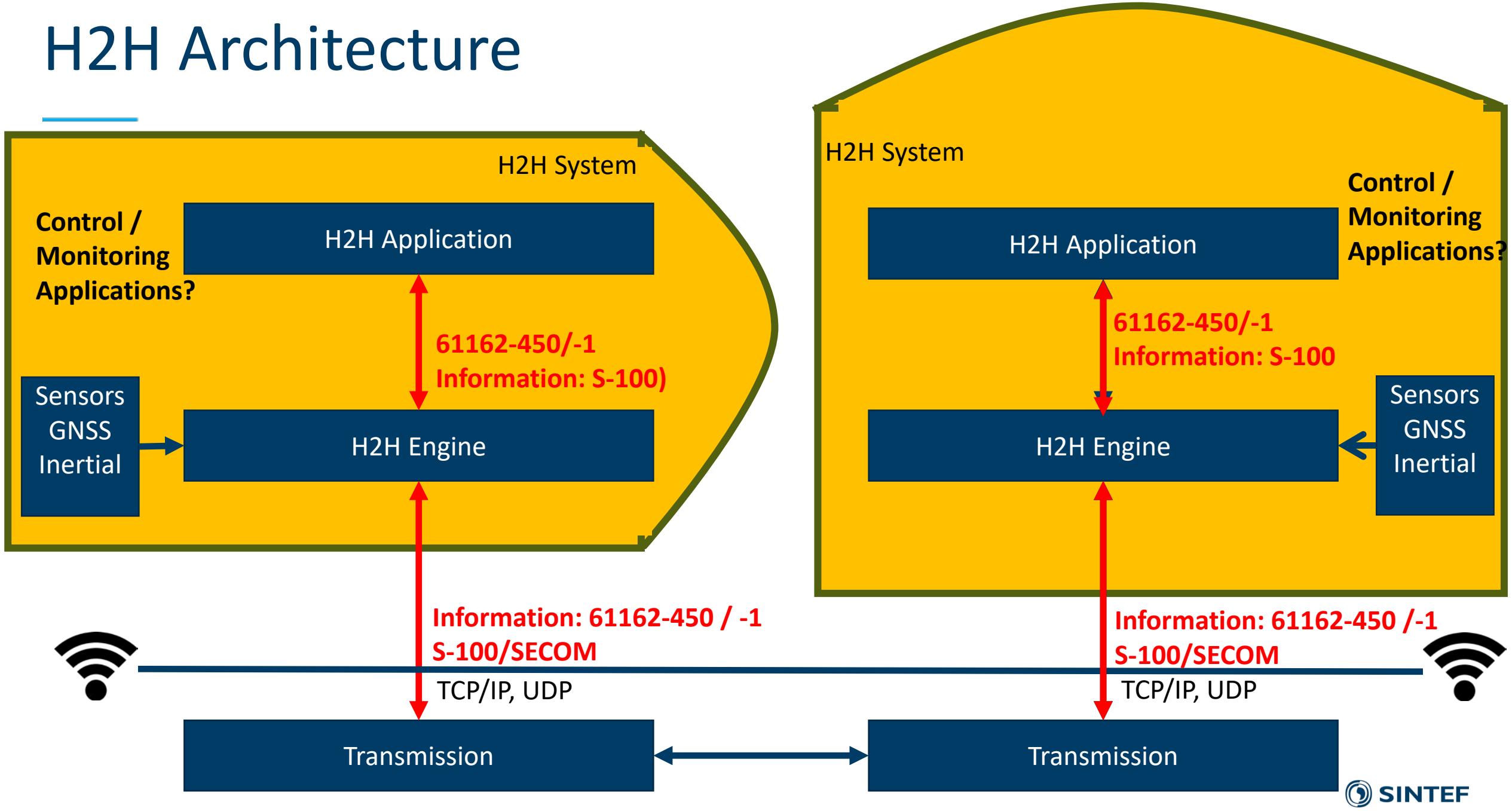
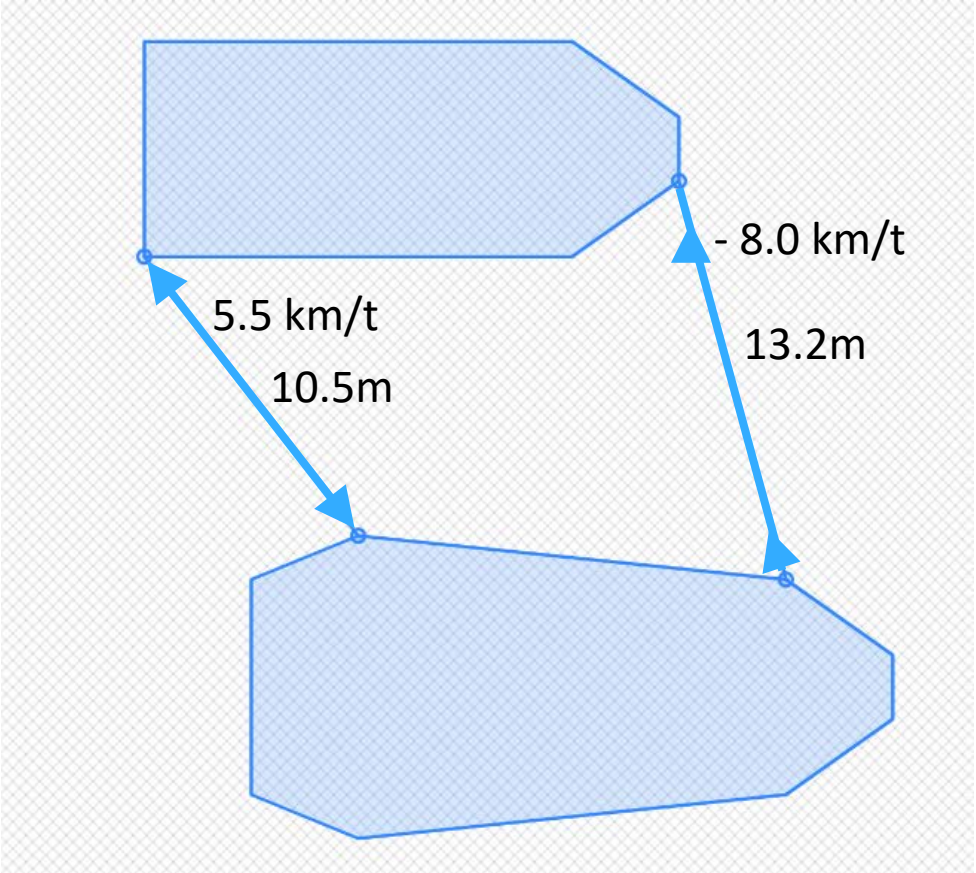
H2H Architecture



Broadcast **multi-point position**

- This is an extention to single-point (lat/lon)-position
- Can be based on various information:
  1) Length and Width of the ship (Simplest, less accurate)
  2) 2D outline of the ship (static shape, few points)
  3) Full 2D model of the ship (static, large data)
  4) GNSS Raw data for position and inertial data for ship movements to calculate the uncertainty zone of the ship indicating the 95% probability that the hull is inside this polygon



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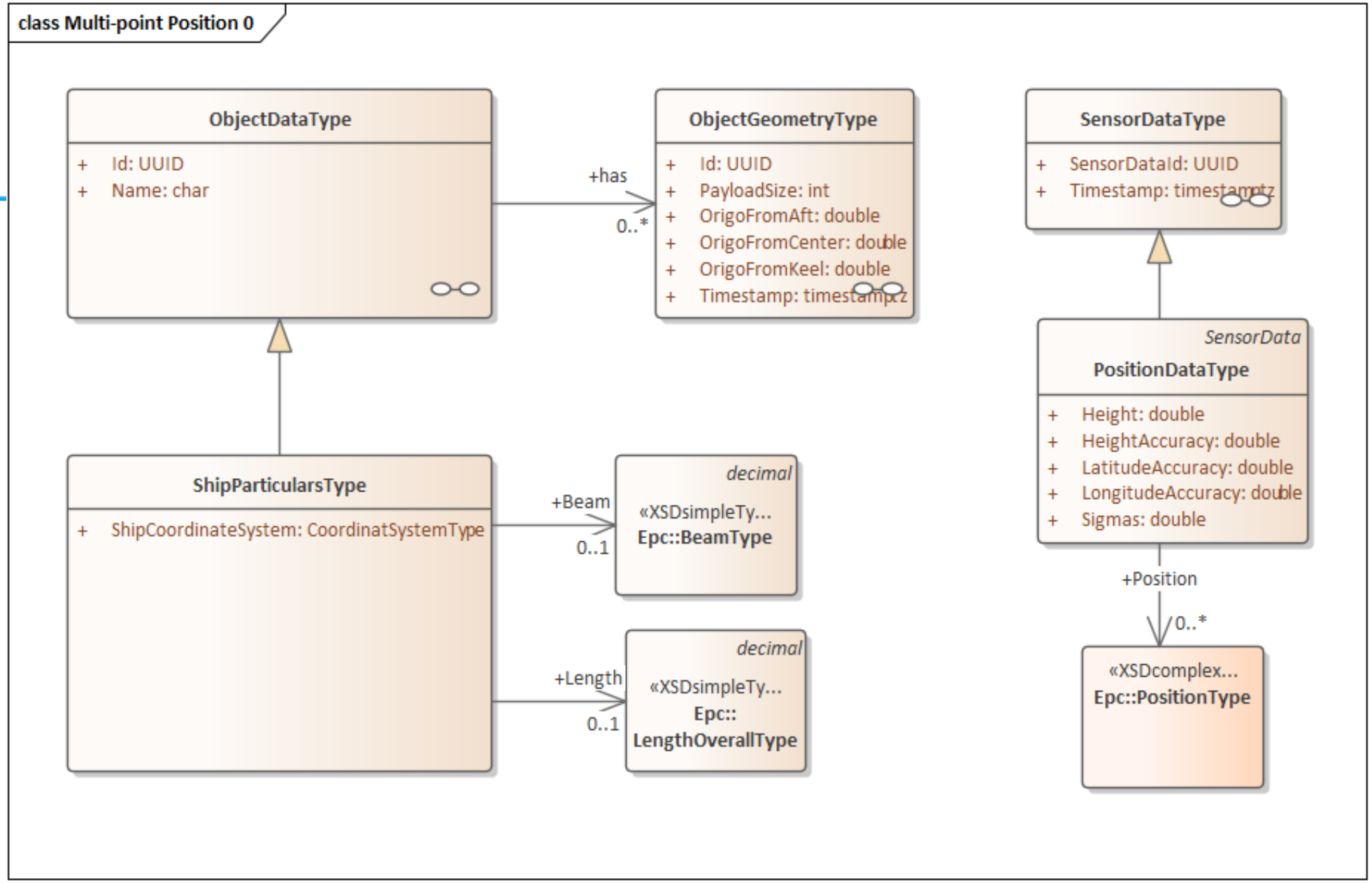
class Multi-point Position 0
ObjectDataType
+ Id: UUID
+ Name: char
+has
0..*
ObjectGeometryType
+ Id: UUID
+ PayloadSize: int
+ OrigoFromAft: double
+ OrigoFromCenter: double
+ OrigoFromKeel: double
+ Timestamp: timestamptz
SensorDataType
+ SensorDataId: UUID
+ Timestamp: timestamptz
SensorData
PositionDataType
+ Height: double
+ HeightAccuracy: double
+ LatitudeAccuracy: double
+ LongitudeAccuracy: double
+ Sigmas: double
+Position
0..*
«XSDcomplex...
Epc::PositionType
ShipParticularsType
+ ShipCoordinateSystem: CoordinatSystemType
+Beam
0..1
decimal
«XSDsimpleTy...
Epc::BeamType
+Length
0..1
decimal
«XSDsimpleTy...
Epc::
LengthOverallType

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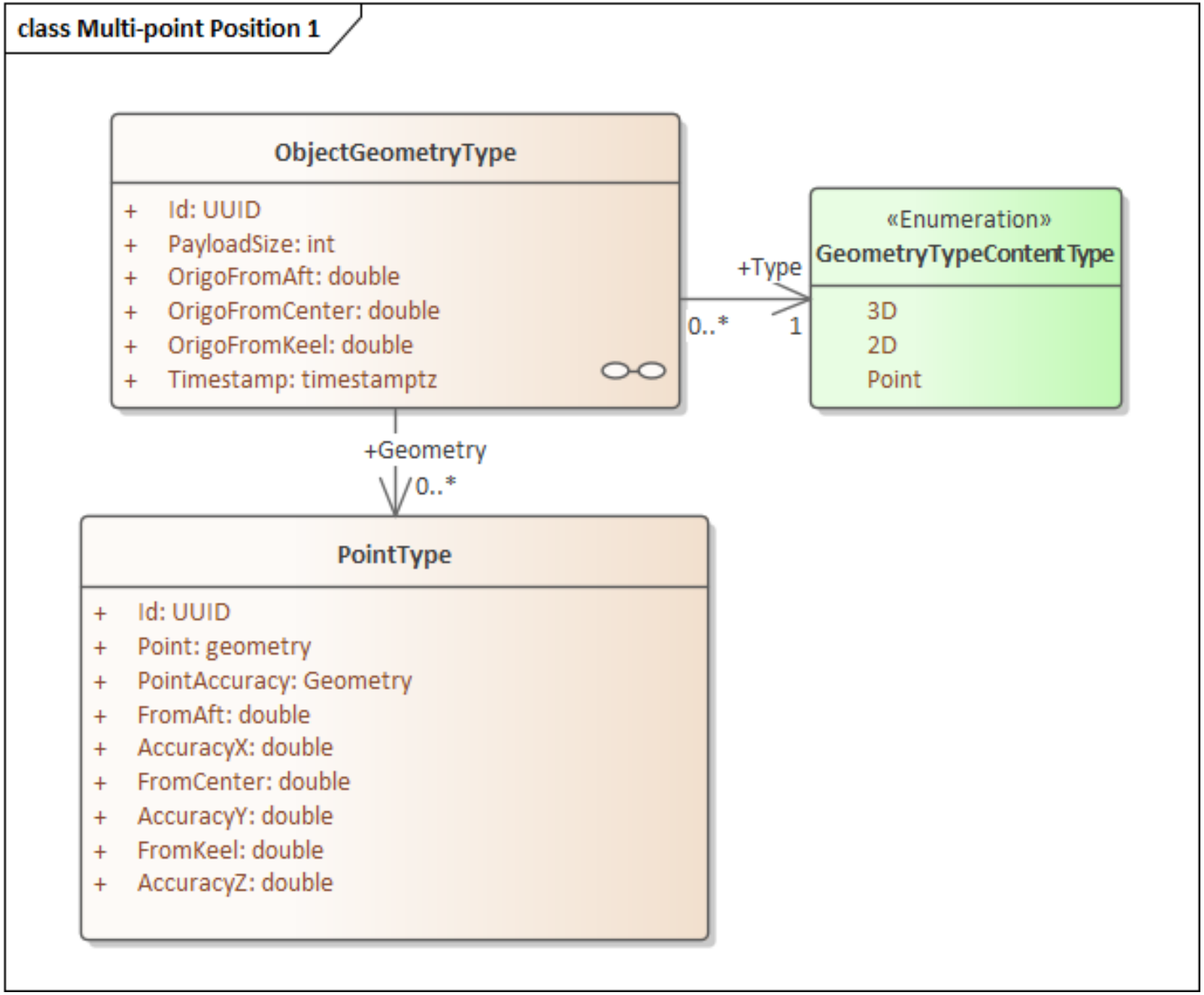
class Multi-point Position 1
ObjectGeometryType
+ Id: UUID
+ PayloadSize: int
+ OrigoFromAft: double
+ OrigoFromCenter: double
+ OrigoFromKeel: double
+ Timestamp: timestamptz
+Type
0..*
1
«Enumeration»
GeometryTypeContentType
3D
2D
Point
+Geometry
0..*
PointType
+ Id: UUID
+ Point: geometry
+ PointAccuracy: Geometry
+ FromAft: double
+ AccuracyX: double
+ FromCenter: double
+ AccuracyY: double
+ FromKeel: double
+ AccuracyZ: double

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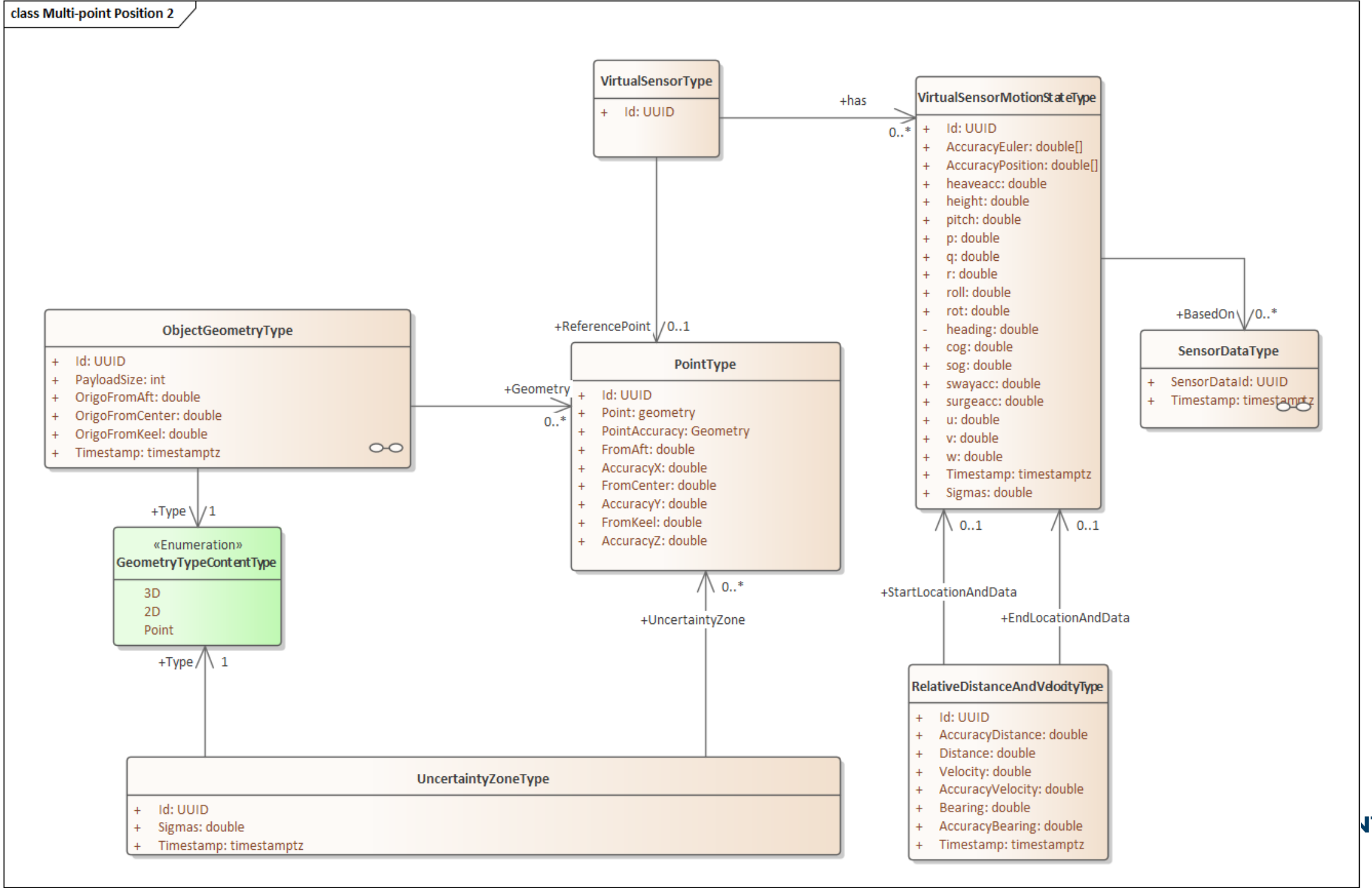
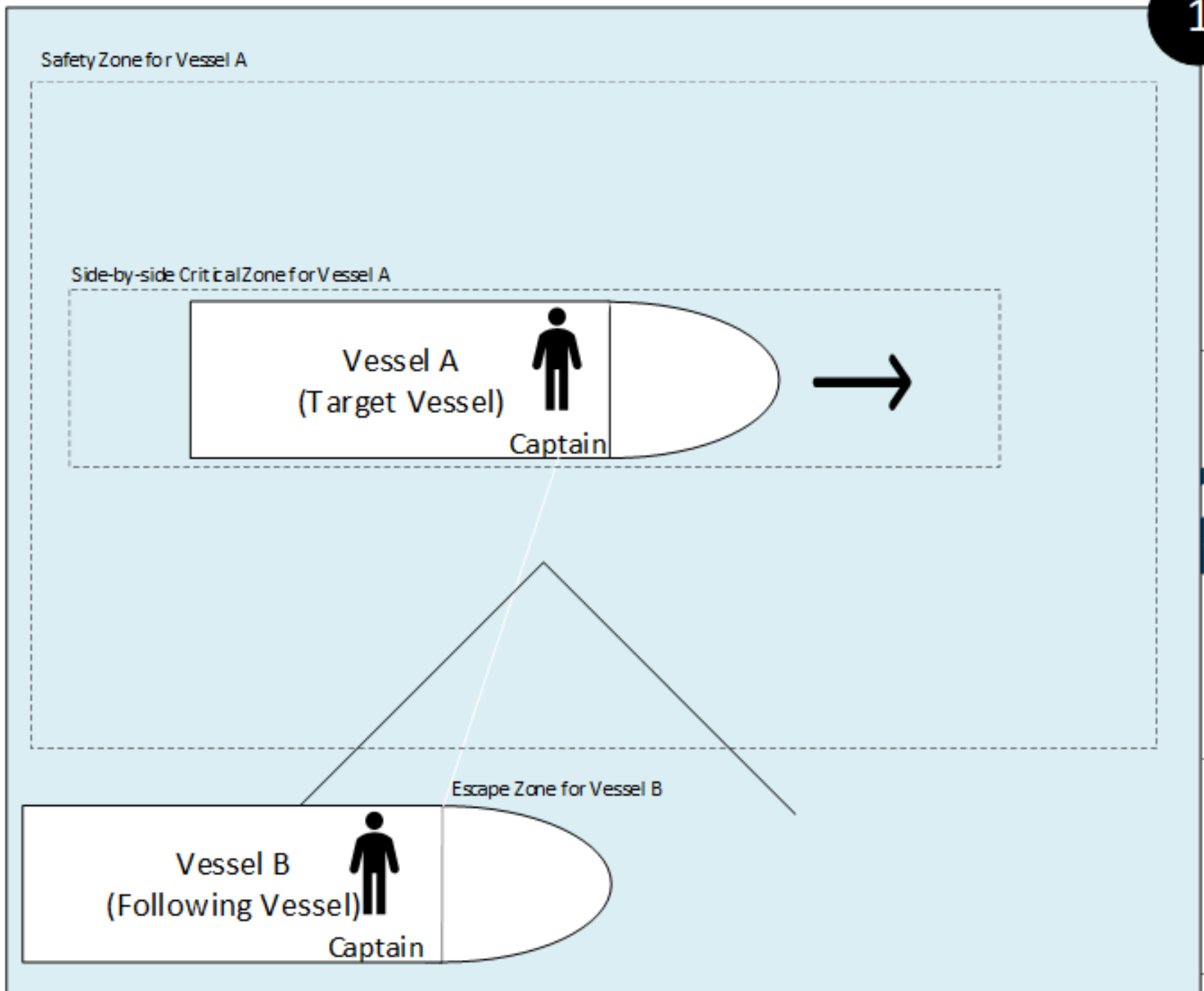

class Multi-point Position 2
VirtualSensorType
+ Id: UUID
+has
0..*
VirtualSensorMotionStateType
+ Id: UUID
+ AccuracyEuler: double[]
+ AccuracyPosition: double[]
+ heaveacc: double
+ height: double
+ pitch: double
+ p: double
+ q: double
+ r: double
+ roll: double
+ rot: double
- heading: double
+ cog: double
+ sog: double
+ swayacc: double
+ surgeacc: double
+ u: double
+ v: double
+ w: double
+ Timestamp: timestamptz
+ Sigmas: double
+BasedOn
0..*
SensorDataType
+ SensorDataId: UUID
+ Timestamp: timestamptz
+ReferencePoint
0..1
ObjectGeometryType
+ Id: UUID
+ PayloadSize: int
+ OrigoFromAft: double
+ OrigoFromCenter: double
+ OrigoFromKeel: double
+ Timestamp: timestamptz
+Geometry
0..*
PointType
+ Id: UUID
+ Point: geometry
+ PointAccuracy: Geometry
+ FromAft: double
+ AccuracyX: double
+ FromCenter: double
+ AccuracyY: double
+ FromKeel: double
+ AccuracyZ: double
+Type
1
«Enumeration»
GeometryTypeContentType
3D
2D
Point
+Type
1
0..*
+UncertaintyZone
0..1
0..1
+StartLocationAndData
+EndLocationAndData
RelativeDistanceAndVelocityType
+ Id: UUID
+ AccuracyDistance: double
+ Distance: double
+ Velocity: double
+ AccuracyVelocity: double
+ Bearing: double
+ AccuracyBearing: double
+ Timestamp: timestamptz
UncertaintyZoneType
+ Id: UUID
+ Sigmas: double
+ Timestamp: timestamptz

Operational Zones



Questions

- Taking into account the dynamic nature of the information related to Uncertainty Zones, and also that this is closely linked to autonomous functions, what considerations should be taken when integrating this into the S-100 framework?
- Which working group/forum is most appropriate to continue this work?

Related Activties – 1, Approximate Areas

- Input paper to DQWG, 2016: Modelling of Approximate Areas:
  - Difference 1: This considers modelling of geographical areas of navigational concerns that have some uncertainty
    - Example 1: Definition of a radio service area, where transmission is 100% is sone of the area, but have more uncertainty closer to the boundary
    - Example 2:Areas with probable occurences of North American right whales
  - Difference 2: Not real-time data, even if it is not static
  - Difference 3: Related to geographical areas, not to ships or quays, locks, etc.
  - Difference 4: Only ship-shore communication needed, not ship-ship
  - Similarity1: Both need to cover uncertainty of the data

Related Activities – 2, IMO Reference Data Model

- https://www.unece.org/fileadmin/DAM/cefact/LOCODE-AdvisoryGroup/2019_ThirdMeeting/PPT_3_IMO-FAL-project_October2018.pdf
- IMO reference data model:
- http://www.imo.org/en/OurWork/Facilitation/Pages/IMOCompendium.aspx
- Need common definition of operational data, for instance for ship particulars (call sign, MMSI, length, width, draught, etc)
- Which product specification to use for operational data?

Related Standard -3: S-421 Route Exchange

- Similarities: Two-ways communication between ships
- Difference:
  - Not exchange of routes, but of multi-point positions
  - Real-time requirements

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