Towards ontology patterns for ocean science repository integration

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The presented work is part of the NSF *OceanLink* project: EarthCube Building Blocks, Leveraging Semantics and Linked Data for Geoscience Data Sharing and Discovery

OceanLink and EarthCube

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EarthCube:

Developing a Community-Driven Data and Knowledge Environment for the Geosciences

“concepts and approaches to create integrated data management infrastructures across the Geosciences.”

“EarthCube aims to create a well-connected and facile environment to share data and knowledge in an open, transparent, and inclusive manner, thus accelerating our ability to understand and predict the Earth system.”

OceanLink

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Bottom-up constructed project.

Currently first phase:

- **Integrating ocean science respositories BCO-DMO and R2R, as well as datasets from the WHOI Library, AGU abstracts, NSF projects.**
- **Demonstrable added value (faceted integrated search).**
- **Key: extensible architecture that has the potential to grow to EarthCube size**

Logic

Many axioms / strong theory

Few models

Many inferences

Few axioms / weak theory

Many models

Few inferences

Ontologies

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Strong / many ontological commitments

Few models

Many inferences

Not very reusable

Many models

Few inferences

More easily reusable

Weak / few ontological commitments

Ontology Design Patterns

Strong / many ontological commitments

Few models

Many inferences

Not very reusable

Weak / few ontological commitments

Many models

Few inferences

More easily reusable

Ontology Design Patterns

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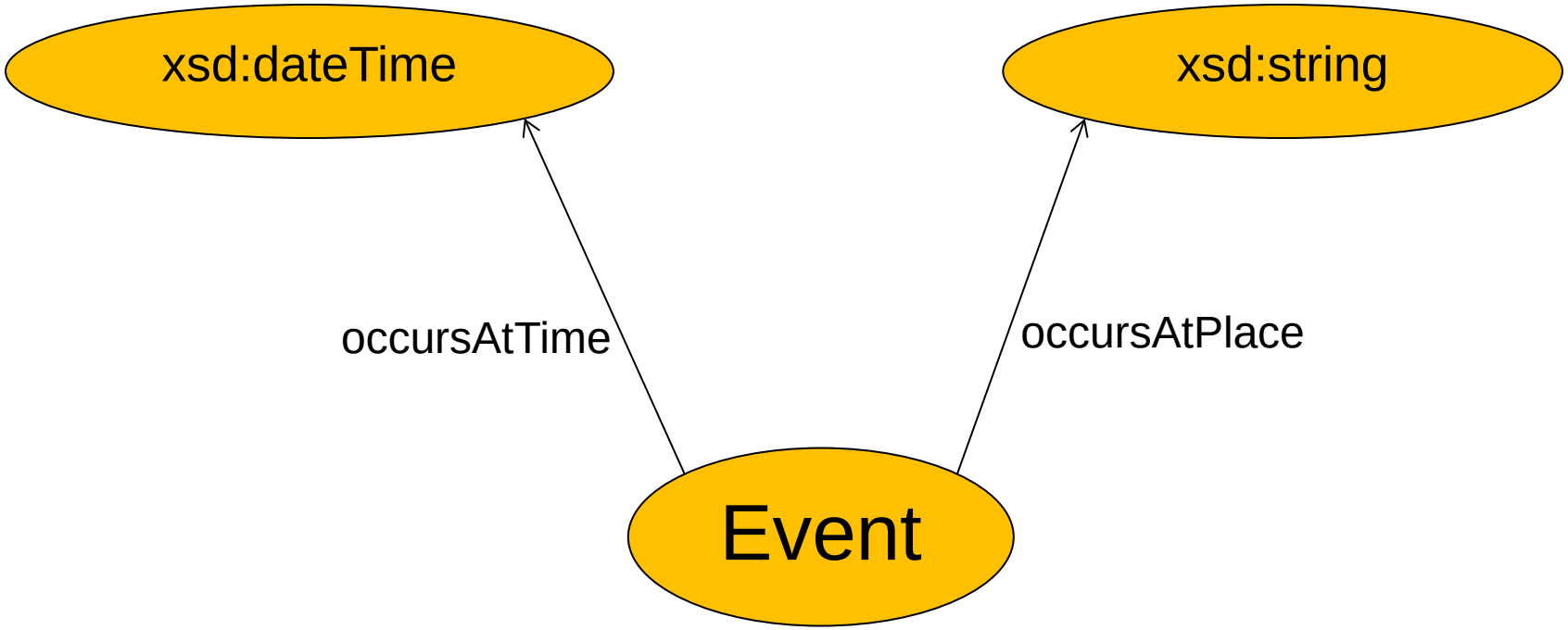
“An ontology design pattern is a reusable successful solution to a recurrent modeling problem.”

So-called *content patterns* usually encode specific abstract notions, such as process, event, agent, etc.

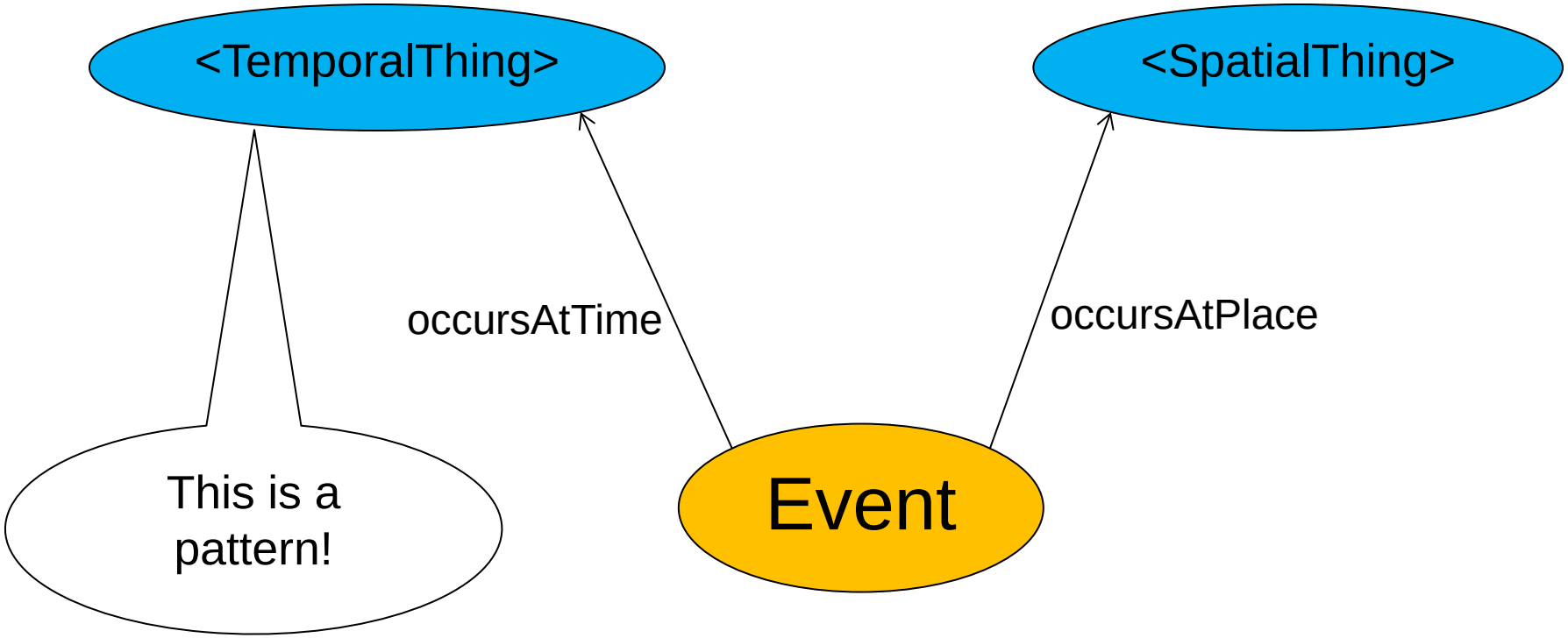
E.g., “Event”



$$\text{Event} \sqsubseteq \text{occursAtTime.xsd:dateTime}$$

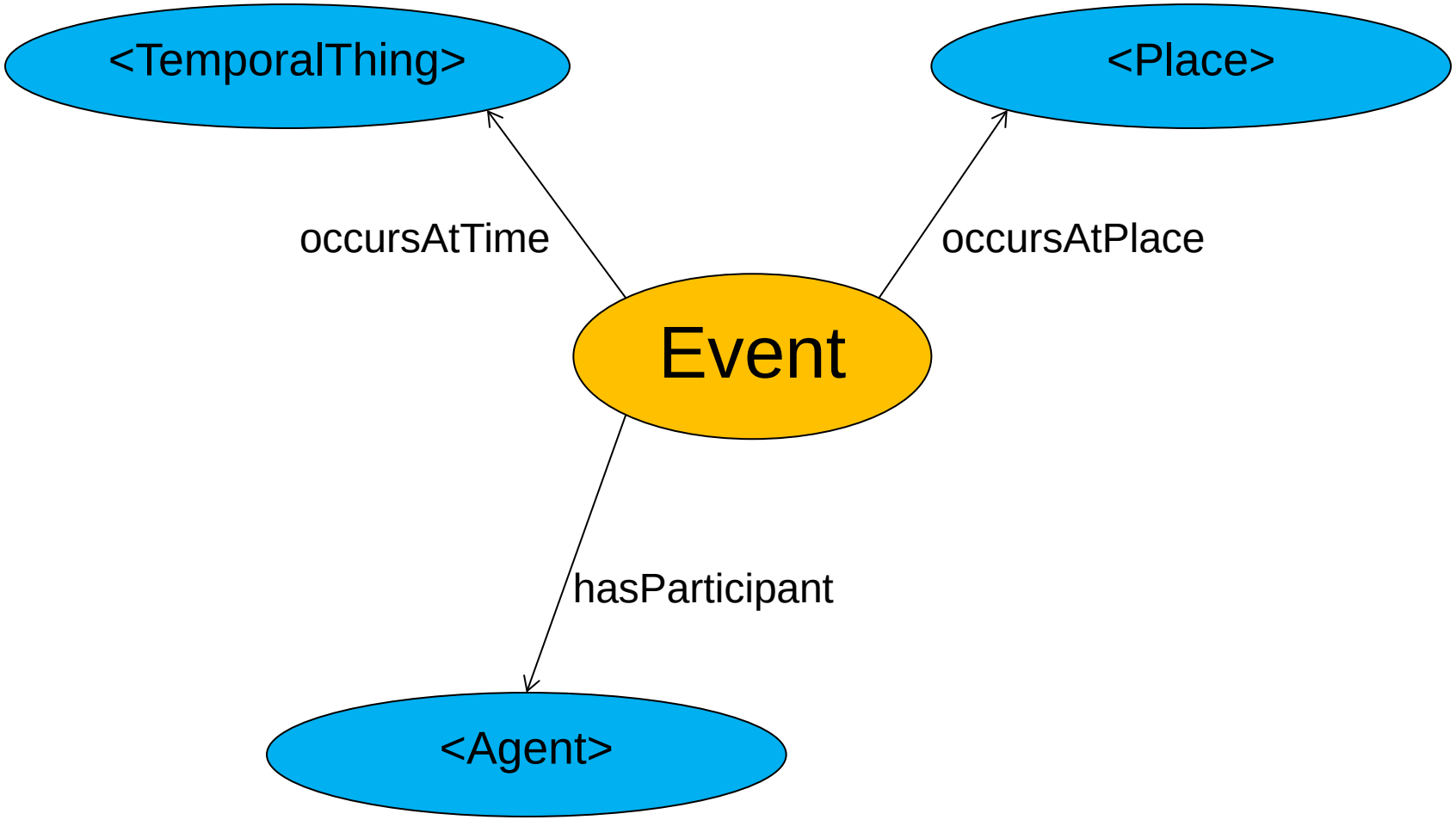
$$\text{Event} \sqsubseteq \text{occursAtPlace.xsd:string}$$

Better Event (more general)

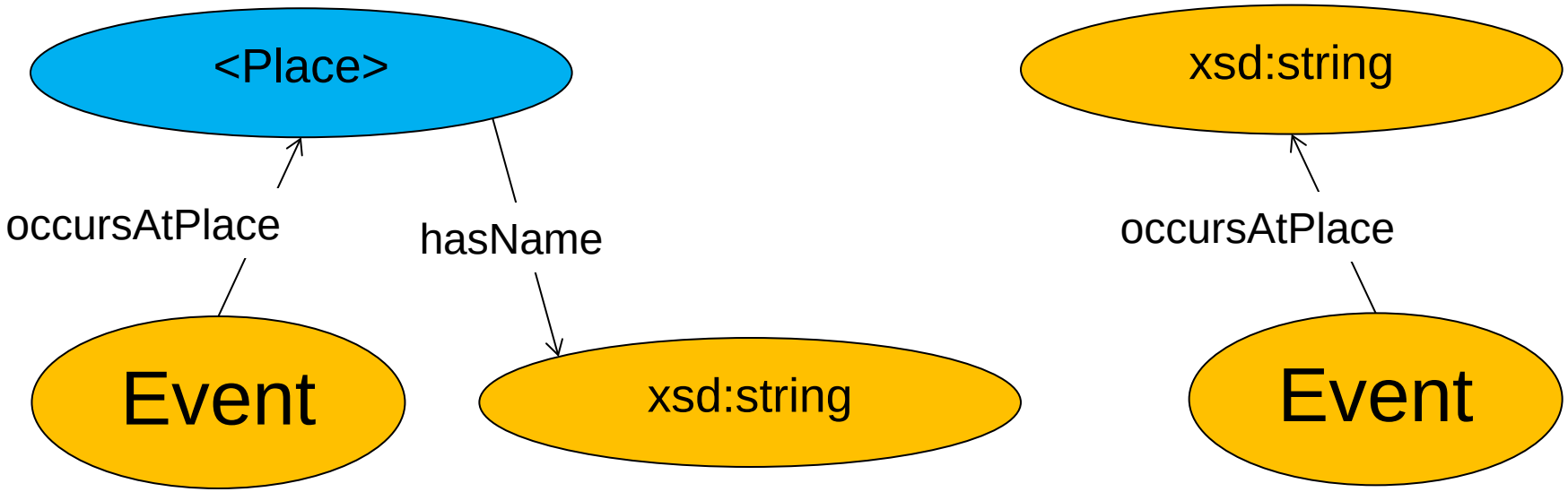


But what about events taking place in Second Life?

Perhaps even …



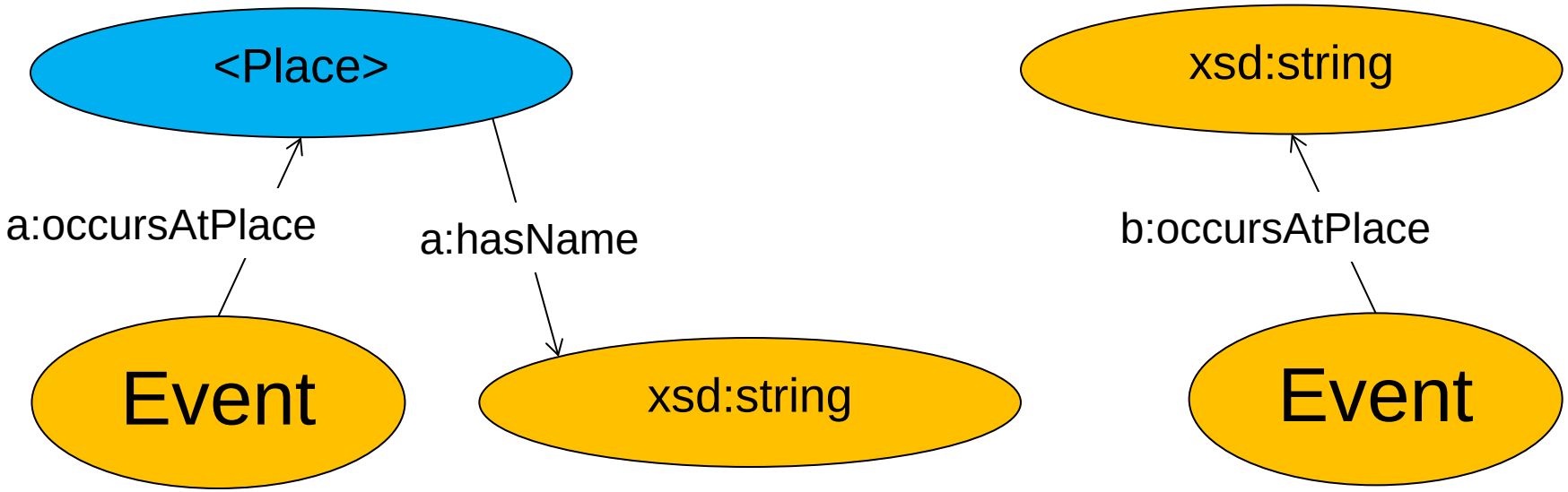
Shortcuts / views



$$\text{occursAtPlace} \circ \text{hasName} \equiv \text{occursAtPlace}$$

There are several things wrong here!

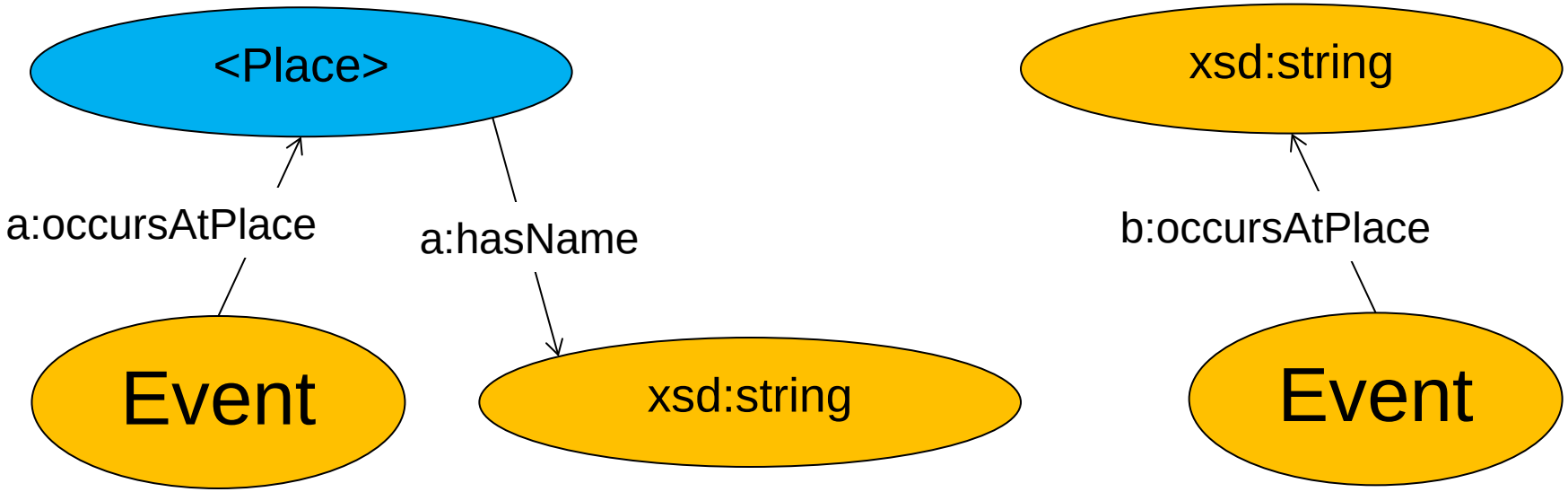
Shortcuts / views



$$\text{a:occursAtPlace} \circ \text{a:hasName} \equiv \text{b:occursAtPlace}$$

Better, but …

Shortcuts / views

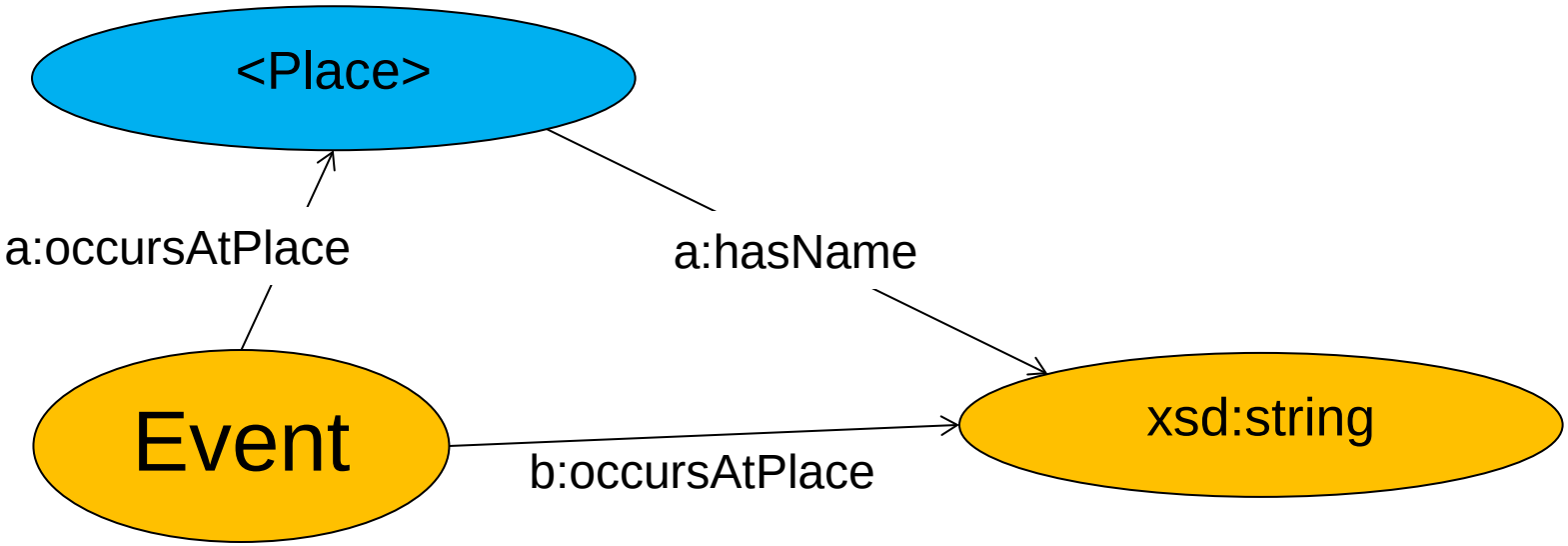


$$\text{a:occursAtPlace} \circ \text{a:hasName} \sqsubseteq \text{b:occursAtPlace}$$

$$\text{a:occursAtPlace} \circ \text{a:hasName} \sqsupseteq \text{b:occursAtPlace}$$

The latter is not in OWL!

Shortcuts / views



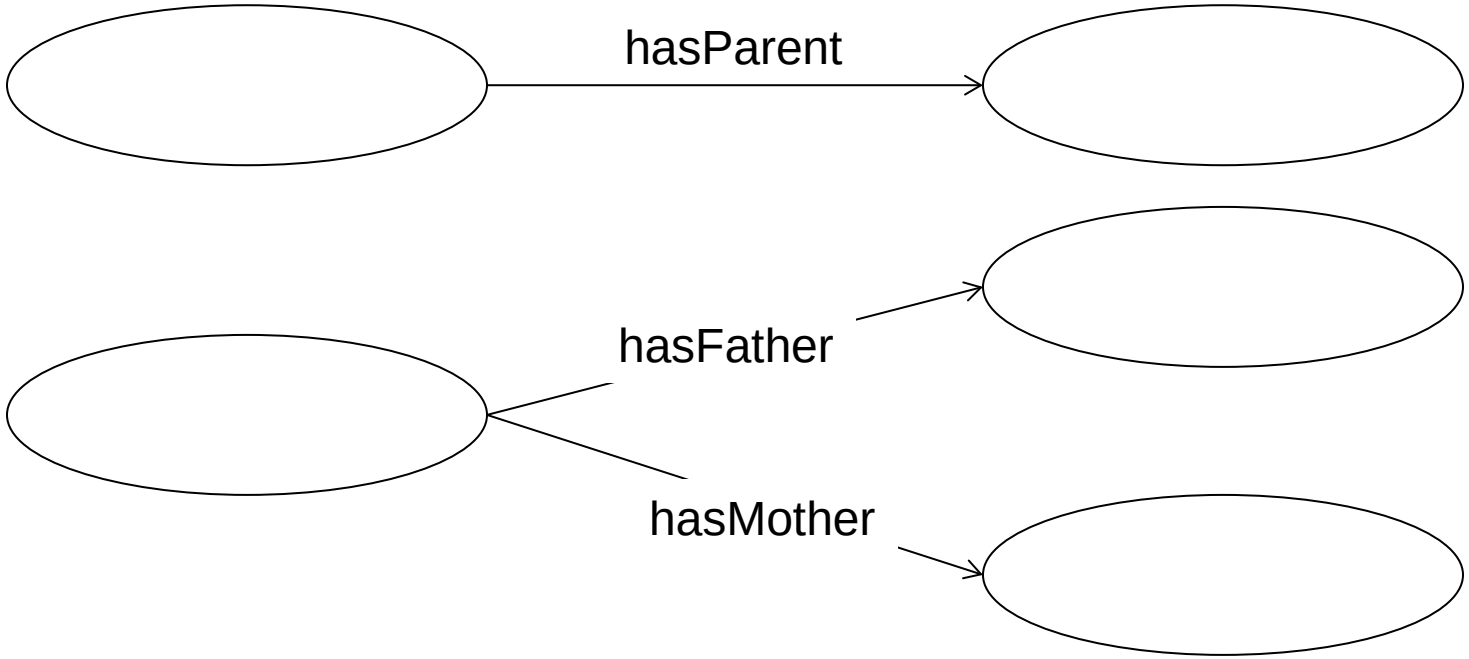
$$\text{a:occursAtPlace} \circ \text{a:hasName} \sqsubseteq \text{b:occursAtPlace}$$

$$\text{a:occursAtPlace} \circ \text{a:hasName} \sqsupseteq \text{b:occursAtPlace}$$

The latter is not in OWL!

Similar problem

Splitting a role:



$$\text{hasFather} \sqsubseteq \text{hasParent}$$

$$\text{hasMother} \sqsubseteq \text{hasParent}$$

$$\text{hasParent} \sqsubseteq \text{hasFather} \sqcup \text{hasMother}$$

Cruise

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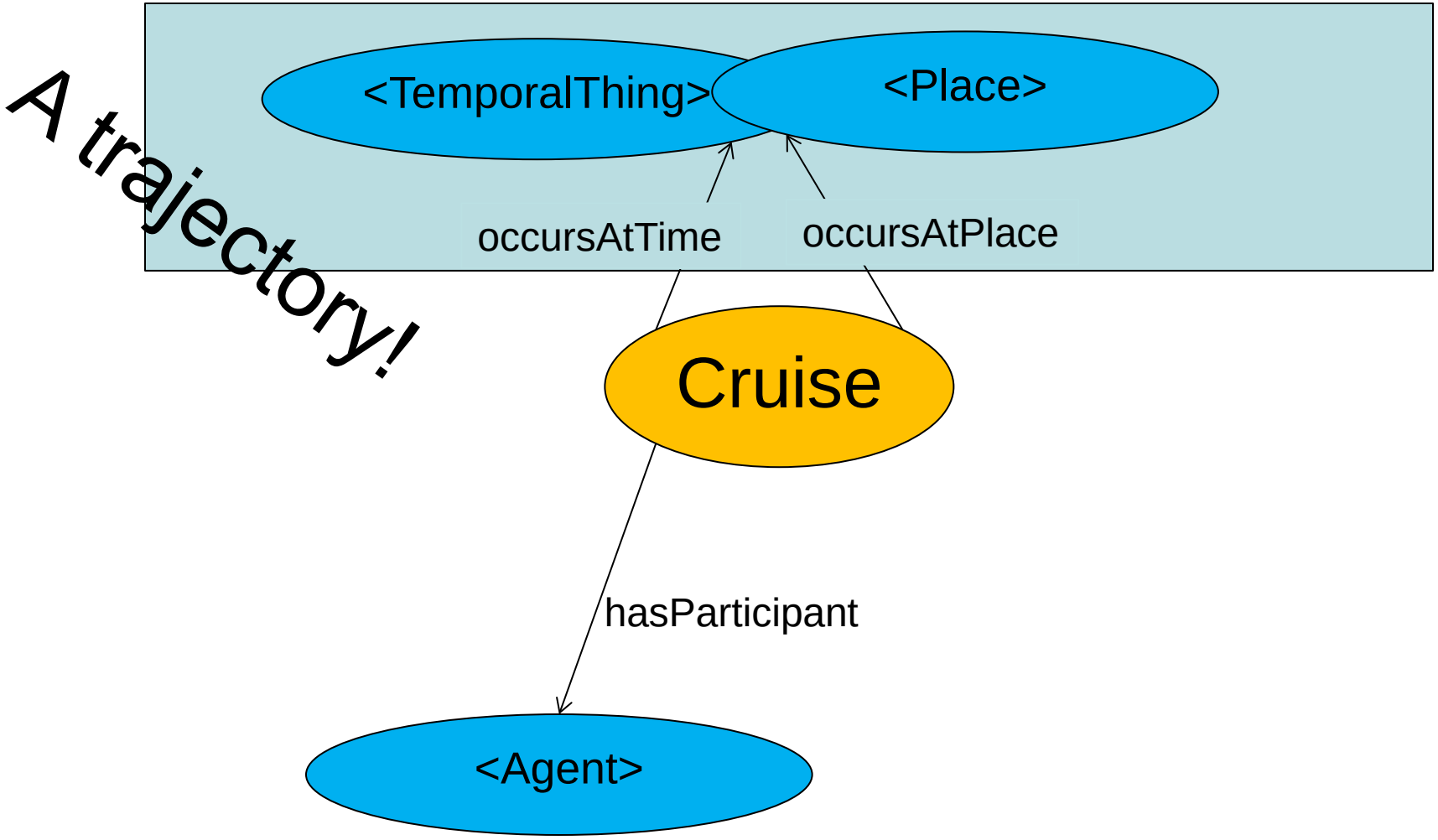
For us: *ocean science cruise*.

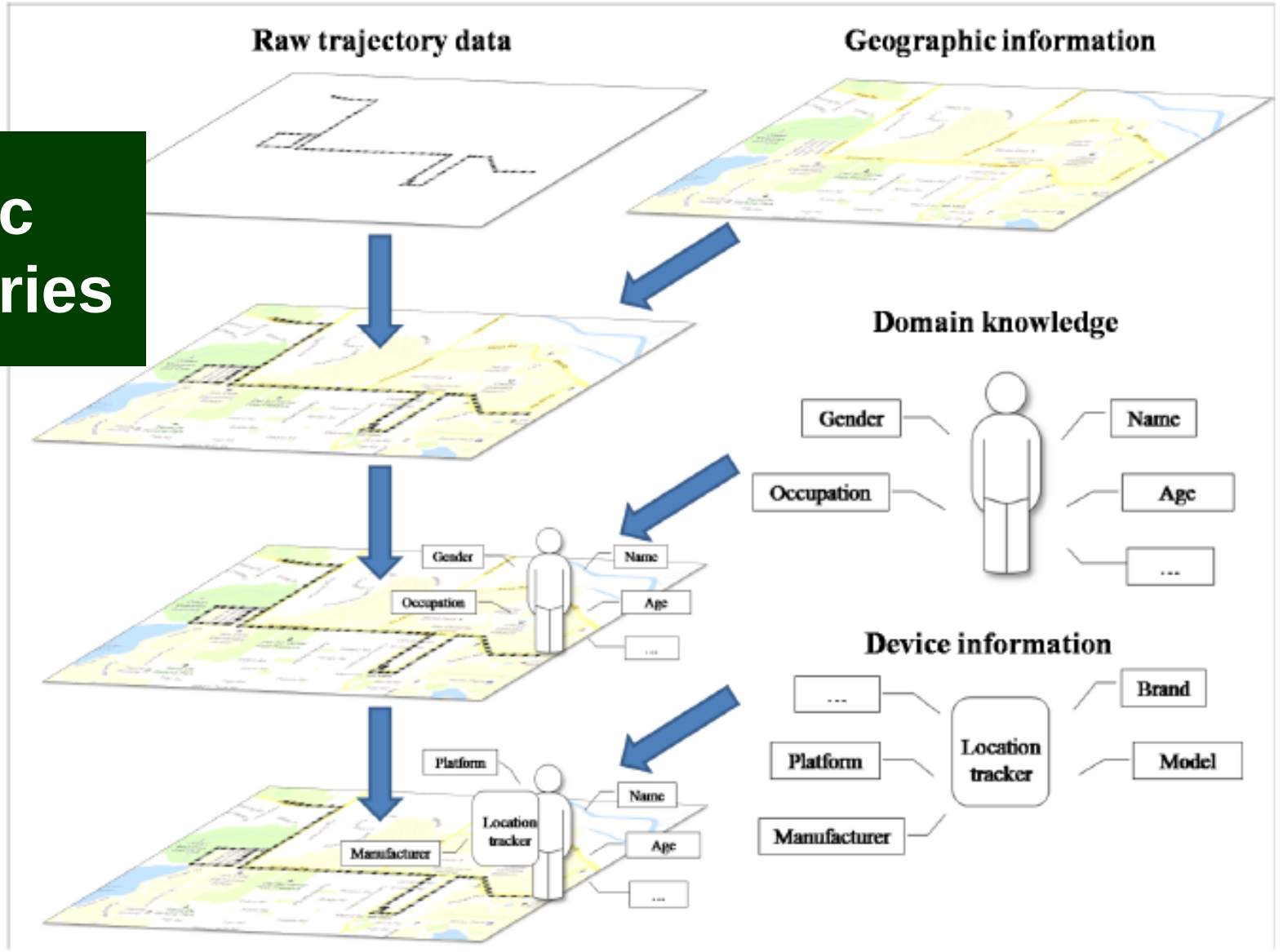
A cruise is a type of event.

But what kind of place does it occur at?

Cruise


A trajectory!
<TemporalThing>
<Place>
occursAtTime
occursAtPlace
Cruise
hasParticipant
<Agent>

Semantic Trajectories



[Hu, Janowicz, Carral, Scheider, Kuhn, Berg-Cross, Hitzler, Dean, COSIT2013]

Semantic Trajectories

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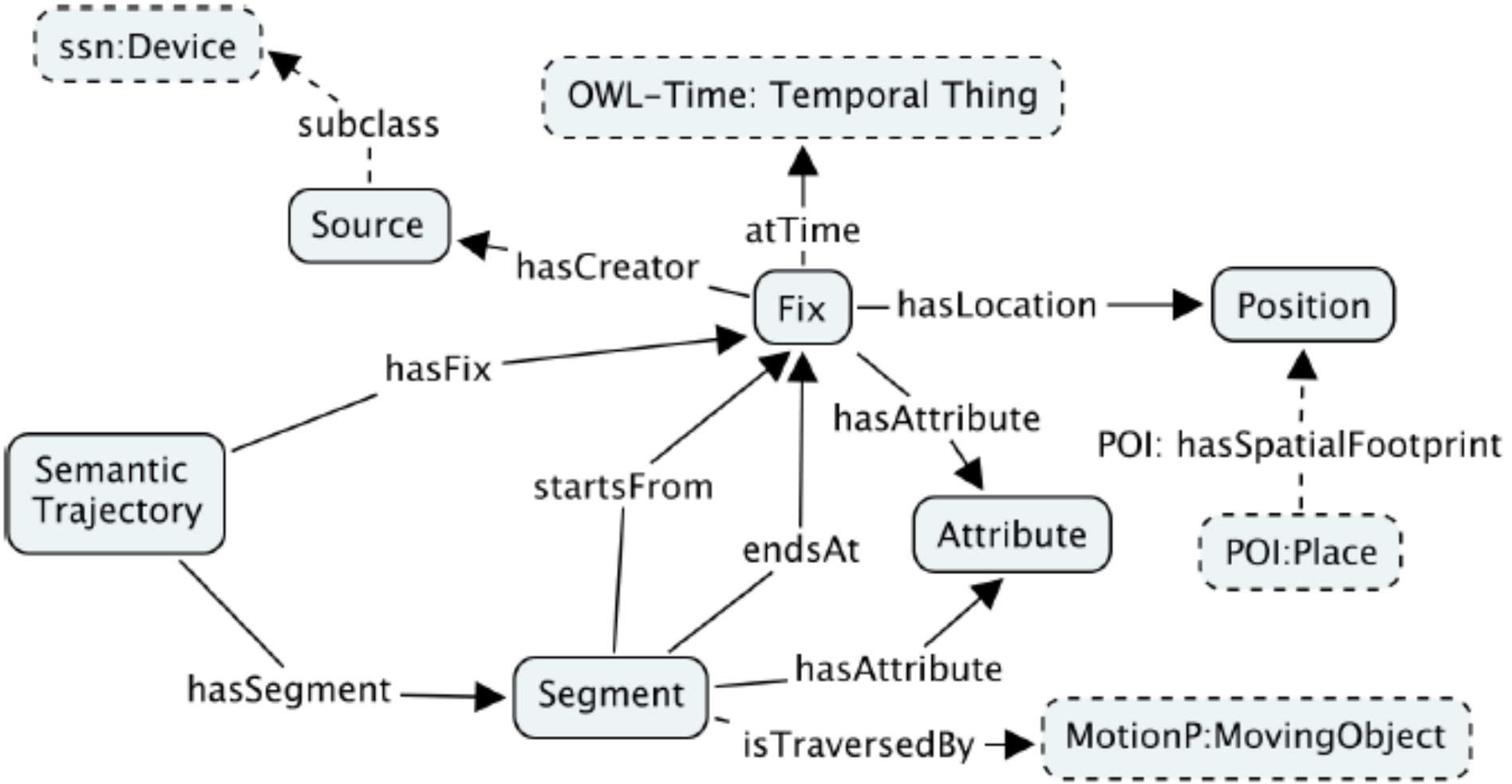

Semantics in OWL

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$$Fix \sqsubseteq \exists atTime.OWL\text{-}Time{:}Temporal\ \ Thing \sqcap \exists hasLocation.Position \sqcap \exists hasFix^{-}.SemanticTrajectory \quad (1)$$

$$Segment \sqsubseteq \exists startsFrom.Fix \sqcap \exists endsAt.Fix \quad (2)$$

$$\top \sqsubseteq \leq 1 startsFrom.\top \quad (3)$$

$$\top \sqsubseteq \leq 1 endsAt.\top \quad (4)$$

$$Segment \sqsubseteq \exists hasSegment^{-}.SemanticTrajectory \quad (5)$$

$$startsFrom^{-} \circ endsAt \sqsubseteq hasNext \quad (6)$$

$$hasNext \sqsubseteq hasSuccessor \quad (7)$$

$$hasSuccessor \circ hasSuccessor \sqsubseteq hasSuccessor \quad (8)$$

$$hasNext^{-} \sqsubseteq hasPrevious \quad (9)$$

$$hasSuccessor^{-} \sqsubseteq hasPredecesor \quad (10)$$

Semantics in OWL

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$$Fix \sqcap \neg \exists endsAt.Segment \sqsubseteq StartingFix \quad (11)$$

$$Fix \sqcap \neg \exists startsFrom.Segment \sqsubseteq EndingFix \quad (12)$$

$$Segment \sqcap \exists startsFrom.StartingFix \sqsubseteq StartingSegment \quad (13)$$

$$Segment \sqcap \exists endsAt.EndingFix \sqsubseteq EndingSegment \quad (14)$$

$$SemanticTrajectory \sqsubseteq \exists hasSegment.Segment \quad (15)$$

$$hasSegment \circ startsFrom \sqsubseteq hasFix \quad (16)$$

$$hasSegment \circ endsAt \sqsubseteq hasFix \quad (17)$$

$$\exists hasSegment.Segment \sqsubseteq SemanticTrajectory \quad (18)$$

$$\exists hasSegment^{-}.SemanticTrajectory \sqsubseteq Segment \quad (19)$$

$$\exists hasFix.Segment \sqsubseteq SemanticTrajectory \quad (20)$$

$$\exists hasFix^{-}.SemanticTrajectory \sqsubseteq Fix \quad (21)$$

Ocean Science Cruise (draft)

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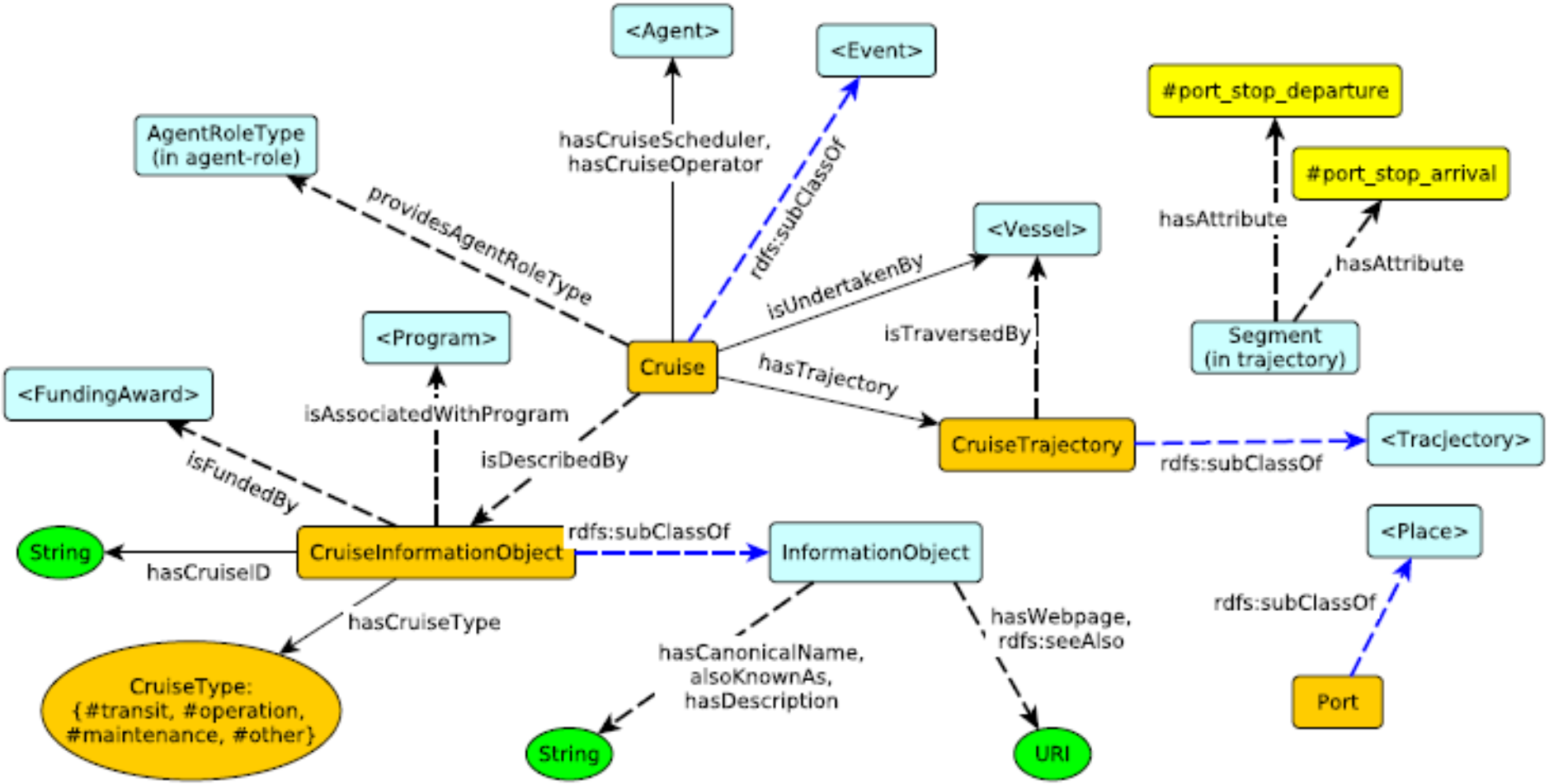

Cruise trajectory (draft)

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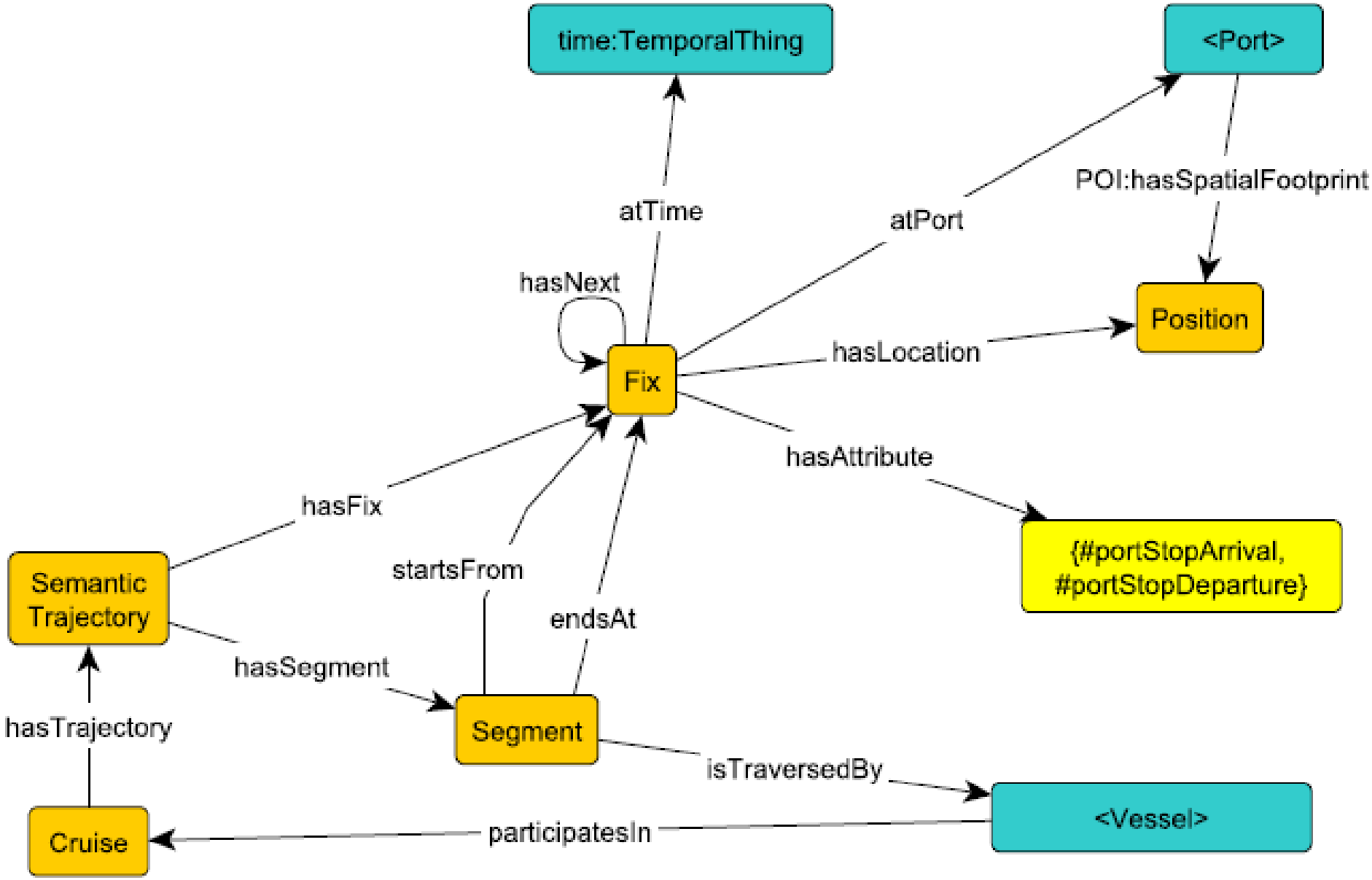

Cruise trajectory

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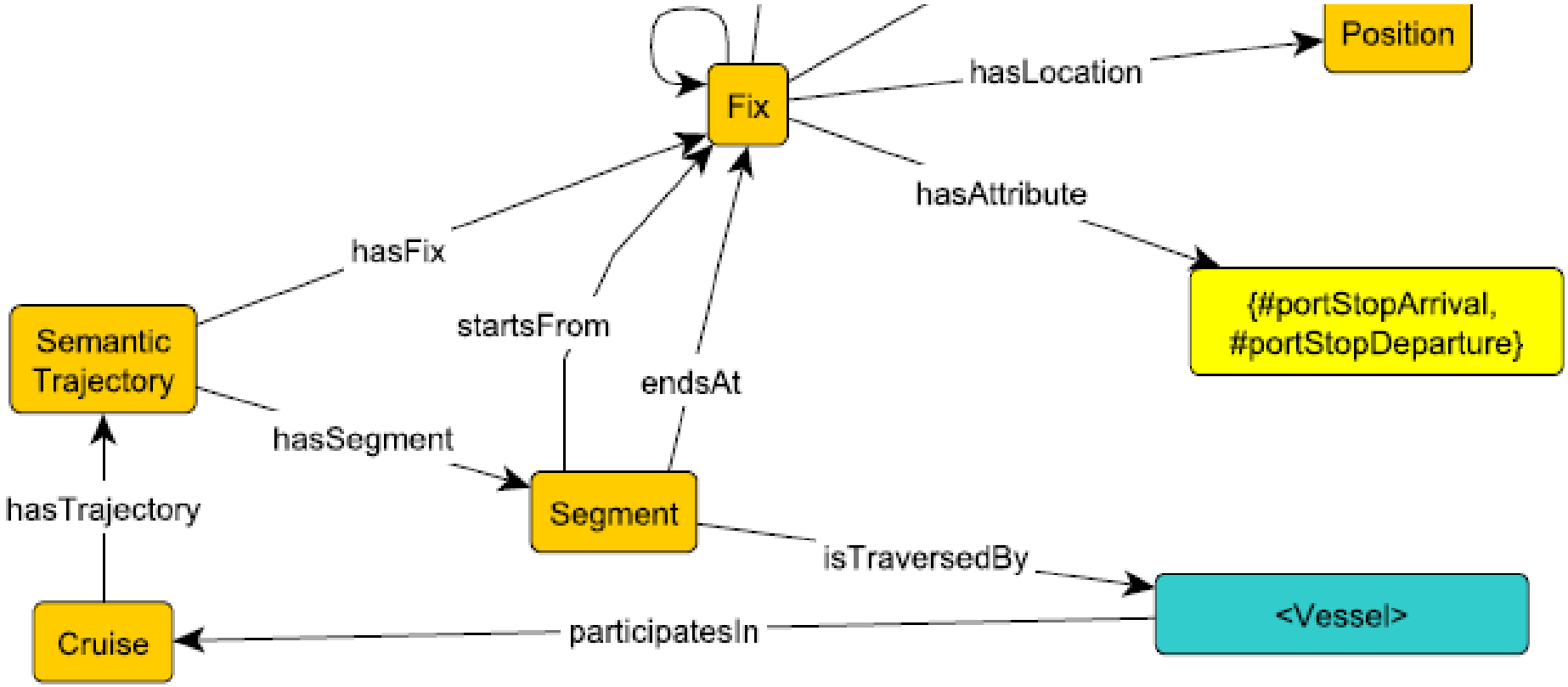
$$\text{Cruise}(x) \wedge \text{hasTrajectory}(x, y)$$
$$\wedge\, \text{hasSegment}(y, z) \wedge \text{isTraversedBy}(z, v)$$
$$\rightarrow \text{participatesIn}(v, z)$$



Cruise trajectory

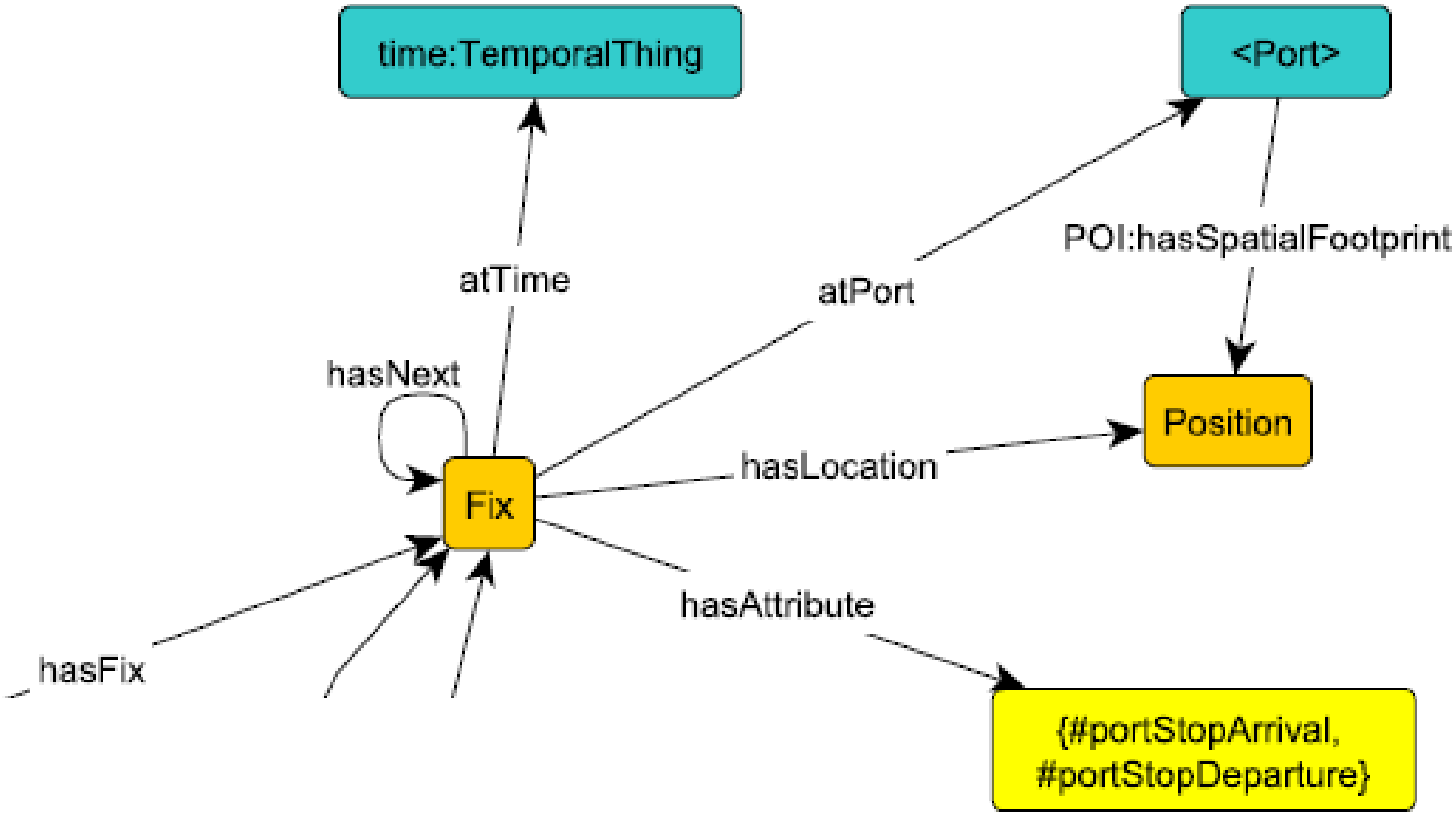
$$\mathrm{Cruise}(x) \wedge \mathrm{hasTrajectory}(x, y) \wedge \mathrm{hasSegment}(y, z) \wedge \mathrm{isTraversedBy}(z, v) \rightarrow \mathrm{participatesIn}(v, z)$$

$$\mathrm{Cruise} \equiv \exists \mathrm{cruise}.\mathrm{Self}$$

$$\mathrm{cruise} \circ \mathrm{hasTrajectory} \circ \mathrm{hasSegment} \circ \mathrm{isTraversedBy} \sqsubseteq \mathrm{hasParticipant}$$

$$\mathrm{hasParticipant} \equiv \mathrm{participatesIn}^{-}$$

Cruise trajectory



$$\mathrm{Fix}(x) \wedge \mathrm{hasAttribute}(x, \#\mathrm{portStopArrival})$$
$$\wedge\, \mathrm{atPort}(x, y) \wedge \mathrm{hasSpatialFootprint}(y, z)$$
$$\wedge\, \mathrm{hasLocation}(x, w) \rightarrow \mathrm{locatedIn}(w, z)$$

Cruise trajectory

$$\mathrm{Fix}(x) \wedge \mathrm{hasAttribute}(x, \#\mathrm{portStopArrival}) \wedge \mathrm{atPort}(x, y) \wedge \mathrm{hasSpatialFootprint}(y, z) \wedge \mathrm{hasLocation}(x, w) \rightarrow \mathrm{locatedIn}(w, z)$$

$$\mathrm{Fix} \wedge \exists \mathrm{hasTrajectory}.\{\#\mathrm{portStopArrival}\} \equiv \exists \mathrm{fixps}.\mathrm{Self} \sqsubseteq \mathrm{hasLocation}^{-} \circ \mathrm{fixps} \circ \mathrm{atPort} \circ \mathrm{hasSpatialFootprint} \sqsubseteq \mathrm{locatedIn}$$

Why ODPs?

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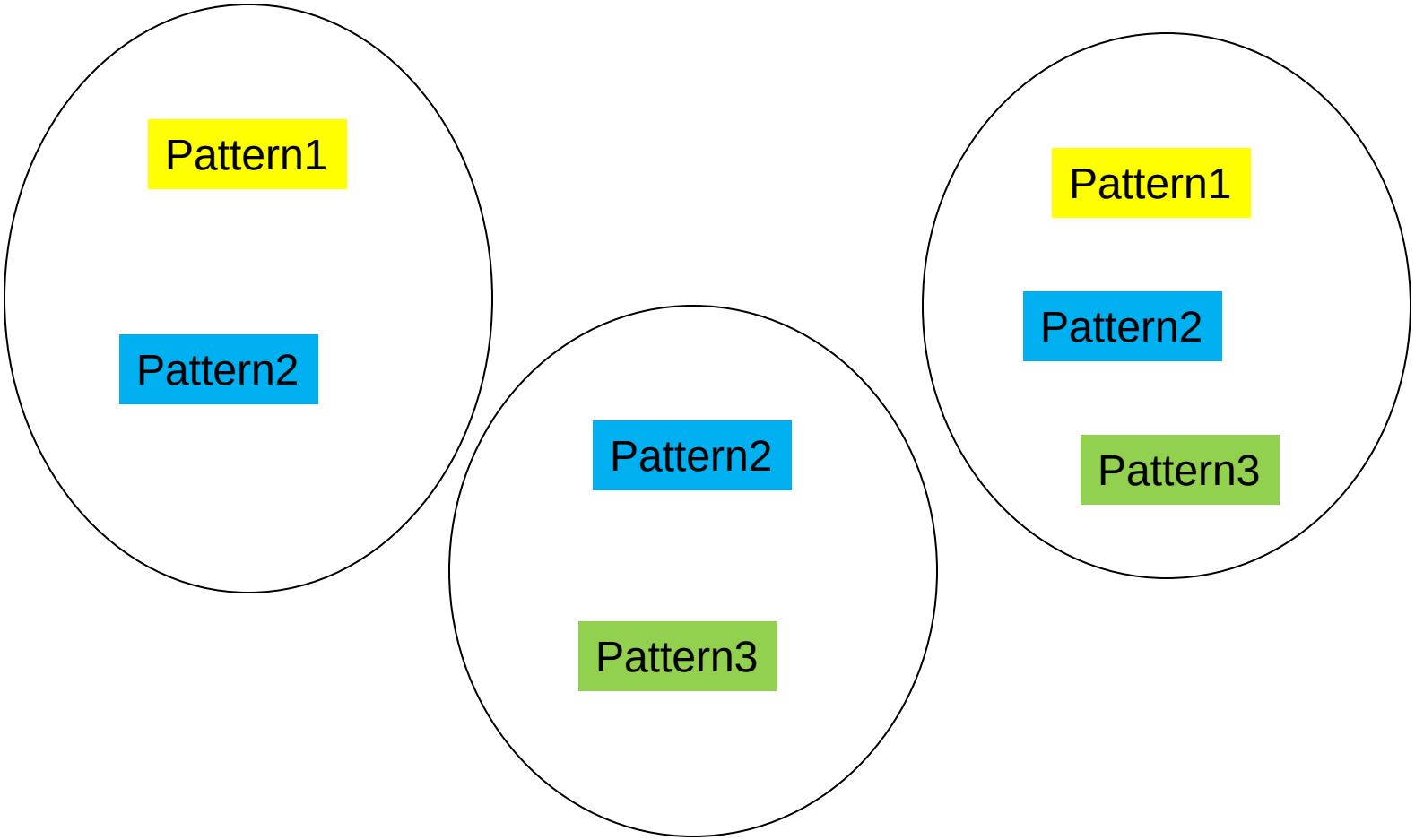
Traditionally, ODPs are thought of as building blocks for ontology modeling.

This idea is certainly valid in the context of special purpose ontology-based systems.

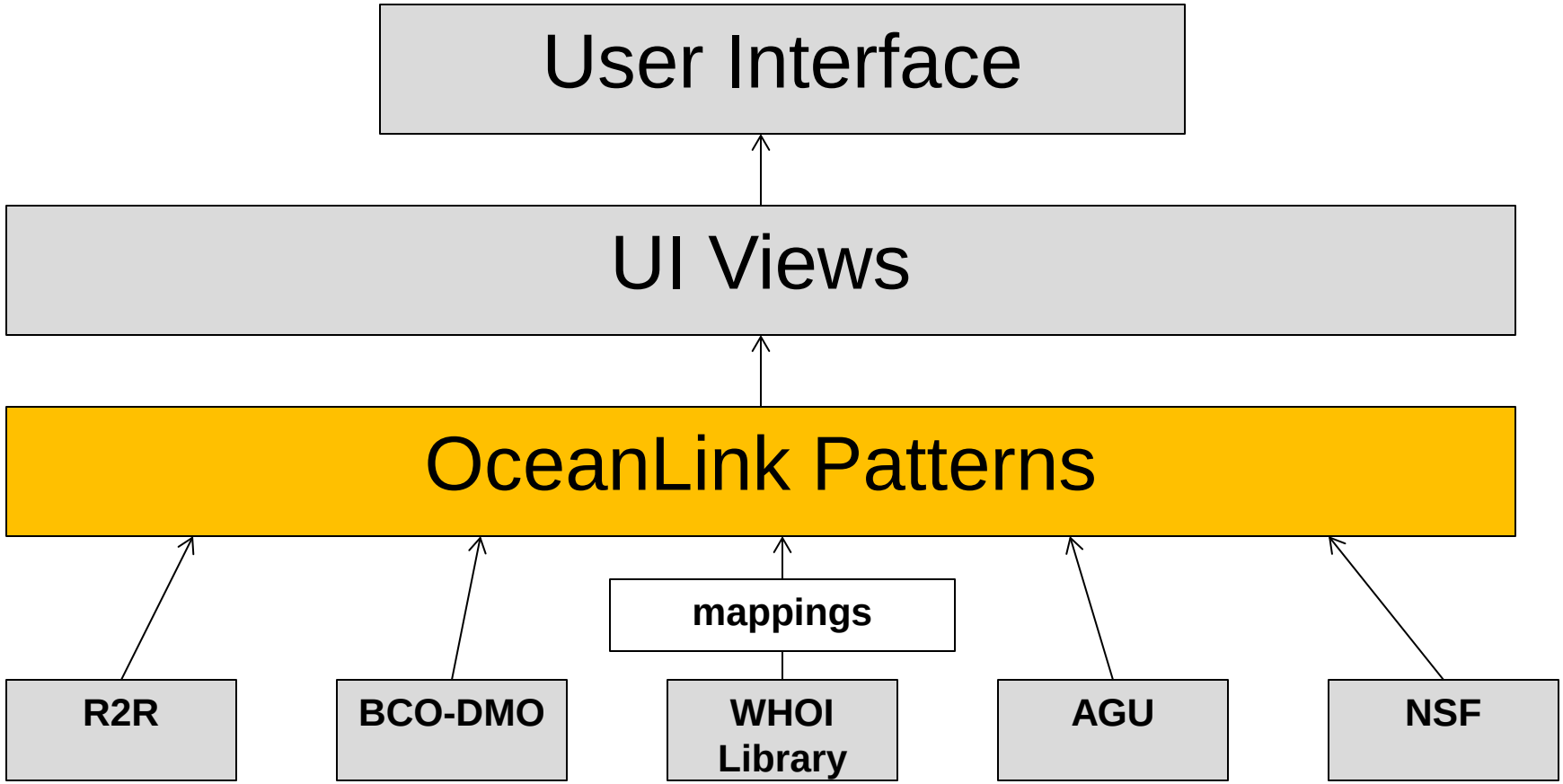
However, it can be argued that ODPs can be much more than mere building blocks.

Horizontal alignment



“Horizontal” alignment via patterns

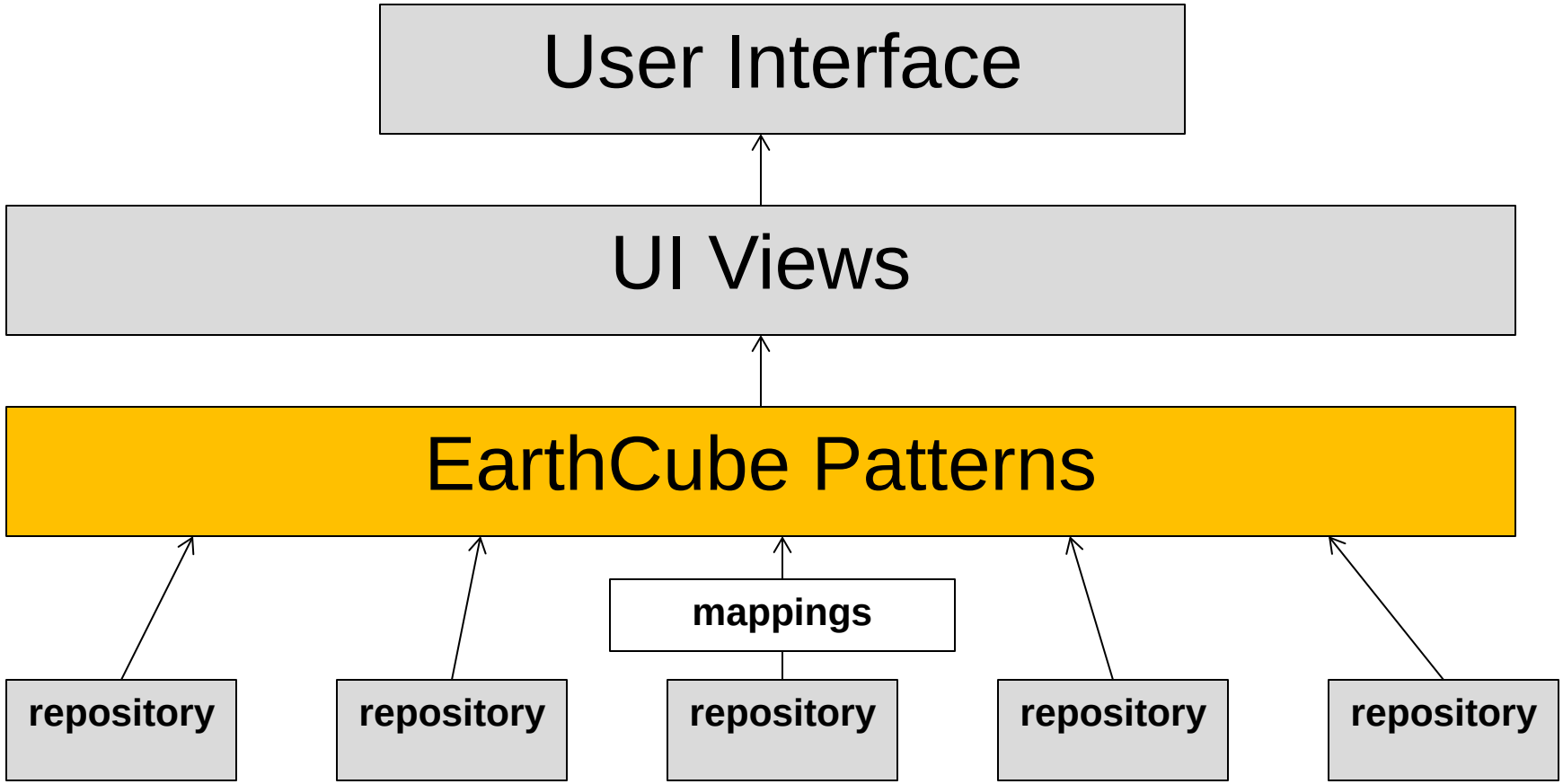
OceanLink setup



Other added values of patterns

- Pattern-driven GUIs
- Pattern-driven mapping tools
- Pattern-driven query rewriting
- Pattern-driven reasoning modularization
- …

OceanLink setup



Thanks!

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