PR-OWL 2 Case Study: A Maritime Domain Probabilistic Ontology

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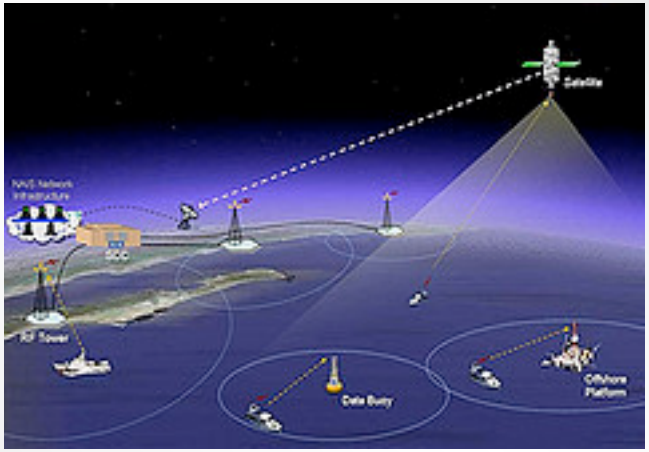
Maritime Domain Awareness

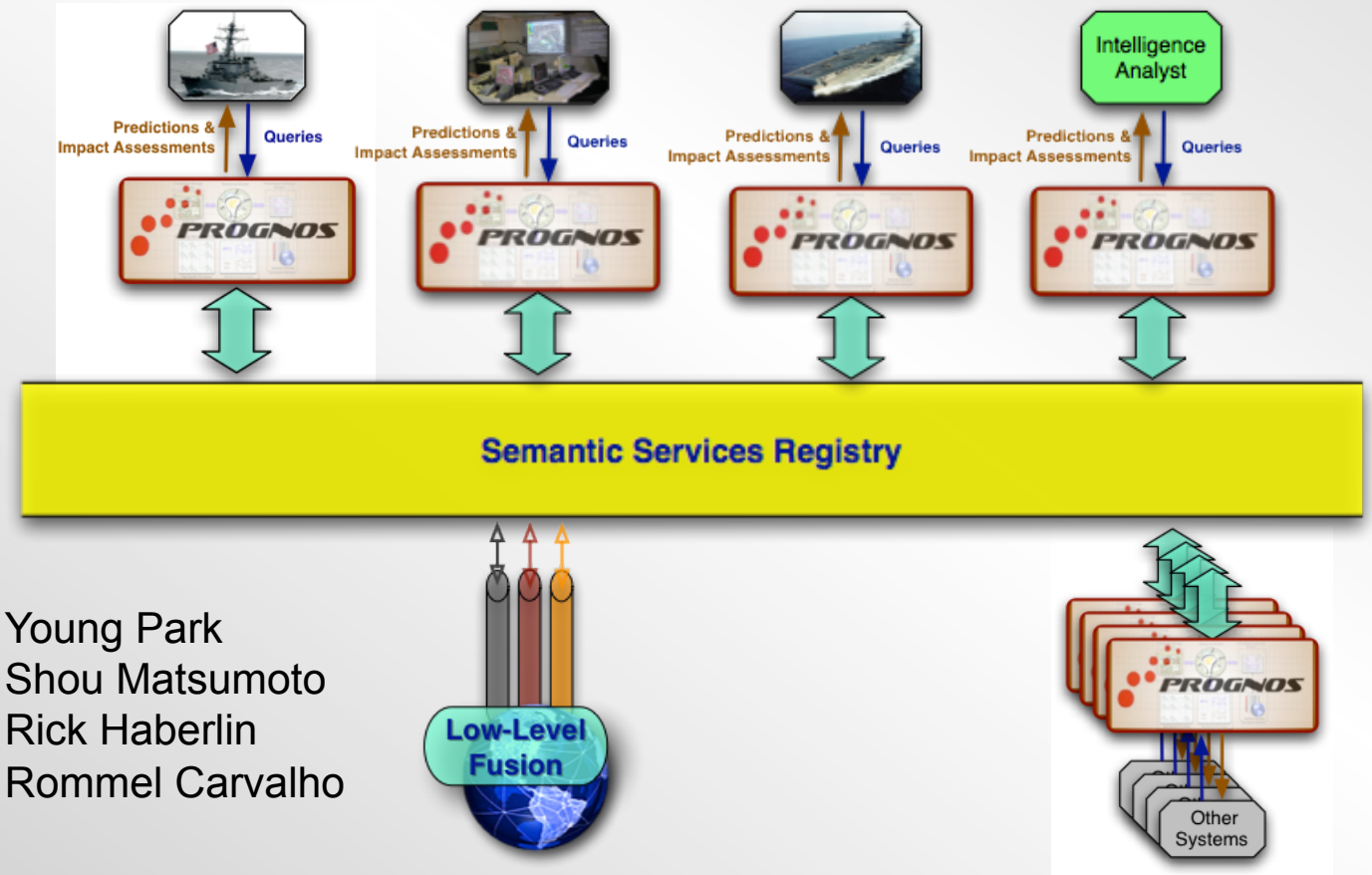
- "Effective understanding of anything associated with the maritime domain that could impact the security, safety, economy or environment"
  - National Plan to Achieve Maritime Domain Awareness

★ *Current technology uses stovepiped systems to provide low-level fusion*
★ *Humans are responsible for high-level fusion*
★ *Cognitive overload limits effectiveness*



PROGNOS

ONR-sponsored research project to provide high-level fusion for predictive situational awareness in maritime domains



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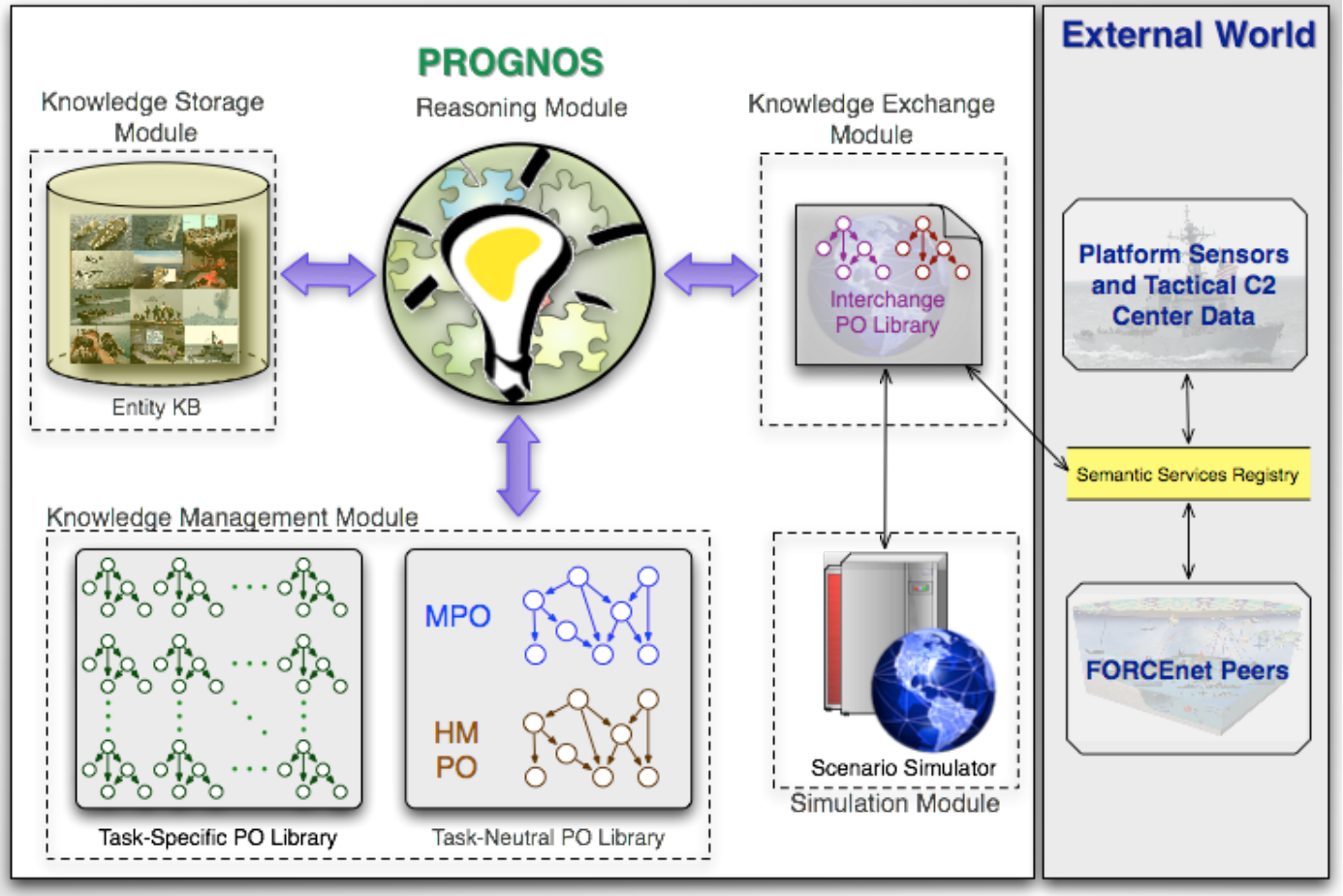
Architecture Components

* Interchange POs to provide interoperability with FORCENet and external systems
* Reasoning module to accrue evidence and perform fusion
* Internal entity storage module in FORCENet format
* Task-specific POs for optimal mission-based inferences
* Domain-agnostic PO library in support to general reasoning and hypothesis management.
* Simulation module for both system training and evaluation



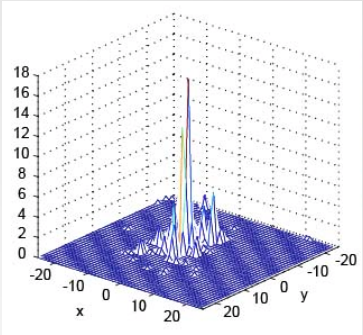
Uncertainty is Ubiquitous

- There are many kinds of uncertainty, including:
  - Noise in sensors
  - Intrinsic unpredictability of complex processes
  - Incorrect, incomplete, deceptive intelligence reports
  - Poor understanding of cause and effect relationships
- Representing and reasoning with uncertainty is essential
- Traditional semantic technology provides no support for uncertainty management

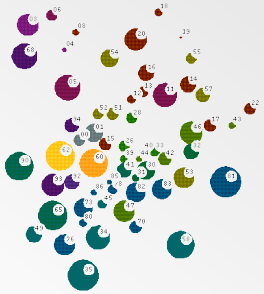
"Traditional or deductive logic admits only three attitudes to any proposition: definite proof, disproof, or blank ignorance." - Jeffreys

Probability and Ontologies

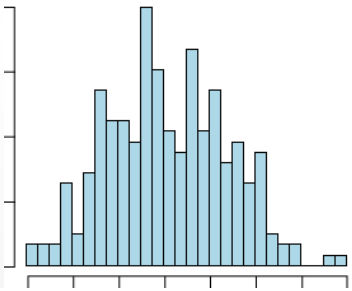
- A computational ontology (little o) represents
  - Types of objects
  - Relationships among objects
  - Properties of objects
  - Processes and events involving objects



- A *probabilistic ontology**
  - Assigns probabilities in a way that respects the domain semantics
  - Make use of knowledge that falls short of proof
  - Support evidential accrual
  - Provide built-in learning theory

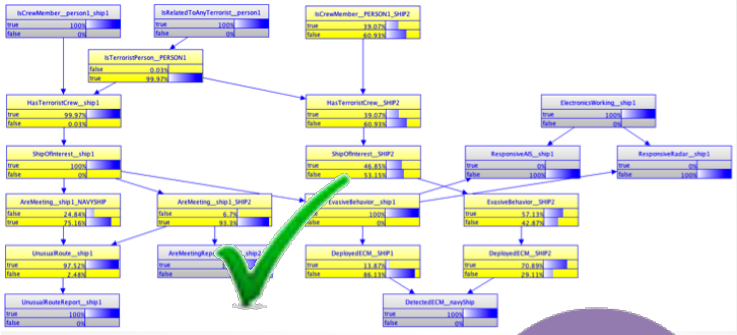


- Technology for semantically aware uncertainty management is a powerful innovation



**Some object to using the word "ontology" for probabilistic knowledge. Regardless of label, there is a need for semantically aware uncertainty management*

PO Modeling Cycle



Goals
- Queries
- Evidence

Goal: Identify whether a ship is a ship of interest

Query: Does the ship have a terrorist crew member?

Evidence: Crew member related to terrorist or associated with terrorist organization

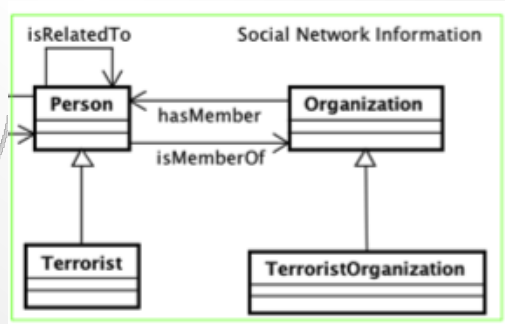
Entities
- Attributes
- Relationships

Ship
Person
Organization
isTerroristPerson
hasCrewMember
isRelatedTo

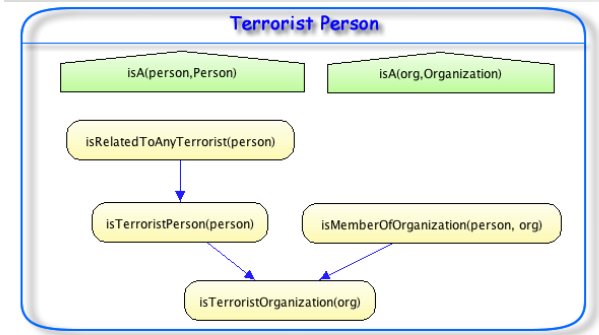
Rules
- Deterministic
- Stochastic

IF a crew member is related to a terrorist
THEN it is more likely that he is also a terrorist

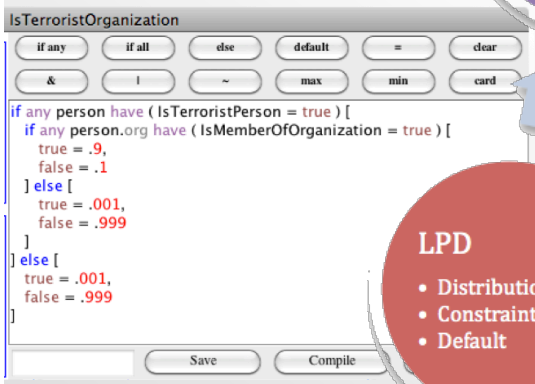
Group
- Entities
- Rules
- Dependencies



Mapping
- Entities
- MFrag
- Nodes
- Relations

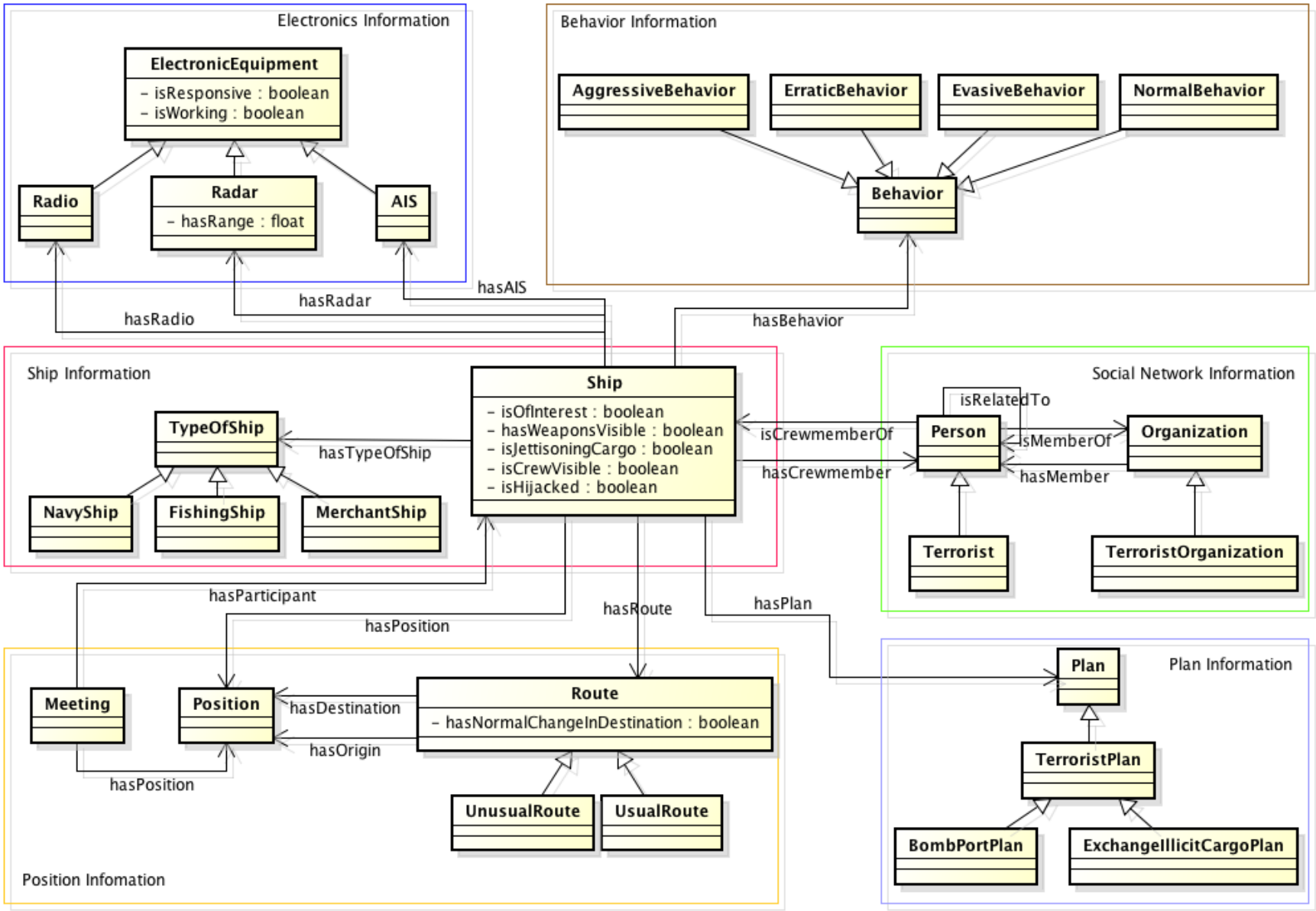


LPD
- Distribution
- Constraints
- Default

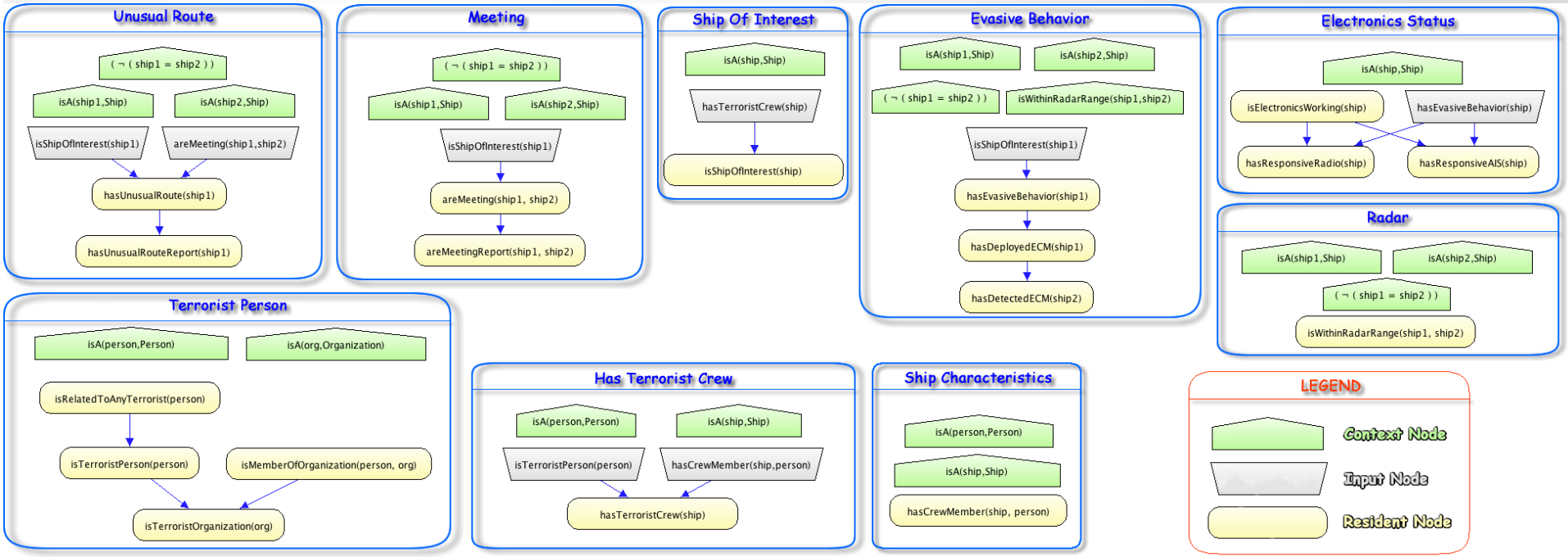


Evaluation
- Verification
- Validation
  - Requirement
  - Behavior
  - Scenario

Entities, Attributes, Relations



PO for Identifying Ship-of-Interest

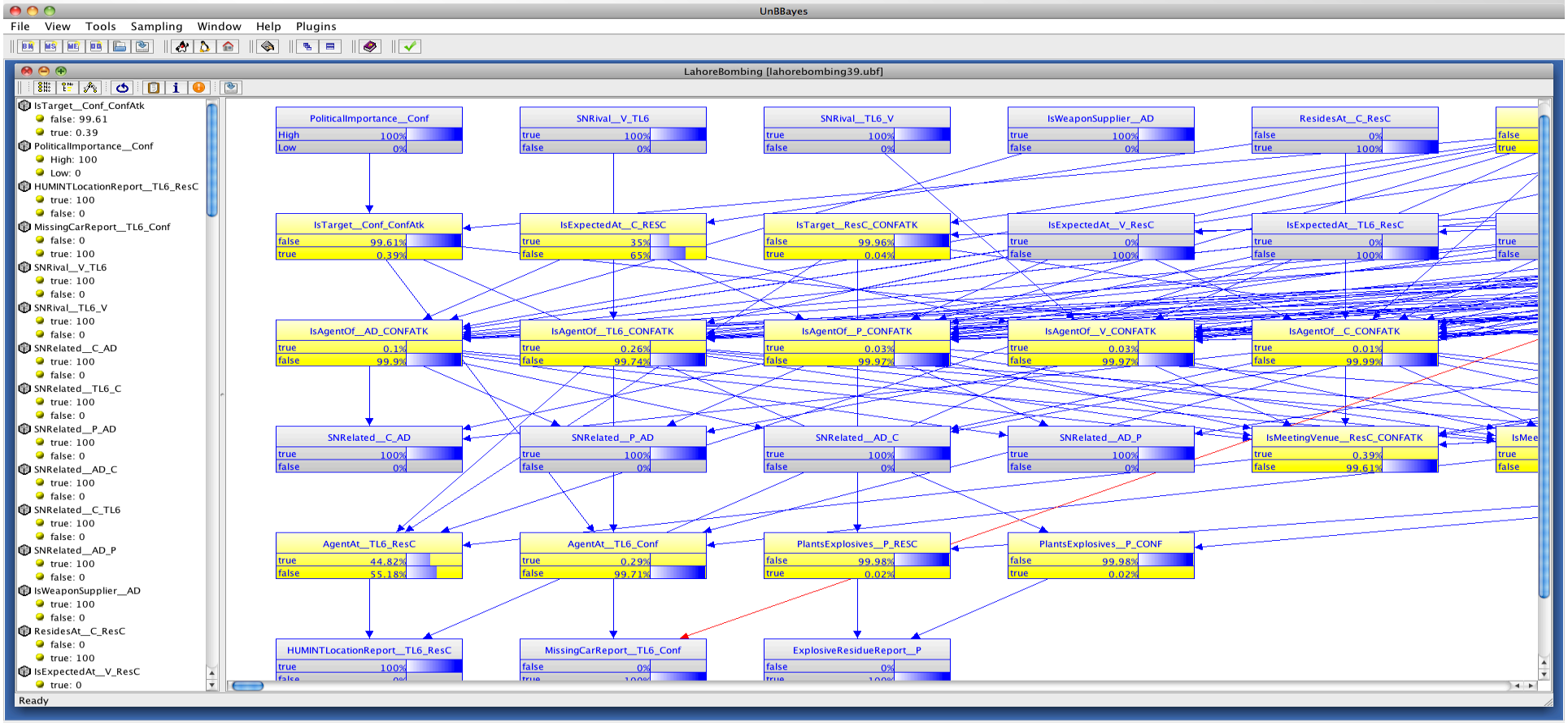


Built in UnBBayes-MEBN

open source PR-OWL tool

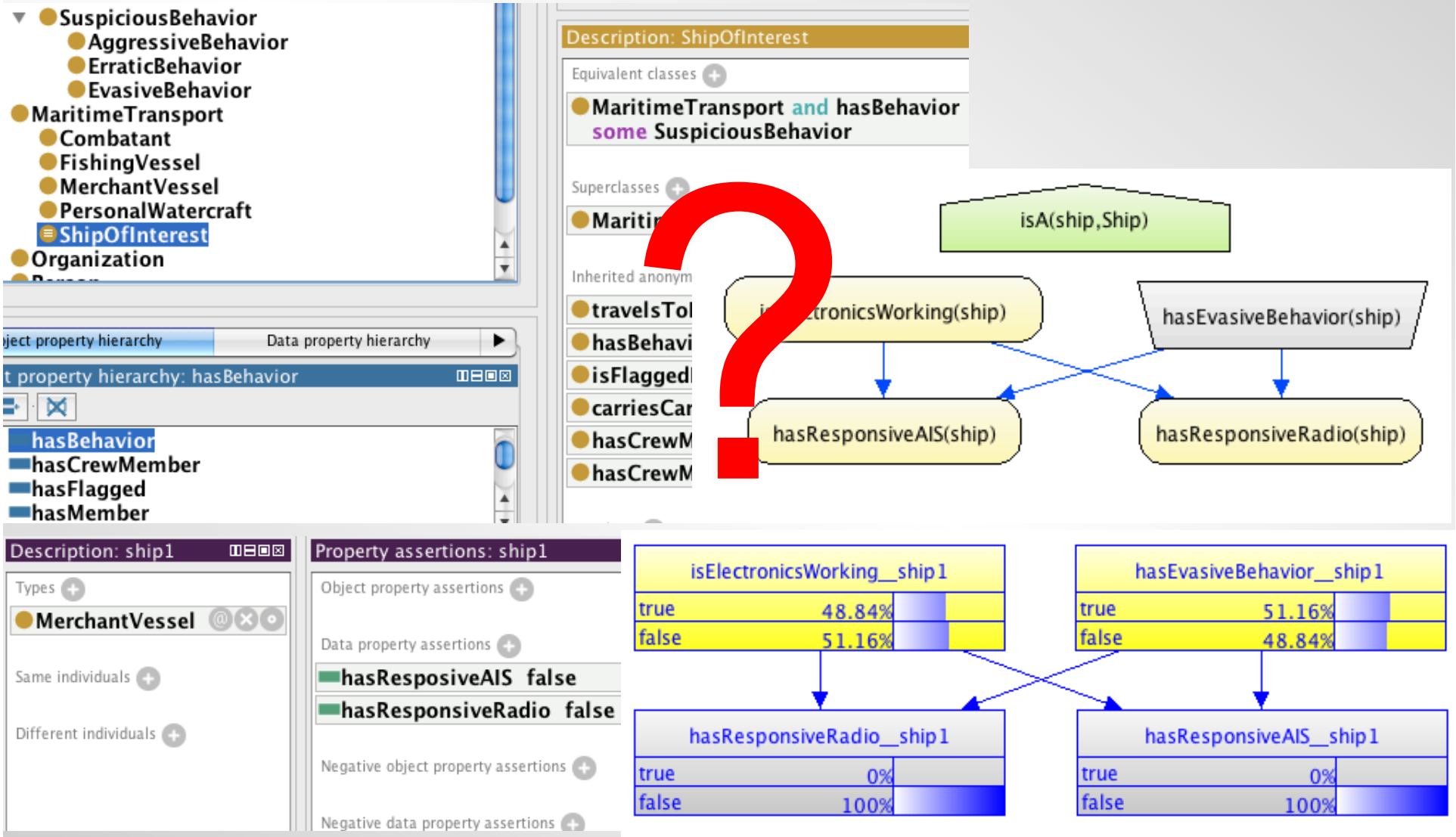
Matsumoto, S.; Carvalho, R.; Ladeira, M.; Costa, P.; Santos, L.; Silva, D., Onishi, M.; and Machado, E. (2011) UnBBayes: a Java Framework for Probabilistic Models in AI, In Java in Academia and Research, Ke Cai (ed.). iConcept Press, Ltd. ISBN 978-0980733082.

Situation-Specific Bayesian Network

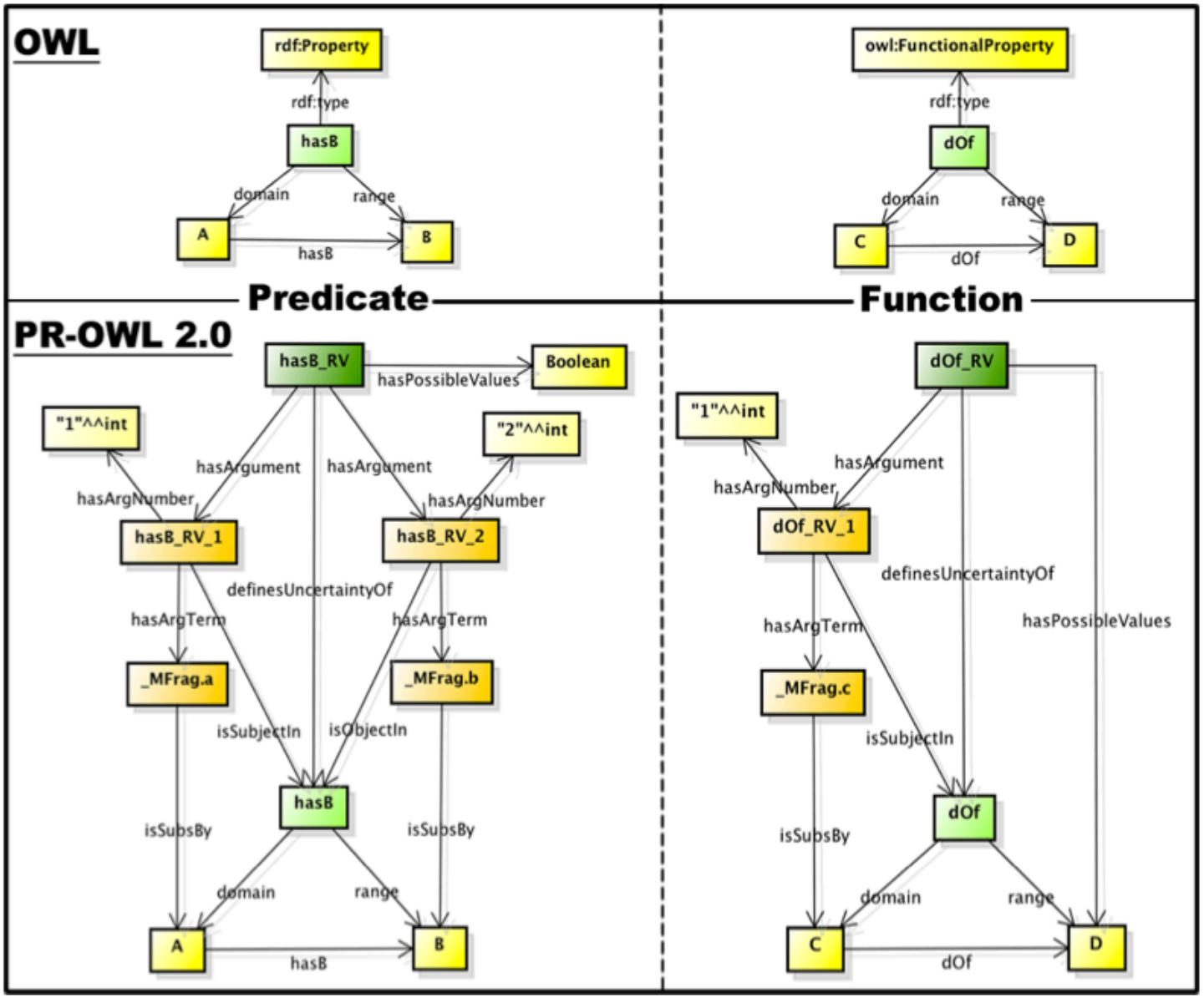


Constructed using UnBBayes-MEBN

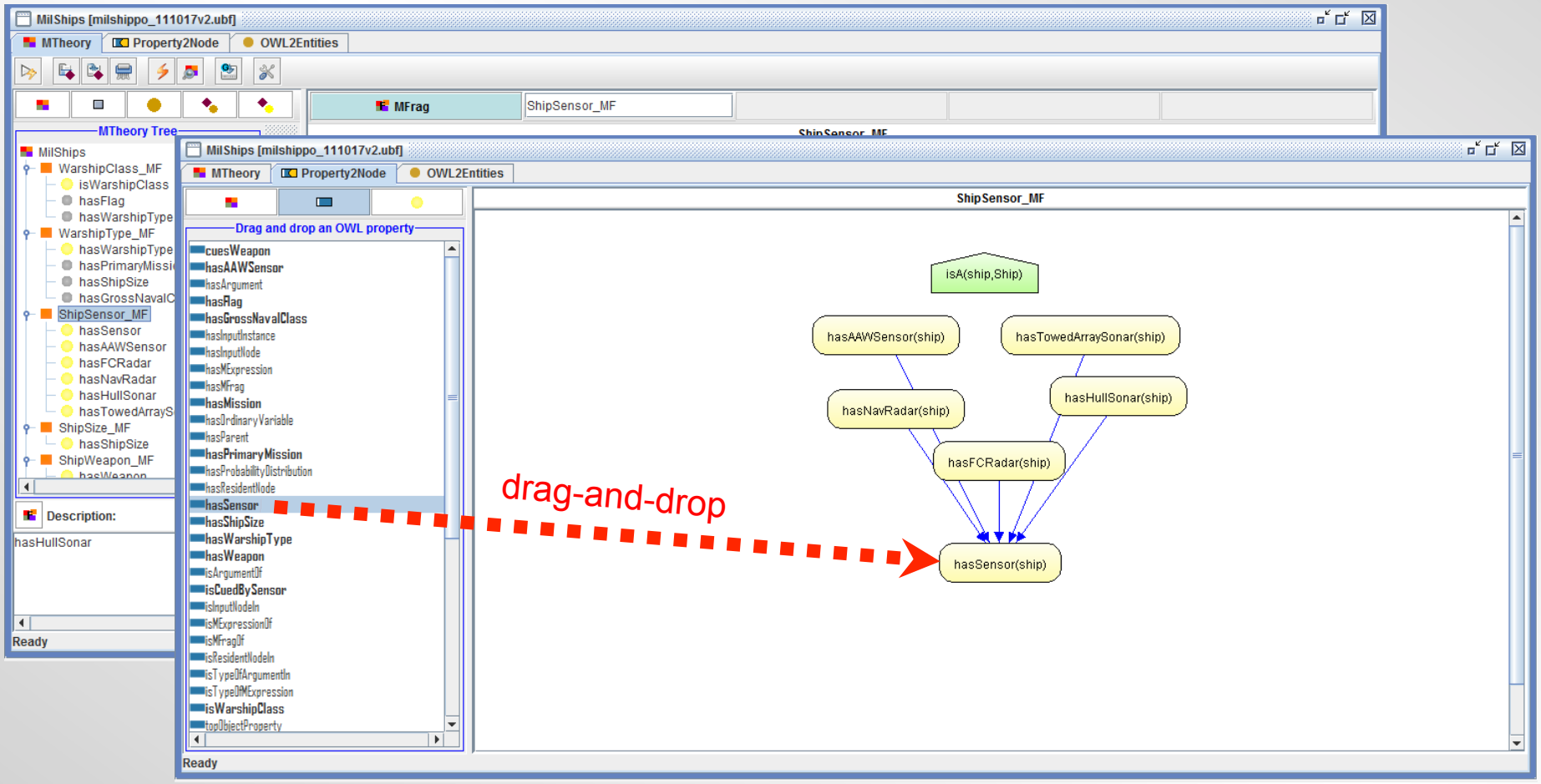
PR-OWL ←→ OWL ?


SuspiciousBehavior
AggressiveBehavior
ErraticBehavior
EvasiveBehavior
MaritimeTransport
Combatant
FishingVessel
MerchantVessel
PersonalWatercraft
ShipOfInterest
Organization
Description: ShipOfInterest
Equivalent classes
MaritimeTransport and hasBehavior some SuspiciousBehavior
Superclasses
Inherited anonym
Data property hierarchy
t property hierarchy: hasBehavior
hasBehavior
hasCrewMember
hasFlagged
hasMember
isA(ship,Ship)
tronicsWorking(ship)
hasEvasiveBehavior(ship)
hasResponsiveAIS(ship)
hasResponsiveRadio(ship)
Description: ship1
Types
MerchantVessel
Same individuals
Different individuals
Property assertions: ship1
Object property assertions
Data property assertions
hasResposiveAIS false
hasResponsiveRadio false
Negative object property assertions
Negative data property assertions
isElectronicsWorking__ship1
true 48.84%
false 51.16%
hasEvasiveBehavior__ship1
true 51.16%
false 48.84%
hasResponsiveRadio__ship1
true 0%
false 100%
hasResponsiveAIS__ship1
true 0%
false 100%

Mapping PR-OWL←→ OWL



PR-OWL 2 in UnBBayes



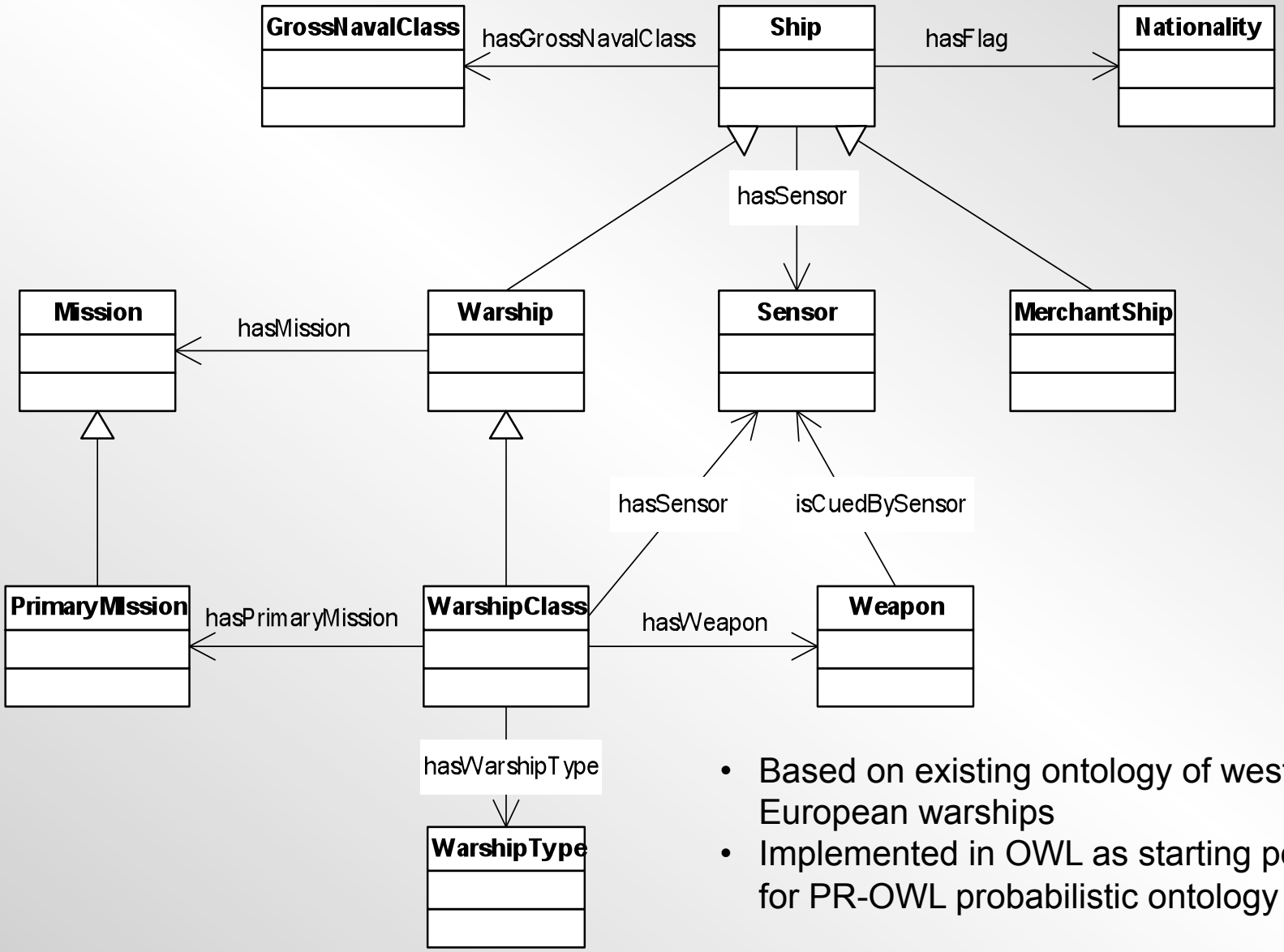
implementation still alpha status

PR-OWL 2 Case Study

***Overall Goal**: Given uncertain or absent attribute information about a specific ship, what is the most likely European warship class that satisfies these attributes?*

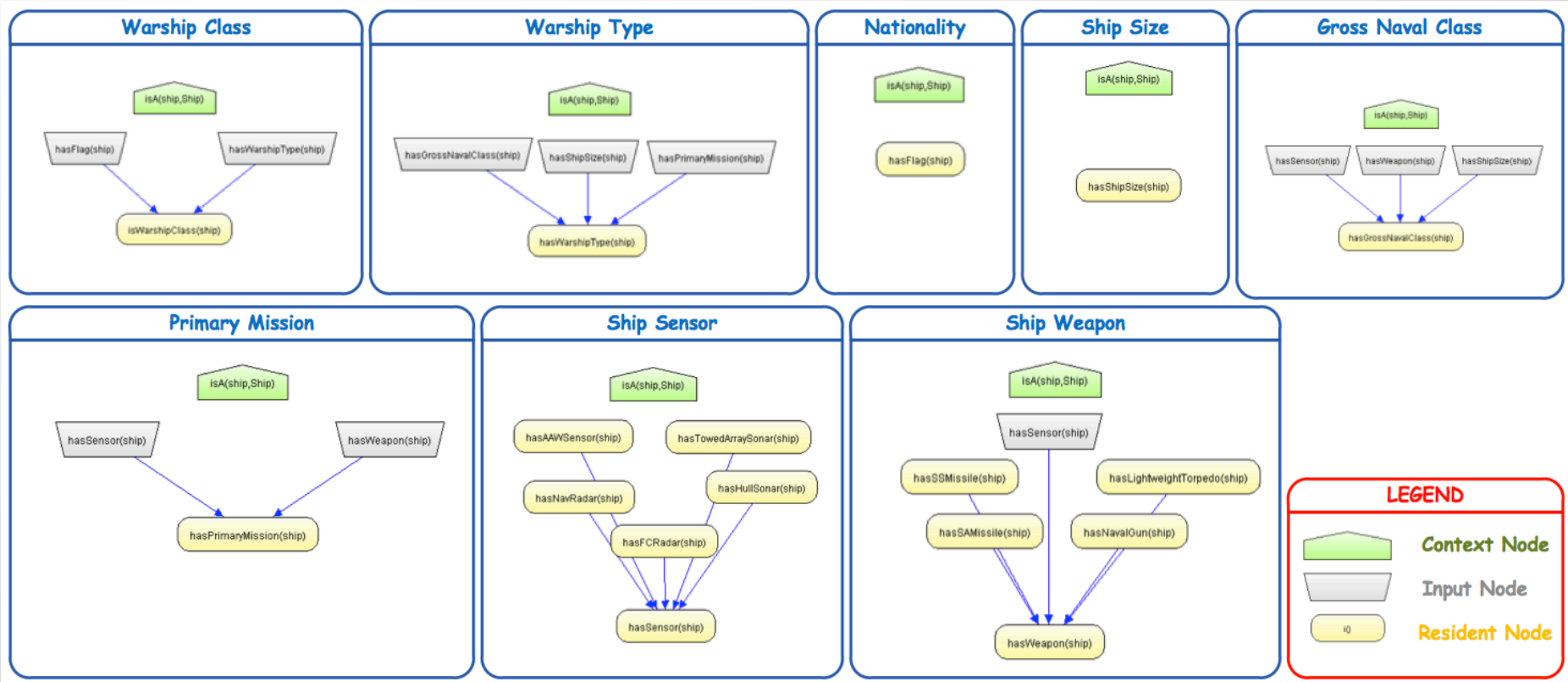
1. **Query**: What is the type of warship?
   a) **Evidence**: Identify the size of the ship;
   b) **Evidence**: Confirm the ship is a warship;
   c) **Evidence**: Identify the primary mission of the ship based on its weapons and sensors.
2. **Query**: What nation has flagged the ship?
   a) **Evidence**: Identify the nation under which the ship is registered.

Entities and Relationships



- Based on existing ontology of western European warships
- Implemented in OWL as starting point for PR-OWL probabilistic ontology

PO for Identifying Warship Class



- Added uncertainty to properties of OWL ontology
- Probabilities obtained from open source literature and subject-matter expert review

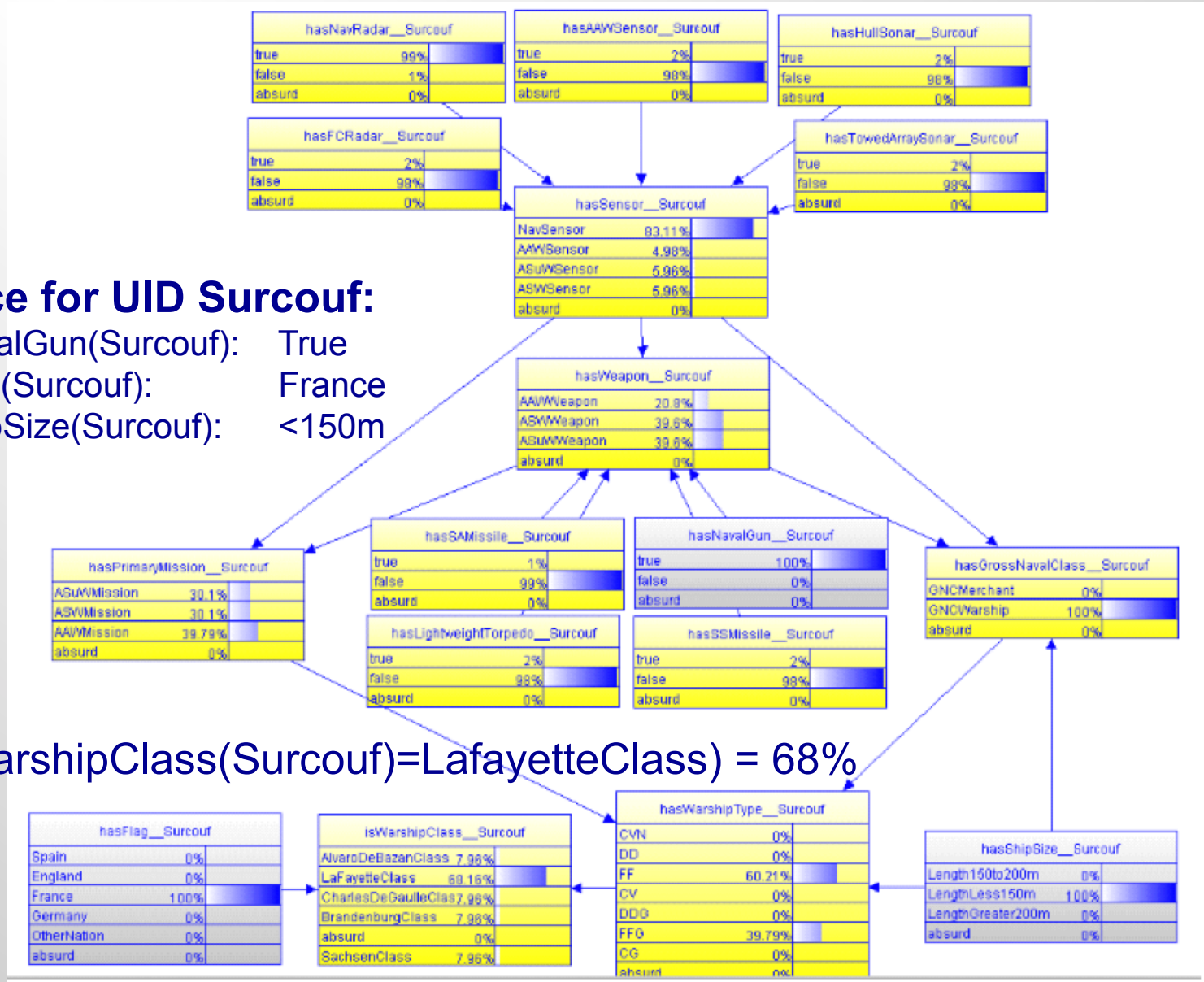
Situation-Specific Bayesian Network

Evidence for UID Surcouf:

hasNavalGun(Surcouf): True
hasFlag(Surcouf): France
hasShipSize(Surcouf): <150m

Result:

Pr(isWarshipClass(Surcouf)=LafayetteClass) = 68%



Scalability

- **The bad news**: worst case tractability of logic + probability is, of course, undecidable
- **The good news**: highly scalable algorithms exist for restricted (but useful) classes of problems
- **The research frontier**: characterizing classes of problems and their scalability properties
- **The applications frontier**: learning what works and implementing it

Conclusion

- Technology for semantically aware uncertainty management is essential
- Probabilistic ontologies provide this capability
- PR-OWL 2 can represent uncertainty about properties in OWL ontologies

The French Frigate *Surcouf*
http://en.wikipedia.org/wiki/Surcouf_(F711)

- A case study in maritime domain awareness illustrates how to enhance an existing domain ontology with uncertainty information