Probabilistic Ontology Architecture for a Maritime Domain Decision Support System

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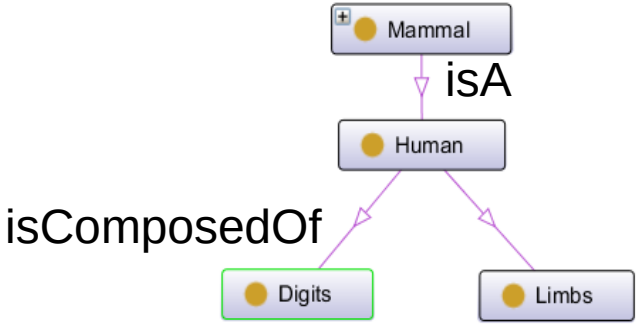
Background

Why Probabilistic Ontologies?

- Suppose an ontology of organisms contains the following classes and relationships:



- Humans *usually* have:
  - 2 arms & 2 legs
  - 10 fingers & 10 toes
- However, if a man loses a limb….
  - Is he no longer human?

Premise of an argument can be uncertain (e.g. Humans have 2 legs): (in)validity of the argument imposes no condition on the certainty of the conclusion (an amputee is Human).

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Probabilistic Ontology Defined

A *probabilistic ontology* is an explicit, formal representation of knowledge about a domain of application. This includes

Ontology

- Types of entities that exist in the domain;
- Properties of those entities;
- Relationships among entities;
- Processes and events that happen with those entities;

Uncertainty

- **Statistical regularities that characterize the domain;**
- **Inconclusive, ambiguous, incomplete, unreliable, and dissonant knowledge related to entities of the domain;**
- **Uncertainty about all the above forms of knowledge;**

where the term entity refers to any concept that can be described and reasoned about within the domain of application [Costa, 2005].

An ontology is an explicit specification of a conceptualization [Gruber, 95].

A probabilistic ontology extends a traditional ontology to represent uncertainty.

Our Solution

- A systematic approach to probabilistic ontology development
  - Facilitated through a reference architecture
    - Formalizes the application of the methodology
    - Extensible to various domains

- Reference Architecture for Probabilistic Ontology Development (RAPOD)
  - A generalized reference architecture designed to collect, catalogue, and define the components required for development of probabilistic ontologies and establish the criteria to be satisfied by any set of selected tools and methods

RAPOD provides a flexible solution

Reference Architecture

- Provides a blueprint for architects to develop specific solution architectures within a defined domain.
  - Template for development
  - Defines integral components and their relationships
  - Reduces development time and project risk
- Standardizes language among participants
- Provides consistency of development within a domain
- Provides a reference for evaluation
- Establishes specifications and patterns

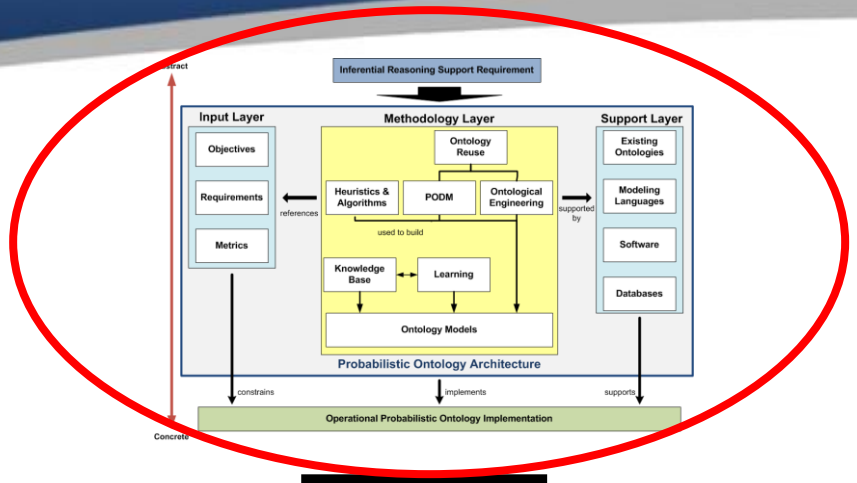
[A Reference Architecture is] "… an authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple architectures and solutions [OASD/NII, 2010]*."*

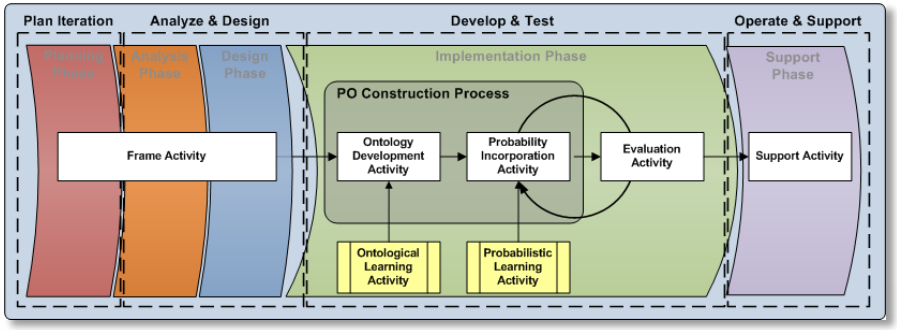
RAPOD Summarized

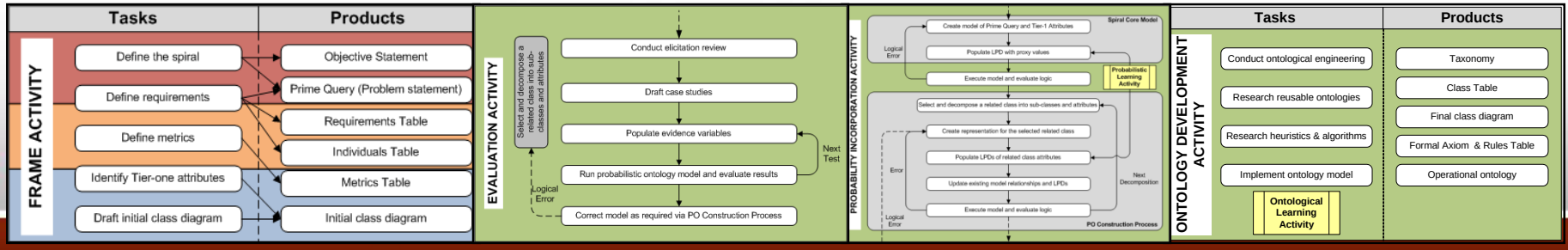
- Provides synergy of effort within the ST community
  - Identifies concepts, processes, languages, theories and tools
  - Synergizes effort of probabilists, logicians, decision analysts, computer scientists
- Spans knowledge, processes, models and tools necessary to engineer POs at a high level of abstraction
- Output defines a domain specific architecture that may be used to produce probabilistic ontologies in similar domain contexts

RAPOD output is an architecture

The RAPOD in Probabilistic Ontology Development







Architecture for the Military Ship (MilShip) Probabilistic Ontology

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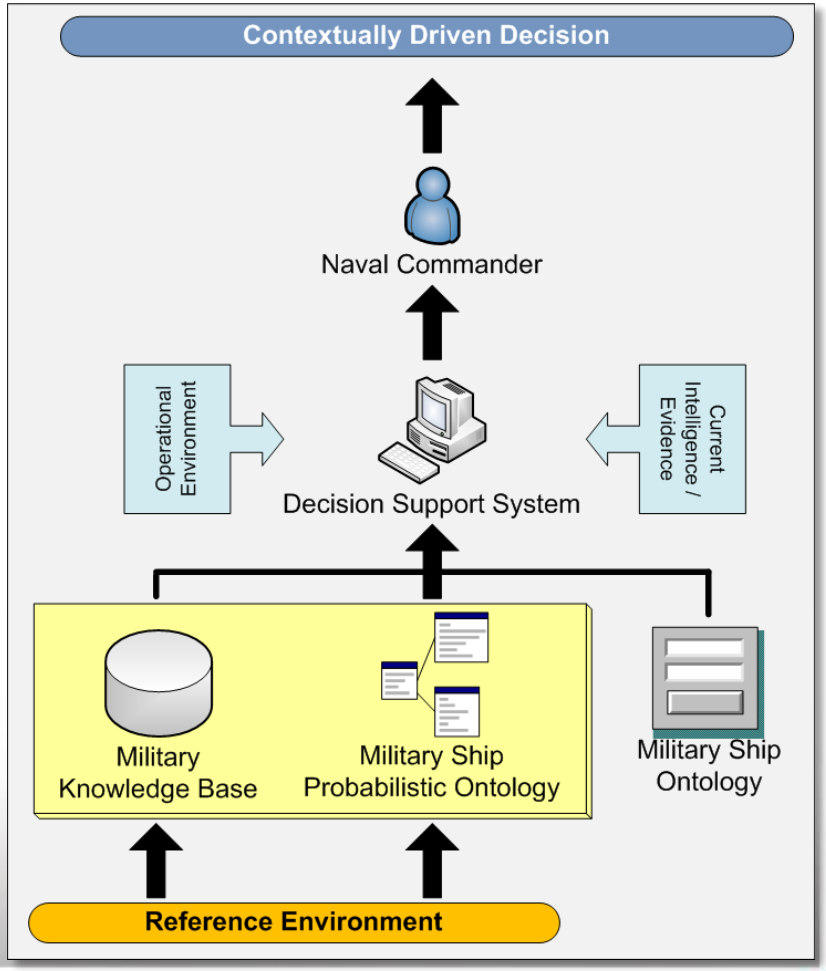
Military Ship PO Concept

Objective

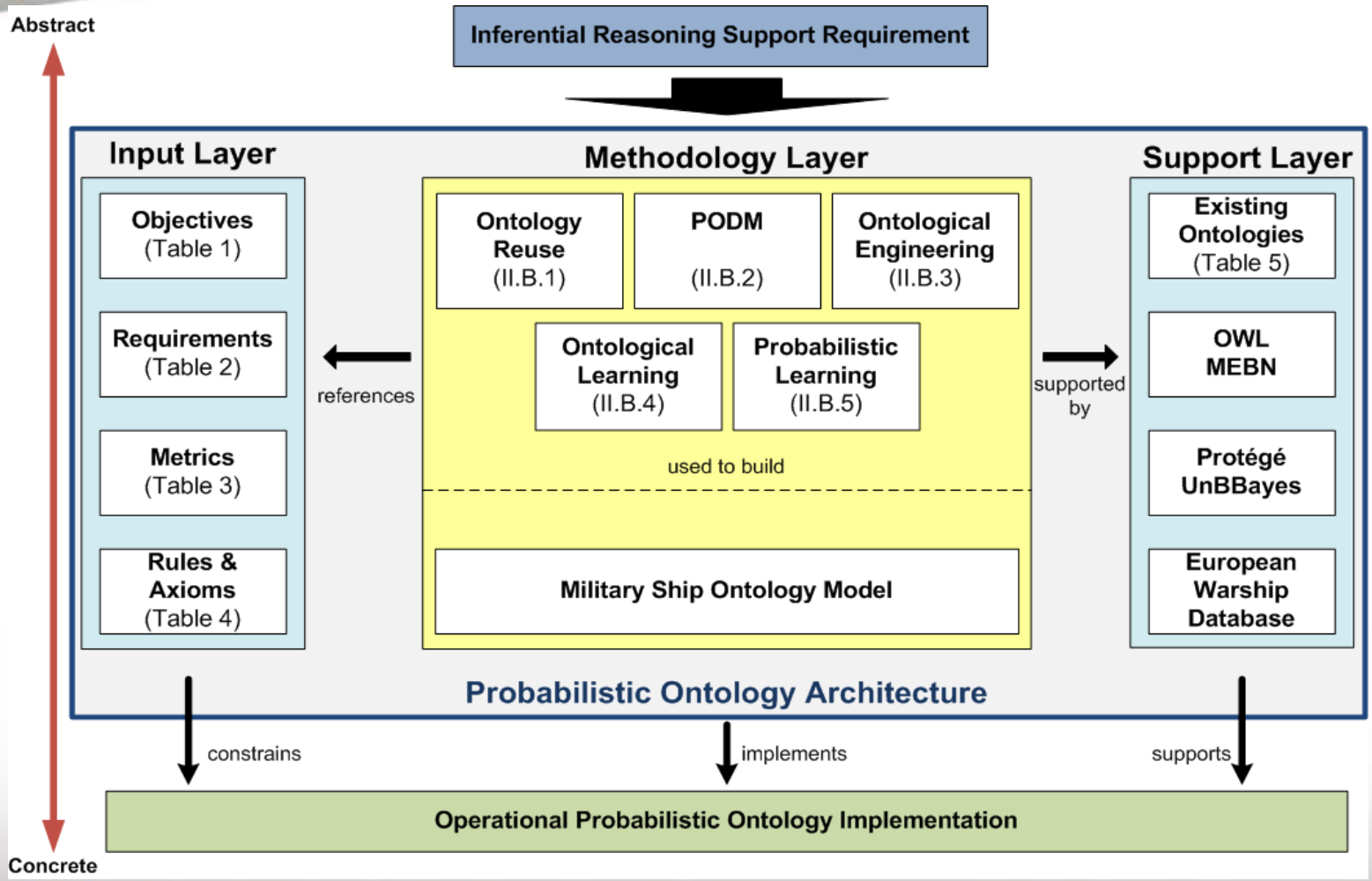
Develop a DSS that assists in the determination of a class of warship given limited input information.

"A DSS is a system under control of one or more decision makers that assists in the activity of decision making by providing an organized set of tools intended to impose structure on portions of the decision-making situation and to improve the ultimate effectiveness of the decision outcome [Marakas, 2003]*."*

Concept Diagram



Architecture for MilShip Probabilistic Ontology



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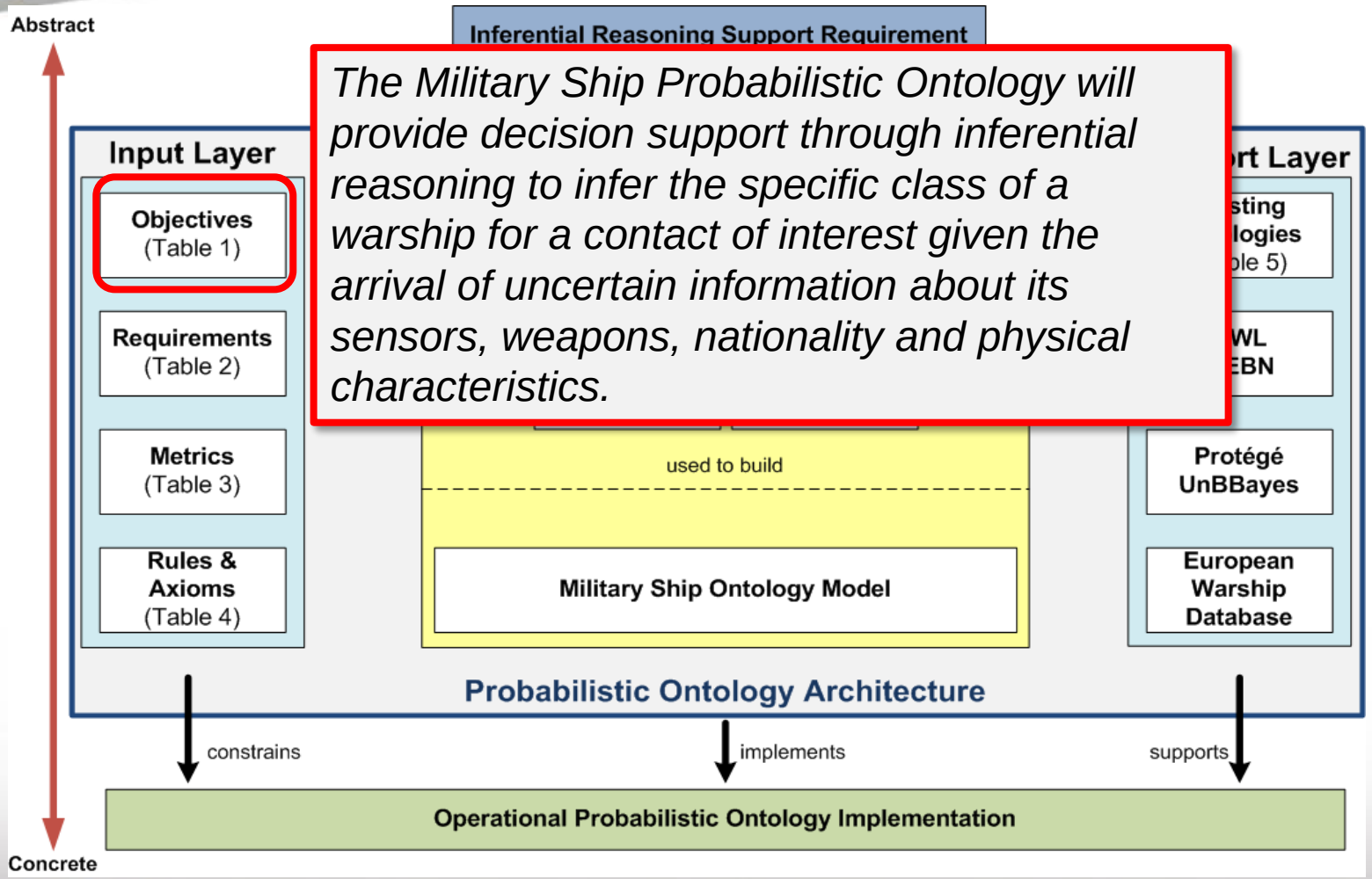

The Military Ship Probabilistic Ontology will provide decision support through inferential reasoning to infer the specific class of a warship for a contact of interest given the arrival of uncertain information about its sensors, weapons, nationality and physical characteristics.

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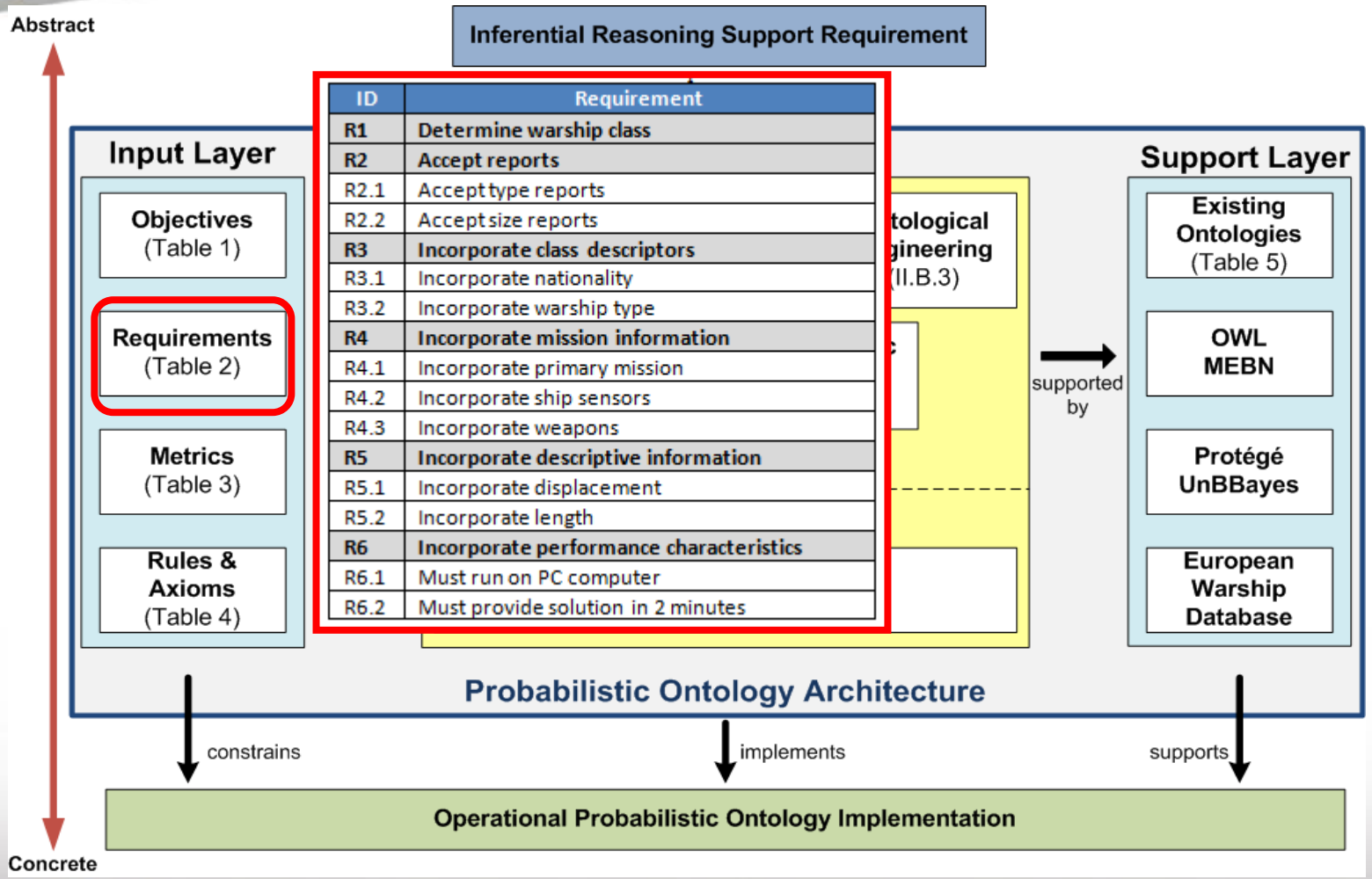

ID	Requirement
R1	Determine warship class
R2	Accept reports
R2.1	Accept type reports
R2.2	Accept size reports
R3	Incorporate class descriptors
R3.1	Incorporate nationality
R3.2	Incorporate warship type
R4	Incorporate mission information
R4.1	Incorporate primary mission
R4.2	Incorporate ship sensors
R4.3	Incorporate weapons
R5	Incorporate descriptive information
R5.1	Incorporate displacement
R5.2	Incorporate length
R6	Incorporate performance characteristics
R6.1	Must run on PC computer
R6.2	Must provide solution in 2 minutes

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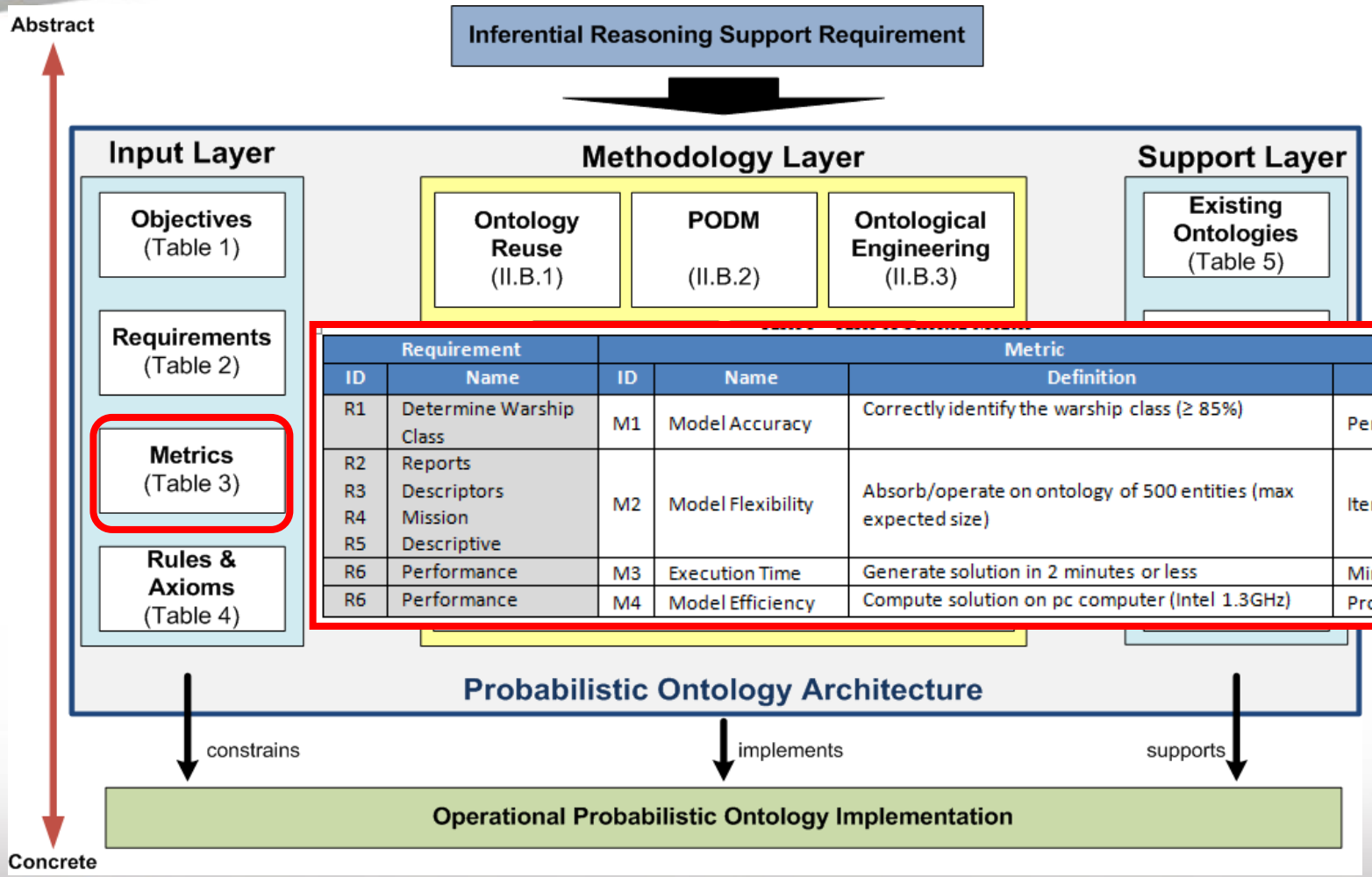

Requirement		Metric			
ID	Name	ID	Name	Definition	Units
R1	Determine Warship Class	M1	Model Accuracy	Correctly identify the warship class (≥ 85%)	Percent
R2 R3 R4 R5	Reports Descriptors Mission Descriptive	M2	Model Flexibility	Absorb/operate on ontology of 500 entities (max expected size)	Items
R6	Performance	M3	Execution Time	Generate solution in 2 minutes or less	Minutes
R6	Performance	M4	Model Efficiency	Compute solution on pc computer (Intel 1.3GHz)	Processor

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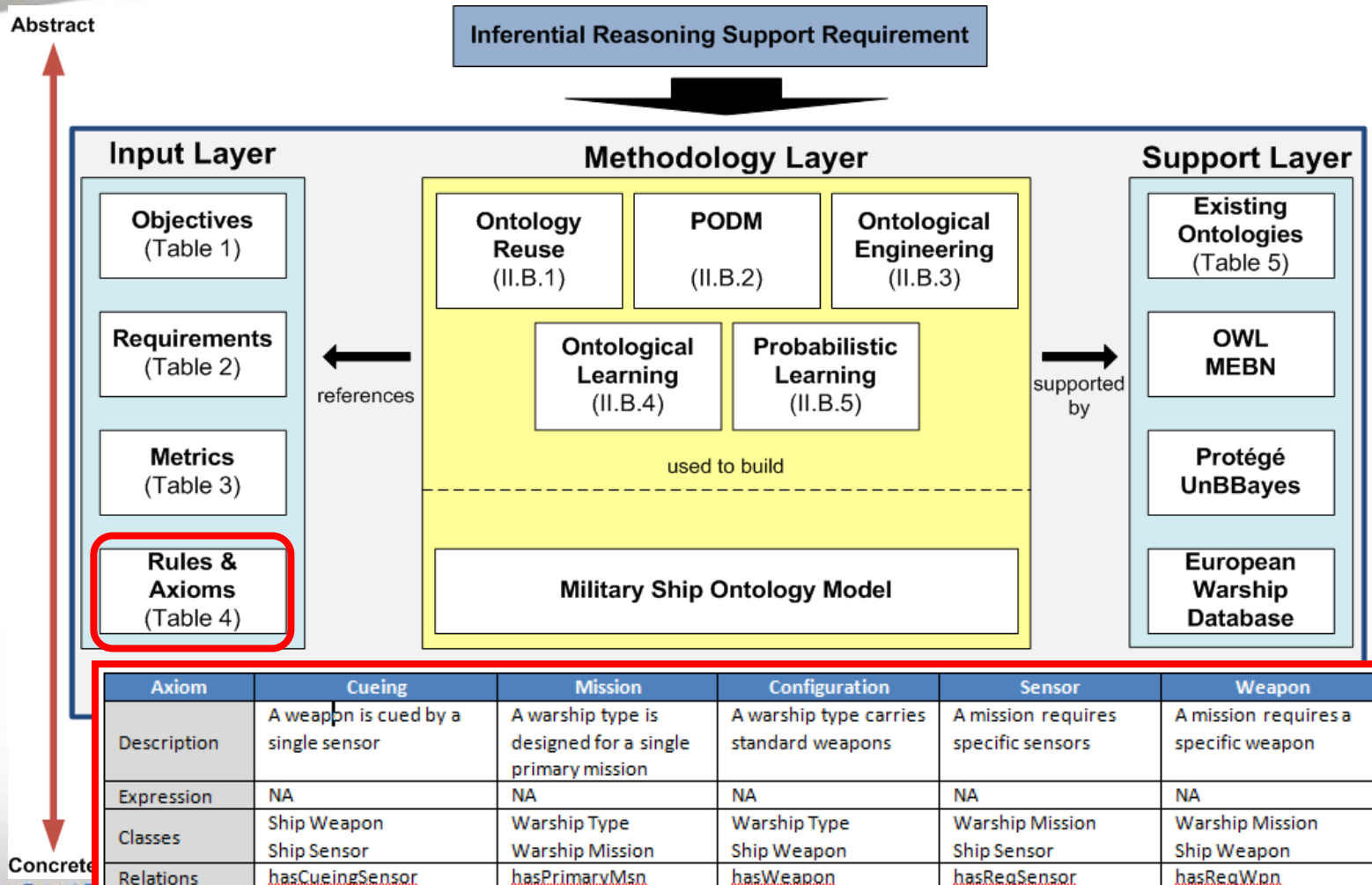

Axiom	Cueing	Mission	Configuration	Sensor	Weapon
Description	A weapon is cued by a single sensor	A warship type is designed for a single primary mission	A warship type carries standard weapons	A mission requires specific sensors	A mission requires a specific weapon
Expression	NA	NA	NA	NA	NA
Classes	Ship Weapon Ship Sensor	Warship Type Warship Mission	Warship Type Ship Weapon	Warship Mission Ship Sensor	Warship Mission Ship Weapon
Relations	hasCueingSensor	hasPrimaryMsn	hasWeapon	hasReqSensor	hasReqWpn

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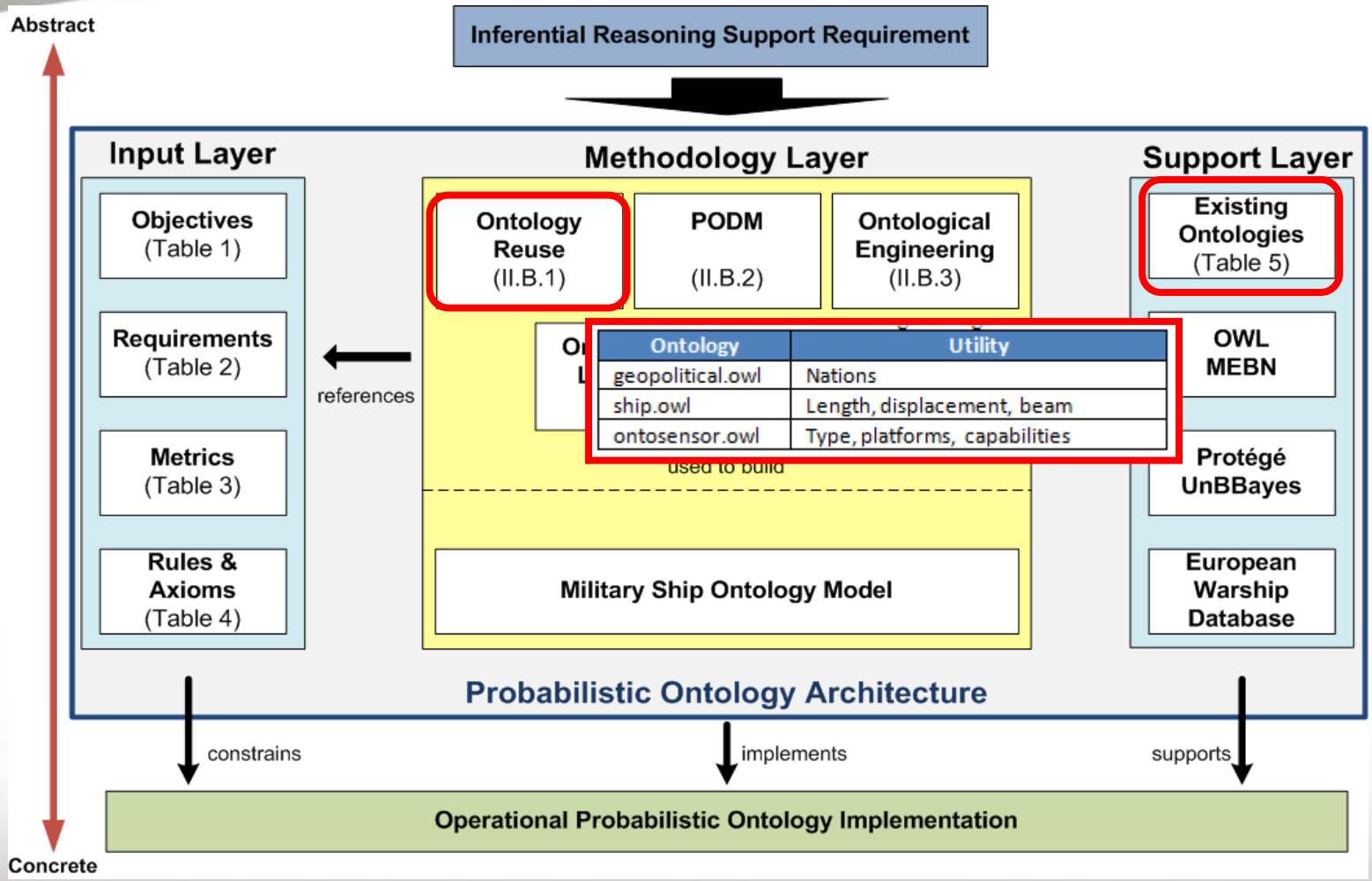

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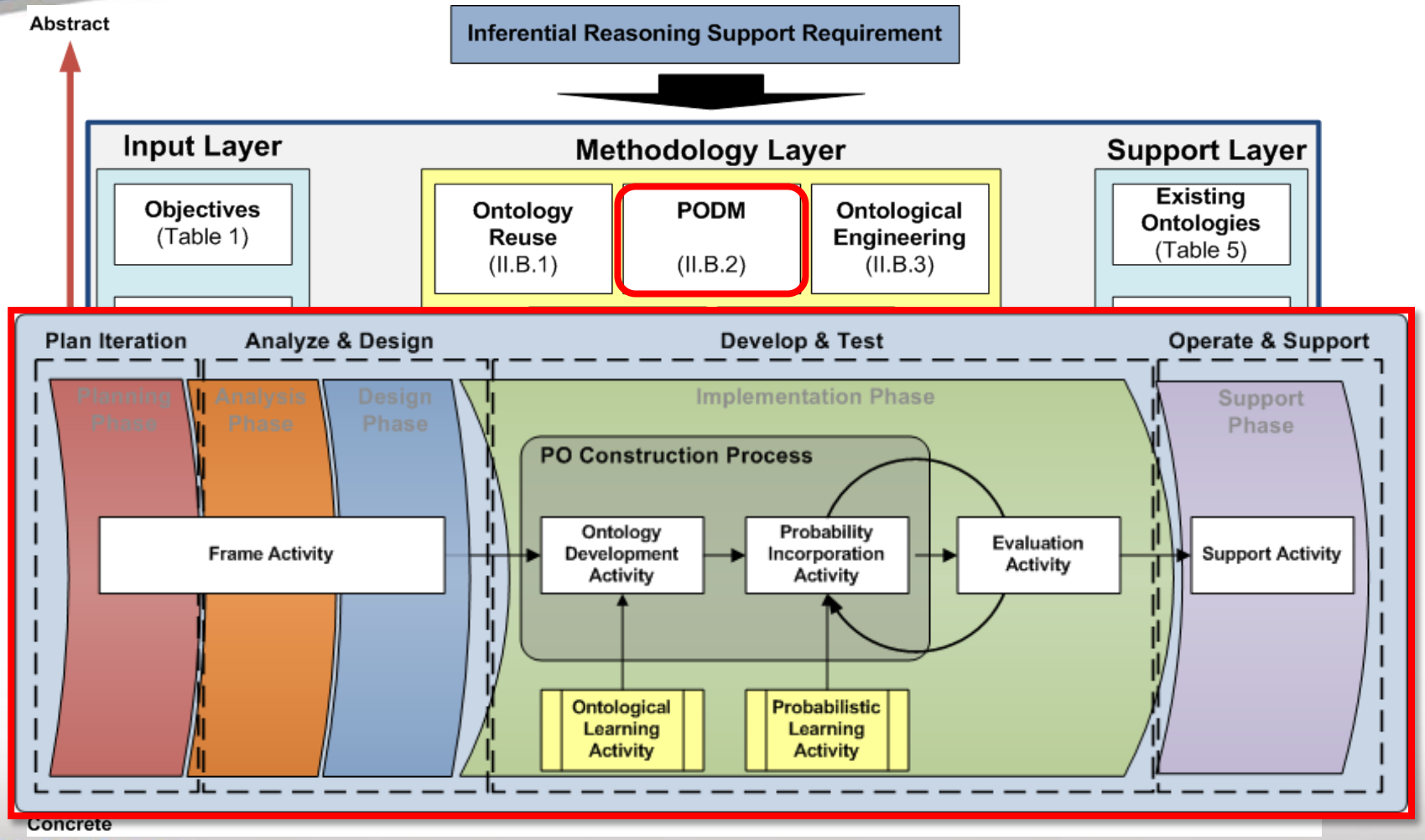

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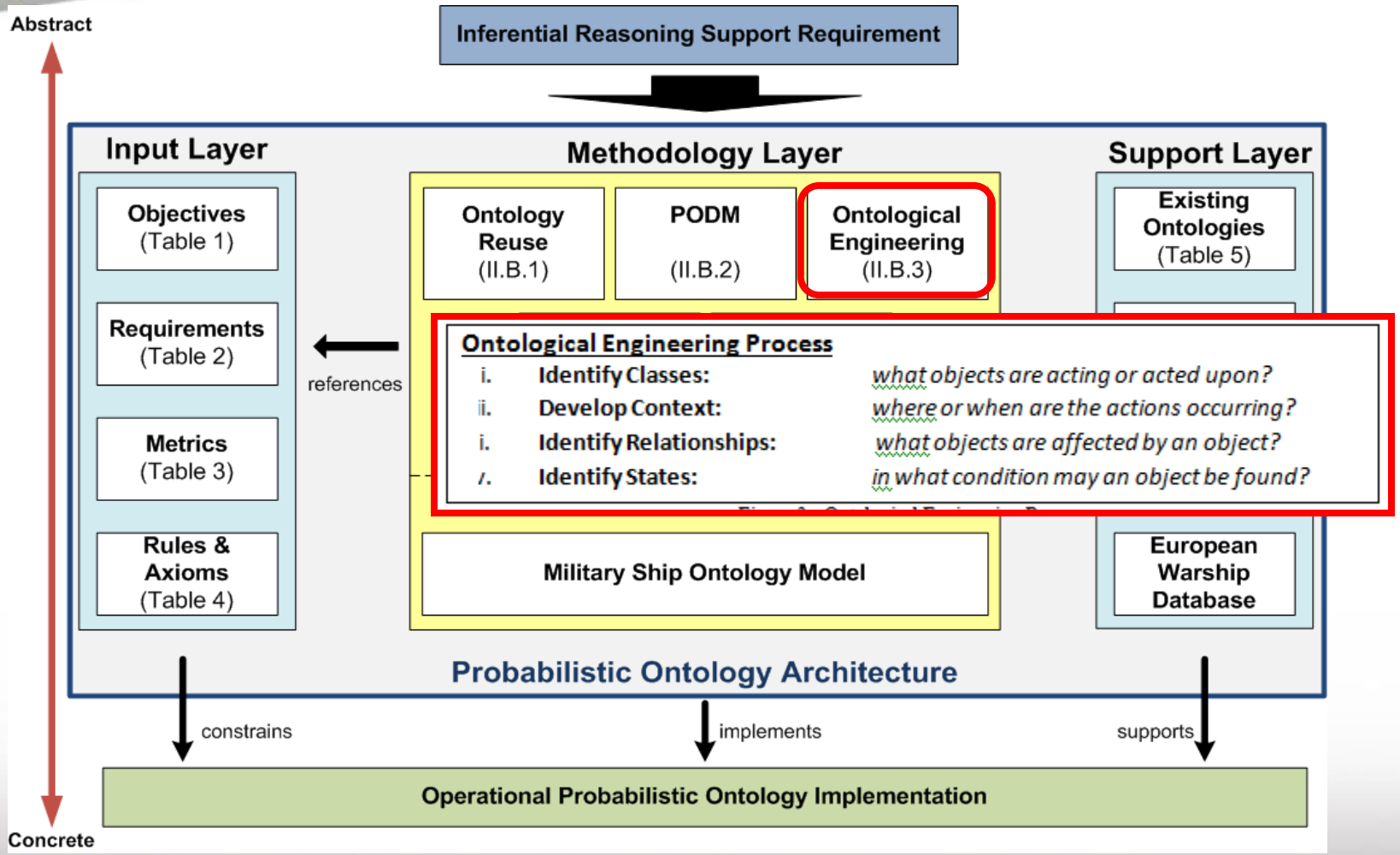

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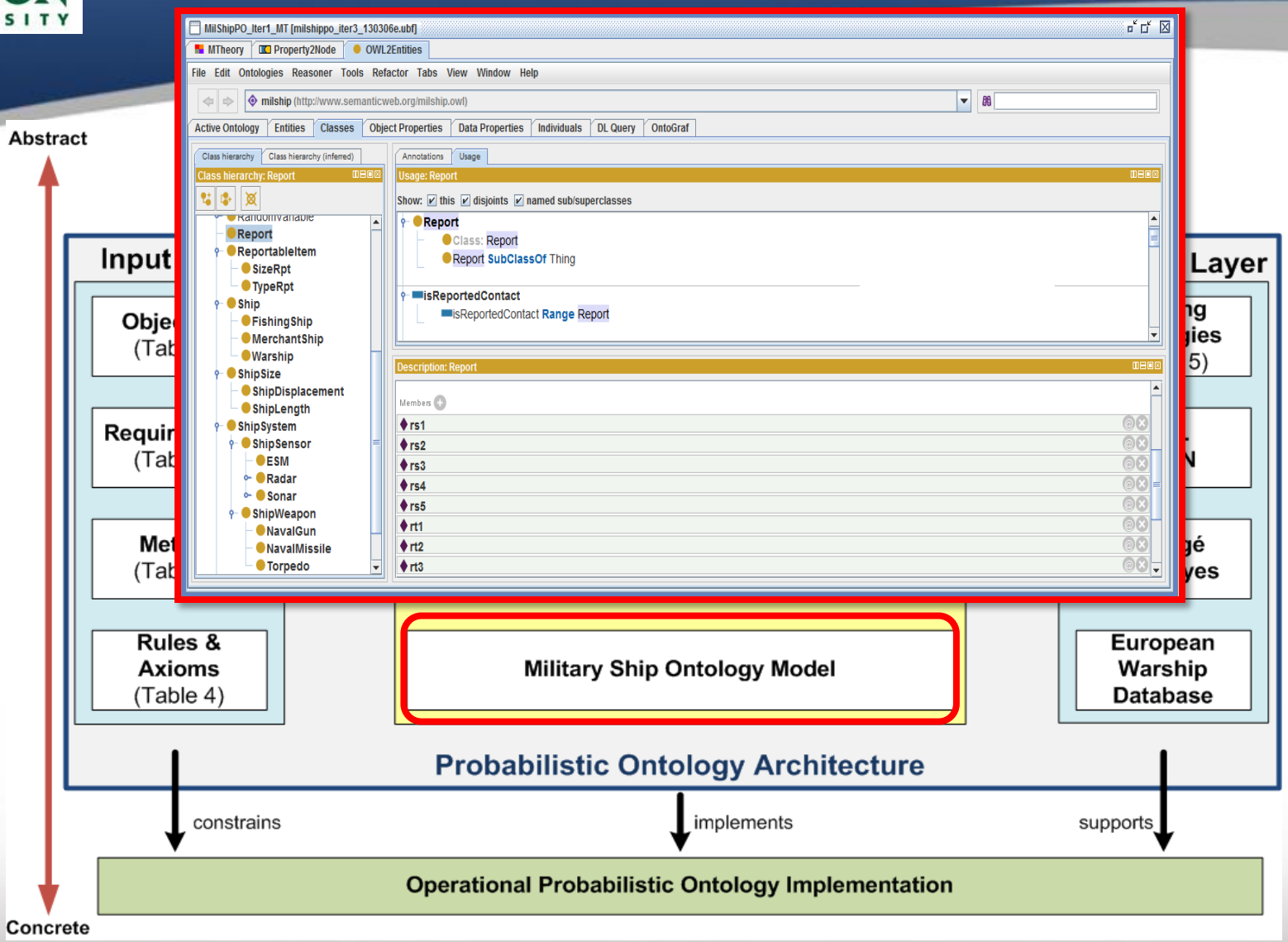

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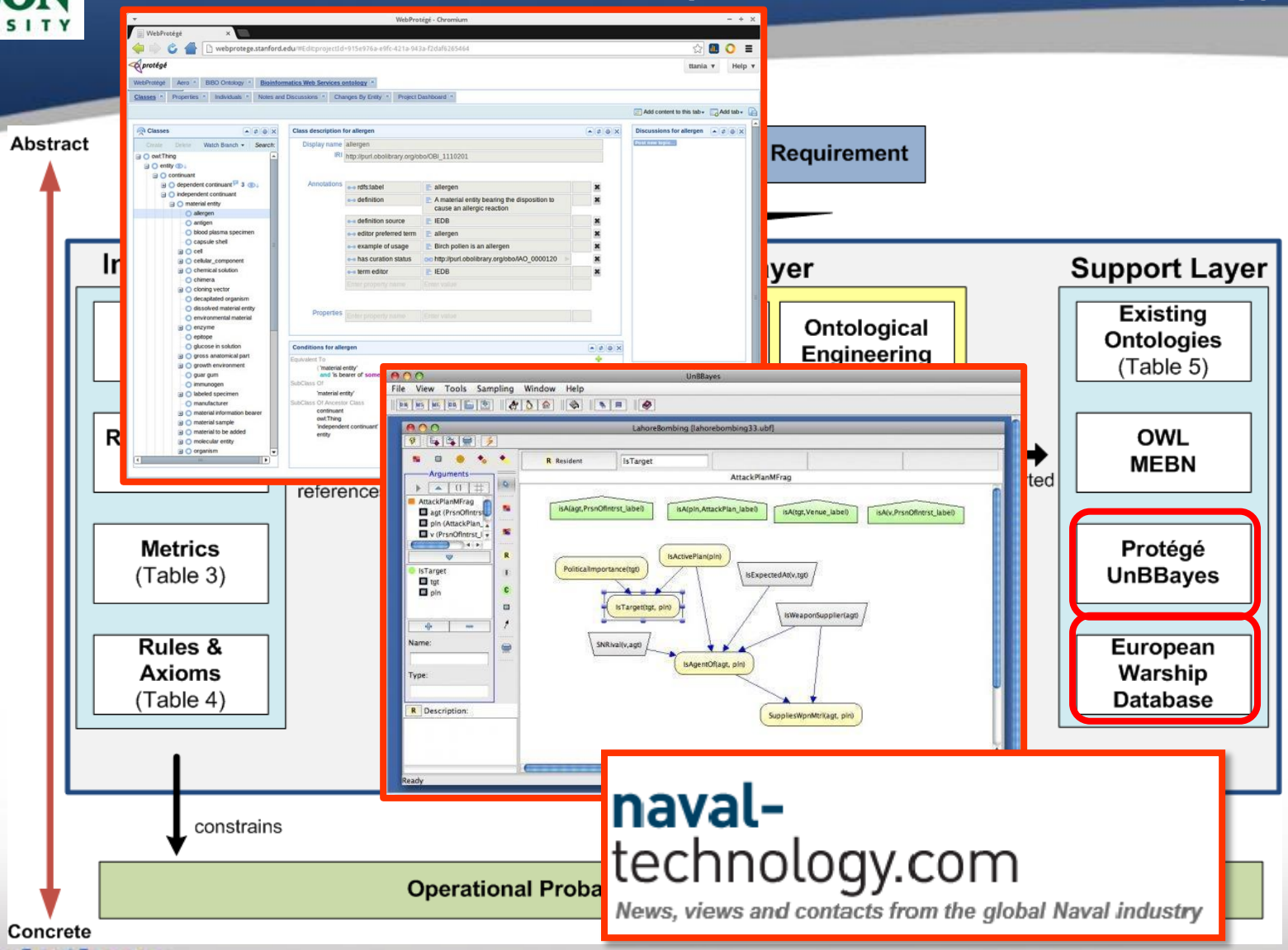

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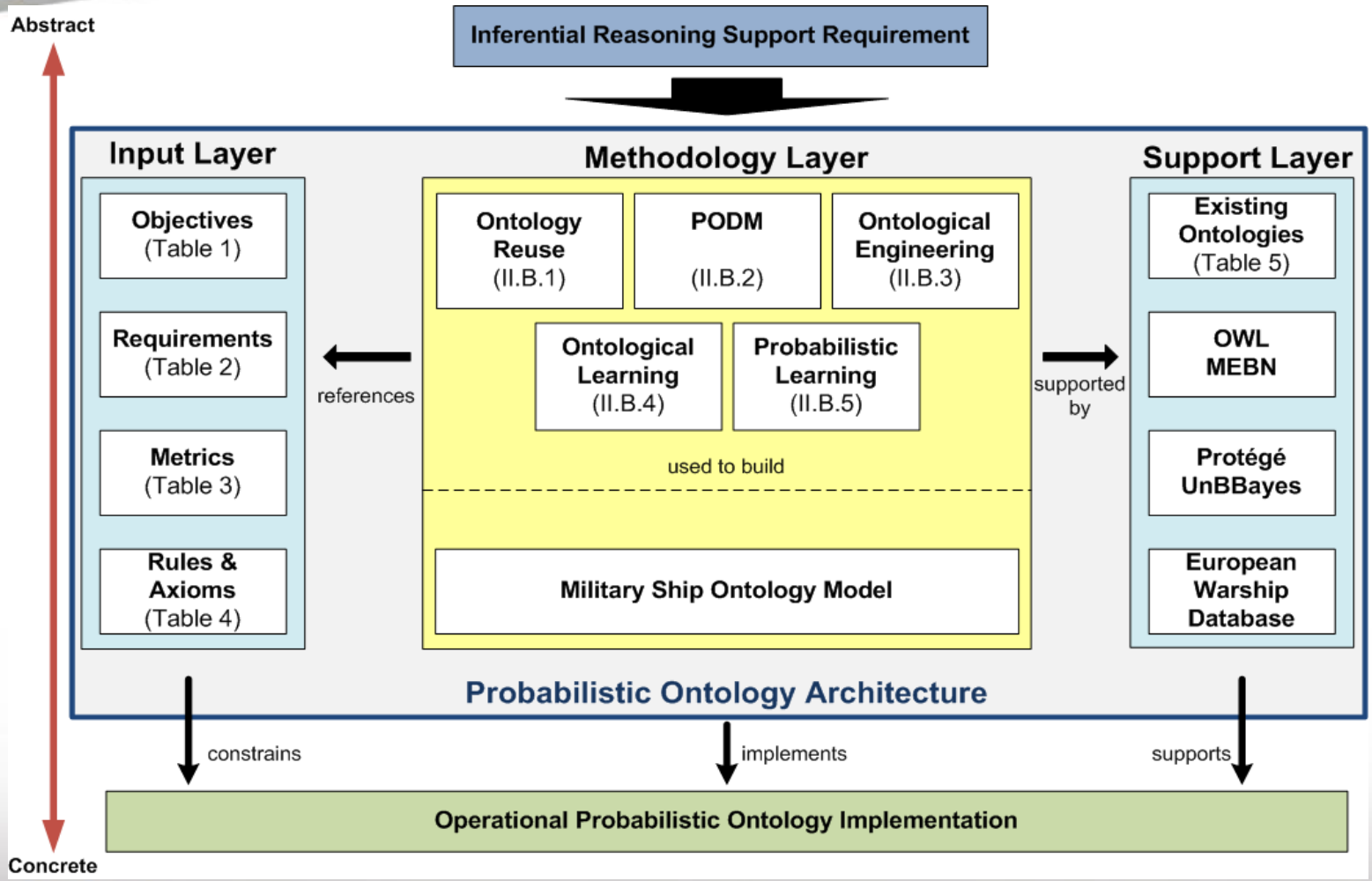

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