s a n d p i p e r   s o f t w a r e

The Ontology Definition Metamodel

Motivation & Brief Introduction

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Sandpiper Software

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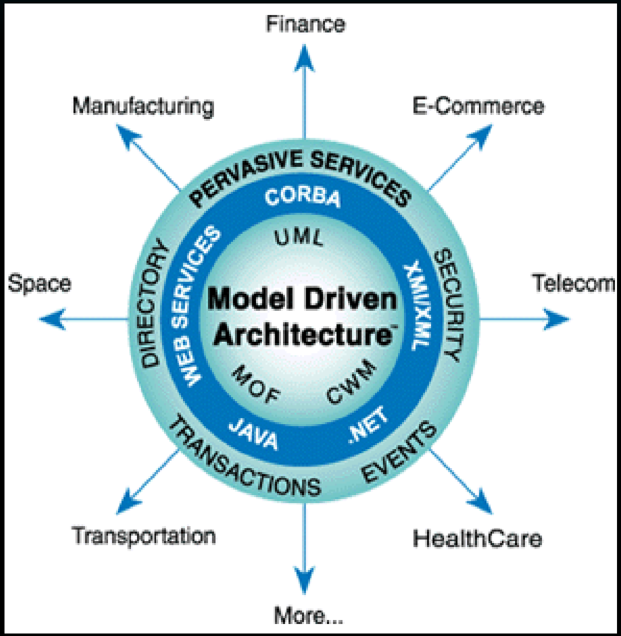
Agenda

- Brief Review of OMG MDA
- Semantics & MDA – Complementary Technologies
- The Ontology Definition Metamodel (ODM)
  - What it is
  - RDF & OWL Metamodel Highlights
  - Common Logic Metamodel Highlights
  - Developing ontologies in UML – the UML profile for RDF & OWL
- Relationship to other OMG & W3C standards
- Relationship to metadata standards
- Next steps, implication for emerging MDA architectures
  - Semantics for Service Oriented Architectures
  - InferenceWeb – semantics supporting registration, explanations & trust for semantically-enabled services

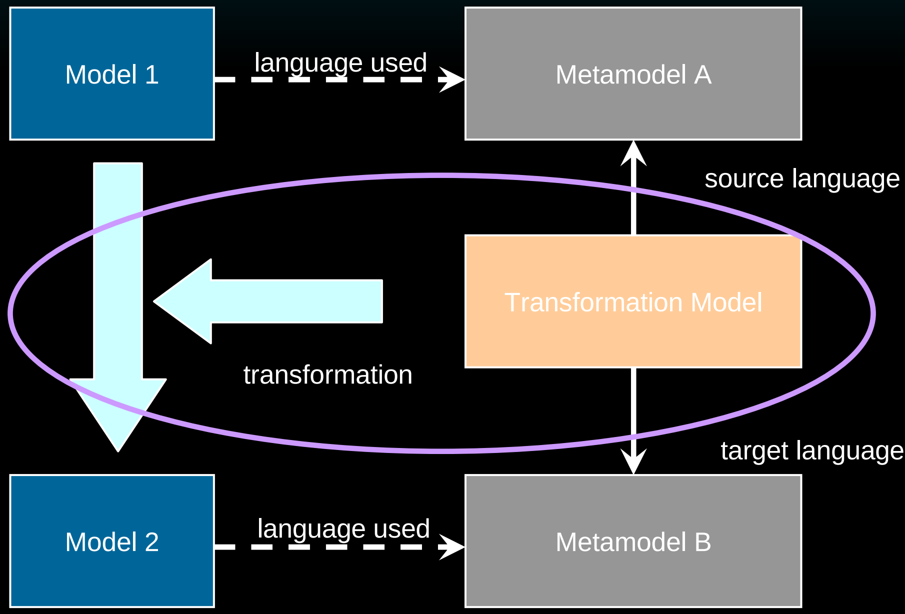
Model Driven Architecture® (MDA®)

- Insulates business applications from technology evolution, for
  - Increased portability and platform independence
  - Cross-platform interoperability
  - Domain-relevant specificity
- Consists of standards and best practices across a range of software engineering disciplines
  - The Unified Modeling Language (UML®)
  - The Meta-Object Facility (MOF™)
  - The Common Warehouse Metamodel (CWM™)
- MOF defines the metadata architecture for MDA
  - Database schema, UML and ER models, business and manufacturing process models, business rules, API definitions, configuration and deployment descriptors, etc.
  - Supports automation of physical management and integration of enterprise metadata
  - MOF models of metadata are called *metamodels*



MOF-Based Metadata Management

- MOF tools use metamodels to generate code that manages metadata, as XML documents, CORBA objects, Java objects
- Generated code includes access mechanisms, APIs to
  - Read and manipulate
  - Serialize/transform
  - Abstract the details based on access patterns
- Related standards:
  - XML Metadata Interchange (XMI®)
  - CORBA Metadata Interface (CMI)
  - Java Metadata Interface (JMI)
- Metamodels are defined for
  - Relational and hierarchical database modeling
  - Online analytical processing (OLAP)
  - Business process definition, business rules specification
  - XML, UML, and CORBA IDL



MDA from the KR Perspective

- EII solutions rely on strict adherence to agreements based on common information models that take weeks or months to build
- Modifications to the interchange agreements are costly and time consuming
- Today, the analysis and reasoning required to align multiple parties' information models has to be done by people
- Machines display only *syntactic* information models and informal text describing the semantics of the models
- Without formal *semantics*, machines cannot aid the alignment process
- Translations from each party's syntactic format to the agreed-upon common format have to be hand-coded by programmers
- MOF® and MDA® provide the basis for automating the syntactic transformations

MOF and KR Together

- MOF technology streamlines the *mechanics* of managing models as XML documents, Java objects, CORBA objects
- Knowledge Representation supports *reasoning* about resources
  - Supports semantic alignment among differing vocabularies and nomenclatures
  - Enables consistency checking and model validation, business rule analysis
  - Allows us to ask questions over multiple resources that we could not answer previously
  - Enables policy-driven applications to leverage existing knowledge and policies to solve business problems
    - Detect inconsistent financial transactions
    - Support business policy enforcement
    - Facilitate next generation network management and security applications

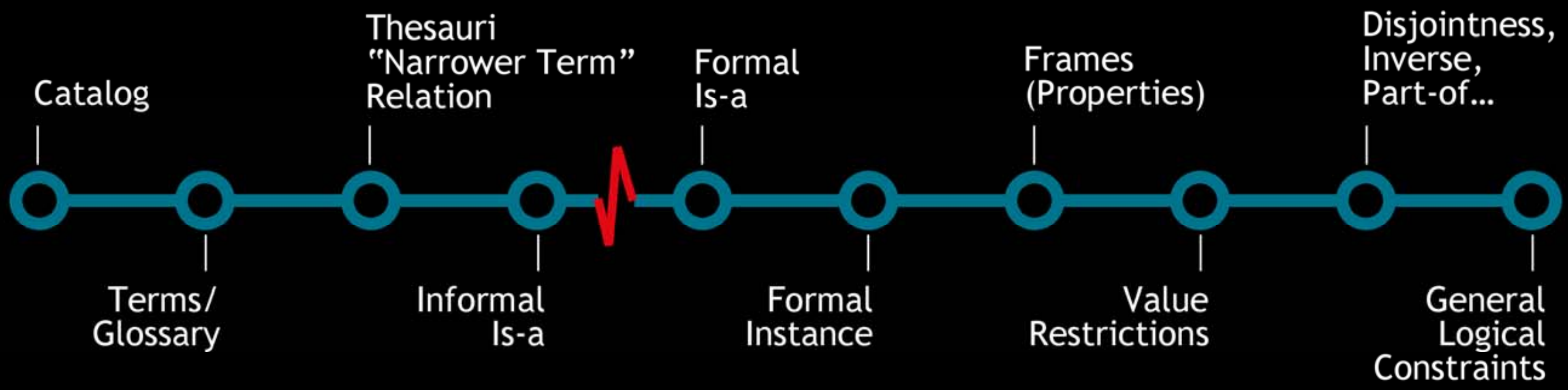
  while integrating with existing RDBMS and OLAP data stores
- MOF provides no help with reasoning
- KR is not focused on the mechanics of managing models or metadata
- Complementary technologies – despite some overlap

Level Setting

An ontology specifies a rich description of the

- Terminology, concepts, nomenclature
- Properties explicitly defining concepts
- Relations among concepts (hierarchical and lattice)
- Rules distinguishing concepts, refining definitions and relations (constraints, restrictions, regular expressions)

relevant to a particular domain or area of interest.

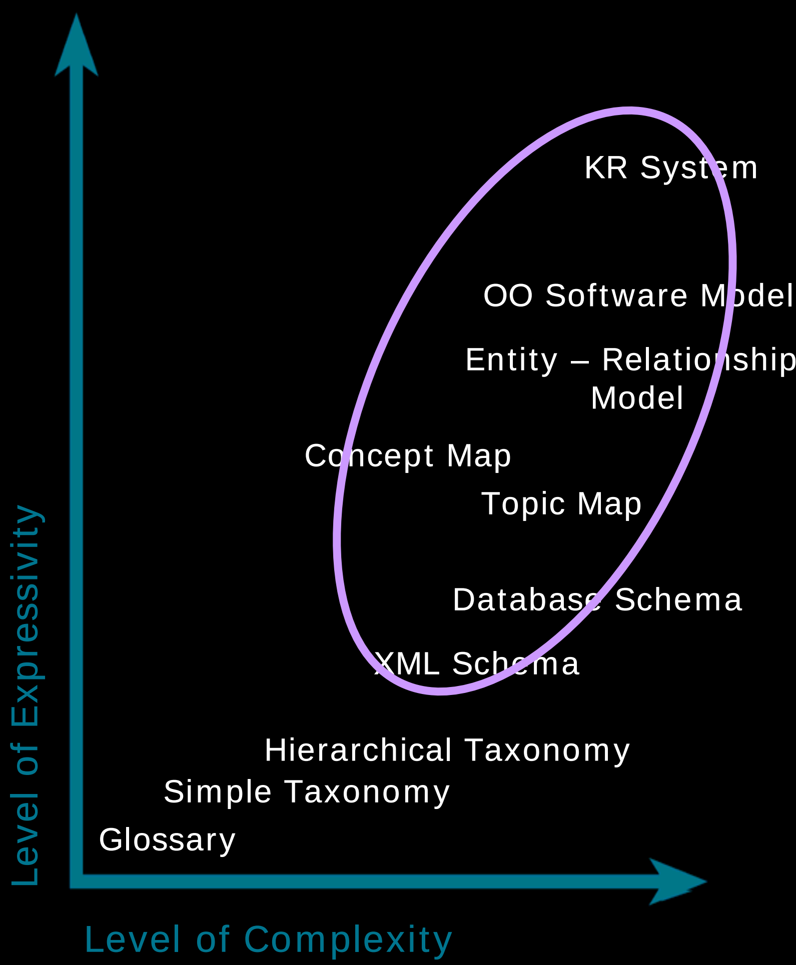


*Based On Aaai '99 Ontologies Panel - Mcguinness, Welty, Ushold, Gruninger, Lehmann

Classifying Ontologies

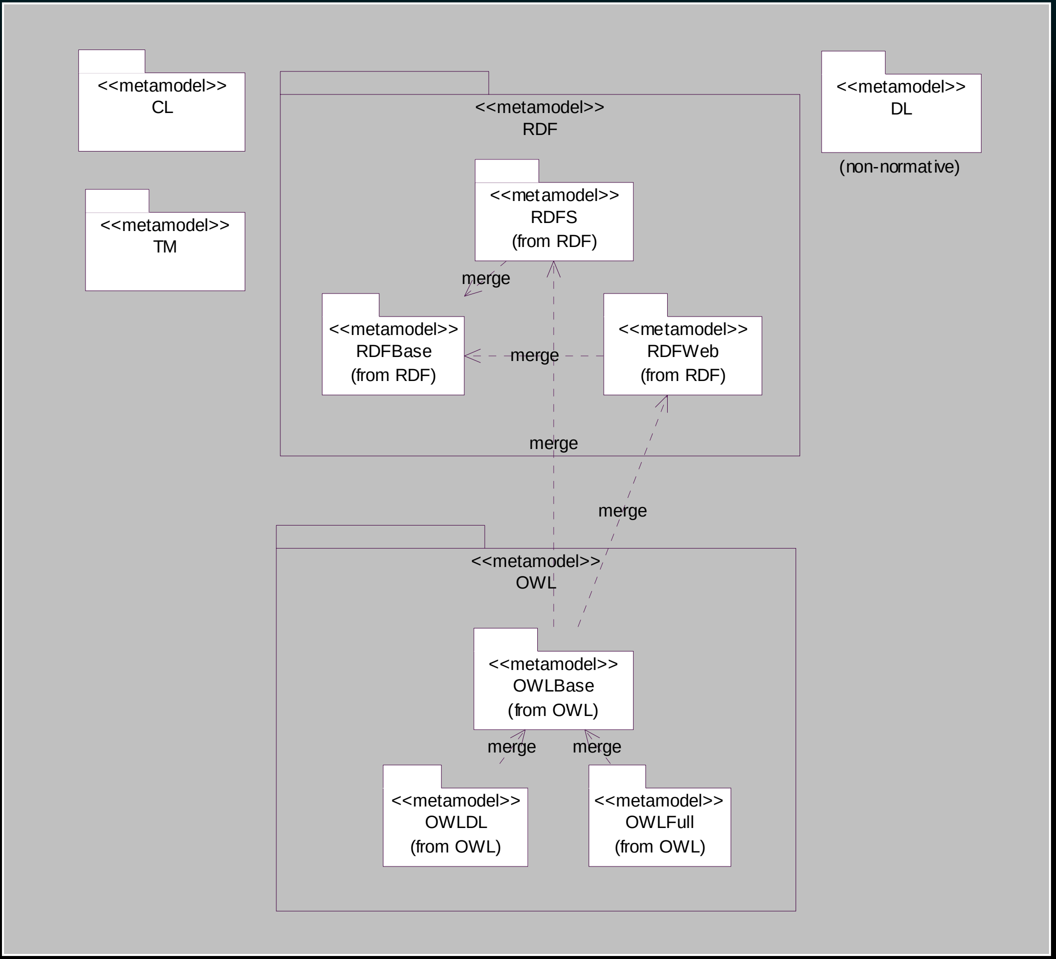
Classification techniques are as diverse as conceptual models; and generally include understanding

- Methodology
- Target Usage
- Level of Expressivity
- Level of Complexity
- Reliability / Level of Authoritativeness
- Relevance
- Amount of Automation
- Metrics Captured and/or Available



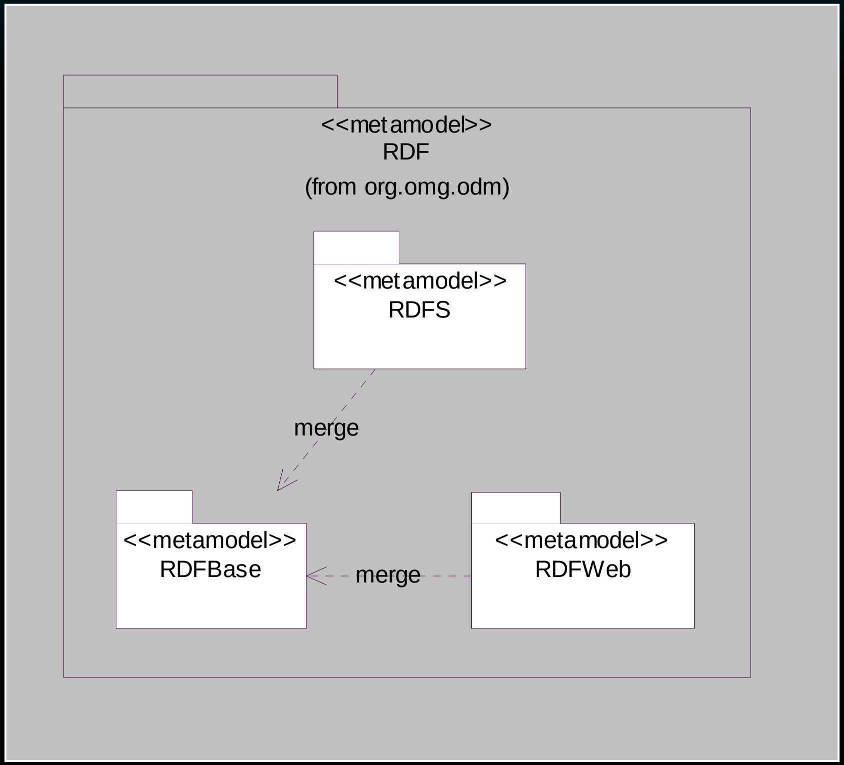
Towards Model Driven Ontology Development - ODM

- Five EMOF platform independent metamodels (PIMs), four normative
- Mappings (MOF QVT)
- UML2 Profiles
  - RDFS & OWL
  - TM
- Collateral
  - XMI
  - Java APIs
  - Proof-of-concepts
- Conformance
  - RDFS & OWL
  - Multiple Options
  - TM, CL Optional
  - Informative Mappings

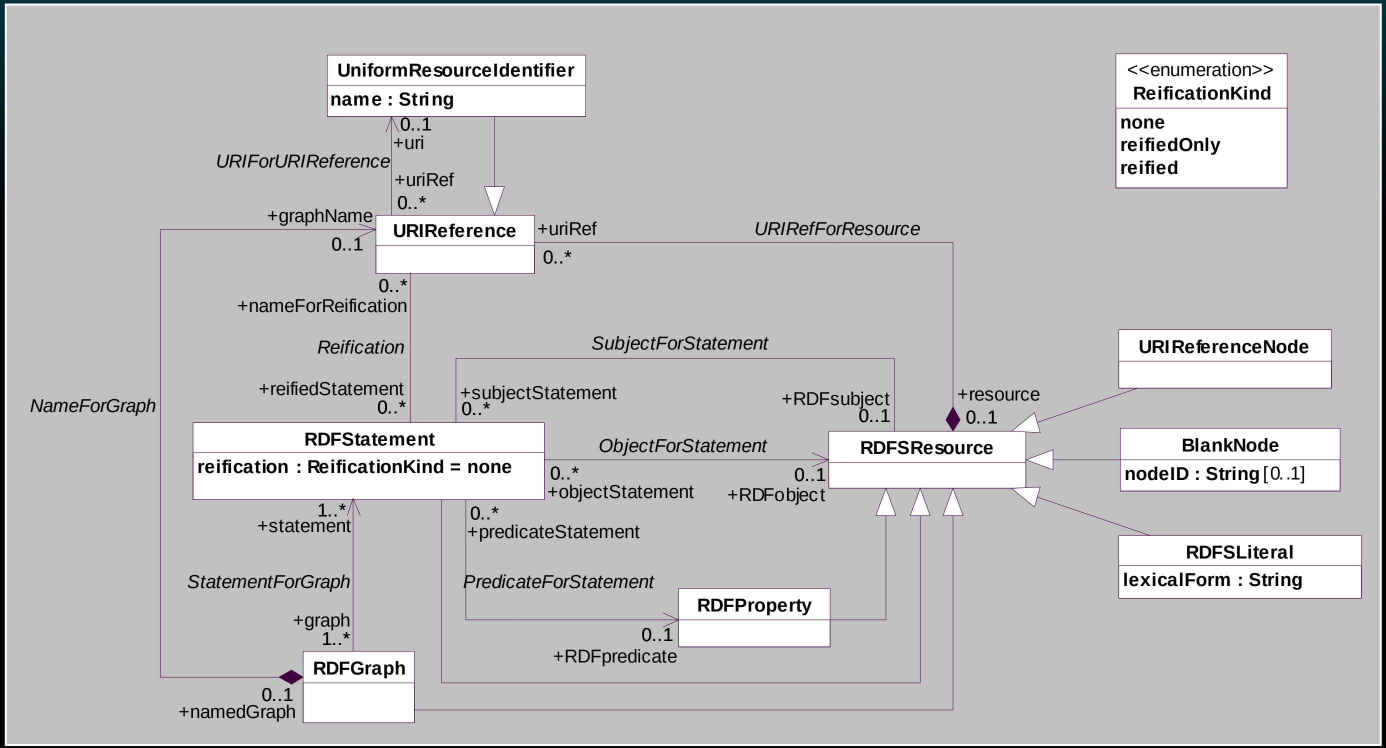


Resource Description Framework (RDF) Metamodel Overview

- RDFBase – primary package
  - Reflects basic abstract syntax from RDF Concepts
  - Minimal implementation requirements, e.g., for RDF triple/quad store
- RDFS – adds vocabulary related to RDF Schema, few additional RDF features
- RDFWeb – fits the model to the Web via document model, required for RDF/XML syntax, among others

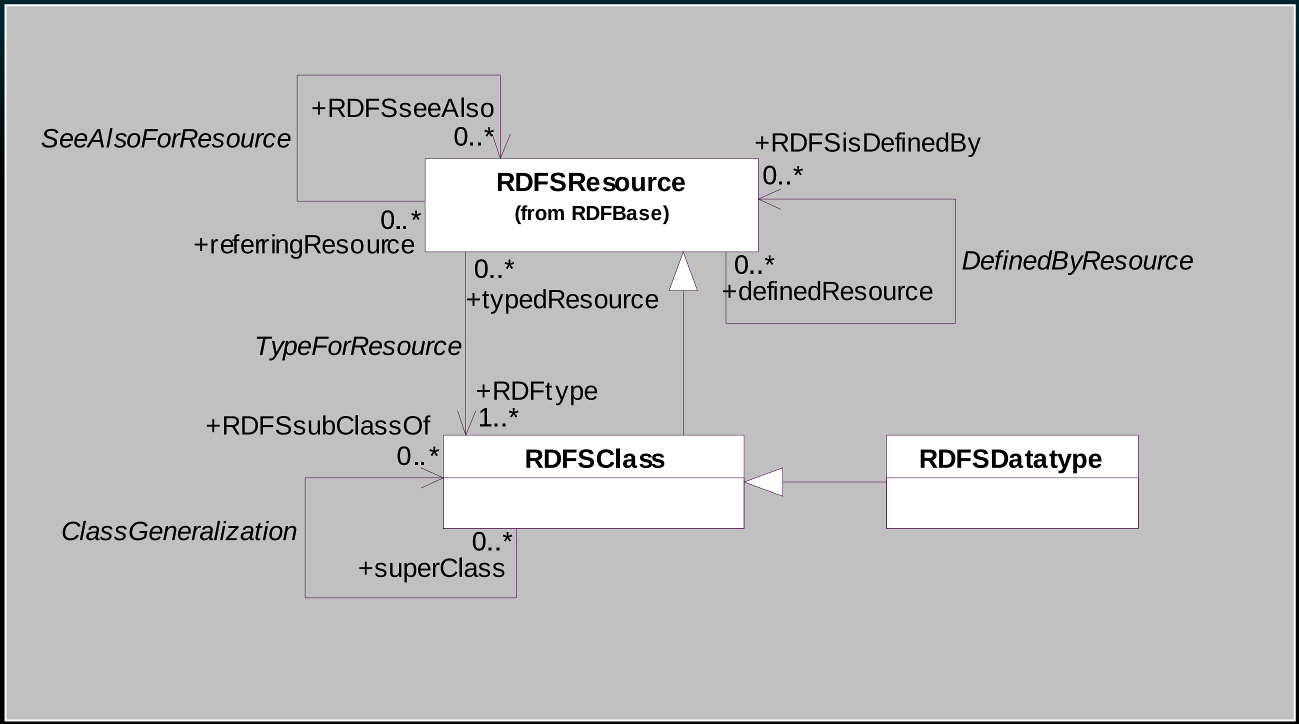


RDFBase Package – Statements



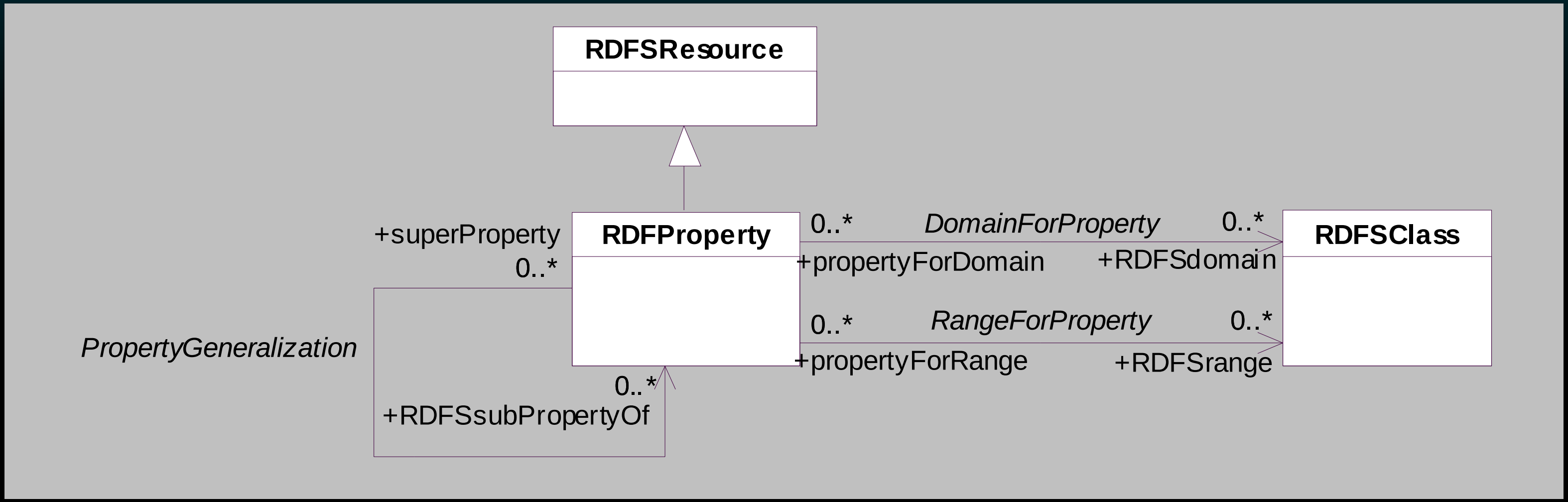
- Supports named graphs (*e.g.*, per SPARQL), reification, blank node identifiers, essentially RDF basics
- Limited coverage to RDF Concepts document rather than along namespace boundaries, which didn't work from a UML perspective
- Promotion of the blank node identifier to RDFSResource addresses MOF multiple classification, non-normative work-around

RDFS Package – Classes & Utilities



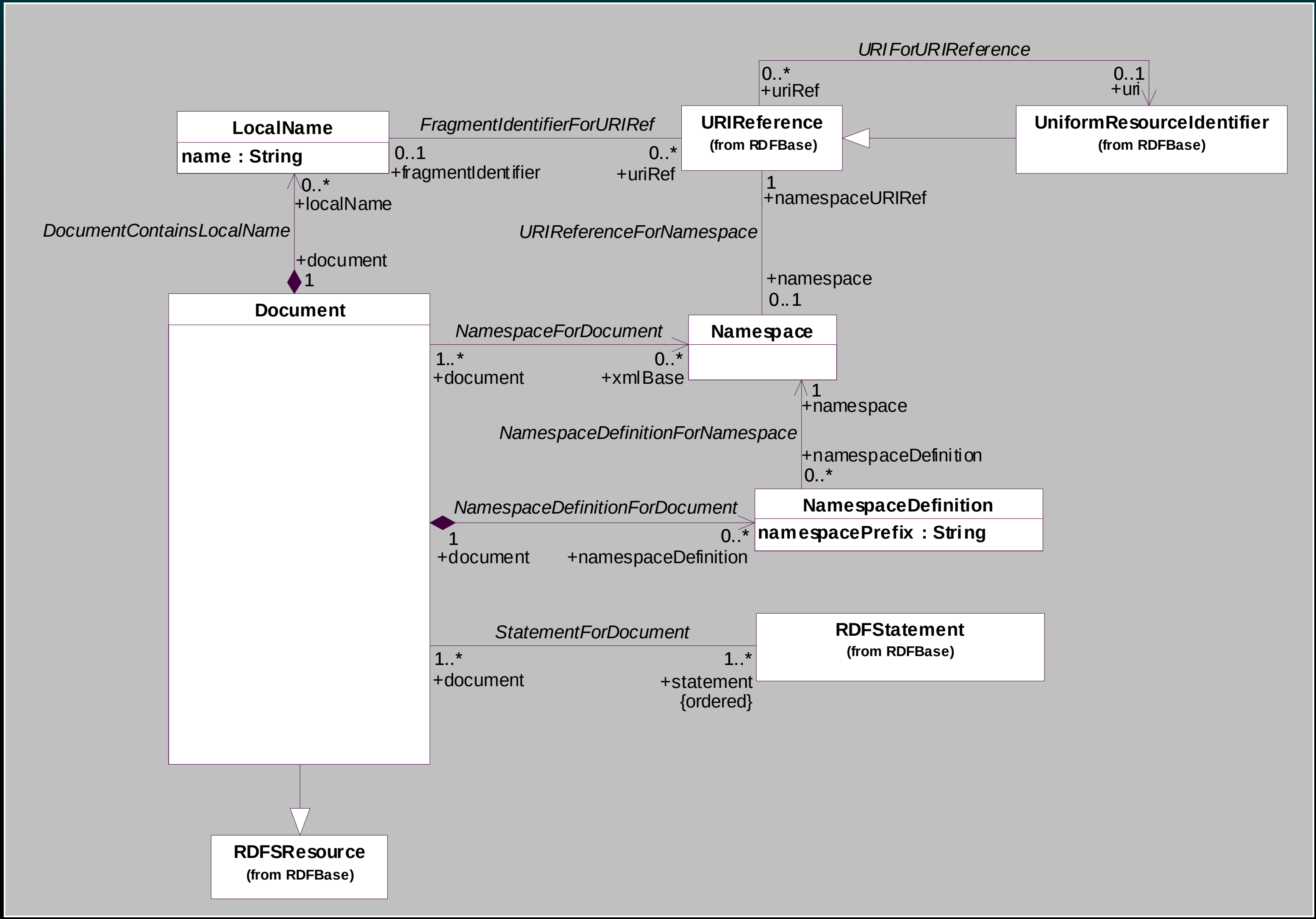
- RDFS assists us in “getting around” MOF multiple classification limitations through rdf:type

RDFS Package - Properties

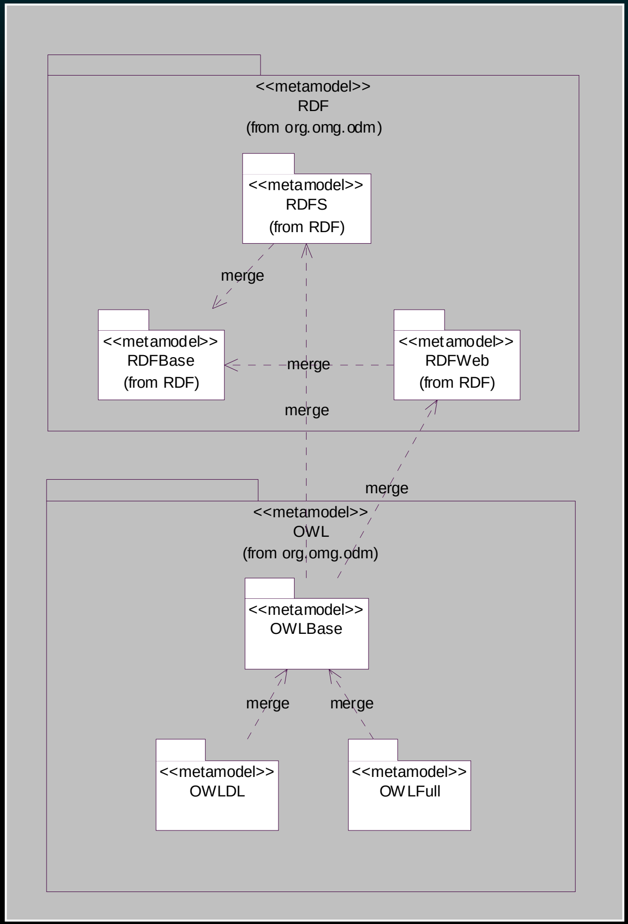


- **Note that rdf:domain and rdf:range are global properties – limiting their usage enhances reusability of ontology components**

RDFWeb Package - Documents

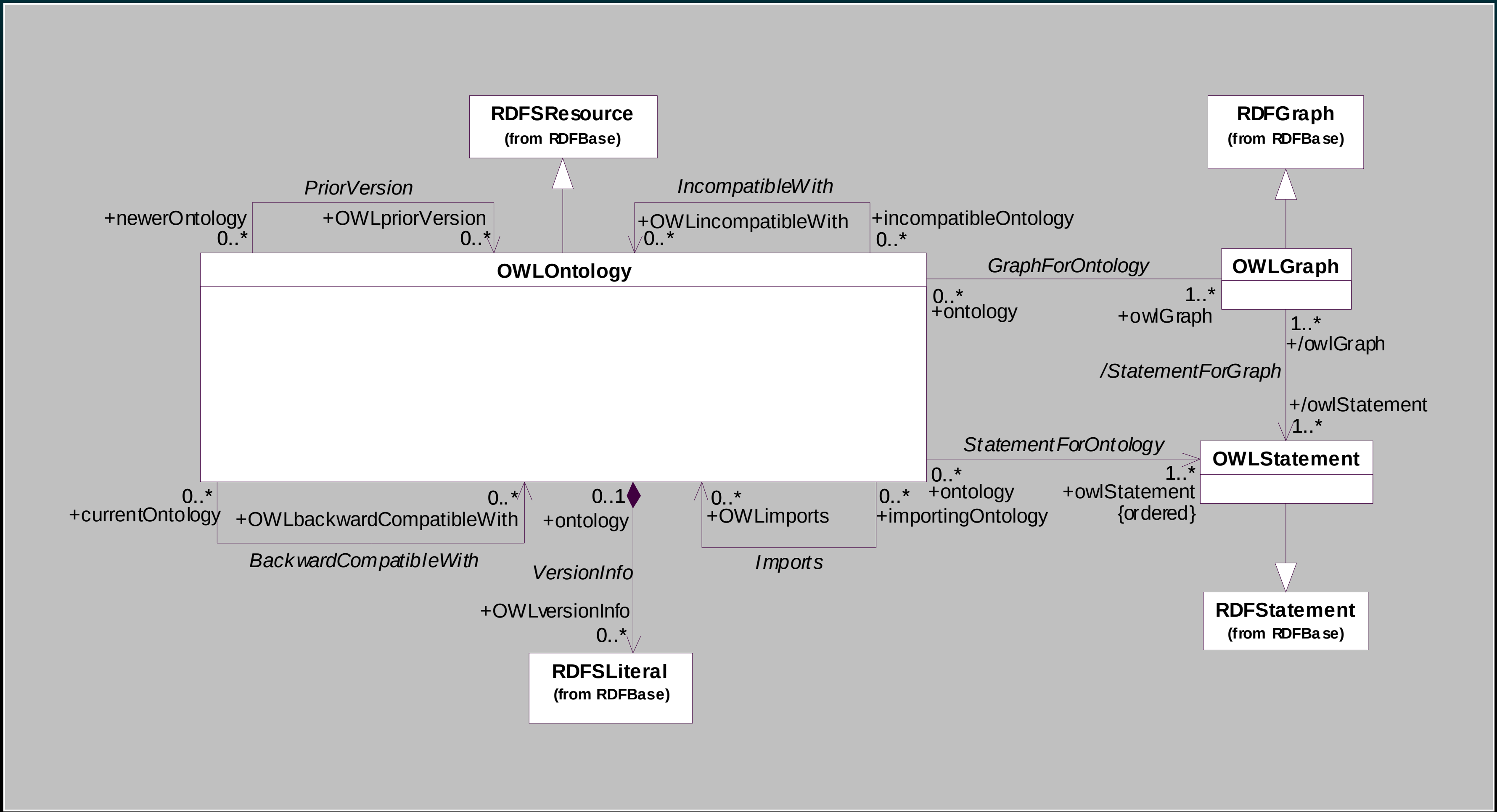


Web Ontology Language (OWL) Metamodel Overview



- OWL metamodel components include:
  - OWLBase, covering all common abstract syntax & constraints
  - OWLDL – containing OWL DL constraints
  - OWLFull – containing OWL Full constraints
- Non-normative models for OWL, including changes to property representation & intersection classes for OWL Full, to address MOF multiple classification, are posted to the OMG web site

OWLBase Package – OWL Ontology



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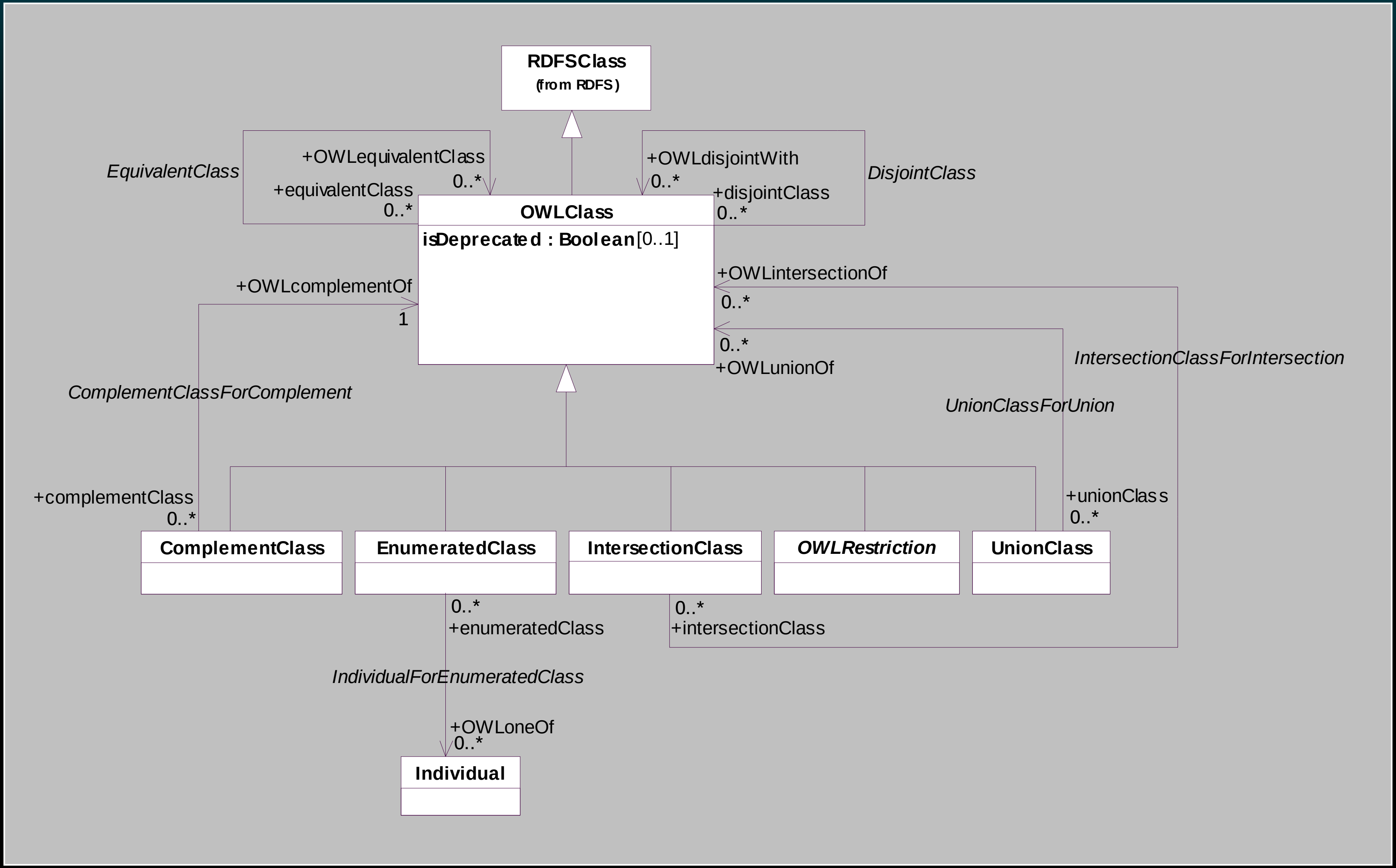
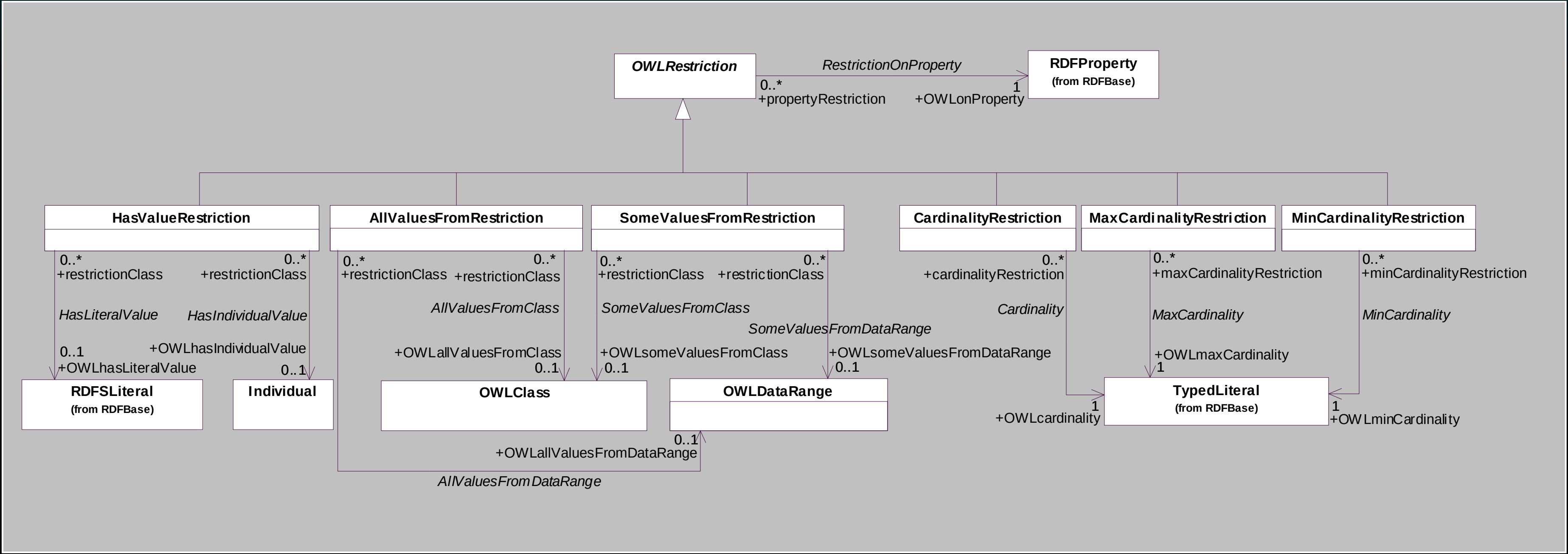
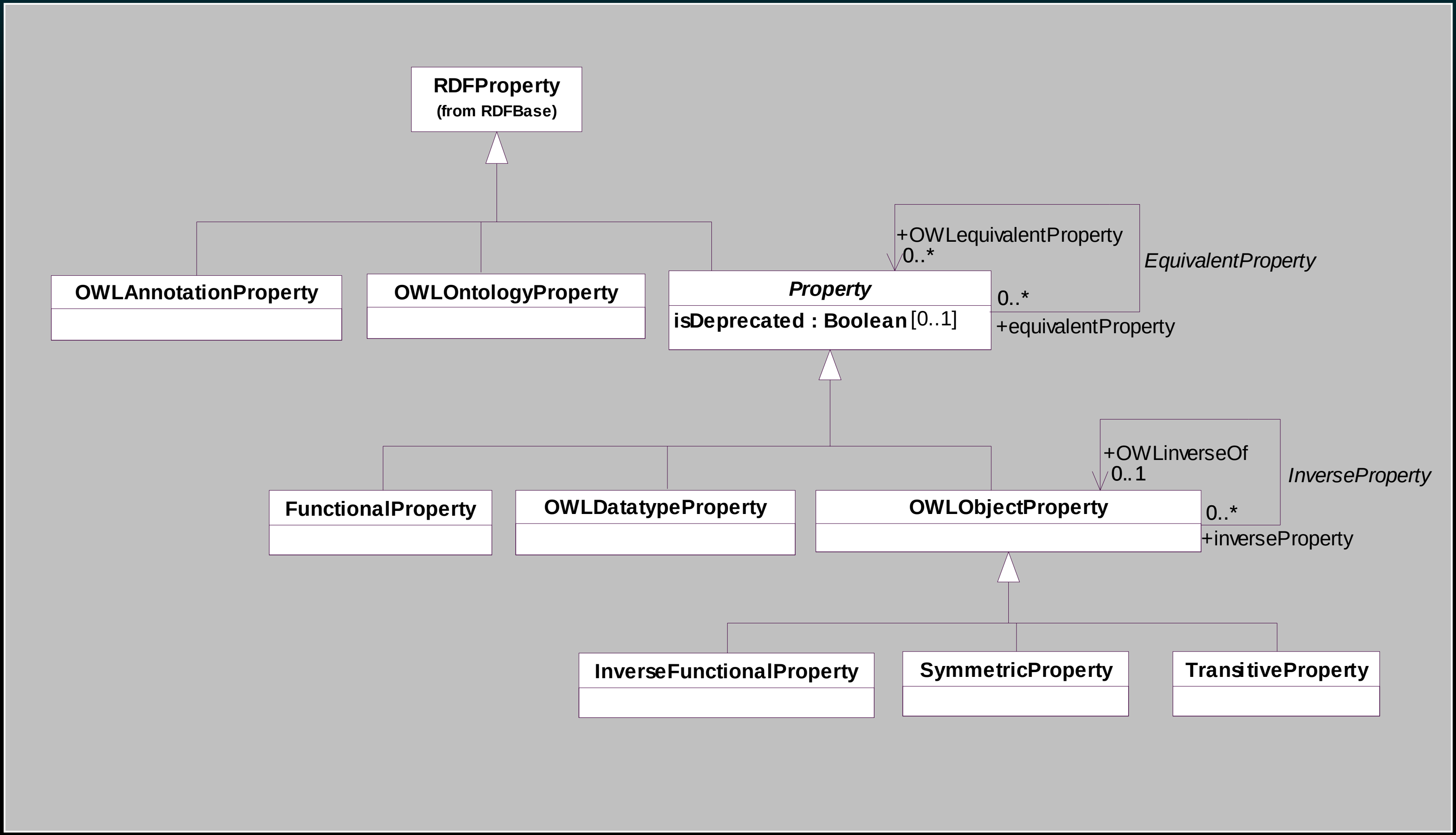
OWLBase Package – OWL Classes



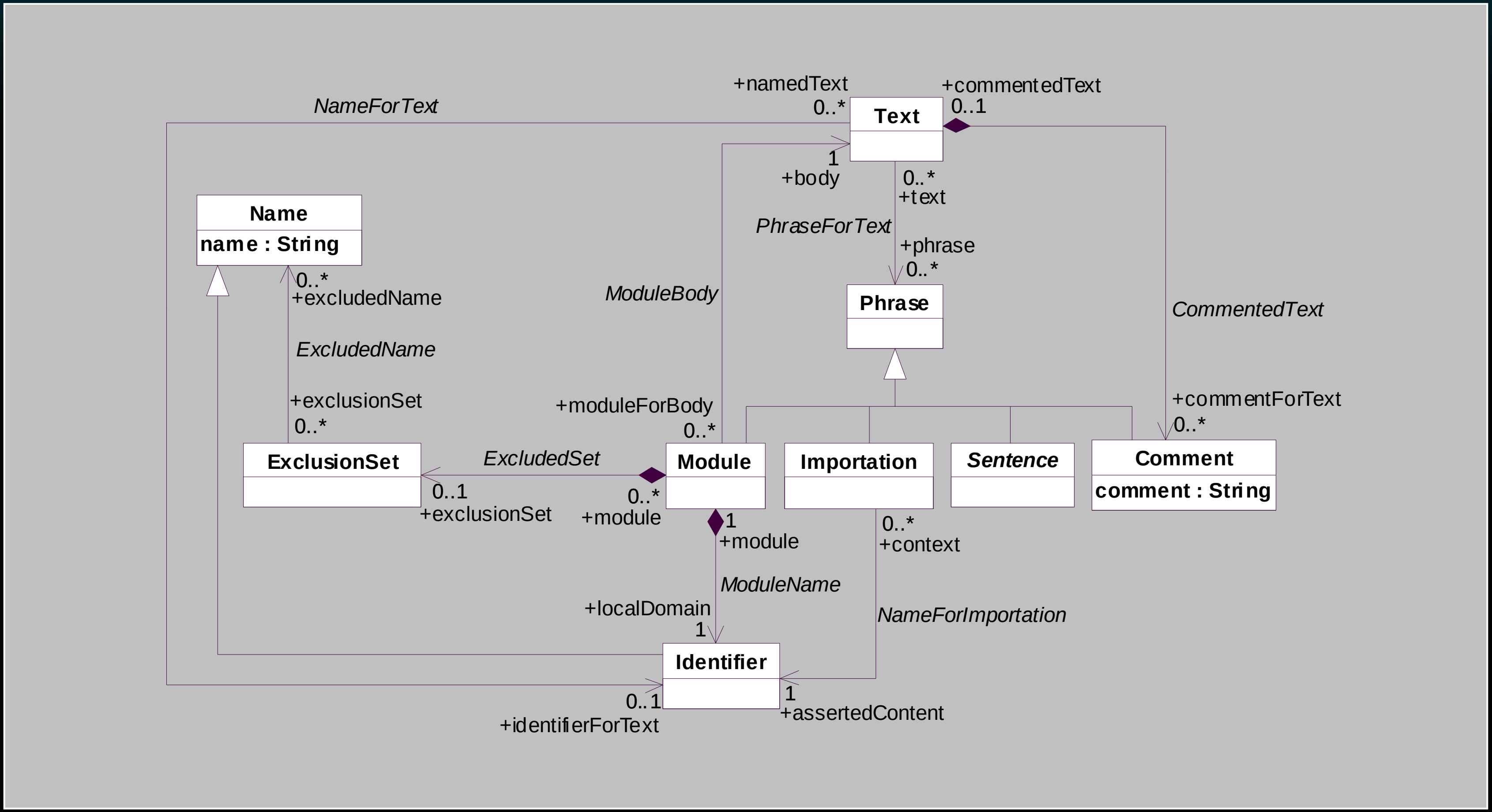
OWLBase Package – Restrictions



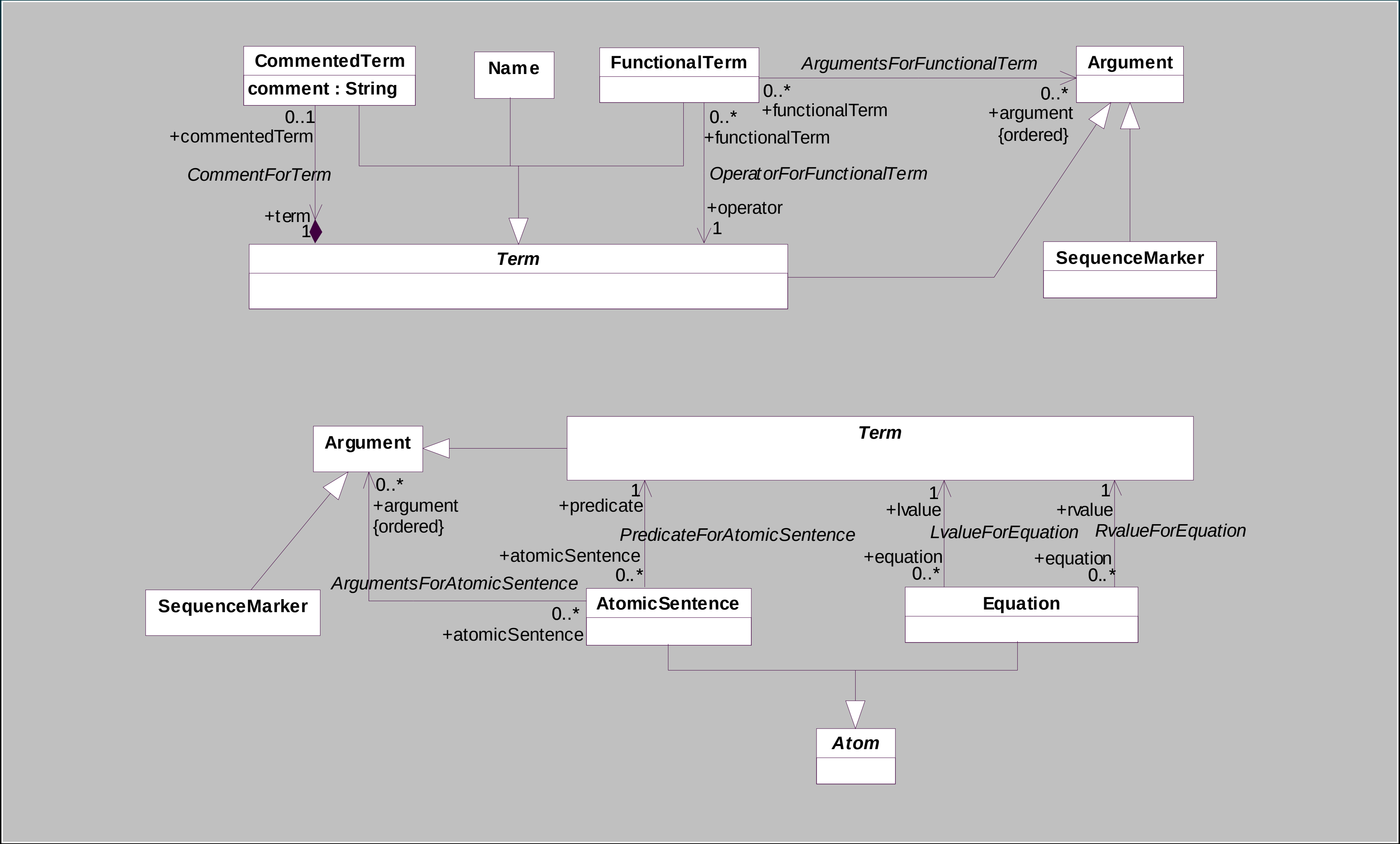
OWLBase Package – OWL Properties



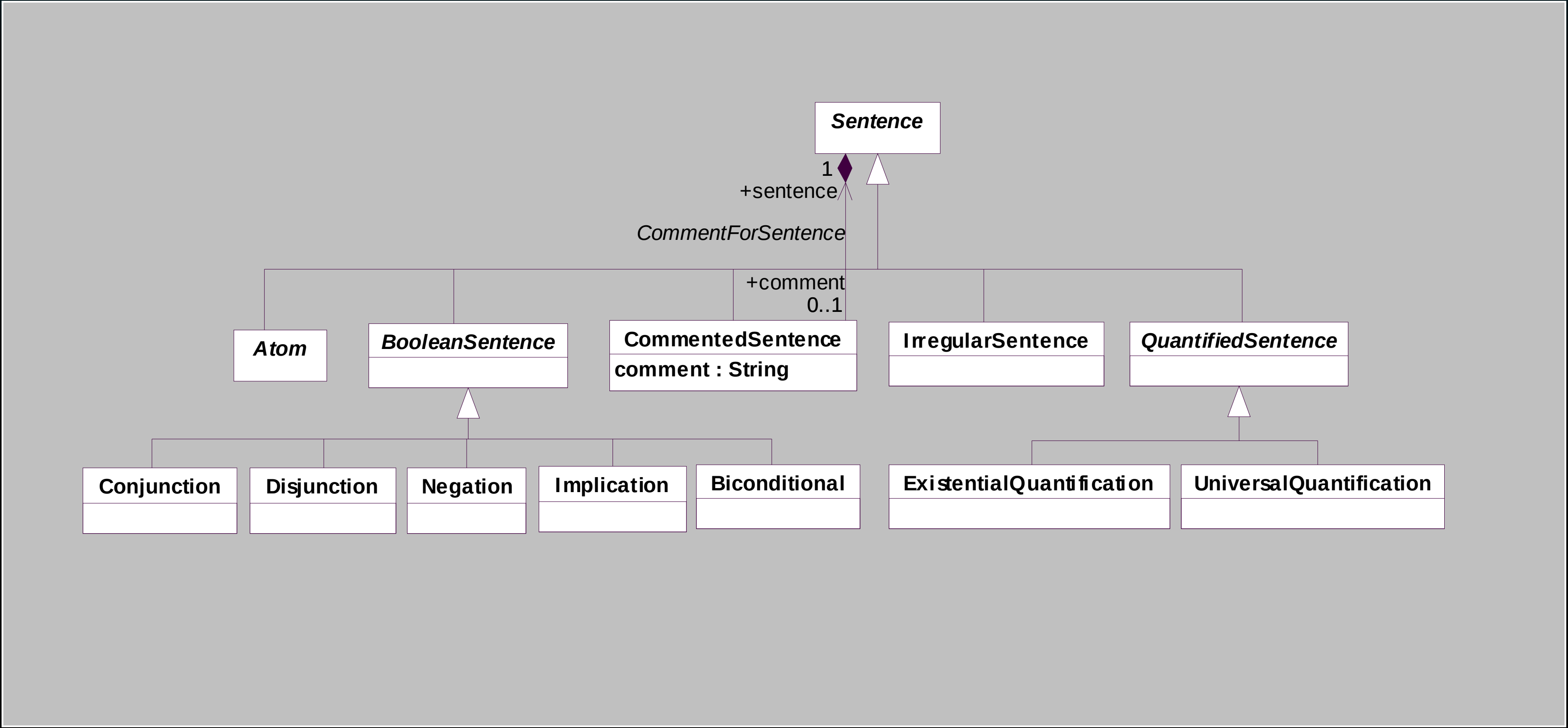
Common Logic Phrases



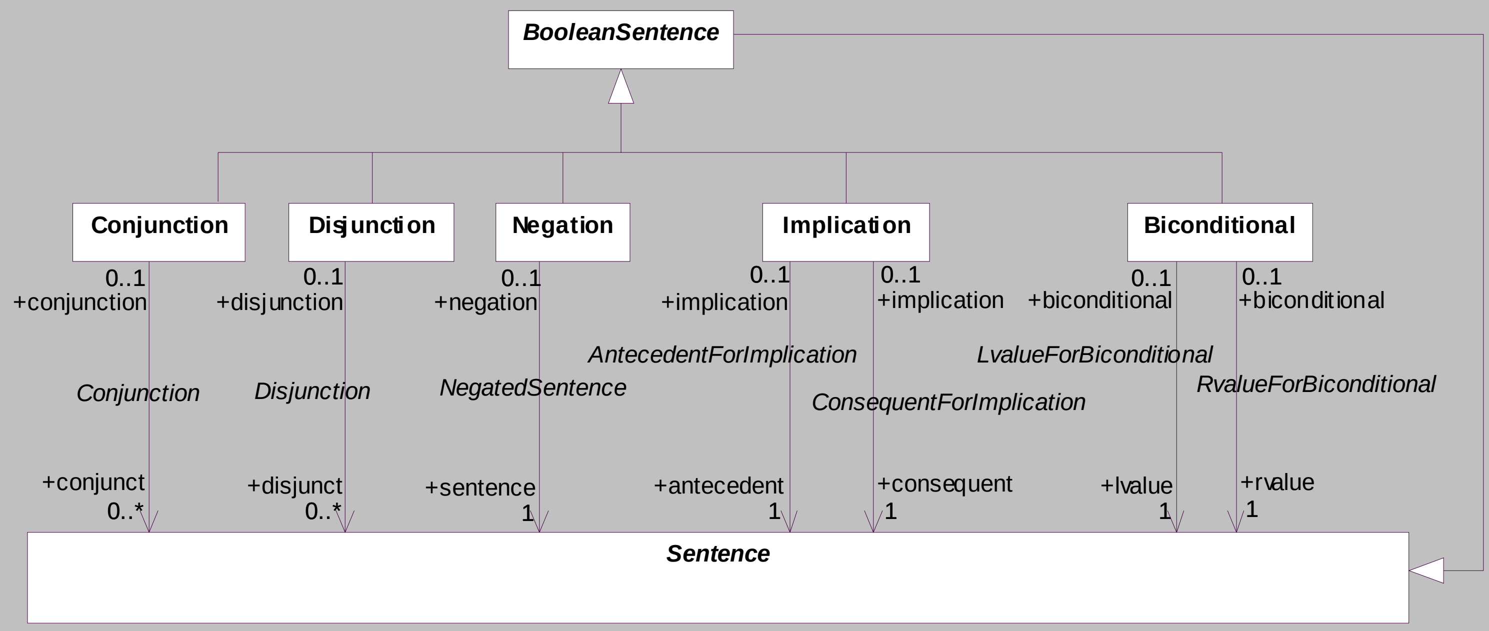
CL Terms & Atoms



Sentences


Sentence
1
+sentence
CommentForSentence
+comment
0..1
Atom
BooleanSentence
CommentedSentence
comment : String
IrregularSentence
QuantifiedSentence
Conjunction
Disjunction
Negation
Implication
Biconditional
ExistentialQuantification
UniversalQuantification

Boolean Sentences



There are no explicit 'true' and 'false' elements in the metamodel. These are empty cases of Conjunction (true) and Disjunction (false). That is why a Disjunction or Conjunction of zero sentences is allowed.

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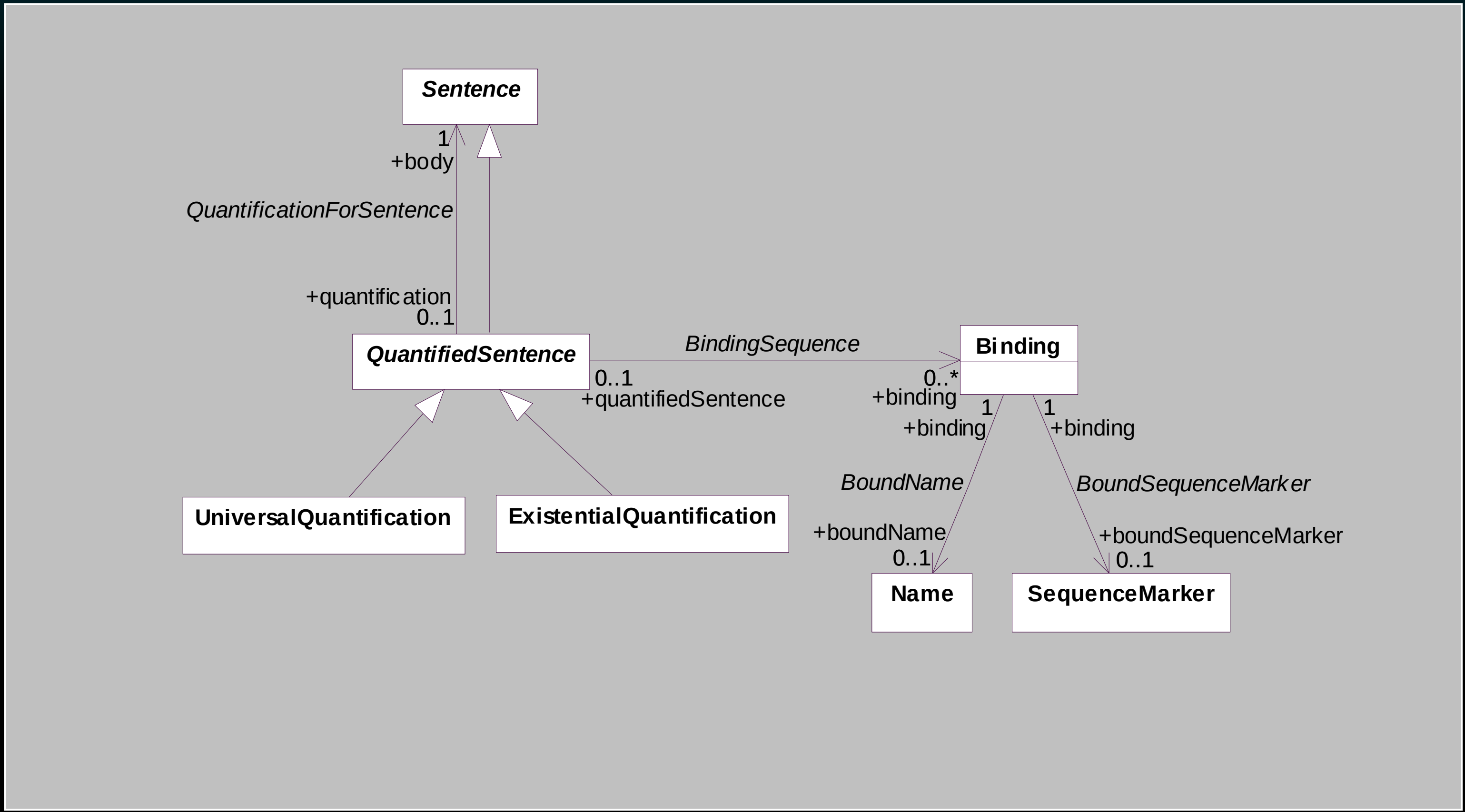
Quantified Sentences

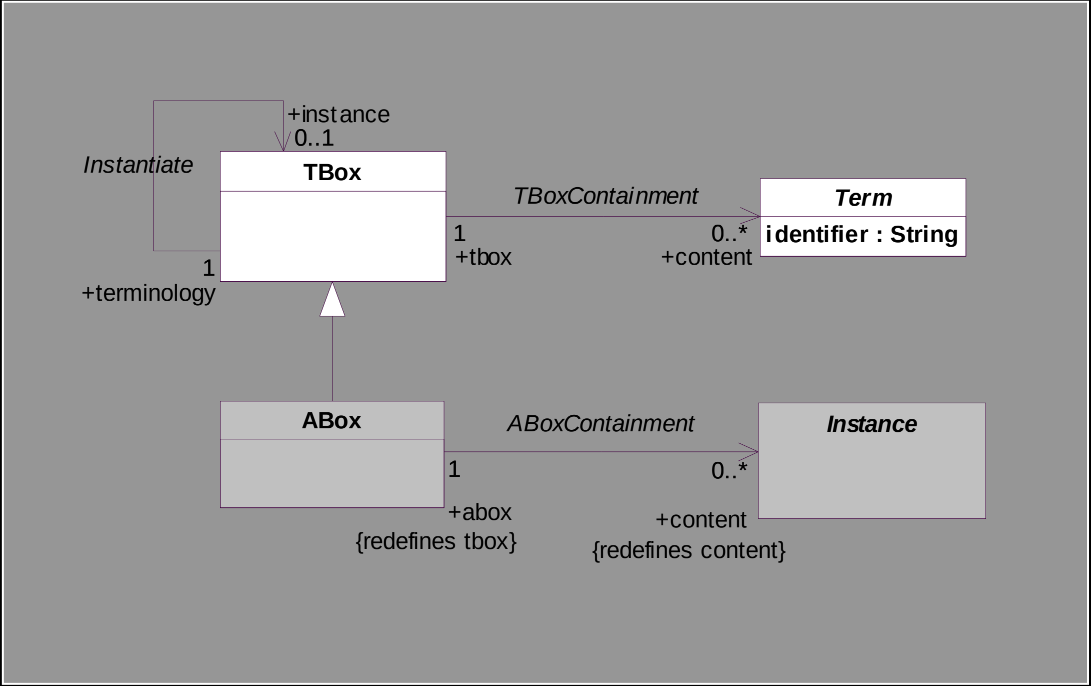


Topic Maps

- Topic Maps represent another XML Schema based approach for conceptual knowledge representation
  - Part of the semantic web family of standards
  - Less expressive than RDFS/OWL
- Topic Maps are collections of topics, each of which represent a single subject, that are related to one another by associations.
  - Similar to RDF, but less expressive (currently)
  - Originally based on the notion of a publications index
  - Used primarily by the business community in Europe
- Recently standardized through the ISO
  - ISO 13250 – Data Model and XML Serialization
  - ISO 18024 – Query Language (early draft)
  - ISO 19756 – Constraint Language (early draft)

DL Metamodel

- Many variations on DLs, depending on application requirements and reasoning capabilities (OWL represents a commonly used subset)
- Developed primarily as an educational tool, to assist in understanding description logics in general

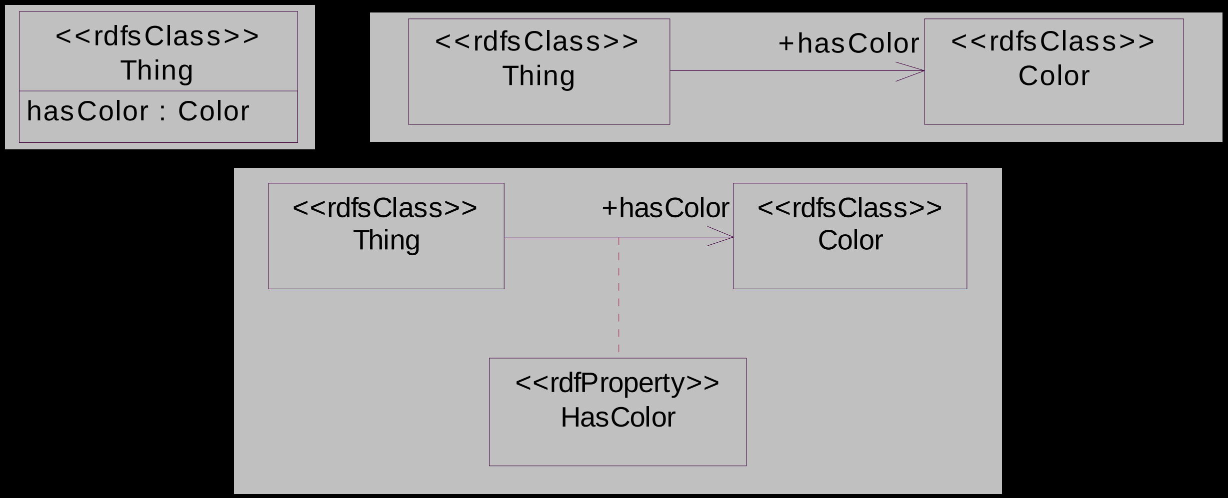


The UML Profile for RDF & OWL

- Intended to be highly intuitive for UML users
- Reuses UML constructs when they have the same semantics as OWL
- When this is not possible, stereotypes UML constructs that are consistent and as close as possible to OWL semantics
- Uses standard UML 2 notation
- In the few cases where this is not possible, follows the clarifications and elaborations of stereotype notation defined in UML 2.1
- Leverages the model library included in Appendix A for a number of constructs, for example statements, rdf:value, container and list elements, as well as built-in properties

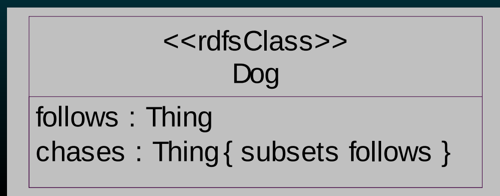
Key Features of the RDF Profile

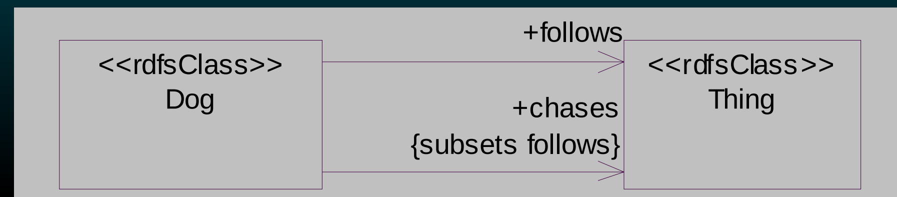
- rdfs:Resource is modeled as UML::InstanceSpecification
- Introduction of <<reifies>> stereotype of UML::Dependency to allow such instance specifications to reify classes, properties, individuals, statements, etc.
- rdf:Property is modeled as UML::AssociationClass *and* UML::Property, to provide greatest possible flexibility
- Several possible representations of various aspects of rdf:Property:

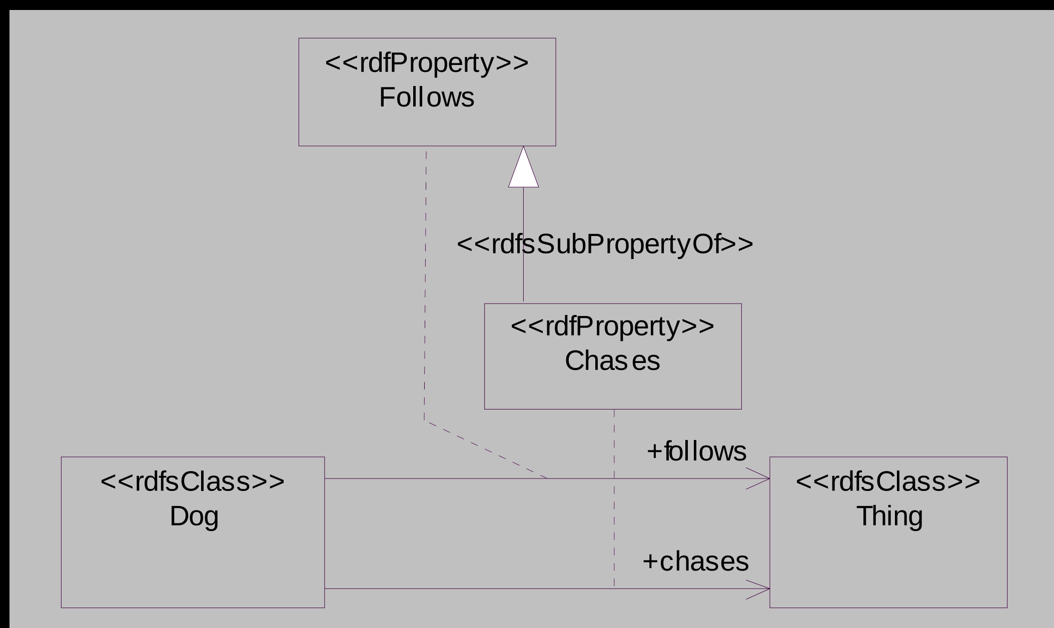


Alternate forms for rdf:Property, without a specified domain

RDF Property Subsetting Options

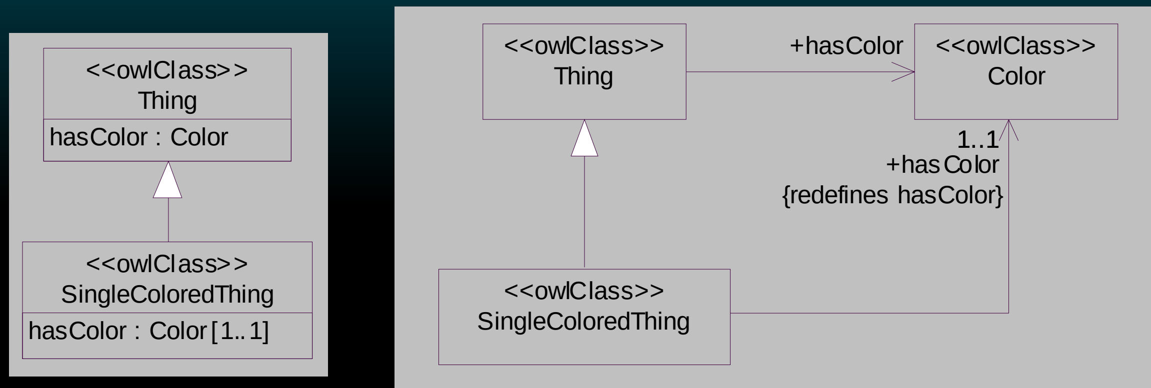




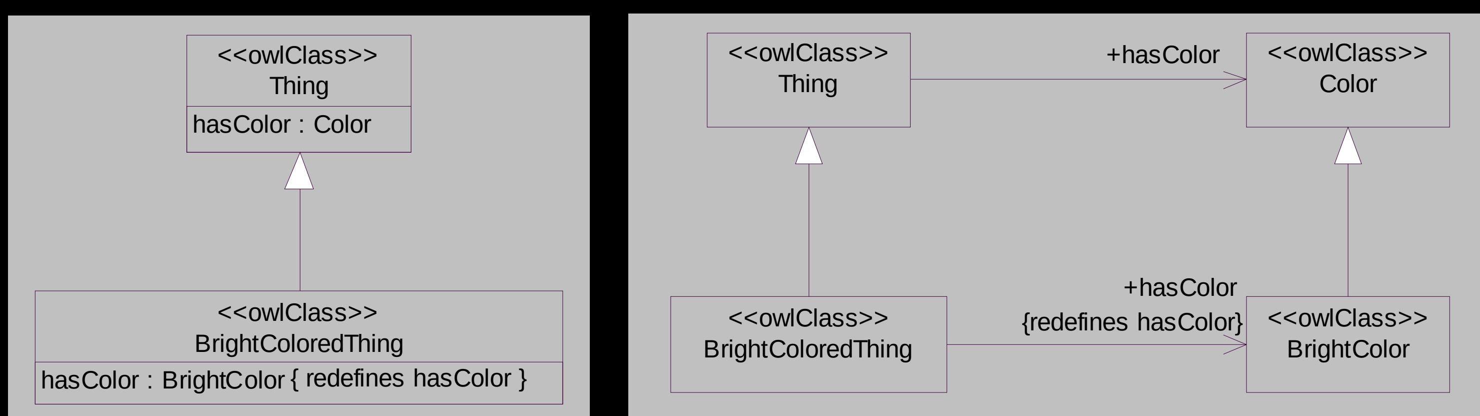


Alternate forms for rdf:Property, without a specified range

Example OWL Number, Value Constraints

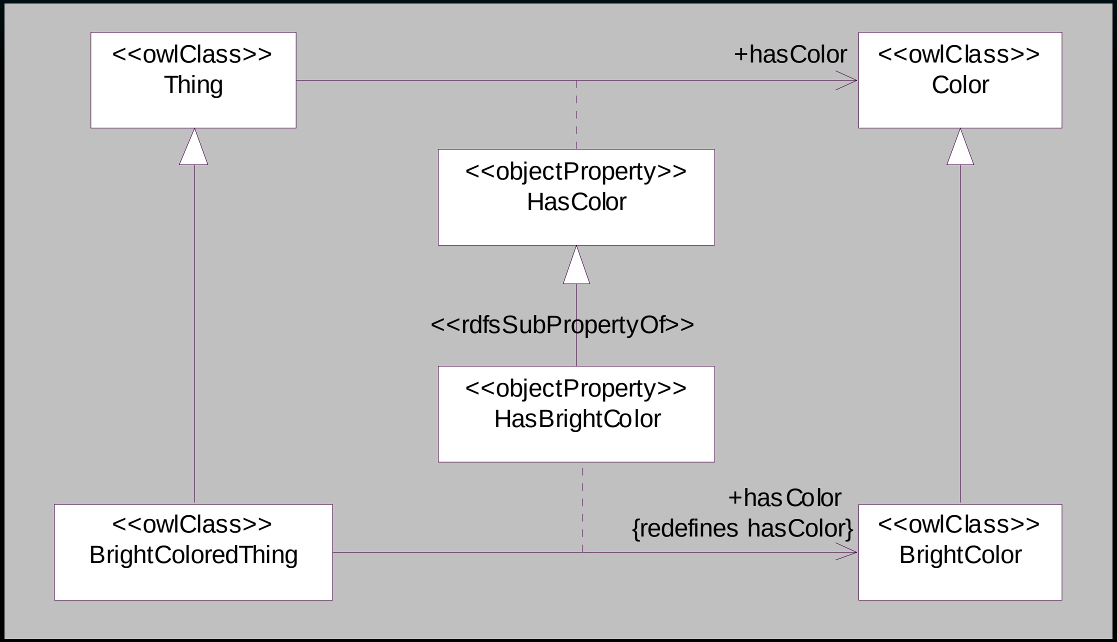


OWL Cardinality – Restricted Mulitplicity in Subtype

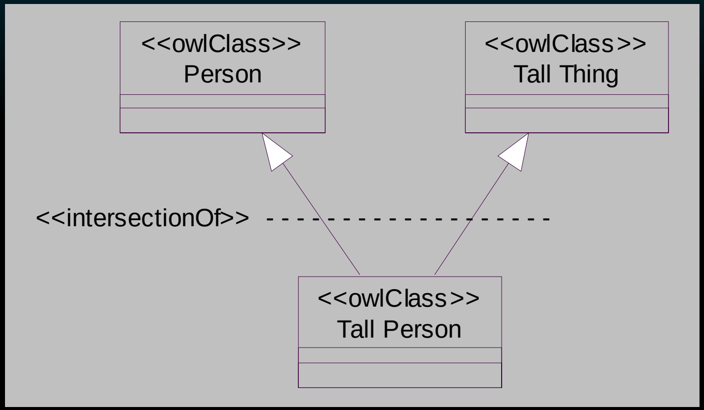


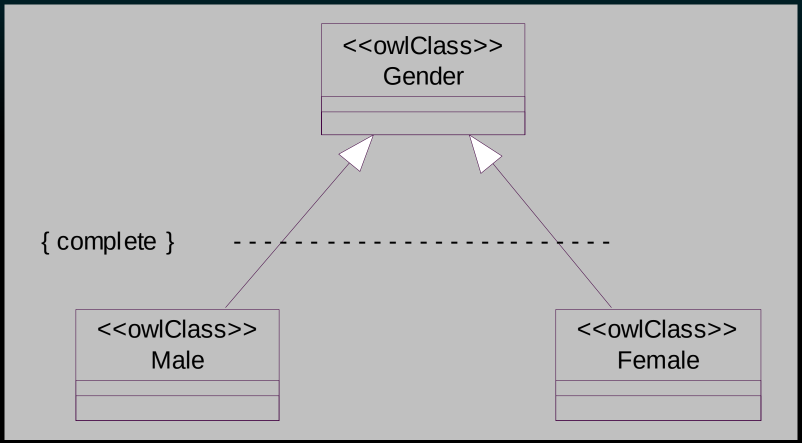
OWL allValuesFrom – Property Redefinition

OWL Property Redefinition (allValuesFrom) Using Association Classes

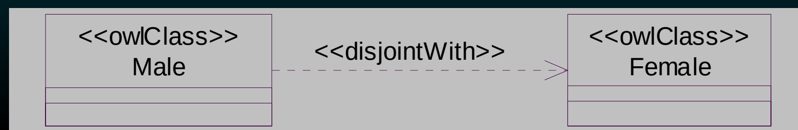


OWL Intersection, Union, Complement

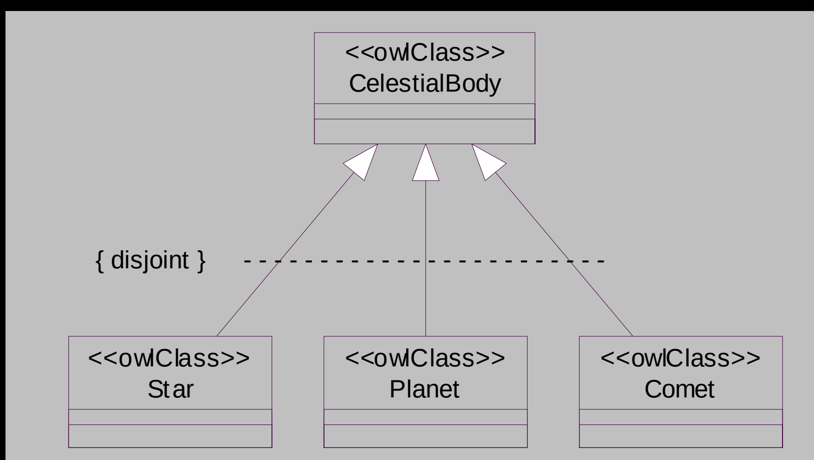




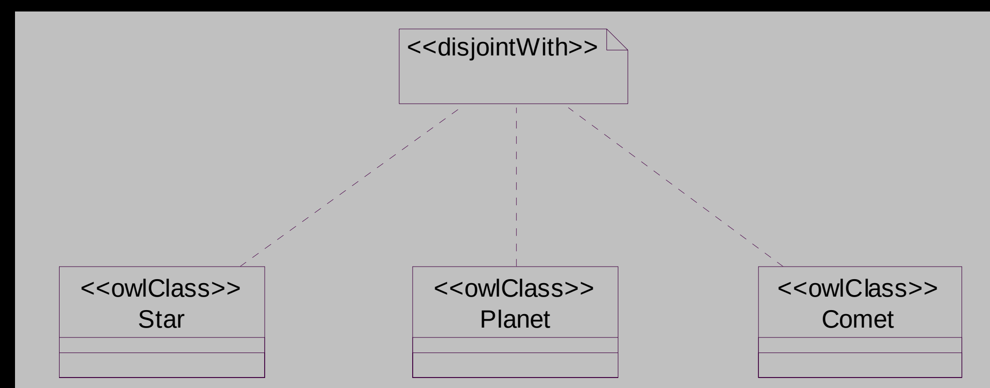
OWL Disjointness Options



Simple binary disjoint relationship

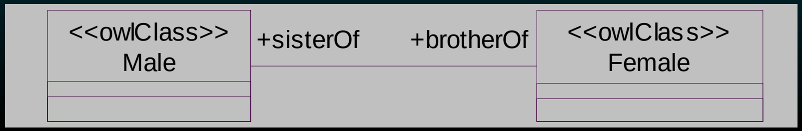


Disjointness, multiple participants, common parent

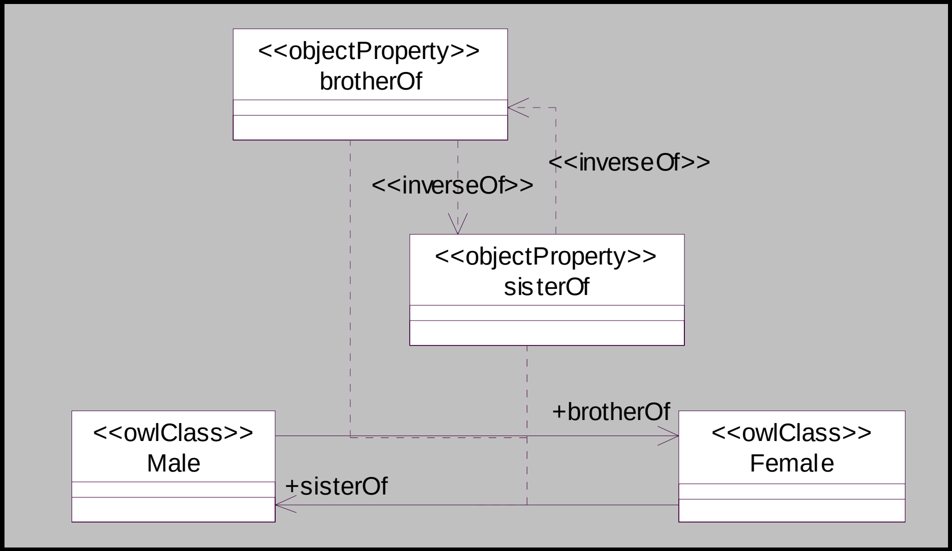


Disjointness, multiple participants, no common parent

OWL Inverse Options



Simple inverse relationship

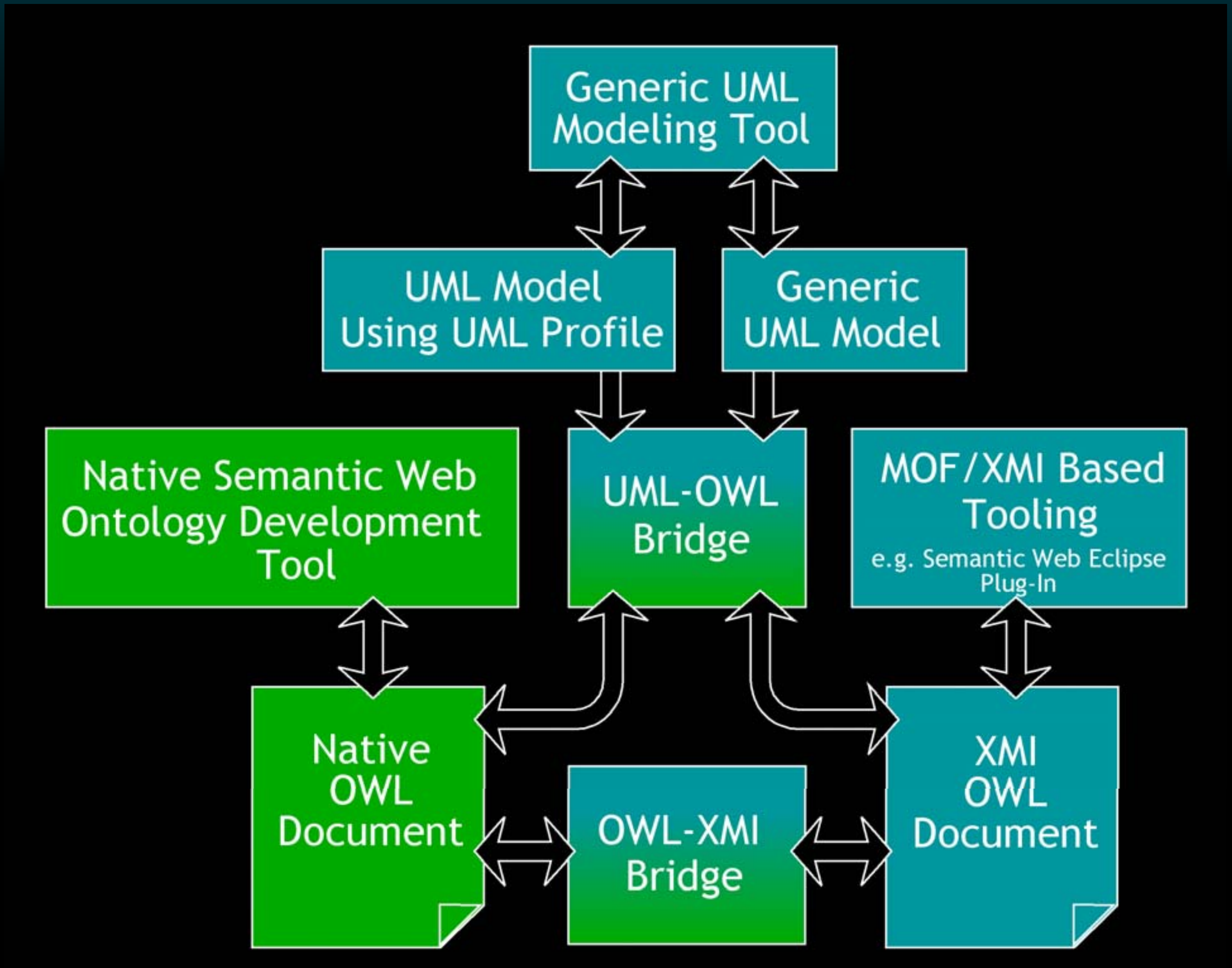


Inverse relationship among association classes

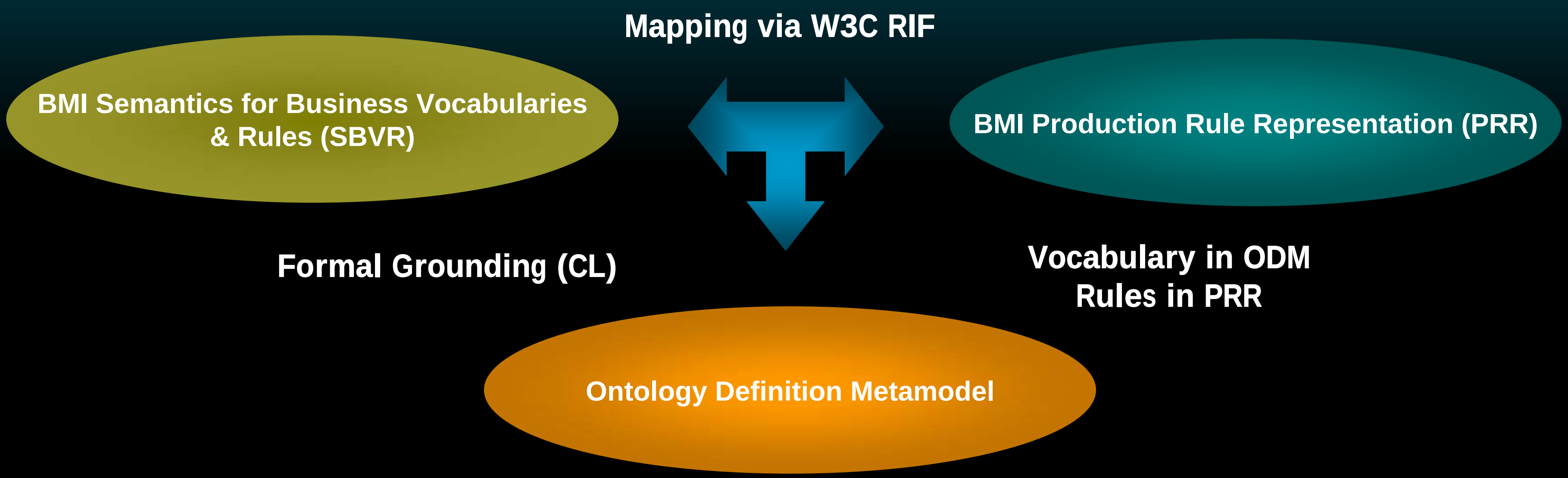
ODM Summary & Status

- Platform Independent (Normative) Metamodels (PIMs) include
  - RDF & OWL – abstract syntax, constraints for OWL DL & OWL Full, several compliance options
  - ISO Common Logic (CL)
  - ISO Topic Maps (TM)
- Informative Models
  - DL Core – high-level, relatively unconstrained Description Logics based metamodel (non-normative, informational)
  - Identifier (keys) model extension to UML for ER
- Adopted as an OMG standard in October 2006
- Final Adopted Specification is now publicly available from the OMG web site at http://www.omg.org/cgi-bin/doc?ptc/2006-10-11
- Finalization (FTF) is underway, with window for public comments through March 2007

Bridging KR and MDA



ODM Relationship to Other OMG Standards



ODM extensions under consideration

- Lossy mapping from CL to RDF/S & OWL
- Support for Semantic Web Services (SWSF, OWL-S), bindings to WSDL & possibly SOAP
- Mappings for W3C Rule Interchange Format (RIF) (*i.e.* vocab/ontology → rules, including PRR)
- New requirements from SOA ABSIG anticipated

Relationship to ISO Standards

- CL Metamodel is identical to the UML diagrams in ISO FDIS 24707
- High degree of synergy between ODM and Topic Maps ISO FCD 13250-2 working group
- All ODM metamodels are referenced and used in ISO CD 19763 (MMF – Metamodel Framework, Model Registry specification)
- Current work in OMG to develop a metamodel for ISO Express will include mappings to ODM
- Mappings from multiple components of IMM (*e.g.*, ER) are under consideration

Relationship to Metadata Standards

- Sandpiper participates in W3C Semantic Web Deployment (SWD) WG
  - Products will include RDF Vocabulary recommendations, SKOS for thesauri
  - Continuation of other best practices work initiated in original Semantic Web Best Practices & Deployment WG
- ODM metamodels inform latest modifications proposed for revisions to ISO 11179 Metadata Registration specification
- We are also working with NCITS L8 & DoD XMDR project to promote interoperability with ISO 19763, ISO 11179 metadata standards efforts

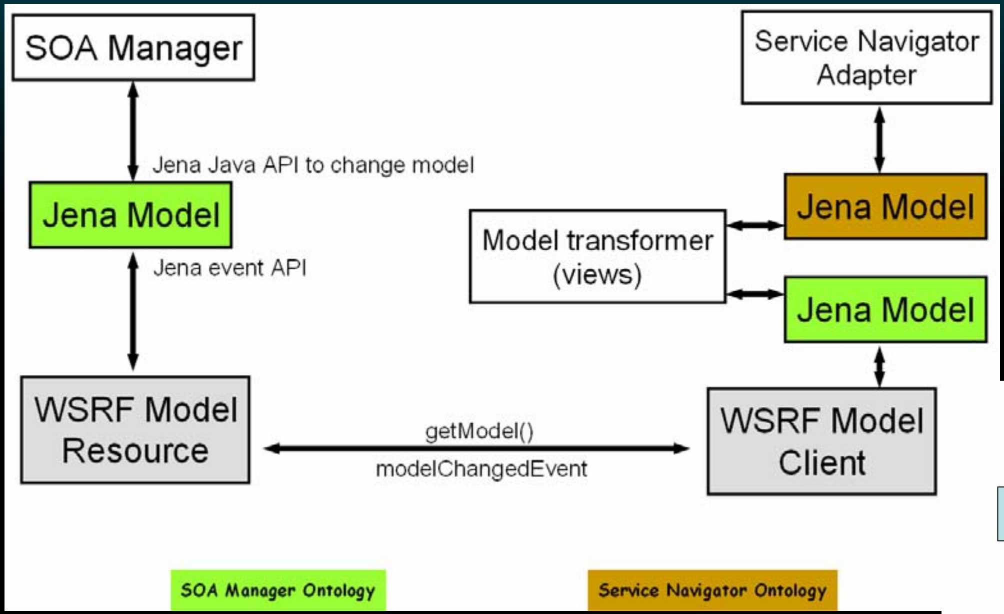
Next Steps

- W3C is moving the ball forward on a number of relevant fronts: RDF Query, Rules, SWS
- Ontology PSIG roadmap includes MOF revisions to support multiple classification, "Reverse ODM" – representation for MOF in RDF
- Longer term: extensions to ODM to support Semantic Web Services, mappings to IMM Metamodels for ER & ISO Express, Rules
- OMG BMI DTF Semantics for Business Vocabularies & Rules (SBVR) will be logically grounded in Common Logic / ODM CL Metamodel
- Planned mapping to forthcoming Production Rule Representation (PRR) specification
- May also consider leveraging mapping from UML for BPEL to ODM extensions (*e.g.*, to the PSL component of SWSF)
- Requirements and assistance needed

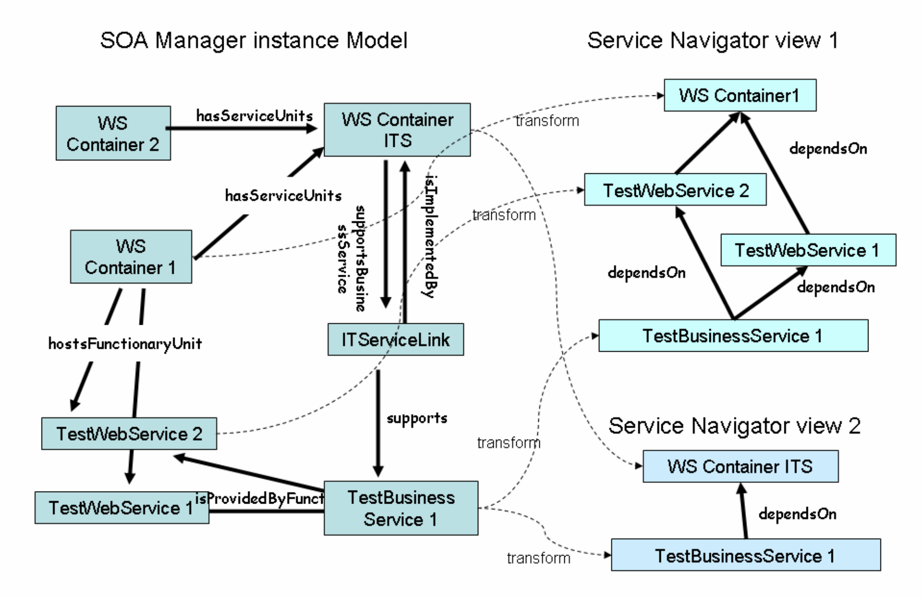
Application Vision

- Rich content services
  - Search relevance
  - Collaborative applications
  - Dramatic increases in personalization
  - New analytics and business intelligence capabilities
- Dramatic increases in interoperability through much deeper semantic integration
- Achieve MDA vision through
  - Model validation
  - Separation of vocabulary from software & rules – increased value in patterns, abstraction
  - Component based vocabulary & semantics – increased scalability, support for grid-based applications, Web 2.0
  - Semantics for Web services
    - Declarative exchange of behaviors, policies, and agreements
    - Dynamic discovery of new services
    - Reasoning to support on-the-fly composition
    - Integrated use with discovered information services → ultimate fully-automated & customized user experience
- New capabilities in policy and context based applications

Management Application Integration (MAI)



Synchronization of model repositories using RDF/S & OWL based representation & transformations provides new integration capabilities for HP OpenView

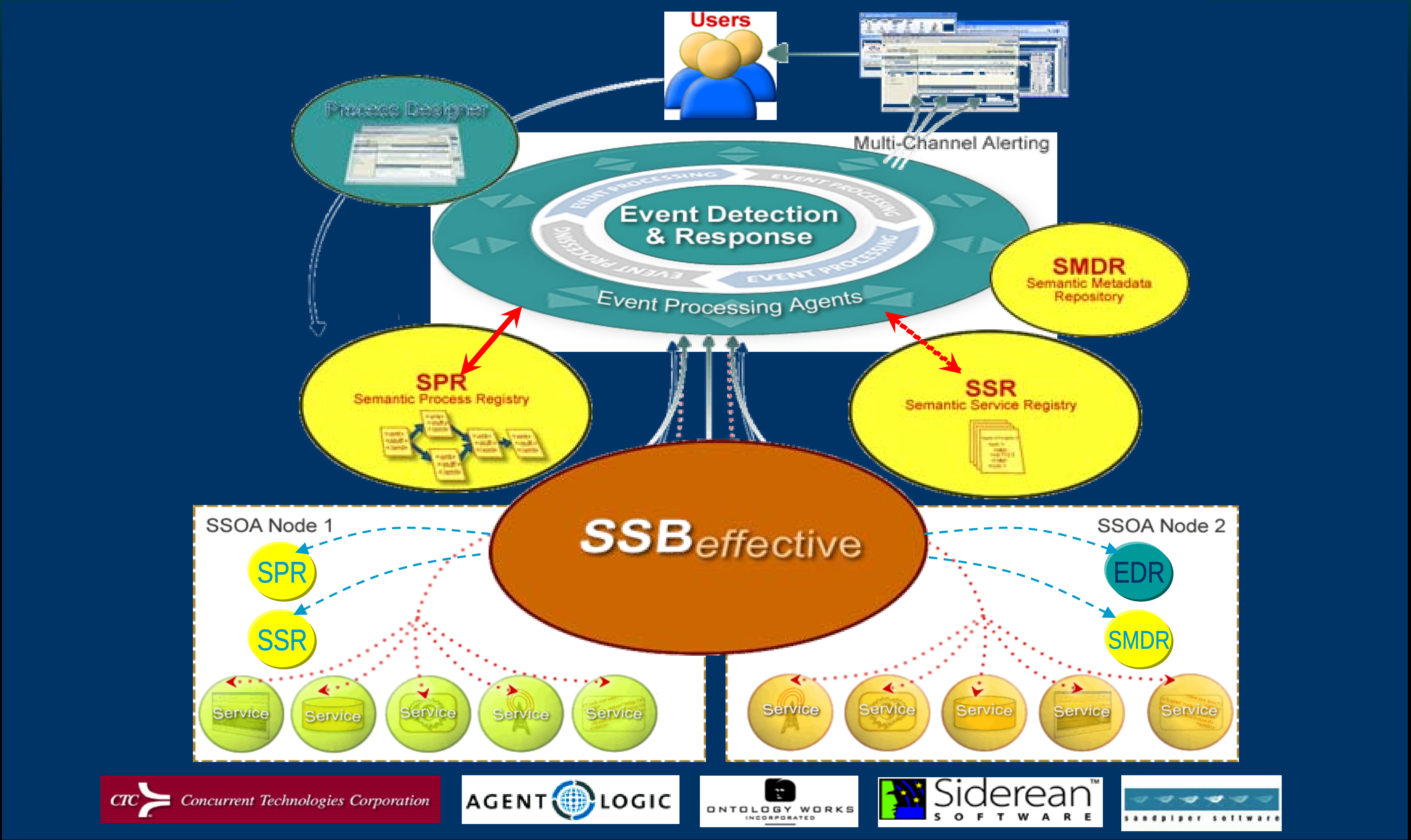


Ontology was developed using an ODM-based development environment;

Jena Rules support model transformations

"Using Semantic Web Technologies for Management Application Integration", Tilo Nitzsche, Jishnu Mukerji, Dave Reynolds, and Elisa Kendall, ISWC2005, Workshop on Semantic Web Enabled Software Engineering, Galway, Ireland
See http://www.mel.nist.gov/msid/conferences/SWESE/accepted_papers.html

SSOA System View

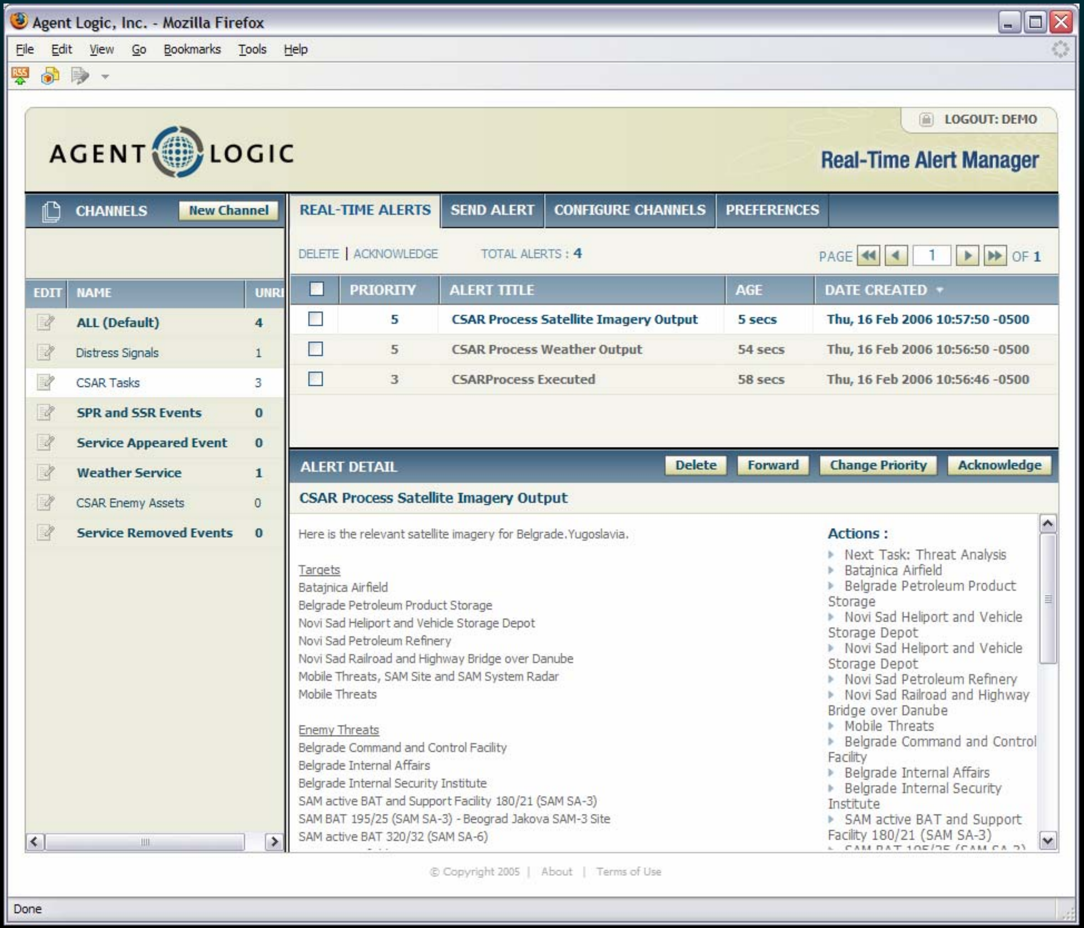


"Standards for Model –Driven Semantics" and "Semantic Service Oriented Architecture", Elisa Kendall, Sam Chance & Michael Seebold, Fourth Semantic Interoperability for E-Government Conference, McLean, VA
See http://colab.cim3.net/cgi-bin/wiki.pl?FourthSemanticInteroperabilityforEGovernmentConference_2006_2_0910

s a n d p i p e r   s o f t w a r e

Automated Data Gathering / Contextual Actions

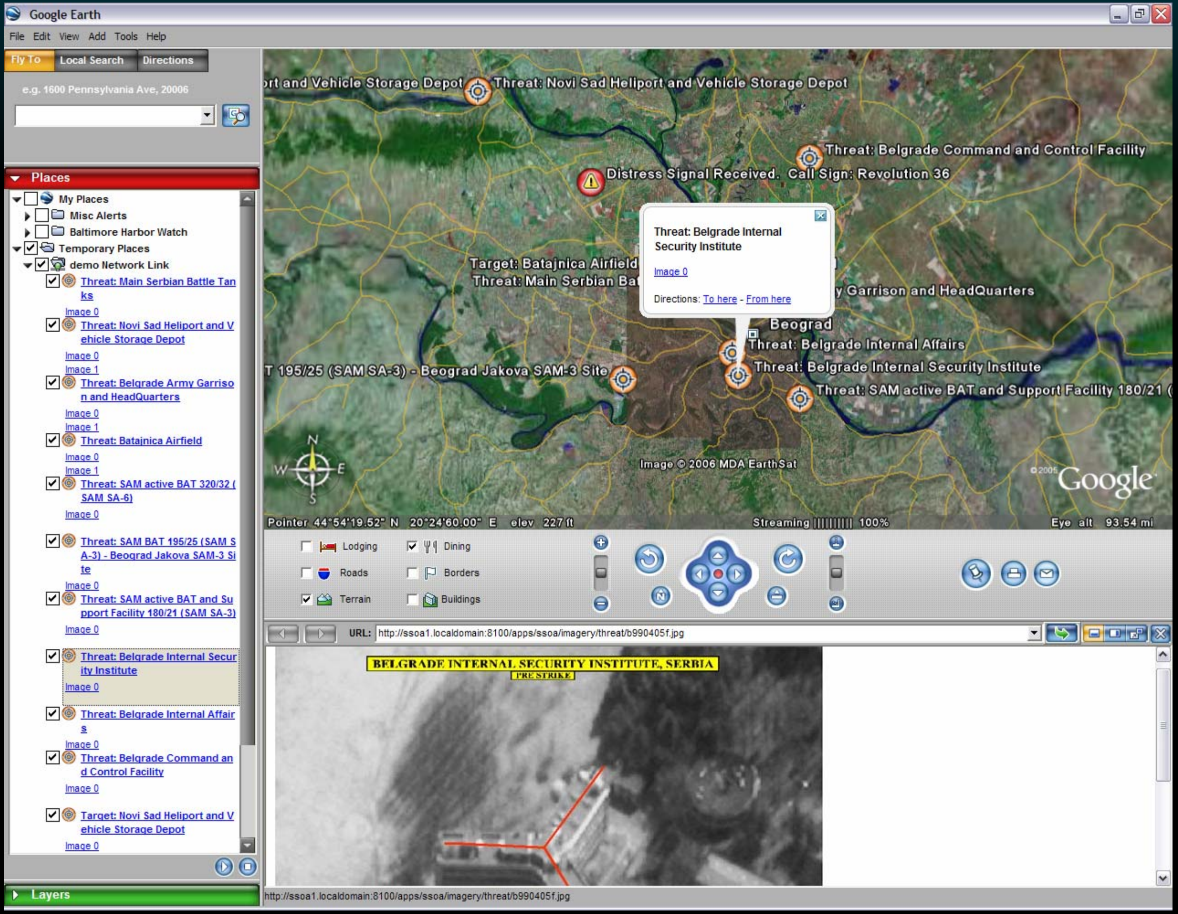
- Agents retrieve data from other business services, using attributes of the original event to formulate queries (i.e. LAT/LONG)
- These data points are processed and presented to subscribed users in real time as RTAM alerts



Courtesy Mauricio Renzi, AgentLogic

Geospatial Threat Map

- As the agent gathers additional intelligence from other services, a ‘threat map’ begins to take shape…
- Mission commanders utilize this event-driven, automated process to assess mission risks
- Friendly force information is added to the threat map to allow mission commanders to identify which resources can be tasked for a rescue mission



Courtesy Mauricio Renzi, AgentLogic

Cognitive Assistant that Learns & Organizes

- DARPA IPTO funded program
- Personal office assistant, tasked with:
  - **Noticing** things in the cyber and physical environments
  - **Aggregating** what it notices, thinks, and does
  - **Executing, adding/deleting, suspending/resuming** tasks
  - **Planning** to achieve abstract objectives
  - **Anticipating** things it may be called upon to do or respond to
  - **Interacting** with the user
  - **Adapting** its behavior in response to past experience, user guidance
- 22 participating organizations

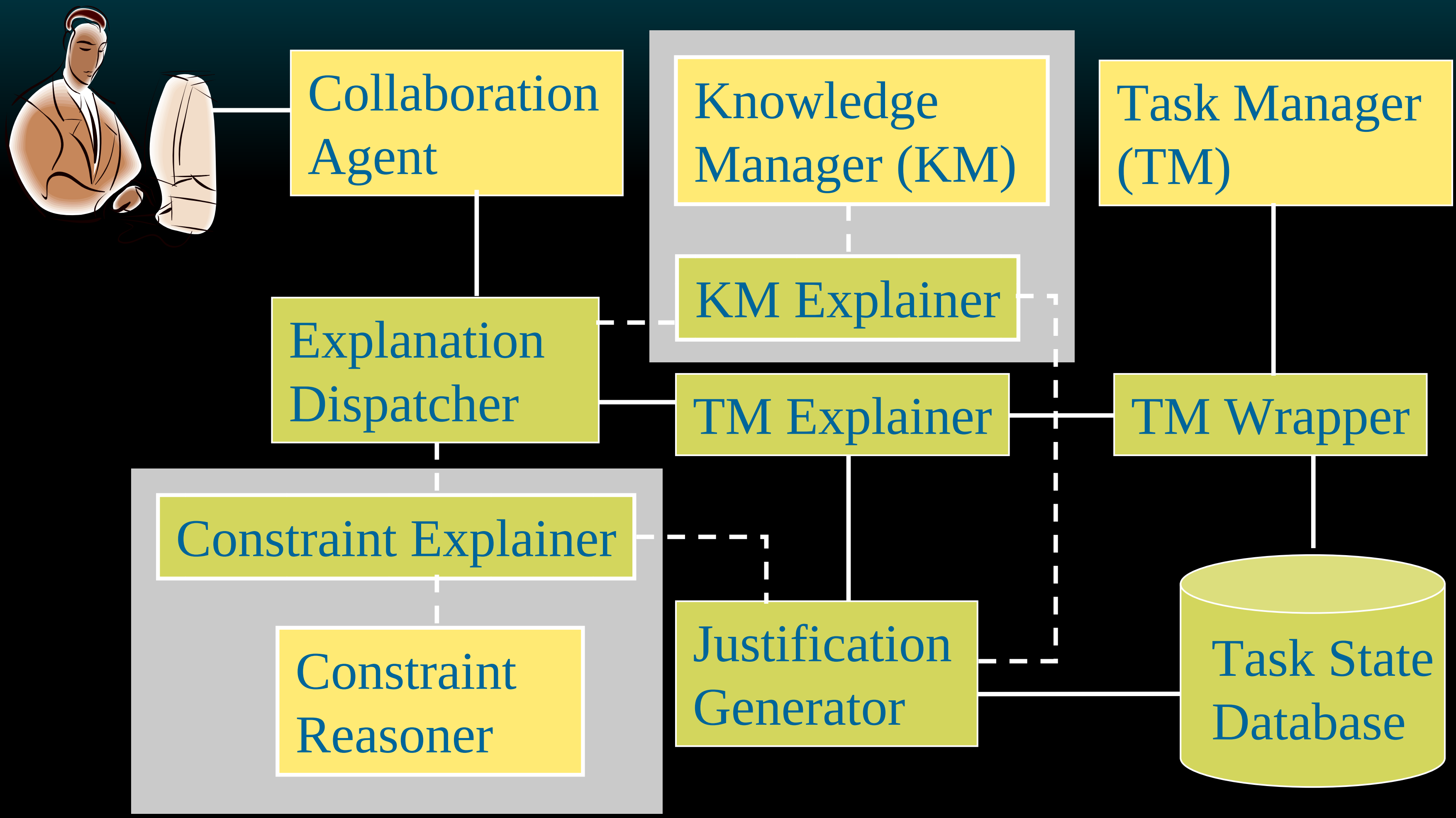
CALO & InferenceWeb Slides courtesy Dr. Deborah L. McGuinness, Stanford Knowledge Systems, AI Laboratories
See http://iw.stanford.edu for more on InferenceWeb

Working with a Cognitive Assistant

- CALO users need to
  - **Understand** system behavior and responses
  - **Trust** system reasoning and actions
- To believe and act on recommendations from CALO, users need ways of exploring how and why the system acted, responded, recommended, and reasoned the way it did.
- Additional wrinkle: CALO knowledge, behavior, and assumptions are constantly changing through several forms of machine learning.

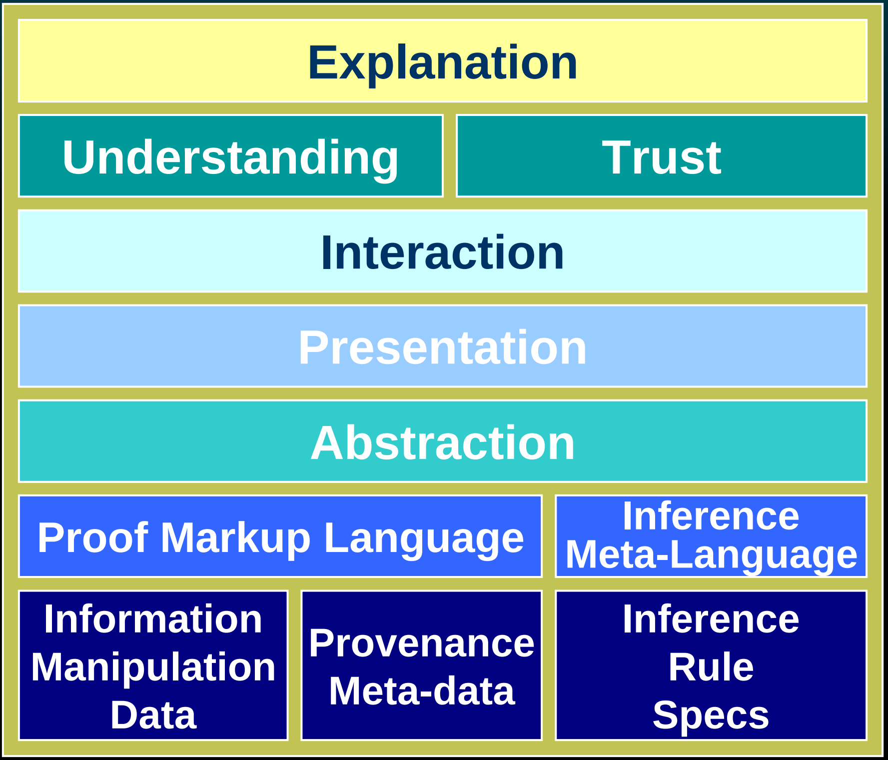
A unified framework for explaining behavior and reasoning is essential for users to trust and adopt cognitive assistants.

ICEE Architecture



An InferenceWeb Primer

1. Registry and service support for knowledge provenance.
2. Language for encoding hybrid, distributed proof fragments (both formal and informal).
3. Declarative inference rule representation for checking proofs.
4. Multiple strategies for proof abstraction, presentation, and interaction.



Framework for *explaining* reasoning and execution tasks by abstracting, storing, exchanging, combining, annotating, filtering, comparing, and rendering justifications from varied cognitive reasoners.

Discussion

Acronym Soup

- **AD PTF** – OMG Analysis & Design Task Force
- **BMI DTF** – OMG Business Modeling & Integration Domain Task Force
- **BPEL** – Business Process Execution Language (OASIS), http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=wsbpel
- **BPEL4WS** – Business Process Execution Language for Web Services
- **CL** – ISO 24707 Common Logic: a family of first order logic languages, including Conceptual Graphs & Common Logic Interchange Format – a successor to the Knowledge Interchange Format (KIF), http://cl.tamu.edu/
- **DAML** – DARPA Agent Mark-up Language, one of the primary languages leading to the development of OWL, http://www.daml.org/
- **DAML-S** – Services ontology for DAML, http://www.daml.org/services/
- **DARPA** – Defense Advanced Research Projects Agency, http://www.darpa.mil/
- **DL** – Description Logics: a subset of first order logic, for which tractable & complete reasoning systems are available
- **ER** – Entity Relationship modeling
- **IMM** - Information Management Metamodel (a.k.a CWM2)
- **MDA** – Model-Driven Architecture, http://www.omg.org/mda/
- **MMF** - Metamodel Management Framework (ISO 19763)
- **ODM** – Ontology Definition Metamodel

More Acronym Soup

- **OWL** – W3C Web Ontology Language, a formal W3C Recommendation as of 10 February 2004, http://www.w3.org/TR/owl-semantics/
- **OWL DL** – the normative description logics dialect of OWL
- **OWL Full** – the normative OWL dialect that has increased expressivity over OWL DL, but does not conform to DL reasoning requirements
- **OWL-S** – a set of OWL ontology components that extend the W3C OWL specifications to support Semantic Web Services, http://www.daml.org/services/
- **PRR** – Production Rules Representation
- **QVT** – MOF Query / View / Transformations Specification, http://www.omg.org/docs/ptc/05-11-01.pdf
- **RIF** – Rule Interchange Format, http://www.w3.org/2005/rules/wg
- **RDF** – Resource Description Framework, http://www.w3.org/TR/rdf-concepts/
- **SBVR** – Semantics for Business Vocabularies and Rules
- **SOA** – Service Oriented Architecture
- **SOAP** – Simple Object Access Protocol, http://www.w3.org/TR/soap/
- **SWSF** – Semantic Web Services Framework, http://www.w3.org/Submission/SWSF/
- **TM** – ISO 13520 Topic Maps, http://www.isotopicmaps.org/sam/sam-model/
- **WSDL** – Web Services Description Language