Applying UML to Model Web Service Ontologies for the Semantic Web

Dr. Prasanta Bose – Lockheed Martin Advanced Technology Center
Dr. Paul Kogut- Lockheed Martin Management & Data Systems
Yui H. Leung - Lockheed Martin Management & Data Systems
Mark Woodward - Stanford University

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Outline

- Semantic Web – The Vision
- Challenges
- Key Enabling Technologies
  - Agents
  - Semantic Web
  - Resource descriptions and ontologies
- Web Services – Research in Progress
  - Scenario
  - Service descriptions
  - UML based modeling
- Conclusions

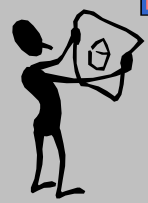
Semantic Web: The Vision

Hi Pe… e.
Mom … as
to hav… ons.
Biwe… e

Great! I'll have my agent set up the appointments.

* Berners-Lee, Hendler, Lassila "The Semantic Web" Scientific American, May 2001

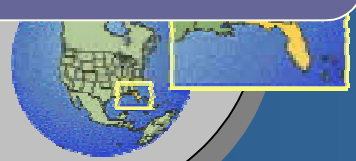
The Vision



Schedule a treatment plan for Mo
using Pete and my schedules. Only
providers that are in-plan for Mom
insurance, are within a 20-mile rad
and have a rating of excellent or very g

Lucy's agent formulates a schedule of appointments for therapists with appointments available that fit into Pete and Lucy's schedule.

Lucy's agent looks up several lists of providers and checks for ones
m's insurance, within
us of her home, and
excellent or very good.
d treatment
from the doctor's agent.



Semantic Web

* Berners-Lee, Hendler, Lassila "The Semantic Web" Scientific American, May 2001

Challenges and DAML Approach

- How To Enable *Agent* based discovery, composition, execution, trusted invocation of services and information retrieval?
- Approach – Key Ideas
  - Agents mediated interactions
  - *Semantic Web - a Distributed Knowledge base*
  - Semantic descriptions of resources and machine interpretable *ontologies*
- Enabling Technology: DAML
  - Standard language with formal semantics
  - Engineering tools (consistency checker, editor,..)

Why Agents?

- Reduce information overload
- Enable more flexible “self-integrating” systems
  - Next generation of web services!
- Automate routine tasks
- Find answers on the web more quickly
- Improve decision making by having more information available during the limited time needed to complete a task.

Why the Semantic Web?

- Need to make machine-readable ontologies accessible to agents on the web
  - HTML tells a browser HOW to display information
  - XML tells WHAT the data is
    - <company>Delta</company>
  - The Ontology Web Language(OWL) will tell more precisely what the data is
    - Delta is a “business institution” not a “guest at your house” or a “military unit”
    - <!ENTITY ontologyA 'http://www.acme.com/ontologyA.daml#'>
    - <ontologyA:COMPANY rdf:ID="Delta”/>
- Need to markup a website or web service so that terms are linked to specific classes in ontologies

Why Ontologies?

- Semantic interoperability is the major challenge for agents and web services
- Need explicit semantic models to understand queries and reason with knowledge

What are Agents?

- Definitions that capture the essence of agents:
  - Functional: an Object that decides when to say go and when to say no – OMG Agent SIG
  - Operational: “programs that operate at a high enough semantic level that they can form new connections to other programs in order to get a job done” Burstein, McDermott

What are Agents?

- Definition of agents from the multi-agent systems community*:
  - *situatedness* - perceive and change environment (e.g., physical world, internet)
  - *autonomy* - delegation (acts on behalf of user without direct intervention)
  - social ability - interacts with other agents and humans (peer-to-peer)
    - cooperation, collaboration, negotiation
  - *adaptivity* - goal-directed initiative, learning from experience and environment
    - no adaptivity - hard coded responses
    - simple adaptivity - inference/search for maximum goal satisfaction
    - complex adaptivity - machine learning to improve accuracy, response time or adjust autonomy levels

*Sycara "The Many Faces of Agents" AI Magazine Summer 1998

What is the Semantic Web?

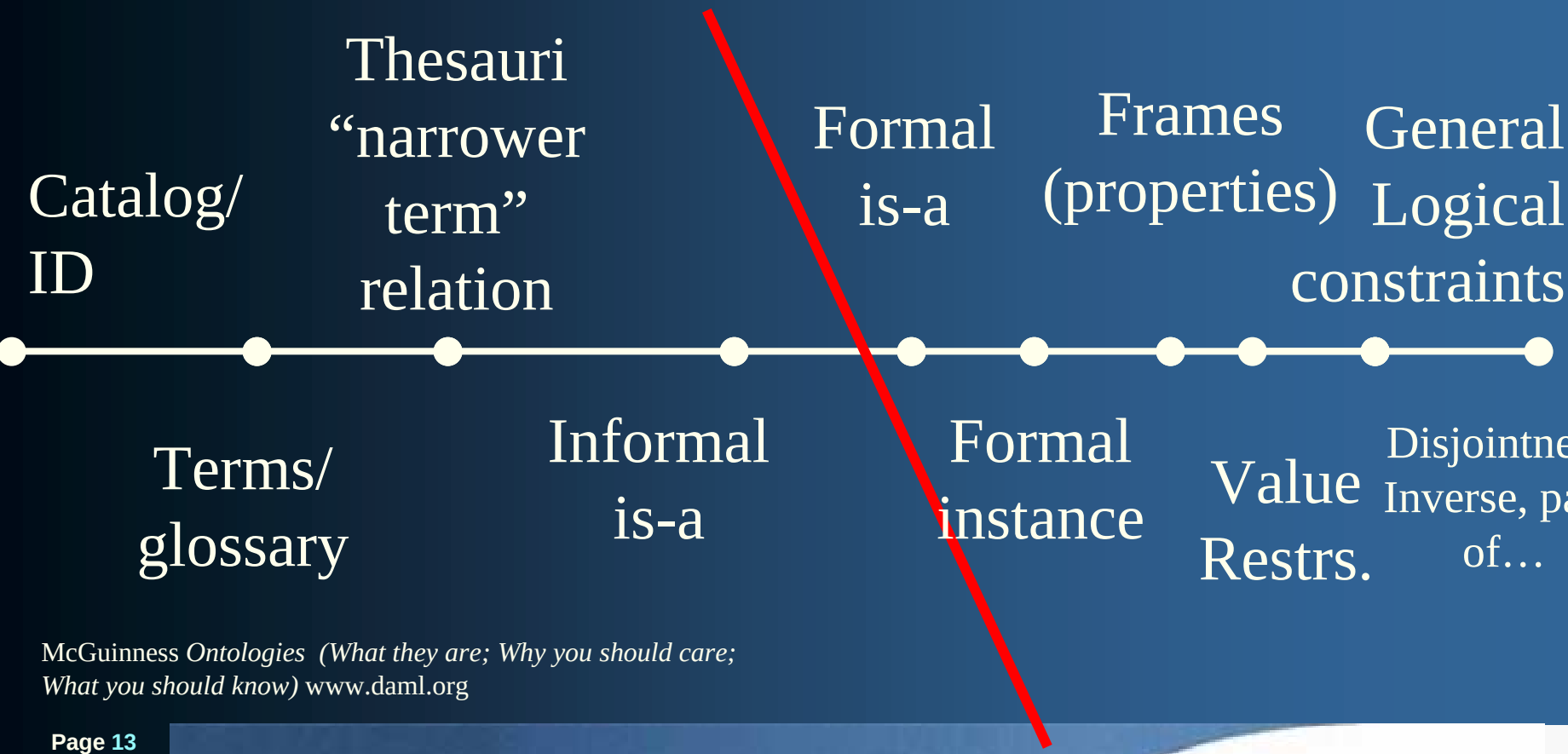
- "The Semantic Web is an extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation."
- Objectives:
  - Insert machine-readable ontologies on the web
  - Use ontologies in semantic markup of web pages
- XML is Not Enough!!!
  - Allows definition of syntax, but not semantics (meaning)
  - XML is the "assembly language" of the Web.
- World Wide Web Consortium (W3C) Semantic Web Initiative http://www.w3.org/2001/sw/
  - WebOnt Working Group - http://www.w3.org/2001/sw/WebOnt/
    - DAML+OIL submitted as draft Ontology Web Language(OWL)
    - Currently defining OWL requirements based on use cases

Semantic Web Research

- DARPA Agent Markup Language (DAML) Program - www.daml.org
  - Develop language, tools, applications based on W3C Semantic Web vision - August 2000 to 2005
  - Extend XML and Resource Description Framework(RDF)
    - represent ontologies and rules
    - annotate/markup web pages and other information with links to ontologies
    - apply expertise in AI knowledge representation, logic and web technologies
    - cooperation with European Union IST Program www.daml.org/committee
  - Lockheed Martin UBOT Project

What are Ontologies?

- ontology: explicit model of world or domain
  - vocabulary, relationships and taxonomies

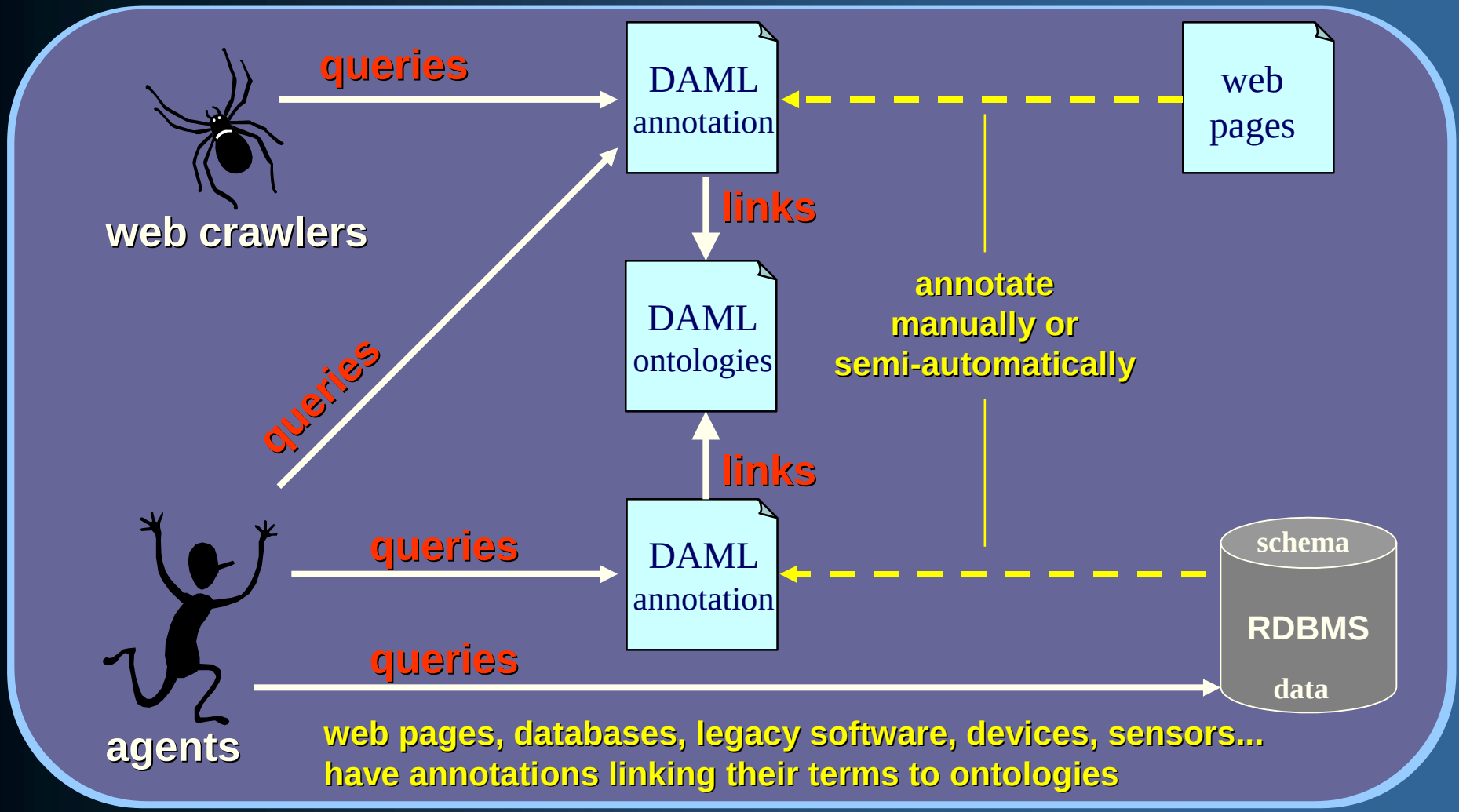


McGuinness *Ontologies (What they are; Why you should care; What you should know)* www.daml.org

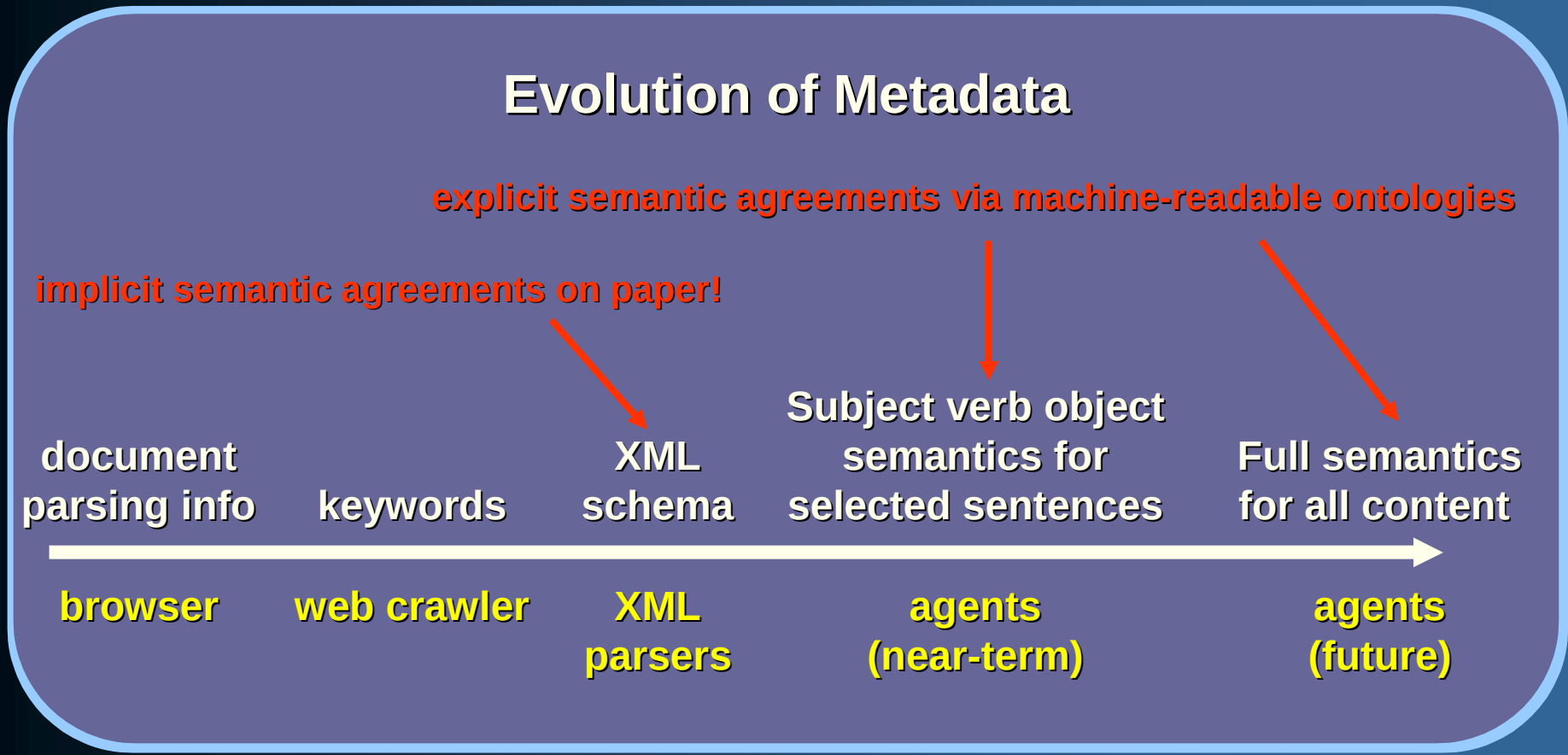
Example Ontologies

- E-commerce – Yahoo, Amazon.com, Universal Standard Products and Services Classification Code (UNSPSC), UDDI
- WordNet - word meanings (www.cogsci.princeton.edu/~wn/)
  - Taxonomy of 60,000 noun concepts and 11,500 verb concepts
- Cyc - common sense knowledge (www.cyc.com/index.html)
  - knowledge base of consensus reality - started in 1984
    - once people die they stop buying things
    - glasses of liquid should be carried rightside-up
  - Cycorp proprietary version >1 million assertions
  - OpenCyc (www.OpenCyc.org) - available 2002
    - 6000 concepts, 60000 assertions
    - inference engine, KB translators, Java API
- IEEE Standard Upper Ontology - http://suo.ieee.org
  - focus on taxonomy of abstract categories and axioms

DAML: Basic Idea



DAML Annotation = Extreme Metadata

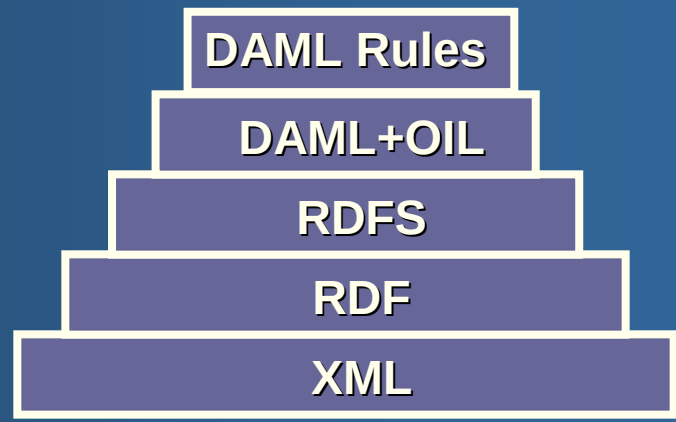


The Origins of DAML+OIL

- Extensible Markup Language (XML)
- Ontology Inference Layer (OIL)
- Resource Description Framework (RDF)
  - designed to represent metadata for web resources in an XML syntax
  - triples:

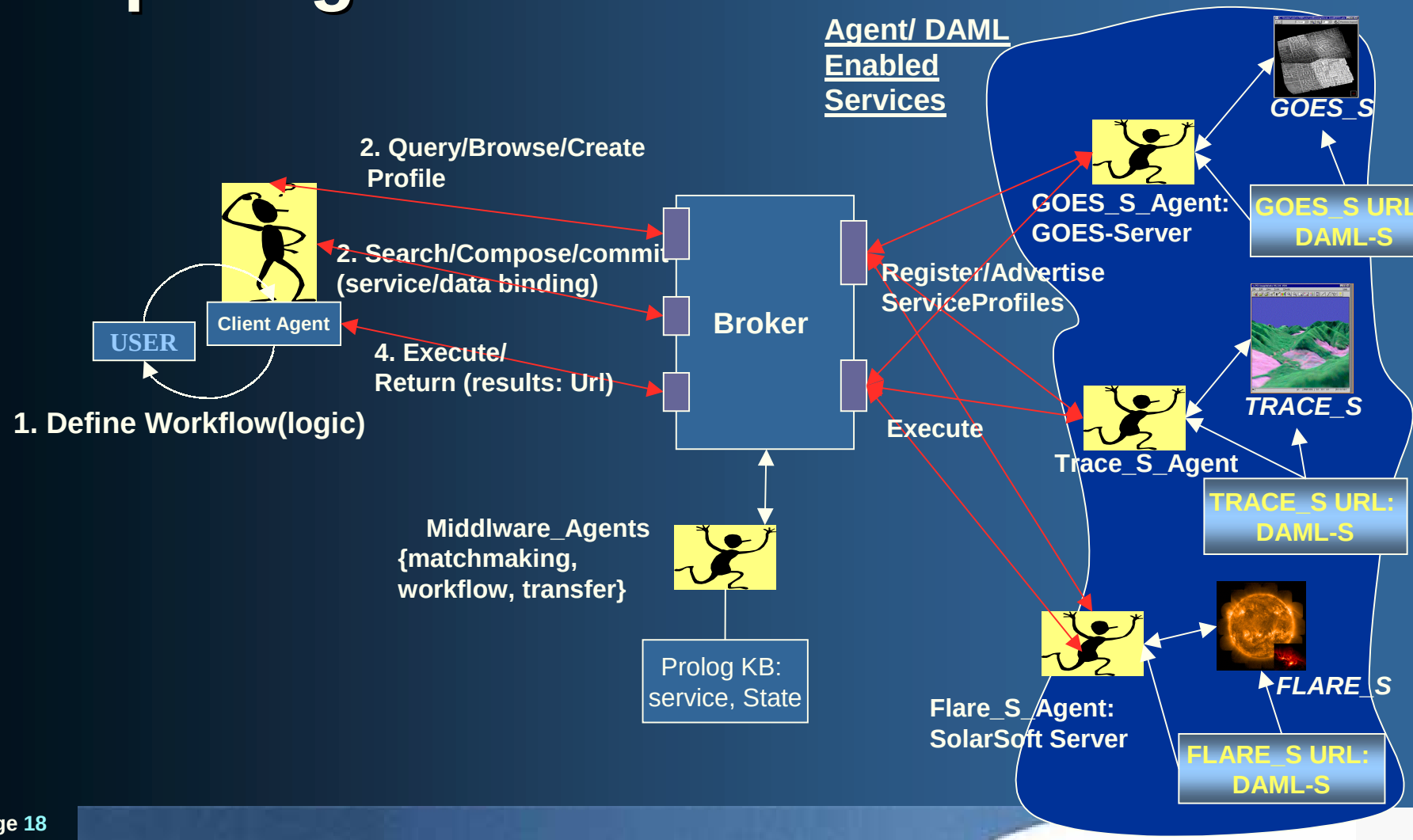
```
<shoeGen:GovermentOrganization rdf:ID="DARPA”/>
<shoeGen:OrganizationHomePage rdf:about="http://www.darpa.mil/">
   <shoeProj:authorOrg rdf:resource="#DARPA" />
</shoeGen:OrganizationHomePage>
```

- RDF Schema (RDFS)
  - adds OO concepts: class and subclass



* For more information see www.w3.org

Semantic Service Web Based Computing: A Scenario



DAML-S

- DAML+OIL ontologies for describing properties and capabilities of Web servic to support self-integrating systems
- Influenced by AI planning research
- DAML-S automates:
  - Web service discovery
    - Find me shipping service that transports goods to Dubai.
    - Find me solar-imaging service that provides x-ray images of solar atmosphere
  - Web service selection and composition
    - Arrange food for 500 people for 2 weeks in Dubai.
    - Analyze solar-images for solar-flares event having spatial and temporal profile
  - Web service invocation
    - Buy me 500 pounds of powdered milk from www.moo.com
  - Web service execution monitoring
    - Has the powdered milk been paid for yet?
    - Have the solar-images been cued for analysis yet?

Based on "DAML-Services Update" by David Martin http://www.daml.org/meetings/2002/02/pi/agenda.html

DAML-S

- DAML-S service profile
  - What capabilities does the service provide?
  - Enables query goal driven and inference-based matchmaking
- DAML-S process model
  - How does the service work?
  - Inputs, outputs, preconditions and effects
  - Process steps and control flow
- DAML-S service grounding
  - How do you access the service?
  - Implementation specific – SOAP, HTTP, CORBA IDL, Java RMI
  - Maps to W3C Web Services Description Language (WSDL)
- Experiments with DAML-S and UDDI
  - See http://www.daml.org/meetings/2002/02/pi/agenda.html

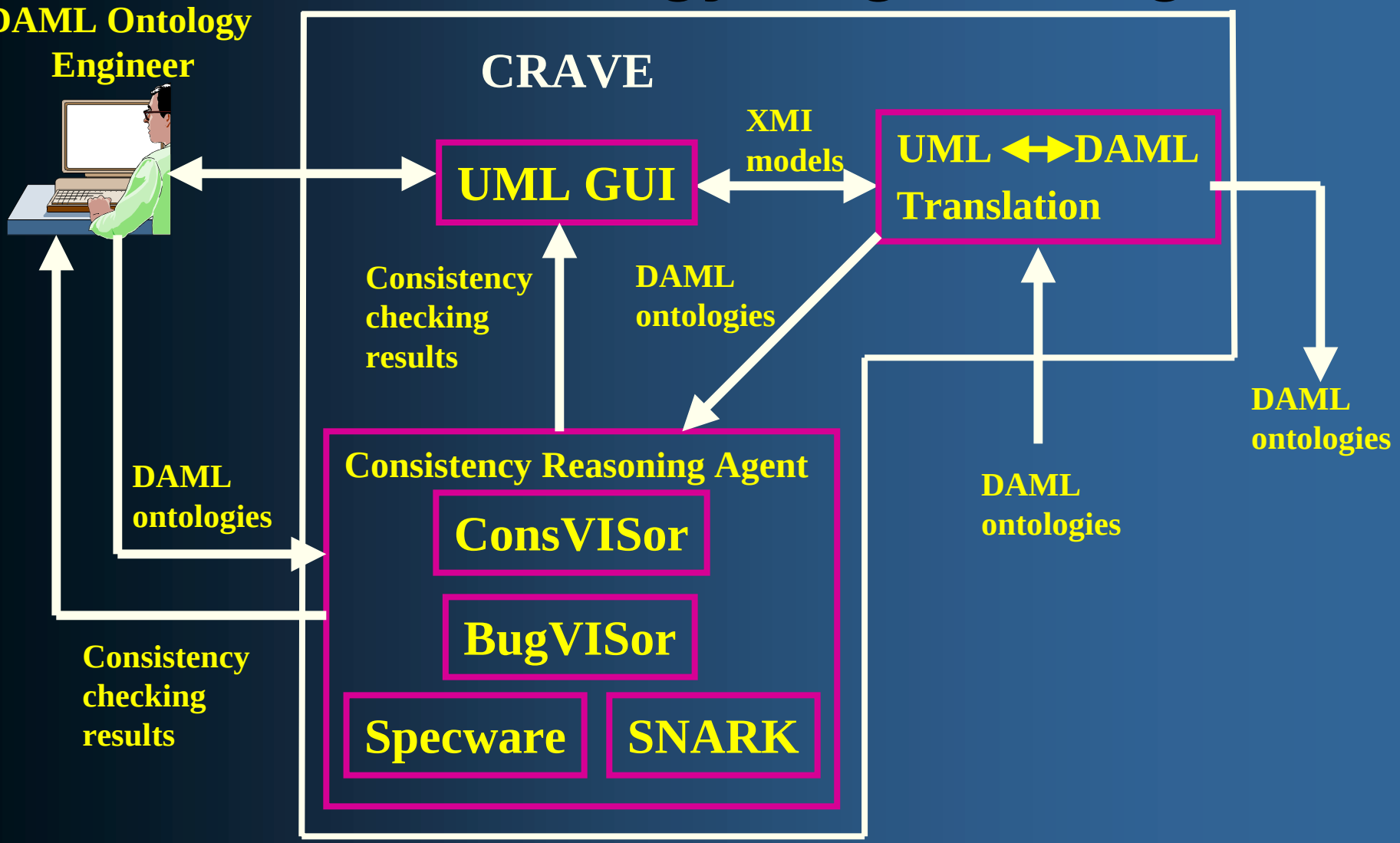
See http://www.daml.org/services/ for DAML-S details

UML-Based Ontology Toolset (UBOT) Project

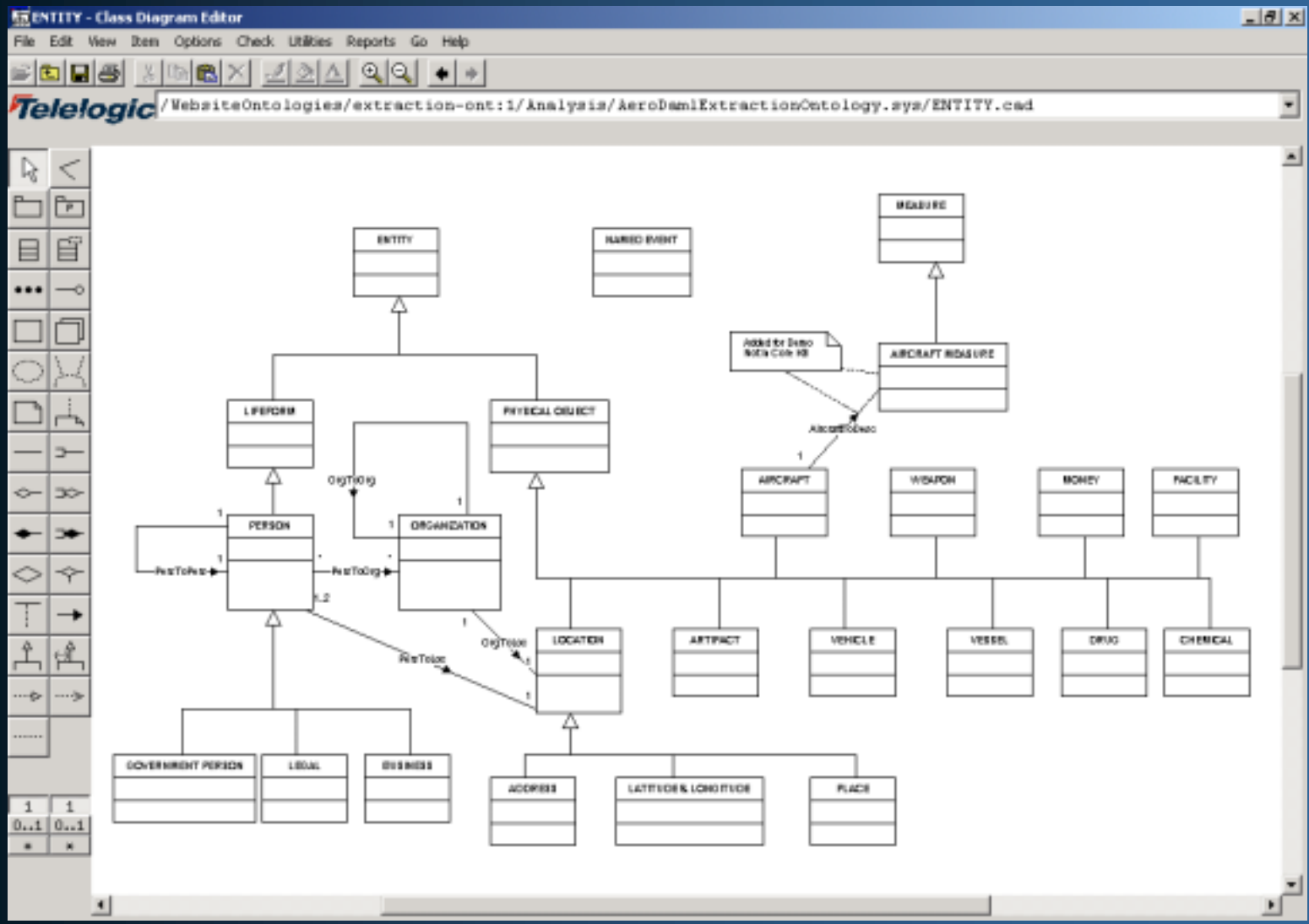
- Lockheed Martin Management & Data Systems
  - Project Leader, ontology engineering, annotation generation
  - Developing UML profile for DAML in cooperation with GRCI DAML team
- Versatile Information Systems (Northeastern Univ.)
  - Formal methods and model consistency reasoning (UML and DAML)
- Lockheed Martin Advanced Technology Center
  - Applications of DAML and UBOT
- Kestrel Institute
  - Formal methods and theorem proving
- Lehigh University
  - Mixed initiative annotation tools
  - Semantic Web application engineering

See http://ubot.lockheedmartin.com/

UBOT Ontology Engineering



Consistency Reasoning and Visualization Environment



CRAVE Output: DAML Ontology

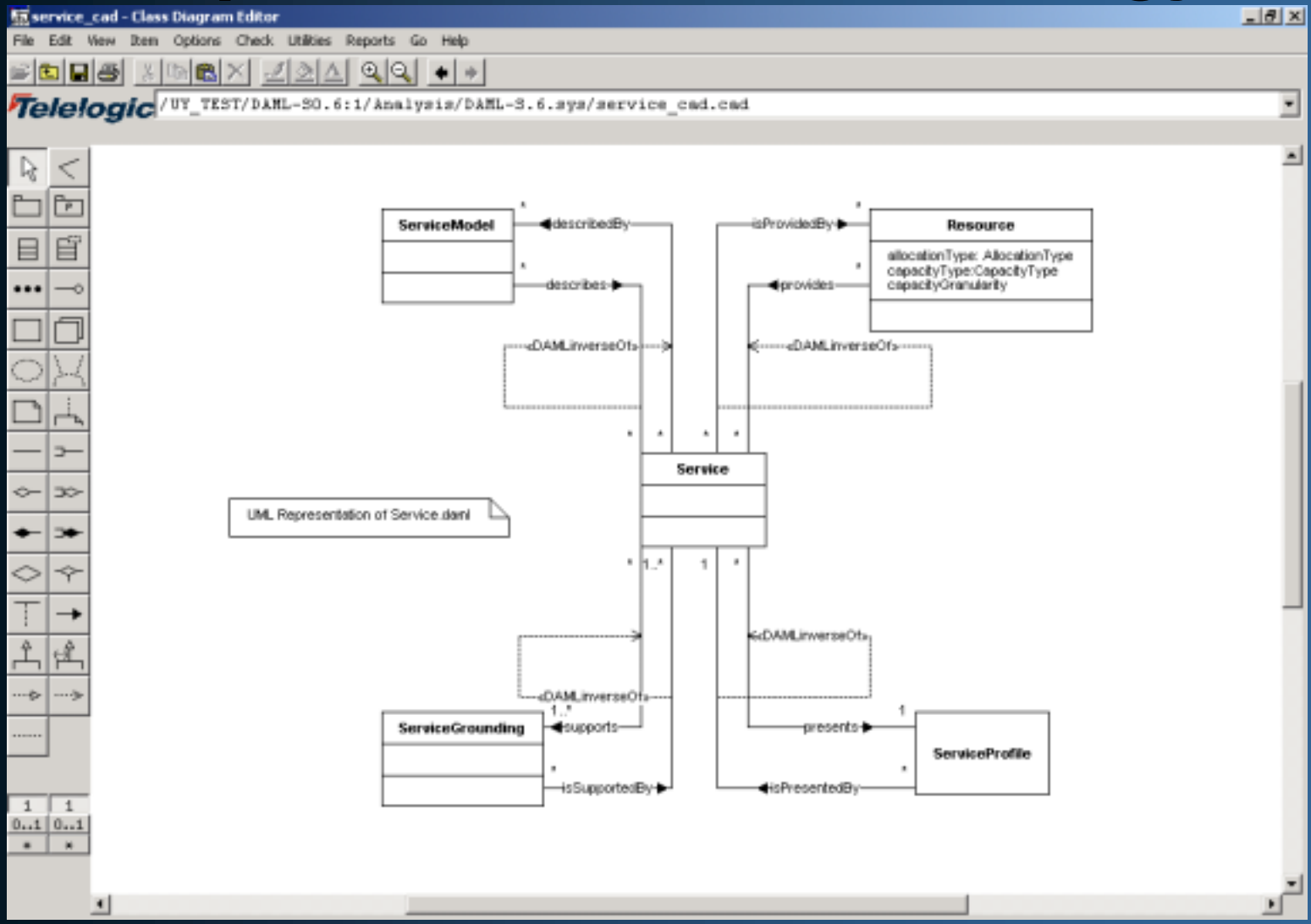
Posted at http://ubot.lockheedmartin.com/ubot/2001/08/extraction-ont.daml

```
<daml:Ontology rdf:about="">
    <daml:imports rdf:resource="http://www.daml.org/2001/03/daml+oil#"/>
    <daml:label><![CDATA[AeroDamlExtractionOntology]]></daml:label>
  </daml:Ontology>
<daml:Class rdf:ID="ORGANIZATION">
    <daml:label><![CDATA[ORGANIZATION]]></daml:label>
</daml:Class>
<daml:Class rdf:ID="LOCATION">
    <daml:label><![CDATA[LOCATION]]></daml:label>
</daml:Class>
<daml:Class rdf:ID="ADDRESS">
    <daml:label><![CDATA[ADDRESS]]></daml:label>
    <daml:subClassOf rdf:resource="#LOCATION"/>
  </daml:Class>
<daml:ObjectProperty rdf:ID="OrgToLoc"/>
```

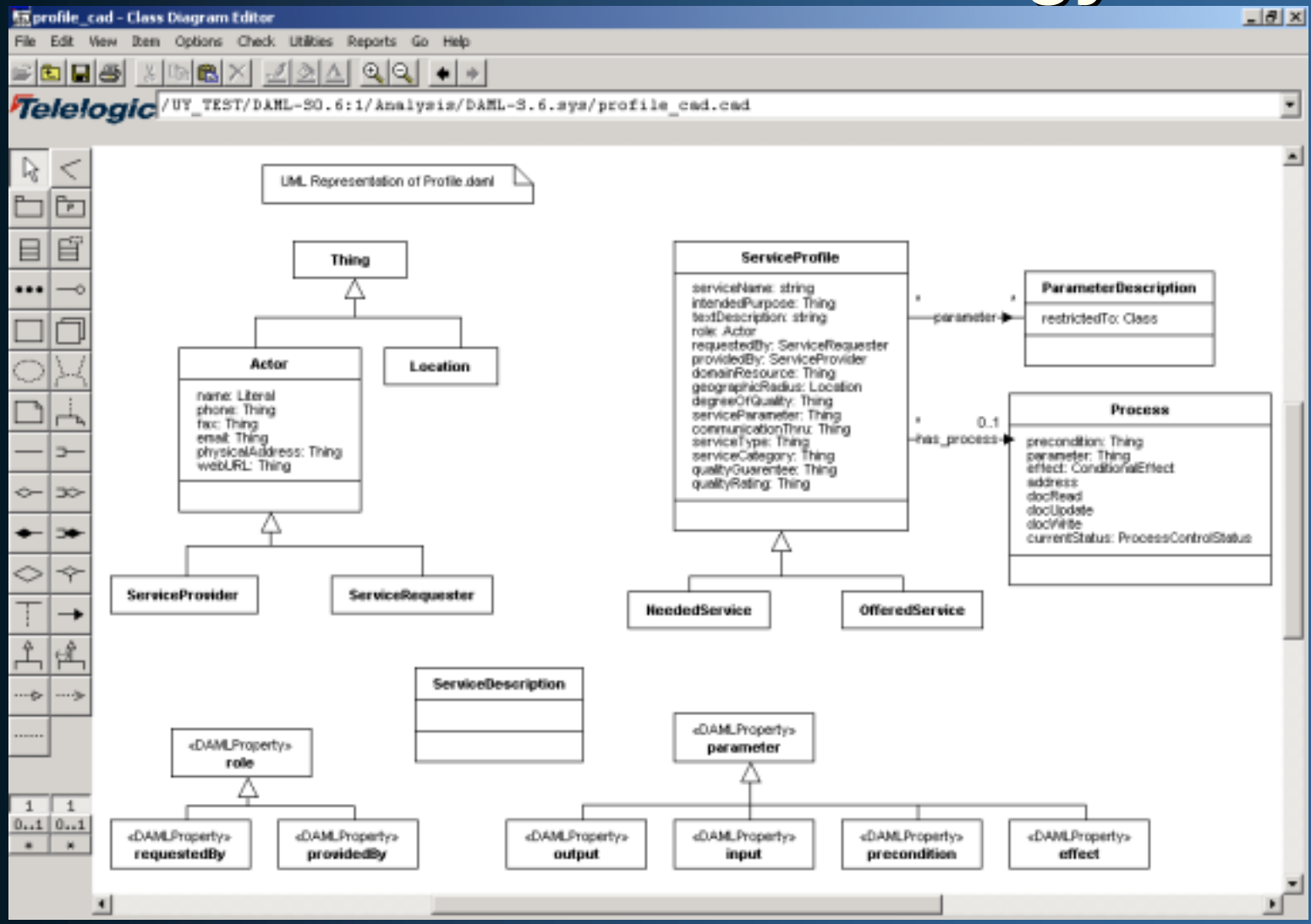
Initial Experiments

- Modeled DAML-S ontologies in UML with Telelogic Tau UML Suite 4.5
  - DAML-S service profile
  - DAML-S process model
  - DAML-S service grounding ontology - not yet released
- Extended/instantiated the models for sample web services
- Developing agents that are DAML-S powered to
  - Enable user goal driven service discovery and compositio
  - Coordinate service execution
  - Applications - Living-with-Star NASA Application

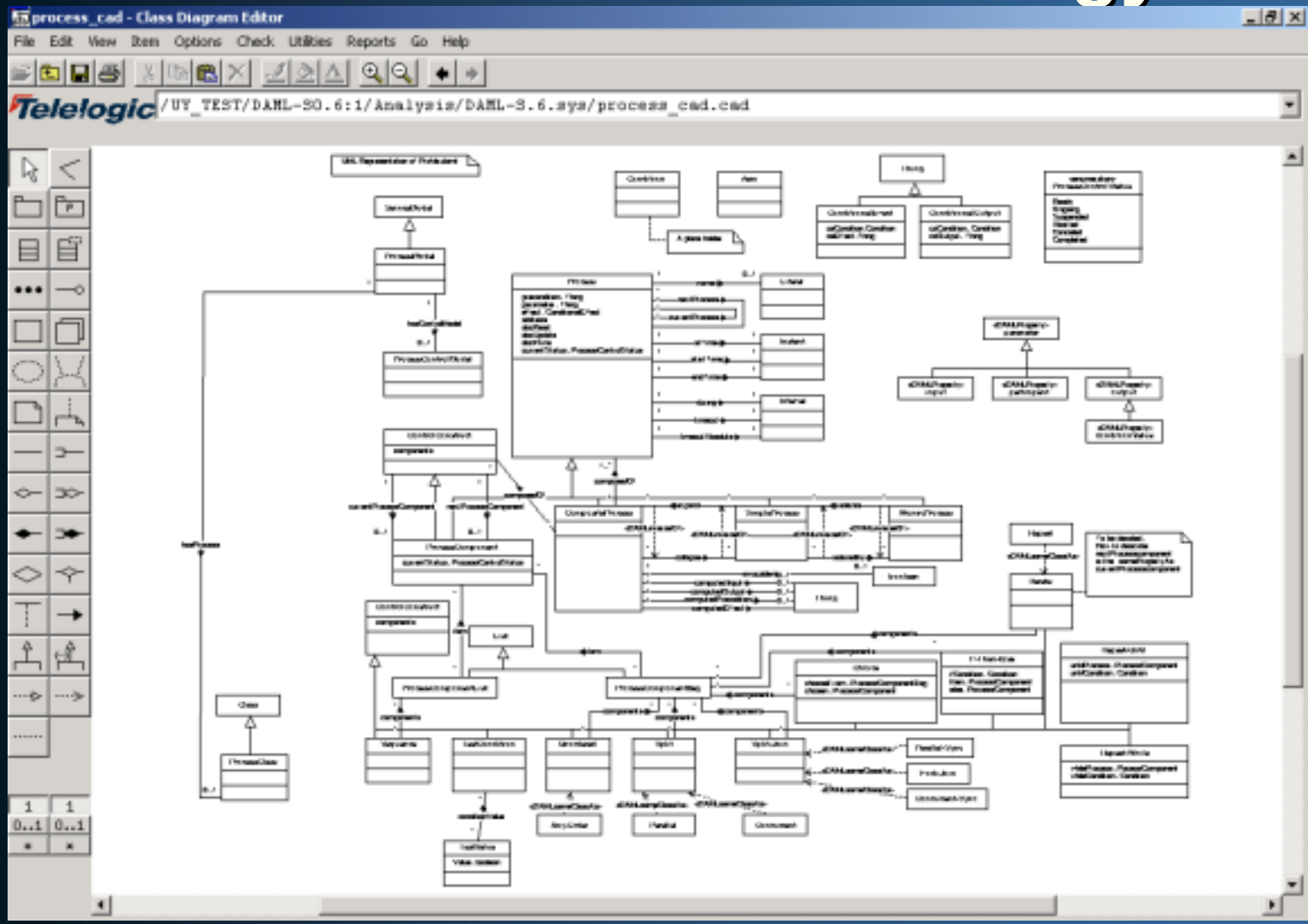
Top Level DAML-S Ontology



DAML-S Profile Ontology

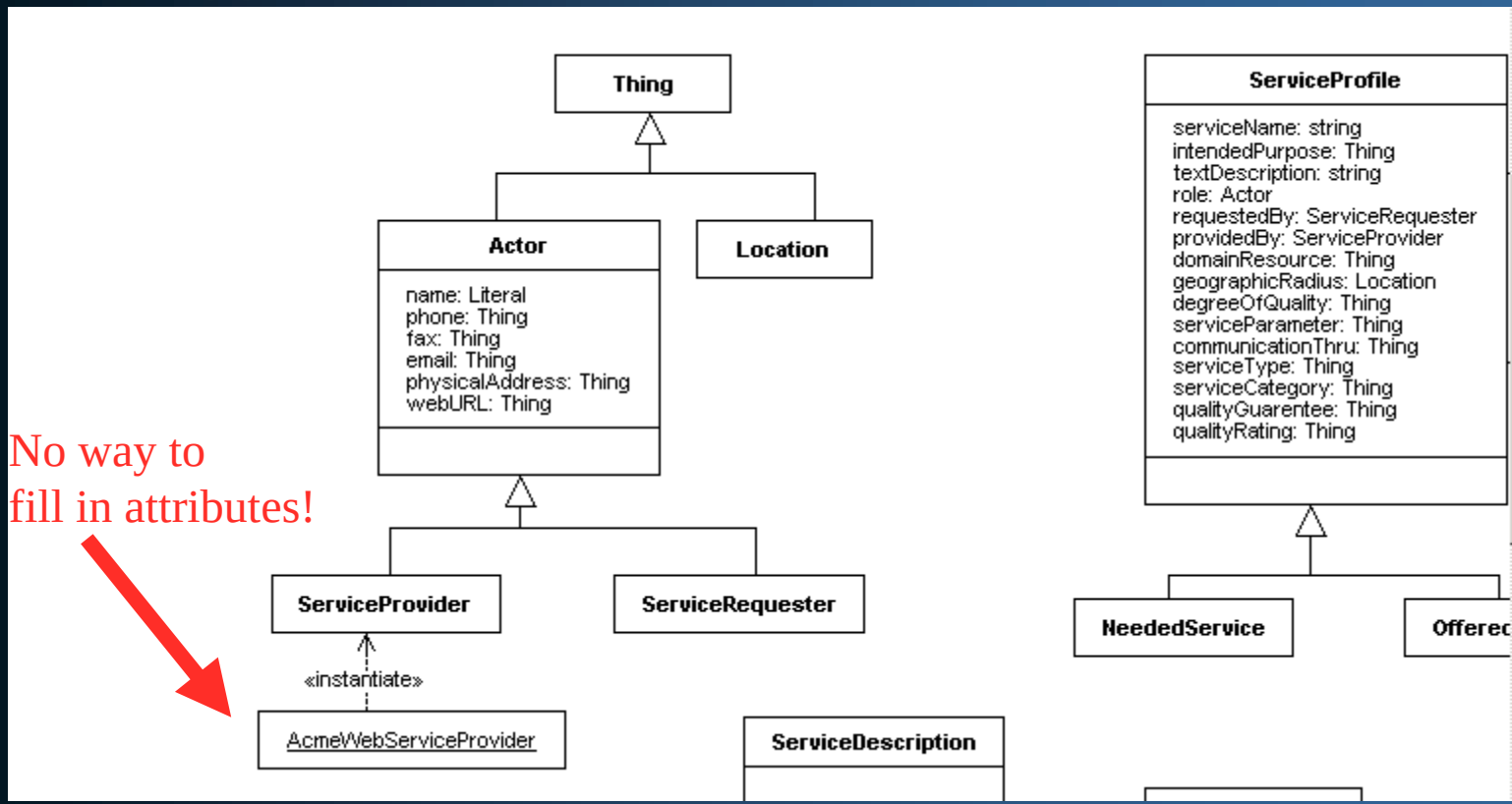


DAML-S Process Ontology



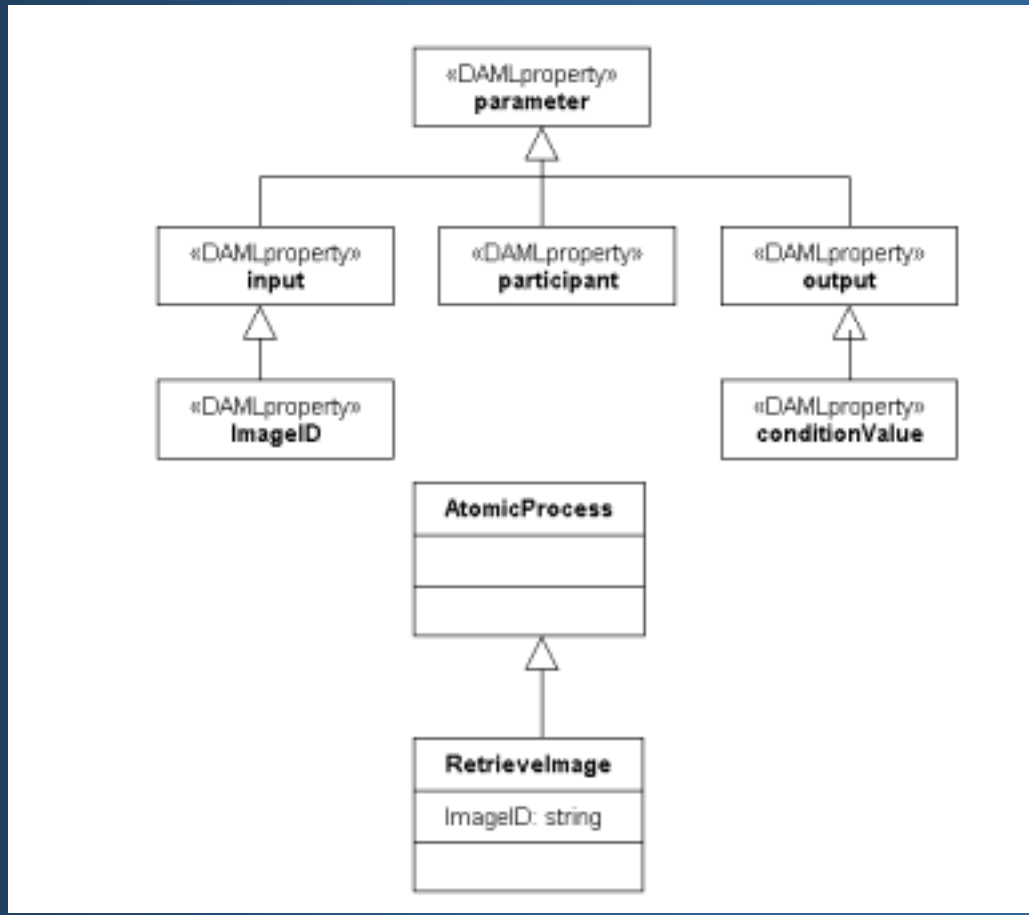
Results

- Applying the DAML-S profile ontology requires the creation of instances (objects) and filling in attribute values which is poorly supported by most UML tools



Results

- Applying the DAML-S process ontology requires extending complex class diagrams which is awkward
  - Unresolved issues with UML profile for DAML
  - Class diagrams not well-suited for modeling control constructs
    - E.g., if-then-else
- Service model ontology in DAML-S is not readily mapped into process constructs/elements in UML (workflow, activity diagrams)

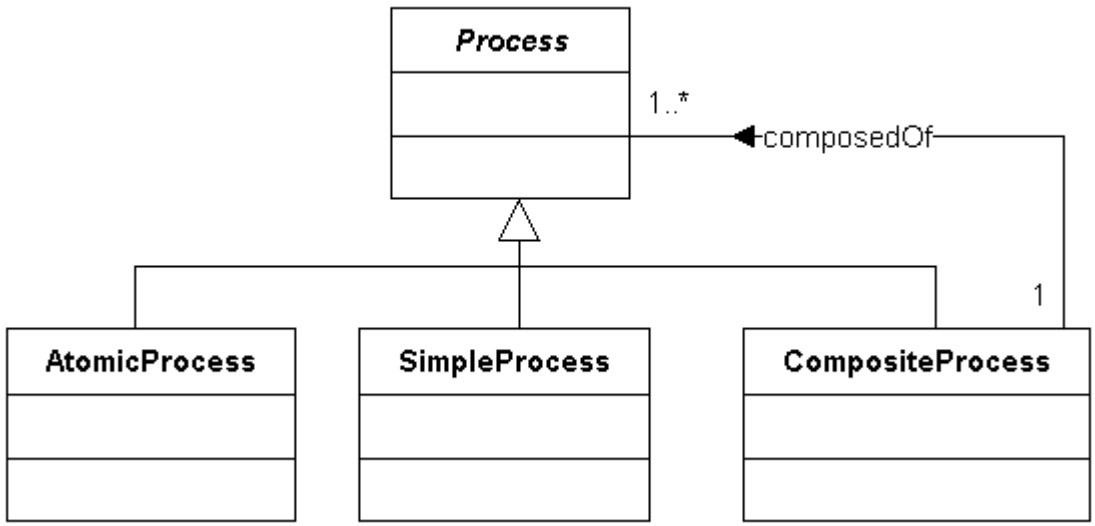


Results

- Example unresolved issue with UML profile for DAML

```
<daml:Class rdf:ID="Process">
 <daml:unionOf rdf:parseType="daml:collection">
  <daml:Class rdf:about="#AtomicProcess"/>
  <daml:Class rdf:about="#SimpleProcess"/>
  <daml:Class rdf:about="#CompositeProcess"/>
 </daml:unionOf>
</daml:Class><daml:Class rdf:ID="CompositeProcess">
 <daml:intersectionOf rdf:parseType="daml:collection">
  <daml:Class rdf:about="#Process"/>
  <daml:Restriction daml:minCardinality="1">
   <daml:onProperty rdf:resource="#composedOf"/>
  </daml:Restriction>
 </daml:intersectionOf>
</daml:Class>
```

Is this UML model semantically equivalent to the ontology above?



Conclusions

- Need to extend/refine UML profile for DAML
  - Submit to OMG standardization process
- Partitioning the service model into separate diagrams may simplify application
  - Activity diagrams or other UML diagrams for modeling may be better for modeling DAML-S process ontology control constructs
  - Need to consider alternative ontologies for service model that are interaction protocol-oriented as opposed to process oriented
- Need to investigate alternative tools for DAML-S modeling
  - form-based for profile
  - ontology-specific tools for process
- Need to develop a strategy for representing DAML rules in the context of UML models of DAML-S ontologies