11S-SIW-061
Management of C4I and M&S Data Standards with Modular OWL Ontologies

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Introduction

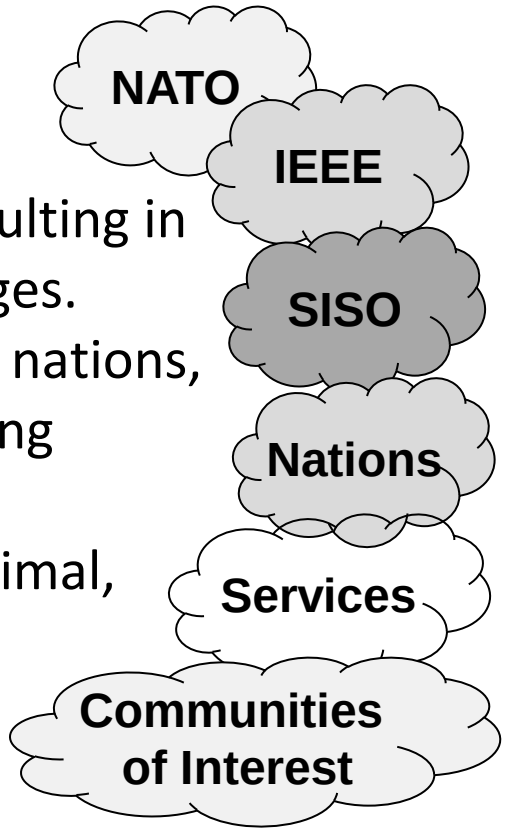
Standards are increasingly used as a means to **increase productivity** and **enable interoperability**, as shown by the current **development of numerous C2 and M&S standards** applied to **software & system development, integration and maintenance processes** that support **military enterprise activities involving information exchange**.

Standards solve some problems…but also create new challenges…

Problem Statement (1/2)

Relationship between Standards

- Often weak cohesiveness among standards, resulting in duplication, conflicts, and maintenance challenges.
- Standards may span multiple domains, multiple nations, and public and private organizations, each serving varying overlapping purposes.
- Current methodologies do not allow for the optimal, complementary use and re-use of C2 and M&S Standards.



Systems of systems that use multiple standards across multiple domains and organizations … also create multiple opportunities for mis-use and misalignment!

Problem Statement (2/2)

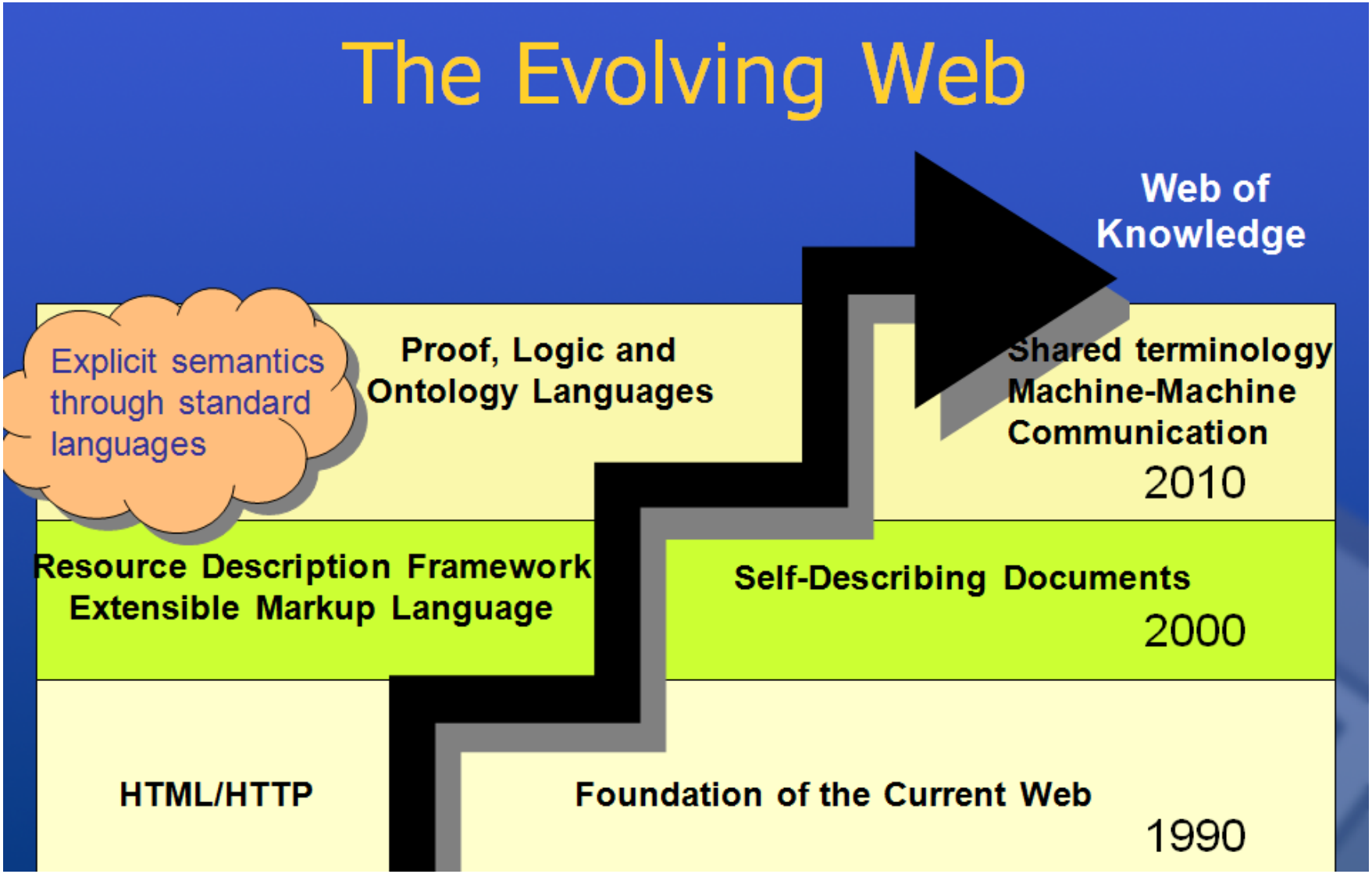
Representation of Standards

- Expressing standards in natural language is ambiguous, lacks formalism and can be difficult to implement.
- XML schemas are insufficient for expressing logical data models, while IDEF1X and UML can be difficult to implement consistently.
- Data Alignment and Transformation processes are often manual and error-prone, dependent on human interpretation of textual specs.

Cross-cutting multi-domain standards require a formalism and framework that can support:

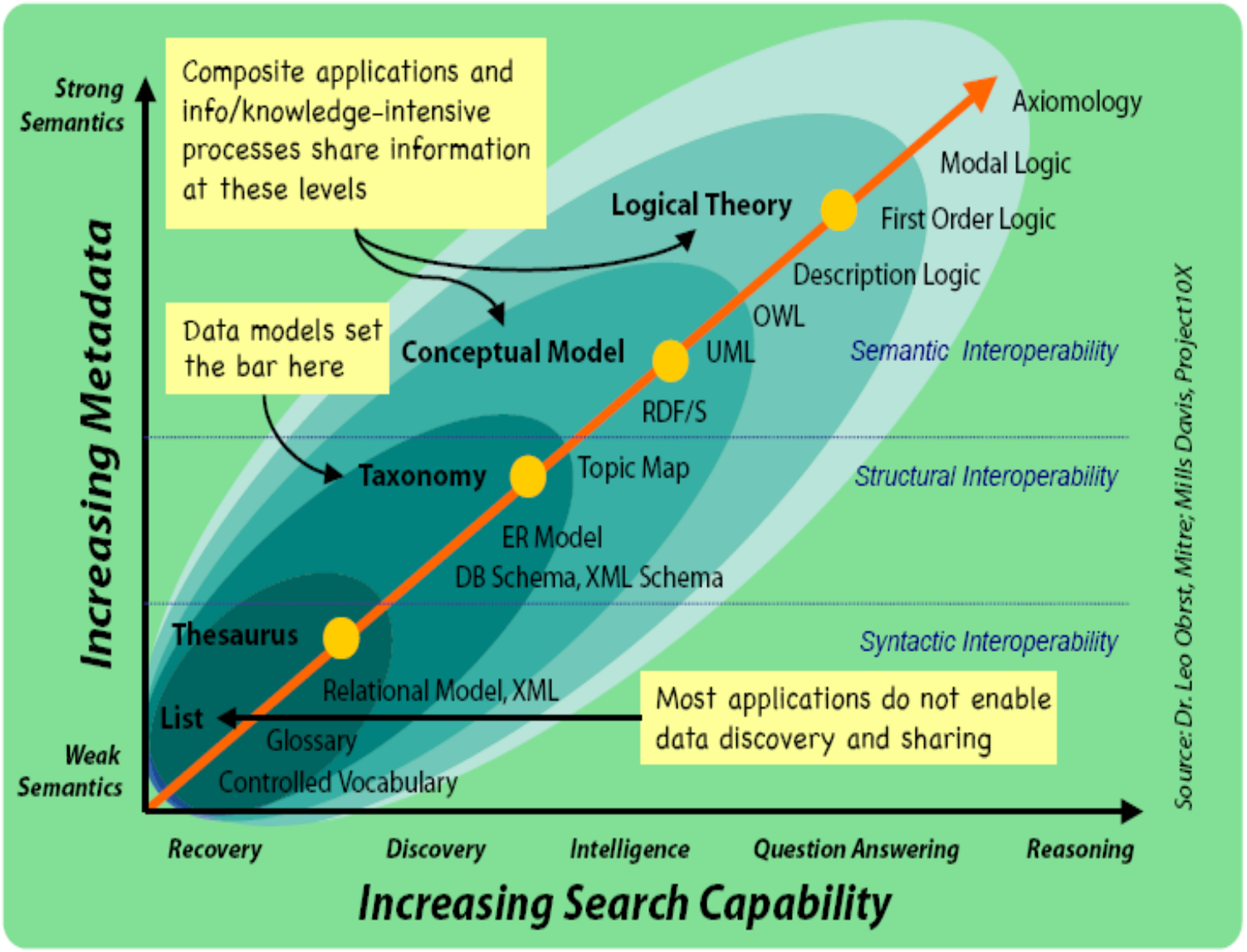
- ***Communication of purpose and use, caveats and relationships to other standards,***
- ***Analysis (e.g. gaps, data alignment) and***
- ***Transformation (e.g. code generation).***

The Journey Toward the Semantic Web (1/2)



J. Hendler presentation, W3C 2001

The Journey Toward the Semantic Web (2/2)



Proposed Approach

Alignment between standards is vital

- Weak alignment means incomplete/insufficient information exchange.
- Unknown alignment! A system development & integration nightmare!

Ontology-based technologies provide capabilities for formalizing and interlinking standardized application data and models. Our approach aims to:

- ***Establish a framework for the development and maintenance of standards that improves integration, collaboration, and consistency among standards products.***
- ***Use the Web Ontology Language (OWL) as a basis for distributed, linked M&S and C2 standards.***

Developing and Managing Data Standards

How to establish standards across multiple domains?	C2, Logistics, M&S, intelligence, signals physics, etc.
How to extend standards? **How to manage extensions?**	JC3IEDM, C2 Core, SEDRIS EDCS, NFDD, DIS enumerations, HLA RPR FOM, etc. JC3IEDM →MSDL→OBS JC3IEDM → GFMIEDM → US JC3IEDM → …
How to bridge legacy solutions to standards?	{Old system} ←→JC3IEDM, MSDL, C2 Core
How to manage dependencies among standards?	JC3IEDM →MSDL→OBS … →C2CORE; →HLA RPR FOM; →C-BML … ←→HSCB M&S Glossaries → * DIS Enumerations → * DFDD→NFDD←→SEDRIS EDCS
How to manage standards in distributed environment?	SISO, IEEE, OGC, ISO, MIP. DoD, MSCO, services, coalition, industry, DoD COIs.

Example Alignment and Integration Issues

- **Integration**
  - **Geospatial features: edcs:Facility =?= nfdd:Facility**
  - **Data models: JC3IEDM ←→ HLA RPR FOM (or any other FOM)**
- **DIS Enumerations:**

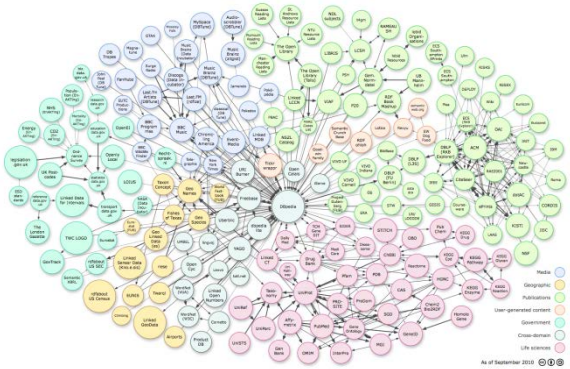
  Tank M1A2 → JC3IEDM?
- **Formal traceability:**

  JC3IEDM→ MSDL, C-BML?
- **Official terminology:**

  SISO or M&SCO glossaries → SISO or DoD standards?
- **Semantics frozen in text:**

  EDCS, JC3IEDM-BR, guidelines, field manuals, doctrine

Why use the Web Ontology Language?



Distributed, web-centric architecture - RDF

OWL-DL

W3C Semantic Web

Dynamically extensible structure – RDF, OWL

Formal semantics - DL

$SROIQ(D)$

$SHIF^{(D)}$

OWL is currently being used in support of standards, e.g. biology, NASA Ontology Architecture.

Why use OWL instead of XML?

- Semantics
  - OWL – a structural specification for expressing a conceptual data model.
  - Ontology – A formal specification of a conceptualization.
  - XML – a syntax specification for encoding data in machine-readable form.
  - XML Schema (XSD) – An expression of syntactic constraints to form languages in XML. All constraints are grammatical, not semantic.
  - *W3C defers expression of semantics to OWL, not XML schemas alone!*
- Web-centric
  - RDF and OWL use URIs to identify all things, not just documents.
  - Implementations using XML rarely use URIs as identifiers.
- Dynamic structure
  - Combining, importing, and linking OWL data and data models is simple.
  - XSDs must be built carefully to make XML or XSDs combinable in ways that make sense.

Framework for Model Management

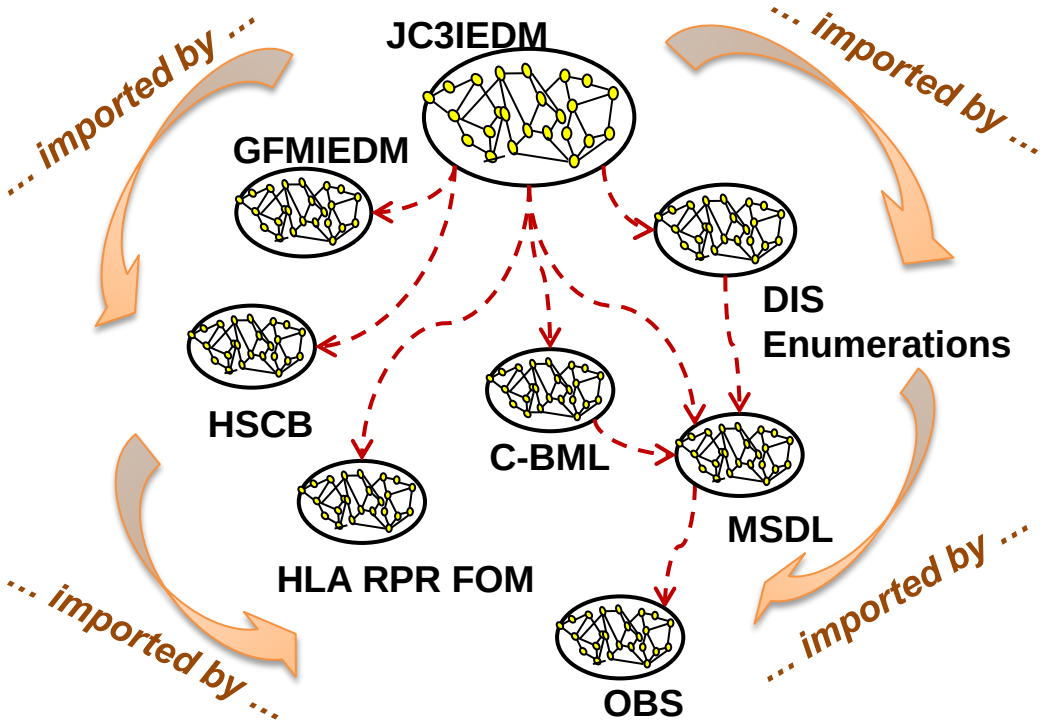
1. **Extract implicit semantics <u>out of documents</u> and <u>into OWL</u>.**

   a) Build OWL models around XML and DB schemas, and reference data (DIS enums).

   b) Convert lists and glossaries into "linkable" resources.

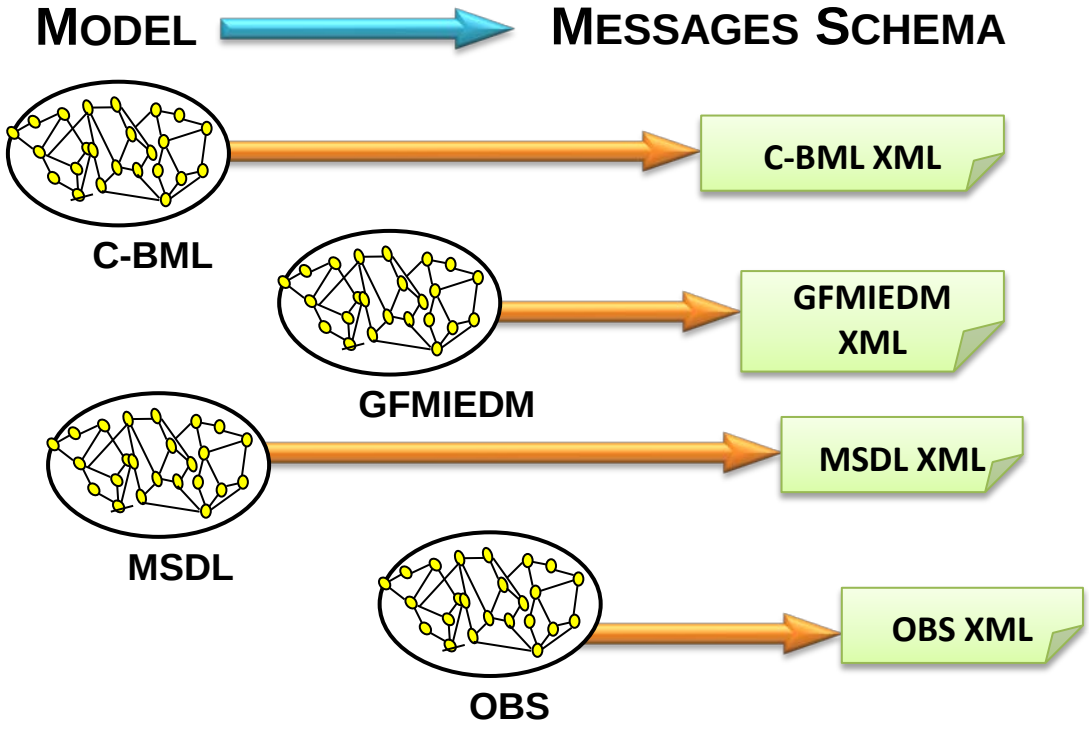
   c) Identify existing interdependencies among standards (citations, redundancy, conflicts).

2. **Construct modular composed ontologies**



Framework for Model Management

3. Derive message schemas and data formats from shared reference ontology



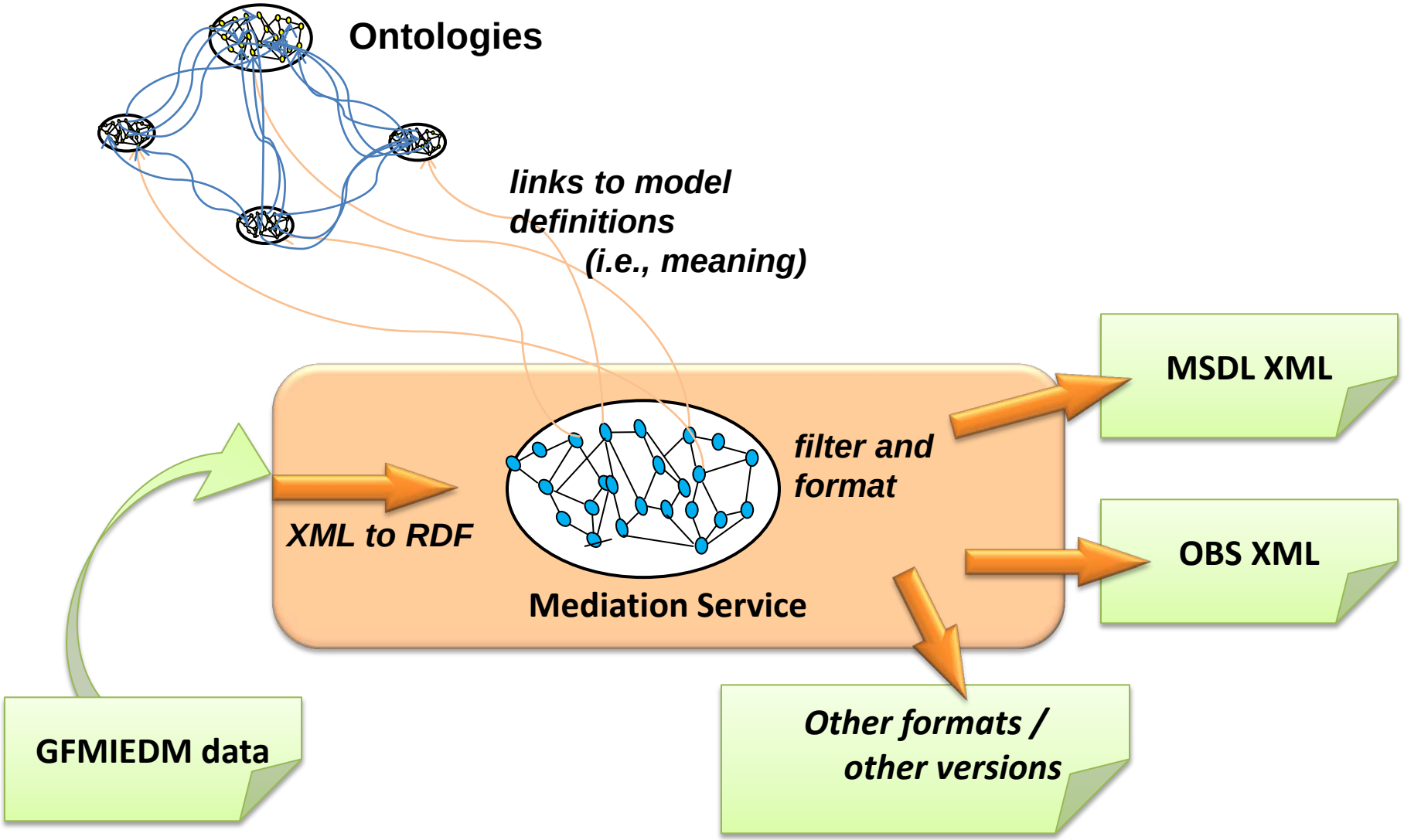
4. Use ontologies in lossless translation of data across semantic bridges

→ Work with multiple existing schemas at once

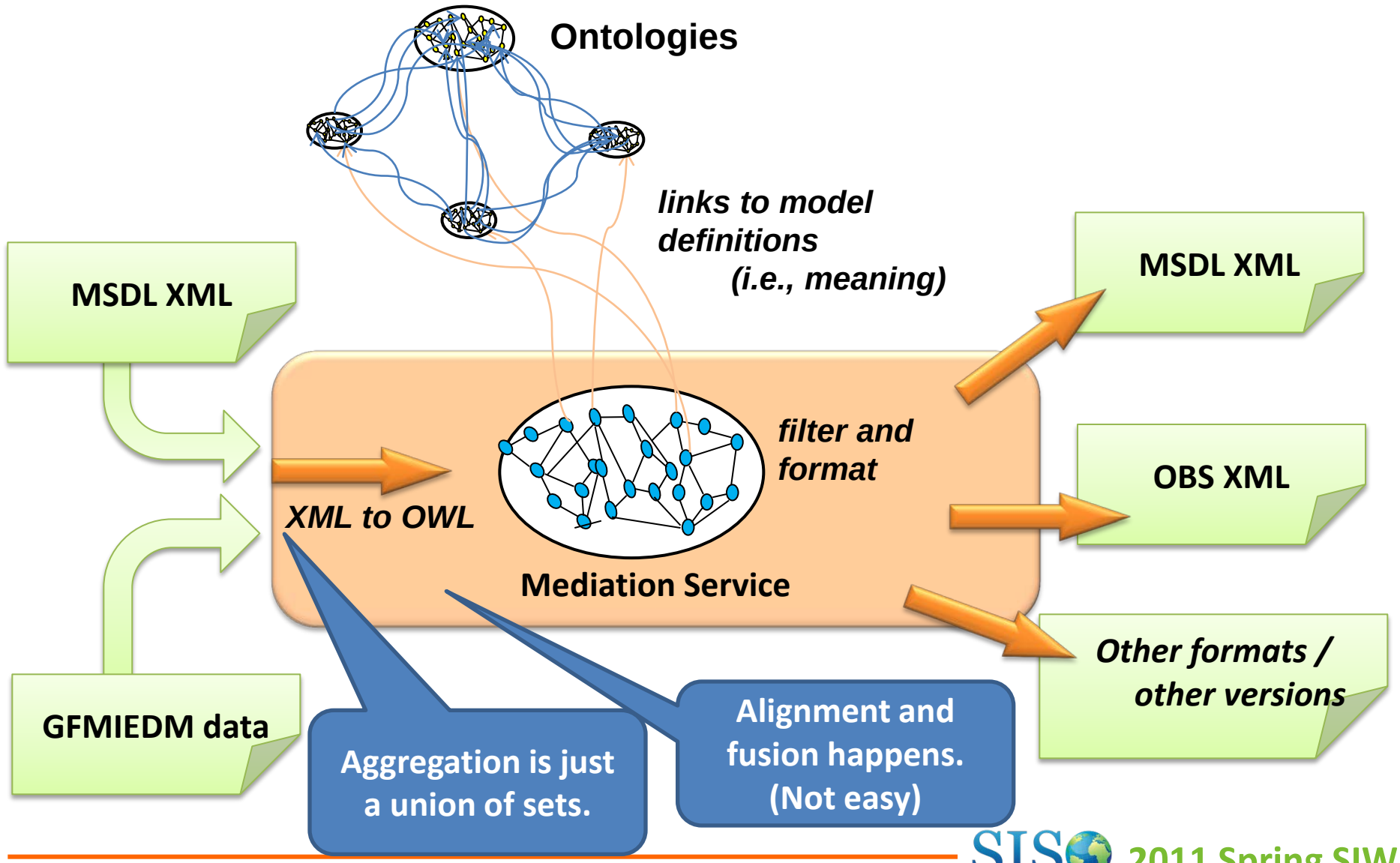
→ Meaningful data translation

→ Enable data fusion

Execution: Ontologies in Mediation



Execution: Ontologies in Aggregation



Conclusions (1/3)

- **Numerous standards in the domains of C2 and M&S are currently under development, which creates challenges:**
  - **Relationship between standards and**
  - **The representation of the underlying models**

- **The successful use of XML technologies over the past decade and the availability of COTS toolsets have made XML Schemas (XSD) a widely adopted means for representing models, especially structure and content.**

- **However, XSDs do not support semantic requirements for Data Alignment and Data Transformation processes.**

Conclusions (2/3)

- OWL has matured over the last decade: as a set of standards, and as a set technologies in the form of COTS tools. OWL is being used today in standards communities to solve real-world problems.

- An OWL-based approach as the basis for a modular-ontology framework for model management can greatly facilitate:
  - DATA MEDIATION
  - DATA ALIGNMENT and SEMANTIC ALIGNMENT
  - DATA TRANSFORMATION

- The C2 and M&S community must seek a means to measure and manage alignment across related standards.

Conclusions (3/3)

- **The use of a modular OWL-based standards management framework will support the product life-cycle of C2 and M&S standards will:**
  - **Reducing duplication of effort**
  - **Allow for easier maintenance and extensions**
  - **Provide the means for deconfliction**
  - **Ultimately result in cost-reduction.**

- **From a user-perspective, systems of systems that use multiple standards will benefit from this approach:**
  - **Easier design and integration of new systems**
  - **Support for integrating legacy systems**
  - **Cost-reduction due to fewer unknowns**

Questions?

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