
# Implementation of the International Defence Enterprise Architecture Specification (IDEAS) Foundation in DoD Architecture Framework 2.0

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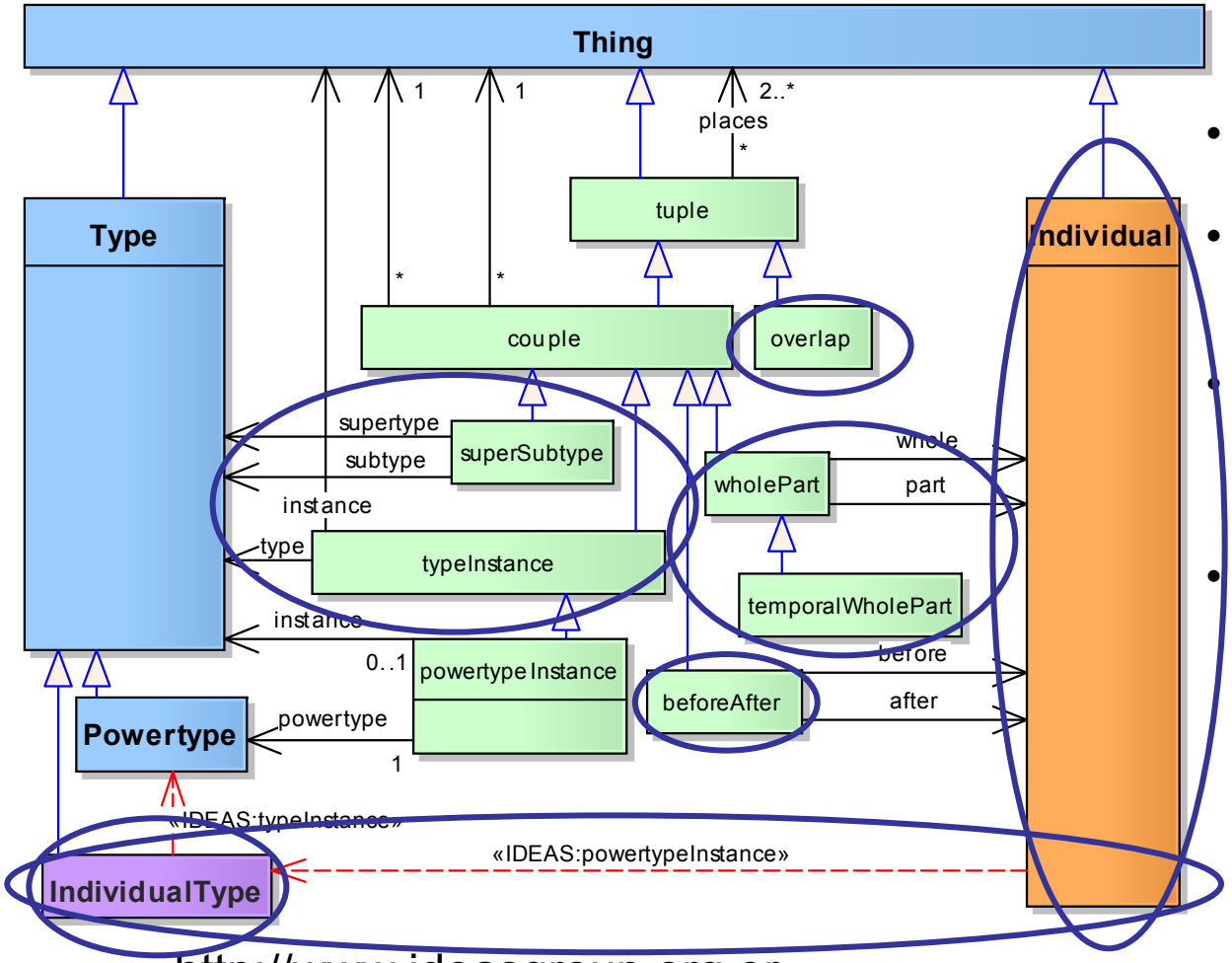
# Outline of Presentation

- IDEAS Recap
- Why we used IDEAS – benefits
  1. Re-use of common patterns saved a lot of work
  2. Reconciliation and analysis tool
  3. Information pedigree model
  4. Design reification and requirements traceability
  5. Services description
  6. Semantic precision
  7. Mathematical precision
- How we implemented IDEAS
- Implementation challenges


# IDEAS Recap

# Top-Level Foundation




- Four dimensionalist -- xyzt
- Extensional -- physical existence is the criterion for identity
- Signs and representations are separated from referents
- Mathematics:
  - Type theory ~ Set theory
  - Mereology (wholes and parts)
  - 4D Mereotopology (spatio-temporal relations)

http://www.ideasgroup.org or
http://en.wikipedia.org/wiki/IDEAS_Group

# Type Theory Math Examples

Commutative and anti-commutative, e.g., $A \cap B = B \cap A$

Reflexive and irreflexive, e.g., $\mathrm{A} \subset \mathrm{A}$, $\mathrm{A} \subsetneq \mathrm{A}$

Associative, e.g., $A \cup (B \cup C) = (A \cup B) \cup C; \quad A \cap (B \cap C) = (A \cap B) \cap C;$

Transitive, e.g., $\mathrm{A} \subset \mathrm{B} \wedge \mathrm{B} \subset \mathrm{C} \Rightarrow \mathrm{A} \subset \mathrm{C}$

others:

$a \in A \wedge A \subset B \Rightarrow a \in B$

if $\{A_i\}$ forms a partition of A then $a \in A_j \Rightarrow a \notin A_k \forall j \neq k$

# Mereotopologic Math Examples

- Overlaps, spatial relationships (mereotopology)

  Parthood $xPy \equiv x \text{ is a part of } y$

  Proper part x is a proper part of y $x\langle P\rangle y \equiv xPy \wedge \neg yPx$

  P and $\langle P\rangle$ are transitive : $xPy \wedge yPz \Rightarrow xPz$

  $aPb \wedge a \neq b \Rightarrow \neg bPa$;

  P is antisymmetric : $xPy \wedge yPx \Leftrightarrow x = y$

  Overlap proposition $xOy \Leftrightarrow \exists z \ni zPx \wedge zPy$

  Overlap operator : $x \bigcap y = z_o \ni z_oPx \wedge z_oPy \wedge \forall z_i \neq z_o, z_iPx \wedge z_iPy \Rightarrow z_iPPz_o$

  Underlap $xUy \equiv \exists z \ni xPz \wedge yPz$

  $xOy$ and $xUy$ are reflexive, symmetric, and intransitive

  Overlap Associative $aO(bOc) = (aOb)Oc$

- Behaviors -- Sequences, before-after (4D mereotopology)

  Before $xBy$ is transitive : $xBy \wedge yBz \Rightarrow xBz$

  Proper before is irreflexive $\neg u\langle B\rangle u$

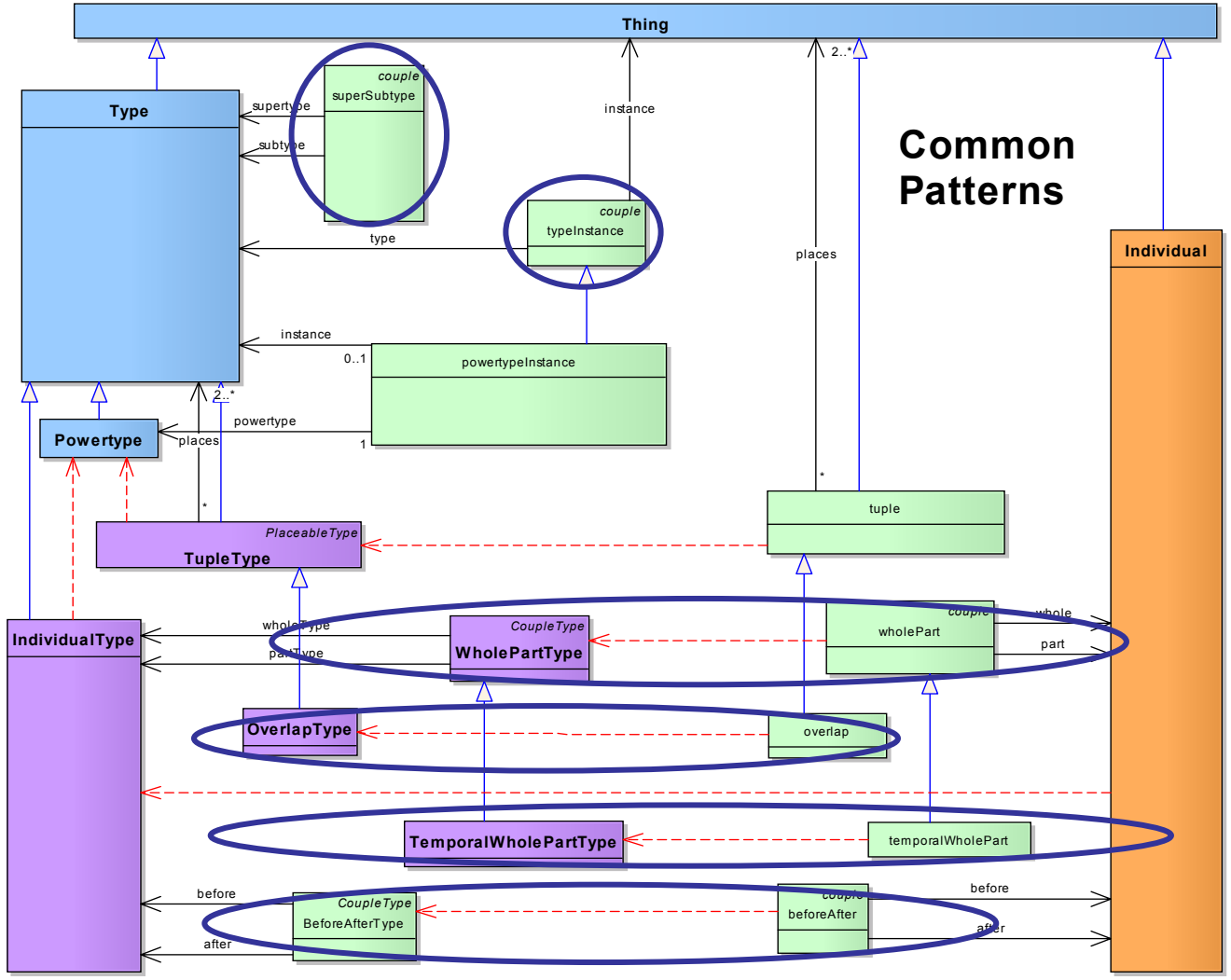
  Properbeforeisanti-commutative $a\langle B\rangle b \Rightarrow \neg b\langle B\rangle a$

# Some Math Sources

- National Center for Ontologic Research (NCOR), http://ontology.buffalo.edu/smith/
- Direct Model-Theoretic Semantics for OWL 2, http://www.w3.org/TR/2009/REC-owl2-direct-semantics-20091027/
  - Vocabulary
  - Interpretations
    - Object Property Expressions
    - Data Ranges
    - Class Expressions
  - Satisfaction in an Interpretation
    - Class Expression Axioms
    - Object Property Expression Axioms
    - Data Property Expression Axioms
    - Datatype Definitions
    - Keys
    - Assertions
    - Ontologies
  - Models

# Benefits of IDEAS for DoDAF 2

# 1. Rigorously worked-out common patterns are reused

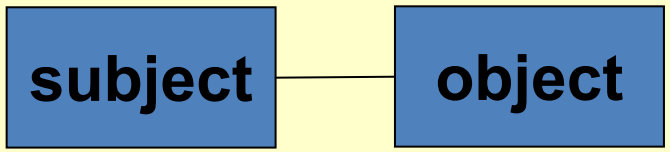



- Saved a lot of repetitive work – “ontologic free lunch”
- Concentration of rigor on common patterns results in higher quality and consistency throughout
- Model compactness -- DM2 is tiny compared to its predecessor by ***two*** orders of magnitude!
- Easier to learn -- a few hard concepts are easier to learn than thousands of conceptually intractable ones.
- Implementations get reuse too – same code, queries, … work for many datasets

# 2. Reconciliation and analysis tool (slide 1 of 4)

- State of practice in data modeling:
  - Noun and adjective analysis
  - Similar to natural language written in a diagram
  - Often laden with entrenched but obsolete technology considerations

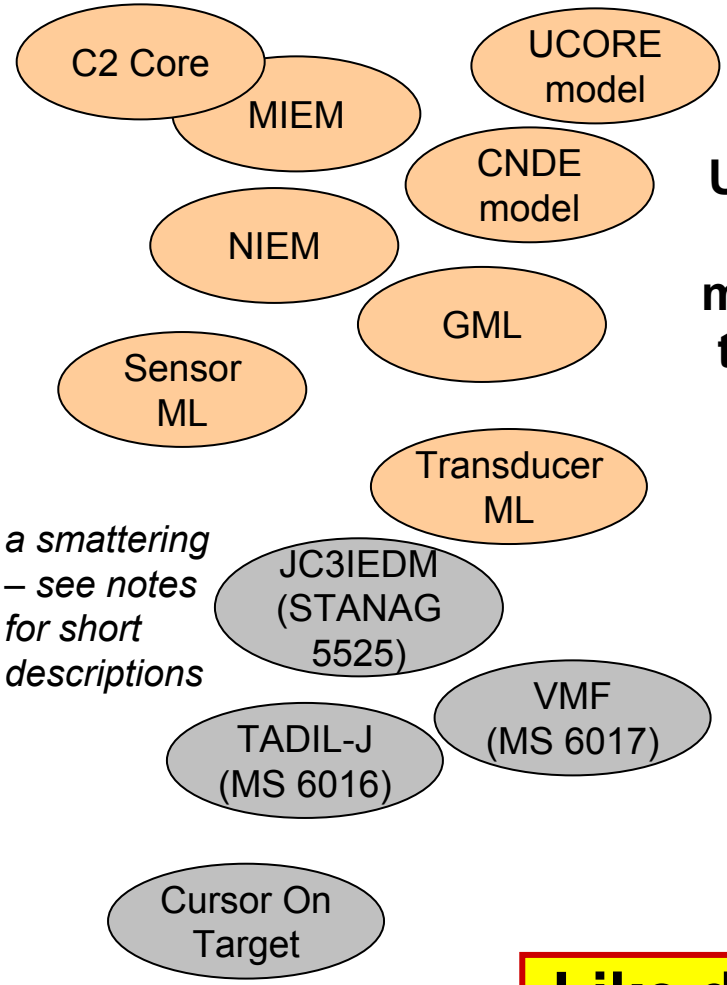
The fundamental concepts of Entity-Relationship and Class Models:




Implicit, built-in, language features:

- predicate "has" (for attributes)
- Plural, singular notions (cardinality)
- Sufficiency and completeness notions (e.g., no-nulls)

# One Result of this practice -- data model "wars"




*a smattering – see notes for short descriptions*

**Users of these different models believe their model is the best for many purposes, in many cases overlapping purposes.**

- Anti-Submarine Warfare (ASW) COI
- Blue Force Tracking (BFT)
- C2 Interoperability Group
- CBRN
- Coalition C2 Interoperabilty (Coal C2)
- Common Sensor
- GEOINT Standards COI (GWG COI)
- Global Force Management (GFM)
- GPS Based Positioning  Navigation Timing Service
- Integrated Fires
- Joint Air and Missile Defense
- Joint Air Track (JAT)
- Joint Electronic Warfare Data Standardization
- Joint Targeting Intelligence (JTI)
- Maritime Domain Awareness
- Meteorology-Oceanography (METOC)
- Mine Warfare
- Symbology (SYM)
- Undersea Warfare XML (usw-xml)

**Like diverse languages, there is a high cost to learn**

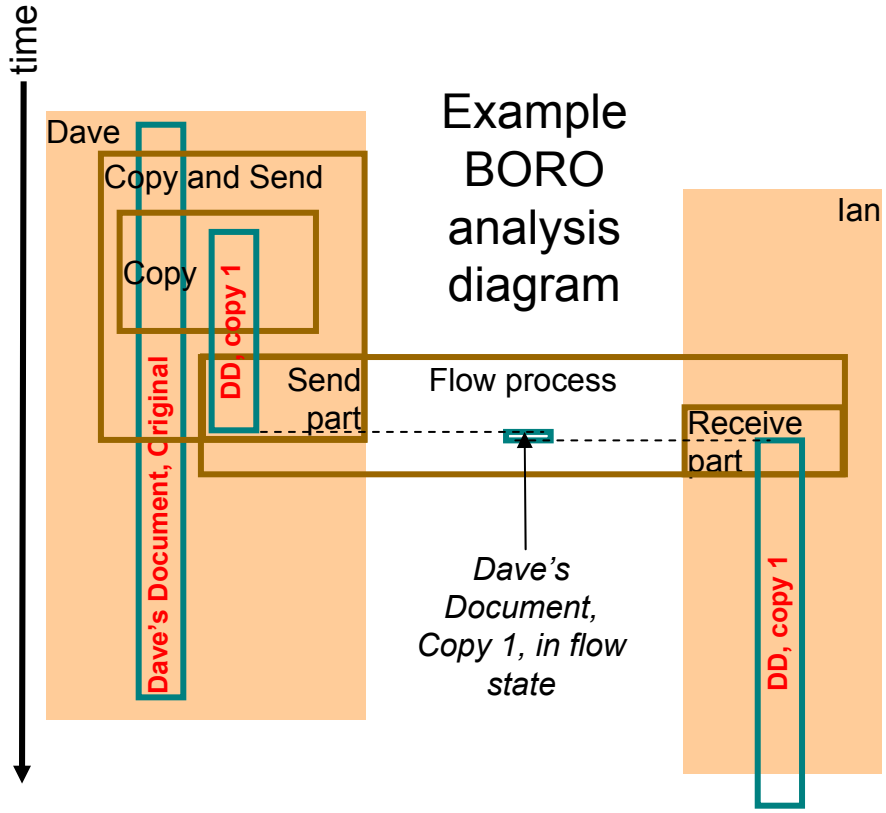
# Some real-world and costly results of this practice

- Cost and project risk
  - Developers and integrators must learn multiple proprietary "languages"
  - Need to build many ***translators***
  - Over promised ability of "translation hubs"
  - Context, interdependent, and value-dependent translations
- Operational impact
  - E.g., from "lossy" translations, mis-translations, …
  - Difficulty in transitioning new technologies, e.g., automated processing tools
  - Prohibits or impedes scaling and cross-domain integration and data sharing
  - Impedes Net-Centricity / OA / SoA due to need for much human interaction, e.g., no automated unanticipated users

**The costs and risks – both project and operational -- are usually underestimated**

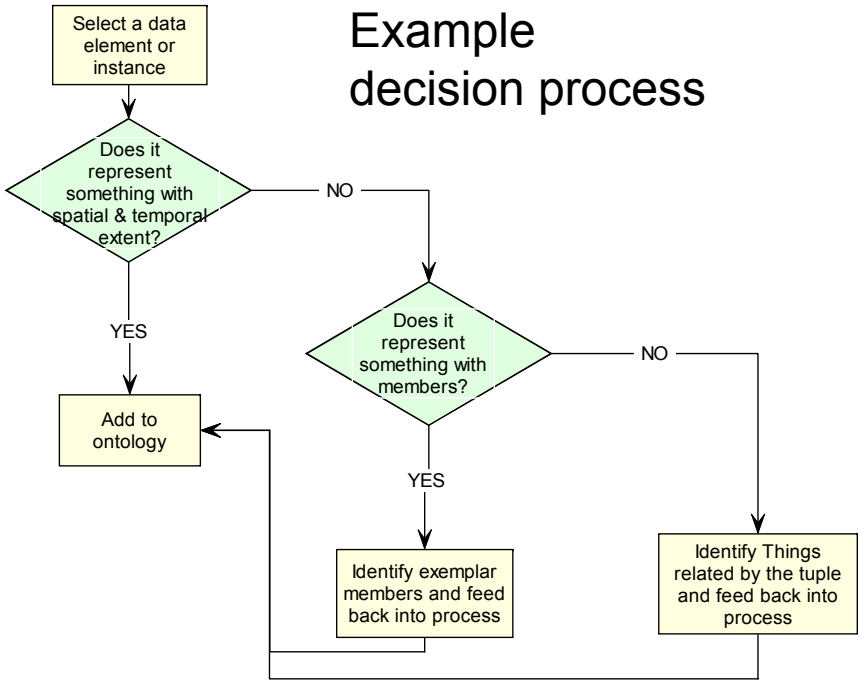
# Reconciling Using IDEAS Analysis Technique: BORO[1]

- Agreed-upon principles that provide a principled basis for issue analysis



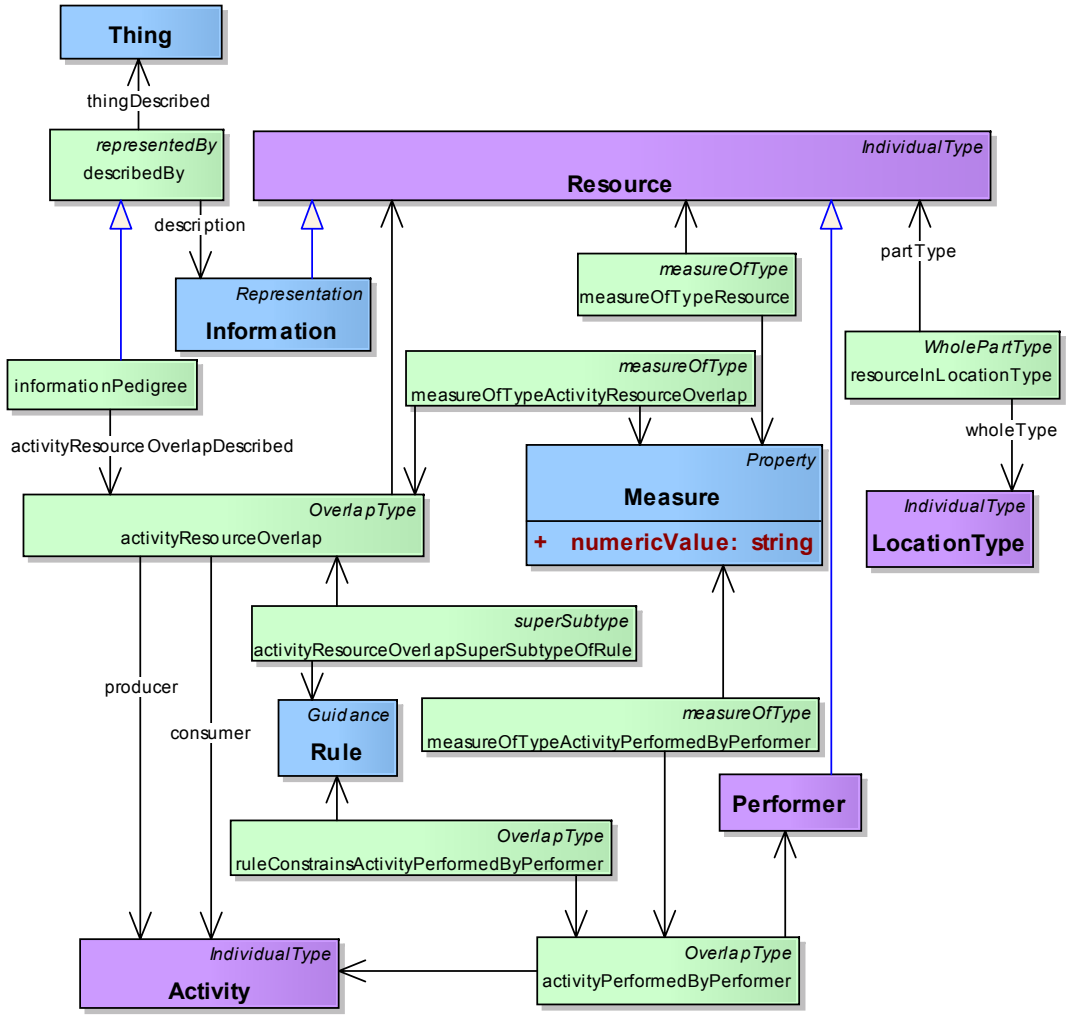

Example BORO analysis diagram

Example decision process




1. Business Objects Reference Ontology, http://www.boroprogram.org/ or http://en.wikipedia.org/wiki/BORO_Method

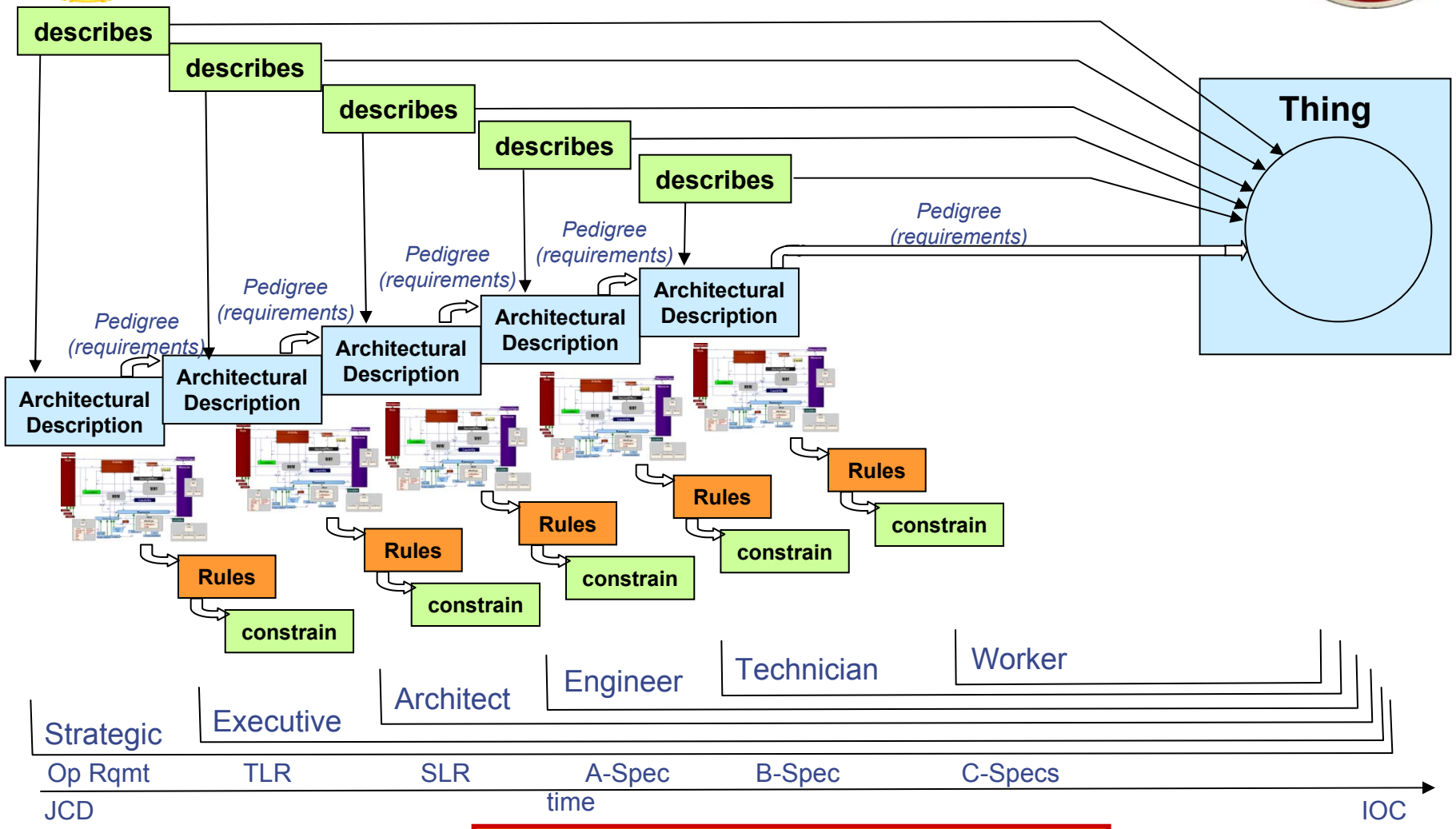
# 3. Information Pedigree Model




- Workflow model, e.g., Open Provenance Model (provenance = linked together pedigrees)
- = Activity model (OV-5 + 6c) ➔ got nearly for free!

**Got this one nearly for free!**

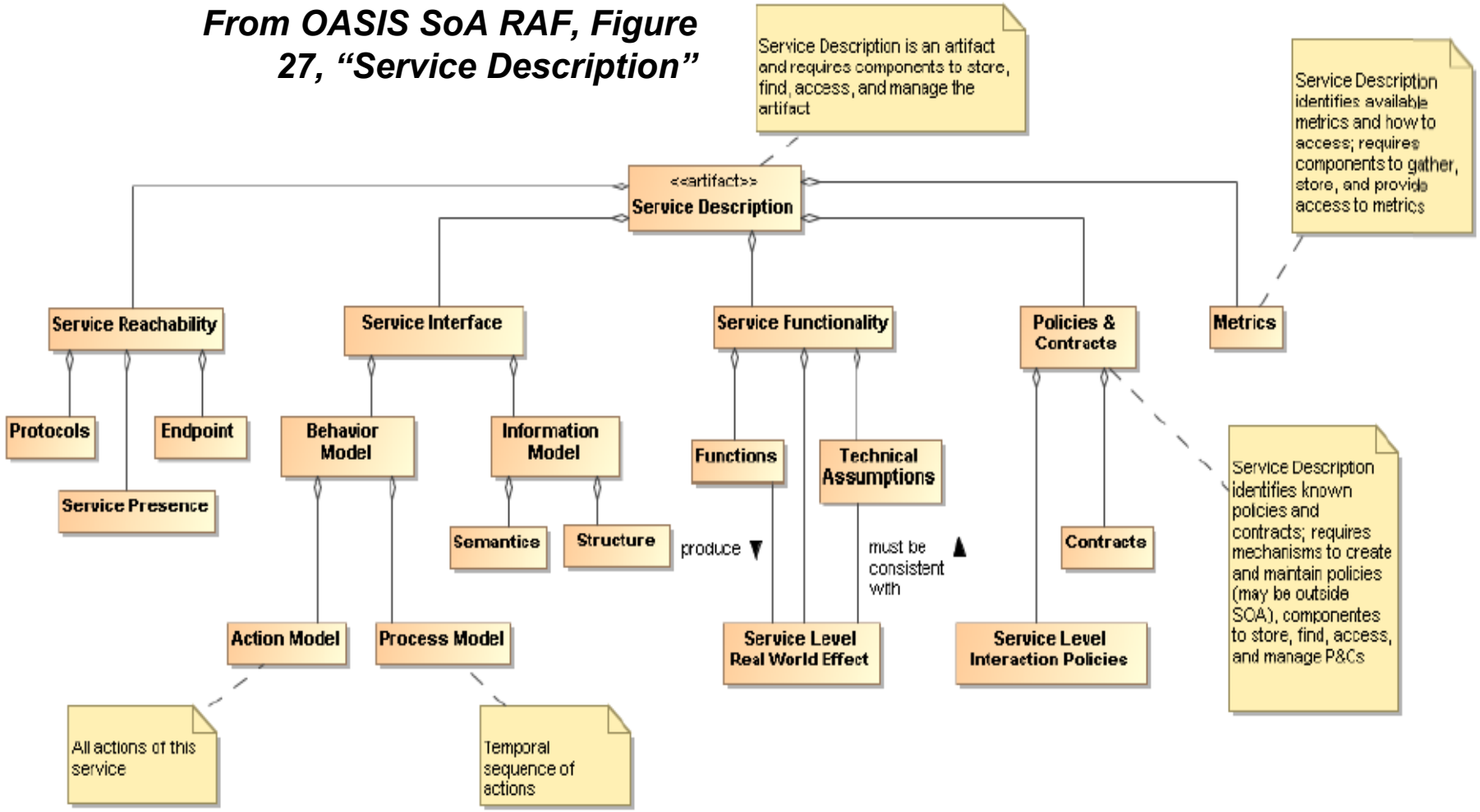
# 4. Design Reification and Requirements Traceability



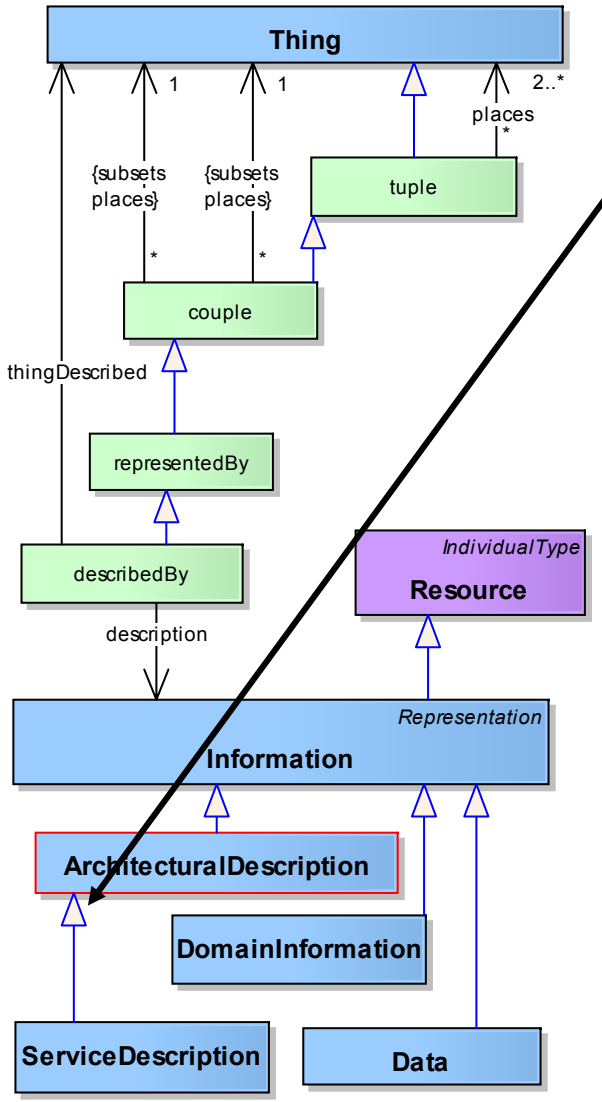

**Got this one for free too!**

# 5. Service Descriptions (1 of 2)

***From OASIS SoA RAF, Figure 27, "Service Description"***



# Service Descriptions as Modeled in DM2




This means a Service Description can have all the structure of an Architectural Description, e.g.,

- Activities
- Before-After
- Rules
- Conditions
- Data structures
- Locations
- Dependencies
- Etc.

**Got this one for free too!**

# 6. Semantic Precision for Heterogeneous Data Integration

**Free-text**

Human-interpretable only

**Structured document**

Human-interpretable but with a predictable organized arrangement

**Database**

More structure than structured text

- Named records (or tables or classes) that are some sort of container for named fields (or attributes or columns).
- Associations and relationships, containers can point to information in other containers
- Because of the labeling, you can tie the information together and query them. A SQL query is just fundamentally a selection of the information.
- Referential integrity, data validation, cardinality rules, etc.

**Mathematically structured**

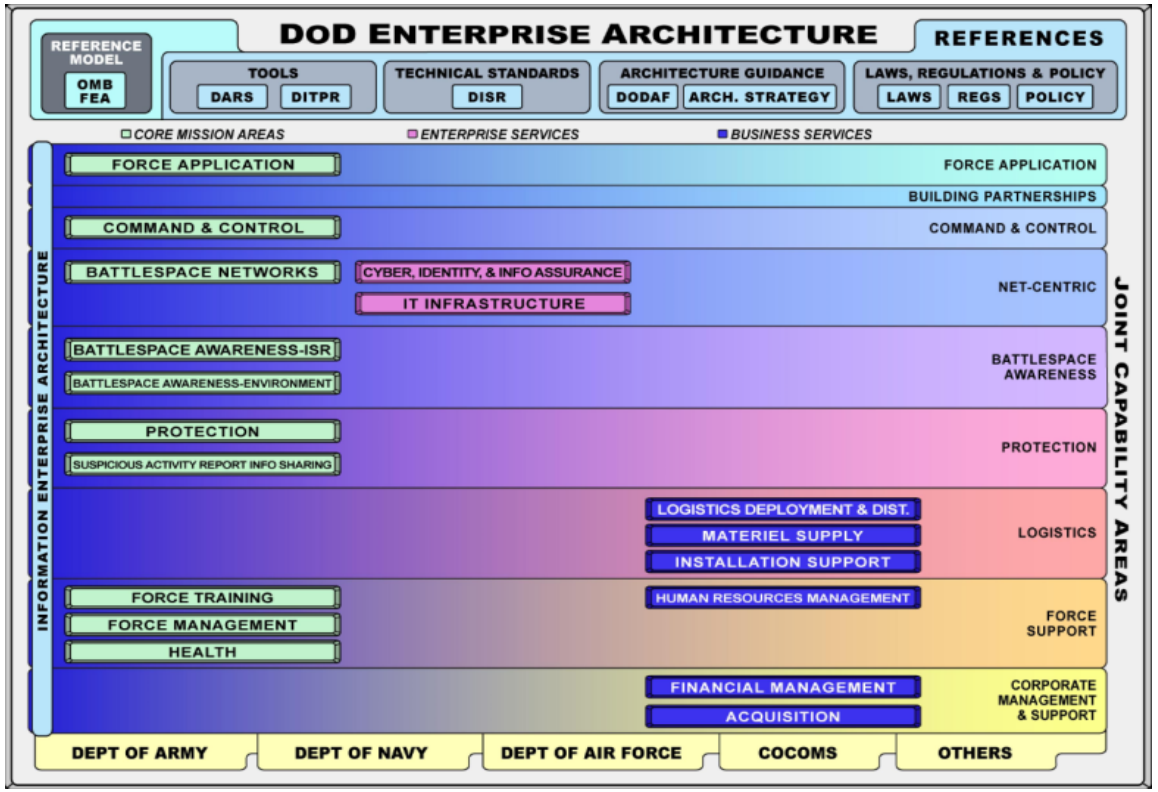
- Applicable mathematics:
  - Set or type theory
  - Mereology
  - Mereotopology
  - 4 dimensionalism
  - Predicate calculus
  - Logics: modal, Kripke, …
- Rules, operators:
  - Commutative, reflexive, transitive, …
  - Member-of, subset-of, part-of, …

**Depends on near-universal mathematics and science that all learn very similarly**

## A spectrum of information sharing

# Heterogeneous Data and EA

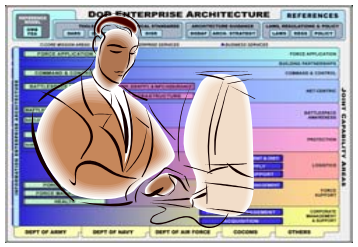
- For example:
  - –Interoperability assessment
  - –Capability gaps and overlaps
  - –Capability evolution measures
  - –SoS, FoS
  - –Portfolio optimization
  - –Joint, multi-agency, coalition operations
  - –Analysis of alternatives




**The very reason for EA implies a need to look at data from multiple sources**

# 7. Mathematical precision

**Create architectural descriptions**




**Submit for core process event**

For example:
1. Capability solution proposal
2. Acquisition milestone review
3. Interoperability and supportability assessment checkpoints
4. Budget cycle (PPBE, IRB, CPM)
5. Ops Plan (contingency update cycle, actual)

**Get and integrate relevant datasets**

For example:
1. Queries for disconnects, inconsistencies, …
2. Specialized tools (e.g., cost / risk / performance / sustainment models, interoperability assessment)
3. Process simulators (e.g., comms flow, workflow, Petri nets, state machines)
4. Campaign, mission, engagement, etc. simulators

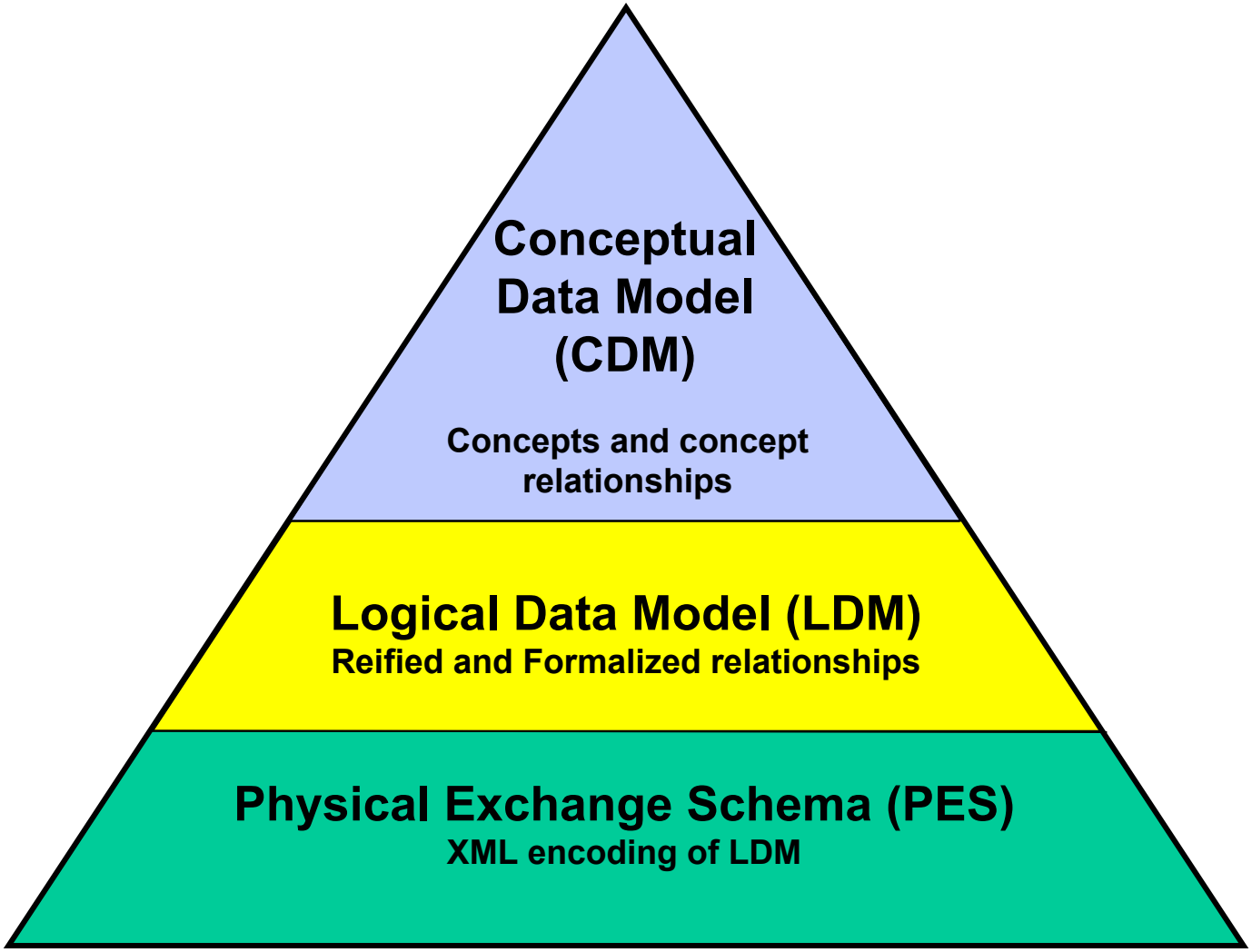
**Analyze and assess**

**Present Results for core process decisions**

**All have high-sensitivity to mis-interpreted, erroneous, incomplete, incompatible, … data**

# How did we implement IDEAS in DM2?

# The DM2 Has Three Levels




- DIV-1
- DIV-2
  (This is where almost all the design and analysis work is done)
- DIV-3
  (Auto-generated from the LDM)

# Conceptual Phase

**DoDAF 2.0 "Core" Process Workshops**

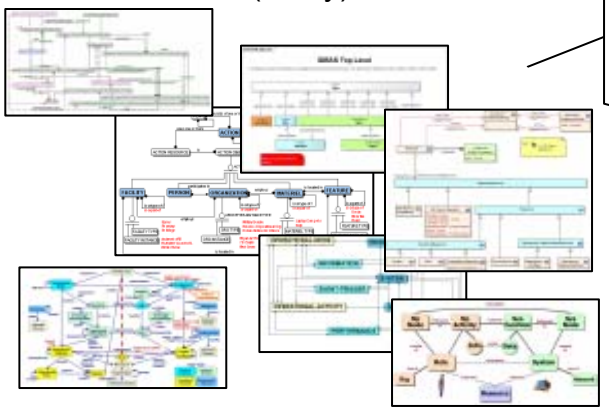
1. Joint Capabilities Integration and Development System (JCIDS)
2. Program, Planning, and Budgeting Environment (PPBE)
3. Defense Acquistion System (DAS)
4. Operations Planning
5. Systems Engineering
6. Capabilities Portfolio Management

Design information collection template → Conduct and facilitate → Compile process information needs

**Authoritative Documents (e.g., DODI, CJCSI, …)**

**Process EA information needs**

**Existing Models and Databases**
(many)



**Data dictionaries & models**

**DoDAF 1.5 "Parking Lot" Issues**

EA Presentation WG

**Data WG**

1. Collect terms
2. Make a pass on "core" terms
3. Group related terms
4. Gather authoritative definitions for "Core" terms
5. Proposed definitions (+rationale, examples, and aliases)

EA Methods WG

**Terms with rough consensus definitions, sources, aliases, rational, examples**

# Logical Phase

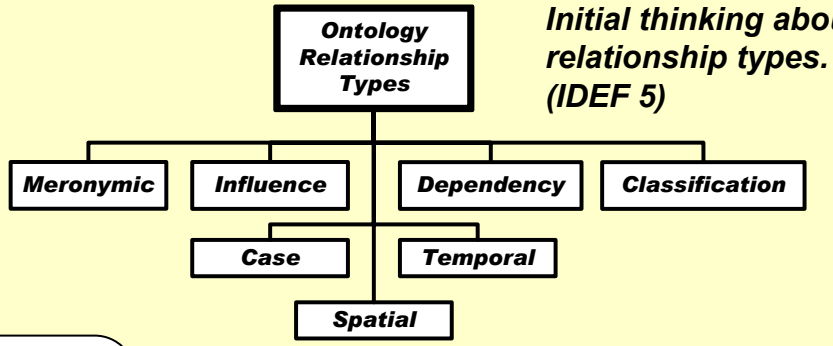
CDM

## Data WG

**Using a UML class modeling tool:**

**Add relationships**

***During this activity, repeating association patterns became apparent – IDEAS!***




***Initial thinking about relationship types. (IDEF 5)***

**Add attributes**

***During this activity, normalization led the WG to see that attributes are just relationships – IDEAS!***

**Refine detail**

***During this activity, it became apparent:***

- ***Details are just specializations – IDEAS!***
- ***Term reconciliation could be done using BORO – IDEAS!***

EA Methods WG

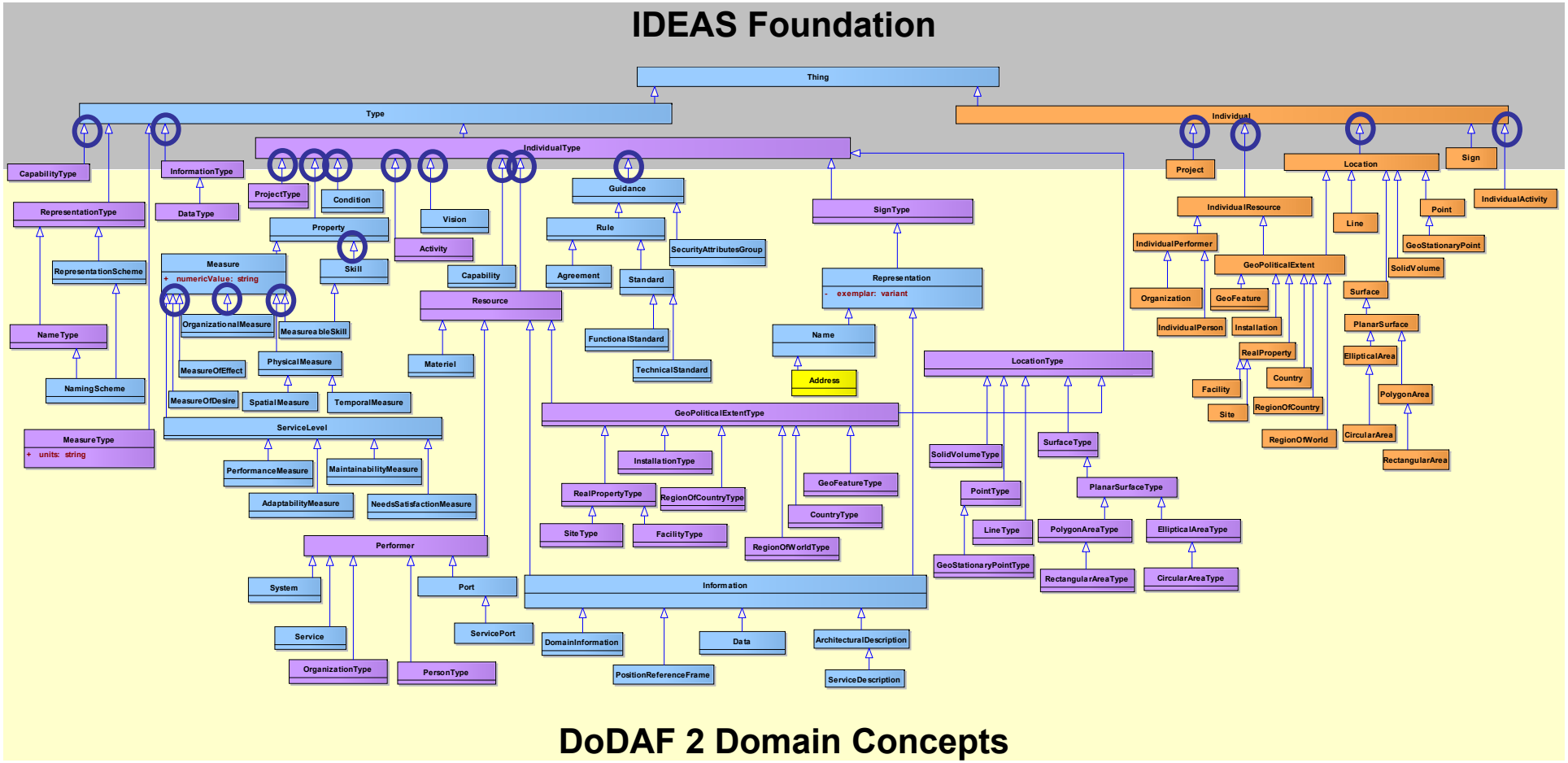
EA Presentation WG

**1. Data Dictionary**
**2. UML Ontology Model**

# Mechanization

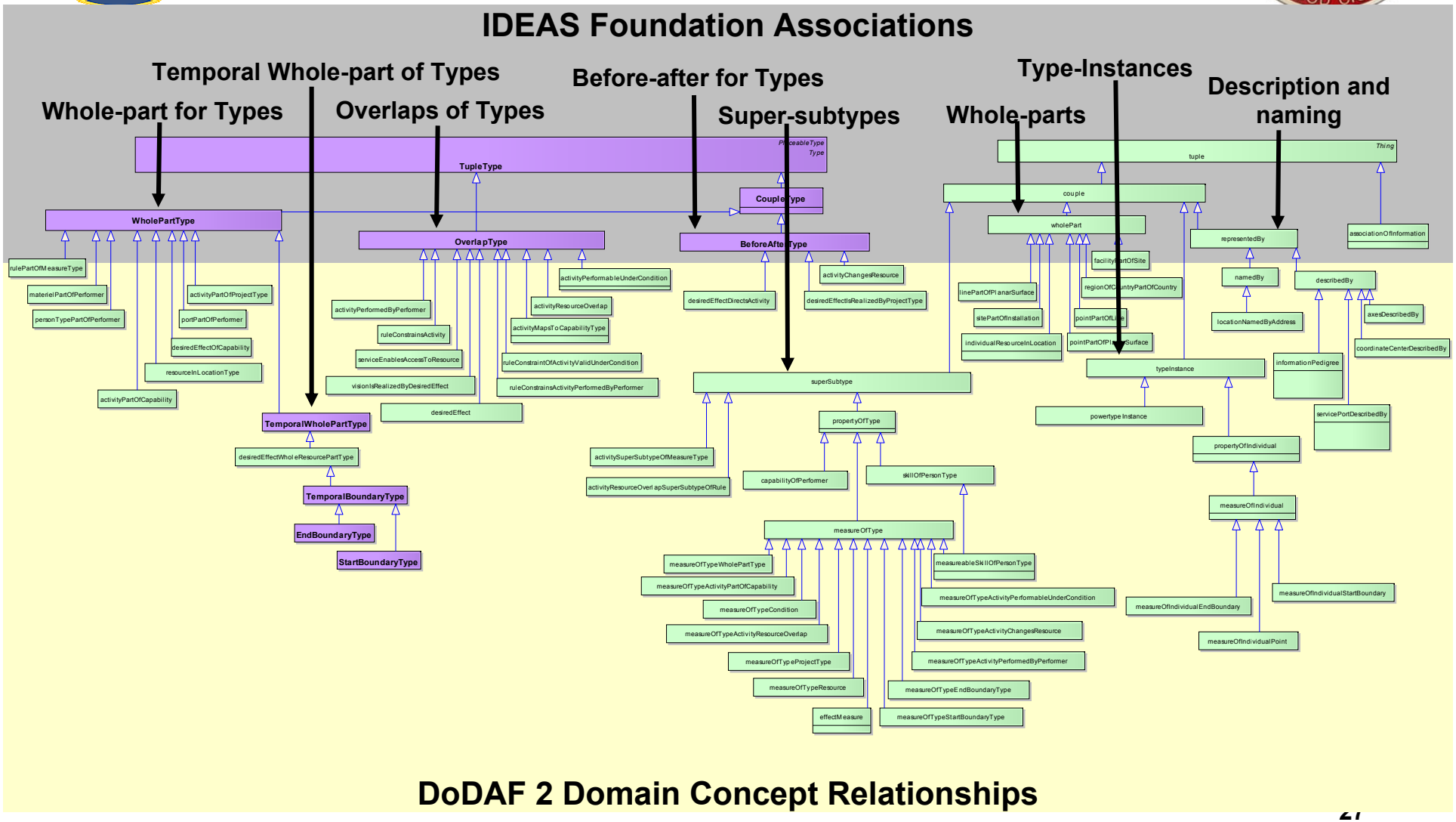
- Add DoDAF concepts and concept relationships as extensions (subtypes) to IDEAS
  1. Start with words and definitions
  2. Use BORO analysis to figure out the IDEAS type
  3. Identify and include in data dictionary aliases and composites (concepts that are modeled as a structure, e.g., Role, Goal.)

# Independent Entities Specialization



# Associative Entities Specialization

*So their mathematical meaning is known*

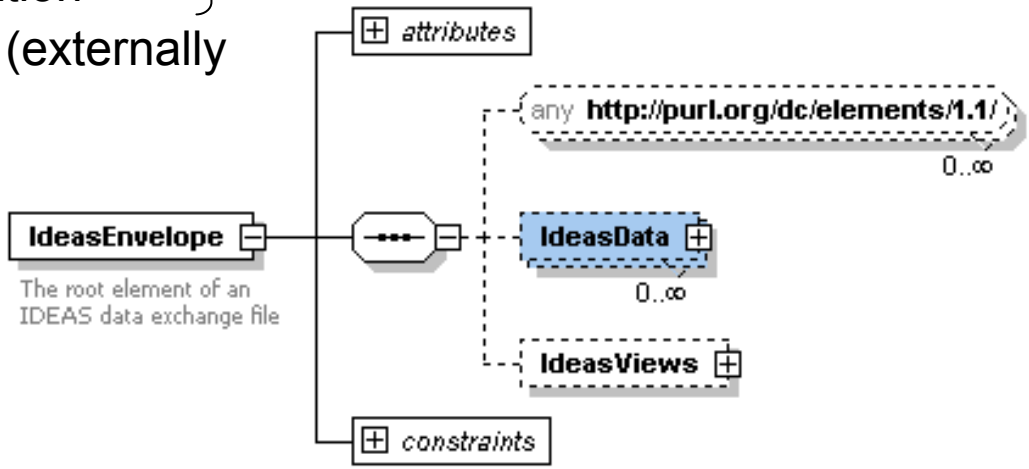



**DoDAF 2 Domain Concept Relationships**

# Physical Level

- Auto-generated from UML-ish file – no additional semantics added or changed
- Because the native XSD generator in the UML tool did not understand IDEAS Profile, an XSD generator had to be developed (UK and US)
- Four XSD's:
  1. IDEAS Foundation, version 1.0
  2. DM2 additional foundation
  3. Classification marking (externally controlled)
  4. DM2 exchange data
- Very simple structure

*never instantiated, metadata reference only*



# Challenges

# Frameworks

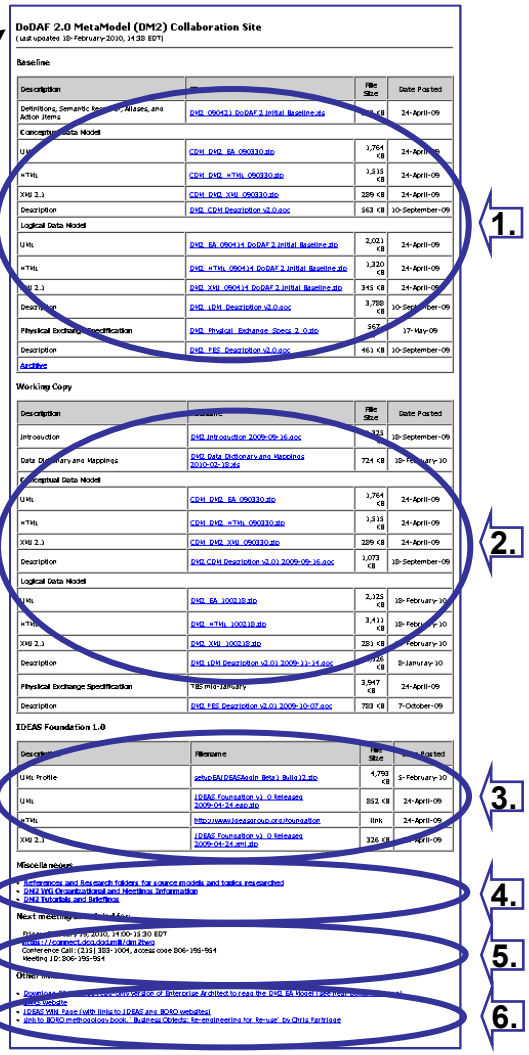
- IDEAS precision reveals ambiguities in framework models which requires revisions of the descriptions, deeper analysis of purposes, …
- The mathematics of some associations are ambiguous and take work to figure out, e.g., maps-to, depends-on, has-authority-over

# Socialization Challenges

- Ontology education
  - Computer Science education unwittingly emphasizes human interpretations of names and descriptions
  - Ontologic experience is so everyday, conscious dialog about it is difficult
  - Marketing claims about ontology, semantics, interoperability, … have, and continue to, confuse the user community
- Educating the business value of precision
  - Makes work harder for architectural description producers
  - Integration and analysis needs have often been forgotten

# DM2 Collaboration Helped

- DM2 WG open to all
- Collaboration Site
- Business rules, e.g.,
  - Aggregation and subtype rules
- Coordination with many other groups, e.g.,
  - Controlled vocabulary
  - Data models
  - Vendors and implementers
  - Software and systems organizations




1. Current baseline CDM, LDM, and PES files and documentation
2. Working copy
3. IDEAS model and profile
4. Folders with:
   - WG information
   - References and research
   - Tutorials and briefings
5. Next meeting info
6. Links to IDEAS & BORO

# Adoption Challenges

## Adopter Types

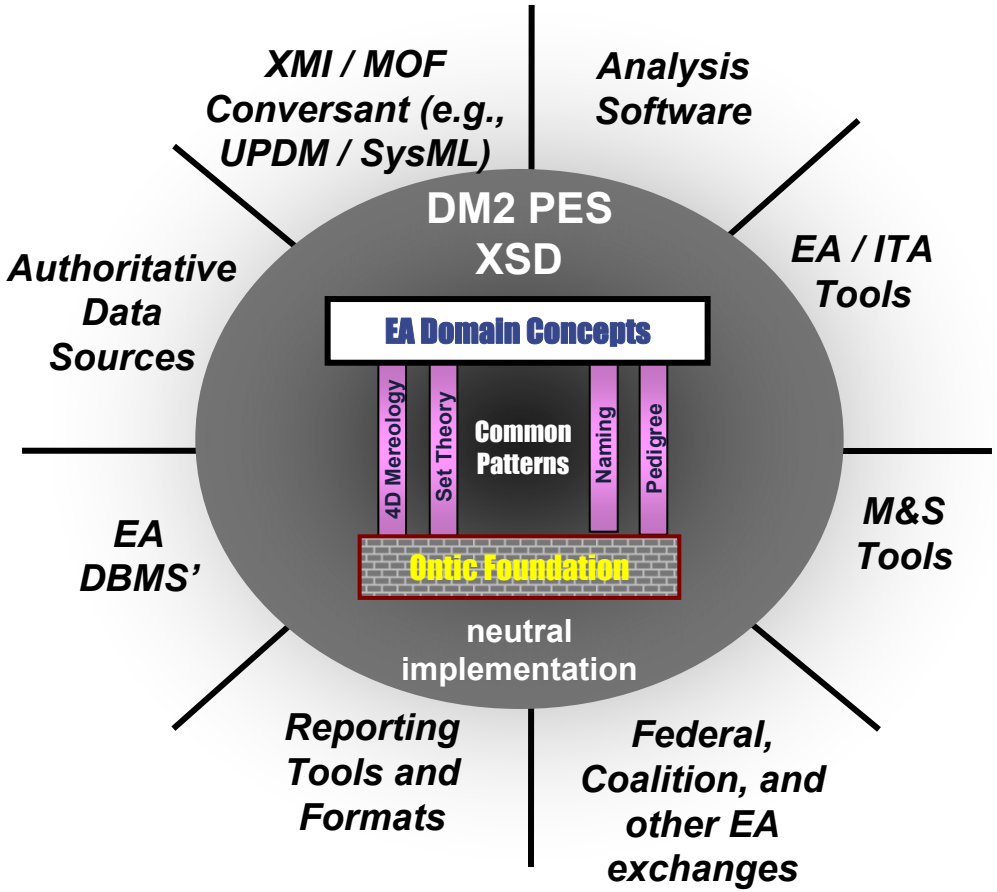
- Database or repository implementers – how to
- Software and systems engineering tool vendors – mapping semantics
- Modeling and Simulation and Executable architecture tool vendors and developers – scenario, C&P, … representation
- Custom analysis tool vendors and developers, e.g., portfolio analysis or interoperability assessment tools – relevant parameter representation

## Mitigators

1. Pilot, early adopter, and vendor support
2. Sample database
3. Education and communication program on wide range of EA data assets
4. Semantic interoperabilty layers definition
5. Exemplars and corresponding education

# The Wide Range of EA Data Assets

*DM2 is the neutral format for Interchange*

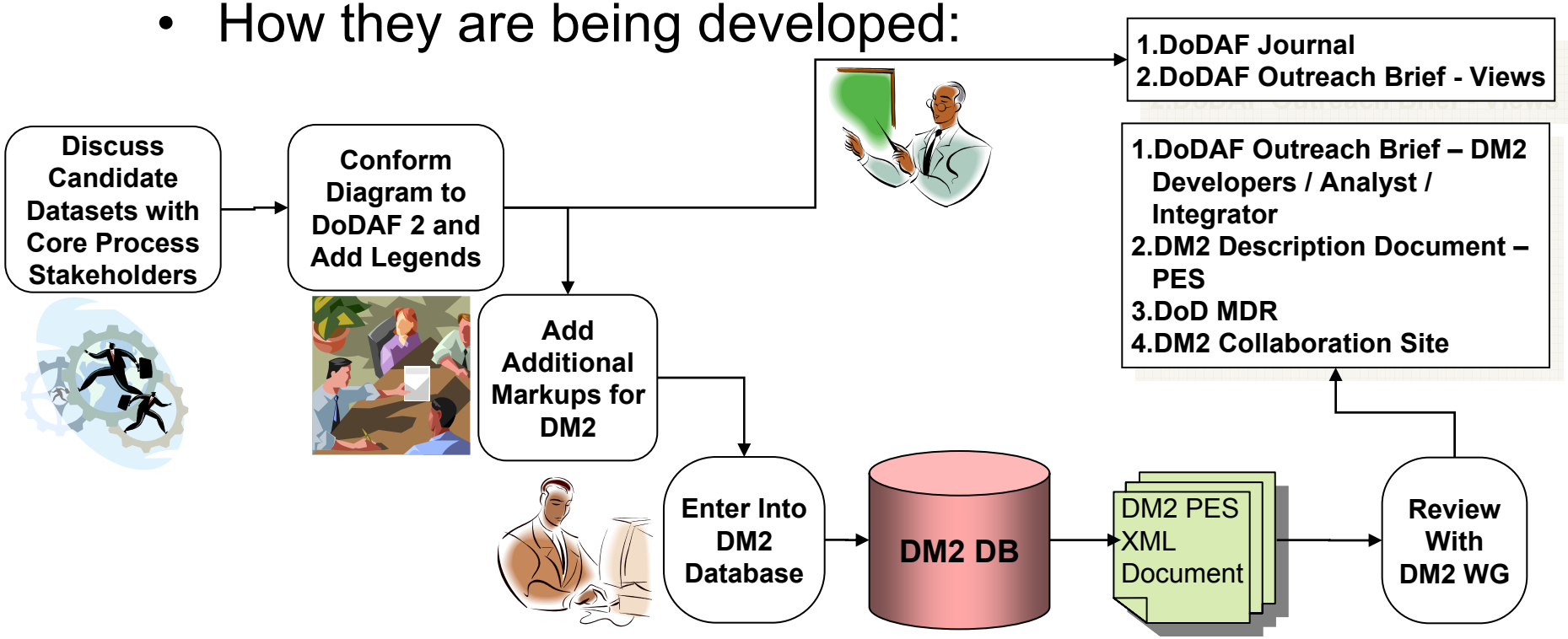



**Interoperability Layers (notional)**

| IDEAS, OWL, SUMO, … | | | |
|---|---|---|---|
| DM2 | DMM | User Props | |
| PES | XMI w/DMM | | |
| | XMI | SA Ency | |
| XML | XML | ODBC | |
| etc. | etc. | etc. | |
| | | | |
| | | | |

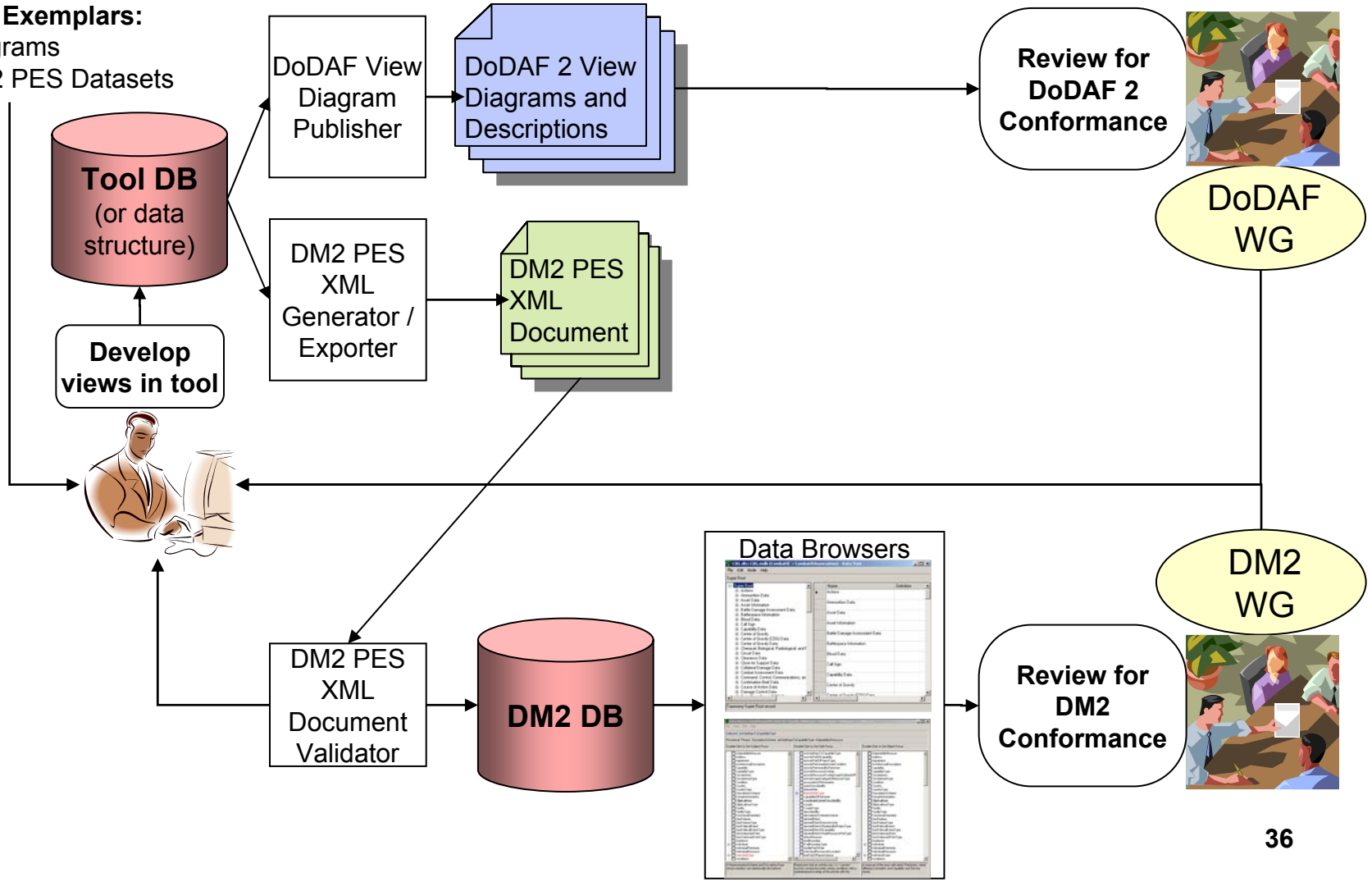
# DoDAF 2 Exemplars

- They are:
  - Collections of architectural views and their corresponding DM2 PES XML document examples
  - From coherent datasets, e.g., UPDM S&R, NCES ISP
- How they are being developed:



# DM2 / DoDAF Testbed Plan

1. **DoDAF 2 Exemplars:**
   View Diagrams
   View DM2 PES Datasets



# Summary

- The IDEAS project started as a data sharing project.
  - It produced fruit that was not originally anticipated, e.g.,
    - A formal foundation based on solid mathematics
    - A methodology for analysis of domain concepts
- The adoption by DoDAF is the beginning of being able to integrate, cross-walk, and analyze heterogeneous federated architectural description data sources
  - This is critical in achieving DoD's EA goals
- To introduce this level of rigor takes care, patience, and a good communications team

# Questions and Comments?