DoDAF 2.0 Meta Model (DM2)

Briefing for the JAWG

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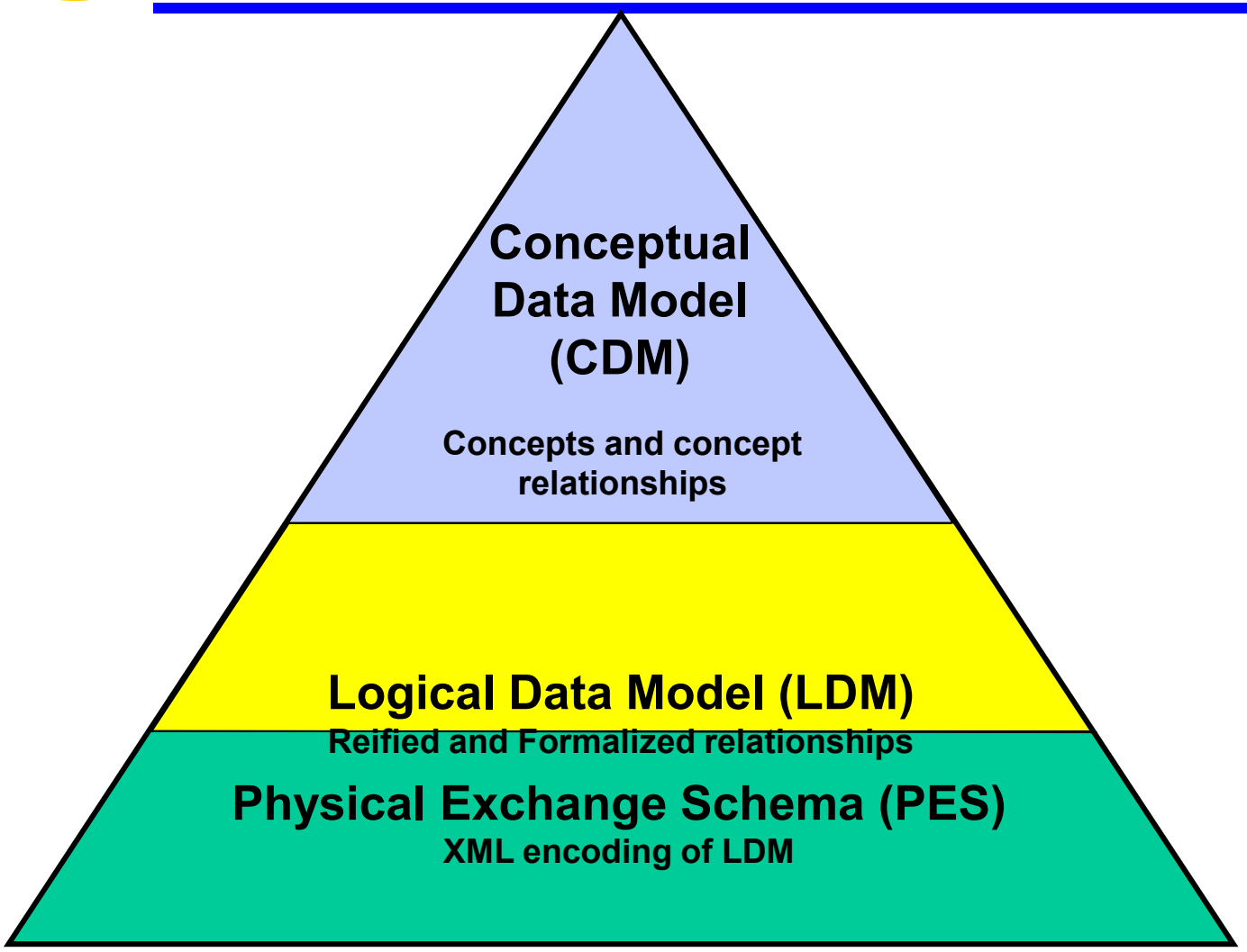
Outline of Presentation

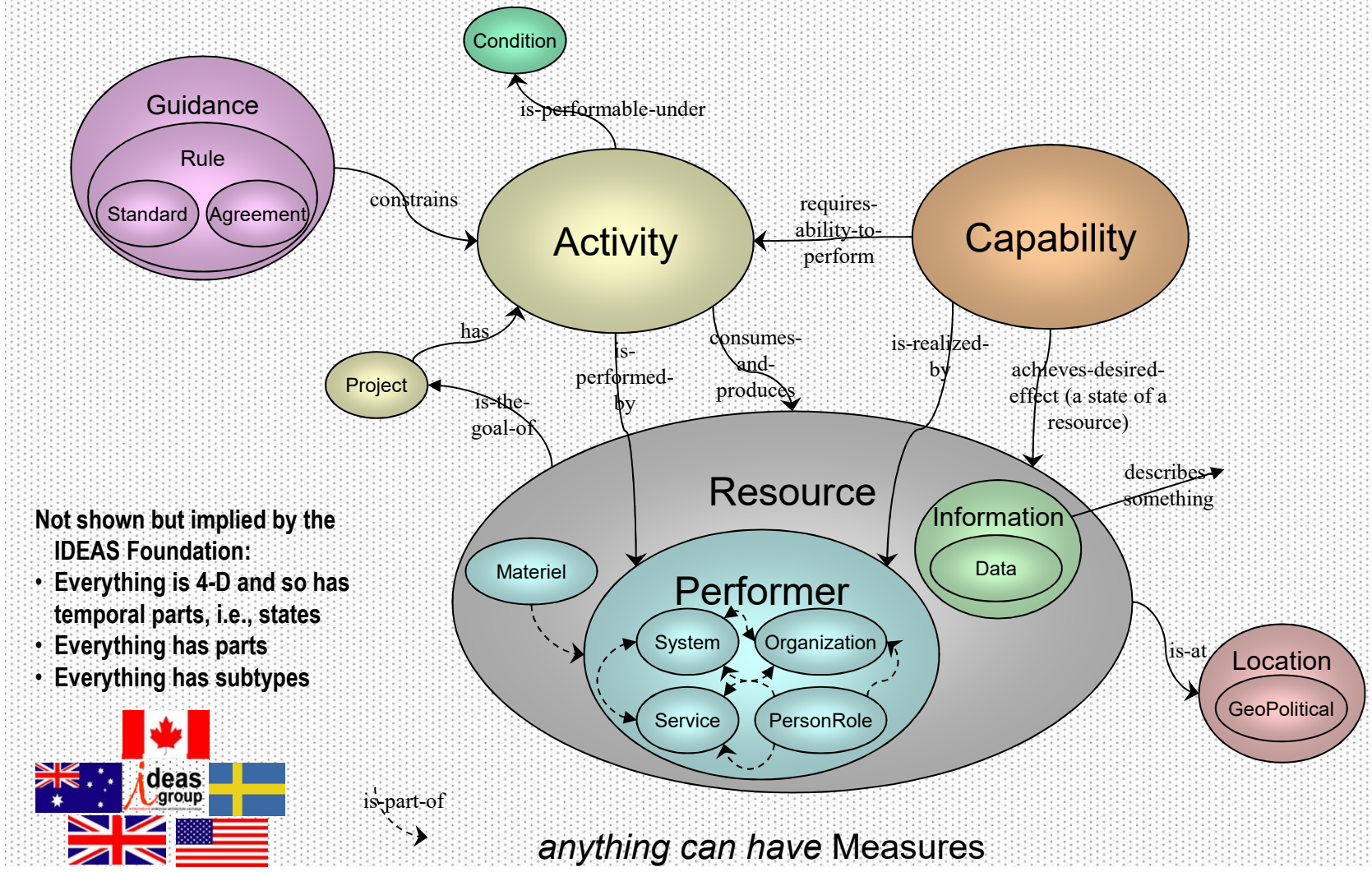
- DoDAF Meta Model (DM2) pieces
- Formal ontologic foundation: International Defence Enterprise Architecture Specification (IDEAS) overview
- Why we used IDEAS – benefits
  - Simplification
  - Quality
  - Expressiveness
- The Physical Exchange Specification (PES)
- Active Configuration Management
- GFI Resources

The DM2 Has Three Levels

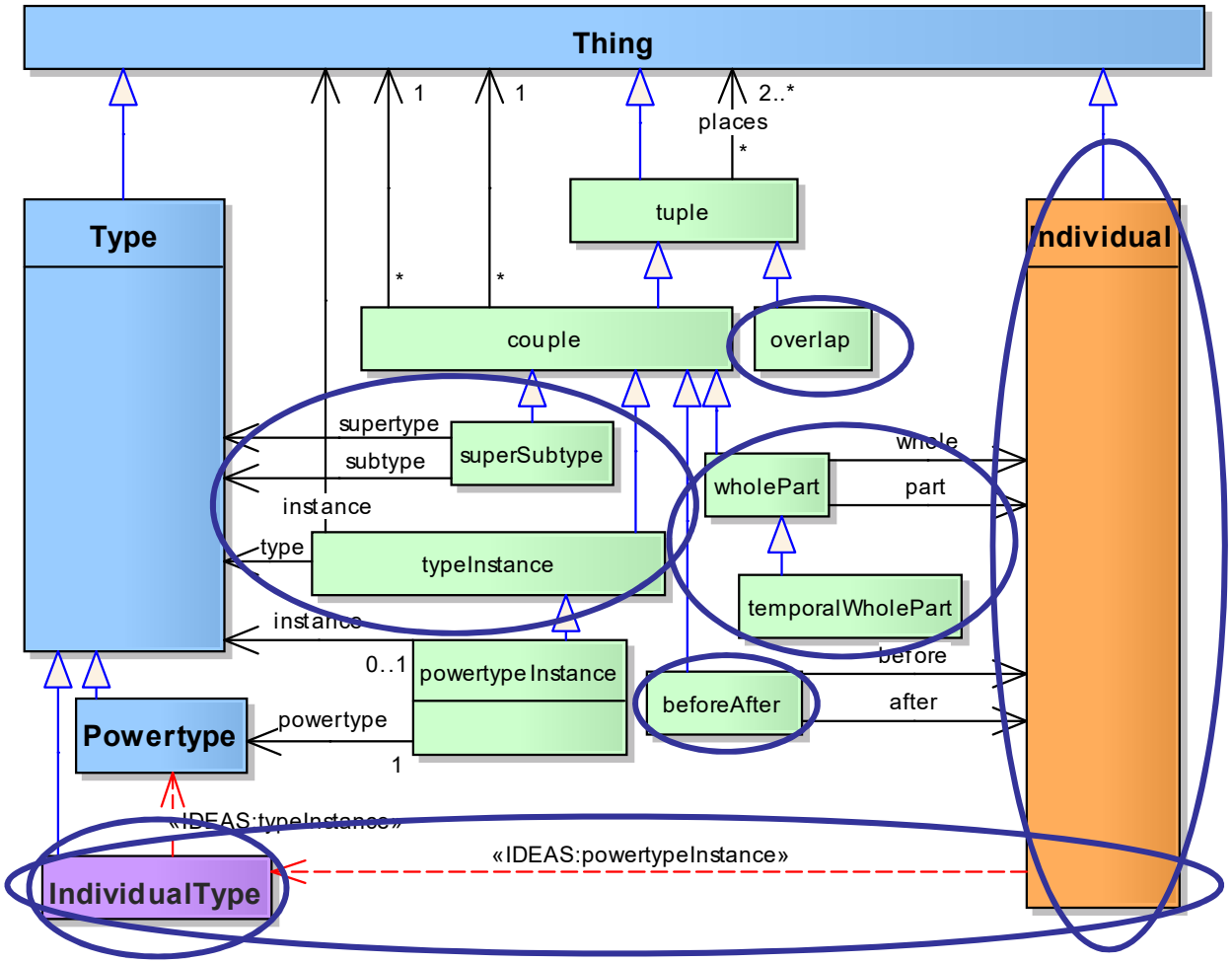


- DIV-1
- DIV-2
  (This is where almost all the design and analysis work is done)
- DIV-3
  (Auto-generated from the LDM)

Conceptual Level is Simple



IDEAS 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

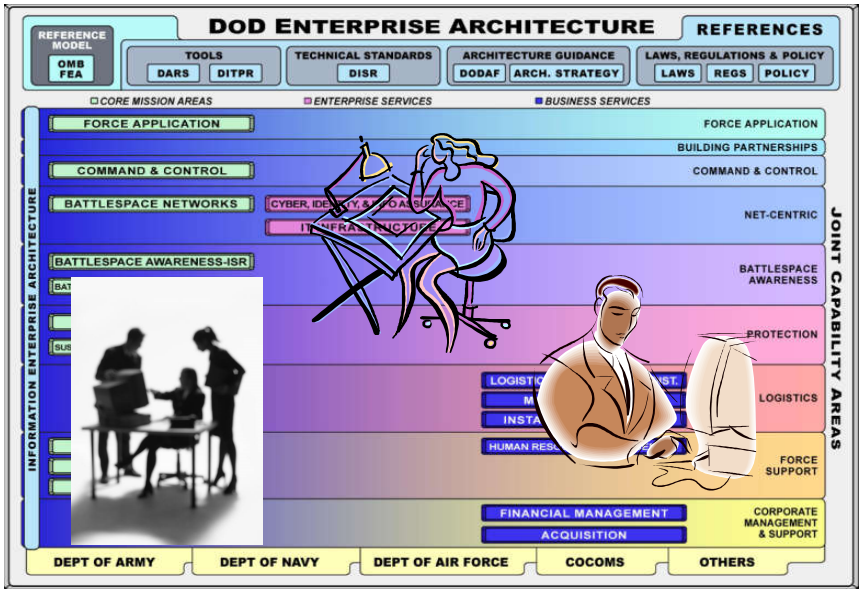
Why Formal Ontology for DoDAF 2

- Preface: the general pattern of architecture data development and usage
- Benefits of IDEAS:
  1. Model quality and simplification
  2. Mathematical rigor
  3. Expressiveness

General Pattern of Architectural Description Usage

Create architectural description

Use architectural descriptions



- JCIDS
- PPBE
- DAS
- SE
- Ops Planning
- CPM

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

Simplification and Quality: Rigorously worked-out common patterns are reused

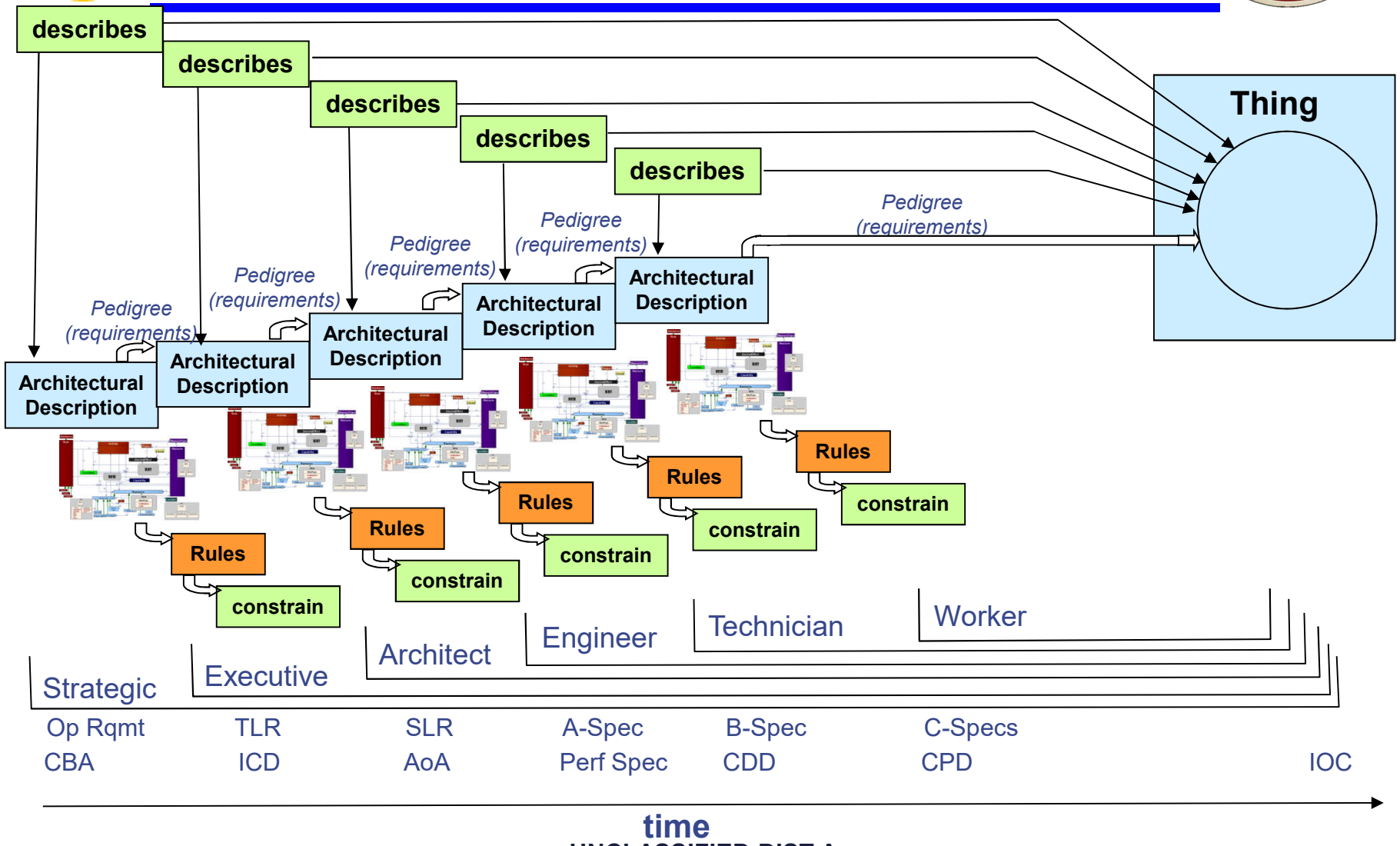
- Saved a lot of repetitive work – “ontologic free lunch”
- Concentration of rigor on common patterns results in higher quality and consistency throughout
- Model compactness -- DM2 is tiny compared to its predecessor by two orders of magnitude!
- Easier to learn -- a few hard concepts are easier to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

Mathematical Rigor: Some Math Sources

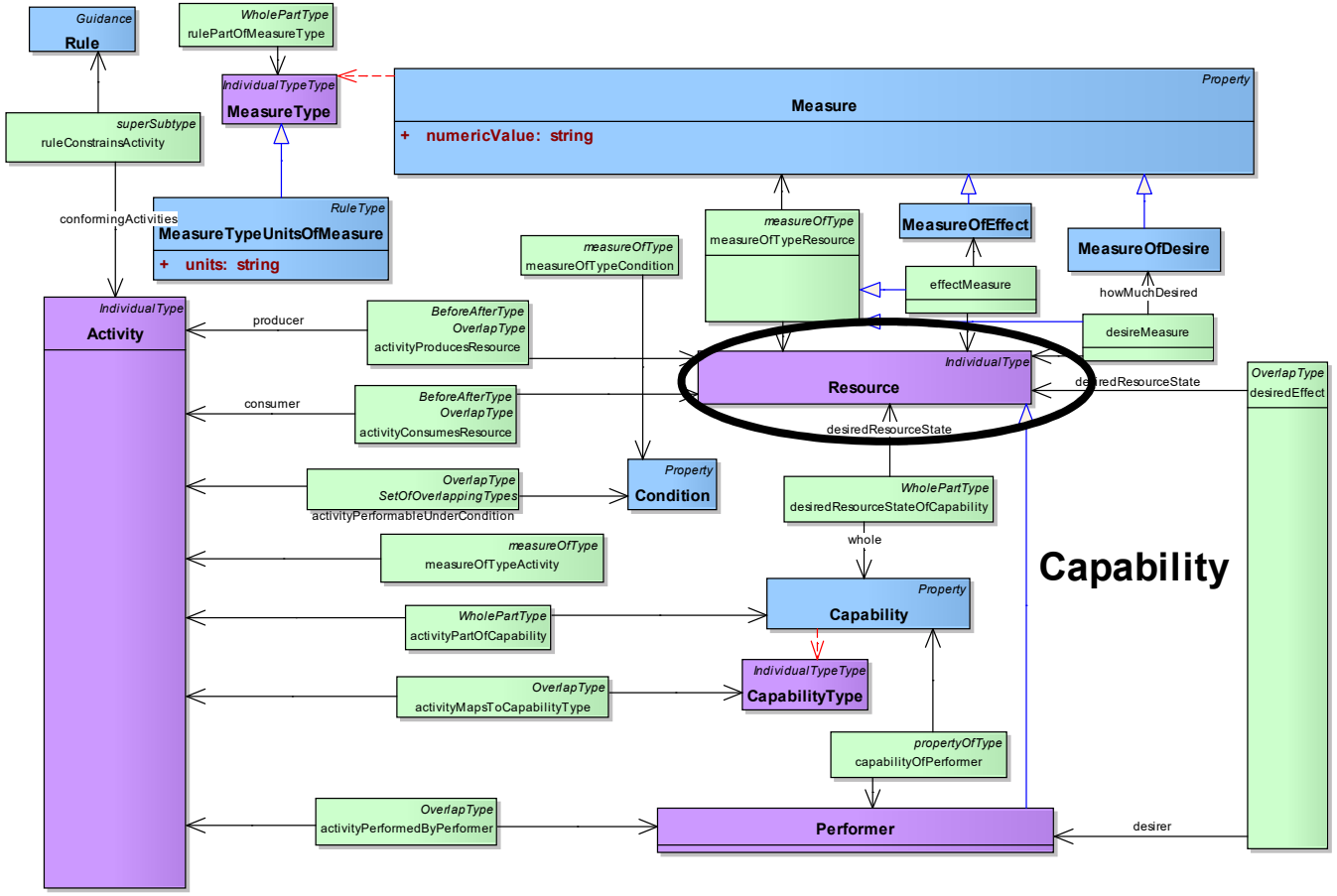
- National Center for Ontologic Research (NCOR), http://ontology.buffalo.edu/smith/
- Direct Model-Theoretic Semantics for OWL 2, http://www.w3.org/TR/2009/REC-owl2-direct-semantics-20091027/
  - Vocabulary
  - Interpretations
    - Object Property Expressions
    - Data Ranges
    - Class Expressions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

Examples of Improved Expressive Power

Design Reification and Requirements Traceability



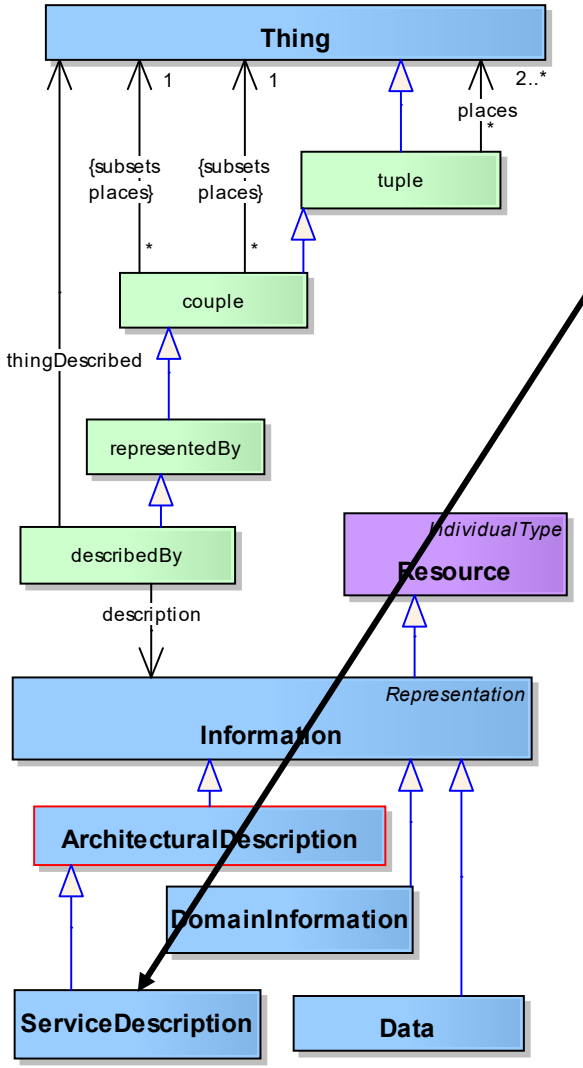
Capabilities and Desired Effects



- Desired Effect = state of some resource + desired by somebody, e.g.,
  - State of enemy becomes neutral
  - State of disastered peoples becomes healthy
- Takes getting used to thinking 4-dimensionally but most users have had an “aha” moment and seen great power in thinking so

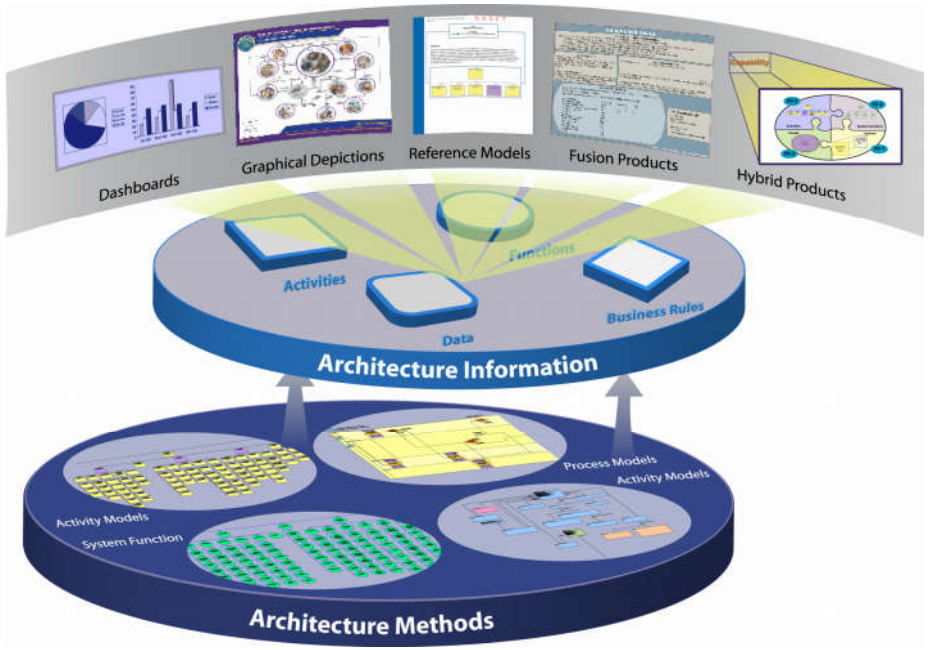
The ability to achieve a Desired Effect under specified [performance] standards and conditions through combinations of ways and means [activities and resources] to perform a set of activities.

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.
- Continuing work with OASIS and OMG (SoAML) on fine structure, e.g., for:
  - Reification process for agreement for establishment of Execution Context for Joint Action

"Fit for Purpose" Architecture Descriptions



- Based on DM2, the architectural description can support desired presentations for multiple purposes.
- The Physical Exchange Specification (PES) supports this
- Working on governance for FFPs in the DoD EA COI

Active Configuration Management

Monitors and redirects

Monthly reports and new baseline decision briefs

Framework Groups
- OMG / INCOSE / NDIA
- MODAF / NAF / TOGAF
- FEA / FSAM

Core Process Stakeholders
- CJCSI revs
- AT&L SoSE & Acq Reform
- Combatant Command architectures
- CPM Governance
- PA&E

Framework & Ontology Groups
- OMG / INCOSE / NDIA
- IDEAS / NAF
- UCORE
- Enterprise Vocabularies

DoDAF-DM WG – Collaborative – Agreed-upon business rules enable analysis of different opinions

Vendors
- EA/ITA Tool
- M&S
- Data Analysis
- Repository
- Data Integration

Data Exchange
- Pilots
- Early Adopters
- Federation

COI Coordination Groups
- DoD MDR WG
- DoD COI Forum

- ~ 300 members
- Meets weekly

Resources

- DoDAF-DM2 WG
- Collaboration site
  - Reference material
  - IDEAS Bibliography
  - Oracle and SQL Server DDL scripts
  - Physical Exchange Specification (PES) XML generation queries
  - DM2 in OWL
- DoDAF Journal
  - DM2 PES XML examples

Summary

- The basic structure of DoDAF / DM2 is holding up well.
- Refinements by the community are making it simpler, clearer, and more responsive to DoD's needs.
- Pilots and early adopters – Government and vendors are very helpful.
- The GFI database scripts and PES queries are speeding adoption of DoDAF 2.
- Core process dataset requirements should lead to the end of "checklist architectures".

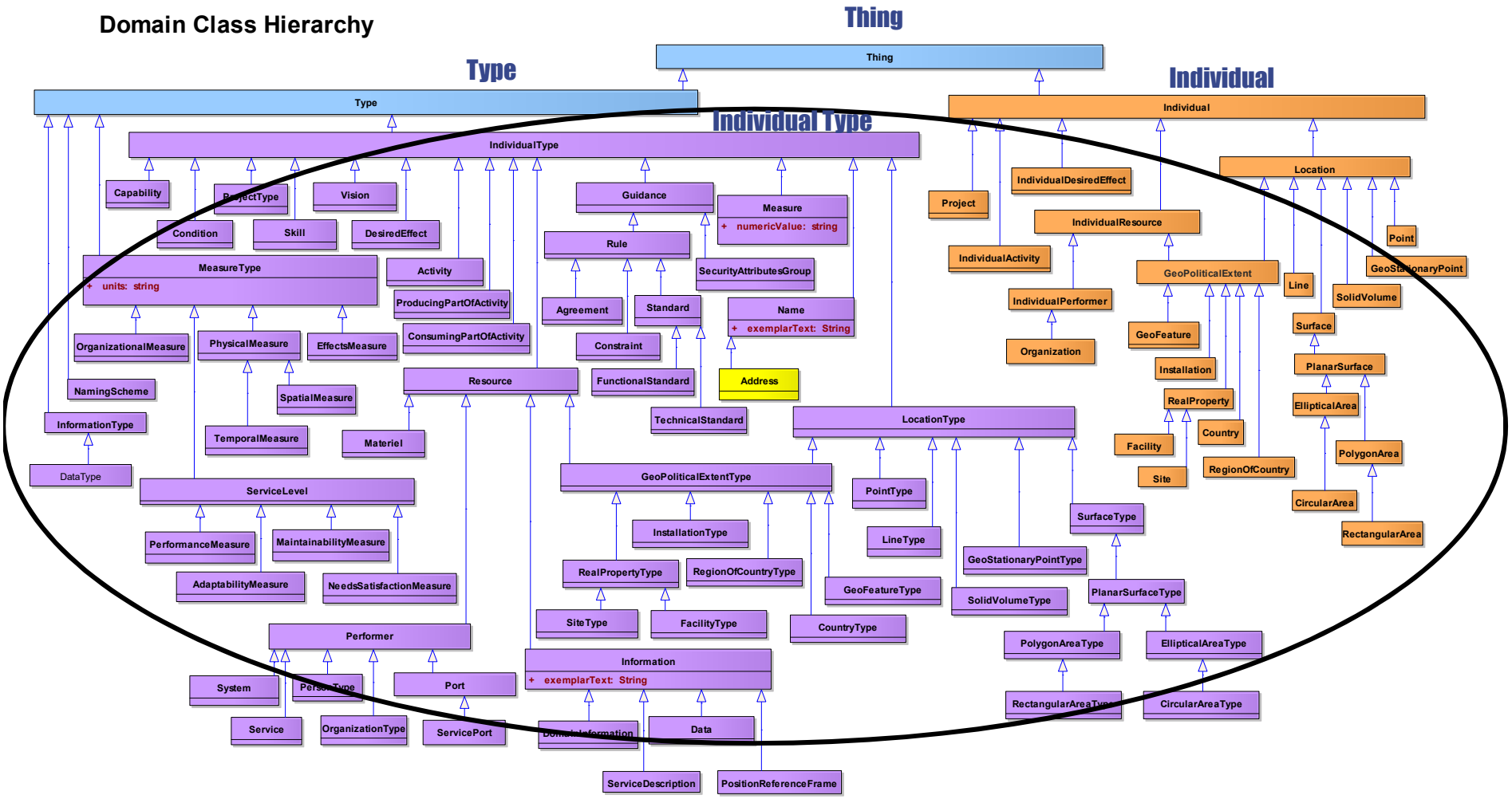
Questions

Backup

DoDAF Domain Concepts are Specializations so they Inherit

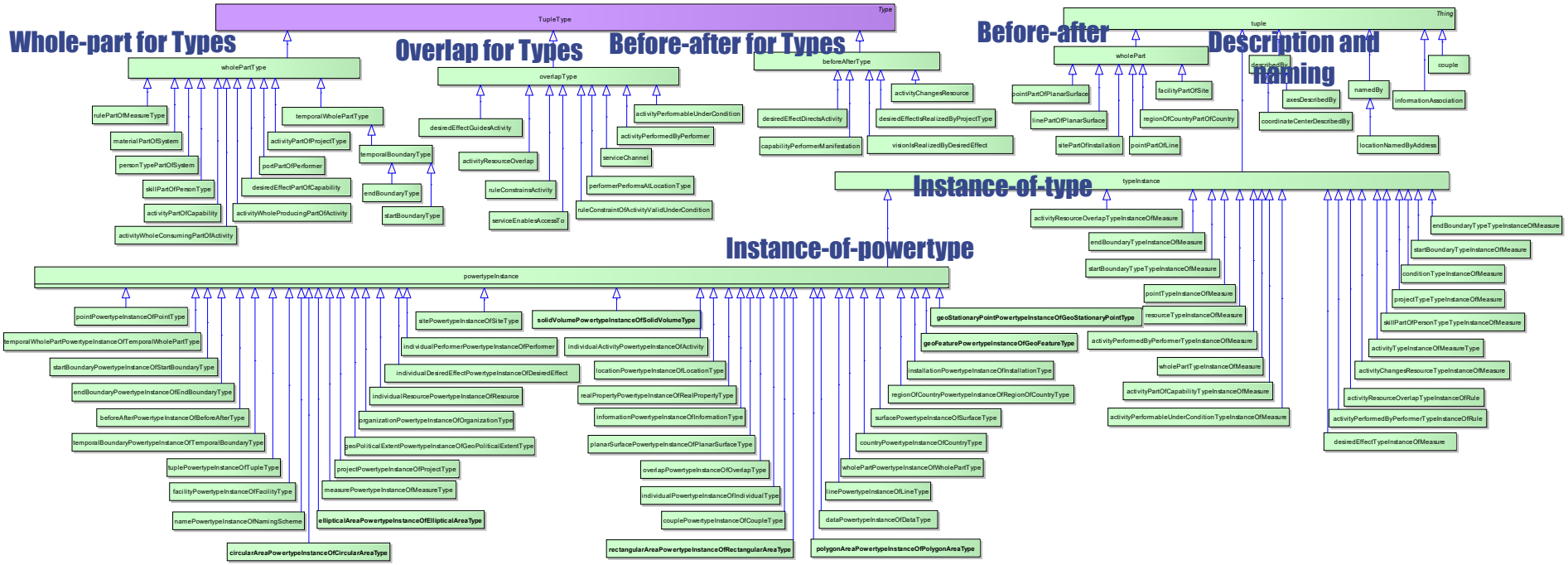
-- *Enables reuse of common patterns*

Domain Class Hierarchy



All Associations are Typed
-- *so their meaning is mathematically defined*

Foundation For Associations



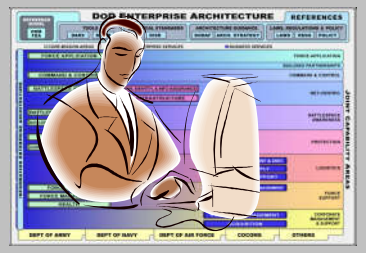
Example: Assessment Pattern

Create Side | **Use Side**

register

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

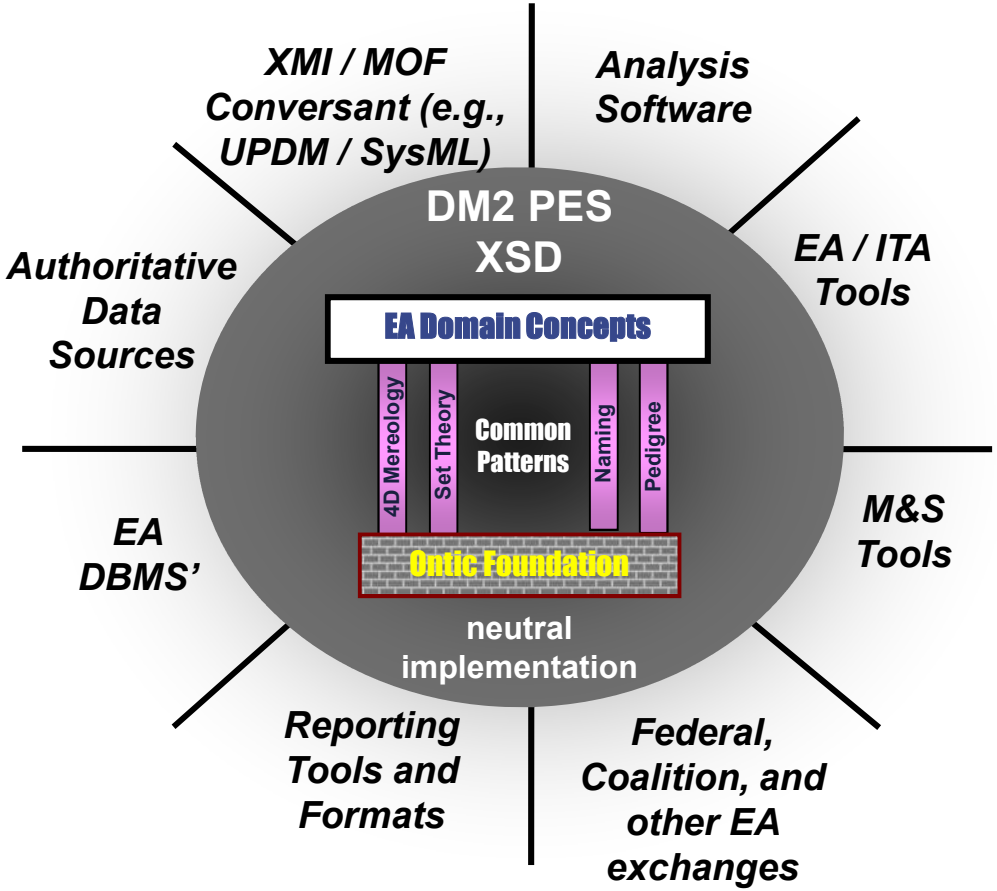
All have high-sensitivity to mis-interpreted, erroneous, incomplete, incompatible, … data

Analyze and assess

Present Results for core process decisions

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.	

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.

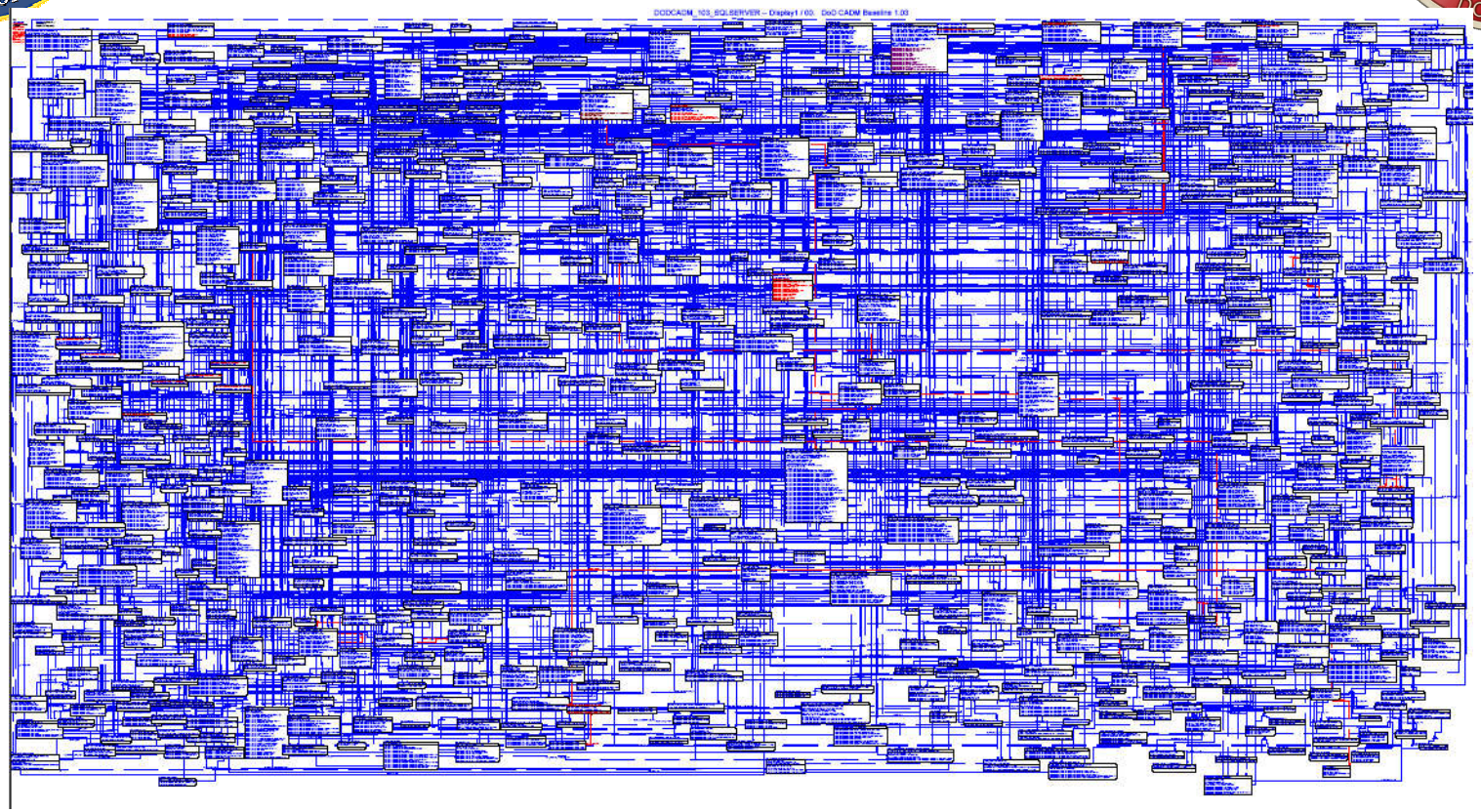
Mathematically structured

- 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, …

A spectrum of information sharing

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

Simplification: Compare DM2's Predecessor, a classic E-R model

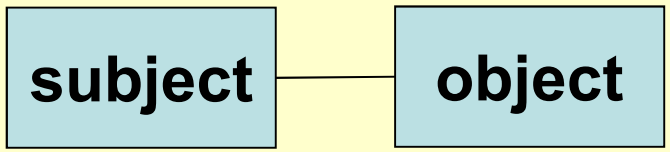


- CADM had 687 entities, 3,914 attributes, 11,911 domain values, and 1,249 associations = 17,762 data elements!
- DM2 has 217 foundation and domain data elements, 37 IC-ISM's, and 4 metadata for a total of 258 data elements – two-orders of magnitude smaller yet far more expressive

Enterprise Data Modeling -- Reconciliation and analysis method

- 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

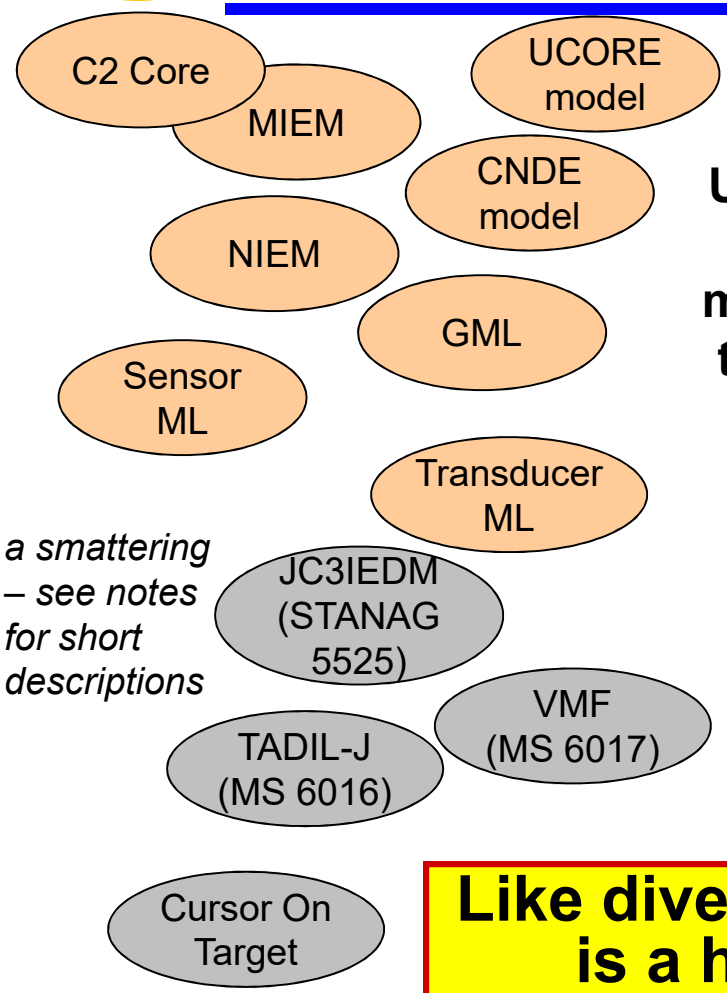
The fundamental concepts of Entity-Relationship and Class Models:



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

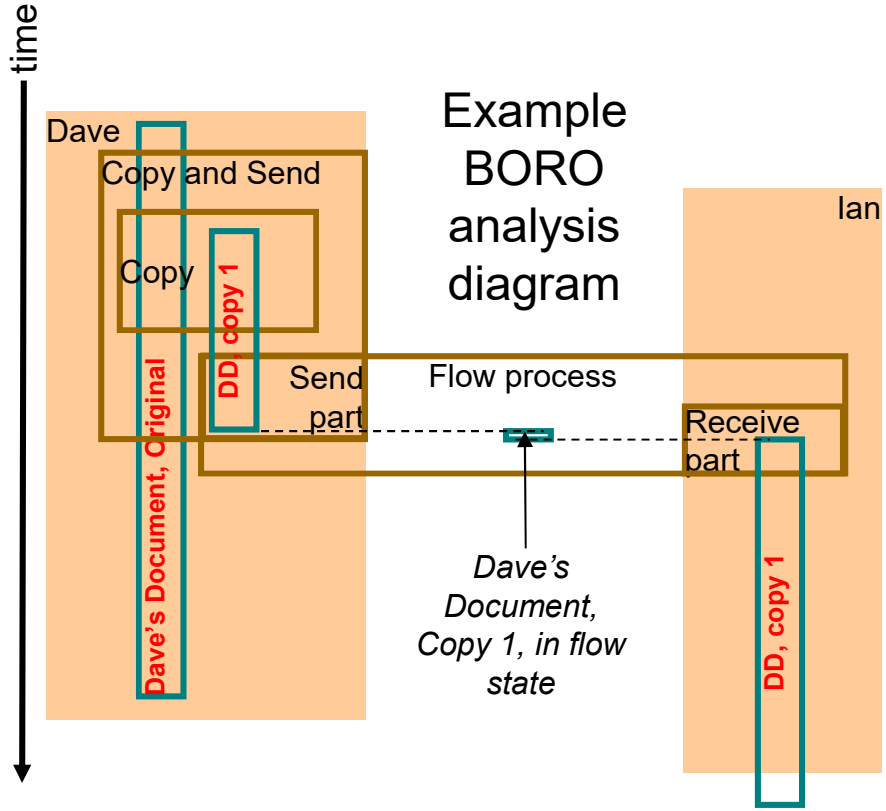
Some real-world and costly results of this practice

- 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
    - Only unanticipated users of the same "language" can understand your data

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

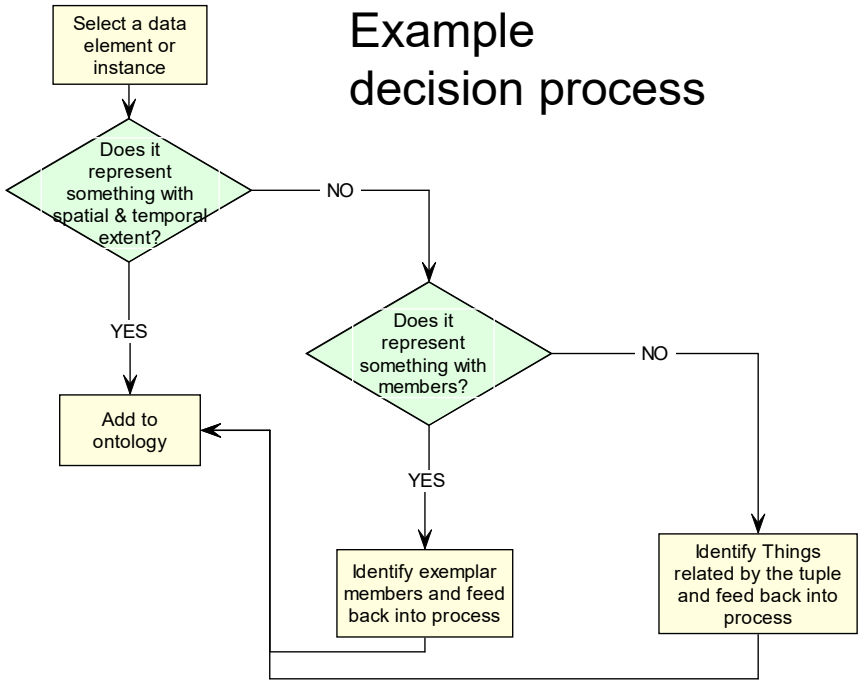
Reconciling Using IDEAS Analysis Technique: BORO[1]

- 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

The PES schema is auto-generated from the Logical Data Model

DM2 elements (~ 300)

DoDAF models (52)

(see Data Dictionary to read entire matrix)

Technical Term	AV-1	AV-2	OV-1	OV-2	OV-3	OV-4	OV-5a	OV-5b	OV-6a	OV-6b	OV-6c	SV-1	SV-2	SV-3	SV-4	SV-5a	SvcV-5	SvcV-6
Activity	n	o		n	n		n	n	o	n	n	n	n	n	n	n	n	o n
activityChangesResource	o								o	o	o							
activityChangesResourceTypeInstanceOfMeasure	o								o	o	o							
activityPartOfCapability																o	o	
activityPartOfCapabilityTypeInstanceOfMeasure																o		
activityPartOfProjectType																		
activityPerformableUnderCondition								o	o	o	o				o	o		
activityPerformableUnderConditionTypeInstanceOfMeasure								o	o	o	o				o	o		
activityPerformedByPerformer																		
activityPerformedByPerformerTypeInstanceOfMeasure																		
activityPerformedByPerformerTypeInstanceOfRule																		
activityResourceOverlap																		
activityResourceOverlapTypeInstanceOfMeasure																		
activityResourceOverlapTypeInstanceOfRule					o			o	o	o	o	o	o	o	o			o
activityTypeInstanceOfMeasureType	o				o			o	o	o	o	o	o	o	o			n
activityWholeConsumingPartOfActivity				n	n		o	n	o	n	n	n	n	n	n			n
activityWholeProducingPartOfActivity				n	n		o	n	o	n	n	n	n	n	n			n
AdaptabilityMeasure		o			o			o	o	o	o	o	o	o	o			o
Address	o											o	o					o
Agreement	o	o						o	o	o	o							
axesDescribedBy									o			o	o					
beforeAfter	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
beforeAfterPowertypeInstanceOfBeforeAfterType	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
beforeAfterType	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
Capability		o														o		

- The PES has three parts:
  - Reference to the IDEAS and DM2 structures
  - The data
  - Indicators of what DoDAF Models (AV-DIV) this data pertains to

- Legend:
  - "n" = Necessary data for this DoDAF model
  - "o" = Optional
  - "f" = Foundational
  - Blank = cannot be included in this DoDAF model

Improved ability for analysis: Mathematical Foundation

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 $\langle \mathrm{P} \rangle$ 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)

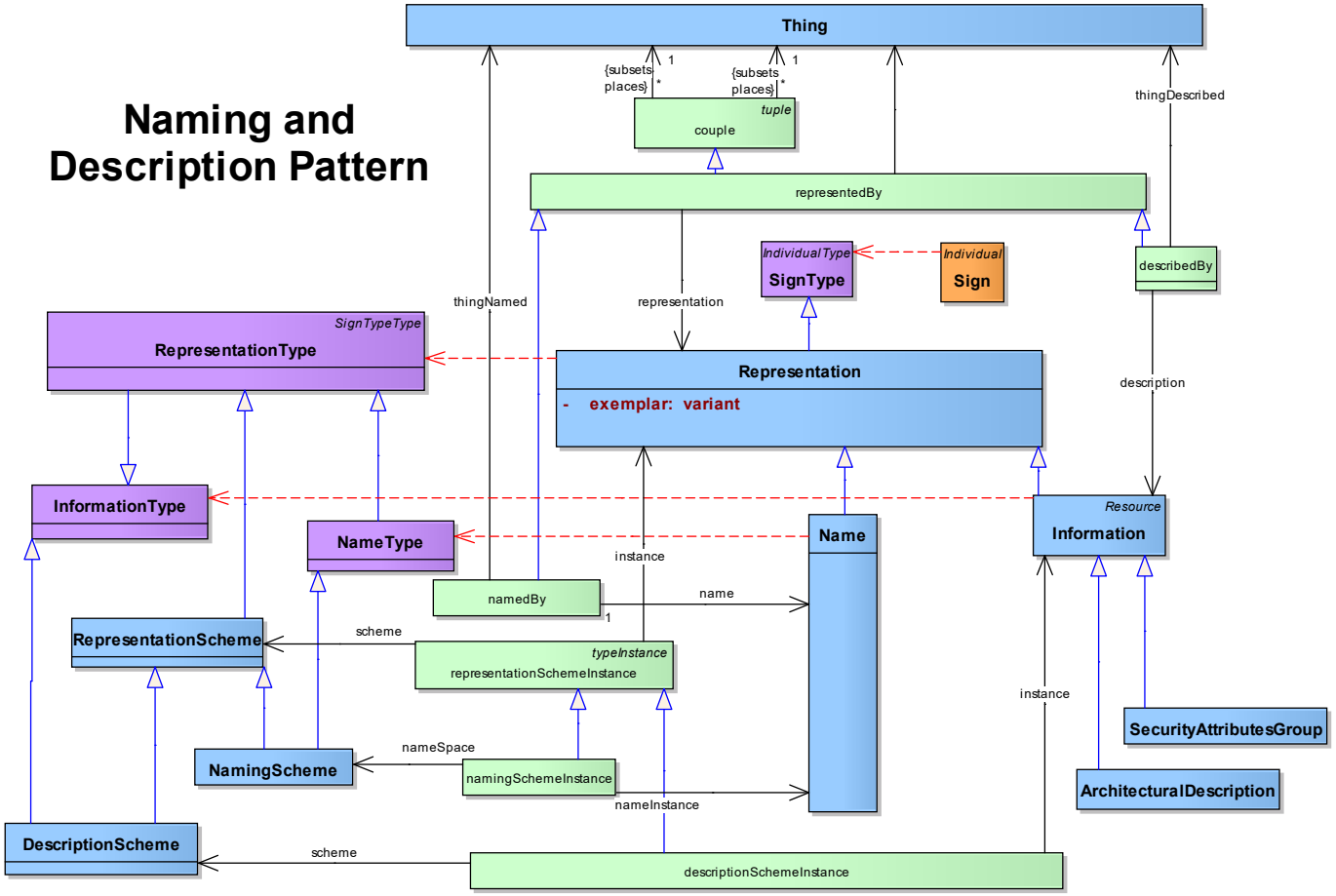
Before xBy is transitive : $xBy \wedge yBz \Rightarrow xBz$

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

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

Representation Pattern

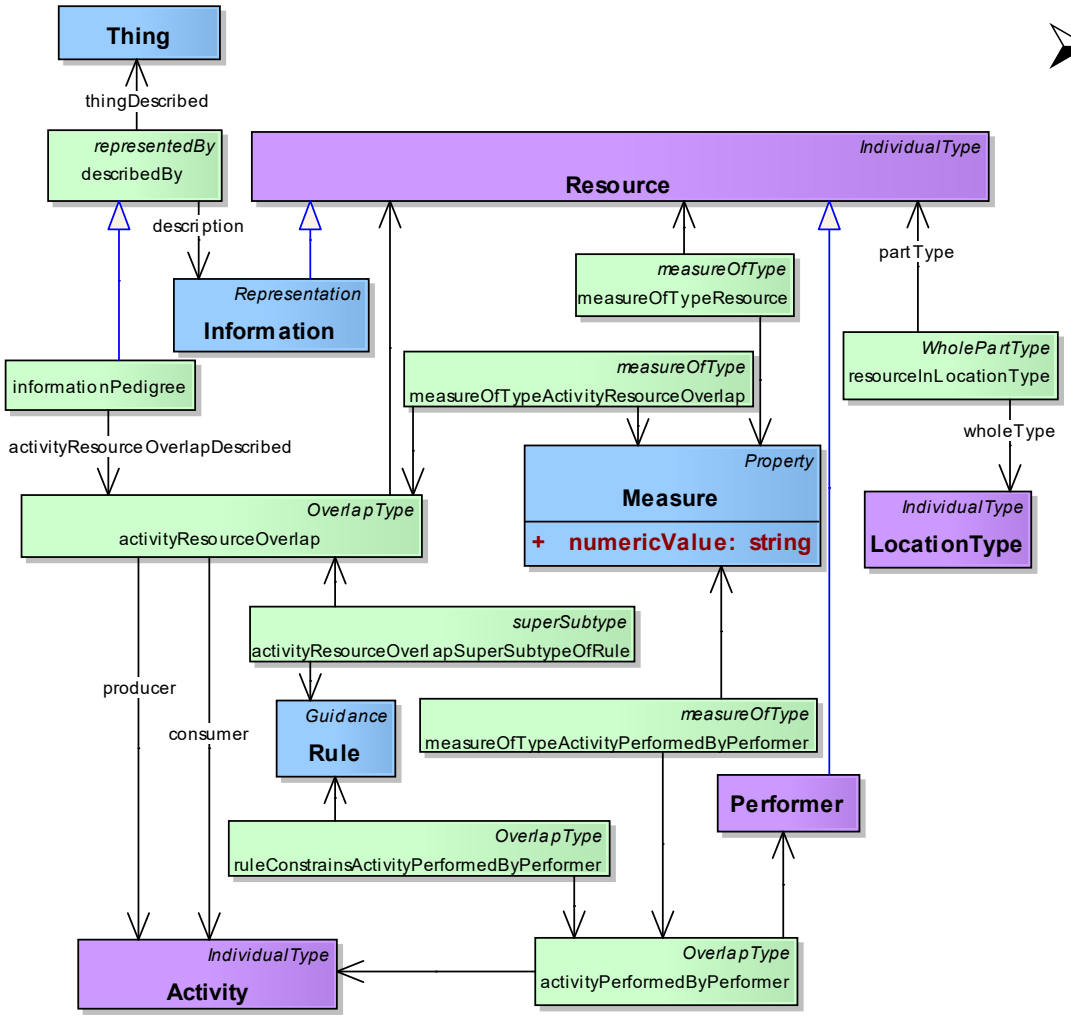
Naming and Description Pattern



- Links:
  - Information and Data (in the DIV's) with the Things being described, e.g,.
    - Imagery
    - Formatted data
    - Messages
  - One level of reification to another – describing the same Thing
  - Architectural descriptions to the Thing that has the architecture*

* Consistent with ISO/IEC 42010 / IEEE Std 1471-2000

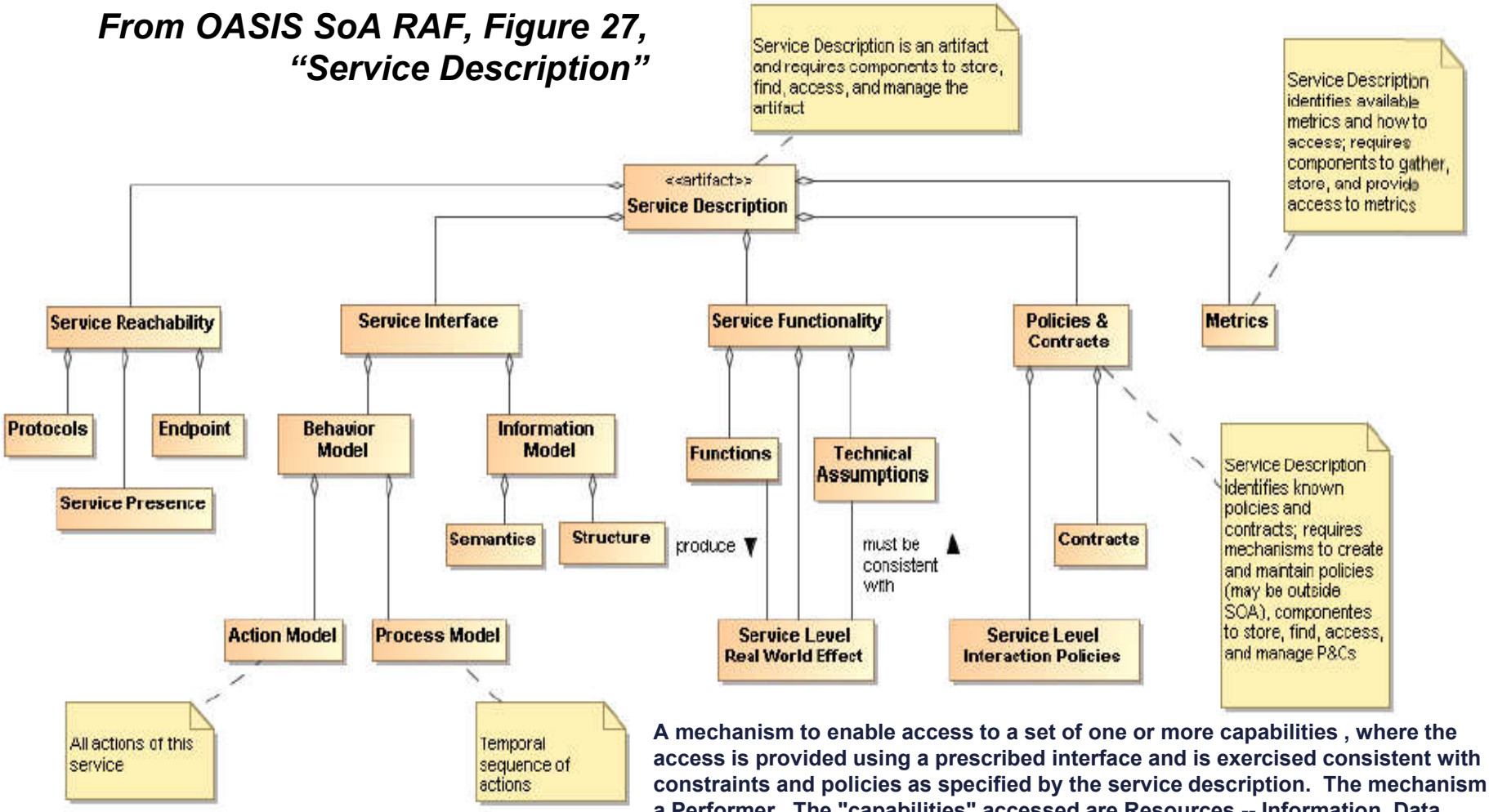
Information Pedigree Model



- Workflow model, e.g., Open Provenance Model (provenance = linked together pedigrees)
  - ~ Activity model (OV-5 + 6c)

Service Descriptions

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



A mechanism to enable access to a set of one or more capabilities , where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description. The mechanism is a Performer. The "capabilities" accessed are Resources -- Information, Data, Materiel, Performers, and Geo-political Extents.

Diagram and XML Examples are Available!

CIO Governance Framework