Design Refinement and Requirements Satisfaction in OWL DL

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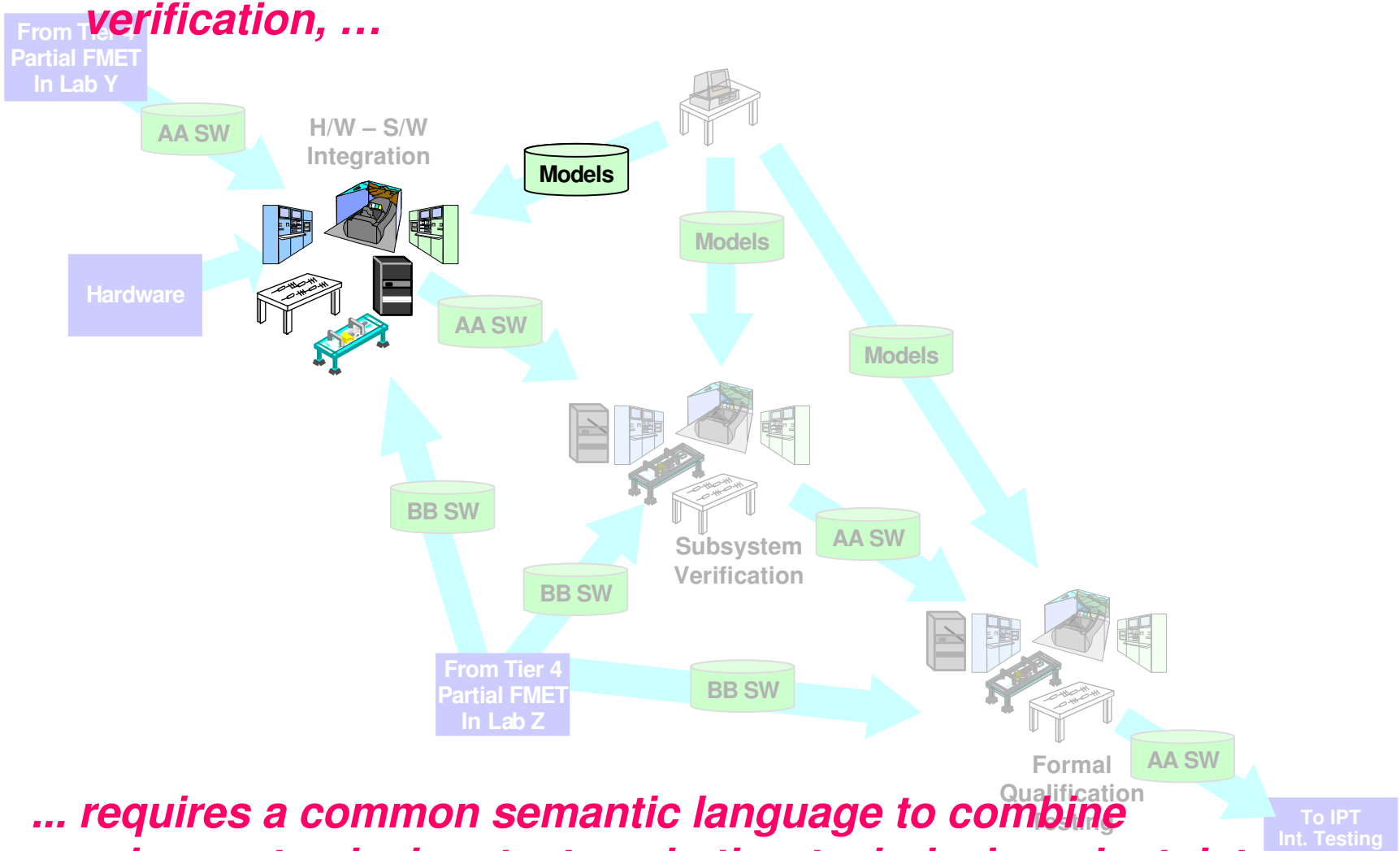
W. Henson Graves
Lockheed Martin Aeronautics Company
henson.graves@lmco.com,
817.735.5911

Outline

- **Performing design assessment requires**
  - a common semantic language to combine design, requirements, and criteria to evaluate evidence
- **However, aerospace product development is an incremental process**
  - May last many years
  - Produces millions of artifacts used in design decisions
- **And information interoperability for product development is difficult to achieve**
  - Because of multiple repositories, data formats, and little interconnectivity
  - SysML offers common machine parse-able language
- **Semantic Web Standards go a long way toward enabling syntactic interoperability**
  - The Semantic Web Ontology language, OWL DL provides a common semantic language for product development information
- **Can OWL use scale?**
  - Some positive, but no conclusive, evidence

Performing Design Assessment

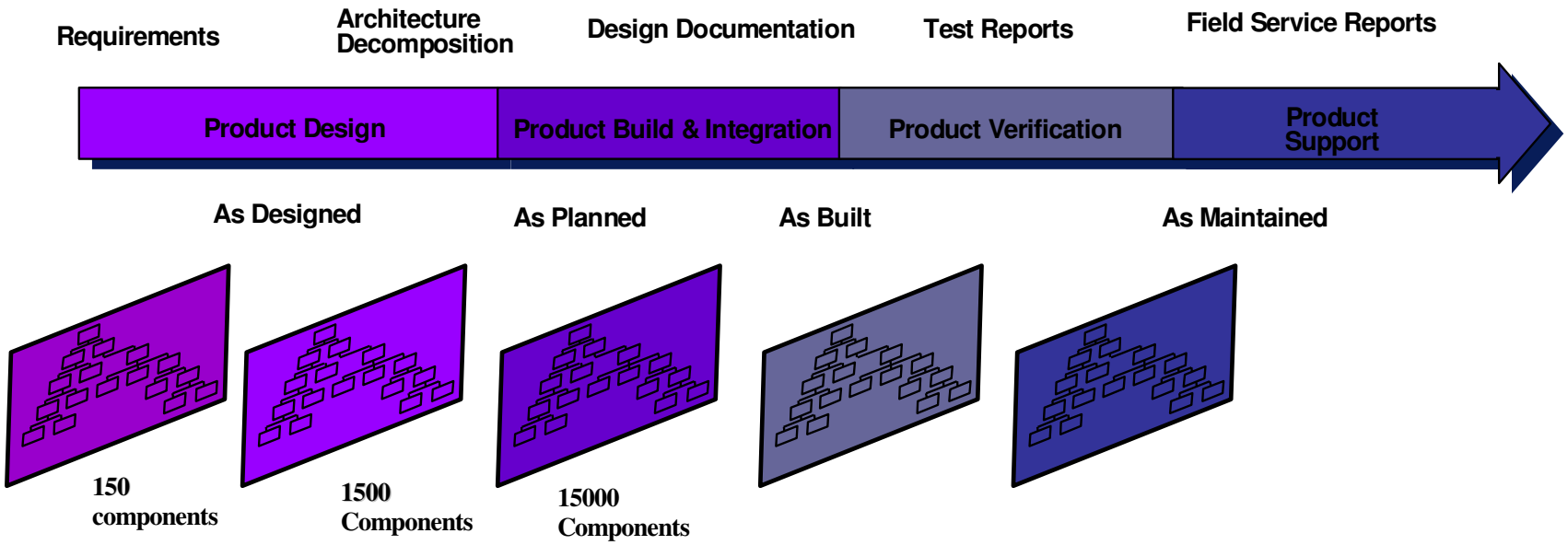
... e.g., checking design consistency, maturity, producibility, and verification, …



... requires a common semantic language to combine requirements, design, test, and other technical product data

However, Aerospace Product Development Is Characterized by

... tens of millions of data artifacts produced over a long time span

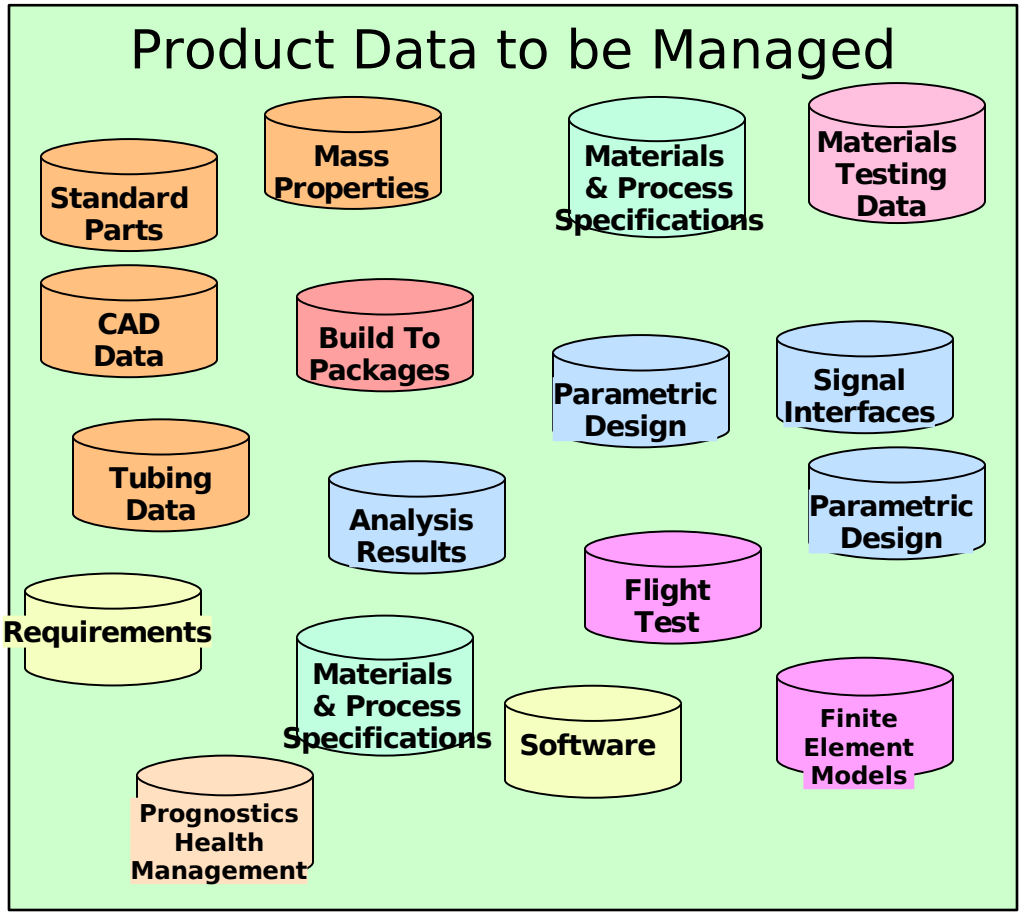


… the data is used to describe what is to be built and to provide analysis, simulation, and test results leading to final verification

... And Information Interoperability Is Difficult To Achieve

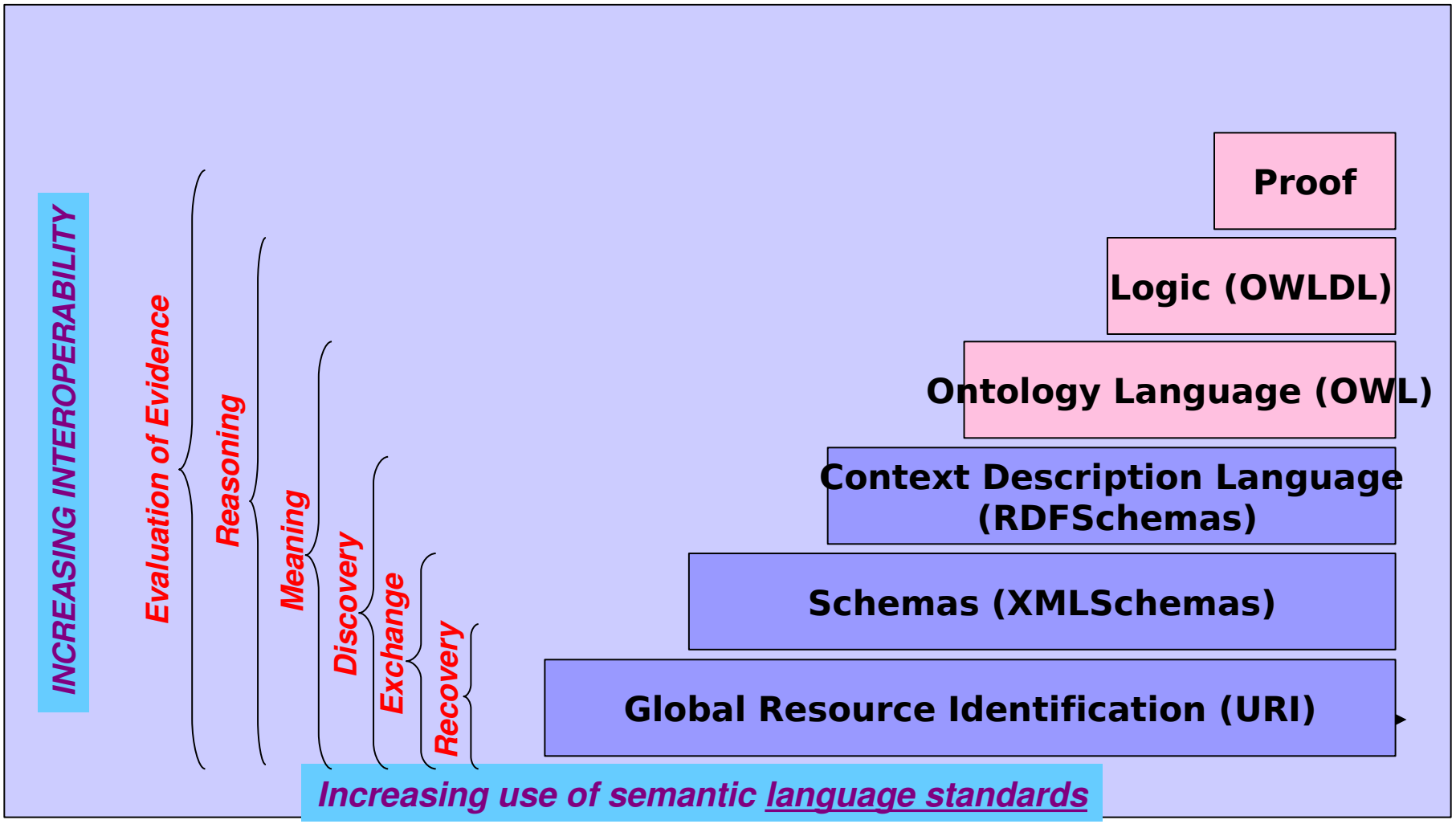
... because the information space is characterized by:

- *Large number of independent data repositories, each with its own organization and interface*
- *Redundant information in different repositories*
- *Little support for locating data across repositories*
- *Little support for maintaining traceability relationships across repositories*



Layered standards are needed to recover, exchange, discover, understand, and evaluate data

The Semantic Web Standards Go Along Way Toward Enabling Syntactic Interoperability

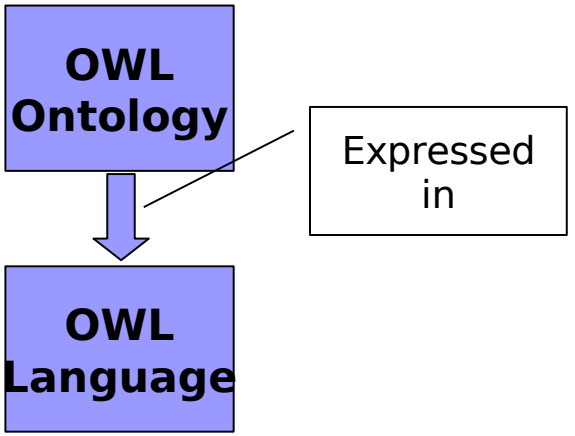


… and show promise of enabling semantic interoperability

The Semantic Web Ontology Language, OWL DL,

… is a good candidate to represent designs and design assessment criteria in a common semantic context

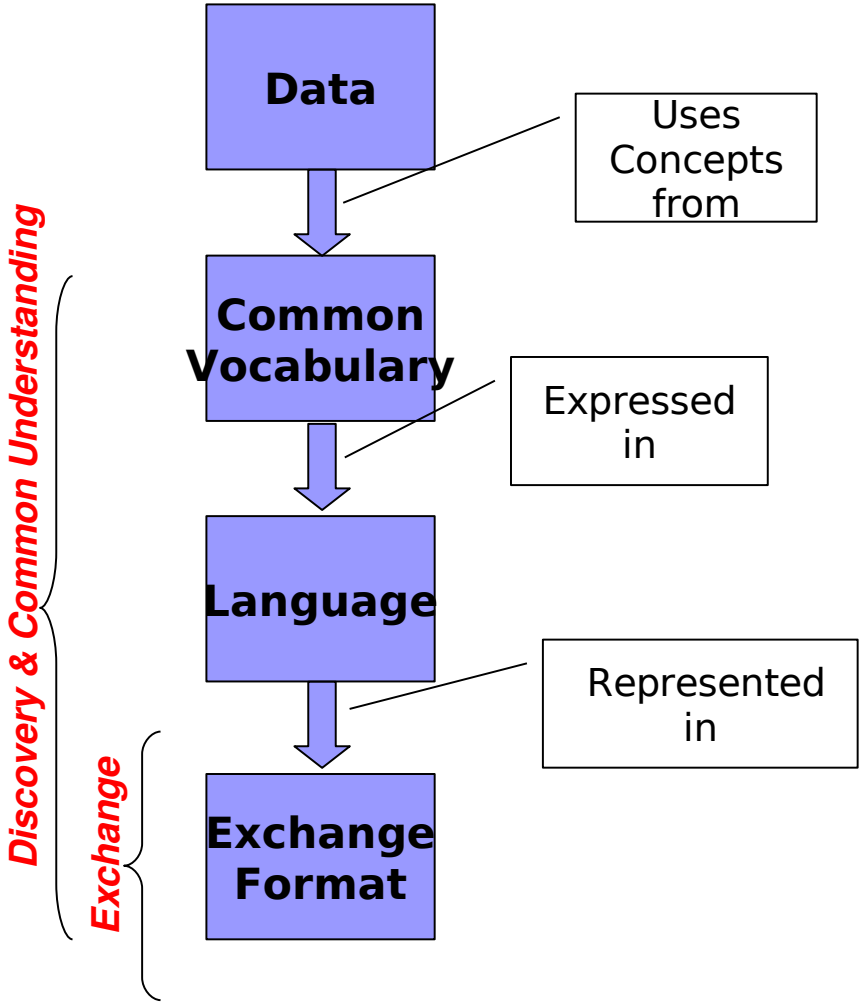
- **OWL Language variants (OWL Lite, OWL DL, SWRL)**
  - Describes domain in terms of concepts (classes), roles (properties, relationships) and individuals
  - Properties and attributes of concepts
  - Class membership
  - Constraints on properties and attributes
- **OWL Use Cases (W3C req. doc.)**
  - Information portal
  - Technical data management
- **Potential Use of OWL DL in Product Development**
  - Representation of designs, requirements
  - Establishment of assessment criteria
  - Checking assessment results
  - Not providing automation of assessment



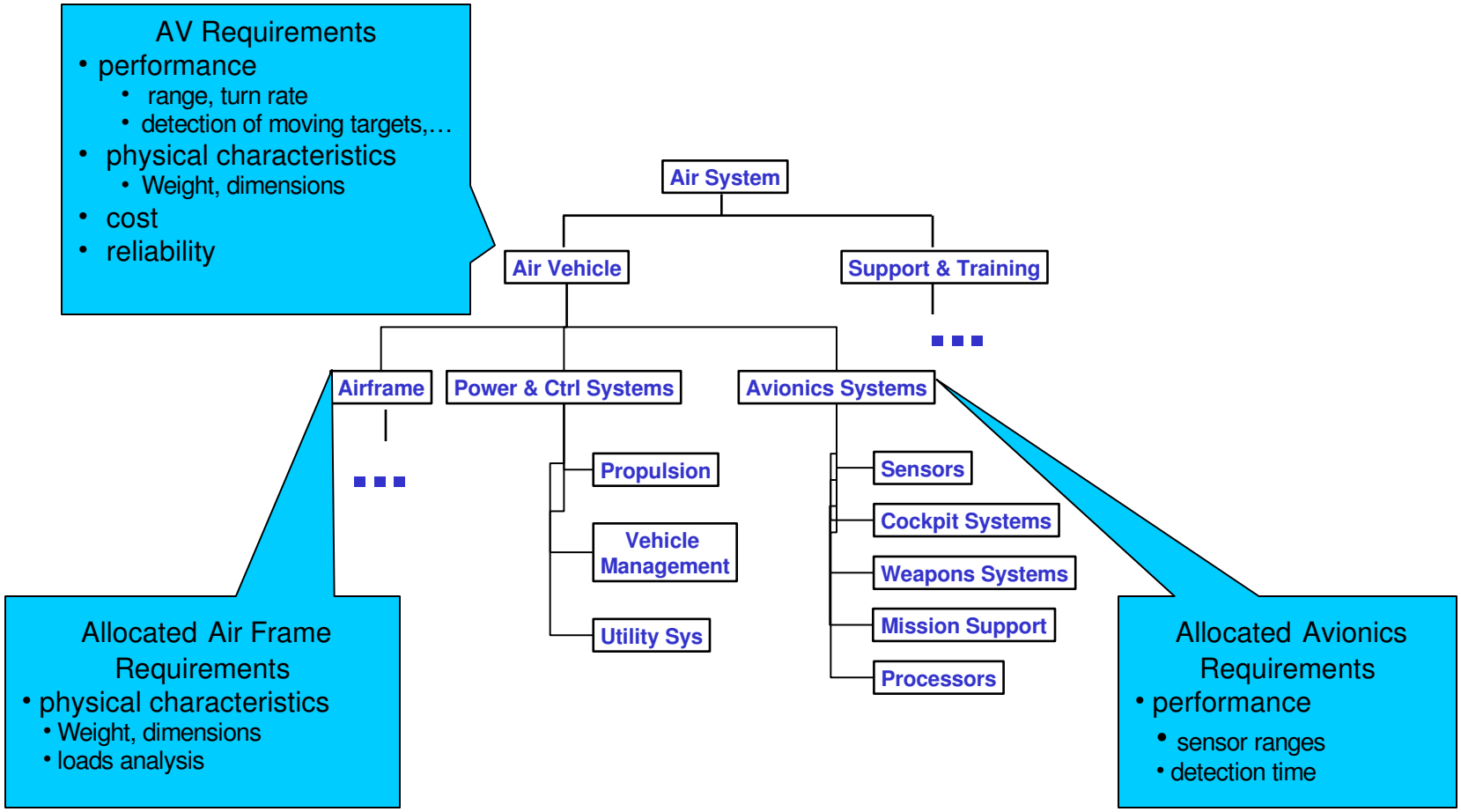
The PLM/PLCS Communities Recognize That Semantic Interoperability Requires

…a layering of standards for concepts, languages, and data exchange formats where each layer can be changed independently

- **Enterprise specific information (knowledge base)**
- **Common domain vocabulary (Ontology)**
  - GEIA 927, STEP AP233 & 239,
- **Language to express domain terms (Ontology Language)**
  - Express, UML, OWL…
- **Language exchange format (Data Exchange Format)**
  - XML, DEXs



To Represent Designs and Requirements in the Same Semantic Language



... requires representing product structure and requirements statements

David Price Suggests That The Design Satisfaction Problem Can Be Represented In OWL DL As:

Showing that some member *a* of the design class is a member of the requirements class, i.e., showing

a : AVDesign

Implies

a : AVRequirements

The class AVDesign describes properties that apply to all members this class

This expression means that *a* is a member of the class AVRequirements

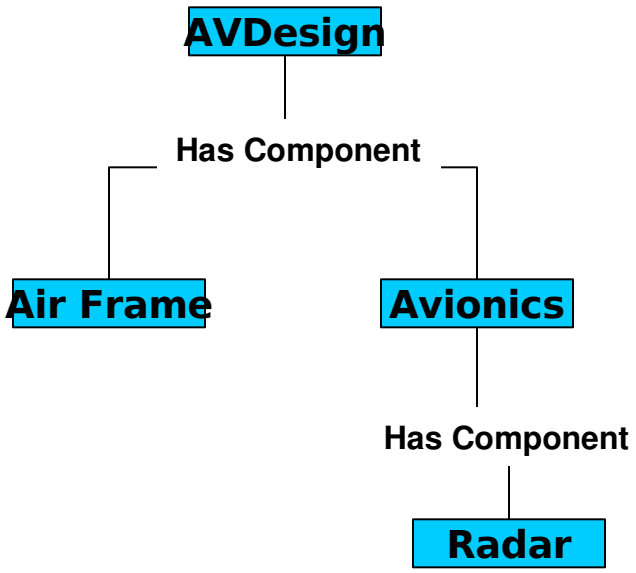
This means showing that a design, *a,* satisfies each of the conditions that define the requirements class

We must first show that we can use classes to represent designs and requirements, and then show membership properties

To Show That Design Structure Can Be Represented In OWL DL

…start with a simple statement that any air vehicle has an airframe component and an avionics component and the avionics component has a radar component.

Diagram of Design Component Hierarchy



… of course, the air vehicle design will also have properties such as size, shape, ….

The OWL DL "SomeValuesFrom" Construction Can Be Used To Define Component Structure

For example, the assertion

a : SomeValuesFrom (hasComponent, Airframe)

Means that

there exists b with

(a,b) : HasComponent and

b : Airframe

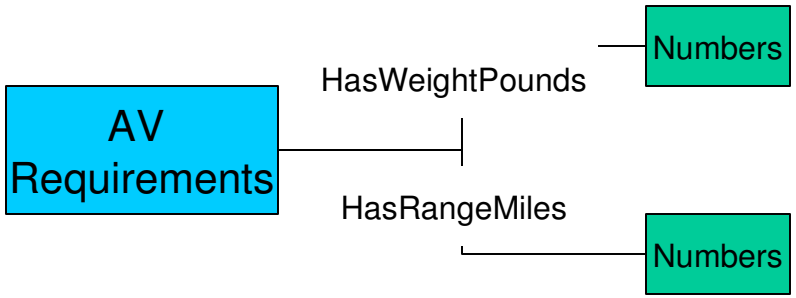
OWL Representation of the component diagram is:

AVDesign =
SomeValuesFrom(hasComponent, Airframe)
AND
SomeValuesFrom(hasComponent, Avionics)
AND
SomeValuesFrom(SomeValuesFrom (hasComponent,Avionics),Radar)

Additional design properties will have to be represented to get a complete (buildable) design solution

The Air Vehicle Requirements That The Weight Is < 33K Pounds and The Range Is > 500 miles

Can Be Represented in OWL DL using the "SomeValuesFrom" class construction



AVRequirements =
SomeValuesFrom (hasWeightPounds (Number < 3300))
AND
SomeValuesFrom (hasRangeMiles (Number > 500))

These requirements can be represented graphically by properties having values in restricted data types

There Are Many Kinds Of Weights

For example, parametric estimates, measured weights, etc. – and there are established procedures to calculate the different weights

a : SomeValuesFrom (hasParametricWeightPounds (Number < 3300))

a : SomeValuesFrom (hasMeasuredWeightPounds (Number < 3300))

... The hard part is how to establish that a member of AVDeisgn satisfies the requirements represented in AVRequirements

… And Rules Can Be Used To Express Validation Conditions For Property Values

a : SomeValuesFrom (hasParametricWeightPounds (Number < 3300))

IF k = sum of weights of components where weight of component is material x volume

a : SomeValuesFrom (hasMeasuredWeightPounds (Number < 3300))

IF k = sum of measured weights of components

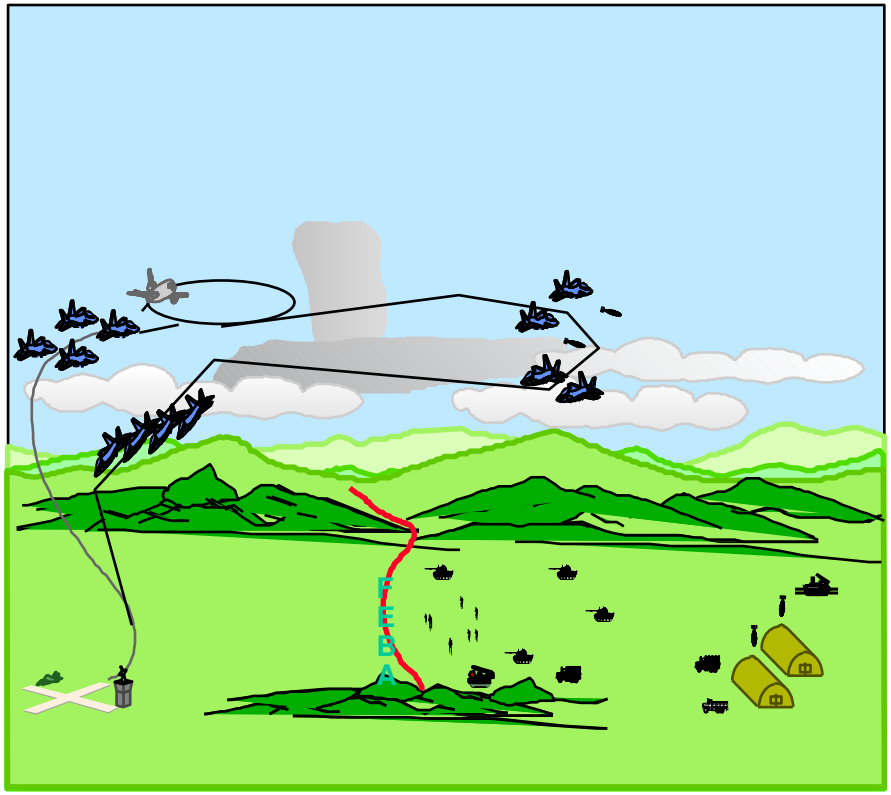
... rules can be used to give precise validation conditions for properties

The Requirement For An Air Vehicle To Detect a Moving Target Within 20 Miles In Any Battle Space

…starts by representing the detection requirement for a specific battle space

A Battle Space has many parameters

- Mission scenario
- Natural environment
- Targets
- Threats
- AV configuration
- Weather
- Friends
- Initial conditions



AV Requirements is contained in the intersection of the classes for each battle space

The Class Describing Target Detection In a Specific Battle Space

… is defined in terms of a distance relation between an air vehicle and a target moving in the battle space using the "AllValuesFrom" class specification

Using a relation

MovingTargetDistance<20

Whose meaning is

{ (a, t) | (a,t) : Distance<20, AND a: AV AND t : TargetInBattleSpace }

we define

AllValuesFrom(MovingTargetDistance<20, Detection)

Which specifies that all moving targets in the battle space less than 20 miles are detected

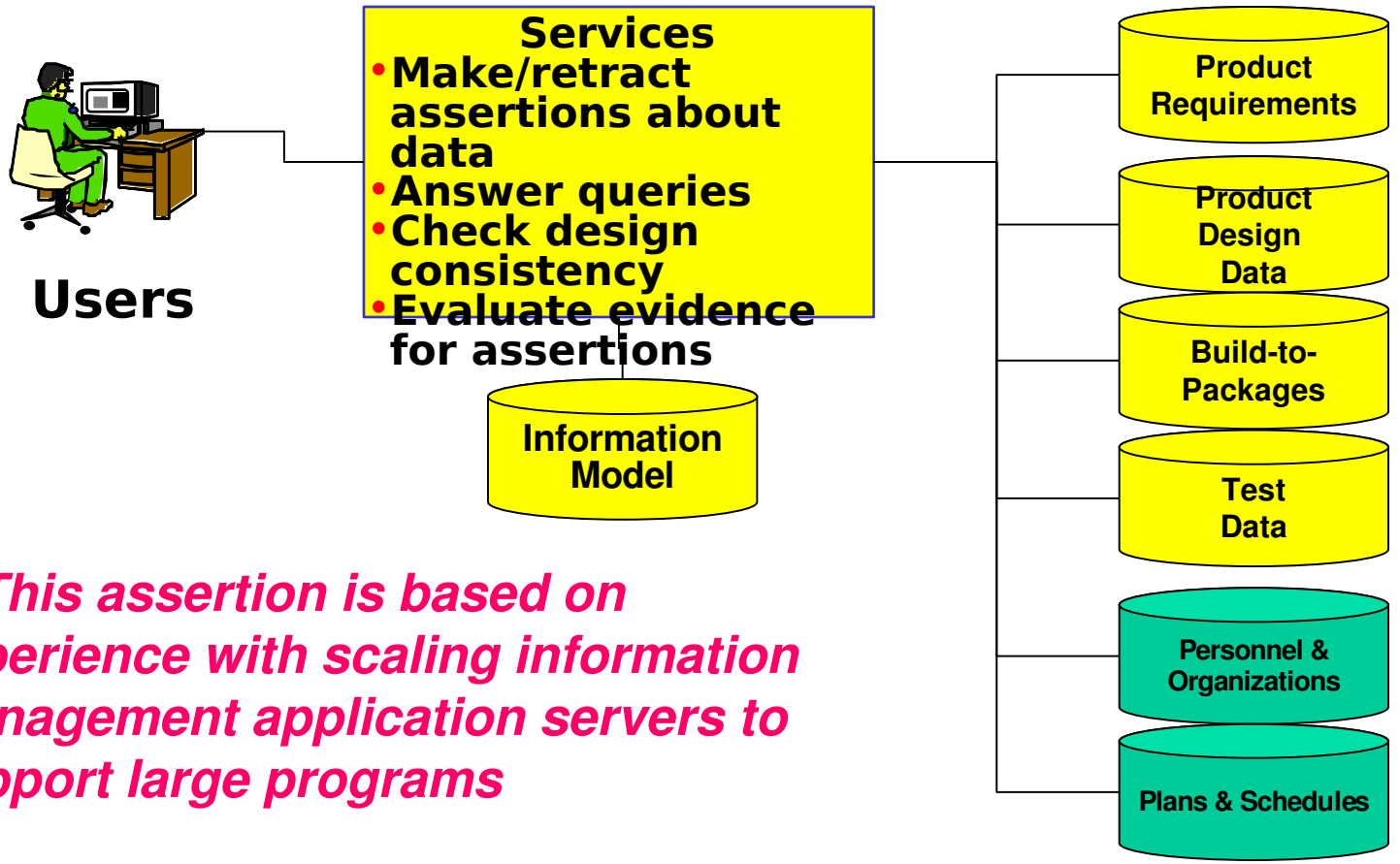
What We Have Gained With The OWL DL Representation of Design Information is

… the ability to precisely represent design information in a common semantic language

- How can this accommodate the millions of data items produced in product development?
  - The volume of data is in property values in complex data types, e.g., a property value is a geometry file, not in the number of classes and relations
- How complex are these representations?
  - A product development ontology will have only hundreds of classes and relations
  - A program knowledge base will be approximately the size of current UML models for complex products
- What are realistic expectations regarding application programs to reason, or otherwise process this information?
  - Applications can locate and assemble relevant evidence for design assessment

An OWL DL Ontology Can Be Used By An Application Server On a Large Program to

... represent designs, requirements, and follow relationships to combine design, requirements, and assemble and evaluate evidence for design assessment



... This assertion is based on experience with scaling information management application servers to support large programs