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ADVANCED & EXPLORATORY SYSTEMS

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Model Interoperability/Credibility FY19 Research Demonstration Results

SANDIA NATIONAL LABORATORIES

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Model Interoperability / Credibility

The DOD has placed significant emphasis on digital engineering.
Why? Because digital models contain significantly more information than paper.
<u>However, a digital strategy assumes that models interoperate.</u>

Sandia National Laboratories develops many digital engineering models

Our customers have asked to receive copies of our models

When modeling tools do not interoperate, our customers' tools cannot read our models

Translating the model to PDF or paper looses significant context/information

Our customers do not have a plan for model sharing/interoperability?

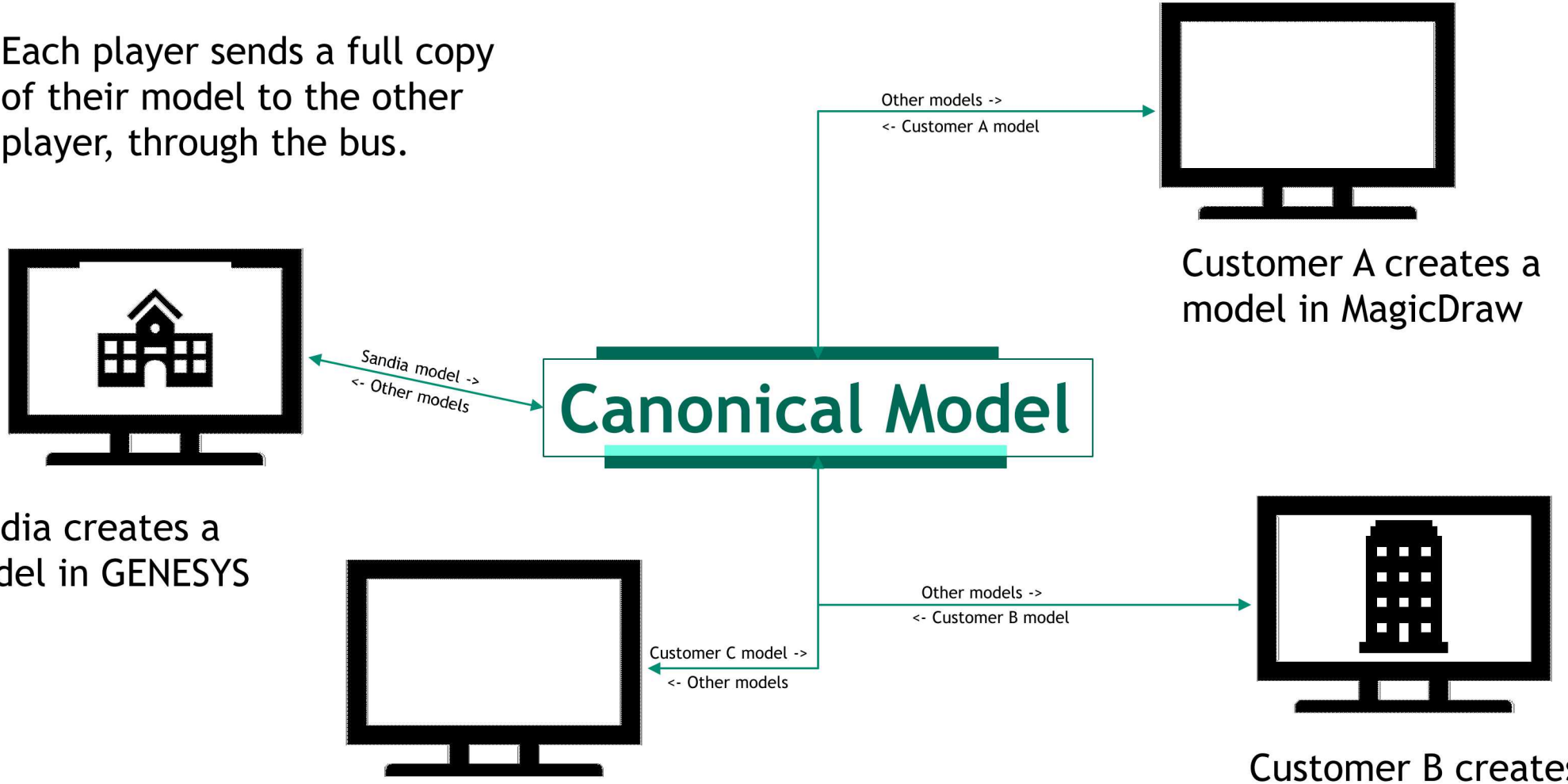
– across tools and layers of fidelity?

- We estimate that just at Sandia, our portion of a full system will include a 1,000 models
- When we make models the source of truth, how will we ensure they are authoritative, trusted, credible?

Model Interoperability / Credibility

Example Use Case: Full Model Transfer/Transformation

Each player sends a full copy of their model to the other player, through the bus.



Customer A creates a model in MagicDraw

Sandia creates a model in GENESYS

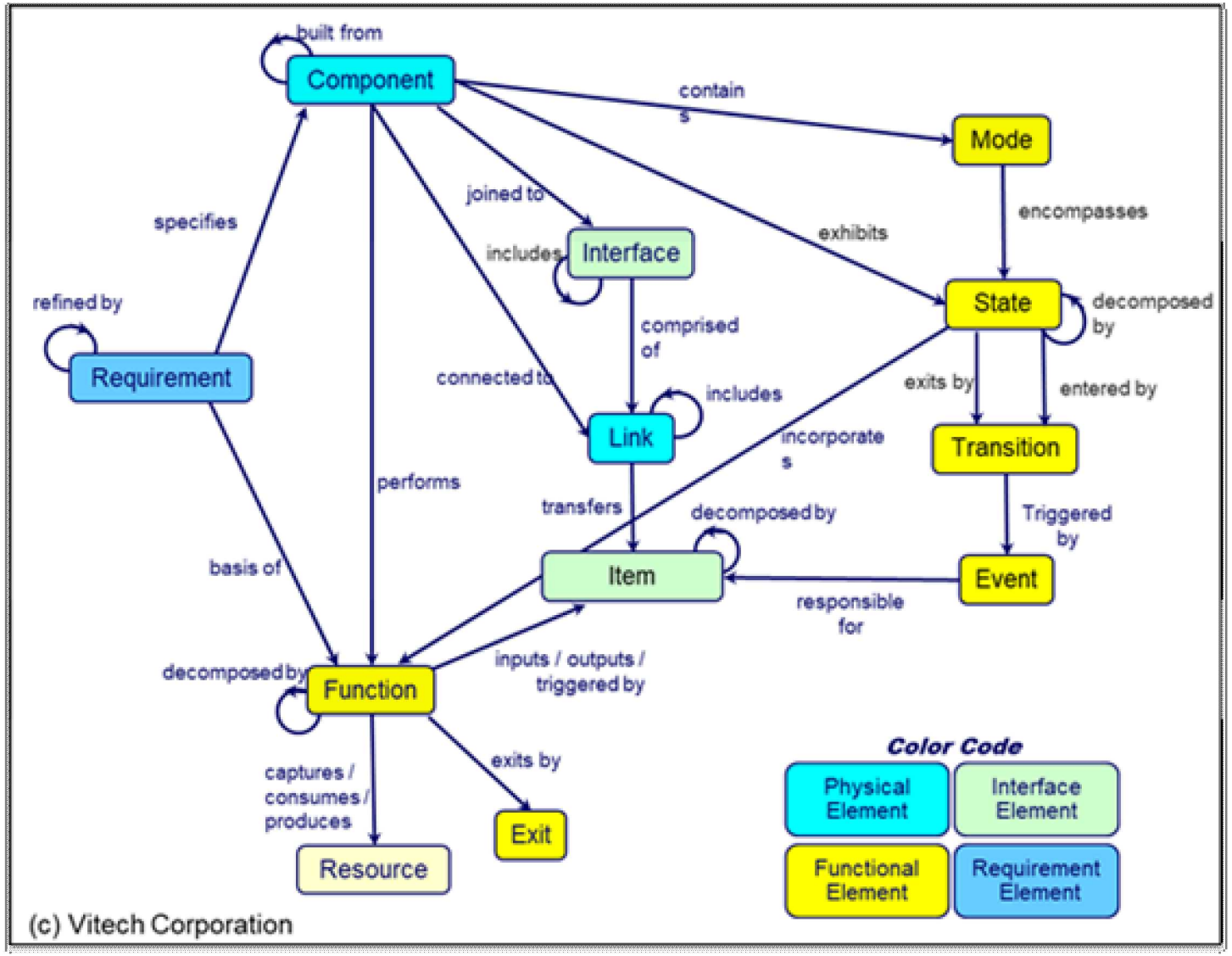
Customer C receives all models into separate models in MagicDraw

Customer B creates a model in Rhapsody (or some other tool)

Model Interoperability / Credibility

Unlike Traditional Databases, Systems Engineering Models Have Structure

Traditional databases do not retain the integrity of an ontological structure, so they lose data (the model meaning)



Whereas, a standard ontologically well formed canonical reference model provides the foundational structure for object mapping and comparison

In a manner that preserves that model structure (a graph data structure)

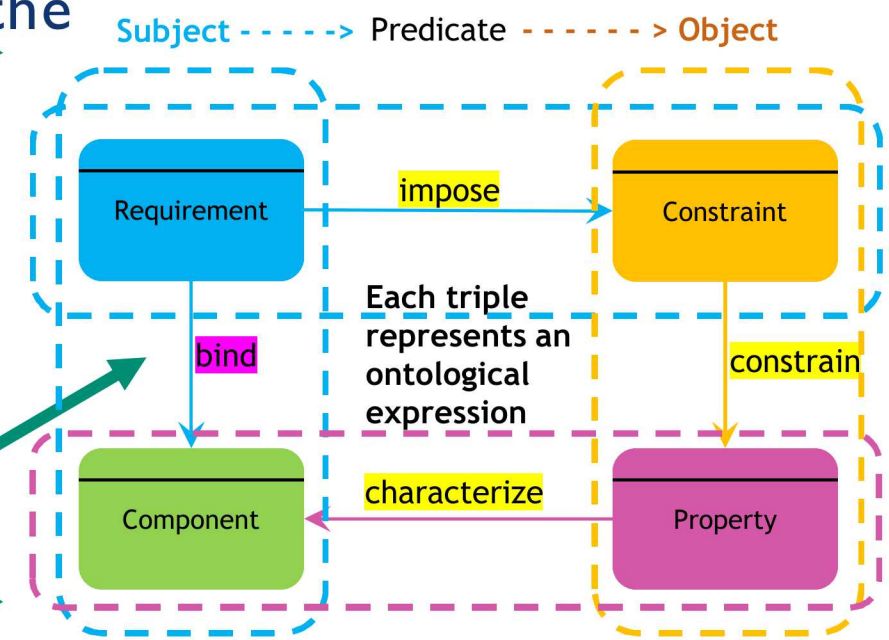
Component - performs - Function
Function - ouputs - Item
Function - triggered_by - Item
Component - built_from - Component
Component - connected_to - Link
Component - documented_by - Document
Component - joined_to - Interface
Component - provided_by - Organization
Environment - experienced_during - Phase
Link - connects_to - Component
Product - triggers - Program Activity

Model Interoperability / Credibility

Our Approach: Can we enable (Systems) engineering models to interoperate if we retain the integrity of the underlying ontological-structure?

What is an ontology? Models derive meaning from their structure. For SE models, in the form of: facts, roles, relationships, and intent, the way a sentence does in natural language processing (NLP).

For example



Challenge Example: When we transfer data related to "**Requirements** bind **Components**", we must also capture the other three triples or the model meaning is lost and we cannot analyze accurately. This is called the compositionality of the model, where the meaning of a complex expression is systematically put together from the meanings of its parts. The challenge is that each object may have many unrelated relationships to any specific question, so we are researching if we can reason through the model navigation to only the triples that relate to the questions being asked in the analysis.

NLP reasons the meaning in a sentence.

In the model above are four triple expressions:

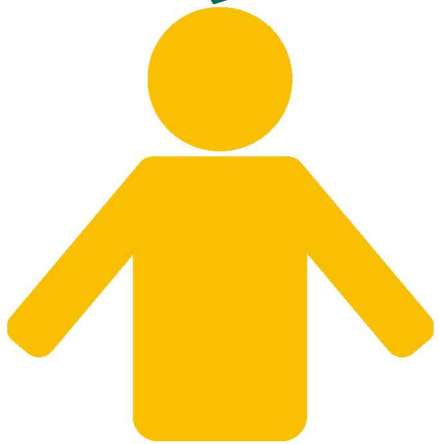
- **Requirements** impose **Constraints**;
- **Constraints** constrain **Properties**;
- **Property** characterizes **Components**;
- **Requirements** bind **Components**

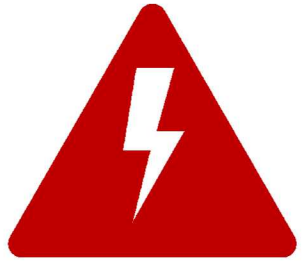
Based on the first three triples, we can reason that Requirements bind Components. We need all four triples in this structure to understand <u>why</u> Requirements bind Components.

Model Interoperability / Credibility

Another Example

Make sure we use a **Safety Harness** to transport the rocket, and transport it on **Low-Traffic Roads**.

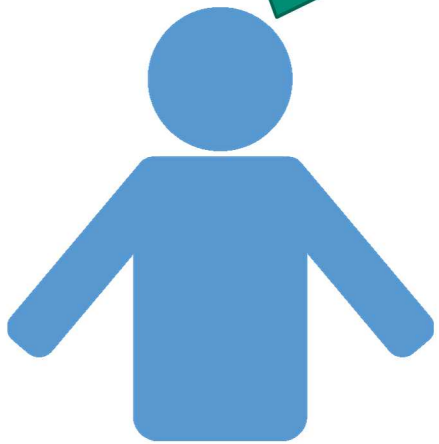




Semantic Disconnect

Same words; same data types.
Meaning different things.

Low-Traffic Roads and a **Safety Harness** Got it!



An Ontology recognizes this semantic disconnect.
An Ontology knows that these two separate meanings are not equivalent.

What he Said!

Low-Traffic Roads Any road with < 5,000 cars a day

Safety Harness: Any suspension system with belts having 5-points or more

What he Understood!

Low-Traffic Road: Any road that is not a highway

Safety Harness: Any harness with 3-points or more

Translating Languages (One Language and back)

English

- It's always hard to explain puns to kleptomaniacs because they're always taking things literally.

Chinese (Traditional)

- 總是很難向雙關語者解釋雙關語，因為他們總是從字面上理解事物。

Back to English

- It is always difficult to explain puns to puns because they always understand things literally.

Translating Languages
(Round trip with intermediary language)

English
- It's always hard to explain puns to kleptomaniacs because they're always taking things literally.

Chinese (Traditional)
- 總是很難向雙關語者解釋雙關語，因為他們總是從字面上理解事物。

French
- Il est toujours difficile d'expliquer les jeux de mots aux joueurs car ils comprennent toujours les choses au sens littéral.

Back to Chinese(Traditional)
- 向玩家解釋文字遊戲總是很困難，因為他們總是從字面意義上理解事物。

Back to English
- It is always difficult to explain word games to players because they always understand things literally.

Our Model Translation Problem

Genesys -> RDF

RDF -> Magic Draw

Magic Draw -> RDF

RDF -> Genesys

What is RDF?

- Resource Description Framework - a file format that conforms to the ontology structure
  - As an alternative to a traditional database structure
  - So, by translating the model into RDF format, we retain the integrity of the ontological structure of the model.

Why RDF?

- We can use natural language reasoning rules to assess the model for consistency (does it follow good ontological rules?)
  - Including translation issues related to alignment between the target model's ontology and that of the reference model
- We can also use natural language reasoning rules to assess for programmatic requirements (is the data, data format, context correct>)

Model Interoperability / Credibility

Genesys to RDF mapping.

Entity Definitions => Classes

- The subclass predicate allows us to maintain inheritance and polymorphism.
- This doesn't account for the Entity Definition's attributes

Relationship Definitions => Classes

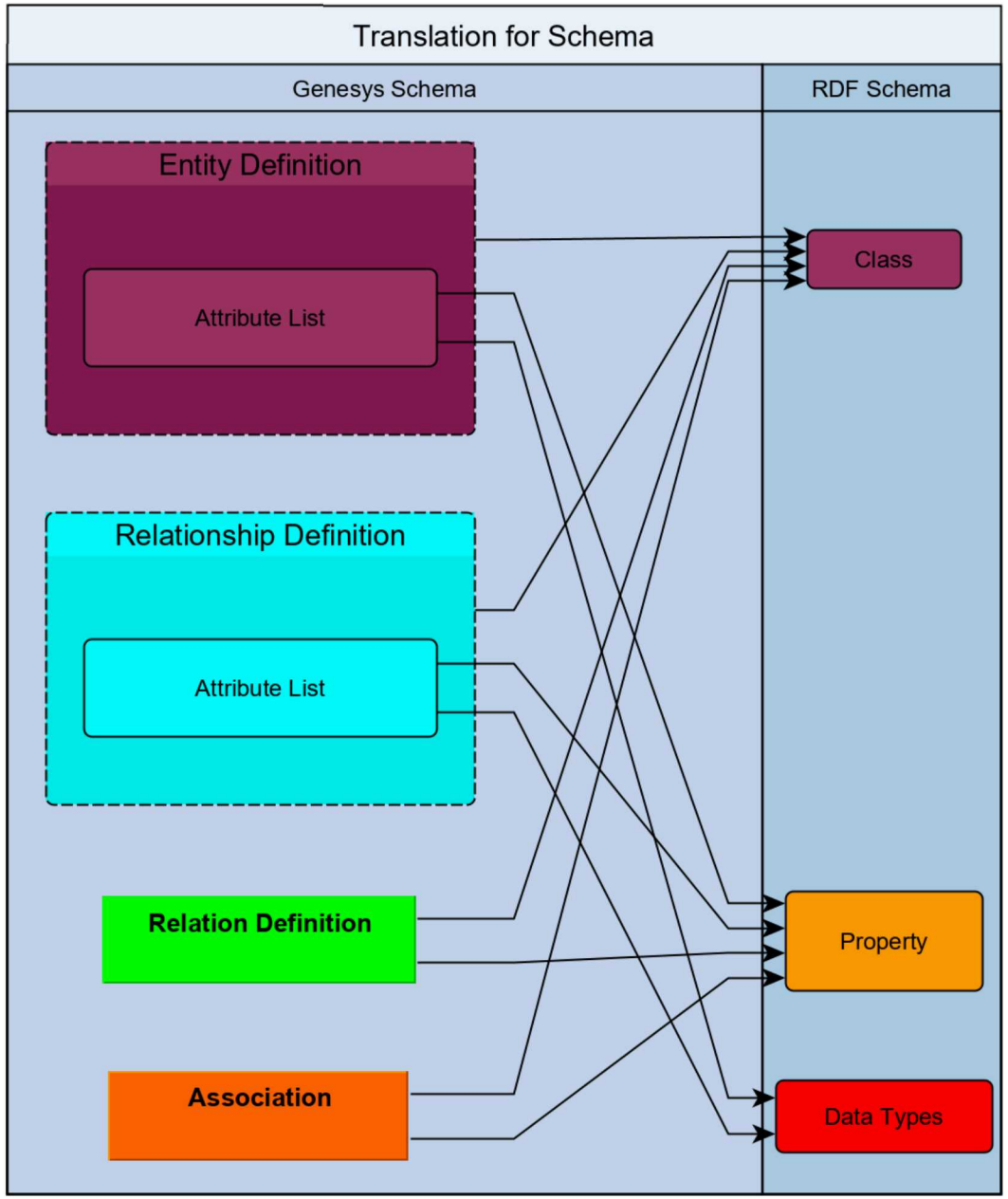
- This doesn't account for the Relationship Definition's attributes

Attributes => Properties and Data Types

- We also require the use of the Domain and Range predicates

Relation Definitions and Associations => Classes and Properties

- These two must be translated with each other in mind. Together they let Entities and Relationships be constrained.



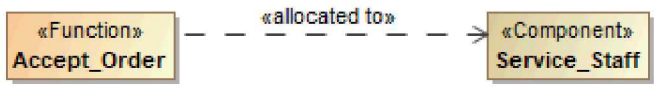
Model Interoperability / Credibility

Then we translated the GENESYS/RDF model into MagicDraw

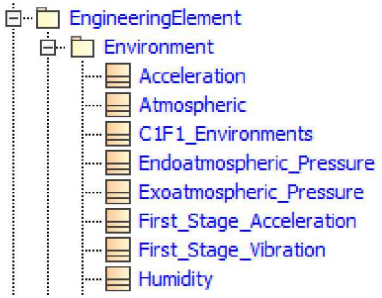
GENESYS/RDF Entity definitions are imported as custom stereotypes.

- The GENESYS/RDF schema (particularly, the relationships allowed between objects) was subjectively compared to SysML and UML object definitions and model semantics to determine equivalency. Custom stereotypes preserve the semantic meaning of the system model.

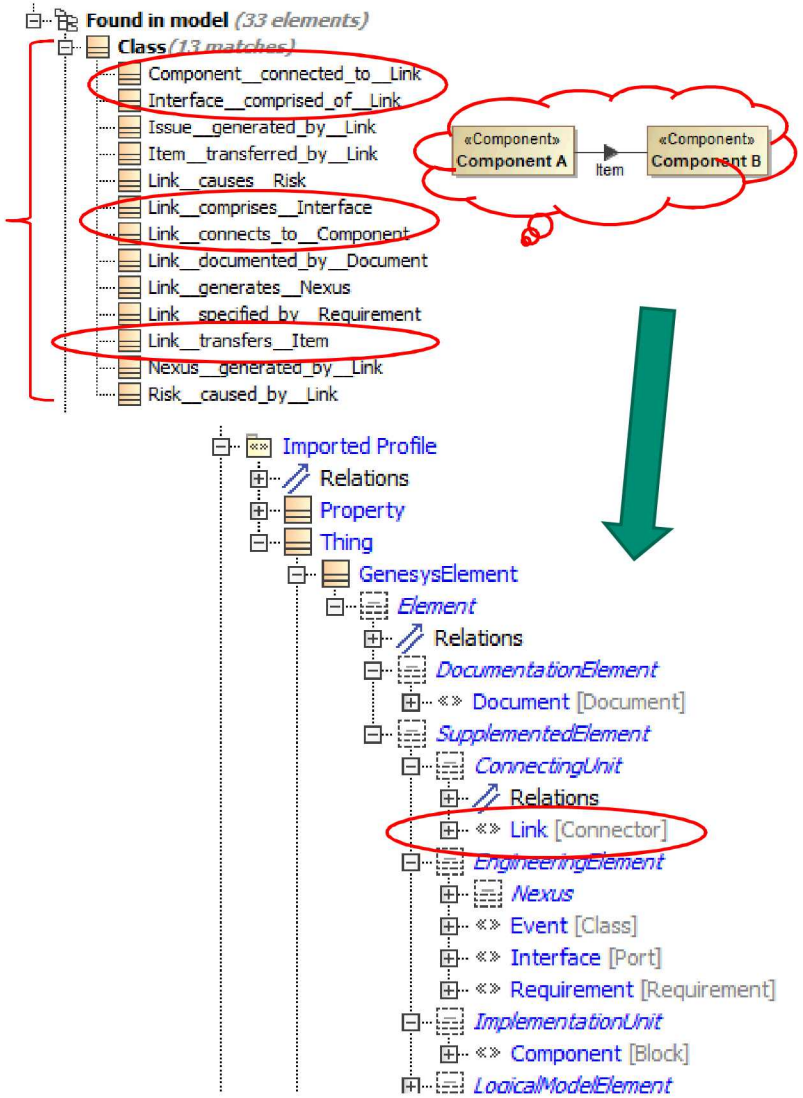
Genesys relationships are mapped to equivalent SysML/UML relationships.



Usage of custom stereotypes permits the preservation of attributes defined for GENESYS/RDF entities and relationships.



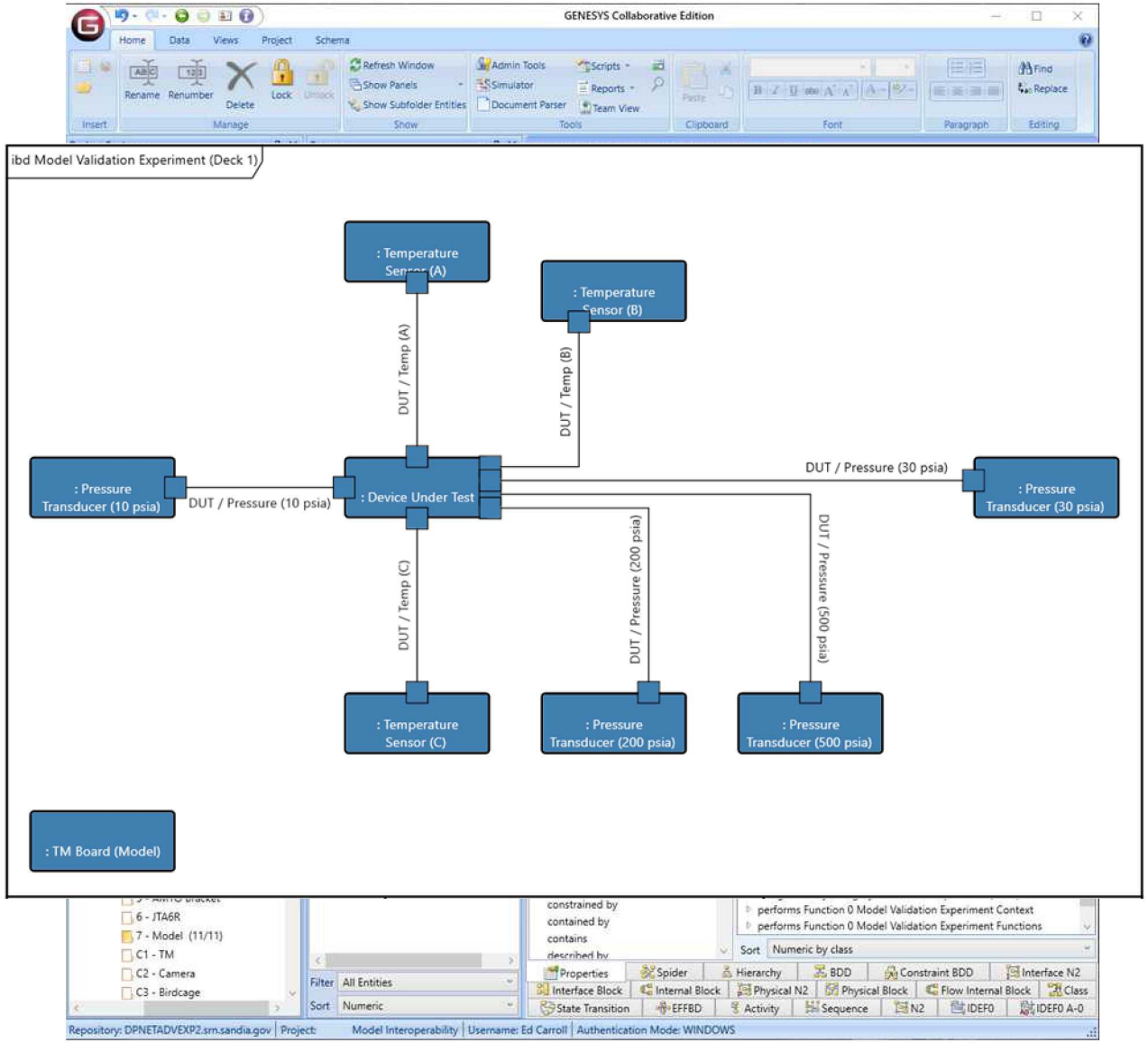
100% of RDF individuals (GENESYS entities) are imported and placed within the model.



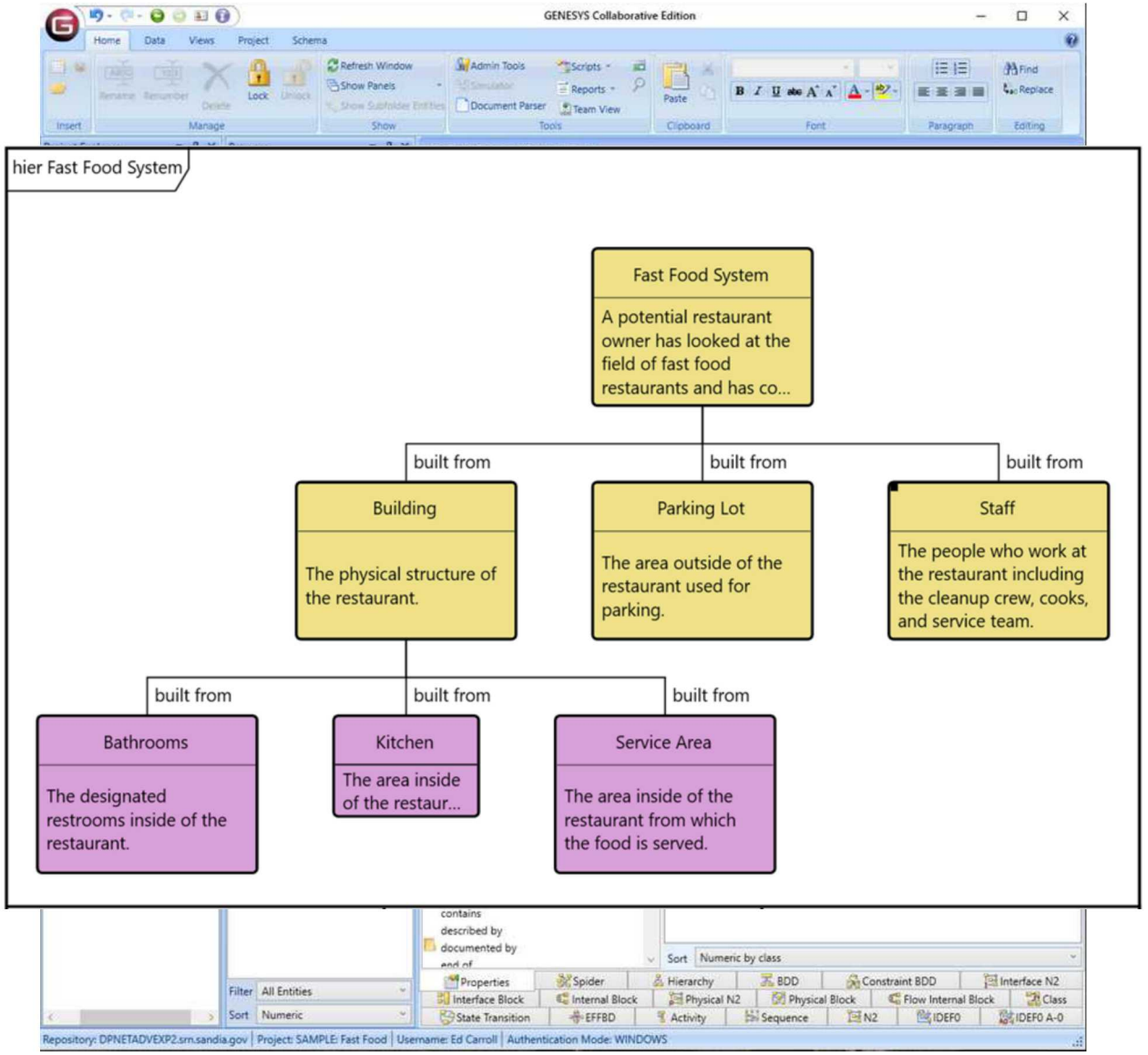
Model Interoperability / Credibility

Our Demo: We started with 2 GENESYS models (to test with)

A model from HotShot

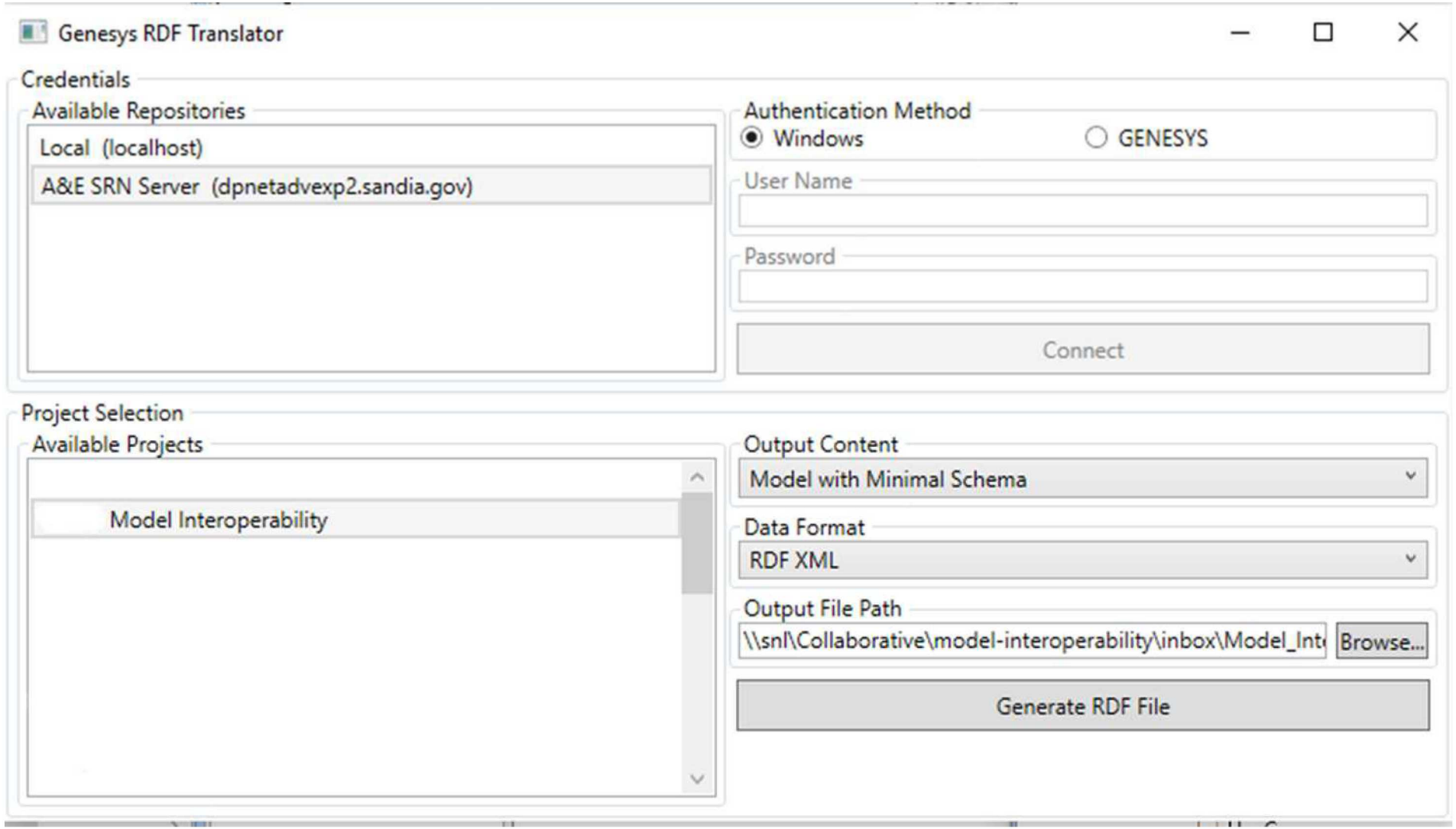


And a Fast Food Restaurant model



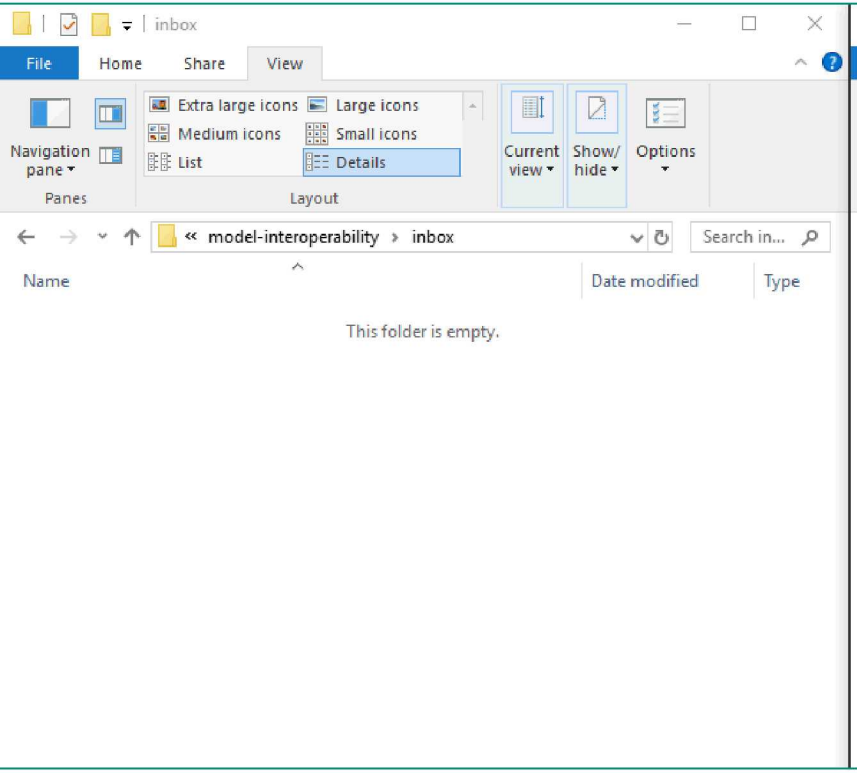
Model Interoperability / Credibility

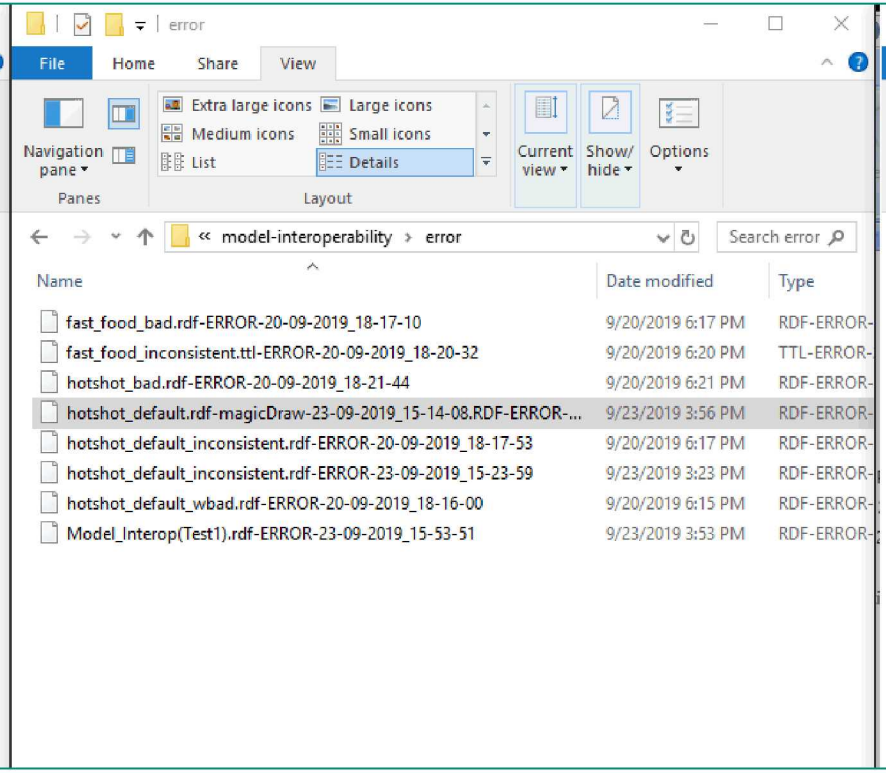
Our Demo: We developed an Application Program Interface (API) that extracted the entire models from GENESYS and transformed them into RDF formatted files

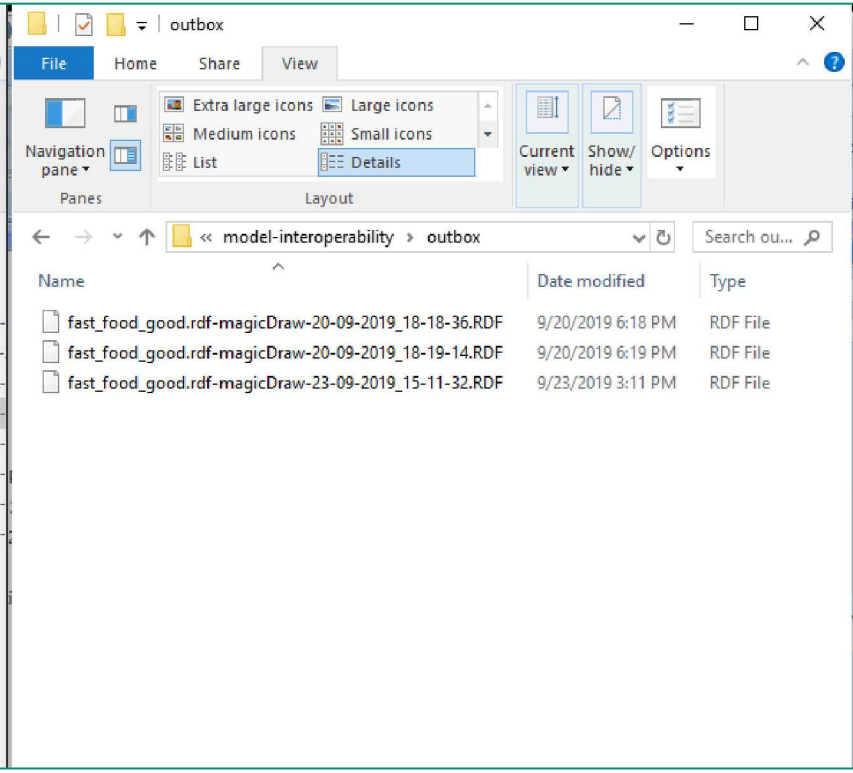


Our Demo: We also created a Service Bus to process the model transfer and apply our reasoning rules against the model – in transit

1. The Bus picks up the RDF file from the INBOX and passes it to the Reasoner.
2. If it fails the reasoning rules the Bus moves the RDF file to the ERROR box.
3. If it passes the reasoning rules, the RDF file is moved to the OUTBOX



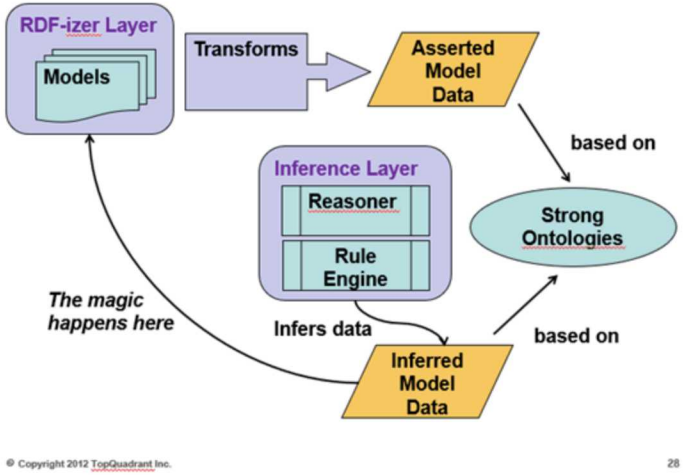




Not your typical science project. This was a proof-of-concept that combined 4 well known sciences into a new approach. When it is time to transition from research to the development team, we are ready with a standard approach, patterns, and tooling architecture.

Model Interoperability / Credibility

Our Demo: We reason against the model's ontology
Demonstrating that we can assess a model for credibility



We chose the Pellet reasoner in conjunction with Jena:

- Jena is an inference subsystem designed to allow a range of reasoners as plugins.
- Pellet is an open-source Java OWL 2 reasoner – an inference engine used to derive RDF assertions

```
(version 4.2.8.20170104-2310) https://github.com/owlcs/owlapi --><!-- Error(s) Found in the Ontology, Reasoning Type CONSISTENCYError (KB
is inconsistent!): An individual belongs to a type and its complement-->
```

We chose SHACL (shapes constraint language) reasoning language:

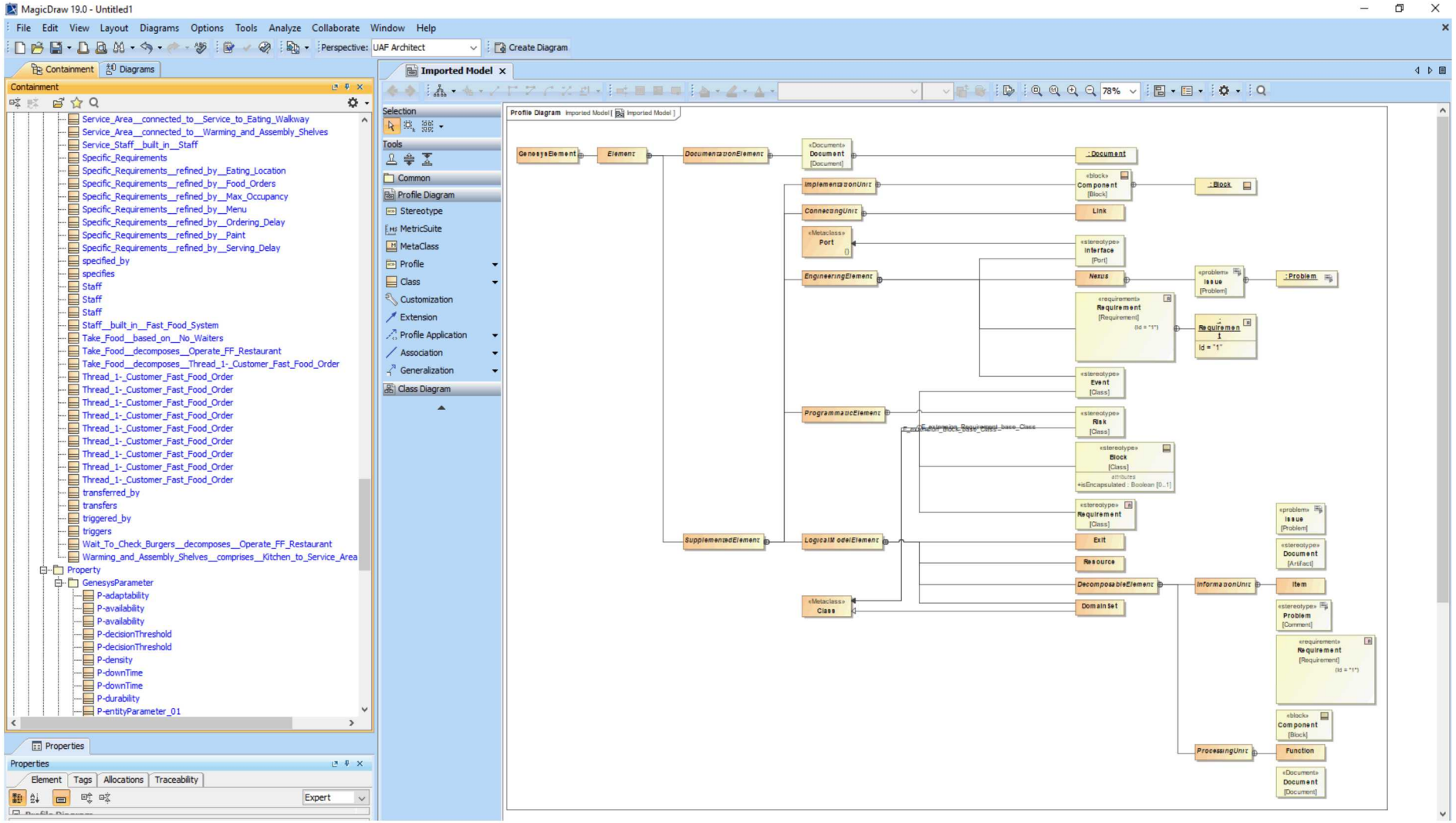
- To validate RDF graphs against a set of conditions (i.e., programmatic Systems Engineering model requirements)

```
(version 4.2.8.20170104-2310) https://github.com/owlcs/owlapi --><!-- Error(s) Found in the Ontology, Reasoning Type SPECIFICThe
focusNode is Generate_PPTB_Ignite_Signal, Function without allocation to Resource.-->
```

Model Interoperability / Credibility

Our Demo: The (passed) RDF file is picked up from the OUTBOX and ingested into MagicDraw

Below is the Fast Food Restaurant model



The results are not an identical match (because this was a proof-of-concept), but 100% of the data has been verified.

If you are a MagicDraw user, you should see that we have mapped the GENESYS objects into MagicDraw Stereotypes

Research direction in FY20 – From Model Interoperability to Model Credibility

In FY19 we:

- Conducted preliminary research on the use of graph theory against an ontology to expand our reasoning:
  - Is the model well formed (OWL 2.0 compliant)?
  - Does the model conform to the reference ontology?
  - Are certain required model objects present?

In a tangential FY19 (Corporate SE Ontology) study:

- Assembled a list of questions that a Systems Engineer should ask to assess whether a model is credible.
- Compared ontology objects from JPL, NASA and DoDAF
- Analyzed ISO 15288 to identify the objects and relationships of tasks and activities.

In FY20+ we hope to leverage our work to:

- Expand interoperability successes
  - More complex models
  - Physics/Simulation models, MCAD/ECAD models
  - Explore ontology discovery, matching, and alignment reasoning
- Demonstrate reasoning rules to assess model credibility
  - Transform the questions into reasoning rules (combining ontology theory, pattern analysis theory, and graph theory)
  - Build a library of reasoning rules - does the model:
    - Follow good practice (Compliance),
    - Fulfill intended use (Accuracy),
    - Describe the real world (Correctness),
    - …
    - Incorporate VVUQ concepts (Testability)

SUMMARY OF MBSE MODEL CREDIBILITY EVALUATION CRITERIA

A	**Compliance (with MBSE good practices and domain standard ontology)**
	CRITERION DESCRIPTION: the model properly and fully conforms to the good practices and established guidelines for implementing MBSE models. There are no errors and/or omissions relative to implementing MBSE guidelines, to include properly applied configuration management of the model. The MBSE model should properly employ the standard ontology for the domain of interest and all external data should be entered into the proper ontology elements.
B	**Accuracy (ability to accurately and effectively fulfill the intended use of the model)**
	CRITERION DESCRIPTION: the model must be able to answer the questions that are put to it; note that these questions should be defined up front and should drive the design and development of the MBSE model. The model must be properly structured to answer the questions and should contain sufficient information to produce the answers.
C	**Correctness (how well the model describes the real world system)**
	CRITERION DESCRIPTION: the model must properly and fully represent the real world system of interest, including the composition of the system, the behaviors of the system, and the critical characteristics for employment of the system. A correct model can be used in lieu of the real system to answer questions of interest, to include questions of the appropriateness of the system design for the real world system's real world mission.
D	**Completeness (maturity of the model in the context of the program developing the model)**
	CRITERION DESCRIPTION: Is the model's maturity sufficient for the current stage of the system lifecycle (including content reviews and configuration management)? Are the contents of the model sufficient to accomplish the intended use of the model and the intended use of the system being modeled?
E	**Testability (ability of the model to participate in testing the design)**
	CRITERION DESCRIPTION: the architecture model should serve as a key element of design for testability and test first/test exploration. One aspect of this is that the model itself should be part of "testing" by providing behavior representations that are executable. Another aspect is that the model shall provide useful guidance to other test first/test exploration of design options (such as identifying test exploration of unknown aspects of the architecture/design)
F	**Reusability (reuse of previous models in the current model + ability to reuse current models elements)**
	CRITERION DESCRIPTION: the model should be built from elements reused from previous models and should provide elements to a library for reuse. The model should display the patterns appropriate to the domain of the system.

Collaboration between SNL (my research) and DOD?

Model Interoperability to Model Credibility

Research into Model/Ontologies:

- Evolve Reference Ontologies Specific to Problem Sets
- Discovery of Target Model/Ontologies
- Match/Align Target Model/Ontologies

Evolve from TRL 3 to TRL 4 and TRL 5

- More complex models
- Physics/Simulation models, MCAD/ECAD models

Develop AI reasoning rules to assess model credibility

- Transform the questions into reasoning rules (combining ontology theory, pattern analysis theory, and graph theory)
- Build a library of reasoning rules - does the model:
  - Follow good practice (Compliance),
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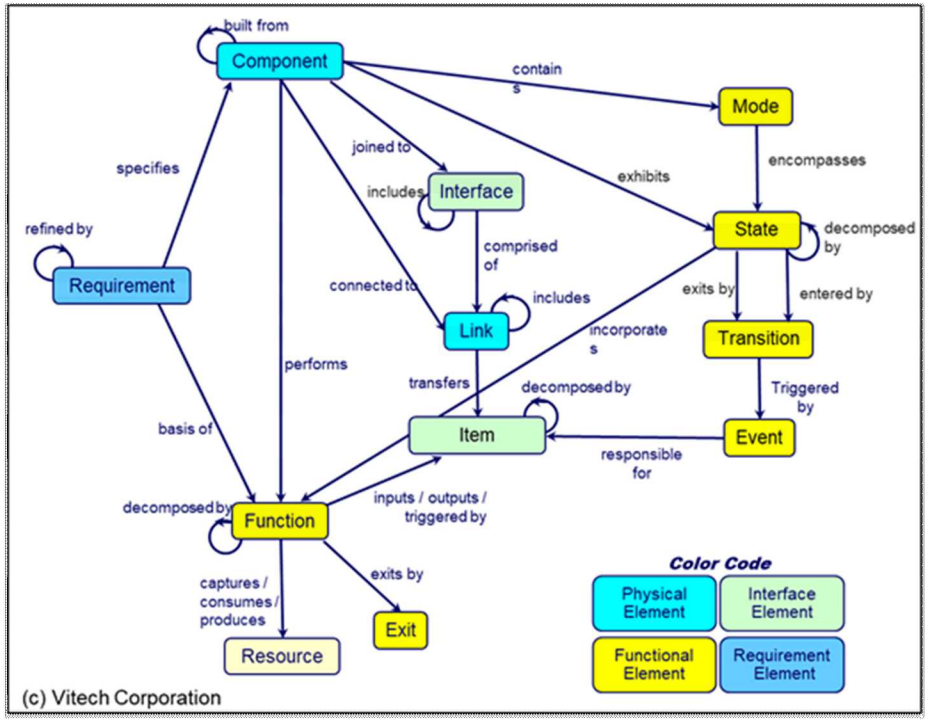
  - …
  - Incorporate VVUQ concepts (Testability)

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Collaboration between DOE/NNSA/NSE and DOD?

This is a Forum intended to create agreement across the Federal Government and the National Security Enterprise toward a common vision of our digital interfaces for the future.

- to explore digital engineering strategies
- to establish common cause, to share where we each are at, and to collaborate on a consensual vision of digital engineering practice across the Complex for the future.

The goal of this forum is to conclude with a framework that: ***aligns our efforts across the NSE, identifies near-term wins, and supports long-term investments.***