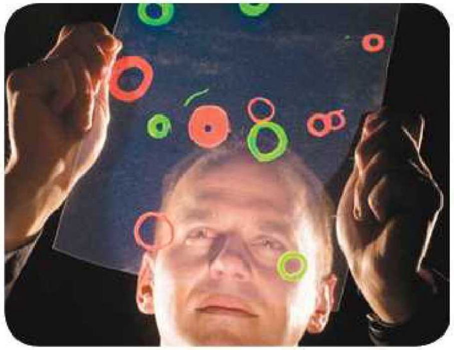
SAND2019-3729C

A Research Proposal:

Assessing Credible Systems Engineering Models Through Rigorous Augmented Intelligence Analysis



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Challenge: We have Digital Systems Engineering Models. Are they credible?

We are building systems models, are they CREDIBLE - correct, complete, compliant, reusable, or interoperable?

Today we peer-review models with human reviewers

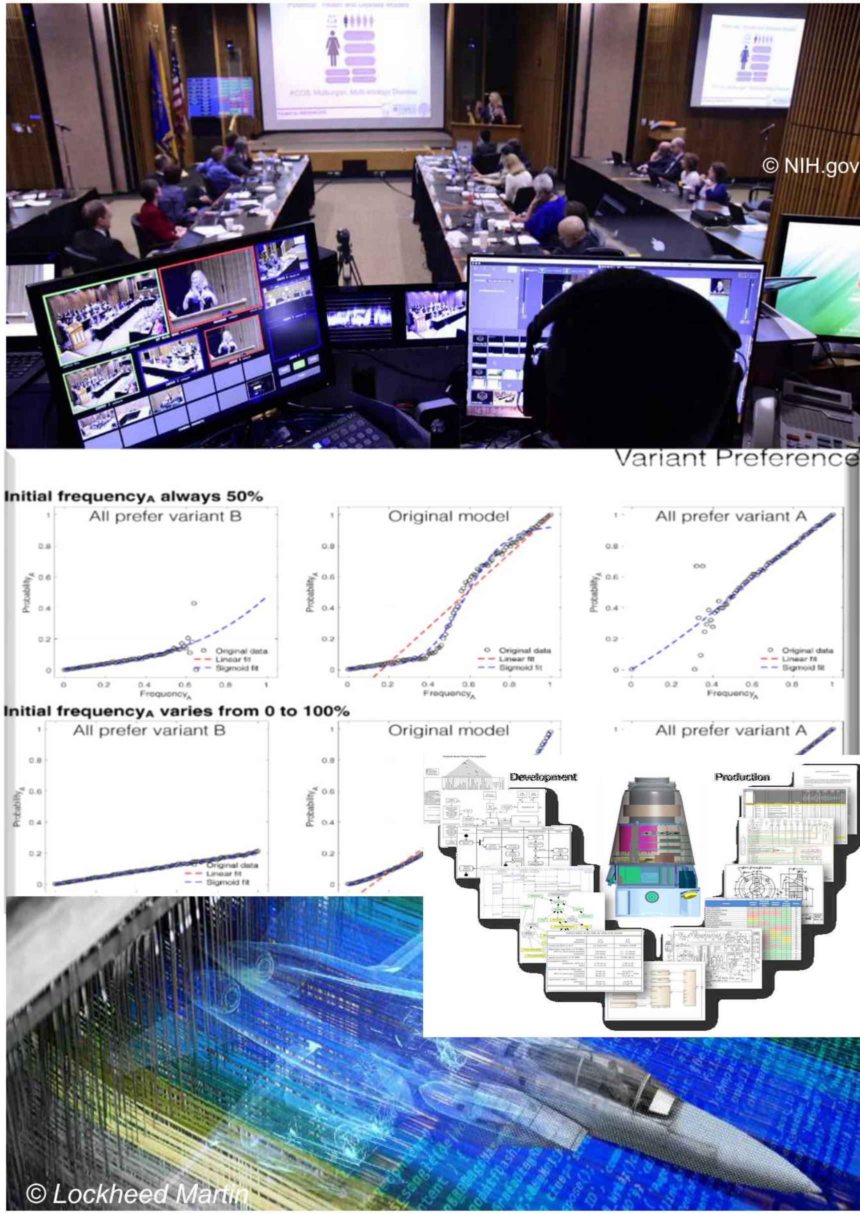
- Some of our Systems Engineering (SE) models have grown to over 10,000 nodes.
- It is estimated that 1,000 models are needed for a large system development effort.

Augmented intelligence (AI)-based assessment rules can dramatically improve assessment, computationally

NNSA and DOD will require credible models

- Imagine a fully interoperable Digital Twin capability - supporting dramatically accelerated configurable, modular, and trusted system architectures and designs - eliminating errors and streamlining qualification via AI tested patterns – cutting the time it takes to field or upgrade a system to one quarter of current timelines.

We propose a research project to explore the use of AI to assess SE models for credibility, applying the same VVUQ rigor used to ensure credible physics/simulation models.

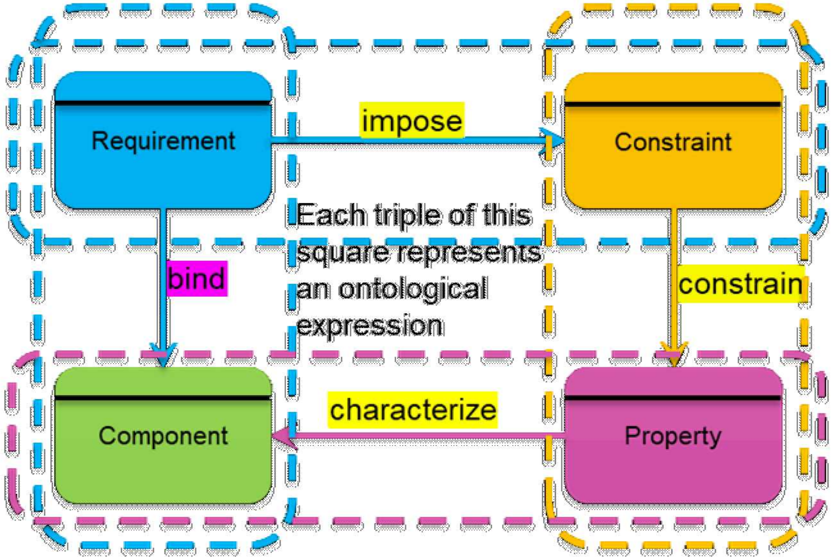


Research Question:

Can augmented intelligence be applied to interoperable, ontology-structured Systems Engineering (SE) models – to establish system models as a credible source of truth?

What is an ontology?

SE models derive meaning from their structure, in the form of: facts, roles, relationships, and intent, the way a sentence does in natural language processing (NLP). The integrity of this structure (an ontology) must be maintained throughout any model interrogation or the model meaning is lost.



NLP reasons the meaning in a sentence.

In the model to right are four triple expressions:

- **Requirements impose Constraints;**
- **Constraints constrain Properties;**
- **Properties characterize Components;**
- **Requirements bind Components**

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

Key Challenge: When we analyze data related to "Requirements bind Components", we must also transverse 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 need to research if we can limit the model navigation to only the triples that relate to the questions being asked in the analysis.

Research Approach (the underlying science):

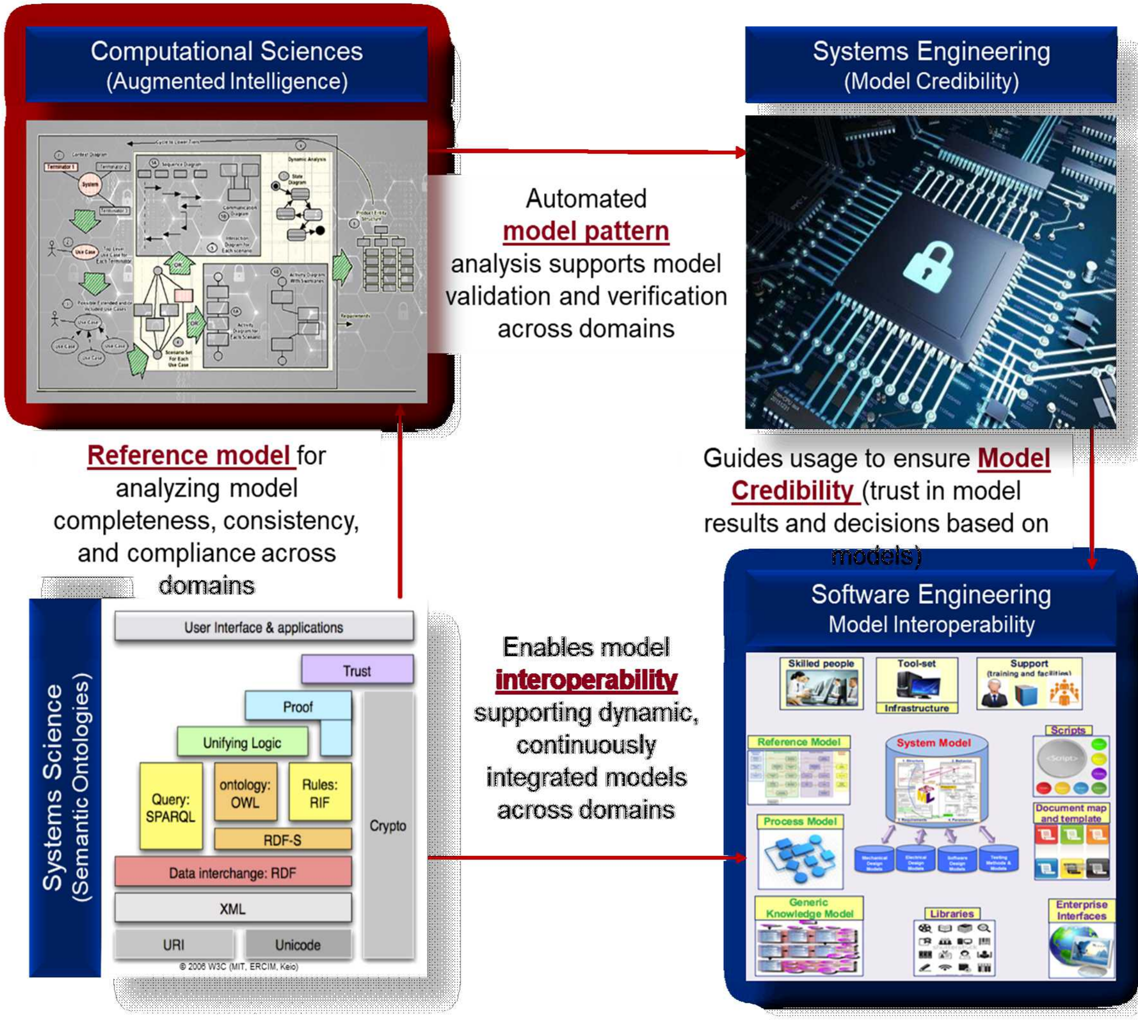
We hypothesize that credible SE models might be crafted by combining what we know from 4 different fields.

Computational science –we analyze patterns in geospatial photographs, maps, and mechanical Models – we need to research the computational aspects of an SE ontology.

Systems science – In NLP, sentence expressions of triples (subject-predicate-object) are called an ontology – we need to research how to reason the correct triples from any number of triples.

Systems engineering – the structure of SE models fit an ontology – we need to research rules to transform an ontology from many SE models, while retaining model meaning.

Software engineering – there is a semantic ontology-based technology used for enterprise database integration – we need to research adapting AI rules to this technology for model analysis.



Proposal: An ontology-based AI analysis capability

Primary deliverable: a proof-of-concept demonstration

What We Will Do:

- From **computational science** – develop AI pattern analysis and graph theory algorithms.
- From **systems science** – develop NLP reason rules for the right comparisons and transfers.
- From **systems engineering** – define the ontology classes and taxonomy for the Sandia domain.
- From **software engineering** – adapt a semantic ontology-based technology to SE model interoperability.

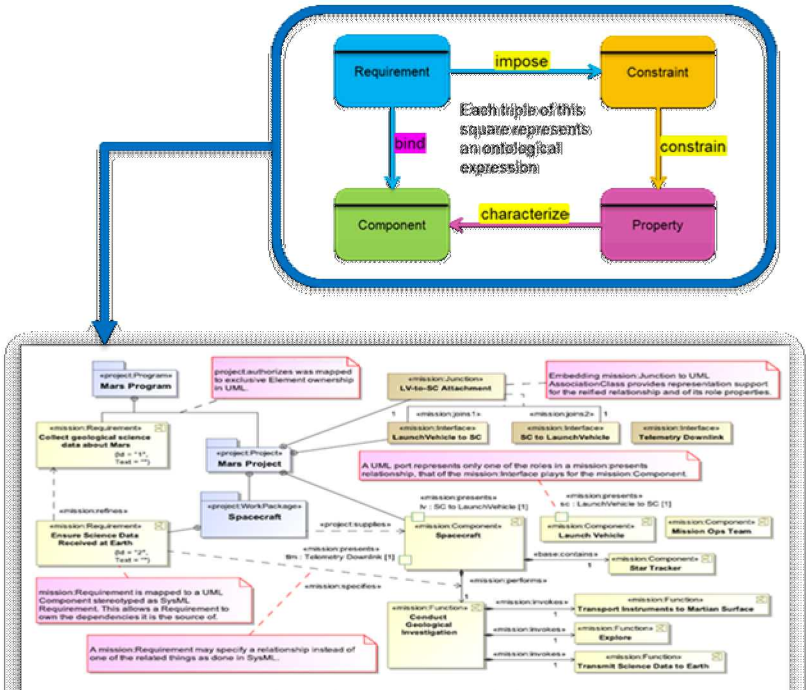


Figure 1: Example of profile application.

Building Profiled System Models

The simple key success factor: Demonstrate a credible SE model through relevant augmented intelligent pattern analyses and graph theory routines.

- Integrating without degradation of the model construct or redevelopment of the model
- Validated analyses results (pattern analysis and graph theory) via manual reconstruction

Target SE Models to Test With: We will start with a comparison of a small SE model and a simple pattern

Then we iterate the process to progressively more complex patterns and more complex and partial model transformations

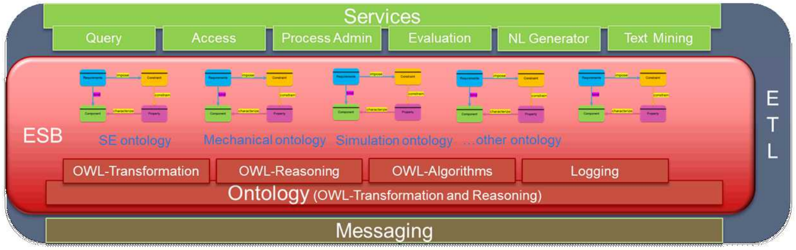
R&D Plan

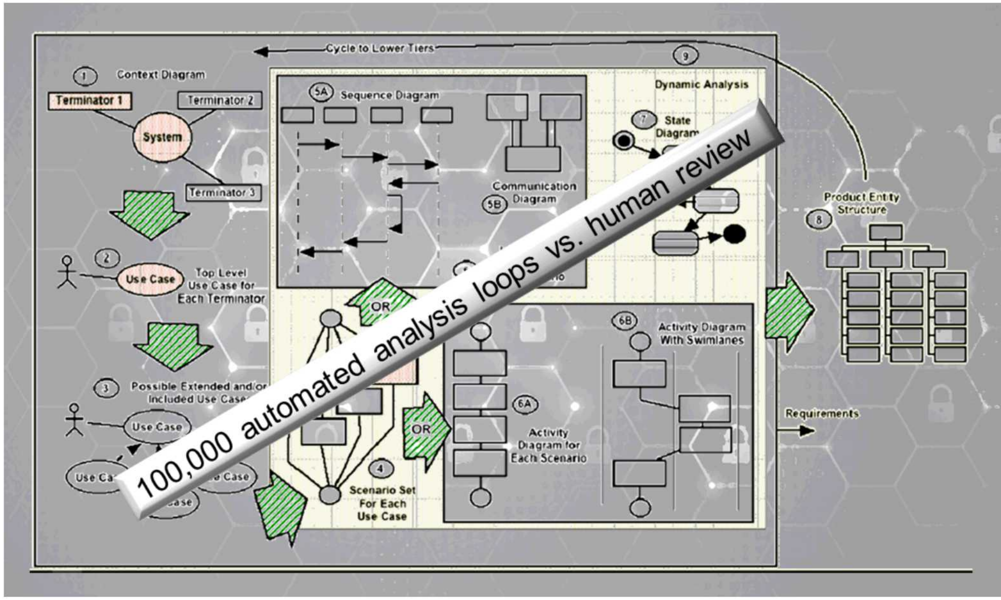
Challenges (and what we will learn):

- The patterns and ontologies might not be stable, controllable, predictable, or deterministic.
  - We need to analyze multi-dimensional axis to obtain the effect of all variables on the desired response
  - We may not be able to design a composition operator that ensures the same results from two or more mappings
  - The model may not be stable enough for alignment, for uncertainty quantification
  - Our solution may not be usable to non-expert users
  - We will learn the limitations of ontology-based constructs
  - We will learn new techniques for applying ontology-based constructs to new domains
  - Whether we succeed or fail: we will learn if we are using the right patterns, equations, inputs, parameters, comparisons, etc?
- The semantic technology we choose might not adapt to the rule-based logic we require
  - We will learn new techniques for rule development and rule application of ontology-based constructs

Primary deliverables:

- A proof-of-concept demonstration (see success factor), leverageable by follow-on projects, with documented results; test results; recommendations for path forward; and formal publications.



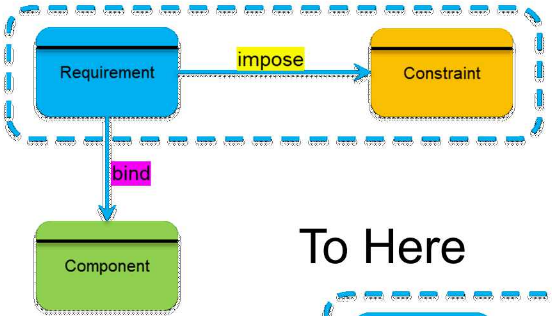


Backup

Research Challenges

Conceptualizing: reasoning rules to navigate/transform ontologies

From Here



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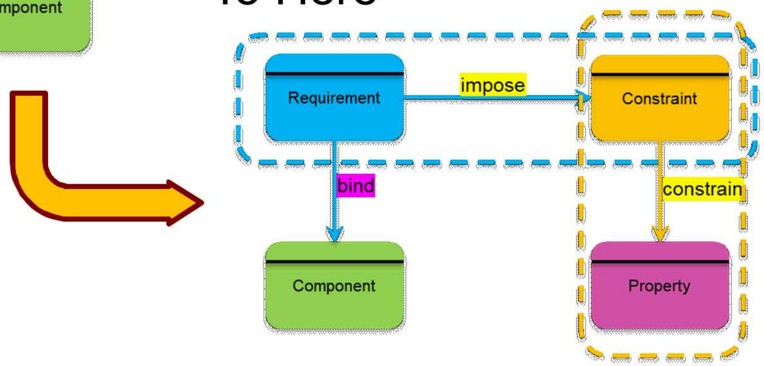

Can we compose reasoning rules:
Rules that will enable us to navigate, search, and transform the structure (ontology) of a model.

- Note, there will be 1,000s of boxes and arrows to work with in a real model, not just 4

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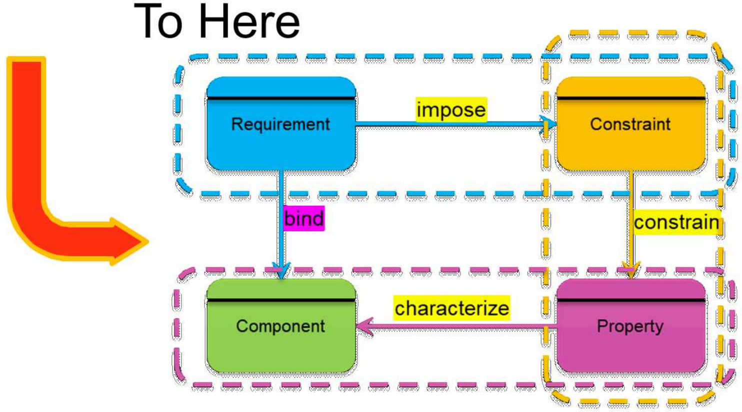

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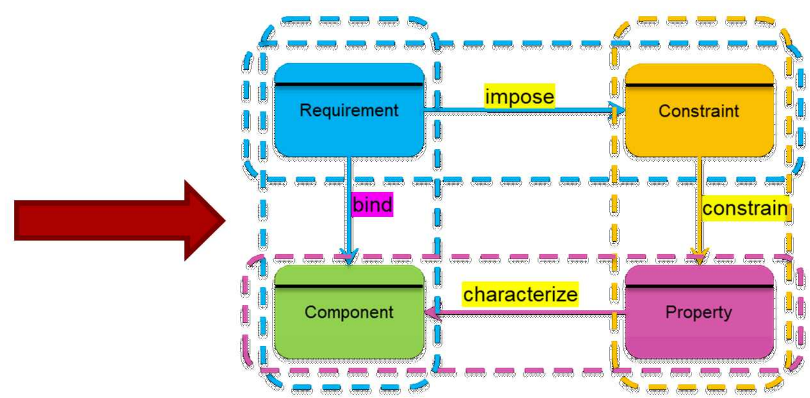
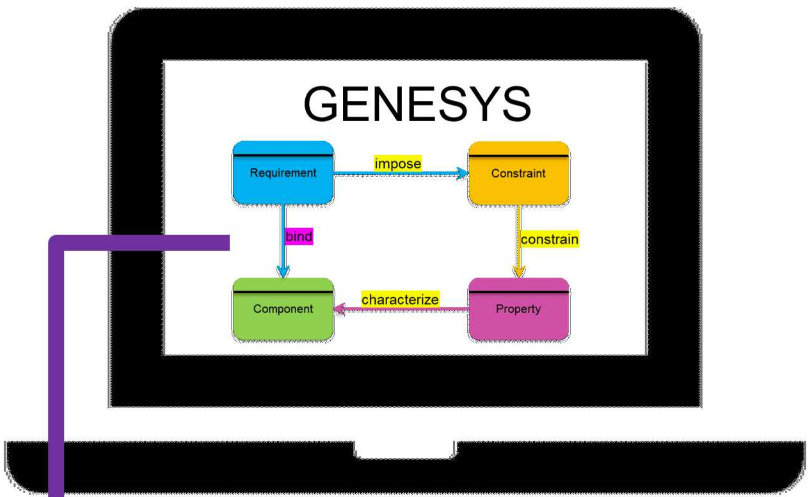


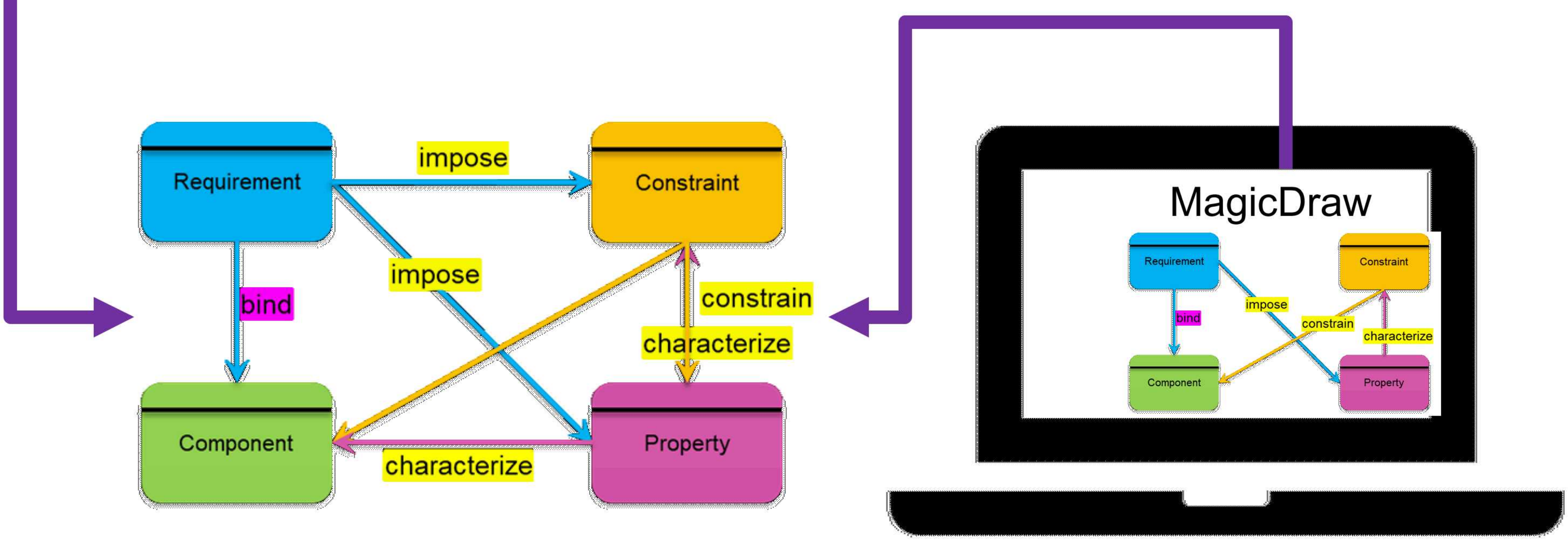
Research Challenges

Conceptualized: reasoning rules to align structures of multiple models



Can we recognize the structure (ontology) of a model: And then merge that structure to create a common structure?

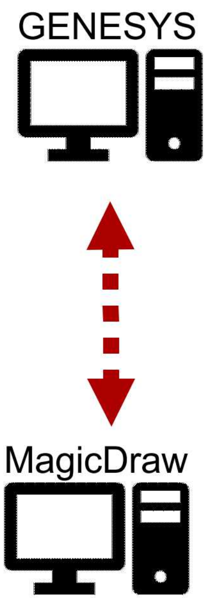
- Without human involvement each time (note, there will be 1,000s of models for a full system)

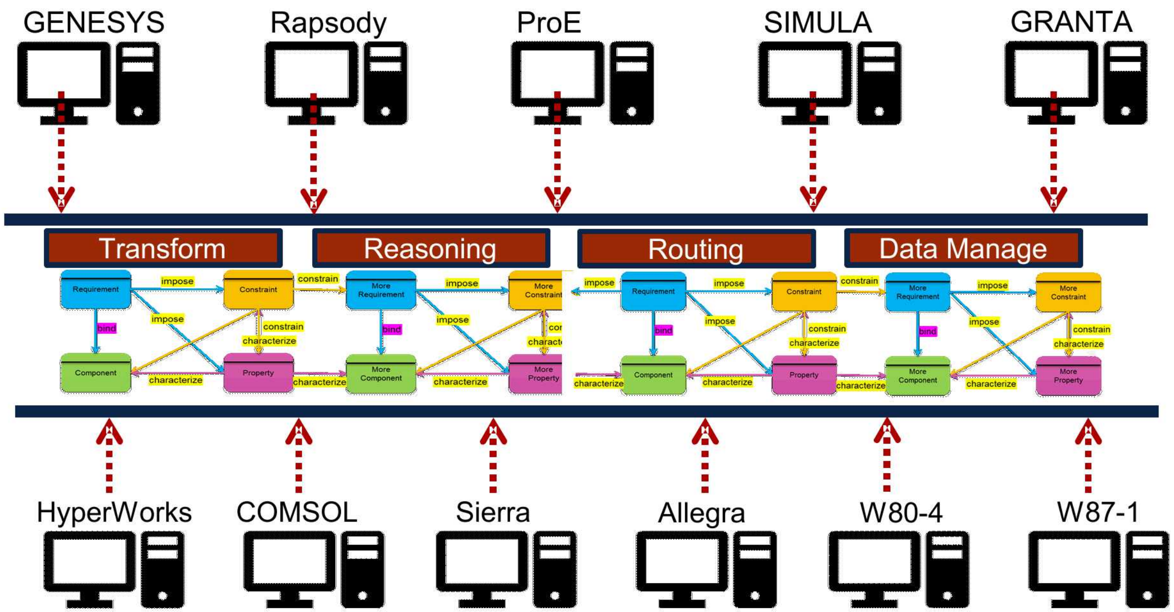


Research Challenges

Conceptualized: a demonstration of a scalable interoperability layer

Can we adapt a semantic technology to give us a scalable solution? So that we can apply reasoning rules to all models in a system





This is our objective – a scalable solution

scalable to 1,000s of engineering models

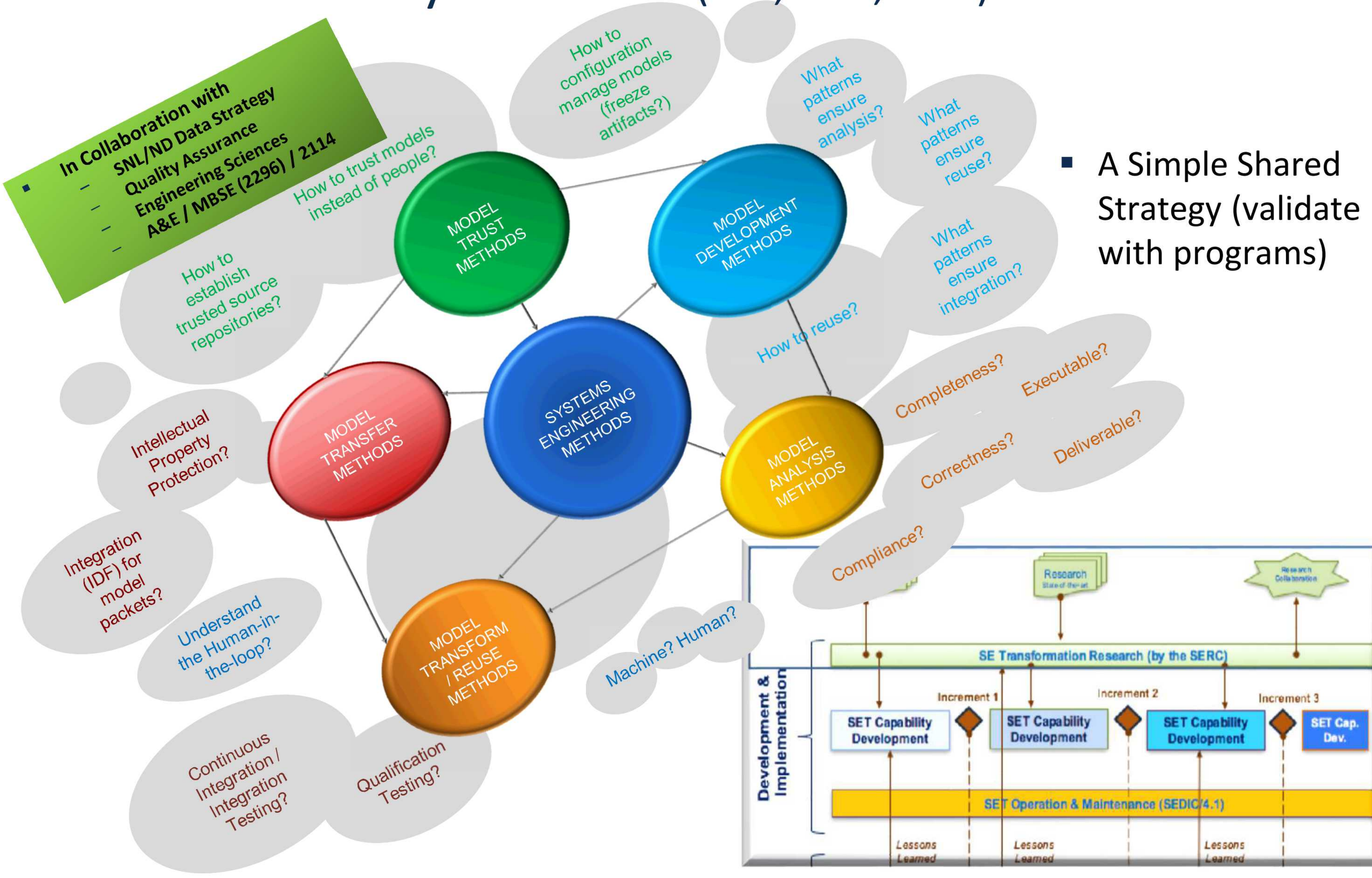
- With little or no human involvement

This is a point-point solution,

Where each point is manually interfaced by a human. Imagine doing this for 1,000 models

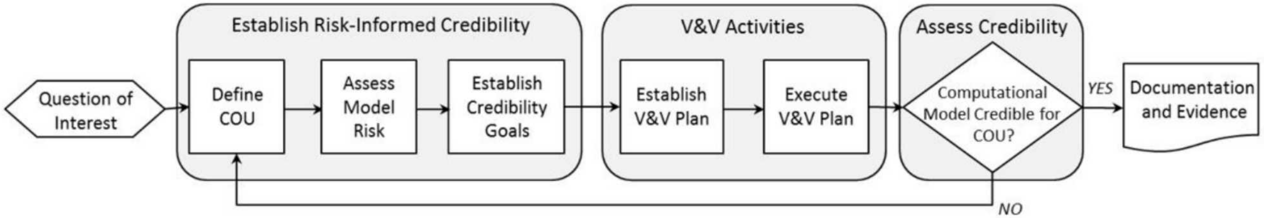
Model Credibility and Trust (CM, NTK, HMI)

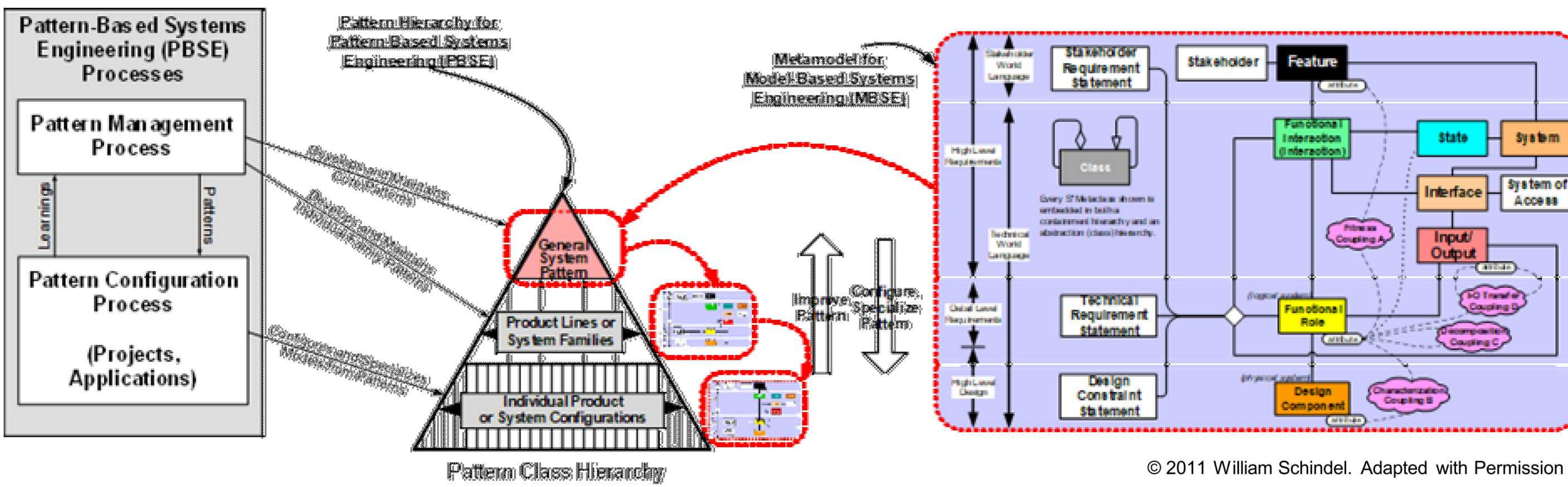
- A Simple Shared Strategy (validate with programs)



How do we trust a digital system model?

What if we automated the validation (VVUQ) of new models to known patterns using augmented intelligence rules?





Bill Schindel has proposed the creation of patterns formulated in a Pattern-Based-Systems-Engineering S*Model – similar to how a modular architecture library of design models is implemented. A pattern catalog and processes for pattern capture are developed to manage the verification, validation, and uncertainty quantification (VVUQ-regression test and analyses), reuse, and integration of model patterns based on a shared ontology.
– Analyzing for completeness, traceability, compliance, recognition, reusability, and more.