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# Model-based representation of new insights from historical cases

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# Outline

- Acquisition Problem
- Research Objective
- Approach
  - Methodology, Processes and Tools
  - Ontologies
  - Smart Experiential Dashboard
- Exemplar Application
- Expected Research Outcomes

# Defense Acquisition Problem

- Defense acquisition is under perpetual review and reform by the DoD and Congress
  - numerous studies performed
  - textbooks, regulations, handbooks, and guidelines written
- Today practitioners (especially new program managers and engineers) get overwhelmed with acquisition problems
- In defense acquisition it takes several years for program managers and systems engineers to mature
- In today's world of increasingly compressed timelines, there is seldom enough time to gain the depth and breadth of experience needed
- This recognition provides the motivation to explore model-based and historical cases-driven approach to accelerate experience accumulation on the part of new and transferring program managers

# Limitations of Acquisition Case Studies

- Case study information is non-generalizable for a wider audience
  - These are limited to a single individual, group, or event
- Subjectivity in a case study can be a concern
  - The researcher's bias may influence the case study and its results.
- The volume of the data, coupled with time limitations within the available resources, may impact the depth of analysis
- A historical case only captures a static set of assumptions and characteristics of the acquisition for that specific context of the case study
  - Resulting in a fixed set of outcomes
- Understanding sensitivities of and tradeoffs between critical factors in system design and operation can contribute new insights and accelerate training of new or inexperienced program managers

# Research Objective

- Develop a model-based approach for exploring historical cases to accelerate learning on the part of new/inexperienced acquisition program managers and system engineers

*Note: I want to sincerely acknowledge the contributions of Dr. Barry Boehm who provided guidance and was a member of my dissertation committee.*

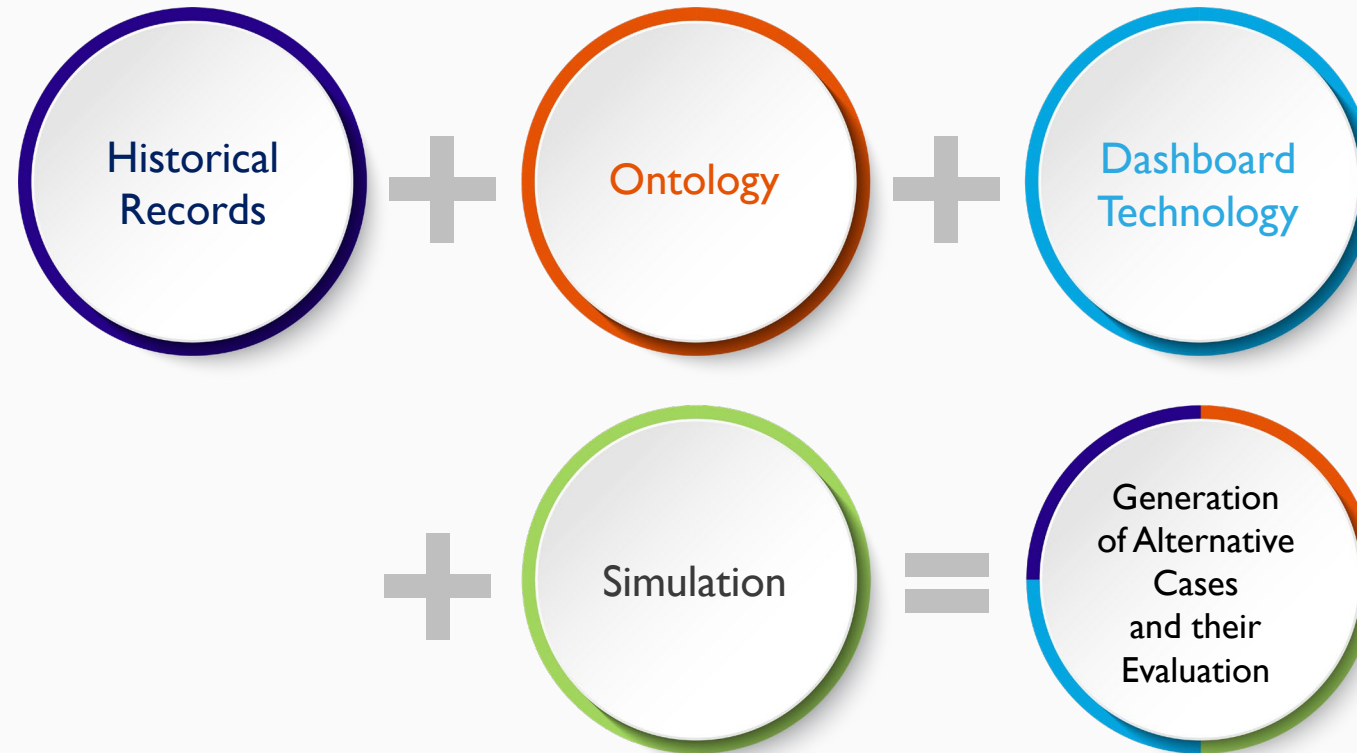
*This research leverages his contributions in systems engineering parametric cost modeling.*

# How Can A Model-Based Approach Help?

- Represent the case entities in an ontology
  - Technical system characteristics
  - Programmatics such as cost and schedule
  - Technology maturity and risk
  - Socio-political environment
- Establish relationships between the entities
- Perturb the conditions of these entities to conduct what-if sensitivities
- Capture new outcomes from analyses
- Result is expanded value from the original case
- Outcomes can be stored in a database for query and retrieval

# Methodology Overview

Leveraging  
previous  
research in:



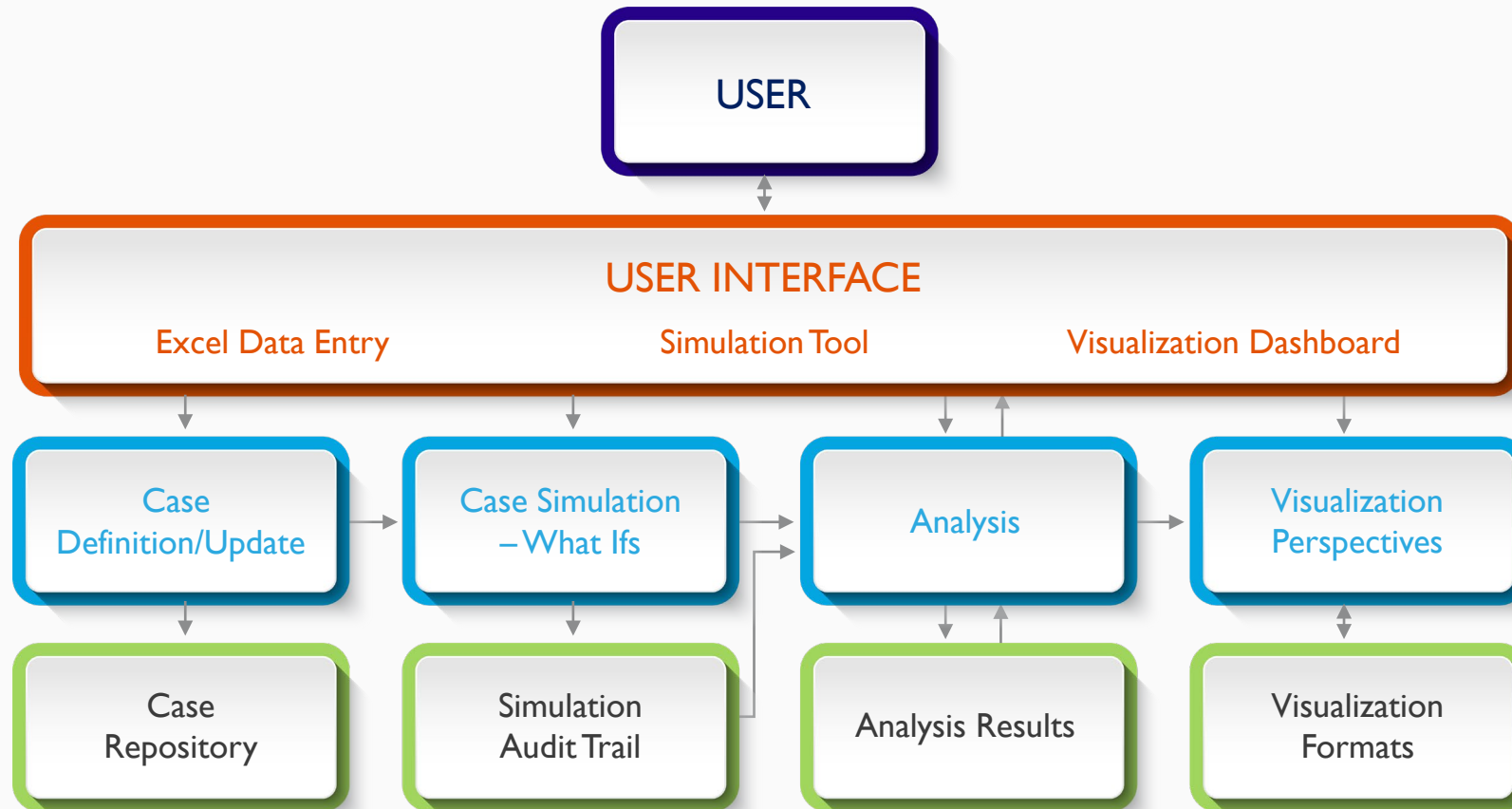
# Approach: Methodology Overview

- Define use cases of interest to stakeholders for a particular system of interest (Sol)
- Combine dashboard technology and ontology-enabled case representation with sensitivity and cost analyses
  - Dashboard for visualization
  - Techniques for alternative generation and selection
  - Historical case studies provide context for proof-of-feasibility
  - Data analytics to show impact of data on sensitivity analysis (simulations)
- Demonstrate research advances (i.e., new methods) through a representative case study and summarize findings and potential impact on stakeholder insights

# Approach: Methodology Details

- Develop scenarios and use cases from historical cases with adequate documentation
- Develop ontology to capture key concepts and relationships in scenarios
- Develop case scenario visualization interface using a smart dashboard
- Employ ontology to define dashboard elements
- Use open-source components and unclassified data
- Perform what if analysis of changes in case parameters (e.g., assumptions, decisions, technologies, regulations) to assess impact on outcomes
- Visualize sensitivities of key parameters that bear on decision making
- Capture findings in a metadata tagged lessons learned database

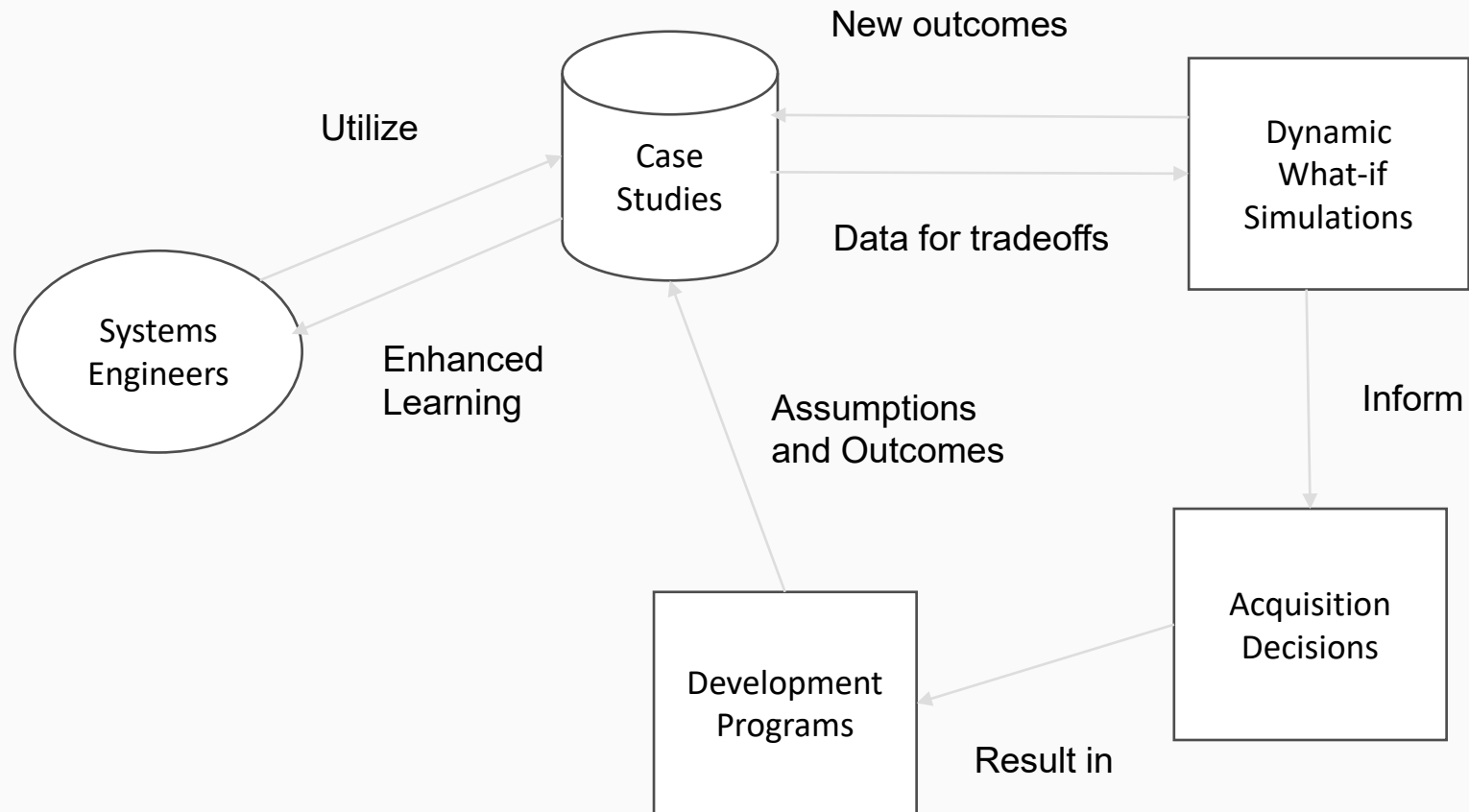
# What-If Case Analysis System Concept



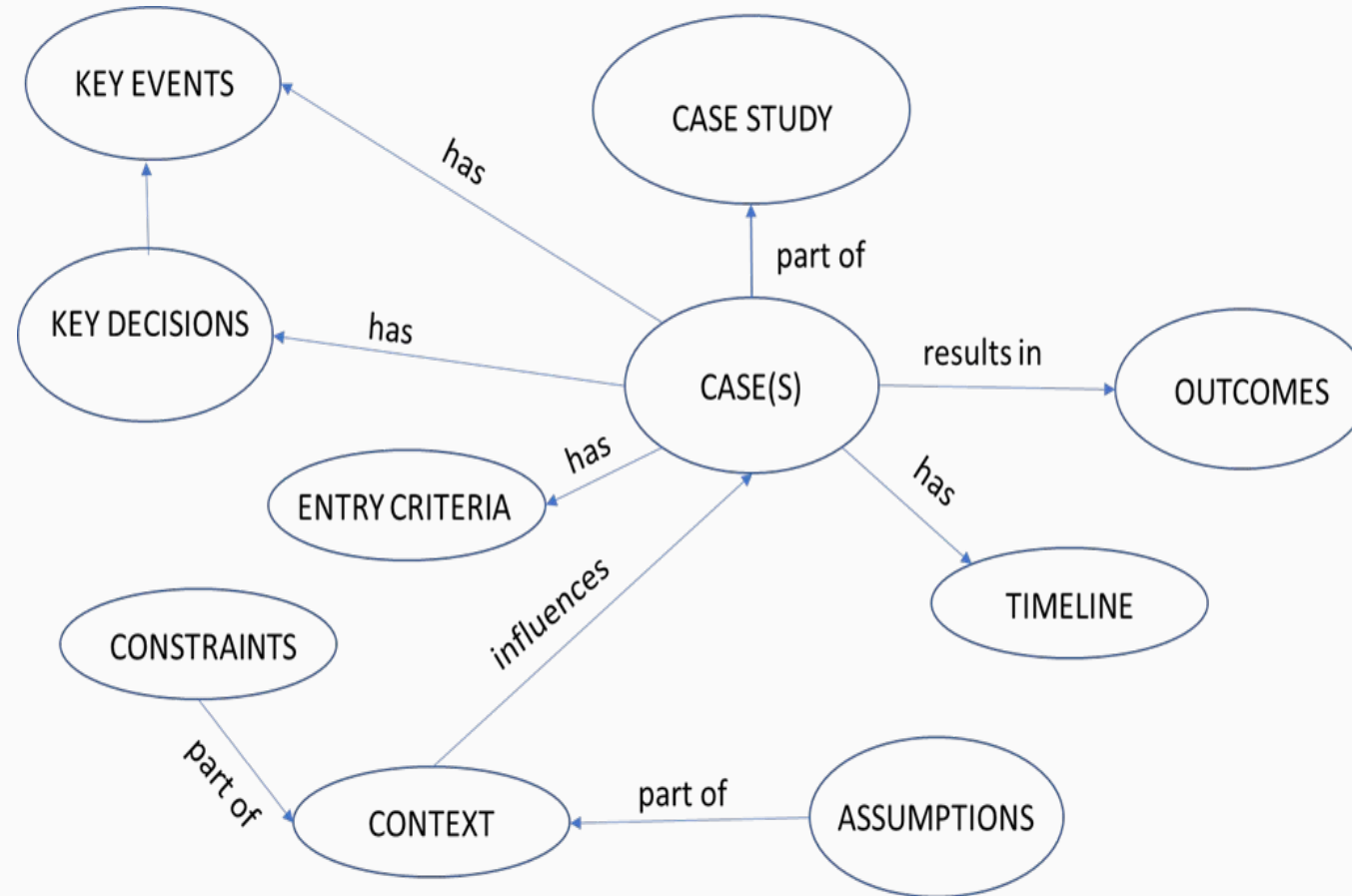
# Role of Ontology in SE/SA

- Ontology is increasingly used in systems engineering/systems architecting to circumscribe the domain and to capture key concepts and relationship in the domain
- Ontology elements can also serve as metadata for cases thereby facilitating case retrieval from a database of case studies
- Ontologies enable identification of entities and their relationships and the rules that govern them
- Ontologies facilitate reasoning and collaboration by enforcing common terminology
  - This common terminology helps with a shared understanding of terms among stakeholders
- Responses to user queries can be stored with the queries for future use
- Allows retrieval of domain knowledge such as key events, key decisions, entry criteria, and timeline; and to explicate domain assumptions and constraints

# Case Study Ontology for Acquisition



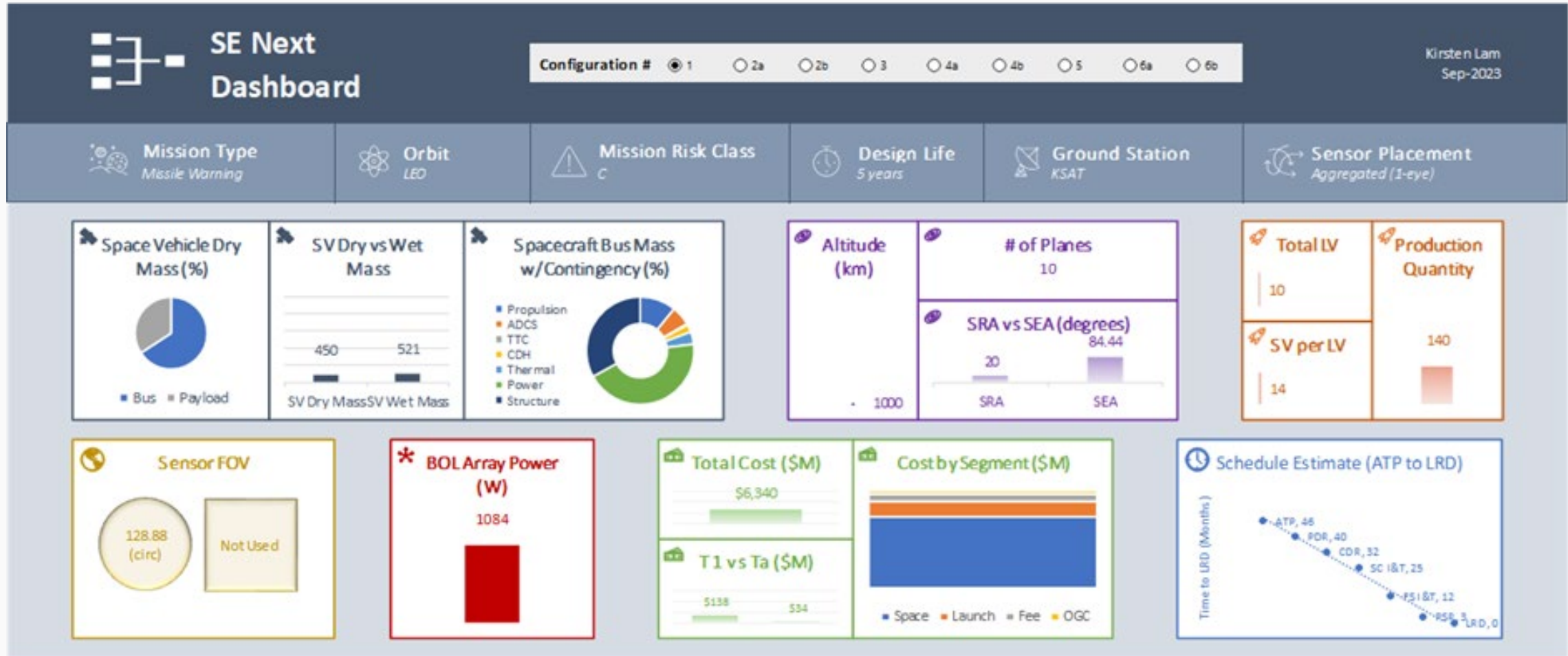
# Case Ontology for Model-Based Analysis



# Smart Experiential Dashboard (based on Madni et al., 2016)

- Capture and visualize simulation execution and sensitivity of outcomes to key case parameters
- Provides a compact and structured way to visualize multidimensional problem space
- Need to visualize the decisions and assumptions that went into a specific case and impact of changes to these assumptions and decisions on outcomes
- Illuminating sensitivities to changes in parameters in case studies can potentially provide valuable insights for acquisition managers, system architects, and systems engineers as they explore future decisions

# Dashboard-Based Representation of Historical Cases



# Exemplar Application: Smallsat

- My research is focused on the use of smallsats and cubesats for augmenting space system missions
- Currently, in support of national security space, mission capabilities are being augmented by smaller satellites (smallsats) due to their
  - Shorter acquisition and development schedules
  - Lower cost as compared with many of the existing programs of record
- In addition to smallsats, cubesats are also being utilized as prototypes to demonstrate new technologies on an exceeding responsive timeline
- In this research, we use a notional smallsat example to demonstrate the use and convey the value proposition of using “dynamic case studies” as an experience accelerator for program managers and system engineers
- The value proposition stems from the fact that model-based case studies can enable what-if exploration of decisions and assumptions made

# Exemplar Use Cases

- Can the development of the small sat (with a proposed design) meet the schedule to support the responsive space objective?
- How does an increase/decrease in performance capability of the small sat design affect mission augmentation requirements?
- How does an increase/decrease in program funding for the small sat program affect the schedule for delivery of capability?
- Does a projected level of Technology Readiness Level (TRL) on a timeline affect the desired outcome for performance?
- Does a required TRL to achieve performance objective affect the planned schedule for the small sat delivery?
- How does increasing/decreasing the level of design or system complexity of the small sat affect the cost or schedule?
- What is the impact of the socio-political complexity on meeting the cost or schedule objectives?

# Expected Research Outcomes

- Framework and methodology for what-if analysis using historical cases and expert judgment
- Case study ontology that enables integration of case studies in repositories for easy search and retrieval
- Methods and processes that:
  - Analyze sensitivities and conduct tradeoffs
  - Demonstrate impact of decision and assumptions on case study outcomes
- Dashboards for visualizing models and what-if analyses

# Summary

- Historical records are an untapped source of knowledge
- Ontologies provide a convenient means to organize knowledge associated with models of cases
- Exploring case models with different assumptions can produce new insights
- New insights can accelerate learning and help decision makers in making informed, timely decisions in the systems engineering community
- Research contribution will be to the body of knowledge in MBSE, case studies, and in model-based analysis

# Thank you

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# Back Up Slides

# Selected Literature Review

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- Madni, A.M., Ontology-Aided Systems Engineering Lecture, USC SAE Program, SAE 549 Systems Architecting Course, Oct. 2019.
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# Selected Literature Review (cont.)

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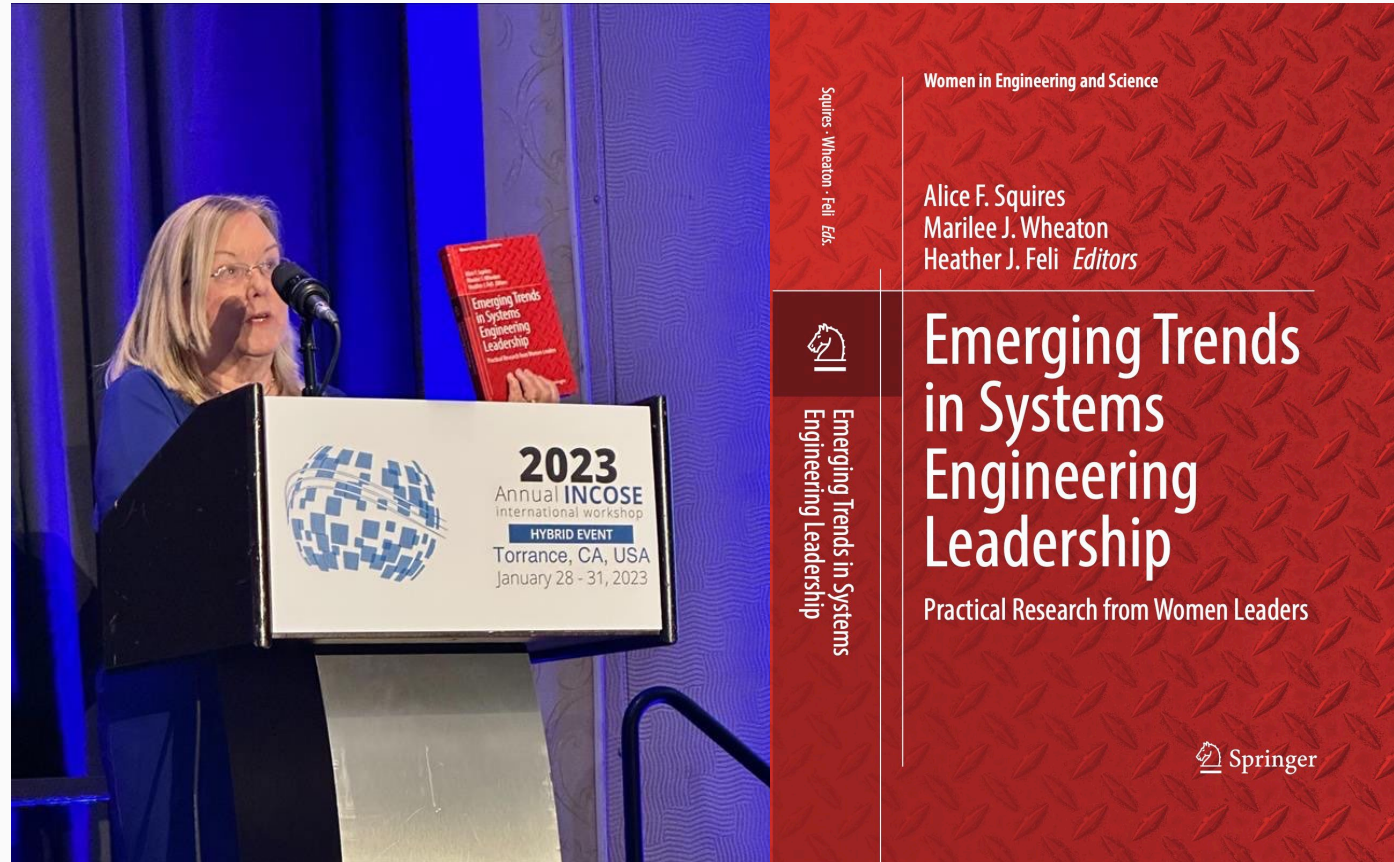
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- Pakpe, G. and Wang, G., Integration of Parametric Cost Estimation with System Architecture, INCOSE International Symposium, Aug 2018

# Selected Literature Review (cont.)

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# Springer Women in Engineering Series



<https://link.springer.com/book/10.1007/978-3-031-08950-3>

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