SYSTEMS ENGINEERING RESEARCH CENTER

USC Viterbi School of Engineering
Systems Architecting and Engineering

Modeling of Case Studies for What-if Exploration with Different Assumptions

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Outline

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Background

- Tradeoffs are integral to the engineering of complex systems
- Since tradeoffs are performed in a multidimensional space, need a way to visualize them
- Case studies usually reflect the tradeoff that went into a particular case and the resulting outcome
- However, case studies reflect a point outcome and do not capture all assumptions and decision rationale
- Illuminating key tradeoffs in case studies would be invaluable for acquisition managers and systems engineers
- This recognition has motivated this research

What is a Case Study?

- A detailed temporal record of a decision or event in which outcomes and eventual consequence are captured
- Used to illustrate a thesis, principle, or lesson
- Deficiency in Case Studies
  - Cannot explore performance boundaries or perform sensitivity analysis by perturbing specific parameters
  - Consequently unable to draw implications from case studies and inform future plans and decisions

Operational Needs

- Increasing focus on enterprise systems engineering for national security space (NSS) domain
  - —Air Force Space Command Future Architectures
  - —Space and Missile Systems (SMC) 2.0 Portfolio
  - —Collaboration between DoD and IC
- Historical case studies are a key source of information for enterprise systems engineering
- However, lessons learned are only for that one instance and outcomes
- What is needed is a way to explore the decision space and assess impact on the outcome space
- My research will directly address this important problem

Research Goals

- Research being performed at USC with primary PhD dissertation advisor, Executive Director for the SAE program, Dr. Azad M. Madni, and with Dr. Barry Boehm as a member of my dissertation committee
- Formalize representation of cases to illuminate key tradeoffs (e.g., affordability-resilience)
- Represent case study in computer-manipulable form to enable sensitivity and tradeoff analysis
- Benefits and Payoffs
  - —Greater likelihood that case studies could inform future decision making
  - —Enhance efficiencies and effectiveness of case studies to inform decision making

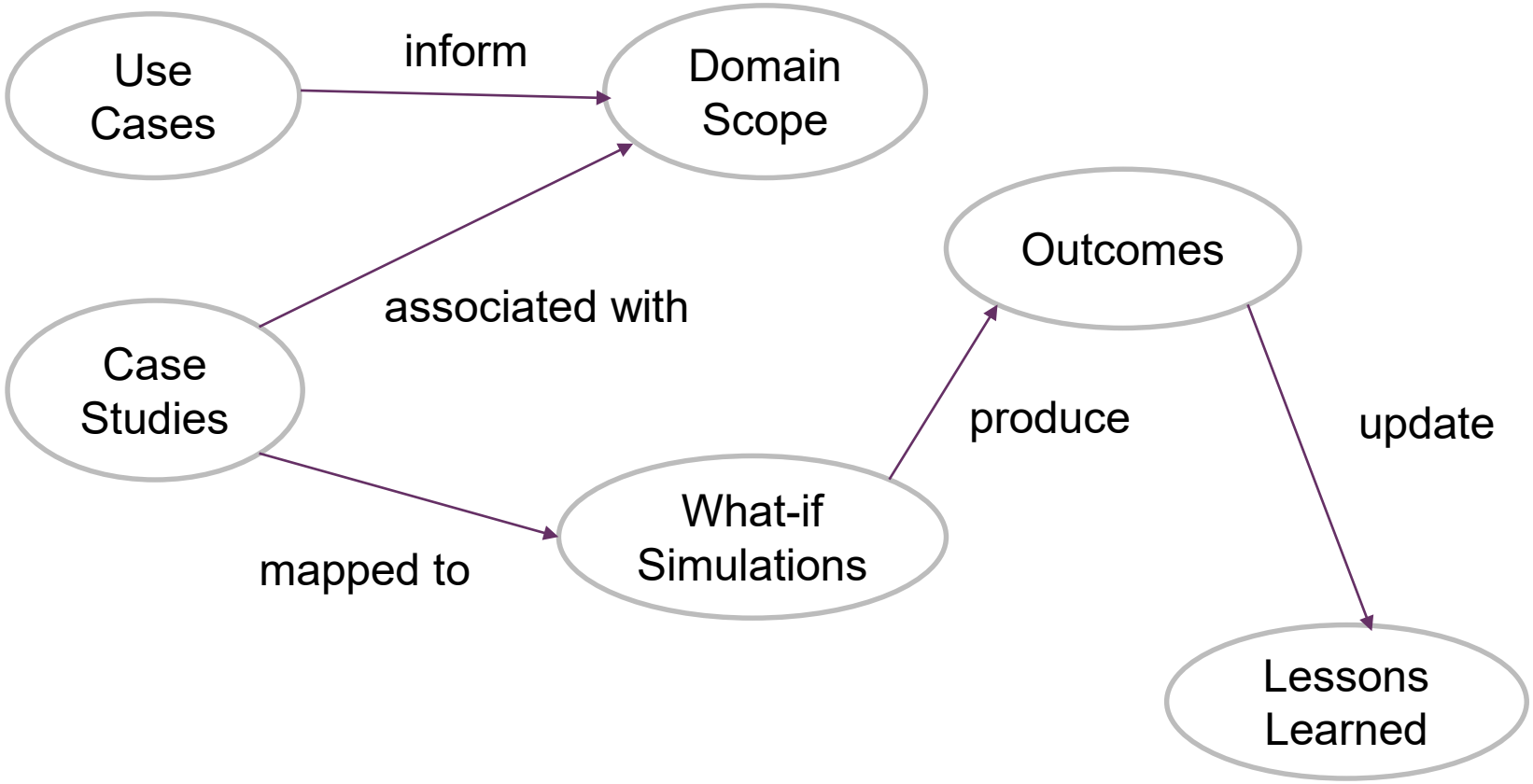
Research Contribution

- Dynamic framework for exploring decisions and outcomes in historical case studies
- Utilize static case studies and transform them into dynamic tradespace
- For example, identification of decisions in early architecture and design tradeoffs by simulating what-if use cases from existing case studies for
  - —Technology
  - —Programmatics (cost and schedule)
  - —Uncertainty and Risk

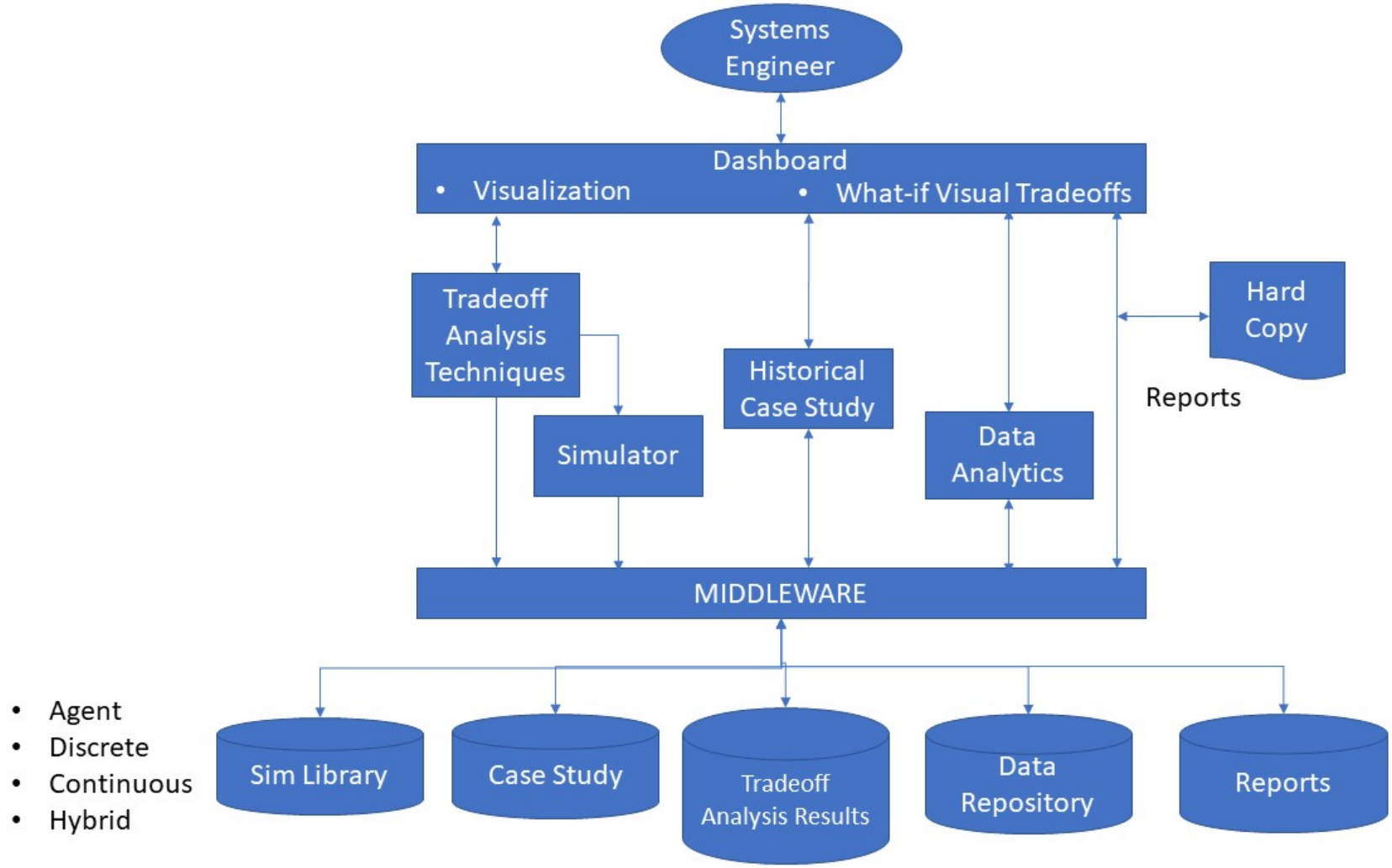
Research Approach

- Define use cases associated with system acquisition and conceptual engineering case studies
- Define domain ontology from the use cases
- Combine dashboard technology, tradeoff analysis techniques, historical case representation and data analytics
  - —Dashboard for visualization
  - —Techniques for alternative generation and selection
  - —Historical case studies provide context for demo
  - —Data analytics to show impact of data on tradeoff analysis (simulations)

Case Study Ontology



Research Architecture

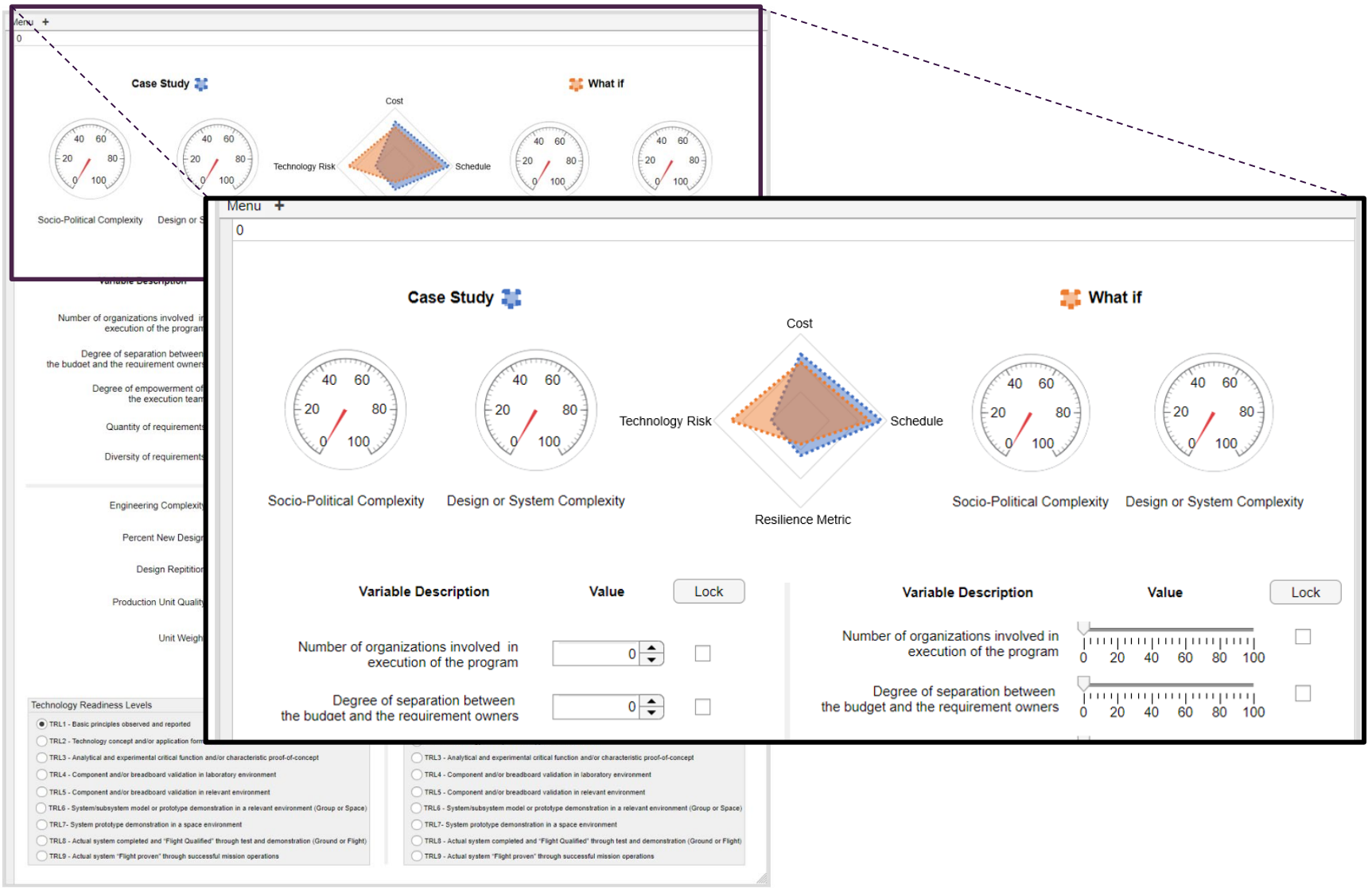


- Agent
- Discrete
- Continuous
- Hybrid

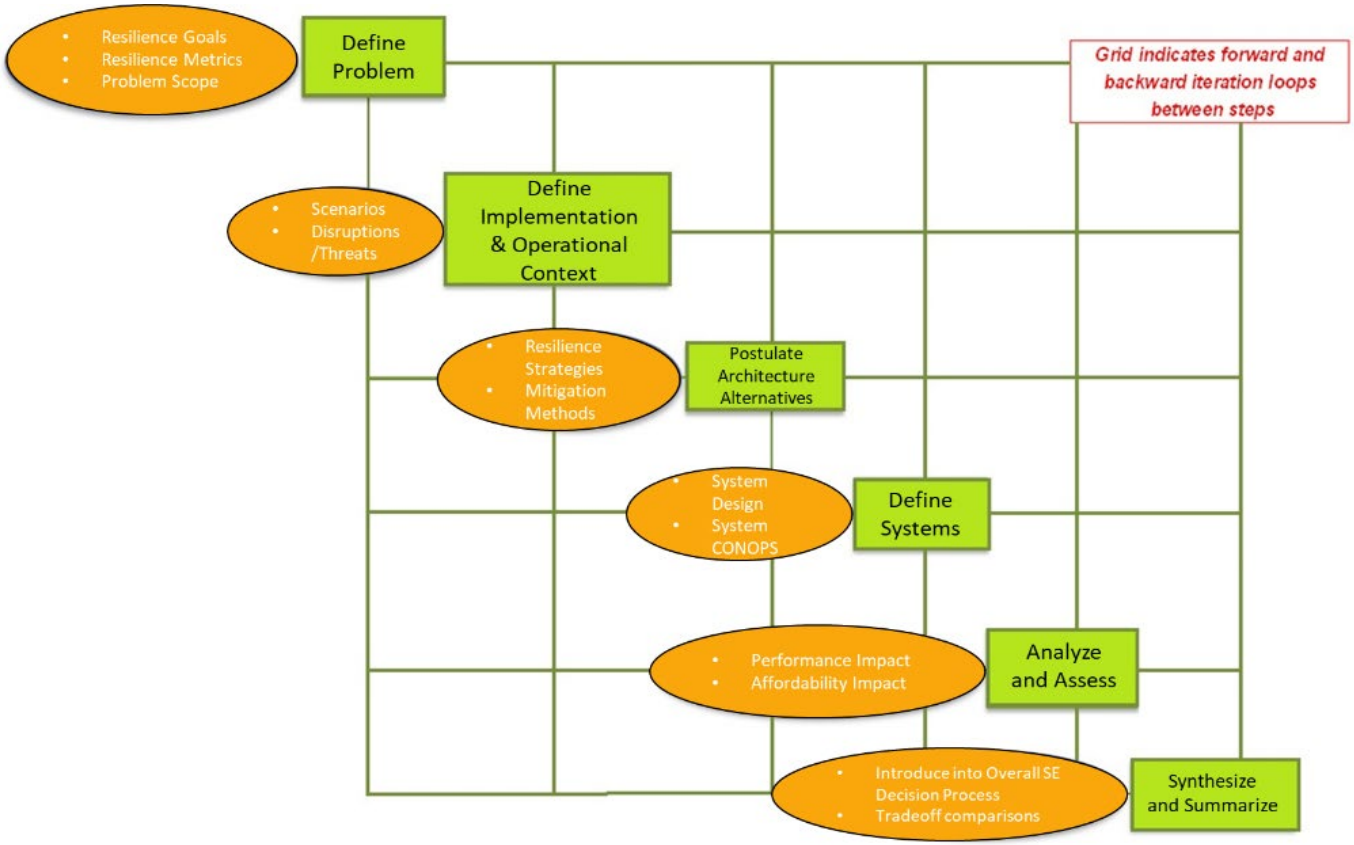
Research Methodology

- Choose an illustrative scenario and create use cases
- Specify ontology of a tradeoff case study
- Implement the ontology, scenario, and use cases in a COTS or GOTS tool
- Develop visualization interface (smart dashboard)
- Initialize simulation with selected case
- Perturb case scenario to explore decisions and outcomes space
- Use findings to update lessons learned
- Metadata tag cases and lessons for fast and easy retrieval

What-if Analysis Dashboard



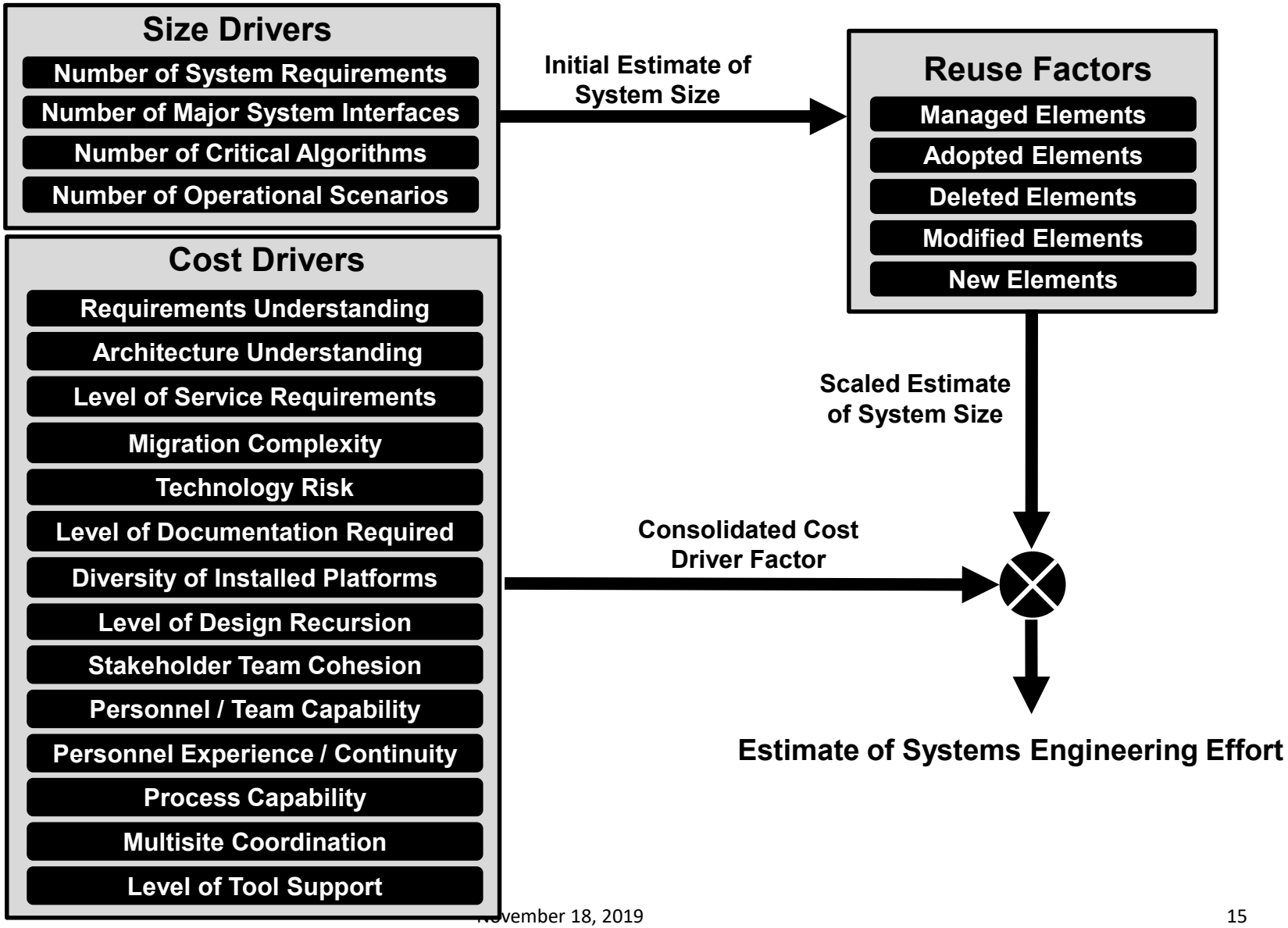
Resilient System Design Analysis and Evaluation Framework



Analysis Framework

- Analysis framework incorporates the usage of 3rd party tools such as MATLAB for algorithms, AnyLogic for simulation, and parametric models for cost estimating
- There is strong evidence for the link between systems engineering effort and program cost
  - USC CSSE development of COSYSMO as a parametric model for estimating systems engineering costs
  - COSYSMO extended by Cole and Roedler at Lockheed Martin to use as a proxy for systems cost estimation
- This parametric approach serves as powerful affordability analysis method supporting rapid-turnaround analysis of tradeoffs as part of the simulation

Exemplar Cost Drivers

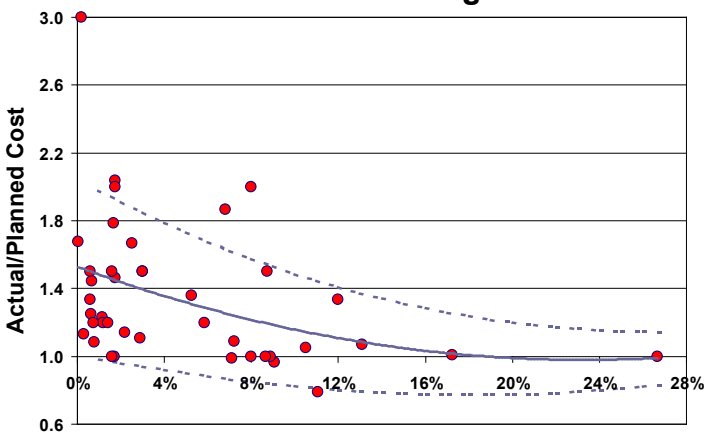


COSYSMO as a Proxy for Systems Cost

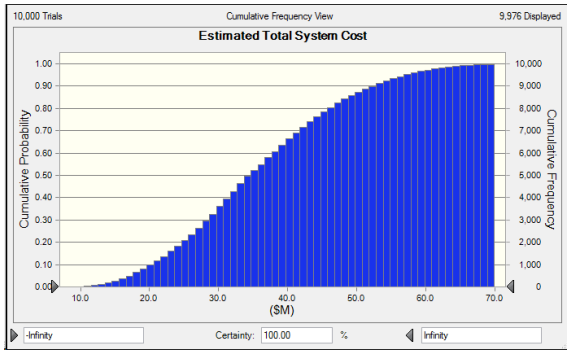
- **Size Drivers (Problem Space)**
  - Customer Requirements
  - System Interfaces
  - Major Algorithms
  - Operational Scenarios
- **Complexity Drivers (Problem/Solution)**
  - Requirements Understanding
  - Architecture Understanding
  - Level of Service Requirements
  - Migration Complexity
  - Technology Risk
  - Documentation Needs
  - Installations/Platform Diversity
  - Levels of Recursion in the Design
  - Stakeholder Team Cohesion
  - Personnel/Team Capability
  - Personnel Experience/Continuity
  - Process Capability
  - Multisite Coordination
  - Tool Support
- **Reuse Factors (Solution Space)**
  - New
  - Modified
  - Deleted
  - Adopted
  - Managed

SE Effort is an estimator for total system cost…but it is a biased estimator

Estimator Bias Function is Based on the Well-Established Relationship Between SE Effort and Overall Program Effort



SE Effort = SE Quality * SE Cost/Actual Cost



Estimation of Total System Cost

Source: Reggie Cole and Garry Roedler, *COSYSMO Extension as a Proxy Systems Cost Estimation*, Presentation at CSSE Annual Research Review, April 2014

Summary

- Formalizing the representation of cases associated with key tradeoffs, such as affordability–resilience, provides benefits to decision making by extending lessons learned
- Having a computer-manipulable representative of cases will enable both sensitivity and tradeoff analysis, thereby increasing the predictive power of affordability studies
- Tradeoff exploration becomes possible through what-if simulations derived from case studies
- Superior decision making on behalf of the national security space domain would benefit from such a capability

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