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

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Outline

• Background
• Research Goals
• Research Approach
• Analysis Framework
• Summary
• References
• 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

- **Use Cases** inform **Domain Scope**

- **Case Studies** associated with **What-if Simulations** mapped to

- **Outcomes** produce **Lessons Learned** updated
Research Architecture

- **Systems Engineer**
  - Dashboard
    - Visualization
    - What-if Visual Tradeoffs
  - Tradeoff Analysis Techniques
    - Simulator
  - Historical Case Study
  - Data Analytics
    - Hard Copy
    - Reports

**Middleware**

- Agent
- Discrete
- Continuous
- Hybrid

- Sim Library
- Case Study
- Tradeoff Analysis Results
- Data Repository
- Reports
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

- Resilience Goals
- Resilience Metrics
- Problem Scope

Define Problem

- Scenarios
- Disruptions/Threats

Define Implementation & Operational Context

- Resilience Strategies
- Mitigation Methods

Postulate Architecture Alternatives

Define Systems

- System Design
- System CONOPS

Analyze and Assess

- Performance Impact
- Affordability Impact

Synthesize and Summarize

- Introduce into Overall SE Decision Process
- Tradeoff comparisons

Grid indicates forward and backward iteration loops between steps
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

Size Drivers
- Number of System Requirements
- Number of Major System Interfaces
- Number of Critical Algorithms
- Number of Operational Scenarios

Cost Drivers
- Requirements Understanding
- Architecture Understanding
- Level of Service Requirements
- Migration Complexity
- Technology Risk
- Level of Documentation Required
- Diversity of Installed Platforms
- Level of Design Recursion
- Stakeholder Team Cohesion
- Personnel / Team Capability
- Personnel Experience / Continuity
- Process Capability
- Multisite Coordination
- Level of Tool Support

Reuse Factors
- Managed Elements
- Adopted Elements
- Deleted Elements
- Modified Elements
- New Elements

Initial Estimate of System Size
Scaled Estimate of System Size
Consolidated Cost Driver Factor
Estimate of Systems Engineering Effort
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

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.
References