

System Development and Risk Propagation in Systems-of-Systems

Muharrem Mane

Email: mane@purdue.edu

Daniel DeLaurentis

Email: ddelaure@purdue.edu

Sponsor: NPS Acquisition Research Program

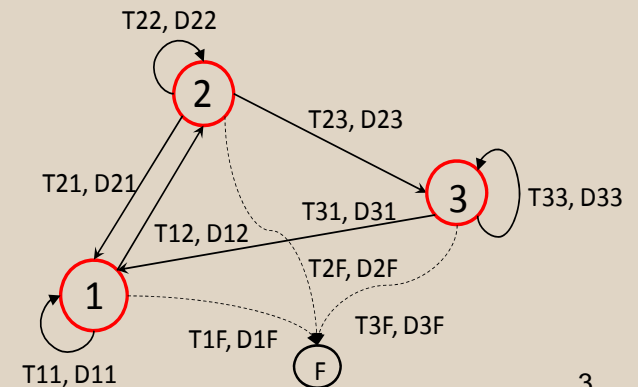
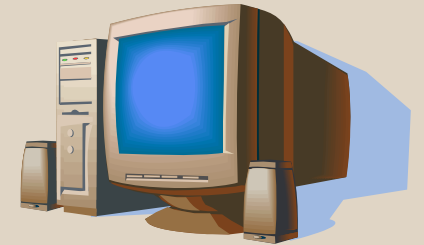
Research Questions

- How do system-specific characteristics impact the successful development of systems of systems for capability-based acquisition?
- How do system interdependencies impact the development process?
 - How do disruptions propagate in complex networks of interdependent systems?
 - How can we quantify the cascading effects of development risk?
- Objective: Answers to these questions can increase the probability of success in systems of systems development

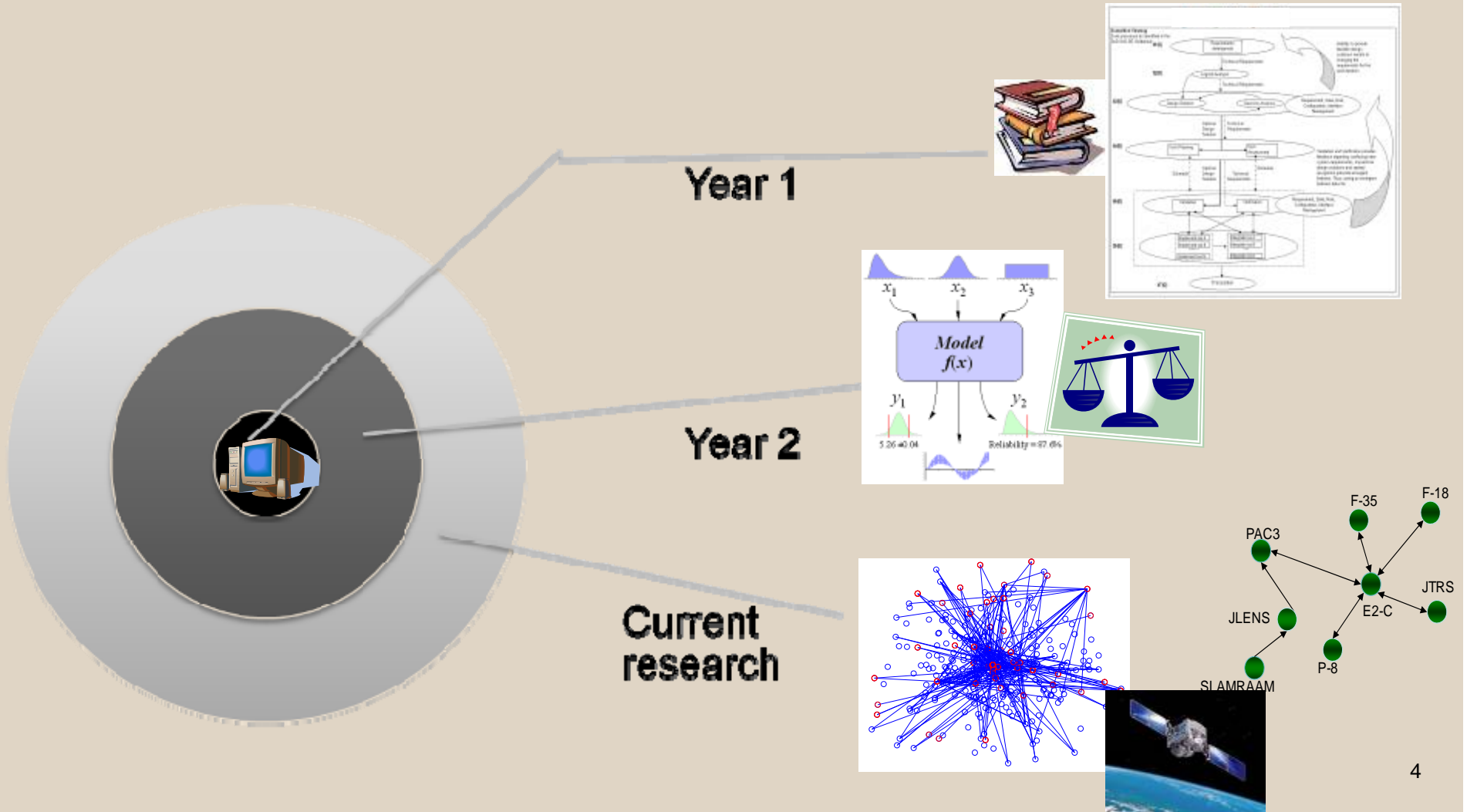
Methods of Approach

- Simulation Approach
 - Developing Computational Exploratory Model (CEM)
 - Discrete-event, stochastic simulation based on steps in DoD SoS SE Guide

- Analytical Approach
 - Based on probability and network theory
 - Analysis of expected delay propagation for arbitrary SoS network configurations



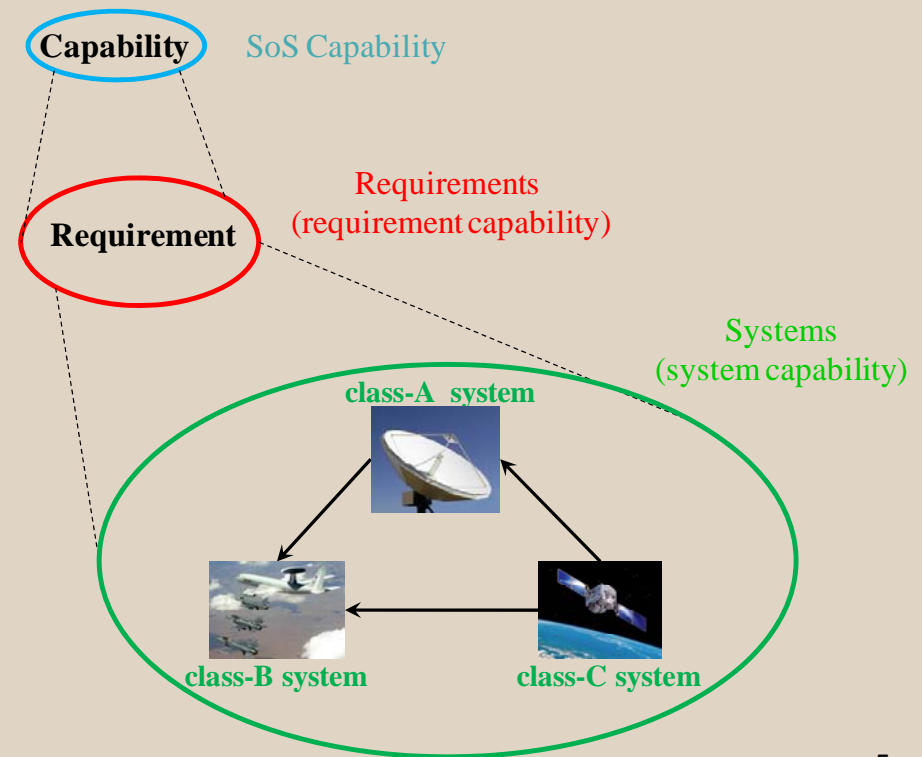
CEM Development via NPS Acquisition Research Program Grants ('08-present)



Current Research Efforts

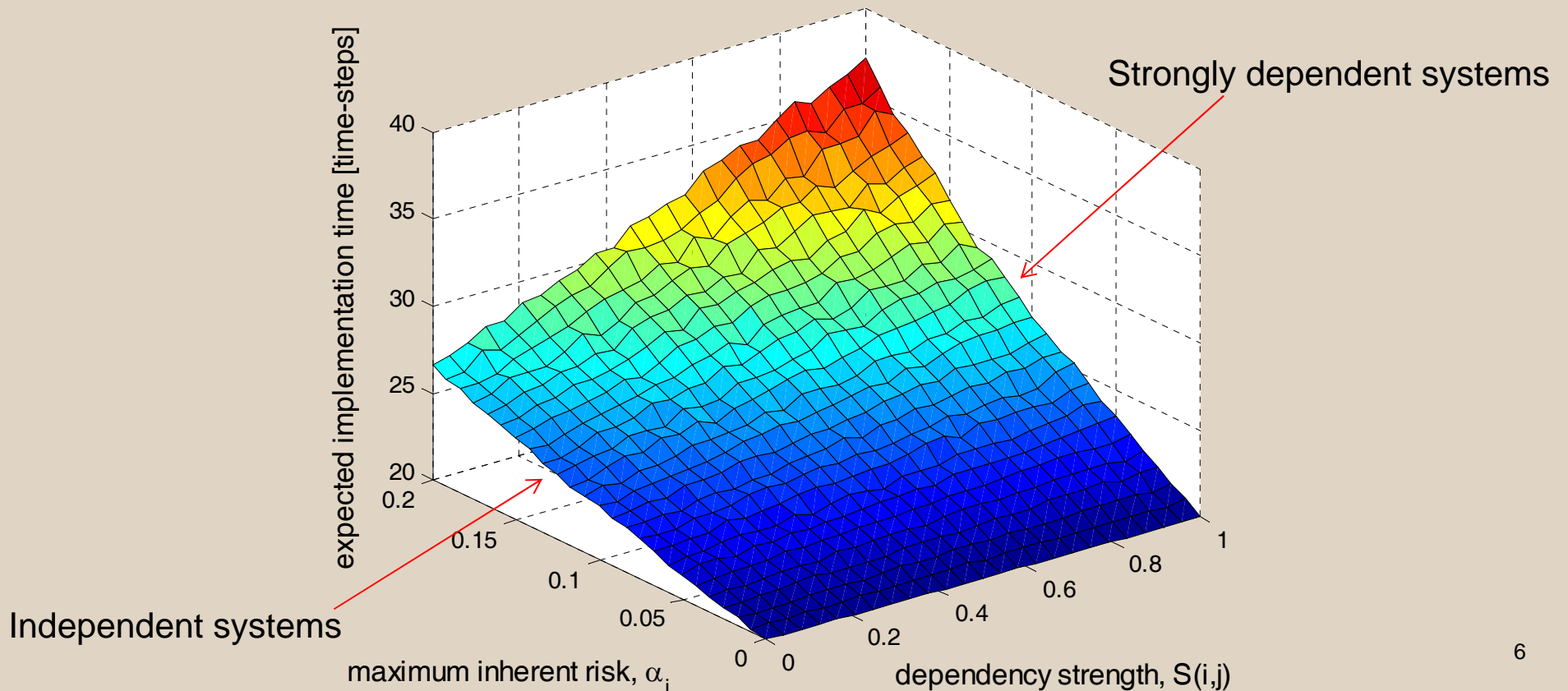
- System risk (R_{sys}) as a function of system readiness-level (m)
 - Similar to TRL metric and SRL metric proposed by Sauser et al.
- SoS risk a function of system risk and topology and strength of system interdependencies
 - Disruptions propagate to dependent systems
 - Cascading effects of disruptions captured

$$R_{sys}(i, r) = \alpha_i (1 - m(i, r))^{\beta_i}$$



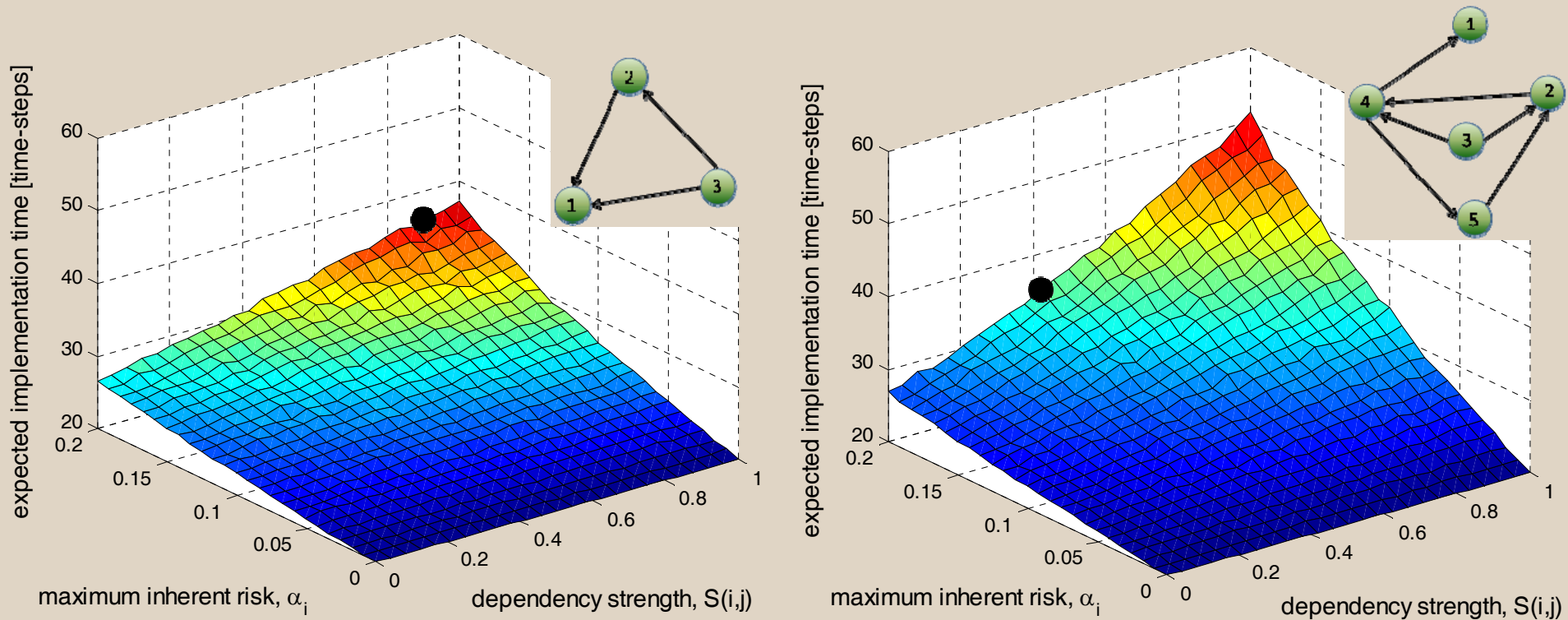
System Risk and Interdependencies

- Candidate families of systems can have different combinations of system-risk and interdependency strengths
 - These characteristics have different impact on development success



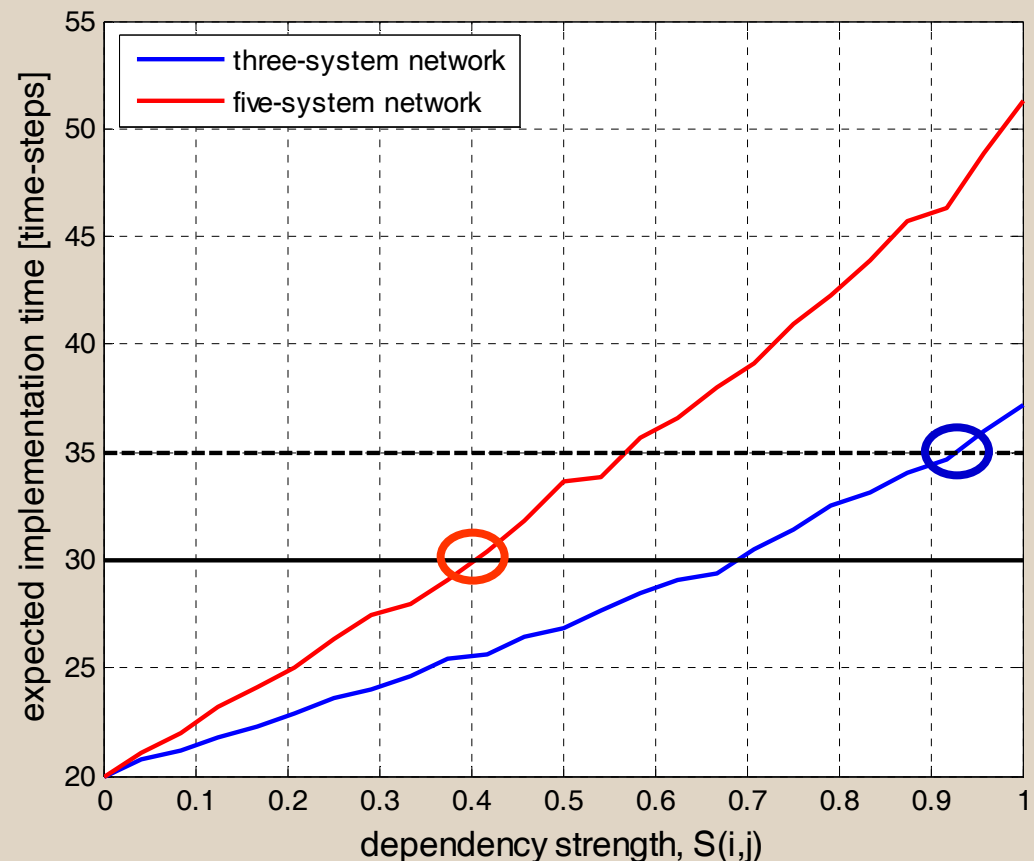
Comparison of Alternatives

- What effect does the number of systems and interdependencies have on development time?
 - If candidate systems can provide same capability-level, which one should be favored?



Observations

- Five-system SoS has largest completion time (regardless of dependency strength)
 - Different dependency strengths can still lead to faster development
- Number of systems and system-risk alone insufficient to describe the risk profile of a SoS
 - Strength of interdependencies is important network characteristic

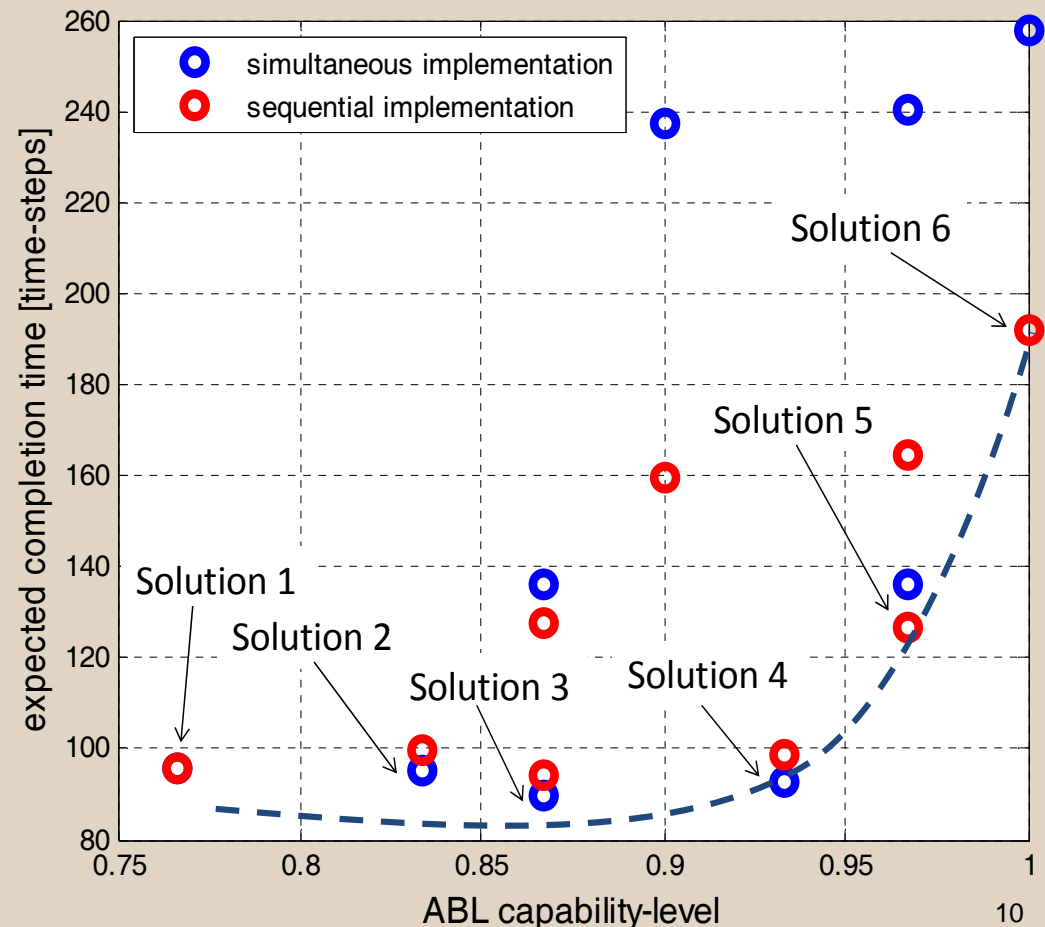


Reflections on CEM

- Exploratory model helps identify markers of failure and success
- Understand the system dynamics so that a motivator for PMs is identified
- Understand cascading effects of risk and requirement changes

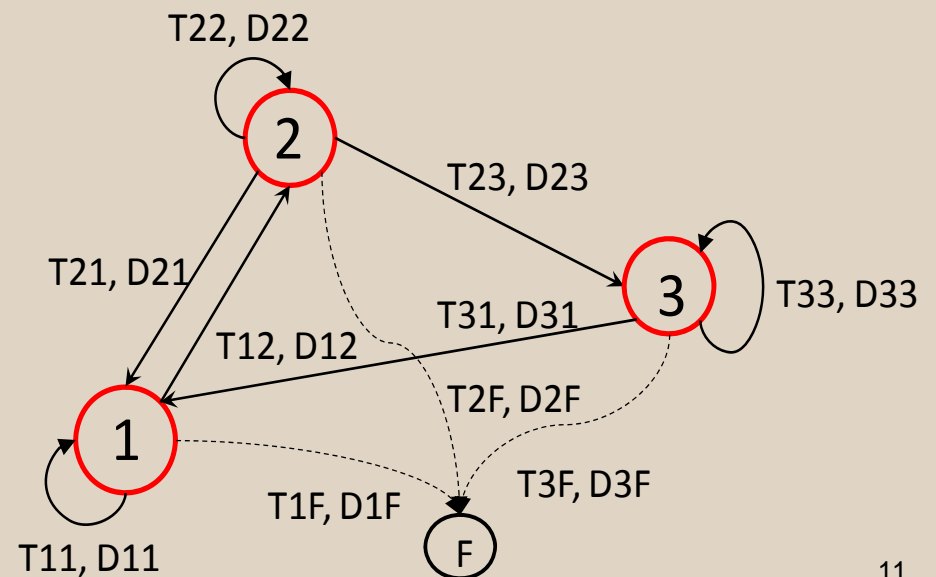
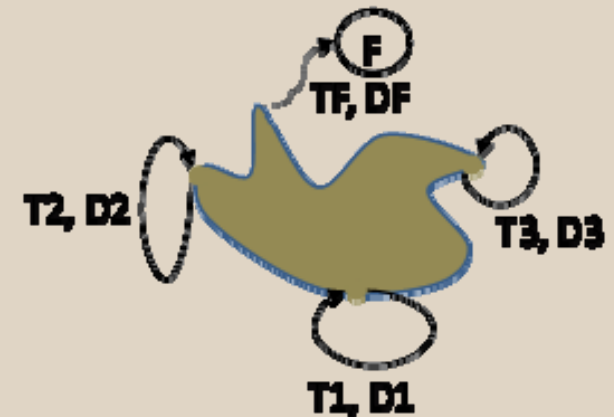
Balancing Capability Potential and Risk Among Alternatives

- Added rudimentary capability estimation to the CEM
- Enable tradeoff studies between capability and development time
- Examines a Pareto frontier for alternate configurations of an Airborne Laser Platform used in missile defense applications



Analytical Approach

- Based on network and probability theory
- Capture and quantify the cascading effect of risk
 - Delay propagation as a metric for comparing the performance of SoS networks
- Enable the design of networks that reduce (minimize) impact of risk



Ongoing/Future Work

- Analytical model for delay propagation
- Capability-module
- Tradeoff between development time and capability
- Dynamic time-scales
- Ongoing data search to test the CEM

Discussion

Back-Up Slides

System Risk and Interdependencies

- Candidate families of systems can have different combinations of system-risk and interdependency strengths
 - These characteristics have different impact on development success

