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Monterey, California. Naval Postgraduate School

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# **System Development and Risk Propagation in Systems-of-Systems**

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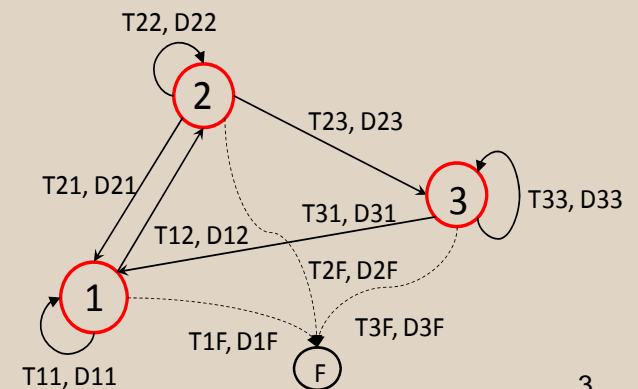
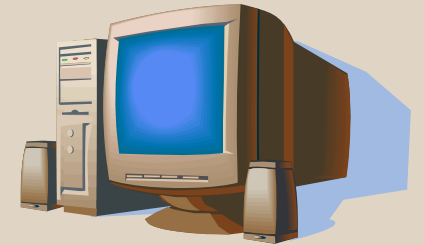
**Sponsor: NPS Acquisition Research Program**

## Research Questions

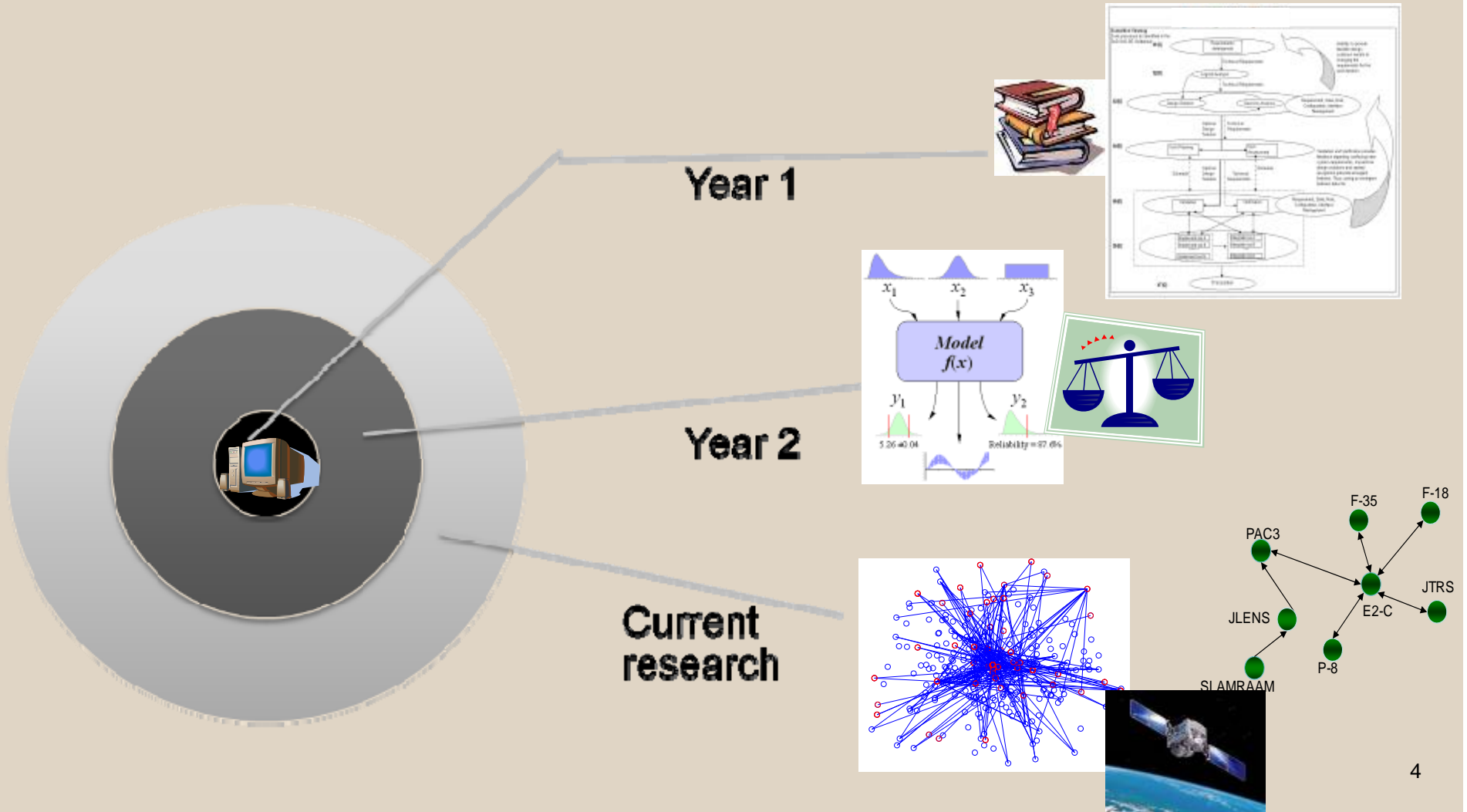
- How do system-specific characteristics impact the successful development of systems of systems for capability-based acquisition?
- How do system interdependencies impact the development process?
  - How do disruptions propagate in complex networks of interdependent systems?
  - How can we quantify 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



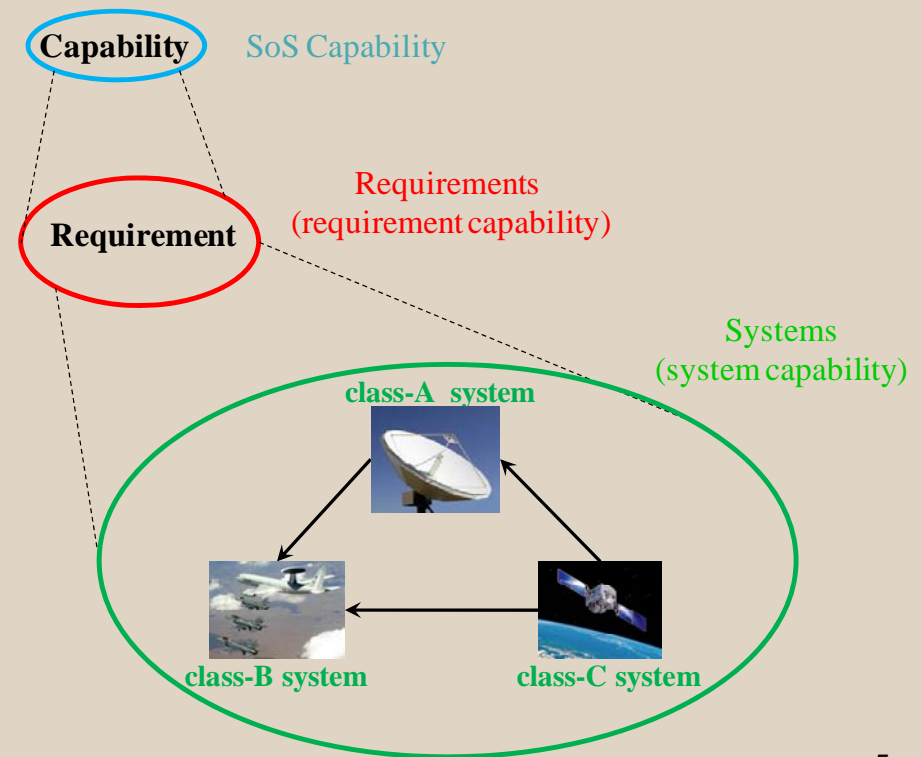
# CEM Development via NPS Acquisition Research Program Grants ('08-present)



## Current Research Efforts

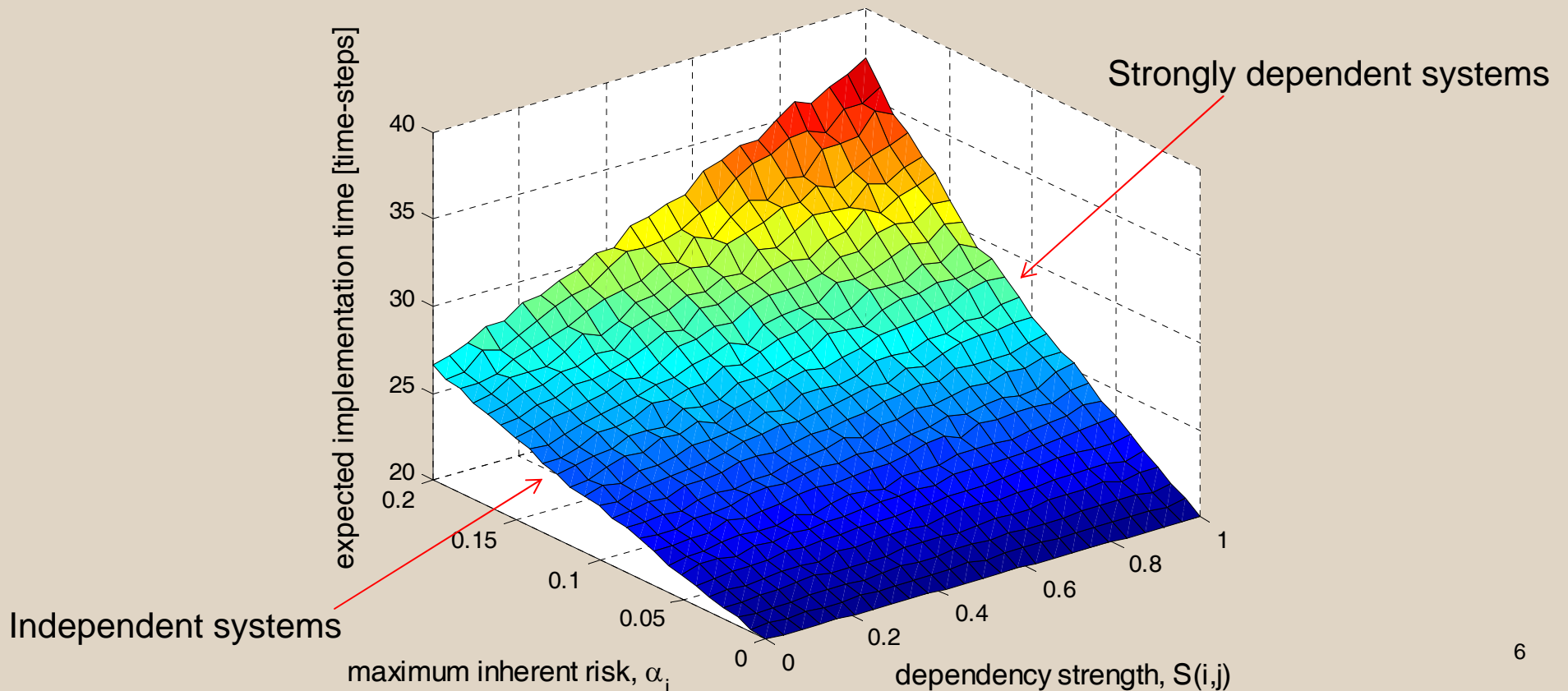
- System risk ( $R_{sys}$ ) as a function of system readiness-level ( $m$ )
  - Similar to TRL metric and SRL metric proposed by Sauser et al.
- SoS risk a function of system risk and topology and strength of system interdependencies
  - Disruptions propagate to dependent systems
  - Cascading effects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

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



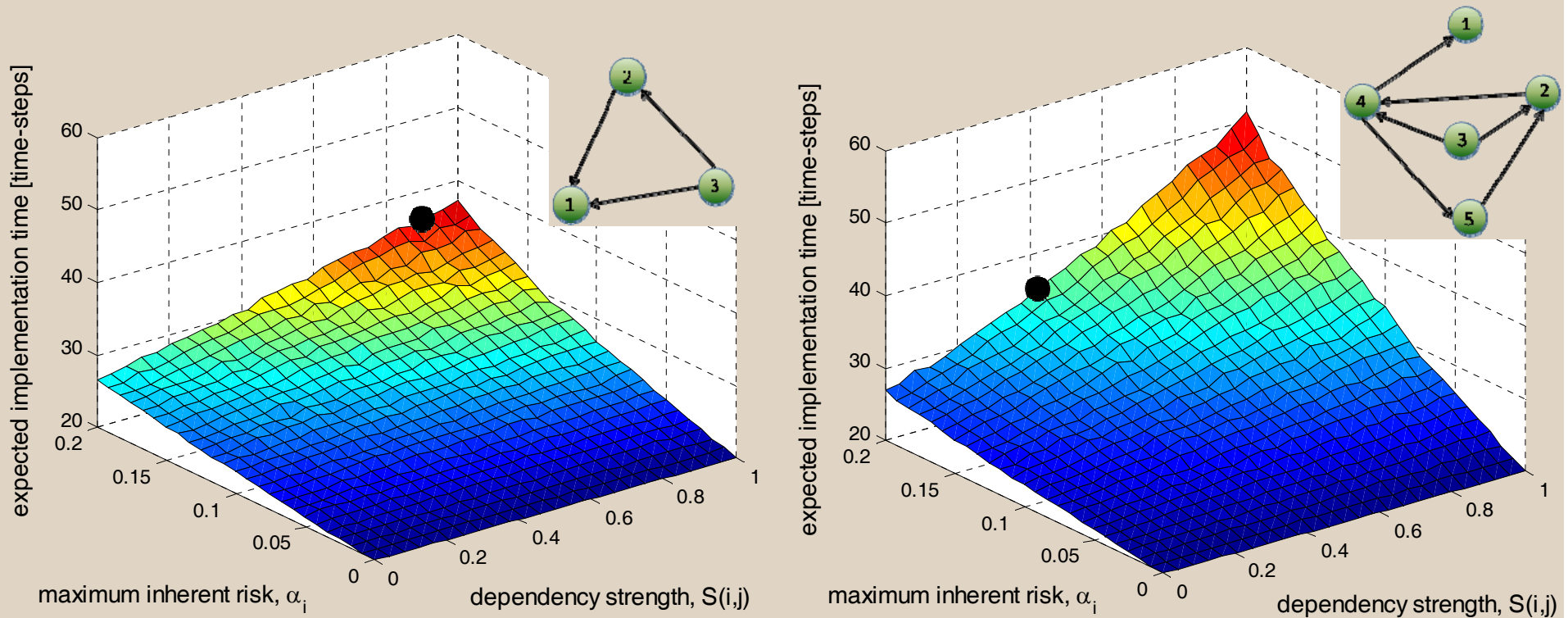
# System Risk and Interdependencies

- 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

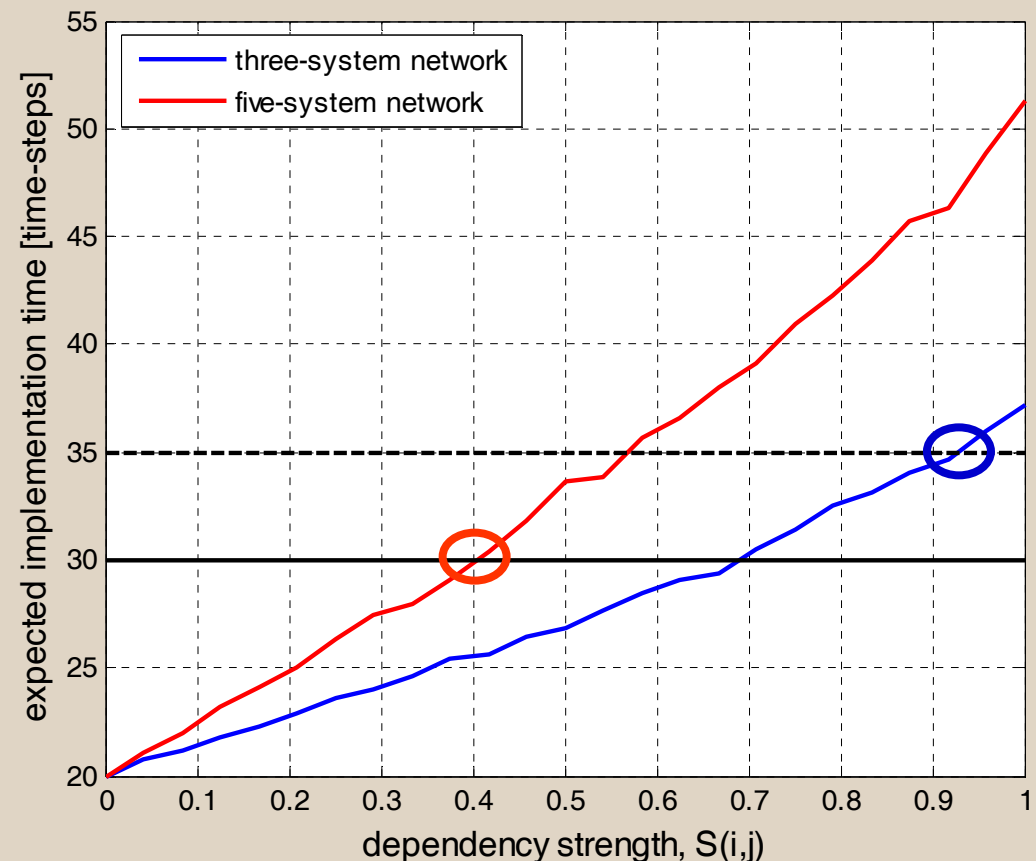
- What effect does the number of systems and interdependencies have on development time?
  - If candidate systems can provide same capability-level, which one should be favored?





## 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

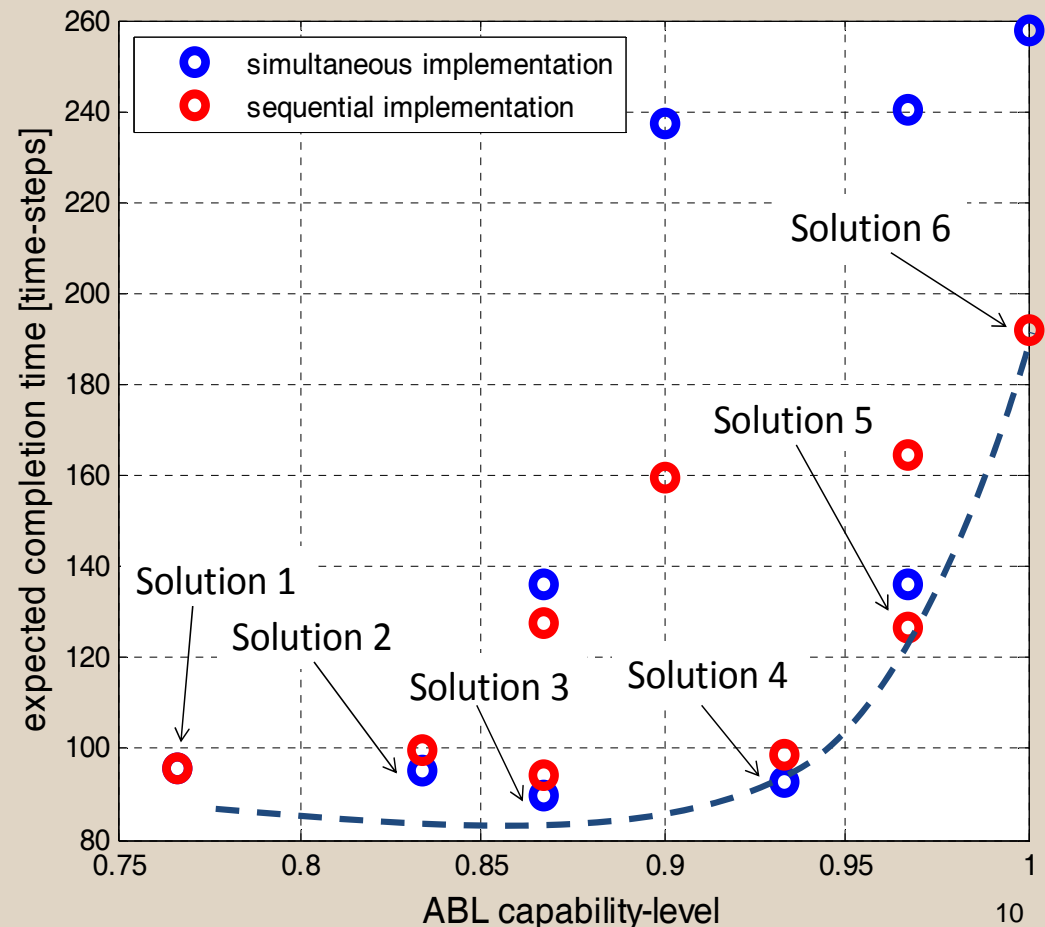


## **Reflections on CEM**

- 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

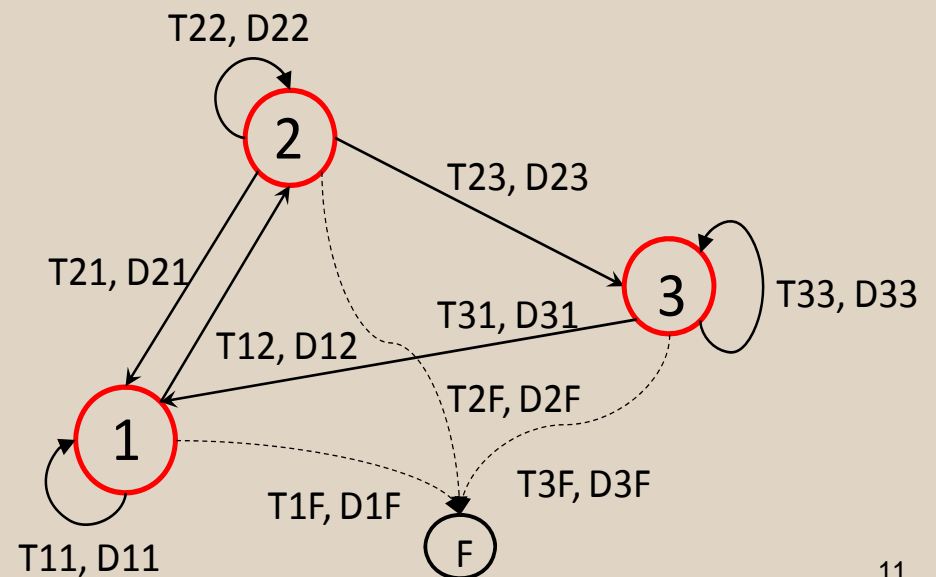
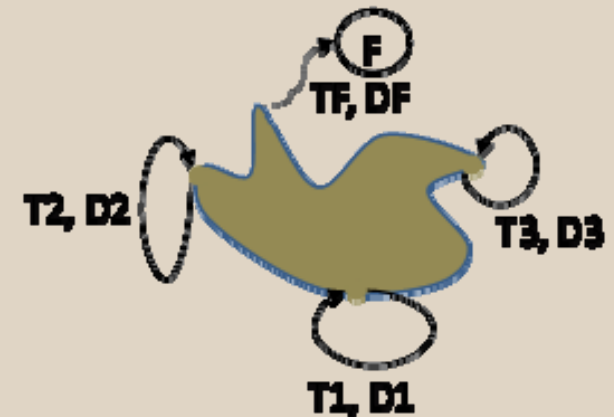
## Balancing Capability Potential and Risk Among Alternatives

- 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

