Taming Complexity:
A System of Systems Challenge

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System of Systems

A set or arrangement of systems that results when **independent and useful systems** are integrated into a larger system that delivers unique capabilities

Systems of Systems Engineering

The process of **planning, analyzing, organizing, and integrating** the capabilities of a mix of existing and new systems into a system-of-systems capability that is greater than the sum of the capabilities of the constituent parts

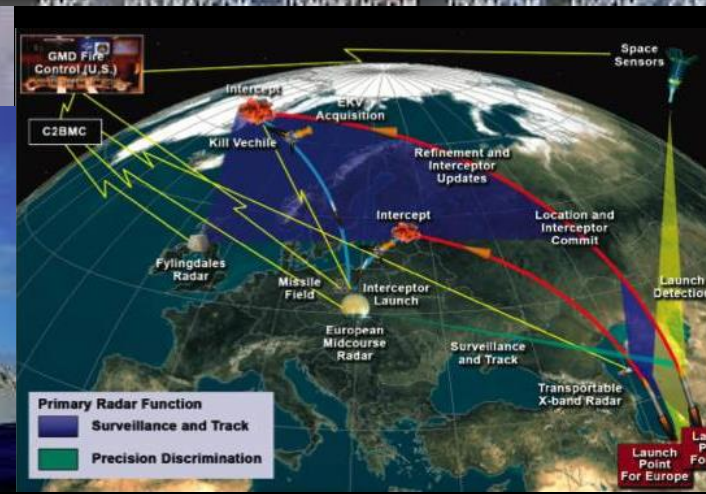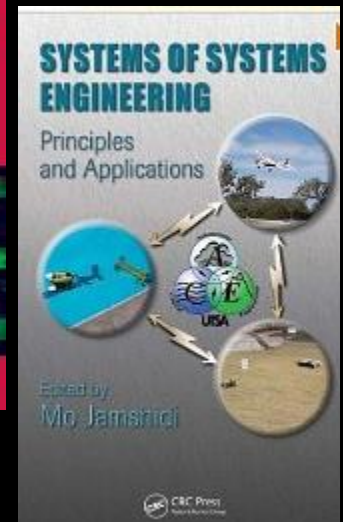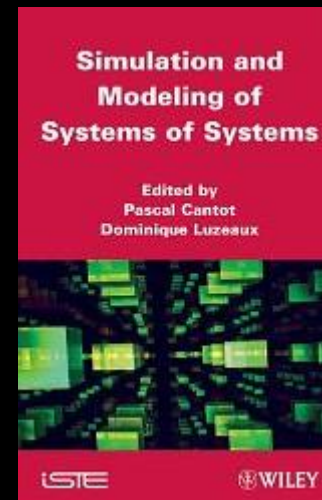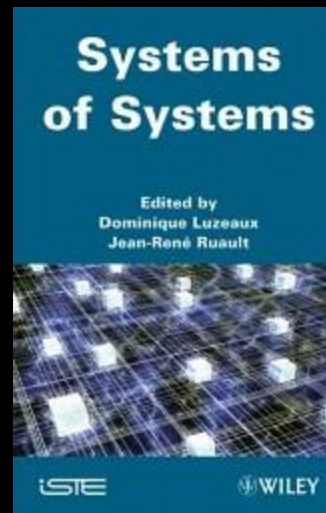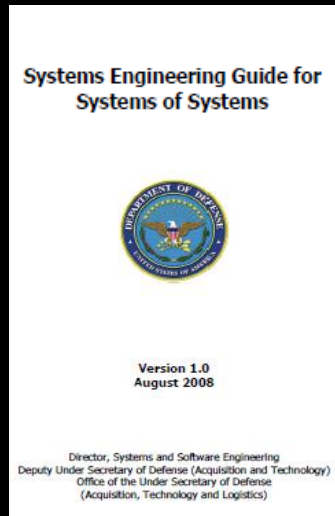**US DoD SE Guide for SoS**
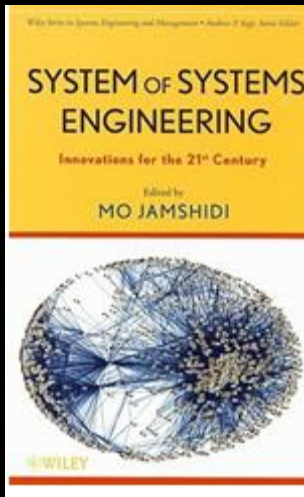
Energy

Water
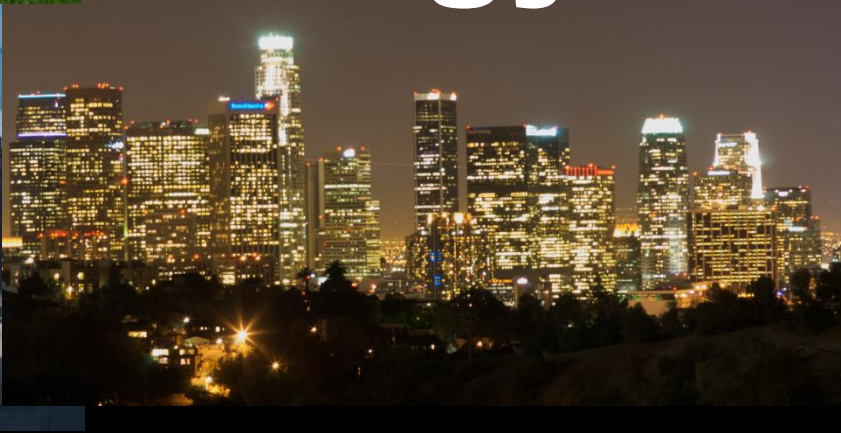
Air Transportation

Global Finance

Missile Defense

Growing SE Attention to SoS

Complexity

The degree of **difficulty in predicting** the properties of a system if the properties of the system's parts are given

Complex Adaptive Systems

System where the individual elements **act independently** but jointly behave according to **common constraints and goals**

Maier SoS Characterization

- Maier (1998) postulated five key characteristics of SoS:
  - Operational independence of component systems
  - Managerial independence of component systems
  - Geographical distribution
  - Evolutionary development processes
  - Emergent behavior

Maier, 1998, "Architecting Principles for Systems-of-Systems," Systems Engineering.
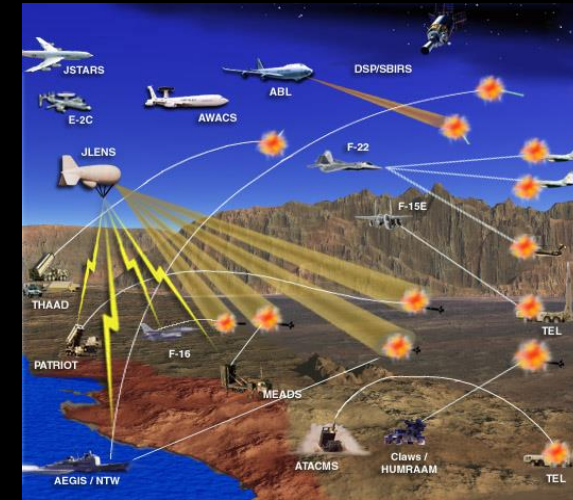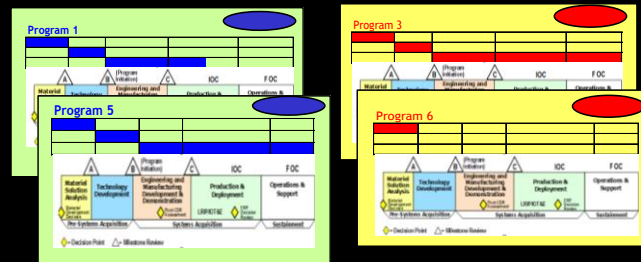
Why is This Hard?

Management And Funding
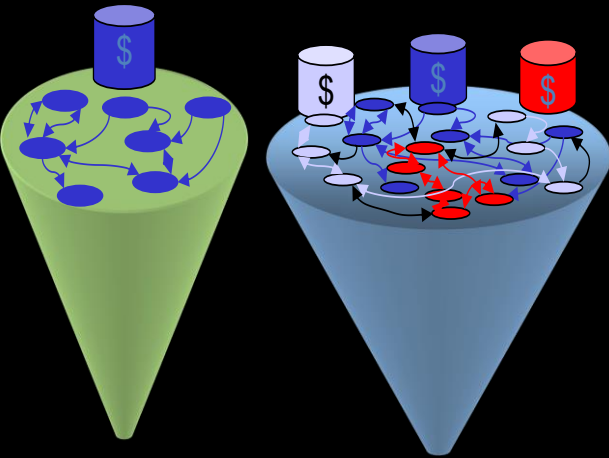
Independent Development
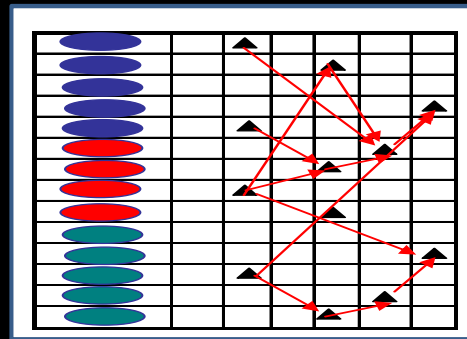
Multiple Concurrent SoS

SoS Pain Points

- **2012 INCOSE** survey identified seven 'pain points' raising a set of questions for systems engineering of SoS

SoS Authority

What are effective collaboration patterns in SoS?

Leadership

What are the roles and characteristics of effective SoS leaders?

Capabilities & Requirements

How can SE address SoS capabilities and requirements?

Autonomy, Interdependencies & Emergence

How can SE address the complexities of SoS interdependencies and emergent behaviors?

Constituent Systems

What are effective approaches to integrating constituent systems?

Testing, Validation & Learning

How can SE approach SoS validation, testing, and continuous learning in SoS?

SoS Principles

What are the key SoS thinking principles?

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Sources of SoS Complexity

- Systems
- Users/stakeholders
- Development
- Operations

Technical **Complexity** Across Systems

Diversity in system concept, design, control structures, data syntax, semantics…..

User/Stakeholder Complexity

Independent system owners and stakeholders with their own goals, objectives, motivations......
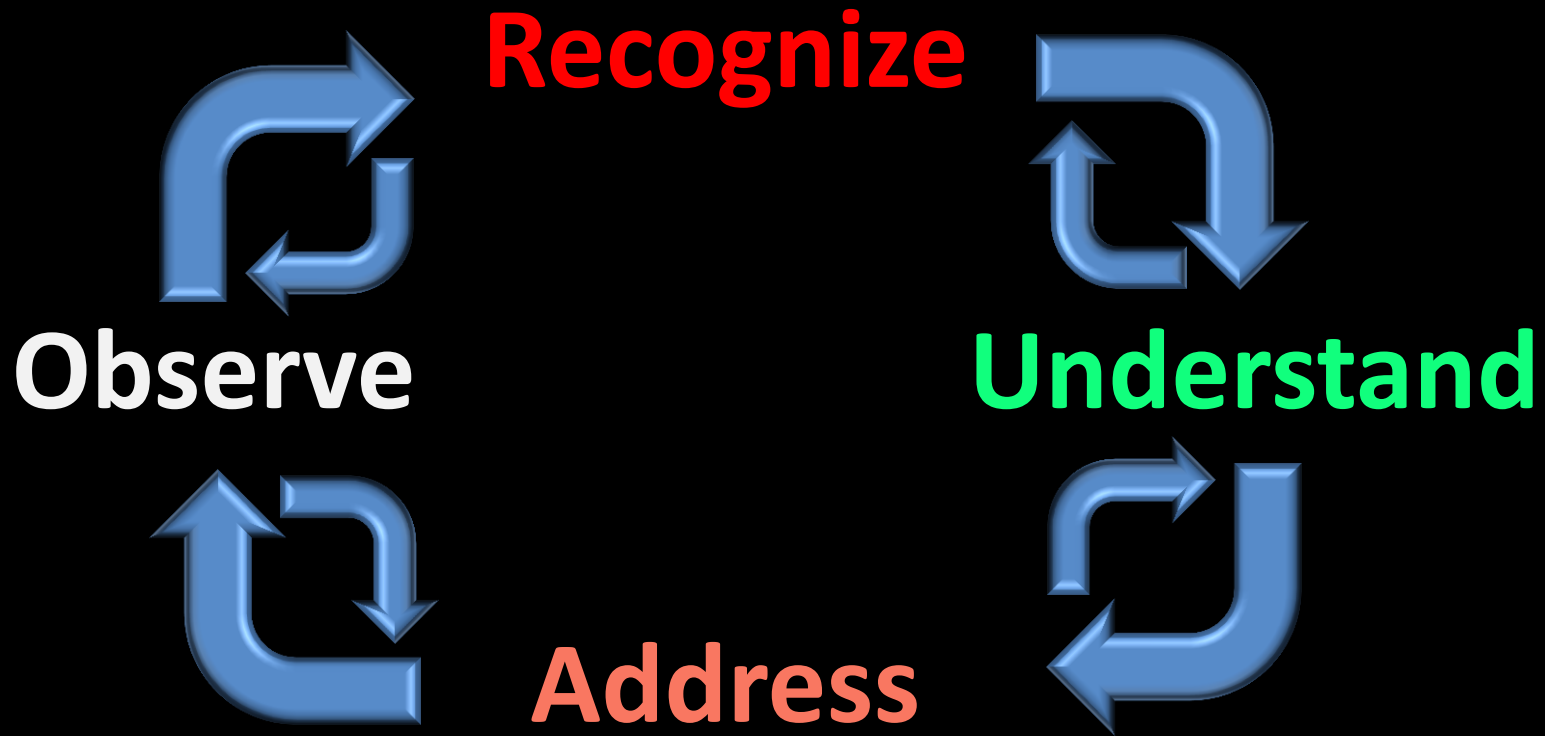
SoS Development Complexity

Dynamics of asynchronous development

Complex Operational Dynamics

Dynamics of independent operations

Addressing SoS Complexity

Where others see **complexity**, the person of action sees the thing that needs to be done.

Michael Lipsey