Accelerating System of Systems Engineering Understanding and Optimization through Lean Enterprise Principles

SoS SE Collaborators Information Exchange
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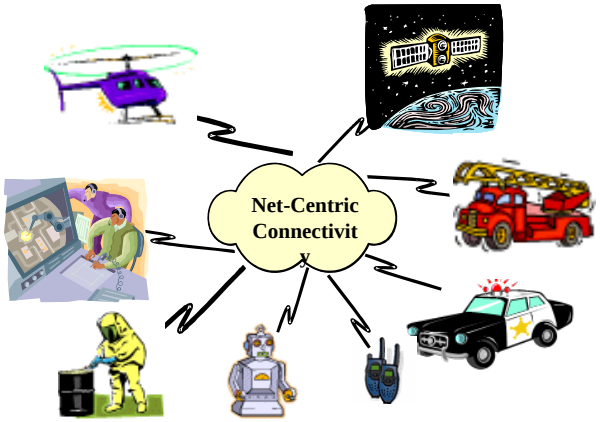
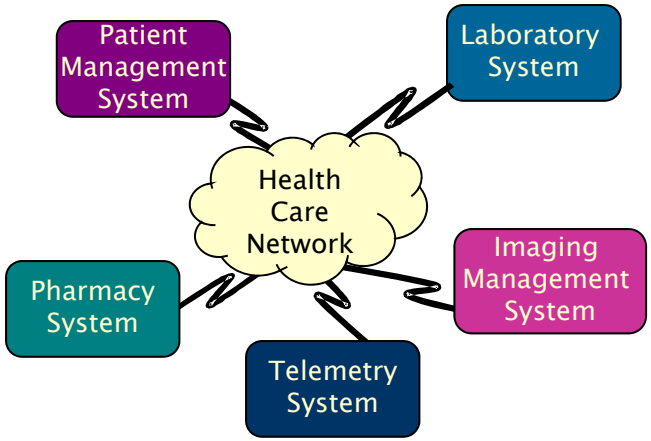
Overview

- Background
  - System of systems engineering (SoSE)
  - Lean enterprise principles
- Relationship between SoSE and lean enterprise principles
  - Analysis
  - Findings and conclusions
- Future plans
- Acknowledgements

What is a "System of Systems"?

- Very large systems using a framework or architecture to integrate constituent systems
- Exhibits emergent behavior not otherwise achievable by constituent systems
- SoS constituent systems
  - Independently developed and managed
  - New or existing systems in various stages of development/evolution
  - May include a significant number of COTS products
  - Have their own purpose
  - Can dynamically come and go from SoS
- Typical domains
  - *Military/Crisis Response:* Dynamic communications infrastructure
  - *Business:* Enterprise-wide and cross-enterprise integrations





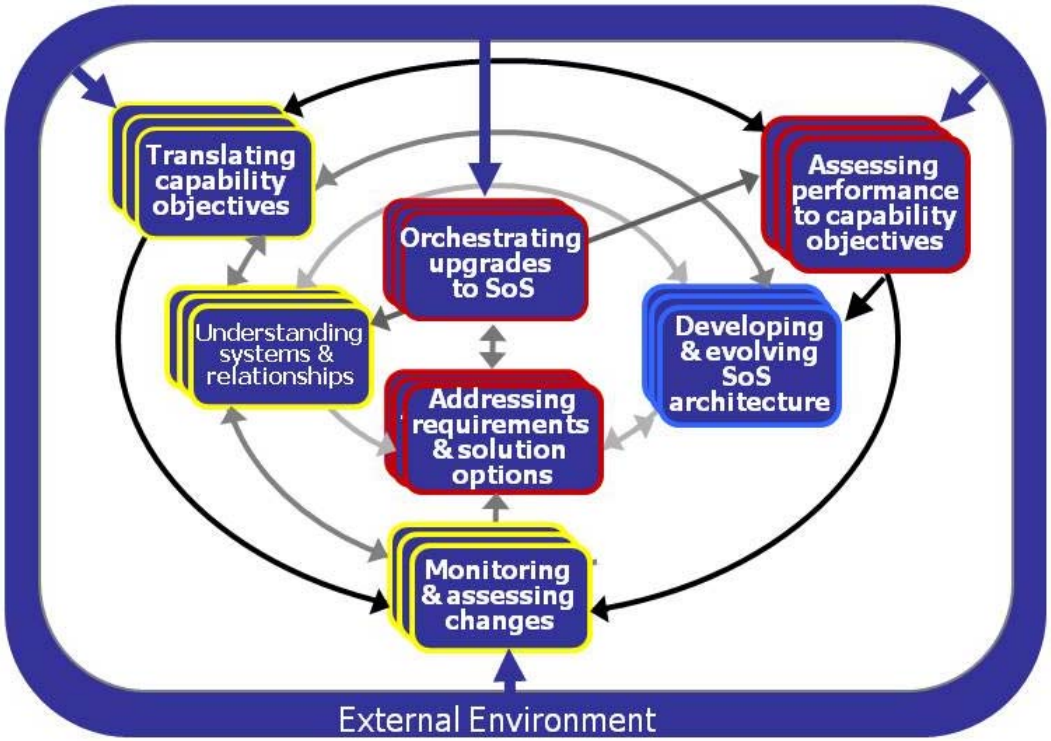
Based on Mark Maier's SoS definition [Maier, 1998]

SoS Taxonomy

- **Virtual** [Maier, 1998]
  - Lacks a central management authority and a clear SoS purpose
- **Collaborative** [Maier, 1998]
  - Constituent system engineering teams work together, but no overarching SoSE team to guide
- **Acknowledged** [Dahmann, 2008]
  - Have recognized objectives, a designated manager, and resources at the SoS level (SoSE team)
- **Directed** [Maier, 2008]
  - SoS centrally managed by a government, corporate, or Lead System Integrator and built to fulfill specific purposes

Focus area of lean analysis…

Characterization of SoSE*



- Based on analysis of 18 DoD SoSs in various stages:
  - Communications systems
  - Command and control systems
  - Integrated combat systems
  - Ballistic missile defense systems
  - Intelligence information systems
  - Space-related systems

* Department of Defense, Systems Engineering Guide for System of Systems, Version 1.0, 2008.

Objectives of Lean Enterprise Principles*

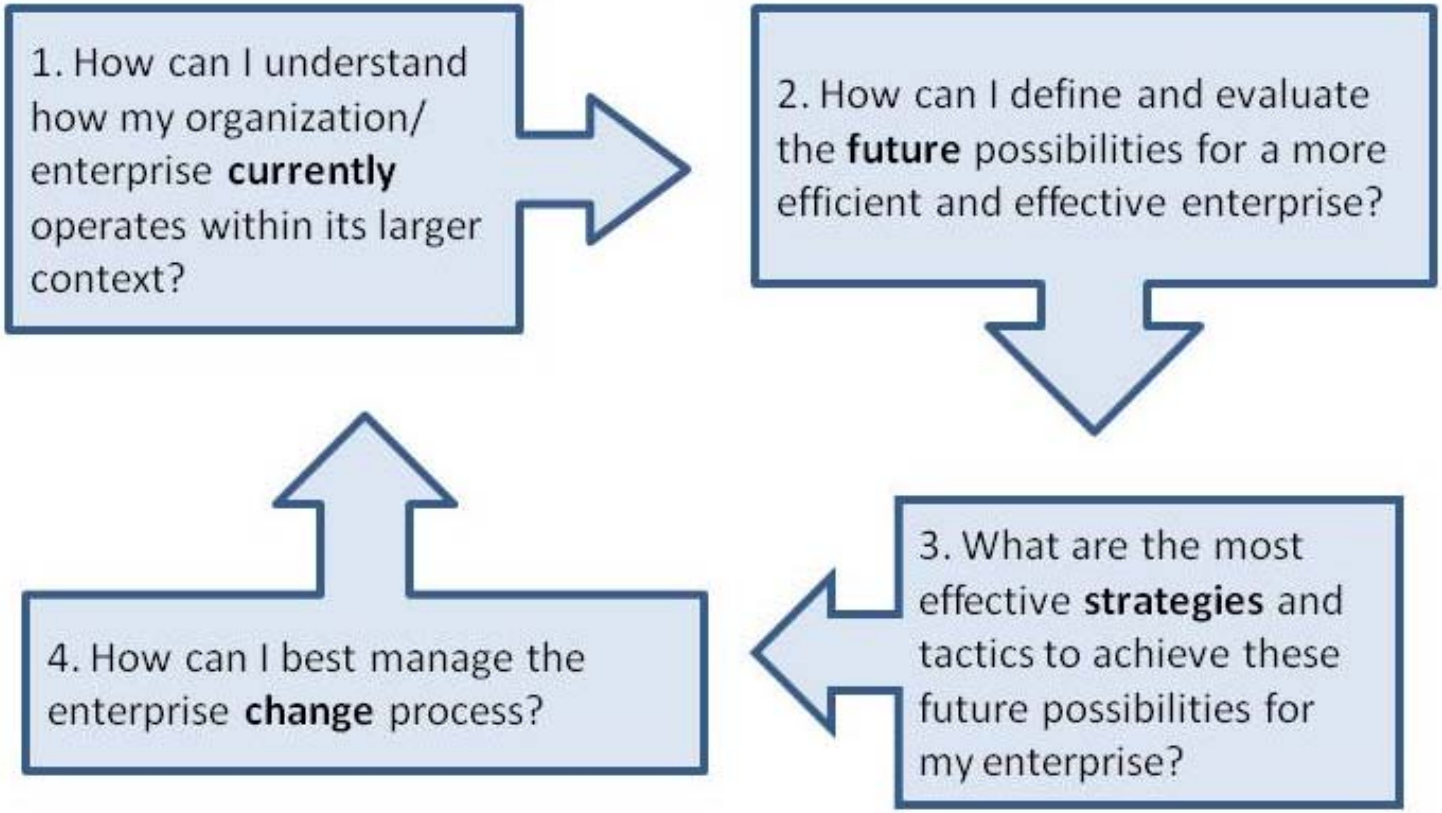
- Minimize waste
- Responsive to change
- Right thing at the right place
  - At the right time
  - In the right quantity
- Effective relationships with the value stream
  - People
  - Organizations
- Continuously improve
  - Processes
  - Products
- Quality from the beginning

* E. Murman, et al., Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative. New York , NY: Palgrave, 2002

Initial Lean Indicators in SoSE

- Holistic view across SoS, focus on long term goals
- Guided by prioritized stakeholder capability needs
- Continuous learning organization
  - Monitoring and assessing changes
  - Assessing performance to capability objectives
- SoSE "battle rhythm"
  - Make decisions slowly by consensus
  - Consider all options
  - Continuous process flow through concurrent engineering
  - "Pull" constituent system engineering knowledge as needed
  - Implement rapidly
  - Level the workload—use systems with available "bandwidth"
- Minimize waste by
  - Avoiding duplication of engineering efforts at constituent system level
  - Eliminating none-valuing adding engineering activities
- Respect and challenge suppliers
  - Constituent system engineering teams
  - Constituent system stakeholders

Lean Enterprise Four Grand Questions*



* D. Nightingale, "Principles of enterprise systems", Proceedings of the Second International Symposium on Engineering Systems, MIT, Cambridge, MA, June 15-17, 2009.

SoS Data Analyzed for Lean Principles
(13 of 18 DoD SoSE Case Studies)

- Air Operations Center
- Ballistic Missile Defense System
- Common Aviation Command and Control System
- Distributed Common Ground Station
- DoD Intelligence Information System
- Ground Combat Systems
- Military Satellite Communications
- National Security Agency
- Naval Integrated Fire Control–Counter Air
- Naval Surface Warfare Center Dahlgren Division
- Space and Missile Systems Center
- Theater Medical Information Systems–Joint
- United States Coast Guard Command and Control Convergence

Analysis of SoSE Core Elements and Lean Enterprise Principles/Four Grand Questions

SoSE Core Element	Lean Enterprise Grand Questions				Stakeholder Considerations	Holistic Enterprise View
	Q1: Understand Current State	Q2: Future Possibilities	Q3: Strategies and Tactics for Future	Q4: Change Process		
Translating Capability Objectives		X			X	X
Understanding Systems and Relationships	X				X	X
Assessing Performance to Capability Objectives	X	X			X	X
Developing and Evolving an SoS Architecture	X	X	X			X
Monitoring and Assessing Changes	X			X	X	X
Addressing Requirements and Solution Options			X	X	X	X
Orchestrating Upgrades to SoS				X	X	X

Analysis of DoD SoSE Case Studies and Lean Enterprise Principles/Four Grand Qs (1 of 2)

SoS ID	Lean Enterprise Grand Questions				Scope of Key Stakeholder Considerations	Number of Constituents
	Q1: Understand Current	*Q2: Future Possibilities*	*Q3: Strategies and Tactics for Future*	*Q4: Change Process*		
1	X	X	X	Monitor and attempt to guide, but do not manage	Across all DoD services/coalitions	16
2	X	X	X	Work in concert with constituent systems to manage upgrades	Across multiple DoD services and government agencies	9
3	X	X	X	Monitor and attempt to guide, but do not manage	Across all DoD services	10
4	X	X	Coordinated by larger overarching SoS	Managed from above – this SoS is also part of a larger SoS	Single service	Many – exact number not available
5	X	Weak evidence in this area	X	Monitor and attempt to guide, but do not manage	Across all DoD services	12
6	X	X	X	Monitor and attempt to guide, but do not manage	Multiple DoD services and government agengies—includes coalitions	Data not availabe

⋮

Note: Entries in this table are in a random order in order to protect the identities of the specific SoSs with respect to their processes…

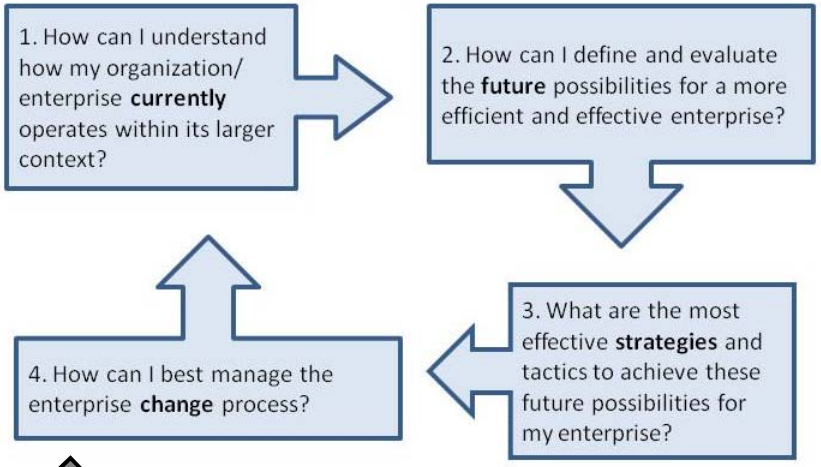
Analysis of DoD SoSE Case Studies and Lean Enterprise Principles/Four Grand Qs (2 of 2)

SoS ID	Lean Enterprise Grand Questions				Scope of Key Stakeholder Considerations	Number of Constituents
	Q1: Understand Current	*Q2: Future Possibilities*	*Q3: Strategies and Tactics for Future*	*Q4: Change Process*		
⋮						
7	X	X	X	X	Across all DoD services	40+
8	X	X	X	Some high level management and guidance	Across multiple DoD services and government agencies	Data not available
9	X	X	X	X	Across multiple DoD services and government agencies	Data not available
10	X	X	X	X	Across multiple DoD services and government agencies	264
11	X	Sparse data	Sparse data	Monitor and attempt to guide, but do not manage	Across multiple DoD services and government agencies – includes international customers	Many—exact number not available
12	X	X	X	In general, monitor and guide. Manage some aspects.	Across multiple DoD services and government agencies	Many—exact number not available
13	X	X	Sparse data	In general,monitor and guide. Manage some aspects.	US and international services and agencies	25

Note: Entries in this table are in a random order in order to protect the identities of the specific SoSs with respect to their processes…

Summary of SoSE and Lean Enterprise Analysis

SoSE guided by LAI Lean Enterprise 4 Grand Questions



Lean Enterprise 4 Grand Questions mapped to DoD SoSE case studies….

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4	X	X	Coordinated by larger	Managed from above	[illegible]	Many – exact [illegible]

Lean Enterprise 4 Grand Questions mapped to SoSE core elements….

SoSE Core Element	Lean Enterprise Grand Questions				*Stakeholder Considerations*	*Holistic Enterprise View*
	Q1: Understand Current	*Q2: Future Possibilities*	*Q3: Strategies and Tactics for Future*	*Q4: Change Process*		
Translating Capability Objectives		X			X	X
Understanding Systems and Relationships	X				X	X
Assessing Performance to Capability Objectives	X	X			X	X
Developing and Evolving an SoS Architecture	X	X	X			X
Monitoring and Assessing Changes	X			X	X	X
Addressing Requirements and Solution Options			X	X	X	X
Orchestrating Upgrades to SoS				X	X	X

Conclusions

- Analysis presented shows how lean concepts manifest themselves in the SoSE environment
- By leveraging lean principles, SoSE teams gain
  - Confidence in the process changes they have adopted
  - A vision to guide
    - Further optimization of their processes
    - How they engage with the constituent system engineering teams
    - How to better balance the needs of the constituent system stakeholders and the SoS stakeholders

SoSE teams are employing lean concepts whether or not they are aware of it

Future SoSE Research Plans

- Conduct deeper dives into
  - ***Lean enterprise lens analysis***
  - Test and evaluation analysis
  - SoSE artifacts
  - SoS architecture evolution
- SoSE cost model
  - Incorporate additional cost factors into COSYSMO to capture additional SoS characteristics and non-traditional SE effort
  - Evaluate impacts of insufficient SE at SoS level on rework
  - Break out SoSE effort
    - Planning
    - Implementation
    - SoS-level testing

Lean enterprise lens analysis has implications for other on-going SoSE research as well as DoD initiatives to quickly deploy quality systems and system upgrades which are often part of one or more SoSs…

Acknowledgements

- DoD Director, Defense Research and Engineering (DDR&E)
  - Stevens-USC Systems Engineering Research Center (SERC) support
  - SoS case study work that has provided considerable engineering insights into SoSE
- LAI for their research into lean enterprise concepts

- For copy of full paper, see

  J. Lane and R. Valerdi (2010); How to Accelerate Understanding and Optimization of System of Systems Engineering through Lean Enterprise Principles, *Proceedings of the IEEE Systems Conference*, 5-8 April, in San Diego, CA.

Questions?