Relative Comparison of the Rate of Convergence of Collaborative Systems of Systems: A Quantified Multi-Case Study

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Relative Comparison of the Rate of Convergence of Collaborative Systems of Systems

• Introduction
• Modelling Approach
  • Conceptual Dynamic Bayesian Network
• Initiatives to Counter Improvised Explosive Devices as a System of Systems
  • Factors which influence convergence of functionality
  • Constituent systems and Metrics of functionality
• U.S. Smart Grid as a System of Systems
  • Factors which influence convergence of functionality
  • Constituent systems and Metrics of functionality
  • Representative model of the System of Systems
• Expected Results
• Several industries including Defense, Transportation, Health Care and Energy are pursuing increasingly ambitious functionality through Systems of Systems

• The functionality evolves over time to provide a highly sophisticated and integrated capability

• System of Systems engineers need to be able to describe the status of the System of Systems to stakeholders and customers

• This presentation describes a modeling approach which will quantify the relative rate of convergence of a System of Systems

• The model will incorporate representations of factors which influence the rate of convergence

• Observations from analyzing multiple case studies will be instrumental for refining the construct of the model and the representation of the factors

• The analysis will focus on documented, incremental functionality of System of Systems such as the Smart Grid and the operational infrastructure created collaboratively by the Joint Improvised Explosive Device Defeat Capability Approval and Acquisition Management Process

• The model will advance the state of the art of architecting System of Systems by improving the ability to describe current and forecasted functionality

• It is envisioned that the convergence metric will provide translation of technical progress to business capability that can be used to communicate status to stakeholders and customers and be used to make comparative decisions among competing Systems of Systems.
• Identify Quantifiable Factors which Influence the Rate of Convergence
  • Policy – Legislation, Directives, Control Documents, Vision Statements
  • Societal – Public or Subversive Support or Resistance
  • Economic – Financial/Quantifiable Factors to Close the Business Case
  • Technological – Capability to Interoperate, Capacity to Contribute

• Specify the Systems and the System of Systems; Determine Metrics for Functionality

• Construct Relative Conditional Tables for each System Based on Relevant Observations or Expert Elicitation

• Validate the Model; Use the Model to Explore Contributions of and Dynamics with the Factors which Influence

Dynamic Bayesian Networks are Directed Acyclic Graphical models of Stochastic processes
Conceptual Dynamic Bayesian Network

- Factors which Influence may be directed towards one system or many
- Systems may be closely related or diverse
- Time Phased Convergence of System Capability (and resultant Functionality) may be depicted
- A SoS-level DBN is comprised of nested System-level DBN
Counter – Improvised Explosive Device SOS
Factors which Influence

Policy

Societal

Economic

Technological

Factors which Influence Policy

Economic

Technological

Policy

Societal

Economic

Technological
The C-IED SOS and Factors are Dynamic
U.S. Smart Grid Framework

Smart Grid - Factors which Influence

Policy

Economic

Societal

Technological
## Smart Grid – Factors which Influence AMI Deployment

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### Legislative Roadmap
- **Roadmap**: 0 0 1 1 1 1 1
- **Policy Statement**: 0 0 0 1 1 1 1
- **Resistance**: -1 -1 -1 -1 -1 -1 -1
- **Societal Opt-out**: 0 0 0 0 0 0 0
- **Customer Education**: 0 0 0 0 0 0 0
- **Dynamic Pricing**: 0 0 0 0 0 0 0
- **Economical ARRA Funding**: 0 0 0 5 13 10 2
- **Technological Demonstration Project**: 4.59
- **Evidence AMI FOM (Growth)**: 0.02 0.03 0.04 0.07 0.05 0.11 TBD

### State Public Utility Commissions and Utility Industries Deploy the Smart Grid Constituent Systems Independently

Ratio of AMI to Total Meters by State

[Source: U.S. Energy Information Administration, 2007 - 2013]
Smart Grid AMI – Phased SOS Deployment

- Data represents project-level changes in meter operations costs
- Data are from 15 Smart Grid Investment Grant (SGIG) Projects
  - Represents 3.7 million operating smart meters
  - Based on operational experiences from April 1, 2011 to March 31, 2012
Dynamic Bayesian Model of Smart Grid

System-level:
  Single State; Single Year

System of Systems:
  Multiple States; Multiple Years
Expected Outcomes

• Application of a Dynamic Bayesian Network to evaluate convergence will advance the state of the art of architecting System of Systems

• The model will improve the ability to describe current and forecasted functionality

• A convergence metric will be developed to:
  • Provide translation of technical progress to business capability in order to communicate status to stakeholders and customers
  • Make comparative decisions among factors influencing the convergence of Systems of Systems.
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References


NamaStar: the Ultimate SE/PM Challenge

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