Critical Integration Links Identification for System of Systems

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Overview

- **Background**
- **System of Systems**
  - Complexity
  - Challenges
  - Integration
  - Testing
  - Prioritizing Critical Integration Links for Testing
- **Research Solution: Matrix Operation Approach**
- **Summary**
- **References**

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Background

- SoS are increasingly being used to deliver critical capability and services
- Systems (Government or Private) are becoming complex due to increase in dependencies between systems
- Systems, Sub-Systems, and System Components get added to satisfy increasing requirements
- Information flows between systems are key for successful Implementation
- Integration of these elements - 10,000 lbs. gorilla

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System of System Challenges

- One of the biggest challenges is in achieving cooperation and interoperation among systems through some form of system integration (2)
- How data will flow and how control will be managed are the key aspects of SoS Integration
- Failure to conduct adequate SoS integration testing can lead to potentially catastrophic failures (6)

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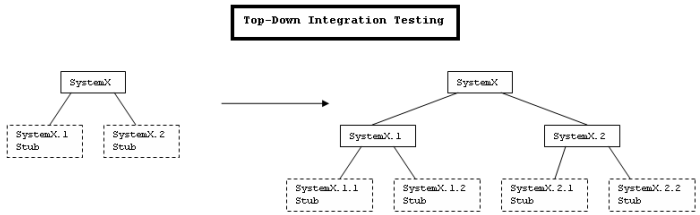

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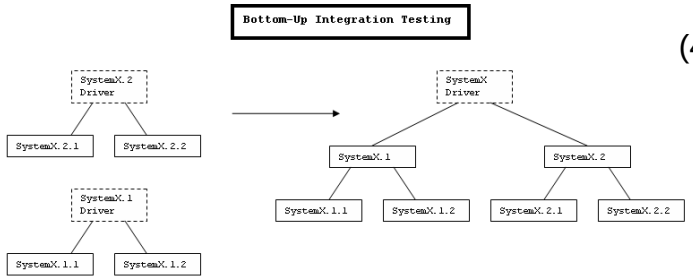

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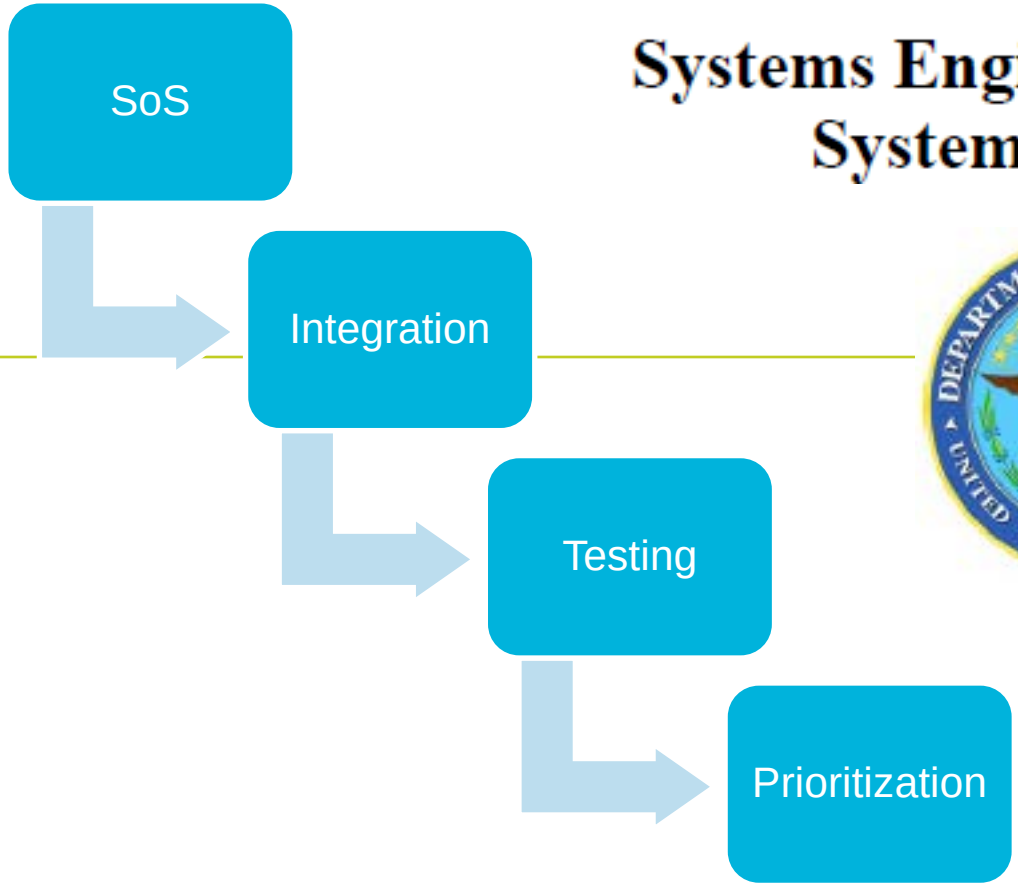
System of Systems

DEPARTMENT OF DEFENSE

Systems Engineering Guide for Systems of Systems (7)



SoS Development Model

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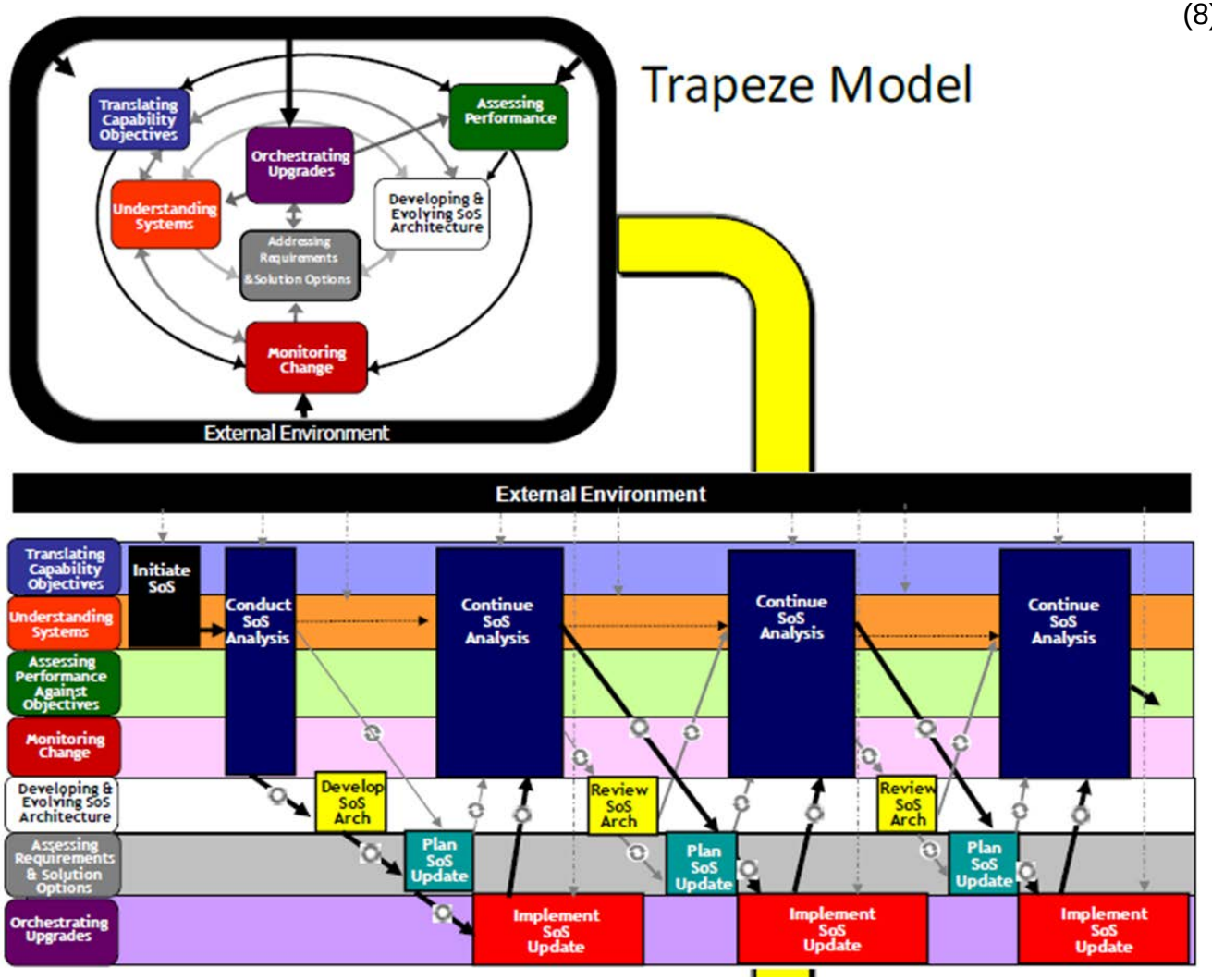
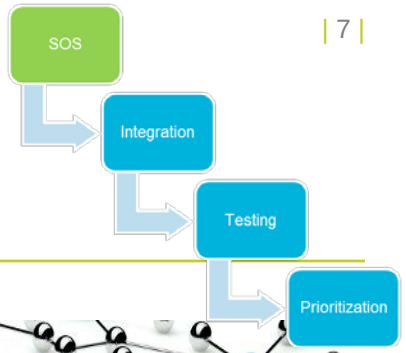
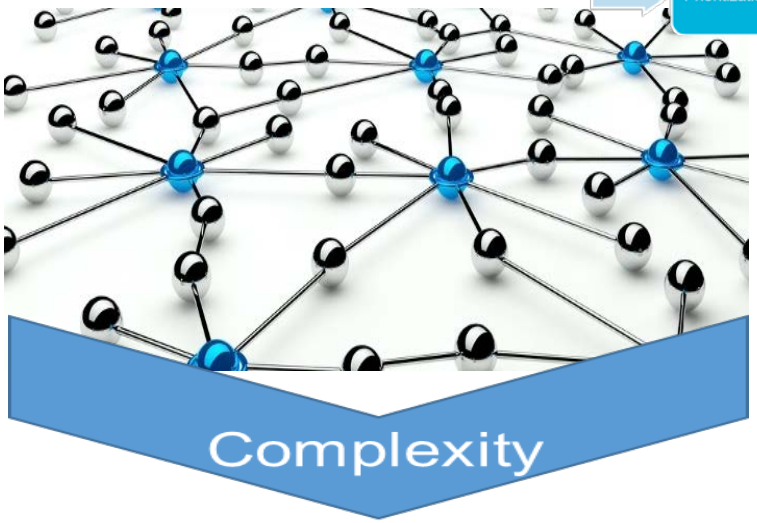


System of Systems - Complexity



- "A system of systems is an ***assemblage of components*** which ***individually*** may be regarded as ***systems*** that are simultaneously working as ***independent entities***" (9)
- **Key SoS characteristics by Maier** (10) operational independence of component systems
  - managerial independence of component systems
  - geographical distribution
  - emergent behavior
  - evolutionary development processes.



- Multiple Stakeholders
- Multiple Missions
- Different Priorities
- Different Schedules for Individual Systems
  - ✓ Design
  - ✓ Development
  - ✓ Deployment
  - ✓ Operation
  - ✓ Disposal

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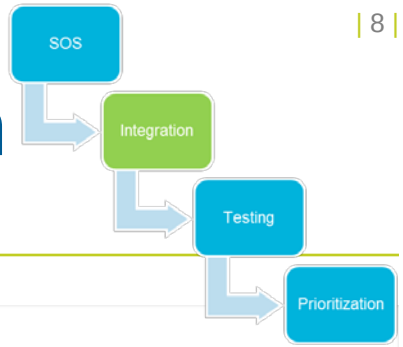
System of Systems – Integration



- ***Integration*** of the end-to-end functionality and performance across the SoS (11)
- Because ***implementation*** in an SoS may be ***asynchronous***, ***integration*** may be ***asynchronous*** as well
- Understanding the systems and their ***relationships/dependencies***
- ***Monitoring*** and ***accessing*** impacts of ***changes/updates***
  - Continuous evolvement and updates
- Coordinating upgrades, integration and testing

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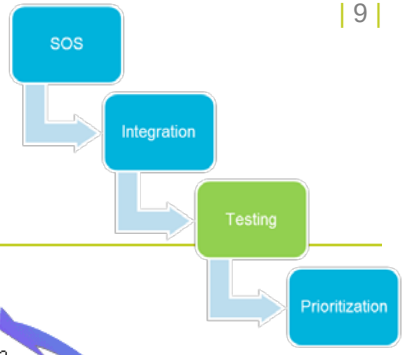
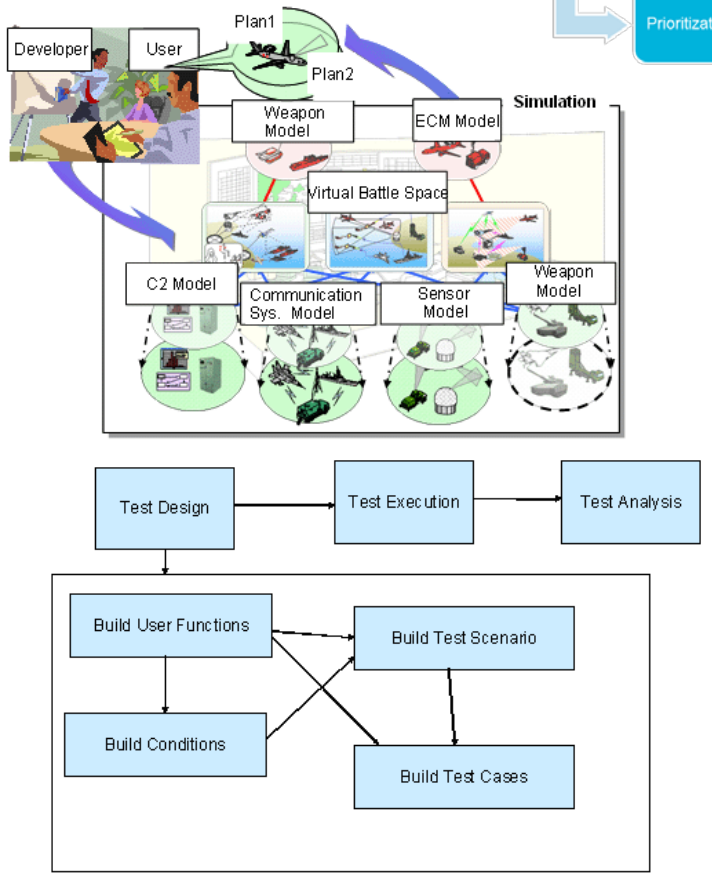
System of Systems – Testing



- Is typically planned and executed ***prior to turning*** the system over for operational (***end-to-end***) testing
- Should include ***scenarios*** that ***demonstrate the capability*** to perform ***mission essential tasks*** across the SoS segments (14)
- A ***comprehensive, automated, and maintainable testing methodology*** is critical for the successful integration testing and functional testing of SoS
- Failure to conduct adequate SoS integration testing can lead to potentially catastrophic failures



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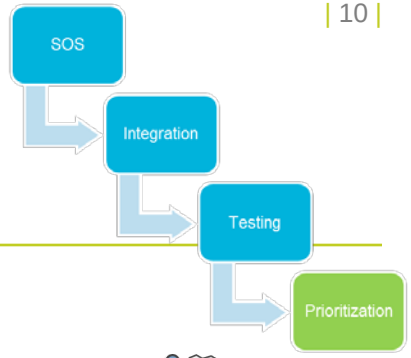
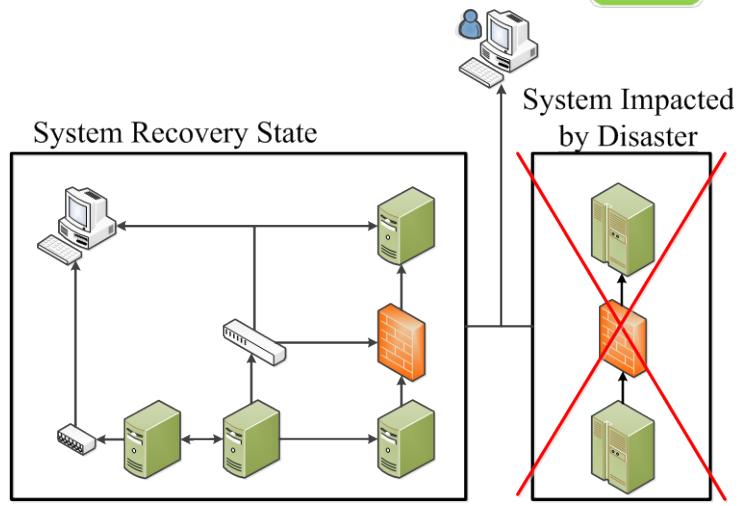
System of Systems – Prioritizing Critical Integration Links for Testing



- **Integration Links: relationships through which information is exchanged**
- **Analysis of links helps in**
  - identifying systems more vulnerable to defects
- **Prioritizing Integration links for testing**
  - Necessary to conduct well-organized testing
  - Possible only if the links can be distinguished based on their dependencies
  - Testing the minimum number of integration links while satisfying risk management requirements



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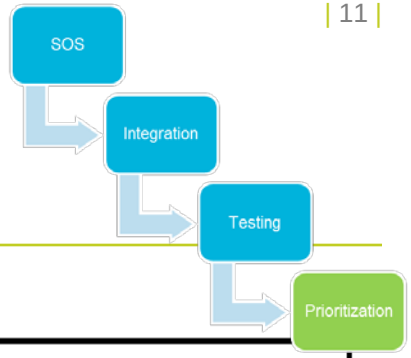
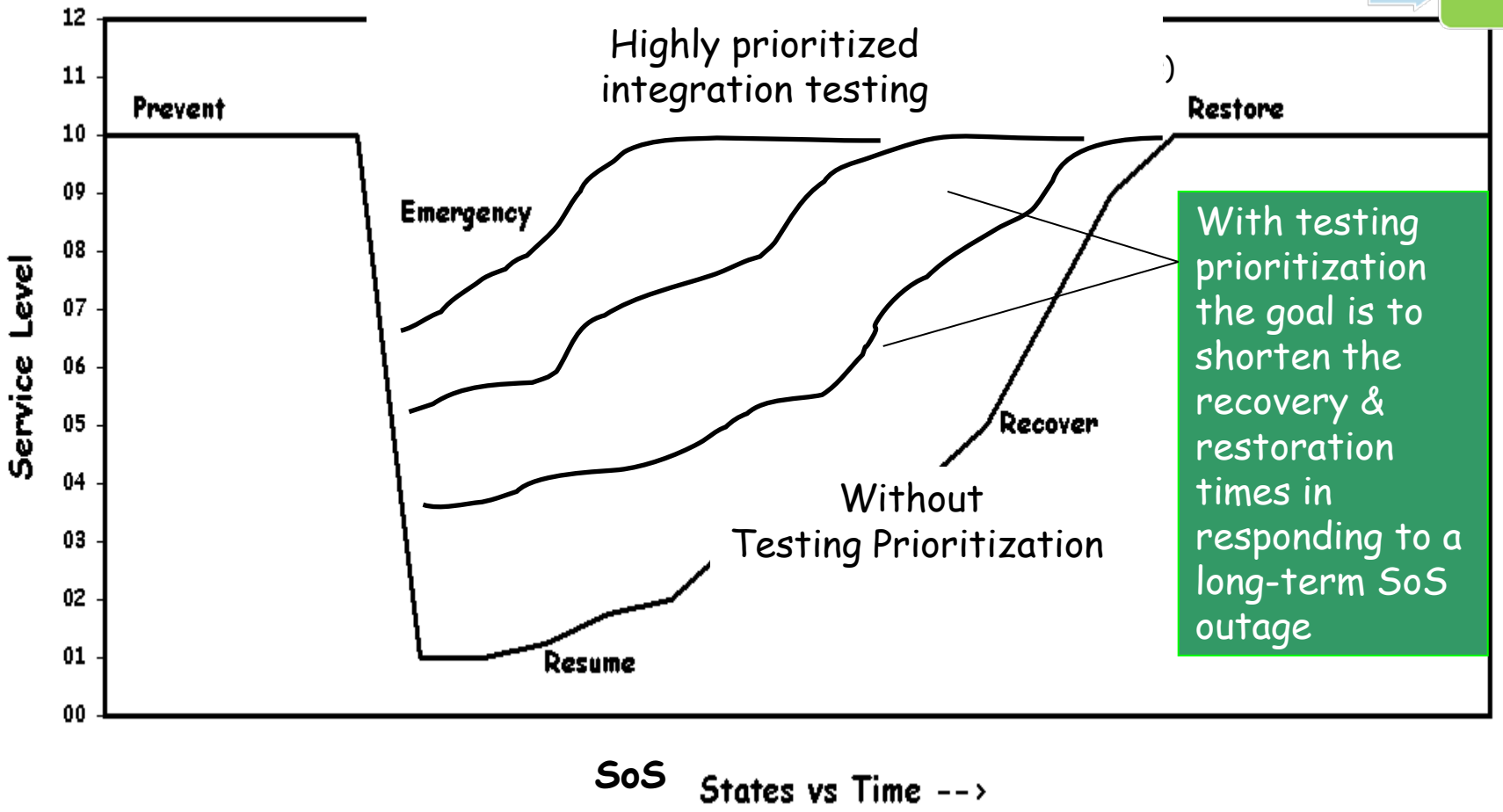
Goal of Prioritization Testing





With testing prioritization the goal is to shorten the recovery & restoration times in responding to a long-term SoS outage

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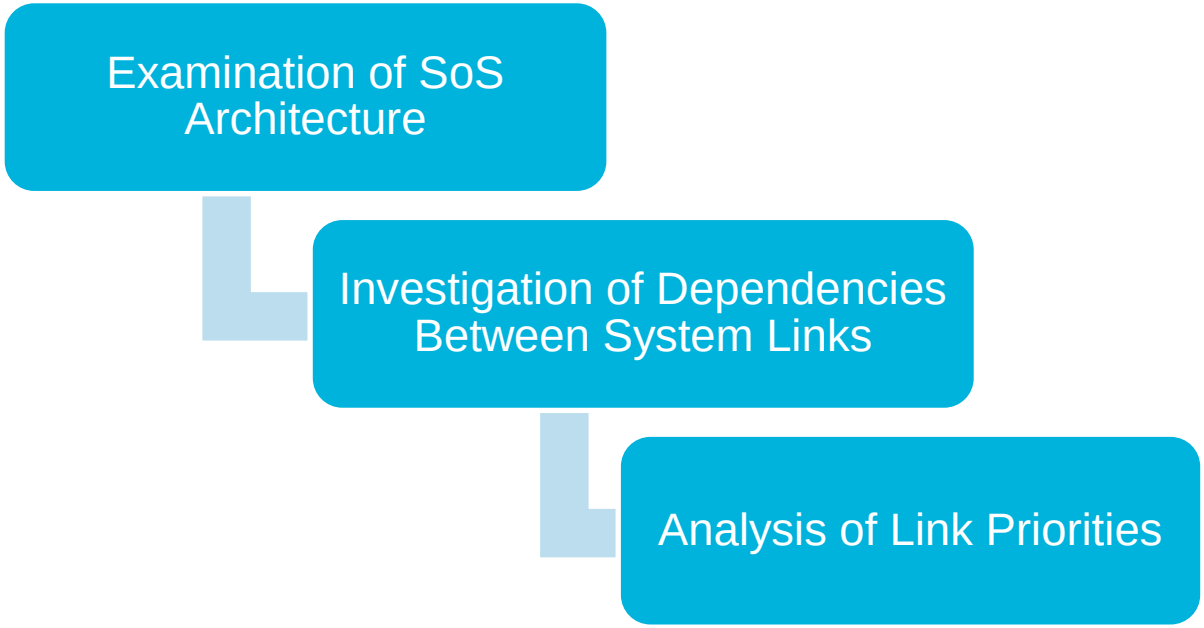
Research Solution: A Matrix Operation Approach



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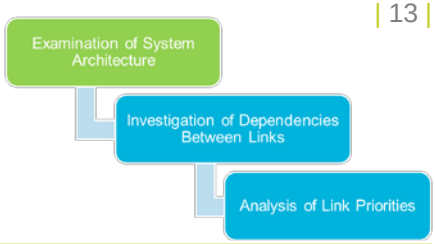
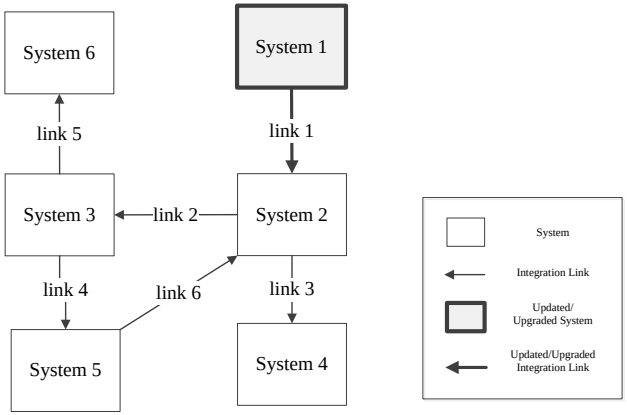
Research Solution: Examination of SoS Architecture



- Examining SoS and the Links between systems
- System vs System Matrix
  - Systems links with one another
- System vs Link Matrix
  - Types and level of information exchanged



System Architecture

	S1	S2	S3	S4	S5	S6
S1	0	1	0	0	0	0
S2	0	0	1	1	0	0
S3	0	0	0	0	1	1
S4	0	0	0	0	0	0
S5	0	1	0	0	0	0
S6	0	0	0	0	0	0

System vs System Matrix

	S1	S2	S3	S4	S5	S6
L1	0	1	0	0	0	0
L2	0	0	1	0	0	0
L3	0	0	0	1	0	0
L4	0	0	0	0	1	0
L5	0	0	0	0	0	1
L6	0	1	0	0	0	0

System vs Link Matrix

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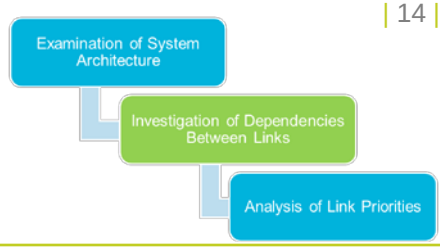
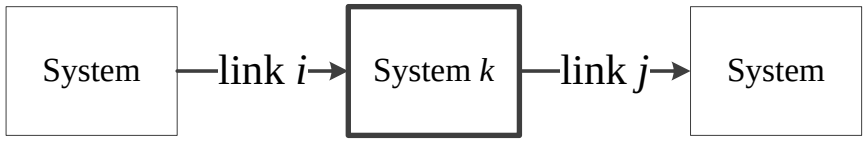
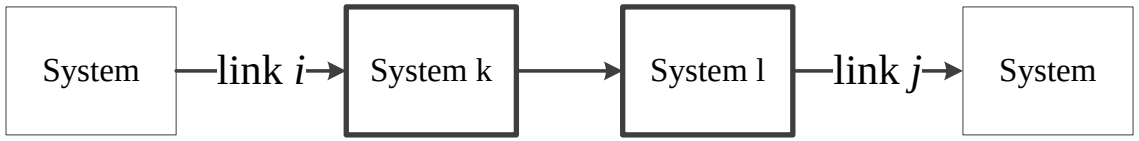
Research Solution: Investigation of Dependencies Between Links



- **Information Exchanged via Integration Links**
  - Direct
  - Indirect
- **Direct**
  - Links associated with a common System



- **Indirect**
  - There exist a link between the affiliated Systems and their respective neighboring systems



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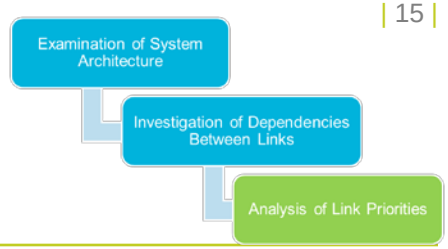
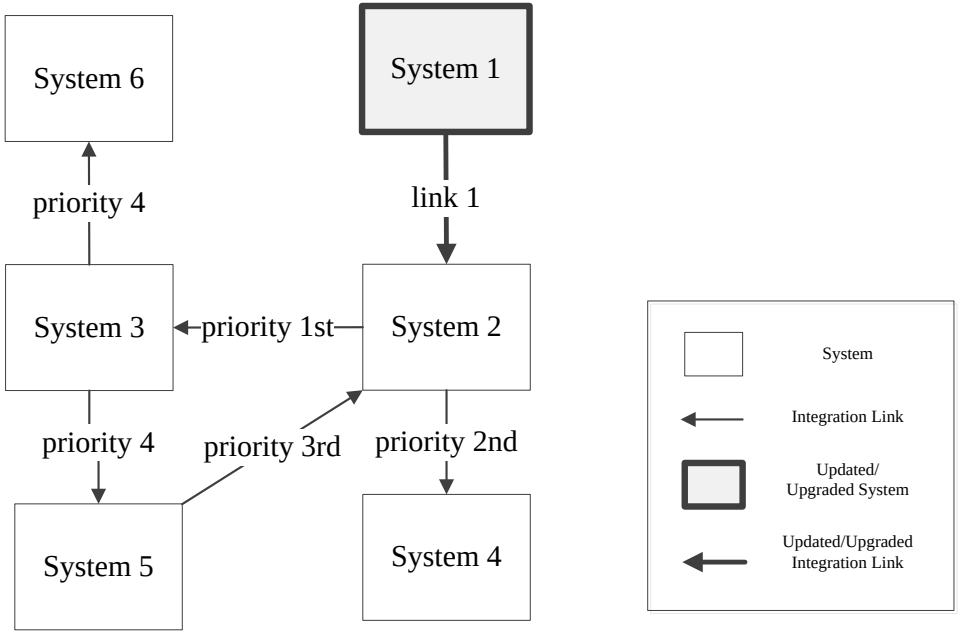
Research Solution: Analysis of Link Priorities



- **Translating direct and indirect dependencies into dependency strength between links**
- **Dependency strength is directional proportional to the link priority**



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Summary

- **SoS SE life cycle very different from traditional SE life cycle**
- **Existing Challenges**
  - Evolving Requirements
  - Asynchronous Design, Development and Integration
  - Multiple Stakeholders
- **Prioritization of integration links makes it less complex**
  - Enables locating critical links
  - Helps integration testing
  - Enables less testing time and resources
- **Research Solution: Provide promising method to prioritize integration links**
- **Future Research Focus: Method implementation on large scale systems**

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