



**Carnegie Mellon
Software Engineering Institute**

Pittsburgh, PA 15213-3890

SOSI: System of Systems Interoperability

B. Craig Meyers, Linda Levine, Ed Morris,
Patrick Place and Daniel Plakosh

Sponsored by the U.S. Department of Defense

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE JAN 2004		2. REPORT TYPE		3. DATES COVERED 00-00-2004 to 00-00-2004	
4. TITLE AND SUBTITLE SOSI: System of Systems Interoperability				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Carnegie Mellon University, Software Engineering Institute, Pittsburgh, PA, 15213				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



Carnegie Mellon
Software Engineering Institute

Purpose

To present results of an SEI IR&D project dealing with system of systems interoperability. We wanted to:

- Identify critical interoperability issues
- Gain insight into programs that are solving critical problems
- Develop recommendations for future research



SOSI Motivation

Interoperability between systems has become increasingly important – no modern system stands alone.

- Future Combat System
- Air Operations Center
- Navy battle groups
- Joint battle forces

Improved interoperation will not happen by accident.



Approach

This work included

- Development of a model for interoperability.
- Workshops with an expert advisory panel.
- Selected interviews.
- Literature review.

Emphasis is on problem setting, not problem solving.



Defining Interoperability

Lots of definitions are available, and involve different views, e.g.,

“The ability of systems to work together.”

“The ability of systems to exchange and use services.”

Ours:

“The degree to which a set of communicating entities are (i) able to exchange specified state data, and (ii) operate on that state data according to a specified, agreed to, operational semantics.”



Life in the Real World - 1

A program was building a large, distributed combat system. They were integrating many subsystems, many provided by other programs. As part of their system test, they require a simulator, which was developed by yet another program.

Funny, but the simulator was late. When it arrived the simulator did not implement the interface as expected.

Should we be surprised when things started going wrong?



Life in the Real World - 2

Two systems were being built using industry standard object request brokers provided by different COTS vendors. The program offices assumed conformance to an industry standard implied interoperability. Turned out, one vendor added unique features that extended the standard.

When the systems were tested they did not interoperate as planned. Why?



Life in the Real World - 3

Multiple combat systems are exchanging data over different communication links. Each type of link is ultimately based on a data model, with its own idea of the meaning of things. So different users can get different views of the battle space.

How can users be wholly confident in the information that they are receiving? How do they resolve conflicts?



Models

Models provide a context for discussion and understanding.

Several models for interoperability exist, e.g.,

- Levels of Conceptual Interoperability Model
- Levels of Information System Interoperability (LISI)
- NATO Reference Model for Interoperability
- Organizational Interoperability Maturity Model

These models focus on technical or operational aspects of a system.



Carnegie Mellon
Software Engineering Institute

SOSI Model View

Our focus includes the programmatic aspects related to interoperability. This extends other interoperability models. We suggest the term *programmatic interoperability*.

The SOSI model addresses

- activities
- organizations



Activities

Program
Management

Activities performed to manage the acquisition of a system.

System
Construction

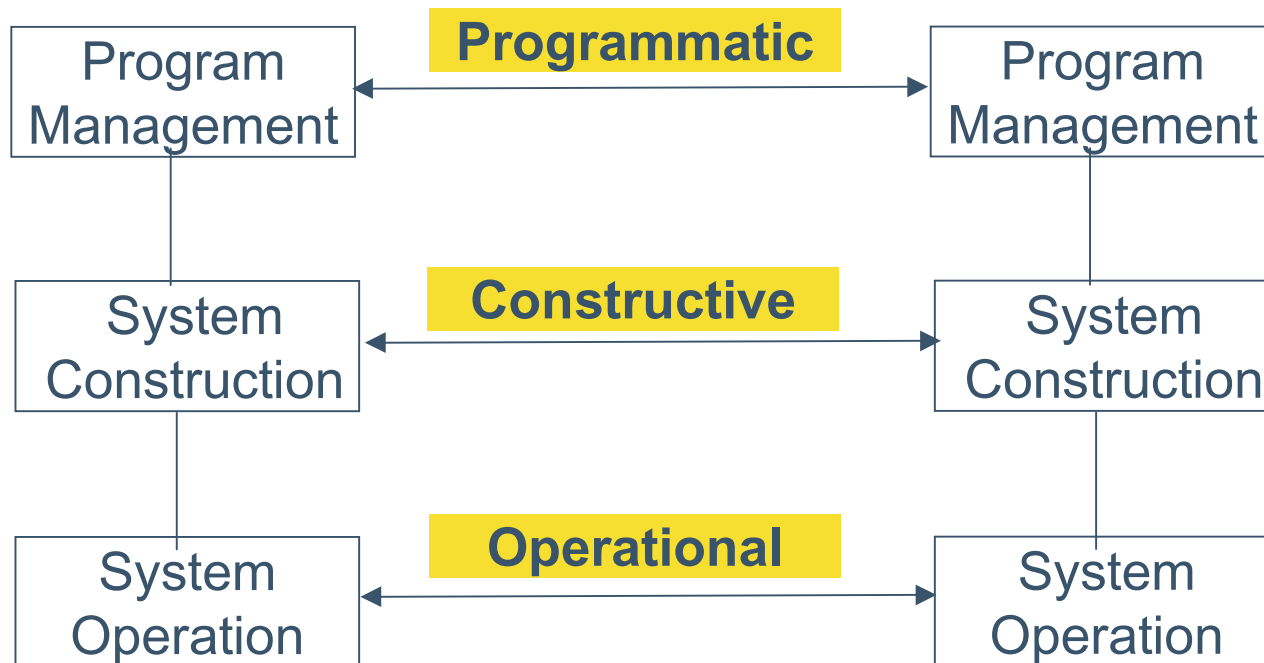
Activities performed to create a system. Focus is on architecture, standards, COTS.

System
Operation

Activities performed to operate a system. Focus is on interactions with other systems, and data distribution.

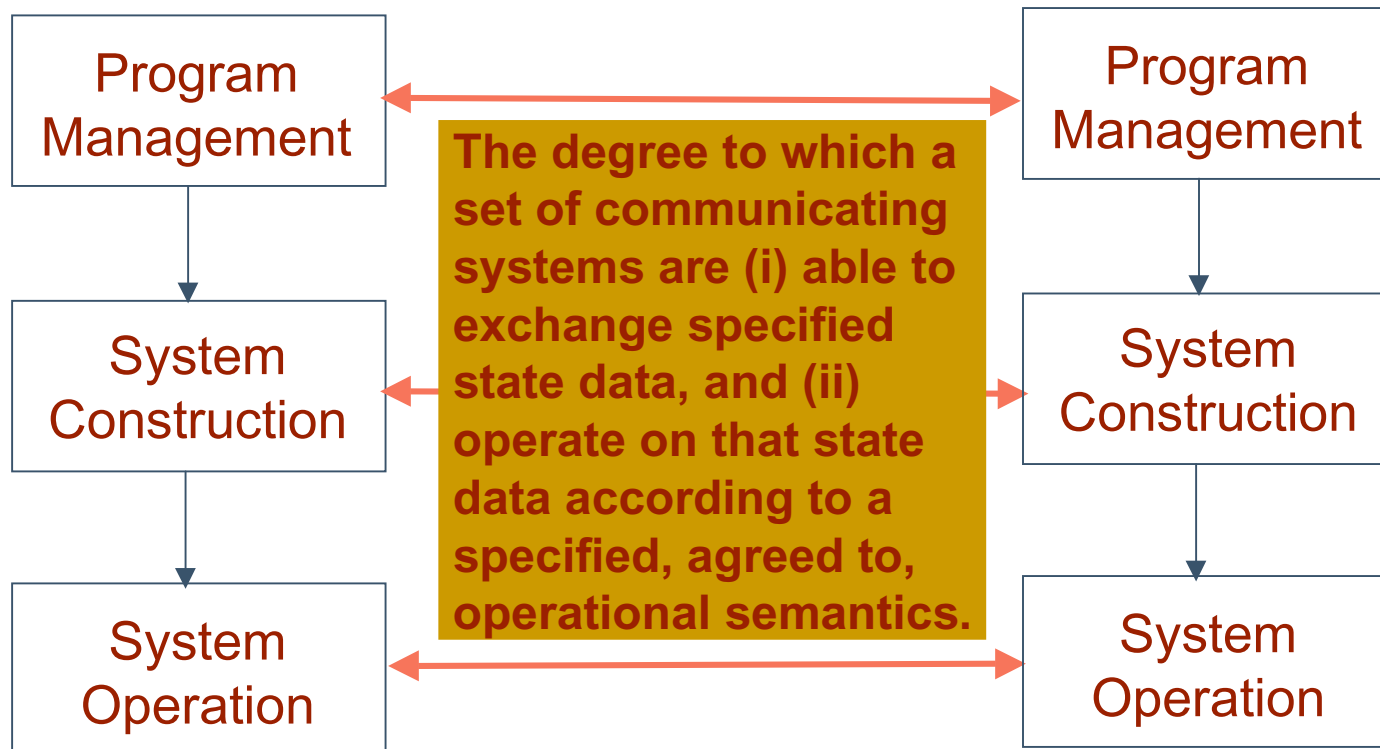


SOSI Model





Widening the Context





Carnegie Mellon
Software Engineering Institute

Summary of Results

Leadership & Policy

Vision

Funding & Control

Motivation & Incentives

Requirements

Contractor Processes

Technology & Architecture

Standards

Legacy and Evolution

Remember, we still acquire systems, not capabilities.



Leadership & Policy

Policies are insufficient. They are often rigid and reflect only one domain. What evidence is there for their success? Are there metrics?

A barrier to interoperability is a lack of centralized or coordinated ownership of the problem. Policies don't reach down far enough.

Short-sighted decisions promote a single system view at the expense of other systems.

Remember the golden rule.



Vision

There are grand plans. But insufficient understanding of what the services are trying to achieve.

Solutions can often be local in scope, and inconsistent with higher vision.

Should the approach for the vision be top-down or bottom-up? Do we know enough to ask the right questions and to answer them?

Where's the belly button? How many are there?



Funding & Control

Interoperability is insufficiently funded, and reaching agreement with other programs depends on money.

There are funding and control limitations. Loss of control can be frightening.

PMO staff is often inexperienced in estimating costs for interoperability.

Interoperability must be planned and resourced appropriately. How much of the overall funding model needs to change?



Motivation & Incentives

There is limited motivation to provide an interoperable system. The real motivation is to produce the system.

No one wants to spend the money to make interoperability work.

We need better incentives. Incentives are program oriented, not in the context of how the system will be used with other systems.

Cross-program management is ad hoc or missing.

It comes down to a big stick and money.



Requirements

Until recently, few interoperability requirements were identified. Interoperability often came about when the system was deployed.

Requirements across multiple systems can lead to sub-optimal solutions for any one system. Not mine!

The first thing that goes when things get tight is interoperability with non-critical systems.

Organizations are struggling with Information Exchange Requirements in a net-centric environment.

Requirements must interoperate also.



Contractor Processes

Interoperability can be hindered by size and diversity of systems and number of necessary contractors.

Few processes that allow contractors to work as peers to achieve interoperability.

Large cast of characters trying to provide solutions.

Interoperability requires a full service approach.



Technology & Architecture

At the management level, most believe that technology is not the problem, e.g., XML is a solution. The market has converged on data transmission standards.

But some elements are missing (e.g., joint risk management, real-time).

Current architectures provide insufficient information to achieve interoperability.

There is a lack of a system of systems architecture, and it is needed.

What do we really need?



Standards

Use of standards gives a false sense of security.

Standards are often inconsistent and not fully specified.

Who selects standards can have major implications in a performance-based environment.

Standards bodies have a built-in tension due to constituency.

Certification processes can be passed; systems fail but are deployed anyway.

Standards are necessary but not sufficient.



Legacy & Evolution

Backward compatibility is an issue since there is never enough to upgrade all systems. This can limit interoperability with new systems.

Interoperability can degrade over time.

We need more of a lifecycle focus, including training and simulation.

Today's system is tomorrow's legacy.



Signs of Progress

DoD Interoperability Initiatives

- Commands, Directorates, and Centers (14) e.g., DISA Interoperability Directorate
- Standards (3) e.g., DoDAF Architecture Framework
- Strategies (4) e.g., Global Information Grid (GIG)
- Demonstrations, exercises and test beds (4) e.g., Joint Distributed Engineering Plant (JDEP)
- Joint and Coalition Force initiatives (19) e.g., Single Integrated Air Picture (SIAP)
- DoD sponsored research e.g., DARPA



The Nature of the Progress

There is clear understanding of the importance of the problem, although solutions are not yet aligned.

Some organizational restructuring has been done, e.g., JFCOM.

Resources are now being dedicated to finding solutions.

Some solution approaches are being implemented and appear promising, e.g., Army Blocking Policy, Air Force C2 Constellation, SIAP.



There is More to Do

We see a need for

- identification of barriers to programmatic interoperability.
- mechanisms to improve programmatic interoperability (e.g., joint risk management, assessment instruments, interlocking award fees, experience sharing).
- understanding implications of network-centric systems for interoperability and emergent, unbounded behavior.
- understanding effects of component architectures on quality attributes (e.g., performance, etc.) in large context.
- approaches for legacy system integration and migration.
- an understanding of the basic theory.



Carnegie Mellon
Software Engineering Institute

Summary

The SOSI work has begun to explore the subject of interoperability—problems and solutions.

The work is continuing under the *Integrated System of Systems (ISIS)* initiative at the SEI.



Carnegie Mellon
Software Engineering Institute

Reports

The SOSI work is described in two reports (available on the SEI website):

Linda Levine, B. Craig Meyers, Ed Morris, Patrick R. H. Place, and Daniel Plakosh, *“Proceedings of the System of Systems Interoperability Workshop (February 2003)”*, SEI TN-016, June 2003.

Linda Levine, B. Craig Meyers, Ed Morris, Patrick R. H. Place, and Daniel Plakosh, *“System of Systems Interoperability: Final Report SEI TR-004, 2004.*