Software Engineering Institute

Programmatic Interoperability

B. Craig Meyers
James D. Smith

December 2007

TECHNICAL NOTE
CMU/SEI-2008-TN-012

Integration of Software-Intensive Systems Initiative

http://www.sei.cmu.edu

Carnegie Mellon

This report was prepared for the

SEI Administrative Agent
ESC/XPK
5 Eglin Street
Hanscom AFB, MA 01731-2100The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

This work is sponsored by the U.S. Department of Defense. The Software Engineering Institute is a federally funded research and development center sponsored by the U.S. Department of Defense.

This work was created in the performance of Federal Government Contract Number FA8721-05-C-0003 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center. The Government of the United States has a royalty-free government-purpose license to use, duplicate, or disclose the work, in whole or in part and in any manner, and to have or permit others to do so, for government purposes pursuant to the copyright license under the clause at 252.227-7013.

For information about purchasing paper copies of SEI reports, please visit the publications portion of our Web site (http://www.sei.cmu.edu/publications/pubweb.html).

Table of Contents

List of Figures

Acknowledgements

This work was supported in part by the Carnegie Mellon®[1] Software Engineering Institute Independent Research and Development project called “Toward Interoperable Acquisition: The Case of Risk Management.” We also acknowledge discussions with colleagues Lisa Brownsword, Suzanne Garcia, and Ed Morris.

1. ® Carnegie Mellon is registered in the U. S. Patent and Trademark Office by Carnegie Mellon University.

Abstract

Interoperability has traditionally been considered a property of operational systems, where systems are able to exchange information in some agreed-upon fashion. However, other aspects of interoperability are often overlooked. This report introduces one of those aspects—the concept of programmatic interoperability, which is the application of principles of interoperability to the acquisition management of systems. It shows how programmatic interoperability contributes to fielding interoperable capabilities and relates this aspect to current trends such as network-centric operations. The report also discusses the orchestration of decisions and activities that are applicable to acquisition in a system-of-systems environment. Finally, the report suggests several research topics.

1 Introduction

There is increased emphasis—in commercial industry and government—on moving toward a network-centric perspective to provide operational capabilities to end users. For acquirers and developers, this perspective shifts the view from an individual system to a system-of-systems environment and fundamentally alters the nature and extent of the requirements for interoperability. We use the phrase *system-of-systems environment*, not systems-of-systems acquisition. The former term describes the integration of multiple separate acquisitions; the latter connotes a single acquisition of some larger system.

Interoperability has traditionally been considered a property of operational systems. Efforts to achieve interoperability have usually focused on defining communication protocols and interface standards and verifying (usually through testing) conformance to them.

Recent work at the Carnegie Mellon®[2] Software Engineering Institute (SEI) has led to the recognition that achieving interoperability actually requires an understanding and orchestration of activities across all aspects of the affected systems. A useful approach growing from that work is to consider interoperability in terms of these distinct aspects:

- operational—interoperability among entities engaged in the operation of systems (As previously discussed, this aspect is the focus of the traditional approach to achieving interoperability.)
- constructive—interoperability among entities engaged in the development and maintenance of systems
- programmatic—interoperability among entities engaged in the acquisition management of systems

This report examines programmatic interoperability and discusses its relation to the other aspects of interoperability. The discussion is focused on government acquisitions, but many of the principles are believed to apply to commercial acquisitions as well. We suggest that achieving interoperability in fielded systems requires considering the activities in *each* of those aspects—as well as their interrelations.

This report is organized as follows:

- Section 2
  - sets the context through an overview of network-centric principles and systems of systems and a discussion of interoperability
  - broadens the scope of interoperability to include aspects beyond the traditional context of operational systems

2. Carnegie Mellon is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University.

- Section 3 examines programmatic interoperability in more detail through discussion, examples, and research questions.
- Section 4 includes a discussion of the orchestration of activities and decisions across all aspects of a system of systems.
- Section 5 provides a summary of the report.

2 Setting the Context

2.1 DEFINING NETWORK-CENTRIC OPERATIONS AND SYSTEMS OF SYSTEMS

The terms *network-centric operations* and *systems of systems* have been heavily used in the commercial and Department of Defense (DoD) domains. Both terms express a contrast to a *monolithic system* that is managed by a single agency, composed of tightly coupled components, and designed for a particular set of tasks. In both domains, the hope is that a network-centric, system-of-systems approach can reduce the time needed to field a new capability and increase flexibility in dealing with changes in requirements or technologies.

Network-centric operations refers to a collection of concepts that attempt to derive power from distributed, interacting entities based on a significantly improved access to information. These principles are expected to provide [Alberts 99]

- shared awareness through the fusion of data from many different types of sensors

  It is in this context that a phrase *common operational picture* is often used.
- collaboration among virtual organizations designed to accomplish a specific purpose
- execution of activities by other entities, often distributed, consistent with management intent, giving rise to the expression *power to the edge*

A *system of systems* can be viewed as a way to implement the principles of network-centric operations. The term *system of systems*[3] has been given various definitions; one definition that we use reads [Levine 03]

> ***system of systems:*** *a set or arrangement of interdependent systems that are related or connected to provide a given capability*

One set of characteristics for systems of systems, provided by Maier, includes the following [Maier 96]

- managerial independence

  The management of each system in a system of systems is independent from the management of the other systems.
- operational independence

  Each system within the system of systems can function usefully in the absence of other systems.
- evolutionary character

  Each system within the system of systems evolves independently of other systems.

3. A related term is *family of systems*. We will not go into a distinction between the terms system of systems and family of systems. Some discussion about these terms appears in *Requirements Management in a System-of-Systems Context: A Workshop* [Meyers 06a].

- emergent behavior

  The behavior of the system of systems is a characteristic of the interaction of the individual systems that compose the system of systems; it is not embodied in any particular system and is a consequence of the *interactions* that take place among the systems.

The combination of these characteristics means that the policies, practices, procedures, and techniques used now to acquire, develop, field, use, and sustain stand-alone systems—while still important—must be reinterpreted and perhaps changed for a system-of-systems context.[4] Furthermore, new policies, practices, procedures, and techniques may need to be formed and integrated throughout the acquisition life cycle to meet the needs of acquisition in a system-of-systems context.

2.2 DEFINING INTEROPERABILITY

We also recognize that the current approaches to interoperability may be inefficient. Because of their emphasis on principles such as collaboration and characteristics like emergence, network-centric operations and systems of systems necessarily rely on interoperability. Like the term system of systems, *interoperability* has many definitions. For example, this Institute of Electrical and Electronics Engineers (IEEE) definition is often cited [IEEE 00]:

> ***interoperability:*** *the ability of two or more systems or elements to exchange information and to use the information that has been exchanged*

The DoD uses multiple definitions of interoperability, all of which are based to some degree on definitions developed by IEEE. For example, one definition is [DoD 00]

> *1. The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.*
>
> *2. The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases.*

Other definitions of interoperability from the IEEE, the DoD, and other sources are in the Appendix. An examination of the IEEE and DoD definitions presented here and those in the Appendix can be summarized by noting the following point: *The term interoperability has been traditionally used in the context of an operational system*.

We believe, however, that a broader approach to interoperability is needed. We base our determination on the view that interoperability is independent of a domain of application. Interoperability applies to the acquisition management and construction of a collection of systems just as much as it does to its operation.

4. It is important to underscore the difference between the terms *network-centric operations* and *system of systems*. The former emphasizes concepts, while the latter emphasizes a realization of those concepts.

In keeping with that view, we offer the following definition ([Levine 03], [Morris 04]):

> ***interoperability****: the ability of a set of communicating entities to (i) exchange specified information and (ii) operate on that information according to a specified, agreed-upon, operational semantics.*[5]

We emphasize the domain-neutrality and primary nature of this definition. Our definition may be applied to any context, such as the acquisition management, construction, or operation of a system of systems. We suggest that our definition is fundamental, in that the IEEE and DoD definitions given earlier can be derived from it.[6]

2.3 INFLUENCE OF INTEROPERABILITY IN ACQUISITION

Given that interoperability is central to achieving network-centric concepts in systems of systems and can be applied in many contexts, it is relevant to discuss key influences that affect the acquisition process. Although there may be many such factors, our focus here is on those factors that closely relate to the considerations regarding the basic elements of interoperability. Thus, the following discussion is couched at a higher level to emphasize principles.

2.3.1 Scope of Interaction

Interoperability in the acquisition process is influenced by the scope of interaction among organizations that participate in the process. In support of this claim, we consider the basic situations shown in Figure 1.

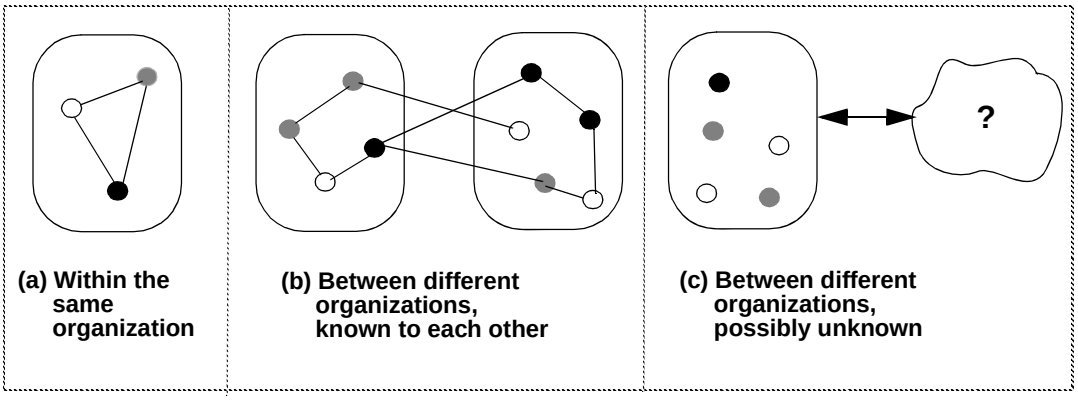

Figure 1: Models of the Scope of Interaction

5. Operational semantics refers, loosely, to the semantics of operations that are performed by an abstract machine capable of executing a specification. Operations may be defined in terms of pre- and post-conditions whose application may result in a state change. The meaning of the (abstract) specification, then, is defined in terms of the operations that may be performed.

6. Quality characteristics such as interoperability are sometimes defined in measurable terms. In this approach, our definition of interoperability would begin with the phrase "The degree to which." Although such an approach can be taken and has interest in its own right, we shall not pursue that path here. The idea of measuring interoperability does, however, raise the interesting issue of determining the relevant metrics.

The different cases depicted by the models in Figure 1 are described as follows:

- Case (a) represents interoperability within a particular organization. In general, this is the easiest case because a single organization is likely to have common practices, culture, and decision-making processes.
- Case (b) represents interoperability between different, but known, organizations.[7] Dealing with different organizations adds consideration for organizational policies and practices that might be in conflict. It is assumed in this model that the set of communicating entities is known and relatively stable over time.
- Case (c) is fundamentally different from (b) in that the identity of the other organizations may not be known. This case is analogous to an organization presenting information about risk management to others that may need such information—independent of any prior agreement about which organizations should be given that information.

The three cases can be seen as depicting two situations that are quite different. The first two cases are typical of a *bounded* environment, in that the communicating entities and their number are known (and traditionally they are relatively stable over time). The last case is characteristic of an *unbounded* environment in which the identity and number of communicating entities may not be known. That situation, an unbounded environment, is often found in network-centric operations and systems of systems.[8]

There are additional concerns that are related to the question of scope. For example, each of the three cases presents different governance frameworks. As organizations interact, the consequences of those different governance frameworks may lead to conflicts among the entities that are less likely when one considers a single organization. The question of governance is but one example; we would suggest any process performed, such as requirements management or schedule management, may be a source of contention.

2.3.2 Nature of Agreements

Interoperability in the acquisition process is also influenced by the nature of agreements among organizations that participate in the process. Various types of agreements can be considered as part of achieving interoperability:

- public law
- contractual relationships
- memoranda of understanding (explicit, yet informal, agreements)

7. There are gradations possible for this case. For example, one could distinguish between organizations that are different but somehow closely related (within the same agency) and organizations that are unrelated (such as an acquisition organization and a contractor).

8. Our intent here is not to go into the details of the unbounded case. However, consider an environment in which information is available to others, although the identity of the consumers of information may not be known. Some organization may take information from this environment and, if it chooses, enter into an agreement with the organization that placed the information there. This is still an unbounded environment in that others, who may not be known, can gain information, and then, if necessary, engage in binding agreements with providers of information. Of course, the nature of agreements need not involve only pair-wise interactions.

- implicit agreements (For example, if two organizations agree to conform to the same standard, they have in effect entered into an agreement.)

In some sense, any type of agreement can be regarded as an *influence relation*. The nature of the influence is often connected to the expected behavior of the entities that engage in an agreement. For example, a contract specifies expected behavior as agreed to by the contracting agent and the contractor. In this sense, a contract represents a strong form of influence.

Different types of agreements are related to the character of an organization entering into an agreement. The character is determined in part by the environment in which the agreement takes place. When a government agency enters into an agreement, for example, that agreement is determined in part by the regulations that govern the behavior of the agency. Such regulations are different when an agreement is undertaken by two commercial firms. The subject of organizations and their agreements is discussed in *System-of-Systems Navigator: An Approach for Managing System-of-Systems Interoperability* [Brownsword 06].

2.3.3 Shared Information

Fundamental to any discussion of interoperability is the information that is shared. Two significant considerations are what information needs to be shared and who decides that information. The unbounded environment, Case (c) in Section 2.3.1, presents problems in the implications for sharing information and the issue of whether the necessary information can be determined at runtime. Further, if that determination can be made at runtime, the unbounded environment is also *dynamic*, making it considerably more challenging—and interesting—than a static, bounded one.

2.4 ASPECTS OF INTEROPERABILITY

Our definition of interoperability recognizes that it is a *general* property of some collection of entities and is applicable to different functional domains. In particular, the acquisition management, system construction, and system operation functional domains are important for a discussion of acquisition.

The functions in those domains are performed by organizations. In Figure 2, we show the nature of the relationship between types of functions (denoted as solid, shaded, and open circles) and the types of organizations that perform them (depicted as solid, shaded, and open squares).

In Figure 2, notice that the same type of function can be performed by different types of organizations and that the same organization can perform different types of functions.

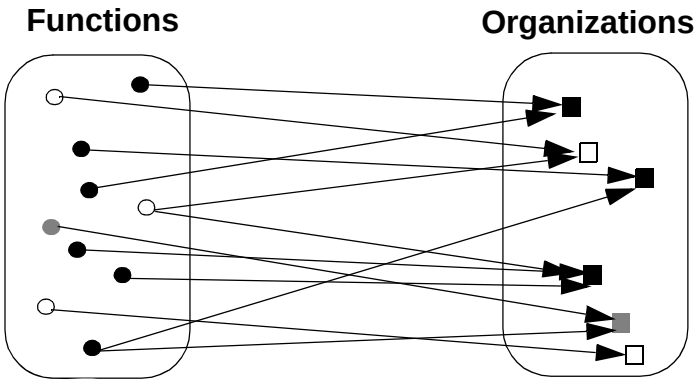

Figure 2: Mapping of Functions to Organizations

As noted earlier, interoperability has traditionally been considered a property of the system operation domain only. The SEI has developed a model showing how interoperability among those aspects works (see Figure 3). The system-of-systems interoperability (SOSI) model arose from an earlier SEI Independent Research and Development effort whose details are described in two previous reports ([Levine 03], [Morris 04]).

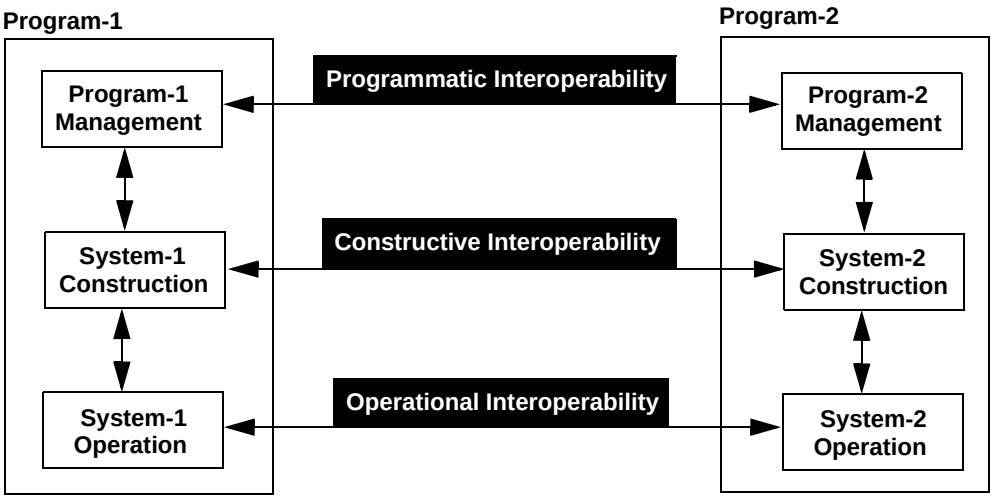

Figure 3: SOSI Model

Figure 3 simply shows two acquisitions, denoted Program-1 and Program-2. The functions performed within each program are identified as well as the various types of interoperability relations between them. While showing only pair-wise interactions,

Figure 3 introduces concepts that are easily extensible to a larger number of organizations. Thus, it includes the terms

- programmatic interoperability

  This concept refers to interoperability in the context of acquisition management; it is our focus and will be discussed further.

- constructive interoperability

  This concept refers to interoperability in the context of the construction of systems.

- operational interoperability

  This concept refers to interoperability in the operational context. The traditional view is that interoperability is viewed as operational interoperability.

There are two dimensions of interaction shown in Figure 3. Along the vertical dimension there is, as one would expect, interoperability among constituents in the context of a *particular* acquisition program. In general, this is the easier case, since

- The interaction between the functions of acquisition management and system construction is governed by a contract, which is a formal agreement having a strong intent. The interaction may also include subcontractual relations (e.g., a prime to a subcontractor). It may also include other contractual agreements, such as with an organization that performs independent verification of a system. Thus, in general, the governance of the relations among the constituents is more formal and stronger in intent.
- The constituents engaged in the acquisition of a system have a vested interest in the acquisition process and may participate to a significant degree. For example, it is often the case that a user (representing the operational community) is involved in acquisition management decisions. Organizations typically communicate more with each other, through, for example, the use of integrated product teams.

The vertical, or program-centric, perspective shown in Figure 3 has strengths and weaknesses. Its strengths rest with its focus on a particular system. Its weaknesses stem from a failure to consider a larger acquisition perspective that limits effectiveness beyond the program-centric perspective and leads to the well-known “stovepipe” behavior. The second dimension of interoperability shown in Figure 3 takes place along the horizontal perspective. This view focuses on interoperability among the functions performed by constituents that are engaged in *different* acquisitions.

This second dimension represents the more difficult case, as the governance process of each organization is more tenable; for example, the relation between different acquisition management organizations may be manifest by verbal agreements rather than a more formal type of agreement. There is also little or no explicit relation between organizations engaged in the construction of different systems.[9]

9. However, there may be implicit relations among organizations producing different systems. A simple example is that each organization may adhere to the same standard. It is through commonality of standards that one might expect interoperability among systems to be achieved. In this sense, a standard serves as the bridge between systems, even in the development context.

Taken together, the interactions shown in Figure 3 represent various *aspects* of interoperability that need to be understood and—to the extent practicable—managed. These aspects lie both within and between organizations that participate in the acquisition process. Furthermore, it is the interaction among the types of interoperability that presents challenges to the success of acquisition in the context of a system of systems.

The diagram in Figure 3 appears quite simple, and there is sometimes a tendency to interpret it in an equally simple manner. For example, it would be quite easy to assume that programmatic interoperability represents interoperability between only acquisition management *organizations*. Such an interpretation is overly simplistic and, at best, ambiguous.

2.5 PROGRAMMATIC INTEROPERABILITY

Our approach to developing a definition of programmatic interoperability[10] is to amend the definition of interoperability from page 5, as follows:

> ***programmatic interoperability:*** *The ability of a set of communicating entities engaged in* ***acquisition management*** *activities to (i) exchange specified acquisition management information and (ii) operate on that* ***acquisition management*** *information according to a specified, agreed-upon, operational semantics.*

The exchanged information has syntactic (form) and semantic (meaning) content. Syntactic matters are easier to resolve than semantic issues. Many concerns can arise out of the interpretation of the semantics, however. It is also necessary to understand the relation between the two elements. For example, a "high risk" (semantic) might be defined as having a value greater than 0.8 (syntactic).

Consideration of behaviors is also relevant. Some of these behaviors relate to communication aspects. For example, it is reasonable to assume that if an entity gains some new information, that entity needs to distribute the information to others. The information passed on, the other entities that need it, and the requirements for its distribution would have to be worked out. This type of communication ensures that entities share information deemed relevant with others that need it.

The sharing of information by some entity emphasizes the behavioral aspects of that particular entity. From this, it is important to consider the collective behavior that multiple entities perform in their approach to programmatic interoperability. For example, sharing of risk information is the first step; what must follow is the collective behavior to deal with that risk information.

To engage in collective behavior, entities must also have some knowledge of the quality of that information. Sharing high-quality information leads to trust among communicating entities. However, shared information of low quality or highly variable quality can lessen trust, resulting in behavior that is less likely to have positive results.

10. In the following we refer explicitly to *acquisition* management, as opposed to simply management. Management operations are performed in all contexts, such as the construction or operation of a system. Correspondingly, a term such as management interoperability would be ambiguous without the context in which that management occurs.

Consider an example from risk management. Most discussions of risk management include some discussion of processes related to risk identification. There are many methods (and tools) to identify risks, such as interviews, brainstorming, questionnaires, and analysis of risks on similar projects. Each of these methods might apply different resources and provide results of differing quality. Despite all of that variety, some knowledge of the quality of information about risks is needed if the sharing of that information is to foster collective behavior.

But the information exchanged and the quality of that information are separate considerations. The quality of information in a standard and the means by which that information is established, for instance, are determined through the implementation of practices by an organization. By implication, organizational practices relevant to some programmatic function can directly impact the quality of the information gathered and exchanged.[11]

The preceding discussion has illustrated several aspects of programmatic interoperability, including sharing of information and engaging in collective behavior in light of concerns regarding syntax, semantics, and qualities of information. The activities, and their characteristics, are relevant when one seeks to face the challenges of viable acquisition in a system-of-systems context successfully.

11. For processes, compliance to some model, such as the CMMI® framework, alone does not always produce high-quality results in an implementation. In short, compliance is necessary, but it is not sufficient. The SEI report *Process Considerations for Interoperable Acquisition* examines the role of process in interoperable acquisition [Garcia 06]. (CMMI is registered in the U. S. Patent and Trademark Office by Carnegie Mellon University.)

3 The Programmatic Aspect of Interoperability

In this section, we explore the main concepts of programmatic interoperability, provide some examples of problems and successes in programmatic interoperability, and raise some questions for research. Programmatic interoperability permits acquisition entities to make better decisions with regard to the acquisition management aspects of a system-of-systems environment. To meet the needs of a system of systems, it is important to stress the perspective of a collection of entities in the processes that influence the product(s) delivered to the end user.

3.1 CONCEPTS

A view of programmatic interoperability that builds from our general definition of programmatic interoperability on page 10 and emphasizes acquisition is as follows:

> ***programmatic interoperability:*** *The ability of a set of communicating entities to achieve a shared understanding with respect to acquisition management functions to allow them to engage in effective collective behavior.*

This definition naturally leads to several questions, namely:

- What are the communicating entities that participate in acquisition management activities?
- What acquisition management information needs to be shared to achieve programmatic interoperability?
- How is the quality of the relevant information determined?
- What behaviors allow effective collective behavior? How is effectiveness of behavior determined?

In the following sections, we briefly comment on these questions through viewing three concepts of programmatic interoperability: communicating entities, sharing of acquisition management information, and operations on the shared information.

3.1.1 Entities and Their Means of Communicating

From a DoD acquisition perspective, we can assume that the entities most relevant to programmatic interests are the acquisition management office (typically a PMO) and program executive office (PEO). Other relevant entities may be a milestone decision agent (MDA) or a resource allocation representative such as the well-known Program, Planning, Budgeting, and Execution System (PPBES).[12] Overall, the range of communicating entities could include

- PMOs, PEOs, MDAs, and service acquisition authorities
- Federal agencies, such as the Department of Homeland Security (DHS)
- Congressional oversight committees
- state and local governments
- international partners

12. Some background on the PPBES system can be found at on the organization's Web site [PPBES 03].

In addition to government organizations, other types of entities may participate in the acquisition management process, such as

- contractors of the systems that are intended to interoperate
- representatives from the user community
- managers of suppliers of commercial products that are used in the systems[13]

Two other factors are as important as the identification of entities: (1) the means by which entities communicate and (2) the protocol employed (where a protocol defines the syntax and semantics of a communication process). When considering a protocol, entities also must address concerns about when and how communication takes place.

3.1.2 Acquisition Management Information

By looking at the acquisition management information, we are moving from a focus on who communicates and how they communicate to *what* is communicated. We are interested here in the information that needs to be visible in order to achieve interoperability in the programmatic context. Certainly, information associated with schedule (especially schedule variance) falls into this category. Information related to products (both function and quality) is a prime candidate, too, as is information related to risk management. Other types of information may be necessary as well, notably drivers from the operational community.

Those elements may be obvious types, but other forms of information are less well recognized. Consider cost, for instance: What information regarding cost needs to be shared, and why does it need to be shared? Questions surrounding the sharing of cost information illustrate a typical difficulty in achieving interoperability in an acquisition management context. Programs are naturally protective of cost information. However, the ability to reprogram funding among programs may justify sharing cost information.[14] Similarly, one might expect to gain insight into risks affecting schedule. However, which risk, what level of detail about the risk, and how the quality of information about the risk is to be assessed need to be identified. Indeed, for all types of information, entities need to specify what details (and at what level of specification) are relevant to share and be able to assess the quality of information shared.

13. The list of other entities can be extended to include various types of organizations involved in short-term, limited interactions—a view that brings one close to virtual organizations and their collaboration, a tenet of network-centric operations.

14. Reprogramming thresholds for costs among programs are specified in statute. Overall, we might ask: Do statutes and DoD policies impose a barrier on achieving programmatic interoperability? If they do, what needs to be changed? The implications of statute (in particular, Title 10) for acquisition in a system-of-systems context is under examination by the authors of this technical note and will appear in a forthcoming report.

3.1.3 Operations

An entity performs behaviors, and a behavior may be viewed as an operation. Of relevance to the programmatic aspect is that these operations are performed on acquisition management information.[15] We consider a process to be an encapsulation of operations. Many types of processes are relevant to acquisition management, such as those dealing with acquisition strategy management, cost management, contract management, schedule management, or risk management.[16] Details of specific processes are not relevant to this report.

There are problematic issues with information about process, particularly with respect to interoperability among processes. Some argue that the *output* from a process is relevant and that *how* the output is produced is not important. A counter to this argument is that sharing details of how a process is performed can be useful, if only as a learning opportunity. Further, those details could be used to judge the quality of work performed. Whether they deem the output or the detail important, entities need to establish a frame of reference to effectively share any process-derived information.

3.1.4 Summary of Perspectives on Programmatic Interoperability

Programmatic interoperability, as we've seen, can be considered from the perspectives of communicating entities, the information they share, and the operations that are performed on that information. In essence, these three perspectives represent elements in an *acquisition* in a system-of-systems context, a situation that we frame as *interoperable acquisition*. The SEI has reported on research into some key areas for interoperable acquisition: challenges facing the entities involved [Smith 06], risk management [Meyers 06b], and schedule [Meyers 06c].

15. The operations (behaviors) of each entity are important; even more significant is *collective* behavior.

16. The SEI work in the area of processes for acquisition includes the CMMI framework for process and product improvement [Chrissis 03] and its extension for acquisition organizations [Dodson 06]. It is also expected that the SEI will release the CMMI for acquisition (denoted CMMI-ACQ) in the near future.

3.2 PROGRAMMATIC INTEROPERABILITY EXAMPLES

These examples are based on our interactions with customers and include both problems and successes.

Table 1: Examples of Programmatic Interoperability

Context	Problem	Resolution or Outcome
Reuse in an integration context	Development of a large system emphasized the reuse of products created by other acquisition efforts. However, the integration agent did not specify any entrance criteria for candidate reusable products. The products were selected without regard to maturity or quality.	Numerous problems plagued the integration effort. One unresolved issue was the question of who should pay to make changes to the reused products.
Synchronization through a contract specifying the use of standards	In an acquisition effort where multiple systems were expected to interoperate, some synchronization among the programmatic entities was needed. One implicit approach to achieving the desired synchronization was through the contract that mandated compliance with various standards.	Unfortunately, different implementations of the same standard caused problems during integration. Contracts are typically structured from the perspective of a particular system, rather than the collection of systems.
Integration of requirements	In an acquisition effort where multiple systems were expected to interoperate, requirements were placed against the individual systems and their integration. But little attention was paid to conflicts among requirements. Furthermore, there was a conflict between the top-down approach specified in DoD policies and the actual, bottom-up process employed to achieve interoperability between operational systems.	The lack of any acquisition management process that addressed the full scope of requirements management (i.e., requirements at the system-of-systems level) was an ongoing source of difficulty. (Requirements management conflicts in a system of systems are discussed in a previous report [Meyers 06a].)
Schedule problems in integration	In a simulation for a large collection of systems, insufficient attention was paid to the coordination and acquisition management of the overall schedule. Thus, it was not surprising when the simulation was not delivered on time.	There was a delay in meeting schedule. Also, the rush to produce one system lessened its quality and caused problems in integration. It was not simply the lack of an agent responsible for coordination of schedules; of greater importance was the lack of sharing of information.
Joint award fee board[a]	Two PMOs used the same prime contractor for their respective systems. The systems being produced had a number of important interoperability requirements. The PMOs decided to conduct a joint award fee board.	Rather than satisfying an individual PMO, the award fee board changed its focus to stress interoperability between systems. The contractor preferred this approach; a decrease in interoperability problems resulted.
System engineering resourcing oversight	A number of large systems were being acquired separately. However, it did not take long to realize that there had been no allocation of resources (funding and staff) in order to address issues related to system engineering of the collection of systems.	The individual programs could not work out the resourcing oversight, because they focused on their own systems. Failure to recognize programmatic concerns related to system engineering caused difficulties throughout the integration.

a. Joint award fee boards have many interesting aspects, including the business strategies of the organizations involved in constructing a system. For example, a contractor may choose to sacrifice part of an incentive fee award to satisfy longer term business goals. Or, intellectual property concerns about sharing information among development organizations may warrant taking such a position. (One counter to this action is the use of past performance evaluations by government, but its use may be difficult.) The preceding examples underscore that acquisition in a system-of-systems context and its inherent interoperability considerations can be significantly different from the acquisition of a particular system.

In each case detailed in Table 1, there are implications for how the management of an acquisition involving a collection of systems can be approached. In the reuse scenario, for instance, the absence of criteria for selecting products proved detrimental; in the example of a contract used to synchronize integration activities, the repeated use of the same standard caused problems due to differing implementations; failure to reconcile requirement conflicts, coordinate schedules, or provide adequate resources for system-of-systems engineering negatively affected other efforts. One approach did have positive results: the use of a joint award fee board provided incentives to focus on the interoperability between systems.

Problems resulted in five of the six examples described in Table 1. One inference from the outcomes is that a traditional approach to acquisition is not sufficient for a system-of-systems environment. Each outcome, the problems as well as the success, supports our contention that operational interoperability is more likely to be achieved if consideration of programmatic (and constructive) interoperability is addressed throughout the acquisition process.

3.3 PROGRAMMATIC INTEROPERABILITY RESEARCH ISSUES

Many issues surround programmatic interoperability, including

How does one identify the communicating entities that participate in programmatic interoperability and their degree of boundedness?

Clearly, it is necessary to identify the entities that need to communicate in order to achieve programmatic interoperability. An interesting aspect of this question is the bounded or unbounded nature of the interactions. We see two relevant perspectives, illustrated in Figure 1 on page 5 where:

1. the entities and their number are known and relatively stable over time (the bounded case)
2. the entities and their number are not known (the unbounded case)

These perspectives represent limits in the temporal interactions among the interested entities. It is one thing to share information with a relatively small number of entities, but it is quite something else to make information available to anyone. Notice that the unbounded case has a close parallel to discussions about network-centric operations.

What information must be shared to achieve programmatic interoperability?

Describing the communicating entities, acquisition management information, and operations on that information is important, as we mentioned in Section 3.1. Of even greater significance is to identify the *specific* entities, acquisition management information, and operations. Consider the case of sharing information about schedule in the context of risk management. Should an organization expose the inability to meet a scheduled milestone? We say yes. But should the organization also expose the risks associated with failing to meet that milestone? This question is problematic. An organization might state a risk in this way: “The integration facility is not on schedule due to a delay in implementing air conditioning in the facility; there is a risk to the sched-

ule for the readiness of the facility." Is it really necessary to expose that there is a risk to the completion of the facility due to an air conditioning problem? Many organizations would argue that the important point is that the facility is "not on schedule."[17]

How does one assess the quality of information shared?

Entities need to know the quality of shared information to make decisions that will affect their collective behavior. Typically, pieces of information are of varying quality. The range of information quality could be reflected in decisions reached on that information. How can an organization know whether the information provided is of sufficient quality that the collective decisions reached and collective behavior performed are appropriate?

What are the implications of programmatic interoperability for process?

The role of process in acquisition is well known; it has been incorporated, for example, into the CMMI framework for acquisition [Dodson 06]. When we add a consideration of interoperability to acquisition, two issues emerge:

1. How should existing processes be modified to account for interoperability when the scope of an acquisition is larger than an individual program?
2. What additional processes are necessary to address interoperability among acquisition management organizations?

Notice that each of the examples given in Section 3.2 has implications for acquisition processes. We expect that questions related to process are important, because a process perspective is expected to be an important component of programmatic interoperability.[18]

What collaborative behaviors support successful programmatic interoperability?

A key to achieving programmatic interoperability is that the relevant entities engage in collective behavior beyond sharing information. In particular, for a function such as risk management, it is necessary to identify behaviors for each entity as well as collaborative behaviors for all relevant entities. A start to identify collaborative behaviors has been discussed for schedule management in *Schedule Considerations for Interoperable Management* [Meyers 06c].

How much automated support can be provided to programmatic interoperability?

We envision acquisition being conducted with greater support from automated systems. We believe more automation is necessary to meet the increased demand for acquisition management information sharing. If one accepts this premise, where can such support be brought to bear? For example, if there is a change to some attribute of a schedule for some system (e.g., a modification to a milestone or the knowledge of its schedule variance), how can that information be efficiently distributed? How can such information be further processed by receiving entities with automated support?

17. An example like this one suggests that how much risk information an organization is willing to share in general and what the term *interoperable risk management* would entail are also interesting areas for investigation. This subject is pursued further in *Risk Management Considerations for Interoperable Acquisition* [Meyers 06b].

18. For more information, see *Process Considerations for Interoperable Acquisition* [Garcia 06].

In the language of the CMMI framework, we seek more automated process control where control can be exercised even by autonomous agents.[19] Notice that the goal here is similar to that for network-centric operations: the benefit gained from the use of automated support in order to obtain greater sharing of information that permits collaborative behavior.

What are the metrics to assess programmatic interoperability?

In discussing our definition of interoperability (see page 5), we mentioned that preceding it with the phrase "the degree to which" recasts the definition in terms of metrics. But what are the useful metrics, and more importantly, how would they be used? Some examples of possible metrics have been discussed earlier in regard to schedule information [Meyers 06c].

What are the impediments to achieving programmatic interoperability due to the legal and regulatory framework?

The environment in which acquisition occurs is influenced by many things—from statutes and regulations (e.g., Federal Acquisition Regulations) to DoD policy, directives, and business practices. Although one may often hear that the legal environment causes problems for achieving interoperability, is this assumption borne out by the text of the statutes and regulations themselves? And if it is, what changes to the statues and regulations need to be made?

What approaches lead to successful programmatic interoperability?

All of the preceding issues apply to the goal of having an approach to achieve programmatic interoperability. In order for that approach to be developed, further identification and examination of all issues, as well as their integration, is necessary. We anticipate that any approach must address the three fundamental characteristics of programmatic interoperability: communicating entities, information shared, and collective behaviors. One initial approach, whose concepts are continuing to evolve, has been described in *System-of-Systems Navigator: An Approach to Managing System-of-Systems Interoperability* [Brownsword 06].

How does interoperable acquisition affect programmatic interoperability?

The phrase interoperable acquisition is a shorthand for interoperability in the acquisition process. An interoperable acquisition approach would address programmatic, operational, and constructive interoperability aspects that are necessary to produce systems required to interoperate, as well as integration of these aspects of interoperability. Some work in interoperable acquisition by the SEI has been done, ranging from ontologies to models (including formal models) ([Meyers 05], [Meyers 06b], [Meyers 06c], [Smith 06]).

How extensible are research questions regarding programmatic interoperability to

19. There is a close connection here with process, particularly in the modeling of a process to achieve some purpose such as interoperability and in the realization of that model.

other aspects of interoperability?

Issues related to interoperability may be described in terms of a programmatic, a system construction, or an operational perspective. However, many issues apply equally to these different domains. For example, the issue of what information is necessary to be shared applies to each domain. To the extent that research findings regarding programmatic interoperability can be applied to other aspects of interoperability, there is the opportunity to develop more general approaches for the resolution of issues.

4 Enlarging the Context

The preceding discussion focused on programmatic interoperability, which is but one aspect of interoperability. As we've shown, the SOSI model (see Figure 3 on page 8) also includes constructive and operational interoperability aspects. To achieve interoperability, it is necessary to understand not only each aspect but also the interactions between them.

4.1 OVERVIEW

We can illustrate the orchestration of aspects of interoperability in a system-of-systems context by extending Figure 2 (from page 8) to consider multiple organizations that are producing systems expected to interoperate in a system-of-systems context.

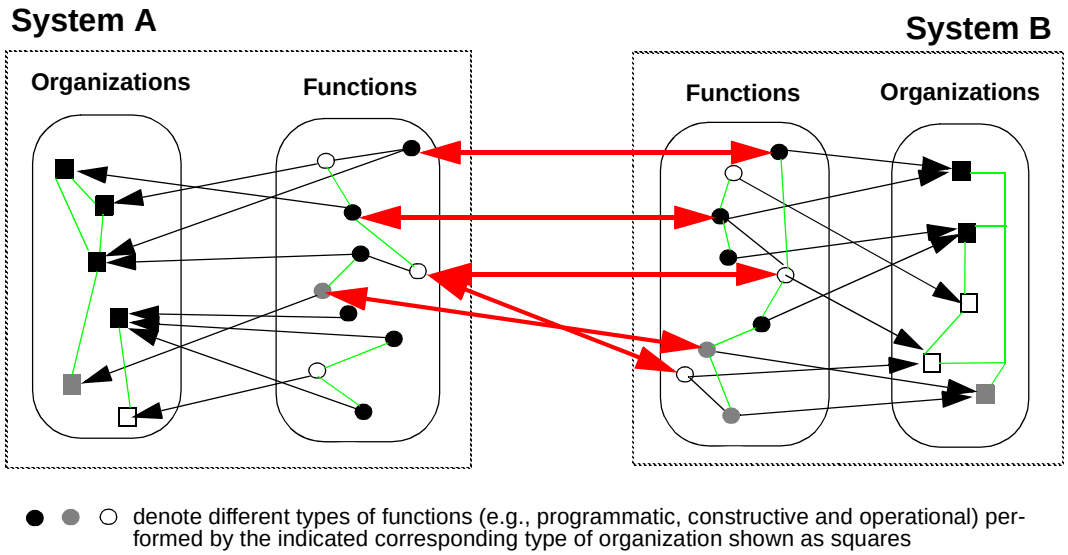

Figure 4: Illustrating Orchestration of Interoperability Aspects in a Multisystem Context

Figure 4 shows the functions performed and the organizations involved for two different systems that are expected to interoperate in a system-of-systems context. As in Figure 2 on page 8, the same organization can perform multiple functions, and the same function can be performed by more than one organization.

In this figure, however, we show interoperability relations between functions within each system through connecting lines; further, other connecting lines between organizations in a system imply interoperable relations that result from the related functions. Also, heavy, arrowed lines between functions performed by organizations in different systems connote that it is necessary to orchestrate the activities relevant to each system in a way that some larger goal is achieved, such as an acquisition man-

agement organization performing a risk management activity and needing to provide its results to multiple organizations.

For an example of this orchestration, consider a situation in which multiple systems are being developed and must synchronize their schedules. This synchronization might require dealing with cost factors related to schedule in one system and technology factors related to schedule in another system. The orchestration of these factors is a subject that must be considered to achieve the broader goal of interoperability.

4.2 PERSPECTIVES ON INTEROPERABILITY INFLUENCES

Just as each aspect of interoperability is influenced by scope, nature of agreements, and shared information (as detailed in Section 2.3), so, too, is the orchestration of those aspects:

- scope of interaction

  An increase to the scope of interaction means that many more organizations participate in the process. The number and type of functions performed by these organizations are relatively constant. All systems, for instance, require cost estimation, risk management, architecture, and testing. However, the implementation of those functions can differ as the number and type (e.g., government or industry) of organization increase. In addition, we would expect changes to existing processes, and perhaps even new processes, are necessary to achieve programmatic interoperability.

- nature of agreements

  The inclusion of more organizations means greater a variety of agreements among them. For example, there may be a need to develop an agreement among organizations for the distribution of information.

- shared information

  The amount of information that must be shared will depend on the functions that are performed. For example, some information regarding cost management, schedule management, and risk management is a likely candidate. With agreements in place regarding how the information may be distributed, one would expect the syntax and semantics of such information to be shared. One might expect that such information would be specified in a standard that can be used by all participants; in that case, the functions shown in Figure 4 would collapse to a single set. This scenario assumes that the specification of functions performed is sufficient to address interoperability considerations among those functions, which need not be (and in our experience is not) the case.

> However, as we pointed out in Section 3.1, it is not simply information relevant to the functions performed that is of interest. The sharing of that information is necessary but not sufficient to achieve collective behavior that meets the goals of acquisition in a system-of-systems context. Knowledge of the quality of information shared is also needed to assess its relevance to any decisions regarding collective behavior.[20]

For each of those three factors, a frame of reference that promotes effective mutual understanding of the information exchanged is needed. For example, consider the case where one program develops cost estimates using a parametric approach. Another program develops cost estimates using activity-based costing. In order for these programs to share cost information effectively, they must first share a frame of reference. The mutually compatible frame of reference permits them to share relevant information and take appropriate collective action (behavior) on it. Thus, to share cost estimating information, the programs in our example need to understand each other's approach to obtaining estimates. Without a common, or at least compatible, frame of reference, effective sharing—and understanding—will not be possible.

4.3 IMPLICATIONS

The orchestration of activities and decisions needed across all aspects of interoperability is a subject in its own right. We are suggesting that orchestration makes achieving programmatic interoperability more complicated than one might at first think. Furthermore, interoperable acquisition must account for the interaction of various aspects of interoperability. Yet, as an increase in scale further breaks the bonds of coupling, how can one understand and address the new environment?

20. If one takes a standards-based view on relevant information that could be shared (such as risk management), it is noteworthy that standards documents rarely, if ever, discuss the means by which information may be obtained or its quality assessed.

5 Summary

The term interoperability has traditionally been used in the context of *operational* systems. This report suggests a broader scope for this term that encompasses operational, constructive, and programmatic aspects. We specifically discuss the aspect of *programmatic interoperability*, which we define as

> ***programmatic interoperability****: The ability of a set of communicating entities engaged in acquisition management activities to (i) exchange specified acquisition management information and (ii) to operate on that acquisition management information according to an agreed, operational semantics.*

We propose that programmatic interoperability is central to acquisition in a system-of-systems context. When we orient our definition toward the needs of the acquisition community, we see that the communicating entities need to achieve a shared understanding about acquisition management functions (through exchanging information and other actions) that allows them to act collectively in the context of a the system-of-systems environment. The purpose, then, of programmatic interoperability is to assure that a collection of entities can successfully operate regarding the acquisition management in the context of a system of systems.

In this report, we examine a number of topics related to programmatic interoperability including concepts, examples, and research questions. Further, we argue that a connection exists among all three aspects—operational, constructive, and programmatic. In order to achieve interoperability in the operational context (which is the desired state), it is necessary to also consider programmatic and constructive interoperability aspects. In addition, it is necessary to consider the orchestration of activities and decisions across all aspects of interoperability.

Appendix A Definitions of Interoperability

In this Appendix we present a number of approaches to the definition of the term interoperability. For example, IEEE has the following definitions [IEEE 00]:

> *the ability of two or more systems or elements to exchange information and to use the information that has been exchanged*
>
> *the capability for units of equipment to work together to do useful functions*
>
> *the capability, promoted but not guaranteed by joint conformance with a given set of standards, that enables heterogeneous equipment, generally built by various vendors, to work together in a network environment*
>
> *the ability of two or more systems or components to exchange information in a heterogeneous network and use that information*

DoD also uses multiple definitions of interoperability, all of which are based to some degree on the definitions developed by IEEE. For example, one definition is [DoD 00]

> *1. The ability of systems, units, or forces to provide services to and accept services from other systems, nits, or forces and to use the services so exchanged to enable them to operate effectively together. 2. The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases.*

Item 2 of the preceding definition was later modified in the following manner in connection with the *Joint Requirements Oversight Council* [DoD 02]:

> *2. The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases. For the purposes of this instruction, the degree of interoperability will be determined by the accomplishment of the proposed information exchange requirements fields.*

Further, in the context of the *Joint Capabilities Integration Development System* [DoD 05], the following appeared:

> *The ability of systems, units or forces to provide data, information, materiel and services to and accept the same from other systems, units or forces and to use the data, information, materiel and services so exchanged to enable them to operate effectively together. Information technology and National Security Systems interoperability includes both the technical exchange of information and the end-to-end operational effectiveness of that exchanged information as required for mission accomplishment.*

In the context of the *Global Information Grid*, the following is found [DoD 01]:

> *(1) Ability of information systems to communicate with each other and exchange information. (2) Conditions, achieved in varying levels, when information systems and/or their components can exchange information directly and satisfactorily among them. (3) The ability to operate software and*

> *exchange information in a heterogeneous network (i.e., one large network made up of several different local area networks). (4) Systems or programs capable of exchanging information and operating together effectively.*

The U. S. Congress also has interest in interoperability. For example in the *E-Government Act* of 2002 [USC 02] one finds the following:

> *'Interoperability' means the ability of different operating and software systems, applications, and services to communicate and exchange data, in an accurate, effective, and consistent manner.*

Of interest to the DoD are statements regarding interoperability that are specified in law, in particular Title 10 is the U.S. Code [USC 04]. Although the term interoperability is not defined there, it is used in a number of ways:

- research and development projects (10 USC § 2358)
- establishing standards and cooperative research work with NATO (10 USC § 2350B and § 2457)
- responsibility of the Chief Information Office to ensure interoperability (10 USC § 2223)
- acquisition authority for joint experimentation by the Unified Combatant Command (10 USC § 485)
- assessment of capabilities, adequacy, and interoperability of coalition forces (10 USC § 153)

Two points are relevant about a perspective of interoperability based on Title 10. First, one must be careful in so strict a view, because the word integration (or a synonym) may be used instead of interoperability. Sometimes interoperability is implied.[21] Second, and perhaps of more practical significance, one cannot forget all the regulations, policies, and practices that are later implemented by DoD in response to the language in Title 10.

We can summarize an examination of the definitions of interoperability by noting the following point: *The term interoperability has been traditionally used in the context of an operational system.*

21. One gains an interesting perspective by examining the language in Title 10. For example, in 10 USC § 124, the DoD is designated as the single lead agency for the Federal Government for detection and monitoring the transit of illegal drugs into the U.S. The word interoperability does not appear in the that text. However, in Pub. L. 106-65 § 1043 (October 23, 1992), the rationale for DoD assuming lead-agency responsibility is explicitly stated as "(3) to promote commonality and interoperability between counter-drug detection and monitoring systems in a cost-effective manner. . . ." Thus, from Public Law to Title 10, consideration of interoperability went from explicit to implicit. This migration should not be viewed as diminishing its importance [USC 04].

References

URLs are valid as of the publication date of this document.

[Alberts 99]
Alberts, David S., Gartska, John J., & Stein, Frederick P. *Network Centric Warfare.* Command and Control Research Program Publication Series, 1999. http:www.dodccrp.org/files/alberts_NCW.pdf

[Brownsword 06]
Brownsword, Lisa, Fisher, David, Morris, Ed, Smith, James, & Kirwan, Patrick. *System-of-Systems Navigator: An Approach to Managing System-of-Systems Interoperability* (CMU/SEI-2006-TN-019, ADA449276). Software Engineering Institute, Carnegie Mellon University, 2006. http://www.sei.cmu.edu/publications/documents/06.reports/06tn019.html

[Chrissis 03]
Chrissis, Mary Beth, Konrad, Mike, & Shrum, Sandy. *CMMI: Guidelines for Process Integration and Product Improvement.* Addison-Wesley, 2003.

[DoD 00]
Department of Defense. *DoD Dictionary of Military and Associated Terms* (Joint Publication 1-02, June 14, 2000). http://www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf

[DoD 01]
Department of Defense. *Global Information Grid (GIG) Capstone Requirements Document (CRD)* (Flag Draft, March 28, 2001). http://www.dfas.mil/technology/pal/spipgmdc/policy-regs/gigcrdflaglevelreview.pdf

[DoD 02]
Department of Defense, *Joint Requirements Oversight Council (JROC) Programmatic Processes for Joint Experimentation and Joint Resource Change Recommendations* (Chairman of the Joint Chief of Staff Instruction [CJCSI] 3180.01, October 31, 2002). http://www.dtic.mil/cjcs_directives/cdata/unlimit/3180_01.pdf

[DoD 05]
Department of Defense, *Joint Capabilities Integration and Development System* (Chairman of the Joint Chief of Staff Instruction [[CJCSI] 3170.01E, May 11, 2005). http://www.dtic.mil/cjcs_directives/cdata/unlimit/3170_01.pdf

[Dodson 06]
Dobson, Kathryn M., Hofmann, Hubert F., Ramamni, Gowri, & Yedlin, Deborah K. *Adapting CMMI for Acquisition Organizations: A Preliminary Report* (CMU/SEI-2006-SR-005, ADA453524). Software Engineering Institute, Carnegie Mellon University, 2006. http://www.sei.cmu.edu/publications/documents/06.reports/06sr005.html

[Fisher 07]
Fisher, David A., Meyers, B. Craig, & Place, Pat. *Conditions for Achieving Network-Centric Operations in Systems of Systems* (CMU/SEI-2007-TN-003). Software Engineering Institute, Carnegie Mellon University, 2007. http://www.sei.cmu.edu/publications/documents/07.reports/07tn003.html

[Garcia 06]
Garcia, Suzanne, Forrester, Eileen, & Alberts, Christopher. *Process Considerations for Interoperable Acquisition* (CMU/SEI-2006-TN-033). Software Engineering Institute, Carnegie Mellon University, 2006. http://www.sei.cmu.edu/publications/documents/06.reports/06tn033.html

[IEEE 00]
Institute of Electrical and Electronics Engineers. *IEEE 100, The Authoritative Dictionary of IEEE Standards Terms*, Seventh Edition. New York, NY: IEEE, 2000.

[Levine 03]
Levine, Linda, Meyers, B. Craig, Morris, Ed, Place, Patrick R. H., & Plakosh, Daniel. *Proceedings of the System of Systems Interoperability Workshop (February 2003)* (CMU/SEI-2003-TN-016, ADA416429). Software Engineering Institute, Carnegie Mellon University, 2003. http://www.sei.cmu.edu/publications/documents/03.reports/03tn016.html

[Morris 04]
Morris, Ed, Levine, Linda, Meyers, B. Craig, Place, Patrick R. H., & Plakosh, Daniel. *System of Systems Interoperability (SOSI); Final Report* (CMU/SEI-2004-TR-004, ADA455619). Software Engineering Institute, Carnegie Mellon University, 2004. http://www.sei.cmu.edu/publications/documents/04.reports/04tr004.html

[Maier 96]
Maier, M. "Architecting Principles for Systems-of-Systems," 567–574. *Proceedings of the Sixth Annual International Symposium of INCOSE*. Boston, MA, July 7–11, 1996. INCOSE, 1996. http://www.infoed.com/Open/PAPERS/systems.htm

[Meyers 05]
Meyers, B. Craig, Monarch, Ira A., Levine, Linda, & Smith, James D. *Including Interoperability in the Acquisition Process* (CMU/SEI-2005-TR-004, ADA441244). Software Engineering Institute, Carnegie Mellon University, 2005. http://www.sei.cmu.edu/publications/documents/05.reports/05tr004.html

[Meyers 06a]
Meyers, B. Craig, Smith, James D., Capell, Peter, & Place, Patrick. *Requirements Management in a System-of-Systems Context: A Workshop* (CMU/SEI-2006-TN-015, ADA449727). Software Engineering Institute, Carnegie Mellon University, 2006. http://www.sei.cmu.edu/publications/documents/06.reports/06tn015.html

[Meyers 06b]
Meyers, B. Craig. *Risk Management Considerations for Interoperable Acquisition* (CMU/SEI-2006-TN-032, ADA465941). Software Engineering Institute, Carnegie Mellon University, 2006. http://www.sei.cmu.edu/publications/documents/06.reports/06tn032.html

[Meyers 06c]
Meyers, B. Craig & Sledge, Carol A. *Schedule Considerations for Interoperable Acquisition* (CMU/SEI-2006-TN-035, ADA465943). Software Engineering Institute, Carnegie Mellon University, 2006.
http://www.sei.cmu.edu/publications/documents/06.reports/06tn035.html

[PPBES 03]
PPBES: Planning, Programming, Budgeting, and Execution System. *Training Material: DSN 734-8717*. http://www.finance.army.mil/ppbes.htm (2003).

[Smith 06]
Smith, James D. & Phillips, Mike. *Interoperable Acquisition: The Challenges* (CMU/SEI-2006-TN-034, ADA461385). Software Engineering Institute, Carnegie Mellon University, 2006.
http://www.sei.cmu.edu/publications/documents/06.reports/06tn034.html

[USC 02]
United States Congress. *E-Government Act of 2002, Public Law 107-347, 116 Stat. 2899 (December 17, 2002).* http://www.reg-group.com/library/E-GovLaw.pdf

[USC 04]
United States Code. *Title 10—Armed Forces.*
http://www.access.gpo.gov/uscode/title10/title10.html (2004).

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. **AGENCY USE ONLY** (leave blank)	2. **REPORT DATE** December 2007	3. **REPORT TYPE AND DATES COVERED** Final	
4. **TITLE AND SUBTITLE** Programmatic Interoperability		5. **FUNDING NUMBERS** FA8721-05-C-0003	
6. **AUTHOR(S)** B. Craig Meyers and James D. Smith			
7. **PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)** Software Engineering Institute Carnegie Mellon University Pittsburgh, PA 15213		8. **PERFORMING ORGANIZATION REPORT NUMBER** CMU/SEI-2008-TN-012	
9. **SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)** HQ ESC/XPK 5 Eglin Street Hanscom AFB, MA 01731-2116		10. **SPONSORING/MONITORING AGENCY REPORT NUMBER**	
11. **SUPPLEMENTARY NOTES**			
12.a **DISTRIBUTION/AVAILABILITY STATEMENT** Unclassified/Unlimited, DTIC, NTIS		12.b **DISTRIBUTION CODE**	

13. **ABSTRACT** (maximum 200 words)

Interoperability has traditionally been considered a property of operational systems, where systems are able to exchange information in some agreed-upon fashion. However, other aspects of interoperability are often overlooked. This report introduces one of those aspects—the concept of programmatic interoperability, which is the application of principles of interoperability to the acquisition management of systems. It shows how programmatic interoperability contributes to fielding interoperable capabilities and relates this aspect to current trends such as network-centric operations. The report also discusses the orchestration of decisions and activities that are applicable to acquisition in a system-of-systems environment. Finally, the report suggests several research topics.

14. **SUBJECT TERMS** acquisition; interoperability; system of systems, programmatic interoperability, interoperable acquisition			15. **NUMBER OF PAGES** 42 16. **PRICE CODE**
17. **SECURITY CLASSIFICATION OF REPORT** UNCLASSIFIED	18. **SECURITY CLASSIFICATION OF THIS PAGE** UNCLASSIFIED	19. **SECURITY CLASSIFICATION OF ABSTRACT** UNCLASSIFIED	20. **LIMITATION OF ABSTRACT** UL