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Four Premises Underlying Collaborative SoS

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Abstract

For many large-scale, systems-intensive organizations, the tempo of operations using software-intensive systems is different from that of their acquisition, procurement, or development processes for those systems. These organizations use a variety of approaches that attempt to synchronize, for operational use, the integration and fielding of interoperating software. They continue to confront the issue of how fielded software can support the increasing agility needed by a deployed, operational workforce. This difference of tempo is a problem space that is explored in this special report. The Report describes four concepts underpinning working with Collaborative SoS that are useful in explaining the problem and in reasoning about possible solutions: recognizing the double challenge, sustaining an edge-driven perspective, achieving demand cohesion, and using stratification effectively. In this special report, those concepts are illustrated through a situation in the U. S. Army, called software blocking.

1 Introduction

Many commercial, government, and military organizations are tending to design, develop, and field systems with the expectation that they will be a part of a larger network of systems, commonly termed a system of systems [Miller 2001, Singh 2007, Beaudouin-Lafon 1999]. The U. S. Department of Defense (DoD), for instance, is moving rapidly toward network-centric operations, in which individual weapons systems are related elements in a global web of independently evolving systems that serve multiple purposes. Additionally, in the finance, manufacturing, healthcare, and service industries, network-based computing is proliferating.

It is not surprising, then, that the tasks of designing, developing, and evolving software-intensive systems are undergoing a shift. Indeed, many of the software engineering disciplines—such as requirements engineering, software architecture, testing, and maintenance/support—are significantly changed from their traditional norms. In the past, optimizing performance for low-level components was often the strategy for creating economical and effective software-intensive systems; however, in the system-of-systems world, optimizing for flexibility at the component level is often a better way to achieve the agility needed to use a system in multiple operational contexts. In many of today's operational contexts, agility in adapting to new, unanticipated user demands is of higher importance than optimizing the performance of their user-facing operations [Treasy 1995]. This shift changes emphasis for

- *requirements*—from point-based requirements to range-based
- *architecture*—from performance-optimizing architectures to flexibility and evolvability-optimizing architectures
- *verification and validation*—from emphasizing testing that assures just that the individual systems work to emphasizing testing of the interfaces and the boundaries of the anticipated system of systems
- *maintenance and support*—from focusing on efficiently evolving a single-purpose system to considering the maintenance effects on purposes of the system beyond its original design

Further, these systems no longer operate in isolation. Rather, they must interoperate, often in ways that are unplanned, with other systems that are known at the time of design as well as systems that are not known until installation or during operations. This situation is reflected within the U. S. Army as it confronts the issue of how to continually build or enhance fielded, interoperating software-intensive systems that can support the agility needed by a deployed, operational force engaged in both U. S. and coalition actions. Software blocking,[2] the Army's current approach, is one instance of the way software-intensive systems are integrated within such organizations. The Army's situation may provide insight to other large-scale, systems-intensive organizations that are facing similar issues.

The struggles that organizations are experiencing with their large-scale, software-intensive systems bring to light the effect a difference in *tempo* between procurement (or development) and operations can have. Increasingly, the agility required by the operational or business elements

[2] "The Army's Software Blocking program is charged with synchronizing software fielding while ensuring horizontal interoperability among participating systems on the battlefield" [SEC 2008].

outpaces the ability of the development and procurement elements to provide support that enables the needed agility.

How, then, are software-intensive systems to be defined, procured, and fielded so that they interoperate and support the agility needed by an organization? To provide effective solutions, this report recommends that the overall focus shift from looking just at the software-intensive nature of systems to also including an examination of the systems-intensive nature of organizing both the social and technical elements so that an evolvable system that has sufficient agility to adequately support its user context results. The report uses the Army's software blocking approach to provide a practical context in which to illustrate four premises underlying working with Collaborative SoS. The premises are responses to four new realities emerging from the problem space of trying to achieve sufficient agility in the field while trying to maintain effective development and system evolution. Table 1 shows the relationship between the new realities and the four premises.

This report first summarizes an example of the problem space, giving consideration to the ways in which system-of-systems issues typically appear (Section 2). Then it analyzes each new reality about the problem space and corresponding Collaborative SoS premise (Section 3), leading to some possible actions (Section 4) that an organization facing the new realities might consider.

Table 1: Relating New Realities about this Problem Space to Collaborative SoS Premises

New Realities	**Collaborative SoS Premises**
The problem space is larger than that defined by the acquisition process and can be described in terms of a *double challenge*. The double challenge revolves around the tensions between different supply-chain complexity and different forms of response to demand within a situation.	To make the double challenge tractable, it is useful to analyze the supply-chain complexity and the forms of response to demand present within a situation.
The larger space that acknowledges the double challenge needs to be approached in terms of the balance among eight organizational dimensions that capture critical factors associated with providing operational capability that is sufficiently responsive to operational needs of *edge-driven* enterprises. (The dimensions are adapted from the DOTMLPF[3] set of constructs used in many military contexts, which are modified to include an *edge-driven perspective*.)	To understand how cohesive operational behaviors are generated at the edge of an enterprise trying to respond to variable demands, it is useful to analyze the forms of balance among eight organizational dimensions that characterize different elements of center-driven and edge-driven strategies (the DOTMLPFS wheel).
An edge-driven perspective leads to a fundamental distinction between *hierarchical* and *stratified* ways of organizing, with associated implications for the types of approaches needed to support stratified forms of organizing.	To align available technologies with the variety of operational contexts in which they will be used, it is useful to analyze their stratification in relation to the required variety of geometries-of-use they must support.
Because of the need for an edge-driven perspective, how we glue things together at the point of need has to be done dynamically to keep responses aligned with the tempo of demand within a situation.	To give an account of the interactions between hierarchies and stratifications, analysis of models of the problem space must include three concepts: functional coupling, accountability hierarchy, and demand cohesion.

3 The DoD uses the acronym DOTMLPF to stand for the components that should be considered when planning policy: doctrine, organization, training, materiel, leadership, personnel, and facilities [Wikimedia 2008b].

2 An Example Problem Space

This Special Report describes a U. S. Army situation and uses it to illustrate the meaning and implications of four Collaborative SoS premises. The Report looks at the Army situation as an example problem space that reflects the ways in which the interoperability of software systems is managed. While situations will vary for different organizations in commercial, government, and military sectors, each of the four premises applies to the problem space the Army typifies.

This section outlines the acquisition context for the Army, considers how system-of-systems issues currently surface, and discusses how software blocking became a proposed solution to assist with the synchronization of developing and fielding software systems where interoperability is critical.

2.1 THE DOD ACQUISITION CONTEXT

The DoD develops its capabilities through three intersecting processes:

- *Budgeting: The Planning, Programming, Budgeting, and Execution System (PPBES)*
  PPBES is the "primary resource management process" in the DoD and operates on an annual budget with a five-year rolling horizon. For the purposes of this special report, it is considered to deal in three types of budgetary allocation: (a) research and development, (b) procurement, and (c) sustainment (operations and maintenance or O&M) [DoD 1998].
- *Required capability: Joint Capabilities Integration Development Systems (JCIDS) process*
  A capability requirement is generated that industry will then translate into a practical solution subject to budgetary and technology constraints [DAU 2008a].
- *Solution life cycle: The Defense Acquisition System (DoD 5000 Series)*
  Given that the DoD retains limited organic capability and capacity to build systems, this system defines the DoD framework for translating capability needs and technology opportunities, based on approved capability needs, into stable, affordable, and well-managed acquisition programs. It defines the synchronization points for three processes: "Do I have a compelling requirement, a feasible solution, and funding to execute?" [DAU 2008b]. From the viewpoint of a commercial organization, the acquisition system can be considered to be a combination of typical product development and procurement systems.

These three processes have different staffs, timelines, and tempos. Their composite effect, however, is to ensure that the most critical solutions are being acquired by means of well-defined requirements and acquisitions/developments. Thus, all programs are system- or gap-specific, and each program is assigned to a Service Acquisition Executive (SAE) and to a Program Executive Office (PEO) that is primarily service-specific[4] but also is associated with a category of capability, such as PEO SOLDIER (equipment for soldiers), PEO STRI (training devices, simulators and the like), or PEO Aviation (helicopters and unmanned aircraft systems).

[4] In the case of a joint program, the SAE and the PEO can be from different Services. For example, the Joint Tactical Radio System (JTRS) is assigned to the Army SAE and a Navy PEO.

2.1.1 The Position of TRADOC in Addressing System-of-Systems Issues

In the Army, the DoD acquisition processes are implemented primarily through two independent organizations, the Training and Doctrine Command (TRADOC) and the Assistant Secretary of the Army for Acquisition, Technology, and Logistics (ASA(ALT)). TRADOC is organized around *school houses* for major competency areas, such as aviation, infantry, and command-and-control. Operational units generate problems, for which TRADOC generates TTP (Tactics, Techniques, and Procedures). If a materiel solution (that is, equipment and supplies for the Army) is required, TRADOC generates and mediates requirements for it that will be addressed through program modifications or new programs. To execute this responsibility, TRADOC assigns a TRADOC Capability Manager (TCM) to every major program. Most materiel solutions related to information technology arise through the process TRADOC coordinates.

2.1.2 The Position of PEOs/PMOs in Addressing System-of-Systems Issues

The need for a new or modified materiel solution falls ultimately to a program under a PMO (Program Management Office), which is placed under a PEO. The PEO does not control requirements or funding; it is solely concerned with managing the portfolio of programs assigned to it. This division of responsibility and authority creates the following kind of problem:

> A PMO under the PEO Aviation is delivering a requirement for a "whole" helicopter. The PEO wants an Aviation-spanning common cockpit and so sets up a dependent or secondary PMO for it. This PMO relies on funding from each primary PMO (i.e., funded directly by Congress). If one of the primary PMOs is cancelled, all the dependent PMOs (such as the one set up for the cockpit) are affected.

In addition to the difficulty in securing the interoperability of software systems managed within an Army PEO, increasingly there are issues that cut across Army PEOs (and further topics that cross service, joint, and coalition lines) in securing the interoperability of software systems managed by the Army.

2.1.3 The Emergence of Software Blocking

The deployed Army is increasingly *digital*. It relies heavily on computers and software for significant operational capabilities (such as the situational awareness provided by Force XXI Battle Command, Brigade and Below [FBCB2]). The challenge it faces, therefore, is how to upgrade these software-dependent capabilities. The Army found that software upgrading was causing disruption to the field, as multiple PMOs were delivering software asynchronously to operational units. This situation put the operational Army in the position of having to choose between fighting wars and integrating software. It chose the former, and the institutional Army launched software blocking[5]—a strategy to synchronize, integrate, certify, and deploy new increments of software capability every 18 months.

The first software block (SWB1) completed testing and was fielded in 2005. The positive result was that there was one software configuration across the whole deployed Army. However, the testing process for SWB1 was frustrating to PEOs/PMOs in that block testing (as opposed to

[5] For a brief introduction to software blocking, see http://www.sec.army.mil/secweb/value_added/software_blocking_vas.html.

stand-alone system testing) was unfunded and unplanned, with no accepted SoS architecture and no way of knowing in advance what the mix of systems was supposed to do. Separate mission threads were used to test for interoperability from a stable software baseline; software blocking intended to establish a new working operational baseline. The resulting difficulty was that all defects were allocated to the new system. In fact, the defects could be in existing systems or from behaviors that occurred through the interaction of components that met their individual functional requirements. Thus, the system under test when the test failed was tagged with having to make (and pay for) the fix, independent of—and often without knowledge of—where the problem really lay.

2.2 THE CHALLENGE

As a result of the lessons learned from SWB1, changes were made in the second software block (SWB2) to synchronize software blocks on annual operational force rotations rather than on calendar time. However, the deployment of a Division is incremental, not all at once, and may take as long as 22 months. Software blocking, then, had to deal with backward compatibility, since forces equipped with SWB2 would have to interoperate with already deployed forces using SWB1. As a result of the replanning and redefinition needed to address this need, the software delivered for integration in 2006 is still not deployed, and the Army is still testing SWB2. The delay in fielding SWB2 has forced systems that would have deployed in SWB2 to retrofit SWB1 interfaces. It also has made future block schedules uncertain; many now question whether the software blocking process is agile enough to support long-term Army needs.

2.3 SUMMARY OF THE PROBLEM

The existing approach defines acquisition programs and deconflicts their outputs with respect to defined capabilities. But it is not providing an adequate basis on which to directly address agendas relating to interoperating systems of systems, particularly when approached from the perspective of the deployed and operational uses of those systems of systems. This inadequacy is further exacerbated by the need to continually deploy new or enhanced systems.

3 Four New Realities and Four Premises of Collaborative SoS

The interoperability issues exemplified by the Army's context illustrate the complex system-of-systems problem space many organizations face. To provide efficient solutions for this type of problem space, the report identifies four new realities that are emerging from it:

1. The problem space is larger than that defined by the acquisition process and can be described in terms of a *double challenge*.
2. This larger space that acknowledges the double challenge has to be approached in terms of the balance among eight organizational dimensions that capture critical factors associated with providing operational capability that is sufficiently responsive to operational needs of *edge-driven* enterprises.
3. An edge-driven perspective leads to making a fundamental distinction *between hierarchical and stratified ways of organizing*, with associated implications for the types of approach needed to support stratified forms of organizing.[6]
4. Because of the need for an edge-driven perspective, how we glue things together at the point of need has to be done dynamically to keep *responses aligned with the tempo of demand* within a situation.

In this section, each new reality is examined and paired with a Collaborative SoS premise that answers it.

3.1 FIRST NEW REALITY: THE PROBLEM SPACE CAN BE DESCRIBED IN TERMS OF A DOUBLE CHALLENGE

Current Army acquisition effort focuses on producing a definable product at the conclusion of a program for which a program management office is accountable. When fielded, this product, if it is a software system, will form part of a solution to some problem that a user has (or had). This problem may or may not have been the one originally used to generate the initial requirement. Because user needs change at a much faster pace than the tempo of system acquisition, it is very likely that the requirement will have changed, a circumstance that may not be communicated to the acquisition program. An approach like the Army's software blocking is a supply-side attempt to deal with this divergence of tempos; however, it is not able to deal with the levels of change on the demand side. There is not one, single Army organization spanning the whole challenge, which is a system-of-systems challenge.

To pursue the implications of this tempo mismatch, this report separates out two uses of the word *organization*. On the one hand, it is used as a noun (organization_n) to refer to a social arrangement; on the other hand, it is used as a verb (organization_v) to refer to the activity that brings order to something (e.g., organize my files) [Wikimedia 2008c, WordNet 2008]. To make this distinc-

6 The different types of approach are written about at greater length in an upcoming *IEEE Software* article and a working paper of a current case study. For more information, contact isis-sei@sei.cmu.edu.

tion clearer, the report will refer to an organization$_n$ as an enterprise with a single overall focus of effective accountability for its performance,[7] which is defined as follows:[8]

> An enterprise is composed of all the establishments that operate under the [effective] control of a single organization$_n$ [as noun]. It is an entity constituted, established, or organized$_v$ [as verb] under applicable laws, whether or not for profit and whether privately owned or governmentally owned. It includes all subsidiary organizations$_n$ and all the establishments that can be directed or managed by the enterprise or any subsidiary; may be a business, service, or membership organization$_n$; consists of one or several establishments; and operates at one or several locations [USCB 2003, ITS 2007].

In this derivation of the standard definition of enterprise, the report uses noun and verb forms of the word organization to reflect two fundamental dimensions: (1) the form of supply chain complexity across which accountability for performance has to be created across one or more enterprises and (2) the way this supply chain complexity is organized$_v$ in response to demand. These dimensions define the system-of-systems problem space (see Figure 1).

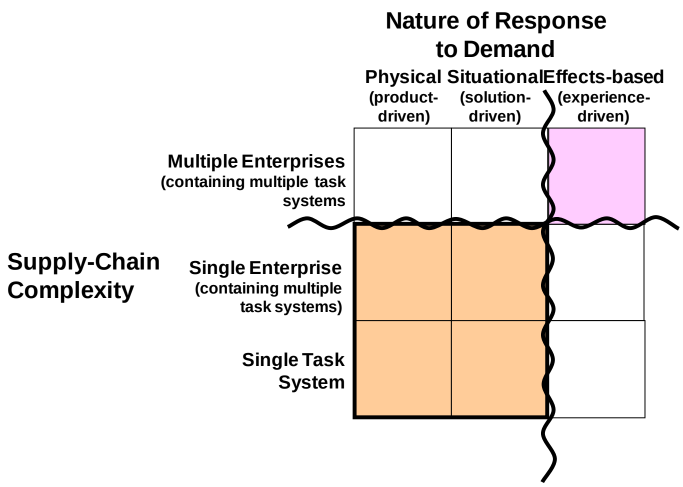

Figure 1: The Double Challenge Space

In this figure

- The vertical axis is concerned with the way effective authority can be exercised across the given level of supply-chain complexity, moving from exercising it over a single socio-technical task system to exercising it in terms of a single enterprise that contains multiple socio-technical task systems.[9] Continuing above the squiggly line is the challenge facing the Army and other organizations, where the effective authority needed across the supply-chain

7 The word *effective* is used here to emphasize that the scope of the enterprise is limited by its ability to maintain this single overall focus. Thus, although the DoD comes together as a single entity at the top, it is in effect made up of a large number of separate enterprises.

8 Our definition is adapted from the definitions provided in the U. S. Economic Census glossary and the Industry Canada agreement on internal trade [USCB 2003, ITS 2007]. In effect, an enterprise is defined by what it has control over.

9 A socio-technical view encompasses the people and technology involved in a system [Wikimedia 2008d].

complexity in order to deal with the system-of-systems challenge has to be negotiated across multiple enterprises within the organization$_n$ as well as across its suppliers.

- The horizontal axis is concerned with the nature of what the supply-chain complexity does for its customers, with customers ultimately meaning the operational contexts giving rise to demands.[10,11,12] In the first column, the effect of the supply-chain complexity is defined in terms of the physical characteristics of a product space. In the middle column, the effect is defined in terms of a solution space relating to particular kinds of customer problems. In the last column, the effect is the experience that the customer has over time of the supplier's activities as the supplier responds to the customer's changing needs.

  This time the vertical squiggly line is between the solution-space and the experience-space, because of the shift needed from a perspective of supply centered on the supplier's view of requirements (before I—the supplier—can offer you a solution, you—the customer—must first tell me what your problem is), to an edge-driven view of supply centered on the customer's ongoing experience (I—the supplier—am here to organize$_v$ and align solutions that will address the ongoing and evolving needs of you—the customer). This squiggly line represents the shift of the supply-chain complexity to being edge-driven. This shift is in the viewpoint with which the problem space is defined (as the organizer$_v$ of its responses to demand), from being supply-centric to being demand-centric.

  Objectively, the difference at the edge is that the needed solution changes over time in ways driven by the nature of the customer's situation. But subjectively, the way the authority within the problem space is defined is more by reference to the nature of the customer's evolving needs than by reference to what the suppliers are able to do. This is what makes the top-right space so different. The challenges of working across multiple enterprises are compounded by the need to do so in ways that are edge-driven—that is, responsive to the dynamically evolving (and emergent) needs of customers. This is the double challenge [Boxer 2007].

If we consider the extent to which asymmetric threat[13] and counter-insurgency roles have come to represent the new challenges facing an edge-driven Army, it is apparent that both the effects the Army is trying to generate and the threats that it is trying to counter (the customers that they are ultimately seeking to "serve") are moving into this top-right space. But the approach to delivering

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10 The word *customer* is here being used to refer to the originator(s) of demand that the problem space is responding to, so that who the *customer* is depends on how the problem space is defined. In the military context, threats are interpretations of various kinds of intelligence that are then treated as demands for effects that the military must generate, making the originators of those threats the *customers* for those effects. Given the complexity of activities within the military, however, there will be large numbers of intermediate customers, in which the user of a particular system generating an operational capability will be being combined with others to generate mission capabilities that then create effects on the ultimate customers.

11 Prahalad and Ramaswamy define this horizontal axis as a progression through distinct forms of competition: the first in a product space, the second in a solutions space, and the third in relation to the customer's experience space [Prahalad 2003].

12 If we understand the authority within the problem space to be defined in terms of what is to be done for its customers, we need to understand competition in terms of how that authority is able to be sustained over time despite what others may try to do.

13 Cadet First Class Kolodzie (USMA) comments on Army viewpoints on asymmetric threats common in the 1990s [Kolodzie 2001]

systems against requirements for a specific product under a fully accountable PMO still falls in the bottom-left space.

Collaborative SoS Premise 1: To make the double challenge tractable, it is useful to analyze the supply-chain complexity and the forms of response to demand present within a situation.[14]

3.2 SECOND NEW REALITY: DEALING WITH THE PROBLEM SPACE REQUIRES ADDRESSING THE SPECTRUM OF EIGHT ORGANIZATIONAL DIMENSIONS REQUIRED FOR EDGE-DRIVEN ENTERPRISES

The U. S. DoD uses a set of seven organizational dimensions referred to by their acronym, DOTMLPF. The Army has the following to say about DOTMLPF (square brackets added):

> *Army transformation is more than materiel solutions. Adaptive and determined leadership, innovative concept development and experimentation, and lessons learned from recent operations produce corresponding changes to doctrine, organizations [as noun], training, materiel, leadership and education, personnel, and facilities (DOTMLPF). DOTMLPF is a problem-solving construct for assessing current capabilities and managing change. Change is achieved through a continuous cycle of adaptive innovation, experimentation, and experience. Change deliberately executed across DOTMLPF elements enables the Army to improve its capabilities to provide dominant landpower to the joint force* [DoA 2005].

These constructs were developed from the perspective of the Army as a whole, but our experience shows that we need to add the implications of being edge-driven to take full account of the problem space as we have defined it. We do this by adding an eighth construct—*situational understanding*—and by changing the emphasis of three of the constructs (organization$_v$, training, and personnel) to adequately accommodate the edge issues. Thus, organization$_v$ becomes edge organization$_v$, training becomes collective training for force composition, and personnel becomes personnel and culture.

The DOTMLPFS wheel (our eight organizational dimensions), adapted from the Army's DOTMLPF viewpoint, is shown divided in Figure 2 to reflect the double challenge. The dimensions driven from the *center* can be defined directly from the source of the authority of the enterprise (its relationship to the problem space in Figure 1); the dimensions driven from the *edge* are those that the enterprise delegates to be shaped by the particular situations at the edge (the effects-based side of Figure 1).

14 For an approach to modeling this whole space, see Appendix A.

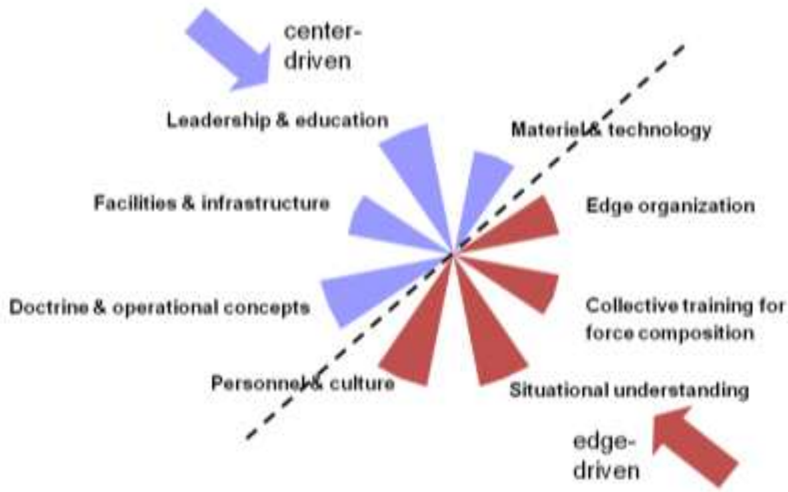

Figure 2: The DOTMLPFS Wheel

The DOTMLPFS wheel arrayed against the double challenge yields the following center-driven dimensions (call them the institutional Army):

1. *Doctrine & operational concepts*: the principles and operational methods underlying the approach to generating ultimate effects
2. *Facilities & infrastructure:* the facilities and infrastructure that are the context within which the enterprise does its work
3. *Leadership & education:* the ability to lead the enterprise creatively and effectively within the context of its chosen domain of action
4. *Materiel & technology:* the tools and technologies that the enterprise needs to be effective within its chosen domain of action

It also provides a view of these edge-driven dimensions (call them the operational Army):

1. *Edge organization$_v$:* the way of organizing$_v$ needed to orchestrate and synchronize the capabilities needed to meet the demands arising from a particular situation[15]
2. *Collective training for force composition:* the people that are needed by the way of organizing$_v$ at the edge, provided with the appropriate know-how and abilities to work together collaboratively
3. *Situational understanding:* the way data is able to be fused and interpreted to provide a composite picture of what is going on in any given particular situation
4. *Personnel & culture*: the socialization, background, and mutual knowledge that people need to be able to trust each other and to work together

The extent to which all eight dimensions can be held in relation to one another through collaborative processes will determine the agility of Army operational behaviors at the edge. Typically, the investment of time and money by the enterprise goes into the first four dimensions (the institutional Army), leaving the second four to informal or joint command processes in theater. The

[15] We describe edge organization$_v$ in more detail below.

challenge, however, is to give balanced attention to all eight, with the edge-driven dimensions becoming increasingly important as the environment demands increasing levels of agility.

Using this wheel, we can evaluate whether models constructed of the problem space can inform the purposes of each of the eight constructs. The eight dimensions become, in effect, the quality criteria for evaluating whether the models are comprehensive.

Collaborative SoS Premise 2: To understand how cohesive operational behaviors are generated at the edge of an enterprise trying to respond to variable demands, it is useful to analyze the forms of balance among eight organizational dimensions that characterize different elements of center-driven and edge-driven strategies (the DOTMLPFS wheel).

3.3 THIRD NEW REALITY: SOLVING THE PROBLEM SPACE REQUIRES AN ALIGNMENT OF THE SUPPLY-SIDE AND DEMAND-SIDE STRATA

Stratification provides us with a conceptual model of what is necessary to align supplied equipment, people, and materials to generate the desired effects on demand. But it also provides an analytical framework within which to determine the kinds of engineering, governance, and processes that are needed to generate alignment in ways that are appropriately dynamic and agile to a particular situation.[16]

3.3.1 Stratification

Figure 3 shows a generalized example of this needed alignment, using terminology common to the military context. At the bottom of this stratification are the technological capabilities available; at the top are the environments in which demands must be satisfied.

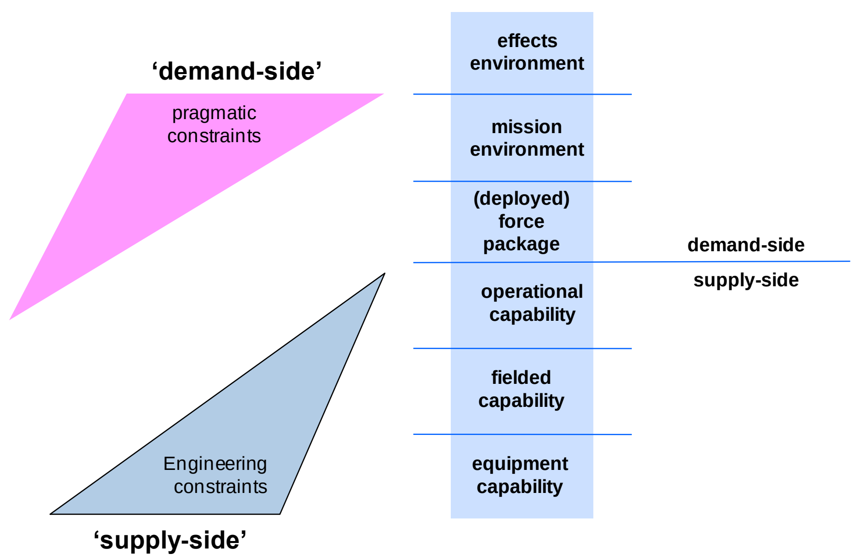

Figure 3: Supply-Side versus Demand-Side

[16] For why standards are not enough to achieve this, see Appendix B.

We can distinguish six layers, each one supporting the layer above it.[17] *Support* here means that a layer is embedded in the one above it, because these are a set of nested contexts. The bottom three of these layers are referred to as *supply-side* layers; the top three, as *demand-side* layers.

- Layer 1 is *equipment capability*, corresponding to the systems provided by suppliers in response to a set of pre-defined requirements. PMOs focus on this layer, because they must make sure that the supplier delivers to requirements, to budget, and on schedule.
- Layer 2, *fielded equipment*, is the equipment from layer 1 together with all the surrounding services that enable it to be used in the field. In this layer, a given system is tested by its users to establish whether it meets its acceptance criteria.[18]
- Layer 3 is an *operational capability* that uses fielded equipment, but surrounds it with the skills and processes needed to make it useful and usable (e.g., the typical DOTMLPF-enhanced equipment planned for by the Army). This layer, therefore, refers to a force element or operational unit that is operationally ready to use the system as part of the way it delivers operational capability.

In Figure 3, these supply-side layers are represented by an inverted pyramid that builds the operational capability on the foundations of the equipment capability in a way that is constrained by the engineering of that equipment. We use the term "over-determining" to refer to the ways that engineering can dictate how a system can be used. Here, and from the point of view of the users of the operational capability at layer 3, these engineering constraints are over-determining if they restrict the choices open to the user. Thus, for example, the way the Osprey aircraft must commit to landing, because of how its propellers rotate, places constraints on the kinds of operational environments in which it can be deployed.[19]

We note the following about the demand-side layers that are defining the actual uses of operational capabilities:

- Layer 4 is a *force package*, a deployed force made up of operational capabilities that must be able to work together in ways that can support the missions and business objectives expected of it. In this layer, individual operational capabilities are orchestrated with other capabilities to create mission capabilities. The particular configurations of interoperating and cooperating operational capabilities within this layer are referred to as *geometries-of-use.* The force package is put together because of the variety of mission capabilities (and their associated geometries-of-use) that it will support.[20]
- Layer 5 is the *mission environment* for which the force package is to be used. In the Army, the nature of this mission environment depends on the campaign plan that the force command

[17] Note that any layer may itself be hierarchically organized$_v$, depending on the level of granularity within the layer. Hierarchy is, in this sense, orthogonal to stratification.

[18] Whole Product thinking addresses this layer 2 [Wikimedia 2008].

[19] The reference here is to approaching unprepared landing zones [FAS 2008].

[20] The use of the word *geometry* in this concept relates to the definition of agility in terms of the variety of geometries that the force package is able to support [Boxer 2006].

unit has in mind and the nature of the *decisive moments* that the plan calls for.[21] Any given mission in this environment will involve the synchronization of mission capabilities with the intention of generating particular forms of effect.

- Finally, layer 6 is the *effects environment* in which that variety of missions is to be used to generate particular effects in response to the threats or demands being presented by that environment. This layer is often described by operational scenarios.

From this viewpoint, the way in which the supply side is able to be aligned to the demand side is, therefore, crucial. In Figure 3, layers 3, 4, and 5 are identified with the pragmatic constraints introduced by the necessity to address the demands in layer 6. Layers 4 and 5 are concerned with the orchestration and synchronization of mission capabilities. For example, the outputs of an unmanned aerial vehicle (UAV) might be orchestrated in layer 4 with outputs from signals intelligence to support a mission capability in layer 5 to pinpoint a new kind of target. Layer 3 is included because the orchestration process may need to reach back to the operational capabilities and customize them so that they can participate in their orchestration with other operational capabilities. For example, the sensors on the UAV might need to be reconfigured for their outputs to be usable in this orchestration. This ability for alignment is of fundamental importance: *if the operational capabilities in layer 3 are too over-determining of the ways in which they can be used in layers 4 and 5 (because of how they were engineered in layer 1 and fielded in layer 2), then the pragmatic constraints will not be satisfied.*

3.3.2 Re-Examining Software Blocking

The acquisition, procurement, or development processes for systems address layers 1 and 2. In the Army, the large number of mission threads that have been defined for SWB2 are defined within layer 2 as an extension to the acceptance testing process. It is not feasible, however, to test all the possible threads that could be generated by the higher layers of the stratification. How, then, are mission threads to be identified and prioritized according to whether they are critical to supporting the (layer 4) variety of geometries-of-use needed pragmatically (i.e., whether they are able to support the mission environment needed to meet the demands of the effects environment)?

[21] A decisive moment "will involve its own particular sequence of events that involve some synchronization of composite capabilities." The IEEE presentation on the pragmatics of demand goes into this way of analyzing campaign plans in more detail [Boxer 2008a].

3.3.3 Managing the Alignment of the Supply-Side and the Demand-Side

Figure 4 shows a more generic stratification and the way this version of the stratification aligns to the military-specific stratification in Figure 3. To accomplish the ultimate goal of software blocking—namely, to align current operational needs with systems coming online—in a manner that takes account of the deployment and other constraints, the Army could try a different approach to balance the program focus of

- systems at layers 1 and 2 with
- the pragmatic constraints introduced by layers 3 to 5, within
- the context of layer 6

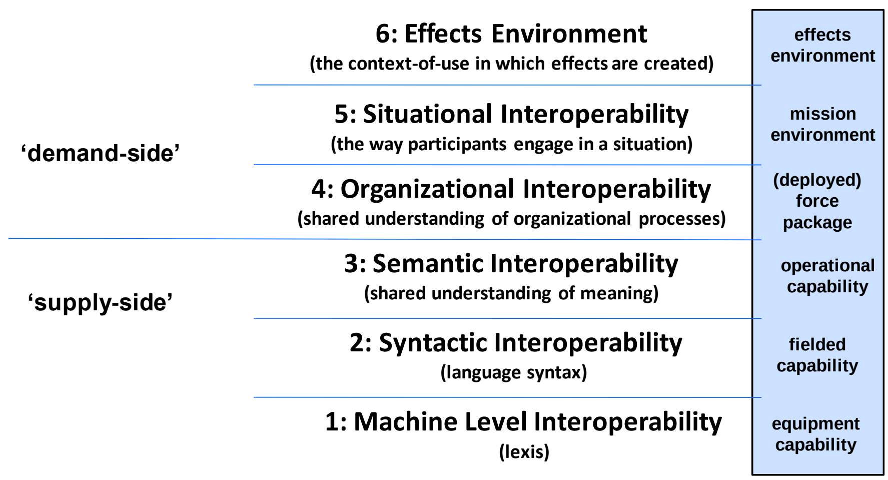

Figure 4: The Full Stratification

This approach involves analyzing the models of the problem space (generated using the methods outlined in Appendix A) to define the content of the different layers and the way each layer is organized, to align the layers below and above it. This means being able to analyze which geometries-of-use are critical to supporting which mission environments, and which functionality and threads are critical to supporting which geometries-of-use.[22]

In this way, we can make the problem space tractable by being able to identify, align, and prioritize the testing and deployment process from the perspective of particular mission environments. It allows us to ask where resources are currently being wasted, and where the greatest impact can be created on mission capabilities.

Collaborative SoS Premise 3: To align available technologies with the variety of operational contexts in which they will be used, it is useful to analyze their stratification in relation to the required variety of geometries-of-use they must support.

[22] For a risk-based approach to managing the alignment of these strata, see Appendix C. For an overview of the economic issues associated with aligning the strata, see Appendix D.

3.4 FOURTH NEW REALITY: ANALYZING THE PROBLEM SPACE REQUIRES THREE INTERRELATED CONCEPTS

Assuming we have a model of the whole problem space that addresses all eight constructs of the wheel and for which we want to understand how the supply side and demand side are aligned, how are we going to analyze it?

3.4.1 Three Types of Paths through the Problem Space

Any analytical approach to such a model would, at present, likely start from a perspective such as that of enterprise architectures, which uses two essential underlying concepts. One concept is rooted in the accountability and responsibility in the Army's hierarchies of accountability (represented as the downward-pointing arrows in Figure 5). These are inverses, with the accountability[23] reflecting a direction towards the top of the hierarchy and responsibility a direction towards the bottom of the hierarchy. The other concept is rooted in how functionality is defined, and particularly in how functionality is coupled with other functionality (i.e., the interoperability of functionality). This coupling defines alternative possible paths of functional coupling (the upwards-and-left arrows in Figure 5).

Models based on these two concepts alone, while necessary, are not sufficient for analyzing stratification, given the contexts described earlier (i.e., the top-right space of Figure 1).[24] A third concept must also be used—namely, the influence of different forms of demand cohesion[25] on the way the possible forms of functional coupling and hierarchy are brought together (the upwards-and-right arrows in Figure 5). How do different forms of demand affect the forms of cohesion needed across multiple enterprises? And how do they influence any existing or needed coupling paths of functionality (i.e., interoperability) across multiple complex systems?[26]

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[23] Accountability hierarchy is a concept originally developed by Elliot Jaques [Jaques 1989].

[24] The way the hierarchy is defined downwards determines the way the underlying activities are deconflicted with respect to each other. The third concept becomes necessary when the organization of deconfliction has to be changed depending on the nature of the demand to be satisfied at the edge.

[25] The issues raised by the nature of demand cohesion are written about at greater length in "Systems-of-Systems Engineering and the Pragmatics of Demand" [Boxer 2008a] and in an internal report on different types of approach to supporting stratified forms of organizing. For more information on the report, contact isis-sei@sei.cmu.edu.

[26] A projective analysis method of modeling gives an account of each of these three concepts (cohesion, coupling, and accountability), using the five different views outlined in Appendix A. These views are highly interrelated: two of them predominantly showing the relationships between functional elements; two others showing the way functional elements are held accountable under accountability hierarchies; and the fifth showing the contexts that give rise to demands. More importantly, this last view shows how particular demands relate to the functional and accountability elements that must be brought together to satisfy them.

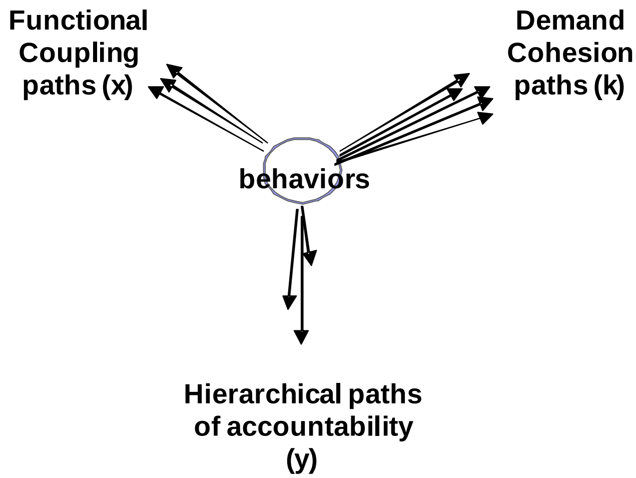

Figure 5: Coupling, Accountability, and Cohesion

Answering these questions is based on analyzing the relational characteristics of the visual models described in Appendix A. The analysis identifies sequences or *paths* through the models. For instance, if process A supplies some input to process B, which then supplies some item to process C, and so forth, this would represent a sequence or path across units of functionality. (An example would be the way one system produces outputs that are used by another system.) In another instance, if X reports to Y, who reports to Z, this would be a path across units of accountability. (An example from the Army situation would be the way a PMO is accountable to a PEO as well as to Congress.) A third instance, a cohesion path, would be outcomes L, M, and N brought together by processes of orchestration O and synchronization P to generate a particular effect on a demand situation Q. (In the military, an example would be the way UAV and signals intelligence are synchronized with a strike capability to achieve a particular effect).

The three different types of paths are represented in Figure 5 by the multiple arrows in each direction. The first type is the way in which the *functional coupling paths* that can be realized by systems constrain their possible behaviors, and the second is the way that the *hierarchical paths of accountability* further constrain the system behaviors. But the third is quite different: it is the way that functional coupling and accountability structures are brought into alignment as particular *demand cohesion paths*. An agile enterprise seeks to ensure that an appropriate variety of geometries-of-use exist and are sustained to provide support for a variety of forms of demand cohesion emerging from customers.

3.4.2 The Relationships between the Different Types of Path

Using this third path type in how we model the top-right (referring again to Figure 1) contexts, we can now add to the familiar notion of hierarchy the analysis of stratification. Our six-layer version was introduced in Section 3.3. Through it, the hierarchical relationships between functionality and accountability are aligned to particular forms of demand cohesion. Stratification also allows us to analyze how the other two types of paths *permit* (i.e., enable as well as constrain) the geometries-of-use needed to support particular forms of demand cohesion. In the strike capability example, this relationship involves analyzing how the larger context of the deployed force and the supplying structures associated with it align to the particular geometry supporting the strike.

The different types of paths derived from the models reveal two kinds of relationship between them (Figure 6). The first kind of relationship, between the functional coupling and accountability paths, reveals how the functionality falls under hierarchical paths of accountability. For example, this would be the hierarchy of accountability under which a PMO works. The second relationship is between the supply side of the enterprise and the demands that are to be addressed, whether in terms of functional behaviors or of costs. This second kind of relationship essentially reveals the alignment between the supply side of the enterprise and the forms of demand cohesion that it is supporting. It can be used to answer such questions as "How will the functionality being supplied to the edge be aligned to the demands in their actual contexts-of-use?"

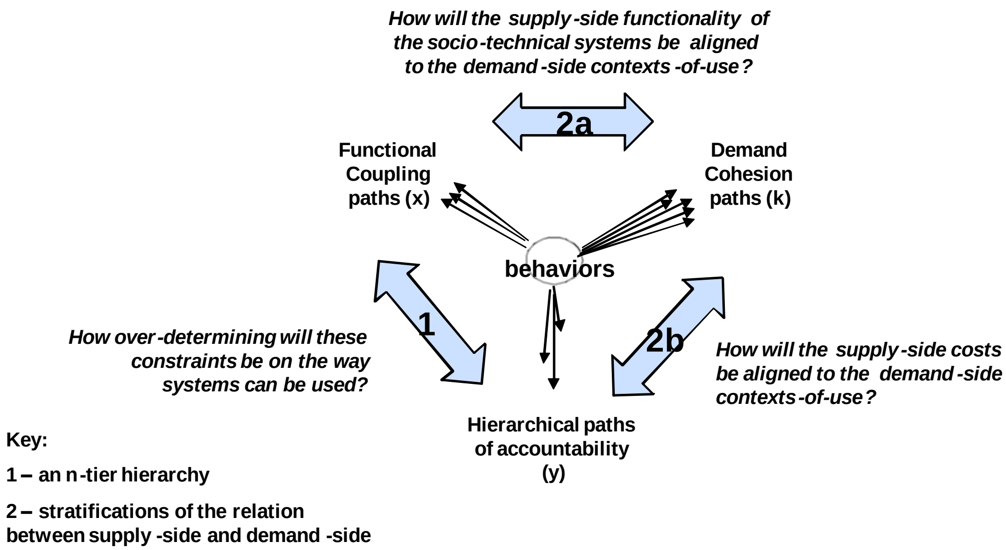

Figure 6: Hierarchy versus Stratification

When we contrast these two kinds of relationship in this way, we see particular difficulties in reconciling the existing hierarchically defined processes—that, for instance, the PMOs must follow—with the cross-cutting demands arising from operational needs that may be spanning the concerns of multiple PEOs. In the face of complex demands for new or different forms of operational cohesion, TRADOC may be trying to identify TTPs that both cut *across* the accountability hierarchies and identify the need for new forms of interoperability. Under the present approach, sustained attention will only be given to those interoperabilities and the demands they support which can be brought under a single accountability hierarchy. As a result, other means of creating alignment will have to be found if the demand is particularly pressing or has a tempo that is faster than that of the acquisition process.[27]

Equally, in software blocking, a unified hierarchy of accountability for managing the software blocks is imposed, through which all the potentially conflicting demands for change can be deconflicted in order to deliver interoperable software. But this is interoperability as defined by the particular test regimes that were used to establish the software blocks. The problem with this approach is that operational demands for new forms of cohesion will cut across the original

[27] Appendix D shows that these other means are typically manpower intensive and, therefore, both costly and slower. A good metaphor for the extreme form of this approach is junkyard wars (http://en.wikipedia.org/wiki/Scrapheap_Challenge).

hierarchy imposed by the Software Blocking process, whether for reasons of tempo or changing mission. In this case, while these exceptions would normally be ignored in the interests of maintaining the unified hierarchy, the nature of the operational demands means that they cannot be overlooked. One result is that the software block delivered will always be following a different tempo to that of current operational demands.

A third example relates to the economics of satisfying new forms of demand cohesion. A capability is delivered to satisfy a given requirement which itself has been generated in response to demand. The operational costs of adapting this capability, once it has been put into use, fall to operational budgets of the organizations providing service using the capability. Excluding consideration of the effect that changes in forms of demand for cohesion have on operational budgets greatly increases the total cost and lessens the ultimate performance of the systems of systems.

Collaborative SoS Premise 4: To give an account of the interactions between hierarchies and stratifications, analysis of models of the problem space must include three concepts: functional coupling, accountability hierarchy, and demand cohesion.

4 Possible Actions

Clearly, the tempo of operations is different from that of acquisition or procurement, for the Army and other systems-intensive organizations$_n$ that acquire, build, deploy, and maintain large-scale, software-intensive systems. How, then, are fielded software systems to be defined in such a way that they support the agility needed by operations?

We suggest a number of opportunities for working with organizations (both military and otherwise) on this question:

- identifying strategies for better investment decisions within the acquisition/development context based on a bigger (stratified) picture
- proposing changes to the synchronization and integration of software based on methods to improve the prediction of and planning for the required varieties of geometry that need to be supported, taking into account the impact of existing systems on the introduction of new ones
- identifying different ways to test and decompose (1) missions or business operations, based on being able to identify the critical variety of demands for effects, and (2) changes to testing and certifying interoperability and net-readiness, based on the corresponding critical geometries

The SEI is interested in pursuing opportunities in a variety of business and operational contexts to further develop the ideas presented here. In particular, we are interested in opportunities to model the bigger picture and analyze a client's situation in ways that pay attention to the four premises we have introduced.[28]

28 The approach to this is outlined in our previous technical note: *SoS Navigator 2.0: A Context-Based Approach to System-of-Systems Challenges* [Boxer 2008b].

Appendix A   Modeling the Whole Space

To give an account of the whole problem space defined by the double challenge, we have to be able to model more than the physical and information processes. For this modeling, we use a visual method of projective analysis that allows capture of multiple dimensions of the problem space, including the relationship between supply and demand situations. Projective analysis uses five overlapping views of the problem space as shown in Figure 7:

- structure-function (how things actually work)
- trace (how information is used)
- hierarchy (how people and things are held accountable)
- synchronization (how processes of communication and data fusion bind people and data together)
- demand (how demands are presented, and how they are organized$_v$)

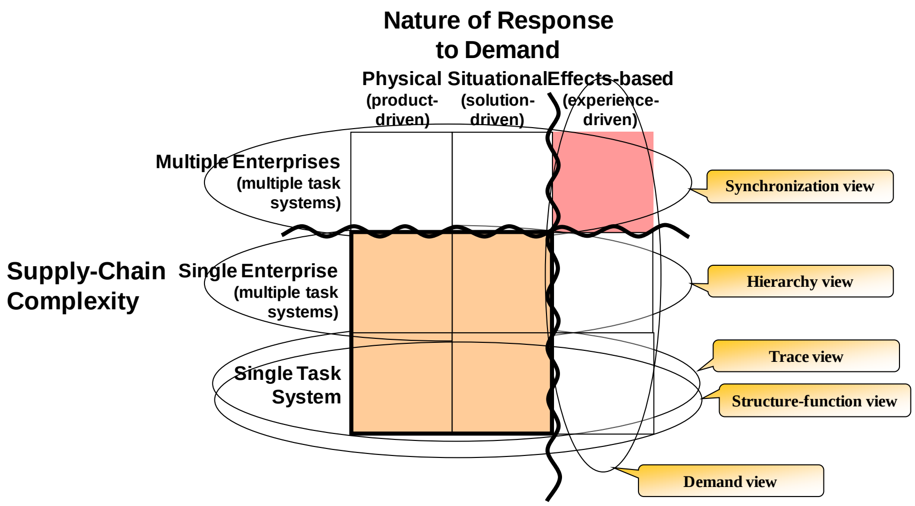

Figure 7: Modeling the Whole Space

Projective analysis produces complex models that represent relevant events and relationships occurring in the problem space. These models are captured by those who are involved directly with different parts of the problem space, since they have the "feel" for what is relevant. The resultant diagrams thus represent their understanding of how things fit together (or fail to fit together). As a result of combining these visual models generated by different modelers, it is possible to: (a) span the whole problem space, (b) represent those truths that the modelers, as members of the enterprise(s) working in the problem space, want to assert about this space, and (c) reflect the particular points of view and biases of the modelers. But it is not possible to say everything about what is going on in the space modeled; no model can.

Appendix B Why Standards Are Not Enough to Achieve Interoperability

We can see the limitations of supply-side viewpoints expressed solely in terms of functionality and accountability, if we look closely at the limitations on the way standards are used as an approach to managing interoperability.[29]

Figure 8 shows a version of the stratification introduced in Section 3.3.1 of this special report. This view emphasizes the interoperability within each layer and the way each layer is embedded in the layer above it. Behaviors of particular equipment capabilities (layer 1) are composed through exercising (layer 2) syntactical controls imposed on the way each capability can be used, to support particular semantics (layer 3) that are defined in terms of the underlying behaviors. Semantic interoperability (layer 3) is then placed within the context of the way the enterprise establishes its organization$_v$—referred to in the figure as *organizational interoperability* to maintain consistency with the names of the lower levels. Each pyramid in the figure represents a particular way of aligning layers 1 through 3.

In these terms, we can see that standards attempt to bring definitional consistency into layer 3, using the same syntactical approaches applied in layer 2. The reason why standards are not enough is that their definition is always relative to the layer 4 enterprise context (or to an equivalent socially defined community of interest). Thus, different enterprise or social contexts demand different semantics.

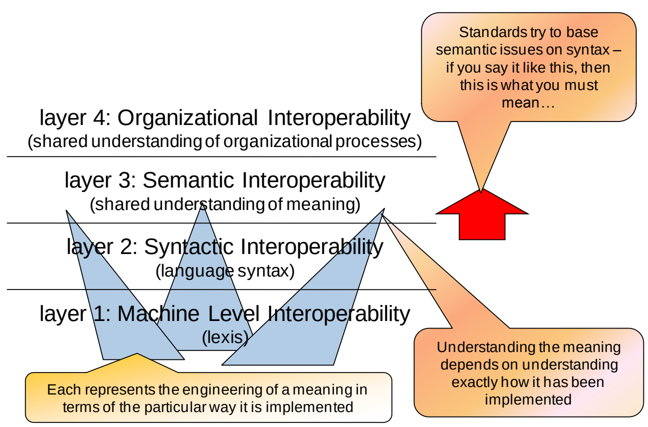

Figure 8: Why Standards are Not Enough

This hierarchical approach guarantees that there can always be a shared approach (layer 4) to defining semantics, enabling standards to be effective within the domain of the hierarchy. But if the enterprise must define semantics differently, depending on the context in which it finds itself, then this places an important limit on the usefulness of a standards-based approach. The nature of this limitation can be understood when we consider the full stratification in Figure 4 on page 14.

[29] In this appendix, we summarize the arguments in "Why Standards Are Not Enough to Guarantee End-to-End Interoperability" [Lewis 2008].

Appendix C Balancing the Stratification Layers

The Report asserts that the Army needs an approach that balances the existing program focus, which is rooted in a hierarchical accountability structure, with the actual operational needs that exist (i.e., at level six shown in Figure 3 on page 11). One way to think about this balance is in terms of the (w)edges and rings in Figure 9. A (w)edge is a way of working at the edge.

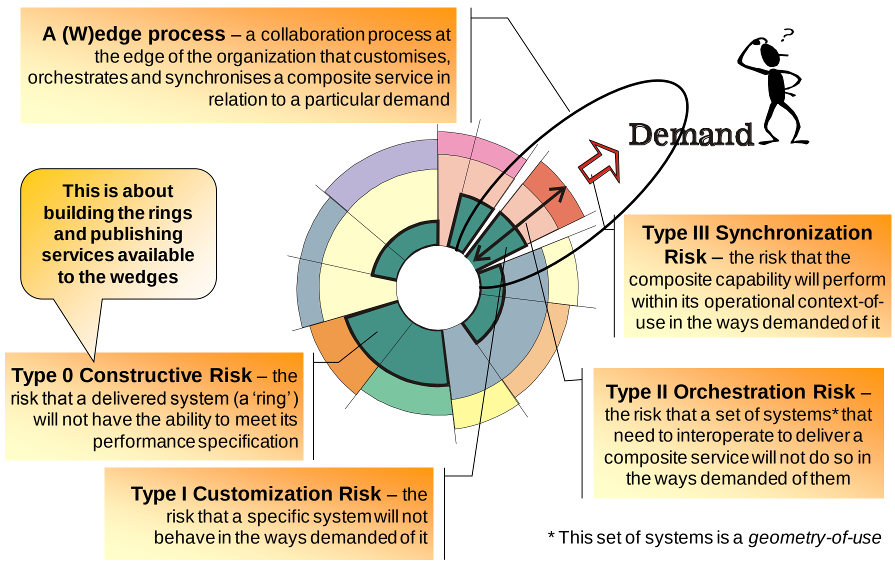

Figure 9: Rings and (W)edges

Figure 9 shows the capabilities that are built from layers 1 to 3 as *rings*. The *wedges* are then the orchestrations and synchronizations of customized ring services, with each wedge using a different orchestration of rings. Layer 3 is here defined as customizable services supported by layers 1 and 2 of the stratification, with service users being part of the wedge process. (In the DoD stratification in , these are operational capabilities.) Relating this back to the stratification, if we start at layer 6 with an effects environment represented in Figure 9 by the puzzled person, then the *(w)edge*

1. customizes individual services provided from rings (the services provided by the bottom three layers)
2. orchestrates them in relation to each other into geometries-of-use (layer 4)
3. synchronizes the resultant mission capabilities (layer 5) in relation to particular demands for effects (emerging from layer 6)

IMPLICATIONS FOR HIERARCHICAL VERSUS STRATIFIED APPROACHES

Figure 9 also distinguishes four kinds of risk:[30]

- Type 0 constructive risk: the risk that a delivered system will not be able to meet its performance specification (as a *ring* service)
- Type I customization risk: the risk that a specific system will not behave in the ways demanded of it by a (w)edge
- Type II orchestration risk: the risk that a set of systems that need to interoperate within a (w)edge to deliver a mission capability will not do so in the ways demanded of them
- Type III synchronization risk: the risk that the synchronized mission capabilities generated by a (w)edge will not perform as expected within a particular operational context-of-use

This definition of the risks to be mitigated in deploying systems is consistent with a stratified analysis. Consider the example of the Army's software blocking approach. By adding mission threads to the acceptance criteria for systems, software blocking treats the problems of interoperability as type 0 constructive risk. A stratified approach, on the other hand, limits constructive risk to the performance of the individual systems and defines the interoperability risks in terms of types I, II, and III risks explicitly related to demand. Thus, the Army can use testing resources more efficiently and separate verification and validation for future software blocks. A stratified approach also provides a strategy to verify and validate performance against something other than requirements, which has been a stated problem within the software blocking effort.

Traditional acquisition or procurement processes focus on supply-side interests and possess a limited view of demand-side interactions. The hierarchical approach associated with a view of the problem space based solely on functionality breaks down and ceases to serve the organization's analysis needs. Instead, systematic ways are needed to factor into the supply side the types of and variety of interoperating operational capabilities that are needed as the effects environment changes.

[30] These different forms of risk are further elaborated in the NATO project discussed by Anderson et al [Anderson 2006].

Appendix D The Economies of Scale, Scope, and Alignment

Without addressing the economies of alignment along with economies of scale and scope, we cannot be cost effective in how we provide requisite agility. A stratified approach allows us to consider how each kind of economy impacts on the others. Economies of scale and scope apply naturally to the *ring* services in Figure 9. In these terms, we can understand service-oriented architectures as a logical development in delivering such economies. The *(w)edges* define, however, the economics of aligning these services to demand. In these terms, we can see that network-enabled capabilities delivered into a web-enabled environment will impact on these economics of alignment by increasing the agility of the way the underlying capabilities can be made to interoperate.

What geometries-of-use introduce, however, is the idea that this alignment cannot be done in general, but rather must be done in relation to particular required varieties of geometry. Thus, the rings can be optimized to deliver economies of scale (we can do more without it costing us more) and economies of scope (we can deliver our services to a wider variety of users without it costing us more). But it is the (w)edges that deliver economies of alignment (we can dynamically customize, orchestrate, and synchronize capabilities across a wider variety of contexts-of-use without it costing us more).

The typical acquisition or procurement system focuses only on securing economies of scale and scope. What this perspective adds is the possibility of considering the tradeoffs between securing these economies and the current economics of alignment associated with delivering mission capability across the full DOTMLPFS spectrum.

Acronyms

Acronym	Description
ASA(ALT)	Assistant Secretary of the Army for Acquisition, Logistics, and Technology
DoD	Department of Defense
DOTMPLF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities
DOTMLPFS	This is an eight dimension concept drawn from the DOTMLPF view. The eight dimensions are as follows: doctrine and operational concepts, edge organization$_{v}$, collective training for force composition, materiel and technology, leadership and education, personnel and culture, facilities and infrastructure, and situational understanding.
FBCB2	Force XXI Battle Command, Brigade-and-Below
JCIDS	Joint Capabilities Integration Development Systems
JTRS	Joint Tactical Radio System
O&M	Operations and Maintenance
PEO	Program Executive Office
PMO	Program Management Office
PPBES	Planning, Programming, Budgeting, and Execution System
SAE	Service Acquisition Executive
SWB	Software Block
TCM	TRADOC Capability Manager
TRADOC	Training and Doctrine Command
TTP	Tactics, Techniques, Procedures
UAV	Unmanned Aerial Vehicle

Glossary of Terms

Accountability hierarchy	The hierarchy in relation to which the activities of the *enterprise* are held accountable
Agility of a system of systems	The variety of *geometries-of-use* that a system of systems is capable of supporting
Bottom-up analysis	Analysis in terms of the functionality and forms of interoperability being made available to the *enterprise*
Coupled functionality	The way functional elements can be chained together to produce an outcome
Demand cohesion	Which functional elements have to be brought together, and how, in order to satisfy particular forms of demand
Demand-side layers	The top three layers of a *stratification*
DOTMLPFS wheel	Eight organizational dimensions that, in being held in relation to each other through collaborative processes, determine the cohesion of an enterprise's behaviors at the *edge*. The eight concepts are doctrine and operational concepts, facilities and infrastructure, leadership and education, materiel and technology, edge organization$_v$, collective training for force composition, situational understanding, and personnel and culture.
Double articulation	The articulation of *coupled functionality* in relation to *accountability hierarchy*
Double challenge	The challenge of being both *edge-driven* and collaborating with multiple *enterprises*
Edge	The place where the *enterprise* encounters demands that are organized$_v$ in ways that are not consistent with its own organization$_v$
Edge-driven view of supply	"I am here to organize$_v$ and align solutions that will address your ongoing and evolving needs."
Enterprise	An organization$_n$ with a single overall focus of effective accountability for its performance
Experience-space	A space in which customers' choices are expressed in terms of their own experience, in which they anticipate the experience of effects. These are the through-time experiences of effects that the customer has as recipient of the suppliers' services
Geometry-of-use (geometries-of-use)	Particular configurations of interoperating and cooperating operational capabilities creating a mission capability
New Realities	The new realities in Table 1 that give rise to the four premises needed to make the system-of-systems challenges tractable: *double challenge*, the *DOTMLPFS wheel*, *triple articulation,* and *stratification*
n-tier hierarchy	A hierarchy with an unlimited number of levels
organization$_n$	A social arrangement
organization$_v$	An activity that brings order to something (e.g., organize my files)
Over-determined system	A system in which the *operational closure* of its behaviors is deterministic

Problem space	The space defined by the relationship between supply-chain complexity and demand within which accountability for performance has to be established
Product-space	A space in which customer's choices are expressed in terms of the qualities of one product versus another
Projective Analysis	A modeling approach that combines five different views of the enterprise: (i) structure-function (how things actually work); (ii) trace (how information is used); (iii) hierarchy (how people and things are held accountable); (iv) synchronization (how processes of communication and data fusion bind people and data together); and (v) demand (how demands are presented to the enterprise, and how they are organized$_v$).
Socio-technical system	An approach to complex organizational work design that recognizes the interaction between people and technology in workplaces
Solution-space	A space in which customers' choices are expressed in terms of the different solutions offered to customers' stated problems
Stratification	The way in which underlying behaviors are aligned to the particular forms of cohesion being demanded
Supplier-centric view of supply	"Before I can offer you a solution, you must first tell me what your problem is."
Supplier economies of alignment	"We can dynamically customize, orchestrate, and synchronize capabilities across a wider variety of contexts-of-use without it costing us more."
Supplier economies of scale	"We can do more without it costing us more."
Supplier economies of scope	"We can deliver our services to a wider variety of users without it costing us more."
Supply-side layers	The bottom three layers of a *stratification*
Top-down analysis	Analysis in terms of the way the functionality available to the enterprise is brought together as a whole, given the scope and motivation of the enterprise
Triple articulation	The articulation of both *coupled functionality* and *accountability hierarchy* in relation to *demand cohesion*
Type 0 constructive risk	The risk that a delivered system will not be able to meet its performance specification
Type I customization risk	The risk that a specific system will not behave in the ways demanded of it
Type II orchestration risk	The risk that a system of systems that need to interoperate to deliver a mission capability will not do so in the ways demanded of them
Type III synchronization risk	The risk that the mission capability will not perform within its operational context-of-use in the ways demanded of it
Under-determined system	A system in which the operational closure of its behaviors is non-deterministic
(w)edge	A way of working at the *edge*, customizing individual services provided from rings, orchestrating them in relation to each other into a *geometry-of-use* and synchronizing the resultant mission capability alongside other mission capabilities in relation to particular demands for effects

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13 ABSTRACT (MAXIMUM 200 WORDS)

For many large-scale, systems-intensive organizations, the tempo of operations using software-intensive systems is different from that of their acquisition, procurement, or development processes for those systems. These organizations use a variety of approaches that attempt to synchronize, for operational use, the integration and fielding of interoperating software. They continue to confront the issue of how fielded software can support the increasing agility needed by a deployed, operational workforce. This difference of tempo is a problem space that is explored in this special report. It describes four concepts underpinning Collaborative SoS that are useful in explaining the problem and in reasoning about possible solutions: recognizing the double challenge, sustaining an edge-driven perspective, achieving demand cohesion, and using stratification effectively. In this special report, those concepts are illustrated through a situation in the U. S. Army, called software blocking.

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