America's Innovative Advantage: Systems Integration in the U.S. Defense Industry

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The Bush administration came into office with a new commitment to transform the American military. The pressure behind the process was temporarily diverted by the September 11 attacks and the American response to them, but now the "war on terror" is being used as a new justification to speed the process. The general goal is to apply the information revolution to the military, radically improving capabilities and presumably augmenting America's national security. Each of the services has developed its own particular version of the vision, and the joint community and political leadership are conducting warfighting experiments and trying to develop integrating documents to set overarching objectives. The realization of the vision in part depends on organizational changes in the armed forces to help them fight in new, information-oriented ways, but it also depends on the acquisition of new weapons and communication technologies. The key first step in transformation – defining the way in which scientific advances will be applied in the military context, making technical progress into innovation – relies on America's unique capabilities in systems integration.

The information revolution in military affairs is, in fact, the apotheosis of the "systems approach" to warfare, on which the United States military embarked in the early days of the Cold War. During World War II, land forces learned the advantages of combined arms, melding the advantages of infantry, artillery, and armor into a system for overcoming defensive obstacles; later in the Cold War, aviation became truly integrated into that force package, improving combined arms capabilities still further.[1] Similar advances were made, also drawing on World War II antecedents, in antisubmarine warfare, using aviation, surface, and subsurface platforms and independent sensors like

[1] Paul Herbert, "Deciding What Has to be Done: General William E. DePuy and the 1976 Edition of FM 100-5, Operations," *Leavenworth Papers*, No. 16 (1988).

the SOSUS network in a system approach.[2] Forces for air defense, over-the-horizon strike targeting, strategic ballistic missiles, and many other categories drew from the cooperative use of many different weapon and support systems. In modern militaries, and especially in the American military, heterogeneous types of forces cooperate to achieve levels of combat power greater than the sum of the combat power of the parts. Today, advocates of network-centric warfare, which has spread beyond its roots in the U.S. Navy to all of the services, believe that improved communications networks and sensor technologies will allow new, more decentralized and more capable American forces to work together as a system to achieve a quantum increase in military power.

The network-centric transformation vision relies heavily on the ability of various platforms to share information in real time using a range of interconnected networks. Achieving the NCW vision will require lashing networks together, maintaining networks in the face of constant change, making intelligent trade offs amongst competing system designs, and tasking various platforms with their operational roles. Transformation thus places a high premium on systems integration skills and the organizations that possess them.

A basic definition of systems integration emphasizes interoperability – the requirement that each military system work in concert with other systems based on sufficient communication across well-defined interfaces. Network-centric warfare concepts obviously stress such inter-system compatibility, and casual discussions of systems integration in the context of transformation often refer only to interoperability

[2] Harvey M. Sapolsky and Owen R. Coté, Jr., "The Third Battle of the Atlantic," *Submarine Review* (July 1997).

requirements.[3] However, ensuring interoperability is only one part of the systems integrators' task. Systems integrators are responsible for a number of key roles during the overall acquisition process, beginning with translating objectives derived from military doctrine into technical requirements suitable for launching acquisition programs. The key part of this process is making trade-offs of capabilities among various systems – given a set of desired capabilities, which component of the system of systems should perform each of them? In the current, early stages of thinking about network-centric warfare, systems integration will define the nodes that make up the network, the capabilities that will be essential for each type of node, the number of nodes that must participate in various operations, etc. Later in the acquisition process, systems integrators maintain control of technical standards and interfaces (ensuring interoperability), manage the cooperation among contractors and subcontractors, test products and their subcomponents, and support the users' efforts to customize and modernize products as missions and technologies evolve.

This paper will argue that the military needs to exploit certain organizational innovations as the first step in its broader transformation effort – organizational innovations that facilitate systems integration. The first section defines systems integration in the defense sector. The second continues by describing the set of organizations that currently provide systems integration capability to military customers. The third section reviews the key issues in successful systems integration performance – the key measures by which systems integration organizations can be evaluated and can contribute to military transformation. Finally, the fourth section discusses organizational

[3] Amy Svitak, "Disjointed First Steps: U.S. Services' Transformation Plans Compete, Don't Cooperate," *Defense News* (August 19-25, 2002), p. 1.

changes that might be necessary early on in transformation to nurture sufficient systems integration and to focus systems integrators' efforts on the key tasks to promote the information technology revolution in military affairs. These organizational changes are not the ones on which apostles of transformation usually focus: they normally discuss changing the military's operational chain of command and its promotion patterns.[4] Those are very real concerns for the long-term ability of the military to augment its combat power using network-centric systems. However, to even acquire those systems, the military needs to begin by investing in systems integration organizations that will define the network itself.

Systems Integration in Defense

There are several levels of systems integration in the defense sector, all of which involve decisions among technical alternatives and linking disparate equipment so that heterogeneous parts can operate together. First, at the "lowest" level, weapon system integration ties various components, often supplied by subcontractors, into a single product (e.g., a surface-to-air missile or a fire-control radar).[5] Some key facilities owned by the prime contractor segment of the defense sector specialize in this type of systems integration (e.g., Raytheon in Tucson, Arizona, for missiles or Northrop Grumman in Linthicum, Maryland, for radars). Second, platform integration combines various types of equipment (weapons, propulsion, sensors, communications, etc.) into a mission-

[4] For good evaluations of these concerns, see Richard J. Harknett and the JCISS Study Group, "The Risks of a Networked Military," *Orbis*, Vol. 4, No. 1 (Winter, 2000), pp. 127-143; Elizabeth Stanley-Mitchell, "Technology's Double-Edged Sword: The Case of U.S. Army Battlefield Digitization," *Defense Analysis*, Vol. 17, No. 3 (December, 2001), pp. 267-88.

[5] Other prime contractors perform a similar, product-specific kind of system integration for sensor equipment, propulsion equipment, and other major platform components.

capable form. It is not necessarily more or less complex than weapon system integration, nor is it necessarily a higher or lower value added activity; different types of systems integration must be analyzed on a case-by-case basis. But again, some prime contractors (Lockheed Martin Aeronautics in Fort Worth, Texas, or General Dynamics' Bath Ironworks in Bath, Maine) define this capability as one of their core competencies.

The real emphasis in transformation – and the level of systems integration that is now most ardently pursued by defense-oriented organizations – is "system of systems integration" or "architecture systems integration." It connects different types of platforms to facilitate cooperative military operations, providing the technical counterpart to the military services' operational expertise (knowledge of how to fight). It essentially translates doctrine-writers' statements of objectives into sets of requirements that can be written into the acquisition community's contracts with industry; it involves broad tradeoffs among different technical approaches – for example, hardware vs. software solutions, or the decision whether to transmit raw or processed data across the network. Historically, system of systems integration has been accomplished by organizations within the military services (e.g., the laboratories that support systems commands, like the Naval Surface Warfare Center, Dahlgren Division) or closely allied to them (specialty organizations, including Federally Funded Research and Development Centers like MITRE). Network-Centric Warfare's emphasis on simplified platforms, distributed capabilities, and inter-connection of military assets via advanced communications networks will force the acquisition community to rely more than ever on first class system of systems integration.

Military-oriented systems integration skill is based on advanced, interdisciplinary technical knowledge – enough to understand all of the systems and subsystems well enough to make optimizing trade-offs. It also requires detailed understanding of military goals and operations, and a sufficient reservoir of trust to bridge military, economic, and political interests. Even if some systems integration organizations also have some production capabilities (which may be either an advantage or a liability to the integration process), systems integration is a separate task from platform building and subsystem development and manufacturing.

Systems integration is an independent sector of the defense industrial base, but one with porous boundaries that sometimes allow members of other sectors (e.g., platform builders) access to the systems integration task. Different combinations of systems integration capabilities are found in traditional defense industry prime contractors, specialized systems integration houses, Federally Funded Research and Development Centers (FFRDCs) and other quasi-public organizations, and the military laboratories. Because all of those types of organization understand the crucial role of systems integration in transformation, most are maneuvering to establish their credibility as systems integrators: for example, prime contractors justify acquisitions on the grounds that they contribute to a "systems integration capability," and military laboratories have re-written mission statements to emphasize systems integration.[6]

Organizations that can provide systems integration services have a key, early role in implementing transformation. Objectives for projects in other sectors of the defense industry – e.g., for platform makers like shipbuilders – will flow down from the overall

[6] Scott Tumpak, "Limit Super Primes," *Defense News* (July 15-21, 2002), p. 23; Andrew Chuter, "Honeywell Eyes FCS Systems Integration," *Defense News* (July 29-August 4, 2002), p. 4.

definition of the network-centric system of systems. Early in transformation, systems integrators need to determine what capabilities are necessary for each type of node in the network, considering technical, operational, and economic implications of how capabilities are distributed. This job is one for which the massive, complex Cold War defense effort left the United States well prepared. Organizations that specialize in systems of systems integration were established as part of the Cold War ballistic missile and air defense programs, and in cooperation they also played vital roles in developing equipment for maritime strategy, missile defense, and other system of systems-type missions. Network-centric warfare calls for sustaining innovation in the systems integration sector, but transformation advocates need to recognize and exploit the established skills at the front end of the process.

The Landscape of System of Systems Integration Organizations

Many organizations have at least some expertise that might contribute to system of systems integration for the Navy (for a list of examples, see Table 1).

Table 1

Examples of NCW-Related System of Systems Integration Organizations

	Government	Private, Non-Profit	Private, For-Profit
Policy Analysis	System Commands (SPAWAR, NAVSEA, NAVAIR)	Center for Naval Analysis, Institute for Defense Analysis, Rand	ANSER, TASC, Booz-Allen
Scientific Research	Naval Research Laboratory, SPAWAR Systems Center – San Diego*	APL, Lincoln Laboratory, Software Engineering Institute	
Technical Support	SPAWAR Systems Center – San Diego*	APL, MITRE, Aerospace	SAIC, SYNTEK

		Corporation	
Production			Lockheed Martin – Naval Electronics and Surveillance Systems, Raytheon Command Control Communications and Information Systems
Testing and Fleet Support	SPAWAR Systems Center – San Diego*		

* Each of the Navy's acquisition system commands has related technical organizations equivalent to the SPAWAR Systems Center – for example, the Naval Air Warfare Center – China Lake and the Naval Surface Warfare Center – Dahlgren.

Note: Some organizations have additional small-scale activities that give them limited capability in other boxes in the above matrix – for example, SPAWAR Systems Center – San Diego manufactures Link 16 antennas for surface combatants. The above designations are intended to capture organizations' core competencies rather than ancillary work.

As the customer for military equipment, the Navy must define projects' objectives, but the actual technical system of systems integration task is very difficult for the Navy itself to accomplish. The acquisition community's core competencies, resident in the system commands, are in understanding government regulations and monitoring suppliers' compliance with cost, schedule, and other contractual terms; acquisition agents are usually not expert in understanding state of the art technologies and the innovative capabilities of various firms. The Navy's old technical bureaus were phased out during the second half of the cold war, and technical tasks were increasingly outsourced to private industry.[7] Systems commands can still draw on expertise from subsidiary laboratories (e.g., SPAWAR Systems Center – San Diego for C^4ISR), which maintain important niche capabilities, research expertise, and key physical assets required to develop and test new designs end-to-end (e.g., model basins). Unfortunately, the

[7] Harvey M. Sapolsky, Eugene Gholz, and Allen Kaufman, "Security Lessons from the Cold War," *Foreign Affairs*, Vol. 78, No. 4 (July/August, 1999), pp. 77-89.

relationship between science-oriented military laboratories and regulation-oriented system commands is normally tense. Scientists often feel that the continuity of their research and their technical skills are undermined by frequent "cherry-picking" of researchers out of the laboratory and into the system command itself. For their part, systems command personnel tend to believe that scientists should support their immediate need for technical advice and technologies rather than pursue research projects that may or may not pay off in the future.

This difficult interface between "pure" science and system acquisition is a challenge for all forms of technical advisory organization – not just for the military's in-house laboratories – but the difficulty is magnified within the military chain of command. Internal Navy technical capabilities are on the one hand constrained by civil service rules, which prevent the Navy from competing to employ many of the top scientists and engineers. On the other hand, those very same rules also protect internal technical staff from competitive and budgetary threats. The operational Navy often perceives the Navy laboratories and technical advisors as less cooperative than the highly responsive private defense industry, whose scientists and engineers can be induced to work hard for the military through appropriate contractual compensation. As a result, the operational Navy often fails to support the Navy laboratories aggressively.[8] This tension may be exacerbated by "industrial funding," which forces laboratories to seek "business" from within other parts of the Navy, other government agencies, and even private industry by drumming up external contracts and participating in various project "teams," usually with specific, short-term deliverable products.

[8] For a related discussion of the tensions between operational Navy commanders and research scientists at the Office of Naval Research, see Harvey M. Sapolsky, *Science and the Navy: The History of the Office of Naval Research* (Princeton: Princeton University Press, 1990), pp. 86, 89, 96-98.

Warfighters do support the laboratory system, but only in a particular way that undermines the labs' ability to conduct analyses of alternatives and to make high-level trade-offs among technical approaches. The Navy's system centers are very good at fleet support. But those close ties to quick-reaction demands of the fleet undermine the standardization and interface stewardship role of the systems integrator, and the skills that enable fast, in-the-field fixes – especially fixes of particular systems or subsystems – are not the same as the skills that enable thoughtful optimization of the system of systems.

The emphasis in the laboratories is on testing system performance, confirming that prototypes meet specifications and determining which of several submissions best meets military acquisition criteria. This emphasis permeates these organizations so strongly that several scientists that we interviewed in military laboratories even defined systems integration in terms of testing performance and interoperability. While they understand the importance of technical advice during the analysis of alternatives before projects' performance evaluation criteria are defined, laboratory personnel emphasize the value of feedback from testing physical systems in improving the ability to define later projects. On the other hand, organizations other than in-house labs do extensive testing and prototype evaluation as part of system development, even though they do not do the final stage of customer acceptance tests. If in-house scientists are right that testing can help maintain technical skills and reveal important lines of evolutionary research, it might be desirable to sell the major testing facilities – the remnants of the unique intellectual and physical capital inside the military – to the organizations that can act as full system of systems integrators. The goal would be to leave the systems commands with enough

technical competence to act as "smart buyers," who could react to technical advice and choose among systems integration proposals developed by outside organizations with the full range of facilities and skills at the system of systems level.

With the services' increasing emphasis on high-level systems integration in their visions of the future, traditional prime contractors that specialize in platform design and production have begun to try to supply architecture systems integration. Firms with core competencies in electronics and network-oriented activities are also angling for platform systems integration work, arguing that inter-platform integration (interoperability) is becoming ever more important in the design of the platforms themselves. Prime contractors have focused for years on understanding the unique demands of the military customer, including hiring retired military officers for important positions in the businesses' strategic planning departments. The private firms are also largely exempt from civil service rules, allowing them the flexibility to hire top technical talent when necessary,[9] and for those scientists who crave equity compensation, private firms can also offer stock options.[10] If, on the other hand, technical team members develop a particular rapport with each other that generates extra value from synergies or experience, private firms have an incentive to support that built-up human capital. Managing technical personnel is a core competency of technology-dependent private firms, including defense industry prime contractors.[11]

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[9] The defense business remains a political one, and it is unrealistic to believe that efficiency will ever be the only or even the paramount goal. Defense contracts impose certain social goals on the defense industry labor force, like a preference for mentoring small, minority-owned, or disadvantaged subcontractors.

[10] Although this issue was recently highlighted by defense industry leaders' complaints about their firms' stock prices during the late-1990s tech bubble, it is actually a timeworn issue for high-end engineering workers in the defense sector. See, for example, Claude Baum, *The System Builders: The Story of SDC* (Santa Monica: System Development Corporation, 1981), pp. 129-31.

[11] Private firms are sometimes accused of under-valuing research staff continuity in the face of investor pressure for short-term earnings. It is not clear why investors should be expected to make systematic

However, platform systems integration and system of systems integration are not the same task, and it is not even clear that developing skill at one helps very much in developing skill at the other. Platform integrators may improve their performance through any of a number of different activities: repeated design or prototype development experience; production experience; and maintenance of close relationships with applied technical laboratories, basic science research establishments, academic institutions, and/or the operational user community.[12] Their unique advantage is in linking systems engineering capability with intricate knowledge of the manufacturing process, allowing them to take advantage of production efficiency advantages in the design process. Naturally, prime contractors emphasize the importance of production capability in their discussions of systems integration – just as military laboratories emphasize the importance of full-scale system testing. However, while this advantage surely carries some weight, it is likely to be relatively small in the defense sector, where production runs are often short and very-close-tolerance production processes are often craft-like, minimizing the potential for major savings. Such production issues should consequently receive a relatively low weighting in the system of systems integration trade space, although system of systems specialists should still strive to consider platform-makers' concerns when they do their overall analyses and requirements definitions. System of

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mistakes in valuing research teams: they can simply discount future payoffs of research investment back to a net present value for comparing investments. In the 1990s, investors tended to over-value the promise of technological progress, including in the defense industry (expectations for which were briefly confused with those for the "dot com" companies). Eugene Gholz, "Wall Street Lacks Realistic View of Defense Business," *Defense News* (December 20, 1999), p. 31.

[12] Each of these sources of systems integration skill was cited in one or more interviews—usually in self-serving ways. That is, a systems integration organization with close academic ties would emphasize the importance of access to basic scientific research to their work, while an organization with ties to a major defense production organization would emphasize production experience as a key underpinning of systems integration skill.

systems concerns about platforms' interfaces with the network should take precedence in transformation planning and acquisition.

Moreover, the potential for conflicts of interest—or at least for the appearance of conflicts of interest, the more stringent standard that has been deemed appropriate for government organizations – mandates a separation between architecture systems integration and production in the defense industry. Production prime contractors have the technical capability to scan subcontractors' products, including the offerings of innovative commercial firms, for likely partners in the network-centric defense industry—that is, they can fulfill one of the key technical and management requirements of a systems integrator. They also can make technical decisions about interfaces, network standards, and other requirements definitions; by vertically integrating to combine platform- and components-oriented design and production organizations, large prime contractors might provide technical systems integration services with minimal transaction costs. But expanding the roles of established prime contractors faces a crucial non-technical barrier: lack of trust. Manufacturers certainly test their products before delivery to the customer, but the customer also needs an independent ability to verify product performance – just as military laboratories emphasize. Moreover, the customer might reasonably fear that a manufacturer's trade-off analysis might be biased in favor of the sort of alternatives that the manufacturer is expert at making – even unintentionally biased, perhaps, by the production contractors' better technical understanding of particular systems and solutions.

This problem was first manifest in the defense industry in a 1959 Congressional investigation of the relationship between TRW's satellite and missile production

businesses and the TRW-owned Space Technology Laboratory, which played a technical direction role on Air Force development and production projects—including some for which TRW submitted proposals. Neither protectors of the government trust nor members of the defense sector that competed with TRW on those space systems contracts would accept the situation, even though no specific malfeasance was uncovered or even alleged. STL was essentially split off from TRW to become Aerospace Corporation, an independent, non-profit, non-production, systems integration specialist, later called an FFRDC.[13] That organizational innovation, which spread with the establishment of other FFRDCs and the similarly organized University Applied Research Centers (UARCs), allowed the military's acquisition organizations to outsource the technical advisory role during the Cold War in a way that was protected from conflict of interest scandals.[14] Some FFRDCs like MIT Lincoln Laboratory specialize in particular kinds of military-oriented research (advanced electronics, in that case), comparable in some ways to the in-house military laboratories but more closely tied to frontier academic research. While the core tasks of various FFRDCs overlap to some extent, Aerospace Corporation (space systems), MITRE (air defense), and APL (naval systems) are the ones that specialize in architecture systems integration.[15]

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[13] Davis Dyer, *TRW: Pioneering Technology and Innovation since 1900* (Boston: Harvard Business School Press, 1998), pp. 225-39. Also, William L. Baldwin, *The Structure of the Defense Market 1955-1964* (Durham, NC: Duke University Press, 1967), pp. 45-46, 138-39. A similar situation led to the creation of the MITRE Corporation. See John F. Jacobs, *The Sage Air Defense System: A Personal History* (Bedford, MA: MITRE, 1986), pp. 137-138 and 139-141.

[14] Bruce L. R. Smith, *The Future of the Not-for-Profit Corporations*, P-3366, (Santa Monica: RAND Corporation, May 1966), p. 18. Smith predicted that the FFRDC role would fade as the military improved its in-house technical capabilities. But for the reasons discussed in the text—and because the FFRDC's success, which Smith underlines in his report, reduced the demand for in-house systems integration capability—the military services never developed sufficient expertise to replace the FFRDCs. For-profit systems integration contractors (e.g., SAIC) have proven to be a bigger threat to the FFRDCs than any resurgent government laboratories.

[15] Johns Hopkins University APL is not technically an FFRDC at present (it was until 1977), but it remains a non-profit systems integration organization with a long-term contractual relationship with the U.S. Navy.

The historical strength of FFRDCs has been their reputation for high-quality, objective advice. Through flexibility in salary negotiations and quasi-academic status, FFRDCs have been able to attract high-quality personnel. Their promise not to compete for production contracts and to provide equal access to all contractors while safeguarding proprietary information has given them unique, independent technical capabilities.[16] However, they have frequently been criticized as inefficient and relatively expensive: while leaders of FFRDCs frequently claim that their non-profit status allows them to charge less than a hypothetical technically equivalent for-profit technical advisor, many others (notably leaders of for-profit firms like SAIC) allege that the lack of a profit motive in FFRDC work leads to inefficient performance and the potential for feather-bedding.[17] Congressional legislation currently limits the budget available to FFRDCs and prevents the military from establishing any new FFRDCs.[18]

For-profit, non-production firms might be able to offer the benefits of FFRDCs while avoiding the controversies linked to non-profit status. Small engineering companies like SYNTEK can offer technical advice to the military with a credible

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Like an FFRDC, APL does not primarily engage in production, and it sometimes acts as the technical direction agent on major naval systems contracts. For present purposes, APL can be grouped with MITRE and Aerospace as a systems integration FFRDC, although it also has a strong research program analogous to Lincoln Laboratory.

[16] U.S. General Accounting Office, *Strategic Defense Initiative Program: Expert's Views on DoD's Organizational Options and Plans for SDI Technical Support*, GAO/NSIAD-87-43 (November, 1986), p. 4.

[17] U.S. General Accounting Office, *Federally Funded R&D Centers: Issues Relating to the Management of DoD-Sponsored Centers*, GAO/NSIAD-96-112 (August, 1996), pp. 5-6; U.S. Congress, Office of Technology Assessment, *A History of the Department of Defense Federally Funded Research and Development Centers*, OTA-BP-ISS-157 (Washington, DC: U.S. Government Printing Office, June 1995), pp. 28-33. SAIC specifically acknowledges the technical skills of FFRDCs and actually tried to purchase Aerospace Corporation in 1996 – claiming that they could maintain the skills while adding efficiency due to the profit motive. Air Force resistance blocked this controversial move; many scientists at Aerospace were also skeptical of the acquisition and report that they would have considered leaving the company if the SAIC deal had gone though. See John Mintz, "Air Force Halts Merger of 2 Companies," *Washington Post* (November 16, 1996), p. D1.

[18] Some people involved in these Congressional decisions believe that the perceived high cost of FFRDCs was the crucial issue in establishing these limits; others see the effects of a lingering controversy over missile defense. The most recent proposal to establish a new FFRDC would have created a Strategic Defense Initiative Institute to support the missile defense effort.

promise not to engage in production, but it is difficult to imagine such a firm nurturing a major laboratory with an independent research capability and agenda, at least under current procurement rules. Without direct access to such scientific assets, it is reasonable to question the ability of a consultancy to maintain top-level system of systems integration skills.[19] Larger for-profit firms like SAIC, which owns Bellcore, the former research arm of the Regional Bell Operating Companies (a partial descendant of Bell Laboratories), offer to fill this niche, but to cover the overhead cost of such laboratories they resist promising to abstain from all production work. Although for-profit firms in the defense industry have learned to form teams to develop major systems and sometimes even join a team on one contract with a firm against which they are competing on another contract, real questions persist about how much proprietary data the for-profit contractors are willing to share with one another. Although a promise not to engage in production would allay some of the fears that prevent platform firms from becoming architecture systems integrators, major for-profit advisory firms are still limited by customers' and competitors' skepticism about their true, long-term independence.

Systems Integration Performance Metrics

So far, the metrics available to compare systems integration capabilities are limited, so project managers may have difficulty selecting sources for technical advice and deciding how much investment in up-front systems integration work is enough. Carnegie Mellon University's Software Engineering Institute (SEI), a research FFRDC,

[19] SYNTEK, for example, has benefited by hiring a number of technical experts who gained experience working in military laboratories at a time (in the 1960s and 1970s) when they had a stronger role in architecture definition. SYNTEK executives fear that their skills will be hard to maintain in future generations of technical staff. Author interviews, September, 2000.

has developed a rating system for several computer-related skills, including software engineering and systems engineering. The ratings assigned according to the SEI "Capabilities Maturity Models" are based on a business' commitment to follow certain procedures designed to manage complex projects: specifically, they emphasize maintaining control of documentation and interfaces to ensure system-wide performance as components and subsystems are improved in parallel. These software-oriented procedures are at least related to the broader systems integration task, and they may provide a useful model for further work defining metrics for overall systems integration capabilities.[20]

For a broad discussion of the relationship between systems integration and transformation, however, such detailed metrics for evaluating systems integrators are not necessary. The key questions are which of the established systems integration organizations can provide the support required to implement transformation and how can the military services best stimulate that system of systems integration.

Technical awareness. The bedrock of systems integration is familiarity with the technical state of the art in the wide range of disciplines that contribute to the components of the system. Systems integrators must be able to set reasonable, achievable goals for the developers and manufacturers of the components even as they "black box" the detailed design work for those components. If one component maker has a problem that it can solve only at great expense that could be solved much more easily by shifting the

[20] The SEI has begun to develop a new Capabilities Maturity Model to evaluate "Integration" skills: at the direction of OSD, they are trying to apply software systems engineering procedures to software-hardware integration. The goal is to develop best practice methodologies for reducing the rate of failures in complex projects. Even this on-going broadening of the SEI's research remains at a "lower" level than the overall system of systems integration that is the key, initial step in transformation.

requirements of a different component or by altering the interface standard in a way that would cost other component manufacturers less, it is the responsibility of the systems integrator to understand and implement the necessary trade-off in the various component specifications. The more access the systems integrator has to technical knowledge of subsystems, the better it will be able to perform that role. There are many ways that a systems integrator can obtain this technical knowledge, including systematically and continuously training and educating critical engineers, hiring personnel from subsystem contractors, and seconding employees to other organizations to work in all phases of component design and production.

Transformation is unlikely to change the role of technical awareness as a systems integration performance metric. To the extent that network-centric warfare draws on unfamiliar component systems, it may strain the technical awareness of established systems integration organizations. For example, emerging unmanned vehicle technologies may take over a number of tasks previously assigned to manned systems, requiring systems integrators to be familiar with the state of the art in UV technology to make trade-offs between manned and unmanned systems. However, the systems integrator need not have the capability to actually design and build either the manned or the unmanned systems: the specific technical knowledge is not the core competency for the systems integrator; instead, the ability to gain access to that knowledge by working with subsystem contractors, academic experts, and / or in-house researchers is the *sine qua non* of systems integration.

Developing new sources and kinds of technical awareness may be the core competency of a systems integrator, but it is only natural that the less familiar the

component technologies of a particular project are to a systems integrator, the less suited that integrator is to work on it. Even the organizations with the broadest architecture systems integration capability have specialties – Aerospace Corporation in space systems, for example, or MITRE in command and control. It is by no means obvious, however, that network-centric warfare demands new specialties. Instead, it seems to involve the advanced application of a combination of established ones – reliance on space systems for surveillance and communications relays, on intensive exploitation of command and control networks and battle management computation, etc. If a new focus on the network characterizes the systems integration task for network-centric warfare, surely MITRE, APL, and for-profit firms like Logicon and SAIC have the necessary technical awareness. Perhaps even the Software Engineering Institute's foray into integration offers a basis for a transition from a pure research FFRDC into a research and systems integration combination that specializes in network technology (akin to APL).[21] Although the commercial Internet has burgeoned well beyond its defense origin, the ARPANET, the original DARPA program has been cited as a classic example of the military's "systems approach" to advanced technology.[22]

The organizational framework through which established organizations' specialties should be applied to the new problems of network-centric warfare, however, remains an open question. Various systems integrators might offer competing technical proposals, each offering its best system solution to network-centric warfare challenges and pointing out flaws in alternative proposals. American pluralist government is built

[21] In interviews, several respondents noted that the Capabilities Maturity Model – Integration (CMM-I) project is causing tension between the SEI and MITRE as they both clamor for the attention of their key customers at the Air Force Electronic Systems Command at Hanscom Air Force Base.
[22] Thomas P. Hughes, *Rescuing Prometheus: Four Monumental Projects that Changed the Modern World* (New York: Vintage Books, 1998).

on the principle that the clash of ideas yields the best policy solutions, and that clash of ideas might help to compensate for each existing organization's implicit biases in favor of its technical specialties. APL might point out any pitfalls of Aerospace Corporation's space-based solutions, while Aerospace could reciprocate by illuminating the risks of APL's hypothetical bandwidth-consuming approach. Still, it remains the responsibility of the customer/buyer to evaluate competing claims in order to make decisions in the corporate interest of the Navy or, better yet, the U.S. military as a whole.

Alternatively, a team combining the relevant technical groups from the established systems integrators might be able to offer a comprehensive technical base for network-centric systems integration. Ten FFRDCs and national laboratories combined to provide technical support to the Ballistic Missile Defense Organization through a teaming arrangement called the POET.[23] A full evaluation of the technical performance of the POET is beyond the scope of this report, but some preliminary observations are relevant. On the one hand, the POET clearly provided access to an exceptional breadth of technical talent.[24] On the other hand, the participant organizations retained their traditional customers, missions, and cultures, such that they may not have invested their best resources or their full attention in the missile defense effort.[25] A systems integration team for network-centric warfare would gain similar advantages and would face similar limitations.

[23] The reorganization of the BMDO into the Missile Defense Agency has been accompanied by the creation of a "National Team" to provide technical support and systems integration for missile defense. The National Team involves prime contractors that produce platforms – specifically including platforms that will be deployed as part of the tiered missile defense system of systems.
[24] Author interview, August, 2001.
[25] Author interview, July, 2002.

To apply the full resources of the established systems integrators to the new challenges of network-centric warfare, it might be best to create a new systems integrator with a new bureaucratic identity. But it would not be necessary to create such an organization from scratch – and it would be very costly to replicate the investment in human capital that has already been made by established organizations. When MITRE was created as the systems integrator for the SAGE air defense system, its core was formed from Division 6 of Lincoln Laboratory, which chose at that point to focus on research rather than systems integration. MITRE then proceeded to expand its technical awareness into new areas, integrating air defense missiles like the BOMARC into an air defense system initially designed to cue fighter interceptors.[26] Today, it might be possible to blend various technical groups spun off by the established organizations, again forming a new FFRDC. The new institution would maintain the well-understood core competency in nurturing technical awareness but would do so in the service of a new customer and organizational mission.[27]

Each of these three candidate organizational forms to supply systems integration to transformation relies on the built-up skills of established institutions: they are evolutionary changes required to proceed with sustaining innovation along the technical awareness performance metric. The financial ownership structure of the technical

[26] Jacobs, p. 131; Hughes, p. 62; Baum, pp. 38-39.

[27] A similar idea was proposed to provide technical support to the missile defense program: either personnel from established FFRDCs would have been reassigned to the new SDII or a new division of one of the established FFRDCs would have been created. This approach was rejected in favor of the POET, arguably because the new FFRDC approach was perceived as too slow to set up and too costly. Others suggest that the SDII proposal was blocked by political opponents of missile defense, who hoped to hamstring the effort by denying high-quality technical advice to the Strategic Defense Initiative Office. See Donald Baucom, "The Rise and Fall of the SDI Institute: A Case Study of the Management of the Strategic Defense Initiative," Incomplete Draft, August, 1998.

advisor is less important than its underlying skill base, which can be derived from existing systems integration groups.

Project management skill. Efficiency has rarely if ever been the only goal of military acquisition programs. In addition to serving economic goals, the projects need to meet military requirements and to satisfy political constraints.[28] Nevertheless, efforts to control costs have been a continuous feature of defense policy, because warfighters always have more systems that they would like to acquire, technologists always can use additional resources to push the performance envelope further, and politicians always have non-defense priorities including pressure to lower taxes. All three groups also try to plan their expenditures as part of the budgeting process, and so they need estimates of projects' cost and schedule that are as accurate as possible.

For complex acquisitions with numerous, heterogeneous components – a system of systems – reliable estimates are difficult to come by due to the vast amounts of information that must be managed to describe the current and projected state of progress. Participants also have incentives to hide some information from oversight efforts. Sometimes they believe setbacks to be temporary (that they will get back on schedule, the promised performance trajectory, or the estimated cost projection before they have to report problems), and sometimes they fear the full disclosure will aid competitors or will lead to pressure to renegotiate fees and expropriate profits. Managers learn to report data in favorable ways, almost always without real malfeasance, that can give a biased picture

[28] Thomas L. McNaugher, *New Weapons, Old Politics: America's Military Procurement Muddle* (Washington, DC: Brookings Institution, 1989), pp. 3-12.

of progress that protects on-going projects from oversight.[29] They also enthusiastically adopt acquisition reform efforts and management fads that promise to reduce costs in the future – after enough investment has been sunk into the project to lock it in to the political landscape, whether or not the efficiency benefits of the reform ever actually materialize.[30]

System of systems integrators have the expertise to manage projects as well as possible in the face of these constraints. The better a given systems integrator performs in that project management task – setting accurate schedules, projecting attainable technical goals, and minimizing transaction costs among the many organizations that have to contribute to a systems contract – the greater the incentive the buyer has to hire that systems integrator. Project management skill is a key performance metric for systems integration organizations.

Transformation calls for sustaining innovation in project management. Ultimately, for network-centric warfare to be useful to the warfighter, a number of different programs (ships, aircraft, unmanned vehicles, munitions, sensors, etc.) need to deliver compatible systems to the fleet in the correct order; the schedules need to be timed so that the various deployment dates form the network. Cold War programs like the Polaris fleet ballistic missile program, which required tremendous innovation in missiles and guidance, in communications and navigation, and in submarine platforms, faced the same sort of management and scheduling problems. System of systems

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[29] Harvey Sapolsky, "Myth and Reality in Project Planning and Control," in F. Davidson and C. Lawrence Meadow, eds., *Macro-Engineering and the Future* (Boulder, CO: Westview Press, 1982), pp. 173-82. On rare occasions, oversight officials and / or firms have been known to falsify reports, but those cases are truly the exception rather than the rule. Robert Wall, "V-22 Support Fades Amid Accidents, Accusations, Probes," *Aviation Week and Space Technology* (January 29, 2001), p. 28.

[30] Cindy Williams, "Holding the Line on Infrastructure Spending," in Cindy Williams, ed., *Holding the Line: U.S. Defense Alternatives for the Early 21st Century*, Cambridge: MIT Press, 2001, pp. 55-77.

integration was effectively invented precisely for the purpose of managing such massive, heterogeneous acquisitions.[31] Network-centric warfare may require integration of an even broader array of components, making the system of systems integration task even more difficult. But systems integrators are already applying modern information technology to manage complex subcontractor networks, to scan for technological leads that might contribute innovative solutions to military problems, and to interact with potential new suppliers, innovating to support this core task.

At the platform integration level, the project management task under transformation will be little changed from its previous incarnations. Whether any given platform integrator is well positioned to participate in transformation will depend on the demand for its technical skills – whether network-centric warfare calls for sustaining or disruptive innovation in that sector of the defense industry. The platform integration task will continue to include management of subcontractor relationships and the detailed design of military systems. In sectors dominated by sustaining innovations, platform integrators' databases of successful subcontractors and procedures for working with the social and political constraints of the government contracting environment will contribute to successful acquisition programs. Despite acquisition reform advocates' appropriation of phrasing from transformation advocates – the "revolution in acquisition affairs" or "revolution in business affairs" – the quest for acquisition reform is separate from military transformation.

At the architecture systems integration level, transformation's biggest challenge in project management will stem from the need to integrate plans and schedules of several

[31] Harvey M. Sapolsky, *The Polaris System Development: Bureaucratic and Programmatic Success in Government* (Cambridge: Harvard University Press, 1972).

powerful customer organizations. The mechanism by which a technical direction agent for network-centric warfare can assert control of the technical aspects of project management may change (changes in the customer relationship will be discussed below, in the section on customer understanding). But the core project management task will not change much: system of systems integrators will have to integrate some new technical tasks into military systems development, but the disruptive innovations, if any, will fall at the platform or component level rather than in the techniques for organization and management of the system of systems project. Transformation requires high-level systems integration to evolve along a familiar performance trajectory, contributing as much efficiency and scheduling accuracy to major systems acquisition as possible. The core of the Cold War system of systems integration sector – meaning FFRDCs and for-profit systems integration specialists, at least with respect to transaction costs in architecture integration – can provide the necessary technical support to transformation efforts.

Lack of bias. The key role of a system of systems integrator in defining the technical requirements of various system components (and hence of the system as a whole) requires that it be able to make trade-offs in the interest of system performance rather than in the interest of the organizations that design or make the system. The architecture systems integration task is tremendously complicated, because military systems have multiple goals – peak warfighting performance, sustained political support for the acquisition program and for the national security strategy, and minimal

expenditure of resources for acquisition, maintenance, training, and operations.[32] That complexity, along with the requisite technical expertise, essentially guarantees that detailed decisions in system of systems integration will not be completely transparent to military customers, Congressional appropriators, or defense industry prime and subcontractors that supply components of the system. All of those groups must trust that the systems integrator has considered and protected their interests in making its architecture definition decisions, and any organizations that feel that their trust has been violated have an opportunity to create a scandal by complaining publicly. They are constrained by the understanding that complaining too often or too loudly can subvert the entire process of providing for the national defense. They cooperated in the Cold War evolution of system of systems integrators that minimize the problem of bias in system definition, and that lack of bias as a result is a key performance metric for system of systems integrators.

The difficulty in maintaining independence for architecture systems integration is compounded by the pecuniary incentives in defense acquisition. Like all organizations, systems integrators have an incentive to favor solutions that maximize their own organizational rewards, maintaining and exploiting their position as a key node connecting customers and producers in the organizational network of the military-industrial complex.[33] This bias may be purely tacit, as scientists propose certain types of technical solutions based on their particular expertise, thereby reinforcing the value of

[32] Conflicts among those tasks have been barriers to the successful application of the systems approach outside of the acquisition environment. Stephen P. Rosen, "Systems Analysis and the Quest for Rational Defense," *Public Interest* (Summer 1984), pp. 3-17.

[33] For a general discussion of this form of organizational behavior, see Jeffrey Pfeffer, "A Resource Dependence Perspective on Intercorporate Relations," in Mark S. Mizruchi and Michael Schwartz, eds., *Intercorporate Relations: The Structural Analysis of Business* (New York: Cambridge University Press, 1987).

that particular expertise. Moreover, profits in the defense industry have disproportionately accrued to production rather than research or technical advisory organizations, in large part because profits are regulated, formally and informally, to remain at a certain percentage of projects' revenue, and the bulk of the acquisition spending is concentrated during the procurement rather than the systems development phases of acquisition.[34] In the post-Cold War threat environment where the United States faces no peer competitor, those firms with a critical mass of workers, generally production rather than technical organizations, have been able to add considerable political weight to their pleas for financial support from Congressional appropriators.[35] Consequently, the financial prospects for pure system of systems integrators are weak, and they face pressure to vertically integrate systems integration with production capability. Freedom to choose optimal technical solutions is constantly threatened at the margin by pressure from the bureaucratic interests of the services and the political power of platform producers. Because this pressure is well known, trust from the customers that the systems integrators will steward the military's interests and not simply the venal interests of the systems integrators themselves is also threatened.

Most established systems integration houses had bias built in to their very make up. They served a particular customer, and the needs of that customer were well known. Lack of bias in this context meant within their own issue domain where they might rightfully be expected to play honest broker. In turf battles with external forces, however, they might favor particular types of solutions. Thus Aerospace Corp. might be

[34] William Rogerson, "Incentives in Defense Contracting," Paper presented at the MIT Security Studies Program, October, 1998; Thomas L. McNaugher, "Weapons Procurement: The Futility of Reform," in M. Mandelbaum, ed., *America's Defense* (New York: Holmes & Meier, 1989), pp. 68-112.
[35] Eugene Gholz and Harvey M. Sapolsky, "Restructuring the U.S. Defense Industry," *International Security*, Vol. 24, No. 3 (Winter, 1999-2000), pp. 5-51.

unbiased in telling the Air Force about how to organize and equip its own space capabilities, but it would be less so when arguing for space-based solutions rather than non-space based solutions proposed by other government entities. Outside its immediate area of expertise, solutions proposed by Aerospace must be weighed carefully against alternatives proposed by rival organizations working for rival customers.

By and large, the FFRDC / UARC system of non-production technical advisors functioned successfully during the cold war.[36] The FFRDCs and UARCs promise as part of their contractual relationship with the government not to engage in production. Some tensions inevitably remain between the producer firms and the FFRDCs, who insist that they need to engage in some prototype building that is quite similar to production in order to maintain their SI skills. These tensions may be particularly likely to escalate in the software industry, where the development and production phases of a code-writing project frequently overlap.

APL, for example, has gotten into trouble for mixing production with systems integration, specifically in the current dispute over the best technology for the Navy's Cooperative Engagement Capability (CEC). Solypsis, a software firm founded recently by disenchanted former employees of APL, has created a rival system, the Tactical Communications Network (TCN). Solipsys claims that it has not had a fair hearing with in the Navy, at least in part because APL is both the technical advisor to the Navy and the developer of CEC. Regardless of the technical merits of CEC versus TCN, and here opinions vary widely,[37] the controversy would be less bitter if APL were not exposed to charges that it favors one solution over the other because it developed that alternative and

[36] Office of Technology Assessment, "History of Department of Defense Federally Funded Research and Development Centers."
[37] Add citation from *Proceedings*

would participate in its production. The Navy, which will have to decide between the two approaches for its Block 2 acquisition of CEC in 2004, has a real problem evaluating the technical claims of the competing organizations, because its usual technical advisor for this sort of systems integration competition, APL, has a stake in the outcome of the competition.[38] Even if the Navy finds a way to make the technically correct decision, conflict of interest claims will arise – as they already have – and the likely outcome will be to cause extra oversight of the CEC program, increasing costs and undermining political support for that key early procurement step in developing the Navy's "Common Operational Picture" that is required for Network-Centric Warfare.

Scandals, alleging "waste, fraud, and abuse" and cost and schedule failures have derailed military investment in the past, and conflicts of interest might be a threat to the Navy's move forward toward Network-Centric Warfare. The peaks in the major cycles of the U.S. Cold War defense budget were associated with procurement scandals, which at least superficially played a role in reversing the defense budget trend. Even if structural factors like the changing threat environment or the completion of a generational change in the service's key equipment were bringing the procurement cycle to an end, calls to rein in abuse in defense acquisition generally contributed as the proximate cause that determined the timing of the downturn in the defense budget.[39] The Future Years Defense Budget now calls for a major increase in procurement spending for the next several years – the defense budget's new cycle. To the extent that the military leadership hopes to use that spending to acquire the systems to implement transformation, the cycle

[38] Author interviews, May, 2002; Gopal Rotnam, "U.S. Navy to Set New CEC Requirements," *Defense News* (July 22-28, 2002), p. 44.
[39] McNaugher, "Weapons Procurement;" Ethan McKinney, Eugene Gholz, and Harvey M. Sapolsky, *Acquisition Reform,* MIT Lean Aircraft Initiative Policy Working Group, Working Paper #1, 1994.

must not end prematurely due to scandal. As a result, military transformation relies on sustaining innovation on this metric of system of systems integration.

Customer understanding. The Navy with all its communities (primarily the three led by aviators, submariners, and surface warfare officers) is a complicated organization with a long institutional history, unique traditions, and organizational biases developed from generations of operational experience. More formally, there is a large body of strategy, tactics, doctrine, and training processes that distinguish the Navy from the other Services and from other government and private sector organizations. The other Services and supporting intelligence organizations have similarly developed their own organizational identities and perspectives on warfighting and national security strategy.[40] The success of each system of systems integrator depends on its deep understanding of the naval and military environments, because the integration organization's architecture definitions and project management decisions must serve its customer's true goals, which can be difficult to articulate in a simple, program-specific, written "statement of objectives." Navy-oriented systems integrators (for example, APL, SYNTEK, and Lockheed Martin Naval Electronics and Surveillance Systems) have built up a great deal of tacit knowledge about how and why the Navy operates without which they would not be trusted to perform the system of systems integration service. While customer understanding is important for any organization, it is a uniquely vital performance metric for architecture systems integration organizations.

Customer understanding is a moving target. On this metric, long experience alone is insufficient. A systems integrator must commit to investing continuously in its

[40] Carl H. Builder, *The Masks of War* (Baltimore, MD: Johns Hopkins, 1989).

military-operational knowledge base. It must monitor lessons learned from recent exercises and operational deployments and changes in military doctrine and national grand strategy in order to keep up with the "right" kind of technical awareness. Ideally, members of the SI organization should participate in war games and exercises where the Navy tests new operational concepts and introduces virtual prototypes of future platforms and subsystems. Teaming in various forms can only help personnel and organizations develop a greater appreciation for mutual idiosyncrasies. A large part of customer understanding is the maintenance over time of inter-organizational relationships that transcend individuals and projects.

Unfortunately, "customer understanding" might reinforce institutional inertia and reify the status quo; in many ways, this is an analog to bureaucratic "capture" where the regulator sees things from the perspective of industry rather than the public interest. Yet, these dangers are best avoided not by creating firewalls or by artificially introducing change from the outside. Rather both the customer and the SI organization must self-consciously distinguish between customer understanding for the sake of overall success and close relationships for the sake of blocking change or protecting institutional interests. In short, the systems integrator must be free (and protected) to resolve trade off in ways that may harm short-term customer interests but guard the long-term health of the organization as a whole.

The need to make trade-offs and provide analyses of alternatives that threaten the existing programs and short-term plans of system of systems integrators' customers puts the organizations in a very delicate position. Individual services are wary of criticism and fear losing ground in budgetary competition with other services, just as individual

platform makers may resent the oversight that an independent systems integrator provides on particular projects even while understanding that the systems integration role is essential for maintaining the overall success of national defense investment. System of systems integrators' customers must trust that the systems integrator has the customers' true interests at heart.[41]

At the architecture systems integration level, transformation's biggest challenge is its requirement that the system of systems cross many organizational boundaries. This requirement is especially severe in the more expansive visions of transformation that emphasize network-centric warfare as a joint rather than a service vision, because the different communities within services have strong, independent identities, ideas about how wars should be fought, and priorities for setting schedules and allocating funding. Each service will try to influence the course of transformation – and to influence the definition of the system of systems by pushing preferred definitions of the systems integration trade space and by defending and funding particular programs that the overall systems integrator will then be forced to integrate into the network-centric force structure. Architecture systems integrators will have to understand and balance the conflicting motivations of the several customer organizations. Most organizations have great difficulty incorporating multiple goals into their organizational identity.[42] This

[41] This requirement is another reason that it is difficult for government agencies to perform systems integration in-house: subordinate project managers in the systems commands might not risk criticizing their bosses or their bosses' preferred programs. OTA, p. 5. Quasi-public FFRDCs face similar pressure not to criticize their customer too much, but their support and promotion prospects do not come in as direct a chain of command from the potential targets of their technical advice. The position of for-profit systems integration houses is similar to that of the FFRDCs: they perhaps are more responsive to short-term budget pressures from sponsoring organizations than FFRDCs are, but on the other hand they may have more independence to seek alternative customers if their relationship with a particular contracting command temporarily sours.

[42] James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It* (New York: Basic Books, Inc., 1989).

problem suggests that a shift to a truly joint systems approach as part of transformation may require establishment of a single, joint acquisition agency to which a single system of systems integrator could be attached. On the other hand, added organizational layers between system of systems integrators and their service customers who will actually operate military systems might degrade the level of customer understanding, reducing their effectiveness in the analysis of alternatives role, and adopting a single buyer for transformational systems might threaten the diversity of approaches that inter-service rivalry could otherwise provide.

Organizing for Systems Integration's Contribution to Transformation

Because transformation relies explicitly on intense interoperability, and ensuring that interoperability is one component of systems integration, transformation and systems integration have become tied together in a very public way. At this early stage of transformation, however, another component of system of systems integration is even more important: trade-off studies are needed to establish the objectives and requirements for the component systems that will be acquired as nodes and network elements.

Certain established systems integration houses like APL and the Mitre Corporation clearly have expertise that is closely related to the plans for Network-Centric Warfare, and those established organizations should play a major part in the network-centric defense sector along with any newly established FFRDC. Similarly, some of the production-oriented prime contractors have high-level systems integration groups that might join the nucleus of competitive SI suppliers—if the Navy encouraged them to spin off those independent SI organizations (including through the use of direct financial

incentives).[43] The bottom line is that the key step in preparing the defense industrial base for Network-Centric Warfare is not to try to change the cast of production firms in the defense sector but instead is to update and focus the technical emphasis of the Navy's acquisition community.

There is no reason to invite platform-making prime contractors into the systems integration sector as part of transformation. The primes want in, because they perceive that systems integration is "where the money is," at least in the short term, and they perceive it as the level of greatest responsibility in the future defense industry. Moreover, with political pressures building in support of transformation, and with systems that are not perceived as transformational vulnerable to cancellation (like the Army's Crusader self-propelled howitzer), prime contractors are looking for ways to link their activities to transformation. The logic for the primes is the same as it always has been: if a particular kind of acquisition reform is popular, your programs should be "demonstrators" of the new technique; if systems analysis and PERT charts are the way to show budget and schedule control, then your programs should use them; if network-centric warfare is the future operational concept, then your programs should emphasize their connectivity.

Acting as a systems integration agent might be the best protection of all for a prime contractor's business base. Production firms in the defense sector should be expected to complain about outside systems integration houses' role on particular projects, because the advisor's job includes raising awkward criticism of the prime

[43] For example, Lockheed Martin has a large systems integration group in Valley Forge, Pennsylvania, with specific expertise in satellites and intelligence collection. Lockheed Martin, of course, would need to keep some proprietary systems integration capability, even if it were clear that Navy did not plan to delegate high-level systems integration / technical decision-making to the production prime contractors. Each member of the production DIB would then have to make a business decision about what level of in-house funding to allot to SI, given that the main institutional home of that core competency would be outside the production industrial base.

contractors' technical approach and production skills. One way to avoid such criticism would be to make systems integration part of the prime's job. However, given the importance of independence for quality systems integration, and given that up-front technical advice and coordination will help to keep transformation programs on schedule and budget, production contractors should find it in their interest to support systems integration organizations (especially if paid for mostly from the military infrastructure budget rather than from specific projects' budgets).

On the other hand, no top-down metric that is developed for systems integration skill will be able to substitute for organizational competition. The consolidation of the defense industrial sector through mergers and the reduced post-cold war demand for long production runs has limited competition for production contracts; the overhead cost of maintaining multiple production lines for each weapon system is also unsustainable in the current defense budget environment. However, competition among technical advisory organizations—each with a different design philosophy or technical focus—is relatively inexpensive to sustain, and those dedicated systems integrators should be able to help monitor technical efficiency during the production phase of the acquisition process. Meanwhile, in competing for their shares of the technical advisory role during the upcoming military transformation, these organizations will monitor each other's performance, point out technical flaws in competitors' proposals, and help to solve the policy problems of deciding how and how much to invest in systems integration. Exploiting competition among dedicated systems integration organizations should be a

relatively low-cost response to the tension between budgetary pressure and the high resource demand of investing in military transformation.

In the end, however, the buck must stop somewhere. Competition among systems integration organizations may keep everyone honest and allow ideas to be triaged, but it cannot continue indefinitely. The military services must both be able to sort through competing claims and make final decisions. They must take particular care in the early stages of transformation, because fundamental decisions regarding systems architecture may commit them to a particular evolutionary path that can only be revisited at great cost and operational peril.

Major acquisition projects or groups of related projects often spawned new procurement and advisory organizations during the cold war. A new acquisition organization-systems integrator partnership might facilitate the transformation effort for the Navy after Next. Advocates of Network-Centric Warfare frequently note that the current acquisition system is organized on a platform-by-platform basis, which naturally de-emphasizes crucial network investment. The potential problem is very much akin to the barriers to investment in missile defense through traditional acquisition channels that led in the 1980s to the creation of the Strategic Defense Initiative Office, predecessor of the Ballistic Missile Defense Office (BMDO). The Navy should consider giving Network-Centric Warfare a similar home in a new acquisition organization that will develop a bureaucratic interest in acting as the budgetary advocate for transformation.[44]

The new organization could also take responsibility for supporting a new technical advisory organization that will develop expertise specifically in the network and

[44] On organizational, or bureaucratic, identity, see James Q. Wilson, *Bureaucracy: What Government Agencies Do and Why They Do It* (New York: Basic Books, Inc., 1989).

node requirements for the Navy after Next. This organization will, in all likelihood, borrow personnel and even intellectual capital (lessons learned databases, etc.) from existing systems integrators as well as develop new competencies necessary to handle the complexities of the network-centric environment. Any such new systems integrator would need an high level sponsor, a reasonable budget, insulation from the inevitable bureaucratic infighting, and, most of all, time to develop the trusted relationships and track record of success that characterize all SI houses. The political pressure behind transformation may not be able to wait for those conditions. In the case of the Reagan-era surge in funding for missile defenses, a new acquisition organization was organized, because the bureaucratic identities of the services' systems commands diverted their efforts from missile defenses into traditional systems; however, technical support for the missile defense systems' diverse components fundamentally relied on the same systems integration skills that were available from established organizations. As a result, the POET team, comprised of the established systems integration houses, successfully provided technical support.

In the current policy environment, the balance is tipping away from dedicated systems integration houses like FFRDCs and the technically skilled professional service corporations and towards prime contractors that build platforms. If the military services succeed in reversing that trend and creating a POET-like team for network-centric systems integration, perhaps that should be considered enough of a victory. It would provide at least minimal protection from scandal that might derail the trajectory of the information technology revolution in military affairs. Despite the questions that some have raised about whether the POET has optimized technical support for missile defense,

a POET-like team for network-centric warfare might well make important strides towards improving the technical future of the American way of war.