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OF THE

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Volume II: Defense Acquisition in Transition

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GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
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Preface and Acknowledgements

For the first time in recent memory, acquisition reform has emerged as a significant topic in Presidential discourse. While procurement surfaced occasionally as a second-tier issue in last fall's debates, its importance has increased considerably in the current economic crisis. The massive federal spending of recent months has highlighted the need for cost-savings elsewhere, and the President has announced acquisition reform as a priority of his Administration to help achieve those savings.

That our new President would use his "bully pulpit" to advance acquisition reform should be good news for the nation. Too often in the past, champions of reform have lacked the political standing necessary to bring about substantive and enduring change. If the President, with his own party in control of the Congress, is unable to successfully lead such an effort, we may rightfully despair that anyone can.

Of course, students of acquisition know only too well that such comprehensive change must be led by leaders who grasp and can address the complex interplay of interests and issues faced by the various institutions and organizations that make up the acquisition culture. Accordingly, the discourse of today's reform agenda must rise well above the "sound-bite" level of so-called "no-bid" contracts which seems to dominate the popular media. Rather, the reform agenda must reflect the experiences and judgments of the "best and the brightest" from government, industry, and academia, many of whom are convened at this Symposium. We sincerely hope that the Administration will be open to their voices.

Such "informed reform" is a primary goal of the Naval Postgraduate School's Acquisition Research Program (ARP). Established in 2003, the ARP provides leadership in innovation, creative problem solving and an on-going dialogue, contributing to the evolution of Department of Defense (DoD) acquisition strategies. The program continues to grow and mature with the number of projects, products, collaboration opportunities and faculty/graduate student participation continuing to increase substantially. Our goals remain the same as noted below:

- Position the ARP in a leadership role to continue to develop the body of knowledge in defense acquisition research
    - Over 300 published works since inception
    - Sponsoring an annual Acquisition Research Symposium, the first of which was held in May 2004, which draws the thought leaders of the DoD acquisition community.
- Establish acquisition research as an integral part of policy-making for DoD officials. Some processes informed by this research include:
    - Contract close out procedures;
    - The impact of spiral development in the acquisition process;
    - Cost estimating for new design Ballistic Missile Submarine
    - Termination liability clauses for Major Defense Acquisition Programs

- Contractual language and context to incorporate Open Architecture in weapons system contracts
  - All completed research is published in full text on the ARP website, www.acquisitionresearch.net, allowing ready access by any and all parties interested in the DoD acquisition process.

- Create a stream of relevant information concerning the performance of DoD Acquisition policies with viable recommendations for continuous process improvement.
  - The body of knowledge on the DoD acquisition process has been greatly increased.
  - Faculty researchers routinely give multiple presentations, in both national and international fora, featuring their research work—thereby increasing exposure to a broader audience. Typical audiences include the London School of Economics, the Federal Reserve and the International Procurement Conference.
  - With the launch of the ARP's International Journal of Defense Acquisition Management (IJDAM), the '"reach" of our products has increased substantially. In addition, the IJDAM provides another forum in which acquisition scholars might publish and recognize the globalization that is occurring in the defense industry.

- Prepare the DoD workforce to participate in the continued evolution of the defense acquisition process.
  - The ARP plays a major role in providing a DoD-relevant graduate education program to future DoD officials. Synergy between research conducted and course content delivered enhances both the teaching and learning processes.
  - The number of students engaged in focused acquisition research for their MBA project continues to grow dramatically. These students have the benefit of being able to immediately apply their newly acquired acquisition skills to real-world issues.

- Collaboration among universities, think tanks, industry and government in acquisition research.
  - Over 50 universities/think tanks participated in the 5th annual Acquisition Research Symposium as a result of a focused effort to create a Virtual University Consortium.
  - Emerging collaborative research efforts continue to bring new scholar and practitioner thought to the business issues facing the DoD as was demonstrated by the large response to our second Broad Area Announcement (BAA) in support of the OSD-sponsored acquisition research program. As we write this, our third BAA is being prepared for release.
  - The International Journal of Defense Acquisition is attracting scholars from the United Kingdom, Canada, Nigeria, Singapore, The Netherlands and Australia.

We gratefully acknowledge the ongoing support and leadership of our sponsors, whose foresight and vision have assured the continuing success of the Acquisition Research Program:

- Office of the Under Secretary of Defense (Acquisition, Technology & Logistics)
- Program Executive Officer SHIPS
- Commander, Naval Sea Systems Command
- Army Contracting Command, U.S. Army Materiel Command
- Program Manager, Airborne, Maritime and Fixed Station Joint Tactical Radio System
- Program Executive Officer Integrated Warfare Systems
- Office of the Assistant Secretary of the Air Force (Acquisition)
- Office of the Assistant Secretary of the Army (Acquisition, Logistics, & Technology)
- Office of Naval Air Systems Command PMA-290
- Office of the Deputy Assistant Secretary of the Air Force (Management Policy & Program Integration)
- Deputy Assistant Secretary of the Navy (Acquisition & Logistics Management)
- Director, Strategic Systems Programs Office
- Deputy Director, Acquisition Career Management, US Army

We also thank the Naval Postgraduate School Foundation and acknowledge its generous contributions in support of this Symposium.

James B. Greene, Jr.
Rear Admiral, US Navy (Ret.)

Keith F. Snider, PhD
Associate Professor

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The Acquisition Research Program Team

Rear Admiral James B. Greene, Jr. USN (Ret.)—Acquisition Chair, Naval Postgraduate School. RADM Greene develops, implements and oversees the Acquisition Research Program in the Graduate School of Business and Public Policy. He interfaces with DoD, industry and government leaders in acquisition, facilitates graduate student research and conducts guest lectures and seminars. Before serving at NPS, RADM Greene was an independent consultant focusing on Defense Industry business development strategy and execution (for both the public and private sectors), minimizing lifecycle costs through technology applications, alternative financing arrangements for capital-asset procurement, and “red-teaming” corporate proposals for major government procurements.

RADM Greene served as the Assistant Deputy Chief of Naval Operations (Logistics) in the Pentagon from 1991-1995. As Assistant Deputy, he provided oversight, direction and budget development for worldwide US Navy logistics operations. He facilitated depot maintenance, supply chain management, base/station management, environmental programs and logistic advice, and support to the Chief of Naval Operations. Some of his focuses during this time were leading Navy-wide efforts to digitize all technical data (and, therefore, reduce cycle-time) and to develop and implement strategy for procurement of eleven Sealift ships for the rapid deployment forces. He also served as the Senior Military Assistant to the Under Secretary of Defense (Acquisition) from 1987-1990; as such, he advised and counseled the Under Secretary in directing the DoD procurement process.

From 1984-1987, RADM Greene was the Project Manager for the AEGIS project. This was the DoD’s largest acquisition project, with an annual budget in excess of $5 billion/year. The project provided oversight and management of research, development, design, production, fleet introduction and full lifecycle support of the entire fleet of AEGIS cruisers, destroyers, and weapons systems through more than 2500 industry contracts. From 1980-1984, RADM Greene served as Director, Committee Liaison, Office of Legislative Affairs followed by a tour as the Executive Assistant, to the Assistant Secretary of the Navy (Shipbuilding and Logistics). From 1964-1980, RADM Greene served as a Surface Warfare Officer in various duties, culminating in Command-at-Sea. His assignments included numerous wartime deployments to Vietnam, as well as the Indian Ocean and the Persian Gulf.

RADM Greene received a BS in Electrical Engineering from Brown University in 1964; he earned an MS in Electrical Engineering and an MS in Business Administration from the Naval Postgraduate School in 1973.

RADM Greene received the **2009 Richard W. Hamming Annual Faculty Award for Achievement in Interdisciplinary Activities.** The selection is based on his work in leading and administering the Naval Postgraduate School's Acquisition Research Program.

Dr. Keith F. Snider—Associate Professor of Public Administration and Management in the Graduate School of Business & Public Policy at the Naval Postgraduate School in Monterey, California, where he teaches courses related to defense acquisition management. He also serves as Principal Investigator for the NPS Acquisition Research Program and as Chair of the Acquisition Academic Area.

Snider has a PhD in Public Administration and Public Affairs from Virginia Polytechnic Institute and State University, a Master of Science degree in Operations Research from the Naval Postgraduate School, and a Bachelor of Science degree from the United States Military Academy at West Point. He served as a field artillery officer in the US

Army for twenty years, retiring at the rank of Lieutenant Colonel. He is a former member of the Army Acquisition Corps and a graduate of the Program Manager's Course at the Defense Systems Management College.

Professor Snider's recent publications appear in *American Review of Public Administration*, *Administration and Society*, *Administrative Theory & Praxis*, *Journal of Public Procurement*, *Acquisition Review Quarterly*, and *Project Management Journal.*

Dr. Snider received the **2009 Richard W. Hamming Annual Faculty Award for Achievement in Interdisciplinary Activities.** The selection is based on his work in leading and administering the Naval Postgraduate School's Acquisition Research Program.

Karey L. Shaffer—Program Manager, General Dynamics Information Technology, supporting the Acquisition Research Program at the Graduate School of Business & Public Policy, Naval Postgraduate School. As PM, Shaffer is responsible for operations and publications in conjunction with the Acquisition Chair and the Principal Investigator. She has also catalyzed, organized and managed the Acquisition Research Symposiums hosted by NPS.

Shaffer served as an independent Project Manager and Marketing Consultant on various projects. Her experiences as such were focused on creating marketing materials, initiating web development, assembling technical teams, managing project lifecycles, processes and cost-savings strategies. As a Resource Specialist at Watson Wyatt Worldwide in Minneapolis, Shaffer developed and implemented template plans to address continuity and functionality in corporate documents; in this same position, she introduced process improvements to increase efficiency in presentation and proposal production in order to reduce the instances of corruption and loss of vital technical information.

Shaffer has also served as the Project Manager for Imagicast, Inc., and as the Operations Manager for the Montana World Trade Center. At Imagicast, she was asked to take over the project management of four failing pilots for Levi Strauss in the San Francisco office. Within four months, the pilots were released; the project lifecycle was shortened; and the production process was refined. In this latter capacity at the MWTC, Shaffer developed operating procedures, policies and processes in compliance with state and federal grant law. Concurrently, she managed $1.25 million in federal appropriations, developed budgeting systems and helped secure a $400,000 federal technology grant. As the Operations Manager, she also launched the MWTC's Conference site, managed various marketing conferences, and taught student practicum programs and seminars.

Shaffer holds an MBA from San Francisco State University and earned her BA in Business Administration (focus on International Business, Marketing and Management) from the University of Montana.

A special thanks to our editors Jeri Larsen, Jessica Moon, Breanne Grover and Adrianne Malan for all that they have done to make this publication a success, to David Wood, Tera Yoder, Jordy Boom and Ian White for production, web and graphic support, and to the staff at the Graduate School of Business & Public Policy for their administrative support. Our program success is directly related to the combined efforts of many.

7TH ANNUAL
ACQUISITION RESEARCH SYMPOSIUM

May 12 - 13, 2010

Monterey, California

Announcement and Call for Proposals

The Graduate School of Business & Public Policy at the Naval Postgraduate School announces the **7th Annual Acquisition Research Symposium** to be held **May 12-13, 2010 in Monterey, California.**

This symposium serves as a forum for the presentation of acquisition research and the exchange of ideas among scholars and practitioners of public-sector acquisition. We seek a diverse audience of influential attendees from academe, government, and industry who are well placed to shape and promote future research in acquisition.

The Symposium Program Committee solicits proposals for panels and/or papers from academicians, practitioners, students and others with interests in the study of acquisition. The following list of topics is provided to indicate the range of potential research areas of interest for this symposium: **acquisition and procurement policy, supply chain management, public budgeting and finance, cost management, project management, logistics management, engineering management, outsourcing, performance measurement, and organization studies.**

Proposals must be submitted by **November 6, 2009**. The Program Committee will make notifications of accepted proposals by **December 4, 2009**. Final papers must be submitted by **April 2, 2010**.

Proposals for papers should include an abstract along with identification, affiliation, contact information and short bio for the author(s). Proposals for papers plan for a 20 minute presentation. Proposals for panels (plan for 90 minute duration) should include the same information as above as well as a description of the panel subject and format, along with participants' names, qualifications and the specific contributions each participant will make to the panel.

Submit paper and panel proposals to www.researchsymposium.org .

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NPS BAA-09

BROAD AGENCY ANNOUNCEMENT
Acquisition Research Program
Open until 4:00 pm PDST 30 June 2009

Primary objective is to attract outstanding researchers and scholars to investigate topics of interest to the defense acquisition community. The program solicits innovative proposals for defense acquisition management and policy research to be conducted during fiscal year (FY) 2010 (1 Oct 2009 - 30 Sep 2010).

Defense acquisition management and policy research refers to investigations in all disciplines, fields, and domains that (1) are involved in the acquisition of products and/or services for national defense, or (2) could potentially be brought to bear to improve defense acquisition. It includes but is not limited to economics, finance, financial management, information systems, organization theory, operations management, human resources management, and marketing, as well as the "traditional" acquisition areas such as contracting, program/project management, logistics, and systems engineering management.

This program is targeted in particular to U.S. universities (including U.S. government schools of higher education) or other research institutions outside the Department of Defense.

The Government anticipates making multiple awards up to $120,000 each for a basic research period of twelve months. NPS plans to complete proposal evaluations and notify awardees in early September 2008. The actual date of grant award will depend on availability of funds and the capabilities of the grants office. Prior year awards occurred in the November – January timeframe. Awardees may request approval of pre-award costs (up to three months), or they may request adjustments in the grant period of performance.

Full Text can be found at

http://www.nps.edu/Research/WorkingWithNPS.html

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Thursday, May 14, 2009

Panel 11 - Lead Systems Integrators: Challenges and Prospects

Thursday, May 14, 2009	Panel 11 - Lead Systems Integrators: Challenges and Prospects
9:30 a.m. – 11:00 a.m.	**Chair: James E. Thomsen**, Principal Civilian Deputy, Assistant Secretary of the Navy (Research, Development & Acquisition) **Discussant: Lenn Vincent, RADM, USN, (Ret.)**, Industry Chair, Defense Acquisition University ***The Role of Lead System Integrator*** **Jacques Gansler, William Lucyshyn** and **Adam Spiers**, University of Maryland ***Organizing for a Complex World: The Way Ahead*** **David J. Berteau**, Senior Adviser and Director of the Defense-Industrial Initiatives Group, Center for Strategic and International Studies

Chair: Mr. James E. Thomsen is currently the Principal Civilian Deputy Assistant Secretary (RD&A). His responsibilities include leadership of the acquisition workforce and systems engineering.

Previously, Thomsen served as the Program Executive Officer for Littoral and Mine Warfare. As PEO LMW, he had lifecycle responsibility to design, produce, field, and support warfighting capability for the littoral battle space and for the Global War on Terrorism. Thomsen led seven program offices that comprised 224 programs—ranging from ACAT I through ACAT IV—and included several developmental programs that addressed urgent warfighting needs for OIF and OEF. In 2003, Thomsen was selected as the Executive Director for the Program Executive Office, Littoral and Mine Warfare where he executed the Navy's material acquisition programs for Integrated Undersea Surveillance, Naval EOD/JCREW, Naval Special Warfare, Mine Warfare Surface and Aviation, Unmanned Maritime Vehicles, Naval Anti-Terrorism/Force Protection Ashore and Afloat, and LCS Mission Modules for ASW, Mine Warfare, and ASUW.

Prior to this position, Thomsen was assigned as Head of the NAVSEA Dahlgren Division's Weapons Systems Department, directing over 550 scientists, engineers, technicians, and advancing key technical achievements in Naval Surface Weapons systems.

Thomsen was selected as a member of the Senior Executive Service (SES) in November 1998 and then named as Head, Coastal Warfare Systems Department. Here, he directed all of the Littoral Warfare RDT&E programs at Naval Surface Warfare Center (Panama City), which included 360 scientists, engineers, technicians, and military personnel.

Prior to November 1998, Thomsen served as Program Manager for Mine Warfare programs, for which he was awarded the NDIA Bronze Medal for his achievements in Mine Warfare; Senior Systems Engineer for the Shallow Water Mine Countermeasures program; Project Manager for the ACAT 1D Joint US/UK Surface Ship Torpedo Defense (SSTD) program, for which he received the Commanding Officer/Technical Director Award for special achievement in technical management; and Head, Torpedo

Defense Systems Development Branch. He also served as the System Integration Agent in Submarine Torpedo Defense Countermeasure programs for PMS 415.

In the early years of his 27-year career, he held engineering positions—including design engineer, test engineer, project engineer, and systems engineer for several undersea warfare programs at Carderock, Panama City, and NAVSEA Headquarters.

Thomsen received his Bachelor's degree in Ocean Engineering from Florida Atlantic University in 1981 and his Master of Science degree from Florida State University in 1986.

Discussant: Lenn Vincent is the Industry Chair at the Defense Acquisition University (DAU). He uses his Defense and Industry experience, expertise and perspective to advise the DAU management team, OSD, and the uniformed services on matters relative to contracting and program management issues. As a professor at DAU, he presents views to foster a more viable and effective defense acquisition management system. He serves on various DAU advisory councils and on its academic review committee. Additionally, he provides independent consulting services to a variety of industry clients relative to procurement, contract management, logistics and supply chain management.

As a Vice President at CACI International, Vincent was responsible for working with senior Department of Defense and Industry leaders to build long-term CACI relationships and to help identify solutions to acquisition, logistics, and financial management challenges. His strategic focus was an initiative to create an integrated digital environment that will extend the DoD's automated procurement system into industry and into the DoD program management offices, as well as into implementation and training strategies for new products and service.

As a Vice President at American Management Systems, he led a 130-member business unit responsible for the deployment and launch of government and industry procurement and contract management software solutions. His acquisition business solutions profit center was responsible for implementing the DoD's Standard Procurement System currently being used by over 23,000 procurement personnel and for launching a commercial contract management system for industry that was purchased by The Boeing Company.

Prior to entering civilian life, Vincent completed a distinguished career in the United States Navy, serving at both sea and ashore. He has over 30 years of broad-based and in-depth leadership and management experience in acquisition, supply chain management, logistics and financial management.

When he retired on August 1, 1999, at the rank of Rear Admiral, he was the Commandant, Defense Systems Management College (DSMC), where he led a graduate-level DoD College with a faculty and staff of 300 people and an annual budget of $25 million. While in this position, he began an overhaul of acquisition education to include reform principles and technology-based distance learning.

Prior to leading DSMC, Vincent had served as the Logistics, Ordnance and Fleet Supply Officer for Commander-in-Chief Pacific Fleet, where he established policy and coordinated logistics requirements to support supply chain operations in the Pacific Fleet and Indian Ocean.

Vincent was the Commander of the Defense Contracts Management Agency (DCMA), a diverse worldwide organization of 19,000 people responsible for administration and oversight of over 400,000 contracts valued at $800 billion. Concurrently, he also served as the senior acquisition executive responsible for procurement policy within the Defense Logistics Agency (DLA).

His afloat tours included Supply Officer on both USS Pensacola (LSD 38) And USS Dixon (AS 37). Some of his other shore-based assignments included: Assistant Commander for Contracts at the Naval Air Systems Command; Commander, Defense Contract Management Command International; Commander, Defense Contract Administration Services Region, Los Angeles; Director, Contracts

Director at Navy Inventory Control Point, Mechanicsburg; Contracting Officer, SUPSHIP Bath, Maine; and Director, Contracts Navy Supply Center, Puget Sound.

Vincent holds a Master's in Business Administration from George Washington University. He also is a Certified Navy Material and Acquisition Professional, and is DAWIA Level III certified in both Contracting and Logistics.

He is President-elect of the National Contract Management Association and serves on its Board of Directors and Board of Advisors. He also serves on the following: Board of Directors, Navy League National Capital Council; Board of Directors, NDIA Washington, DC Chapter; Board of Visitors, Defense Acquisition University; Board of Directors Procurement Round Table. He is also a member of AFCEA and AUSA.

Presenter: The Honorable Jacques S. Gansler, former Under Secretary of Defense for Acquisition, Technology, and Logistics, is a Professor and holds the Roger C. Lipitz Chair in Public Policy and Private Enterprise in the School of Public Policy at the University of Maryland. He is also the Director of both the Center for Public Policy and Private Enterprise and the Sloan Biotechnology Industry Center. As the third-ranking civilian at the Pentagon from 1997 to 2001, Gansler was responsible for all research and development, acquisition reform, logistics, advance technology, environmental security, defense industry, and numerous other security programs.

Before joining the Clinton Administration, Gansler held a variety of positions in government and the private sector, including Deputy Assistant Secretary of Defense (Material Acquisition), Assistant Director of Defense Research and Engineering (Electronics), Executive Vice President at TASC, Vice President of ITT, and engineering and management positions with Singer and Raytheon Corporations.

Throughout his career, Gansler has written, published, and taught on subjects related to his work. He recently served as the Chair of the Secretary of the Army's "Commission on Contracting and Program Management for Army Expeditionary Forces." He is also a member of the National Academy of Engineering and a Fellow of the National Academy of Public Administration. Additionally, he is the Glenn L. Martin Institute Fellow of Engineering at the A. James Clarke School of Engineering, an Affiliate Faculty member at the Robert H. Smith School of Business, and a Senior Fellow at the James MacGregor Burns Academy of Leadership (all at the University of Maryland). For 2003–2004, he served as Interim Dean of the School of Public Policy. For 2004–2006, Gansler served as the Vice President for Research at the University of Maryland.

Authors:

William Lucyshyn is the Director of Research and Senior Research Scholar at the Center for Public Policy and Private Enterprise in the School of Public Policy at the University of Maryland. In this position, he directs research on critical policy issues related to the increasingly complex problems associated with improving public sector management and operations, and how government works with private enterprise.

Current projects include modernizing government supply chain management, identifying government sourcing and acquisition best practices, and Department of Defense business modernization and transformation. Previously, Lucyshyn served as a program manager and the principal technical advisor to the Director of the Defense Advanced Research Projects Agency (DARPA) on the identification, selection, research, development, and prototype production of advanced technology projects.

Prior to joining DARPA, Mr. Lucyshyn completed a 25-year career in the US Air Force. Lucyshyn received his Bachelor Degree in Engineering Science from the City University of New York, and he earned his Master's Degree in Nuclear Engineering from the Air Force Institute of Technology. He has authored numerous reports, book chapters, and journal articles.

Adam Spiers is a Graduate Research Assistant at the Center for Public Policy and Private Enterprise in the School of Public Policy at the University of Maryland. In this position, he researches and writes draft versions of final reports on selected defense acquisition topics. He has coauthored "Using Spiral Development to Reduce Acquisition Cycle Times," published in September 2008 by the Naval Postgraduate School.

Spiers is currently pursuing a Master's in Public Policy, expected graduation May 2009. He graduated summa cum laude from the University of Maryland, College Park, with dual Bachelor of

Arts degrees in Economics and History. Spiers currently plans to further his education by pursuing either a doctorate or a law degree.

Executive Summary[1]

The Department of Defense (DoD) (as well as other government agencies) has used a strategy of contracting with a Lead System Integrator (LSI) when pursuing large System-of-System (SoS) acquisition programs. A SoS acquisition program involves the purposeful integration of individual weapon systems, along with other task-oriented assets, yielding a sum greater than the constituent parts. A SoS acquisition program will typically integrate legacy systems with new weapons platforms; in some cases, however, a SoS program will completely design and integrate a new set of systems.

A SoS is most likely to attain its potential benefits if a sole entity is responsible for managing the process. In order to properly manage the risks of a SoS development, a responsible agent is needed to coordinate and manage the complex effort, provide commonality across multiple weapons platforms and ensure a common vision for the program. Responsibilities can include systems engineering, architecture development, cost estimating, element selection, and SoS validation. This function is known as SoS integration. Believing that it did not have the organic managerial capability to oversee such monumental development tasks, the government has employed private contractors, which have come to be known as Lead System Integrators (LSIs), to manage the development of selected SoS programs. Due to difficulties faced by the Coast Guard's Deepwater SoS development, Congress prohibited the awarding of new LSI contracts, effective October 1, 2010, to firms that supply systems hardware for the SoS or perform an inherently governmental function (Congress, 2008). Despite this prohibition, the SoS integration functions performed by LSIs remain critical if the government wishes to pursue SoS engineering programs.

The impetus for SoS development has two foundations. First, the military has adopted a new fighting doctrine known as Net-centric Warfare (NCW). NCW attempts to leverage the advantage of information integration by distributed "sensors and shooters" to fight more effectively. NCW is characterized by complete battlefield awareness, self-synchronization of forces, and the overwhelming and precise application of force. This doctrine potentially reduces individual weapon system requirements but raises new issues such as communication system vulnerabilities. Second, many military assets are approaching the end of their originally intended lifespan and require replacement. This situation is a result of a lack of military development during the 1990s, combined with the increase in military requirements since the terrorist attacks of 9/11/01.

System-of-systems acquisition provides the crosslink between the DoD's change of military doctrine and its need to modernize its current forces. A SoS development provides the DoD with the unique ability to simultaneously field the full range of capabilities that it seeks in its next generation of military units. The integrated nature of the SoS, centered around an extensive communications network, lays the groundwork for complete implementation of NCW.

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[1] Research conducted at the Center of Public Policy and Private Enterprise at the University of Maryland's School of Public Policy. Research partially sponsored by a grant from the Naval Postgraduate School. The full report is available at www.acquisitionresearch.net .

System-of-Systems Engineering (SoSE) offers the military two significant potential benefits. First, SoSE enhances the value of the end product by purposely synthesizing the attributes of a group of units into something that is greater than the sum of the individual parts. Second, SoSE, by taking a holistic view of the project, has the potential to improve development decision-making by better valuing overall development tradeoffs. In a SoS framework, the SoS development output is maximized, as opposed to individual assets. In order to achieve optimal SoS performance within affordability constraints, SoSE requires development tradeoffs among the assets that comprise a given SoS.

SoSE differs from traditional engineering in significant ways. Traditional engineering seeks to optimize the performance of a single system, given specific end-requirements. SoSE attempts to develop a certain overall mission capability. SoS has two unique challenges not faced by traditional engineering. First, a SoS has a theoretically infinite lifespan as elements come and go in the SoS as it evolves. As long as the mission capability is supported, the SoS changes to continue to fulfill its role, even as the elements that constitute the SoS can be continuously replaced. Second, a SoS has undefined requirements, within cost, schedule and technology constraints. Without a specified end-point that encapsulates firm performance requirements, engineers have difficulty making explicit tradeoffs in functionality. Traditional engineering practices are not adequate to develop a truly integrated SoS.

DoD faces many challenges that may undermine effective SoS development. DoD-wide challenges include greatly broadened military requirements in response to the terrorist attacks of 9/11; impending budget constraints, stemming from the need to increase federal mandatory spending programs as the baby boom enters retirement; the inadequate capability and capacity of the current acquisition workforce to undertake SoS development programs due, in part, to human resource management decisions since the end of the Cold War; and the consolidation of the defense industry, which has significantly reduced competition and eliminated many independent systems engineering firms (primarily through acquisitions by the weapon systems producers). SoS-specific challenges include: an inconsistent understanding of the term SoSE by the acquisition workforce (including the role of cost in systems engineering analyses); the lack of a codified approach to SoSE, a function of the newness of the process; the interconnected nature of SoS development—which, if not handled properly, could lead to systemic failure, as disaster in one portion can have deleterious ripple effects throughout the entire SoS; ensuring adequate adaptability, so the SoS is flexible enough to meet future needs but provides enough stability to be a base for future design; the scale of development that necessitates the simultaneous development of a large number of assets, each of which would have traditionally been viewed as a major acquisition program; and, finally, budget instability, which is a constant challenge to DoD programs but which SoS development is particularly susceptible to.

The LSI, like a traditional prime contractor, must oversee technological maturity and subsystem development, as well as make decisions regarding tradeoffs within the context of the entire program. LSIs, however, have been given broad, government-like authority to execute acquisition programs that includes development of individual system requirements, contracting for their development and procurement, and coordination of development schedules and efforts. The degree of authority and responsibility given to an LSI, however, depends upon the program in question. Regardless of the authority the government delegates to the LSI, the government is still responsible for the program and must oversee the actions of the LSI and retain final decision authority.

Although the government could potentially perform the SoS integration function, its acquisition workforce lacks the numbers of personnel with the required skills that this effort requires. Consequently, the government chose to employ LSIs for its two largest SoS programs: the Coast Guard's Deepwater and the Army's Future Combat Systems.

Congress has defined two types of LSI contracts. An LSI with SoS system responsibility is a prime contractor that is primarily responsible for developing or producing the SoS, but which will subcontract much of the actual work. In this case, the LSI is responsible for the delivery of the completed, integrated system to the government. An LSI without SoS system responsibility is a prime contractor that is delegated government-like authority to perform what are typically considered inherently governmental functions. Although Congress has defined LSI in only two ways, the relationship that exists between the government and its chosen LSI can vary considerably, depending on how the contract is structured.

A principal fear stemming from use of an LSI is that the entity infringes upon inherently governmental functions. Critics warn that by awarding LSI contracts, the government avoids its primary responsibility without being able to provide adequate oversight of the LSI. Ultimately, they argue, the LSI has a strong incentive to take actions beneficial to the firm at the expense of the government's interests—e.g., regarding make/buy decisions on elements of the system and shaping the architecture around the firm's products. Proponents of LSI believe the fears of critics are either unfounded or can be addressed by proper government oversight.

This report examines two case studies of LSIs, the Coast Guard's Integrated Deepwater System Project (Deepwater) and the Army's Future Combat Systems (FCS), to illustrate the challenges and benefits of using LSI by the federal government. Both programs have faced significant development challenges, especially in adapting to new requirements arising from post-9/11 legislation.

The Integrated Deepwater System Program is the Coast Guard's effort to completely modernize its entire service. The program has faced many challenges, including an increase in required capabilities, acceleration of the program, and a natural disaster. Deepwater has experienced significant cost increases and schedule slippages that have led to the cancellation of several components. Due to these problems, the Coast Guard has taken over the role of LSI, although the Coast Guard still relies upon the original LSI for support of their program management.

The Future Combat Systems, an Army brigade-modernization program, has also experienced cost growth and schedule problems. In this instance, initial development problems were compounded by an acceleration of the delivery schedule and the need to deliver incremental improvements to soldiers in the field that were not previously planned. Although the program has experienced some challenges, these are, in general, not attributable to the use of an LSI.

These case studies have produced three key "lessons learned." First, although SoS integration is widely acknowledged as necessary to pursue SoS development, the presence of an LSI is not a cure-all. The military, lawmakers and industry must limit development programs based upon immature technologies in order to avoid these development problems. Second, while the government retained final authority rule over all important decisions, the Coast Guard and Army have been criticized for not exercising effective oversight of the LSI. Third, as presented by the FCS case study, it is important for military and industry to establish key shared-interests early in the development process. The benefit of establishing key shared-interests should be built upon, however, consideration of resource constraints.

The authors of the report arrived at the following findings:

1. The military is committed to SoS development.
2. SoS engineering and integration is a complex undertaking.
3. SoS development and integration is still a maturing discipline.
4. Government does not currently have capability or capacity to perform SoSE.
5. LSI programs have experienced technical difficulty for a variety of reasons.
6. Despite retaining final decision authority, the government has not consistently provided effective oversight of private LSIs.
7. The greatest concern regarding the use of LSI is the government's delegation of "inherently governmental functions."
8. A potential conflict-of-interests exists for private LSIs.
9. Unified leadership of the SoS integration affords the best chance of successful completion.

The authors of this report arrived at several conclusions:

1. The government should continue development of SoS programs that, if developed correctly, offer the potential for better value—more capability at equal or lower cost—to the military, than do individual procurements.
2. The government must effectively partner with the private sector to adequately perform the LSI function. To perform its responsibilities adequately:
    a. The DoD must provide better oversight and write contracts that are better defined.
    b. The DoD should accelerate its efforts to recruit, hire, and retain the required human capital required for program oversight (and, when required, program management) for the challenging SoS acquisitions.
    c. The government should enforce hardware and software exclusion provisions for system-of-system integration contracts.
3. Congress should modify the prohibition on the use of LSIs to permit either: (1) small-scale limited programs for LSIs or (2) large-scale programs for LSIs that are willing to take hardware and software exclusions. These pilot programs will help the DoD examine and evaluate strategies to fully leverage private-sector capacity while ensuring adequate government oversight and avoiding conflict-of-interest concerns.

References

Congress. (2008). *National Defense Authorization Act for Fiscal Year 2008* (H.R.1585 Sec. 802: Lead Systems Integrators). Retrieved from http://thomas.loc.gov/cgi-in/query/F?c110:7:./temp/~c110qDUaya:e661818

Panel 12 - Utilization of Award Fees, Incentives and Other Transaction Authority in DoD Contracting

Thursday, May 14, 2009	Panel 12 - Utilization of Award Fees, Incentives and Other Transaction Authority in DoD Contracting
9:30 a.m. – 11:00 a.m.	**Chair: Steve Kelman**, Weatherhead Professor of Public Management, John F. Kennedy School of Government ***Effect of Information and Decision-making on DoD Performance Incentives and Award Fees*** **Gregory Hildebrandt**, Naval Postgraduate School ***Incentive Arrangements for Space Acquisitions*** **James Gill**, Space & Missile Systems Center ***Injecting New Ideas and New Approaches in Defense Systems: Are "Other Transactions" an Answer*** **Richard Dunn**, University of Maryland

Chair: Dr. Steven Kelman is the Weatherhead Professor of Public Management at Harvard University's John F. Kennedy School of Government. A summa cum laude graduate of Harvard College, with a PhD in government from Harvard University, he is the author of many books and articles on the policymaking process and on improving the management of government organizations. His latest book, *Unleashing Change: A Study of Organizational Change in Government*, was published in 2005 by the Brookings Institution Press. His other books include a study on how to improve the government computer procurement process, entitled *Procurement and Public Management: The Fear of Discretion and the Quality of Government Performance* (AEI Press, 1990), and *Making Public Policy: A Hopeful View of American Government* (Basic Books, 1987). In 1996, he was elected a Fellow of the National Academy of Public Administration. In 2001, he received the Herbert Roback Memorial Award, the highest achievement award of the National Contract Management Association. In 2003, he was elected as a Director of The Procurement Roundtable, and he was inducted in 2007 into the Government Computer News Hall of Fame. He currently serves as editor of the *International Public Management Journal*, and he writes a regular column for *Federal Computer Week* and a blog at FCW.com.

From 1993 through 1997, Dr. Kelman served as Administrator of the Office of Federal Procurement Policy in the Office of Management and Budget. During his tenure as Administrator, he played a lead role in the Administration's "reinventing government" effort. He led Administration efforts in support of the *Federal Acquisition Streamlining Act of 1994* and the *Federal Acquisition Reform Act of 1995*.

Effect of Information and Decision-making on DoD Performance Incentives and Award Fees

Presenter: Greg Hildebrandt worked in the areas of procurement, military operations research and defense intelligence during his Air Force career. As an Air Force officer, he was also a Tenured Associate Professor of Economics at the Air Force Academy. One of his specializations in Air Force procurement was in the use of multiple-incentive contracts. He has been a Senior Economist at the RAND Corporation, focusing on Soviet-Military Economics and Cost Analysis, and an economics professor at the Naval Postgraduate School. He is a graduate of the Air Force Academy and holds an MS in Operations Research from USC and a PhD in Economics from Princeton.

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Abstract

This analysis discuses DoD policy for the use of Performance Incentives and Award-fee Contracts during System Development and Demonstration (SDD). Both a review of the use of Performance Incentive Contracts since the 1960s, as well as the current policy required by the DoD to develop performance incentives are provided. A performance incentive should be structured such that the contractor receives a profit for improved performance equal to the value to the government of the improved performance times the cost-sharing ratio. This formula will motivate a contractor to spend no more than the government's value to enhance performance. If exactly that amount is spent, the loss in profit resulting from increased cost will just equal the profit received from enhanced performance. This project also shows how a similar logic can be extended to Award-fee Contracts. The analysis examines alternative decision-making and informational structures to determine the effect on contract outcome when the performance incentives are structured in accordance with policy. In certain situations, more complex incentive structures may be required. However, the informational requirements to properly develop these more complex Incentive Contracts may be substantial.

Introduction

Recently, the General Accounting Office issued a report in which questions were raised about the role of profits in motivating defense contractors (2005). In fact, a RAND 1968 study was cited as evidence for this claim (Fisher, 1968). The GAO report emphasizes that Award Fee pools on a particular contract are "rolled-over" from one evaluation period to the next, which provides the contractor with additional opportunities to obtain higher awards. Typically, concludes the GAO, the final Award Fees that are received tend to be toward the high end of the possible range.

In light of this report, it is appropriate to review the history of incentive contracting to include both the use of objectively measurable performance characteristics and Award-fee

Contracts. We focus on the use of these contractual arrangements when costs are shared between the government and the contractor.

This area has not escaped the notice of the academic community, and recently, a number of economists have suggested that the efficiency of the defense procurement process could be enhanced by employing new developments from the economics of information. While these recommendations have not yet been embraced by the procurement policy community, they do represent another area in which economic analysis may contribute to the efficiency of the defense sector. The areas of particular interest to economists include incentive contracting, profit policy, source selection, and negotiation (for example, see Leitzel and Tirole (1993) and Bower and Dertouzos (1994)).

Incentive contracting has probably attracted the greatest attention. Incentive contracts are primarily employed for the development and production of weapons systems. In the situation in which there are only cost incentives in the contract, the defense contractor shares some proportion of the contract costs with the government. Contracts, however, may also include performance incentives in which the profit received by the contractor varies with the performance level of the equipment being developed or procured.

We begin with a brief discussion of the history of performance incentives from the standpoint of usage and policy, and relate these to the new developments in economic analysis. Then, we discuss the approach recommended by policy directives since the 1960s. Given this policy prescription, we show how predicted contract outcomes depend on the model used to describe contractor behavior.

We then turn to Award-fee Contracts and combine performance incentives with an Award Fee. Award-fee contracts are based on the subjective evaluation of the difficult-to-measure characteristic of contractor performance.

Performance Incentives in DoD Contracting and Economics

The government contracted for its first aircraft with the Wright Brothers in July 1909 at a target price of $25,000 and a target aircraft speed of 40 miles per hour. However, for every mile per hour over the target, the contractor would receive an additional $2,500; and for every mile per hour under the target, the contractor would lose $2,500. The minimum required speed under the contract was 36 miles per hour. The speed achieved by the aircraft was 42 miles per hour; therefore, a performance incentive award of $5,000 was received in addition to the target price of $25,000 (Cook et al., 1967, August, p. 1).

Interest in performance incentives, however, greatly increased during the 1960s. The *DoD Incentive Contracting Guide* in 1962 stated:

> Perhaps no other DOD procurement policy offers greater potential rewards than the expanded use of performance incentives in developmental contracts. Properly conceived and applied, these incentives can do more than any other factor to encourage maximum technological progress under a single contractual effort. (p. 30; Sherer, 1964, p. 172)

As a result of this guidance, contracts including performance incentives were widely used by the DoD during the 1960s and 1970s. Interestingly, procurement policy for performance incentives developed by the Department of Defense and NASA in the 1960s (and still in effect today) is based on the assumption of hidden knowledge possessed by the single contractor, not the government.

This example of adverse selection occurs because the contractor knows the non-stochastic relationship between performance, q, and contract cost at the time that trade-offs are made, say, between cost and reliability, but the government does not. In this situation, the reward received for enhanced performance, Δq, should equal the contractor's share of contract costs, s, times the value to the government of the enhanced performance.

There is a simple logic behind this performance reward. During the development process, the maximum the government is willing to let the contractor spend for enhanced performance is the value to the government of the extra performance. The government, therefore, is indifferent between such an expenditure and the extra performance achieved.

Similarly, under this performance-incentive function, if the cost of enhanced performance is less than the value of that performance to the government, the contractor's profit would rise; if the cost is greater than its value to the government, the contractor's profit would fall. The contractor, therefore, is motivated to make the trade-off decisions that are in the interests of the government, even though the government does not know the cost to the contractor of the performance enhancement. This approach was taught in DoD-sponsored procurement courses as early as 1964.[1]

In October 1969, the DoD/NASA *Incentive Contracting Guide* explained that the above method achieves two important objectives, “first, it communicates the Government's objectives to the contractor; second, of greater significance, **it establishes the contractor's profit in direct relationship to the value of combined performance in all areas**” (p. 107, emphasis in original).

As the DoD/NASA *Incentive Contracting Guide* has never been superseded, this policy remains in effect today.

During the 1970s, attention shifted to the determination of the optimal risk-sharing relationship between the contractor and the government. It has been established that when the performance-incentive function is determined in accordance with policy, and when the government doesn't know the cost relationship, the contractor's share of contract costs, s, is the parameter that determines the optimal risk-sharing relationship between the contractor and the government.[2]

However, the early discussions of optimal risk sharing focused on a situation in which there was only hidden knowledge, which has also been called subjective uncertainty. In such situations, the contractor is assumed to maximize accounting profit on the contract. The above analysis of risk sharing using the cost-sharing ratio during was also extended to the case of objective uncertainty, which occurs when there remains contractor uncertainty at the time the performance level is selected. In this situation, the contractor is assumed to maximize the expected utility of accounting profit. This is a different level of uncertainty than that implicit in

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[1] Case materials using this technique were developed by Harbridge House, Inc., in 1964.

[2] The risk-sharing problem as it relates to performance incentives was analyzed by Hildebrandt and Tyson (1979).

the policy implications of the DoD/NASA *Incentive Contracting Guide.* Objective uncertainty occurs when the there is cost uncertainty for the contractor (as well as the government) at the time the trade-off decisions are made.

The risk-sharing approach, however, raises an interesting issue. If, as many believe, the government is risk neutral while the contractor is risk averse, then under the assumptions of this analysis, it is optimal for the government to bear all the risk. The optimal sharing ratio, s, therefore, equals zero.

In the late 1970s and during the 1980s, economists addressed this issue by explicitly introducing the contractor's unobservable effort level into the objective function of the contractor. If the government is the principal, and the contractor is the agent, then the agent's economic profit is assumed to equal contractual profit less the implicit cost of effort. Typically, the contractor is assumed to be either risk neutral or risk averse, and maximizes expected economic profit in the former situation and expected utility in the latter.[3]

In addition, the contractor's effort was assumed to represent a hidden action that is not observed by the government, so that moral hazard is present. To address this problem, however, it is necessary for the government to know how this unobservable hidden action affects the contractor's economic profit. There are numerous other informational requirements, which, in total, may prevent this approach from becoming operational.

In fact, while there were extended discussions of the role factors such as effort and extra-contractual considerations play in such contractual relationships, during the late 1960s, the only method of addressing this informational issue was through the use of award-fee contracts. In award-fee contracts, the contractor receives fees that are, in part, based on a subjective assessment of "development efficiency." The term development efficiency represents the many factors that provide an incentive to the contractor not to maximize accounting profit. The term most frequently used is "effort," for which there is an implicit cost to the contractor that is not part of accounting profit, but which affects the contractor's decision-making, and therefore, must be taken into account by the government. These award-fee contracts have remained popular with NASA from the 1960s to the present and recently have been used extensively by the Department of Defense.

DoD Policy Prescription

We now turn to a discussion of the method of structuring an incentive contract with the performance incentives advocated by the DoD. To formalize the DoD prescription, let $B(q-q_T)$ equal the value to the government of the performance level developed relative to some target performance level, q_T; and let $C((q-q_T),\theta)$ equal the cost of performance to the contractor, where θ is an exogenous variable known to the contractor, but not the government, at the time q is selected. The variable θ, therefore, represents the hidden information dimension of the problem.

The objective of the government is to maximize, by choice of q, net social benefits:

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[3] One of the clearest summaries of the modern approach to incentive contracts is contained in Kreps (1990, pp. 577, 616). Extensive references to the modern approach to incentive contracting are also provided.

(1) Maximize $B(q-q_T) - C((q-q_T),\theta)$

The first order condition for this problem is:

(2) $B_q = C_q$,

where the subscript equals the variable with respect to the partial derivative of the function.

Let π_A equal the total accounting profit received by the contractor. This total equals target profit, π_T, plus the performance incentive function, $P(q-q_T)$, less the share of costs borne by the contractor, $s(C-C_T)$, where C_T equals target cost.

If the government sets $P(q-q_T)$ equal to $sB(q-q_T)$ as specified by procurement policy, then the contractor solves, by choice of q:

(3) Maximize $\pi_A = \pi_T + sB(q-q_T) - s[C((q-q_T), \theta) - C_T]$

Equation (2), the first order condition desired by the government, is satisfied when the contractor solves this problem; as a result, the objectives of the government and the contractor are both satisfied. It is quite interesting that in this profit-maximization formulation, the optimal q selected by the government does not depend on s, π_T, or C_T.

An important purpose of this analysis, however, is to consider objective functions that are more general than Equation (3), in order to determine the qualitative nature of the dependence of q on s, and π_T under the assumption that the performance incentive function, $P(q-q_T)$, is structured in accordance with policy.

First, we consider a situation in which unobserved contractor effort affects the contractor's economic profit. Next, we generalize Problem (3), augmented to include the implicit cost-of-effort function, to allow for contractor uncertainty at the time q is selected. For this situation, the contractor maximizes the expected utility of economic profit, and we consider both situations in which unobserved effort alternatively affects and does not affect expected utility. Finally, we give recognition to the fact that the government's program office has a significant amount of information about contractor effect. This information, which may only be available during or at the completion of a contract is used to structure a contract which combines performance incentives, cost sharing and an award fee. These contracts have been called Cost-plus-incentive-fee/Award-fee (CPIF/AF) contracts with multiple incentives.

Contractor Accounting, Cost Certainty and Implicit Cost of Effort

Following the economics of information revolution, economists now routinely assume that a contractor (agent) knows more about its own conditions of production and level of effort than does the government (principal).

While the asymmetric information assumption probably does not hold true nearly as widely as economists would have one believe, it does have great deal of merit when it comes to the myriad trade-off decisions that must be made during weapons system development. Cost-performance trade-offs must be made by design engineers on a day-to-day basis, and government contract administrators—even those who work at the contractor's facility—are unlikely to be familiar with these detailed trade-off opportunities that materialize during the contract. Therefore, it seems reasonable to assume that there is hidden information associated with the contract that is known to the contractor, but not the government. The contractor knows more about the nature of effort and the effect of effort on implicit cost than the government.

With respect to the effort level of contractors, however, the asymmetric information assumption may be false. The contract administrators and members of the program office staff may know as much, if not more, about the effort of contractors than members of the company's leadership. Awarding fees based on a subjective evaluation of the contractor's effort level is permitted in the policy directives, and we return to this issue below.

It is, however, true that is difficult for the government to both quantitatively measure effort and properly specify the relationship between effort and economic profit at the time the contract is awarded. Therefore, we first explore the implications of the assumption that economic profit depends on unobserved effort.

In the previous section, the variable θ represented exogenous factors affecting cost that are unknown to the government but are known to the contractor. In this section, we add the contractor's effort level, e, which generates an implicit cost to the contractor. This variable, like θ, is not observed by the government. Unlike θ, however, e is chosen by the contractor. The implicit cost of effort is represented by the function h(e), where $h_e > 0$. The implicit cost of effort, h(e) is subtracted from the accounting profit identified in Problem (3) to yield economic profit, π.

The effort level also affects the observable contract cost, so the cost function is now expressed as $C(q-q_T, \theta, e)$. We assume that $C_e < 0$, so that increased effort reduces contractor's cost; and C_{qe}. < 0, so that the marginal cost of performance decreases with increased effort.

The problem faced by the contractor is now to choose q and e to so as to solve the following problem:

(4) Maximize $\pi = \pi_T + sB(q-q_T) - s[C(q-q_T), \theta, e) - C_T] - h(e)$.

The first order conditions for this problem are:

(5) $B_q = C_q$, and

(6) $sC_e = h_e$.

While Equation (5) is the government's desired first-order condition with respect to q, the effort level selected would not be that desired by the government.

On the other hand, because h(e) is a social cost, this term should be subtracted from Problem (1), and the government's objective is for the contractor to select effort so that $C_e = h_e$: the marginal cost of increasing effort should equal the marginal implicit cost of effort. Because $C_e < 0$, this effectively states that the marginal benefits of effort should be equated to marginal implicit cost.

This suggests that when effort affects the contracts economic profit, it is no longer appropriate for decision-makers to structure the incentive in the manner stipulated simply by: $P(q-q_T) = sB(q-q_T)$. It is important, therefore, to be able to test whether contractor decision-making is affected by the disutility of effort.

It is clear from Equations (5) and (6) that the optimal q does not does not depend on π_T or C_T. However, the sharing rate, s, enters Equation (6), so we must determine how the optimal performance level q* depends on s. Setting the total derivatives of Equations (5) and (6) with respect to q*, e*, and s equal to zero, and solving for dq*/ds and de*/ds yields:

$$(7) \quad dq^*\Big/ds = \frac{C_{qe}C_e}{|H|} > 0$$

$$(8) \quad de^*/ds = \frac{C_e\left[B_{qq} - C_{qq}\right]}{|H|} > 0.$$

Because of the second-order conditions, the bordered Hessian, |H| is greater than zero under our assumption that $C_{qe} < 0$and C_e. < 0, dq* /ds > 0, as indicated by Equation (7). We can also derive the fact that de*/ds > 0 because the second-order conditions require that $B_{qq} - C_{qq} < 0$.

Therefore, when the performance-incentive function is specified in accordance with policy (and the unobserved effort results in contractor disutility), optimal performance, from the standpoint of the contractor, increases with the sharing rate. It may be suggestive to say that higher cost sharing by the contractor induces greater effort, which reduces the marginal cost of performance. Given the specified marginal benefit function, the performance level selected increases.

Contractor Accounting Cost Uncertainty and Implicit Cost of Effort

We turn now to an analysis of contractor decision-making under uncertainty. At the time the contractor picks q and e, a random variable y determines the level of cost that actually occurs. In other words, the contractor can select a performance and effort level with certainty, but the resources that must be applied to achieve the q selected with effort level e are uncertain.

The contractor's cost function becomes $C(q-q_T,\theta,e,y)$, where the random variable y has a known distribution. We assume $C_y > 0$ and $C_{qy} > 0$, so both total cost and the marginal cost of performance increase with the value of y that emerges, when the other arguments of the function are held constant.

It might be helpful to restate the meaning of "θ," "e," and "y." The variable, θ, represents exogenous factors that are known to the contractor but not the government (hidden information or subjective uncertainty); the variable, e, represents the effort level selected by the contractor but unobserved by the government (hidden action); and the variable, y, is a random variable representing the uncertain effect of q and e on contractor cost, given that "θ" is known to the contractor (objective uncertainty).

Also, while economic profit, π, continues to be defined in the manner described above, the contractor now maximizes the expected utility of economic profits, EU(π), where U is a von Neumann-Morgenstern utility function. The contractor, therefore, computes the expected value over the random variable y, and chooses q and e to solve:

(9) Maximize $W = EU\{\pi_T + sB\,(q\text{-}q_T) - s[C(q\text{-}q_T), \theta, y) - C_T] - h(e))\}$

For this problem, we obtain the following first-order conditions:

(10) $E\{U'\,(.)\,[sBq - sCq]\,\} = 0$

(11) $E\{U'(.)[-sCe - he]\} = 0$,

where U'(.) equal the partial derivative of U with respect to π. This partial derivative is evaluated at the optimal level of economic profit, π*. It is important to appreciate that everything inside the brackets, {}, is inside the expectation operator. We also use ( ) to represent the arguments of a function, and [ ] to contain terms that multiply other terms inside the expectation operator. From Problem (9), we see that π* depends directly on s, π_T, and C_T, which are parameters to the contractor but variables determined by the government.

Unfortunately, we have been unable to sign dq*/ds, or $dq^*/d\pi_T$, or dq^*/dC_T when the general Problem (9) applies. We can however, see from the objective function that $dq^*/dC_T = dq^*/d\pi_T$. A dollar of target profit and the contractor's share of target cost are perfect substitutes in the calculation of economic profit. To proceed further, we simplify Problem (9) by assuming that there is no implicit cost associated with effort—i.e., h(e) = 0.

Contractor Cost Uncertainty without Implicit Cost of Effort

The contractor's problem is to compute the expected value of utility over y and choose q to solve:

(12) Maximize $W = EU\{\pi_T + sB\,(q\text{-}q_T) - s[C(q\text{-}q_T), \theta, y) - C_T]\,)\}$,

yielding the single first-order condition:

(13) $E(U'(.)[sBq - sCq]\,) = 0$.

Equation (13) differs from Equation (10) because now economic profit does not depend on the effort of the contractor. With a single first-order condition, we can use the rule for taking the derivative of an implicit function to calculate the comparative statics derivatives:

(14a) $dq^*/ds = -Wqs/Wqq$

(14b) $dq^*/dC_T \quad = -\,W\pi_T/Wqq$

(14c) $dq^*/dC_T = -Wqc_T/Wqq$,

where the second-order condition ensures that Wqq < 0.

Tackling Equation (14a) first, we obtain

(15) $Wqs = E\{U'\,(.)[Bq - Cq]\,\} + E\{U''\,(.)\,[Bq - Cq][B - C + C_T]\}$

The first term on the right-hand side of Equation (15) equals zero because of the first-order condition. However, we are unable to sign the second term without making further assumptions.

Turning to Equation (14b), we obtain

(16) $W_{q\pi_T} = E\{U''(.)\quad[Bq - Cq]\}$.

To sign W_{qs_T}, we use Pratt' s absolute measure of risk aversion, r, where

(17) $r(.) = -U''(,)/U(,)$

Substituting for U"(.), using Equation (17) we obtain

(18) $W_{q\pi_T} = -E\{r(.)U'(.)\quad[Bq- Cq]\}$.

If r is constant, then Equation (18) reduces to the first-order condition and $W_{q\pi_T} = 0$, implying that $dq^*/d\pi_T = 0$.

Similarly,

(19) $W_{qc_T} = -sE\{r(.)U'(\bullet)\quad[Bq - Cq]\}$.

Under constant absolute risk aversion, $dq^*/dC_T = sdq^*/d\pi_T$. Otherwise, the sign of dq^*/dC_T is indeterminate.

Award Fees and Performance Incentives with Observable Effort

Thus far, we have focused on the implications of employing government policy when the objective function of contractors is more complex than the basic policy assumes. We have not presented the optimal incentive structures that might be employed in these situations. The optimal incentive structure has only been provided for the model in which the contractor maximizes contract profit, and at the time cost versus performance trade-offs are made, the contractor has no uncertainty associated with the nature of these trade-offs. The contractor is much better informed about these trade-offs than the members of the program office. We will continue to employ this model, which will be augmented with an Award-fee Incentive. Award-fee Incentives are based on a subjective evaluation of some aspect of the contractor’s behavior that it is difficult to measure. While we will continue to employ the term *effort*, the performance characteristic being evaluated should be viewed more broadly. For example, it might be some characteristic of the efficiency with which engineering development is conducted.

In this part of the analysis, we assume that contractors maximize economic profit, π, equal to accounting profit, π_A, minus the implicit cost (or disutility) of effort, h(e). Therefore, the contractor maximizes economic profit: $\pi = \pi_A - h(e)$.

We now assume that government personnel in the program office and those who work in the contractor’s plant possess a great deal of information about the contractor’s effort and the disutility of this effort. We assume, therefore, that the government has a firm understanding of the function, h(e), by the time the Award Fee is granted. Furthermore, we view these implicit costs as social costs that the government must take into account.

However, we continue to assume that there is an observation horizon below which the government does not have a great deal of information about the contractor’s behavior. For example, we continue to assume that detailed trade-off information available to the contractor’s engineers is not known.

In contrast to Equation (1), the government now selects q and the now-observable e to solve the following problem:

(20) Maximize $B(q\text{-}q_T)$- $C((q\text{-}q_{T,}\ e\ ),\theta) – h(e)$.

The government's first-order conditions for the Award-fee Contract follow:

(21a) $B_q = C_q$

(21b) $-C_e = h_e$

The contractor is given a performance incentive in the form $P(q - q_T)$, and the cost-sharing ratio equals s. In addition, the contractor is now given an Award Fee in the form A(e), where (as indicated) *effort* is measurable by the government. To maximize economic profit, the contractor selects q and e to solve the following problem:

(22) Max $\pi = \pi_T + P(q - q_T) – s(C\ (q\text{-}q_{T,}\ e\ ) - C_T) + A(e) – h(e)$,

and the following first-order conditions are obtained:

(23a) $P_q = sC_q$

(23b) $A_e – sC_e = h_e$

With respect to q, the same condition of contractor cost certainty at the time of cost-performance trade-offs that applies in the performance-incentive model continues to hold. Comparing Equations (21a) and (23a), we see that the performance incentive should be set so $sB_q = P_q$. Again, the extra reward for additional performance provided should equal the contractor's share of the benefits to the government from the additional performance. Then, the contractor will be motivated to spend no more than sB_q for the associated incremental improvement in performance. By spending this amount, the contractor will reduce economic profit by sC_q, and both the government and the contractor will break even. If expenditure less than this can achieve the additional performance, both the government and the contractor are better off.

If we compare Equations (21b) and (23b), we see that the following condition holds:

(24) $A_e = (1 – s)h_e$

The incremental award fee should equal the government's share of the incremental cost of effort. Equation (21b) shows that the contractor is compensated for the reduction in cost that results from additional effort. Therefore, the remaining compensation required is shown in Equation (24). One obtains the government's desired result shown in Equation (21b).

The achievement of this condition will not be affected by a change in the cost-sharing ratio. As this ratio changes, Equation (24) indicates that the structure of the Award Fee will change correspondingly.

Nor are any of the first-order conditions affected by π_T or C_T. The objectives of the government and the contractor are both achieved.

Comparative Statics Summary

It is helpful to summarize the summary of our findings for the various models addressed. Models A through F assume that the contract is structured based on existing policy, and Model F addresses a model that is employs both performance incentives and Award Fees.

MODEL	CONTRACTOR CHARACTERISTICS
A	Cost certainty during trade-offs and no implicit effort cost
B	Cost certainty and unobservable effort cost
C	Cost uncertainty and unobservable effort cost
D	Cost uncertainty and no implicit effort cost
E	Cost uncertainty, constant absolute risk aversion, and no implicit effort cost
F	Cost certainty during trade-offs and observable effort and effort cost

For these models, we examined the comparative static derivatives: dq^*/ds, $dq^*/d\pi_T$, dq^*/dC_T. The following table summarizes the findings:

MODEL/SIGNS	dq^*/ds	$dq^*/d\pi_T$	dq^*/C_T
A	0	0	0
B	+	0	0
C	?	?	? (= $sdq^*/d\pi_T$)
D	?	?	? (= $sdq^*/ d\pi_T$)
E	?	0	0
F	0	0	0

While many of the derivative signs remain ambiguous, several results are obtained. We turn now to the informational requirements associated with each of the models discussed.

Conclusions

This analysis has focused on the relationship between the DoD policy prescription in the use of performance incentives and the decision-making process of the government and contractor. The policy rule discussed above—that states that a performance incentive fee should equal the contractor's cost-sharing ratio times the value to the government of the enhanced performance—is applicable when cost uncertainty is eliminated at the time the contractor chooses the cost versus performance trade-offs and there is no implicit cost of effort (Model A). If there is an implicit cost associated with effort, and this contractor behavior is observed by the government, then an Award Fee can be structured that meets the objectives of the government (Model F).

Other informational situations may result in behavior that does not meet the government's objectives. While optimal incentive contracts can be constructed for these alternative situations (Models B through E), the information requirements may be quite demanding and the resulting incentive arrangements quite complex.

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Incentive Arrangements for Space Acquisitions

Presenter: James Gill

Executive Summary

Disclaimer: The views represented in this report are those of the author and do not reflect the official policy position of the US Air Force, the Department of Defense, or the Federal Government.

Space Systems acquisition has experienced a paradigm shift in its approach toward the use of contract incentives. This shift in the use of incentives is a matter of tremendous importance to those who develop and buy major Space Systems, but, more importantly, to the industry partners that deal with the Space & Missile Systems Center. This shift began under the Bush Administration and, based upon initial signs, may accelerate under the Obama Administration.

What are some of these changes, and what will be the impact of revising the government's business strategy? In order to get some perspective on the reasons for the changes, it is necessary to understand the history of the use of incentives in the acquisition of major systems by the DoD.

How does the DoD incentivize contractors to perform this important job? What do they use to motivate performance, and how do they monitor that performance to ensure that this fee is truly earned?

In the acquisition business, we face these questions on almost a daily basis. We get them from the media. We get them from the Congress. We get them from the senior leadership within the Executive Branch, right up to and including the President of the United States.

Why can't we get answers to these questions? To some degree, it is because incentives are a part of human nature, and their effectiveness is somewhat relative. We use them in daily life to varying degrees of success. Would your son or daughter do their homework every night if you provided no incentive? What form of incentive works more effectively: positive or negative? How do we know? Some would work, some would not. It seems intuitive that people respond to stimuli, both in positive and negative forms.

If that is the case, then why is there even a question as to whether incentives motivate performance? Perhaps the more important question goes to the effectiveness of the incentive applied. If we read the GAO Report entitled *DOD Has Paid Billions in Award and Incentive Fees Regardless of Acquisition Outcomes* (2005, December), the GAO does not believe the Department of Defense uses incentive arrangements very effectively.

The discussion must depend upon the definition of effectiveness. There is a difference as to the relative importance of cost, schedule and technical elements of incentive arrangements to those assessing the performance of the Program Offices that are responsible for the acquisition of these systems. Program Managers have tended to view technical performance and mission success as the more important criteria, while Congress looks at cost and schedule for validation on a program's success or failure. On the other hand, the user wants it when he needs it and wants it to work.

The beauty of the DoD acquisition process is both in its simplicity and its complexity. The President has articulated his vision of the federal contracting process and has stated his goals, which are consistent with the regulatory directions found in the *Federal Acquisition Regulation*. There should be a preference for fixed-price contracts; cost overruns are never a good thing, and profit should be tied in some manner to successful outcomes.

The simplicity of those thoughts articulated in his Executive Order (2009) becomes complicated in their application to major defense programs—especially major space systems development, which has enormous complexity and technical challenges. Many of these systems require pushing the state-of-the-art well beyond previous capabilities and into areas that have not been attempted in the past.

Why has this issue become so important? To some extent, it has always been a matter of pressing urgency, but recent economic circumstances have made our ability to get more "bang for the buck" a national emergency. One way to add to the capabilities of the warfighters, while reducing the dollars required supporting them, is to more effectively manage the money expended in the procurement of major systems. This may be accomplished through a more effective use of incentive techniques.

The GAO Report (2005, December) focused attention on the problems that the DoD has had in using award and incentive fees in the development and production of major systems. It was highly critical of the use of award and incentive arrangements and recommended a number of changes to the use of award-fee contracts.

This Report was followed by a number of policy directives issued from the OSD, the Secretary of the Air Force, Major Air Force Commands and respective Buying Organizations and Program Offices. This article will focus on the impact that the GAO 2005 Report has had on the way that the Air Force, and most specifically, the Space & Missile Systems Center, has addressed contracting concerns.

After receiving direction to implement several of the recommendations of the GAO Report from AT&L and SAF, the PEO for Space (General Hamel) issued a policy directive implementing a series of changes and mandating the development of an Incentives Guide. A follow-on initiative by the SMC Commander was that a course on incentives would be created to train the SMC workforce on the theory of Incentive Contracting.

In the Air Force, there had been a preference for the use of award-fee contracts for a period of 15-20 years. Acquisition Plans would not be approved without the use of award fee as the primary incentive arrangement. This dependency upon award fee was predicated upon two basic theories: first, that fee has a significant ability to influence performance on the part of a contractor, and second, that award fee can be used to leverage performance immediately. The decision of the Fee Determining Official was not initially deemed to be subject to the "Disputes" remedies, so it gave significant leverage to the Program Manager, as Fee Determining Official, over the behavior and performance of the contractor.

Why was this so important? Well, in conjunction with the normal budgetary turbulence associated with the acquisition of a program worth billions of dollars, the era of acquisition reform had turned over responsibility for development to the contractors, often through the use of an approach known as Total System Performance (or Program) Responsibility (TSPR). TSPR was a natural outgrowth of several factors, not the least of which was the "Peace Dividend" and the resultant reduction in the DoD workforce. In order to save dollars, the concept of TSPR allowed the government to eliminate many of the positions that were linked to the "Oversight" of contractor performance. It also eliminated the need for many of the "overly demanding" specifications and standards that industry had suggested for many years were not necessary and were overly burdensome.

The concept of "Insight not Oversight" was a mantra that was repeated almost as a solution to all of the problems that were associated with the development of major DoD systems. Unfortunately, it became apparent that without this oversight, many of the processes that had contributed to the technical successes were no longer utilized. The initial reports on systems such as SBIRS were overly optimistic and did not recognize the problems that were being experienced until hundreds of millions of overrun dollars had been incurred.

The incentive structure (award fee) was designed to give the government the opportunity to monitor performance and to provide direction, especially to those programs experiencing cost, schedule and technical problems. The Award Fee Review Board would evaluate performance against the Award Fee Plan and distribute each award fee based upon the contractor's performance. The GAO Report (2005, December) indicated that this approach did not always result in successful acquisition outcomes as anticipated.

Accordingly, under a "Back to the Basics" approach, there has been a move away from the CPAF paradigm. The shift in approach has taken SMC to a slightly different strategy. There is now an emphasis upon ensuring successful outcomes though the use of more mission-success initiatives and of more objective criteria both in CPIF arrangements and when appropriate, within the Award Fee itself.

To facilitate this shift, the Incentive Guide was published March 2007, and the first Incentives course was held in November 2008. The basics of incentive contracting has not changed; the emphasis on utilizing the correct strategy for each acquisition is now a mandatory requirement for all Acquisition Strategy Plans. Leadership now requires a cogent use of a number of incentive techniques when managers are formulating the strategy for the development of major systems. File documentation reflects the degree of analysis that was used in formulating the incentives approach.

So what is the change? The change will most likely be one of emphasis. This emphasis has manifested itself in several ways, the first of which highlights the nature of the relationship between the government and the contractor. Since the onset of the Acquisition Reform period, the concept of teaming has been the norm. The Integrated Program Team demonstrates the concept as a practice, with the members of the team working toward a common end: delivery of the system.

The focus on Incentive arrangements is now one of accountability and outcome-based arrangements. How will this translate into contract language? It is likely there will be a shift in the payment of incentives; they may become more back-loaded, giving the government the opportunity to see what the outcome will be prior to payment of much of the fee. A second possibility would be a form of payback in which fee already paid will be tied to the eventual successful demonstration of the program. This approach has been used in the past, most notably by NASA to varying degrees of success. It does cause some accounting issues for contractors in the manner in which they are able to book profit.

Other areas that are under consideration include the use of negative incentives. These may be used to offset positive incentives such as on-orbit satellite incentives. We have used these in the past, and the results have been mixed. Most of the satellite systems have exceeded their life expectancy, but that begs the question as to how reasonable were the initial requirements against which the incentives were based?

The most apparent consequence of the shift in policy is that there will be some difficulty in getting approval for the use of CPAF-type arrangements with subjective criteria. This, in itself, is not a bad thing. It is reasonable to challenge any approach that does not use a firm-fixed-price type of contract. The *FAR* requires it. In the arena of major space systems, there can be a broad spectrum of contract types and incentives that should be considered before deciding upon a specific type.

These include the cost-plus-award-fee type of contract. It may certainly be reasonable to advocate this type of arrangement for the development of high-risk/ high-reward type of programs. The supporting rationale should stand up to close scrutiny by reviewing bodies. In some cases, we have been able to find more objective criteria that can be used to show that performance has been accomplished; such data contribute to supporting the desire for outcome-based incentive expectations.

There has also been a shift in the approach to the development process in two ways: first, a return to the basics—including a more vibrant systems engineering process, a more diligent cost-estimating approach and more oversight on the contractor. In conjunction with these changes, we will be tying the earning of fee to cost, schedule and performance criteria, in part through a more robust earned value system. One fault in the acquisition reform process is the lack of visibility into performance that had been available to the government through the Cost Schedule Control System Criteria

(CSCSC) prior to the reform period. Earned Value is a high-emphasis program for tracking contractor performance, and incentives may be tied more closely to this system in the future. The caveat to this approach is the potential for gaming by the contractor, a fix for which could be the payback mentioned earlier.

Another initiative that has been implemented is the use of Block upgrades. This is a form of evolutionary acquisition in which higher-risk technology is not incorporated into the system until it has been demonstrated through the use of risk-reduction efforts phased into the system in later iterations. This may impact incentives, as it should reduce the program risk from a technical standpoint and allow for better cost and schedule predictability. This reduced risk should allow for a high confidence in predicting contract parameters and may allow for different incentive structures.

So what else lies ahead for contract incentives? It seems likely that more accountability will be incorporated into new incentive arrangements. There will be some pressure to use more fixed-price arrangements. The use of negative incentives will be more prevalent. Consistent with recent legislation, there will be a push to define what constitutes minimum performance against which no fee will be earned. If award fee is used, objective criteria should be developed. Performance-based work statements should help define the criteria against which fee may be evaluated and paid.

This brings about a question as to incentives for a service-type activity. There has been a great deal written concerning the appropriate use of incentives (most notably contract type) for major systems. There has been less written with regard to the use of incentives for service-type effort. Space systems have historically been oriented toward supply type of deliverable end-items. We launched space vehicles that were delivered as hardware (Atlas, Titan, and Delta) and accepted delivery of these rockets. Now, we are launching via service-type contracts, buying a delivery of a satellite into an orbit.

As the DoD shifts from supplies to services, it becomes even more important to define incentives for these services. We have found that future business opportunities are at least as important as fee to these types of arrangements.

But the key question is how will the new Administration put its stamp on the incentives process? As the new leadership assumes its role, we are certain to find out more, but it is safe to bet that there will be some change in the near future. The fundamental philosophy will remain the same: a quality product, delivered on time, for a reasonable profit. The devil will be in the details.

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Injecting New Ideas and New Approaches in Defense Systems: Are "Other Transactions" an Answer?

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Abstract

"Other Transactions" (OT) Authority permits a form of contracting for research, development and conducting prototype projects which is an alternative to military contracting under the Defense Acquisition Regulations and related statutes and regulations. This research shows that OT contracting can produce results better, more cheaply and more quickly than contracting under FAR. Moreover OT contracting has proved to be attractive to commercial firms that traditionally have spurned DoD R&D business and it has the potential to greatly expand the industrial base available to DoD. OT contracting has been limited by a number of factors. DoD acquisition personnel are generally poorly equipped to engage in free form OT contracting. OTs have also been restricted by a broad misperception of their potential and risks involved. There has been a tendency to restrict OTs to a niche role and to impose restrictions by regulation and statute. DoD could benefit greatly by expanding its use of OTs and recognizing them as an equal alternative to traditional contracting.

Introduction

Depending on who is doing the looking, a view of today's defense acquisition landscape might engender a variety of reactions. Some like Dr. Pangloss in Voltaire's *Candide* might see a system that, despite some imperfections, is the "best of all possible worlds." Others might see a cumbersome, arcane, virtually irrational system and ask "why?" Yet others foresee that with strong leadership, changes in culture, a "can-do attitude," and relatively minor changes in laws and regulations, a much improved system could be established. They ask "why not?"

The "best of all possible worlds" view asserts that the defense acquisition system has resulted in the United States military operating world-class weapons systems in virtually every category. How can you argue with that, they challenge. The counter argument is that defense systems cost too much, take too long, and though technically sophisticated, often do not actually meet the needs of the current operating environment. Moreover, US adversaries access commercially available technologies and incorporate them into makeshift weapons, and we are hard pressed to keep up with rapidly changing threat environments. In the “why not” category is the argument that the US knows the weaknesses of the defense acquisition system. The weaknesses have been repeatedly studied over the decades, and they have resisted numerous reform attempts. It is clear that leadership and vision, culture change, getting rid of the deadwood (both unnecessary regulation and business as usual “just say no” personnel), and learning and incorporating the skills needed in the globalized, commercial market-place are the essentials to creating an acquisition system that meets 21st Century needs.

This research explores whether an alternative method of contracting available to the DoD (“Other Transactions”) can be instrumental in answering why not have a rational acquisition system that leads to culture change and accesses a globalized, commercial market in order to satisfy defense needs. Can “other transactions” attract commercial companies (“non-traditional contractors”) to participate in defense programs either on their own or in collaboration with traditional defense contractors? What are the obstacles to achieving that result? Will achieving that result solve significant problems of the defense acquisition process? Are there additional benefits from “other transactions” such as integrating the innovation of commercial firms with the experience of defense primes in major systems acquisitions?

Today’s Challenges: Innovation and the Rapid Transition of Technology to Defense Capabilities

The Response to the Current Threat Environment

In the first decade of the 21st Century, the USS Cole was attacked in a foreign port; the United States was attacked on its own soil and was engaged in hot wars that evolved into counter-insurgency/nation-building operations in Afghanistan and Iraq and responded to a variety of other contingencies. The national security challenges of the period looked very different than those America faced in the Cold War or early post-Cold War period. The force structure, training and equipping of the US military all had to change to meet these new conditions.

The acquisition system was challenged by several new trends. One was the increased presence of civilian contractors going in “harm’s way” to provide essential support to deployed military forces. Another was the prevalence of rapidly developing so-called asymmetrical threats. In Iraq, insurgents accessed readily available abandoned or imported munitions and combined with commercially available technologies created improvised explosive devices (IED). IEDs became characteristic of the conflict in Iraq, inflicting many American casualties and wrecking unarmored or lightly armored vehicles. A variety of suicide bombing techniques required new ways to ensure the security of military personnel and installations. The possibility of cyber-attacks on increasingly net-centric operations constantly looms as a potential catastrophic threat. Challenges such as understanding “human terrain” and battlefield forensics require skill sets and technology that may not be the strong suit of either military or defense industry professionals.

How did the Department of Defense acquisition system react to these new challenges? It inched away from business-as-usual and extemporized. The IED threat was met by the creation of Joint IED Defeat Organization and a Joint IED Defeat Fund (more than $4 billion in FY 2008). In addition to organizations previously established to rapidly demonstrate and transition new capabilities (e.g., Advanced Concept Technology Demonstrations and Joint Technology Demonstrations within USD for AT&L), new offices, projects and funding lines outside the traditional acquisition process proliferated. A number of these were created within the Office of the Secretary of Defense (OSD), while others were created within the Military Departments. Within OSD, one of these was the Rapid Reaction Technology Office. The military services had funding elements (and corresponding program offices) titled Rapid Equipping Soldier Support (Army), Rapid Technology Transition (Navy), and Warfighter Rapid Acquisition Program (Air Force). By some counts there were two dozen of these "rapid" or "agile" acquisition or transition programs. One term applied to these offices and programs ("Heinz 57") suggested there were even more than that. In addition, alternatives to the main requirements process were created (e.g., Joint Urgent Operational Needs process and Joint Rapid Acquisition Cell) and budgeting alternatives (e.g., JIEDDO transfer account) were created.

It is not the purpose of this research to assess the effectiveness of the numerous rapid/agile acquisition programs that exist as partial alternatives to the formal acquisition system. The continued existence of these organizations once supplemental war funding and immediate threats in Iraq and Afghanistan diminish is uncertain. The mere existence of so many alternative programs is evidence that the traditional system is not deemed to be either rapid or agile or able to meet critical needs of troops in combat.

Globalization and the Commercial World

Some argue that the western world is in a post-industrial era, an information age. Whether that is a proper characterization or not, it is clear that even in what were once called third-world countries industrialization and information technology are proceeding apace. Thomas Friedman (2005) pointed out that we are living in an increasingly "flat" world. Internet access and other forms of communication technologies are on the increase. Even adversaries in remote regions can make use of modern technology.

US adversaries not only have access to information and communications technology. They also have access via the commercial market place to products that can become asymmetrical military threats. In the fight against IEDs, it was found that some devices incorporating simple garage-door opener technology could be adapted to detonate explosives. Once simple threats were countered, US adversaries accessed more sophisticated technology. Even unmanned aerial vehicles can be purchased commercially.

Commercial technology is not only a threat but it is an opportunity. Industrial research and development involves billions of dollars of investments. Much of it is relevant to defense systems. Civil-military integration policy exists in law (*USC*, 1988). It is one of those policies more often honored in the breach than in the observance. The contracting regulations state a preference for commercial products and non-developmental items.[1] However, when it comes to integrating commercial technologies and systems into weapons systems, the DoD has generally done a poor job (Defense Science Board, 2009, pp. 9-14). "Commercial" in this sense implies the products and technologies of commercial industry in the general industrial base and global economy—in contrast to products developed by the defense industry under government imposed regulations, standards and processes.

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[1] *Federal Acquisition Regulation* or *FAR* (Title 18 Code of Federal Regulations) 12.101(b), policy for acquiring major weapons systems as commercial items (requires a SECDEF determination) is found at *DFARS* 234.7002.

The Government Accountability Office has pointed out that the DoD has an opportunity to improve its processes of transitioning technology into fielded systems and capabilities by learning from the best practices of commercial industry (GAO, 1999). Again, “commercial industry” is the broader industrial base (unconstrained by government imposed procurement regulations and processes). Commercial industry tends to launch new products only when they embody relatively mature technologies. Cycle-times between improved versions of products are relatively short, often a few years or even months compared to DoD cycle-times of several years.[2]

Innovation

The evolving nature of national security threats and challenges combined with globalization and commercialization of high technology products and services means merely being good at what the DoD has been good at in the past is no longer good enough. If, like Dr. Pangloss, the DoD is comfortable with the acquisition world as it is, it will surely end up between a rock and hard place. One aspect of the problem is dealing with an uncertain future in which the nature of threats cannot be forecast in advance and in which threats change quickly. This requires not only a rapid acquisition process but one where innovation (including innovations in products and capabilities not traditional to DoD) takes place. This need for a vibrant “innovation cycle” should make the fast cycle-times of commercial industry as well as that industry’s huge investments in research and development very attractive to the DoD. Unfortunately, so far the DoD has not implemented a truly effective strategy to emulate the commercial sector nor to leverage its investments through mutually beneficial collaboration. Secretary of Defense Gates has articulated the need to be “more innovative” and “bold” in meeting emerging threats but the challenge to actually do it is daunting (Erwin, 2008).

The System for Acquiring Defense Capabilities

“Big A” and “Little A” Acquisition

It is common in speaking of the defense acquisition process to distinguish “Big A” acquisition from “Little A” acquisition. The big acquisition process encompasses (1) requirements generation primarily exemplified by the Joint Capabilities Integration and Development System (JCIDS) in the formal process; (2) the budget planning and oversight process under the Planning, Programming and Budget Execution (PPBE) process; and (3) the contracting process under *DoD Instruction 5000.2* and the *Federal Acquisition Regulation*. The third area is “acquisition” in the narrow sense (Little A) a primary focus of which is the actual process of buying goods and services (procurement) but also includes testing and other functions. Describing the acquisition system as divided between “Big A” and “Little A” may have value but there are many inter-dependencies between processes that fall within one part of the

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[2] It has been argued (by the Packard Commission among others) that the DoD’s unreasonably long acquisition cycle is a central problem leading to many other problems (Ward & Quaid, 2006, p. 14). The same article points out that the automotive industry reduced its average development cycle-times from nearly eight years to less than two years in the thirty years before the turn of the century. During the same period DoD development cycle-times rose from as low as five to six years (Air Force and Navy) to eight to ten years for all services (p. 16).

system and another. Thus, while this research focuses on a contracting method ("other transactions"), it should be kept in mind that contracting techniques affect, and are affected by, requirements processes and budget processes.

The Defense Industry

Before World War II, the defense industry was relatively small. The government had its own arsenals and shipyards dedicated to developing and producing weapons. Industrial firms also supplied many of the military's needs, but few of them relied solely or primarily on the military as their principal market. During World War II, major industrial firms were mobilized to supply the weapons needed by the military. After the war, most of the firms that had been converted to defense production returned to their former lines of business. As the post-war period chilled into a Cold War, a specialized defense industry began to emerge. It supplied the high tech weaponry and technology that was then unique to the military–jet engines, nuclear materials, sophisticated electronics, advanced materials, and radar, for example.

Today, few areas of high technology are unique to the military, and the non-military commercial sector invests in research and development and introduces or upgrades innovative products rapidly. A comparison of DoD research and development contract awards as reported in *Federal Contract Reports* (and other sources) with industry segment leaders (as identified in *Fortune* magazine) shows that top firms receiving DoD RDT&E awards are not leaders in any industry segment except defense and aerospace. Moreover, leaders in high-tech industry sectors other than defense and aerospace receive little if any DoD RDT&E funding. They do, however, make major investments in R&D. This and other evidence shows that the defense industry is segregated from the broader national industrial base (Spreng, 2008).[3] This segregation is not based on specialized technology needs of the defense industrial base but on government-unique business practices imposed on defense companies via the DoD acquisition system. This is the reason why the decline in defense spending at the end of the Cold War resulted in a consolidation of the defense industry. Defense companies were generally not in a position to diversify into commercial markets because they were burdened with government-imposed business practices that made them non-competitive in the commercial marketplace (Gansler, 1995, pp. 23-24; Daly, 1994).

The DoD recognizes the value of dealing with a broader industrial base and often tries to take advantage of existing commercial systems or emerging commercial technologies that can be adapted to defense purposes. However, in doing so, the DoD often requires the commercial supplier to partner, typically in the subordinate position of subcontractor, with a traditional defense contractor familiar with DoD contracting procedures. This approach has resulted in some recent high profile failures that have been studied and documented by the Defense Science Board (Defense Science Board, 2009). DoD's imposition of government-unique requirements has been demonstrated to add to program costs, while the utility (benefit

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[3] Robert Spreng (former President, Integrated Dual-use Commercial Companies) has conducted and published the results of many similar comparisons and other related research since the 1990s. See for example, Spreng, R. (1995, February). Commercial firms are conspicuously absent from top defense contractors. *National Defense*, p. 3.

compared to cost) of many government-unique business practices are open to question.[4] Many of the government-unique requirements are imposed in the contracting process and appear in contract specifications or terms and conditions, including those mandated by contracting laws or regulations.

Research Findings—General

"Other Transactions"—Background

There is a long history of the military resisting new ideas, concepts and technologies. Napoleon's preference for the smooth bore musket over the rifle, the Navy's reticence to fund the construction of the Monitor, or the years it took the Army to contract with the Wright brothers to demonstrate the aeroplane are historical examples. In the latter case, the inflexibility of the applicable contracting regulations proved to be part of the problem. A partial fix to the inflexibility of the contracting statutes, when applied to research, development and purchases for experimental purposes, came with enactment of the Air Corps Act of 1926 and later with emergency exceptions to the general procurement laws in place for the duration of World War II. A more comprehensive solution came in 1947 with enactment of the Armed Services Procurement Act. The promised flexibility of that statute was soon restricted by narrow implementing regulations (today embodied in the *Federal Acquisition Regulation* and its supplements) and additional legislation (Nagle, 1992, pp. 468-471). In 1958, additional flexibility was sought and resulted in an alternative approach under the Grant Statute. As implemented, however, this non-procurement authority was restricted to basic and applied research with academic and non-profit research institutions.

An important milestone was reached in 1958 with enactment of the National Aeronautics and Space Act. Section 203 (c) of that statute authorized a variety of contractual actions including: "such *other transactions* as may be necessary." In addition to utilizing the basic contracting laws, NASA used this alternative authority selectively to enter into a variety of innovative contractual relationships with the interpretation that the contracting laws did not apply to "other transactions" (usually referred to as "Space Act agreements"). The first active communications satellite was actually privately owned and developed at no expense to NASA, which launched the satellite on a reimbursable basis for AT&T. The technical reports on Telstar that the author delivered to NASA looked exactly like technical reports delivered under a government procurement contract. The relationship between NASA and AT&T became a model for a class of "other transactions" called launch service agreements. Over the years, NASA has found many applications for "other transactions" structured as funded, unfunded or reimbursable arrangements.

In the late 1970s, the enactment of the *Federal Grant and Cooperative Act* distinguished purchasing under the basic contracting laws ("procurement") from grants and cooperative agreements ("assistance"). Procurement (purchasing goods and services for the direct benefit

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[4] Lovell et al., (2003). *An Overview of Acquisition Reform Cost Savings Estimates*, RAND summarizes a number of reports estimating the added cost of government-unique requirements at 10% to 50%. A Coopers & Librand report (*The DoD Regulatory Cost Premium: A Quantitative Assessment*, 1994), probably the most disciplined in methodology, placed the added cost at 18%. Both the Lovell study and a GAO report, *Efforts to Reduce the Cost to Manage and Oversee DoD Contracts* (GAO/NSAID-96-106), indicated that DoD's acquisition reform attempts had done little to reduce the regulatory cost premium.

and use of the government) was regulated by contracting statutes and acquisition regulations. Assistance (supporting and stimulating a recipient for a public purpose) was regulated by Office of Management and Budget (OMB) circulars and certain non-procurement statutes. NASA took the position that its “other transactions” constituted arrangements outside both systems. OMB concurred. NASA continued to enter into Space Act agreements not subject to the procurement laws and regulations, statutes such as the *Bayh-Dole Act* (patent rights), or the OMB circulars covering assistance relationships.

DoD “Other Transactions”

In 1989, the Defense Advanced Research Projects Agency (DARPA) sought and received authority to enter into “other transactions” (OTs) to support basic, applied and advanced research. This authority could be used when *standard* procurement contracts and grants were not feasible or appropriate. This criterion posed little difficulty considering the subject matter of the authority (basic, applied and advanced research), since such activities, while mission oriented, are seldom executed for the primary purpose of acquiring goods and services but have motives such as the acquisition of knowledge, establishing standards or proofs of concept, engendering scientific collaboration and other purposes. Equal cost sharing was not a requirement but was to be considered to the extent *practicable*. This practicability standard was not an inhibitor when flexibly applied by DARPA but tended to become applied bureaucratically when the authority extended beyond DARPA.

In 1994, DARPA received additional authority to carry out prototype projects directly relevant to weapon systems using “other transactions” which were not subject to cost sharing and could be used even if a procurement contract was feasible and appropriate. Unlike the original authority which had a dual-use character and was also aimed at expanding the defense industrial base the prototype (or “Section 845”) authority was specifically aimed at defense contractors and prototyping defense systems. This has been broadly misunderstood and subsequently resulted in an amendment in 2000 that required cost sharing or the involvement of non-traditional defense contractors (very narrowly defined) before a Section 845 project was authorized.[5] Section 845 could be used in situations in which a standard procurement contract was typically used; it is an alternative to a procurement contract.

Congress has been inconsistent in its support for “other transactions.” The original DARPA authority was, after a trial period, made permanent and expanded to the DoD as a whole. Section 845 authority was expanded to the military departments but subsequently encumbered with the restrictions noted above. In 2004, Congress again expanded the authority by authorizing a non-competitive award of a follow-on production contract after a competitively awarded Section 845 prototype project. Section 845 and the follow-on production authority have never been made permanent and are subject to sunset provisions. There have been high-level endorsements of OTs within the DoD on several occasions, but the “bureaucracy” does not

[5] See the notes in the *United States Code* following Section *10 USC 2371*, for the legislative evolution of DoD OTs.

know quite how to deal with them and has written regulations that arguably restrict the potential flexibility of OTs.[6]

Types of "Other Transactions"

Under OT authority a variety of contractual arrangements can be structured. Many OTs look similar to procurement contracts or research grants with the distinction that certain terms and conditions mandated by contracting or assistance regulations are not applicable and in those areas mutually beneficial terms and conditions can be negotiated unfettered by "one-size fits all" rules.

This is not a very imaginative use of OT authority, but it is potentially important in situations in which the recipient of the OT is a traditional defense contractor familiar with *FAR*-based contracting and the primary value of the OT is avoiding flow-down requirements that would be unattractive to a potential subcontractor familiar with commercial practice or a venture capital-supported start up company to whom *FAR*-based contracting is either unfamiliar or unattractive.

Beyond the use of OTs outlined in the preceding paragraph, the authority has been used in some creative and innovative ways. Forms of competition invented for particular programs or a class of programs can be structured unconstrained by contracting statutes and regulations. OTs have been used to structure joint funding arrangements where the DoD and industrial firms pool their funds to sponsor third parties in research that addresses common problems. Innovative systems produced through government research funding that the government is unable or unwilling to use as an operational system can be commercialized, and the government can gain the benefit of its investment through access to the commercial product (and potentially receive payments as a result of successful commercialization). A variety of consortia arrangements can be formulated to bring together a sufficient mass and variety of intellectual power to address difficult problems. Consortia thus formed need not have a "prime contractor" when formed via an OT. Prototype projects can be formed when the industry "team" is a true team and leadership of the project changes as it proceeds through various phases and when one performer may have the skills necessary to manage a particular phase. Several OT consortia have been formed to bring together expert capabilities in particular fields of technology (highly energetic materials; robotics; chemical, radiological and biological threats) and have been able to respond to emerging threats or opportunities by getting new projects started in days rather than weeks, months or years.

Critics of "Other Transactions"

It is worth noting that OTs have their critics. The author met with DoD's senior official for procurement and acquisition policy last summer. During the course of that meeting, the official stridently and authoritatively asserted that the three most wasteful acquisition programs in the Department's history were Section 845 OT programs, citing C-17, LPD-17 and FCS. Two were

[6] High-level endorsement—for example former USD (AT&L) Paul Kaminski personally signed an innovative OT, and, more recently, John Young heartily endorsed an "Open Business Cell" that among other things would specialize in OT contracting. Regulations—the DoD Grants and Agreements Regulatory System; and, "Guidelines" for Section 845 agreements issued by the Director, Defense Procurement and Acquisition Policy.

actually conducted as traditional procurement programs, not OTs. The third, FCS, was a troubled program that was initiated as an OT. However, analytical studies of that program concluded its problems had nothing to do with being conducted as an OT, and in fact, the program benefitted from initially being conducted as an OT. It turns out that the vociferous and inaccurate denunciation of OTs witnessed by the author was not an isolated incident. The author interviewed a GS-15 former employee of that office who had been brought in to oversee OT policy. The employee related that on arrival his supervisor greeted him with diatribe against OTs, citing Arsenal Ship as the prime example. That program is included among the case studies below. It was a well-executed program that was cancelled for reasons having nothing to do with its being conducted as an OT.

The DoD Inspector General's office has issued reports on OTs that contain criticisms of OTs of varying degrees of substance. Generally these criticisms fail to demonstrate an understanding of OTs; and, the essence of the criticism is usually that OTs are not business as usual and their use is not justified. The IG reports often contain a comment that the traditional system has "served us well." They never state that there is a financial cost to operating under the government-unique rules of the traditional system. They also fail to note the isolation of the defense industry caused by government-mandated business practices. Finally, IG criticism follows a consistent trend in which the IG has been dubious of acquisition reform in general.[7]

One of the most highly publicized critics of OTs was Kenneth F. Boehm, chairman of the National Legal and Policy Center who, in March 2005, testified before the Senate Armed Services Committee concerning Boeing's OT agreement in the Army's Future Combat System (FCS) program. Boehm's testimony was filled with examples of abuse, a litany of statutes from which OTs are exempt, and the abuses that could occur. A careful reading of the testimony shows that Boehm's numerous examples of abuse (the Darleen Druyun case included) were not specifically related to the FCS OT agreement. In fact Boehm merely cited examples of "safeguards" from which an OT might be exempt. Boehm never testified to any connection between his examples of abuse and the actual OT agreement. One gets the distinct impression from his testimony that Boehm never actually read the OT agreement. If he had conducted an intellectually disciplined and forthright inquiry, he would have known that the FCS OT contained nearly one hundred *FAR* clauses, and the issues he raised were more hypothetical than real and in the FCS context his testimony was bogus. In contrast, the witness from the Government Accountability Office (Paul L. Francis) found problems in the FCS program but did not include the OT agreement among them. Moreover, a study of the FCS OT agreement by David R. Graham for the Institute for Defense Analyses found a number of benefits flowing from the agreement, among which were the ability of Boeing to deal with innovative companies that might not have participated in FCS under a procurement contract.

Most credible research studies of OTs have found multiple benefits of OTs and few if any negatives. However, one research paper sponsored by the Naval Postgraduate School did find that the version of OTs called Technology Investment Agreements (TIA) had generally

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[7] An example of the DoD IG anti-acquisition reform position is Derek Vander Schaaf, (1995, August 3). *Debunking myths of acquisition reform*. Prepared testimony before US House of Representatives, Small Business Committee. An example of an IG report is DoD. (2001, March 19). *Management of the commercial operations and support savings initiative* (DoD IG, D-2001-081).

failed (data to FY2000) to attract the participation of for-profit commercial firms (Tucker, 2002).[8] Subsequent research shows, that to the extent this finding was accurate for the period reviewed, it is no longer valid (data to FY2006) (Ablard et al., 2007, pp. 2-15). Moreover the finding in the Naval Postgraduate School paper is inconsistent with earlier studies of OTs (prior to the use of the TIA terminology).

In addition to outright criticism, some studies of OTs have noted concerns about OTs raised by government personnel. The most commonly identified concerns are government loss of intellectual property rights, absence of cost standards, and unavailability of metrics for success. These and other concerns remain essentially theoretical, as they have not been documented as actual problems by knowledgeable personnel who have participated in the execution of OTs. All are issues that can be intelligently dealt with in the negotiation process.

Research Findings—Case Studies

Maritime Fire Support Demonstrator (MFSD)

Originally called Arsenal Ship, the MFSD program was a joint DARPA/Navy Section 845 prototype project to demonstrate massive precision fire support (up to 500 vertical launch cells) as well as a variety of acquisition reform techniques.[9] The demonstrator ship was to be capable of being converted to a fully operational fleet asset and of becoming the lead ship for a fleet of up to five additional ships. Technically, the ship was to have on-board or off-board control via Cooperative Engagement Capability; was to demonstrate new approaches to damage control; and was to reduce cost of ownership through innovative maintenance and operating procedures and an exceedingly small crew size. A Unit Sailaway Price ($550 million for the production vessels) was established, and all technical decisions had to be made in the context of both the established acquisition cost and projected lifecycle cost. Starting from award of five concept development phase agreements in July 1996, the program was on track to have the test article in the water, ready for testing, in October 2000 when it was cancelled at the end of 1997.

According to the Arsenal Ship lessons-learned report,

> [The] process being followed by Arsenal Ship demonstrated a 50% reduction in acquisition time for the design portion of the ship compared to the traditional approach[…] This was primarily enabled by using an industry led acquisition [approach] operating under Section 845 authority, with industry having full trade space and responsibility for the design.

The “price as established” trade-off technique spurred innovation and drove down acquisition cost, albeit at some added risk. Summarized findings from the lessons-learned report include that an industry-led design competition could be more meaningful than a government analysis of alternatives. Industry proved to be fully capable of designing a complex

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[8] Data collected for DoD’s FY 2006 report to Congress on OT’s (Via DD form 2759) showed 91% of 116 Section 845 OTs had involvement by a total 185 non-traditional contractors (under a very narrow definition of non-traditional).

[9] The primary sources for this case study are Hamilton (1997) and the author’s personal knowledge of the program and interaction with program participants. Charles Hamilton (RADM., USN, Ret.) reviewed and provided comments on this case study.

Navy ship. Minimum government direction was a key factor in success. When unique industry teaming arrangements are encouraged, adequate time is needed for industry team formation and growth (teams with "cradle to grave" capabilities were required). Section 845 permitted "try before you buy" for Navy ships with no time lost to full production.

In light of the foregoing brief summary, one might ask: if Arsenal Ship was so great, why was it cancelled? With the death of Chief of Naval Operations ADM Jeremy Boorda early in the program, Arsenal Ship lost its chief proponent within the Navy. Arsenal Ship was revolutionary. It was (according to Norman Polmar) the first truly new concept in warships since the ballistic missile submarine. The potential capabilities of Arsenal Ship competed with the submarine navy, which was then seeking to establish new roles, and the aircraft carrier force, which believed it had the primary role of providing support to expeditionary ground forces. One can speculate that Arsenal Ship was viewed as a threat by some of the Navy's key submarine and air admirals (or merely closely associated with their former nemesis ADM Boorda), as well as a number of other vested interests. A relatively small shortfall in one year of Arsenal Ship's funding profile provided an opportunity to terminate the program. More generously, perhaps, the Director of DARPA ascribed the failure to correct the funding shortfall to Navy mismanagement of the budget process.

In the wake of the cancellation of Arsenal Ship, it is well to remember that the Navy's Program Executive Officer (Ships), RADM Charles S. Hamilton, stated at this conference a few years ago that the Arsenal Ship experience revolutionized the way the Navy thinks about warship design and development. In addition, the Arsenal Ship program left many other legacies, including a more affordable and more capable Mark 41 Vertical Launch System. Both acquisition approaches pioneered with Arsenal Ship and a large amount of technology developed under the program found their way into subsequent Navy shipbuilding efforts. Despite its cancellation, Arsenal Ship proved to be an excellent value.

Future Combat System (Early Phases)

FCS is a major Army modernization program. Following some initial work done by DARPA, the Army continued FCS as a Section 845 OT before transitioning it to traditional contracting.[10] FCS joins an array of manned and unmanned systems connected through a common communications network, allowing a flexible and modular response to threats in complex environments.

The FCS OT allowed for fast progress to be made in concept development and enabling technologies while a competition to select a lead systems integrator (LSI) was undertaken. Prior to selection of the LSI, notable innovation was observed through the efforts of non-traditional contractors—especially iRobotics and Austin Information Systems. The OT proved very adaptable to program changes that occurred frequently because of tradeoffs and the evolving nature of the huge and multifaceted program. The degree of involvement of the Army user community was unprecedented. Rapid prototyping and development of manufacturing capabilities occurred. Commercial technologies in existence and under development were effectively transitioned into the program. FCS is currently transitioning important capabilities to ground forces in action in Iraq and Afghanistan.

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[10] Sources for this study include the LMI report (note 17), App. C 12-14; testimony in Senate hearings; conversation with a program participant, and GAO and IDA reports referred to in the "Criticism" section of this paper and helpful comments by Hon. Claude Bolton, former Assistant Secretary of the Army.

A deficiency in this program was a profound need for training of Army acquisition personnel unused to the flexibility of Section 845 contracting. Another problem was the LSI selected for FCS was Boeing—which was soon being highlighted as a poster-child of corruption in the defense industry. The association of Boeing with the Army's highest profile development program and its execution under an OT resulted in bad publicity and an unjustified correlation between OTs and unethical conduct by defense contractors. This has had a profound negative effect on the perception of OTs.

Case Study—Joint Unmanned Combat Air Systems (JUCAS) at DARPA

DARPA, the Air Force and the Navy combined to develop a system of highly capable unmanned combat air vehicles networked through a common operating system.[11] These vehicles are to penetrate deep into high-threat environments, be survivable and constitute a persistent combat capability. The program involved major defense companies, Boeing and Northrop, as well as significant roles for non-traditional contractors.

Cost was reduced in this program because both major contractors organized their efforts as IR&D projects (allowed under OTs: government payments off-set IR&D balances), eliminating general and administrative expenses; facilities capital and cost of money; fee; and reducing labor and material rates by about 15%. In addition Boeing invested about $300 million in the effort. Cost was also saved because the streamlined management and change-order processes adopted were estimated to reduce schedule by more than a year.

The flexibility of the OT helped attract non-traditional companies to the project. Some were unique, including a supplier of composite materials whose main line of business was manufacturing surfboards. In the case of Northrop Grumman non-traditional companies provided essential capabilities. The differing nature of the participants and highly innovative nature of the project operating at close to the state-of-the-art resulted in adjustments in industry's position on intellectual property matters. The OT could accommodate flexible IP arrangements.

The project was financed through payable milestones, which both improved cash flow and focused the project on key technical accomplishments. Milestone payments incentivized contractors to achieve observable results at less-than-estimated cost. Milestones were modified in the light of experience. This type flexibility would have been difficult to achieve under a *FAR* contract with inflexible contract line item numbers.

As in FCS, a need for training and culture change was noted, in this case by both government and industry personnel. Government personnel tried to regulate in a business-as-usual mode rather than to collaborate in a manner consistent with the vision of the program's leadership. Unlike FCS, there was inadequate effort devoted to identifying and engaging the potential user community.

In 2005, DARPA was confronted with a problem created by Congress. The original JUCAS OTs with Boeing and Northrop were nearing the end of their terms. As a result of an amendment to Section 845 in 2000, new Section 845 agreements would require either 1/3 cost sharing or an upfront determination that non-traditional contractors (defined in an exceedingly

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[11] Sources for this study include the LMI report (note 17), App. C 1-3; the author's personal knowledge of the program and interactions with both government and industry participants.

narrow fashion) would be “significantly” involved in the program. Since cost sharing was unlikely and an *a priori* determination of significant non-traditional involvement could not be made for the next phase of the program, DARPA planned to award a traditional procurement contract for that phase. The program successfully transitioned from the DARPA joint program office to Air Force leadership before that occurred. The subsequent history of the program under the Air Force is not part of this case study.

Chemical, Biological and Radiological Technology Alliance (CBRTA)

The CBRTA was part of a multifaceted consortium (National Technology Alliance) authorized by Congress to inject commercial technologies for security and defense needs.[12] It consisted of thirteen commercial firms and academic institutions, awarded under an OT agreement, with 3M leading the consortium in an administrative capacity. The National Geospatial-Intelligence Agency (NGA) acted as executive agent and provided the contracting support.

CBRTA afforded the government access to a reservoir of intellectual talent consisting of thousands of the best and brightest scientists and engineers employed by the CBRTA-member companies and institutions. Projects were initiated as a modification to the basic agreement and were in the form of task orders. Because industry could formulate a program plan in response to a government need in a matter of days (potentially hours), work could begin under an approved plan almost as quickly. Work could be performed by members of the Alliance or subcontracted if the requisite expertise existed outside CBRTA companies.

Administrative costs were funded separately from R&D efforts. Most projects were funded as time and materials efforts, while others were either cost-reimbursement or fixed-price milestones. The government obtains the leverage of industry investment—which was often five or ten times that of the government in many of the technologies supported by CBRTA member companies. Project time was shortened due to the reduced need for cost and pricing data, elimination of a formal engineering change process, and simplified terms and conditions with suppliers—all due to the fact that the OT instrument included these terms and conditions.

This type of consortium embraces non-traditional participants both as members of the consortium and also in the subcontract role. OT allows flexibility in intellectual property and freedom from government-unique requirements such as hourly timecard reporting and DCAA compliance, which would be absolute nonstarters for many of the companies and scientists involved in CBRTA projects.

The CBRTA operated as a highly successful program for several years. It was a potential model that could be applied to many technology areas relevant to DoD needs.

However, chemical, biological and radiological technology was not a main interest of its executing agent, the NGA (CBRTA funding came primarily from agencies other than NGA). A supportive NGA director early on was succeeded by a director uninterested in CBRTA. Even

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[12] Sources for this study include Daly et al., *CBRTA: Six Years of Operation*, (briefing Aug. 2008); the LMI report (note 17), App. C 7-8; and, conversations with program participants. Richard Kuyath, counsel, and George Sundem, contracting officer, of 3M Company, provided helpful comments on this case study. Review and additional comments were provided by Kathleen Harger, former Assistant Deputy Undersecretary of Defense (Innovation & Technology Transition).

more disheartening to industry and damaging to the previous efficiency of CBRTA was the assignment of a new NGA legal counsel in an oversight role who lack a background in OTs to oversee CBRTA. Agreement modifications were subjected to legal reviews that took much longer than previously. This attitude seemed to infect Agreements Officers responsible for administering the OT. Issues between CBRTA and the government that had previously been raised and resolved were reopened, and the government (new legal counsel) took a more restrictive view than previously held. As of this writing, the CBRTA agreement has expired with faint hope that it will be resuscitated. A highly successful program with virtually unlimited potential to provide the government with novel solutions has been allowed to lapse.

Hummingbird Unmanned Aerial Vehicle

The A-160 Hummingbird UAV is a rotor-craft built by Frontier Systems, a small non-traditional contractor.[13] It incorporates revolutionary rotor technology and is intended for reconnaissance; surveillance; target acquisition; communications relay; and precision resupply missions in autonomous operation. It has long endurance and can fly thousands of feet higher than conventional helicopters. Hummingbird has successfully undergone flight tests and is under active consideration for use in a number of operational applications.

The Section 845 OT proved to be very cost-effective. It enabled dealing with the small commercial firm and, particularly, held down cost in the early R&D phase. Cost savings additionally accrued through time savings in both the pre- and post-award phases and as a result of the streamlined changes process. This work would not have occurred under a *FAR*-based contract. Frontier Systems would not have accepted such a contract.

Particularly important in this case was flexibility in intellectual property, especially patent rights, as Frontier has patented inventions related to its revolutionary rotor technology. The flexibility of an OT to accommodate the needs of a performer with specific needs or revolutionary ideas of importance to DoD was demonstrated in this project.

This was a case where an OT was essential to gain access to a technology controlled by a small, non-traditional contractor. An acquisition team well-schooled in OT contracting was critical to successfully dealing with this contractor. Business-as-usual or on-the-job training would not have worked in this case. This may be a case where the follow-on production authority provided by Congress in 2004 (or a modified version of it) would prove particularly useful.

Dual-use and Commercial Operations and Support Savings Initiative (COSSI)

The previous case studies have highlighted individual Section 845 OT programs.[14] Major successes have also been achieved in broad programs involving hundreds of agreements, including DoD's dual-use technology programs (originally the DARPA-led Technology

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[13] Based on LMI report (note 17), App. C 5-7.

[14] Based on Gray et al. (1996). *Dual use research project report*. Arlington, VA: Potomac Institute for Policy Studies; LMI report (note 17), App. C 9-11; the author's personal involvement in these programs and conversations with program participants; former Deputy Assistant Secretary of the Navy (and former Assistant Deputy Undersecretary of Defense responsible for COSSI). Michael McGrath provided insightful comments.

Reinvestment Project) and COSSI. The dual-use programs used the original (*10 USC 2371*) OT authority, and COSSI was executed using a combination of the original authority and Section 845 OT agreements. The interesting thing about both the dual-use programs and COSSI is that despite achieving a record of success, both have been allowed to fade away. Although vestiges of both programs persist, neither exists as a coherent entity. When programs are successfully piloted at the Office of Secretary of Defense level, there is no guarantee of their institutionalization or continued existence when they are transitioned to the military departments. Business-as-usual attitudes and the budget priorities of the individual services seem to trump innovative approaches, opening the technology base to new entrants, and cost savings.

DARPA's success in promoting dual-use technologies (those with both commercial and military applications) through cost-shared collaborations with commercial firms using OT contracting was such that it led a distinguished panel under retired Marine General Al Gray to recommend the dual-use approach as the DoD's primary means of undertaking new technology developments. Other reports also found that these OT programs were highly successful.

COSSI was a program started in 1997 that aimed to reduce operations and support costs by replacing (often expensive and outdated) military-specific components in DoD systems with components adapted from commercial products or technology. The program was premised on the DoD funding the modification, testing and adaptation of the commercial component for military needs on a cost-shared basis, while the commercial partner gained the promise of a fixed-price procurement if the savings was successfully demonstrated. Since OT production authority did not exist, COSSI was designed to use *FAR* Part 12 commercial item contracts for the follow-on procurement. COSSI was successful in the sense that documented OS cost savings exceeding the government's R&D investment were realized, and eventually the program attracted considerable participation by non-traditional firms. However, the DoD's credibility suffered when, contrary to program guidelines, it refused to grant a preferred position to the cost-shared developer and either went out competitively to procure the improved component (often from a traditional defense contractor) or opted not to procure the improved item despite demonstrated cost savings. Eventually, COSSI died as a major program but episodically serves as a model that is put into use by various DoD components.

In both the dual-use programs and COSSI, flexibility in intellectual property rights and streamlined business practices were important to attracting commercial firms. These programs were competitive in nature, but the competitions held were more informal than competitions under Part 15 of the *FAR* and generally resembled the broad agency announcements.

Research Findings—Surveys and Data Collection

Data Sources

This part of the report summarizes and analyzes data collected via interviews, surveys, and other means. It includes research undertaken by a five-person team from the Logistics Management Institute led by John Ablard. This team included three members with many years of experience in DoD acquisition and assistance, including significant experience with OTs (aided by researchers experienced in survey techniques and statistical analysis). This team conducted interviews with twenty-six individuals representing industry and government and including both executives and program personnel. All persons interviewed had recent (as of 2007) experience with OTs. In addition, the responses to thirty questionnaires sent to government program managers and agreements officers were recorded and analyzed. In total, the responses to the questionnaire represented experience on forty-six OT programs with some individuals having experience on more than one program. There was overlapping coverage by more than one respondent on some programs. The data collected by the LMI research team has been made available to other researchers, but as of this writing has not been formally released.

Another compilation of data summarized below was collected by Robert Spreng—the recently retired president of an industry association (Integrated Dual-Use Commercial Companies or IDCC) consisting of large commercial firms with significant R&D budgets that wish to collaborate with the DoD on R&D but which do not want to be subjected to onerous government-imposed requirements that are inconsistent with their normal business practices. Speng's data comes from two sources. Spreng has accessed and analyzed: (1) publically available information (his methodology is described in published articles cited in the footnotes) and (2) data from surveys of IDCC-member companies.

A final Section includes insights from interviews and surveys personally conducted by the author. This is supplemented by notable data uncovered during the author's literature review that is not reported elsewhere in this paper.

LMI Research Data

The top-level findings of the LMI research team were: (1) Persons with experience in using prototype (Section 845) and research OTs (TIA's) viewed them positively; (2) effective use of OTs offers benefits to R&D program managers as well as contracting officers; among the benefits attributed to prototype OTs are streamlining, flexibility, performance improvements, schedule reductions, and cost reductions; (3) use of OTs has given the DoD access to for-profit companies that traditionally do not do R&D business with the federal government; these entities' participation either alone or in consortia has been of significant value; (4) use of OTs is most effective in research and prototyping efforts or in certain programs developing manufacturing technology; and, (5) understanding and acceptance of OTs within the DoD needs to be improved so that the full benefits of these instruments can be realized.

Nearly two-thirds of respondents to the questionnaire stated that OTs reduced pre-award cycle-time, while nearly a quarter said it had no effect and a small minority said it caused an increase. Among those saying there was a decrease in pre-award cycle-time, there was unanimity that the administrative simplicity of OTs resulted in reduced time. Three-fifths of the respondents identified freedom from *FAR* competition standards, and an equal number thought project partners working together efficiently resulted in quick development of a research plan. Among the small number of respondents noting an increase in pre-award cycle-time, the unfamiliarity of offerors with OT contracting and time-consuming negotiations over intellectual property were identified as reasons by all respondents.

About three-fifths of respondents stated that use of OT authority reduced post-award program execution time; about two-fifths said it had no effect. Primary reasons given were: reduced administrative burden allowed more focus on technical research goals; minimum internal systems compliance requirements accelerated process; flexibility to restructure and make mid-course corrections created an efficient work environment; and lack of flow-down clauses sped up the process. About four-fifths of respondents stated that overall (pre- and post-award) OTs resulted in significant or moderate time reductions in their programs. Most of these (63.3%), however, thought the time reductions were only moderate.

Nearly three-fourths of respondents attributed cost reductions to the use of OT authority (compared to 6.7% saying OT increased cost). The top reason given was that tradeoffs allowed better use of available funds. Other top reasons were that shortened cycle-times reduced overall program cost; there were fewer non-value added activities; and use of cost sharing. In addition to reduction in current project cost, more than half the respondents stated use of the OT would result in reductions in future acquisition and support costs for their programs. With a single exception, the remainder of respondents thought use of an OT would have no effect on program costs.

In the area of performance of the systems or products resulting from their OT projects half the respondents said OT authority resulted in significant improvements in performance. Forty percent identified moderate performance improvements, while the remainder saw no impact on performance from using an OT.

More than four-fifths of respondents said that OTs had a positive impact on various aspects of the team relationships and practices. No respondents identified any negative impacts. Positive influences were found in relationship building among team members; focus on technical aspects of the program; management and control of the program; and other practices.

More than 90% of respondents found that OT authority resulted in a streamlined and flexible program. Reasons given included various accommodations of commercial practices including flexibility in negotiating technical data, computer software license rights; various auditing and cost practices; and, elimination of flow-down clauses. Another top factor was ease in making changes.

When asked to access the overall impact of OT authority on their projects 46.7% responded that it had a significant positive impact; 50.0% said it had a moderately positive overall impact; and one respondent (3.3%) said no impact. In addition, more than three-fourths of respondents answered affirmatively to the question, “Did use of OT authority allow development of program/s that may not otherwise have occurred?” These general findings, as well as many of the specifics derived from the survey of government personnel, were reinforced by information derived from interviews of government and industry personnel.

The survey responses summarized above are all the more remarkable in light of additional information LMI derived from its interviews. In nearly all the programs profiled in the interview process, a deficiency in training on OTs was noted. The deficiency sometimes related to both government and industry personnel and sometimes only to government personnel. In one major program, it was identified as “a compelling need.” Thus the benefits of OTs identified in the LMI study were documented despite the fact that these programs may not have been conducted by well-trained government personnel nor executed up to the full potential of OTs.

IDCC Research Data

Beginning in the early 1990s, Robert C. Spreng has conducted a series of studies showing the profound divide between the large defense contractors that receive the vast majority of DoD RDT&E awards and leading US industrial firms that receive little or insignificant DoD R&D funding. Spreng found that a handful of defense contractors account for half of the total DoD RDT&E awards, while adding a few more brings the total to three-quarters of all such funding. Of hundreds of top industrial firms (*Fortune* 500 or 900 firms in *Business Week* R&D Scoreboard), 92% receive little or no DoD research and development funding.

A review of the data sources that Robert Spreng has assessed provides details that are consistent with what former Defense Secretary William Perry and many other knowledgeable observers have said: namely that many technology areas the DoD depends upon—such as electronics, semi-conductors, and computer software to mention a few—have equivalents in the commercial sector, and there is no need to maintain defense-unique capabilities in those areas. However, ending reliance on defense-unique industrial capabilities requires that the DoD be able to access the equivalent commercial market.

IDCC has analyzed some of the government contracting practices that discourage their members' participation in government R&D programs or constitute barriers to entry. In a 2006 survey of IDCC member companies, eight of the top fifteen barriers identified related to intellectual property and three identified barriers to the way the government handled costs. In a 2008 survey, seven of the top fifteen barriers related to intellectual property and two were cost related.

Some of the issues identified were intellectual property rights/proprietary data concerns including trade secrets; Buy-American provisions/concerns with foreign technology/production; cost accounting standards; pass through requirements; profit policy; overhead policy; cost or pricing data; documentation; audit rights; and contract dispute resolution. Other issues were operational in nature such as awareness of business opportunities; work specification problems; government oversight problems; and billing problems. Many of industry's concerns flow from the requirements of the *Federal Acquisition Regulation* (or parallel provisions contained in assistance regulations). Other issues were related to the attitude and culture of government personnel involved in R&D contracting.

The IDCC has recommended expanded use of OTs as a way to address many of the concerns of its member companies. IDCC has noted that many government contracting personnel are not familiar with OTs or even with potential flexibility under the FAR with regard to matters such as technical data. The IDCC recommends the establishment and thorough training of a cadre of contracting officers who understand innovative contracting and are prepared to accommodate key imperatives of commercial companies. The IDCC has noted that typically their companies will not be prime-contractors and therefore the DoD needs to structure changes that will permit the participation of IDCC companies as subcontractors. Commercial firms such as IDCC member companies recognize the need for them to partner with traditional defense primes in order to participate in platform-centered defense systems acquisitions. They are willing to do this if appropriate terms can be structured.

Government policies embodied in legislation promote civil-military integration (*10 USC 2501*) and a preference for commercial products (*10 USC 2377*), but the years of IDCC efforts to open DoD R&D contracting to primarily commercial high-tech companies indicates these policies have been less than fully honored by the DoD in its approach to systems acquisition.

Other Research

In discussions with the former Assistant Deputy Undersecretary of Defense (Industrial Policy), it became clear to the author that IDCC companies do not have a monopoly on seeing barriers to entry in the government contracting system. Moreover, there is not just a single barrier or set of barriers to entry. Numerous interactions with representatives from companies and industry associations convinced the ADUSD (Industrial Policy) as well as the author that depending on the company or industry segment the barriers differed. Thus, no single magic bullet or tweak of the system will suddenly open up government procurement contracting to much broader participation. The entire system is too arcane, prescriptive, and inflexible to be broadly attractive. As one expert observer noted, it is inconceivable that a rational person or committee of rational people charged with devising a contracting system for the federal government would possibly come up with our current system (Nagle, 1992, p. 519).

An example of a barrier caused by a single government requirement provides an informative illustration. According to the government contracts counsel of a major commercial company (multi-$billions in sales; in excess of $2 billion annually in R&D), his company created an accounting system compliant with government Cost Accounting Standards (CAS) so that it could receive government cost reimbursement contracts. The company was attracted to government R&D business due to patriotic motives, as well as to obtain government funds to expand its research capabilities, and also as a possible way to expand its markets (at 2% of sales, the government was already its largest single customer). With its CAS accounting system in place, the company was awarded and performed a number of DoD cost-reimbursement research contracts. The company's ability to obtain government contracts soon declined as its key scientists refused to write proposals for work that would require them to be subject to government requirements for hourly time reporting. The same scientists were, however, willing to do work under an OT without hourly time reporting. The notion that hourly time reporting was a sore point among highly motivated scientists was confirmed by the response to a survey question circulated by the author. One respondent was the executive director of an electro-optics industry association whose previous experience included management at a start-up company, work as a DARPA program manager, and attorney at law! He pointed out that experiments do not always fit into neat eight-hour segments. Hourly time reporting to a highly qualified scientist who is paid an annual salary seems articificial and redundant. In a variation on this theme, legal counsel for a large, highly innovative company advised the author that it was motivated to seek government R&D funding for the same reasons mentioned above. His company investigated setting up a CAS-compliant accounting system and made the determination that it was not worth the expense and effort involved. One additional variation on this theme was given in the 1990s by Martin-Marietta's Norman R. Augustine who included lack of "commercial accounting" in reasons why defense firms could not diversify into the commercial marketplace. Multiply this one example many dozens of times and one gets the Gordian knot of government contracting. Yet, OTs like Alexander's sword can unravel the conundrum.

The author was present at a 2008 briefing by an experienced program manager presented to an Office of Secretary of Defense task force that was considering funding a major prototype project involving a highly innovative airship application and that was seeking an appropriate program office to execute the program. The program manager represented one of the military Service's major development and contracting commands and had been asked to contrast a *FAR*-based approach with an OT approach. The program manager was supported by experienced contracting officials. The way the presentation was made suggested that the program manager had a superficial and stereotyped view of OTs and seemed to have difficulty understanding why anything other than business as usual made sense. Later it also came to light that getting management approval for an OT approach from that command would be a "hard sell."

There have been many reviews or research studies of OTs conducted since the 1990s. Examples of the small minority of reports that have been critical have been mentioned in the section on criticism in this paper. The vast majority of studies have found benefits flowing to the DoD from OTs, with any risks being either minor, manageable or both. Once OTs graduated beyond DARPA, a general deficiency in training and expertise in negotiating and executing OTs has been noted. Inaccurate perceptions, general misunderstanding, and false allegations about

OTs have become common among both policy makers and personnel potentially responsible for executing OTs. The LMI research has been highlighted in this paper because it is a recent and disciplined study of the subject. Its findings are generally consistent with many earlier studies.[15] The IDCC data is also of interest. Unfortunately, it merely represents views of companies that are interested in, and relatively educated about, potential pitfalls of doing business with the DoD. One respondent to a survey question circulated by the author pointed out that many companies including highly innovative companies supported by venture capital never consider doing R&D business with the DoD. Among many companies, DoD contracting has a reputation for being unthinking, bureaucratic and limited to companies that are "usual suspects."

Conclusions and Recommendations

Utility and Potential

OTs have demonstrated that they can be a better, faster, cheaper way to conduct defense research, development and prototype projects compared to using procurement contracts. They have demonstrated outstanding utility and benefit to DoD projects in basic, applied and advanced research; prototype projects relevant to weapons and weapons systems and, in distinctively innovative transactions. They are potentially applicable to transactions that have not yet been conceived. Far from being a niche authority, OTs are capable of being a fully acceptable alternative approach for many of the Department's science, technology and prototype projects. The potential of OTs to transition successful prototype projects seamlessly into production is limited under current legal authority. Amendments to Section 845 enacted in 2000 are inconsistent with original legislative intent and unduly restrictive.

It is recommended that the Undersecretary of Defense (Acquisition, Technology and Logistics) direct that DoD guidance on OTs for research and prototypes be revised to assure that OTs are considered a mainstream authority fully equal to *FAR* contracting and assistance instruments. Such guidance should clearly indicate research OTs may overlap the "assistance" category but are not confined by it. Guidance on both research and prototype OTs should stress their flexibility and minimize unnecessary regulatory restrictions. Delegations of authority to exercise or approve the use of OTs should be issued to effectuate vigorous use of OTs.

It is recommended that Congress repeal the 2000 amendment to Section 845 and restore it to its original intent. In lieu of complete repeal limitations on Section 845 should be substantially modified. If retained the definition of "non-traditional" contractor should be changed to a company whose main focus of business is in markets other than the DoD. Dollar amounts for approval requirements for OTs should be repealed. Follow-on production authority should be simplified.

[15] Studies go back to the early 1990s, e.g., Nash et al. (1995). *Participant views of other transactions.* Alexandria, VA: Institute for Defense Analyses; several have been conducted by RAND, e.g., Smith et al. (2003). *Assessing the use of other transactions for prototype projects.* National Defense Research Institute; and include research done at NPS, e.g., Wong & Liu. (2008). *Analysis of the transitioning opportunities for non-traditional contractors under other transactions authority* (MBA Professional Report). Monterey, CA: Naval Postgraduate School.

Subcontracts

A primary way to get innovative commercial companies involved in major defense programs is via subcontracts. Many commercial firms are unwilling to participate in defense procurement when flow-down clauses under the *FAR* system impose unattractive business practices on them. Many of the same firms will accept OT arrangements. The likely significant participation of a non-traditional firm as currently narrowly defined may not be known up front, so many programs will be initiated as *FAR* contracts under current limitations to Section 845. Once initiated as a FAR contract, mandatory flow-down of *FAR* conditions will discourage participation by innovative commercial companies.

Pending legislative changes to Section 845, *it is recommended that* USD (AT&L) direct the military departments to authorize parallel OT agreements to be used to enter into relationships with commercial ("non-traditional" broadly defined) firms that might contribute to a defense project that is being conducted with a defense prime contractor under a procurement contract. Consistent with policies endorsing the modular open systems approach (and incremental and spiral developments), opportunities should be sought for including commercial firms in prototype and development programs. Parallel OT agreements closely integrated with the main development procurement contract should be funded with any available funds including funds originally allocated to the prime contract.

Training and Education

The defense contracting workforce has primarily been trained in following a set of prescriptive rules that potentially inhibit developing initiative and good business judgment in order to craft transactions advantageous to the DoD while honoring the interests of the DoD's industrial partners. In significant measure, the acquisition workforce is woefully ill-equipped to engage in free-form OT contracting. Both DoD acquisition policy offices and the DoD acquisition education community have failed to provide leadership, incentives and recognition to enable the acquisition workforce to better utilize OTs. Top-level leadership has been absent or insufficient in matters of education and training.

It is recommended that USD (AT&L) engage (through a mandated high-level conference or other means) OSD and service acquisition policy offices, senior acquisition executives, and other key acquisition leaders so as to dispel prevalent misinformation on OTs and initiate leadership education on OTs. The services and defense agencies should initiate OT training and create centers of excellence on innovative contracting emphasizing OTs. The Defense Acquisition University should create a significant on-campus series of courses on innovative contracting emphasizing OTs. DAU online training modules on OTs should be substantially revised and should emphasize the potential flexibility of OTs and how to handle non-standard situations rather than reinforce "look it up in the book" education.

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Panel 13 - Policy, Governance and Performance Management in a Service-oriented Architecture Environment

Thursday, May 14, 2009	Panel 13 - Policy, Governance and Performance Management in a Service-oriented Architecture Environment
9:30 a.m. – 11:00 a.m.	**Chair: Christopher A. Miller**, Program Executive Officer, Command, Control, Communications, Computers and Intelligence (C4I) **Discussant: Michael B. Dettman**, PEO C4I Associate Technical Director, Policy & Guidance, SPAWAR SSC Pacific Engineering ***Outcome-driven Provider Performance under Conditions of Complexity and Uncertainty*** **Kevin Buck** and **Diane Hanf**, The MITRE Corporation ***Aligning Acquisition Practice with Netcentricity Policy*** **Lloyd Brodsky**, CSC

Chair: Mr. Christopher A. Miller currently serves as the Program Executive Officer Command, Control, Communictions, Computers and Intelligence (PEO C4I). In this capacity, he has oversight and responsibility for acquisition and lifecycle management for assigned C4I programs.

Miller, a native of Nashville, TN, received his Bachelor of Arts degree from Vanderbilt University through the Naval Reserve Officer Training Program. Upon commissioning in the United States Marine Corps and completion of The Basic School in Quantico, VA, Miller served as Intelligence Officer for various Marine Aviation Commands. In this capacity, he gained his experience in military intelligence and C4I leadership.

Miller left active duty status in 1999 to work for Booz Allen Hamilton in San Diego, CA. While a consultant, Miller worked on numerous command and control programs for the Navy and was integral in coordinating the Year 2000 transition for the Navy's command and control programs.

In 2001, Miller returned to government service at the Space and Naval Warfare Systems Command (SPAWAR), where he provided technical and systems engineering leadership. He led the development of a common Windows 2000 PC software baseline to replace current legacy Microsoft NT baseline. This software baseline is now the foundation of the Navy's largest tactical network, known as Information Technology 21 (IT-21).

In 2004, Miller joined the PEO C4I staff and served in the positions of Technical Director and Director of Modernization. In these roles, he provided technical leadership and oversight for C4I program execution and fielding. His major accomplishments include leading a cross-service effort with the United States Air Force to establish guidance for implementing the Net-centric Enterprise Solutions for Interoperability (NESI)—which was the PEO's first overarching guidance effort and a key enabler for delivering network-centric C4I capabilities. He also led the development of the first consolidated fielding plan and

Modernization Concept of Operations (CONOPS), which defined and implemented the PEO's modernization planning, design and execution processes.

Discussant: Mr. Michael Dettman serves as the Associate Technical Director (Policy & Guidance) for the Program Executive Office for Command, Control, Communications, Computers & Intelligence (PEO C4I), responsible for developing net-centric warfare capability engineering guidance and for the establishment of Naval Open Architecture policies within the command.

Dettman earned a Bachelor of Science degree from Pennsylvania State University in 1992 before beginning a four-year tour of duty in US Naval Intelligence. He served with SEAL Delivery Vehicle Team II and aboard USS Boxer (LHD-4), where he gained experience in military intelligence and C4I systems. Dettman left active duty in 1997 and joined Titan Systems in San Diego, CA, as a consultant, where worked on numerous Intelligence, Surveillance and Reconnaissance programs for the Navy.

In 2000, Dettman returned to government service at the Space and Naval Warfare Systems Center–San Diego. He led the integration and test of a US Navy Tactical Exploitation of National Capabilities (TENCAP) program, which successfully transitioned to the Joint Deployable Intelligence Support Systems (JDISS) Joint Program Office. The JDISS suite provides Combatant Commanders with an integrated collection management capability.

In 2004, Dettman joined the US Central Command's J2 Intelligence Director's staff for Information Management to provide technical leadership, manage warfighter requirements for C4I system development and serve as the Command's representative to the Joint Staff Intelligence Functional Working Group (IFWG). He led a cross-service implementation with the US Army's All Source Analysis System–Lite (ASAS-L) and the Global Command & Control System–Joint (GCCS-J) Integrated Imagery & Intelligence (I-Cubed) systems, which successfully facilitated the secure exchange of critical intelligence across the multiple security domains in the US Central Command Area of Responsibility. He also led the integration and test effort to ensure Forward Operating Base (FOB) tactical intelligence reporting was accurately and efficiently synchronized with the Modernized Integrated Database (MIDB).

In June 2006, Dettman returned to San Diego as the PEO C4I Associate Technical Director for Policy & Guidance, where he led the net-centric transformation by directing the Net-centric Enterprise Solutions for Interoperability (NESI) initiative, in partnership with the US Air Force and the Defense Information Systems Agency (DISA). Additionally, he has served as the command's Naval Open Architecture Enterprise Team (OAET) Action Officer and worked closely with each of the command's program offices to ensure that the Naval Open Architecture Strategy is executed in an enterprise fashion.

Dettman is a member of the Defense Acquisition Workforce and has received several awards for his service, including the Navy and Marine Corps Achievement Medal, US Army Program Manager for Intelligence Fusion Award, US Central Command Information Management Award and the SPAWAR Exemplary Achievement Award.

Outcome-driven Service Provider Performance under Conditions of Complexity and Uncertainty

Presenter: Kevin S. Buck co-leads research of web services performance in tactical environments and stakeholder-driven performance management. He provides investment and portfolio management support to Government sponsors. Buck has a BS in Marine Transportation from the U.S. Merchant Marine Academy, an MS in Industrial Administration, and an MBA.

Author: Diane P. M. Hanf co-leads research of web services performance in operational environments. She provides modeling and analysis, software acquisition, and test and evaluation support to Government sponsors. Hanf has Bachelor's degrees in Electrical Engineering, Wire Communications Technology and Business Administration and an MS in Systems Engineering.

Abstract

While Service-oriented Architecture (SOA)[1] can help organizations share resources and leverage economies-of-scale, it can increase acquisition complexity (e.g., multiple new/different relationships to manage) and uncertainty (e.g., nature/magnitude of future service demands). Given this additional complexity and uncertainty, MITRE developed a performance management framework to help Government organizations measurably:

- Articulate SOA outcomes and identify outcome drivers;
- Define SOA technical and acquisition performance metrics through the application of Return-on-Investment (ROI) principles and monitor performance as a comparison of current delivery to initial ROI expectations;
- Translate SOA objectives into contractor performance management mechanisms.

This paper describes applying ROI analysis principles for SOA performance management, creating Service-level Agreements (SLAs) to articulate agreements between the Government and external service providers, and managing SLAs through a governance framework (Hanf & Buck, 2009, March).

This white paper highlights key findings of research undertaken by The MITRE Corporation (MITRE) and the resulting recommendations for (1) applying Return-on-Investment (ROI) analysis principles as the foundation for more effective performance management of Government Service-oriented Architecture (SOA), (2) creating comprehensive Service-level Agreements (SLAs) to articulate agreements between the Government and external service providers, and (3) managing SLAs through a governance framework (Oakley-Bogdewic & Buck, 2009; Hanf & Buck, 2009, March 25). As illustrated in Figure 1, MITRE's recommendations address the additional managerial complexity and uncertainty that SOA objectives and proposed solutions often create.

[1] SOA is an architectural style that guides all aspects of creating/applying business processes through service packaging and defines/provisions the Information Technology (IT) infrastructure (Newcomer & Lomow, 2005).

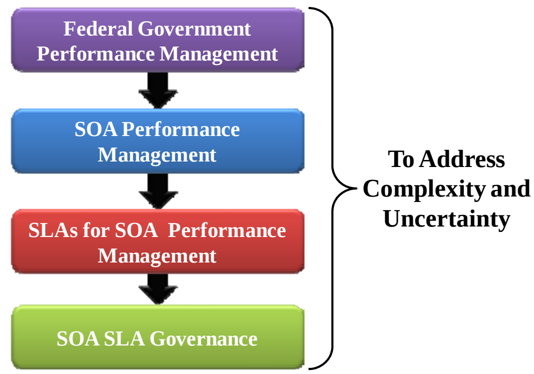

Figure 1. Key Aspects of MITRE's Research

1.0 The Importance of Performance Management

Mechanisms are currently not consistently in place within the Federal Government for programs to identify key stakeholders, quantitatively articulate stakeholder needs, and quantifiably assess, on a timely basis, whether stakeholder needs have been satisfied. The new Administration is currently focused on a key symptom of such improperly functioning mechanisms: lack of transparent accountability. President Barack Obama explained:

> My Administration is committed to creating an unprecedented level of openness in Government. We will work together to ensure the public trust and establish a system of transparency, public participation, and collaboration. Openness will strengthen our democracy and promote efficiency and effectiveness in Government. Government should be transparent. Transparency promotes accountability and provides information for citizens about what their Government is doing. Information maintained by the Federal Government is a national asset. My Administration will take appropriate action, consistent with law and policy, to disclose information rapidly in forms that the public can readily find and use. Executive departments and agencies should harness new technologies to put information about their operations and decisions online and readily available to the public. Executive departments and agencies should also solicit public feedback to identify information of greatest use to the public. (2009)

Over the past year, lackluster demonstration of effective Government performance has resulted in the establishment of new regulations/requirements that compel agencies to more frequently and credibly communicate the value delivered by Government programs in exchange for funds provided by stakeholders. The requirement for a Performance Improvement Officer is one of the provisions of an executive order signed on November 13, 2007, to compel agencies to derive better results from their programs. Agencies will now be required to demonstrate robust performance management efforts, including the development or improvement of strategic plans and aggressive and accurate measurement of progress in achieving overarching performance goals.

Current reporting requirements for programs and expenditures will likely be more closely scrutinized for realism, consistency, accuracy, and alignment with strategic objectives. The

Comptroller General asks federal programs and agencies to improve performance management by:

- Comprehensively reassessing what the federal government does and how it does it: reconsidering whether to terminate or revise outdated programs or services provided.
- Reexamining the beneficiaries of federal programs: reconsidering who is eligible for, pays for, and/or benefits from a particular program to maximize federal investments.
- Improving economy, efficiency, and effectiveness of federal operations: capturing opportunities to reduce costs through restructuring and streamlining federal activities.
- Attacking activities at risk of fraud, waste, abuse, and mismanagement: focusing on minimizing risks and costs. (Mihm, 2000, July 20)

Regardless of whether government programs operate in Information Technology (IT)-intensive environments or not, there is increasing momentum toward sharing of resources, solutions, and risks across government organizations/Agencies. While this trend supports leveraging synergy, reducing stovepipes/redundancy, and economies-of-scale, it often increases acquisition complexity (e.g., multiple new and different relationships to manage) and uncertainty (e.g., nature and magnitude of future demands for supplies/services that are currently being acquired). Given the increased emphasis on transparency and accountability for Federal government expenditures to our ultimate stakeholders (e.g., the taxpayer) in an environment with increased acquisition complexity and uncertainty, foundational steps that we recommend include:

a) Understanding an organization's own performance with respect to its stakeholders' expectations,

b) Finding ways to effectively communicate performance in the right form and at the right time to ultimate stakeholders. This allows for expectations to be effectively managed and/or course corrections to be accomplished before resources are unnecessarily expended for too long on objectives that are no longer worthwhile or on solutions that will not succeed, and

c) Establishing mechanisms to readily re-calibrate performance needs/expectations as the future becomes less uncertain.

We discuss the following recommendations in the context of an SOA environment:

- Application of an ROI-based performance management framework to support sponsors in aligning operational and contract-related performance metrics with monetizable and non-monetizable costs, benefits, and risks deemed critical for achievement of desired outcomes,
- A performance execution process based on SLAs as a key means of communicating and monitoring performance, and
- An SLA governance framework that enables decision-makers to manage SLAs as an on-going re-evaluation of what performance matters to stakeholders.

2.0 SOA Performance Management

As Federal Government agencies transform their enterprises to be service-oriented, a disciplined process to effectively and efficiently manage both operational and service provider performance has yet to be widely embraced. In the absence of such a process, program and portfolio managers are often challenged to clearly and measurably connect SOA stakeholder needs, desired outcomes, and operational, technical, and service provisioning performance. As is illustrated in Figure 2-1, SOA is an architectural approach used to build solutions that contain a set of services, service consumers, service producers and service contracts (Logan, 2008).

SOAP = Simple Object Access Protocol
UDDI = Universal Description, Discovery, and Integration
WSDL = Web Services Description Language

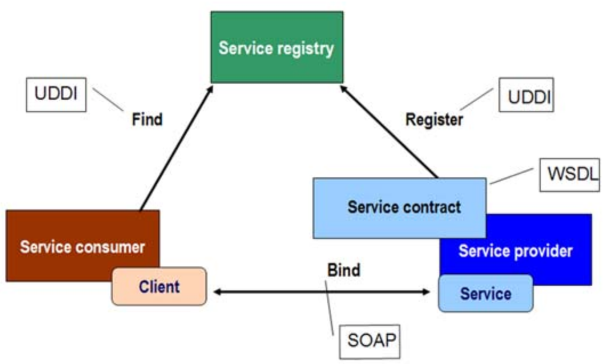

Figure 2-1. The SOA Construct

Through Government case observations and investigation of methodologies successfully employed within commercial industry, the MITRE research team developed a performance management framework—discussed later and shown in Figure 4-1—which guides framework users (e.g., multiple SOA participants in different stages of the SOA lifecycle) through key decisions that will need to be made in effectively and efficiently managing performance of SOA implementations. The SOA (Newcomer & Lomow, 2005) performance management framework helps Government portfolio/program managers and system/performance engineers:

- Measurably articulate expected SOA outcomes and identify outcome drivers,
- Define and monitor technical and acquisition performance metrics through the application of Return-on-Investment (ROI) principles and the on-going comparison of current delivery to initial SOA ROI expectations, and
- Effectively translate operational and overarching government SOA performance objectives into contractor performance management mechanisms.

MITRE's recommendations target critical challenges associated with the increased complexity and uncertainty that are often created by SOA. They also mitigate the risk of measurement overload (i.e., "losing the forest for the trees") by providing a mechanism to derive vital and coherent outcome-focused metrics. These critical challenges are summarized in the paragraphs that follow:

Expectations of Savings without Analysis

For Government agencies and programs that have made decisions to adopt SOA, robust and repeatable methods for effectively and efficiently managing performance over the lifecycle have not emerged. For many Federal Government organizations, there is a mindset that, because SOA is mandated, rigorous investment analysis/management is not necessarily an urgent requirement. The expectation that SOA will save money has resulted in already decreasing funding profiles for programs, increasing the criticality of developing and applying methodologies that result in selection of cost-effective strategies and solutions. These methodologies should directly relate to fulfilling stakeholder needs, closing capability gaps, and achieving multiple outcomes.

Understanding the SOA Lifecycle

One challenge in effectively managing SOA performance is the lack of relevant SOA lifecycle performance benchmarks that Government programs can leverage to determine realistic SOA outcomes and performance thresholds. This lack increases the degree of uncertainty regarding what can realistically be expected from SOA. The current lack of benchmarks is primarily a symptom that (a) many sponsors are still in the initial planning or development stages with SOA and do not have on-going, steady-state results to share yet, and (b) those organizations that do have steady-state performance results often consider the information to be proprietary, requiring close-hold. In the absence of meaningful benchmarks from referent organizations, alternative methods must be implemented by sponsors to evaluate performance of the potentially substantial investments in SOA that will be undertaken by numerous participants in SOA (e.g., SOA developers, service producers, and service consumers).

Measuring Non-fiscal Returns

Our research confirms that SOA expected returns are not always fiscally driven (e.g., compliance with law and regulation or loss of life is more important in many cases), and the SOA construct seeks to align mission and investments that involve promoting a service-oriented culture. As a consequence, the research team proposes an expanded definition of ROI, to include return on closing capability gaps that are targeted by an SOA implementation that includes non-monetizable value propositions such as compliance with law and regulatory mechanisms, avoidance of loss of life and customer (e.g., government user or citizen) satisfaction. This definition is illustrated in Figure 3-1.

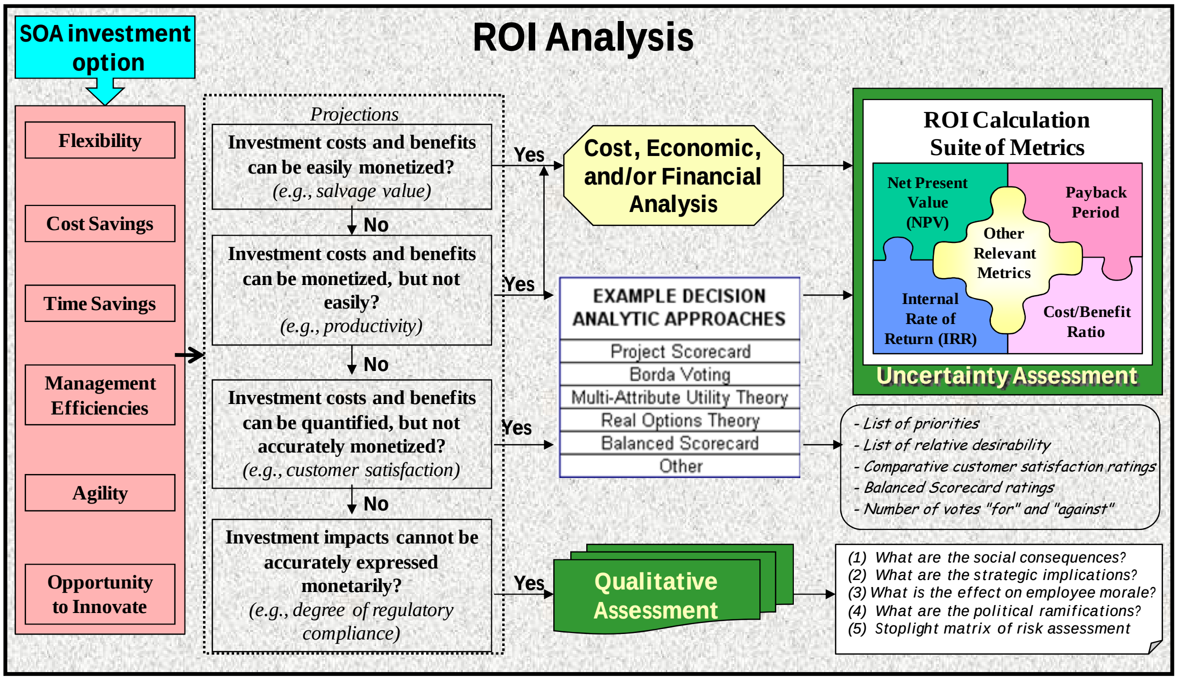

Figure 3-1. ROI Analysis Considerations for SOA

Expectation Management

Application of the expanded ROI methods, in an on-going performance management program, involves comparison of actual *tangible and intangible* results realized from selected SOA investments to realistic, initial investment expectations. Initial expectations, in and of themselves, should reflect an incremental comparison of proposed SOA investment returns to those anticipated should current approaches be continued (i.e., the status quo, or "do nothing" case). The value of ROI analysis for an on-going performance management program must be balanced against the resources required to perform the analysis and will also greatly depend upon the ability of Government sponsors to effectively characterize initial expectations from SOA in measurable terms. According to ZapThink Research, "only by understanding the full range of SOA value propositions can companies begin to get a handle on calculating the ROI of SOA" (Schmelzer, 2005).

Effective SOA Management Can Be Resource-intensive

Application of ROI principles for SOA performance management will likely increase resources devoted to planning and monitoring efforts. ROI analysis can be a relatively resource-intensive effort, and the research team has developed an approach to streamline the process (i.e., "ROI Lite"). This approach involves adoption of an Early Warning System that focuses on more frequent assessment of the "vital few" leading indicators of success/failure. Assessments take the form of variance analyses for key ROI variables (e.g., acquisition costs) and less frequent re-visiting of the overall ROI analysis itself (only required when variances are significant and suggest that either performance needs to be improved or re-baselining is necessary).

Integrating Multiple Perspectives

Another challenge in effectively managing SOA performance is the multitude of conflicting viewpoints regarding key SOA outcomes and which particular SOA-driven benefits can realistically be pursued. This is often the result of confusion in benefit-related terminology (e.g., “flexibility” and “time savings”) and of differing stakeholder needs. For instance, a primary benefit expected from SOA is the ability to expose services for potential re-use by other Government entities, which is typically an enterprise viewpoint; however, an executing program viewpoint could realistically be that the expected benefit from SOA relates to garnering flexibility to quickly respond to a change in the environment. Since SOA supports the exposure of services with the intent of reuse, challenges also include the need to manage multiple inter-Governmental and public-private performance relationships and uncertainty associated with future service demand and performance requirements.

Establishing Stakeholder Targets

The importance of addressing multiple SOA viewpoints, numerous stakeholder needs, and the uncertainty associated with the nature and magnitude of future service demand each increase the complexity associated with acquiring necessary services and capability from other Government entities and commercial industry. Methods that address these limitations, challenges, and pressures for more effective and efficient SOA lifecycle performance management have not been widely adopted within Government settings. Such methods are fundamental to determining whether both SOA *business* (e.g., cost savings through reuse) and *technical* (e.g., flexibility to meet operational needs) targets are being met in a mission-needs context and to manage a more complex stakeholder, provider and consumer environment.

3.0 Applying Service-level Agreements (SLAs) to Manage SOA Service Provisioning

Service-level Agreements (SLAs) have been a highly recommended and time-tested way (in some environments) to establish performance-related agreement between service providers and consumers (other methods, such as Memoranda of Agreement, are typically applied for service provider relationships between Government entities) (GSA, DoD, NASA, 2005). And, effective application of SLAs can help address some of the challenges identified in Section 2.0 (e.g., expectation management, integrating multiple perspectives, and measuring non-fiscal returns). An SLA is a formal, negotiated agreement between two parties. It is a contract between customers and their service providers, and it records the common understanding about service features such as priorities, responsibilities, and guarantees.

The main purpose of the SLA is to articulate agreements reached on the level of service to be provided. For example, it may specify levels of availability, serviceability, performance, operation, or other service attributes, such as billing and even penalties in the case of violation of the SLA (“Service level agreement,” 2007). SLAs have been applied for almost two decades by fixed-line telecom operators as part of their contracts with corporate customers. More recently, some Information Technology (IT) enterprises have adopted the idea of using SLAs with their customers to allow for comparing delivered versus promised quality of service (2007).

Application of Service-level Agreements (SLA) is a recommended, but not required, method to describe performance expectations for services that are acquired by the Government from an external (i.e., commercial industry) service provider, and the use of SLAs is prevalent when services are acquired using Performance-based Acquisition (PBA) techniques.

3.1 Government Experiences in Applying SLAs

Government agency experiences with applying SLAs for managing contract performance objectives have been mixed. In some instances, when SLAs have been applied and performance objectives are not effectively achieved, the primary reason for failure is that the SLAs that were initially created were not consistently applied, maintained, and updated (as necessary) throughout the contract period of performance. In other instances, SLAs fail to support effective performance management because they are managed individually and without sufficient consideration of how all SLAs supporting a particular contract relate to one another to achieve overall outcomes.

SLAs are often exclusively applied as a transactional and computer-generated communication of performance status, which minimizes their inherent power to form binding agreements between parties who may have competing agendas. When efforts are undertaken by the Government to leverage SLAs as a means of achieving and maintaining meeting-of-the-minds between a service provider and consumer, they are often difficult to enforce because of how and when the SLAs were connected to contractually oriented provisioning agreements.

Administration of SLAs often becomes overly resource-intensive, and Government agencies are sometimes motivated to simply replace SLA monitoring efforts with other, potentially less authoritative, monitoring approaches. Alternatively, Government organizations can simply become so involved in SLA administration that they understandably lose sight of performance interdependencies and exactly what performance really should be measured to achieve desired outcomes.

While challenges associated with effective and efficient Government SLA application have existed for many years, the advent of SOA and increased pressures for agile service provisioning in web-enabled environments has added new and more pervasive challenges. In these service-oriented environments, managing delivery against desired outcomes is complex and multi-dimensional, e.g., SLAs may be nested and may be dependent on separate application, hosting, and communications/networks performance needs. The nature and magnitude of future service demand is frequently unclear. And, capabilities will likely be jointly created and maintained by numerous internal and external organizations. The *Federal Acquisition Regulation* (*FAR*) and other government procurement policies can likely accommodate service-oriented provisioning needs, but comprehensive guidance is not available to support Government organizations in establishing SLA monitoring systems that effectively address performance interdependencies among multiple contributors in achieving overarching capabilities.

3.2 Increasing SLA Effectiveness

To increase the effectiveness of SLAs, they should state in measurable terms:

- The service to be performed and outcome expectations,
- Key Performance Indicators (KPIs) and the level of service that is acceptable for each,
- The manner by which service is to be measured and how "success" is defined,
- The parties involved and the responsibilities of each,
- The reporting guidelines and requirements, and
- Incentives for the service provider to meet the agreed-upon target levels of quality.

Figure 3-2 illustrates recommended relational SLA elements.

SLA Element	Description
2.1 CONTEXT	
Purpose/Background	Description of what the SLA has been designed to accomplish
Stakeholders	Identifies who cares about this performance and what they care most about
Service Interdependencies	Explains how the SLA and work scope fit into the entire supply chain
2.2 SCOPE OVERVIEW	
Business Scope and Objectives	A high level description of the SLA's business objectives
2.3 SERVICE DESCRIPTIONS	
Service Descriptions	Detailed description of the services being provided through the agreement
2.4 KEY PERFORMANCE INDICATORS	
Service Levels/Performance Metrics	Required performance and how service is to be delivered
Data Requirements	Data to be provided by the contractor to enable performance monitoring
Security Management	Security issues relevant to services provided
Workload Constraints	Highest expected level of service demand. Degradation schedule if excessive demand
Severity and Priority Levels	Severity levels for service interruption/degradation; service restoration priorities
2.5 ROLES AND RESPONSIBILITIES	
Roles and Responsibilities	Mutually agreed upon roles along with corresponding responsibilities for each team member
2.6 RECOURSE/REWARD SCHEME	
Excused Performance	Conditions under which the contractor will not held to the Absolute KPIs
Escalation Procedures	What actions to take if service delivery is not satisfactory
Service Level Bonuses/Penalties	Consequences for failing to meet Absolute KPIs; rewards for superlative performance
2.7 REPORTING GUIDELINES AND REQUIREMENTS	
Required Performance Reports	Vendor's performance reports to be delivered to government
Update Procedures	How, how often, and by whom, SLA should be updated
Issues Management Procedures	Responsibilities for surfacing and resolving problems/issues
2.8 GLOSSARY	
Glossary of Terms	Written to minimize misinterpretations

Figure 3-2. Recommended Relational SLA Elements

Key SLA lessons learned that should be considered include:

- **Agree to existing service levels:** Some Government agencies agree that the required service levels will be set at existing performance. Doing so preserves the current service that the new contract was designed to improve (Delaney, 2004).
- **Agree to agree on service levels:** Some Government agencies agree to work out service levels after contract award (2004). However, once the contract is signed, the deal team often breaks up, and the provider may not be incentivized to subsequently agree to challenging service levels.
- **Agree to fix service levels at initial provider performance:** Some Government agencies, with no basis for setting service levels, agree to set them at whatever levels the provider can achieve during the initial months of the contract. This can give the provider an incentive to hold down service levels during those initial transitional months, that is, during a potentially volatile time in the contract term (2004).
- **Set the appropriate incentives:** Some Government agencies overlook the idea that the provider will "manage to the money." For example, in a call center contract, agencies might set a service level of "answer 90% of calls within two minutes" without realizing that they are, in effect, telling the provider to ignore any call that's gone over two minutes in favor of one that could still be answered in two minutes (2004).
- **Don't ask for the moon:** Government agencies should be careful about requiring unnecessarily high performance commitments. Providing better service may require the provider to use, for example, redundant systems, excess capacity and better technology (2004).
- **Realize less is more:** Government agencies should make SLAs simple and familiar.
- **Make SLAs measurable and actionable:** Agencies should only collect data upon which they are going to base decisions; they should then pre-set the actions that will be followed if metrics do not hit targets.
- **Detail the unusual areas and boiler plate the rest:** "Must-haves" should be articulated in the contract itself.
- **Describe methods for withholding/reducing fee:** Loss of business/productivity is rarely compensated directly by a service provider. Typically, a rebate proportional to the shortfall of the service vs. the payment is provided by the service provider in future performance evaluation periods. SLAs typically include escalation procedures and conditions under which the provider will not be held responsible for service failings.
- **Incorporate contract language that allows SLAs to be changed:** This language should tie to milestones as SLA changes may impact cost/schedule.

Key reasons for failure of SLAs include: (a) The Government lacks well-defined requirements at the time of Request for Proposal (RFP) issuance, and (b) When Government/contractor performance interdependencies exist, the Government must have enough solid data on its own performance to counter contractor challenges.

3.3 SLA Considerations for SOA Environments

Ideally, IT and business stakeholders must work together to define realistic service-level criteria for SOA, especially for web services (Wainewright, 2003). While traditional infrastructure SLAs typically measure "feeds and speeds," SOA SLAs will often need to measure completed events. Blending IT and business factors will require dialogue and feedback, which can be used to inform the performance measurement and management processes. While the notion of measuring up to specific technical performance benchmarks is well-established in the IT industry, the idea of defining service-level objectives in terms of business factors is less familiar. Preparing and executing an SLA in a SOA environment presents special challenges. Government organizations should follow some basic steps when they craft and manage SLAs in an SOA environment to mitigate risks associated with complexity and uncertainty (Perera, 2008).

- **Define desired outcomes:** SLAs can support an articulation of desired outcomes between business and technology sides of the organization (2008). And, it is recommended that SLAs align with the overall Concept of Operations (CONOPS). By design, an effective CONOPS will define the operational concept relative to overall objectives and will support an understanding of key interdependencies. In a SOA environment, people should consider, from the outset, alternatives to business as usual. Certainly, people can use SOA to perform the same business tasks that previous software performed, but this perpetuation can ignore the opportunities that SOA is supposed to create for flexibility and adaptability to changing business needs.
- **Match technical requirements to business needs:** Software designers must select performance indicators for technical services, including service availability, bandwidth and response times. Forrester Research uses the analogy of a consumer using an automated teller machine to explain how technical SLAs should be crafted. "It's not enough that you put your card and Personal Identification Number (PIN) [in the machine] and request to withdraw cash. There's an expectation of how fast that will happen, the level of reliability and the level of security" (Perera, 2008).

Varied business needs require different technical thresholds. A military targeting application requires the highest levels of availability, whereas a civilian data analysis tool can probably operate at degraded performance levels outside of normal working hours.

Because SOA applications have many loosely coupled services, SLAs can get complicated. For example, software designers need performance guarantees if they're going to reuse a service. In that case, a technical SLA between the service provider and the service consumer will be necessary. Each individual service might be in compliance with its technical SLA, and yet the overall application could still fail to meet its performance benchmarks. SLAs cannot be an afterthought; they should become part of the system engineering process that occurs when SOA application developers are selecting services to incorporate or reuse. "However, from a user standpoint, a SOA application should have one SLA" (2008).

- **<u>Monitor performance</u>:** A technical SLA provides information as to what performance is expected from a SOA application, but how does one know if the application meets that benchmark? DISA's Net-Centric Enterprise Services (NCES) program created a SOA framework, a structured method for monitoring all service information going back and forth. According to Computer Sciences Corporation (CSC), "The common framework captures […] service information regardless of the program or organizational entity" (Perera, 2008). "Performance monitoring is an essential step in avoiding pass-the-buck arguments about who is responsible for performance failures. Consider a scenario in which a service provider agrees to accept 10,000 consumer data queries in an hour. The consumer's service information shows that the queries are not exceeding that level, but the application isn't responding. Logs show that the consumer sent batches of 10,000 requests in ten seconds in hourly pulses, and batch processing wasn't part of the original SLA" (2008).

- **<u>Enforce the agreement</u>:** An agreement to provide service without a mechanism to penalize noncompliance is not much of an agreement. **But, this can sometimes occur with SOA SLAs.** "A user agency could say it has an SLA that guarantees performance levels, but a provider agency could argue that Congress doesn't intend for the money it appropriates to the provider agency to be used to fix another agency's IT problems" (2008). Although under various laws, notably the *Economy Act of 1933*, agencies can contract for services from another agency, the law when applied to SOA "gets into some sticky areas that are way out of the purview of IT people," said Randy Hite, director of IT architecture and systems issues at the Government Accountability Office (GAO). "It starts getting lawyers involved." Partly because of those legal and funding issues, SOA studies show that only 5% of reusable services actually are reused (2008). It's easy to find examples of organizations failing to fulfill their SLA agreements. For that reason, SLAs in the federal government are most effective within a single organization whose various parts are supported by the same source of funding. Not going outside the organization for reusable services is perceived as prudent. That constraint doesn't necessarily apply to contracting with vendors for SOA services. Government agencies can try to financially penalize a vendor for reusable services that fall short of agency expectations. However, vendors are not eager to assume extra responsibility without getting paid (2008).

4.0 A SOA SLA Governance Framework

Government agencies should consider adopting an SLA governance framework to ensure that SLAs can be as effective as possible in managing performance and achieving overall outcomes. Such a framework can help rationally manage all the individual performance agreements and monitoring activities, especially when the Government is contracting for multiple and/or complex services. SLA governance is the ongoing process of reviewing performance measures and contrasting those results to the stated goals and targets. Objectives of an SLA governance framework are to ensure that:

- Performance standards, as communicated through SLAs, provide a clear understanding of how well the contractor is achieving overall service contract goals;
- SLAs continue to describe performance deemed critical at the moment to achievement of overall outcomes;
- SLAs and performance measures are prioritized according to their importance in achieving overall outcomes; and
- All activities and surveillance are undertaken as effectively as possible in order to assess how effectively the provided services support the overall desired outcomes.

Figure 4-1 illustrates the purpose, goals, and key success drivers of an SLA governance framework.

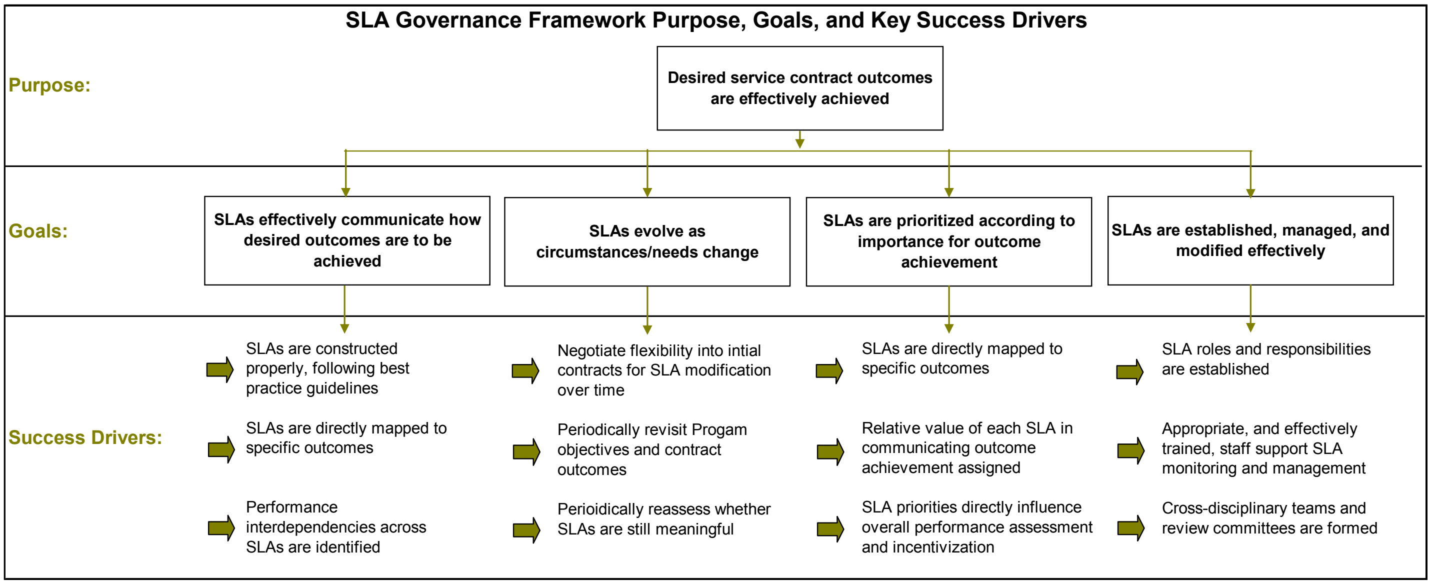

Figure 4-1. SLA Governance Framework Purpose, Goals, and Key Success Drivers

An SLA governance framework should be designed so that all SLAs currently being applied to monitor performance:

- Meaningfully describe progress toward achievement of specific outcomes in the context of overall contract objectives and in consideration of SLA interdependencies that may exist; and
- Are objectively measured at the appropriate times and continually serve as the primary mechanism for objectively determining service provider payment and incentives (both positive and negative).

The framework should assist Government leaders, contracting personnel, and Program Managers in consolidating, synthesizing, and rationalizing information related to service performance on a continuous basis—in such a way that performance status can be accurately determined at any point in time and readily translated into a robust characterization of how effectively vital outcomes are being achieved. The SLA governance framework should clearly identify key service provisioning stakeholders, their performance expectations, and if/how their performance expectations are being satisfied. The framework should enable the maintenance and improvement of service quality through a continuous cycle of agreeing, monitoring, and reporting upon service achievements and instigation of actions to eradicate poor service. To be effective, the SLA governance framework should define roles and responsibilities for performance measurement and management. The framework should also define the types of performance reviews that need to be conducted and the timing of these reviews.

SLA governance does not begin when the SLA itself is documented; rather, governance refers to managing the entire process throughout the acquisition lifecycle. The initial evaluation of current practices before the document is started, the writing of the SLA, the determination of key SLA participants and associated roles/responsibilities, the monitoring of the effort's progress, as well as the need for any changes or updates to the agreement are all part of the governance process. This framework provides guidance for those leaders within the

Government who are responsible for overseeing this process to ensure that the goals laid out in the SLA are realized. The government and service providers must manage the relationship on an on-going basis by continuously monitoring performance, changing business needs and updating benchmarks. At regularly agreed-upon intervals, the government should determine whether existing contracts need to be modified and new SLAs drafted. Figure 4-2 details the proposed governance framework and the steps included in each of the four stages—Prepare, Create, Monitor and Update.

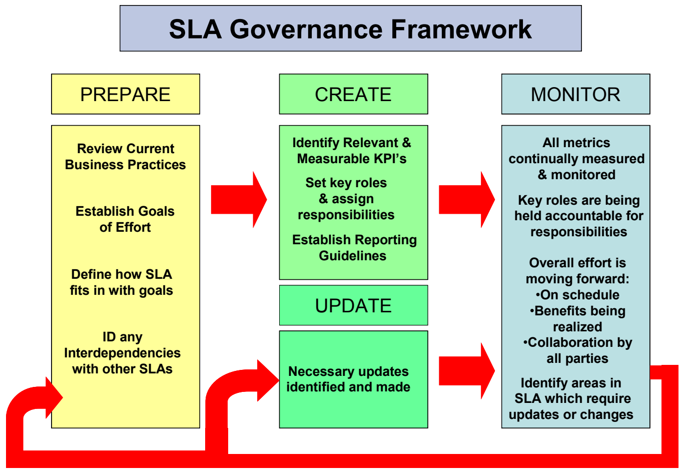

Figure 4-2. Proposed SLA Governance Framework

Essential steps to successful SLA management include:

- Define a service in understandable language. This is the service. This is what it means. This is what is supported and what is not supported. This is how it will be reported, communicated, charged.
- Understand the costs at a granular level, identifying all the different cost elements involved in the delivery of a service. This will give IT the ability to also execute improvement programs aimed at further reducing these costs.
- Price the service delivery accordingly. There will be projects in the future for which the business may not immediately see the value. So price some of the services to allow for some buffer to pay for these yet-to-be-accepted services.
- Implement differentiated charge-backs to reflect the differentiated levels of service you have on offer.
- Have regular service reviews. Reviews are a communication and marketing mechanism for IT to show to business how it is improving and helping the business. Identify what else is needed by the business through this dialogue. A feedback loop is thus created in which both business and IT are able to help each other improve ("Managing," 2007).

5.0 Conclusions

Mechanisms are currently not consistently in place within the Federal Government for programs to identify key stakeholders, quantitatively articulate stakeholder needs, and quantifiably assess, on a timely basis, whether stakeholder needs have been satisfied. The Comptroller General asks federal programs and agencies to improve performance management by:

- Comprehensively reassessing what the federal government does and how it does it; reconsidering whether to terminate or revise outdated programs or services provided.
- Reexamining the beneficiaries of federal programs; reconsidering who is eligible for, pays for, and/or benefits from a particular program to maximize federal investments.
- Improving economy, efficiency, and effectiveness of federal operations; capturing opportunities to reduce costs through restructuring and streamlining federal activities.
- Attacking activities at risk of fraud, waste, abuse, and mismanagement; focusing on minimizing risks and costs. (Mihm, 2000, July 20)

MITRE research on performance management has resulted in recommendations to: (1) apply ROI analysis principles as the foundation for more effective performance management of Government SOA, (2) create comprehensive SLAs to articulate agreements between the Government and external service providers, and (3) manage SLAs through a governance framework.

SOA involves multiple and complex participants (e.g., SOA developers, service providers, service consumers) and organizations (e.g., multiple Government organizations and commercial industry). It also involves potential uncertainty associated with future performance expectations as services are exposed through the SOA; the nature and magnitude of future demand for services will likely not be known with certainty at the outset. Careful planning must be undertaken by Government organizations to determine outcomes for multiple stakeholders and determine how those outcomes are translated to performance expectations that will be communicated to service providers.

If SLAs are applied to support on-going SOA performance management, then efforts should be undertaken to directly connect these SLAs with technical performance requirements and ultimate SOA expectations. The SLAs should be carefully crafted to ensure that flexibility for the Government to evolve performance expectations is maximized.

For SLAs to be effective, a disciplined governance process must be undertaken by sponsors to ensure that the SLAs are actually measured and monitored. On a timely basis, the SLAs should be re-evaluated to determine whether they are actually measuring something of importance and are still relevant to outcomes.

> The problem with SLAs is that once the ink has dried, the provision, monitoring, and management of these agreements can become the bone of contention between the people who are left to execute, monitor and manage the contract. The need to manage SLAs is becoming a necessity if SLAs are to achieve any semblance of success. Without management, SLAs are like cars that go wildly off a highway. You need checks

and balances to make sure that all concerned are running in the same direction and hopefully meeting all the obligations set forth in the contract. (“Managing,” 2007)

With a performance management program in place, well-written and governed SLAs support government programs and provide transparent accountability to their stakeholders. Transparent accountability can support the Government in addressing challenges associated with complexity and uncertainty.

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Appendix A. Acronyms

CSC	Computer Sciences Corporation
CONOPS	Concept of Operations
DISA	Defense Information Systems Agency
FAR	*Federal Acquisition Regulation*
FCW	Federal Computer Week
GAO	Government Accountability Office
IT	Information Technology
KPI	Key Performance Indicator
MOIE	Mission-oriented Investigation and Experimentation
NCES	Net-centric Enterprise Services
PBA	Performance-based Acquisition
PIN	Personal Identification Number
RFP	Request for Proposal
ROI	Return on Investment
SLA	Service-level Agreement
SOA	Service-oriented Architecture

Aligning Acquisition Practice with Net-centricity Policy

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Abstract

Governance is widely viewed in the SOA literature as essential to successful SOA deployments. That literature generally draws little distinction between in-house projects and those carried out by contractors. Because the relationship with contractors is negotiated and managed by the acquisition unit, this paper finds it essential that acquisition integrate the decisions of governance both into solicitation documents and the resulting contracts for outsourced development or operations. It identifies what should be in a model SOA contract, paying particular attention to specifying, monitoring, and enforcing service-level agreements and alternative dispute resolution.

Introduction

Service-oriented architecture (SOA) depends on all participants having deep and abiding trust that software components will work when invoked. Trust must be earned prior to seeing such services existing and working. Earning this trust involves clear communication of what rules are to be followed, hiring people who are capable of following the rules, providing resources to enable following the rules, monitoring that rules are followed, and taking appropriate action when they are not. The governance process is responsible for writing those rules; acquisition is responsible for integrating those rules into solicitations, monitoring compliance, and establishing resolution procedures when those rules are violated. This paper identifies some of the SOA issues that are not well-handled by traditional contracts and proposes writing a model contract that could be customized to meet the needs of individual SOA acquisitions.

Most acquisition organizations do not develop custom contracts for each acquisition. Rather, acquisition organizations reuse so-called boilerplate, which is meant to handle all the reasonably anticipatable contingencies. Since SOA introduces new problems, that boilerplate should be reworked to handle those contingencies.

This legal analysis process would be mutually beneficial for lawyers in acquisition and enterprise architects in governance. As a profession, lawyers have considerable skill in managing the risks inherent in contractual relationships between multiple parties. They identify things that could go wrong with engagements, develop procedures for how to handle those problems, and work out legal language that will stand up in court for carrying out those procedures. This is a higher level of procedural scrutiny than customarily conducted by enterprise architects. For example, while enterprise architects might simply call for service-level agreements, lawyers would spend time drafting precise terms for specifying those agreements, how the SLAs are to be monitored, what the process is for official notification of a breach, and what the remediation and/penalty is for each of the anticipated contingencies that could lead to an SLA breach.

Identifying possible problems and working out the remediation process ahead of time both prevents some problems and reduces the amount of relationship damage if a negative outcome occurs. This section identifies issues that should be dealt with explicitly, including:

- **Intellectual property retention:** Vendors should be required at contract start to identify any intellectual property (IP) claims they intend to assert associated with their service and to grant licenses for using their IP. They also need to identify any third-party IP requiring licensing that might impede usage of the service to be developed in the future. Anything else should be explicitly recognized as work-for-hire owned by the government.

  This is important for two reasons. First, many contractors are themselves using third-party COTS products with their own license restrictions. Decision-makers do not want to be in a situation where their organization is inadvertently in breach of a license purchased on their behalf. Second, vendors have sometimes asserted intellectual property rights in their own work if the contract did not make clear who owned the resulting work product. If a contractor were to claim a copyright or trade secret in contracted work (in all or part of completed work), it could lead to a dispute regarding reuse. This would be particularly problematical if the vendor were able to get a patent issued on software or process. In that case, the vendor would have a legal right to demand royalties from any company doing the same thing, even if the contract was taken away and awarded to another vendor and work product from the patenting vendor was discarded.

- **Service-level agreements (SLAs):** SLAs are widely acknowledged to be of great importance to SOA deployment. However, the literature on SLAs often leaves out much guidance on how to write them into legal contracts or what to do if one of the SLAs has been violated. When dealing with contractors, there is a need for decision-makers to distinguish between "hard" SLAs and "soft" SLAs. Hard SLAs are contractual requirements. For a hard SLA to succeed, it should be written in legally unambiguous language, with a monitoring scheme that provides clear evidence any of breaches, and provide for clear penalties in the event of breach. What are known as "liquidated damages"—fixed amounts of money—are preferred by most lawyers. SLAs should be made hard only if the performance is completely under the control of the relevant contractor, the SLA is clearly monitored for compliance, and the performance being contracted for is clearly feasible. Otherwise, it may become difficult to get qualified vendors to bid or to prove that an SLA has been violated. Unless the service was truly intended to be fail-safe, decision-makers should consider stating a hard SLA as a percentage goal restricted to expected usage hours, such as the service must be available 99% of regular office hours. Otherwise, bids by contractors may increase as they build in multiple levels of redundancy to avoid hard SLA breaches and price in 24x7 staffing. In addition, decision-makers should consider whether all users are to receive equal quality of service. Often, the organizational unit funding the development feels it has a superior claim to available capacity. There are also good reasons why different classes of users might be treated differently.

“Soft” SLAs are stated explicitly and are still monitored but have contractual commitments to work through conflict with a problem diagnosis and remediation process rather than a fixed penalty. Binding arbitration may also be considered, although it is best if both customer and contractor work in a spirit of cooperation. Because SOA applications are often composed of multiple services from multiple hosts, the process of debugging is often complex. In addition, SLA breaches are sometimes caused by events out of control of the service provider, such as a usage surge not in the contract or a change in requirements requiring additional resources. The model contract should have a comprehensive list of both kinds of SLAs thought appropriate to the organization. RFP writers should use that list as a menu to pick what is most appropriate to the problem at hand.

- **Interoperability help desk:** SOA eliminates the need to custom engineer point-to-point interfaces for new connections, which require skilled labor at both ends to establish a connection and security accreditation. While the term plug-and-play has been used in connection with a web service interface, there is no way connecting to a complex service will ever be as easy as plugging in a USB cable. Support will always be needed, but never more so than at the launch of a new service, when there is precisely nobody in the user community with experience getting the new “whatever” to work, and the draft documentation has had no feedback from the people trying to understand it**.** Ideally, there would be a tiered help desk funded to assist. Such an operation would fund retention of this expertise, reduce the amount of wasted developer time, and provide valuable feedback improving the documentation and in understanding the problems of the people using the services.

- **SOA-specific contractual deliverables list:** Development projects have contractual deliverables. These explicitly required deliverables are traditionally milestones in the development schedules which are tied to master schedules. In traditional information technology development projects, these deliverables normally include the requirements document, technical design, unit and system integration test, among others. Listed below are other contractual deliverables which are equally important in SOA environments. There are at least three good reasons to expand the list. First, what is important should be explicit in the contract, and these are very important indeed. Second, inclusion establishes formal evaluation and verification points, which are important oversight tools for acquisition and governance. Third, inclusion of these deliverables as contractual milestones enables progress payments for the vendors, which are a real incentive for timely completion. Important deliverables of special importance to SOA are:

    - **Configuration management plan:** SOA depends on all parties being able to absolutely rely on published services. This implies the existence of very tight rules on changing both the interfaces themselves and on the controlled vocabulary those interfaces use. Indeed, it may be necessary to offer multiple interface versions to the same service during transition periods. While configuration management is hardly new to SOA, it is much more mission-critical. It follows that the configuration management plan should be one of the contractual deliverables, on the general principle that if the vendor cannot develop a credible plan, it will probably have problems actually managing the configuration.

- **Controlled vocabulary:** It is crucial that the same attributes mean the same thing within the relevant domain if the service is to have the interoperability promised by SOA. Being able to exchange data is not worth much if no one knows what it means. The enhanced data dictionary that identifies all the controlled attributes and their possible values needs to be reviewed in the governance process. This dictionary will also be a vital reference document for development and testing.

- **Interoperability artifacts and service registration:** These include XML schemas, web services definition language (WSDL) messages, etc. These are supposed to vetted and entered into the services registry. These are the formal definitions of the data being exchanged and the interface to the service.

- **Independent interoperability verification:** Developed services are supposed to be usable by anybody with appropriate authorization. Interoperability tests are testing the documentation as well as the service itself, so the ideal situation is to have the testing done by an entity completely separate from the development team. It would be third parties implementing the connections in production, so this additional step would be useful and the report of the testing outcome of great interest.

- **Service user communications plan:** An important part of SOA's appeal is the prospect of avoiding development costs by reuse. Most new products and services need some kind of marketing beyond merely announcing availability on a website—or, in this case, a service registry. Careful consideration should be given to including a plan for marketing new services and communicating with the user base.

- **Service-level agreement monitoring plan:** As discussed above, SLAs are central to SOA. Decision-makers need a plan for how to monitor the service levels they decided to enforce. There are commercial products which can do automated monitoring. There should also be a channel for service users to submit a documented complaint of an SLA violation directly to the acquisition office. Ideally, the service user communications plan would include some training in how to provide useful feedback and complaints to acquisition.

- **Dispute resolution mechanism:** The default remedy for breach in contract law, as well as the *Federal Acquisition Regulations*, is to terminate the contract after giving the contractor notice and a remediation period. Firing the contractor solves very few IT problems, however. There are any number of reasons why a service-level agreement would be breached. While a vendor might actually have done something wrong, it is also possible that a component operated by another vendor failed to function properly, that demand exceeded the range specified in the contract, that the component met the contractual requirements but the situation changed, etc.

In an SOA environment, acquisition, governance, and contractors need a framework in which problems can be noted, solutions worked out, and burdens shared in accordance with responsibility. SOA calls for a shift that is as much cultural as contractual, in that different contractors and clients brought together by a problem with a complex, composed application work together to try and solve the problem first and worry about the assignment of blame and assessment of penalties later. The sharing of information about problems between firms that were direct competitors in traditional systems—but whose components have been included in complex applications—may be a particularly large cultural shift. While the exact form of the dispute resolution will be organization-specific and will vary with how governance itself is structured, careful consideration should be given to the use of such alternative dispute resolution mechanisms as binding or voluntary arbitration. Ideally, the COTR or the contracting officer would have enough technical knowledge to understand the issues and have some background in dispute resolution as well.

In conclusion, this paper finds that acquisition is the interface between acquisition and governance. It identifies new issues SOA brings and suggests developing a model contract that explicitly addresses these concerns. It also recommends a more nuanced dispute resolution procedure that focuses more on problem solving and less on punishment.

Panel 14 - Tools for Acquisition Program Design

Thursday, May 14, 2009	Panel 14 - Tools for Acquisition Program Design
11:15 a.m. – 12:45 p.m.	**Chair: Mark D. Rocke**, Deputy Assistant Secretary of the Army (Strategic Communications & Business Transformation) **Discussant: Keith E. Seaman**, Director, Defense Business Systems Acquisition Executive ***Acquisition Strategies to Deal with Uncertainty*** **Renee Stevens, Margaret King** and **Marc Halley**, The MITRE Corporation ***Simulation-based Decision Support for Acquisition Policy and Process Design: The Effect of System and Enterprise Characteristics on Acquisition Outcomes*** **Doug Bodner, Robert Smith** and **Bill Rouse**, Georgia Institute of Technology

Chair: Mr. Mark D. Rocke was selected to the Senior Executive Service in January 2008. He leads the strategy development, communications, Congressional relations, and overall business transformation processes within the Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology.

Rocke champions the effort to create and assess the execution of strategy for the broad acquisition community guided by or supported by his office. This work involves establishing enterprise-level strategic and programmatic direction, reporting on organizational goals, and contributing to the determination of Army and Defense priorities. His team is responsible for promoting understanding and building support for over 650 Army weapons systems and acquisition programs. In support of this objective, Rocke designs relationship-building events to enable interaction with key stakeholders and groups. He and his team perform legislative analysis to support hearings on posture, readiness, and acquisition matters. His team also manages the full scope of Congressional activities and tracks progress relative to authorizations, appropriations, legislative proposals, and objectives. In addition, Rocke directs his office's Business Transformation efforts intended to enhance overall organizational effectiveness and productivity amidst increasing fiscal constraint. In this capacity, he serves as Deployment Director for Continuous Process Improvement and the Lean Six Sigma methodology.

Discussant: Mr. Keith E. Seaman is the Business Transformation Agency's first Deputy Director, Defense Business Systems Acquisition Executive (DBSAE). In this role, Seaman provides operational analysis and advice to the DBSAE in executing Milestone Decision Authority responsibilities for DoD Enterprise-wide business systems within the BTA portfolio of systems. He is responsible to the DBSAE for planning, executing and monitoring the DBSAE portfolio of programs and initiatives.

Prior to joining BTA, Seaman served as a Command and Control (C2) Modeling and Simulation (M&S) Senior Advisor at the Secretary of the US Air Force's Office of Chief Warfighting Integration and Chief Information Officer. In this role, Seaman served as the US Air Force's recognized authority in the areas of M&S C2, and he worked to enhance mission planning, distributed mission operations and multi-disciplinary technology integration in order to rapidly respond to priority combat capability requirements. His leadership both delivered a dynamic, live, virtual and constructive environment to elevate warfighter readiness, as well as accelerated acquisition and development of emerging warfighter capabilities.

Seaman also served as Chief, Operations Integration Division in the Operations Directorate at the US Transportation Command, where he led an operational division responsible for the command's Defense Transportation System portfolio management and advanced new Enterprise-wide information technology initiatives. He oversaw the operational process requirements definition and directed a multi-million dollar information technology initiative that included the development of the Global Transportation Network Integrated Data Environment, Single Mobility System, Agile Transportation for the 21st Century, Operations Knowledge Wall/Dashboard and the futuristic Single Operating Environment for Transportation.

Seaman retired as an officer from the US Air Force after 27 years of service. During his military career, his experience spanned across diverse disciplines—including intelligence, fighter operations, arms control, production management, planning, policy and operations.

Seaman graduated from Cameron University with a Bachelor's degree in Financial Business Management. He completed his Master's of Middle East Studies at Southwestern Baptist and his Master's in National Resource Strategy at National Defense University's Industrial College of the Armed Forces.

He is married to the former Miss Elk City, Colleen Denty. Their daughter Christine is attending medical school.

Acquisition Strategies for Dealing with Uncertainty

Presenter: Renee G. Stevens is a Senior Principal Engineer at The MITRE Corporation and a founding member of MITRE's Advanced Systems Engineering Center. She has 30 years of experience in the analysis, engineering and acquisition of large-scale systems, primarily for the Department of Defense and other government agencies. Stevens is the author of a forthcoming book on engineering of large-scale mega-systems. She received her Bachelor's degree from Hunter College, City University of New York, and a Master's degree from George Washington University. She is a member of the Institute of Electrical and Electronic Engineers and the Academy of Management.

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Abstract[1]

The acquisition and engineering of large scale, complex information systems, particularly those that transcend organizational and functional boundaries, represent well-recognized challenges. The processes and procedures that evolved during the second half of the 20th century are best suited for the development of linear, well-bounded systems. These processes have proven difficult to adapt to situations in which stakeholders do not always agree, requirements evolve, and constraints keep changing. Different processes and procedures are needed to address the acquisition and engineering of information technology systems with evolving requirements and rapidly changing technologies.

This paper is based on the results of a multi-year research program that investigated how uncertainty-based acquisition methods can be used to improve the odds of successful IT acquisitions. The paper presents new concepts for managing uncertainty in acquisition programs: the uncertainty landscape, uncertainty driven acquisition strategies (staged commitment, small bets), the Y model, and a three-step approach to implementation (i.e., diagnosis, strategy selection, and adaptive execution). More than 20 acquisition programs were studied, and pilot programs were initiated to test the frameworks and strategies suggested in the research.

I. Introduction

Traditional systems engineering and acquisition practices evolved during the second half of the 20th century primarily to deal with the particular challenges of developing large-scale weapon systems. These systems are expected to have long service lives, often measured in

[1] MITRE Public Release: 09-1310

decades, and typically require development and harnessing of unique, breakthrough technologies. Because of these challenges, development occurs over a multi-year period before these systems enter production. Changes late in development or in production directly contribute to cost and schedule overruns. Consequently, once the design is completed, there is strong resistance to change, and rightfully so. The ideal situation for these types of programs is one in which requirements remain relatively stable and critical technologies mature over the course of the development period (Stevens, forthcoming). Related to this, there is growing Congressional emphasis on better up-front planning and governance practices that focus on controlling deviations from the plan (Levin & McCain, 2009).

Information technology (IT) systems, particularly those that provide user-facing applications, pose different challenges. These systems are often intended to operate in highly volatile environments and, thus, are subject to changing user needs and expectations. In the most volatile environments, the effective life of IT systems can be measured in weeks to months rather than years. Development and acquisition tempos have to be responsive to such urgent and short-lived needs. Further, these systems often leverage commercial technologies that are also rapidly evolving. Unlike weapons systems in which change is rightfully something to be controlled, for many information technology systems, change is inevitable and must be accommodated. For these systems, there is a risk that requirements are locked in too early and may not be responsive to legitimately changing user needs and that technologies become outdated while the system is still in development.

Traditional processes and procedures are best suited for the development of linear, well-bounded systems and have proven difficult to adapt to situations in which stakeholders do not always agree, requirements evolve, and constraints keep changing. Different processes and procedures are needed to address the acquisition and engineering of IT systems, particular those with evolving requirements and rapidly changing technologies.

Current systems engineering and acquisition practices that are optimized to deal with the unique challenges and risks in the development of weapon systems do not provide the flexibility and agility needed to deal with the uncertainties inherent in many IT systems acquisitions. A tailored approach to IT acquisition that explicitly acknowledges the inherent uncertainties and provides the necessary flexibility is required.

The challenge of developing and acquiring IT-based systems more rapidly and with greater agility complements and does not supplant the very real and widely recognized challenges of developing and acquiring weapon systems. In fact, Dr. Ashton Carter, recently confirmed Under Secretary of Defense for Acquisition, Technology and Logistics, in reply to advance questions from the Senate Armed Services Committee, pointed out these two challenges:

> A first major challenge is to ensure that AT&L is supporting the war effort through rapid acquisition of systems our soldiers, sailors, airmen, and Marines need in Iraq, Afghanistan, and in the war on terror …. A second major challenge is to get under control the many troubled acquisition programs that are supposed to be supporting our forces—both today and tomorrow. Too many of these programs are failing to meet their cost, schedule, and performance expectations, and some are failing even more fundamentally the test of whether they are needed for the future military challenges we are most likely to face. In addition to disciplining these programs, reform of the acquisition system is needed to ensure that we do not get ourselves in this position again in the future. (Carter, 2009)

This paper reports on research conducted by The MITRE Corporation to examine alternative acquisition strategies and practices for IT systems under varying conditions of uncertainty. Alternative strategies, tailored to an understanding of the nature and extent of uncertainty faced by the program, are proposed.

The paper is organized as follows:

- Section I introduces the need for new acquisition approaches for uncertainty.
- Section II discusses the regulations that permit flexible acquisition approaches.
- Section III describes the three phases of this research program.
- Section IV highlights the key research findings, including an uncertainty landscape and strategies for dealing with uncertainty.
- Section V describes a three-step approach for implementing the strategies.
- Section VI introduces a model to describe implementation drivers, enablers, and barriers. Section VII summarizes the acquisition and systems engineering implications of this research.

II. Regulations Support Tailoring Acquisition Practices

Language in federal acquisition regulations specifically encourages the acquisition team to institute innovative practices tailored to the particular needs and circumstances of the program. In particular, the *Federal Acquisition Regulation (FAR)* Part 1.102: Statement of Guiding Principles for the Federal Acquisition System states:

> (d) The role of each member of the Acquisition Team is to exercise personal initiative and sound business judgment in providing the best value product or service to meet the customer's needs. In exercising initiative, Government members of the Acquisition Team may assume if a specific strategy, practice, policy or procedure is in the best interests of the Government and is not addressed in the *FAR*, nor prohibited by law (statute or case law), Executive order or other regulation, that the strategy, practice, policy or procedure is a permissible exercise of authority. (GSA, 2005)

Similarly, *DoD Instruction 5000.02* Section 1, Defense Acquisition Management System (USD (AT&L), 2008) states:

> b. Consistent with this Instruction and Reference (b), the Program Manager (PM) and the MDA shall exercise discretion and prudent business judgment to structure a tailored, responsive, and innovative program.

Despite regulations that allow flexible acquisition methods, there is little guidance on what these methods should be. This research was undertaken to identify particular methods.

III. Research Approach

The research explores strategies and methods for managing uncertainty and offers opportunities to address federal IT acquisition challenges. The objectives of the research are to determine: (1) how best commercial practices for dealing with uncertainty can be adapted to federal IT acquisition, (2) under what circumstances might they work and make a difference, and (3) what needs to change to make it happen. Research activities are organized into three phases as illustrated in Figure 1.

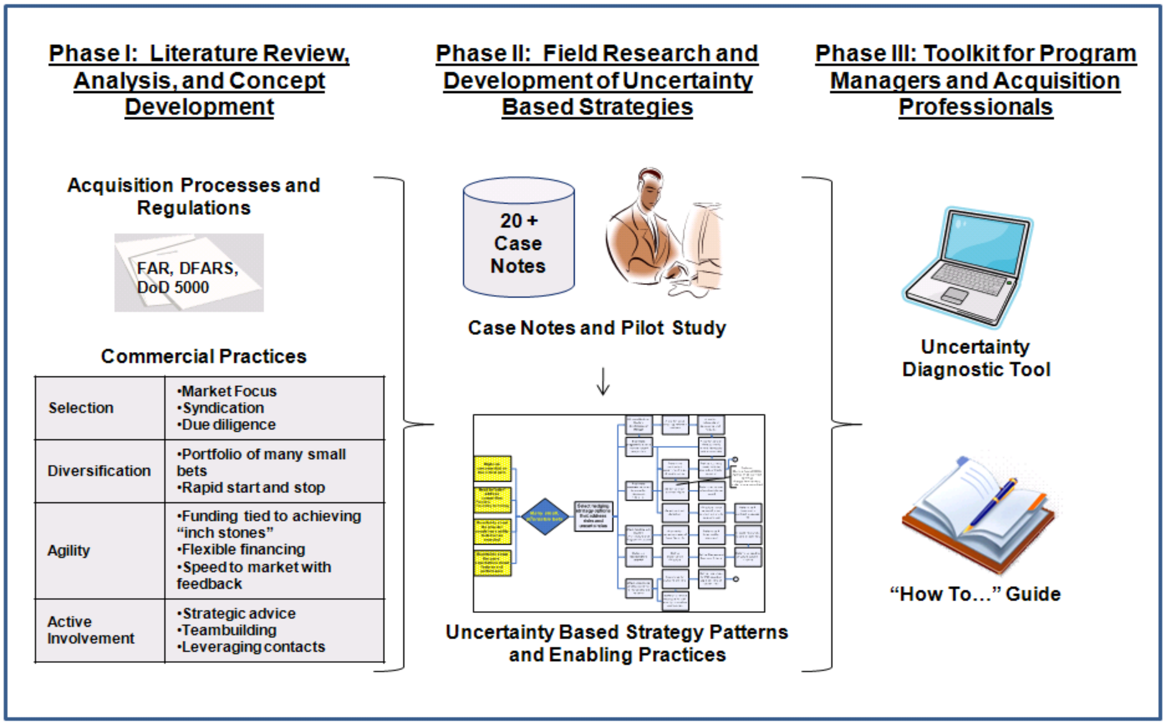

Figure 1. Three Research Phases

Phase I

Phase I of the research characterized and compared commercial entrepreneurial (McGrath & MacMillan, 2000) and federal acquisition environments and methods to develop a research framework to assess the nature and level of uncertainty within an acquisition program. The research was based on literature reviews and analyses of federal acquisition processes and regulations, as well as interviews with venture capitalists, entrepreneurs, government program and project managers, and acquisition, contract, and budget specialists. The concepts and frameworks were refined based on discussions with commercial entrepreneurs, government specialists, and academicians.

Phase II

Phase II developed and detailed alternative acquisition strategies for dealing with uncertainty and initiated field research. The field research was an embedded multiple-case study (Yin, 2002) and included data from more than 20 programs from 12 government agencies responsible for the acquisition of information intensive systems. Working from an interview protocol, the research team collected information on the programs' acquisition, development, contract, incentive, and governance strategies. The case notes provided input for identifying acquisition strategies for dealing with uncertainty and for exploring the motivators, enablers, and barriers to innovation in acquisition practice. A pilot study with an active acquisition program was initiated in Phase II to test and validate the strategies proposed in the research.

Phase III

Phase III focused on synthesizing, validating, and communicating the research. Research findings were captured in an interactive diagnostic tool and a "How to Guide" for program and project managers and key members of the acquisition team. A model for assessing an organization's readiness to implement uncertainty-based strategies was then developed.

IV. Research Findings

Acquisition Uncertainty Landscape

IT acquisitions face both internal and external uncertainty. Within a typical acquisition, the team faces internal uncertainties in design, implementation, and performance. Even though the members of the team have had similar experiences, there are still many new aspects to address. The team can be uncertain about how to design the system, how to optimize the implementation, and how well the system will meet functional and performance requirements.

A typical acquisition also encounters even more challenging external uncertainties. These include changes in the:

- Operational environment, threat or mission,
- Business processes, governing policies and regulations,
- User requirements and expectations,
- Priorities,
- Competitors (including user-initiated efforts),
- Technologies, and
- Stakeholder actions and influence.

Internal and external factors translate into two critical dimensions of uncertainty: uncertainty about what to build and uncertainty about how to build it. Figure 2 describes an acquisition uncertainty landscape based on two key dimensions of uncertainty: evolving requirements and emerging technologies. In the lower left hand corner of the figure, requirements are relatively stable, and technologies are mature. This indicates less uncertainty and, therefore, more predictability in the execution and outcome of the program. Program/project managers know more clearly what needs to be built and the appropriate approach to building it. A traditional acquisition approach often works well in this predictable area of the landscape.

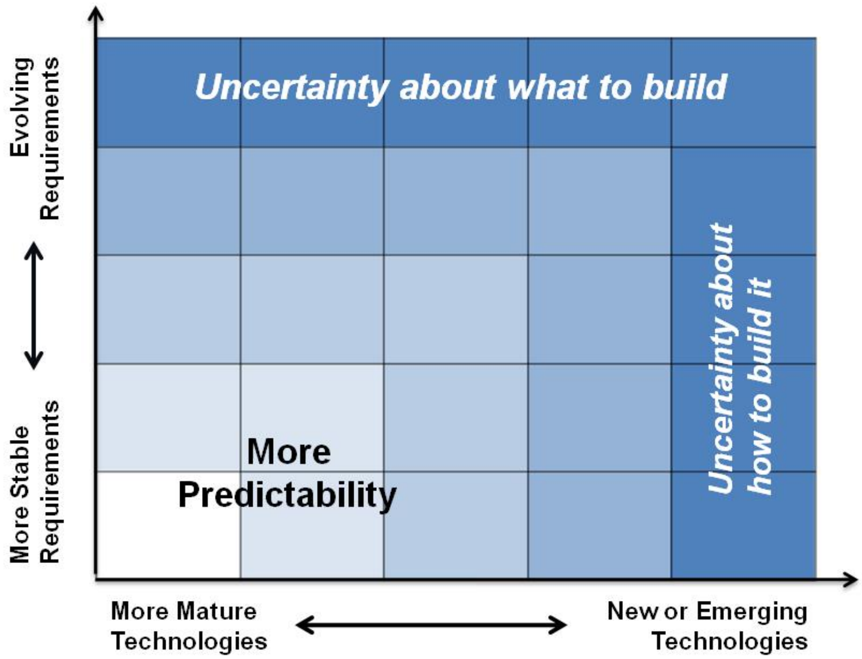

Figure 2. Acquisition Uncertainty Landscape

Farther away from the lower left hand corner, evolving requirements and emerging technologies introduce more uncertainty. The traditional approach of locking down requirements early and following a waterfall development effort do not work as well. Acquisition strategies must expect and accommodate change and build in the flexibility for dealing with uncertainty.

A basic premise of this research is that IT acquisition must take into account a program's position on the uncertainty landscape. Acquisition strategies should be selected depending on the nature and scope of the underlying uncertainties. In addition, not all parts of a program demonstrate the same type and degree of uncertainty. For example, development of the basic infrastructure may be more predictable and fall in the lower left hand quadrant of the landscape, while user facing services are often closer to the upper right hand quadrant due to changing user expectations and new technologies.

As shown in Figure 3, the various components ("chunks") of a program may belong in different locations on the uncertainty landscape. Therefore, not all parts of a program have the same need for flexibility. It is useful to envision the components of a program as constituting a portfolio. The core elements of the portfolio are those that are more predictable and can be managed using a classic approach, while the more uncertain components require a more flexible strategy.

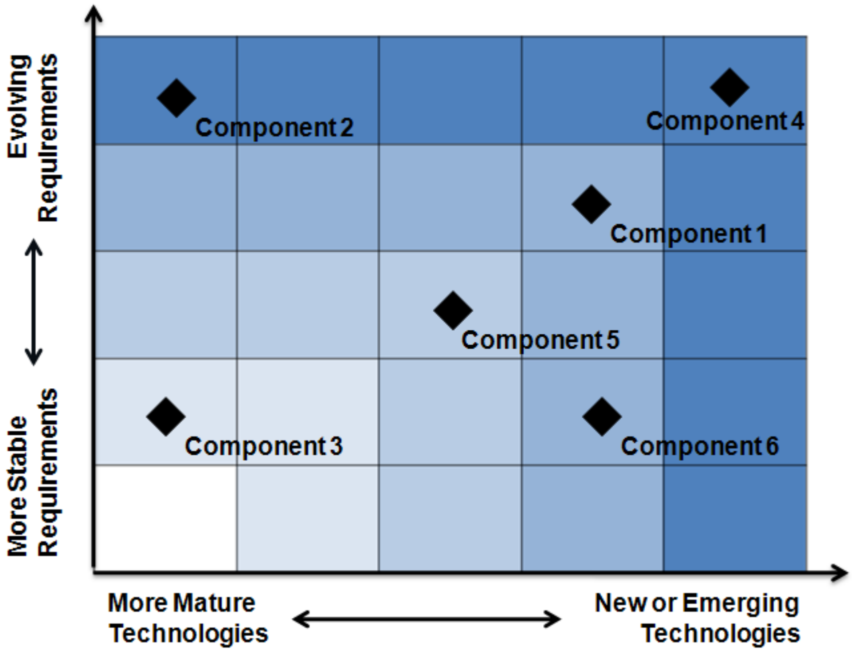

Figure 3. Mapping Program Components on the Acquisition Uncertainty Landscape

Strategies for Dealing with Uncertainty

This research found that different strategies are appropriate for different levels and types of uncertainty. A plan-driven strategy works best when requirements are primarily stable and technologies are mature. As illustrated in Figure 4, staged commitment and small bets strategies are more appropriate for components facing uncertainty about what to build and how to build it, respectively. These findings are consistent with earlier research in project management (Loch, DeMeyer & Pich, 2006), product development (Smith, 2007) and venture capital (Gompers & Lerner, 2001: Stevens, King & Halley, 2008).

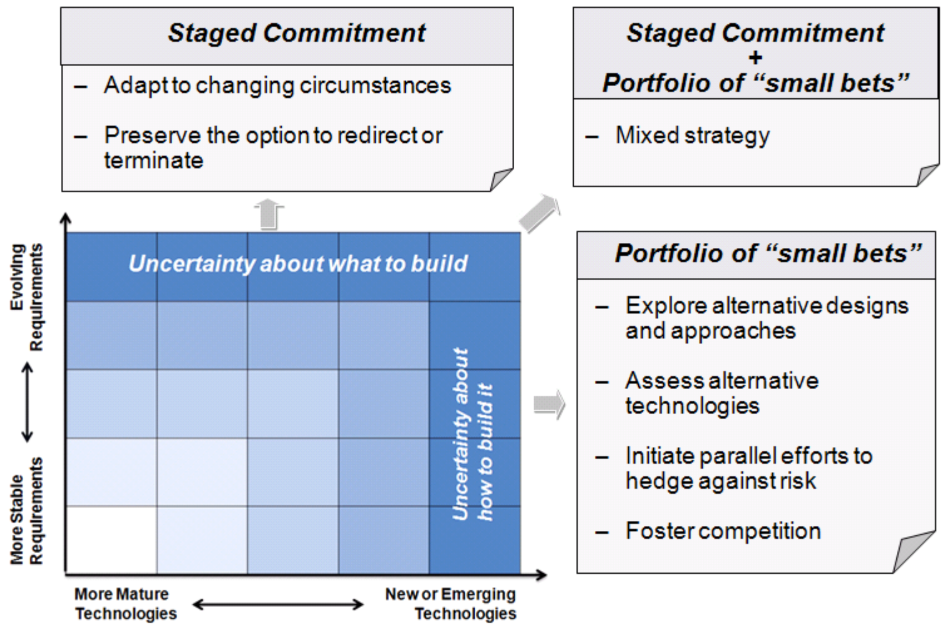

Figure 4. Strategies Used to Manage Uncertainty

The following paragraphs outline three strategies for different areas of the Uncertainty Landscape.

Strategy 1: Plan-driven

When there is little uncertainty in requirements and technology, a program/project manager can successfully use the traditional Plan-Driven Strategy. This traditional method consists of defining a set of requirements, design, cost, and schedule, and then carrying out the associated plan. Since there should be little need to change, progress is measured against the plan, and success is determined by how closely cost, schedule, and requirements goals are met. Project management techniques, such as Earned Value Management (EVM), have been developed to measure execution against the plan. This plan-driven method has been successfully used for years when there is little doubt about what is needed and how to satisfy it. Where risk is present, program/project managers use well-recognized risk management techniques. The idea is to "make a plan and execute to the plan."

Strategy 2: Staged Commitment

When there are rapidly evolving requirements and uncertainty about what to build, a program/project manager can follow an iterative, learning strategy and manage the project by staged commitment. In a staged commitment approach, the acquisition is structured so that funding and payment decisions are made based on small increments of demonstrable capability. Staged commitment enables the program/project manager to scan the environment, assess uncertainty at each stage, and adjust the direction appropriately. The approach preserves the option to re-baseline, re-direct, or terminate the effort if market conditions have changed, priorities have shifted, or the contractor is not delivering as expected.

A staged commitment strategy is warranted when there are uncertainties in the mission, business environment, or user expectations about particular features or performance. In addition, a staged commitment strategy is desirable when there are uncertainties about a provider's ability to achieve agreed-to objectives. Deliverables at each stage are concrete and can involve either early prototypes or small increments of delivered capability. They can be periodically evaluated using feedback from intended users and other critical stakeholders. From a contracting standpoint, staged commitment can be accomplished through such mechanisms as shorter duration contracts/task orders, with renewal options.

Strategy 3: Small Bets

When there are new or emerging technologies, program/project managers can apply a small bets strategy. In a small bets strategy, parallel efforts are initiated to determine technical solutions and a way forward; the pharmaceutical industry makes particular use of this method (Eliasberg & Ding, 2002). Simultaneous, parallel mini-projects are initiated, each one with a different design approach. The projects are completed, and the design with the most successful outcome is adopted. In this way, many design alternatives can be assessed by field trial and experimentation.

"Small bets" strategies are used to:

- Explore alternative designs and approaches to implementation
- Assess alternative technologies
- Initiate one or more parallel activities for high-risk components on the critical path with the understanding that there will be a down-select decision2
- Foster competition
- Hedge against the risk of failure of one contractor/provider or solution

An IT program using small bets should be one that can be structured into small, concurrent increments that can each be developed and acquired independently and subsequently integrated. One critical method to enable a small bets approach is the creation of contract flexibility, which supports key decisions to modify the acquisition strategy efficiently and with controlled impact to cost and schedule**.**

Figure 5 illustrates sample strategies and compares the more traditional approaches of "one big bet" and "one bet with learning" with variants of "small bets." The small bets strategies included in Figure 5 are:

- Design fly-off: Multiple designs are initiated with a competition to select the best design. The winning design is then carried through to the end of the project.
- DARPA model: Multiple prototypes are carried forward in parallel through design, implementation, and field test. Only the winner is carried into operations.
- Two-button model: Multiple systems are presented to the user. The marketplace then decides which system best fits their needs, rather than the development team.

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[2] This is often initiated during design or early prototyping but can also be used downstream if the program encounters design or contractor/solution issues.

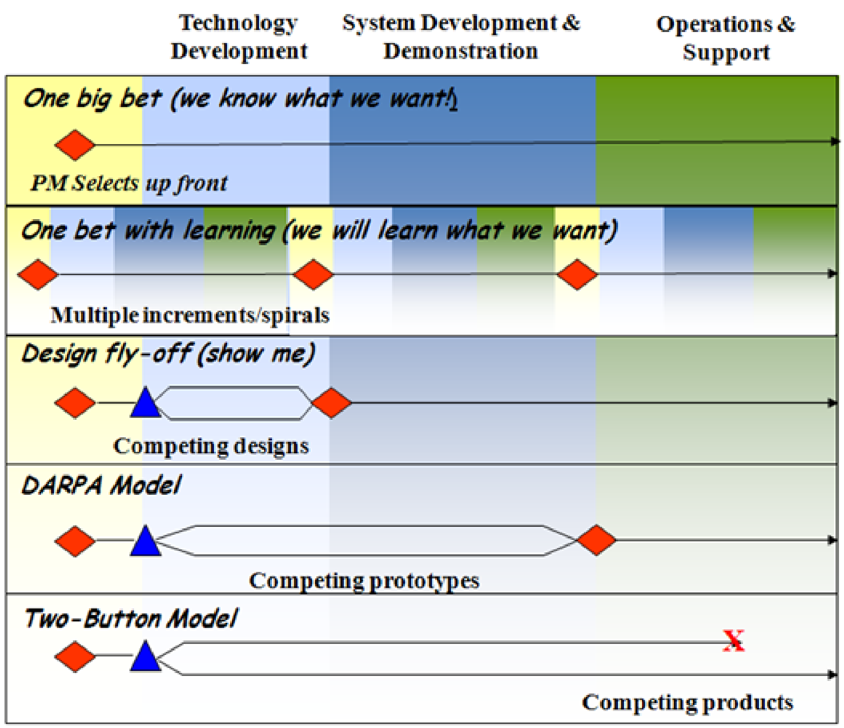

Figure 5. Variants of Small Bets

When both requirements and technology uncertainties exist, the program/project manager can use a combination of staged commitment and small bets strategies. Under these circumstances, the program/project manager could incrementally commit to requirements, and within each increment, initiate alternative designs to reduce technology risk.

V. Implementation: A Three-step Approach

Programs that are the most likely candidates for implementation of the alternative practices introduced above are those that:

- Are initiating a novel endeavor that demands a different approach,
- Have attempted to use traditional strategies, sometimes more than once, and found that they proved to be unsuccessful, and
- Anticipate considerable uncertainty and volatility either in terms of requirements and/or enabling technologies.

These circumstances provide the necessary motivation to try alternative strategies. In addition, the program/project manager must be willing to try these non-traditional practices, and the organization must be willing to support the effort. In effect, senior management must provide the necessary encouragement and "top cover." Finally, the program must lend itself to being structured into small increments that can be developed and acquired independently and subsequently integrated to yield the desired capability.

The implementation approach is organized into three steps (Figure 6).

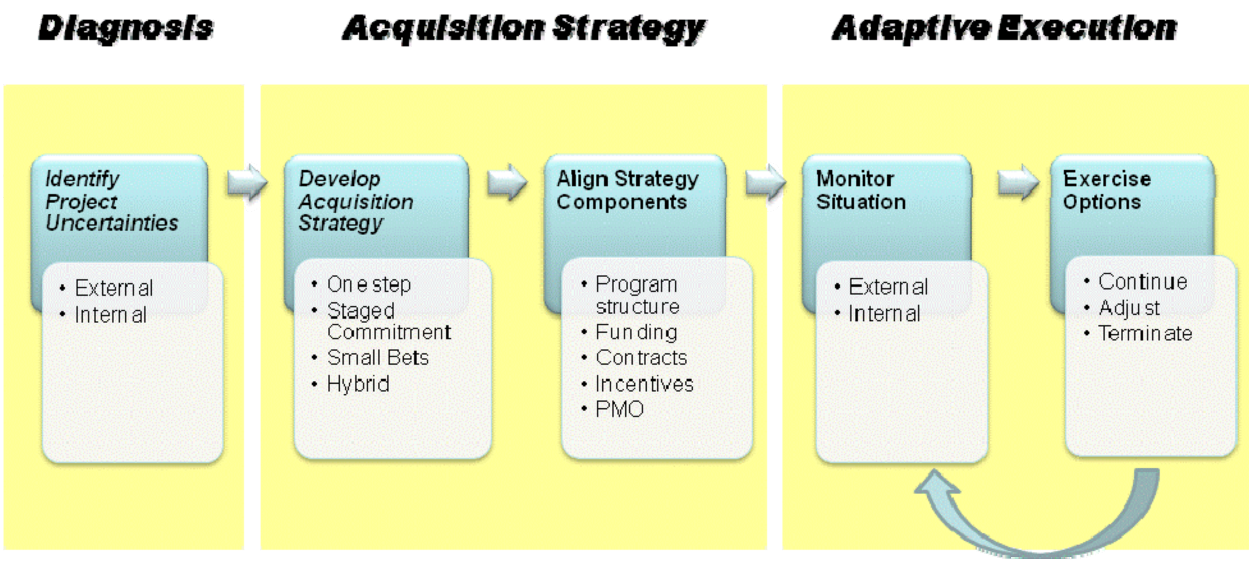

Figure 6. Three-step Approach to Implementation

Step 1: Diagnosis

The diagnosis step is used to determine which parts of the program are subject to uncertainty, as well as the nature and magnitude of the uncertainty. The underlying premise is that uncertainty is not distributed evenly. Different parts of the program face different sources and levels of uncertainty. Examples of uncertainties that may be faced include:

- Changes in the mission environment or underlying business process that result in changing user needs and/or expectations,
- Uncertainties about user expectations and user acceptance of particular features and/or levels of performance,
- The pace of change of the enabling technologies,
- Uncertainties about the ability of providers to achieve agreed-to objectives within the time and resource constraints,
- Items that are on the critical path for which risk-hedging strategies are warranted, and
- Desire to foster competition of ideas, approaches and/or technologies.

The diagnosis step maps each of the relevant project components onto the uncertainty landscape and suggests strategies that may be suitable based on the nature and degree of uncertainty. The research effort has developed an interactive tool to assist in conducting the diagnosis. Figure 7 provides an example output of the diagnosis step for one of the case studies in this research. (Note: the project name is disguised for anonymity).

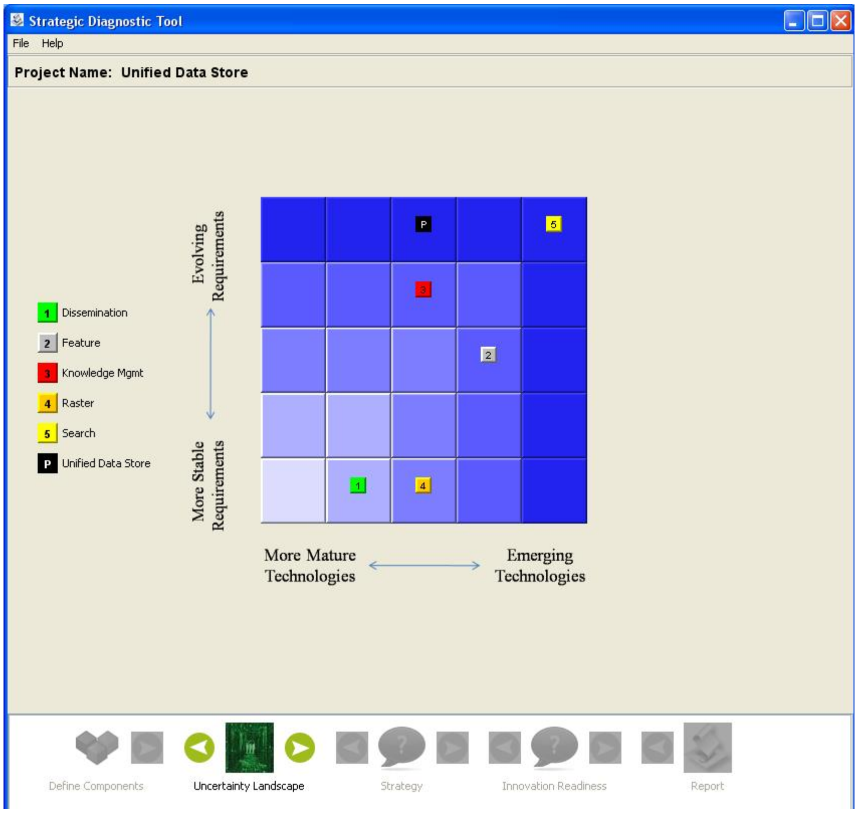

Figure 7. Example Diagnostic Output

Step 2: Select and Implement the Acquisition Strategy

In this step, the program/project manager plans for and implements the selected strategies to provide a set of options that can be exercised as situations warrant. In order to preserve the flexibility to respond to potential uncertainties, conditions have to be built in early in the planning phases of the project. These conditions address program structure, funding, contracting, and contract/contractor performance. In both the staged commitment and the small bets strategies, the project uses a modular system design and lends itself to modular development. An overarching architecture is critical to defining the components, their relationships, and interactions enabling their integration.

The enabling conditions for the staged commitment strategy include:

- **Development approach**: Adopt an agile or spiral development approach to delivery of capability.
- **Funding**: Align funding with the system architecture and project structure. Arrange for payments to be made based on achieving user needs in increments of capability.
- **Contracting**: Structure contract vehicles to allow for incremental periods of performance (modular contracting), including the options for rapid termination, if and when needed.
- **Contract/contractor performance**: Emphasize outcomes (capability delivered).
- **Incentives**: Structure contractor award to delivery of capability—reflecting user feedback.

The enabling conditions for the small bets strategy include:

- **Development approach**: Adopt a modular-based acquisition strategy.
- **Funding**: Provide fiscal flexibility to support establishments of parallel activities as needed.
- **Contracting**: Structure contract vehicles to allow for competitive parallel developments.
- **Contract/contractor performance**: Define business model to foster desired contractor behavior.
- **Incentives**: Structure contractor award to delivery of capability—reflecting user feedback.

These strategies place greater emphasis on initial and recurring trade-space assessment that address not only cost, schedule and performance but also affordability, responsiveness to changing needs, capability delivered, and interoperability with other internal components and external systems. For such strategies to be effective, and not overly costly, there is a need to:

- Limit documentation to what is necessary,
- Find more cost efficient ways to evaluate working prototypes and early capability increments,
- Implement a "light-weight" governance process for small increments and a more traditional governance process for major milestones, and
- Encourage competition to get better products, sooner, at lower cost.

Step 3. Adaptive Execution

The program/project manager who must operate in the today's uncertain environment requires a degree of flexibility to make informed decisions and to adapt to changing circumstances. Laying the groundwork in the acquisition strategy is critical. So, too, is the ability to continuously monitor the situation to identify changes in demand, priorities, the delivery of products, and the "fit" between the product delivered and user expectations. If the program/project manager views and manages the program as a portfolio of interconnecting components, he or she is prepared to rebalance the portfolio as warranted. This includes redirecting, accelerating, slowing, or terminating future increments and initiating risk-hedging initiatives.

VI. Drivers, Enablers, and Barriers to Adopting Uncertainty-based Strategies

Although the strategies proposed in this paper for addressing uncertainties in IT acquisition are supported and encouraged by statute and regulations, in some instances these strategies may be viewed as non-traditional and meet with resistance. To assess an organization's readiness to implement uncertainty-based strategies, the diagnostic tool includes a framework for program/project managers and acquisition professionals to assess whether there is "fertile ground" for implementing the proposed strategies. Will the strategies be successfully adopted or challenged by long-standing practices and culture?

Throughout the field research, the team observed several motivators, enablers, and barriers to trying a new acquisition approach. The findings in the case notes and the extensive literature on innovation provide the basis for a model of innovation readiness. The "Y" Model (named because of its shape) is illustrated in Figure 8.

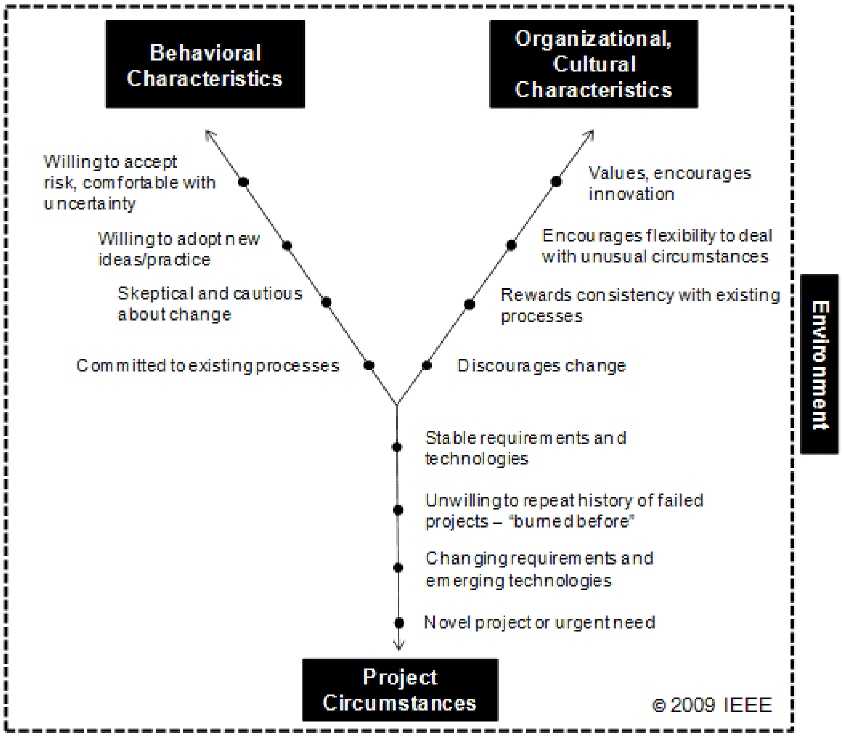

Figure 8. "Y" Model of Innovation Readiness
(Stevens, King, Beard & Halley, 2009)

The three dimensions of the "Y" model portray a range of individual behavioral characteristics, organizational/cultural characteristics, and project circumstances. A program is plotted on the model, and the resulting triangular shape suggests the degree of alignment between the need to implement alternative practices and the ability and willingness of the organization to do so.

The project circumstances dimension of the model was developed primarily from information gathered from the case notes research. The project circumstances are often the motivation for trying an innovative acquisition approach. Project circumstances that may serve as drivers for innovation include:

- The program is trying something novel that necessitates an innovative acquisition strategy.
- The program is responding to a critical or urgent need.
- The program is dealing with rapidly changing circumstances or threats.
- The program has run into difficulties before (in some cases, two or three times) and wants to try a different approach.

The behavioral characteristics and organizational/cultural characteristics dimensions of the model were developed primarily from the literature on innovation (Rogers, 2003) and organizational change (Kotter, 2007; Schein, 2004; Holt, Armenakis, Harris & Field, 2007). The individual behavior and organizational dimensions of the model form the upper arms of the Y. Points that are farther out on the vectors represent a greater willingness to accept innovative acquisition approaches.

A mapping of the programs studied in the field research on the "Y" model highlights some interesting patterns. Figure 9 illustrates a project that maps to the outer points on each vector. In this instance, the project was developing a novel capability—the project leader was comfortable with uncertainty and willing to accept risk, and the senior leadership of the organization was supportive and willing to provide "top cover." This is an example of an aligned project.

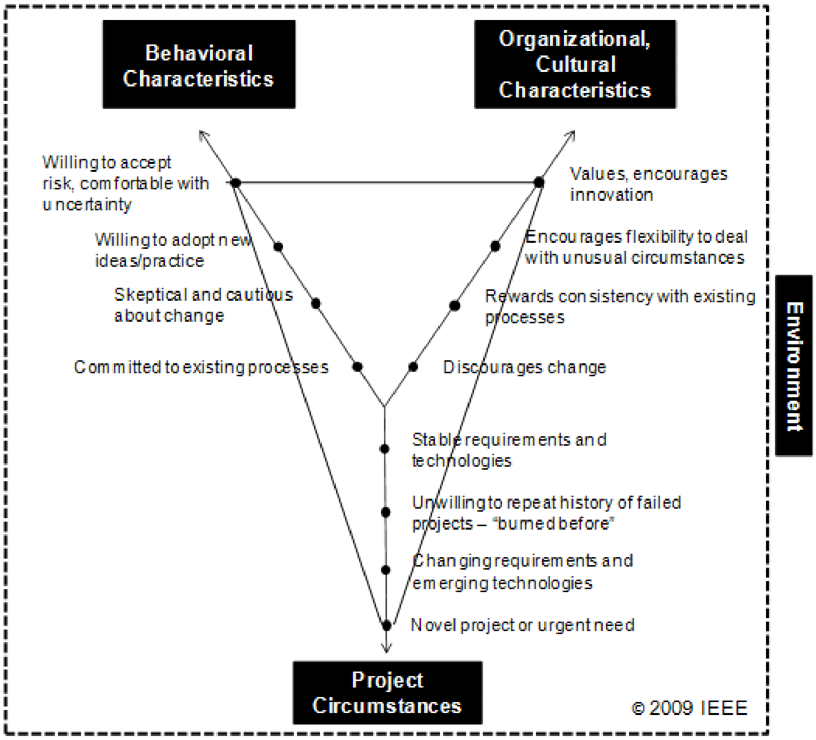

Figure 9. Examples of Aligned Project
(Stevens, King, Beard & Halley, 2009)

Figure 10 provides an example of a misaligned project. In this case, the project was developing a capability that was fundamentally new to that agency, and the project leader was interested in implementing acquisition strategies that were considered to be innovative in that environment. However, higher-level management in that agency actively discouraged change.

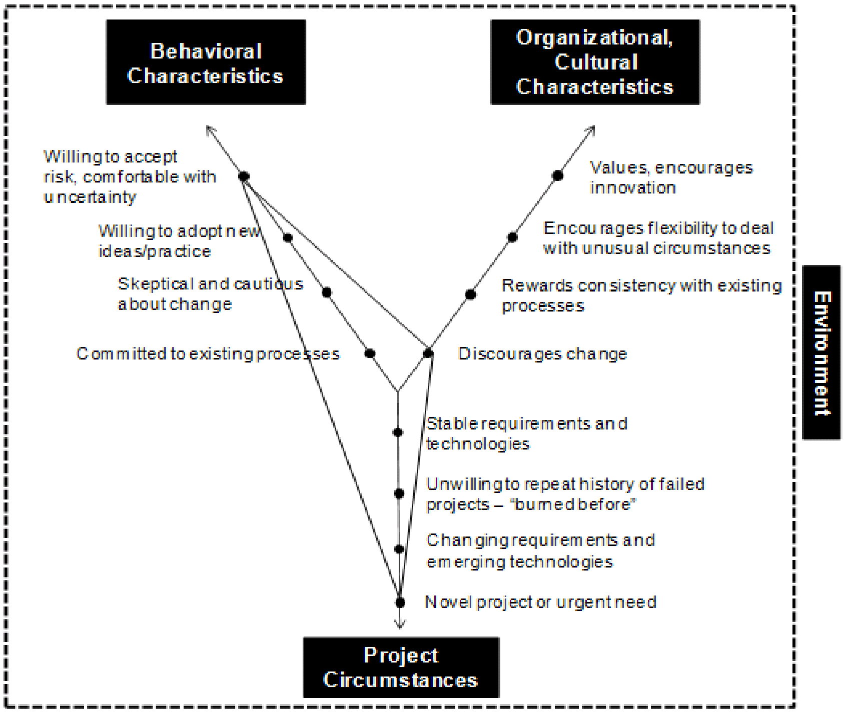

Figure 10. Example of a Misaligned Project

Plotting the overall program and components of the program on the "Y" model can provide an early visual indicator of potential roadblocks to uncertainty-based strategies. A misaligned mapping helps focus attention on the areas that need to be addressed up front when implementing innovative strategies. The areas of concern can become part of a risk-mitigation plan.

A word of caution is warranted. While this model arose from field research observations and is supported by a rich body of literature (Holt et al., 2007), it is still a work in progress. Much of the literature focuses on the commercial and education sectors, not on acquisition practices in the federal government. Follow-on research will be required to refine and validate the model and extend its granularity.

VII. Conclusion

The research effort is an ongoing study of acquisition strategies suitable for dealing with uncertainty, particularly as it applies to IT acquisitions in the federal government. The primary products of the research are an interactive diagnostic tool as well as a *How to Guide* that provides actionable recommendations for program and project managers and acquisition professionals that wish to implement these strategies.

Key to the successful implementation of these strategies is a perspective that allows the program/project manager to:

- Understand that different parts of the program face different types and degrees of uncertainty and urgency,

- Be prepared to tailor acquisition strategies, picking a staged commitment strategy in which there are uncertain or ambiguous requirements and a small bets strategy to hedge against risk or foster competition,
- Balance the need for agility and discipline, applying discipline in executing the current increment while being agile and adaptive in adjusting subsequent increments to changing needs, priorities and evolving technologies,
- Recognize that while statute and regulations encourage flexibility and innovation, non-traditional acquisition approaches are often challenged by long-standing practice and culture,
- Seek an active partnership with the end user and "top cover" within the organization, and
- Strive to implement a culture that emphasized outcomes, "time to value" and responsiveness.

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Simulation-based Decision Support for Acquisition Policy and Process Design: The Effect of System and Enterprise Characteristics on Acquisition Outcomes

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Abstract

Effective acquisition programs, in terms of cost and capability outcomes, are increasingly important in today's cost-constrained environments. Thus, it is important to have effective decision support for acquisition policy and process design. This paper discusses a simulation-based approach for decision support that facilitates analysis of the effect of system and acquisition enterprise characteristics on acquisition outcomes for different policy and process alternatives (e.g., traditional vs. evolutionary). The particular characteristics studied are system modularity and production quantity, plus enterprise architecture and risk characteristics (i.e., mission risk). The modeling approach and results to date are presented.

1. Introduction

With the continued advent of new threats on the one hand, and likely constraints on the ability of the government to fund new systems on the other, effective military acquisition programs are increasingly important. New threats currently derive from asymmetric and regional sources such as terrorism, insurgencies and cyber-warfare. These new threats call for new types of systems. However, the defense acquisition enterprise operates in an increasingly cost-constrained environment. In recent years, acquisition cost overruns have been highlighted by the GAO and have provoked concern from government funding sources. In addition, short-term war expenditures have used, and continue to use, funds that otherwise might have been used for the acquisition of new systems, and long-term government entitlement commitments may constrain future funding for new systems. Finally, sustainment cost is becoming an increasingly significant area of concern.

This, of course, is not a new observation since the past forty years have seen numerous attempts at reforming the acquisition enterprise. One of the most important reforms is the concept of evolutionary acquisition, in which systems are acquired in smaller increments of capability and then evolved after initial deployment with capability upgrades. The theory is that evolutionary acquisition enables shorter cycles for acquisition, allowing new capabilities to be deployed more quickly to warfighters in the field at less cost, as opposed to traditional acquisition approaches that rely on long development cycles (Johnson & Johnson, 2002).

Despite evolutionary acquisition's status as official policy, though, the Department of Defense seems to have had limited success in its implementation (Lorell, Lorrell, & Younossi, 2006). Our previous work has demonstrated that evolutionary acquisition can, in fact, result in quicker deployment of increased capability but that more frequent cycles incur additional overhead that may increase overall costs (Pennock & Rouse, 2008). By expanding on these results, this paper seeks to study the effect of system and enterprise features on the performance of acquisition policies. In particular, the immediate focus is on the effect of system modularity on acquisition lifecycle performance, where performance is considered as (i) the time taken to deploy new capabilities in the field, (ii) the availability of systems in the field once deployed, (iii) and the lifecycle cost associated with acquisition and sustainment. The notion of modularity has potential synergy with evolutionary acquisition—in terms of enabling capability upgrades to be integrated into existing platforms—due to the presence of a modular system architecture.

This paper discusses a simulation-based approach that provides decision support for the design of acquisition policies and processes over the acquisition lifecycle so that issues such as the effect of system modularity can be addressed. The remainder of the paper is organized as follows. Section 2 reviews the literature on system modularity in product design and acquisition processes. Section 3 describes the simulation model used in this research. Sections 4 and 5 discuss an initial experiment and its results, demonstrating the effect of modularity on costs and availability. Then, Section 6 concludes with a description of future research intentions.

2. Literature Review

Modularity is typically conceptualized as a matrix of relationships between different system modules or components, where the relationship may mean that two modules or components are connected or that changes to one impact the other. Here, we adopt the latter as the meaning. For instance, a laptop computer is typically considered less modular than a desktop since many components of a desktop are designed to be assembled and replaced by the user without changes to other components (Hölttä-Otto & de Weck, 2007). The modular architecture of a system often is considered to consist of a set of modules or components and an infrastructure, which connects components or otherwise provides a platform for the system. Here, we adopt the terminology that a simple system is composed of components and that a complex system is composed of modules, which are, in turn, composed of components. In this type of complex system, a module typically has strong relationships among its constituent components.

Assume that a value of 1 means that two components are strongly related, that a value of 0 means that they are not related, and that a value in between represents the probability that they are related over a set of circumstances. Figure 1, then, illustrates the concept of modularity for small systems represented by matrices. It should be noted in the figure that the matrix entry m_{ij} represents the degree to which a change in component *i* affects component *j*. Also, the matrix representation is not standardized in the literature. For instance, other efforts reverse the role of the rows and columns (e.g., Baldwin & Clark, 2000). It is assumed that entries along the diagonal are all 1; however, they are not relevant to the model. In Figure 1e, then, component 1 is the infrastructure, and the example shows that a change to it impacts all components. In Figure 1f, there are two modules, each composed of two components.

a). Completely modular

1	0	0
0	1	0
0	0	1

b). Weak connections

1	½	½
½	1	½
½	½	1

c). Few connections

1	0	1
0	1	0
0	0	1

d). Completely non-modular

1	1	1
1	1	1
1	1	1

e). With infrastructure

1	1	1
0	1	0
0	0	1

f). With modules

1	1	0	0
1	1	0	0
0	0	1	1
0	0	1	1

Figure 1. Modularity Representations

The concept of modularity in system design has been researched fairly extensively over the last twenty years. Much of this literature applies to commercial product design rather than military system design. In this discussion, the terms *system* and *product* will be used interchangeably. Ulrich and Tung (1991) offer one of the first definitions of modularity, focusing on (i) similarity between the physical and functional architectures of a product or system and (ii) minimization of interactions between physical components. While function is one focus of modularity research, another focus is on the system lifecycle—for instance, modularity to facilitate component disassembly, recycling or reuse (Gershenson, Prasad & Allamneni, 1999). The lifecycle focus provides a framework for discussing how modularity affects cost during the different phases of acquisition.

In design, there is considerable literature on how to format for modularity. The research literature, for the most part, does not concentrate directly on cost, though. Baldwin and Clark (2000) discuss three stages of cost with respect to designing for modularity: (i) establishing design rules, (ii) establishing design parameters, and (iii) testing and fixes. Design rules provide constraints within which modules (or components) must operate. As the number of modules increases, the cost of establishing design rules also increases, although no specific relationship is identified (Baldwin & Clark, 2000). Establishing design rules is considered a one-time expenditure, since they are believed to remain in effect for a long time. Design parameters must be established each time a module is designed. The cost increases with product complexity and is applied for each redesign. Costs for testing and fixes start high but decrease over time as personnel gain expertise with the particular product or system.

Hölttä and Otto (2005) support the general relationship described for Baldwin and Clark's "design parameter" costs, but add two boundary cases of significance. First, minor changes often do not require a reworking of the module parameters, largely owing to the allowances of play existing within the system. Second, major changes usually require a much more costly reworking of the module concept itself. Although they do not use the same terminology as Baldwin and Clark, the implication is that these large changes could challenge even the initial design rules. Between those two extremes, however, Hölttä and Otto observe a roughly linear relationship between the degree of change requested and the difficulty—and, by inference, the cost—of enacting that change.

In terms of production, Fixson (2007), in his review of research into modularity and commonality, finds that most studies of modularity have identified economies of scale as a significant cost benefit. Garud and Kumaraswamy (1995) describe the effect as an economy of substitution. The ability to manufacture components separately from the products they comprise permits these component designs to outlive individual product lines. Thus, modularity extends the size of the production runs across both products and through time. This reuse of a design lowers costs by reducing retooling requirements. The relationship is not entirely linear. There is an optimal number of modules where increasing assembly costs balance out the decreasing fabrication costs (Fixson, 2007).

The scale of the product itself may also be significant in whether these cost benefits can be realized. Zhang and Gershenson (2003), investigating a collection of fourteen small-consumer products, "found no general relationships between relative modularity and cost, or between change in modularity and change in cost."

In sales and demand for commercial products, Desai, Kekre, Radhakrishnan, and Srinivasan (2001) find that increasing commonality between products can hurt demand. Shared components reduce the perceived value of high-value products and increase the component costs for low value products, thus eating into profits from both ends. The F-35 Joint Strike Fighter offers an interesting case of commonality across systems in a military context. Its three variants are designed for three different service applications (a traditional fighter for the Air Force, a vertical/short take-off and landing vehicle for the Marines, and a carrier-based fighter for the Navy). If successful, this approach demonstrates a way whereby commonality increases demand via appealing to different classes of customers.

In sustainment, modularity can help reduce inventory cost by pooling demands, an extension of the economies of scale that benefit the production stage. These early findings have seen much elaboration and investigation, leaving the inventory phase one of the most researched phases in the lifecycle of modular architecture. Fixson (2007) offers a thorough account of the various exceptions and extensions of the inventory research, including the roles of demand distributions, correlated demands, component cost structures, inventory time horizon, process and supply networks, and other constraints and considerations.

Aside from inventory, the sustainment phase of the product lifecycle is one of the least researched aspects of modularity. Gershenson et al. (1999) speculate that maintenance costs should diminish with increased modularity, but their focus is elsewhere, and they do not back this speculation with data. Newcomb, Bras, and Rosen (1998) demonstrate that it is possible to modularize a product with respect to lifecycle, i.e. maintenance and disposal. Tsai, Wang, and Lo (2003) offer a similar demonstration. Both papers indicate that modularity can reduce costs of ownership but only if applied properly. Gershenson, Prasad & Zhang (2003) speculate that any modularity is good for maintenance costs; however, this hypothesis does not yet appear to have been tested in the research literature.

Modularity is related to the notion of open systems, which have been adopted as an initiative in the DoD acquisition. An open-systems approach seeks to enable the integration of current and future capabilities into a system via standards. Ford and Dillard (2008) study the interaction between evolutionary acquisition and open systems and find that the use of the two together may improve schedule and cost performance but may also increase cost in sustainment due to a trade-off between increased integration risks (due to evolving standards) and reduced design risks (due to use of currently stable standards).

There are several hypotheses that are of interest when considering modularity. These include, along with supporting evidence from the literature:

1. Increasing modularity decreases the cost of implementing technology upgrades for deployed systems (Fleming & Sorenson, 2001; Garud & Kumaraswamy, 1995; Gershenson et al., 2003; Huang & Kusiak, 1998; Ulrich & Tung, 1991; Ulrich, 1995);
2. Increasing modularity decreases the mean time to repair a system that has failed (Cheung & Hausman, 1995; Gershenson et al., 2003; Tsai et al., 2003);
3. Increasing modularity increases the upfront engineering design hours required for a system (Ulrich, 1995);
4. Increasing modularity increases the cost of changes to infrastructure (Ethiraj & Levinthal, 2004; Fleming & Sorenson, 2001; Garud & Kumaraswamy, 1995; Ulrich & Tung, 1991; Ulrich, 1995).

It should be noted that Fleming and Sorenson (2001) offer mixed support for hypothesis 1 since they find that small technology upgrades are handled easily with a modular architecture but that major upgrades may pose challenges since they may require changes to the modular architecture itself. In addition, Garud and Kumaraswamy (1995) assert that technology upgrade costs decrease only at the expense of an initial infrastructure cost. This paper primarily addresses the first two hypotheses.

As the number of components in a system increases, it is a complex task to compare different modularity matrices and quantitatively determine differences in modularity. Thus, there has been interest in establishing a modularity index to provide a standardized measurement of modularity. Two such indices are given by Guo and Gershenson (2004) and Hölttä-Otto and de Weck (2007). Effective modularity indices remain an area of research.

3. Model Description

This research uses a simulation-based decision support to determine the effectiveness of different acquisition policies and processes. Simulation has traditionally been used in process-based domains such as manufacturing (Law & Kelton, 2000). Increasingly, it is being used to study acquisition. Ford and Dillard (2008) use a system dynamics approach, which models the delayed effects and feedback flows associated with the acquisition enterprise. Discrete-event simulation is used in our previous work (Pennock & Rouse, 2008) and by Olson and Sage (2003). Discrete-event simulation tends to offer better representational support for organizational decision-making processes.

3.1. Existing Model Summary

Our existing model is implemented using ARENA 10.0, a commercially available, discrete-event simulation package. It consists of three interacting components, which address the traditional acquisition system (Pennock & Rouse, 2008):

- <u>Technical Progress Model</u>. The technical progress model accounts for basic research that occurs exogenous to the defense enterprise. This work may be performed in the commercial sector or via government funding. It feeds raw, new technologies into a technology development process model that reflects the DoD's science and technology (S&T) development enterprise. Technologies are characterized by an application area, a maturity level and a capability level. An example of an application area might be radar. The maturity level reflects the readiness of the technology for usage and is measured using the NASA technological readiness level (TRL) scale, recently adopted by the DoD (DoD, 2006, July). Capability level, on the other hand, represents the technology's capability (once deployed) in relation to previous generations within the same application area. Capability level for each succeeding generation is determined by a combination of a learning effect (from the other DoD applications) and an exogenous progress effect (from commercial and outside technical progress). Technologies are put into the technology development process model at an early TRL (e.g., 1).

- Technology Development Process Model. In this S&T enterprise, new technologies for the DoD systems typically undergo a staged process of development whereby ideas are reduced to working technologies that can be integrated into a system. There is considerable technical risk in the development process, as ideas often do not work in practice, do not scale-up to production, or do not integrate into systems. The staged process mitigates risk by not fully funding a technology's development, allowing it to be culled if it fails or if it is outpaced by competing technologies. It should be noted that the S&T enterprise model consists of a single, unified organization rather than the myriad agencies that comprise the actual DoD S&T enterprise.
- System Acquisition Process Model. The system acquisition model primarily represents the first four phases of a defense acquisition program, as specified in the DoD Defense Acquisition Guidebook (2006). These include concept development, technology development, system development and production & deployment. Operations & support is represented by a simple delay function for the period of sustainment. The system acquisition process model pulls technologies from the technology development process model for use in the system being developed. In the existing model, the TRL at which these technologies are selected is an experimental variable used to assess the effect of traditional acquisition (which selects relatively immature technologies and matures them in the program for significant capability leaps in deployed systems) versus evolutionary acquisition (which selects relatively mature technologies for more frequent, but smaller capability leaps).

The remainder of this section discusses two enhancements to the existing model—the introduction of a representation for system modularity and a model of the sustainment phase of the acquisition lifecycle.

3.2. Modularity Matrix

A system is assumed to have *n* components. These components may or may be related with one another for the purposes of repair/replacement and/or technology upgrades during sustainment. One of these components is designated as the system infrastructure, or the platform that integrates the various components. Modular systems often require such an infrastructure to facilitate modularity. Modularity is then characterized as the degree to which the various components interact or are connected, and it is represented as an $n \times n$ matrix. It should be noted that modularity is assumed to be a function of the system design, as determined in upstream stages of the acquisition process.

Each entry m_{ij} in this modularity matrix **M** represents the probability that a change in component *i* necessitates a change in component *j*. Component failures and component technology upgrade opportunities arrive and involve changes to a component. Due to modularity effects, they may also involve changes to other components through the relations represented by **M**. The modularity values for a particular system may differ for repairs and technology upgrades, resulting in two different matrices, $\mathbf{M}_r$ and $\mathbf{M}_t$. Also, a modularity matrix is not necessarily symmetric. That is, changes to component *i* may affect component *j* in a manner different from that in which changes to *j* affect *i*. A simple example of asymmetry is when replacing *i* requires removing *j*, but replacing *j* does not require removing *i*. Components may be organized into modules in complex systems.

3.3. Sustainment Model

The sustainment model has two primary processes—repairs and technology upgrades. Failures and technology upgrade opportunities arrive as random events to a deployed system, according to a Poisson process with a particular rate. Each failure or technology upgrade opportunity directly affects only one component, except that an infrastructure component, when present, is not affected by failures or technology upgrades and is assumed to be component 1. However, repairs or upgrades may cascade to other components, due to modularity relationships. The following notation is used for the sustainment model.

- f_i is the failure rate associated with component *i*. f_1 is undefined when infrastructure is present (since infrastructure is component 1).
- r_i is the repair rate associated with component *i*. r_1 is undefined when infrastructure is present.
- t_i is the arrival rate of new technology upgrades for component *i*. t_1 is undefined when infrastructure is present.
- u_i is the upgrade rate for component *i*. u_1 is undefined when infrastructure is present.
- p_i is the cost of repairing component *i*. p_1 is undefined when infrastructure is present.
- q_i is the cost associated with a technology upgrade to component *i*. q_1 is undefined when infrastructure is present.
- c_{ij} is the compatibility cost associated with making component *j* technologically compatible with component *i* if *i* is upgraded and if the interaction between *i* and *j* necessitates that *j* be made compatible to the new technology for *i*. c_{i1} is undefined when infrastructure is present.

In general, it is assumed that $f_i > t_i$, $r_i > u_i$, and $p_i < q_i$.

The simulation logic works as follows. When a failure to component *i* arrives to the system, it invokes a repair delay for that component, occurring at rate r_i. All components *j* such that $m_{ij} > 0$ are evaluated probabilistically via a Bernoulli variable, using the probability m_{ij}, to determine whether *j* must also be repaired. Any components *j* requiring a repair are then repaired at rate r_j. This repair requirement can cascade to additional components that are dependent on *j*, and so on. The system experiences a repair downtime equal to the maximum repair time of *i* and that of any other affected components.

Similarly, when a technology upgrade to component i arrives to the system, it invokes an upgrade delay for that component. This delay occurs at rate u_i. All components j such that $m_{ij} > 0$ are evaluated probabilistically via a Bernoulli variable to determine whether j must also be made compatible with the upgrade. Any components j requiring a compatibility operation invoke a delay at rate u_j. Upgrade effects can cascade similarly to repair effects. The system experiences an upgrade downtime equal to the sum upgrade time of i and compatibility time of any affected components. This is in contrast to the downtime due to repairs.

If a failure or technology upgrade for i arrives while the system is in downtime, then that failure or technology upgrade queues until the downtime is resolved. Multiple entities in this queue are processed as first-come-first-served.

Clearly, this is a relatively simple model. It is meant to allow basic analysis of the effects of modularity and to provide a basis for more complex models in the future.

4. Experiment

In this section, we detail a simulation experiment to test the effect of different types of modularity matrices on sustainment. The dependent variables are the repair costs, upgrade costs and system availability. Sustainment of a single system is considered in each experimental run. Three classes of modularity are considered:

- Type 1. All non-diagonal entries in the matrix are the same fractional probability value.
- Type 2. All non-diagonal entries in the modularity matrix are either zero or one.
- Type 3. The matrix consists of modules, comprised of components that have strong relationships, but the relationship entries between modules in different components is zero.

4.1. Parameters and Assumptions

The simulation is executed over a period representing ten years of sustainment. The following parameter values are used. These parameter values are selected as notional values for the experimental analysis to illustrate the effects of the modularity.

- f_i = 60 days for all i
- r_i = 1 hour for all i
- t_i = 360 days for all i
- u_i = 6 hours for all i
- p_i = 10 currency units for all i
- q_i = 100 currency units for all i
- c_{ij} = 15 currency units for all i and j

4.2. Experimental Setup

Table 1 shows the variations tested among the different types of modularity matrices. In matrices of types 1 and 2, n equals 10. In matrices of type 3, the size is adjusted to n equals 16 to accommodate modules being the same size (e.g., systems with eight modules, each having two components, or with four modules, each having four components).

Table 1. Modularity Matrix Variations Tested

Matrix Type	Variations
Type 1	Eleven different variations are simulated. Each variation uses a different value for all non-diagonal m_{ij}. The different values used are 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0.
Type 2	Seven different variations are simulated. Each variation has a mix of values (0, 1) for non-diagonal m_{ij}. Each variation uses a different probability to select a specific value for each m_{ij}. These probabilities are 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, and 0.6, and the probability corresponds to m_{ij} equaling one, as opposed to zero. It was determined that probability values above 0.6 had similar behavior; thus, they are not considered here.
Type 3	Five variations are simulated. Each variation has a different size of module. The variations include sixteen modules of size 1, eight modules of size 2, four modules of size 4, two modules of size 8, one module of size 16. Within each module, all m_{ij} equal 1. Relationships between modules have m_{ij} equal 0.

Ten replications of each variation are run for statistical significance.

5. Results and Analysis

5.1. Repair Costs

Figures 2-4 illustrate average repair costs as a function of the level of modularity in a system. The actual average repair cost shown is the average collateral repair cost, or the cost of repairing other components related to a failed component that must be repaired due to a modularity relationship. This shows the variable effect of modularity in terms of average repair cost. The result from each replication across each variation is shown in each figure. The units for cost are in currency units, as specified in the parameters for the model.

According to expectations, as the level of relationship strength (or coupling) increases (i.e., as modularity decreases), the repair cost increases for each type of matrix. The factors of interest include the points at which the costs start to converge to a maximum value and the relative spread of the costs for each level of variation within each type of modularity matrix. In the type 1 matrix, the variance is less than that of the type 2 matrix, suggesting that numerous weak relationships provide a more predictable repair cost for a system than a set of relationships that are either very strong or very weak. Intuitively, this makes sense. It also is reinforced by the outcome from type 3 matrices, in which the repair cost is always the same, since a component failure leads to replacement of the entire module, and each module is the same size and cost. Since module size has a linear relationship with module cost, the cost relationship with modularity is likewise linear.

Since the failure rates are the same across all replications, the patterns for total repair costs of each replication (over the entire ten-year time horizon) are similar to those of average costs (per failure incident). Therefore, only the average costs are shown. However, it should be noted that there would be variance across variations in the type 3 matrix total costs since the number of failures during the time horizon is a random variable.

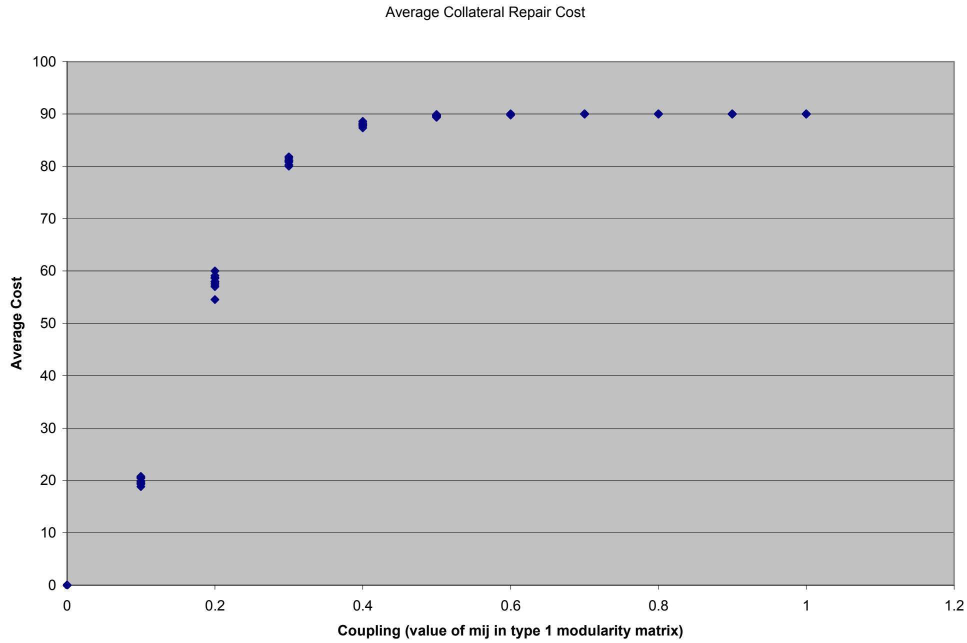

Figure 2. Repair Cost as a Function of Modularity for Type 1 Matrix

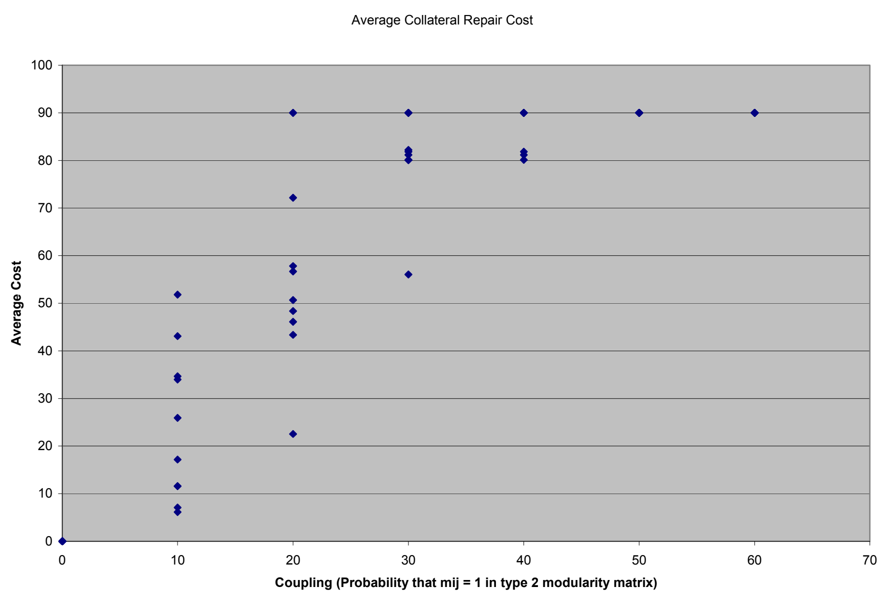

Figure 3. Repair Cost as a Function of Modularity for Type 2 Matrix

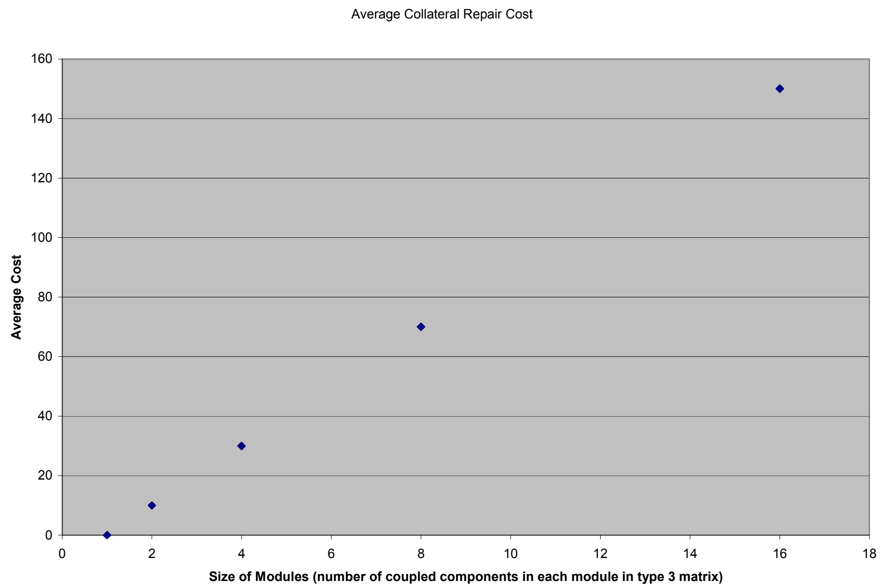

Figure 4. Repair Cost as a Function of Modularity for Type 3 Matrix

5.2. Technology Upgrade Costs

Figures 5-7 illustrate average upgrade costs as a function of the level of modularity in a system. Average upgrade cost addresses the work to make components consistent to upgrades when they are related to the component being upgraded, i.e., the variable portion of cost related to modularity. The result from each replication across each variation is shown in each figure.

The behavior patterns for upgrade costs are comparable to those for repair costs: as the level of relationship strength increases, the upgrade cost increases for each type of matrix. As with repair costs, the pattern for total upgrade cost over the ten-year time horizon is similar to that of the average cost, so only the average costs are shown. The units for cost are in currency units, as specified in the parameters for the model.

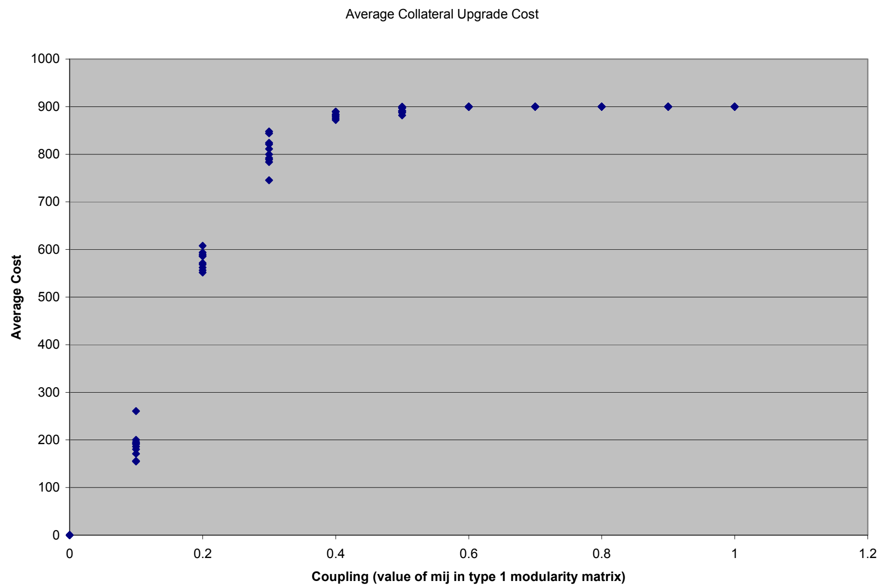

Figure 5. Upgrade Cost as a Function of Modularity for Type 1 Matrix

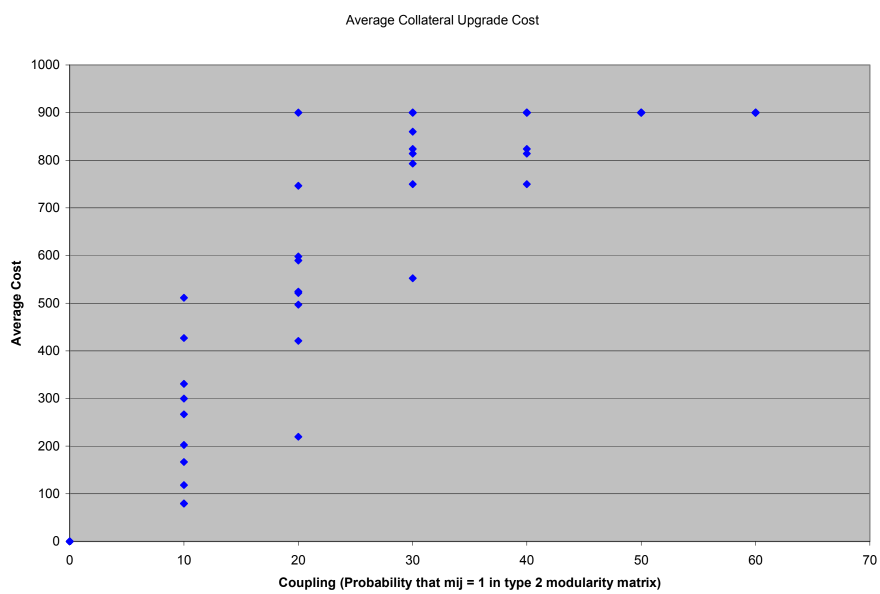

Figure 6. Upgrade Cost as a Function of Modularity for Type 2 Matrix

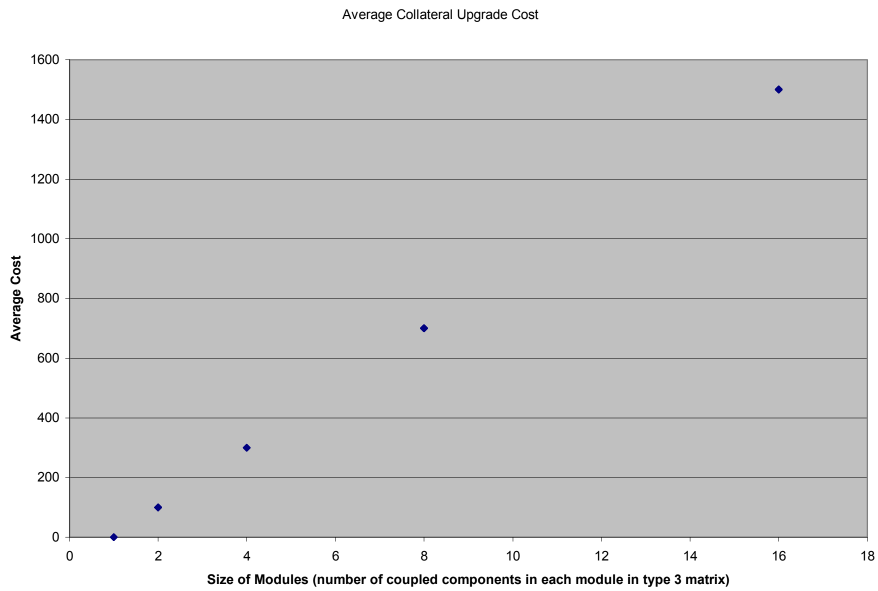

Figure 7. Upgrade Cost as a Function of Modularity for Type 3 Matrix

5.3. System Downtime

Finally, Figures 8-10 illustrate average system downtime during the ten-year time horizon as a function of the level of modularity in a system. Average downtime is a combined effect of failures and technology upgrades. The result from each replication across each variation is shown in each figure.

As the level of relationship strength increases, the average downtime increases for each type of matrix. The behavior patterns are somewhat similar to those for costs. The average downtime values across matrix type 3 variations are not constant, due to the random number of failures and technology upgrades in each replication. The units for downtime are the fraction of time that the system is unavailable.

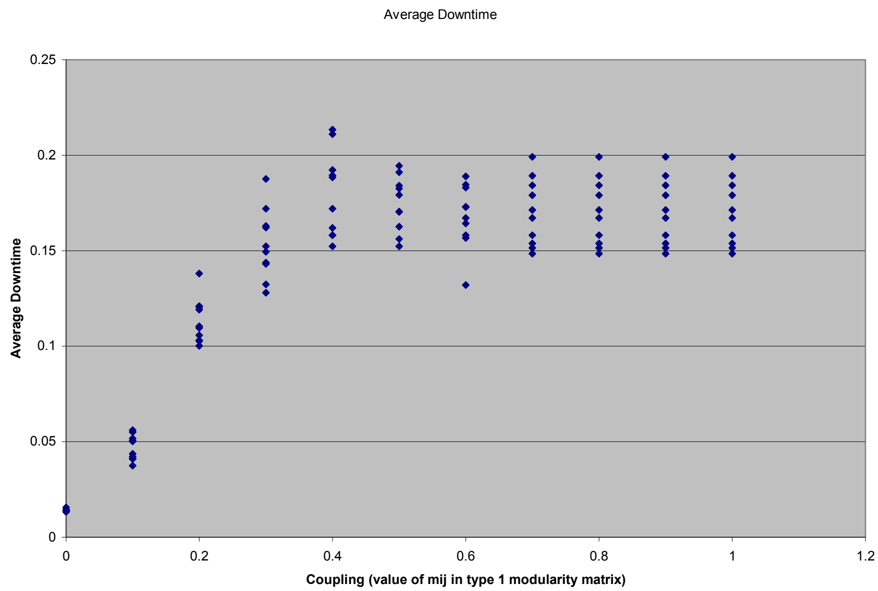

Figure 8. Downtime as a Function of Modularity for Type 1 Matrix

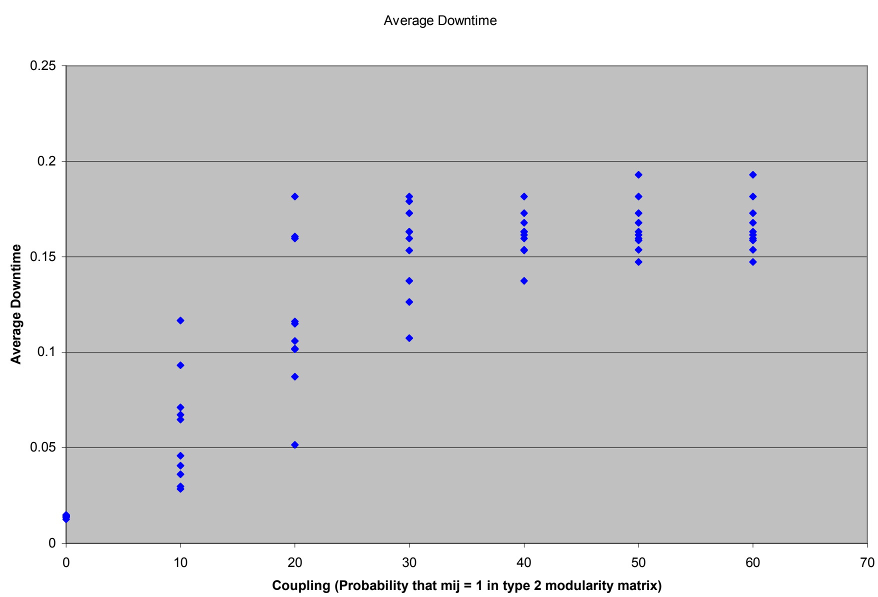

Figure 9. Downtime as a Function of Modularity for Type 2 Matrix

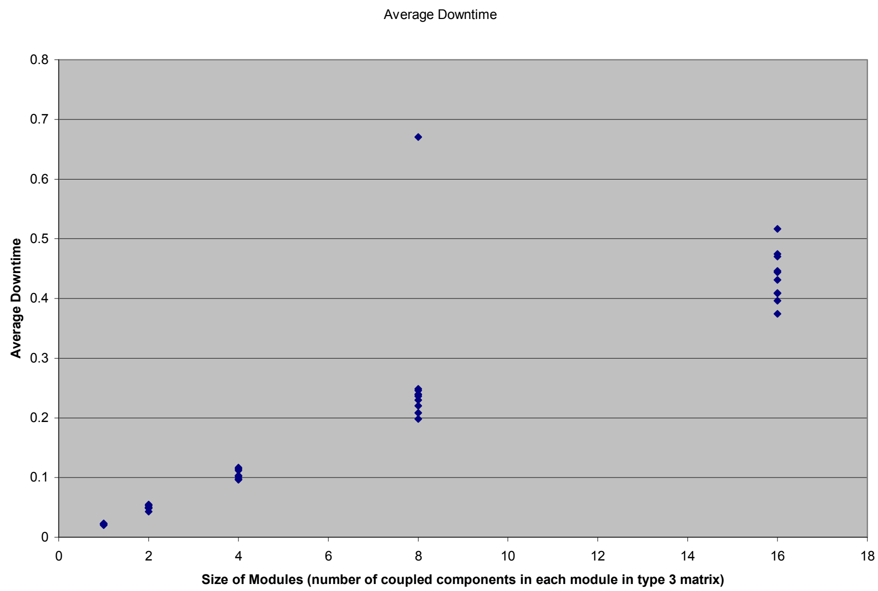

Figure 10. Downtime as a Function of Modularity for Type 3 Matrix

6. Discussion and Future Research

These results provide some insight into the effect of modularity on sustainment costs and system availability. There is some potential for cost savings and improved system availability as modularity is increased. Clearly, the parameter values and complexities of real systems need to be considered, and this will be a focus of future research efforts. Such efforts need to account for the notion of integration risk over the lifecycle, as detailed in Ford & Dillard (2008).

One major goal of this research is to characterize the effect of modularity over the acquisition lifecycle. Thus, current work is focusing on integration of the existing model of acquisition with the new sustainment and modularity models. This involves modeling modularity and its engineering costs in the acquisition model as well as modeling the flow of technology upgrades to the sustainment model from the S&T model. The emphasis on cost modeling will be on parametric models for cost estimation (e.g., Valerdi & Liu, in press). Such models must address not only the initial design of modularity but also adjustments during development such as evolution of design parameters (Baldwin & Clark, 2000). The hypothesis is that modularity tends to increase design and development costs while decreasing production and sustainment costs. The question is to determine what levels of modularity, in combination with other system characteristics, achieve the best results, not only in terms of cost but also in terms of time to deployment and post-deployment availability. One such system characteristic is production level, which has the potential to leverage economies of scale in making modularity more cost effective.

To answer the question about the effectiveness of modularity levels, it is important to be able to characterizer modularity by a standard metric such as a modularity index. This also will be an avenue of future research.

Another goal is to study the effect of enterprise characteristics and their interactions with system characteristics. In particular, we are interested in studying the effects of alignment in the S&T system and the concept of mission risk. The current model assumes a unitary S&T organization rather than the multi-organization S&T enterprise. In terms of cost, schedule and risk, what is the trade-off between the redundancy of a multi-organization S&T enterprise versus the efficiency of a unitary organization? Mission risk is increasingly important, given the evolution of threats that need to be addressed. Does modularity aid in adapting systems in the field to new mission requirements? Finally, we plan to extend previous results by exploring which conditions from the above areas of study make evolutionary acquisition more favorable than traditional approaches.

Acknowledgements

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Panel 15 - Implementing an Open Architecture Strategy at the Program Management Level

Thursday, May 14, 2009	Panel 15 - Implementing an Open Architecture Strategy at the Program Management Level
11:15 a.m. – 12:45 p.m.	**Chair: Daniel Nussbaum**, Naval Postgraduate School, former Director, Naval Center for Cost Analysis **Discussant: Richard L. Coleman, CAPT, USN (ret)**, Director, Cost and Price Analysis Center for Excellence, Northrop Grumman Information Systems ***Improved Methodology for Developing Cost Uncertainty Models for Naval Vessels*** **Cinda Brown**, Class Squadron, LSD/LPD-17 ***Transactions Cost from a Program Manager's Perspective*** **Diana Angelis, John Dillard, Raymond Franck** and **Francois Melese**, Naval Postgraduate School

Chair: Dr. Daniel A. Nussbaum is a Professor at the Naval Postgraduate School in the Operations Research department in Monterey, CA. His expertise is in cost/benefit analyses, lifecycle cost estimating and modeling, budget preparation and justification, performance measurement and earned value management (EVM), activity-based costing (ABC) and Total Cost of Ownership (TCO) analyses.

From December 1999 through June 2004, he was a Principal with Booz Allen Hamilton, providing estimating and analysis services to senior levels of the US Federal Government. He has been the chief advisor to the Secretary of Navy on all aspects of cost estimating and analysis throughout the Navy, and has held other management and analysis positions with the US Army and Navy, in this country and in Europe.

In a prior life, he was a tenured university faculty member.

Nussbaum has a BA in Mathematics and Economics from Columbia University, and a PhD in Mathematics from Michigan State University. He has held post-doctoral positions in Econometrics and Operations Research, and in National Security Studies at Washington State University and Harvard University.

He is active in professional societies, currently serving as the President of the Society of Cost Estimating and Analysis. He has previously been the VP of the Washington chapter of INFORMS, and he has served on the Board of the Military Operations Research Society.

He publishes and speaks regularly before professional audiences.

Finally, he is married, has two children and four grandchildren.

Richard L. "Dick" Coleman was commissioned upon graduation from the US Naval Academy in 1968, where he received a BS in Naval Engineering with a minor in Operations Analysis. He received an MS in Operations Research (with Distinction) from the Naval Postgraduate School in 1974. Graduating first in his class, he was the recipient of the CNO's Award for Excellence in Operations Research. He was a surface warfare officer in cruisers, destroyers and frigates. His career culminated in tours as Section Head in N-815, Commanding Officer of USS Dewey (DDG 45), Director of the SAM Section at COMOPTEVFOR and Director, Naval Center for Cost Analysis, where he was responsible for over 40 Independent Cost Estimates, including: USCGC Healy, New Attack Submarine, AAAV, MIDS, CEC, LHX, DDG 51 Flt IIA, Strategic Sealift, Tomahawk Blk IV and the F/A 18 E/F. He retired from active duty as a Captain, USN, in 1993.

Since retirement, Coleman has worked for TASC and Northrop Grumman Information Systems (NGIS). He has supported MDA, DARO, the Navy Acquisition Reform Office, DD(X), CG(X), the Future Imagery Architecture JMO, and NASA. He supports the intelligence community in cost and risk. He is currently the Director of Independent Cost Estimation for NGIS and conducts Independent Cost Evaluations of Northrop Grumman proposals. He has conducted over 100 NG ICEs including LPD 21, LHD 8, LHA 6, EPCD, DDG 1000, VA Class Submarine Block II and III, CVN 77 IPR, CVN 78 Construction Preparation, CANES, CVN 78, TMOS, F-16 AESA, F-16 India EW, Warfighter Focus, Kennedy Space Center ISC, LA Leader Replacement System, MD Dept of HR IT support, and Virginia's VITA. He received the TASC Sector Rainmaker Award for Program Management; the CMS Program Analysis & Evaluation Office Exceptional Teamwork Award, the NRO Director's Team Award, the Northrop Grumman Contracts and Pricing Award, the TASC President's Award, and the NGIT President's Award for Operational Excellence.

He is a Board Member of the Society of Cost Estimation and Analysis (SCEA) and is the former National and Regional Vice President of that organization. He is co-author of over 70 papers on cost, risk and CAIV at SCEA, ADoDCAS, MORSS, and NPS ARS. He served as an editor and author of SCEA's acclaimed *Cost Estimating Body of Knowledge* training, and has taught courses in industry, the DoD and the UK MoD. He is the recipient of SCEA's Lifetime Achievement Award.

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Improved Methodology for Developing Cost Uncertainty Models for Naval Vessels

Presenter: LCDR Cinda Brown is a native of Phoenix, AZ. She graduated from the United States Naval Academy in May 1998 with a Bachelor of Science in Chemistry and from the Naval Postgraduate School in 2008 with a Master's of Science in Systems Engineering. Brown's sea duty assignments include USS MILIUS (DDG 69) as the Anti-Submarine Warfare Officer and USS COMSTOCK (LSD 45) as the Training Officer and Main Propulsion Assistant. Following her sea duty, she completed a lateral transfer to the Engineering Duty Officer community. Her shore duty assignments include Southwest Regional Maintenance Center and the LSD/LPD-17 Class Squadron.

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Abstract

The purpose of this paper is to analyze the probabilistic cost model currently in use by NAVSEA 05C to predict cost uncertainty in naval vessel construction and to develop a better method of predicting the ultimate cost risk. The data used to develop the improved approach is collected from analysis of the CG(X) class ship by NAVSEA 05C. The NAVSEA 05C cost risk factors are reviewed and analyzed to determine if different factors are better cost predictors. The impact of data elicitation, the Money Allocated Is Money Spent (MAIMS) principle, and correlation effects are incorporated into the research and analysis of this paper. Data quality is directly affected by data elicitation methods and influences the choice of probability distribution used to give the best predictor of cost risk. MAIMS and correlation effects are shown to make a significant impact to the overall cost model. Program managers and analysts can readily implement the enhanced models using commercial Excel® add-ins, such as Crystal Ball® or @Risk and integrate them into their current cost risk analysis and management practices to better mitigate risk and control project cost.

Executive Summary

In order to generate the funds to implement the 30-year plan of future ships and capabilities, the Navy must explore different options for cost savings. Fundamental to the success of complex projects, such as naval vessel construction, is the ability to control, manage, and communicate the status of the risk reduction effort throughout the development and production cycles (Kujawski & Angelis, 2007). It is recognized that the Navy and the shipbuilding industry need to change their technical and business shipbuilding strategies in order to achieve the goal of a future fleet that balances both capability and affordability. Cost risk assessment and analysis is one tool that can be utilized to help recapitalize costs used in the ship acquisition and building process.

This paper analyzes the probabilistic cost model currently in use by Naval Sea Systems Command Cost Engineering and Industrial Analysis Division (NAVSEA 05C) to predict cost uncertainty in naval vessel construction and to develop a method that better predicts the ultimate cost risk. The NAVSEA 05C's cost analysis model for the proposed new cruiser, CG(X), encompasses all aspects of cost for the entire fleet, including inflation and profit. The data used in the NAVSEA model were acquired from subject matter expert (SME) inquiry using three-point estimates of high, most-likely, and low values. The Navy is placing great emphasis on producing the best product for each dollar spent. In order to ensure the continued acquisition of CG(X), it is important that realistic cost risk analysis be performed so that program managers can make informed decisions.

The cost model elements investigated in this paper include data elicitation methods, probability distribution function (PDF) choice, correlation effects, and Money Allocated is Money Spent (MAIMS) principle effects. The most significant impact is seen with MAIMS and data elicitation effects. PDF choice and correlation effects have lesser impact upon the cost model.

Methods of data elicitation are explored and the use of a direct fractile assessment (DFA) is recommended for future use (Kujawski, Alvaro & Edwards, 2004), although the research in this paper does not involve data acquisition. To simulate the use of a DFA methodology, three-parameter Weibull distributions are employed to account for uncertainty associated with SME estimation of data. A Weibull (10%, 50%, 90%) distribution is used to simulate a more optimistic view of the uncertainty of data, while a Weibull (20%, 50%, 80%) distribution models a more pessimistic view.

The methodology in choosing different probability distribution functions and their applicability to the model is evaluated. Specifically, triangular, lognormal, and two variations of the three-parameter Weibull distribution are considered. Once enhanced models are established, program managers can implement them into their current cost risk analysis practice to mitigate risk and control project cost.

Two types of correlation effects are considered and modeled in this paper. The first is the correlation between the components of the radar suite, and the second is the correlation between all the components of the electronics suite. The radar suite is one of the systems that make up the electronics suite. The results suggest that the correlation effects are important for probability values midway between the mean and the extremes, but there is little difference for correlation coefficients beyond 0.5. Further investigations are recommended to quantify correlation effects.

MAIMS modified probability distributions are used to show the significance of budget allocation levels (Kujawski, Alvaro & Edwards, 2004). These distributions reflect an empirically observed effect, namely, that once a budget is allocated, the project cost will most likely be at least equal to the amount allocated. As the MAIMS modification value increases, the overall distribution cost rises with increasing probability.

Credibility and realism are two key cost risk assessment criteria. The use of improved methods, such as those investigated in this paper, are especially significant for today's Navy during a time of budget hardship. If the Navy's plans for a 313-ship fleet are to become a reality, the incorporation of cost risk analysis into acquisition and shipbuilding management is imperative. Reliable cost assessments can help deliver projects on time, at a lower cost, with a higher probability of success. Effective training of personnel involved in cost assessment and continued efforts to improve existing cost models will help improve the Navy's current cost estimating process.

I. Introduction

Admiral Gary Roughead stated in the Chief of Naval Operation's (CNO) Guidance for 2007-2008 that:

> **We manage risk.** We will identify, analyze, mitigate and then accept risk, appreciating that we must always consider the risks in aggregate across the entire force. Zero risk is not achievable nor affordable. We must manage risk and move forward to accomplish the mission while safeguarding our people and infrastructure. (Roughhead, 2007)

Vice Admiral K. M. McCoy took this a step further in 2008, in a statement made on assuming the position of Commander, Naval Sea Systems Command:

> Our Common mission is to develop, deliver and maintain ships and systems on time and on cost for the Navy. To build an affordable future fleet, we will focus on reducing acquisition costs, including applying more risk-based decisions to specifications and requirements. (McCoy, 2008)

The United States Navy is living and functioning in an era of ever-expanding technology, more stringent requirements, and a growing need for more ships and resources, all while working with a limited budget. These factors all lead to inherent cost growth in the projects that are developed to provide the fleet with the capabilities it needs. In order for the United States Navy to acquire and provide a full,
state-of-the-art, 313-ship Navy by 2020, as stated in the fiscal year (FY) 2007 plan (Department of the Navy, 2006) it is imperative that methods allowing full capitalization of each dollar spent by the Navy are developed and implemented.

In February 2006, the United States Navy presented its FY2007 plan, which outlines the objective of increasing the current 285-ship fleet to 313 ships by 2020 (Department of the Navy, 2006). By 2008, the Navy increased the estimate of its annual cost for the 30-year plan by about 44% in real terms, but it is still approximately 7% less than independent cost estimates conducted by the Congressional Budget Office (O'Rourke, 2008). This increase in estimated cost poses a problem for the overall funding of the shipbuilding strategy proposed by the Secretary of the Navy. The credibility of the Navy's estimates and the ability to fund its shipbuilding plans have been questioned by Congress and industry (Cavas, 2008).

In order to adequately generate the funds to implement the 30-year plan of future ships and capabilities, the Navy must explore different options for cost savings. Fundamental to the success of complex projects, such as naval vessel construction, is the ability to control, manage, and communicate the status of the risk reduction effort throughout the development and production cycles (Kujawski & Angelis, 2007). It is recognized that the Navy and shipbuilding industry need to change their technical and business shipbuilding strategies in order to achieve the goal of a future fleet that balances both capability and affordability. Cost risk assessment and analysis is one tool that can be utilized to help recapitalize costs used in the ship acquisition and building process.

A. Background

Risk analysis is an important component of the cost analysis of new vessels because actual costs will always have a probability of differing from the estimate. Several reasons account for the difference between the estimate and actual cost, which can include lack of knowledge about the future, errors associated with assumptions and cost-estimating equations, historical data inconsistencies, and factors considered in making the estimate. The overall purpose of risk analysis is to quantify the potential for error (GAO, 2007). In the case of a cost estimate, it is the probability that the actual cost will exceed the cost estimate or the budget. This cost estimate allows for the assessment of risk of a given program.

Cost overruns and growth are an enduring problem that is not new to the Navy. A 1939 inquiry from Secretary of the Navy Ray Spear asks the question, “Why do naval vessels cost so much?” Answers to this inquiry include increased progress in marine engineering and naval construction, increased horsepower in shipbuilding, improved quality of building materials, inflation, and the practice of paying full price for the best you can buy naturally increases costs. Spear (1939) states that, “care must be taken in approving estimates to make sure that they are reasonable and held to in the cost of production. When contracts are negotiated, the question of costs should be investigated and a detailed knowledge of approximate costs obtained.” Just as cost estimation was recognized by the Secretary of the Navy in 1939, it is recognized by today’s Navy leadership as an integral part of the ship acquisition process.

Risk analysis and management can be used to help program managers more effectively make acquisition decisions and allocate their resources by allowing for a better understanding of program risks. Risk management is a continuous process in the acquisition and development of naval vessels.

The Naval Sea Systems Command, Cost Engineering and Industrial Analysis (NAVSEA 05C) introduced Cost Risk Analysis (CRA) into the Navy’s PR09 Planning, Programming, Budgeting, and Execution System (PPBES) to help assess vessel costs in terms of quantifiable risk. Cost Risk Assessment is defined as the process of quantifying the uncertainties associated with major acquisition programs. It therefore allows for informed decisions with an estimated level of confidence (McCarthy, 2008).

One of the key objectives of CRA is to enable better risk management, which will simultaneously reduce program costs and increase the probability of success. Cost estimating is recognized by NAVSEA 05C as an essential element of effective program management, required for realistic program planning and decision-making. Risk analysis is important because the previous methodology of using point estimates is “precisely wrong” (Deegan, 2007). Risk cannot be assessed with a point estimate, as it represents a single value that serves as a best guess for the parameter to be defined. Decision-makers may not be able to completely understand the influence of different variables on cost with the use of a point estimate. Conversely, the use of risk analysis allows the decision-maker to utilize his or her acquisition experience, while quantifying the qualitative aspects of acquisition scenarios.

Point estimates are not an accurate method for predicting costs in shipbuilding because they do not properly account for problems that may be encountered in the acquisition process, as described above. They may be either overly optimistic or overly pessimistic. Optimistic point estimates ignore the potential risk and uncertainty in a project, which is necessary for management to make informed decisions. Immature technology, uncertain product design, schedule problems, and unforeseen events all have risk associated with their end product. Risk analysis is necessary in order to incorporate the effect of risk into the overall cost. Pessimistic point estimates assume worst scenarios and unlikely high costs. Quantitative risk analysis allows the cost estimator to assign a realistic range of costs around a point estimate, which provides decision-makers with a level of confidence in achieving a credible cost.

The NAVSEA Cost-estimating Process is comprised of three parts, which are further divided into 12 tasks. The three parts consist of Develop Approach, Perform Estimate, and Brief Results. Figure 1 shows the breakdown of the 12 tasks within the three parts. This paper focuses on the Develop Approach and Perform Estimate parts of the cost-estimating process.

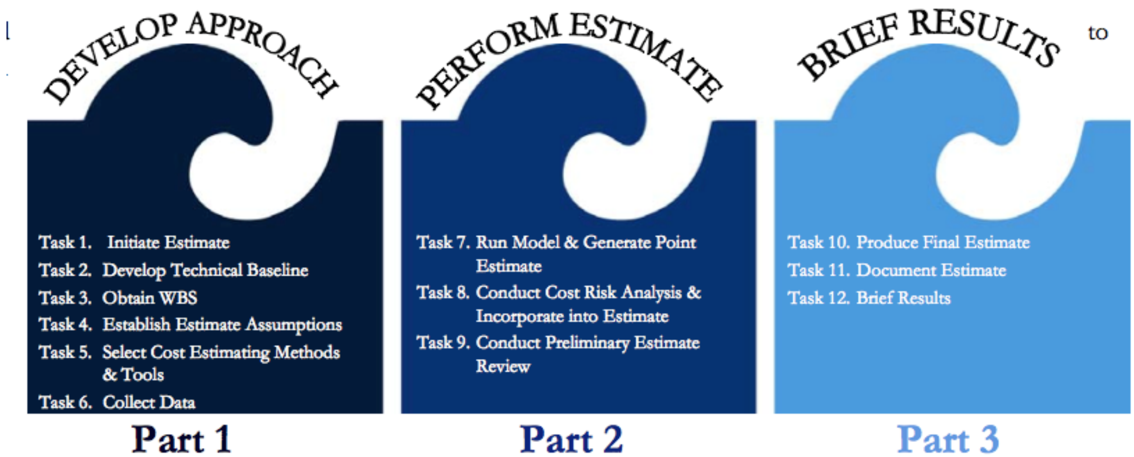


Figure 1. NAVSEA 12-Step Cost-estimating Process
(NAVSEA, 2005)

Data collection is a task within the Develop Approach part of cost estimation and can be regarded as the most important part of risk analysis. Bad data will produce bad results, regardless of the subsequent analysis. Data elicitation is often done ad hoc; however, several reliable methods and sources are available for data collection. Data quality is critical to the success of the analysis and plays a significant part in the results generated for cost estimation. This paper will discuss improved methods for data collection in order to obtain more reliable and standardized data from subject matter experts (SMEs).

Risk analysts use probability distributions rather than point estimates to represent the possible outcomes of an event. There is a significant difference between a point estimate and a distribution, in that the distribution provides the full range of values with their associated probabilities, while the point estimate presents a single value. This allows program management to make budget decisions, based on desired confidence levels. Quality may differ, based on the method of collection. Two methods commonly used for data collection include database queries and interviews of SMEs or stakeholders (Deegan & Fields, 2007). This paper analyzes the current NAVSEA 05C Cruiser (CG(X)) probabilistic cost model including data elicitation.

The direct fractile assessment (DFA) method provides one of the most reliable and least bias-prone procedures for eliciting uncertain quantities from SMEs (Kujawski, Alvaro & Edwards, 2004). Data elicitation from SMEs is innately uncertain; three findings from psychological experiments conducted by Alpert and Raiffia (1982) are:

- A systematic bias toward overconfidence is common.

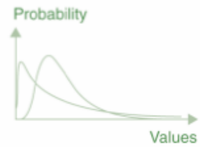
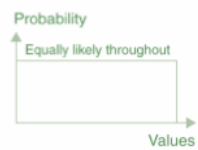
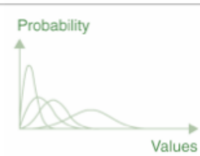
- Extreme value judgment is poor.
- Maximum and minimum values are vague terms. What do these terms really mean?

Based on the findings of Alpert and Raiffia (1982), Kujawski et al. (2004) propose the following guidelines for data elicitation:

- Ask SMEs to provide 10th, 50th, and 90th percentiles values for cost elements. Avoid extreme values, abstract measures such as the mean or standard deviation, or specific distribution functions. Allow for discussion and education of the SME in terms of bias when giving data figures.
- Calibrate each set of percentiles to reflect individual and project specific considerations, both pessimistic and optimistic. For estimates that might be overly optimistic, a cost analyst might choose to shift a 90th percentile value to perhaps 80th or 75th percentiles.

Tasks involved in the Performing Estimate depicted in Figure 1 are running the model and generating a point estimate or probability distribution, conducting a cost risk analysis, and conducting a preliminary estimate review.

Traditionally, triangular distributions have been used in cost estimation models because of the simplicity in entering the required data. The triangular distribution requires minimum or low, most-likely, and high or maximum values. Other commonly used distributions include normal, lognormal, and uniform. Table 1 lists eight of the most common probability distributions used for cost estimation and uncertainty analysis. This paper investigates different methods for data elicitation and selecting appropriate distributions. The effects of using different distributions on cost risk are evaluated and identified.

Distribution	Description	Shape	Typical application
Lognormal	A continuous distribution positively skewed with a limitless upper bound and known lower bound; skewed to the right to reflect the tendency toward higher cost.		To characterize uncertainty in nonlinear cost estimating relationships.
Normal	Used for outcomes likely to occur on either side of the average value; symmetric and continuous, allowing for negative costs and durations. In a normal distribution, about 68% of the values fall within one standard deviation of the mean.		To assess uncertainty with cost estimating methods; the standard deviation or standard error of the estimate is used to determine dispersion.
Beta	Similar to normal distribution but does not allow for negative cost or duration, this continuous distribution can be symmetric or skewed.		To capture outcomes biased toward the tail ends of a range; often used with engineering data or analogy estimates.
Triangular	Characterized by three points—most likely, pessimistic, and optimistic values—can be skewed or symmetric and is easy to understand because it is intuitive. One drawback is the absoluteness of the end points.		To express technical uncertainty, because it works for any system architecture or design; also used to determine schedule uncertainty.
Uniform	Has no peaks because all values, including highest and lowest possible values, are equally likely.		With engineering data or analogy estimates.
Weibull	Versatile, able to take on the characteristics of other distributions, based on the value of the shape parameter "b"—e.g., Rayleigh and exponential distributions can be derived from it.[a]		In life data and reliability analysis because it can mimic other distributions and its objective relationship to reliability modeling.

Source: DOD, NASA, SCEA, and Industry.

[a]The Rayleigh and exponential distributions are a class of continuous probability distribution.

Table 1. Common Probability Distributions Used in Cost-estimating Uncertainty Analysis
(GAO, 2007)

The Money Allocated is Money Spent (MAIMS) principle is based on Parkinson's Law, where "Work expands to fill the time allotted" and "padding schedule estimates directly contribute to cost overruns" (Augustine, 1997). In other words, it suggests that there will be no cost underruns, and that the project will come in at or above the cost to which it is funded. Implementing the MAIMS principle in Monte Carlo simulations modifies the basic probability distribution functions (PDF) by setting any value less than the money allocation point equal to that money allocation value. There will be no costs associated with a value less than this money allocation point. Utilizing the MAIMS principle, the PDFs are modified to include a spike or delta function at an arbitrary point, which is assumed to be the "money allocation point," corresponding to the dollar amount allocated to the program manager for the project and/or project cost elements.

Correlation effects between elements are analyzed. Correlation accounts for interrelationships between cost elements. Data elements can either be negatively, neutrally, or positively correlated and can either exist among cost elements within a subsystem or between elements in different subsystems. For example, take into consideration the elements of a ship. Positive correlation arises when increases in weight, size, and number of weapons systems onboard result in an increase in acquisition and shipbuilding costs. An increase in the complexity of a weapon system further forces an increase in cost of other systems such as power, cooling, control. Analysis would be greatly simplified if analysts could assume that all elements are independent or that all elements are dependent. Since neither statement is true, correct correlation between elements is necessary to provide the most accurate representation of cost.

Many software programs are available for cost risk analysis. This paper uses Crystal Ball® as an add-in to Microsoft Excel®, because of its ease of use and because it is the current program used by NAVSEA 05C. Crystal Ball® generates the Monte Carlo simulations that become the backbone of the cost risk analysis. A Monte Carlo simulation calculates multiple scenarios of a model by repetitively sampling values from the input variable distributions for each uncertain variable and then calculates the result. The resulting cost distributions from Crystal Ball® provide the decision-maker with powerful cost risk information.

A program built on a solid foundation of accurate cost estimating that effectively considers risks, combined with strong systems engineering and program management, gives the program a greater chance of success.

B. Purpose

The purpose of this paper is to analyze the probabilistic cost analysis approach that NAVSEA's Cost Engineering and Industrial Analysis division (SEA 05C) currently uses to predict new naval vessel construction costs and to develop a method that better predicts the ultimate cost risk. This paper uses data collected from analysis of the CG(X) class ship cost model. The model used to determine cost is reviewed and analyzed to determine what factors should be considered to produce more realistic cost estimates.

II. Revised Cost Risk Analysis

A. Introduction

The NAVSEA 05C's cost analysis model of CG(X) encompasses all aspects of cost for the entire fleet including inflation and profit in a 63 worksheet Excel® workbook. The data used in the NAVSEA model were acquired from SME inquiry using three-point estimates of high, most-likely, and low values. In order to ensure the continued acquisition of CG(X), it is important that realistic cost risk analysis be performed so that program managers can make informed decisions.

This chapter presents an approach to improve on the model that NAVSEA 05C has provided for CG(X). The focus is strictly on the methodology used in the cost analysis of the electronics suite of CG(X) cost model and cost uncertainties associated with engineering and manufacturing of the lead vessel. Nine systems make up the electronics suite:

- Radar suite, which consists of the following subsystems: X-band, S-band, Cooling, and Power
- ExComm—External Communications

- TSCE—Total Ship Computing Environment
- IUSW—Integrated Undersea Warfare
- EW-IW—Electronic Warfare-Information Warfare
- EO-IR—Electro Optical-Infrared
- IFF—Identification, Friend or Foe
- MS EI&T (SS Only)—Mission Systems Engineering, Integration, and Testing (Ship Systems Only)
- MS EI&T (CS Only)—Mission Systems Engineering, Integration, and Testing (Combat Systems Only)

The electronics suite cost is determined with the following two equations that treat each of the cost elements as a random variable (RV). The costs in bold represent composite of the costs in regular font, which Crystal Ball® refers to as forecasts and assumptions:

COST(Electronics Suite) = **COST(Radar Suite)** + COST(ExComm) + COST(TSCE) + COST(IUSW) + COST(EW-IW) + COST(EO-IR) + COST(IFF) + COST(MS EI&T (SS Only)) + COST(MS EI&T (CS Only)),

Cost(Radar Suite) = Cost(X-band) + Cost(S-band) + Cost(Cooling) + Cost(Power).

The steps of analysis for the CG(X) model are as follows:

1. Analyze the cost factors used by NAVSEA 05C to develop the electronics suite cost.
2. Analyze the PDFs used for the electronics cost elements.
3. Identify what data elicitation methods were employed.
4. Determine if correlation factors were used in the cost analysis.
5. Develop cost factors to be modeled for cost realism.
6. Decide which PDFs to use for greater fidelity.
7. Develop an improved cost risk model that includes realistic correlation factors; credible PDFs, including MAIMS influences; and SME biases.

B. Review Development of Cost Factors

1. Data Elicitation Methods

The data elicitation methods used by NAVSEA 05C cost analysts are not well documented. It is clear that the engineering and expert judgment of SMEs is heavily relied on for the assessment of uncertain cost elements associated with new designs. This is an area where the use of improved methods can dramatically improve the quality of data that is used in the computation of the cost risk model. Subjective assessments to obtain data have been identified as a critical source of uncertainty in probabilistic risk analyses (Keeney & von Winterfeld, 1991). Kujawski et al. (2004) discuss the use of the DFA method for data elicitation and how this ties in with distribution choice, to provide the most realistic cost assessment.

DFA has been found to provide one of the most consistent and least bias-prone methods for eliciting uncertain quantities (Alpert & Raiffa, 1982). In their research, people were asked to consider uncertain quantities by providing values in terms of percentiles or fractiles. The findings indicated:

- There is a systematic bias toward overconfidence in estimates. The subjective probability distributions were too narrow. Usually, 33% instead of 50% of the actual values fell within the 0.25 to 0.75 fractiles.
- Extreme value judgment is even worse: 20%, rather than 2%, of the actual values fell outside the 0.01 and 0.99 fractiles.
- What is the meaning of minimum and maximum values? Defining these terms, so that they are universal, is difficult.

Kujawski et al. (2004) further suggest using experts to provide the 10th, 50th, and 90th percentile values, as these may be easier to assess than extreme values of maximum and minimum. They recommend avoiding asking for extreme values, abstract values such as the mean or standard deviation, or other specific distribution functions. If the analyst does not fully understand the background of the questions being asked, or if he or she does not fully understand the behavior of the system and associated data, obtaining discrete values will be near impossible.

Education also plays an important role in the quality of the data provided by the SMEs for analysis. The understanding of bias and its role in affecting data elicitation is important. In a presentation to the Navy Cost Analysis Symposium, Fields and Popp (2007) stress the importance of several lessons learned on risk. One of the most interesting of these lessons learned is the importance of training. They indicate that although NAVSEA and its technical community have a broad cross section of educational backgrounds and experience, not everyone has experience in simulation and statistics. The SME for a particular electronics suite component is probably not an expert in probability and statistics, and because of this, tends to give biased answers to the cost analysis. The distributions formed from the biased data have been found to be particularly narrow and centered on a given point estimate, while the extreme values are very rarely taken into account, for reasons described above.

Education of the SMEs while conducting data elicitation is important, so that the experts have a better understanding of what data is required and how it is going to be utilized. This training needs to be continually refreshed due to the high turnover rate of personnel, whether they be military or civilian, and also because of improving methods for cost analysis. An adequate training plan for both the cost analysts and the SMEs providing data will ultimately result in better data acquisition for cost analysis.

In this paper, the use of DFA is simulated though the use of Weibull probability distributions because no new data elicitation was conducted. The differences between the distributions using identical values for 10th, 50th, and 90th percentiles versus the 20th, 50th, and 80th percentiles illustrates data elicitation that is optimistic versus pessimistic. The resulting cost associated with each of the two distributions shows how dramatic the effects of slightly different parameters can have on the estimated cost.

2. Choice and Development of Probability Distribution Functions

Kujawski et al. (2004) emphasize the importance of realistically modeling cost uncertainties through the appropriate choice of probability distribution by meeting the following criteria:

- Capable of fitting three arbitrary percentiles.
- A finite lower range.
- An infinite upper range with reasonable behavior.
- Physically meaningful and easy to estimate parameters.

Three types of PDFs are developed and modeled for this paper, with the goal of finding a realistic and flexible probability distribution. Uncertainty for each cost element in the cost model is represented using the same type of PDF with different parameters (based on NAVSEA data). First, a triangular PDF that uses low, most-likely, and high values for its parameters is developed. A lognormal PDF that uses the mean and standard deviation from the triangular PDF as its parameters is the second distribution. The third PDF is a three-parameter Weibull distribution based on the low, most-likely, and high values of the triangular PDF provided by NAVSEA 05C. The low and high values are calculated by multiplying the low and high percentages obtained with the most-likely value. Two Weibull distributions are created. One of the Weibull distributions uses the data as input for the 10th, 50th, and 90th, percentiles, while the other is more pessimistic and uses these values for the 20th, 50th, and 80th percentiles. For consistency, the triangular distribution is used to determine the 50th percentile. The low, 50th percentile, and high values are substituted for the 20th, 50th, and 80th percentiles and for the 10th, 50th, and 90th, for each three-parameter Weibull distribution, respectively.

a. Triangular Probability Distribution Function

The parameters used to develop the triangular PDF are the low, most-likely, and high values from the Mission Systems Risk Assessment worksheet of the CG(X) model. The determination of the high and low percentages for cost values in the Mission Systems Risk Assessment worksheet were figures given to NAVSEA 05C cost analysts by SMEs from the NSWC Dahlgren. These percentages are based on historical database values and inquiry of the SME for an opinion about what the low and high values would be, based on the most-likely values obtained from the historical databases. In this case, data elicitation plays a big part in the reliability of the data used in the model, which is to be described in more depth in Section IV.B.1.

The triangular distribution is not a good predictor of high and low costs because it uses the low and high values as extreme values for the end points. There is no allowance for costs above or below the input values. It has been argued that a triangular distribution can lead to either underestimates or overestimates. Graves (2001) states that underestimates are likely due to the finite upper limit of the distribution. Moran (1999) believes that overestimates happen because of the distribution's inability to portray the expert's confidence level of achieving the most-likely value and/or knowledge of the shape of the distribution. The triangular distribution is assigned a very low score for criteria (i) and (iii) (Kujawski et al., 2004) and is not the chosen distribution to represent cost in the model for this paper.

b. Lognormal Probability Distribution Function

The lognormal PDF is created with the mean and standard deviation parameters taken from the triangular distribution. Characteristics of a lognormal distribution include being positively skewed with a limitless upper bound and known lower bound. This distribution is assigned an acceptable score for criteria (iii), but a low score for (i), due to the always positively skewed nature of the distribution. The lognormal distribution results in a cost profile that closely follows with the triangular distribution and is one of the narrowest profiles modeled. A lognormal PDF has been associated with providing unreasonably high probabilities at high values, due to the relatively slow falloff to the right. For this reason, it gets an acceptable score for the criteria (iii) but scores low on the criteria (i) because of its always positively skewed characteristic (Kujawski et al., 2004).

c. Weibull Probability Distribution Function (10%, 50%, 90%)

The three-parameter Weibull distribution is characterized by being flexible and able to assume a wide variety of shapes, while also being open-ended. Because of its flexible profile and ability to mimic other distributions, it scores high on all criteria. This paper models one of the three-parameter Weibull distributions with the 10th, 50th, and 90th percentile values for cost. The parameters of 10th, 50th, and 90th percentiles are chosen to simulate a cost environment that allows for some cost flexibility on the upper and lower limits rather than making them extreme as in the triangular distribution. Although this 10% change on either side of the distribution seems large, it actually represents a fairly optimistic assessment of cost. This model is best for a situation in which the data obtained for the model is very reliable.

d. Weibull Probability Distribution Function (20%, 50%, 80%)

The three-parameter Weibull distribution using the 20th, 50th, and 80th percentiles for distribution parameters is intended to correct or account for the overly optimistic biases discussed in Section 2 above. Systems that are new and untested have a certain amount of uncertainty inherent in their acquisition, and most cost assessments made on their components are based on past history if components are being reproduced, or a best estimate for new systems and their components. SMEs are naturally optimistic about their systems and have been shown to give cost estimates that are overconfident, resulting in probability distributions that do not accurately reflect the possible range of costs (Kujawski et al., 2004).

Much of the data for the CG(X) electronics suite is the result of SME inquiry, which explains why the Weibull distribution using 20%, 50%, and 80% parameters is chosen to model costs for the electronics suite components in this paper.

e. Cost Comparisons with the Different Probability Distributions

Figure 2 is the Excel® overlay created with Crystal Ball® that shows of a 10,000-run Monte Carlo simulation for the triangular, lognormal, Weibull (10%, 50%, 90%) and Weibull (20%, 50%, 80%) distributions, representing the electronics suite cost of the CG(X). Figure 10 is the cumulative probability distribution derived from the PDF shown in Figure 9. The triangular and lognormal distributions are very similar in both the probability distribution and cumulative frequency functions, which is expected. Since the lognormal distribution uses the mean and standard deviation from the triangular distribution as its parameters, the end result should be very similar. Both the triangular and lognormal functions show a distinct peak and sharp falloff at both the lower and upper bounds. This behavior does not realistically model the electronics suite cost because of the sharp peak with sharp falloff.

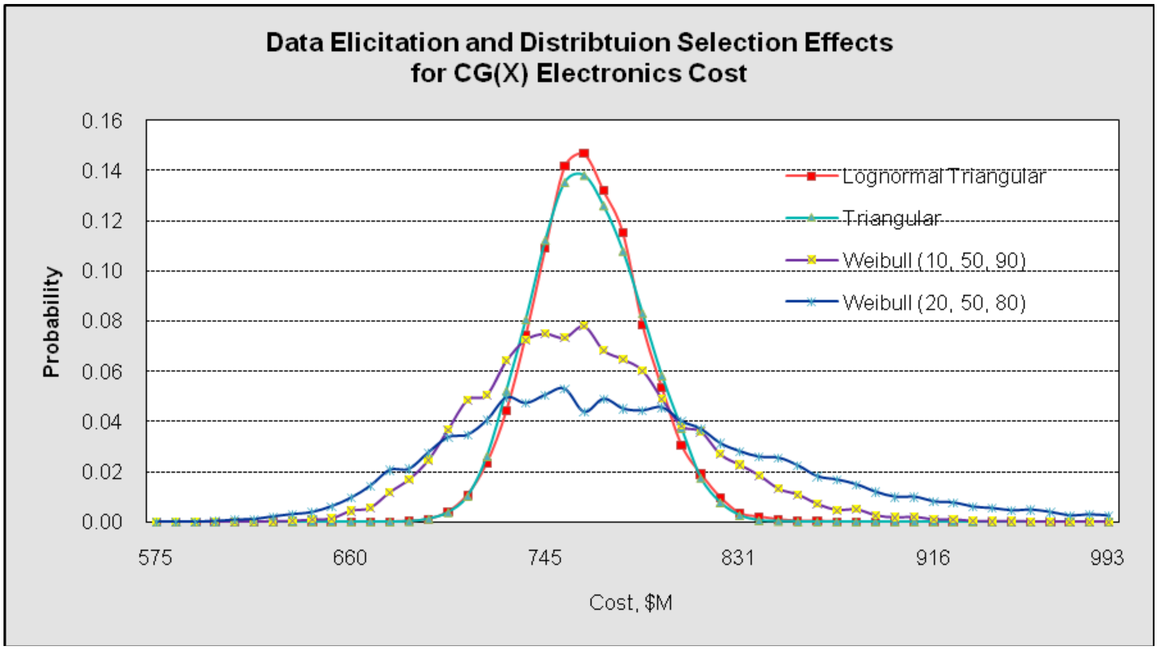


Figure 2. CG(X) Crystal Ball® Analysis, 10,000 Runs Showing the Effects of Distribution Choices on the Cost Probability Distributions

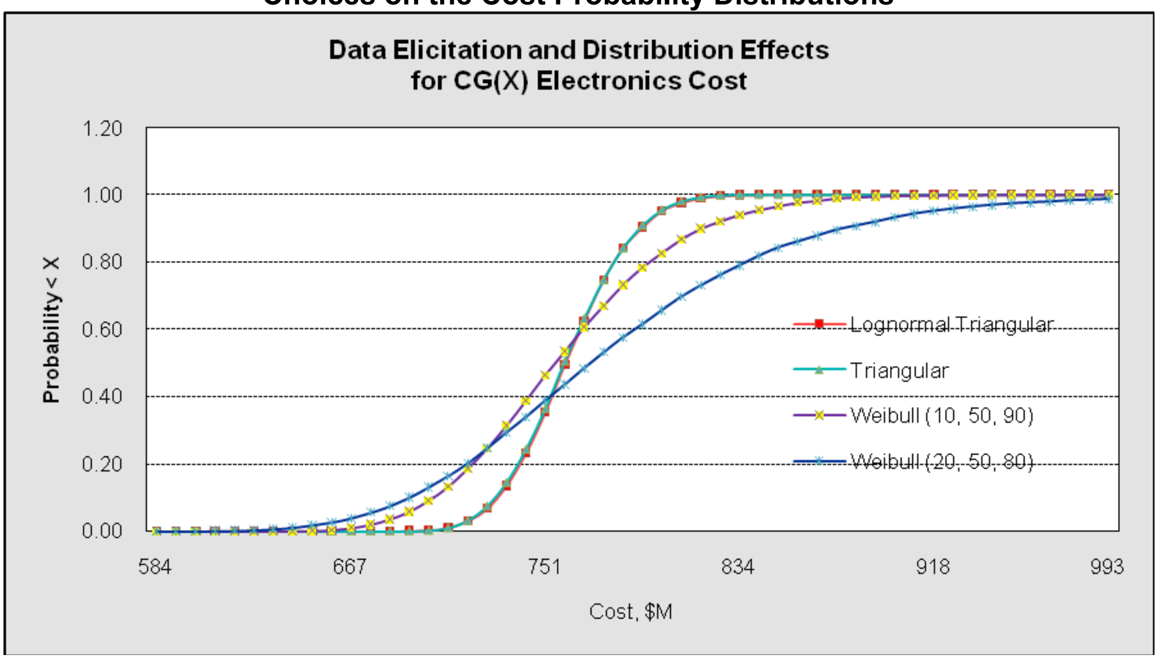


Figure 3. CG(X) Crystal Ball® Analysis, 10,000 Runs Showing the Effects of Distribution Choices on the Cost Cumulative Distribution Functions

The Weibull (10%, 50%, 90%) distribution shows a broader cost range for the given probability brackets. The tapering lower and upper bounds in comparison to the triangular and lognormal distribution represent a more likely cost outcome. The Weibull (20%, 50%, 80%) shows an even larger cost range, which makes sense because this distribution is supposed to model a more pessimistic view of cost. Both of these distributions are associated with higher costs as the probability of the cost increases. It is important to note the difference between the optimistic and pessimistic Weibull distributions in Figure 3. For each, the cost increases with an increase in probability, but it is clear that the model's results indicate that the cost risk is significantly higher using the pessimistic Weibull distribution.

3. Correlation Effects

Correlation effects are potentially important in modeling appropriate cost relationships between different elements of systems and are not conducted enough in current cost analysis models (Book, 2001). Trends with correlation tend to lean toward perfect correlation because of simplicity. Perfect correlation helps to widen the range of outputs in the distribution functions, but this may not be an accurate or reliable representation. Reasonable correlation coefficients may provide more realistic and credible estimates of project costs, rather than assuming perfect or zero correlation. Assessing correlation coefficients is a difficult problem. A need exists for the investigation and development of a realistic and practical model to account for interrelationships between cost elements.

Two types of correlations are modeled in this paper:

- Correlations among cost elements within the radar suite. The radar suite includes elements of X-band, S-band, Cooling, and Power. Dependencies among these components are mainly from subsystem characteristics such as complexity.
- Correlations among cost elements in the entire electronics suite. Dependencies among these cost elements occur from the programmatic and organizational considerations common to all cost elements that are a part of the same project (Kujawski et al., 2004).

There are two types of correlations: Pearson and Spearman. Pearson correlation coefficient determines the degree of linearity between two random variables, while Spearman rank order correlation coefficients measure monotonicity. Correlation among cost elements in the electronics suite is modeled with the use of the Correlation Matrix function in Crystal Ball®. Crystal Ball® uses rank correlations to correlate assumptions. This means that the values are not changed, but they are rearranged to produce the desired correlation. Rank correlation eliminates the need to explicitly model the dependence between the cost elements. Garvey (2000) advocates the use of Pearson's correlation. However, given the limited information, rank correlations offer the advantage of accounting for correlations independent of explicit distribution and dependency models. The use of Monte Carlo simulations generates the full PDF rather than simply expected value and variance.

This paper uses three sets of two correlation coefficients to model the correlation between the radar suite elements and the rest of the electronics suite components. The first set models the distributions with correlation coefficients of 0.5 for the radar suite elements and 0.5 for the entire electronics suite elements. The second set of correlation coefficients is 0.5 and 0.2. The third set uses correlation coefficients of 0.8 and 0.5.

Figure 4 is an overlay of the different probability distributions for the electronics suite cost, produced by using the following three different combinations of correlation coefficients for the radar suite and electronics suite:

- Correlation coefficients of 0.5 among the radar suite components and 0.2 between the different electronic suite components.

- Correlation coefficients of 0.5 among the radar suite components and 0.5 between the different electronic suite components.
- Correlation coefficients of 0.8 among the radar suite components and 0.5 between the different electronic suite components.

As discussed above, positive correlations give rise to broader distributions, which reflect higher uncertainty. The no correlation PDF in Figure 4 is the same as the no correlation shown in Figure 9. They do not appear to be the same due to the difference in scale because they are from separate Monte Carlo simulations. Although the Monte Carlo simulations will give similar results for each run, they will not be identical.

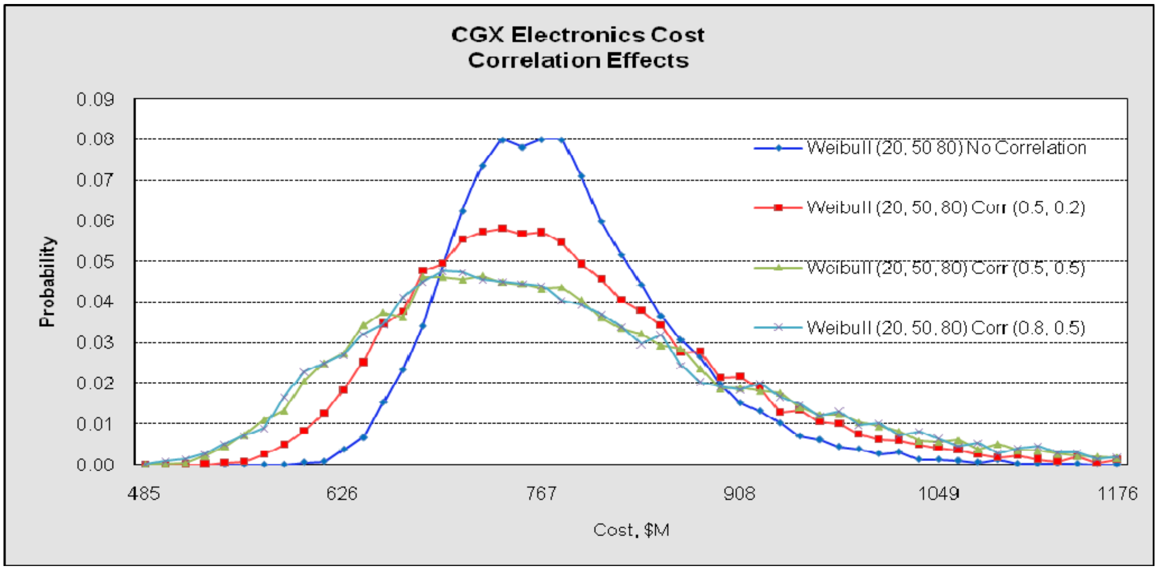


Figure 4. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Based on Different Correlation Effects in Cumulative Probability Form

4. MAIMS Principle Effects

The MAIMS principle is modeled in this paper by using the three-parameter Weibull (20%, 50%, 80%) distribution function and predetermined percentile points for the MAIMS set points. By implementing MAIMS into the distribution function, any value less than the money allocation point is equal to the money allocation value. The percentage parameters used for MAIMS are the 50th percentile or median, the mean, and the 80th percentile funding levels. A spike, or delta function, is observed in the MAIMS modified distributions at the money allocation points. These money allocation points correspond to the budget allocated to the WBS cost elements by the project manager.

The MAIMS modified functions are modeled by using the following equation:

If Distribution *Value < X, then X, else Distribution Value.*

By using this equation, the value of the MAIMS modified distribution will never be less than the value X.

D. Results

1. Effects of Distribution Choice on Cost Forecast

The first distributions modeled were the single electronics suite elements with different distributions. For the purpose of this paper, the element ExComm is chosen for this explanation. Figure 5 shows the cumulative frequency distribution of the different modeled distributions for the ExComm element. The triangular and lognormal distributions show similar characteristics, which is expected since the lognormal distribution uses parameters taken from the triangular distribution (mean and standard deviations). Both Weibull distributions show expected characteristics. The Weibull (20%, 50%, 80%) definitely indicates a more pessimistic cost forecast because as the cumulative probability increases, the cost increases more significantly than for the Weibull (10%, 50%, 90%) distribution. This overlay indicates that the choice of distribution used in modeling plays a significant part in results obtained for cost. The three-parameter Weibull distributions represent a more realistic cost outcome for high-risk components. Weibull distributions allow for modeling of highly complex distributions using DFA, while triangular distributions have a more restrictive shape, making it difficult to fit three arbitrary percentiles for the low, most-likely, and high values (Kujawski et al., 2004).

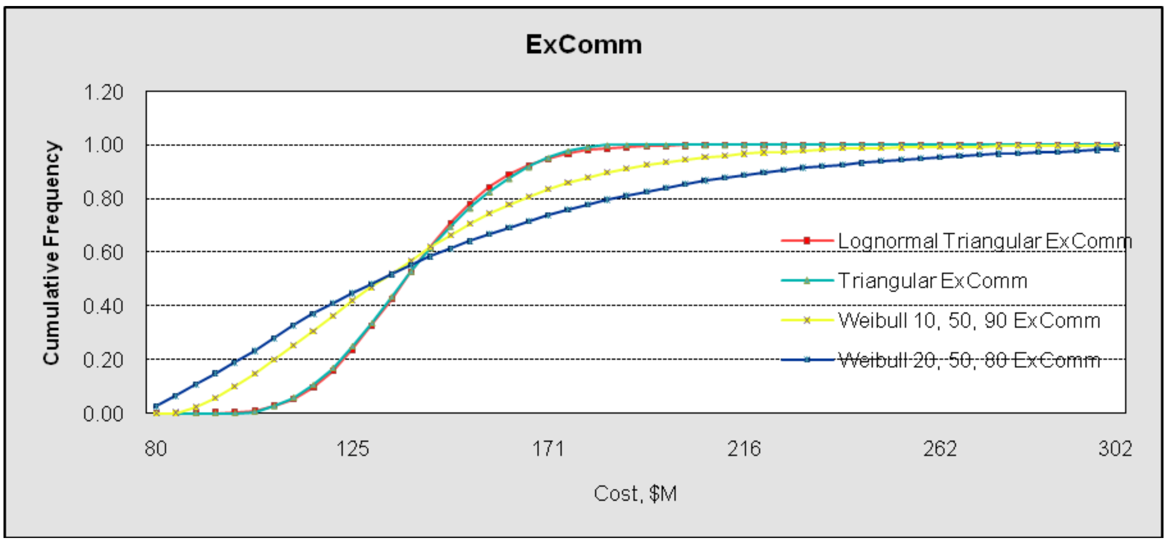


Figure 5. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Element ExComm Cumulative Frequency Distributions for Different Probability Distributions

The probability distribution functions shown in the overlay in Figure 6 illustrate expected behaviors for the ExComm PDFs. Both the triangular and lognormal distributions are narrow because the triangular distribution upper and lower bounds do not allow for infinite upper cost ranges. The sum of the Weibull (20%, 50%, 80%) distributions shows a more pessimistic behavior in comparison to the sum of the Weibull (10%, 50%, 90%) distributions.

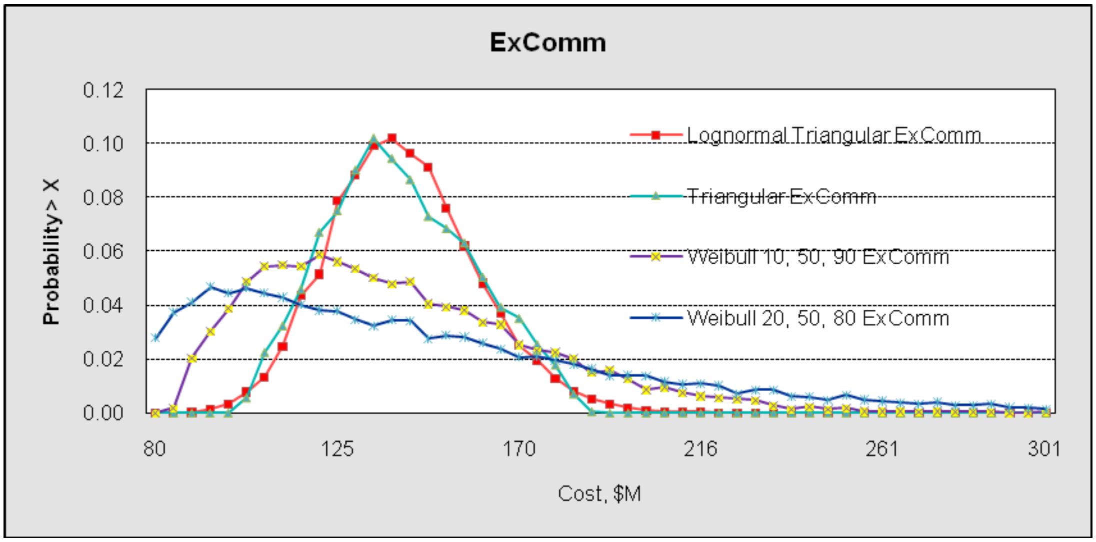


Figure 6. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Element ExComm with Different PDFs

Once all the individual electronics suite elements are modeled, they are summed up probabilistically in the main worksheet in Excel® to obtain the entire electronics suite cost. The simulation selects a random value from each of the element distributions then adds them to create one data point for the total cost. This is repeated 10,000 times to create the total cost distribution. When all the distribution functions (assumption cells in the model) of the electronics suite elements are probabilistically summed, the resulting cost is illustrated in the overlay shown in Figure 7. All four distributions have the appearance of a normal distribution consistent with the Central Limit Theorem (Garvey, 2000).

The lognormal and triangular distribution functions give rise to relatively narrow total cost distributions, consistent with the finite ranges of the contributing triangular distributions and the modeling of the lognormal distributions using the corresponding mean and standard deviation values. The Weibull (10%, 50%, 90%)-based cost distribution shows more narrow behavior for cost range than the Weibull (20%, 50%, 80%)-based distribution. The Weibull (20%, 50%, 80%)-based distribution allows for more uncertainty in data elicitation from SMEs. Weibull distributions not only show higher probabilities of cost overruns but also higher probabilities of cost underruns. These underruns reflect the assumption of 10% and 20% as the low value parameter for the distribution, rather than using it as the minimum value. Figure 8 shows the same data as Figure 7, except that it is in the cumulative probability form.

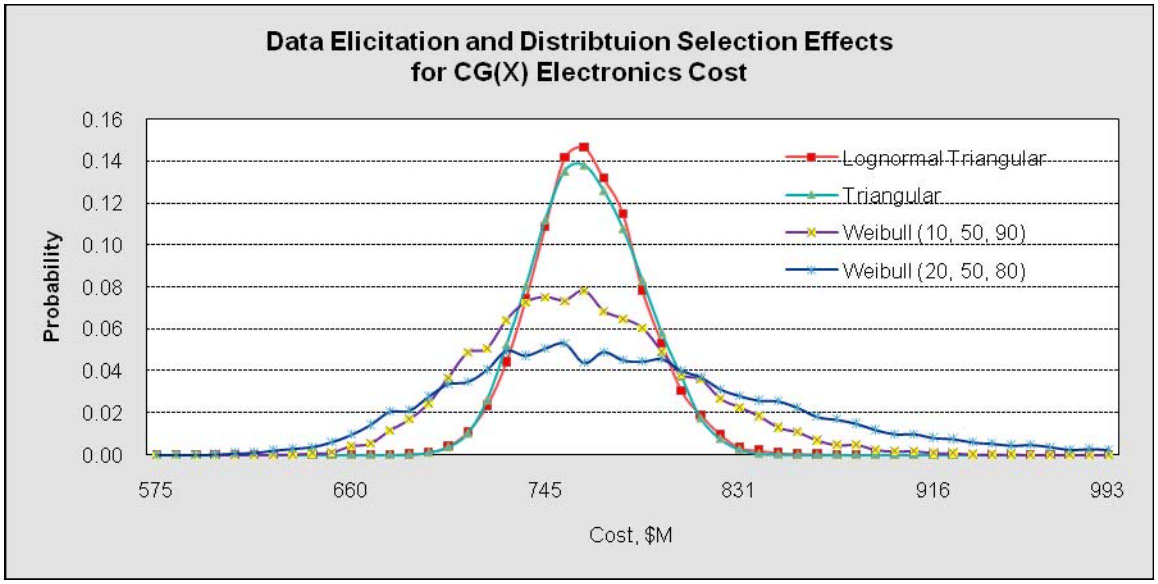


Figure 7. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Based on Different Distribution Selections

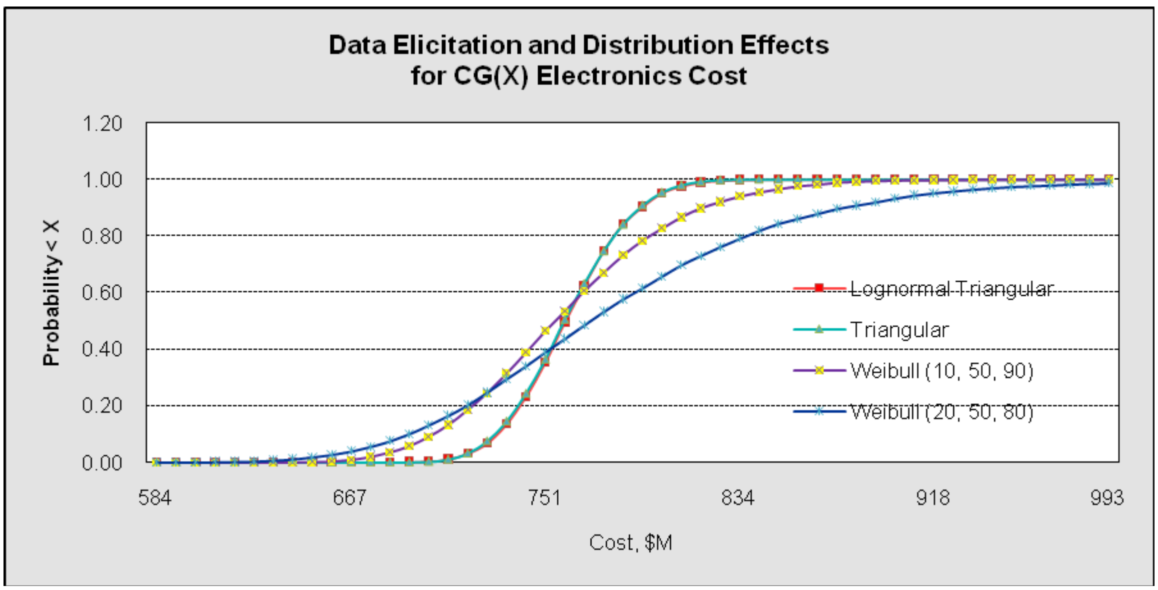


Figure 8. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Based on Different Distribution Selections in Cumulative Probability Form

2. Effects of Correlation on Cost

As discussed in Section II.B.1, two types of correlations are modeled in this paper: (1) Correlations among cost elements within the radar suite, and (2) correlations among cost elements in the entire electronics suite. This paper uses the following three correlation coefficient factors to show the correlation between the radar suite elements and the rest of the electronics suite components:

- Radar suite correlation coefficient = 0.5, electronics suite correlation coefficient = 0.5
- Radar suite correlation coefficient = 0.5, electronics suite correlation coefficient = 0.2
- Radar suite correlation coefficient = 0.8, electronics suite correlation coefficient = 0.5.

The choice of the values listed above simulates an environment that is not a perfectly correlated or no-correlated situation. The (0.5, 0.5) correlation assumes there is an equal correlation relationship between the subcomponents of the radar suite and the elements of the electronics suite. The (0.5, 0.2) correlation illustrates the effects of having a stronger correlation between the elements of the electronics suite than between elements of the entire electronics suite. The (0.8, 0.5) correlation shows the impact of a stronger correlation between components of one system than between different systems. These correlation coefficients represent a limited set of parameters for investigation in this paper. Further research in the determination of appropriate correlation coefficients and their effect is needed to provide a more complete analysis.

The impact of correlation effects is seen in Figures 9 and 10. These overlays show the different distributions that are a result of a 10,000-run Monte Carlo simulation for the correlated distributions in cumulative distribution form (Figure 9) and PDF form (Figure 10). The blue PDF is the reference Weibull (20%, 50%, 80%) distribution with no correlation effects. This distribution has the most narrow cost range when compared with the correlated distributions. The cost ranges of the Weibull distribution increases as the correlation factors increase. Also, in the cumulative probability distribution shown in Figure 9, all the distributions intersect at the mean value for the cost.

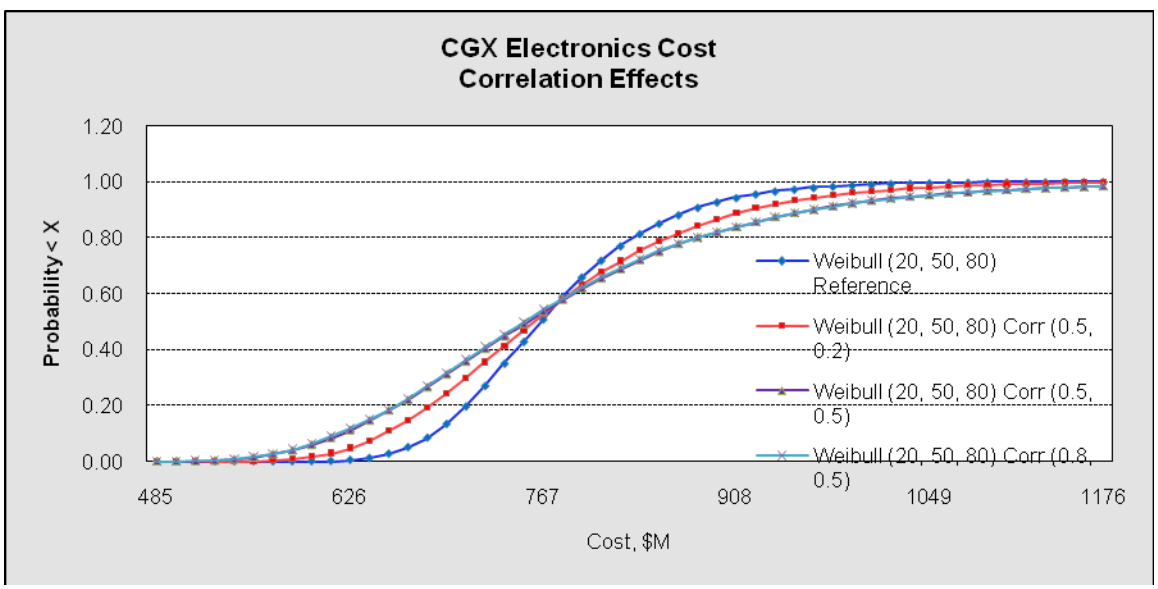


Figure 9. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Showing the Impact of Different Correlation Effects

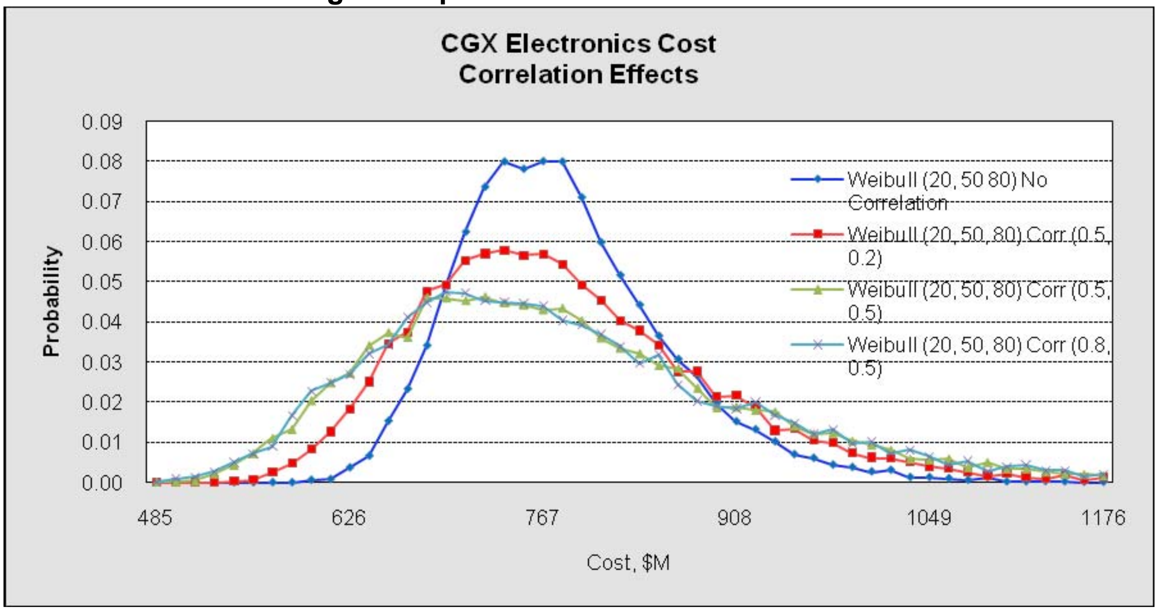


Figure 10. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Based on Different Correlation Effects in Cumulative Probability Form

As expected, the (0.5, 0.2) correlation being the smallest has the least effect on the total cost distribution. It is interesting to note that the distribution resulting from the (0.5, 0.5) correlation does not differ much from the (0.8, 0.5) distribution, but both of these correlations have a more significant effect than the (0.5, 0.2) correlation. This indicates that a change in the correlation factor for the radar suite from 0.5 to 0.8 is not as significant as a change in the correlation factor from 0.2 to 0.5 for the different components of the entire electronics suite. These results suggest that the correlation effects are important for probability values midpoint between the mean and the extremes, but there is little difference for values beyond 0.5. The results in Figure 10 are consistent with theoretical predictions of positive correlation effects in that the total cost becomes broader than for uncorrelated total cost (Kujawski et al., 2004). Further investigations are recommended to quantify correlation effects.

3. MAIMS Effects on Cost

The MAIMS modified cumulative probability and density density distributions for the electronics suite cost are shown in Figures 11 and 12. Characteristics of the MAIMS modified PDF is that they will never have a value less than the chosen value of modification. So, for the MAIMS 50th percentile modified distribution in Figure 11, the distribution has no value less than the 50th percentile baseline cost level. In Figure 12, the spikes or delta functions normally associated with the individual MAIMS distributions are not seen as they are modulated when summed.

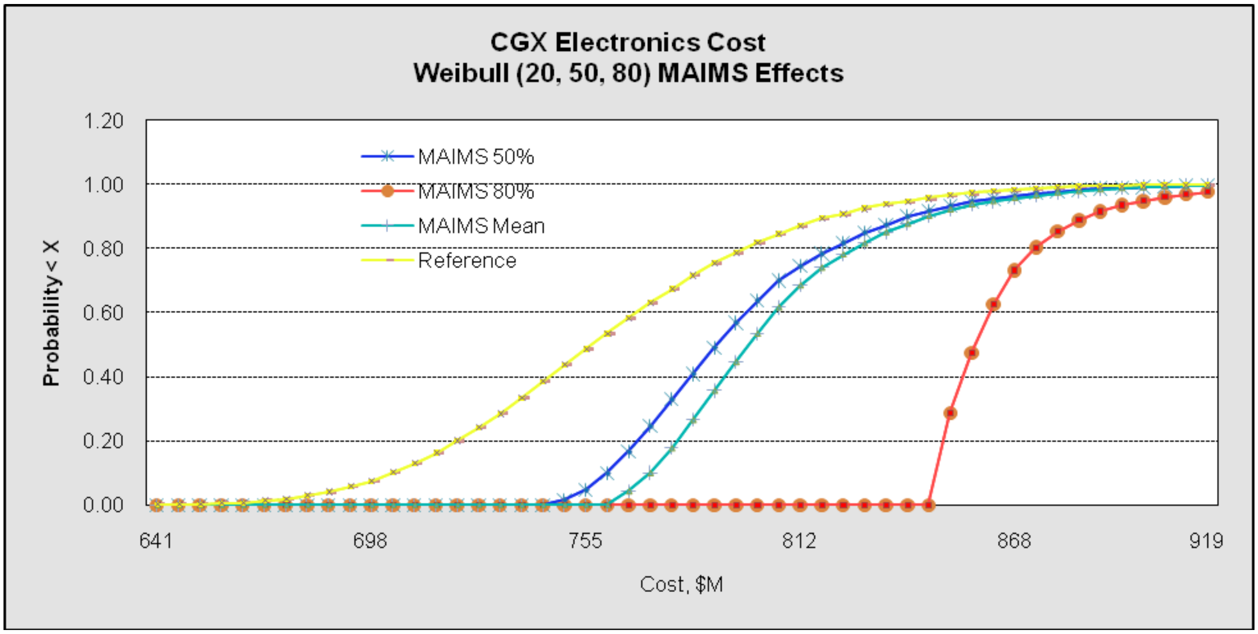


Figure 11. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Showing the MAIMS Effects in Cumulative Probability Form

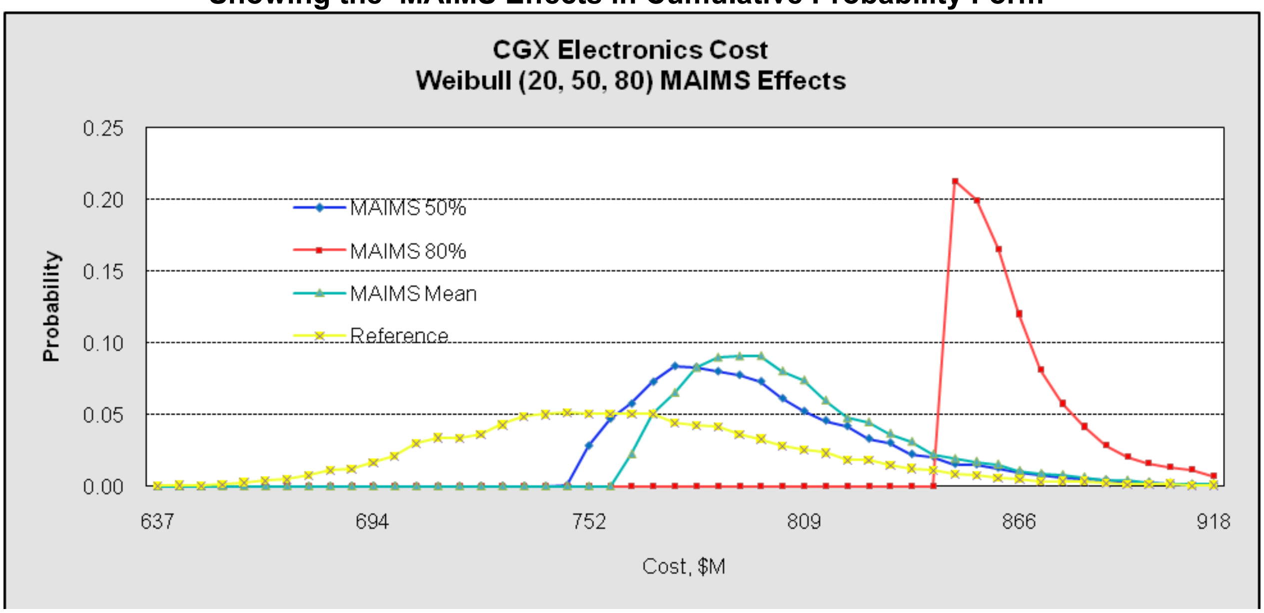


Figure 12. CG(X) Crystal Ball® Analysis, 10,000 Runs, Overlay of Electronics Suite Cost Showing the MAIMS Effects in PDF Form

It is important to note the significant rise in cost curve that occurs as the MAIMS modification value increases. The mean value of the distribtion increases as the funding level increases, and this is very clear in Figure 11. The curve representing the MAIMS 80% distribution shows how the budget is always high when comparing it to the MAIMS 50% or MAIMS mean distribution. This effect is because once money has been allocated to a WBS element, it is almost never seen in cost savings as underruns because cost account managers never return money to the project. Any remaining money from one WBS is subsequently spent on a different existing WBS that has cost overruns.

These simulations can be considered with other cost factors in making program management decisions regarding budgets. Funding projects at a level too low to cover costs will lead to cost overruns, while funding at a level that is too high leads to money not being recouped as savings later. Allocating reasonable budgets is the goal.

E. Chapter Summary

The research for this paper is based on the NAVSEA 05C CG(X) model provided by Mr. Chris Deegan and his CG(X) analysts. The CG(X) model encompasses all factors considered for cost of the entire program, including labor rates, material cost, overhead cost, planning cost, and other factors. Because of the complexity of the model and the numerous factors to consider, one portion of the model was chosen for analysis. The Electronic Suite and its nine elements are specifically targeted as the focus for analysis.

The steps used in the analysis of the CG(X) model include:

1. Analyze the cost factors used by NAVSEA 05C to develop the electronics cost.
2. Analyze the PDFs used for the electronics cost elements.
3. Identify what data elicitation methods were employed.
4. Determine if correlation factors were used in the cost analysis.
5. Develop cost factors to be modeled in a new model.
6. Decide which PDFs to use in the new model.
7. Develop a new cost model using correlation factors, chosen PDFs, and MAIMS influenced distributions.

Identified cost factors include NAVSEA 05C's probability distribution choice—a method used for developing the low, most-likely, and high cost values for the electronics suite elements, data elicitation methods, and correlation effects. This paper explores the methodology in choosing different probability distribution functions and their applicability to the model. Specifically, triangular, lognormal, and two variations of the three-parameter Weibull distribution are considered.

Methods of data elicitation are explored and the use of a DFA method is recommended for future use, although the research in this paper did not involve data acquisition. To simulate the use of a DFA methodology, Weibull distributions are employed to account for uncertainty associated with SME estimation of data. A Weibull (10%, 50%, 90%) distribution is used to simulate a more optimistic view of the uncertainty of data, while a Weibull (20%, 50%, 80%) distribution models a more pessimistic, but probably more realistic, view of the uncertainty associated with data from the SMEs.

Two types of correlation effects are considered and modeled in this paper. The first is the correlation between subcomponents of the radar suite, and the other is the correlation between the elements of the electronics suite. The radar suite is one of the elements that makes up the electronics suite. Analysis shows that a more significant effect is experienced with higher correlation between the elements of the electronics suite than between the subcomponents of the radar suite.

MAIMS modified probability distributions are modeled to show the significance of budget allocation level. These distributions are truncated at the baseline budget with a delta function at the baseline. This is based on the principle that once a budget is allocated, money is almost never seen in the form of cost under runs as the project progresses. As the MAIMS modification value increases, overall distribution cost rises with increasing probability of success.

III. Conclusions

A. Summary

This paper begins by exploring the definitions of risk and how it applies to the guidance set forth by current Navy leadership. Admiral Gary Roughead, Chief of Naval Operations, states that, "We manage risk" (Roughead, 2007). The need to develop effective acquisition and shipbuilding methods to successfully deliver an "affordable future fleet" (McCoy, 2008) is imperative if the Navy is to meet the goal of a 313-ship Navy by 2020. Cost risk analysis is one tool of many that can be used to help attain this goal.

This paper then proceeds to examine the probabilistic cost analysis approach that NAVSEA 05C currently uses to predict new naval vessel construction costs and to develop a method that better predicts the ultimate cost risk. Cost factors analyzed in this paper include the effect of data elicitation, distribution choice, the impact of the MAIMS principle, and the effect of correlation factors. Data elicitation and MAIMS have significant impact. Correlation effects vanish at the minimum, mean, and maximum values. PDF selection has a small impact as long as the distributions fit the three specified percentiles.

The model provided by NAVSEA 05C encompasses all aspects of the ship's cost and only the nine elements of the electronics suite were chosen for analysis in this paper. Using data obtained from SMEs for low-, most-likely, and high-cost values, experiments were conducted for the noted cost factors in the Excel® Monte Carlo simulation add-in Crystal Ball®.

Triangular, lognormal, Weibull (10%, 50%, 90%) and Weibull (20%, 50%, 80%) distributions are modeled and simulated to show the impact that each distribution can have on budget considerations for program managers. Both the triangular and lognormal distributions show narrow cost ranges when compared to the Weibull distribution cost range. The Weibull (10%, 50%, 90%) represents a more optimistic distribution than the more pessimistic Weibull (20%, 50%, 80%) distribution. The Weibull (20%, 50%, 80%) distribution accounts for the optimism bias commonly associated with SMEs. Data elicitation effects are modeled through the use of the Weibull distributions.

Correlation among cost elements in the electronics suite is modeled with the use of the Correlation Matrix function in Crystal Ball®. This paper uses three sets of two correlation coefficients to model the correlation between the radar suite elements and the rest of the electronics suite components. The results suggest that the correlation effects are important for probability values midpoint between the mean and the extremes, but there is little difference for values beyond 0.5. Further investigations are recommended to quantify correlation effects.

MAIMS principle modified distributions are modeled with the 50th percentile cost value, mean, and 80th percentile cost value to show the impact of funding at these different levels. The MAIMS principle is based on the observation that for a given budget, any money allocated is considered money spent. Very rarely are cost underruns experienced on a project once the budget has been allocated. The MAIMS modified distributions in this paper show the impact of either under-funding a budget or over-funding. Under-funding leads to cost overruns and over-funding leads to an overall higher cost, since money allocated is unlikely to be recouped.

B. Recommendations and Areas for Further Research

The analysis conducted in this model is only a starting point for improvements in the area of cost analysis for naval vessels. Although the methodology used in this paper provides a framework for obtaining more accurate predictions of cost than those in use with current probabilistic cost analysis, more work is required to develop a more complete and tested model. Recommendations for future research in the area of probabilistic cost analysis for shipbuilding include:

- Use of the DFA method to obtain data for cost assessment. Recommend eliciting data from SMEs at the 10th, 50th, and 90th percentiles, at a minimum, for relatively optimistic view of the data quality, and at the 20th, 50th, and 80th percentiles if a more pessimistic view of the quality of data is present. Take into consideration the overconfidence of estimates provided by experts in their field and use this knowledge when calibrating data for analysis.
- Select flexible and realistic probability distribution functions for cost analysis. Create probability distribution functions from historical data and adjust for expected differences in new programs.
- Incorporate the use of correlation among cost elements of a system. Aim to use a range of correlation coefficients that is realistic. A reasonable range for correlation coefficients is between 0.3-0.6, with some room for variation. Overly optimistic correlation coefficients that assume independence and overly pessimistic correlation coefficients that assume perfect correlation rarely exist in real data.
- Use the "Money Allocated is Money Spent" (MAIMS) principle to model budget management behavior. The MAIMS function will not allow the system cost to be a lesser amount than the budgeted cost baseline.
- Investigate further capabilities available with advanced modeling software such as Crystal Ball® or @Risk.
- Incorporate systems engineering methodologies and thinking into the development of probabilistic cost analysis. Kujawski et al. (2004) state that this is the single greatest challenge to the development and use of improved cost models.

Continuing with the development of improved cost models is an important step in helping the Navy to ensure the successful acquisition of the 313-ship Navy it desires. Improved cost models can give project managers the ability to develop more realistic and successful plans for their projects, while enabling them to make better budget decisions. The cost analysis methodology presented in this paper can serve as a starting point for further advanced research in this area that can be used by different programs across the Navy.

Acknowledgements

I thank Dr. Edouard Kujawski for his time and mentoring throughout the research and writing of this paper. I also thank Dr. Diana Angelis for her guidance and assistance in the development of this paper. Additionally, I thank Mr. Chris Deegan, the former Director of Cost Engineering and Industrial Analysis, and his staff for providing the data used in this paper; supporting travel to their office in Washington, DC; and for discussions regarding the CG(X) model. Specifically, the help provided by Mr. Morris Fields and Mr. Aaron Ratliff with the CG(X) model is greatly appreciated.

I would also like to thank my special friends Lynne and Charlie Denley for making me a part of their family and their support during my time at the Naval Postgraduate School. In addition, I thank the members of the Wednesday Night Laundry Runners and my dogs for their friendship and good times.

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Transactions Cost from a Program Manager's Perspective

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Abstract

This project continues ongoing efforts by the authors to understand transactions costs within DoD acquisition. Past studies by the authors have been constrained by the data available. As part of continuing effort to acquire more data and take advantage of first-hand knowledge of the issue, we now analyze results from a survey of US Air Force Program Managers (PMs) undertaken in 2008 by the National Academy of Sciences (NAS).

The number of oversight reviews has steadily increased, with increasingly higher-level involvement. Accordingly, the resources and management attention devoted to these reviews has also increased. Within that context, the NAS Study is intended to assess a large number of prescribed reviews (programmatic and technical) with respect to value added and various costs incurred. The fundamental question addressed to the study team is as follows: "Can changes in the number, content, or sequence of program reviews help the Program Manager more successfully execute the program?" Public release of the report is expected in April. (Until that time, we are constrained to withhold our results.)

The theoretical foundations of our supporting inquiry come from the Agency Theory and Transaction Cost Economics (TCE)—well-established fields of study. In particular, we are concerned with the complications and costs of dealing with partners both outside the DoD (TCE) and within (Principal-Agent Problem).

Our analysis of the survey results also distinguishes between technical and programmatic reviews. Technical reviews are conducted by the appropriate Program Office to monitor technical progress of the system contractors (prime and sub-). Program reviews provide management oversight of the Program Manager by higher-level authorities (service or DoD).

Our purpose is to analyze the survey data made available in the NAS study. We will present our results to date at the Acquisition Research Symposium, May 2009.

Panel 16 - Implementing an Open Architecture Strategy at the Program Management Level

Thursday, May 14, 2009	Panel 16 - Implementing an Open Architecture Strategy at the Program Management Level
11:15 a.m. – 12:45 p.m.	**Chair: Captain Brian Gannon, US Navy**, Program Manager, Naval Open Architecture, PEO Integrated Warfare Systems **Discussant: James Wolfe**, Head, Strategic and Weapon Control Systems Dept, Naval Surface Warfare Center Dahlgren ***Facilitating Decision-making, Re-use and Collaboration: A Knowledge Management Approach to Acquisition Program Self-awareness*** **John Robey** and **Chris Odell**, Naval Postgraduate School ***Effective Programmatic Software Safety Strategy for US Navy Gun System Acquisition Programs*** **MAJ Joey Rivera, US Army**, US Pacific Command, J63, **Luqi,** and **Valdis Berzins**, Naval Postgraduate School

Discussant: Mr. James A. Wolfe, Head, Strategic and Weapon Control, Systems Department (K), is a native of Miami, FL. Wolfe's Government career began in 1978 after enlisting in the United States Air Force (USAF). After serving more than four years of active duty and five years as an Air Reserve Technician, he graduated from Florida International University in December 1987 receiving a Bachelor of Science Degree in Computer Science. Shortly thereafter, he was commissioned in the USAF Reserve as an Aircraft Maintenance Officer assigned to the 482 Tactical Fighter Wing at Homestead AFB. Wolfe's next assignment was with DISA as a Communications and Computer Systems Programmer Analysis Officer, where he developed software applications supporting the Worldwide Military Command and Control and Communications System (WWMCCS). He later wrote software to support the Global Command and Control System (GCCS) integration laboratory. Wolfe was then transferred to the DISA Joint Services Support Center in the Pentagon, where he was assigned as Command and Control Operations Officer in the National Military Command Center (NMCC) providing direct support to the Deputy Director of Operations during day-to-day, real-world crises. He also participated in exercise operations with National Command Authority, CINCS, and CJCS.

Wolfe's career at Dahlgren started in 1988 as a system software programmer. Soon after, he was selected as group leader of the SLBM Software Generation System (SGS). To further develop his career, he accepted a position as group leader of the Quality Assurance for SLBM Fire Control Support Software and then as the Group Leader of the Advanced Fire Control System Group. He was then selected as Branch Head of the SLBM Engineering and Facilities Branch, where he managed and directed the branch operations which provided computer systems, Fire Control Engineering, and Facility Engineering support for 400 users. Wolfe was then assigned as Branch Head of the Weapons Software Engineering Branch. He was responsible for the development of several key components of the Tactical Tomahawk Weapon Control System (TTWCS), the Advanced Tomahawk Weapon Control System and a number of key simulators used for development and testing. Wolfe was then selected as Division Head of the Strike Weapon Systems Division. His responsibilities include managing and directing scientific, engineering, technical, and administrative support personnel tasked with performing all areas of development—including system engineering, software development, and system integration and system test for all strike weapons systems and strike weapon control systems. Wolfe is presently the Department Head for the Strategic and Weapon Control Systems Department (K).

Facilitating Decision-making, Re-use and Collaboration: A Knowledge Management Approach to Acquisition Program Self-awareness

Presenter: John Robey, Commander, US Navy, Student, Graduate School of Operational and Information Sciences. Robey earned a BS in 1988 and an MBA in 1995 from the University of South Carolina. He is a graduate of the US Naval War College of Command and Staff. Robey is a P-3 Naval Flight Officer, having served in a wide range of operational and staff assignments in 21 years of active service, to include his most recent tour as Commanding Officer of VPU-2. Upon graduation from the Joint C4I Program at the Naval Postgraduate School in June 2009, CDR Robey will report to the Navy PEO-C4I Office, San Diego, CA.

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Abstract

Decades of reform have been largely ineffective at improving the efficiency of the DoD Acquisition System, due in part to the complex processes and stovepipe activities that result in duplication of effort, lack of re-use and limited collaboration on related development efforts. This research applies Knowledge Management (KM) concepts and methodologies to the DoD acquisition enterprise to increase "Program Self-awareness" (Gallup & MacKinnon, 2008, p. 2). This research supports the implementation of reform initiatives such as Capability Portfolio Management and Open Systems Architecture, which share the common objectives of reducing duplication of effort, promoting collaboration and re-use of components. The DoD Maritime Domain Awareness (MDA) Program will be used as a test case to develop prototype data schemas and apply text and data mining tools to identify duplication and/or gaps in the features of select MDA technologies. This paper will also provide the foundation for future development of the Program Self-awareness concept and KM tools to support decision-making and improve the effectiveness of the DoD Acquisition System.

I. Introduction

A. Background

The Department of Defense (DoD) fiscal year 2009 budget for Research, Development, Test and Evaluation (RDT&E) and procurement exceeds $180 billion (Gates, 2009, p. 37). Given such huge budget outlays and the increasing pressures of shrinking discretionary budgets and fragile economy, the DoD Acquisition System is the subject of intense scrutiny from government oversight activities, industry, and the general public. This scrutiny has been amplified by highly publicized acquisition program failures, continued cost and schedule overruns and lengthy development cycles.

DoD acquisition has endured an environment of seemingly perpetual reform to arrest this chronically poor performance, resulting in complex acquisition process models, increased executive oversight, and incremental policy changes. The effectiveness of acquisition reforms has yet to be evidenced in the overall performance of the DoD Acquisition System. Independent and government-chartered studies and reports have repeatedly highlighted the need for improved systems engineering and business processes to incorporate best practices from the commercial sector.

The DoD has embraced several recommendations from these critical reports and moved to adopt several commercial best practices and process initiatives. Two such policy initiatives relevant to this research are the adoption of Capability Portfolio Management (CPM) and Open Architecture (OA) approaches, discussed at length in later sections of this paper. CPM and OA are relatively early in their implementation and address different levels of the acquisition process, but reflect the overarching DoD goals of improving decision-making regarding systems-of-systems (SoS) acquisitions to avoid duplication, identify gaps, and decrease costs and development times.

The tools and processes used by acquisition decision-makers to support implementation of CPM and OA are not well defined. A fundamental requirement of both CPM and OA approaches is that acquisition managers develop an awareness of related efforts and activities across an enterprise and/or community of interest (COI) to identify duplication of effort, capability gaps, re-use and collaboration opportunities. It is the premise of this paper that development of improved “Program Self-awareness” is fundamental to the success of the CPM and OA reform initiatives. This paper applies commercial and government best practices to develop Program Self-awareness through Knowledge Management (KM) methods and tools.

The DoD Maritime Domain Awareness (MDA) Program will be used as a test case for application of KM decision support tools to provide normalized “views” of program elements and attributes, termed “features”, to support informed program decision-making. The premise of this research is that application of KM tools will improve Program Self-awareness and support the informed decision-making required to realize the full potential of the CPM and OA initiatives.

B. Problem Statement and Research Question

DoD acquisition is an extremely complex system comprised of numerous stakeholders and organizations that navigate an array of procurement processes in an uncertain environment to deliver useful military capability to the warfighter at the best possible value to the government. Acquisition reforms have been largely ineffective at improving the efficiency of the system, due in part to stovepipe activities that often result in duplication of effort, lack of re-use and collaboration on related development efforts. This research applies KM concepts, methodologies, and tools to DoD acquisition programs to increase its self-awareness. It is the goal of this research to demonstrate the Program Self-awareness concept through application of prototype decisions support tools to the DoD MDA Program to answer the following research question.

- How can KM methodologies and decision support tools be used to improve Program Self-awareness and decision-making to reduce duplication and enable collaboration and re-use in complex DoD acquisition programs?

C. Methodology

This paper provides an overview of ongoing thesis research which will explore the problem of duplication, lack of re-use and collaboration in DoD Acquisition and follow the intuition that increased "Program Self-awareness," enabled by KM decision support tools, will improve acquisition process efficiencies in these areas. The research will be grounded in Systems Theory and Congruence Model to develop an understanding of the DoD Acquisition System and identify root causes of the stated problem. This research will apply KM tools to the DoD MDA Program as a test case and evaluate the potential for improved Program Self-awareness based on feedback from the office of the DoD Executive Agent (EA) for MDA. This work will provide the foundation for future research on the Program Self-awareness concept and development of KM tools with the goal of improving decision-making and enabling re-use and collaboration in DoD acquisition programs

D. Scope

The impact of implementation of the concepts and tools suggested in this research on other organizational components within the DoD Acquisition System (structure, processes, people) are not addressed in depth in this research. It is recognized that further research will be required to study organizational congruence and cultural issues to realize the full benefits of the Program Self-awareness concept.

II. Systems Theory and Organizations

This research explores the potential for change in the DoD Acquisition System through application of KM tools to improve Program Self-awareness. The Congruence Model, depicted in Figure 1, is grounded in Systems Theory and provides a framework to understand the complexity of the DoD Acquisition System.

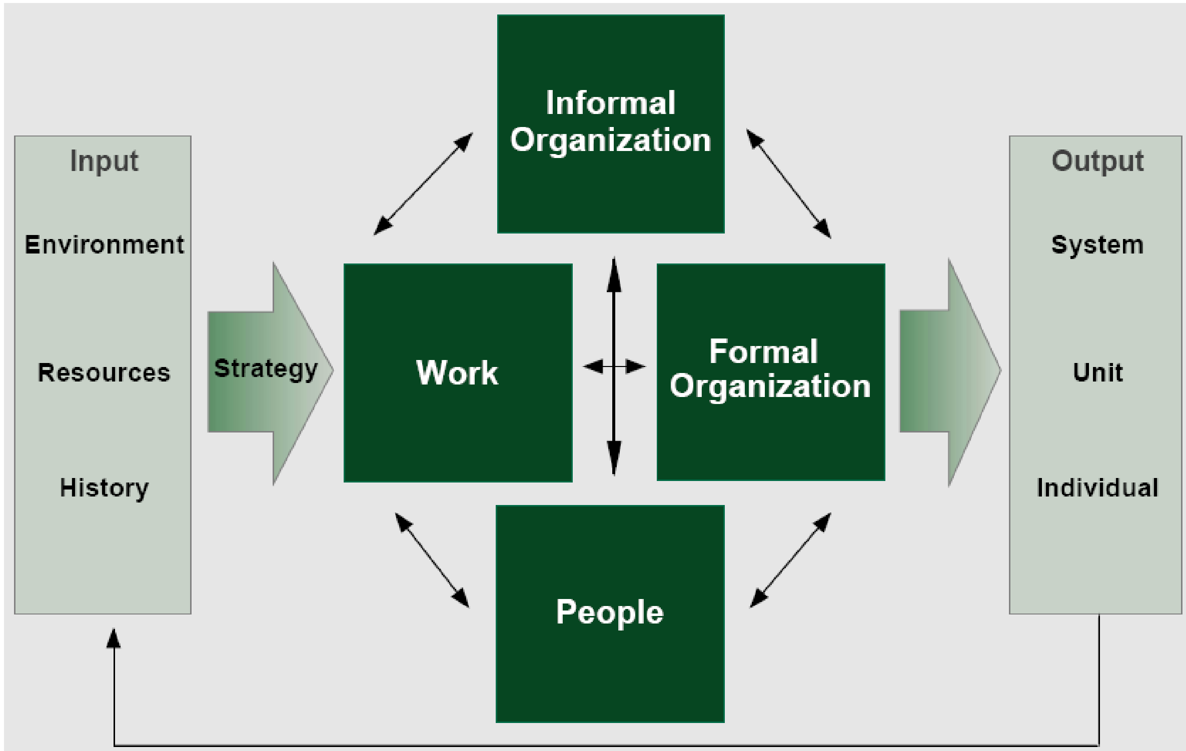

Figure 1. The Congruence Model
(Mercer Delta, 1998, p. 14)

This research focuses on the potential benefit of technology, namely KM tools, to improve "fit" among acquisition system components to achieve improved output efficiency and facilitate implementation of policy objectives such as CPM and OA. The Congruence Model is useful in this context as it highlights the interdependency among system components, which must be considered when introducing such tools into a complex system (Mercer Delta, 1998, pp. 1-15). This research suggests that application of KM tools may form a sort of "glue" to improve the fit among components, and that subsequent change(s) to other system components, namely organizations and processes (work), will likely be necessary due to implementation of these technologies

This research seeks to demonstrate the potential increase in MDA Program Self-awareness, which could facilitate improved decision-making, increased collaboration, object re-use, and reduced development timelines. Figure 2 applies the Congruence Model to the DoD Acquisition System and highlights the opportunity area for application of KM tools and collaboration to improve fit among components and overall efficiency of the system.

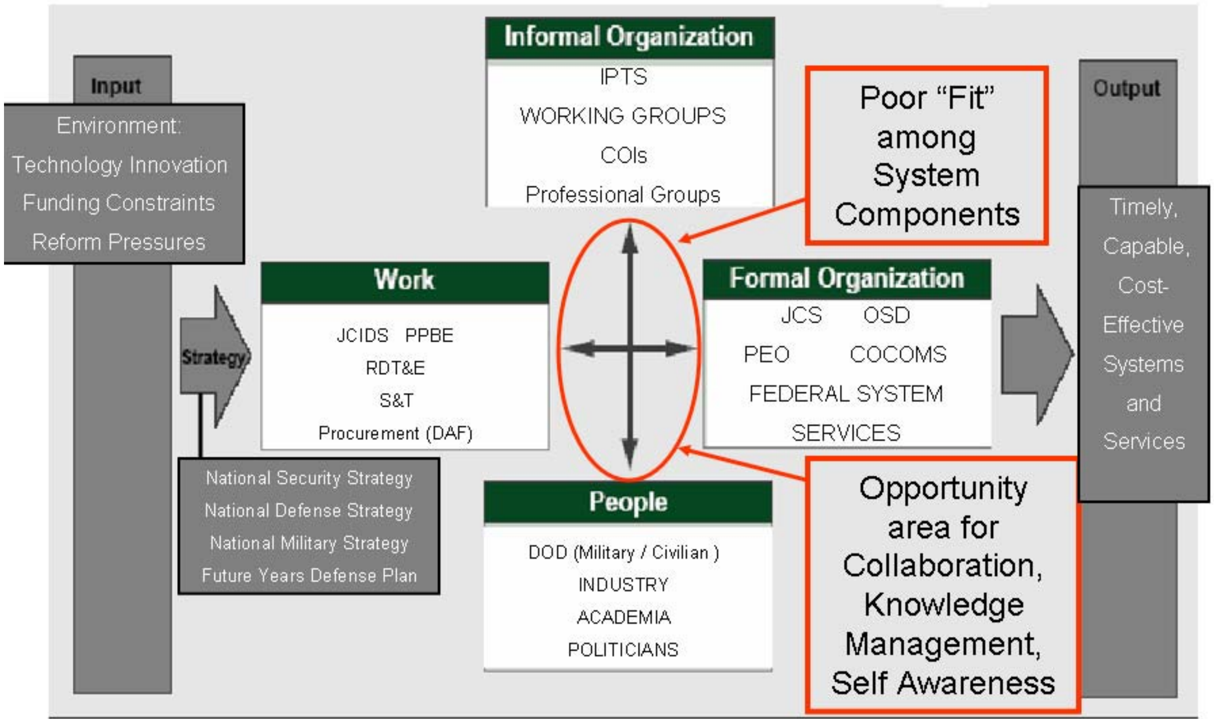

Figure 2. The Congruence Model Applied to the DoD Acquisition System
(Mercer Delta, 1998, p. 14)

III. Program Self-awareness

This research defines Program Self-awareness as the collective and integrated understanding of program attributes (system technology features, R&D activities, etc.) and surrounding environment by program decision-makers (program managers, system engineers, sponsors). Program Self-awareness allows decision-makers to recognize relationships among program attributes and seize collaboration and re-use opportunities to support cost effective acquisitions.

Achieving Program Self-awareness in complex acquisition programs such as the DoD MDA program is a lofty goal considering the myriad of stakeholders, processes, people, activities, and organizational structures involved. This research will highlight the potential of KM tools to provide an incremental improvement in Program Self-awareness. The figure below represents what Program Self-awareness embodies in the MDA Community of Interest, supported by collaboration and use of KM tools to enable improved decision-making (Gallup & MacKinnon, 2008, p. 2).

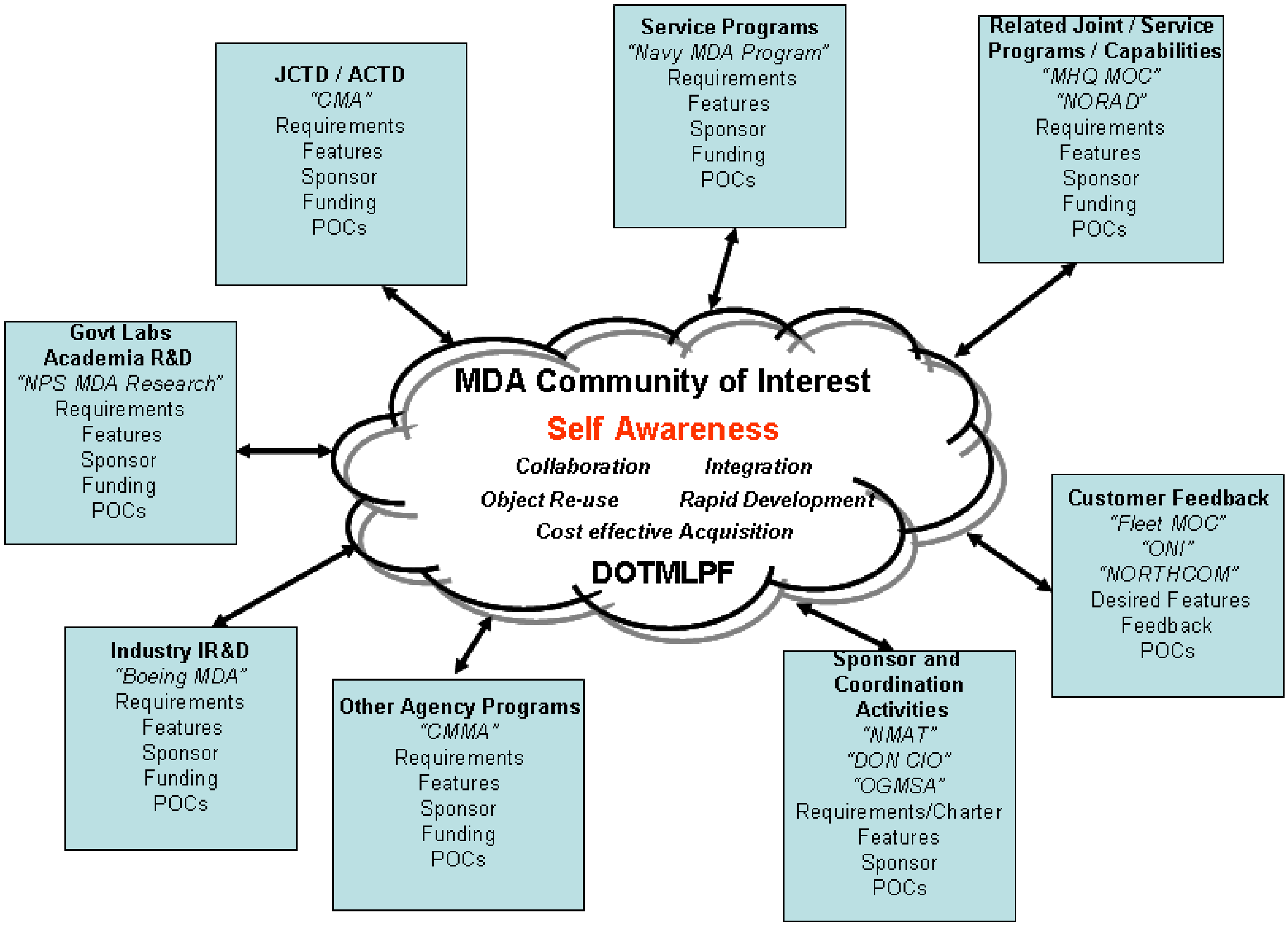

Figure 3. MDA Program Self-awareness
(Gallup & MacKinnon, 2008)

IV. Knowledge Management

The information age continues to shape the organizational environment and produce varying effects on all system components of the Congruence Model. The power of personal computing, global networking, and collaborative technologies are now fundamental to many organizational processes—enabling increased speed, availability, and volume of data to support decision-making. These technology changes have challenged organizational norms and forced organizations to perform varying degrees of self-analysis to assess the impact of these changes to the fit among organizational components (Mercer Delta, 1998, p. 15).

The challenges posed to organizations in the information age are many, to include the task of turning massive amounts of data into pertinent knowledge and leveraging the potential of the network enabled "informal organizations" to improve decision-making. The study of the dynamics and potential of technology, process, and structure to improve organizational knowledge and decision-making has fueled academic study and technology research and development under the umbrella term of Knowledge Management (KM). The formal definitions of KM vary widely among theorists and practitioners in the field, but generally address the common goal of improving the ways organizations transform data into knowledge to support decision-making. This research will focus on how KM methodologies and tools which can be applied to organizations to improve process, structure, and decision-making.

The application of KM principles to DoD acquisition was the subject of research by military fellows at the Defense Systems Management College (DSMC) in January 2000, titled "Program Management 2000: Know the Way. How Knowledge Management Can Improve DoD Acquisition" (Cho, Hans & Landay, 2000). The DSMC fellows draw the following conclusions relevant to this research:

- the commercial sector is successfully adopting KM strategies to achieve competitive advantage;
- Implementation of KM technologies in an organization must consider impacts on its people, processes, and structure to be successful;
- KM initiatives require culture change and must have the full support of the leadership to be successful;
- Mangers who effectively use their company's knowledge were able to overcome knowledge-based barriers and institutional stovepipes to improve collaboration and customer relationships;
- KM is a source of organizational and economic value;
- Communities of Practice or Interest (COP/COI) are forums of networked people with similar interests and issues which come together to address problems, provide solutions, share ideas, and build communication links. COI development provides the foundation for KM implementation;
- KM implementation should be an incremental process built upon small successes. (Cho et al., 2000)

Cho et al. make a compelling case for adoption of a KM concepts, tools and strategy in the DoD Acquisition System. This research will apply specific KM tools to a specific acquisition problem in hopes it will lead to the "small success" the DSMC researchers suggest is vital to foster widespread KM adoption in DoD acquisition.

A. KM Tools

KM tools and methodologies support the transformation of data into information and knowledge. The KM tools relevant to this research include data and text mining, data warehousing, data analysis and visualization.

1. Data and Text Mining

DoD acquisition programs generate massive amounts of documentation during all phases of development process, to include text documents, spreadsheets, and structured relational databases, etc. The amount of data and text contained in these documents is staggering and holds great potential for application of data and text mining techniques to derive and discover useful information that can be used to generate knowledge and improve decision-making from a sea of seemingly unrelated data.

Data mining is a "class of information analysis based on databases that looks for hidden patterns in a collection of data which can be used to predict future behavior. True data mining software does not just change the presentation, but actually discovers previously unknown relationships among the data" (Turban, Shardra, Aronson & King, 2008, p. 13).

Text mining is "the application of data mining to non-structured or less structured text files, which entails the generation of meaningful numeric indices from the unstructured text and then processing those indices using various data mining algorithms" (Turban et al., 2008, p. 224).

This research will apply certain data and text mining techniques to the DoD MDA Program to demonstrate the potential for increased Program Self-awareness of the portfolio of MDA system features to support improved programmatic decision-making.

2. Data Warehouses and Data Marts

Data mining techniques require a set of data be defined from which the various data mining algorithms can be applied and subsequent analysis be performed. This set of data is termed a data warehouse or data mart. A data warehouse is a "physical repository where relational data are specifically organized to provide enterprise-wide, cleansed data in a standardized format." (Turban et al., 2008, p. 223). A data mart can be considered a subset of a data warehouse which can be used to support a functional area, department, or community of interest. These terms will be used interchangeably for the purposes of this research (Turban et al., 2008, p. 222).

The development of data warehouses into the structured form required to support data mining is not a trivial process. The data warehouse will need to be developed to support the functional area being supported and have the following fundamental characteristics: subject-oriented, integrated, time-variant, and nonvolatile. The data warehouse may also be developed to include the following capabilities: web-based, relational/multi-dimensional, client/server, and include metadata (data about data. (Turban et al., 2008, pp. 39-40).

Text mining, on the other hand, is focused on developing new meanings and relationships from unstructured data in the form of documents (memos, e-mails, instructions, policies, etc.) to support decision-making. The set of documents required to support text mining can vary in type and structure, providing much more flexibility in formulation compared to data warehouse development. The additional benefit of text mining is the amount of information available in a form ready for processing, which includes upwards of 80% of the data a typical organization collects. Text mining algorithms are also complex and typically involve the following steps.

1. Eliminate commonly used words (the, and, other);

2. Replace words with their stems or roots (e.g., eliminate plurals, and various conjugations and declarations);

3. Consider synonyms or phrases (e.g., student and pupil may be grouped together);

4. Calculate the weight of the remaining terms (e.g., based on frequency of occurrence in a document or set of documents). (Turban et al., 2008, pp. 159-160)

3. Analytics and Visualization

The development of data described above supports its transformation to information and knowledge through the process of analytics and visualization. Analytics can be defined as a "category of applications and techniques for gathering, storing, analyzing, and providing access to data to help enterprise users make better business and strategic decisions" (Turban et al., 2008, p. 86). This research will apply several analytical applications, to include data mining, text mining and visualization techniques to discover new information and knowledge. These KM tools have the potential to highlight relationships among program "features" to support decision-making regarding duplication of effort, gaps, re-use and collaboration opportunities in the DoD MDA program. For the purposes of this research, a "feature" is a marketable behavior or property of a system, ideally documented in a design, such as the "power window" feature on modern automobiles.

B. Collaboration

This research has repeatedly identified the importance of collaboration to support KM implementation. The DSMC study heavily emphasized the linkage between KM success and the organization's culture of information sharing and collaboration. The DSMC researchers also concluded that a typical DoD acquisition program performs very little collaboration across different programs other than informal networks of functional area experts formed at the same physical location. When development teams were asked how often they go outside their program organization to seek knowledge to problems they faced, the most frequent response was "rarely if ever." The researches found it wasn't that the teams didn't recognize the potential power of collaboration, they just "don't know who else is working on similar issues or don't see any connection between their project and another one in a different area" (Cho et al., 2000, pp. 1-4).

The size of the DoD Acquisition enterprise, lack of enterprise collaboration and KM tools and stovepipe organizational structures do not support a culture of information sharing. The continued explosion and proliferation of networking technologies has penetrated the DoD acquisition environment and spawned several collaboration and knowledge-sharing initiatives germane to this research, which may represent the early stages of a move towards greater collaboration in DoD acquisition:

In recognition of the imperative and potential power of collaboration to support the complex DoD Acquisition System, KM and acquisition experts at NPS (Thomas, Hocevar & Jansen, 2006) studied collaboration in the most complex DoD and Interagency acquisitions to develop a "collaborative capacity" assessment tool. Figure 3 depicts the "Collaborative Capacity" model developed by Thomas et al (2006) to guide their research. The notion that collective self-awareness is integral to the success of solving a common problem can be derived from this model. It can also be inferred from the model that collaboration is the "glue" used to bond "stovepipe" organizations together to solve a common problem such as an inter-agency acquisition.

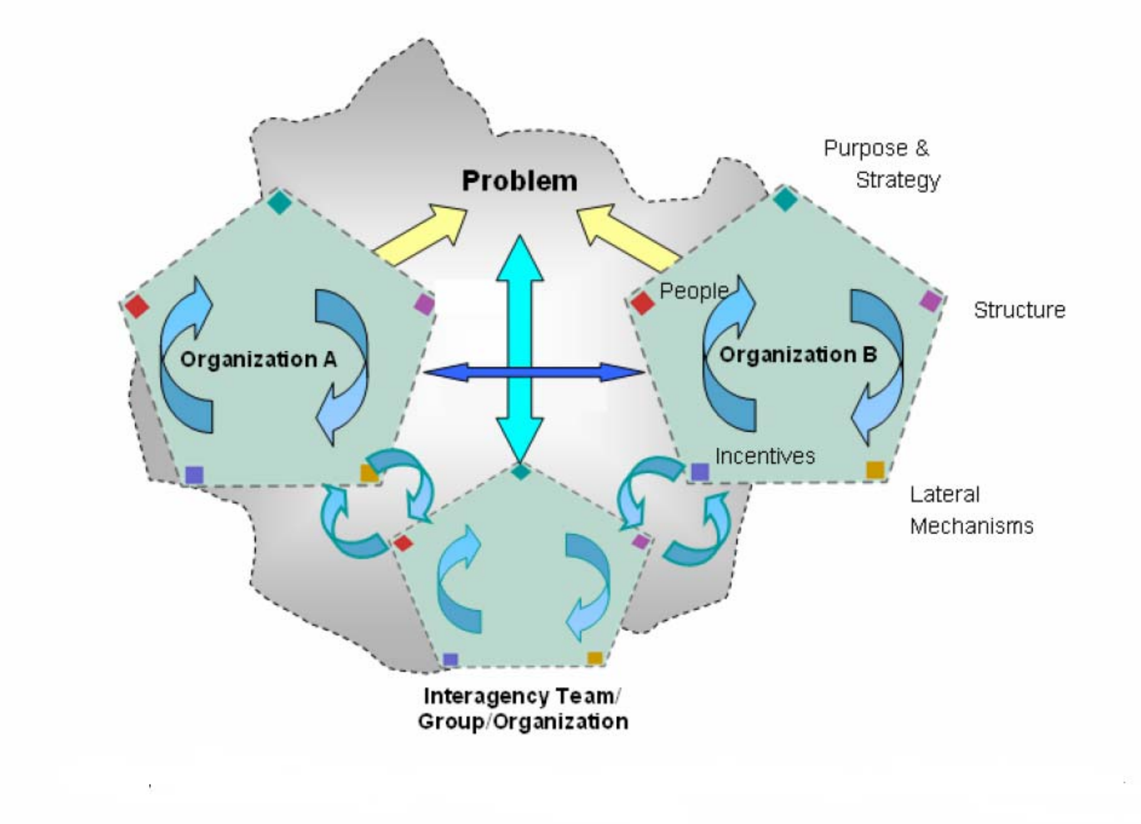

Figure 4. Collaborative Capacity Model
(Thomas et al., 2006, p. 7)

V. DoD Acquisition Initiatives

Two DoD acquisition policy initiatives relevant to this research are the adoption of Capability Portfolio Management (CPM) and Open Architecture (OA) approaches. Both CPM and OA are relatively early in their implementation and address different levels of the acquisition process, but share the common goal of improving DoD decision-making regarding systems-of-systems (SoS) acquisitions to avoid duplication, reduce costs, and decrease development times.

A. Open Architecture (OA)

The emphasis on open systems architecture (OA) has increased over the past decade with OA now recognized as an integral part of DoD systems engineering and acquisition processes. OA is not a new concept, however, and draws from engineering design principles that have shaped mature industries for many decades. The modern automobile is one such example of OA design principles, as it supports integration of thousands of its components through what can be viewed as a system-of-systems design. This OA design allows most components to be built by numerous manufactures to a standard interface specification, which allows tires built by numerous manufactures to fit onto the wheels of a wide range of vehicles. The OA approach is very attractive in the context of DoD acquisition as it offers potential for decreased development timelines and reduced costs largely through re-use of components in system-of-systems acquisitions. OA designs also support quick upgrades and modifications, removing the requirement to redesign other components or entire system as would be necessary due to change propagation in closed or non-modular system designs. The application of OA to the design of software-intensive systems has been the focus of early OA initiatives, to include the Navy PEO-IWS Software Hardware Asset Reuse Enterprise (SHARE) Repository, which serves as a searchable library of ship combat systems software and related assets available for re-use by eligible contractors.(Johnson & Blais, 2008, p. 1).

The increased emphasis on OA has resulted in several initiatives to establish common technical and architectural standards to promote increased re-use and interoperability for OA systems, to include the SHARE repository described above. These efforts are critical to the success of DoD OA implementation and require continued development of common vocabularies and collaboration tools to facilitate discovery of related efforts and potential re-use opportunities.

A fundamental requirement of OA is that acquisition managers develop an awareness of related efforts and activities across an enterprise and/or COI to support decision-making regarding re-use and collaboration opportunities. It is the premise of this paper that development of Program Self-awareness is fundamental to the success of OA policy initiatives.

B. Capability Portfolio Management (CPM)

In 2006, the Deputy Secretary of Defense released a memorandum to introduce the Capability Portfolio Management (CPM) approach to DoD Acquisition. The intent of exploring the CPM approach was:

> to manage groups of like capabilities across the (DoD) enterprise to improve interoperability, minimize capability redundancies and gaps, and maximize capabilities effectiveness. Joint capability portfolios will allow the Department to shift to an output-focused model that enables progress to be measured from strategy to outcomes. Delivering needed capabilities to the joint warfighter more rapidly and efficiently is the ultimate criterion for the success of this effort. (Deputy Secretary of Defense, 2006, p. 1)

The initial implementation of CPM included establishment of four capability area test cases (Joint Command and Control, Joint Net Centric Operations, Battlespace Awareness, Joint Logistics) to evaluate the CPM approach with the long-term goal of achieving broader implementation in the 2009-2013 timeframe. CPM goals, objectives, and guidance emphasized the importance of system-of-systems engineering approaches and “data transparency”:

> test case managers–in conjunction with existing data management stewards and the Institutional Reform and Governance effort–should work together to establish an approach (business rules, data structure changes, knowledge management tools) that will strengthen the linkage of authoritative information to capabilities without compromising information flexibility. (Deputy Secretary of Defense, 2006, Attachment A, p. 4)

CPM implementation was further directed across the DoD acquisition enterprise in 2008 and linked to all nine Tier 1 Joint Capability Areas (JCA). The new policy detailed CPM integration and alignment with existing DoD acquisition structures and processes to achieve widespread implementation. (Deputy Secretary of Defense, 2008, p. 1) The definition of CPM was also refined to “the process of integrating, synchronizing, and coordinating Department of Defense capabilities needs with current and planned DOTMLPF investments within a capability portfolio to better inform decision-making and optimize defense resources" (Deputy Secretary of Defense, 2008, Glossary, p. 8).

The CPM approach is relevant to this research in that it is grounded in improved acquisition decision-making to reduce duplication of effort and identify capability gaps in the DoD portfolio of systems. The emphasis on development supporting data structures, KM tools, and implied expectation of expanded collaboration provide a clear linkage between DoD policy and this area of research. KM tools directly support CPM decision-making at multiple levels of acquisition as will be demonstrated with the DoD MDA Program to identify relationships among a portfolio of system features.

VI. MDA Program

The National Plan to Achieve Maritime Domain Awareness (MDA) from October 2005 defines the Maritime Domain as "all areas and things of, on, under, relating to, adjacent to, or bordering on a sea, ocean, or other navigable waterway, including all maritime-related activities, infrastructure, people, cargo, and vessels and other conveyances." Additionally, it defines MDA as "the effective understanding of anything associated with the maritime domain that could impact the security, safety, economy, or environment of the United States." The stakeholders in this enterprise make up the Global Maritime Community of Interest (GMCOI), which includes "federal, state, and local departments and agencies with responsibilities in the maritime domain. Because certain risks and interests are common to government, business, and citizen alike, community membership also includes public, private and commercial stakeholders, as well as foreign governments and international stakeholders" (DHS, 2005, p. 1).

The problem set that faces the Navy, a key member of the GMCOI, is that:

> commanders lack access to, and the ability to process and disseminate, the broad spectrum of information and intelligence that enables cooperative analysis necessary to understand maritime activity in their area of responsibility, and requisite to early threat identification and effective response against these threats; and when appropriate, to enable partners to respond (Chief of Naval Operations, 2009).

Navy MDA is key to addressing this problem set because it will "enable the warfighter to sustain decision superiority to successfully execute its missions. MDA is fundamental to decision making superiority at all levels of command" (Chief of Naval Operations, 2009). The Navy plans to improve the following capabilities to achieve MDA; "focused data collection; technological enhancements; greater cooperative information sharing; supporting enduring and emerging maritime security partnerships; and the professional development of navy personnel within the maritime operations centers at naval components and numbered fleets" (Chief of Naval Operations, 2009).

VII. MDA Program Self-awareness Test Case

The MDA Program is indicative of complex system-of-systems acquisition efforts being undertaken by the DoD. The MDA program includes additional complexity caused by the extensive international and interagency involvement, which exhibit the complexities shown in the Collaborative Capacity Model shown in Figure 3.

This research will develop and examine a representative data mart of structured and unstructured program and policy documents from members of the GMCOI. This task is especially challenging in that there is not one consolidated repository for MDA-related programmatic documentation. This data will be collected from various members in the GMCOI closely involved in MDA systems development and acquisition. Data and text mining tools will be applied to the MDA Data Mart using the methodology depicted in Figure 5 (Turban et al., 2008, p. 156).

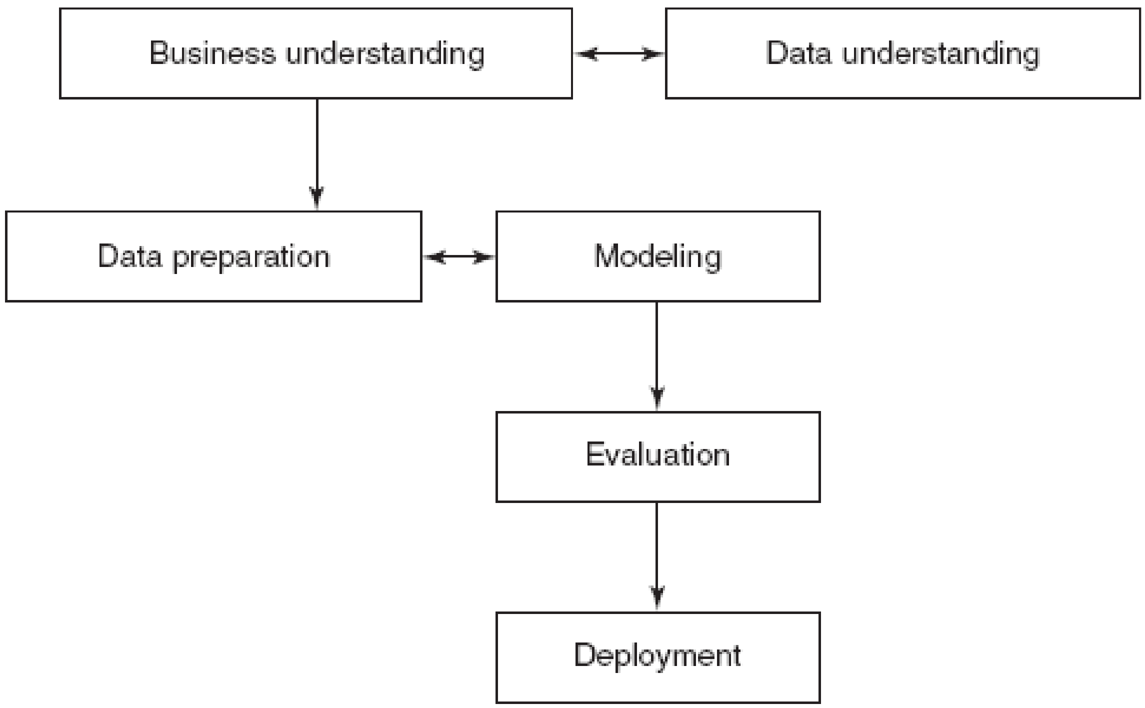

Figure 5. Data-mining Process Recommended by CRISP-DM
(Turban et al., 2008, p. 156)

To date, this research has gathered program documentation related to three prototype MDA systems, to include Predictive Analysis for Naval Deployment Activities (PANDA), a Defense Advanced Research Projects Agency (DARPA) project, Track Assessment and ANomoly Detection–Maritime (TAANDEM) software subsystem, and Comprehensive Maritime Awareness System being developed through the Navy Research Lab (NRL). These documents have been placed into the MDA data mart for use in our modeling and analysis.

The next step in our research will be to further our data understanding and prepare the data for application of the various mining algorithms. This phase of the research is underway as this paper is being prepared. NPS KM research expertise and cutting-edge data and text mining applications will be leveraged during this phase of the research. After the initial data cleansing and preparation, the mining tools will be applied to the data mart for subsequent evaluation and analysis using visualization products to identify common features, capability gaps, and relationships between MDA system features. We expect several iterations of this process to extract useful data from the models.

Using preliminary data and the Quantum Intelligence (QI) data and text tools developed by Dr. Ying Zhao, the visualization products depicted in Figures 6 and 7 were developed to demonstrate representative products of this research to highlight relationships among system feature data.

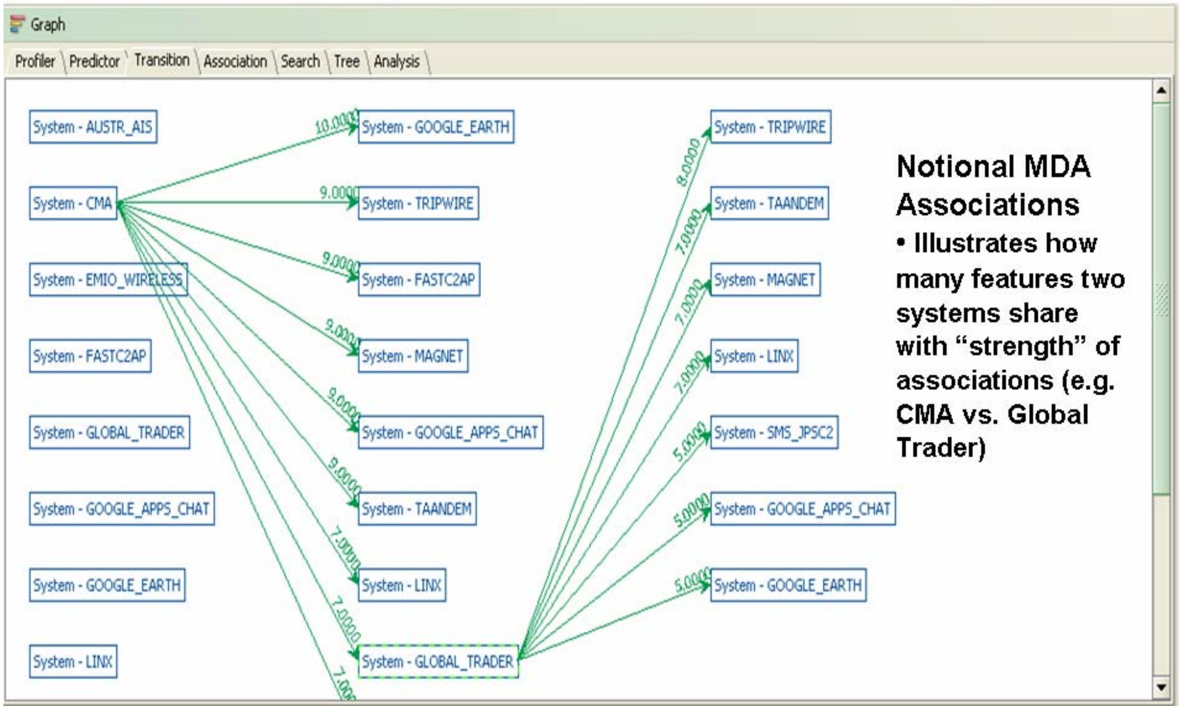

Figure 6. Sample MDA System Cluster Visualization
(Zhao, 2009)

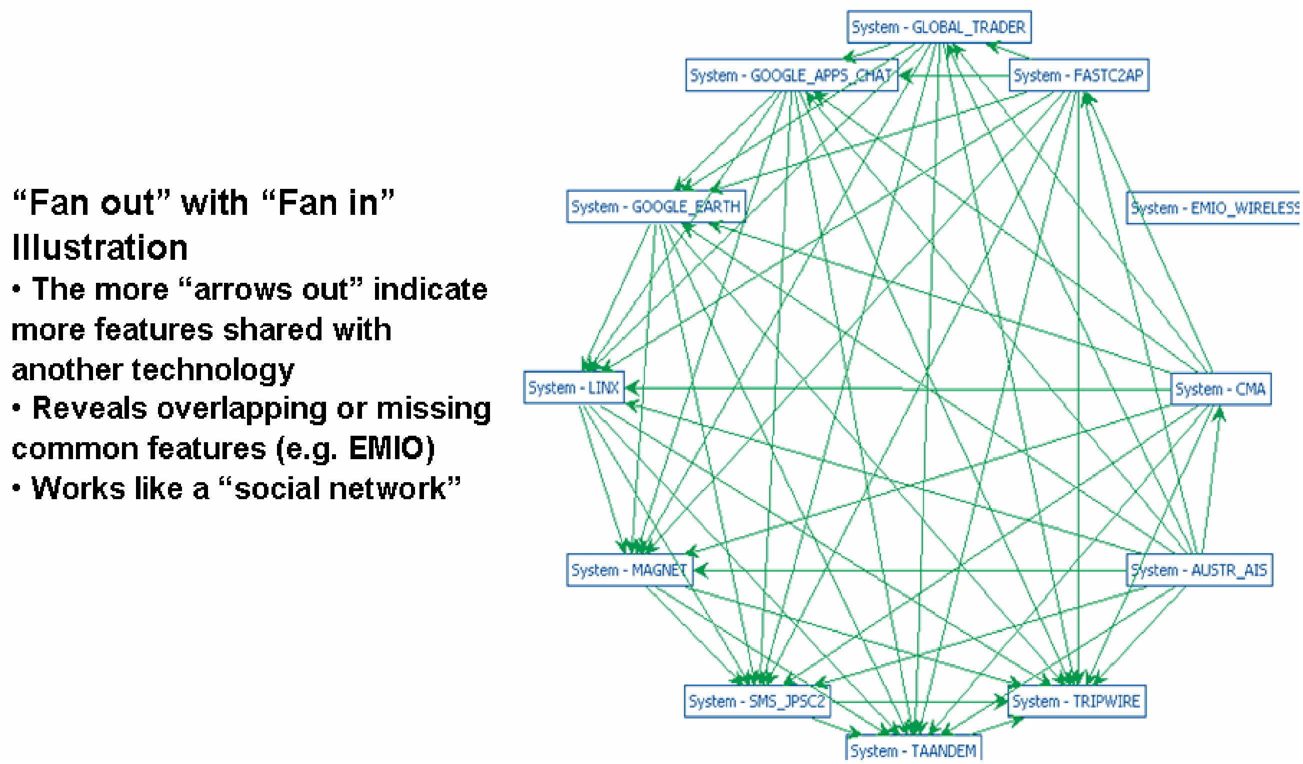

Figure 7. Sample MDA System Cluster Visualization
(Zhao, 2009)

The final step in the data mining process is deployment. As this is only a demonstration of KM tool utility for Program Self-awareness, we do not plan to deploy the algorithms developed during this process. This work will for the foundation for a larger effort by the DoD EA for MDA that will hopefully be applied to a much larger data mart developed from the entire GMCOI.

VIII. Predicted Findings

The MDA Program is representative of complex DoD Acquisition Programs. KM concepts and tools demonstrate utility for improving Program Self-awareness to help identify portfolio gaps and duplication which can lead to improved resource allocation decision-making, collaboration among acquisition activities, and re-use of SoS components. Figure 8 provides an overview of the research methodology described above.

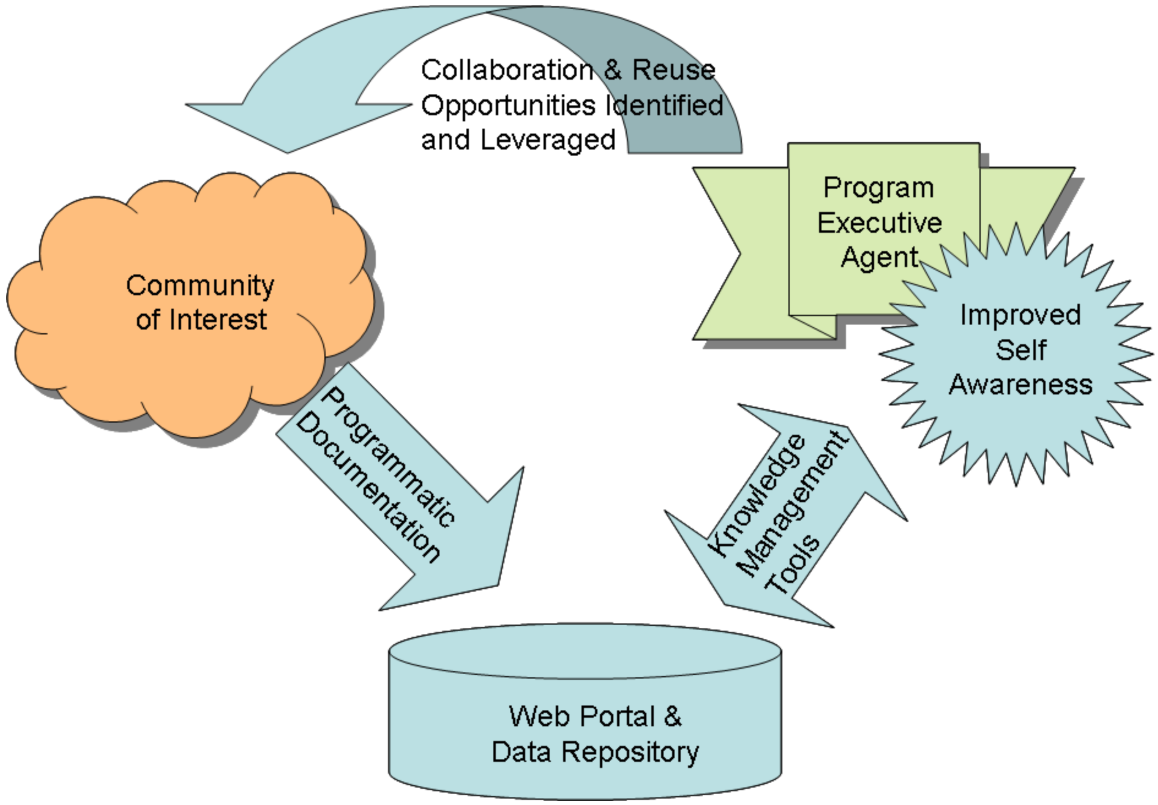

Figure 8. Program Self-awareness KM Process

As mentioned above, a central repository for MDA programmatic documentation does not currently exist. This research will recommend development of a GMCOI MDA web portal for use as a data warehouse to support future KM implementation and to promote collaboration and re-use. We hope this work will provide foundation for future work to refine Program Self-awareness concept and KM implementation in DoD Acquisition.

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Effective Programmatic Software Safety Strategy for US Navy Gun System Acquisition Programs

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Abstract[1]

The System Software Safety Technical Review Panel (SSSTRP) is tasked with reviewing the software safety processes and practices of US Navy software-intensive Gun

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System acquisition programs from the early stages of the acquisition process. As these systems grow in complexity and as Open Architecture (OA) is implemented, the acquisition and demonstration of safe software is becoming a more challenging task— often resulting in unexpected safety risks, schedule delays, and cost overruns. This research presents an approach to mitigate common risks in this domain from the Program Management level. This approach focuses on analyzing historical weapon system SSSTRP data to identify trends that could lead to a strategy to increase software safety as well as reduce unexpected findings at the SSSTRP. This research effort is still in the early stages, but data are being collected, and progress is being made. The goal of this paper is to increase awareness of both the problem and the research effort that is attempting to mitigate the common effects felt by Program Managers.

Background

The United States Navy (USN) formed the Weapon Systems Explosive Safety Review Board (WSESRB) in 1968 as a result of the tragic fire onboard USS FORRESTAL (CV 59). The subsequent investigation recommended an independent review process be established. The report highlighted the need to ensure explosives safety requirements are met for all munitions introduced to the Fleet. WSESRB members participate in numerous weapons system safety-related meetings, technical reviews, and working groups.

The WSESRB's responsibility is to review the overall safety aspects of each weapon system, explosive system, and related system to ensure that weapon system safety requirements are satisfied. Having assessed the degree of compliance with existing criteria, the WSESRB provides an assessment of the adequacy of the safety program and makes recommendations on the advancement of the item to the next stage in the acquisition cycle to the program manager, program sponsor, Chief of Naval Operations (CNO), and the Milestone Decision Authority (MDA).

At the discretion of the WSESRB Chairperson, special WSESRB Technical Review Panels (TRPs) may be established to review specific safety aspects requiring special expertise (e.g., ordnance-related software safety) of weapon systems. These TRPs are scheduled and led by an appointed TRP Chairperson and have at least two other designated members. Naval Systems Commanders, when requested by the WSESRB Chairperson, may identify a member to serve on TRPs. These members are familiar with the responsibilities of their Systems Commands and respective program requirements and have expertise in the applicable area of the TRP. Other members and technical advisors, chosen for their expertise, are appointed at the discretion of the TRP Chairperson. Software System Safety Technical Review Panel (SSSTRP) is one of these special WSERB TRPs.

Recommendations made by TRPs will be presented to the Program Office and the WSESRB at the conclusion of the TRP meeting; however, they do not become official until reviewed and endorsed by the WSESRB. The WSESRB may accept, modify, or reject the recommendations of the TRP. The results of the WSESRB action on the TRP recommendations will be provided to the Program Office.

Naval Surface Warfare Center (NSWC) Dahlgren Division acts as a principal activity for system safety support to the WSESRB, as well as chairing the SSSTRP and other TRPs as assigned. These assignments include: (1) developing and recommending, with WSESRB approval, TRP review criteria and related data, (2) coordinating meetings of the SSSTRP with members and program offices, (3) assisting the program office in tailoring TRP review criteria for each type of program and current program phase, (4) identifying qualified technical advisors to participate in the TRP, and with the WSESRB chairperson's concurrence, arranging for their participation, (5) scheduling meetings of the TRP at the request of the WSESRB chairperson, and (6) providing a summary report of the findings and recommendations of the SSSTRP TRP to the WSESRB.

The SSSTRP's primary focus is to investigate whether the vendor's software engineering processes properly identify and address the risks associated with the implementation of their product. The following list represents the SSSTRP's areas of focus within the software development process:

- Software Development Process Essentials
    - Software Development Plan
    - Configuration Control Management
    - Requirements Management
    - Safety Involvement
        - Change Boards
        - Trouble Reports
        - Build Reviews
        - Test & Integration Plans

Vendors are required to submit Technical Data Packages (TDPs) that contain documentation that details the vendor's quality control procedures associated with the following engineering processes:

- Software Engineering
    - Software Development Plan
    - Software Architecture Design
    - Software Interfaces
    - Software Detailed Design
    - Software Testing & Integration Plans
    - Software Verification & Validation Plans
    - Software Build Schedule
    - Build Milestones
    - Build Functionality
- Specialty Engineering

- Configuration Management
- Requirements Management

The actual components of the TDP are made up of the project documentation submitted by the vendor. The vendor submits the following documents as the TDP:

- System Program
    - System Description
    - Program Organization
    - Program Schedule
    - Concept of Operations
- Software Program
    - Software Development Plan
    - Software Build Plan
    - Software Configuration Management
    - Software Requirements Management
    - Software Change Board Control
- System Safety Program
    - System Safety Program Plan
        - Integrated Safety Schedule
        - Safety Organization
            - Roles & Responsibilities
            - IPT (Cross Product Team) Interactions
        - Software Safety Analyses Descriptions
        - Hazard Tracking System
        - System Safety Working Group (SSWG)
- Current Safety Status
    - Preliminary Hazard List (PHL)

The vendor's responsibility during the SSSTRP presentation is to identify the risks associated with its products relative to all stages of the software lifecycle. The vendor is also required to present the associated mitigation strategy for each risk. Software risks can be found via the following analysis techniques:

- Functional Hazard Analysis (FHA)
- Software Requirements Analysis (SRA)
- Preliminary Design Analysis (PDA)
- Detailed Design Analysis (DDA)
- COTS Analysis
- Code Analysis (CA)
- Software Test Results Analysis (STRA)

Problem Statement

Current and active US Navy gun system acquisition programs are more complex than their predecessors. The systems being acquired are much more software-intensive and present a much greater challenge with respect to understanding and mitigating the risks associated with Navy gun safety. Navy gun systems are much more software-intensive than previous generations due to the increasingly complex requirements for centralized command and control (C2). In order to adapt to new technologies, the Navy has engaged the Open Architecture (OA) concept. Although the OA approach is much more flexible, there are inherent risks associated with it. The Navy acquisition community, specifically the SSSSTRP process, needs to adapt to this new OA environment and standardize the SSSTRP processes.

Significant effort is required to put together a TDP for SSSTRP review. The SSSTRP panel finds issues in the vast majority of systems that come before it. Such findings need to be addressed prior to WSESRB concurrence on the overall program. Typically, every system going in front of the WSESRB and SSSTRP is handled on a strictly individual basis by its respective vendor and Program Managers (PMs). PMs ideally want their programs to be well prepared for the SSSTRP so there are no unexpected surprises resulting in safety hazards, schedule delays and/or cost overruns. However, Navy gun system PMs do not have a good handle on what the trends are in the findings from system to system, and there is always a desire to reduce the programmatic risk involved in passing the reviews.

If commonalities or trends in SSSTRP findings were identified, they could be analyzed—leading to a better programmatic strategy to generate safe systems. This would also result in a minimal number of hurdles during the SSSTRP review, and the end result would be beneficial to all parties involved.

Research Approach

Our proposed strategy for identifying trends in SSSTRP findings on weapon-system-related acquisition programs is to initially meet with PMs, US Navy safety community members, and system developers to discuss experiences and lessons learned. We can also gather data from informal meetings and discussions and analyze it to find more quantitative sources of information.

In addition to collecting data from various participants from the acquisition community, we will also request and analyze TDPs, SSSTRP reports, and WSESRB data related to recent navy gun system acquisition programs. We expect this information to yield quantitative data that can assist us as we identify trends across different acquisition programs. Due to the nature of the OA initiative, we should be able to derive trends specific to OA software-intensive systems from the data, as well.

The third step in this research approach is to analyze the SSSTRP process itself with the goal of quantitatively determining the consistency of the process. This information is a vital data-collection objective because specifics in the consistency of the SSSTRP process from system to system should correlate with similar results for similar cases being presented to the panel.

Our fourth step in this research approach is to connect the identified lessons learned and trends in SSSTRP data reports with data on the SSSTRP process itself. This step is essentially the point at which we can begin to derive conclusions and recommendations. Relationships in the data will primarily focus on how to most effectively reduce programmatic risk in guiding a weapon system acquisition program through the SSSTRP process smoothly. In this assessment, we will pay particular attention to system characteristics that will be consistent throughout future programs, such as OA software.

The end result of this research will be to create a deliverable that can be used by PMs to more effectively manage their OA-based acquisition system programs. A side deliverable will be an analysis of the SSSTRP process and recommendations on how personnel involved in the safety community can improve it.

Current Research Status

Data collection has been a time-consuming task, but progress is ongoing. From October to December 2008, we conducted both project-scope refinement and meetings with safety and acquisition community members. We established relationships with the Naval Gunnery Project Office, NSWC Port Hueneme Division (PHD) Detachment Louisville, NSWC Dahlgren and Naval Ordnance Safety and Security Activity (NOSSA). We also discussed specifics of the process with a majority of players in the community and compiled information on the process itself. Any stakeholders we have missed are encouraged to contact us.

Along with SSSTRP and WSESRB process data, we received recent gun-system-related SSSTRP reports through a request from the Naval Gunnery Project Office to NSWC Dahlgren. For research purposes, we also have had access to reports deemed releasable by the Navy from the past six years. TDPs were not made available for more detailed analysis due to the sensitivity of the majority of the programs. The above-mentioned data were received in February 2009, and our primary focus has been to determine what information is most useful for analysis. Collaboration has taken place with NOSSA personnel to determine how to break down and classify findings from the SSSTRP reports. The analysis is ongoing, but research is still in the early stages at this time.

Panel 17 - The Evolving International Industrial Base

Thursday, May 14, 2009	Panel 17 - The Evolving International Industrial Base
1:45 p.m. – 3:15 p.m.	**Chair: Pierre A. Chao**, Managing Partner, Renaissance Strategic Advisors and Senior Associate, International Security Program, Center for Strategic and International Studies **Discussant: John Birkler**, Senior Policy Analyst, RAND Corporation ***The Role of Trans-Atlantic Defense Alliances in a Globalizing World*** **Nayantara Hensel**, Naval Postgraduate School ***New Patterns of Collaboration and Rivalry in the US and European Defense and Aerospace Industries*** **Raymond Franck** and **Ira Lewis**, Naval Postgraduate School and **Bernard Udis**, University of Colorado, Boulder

Chair: Pierre Chao Managing Partner at Renaissance Strategic Advisors and Senior Associate, International Security Program, Center for Strategic and International Studies. Before joining CSIS in 2003, Chao was a managing director and senior aerospace/defense analyst at Credit Suisse First Boston from 1999-2003, where he was responsible for following the US and global aerospace/defense industry. He remained a CSFB independent senior adviser from 2003-2006.

Prior to joining CSFB, Pierre was the senior aerospace/defense analyst at Morgan Stanley Dean Witter from 1995-1999. He served as the senior aerospace/defense industry analyst at Smith Barney during 1994 and as a director at JSA International, a Boston/Paris-based management-consulting firm that focused on the aerospace/defense industry (1986-1988, 1990-1993). Chao was also a co-founder of JSA Research, an equity research boutique specializing in the aerospace/defense industry. Before signing on with JSA, he worked in the New York and London offices of Prudential-Bache Capital Funding as a mergers and acquisitions banker focusing on aerospace/defense (1988-1990).

Chao garnered numerous awards while working on Wall Street. Institutional Investors ranked Pierre's team the number-one global aerospace/defense group every year eligible from 2000-02, and he was on the Institutional Investor All-America Research Team every year eligible from 1996-2002. He was ranked the number-one aerospace/defense analyst by corporations in the 1998-2000 Reuters Polls, the number-one aerospace/defense analyst in the 1995-99 Greenwich Associates polls, and appeared on the *Wall Street Journal* All-Star list in four of seven eligible years.

In 2000, Chao was appointed to the Presidential Commission on Offsets in International Trade. He was a member of the 2005 Defense Science Board Summer Study (Assessment of Transformation), 2006 DSB Summer Study (Strategic Technology Vectors), and the 2006/2007 DSB Task Force on the Health of the Defense Industry. He is also a guest lecturer at the National Defense University and the Defense Acquisition University. Chao has been sought out as an expert analyst of the defense and aerospace industry by the Senate Armed Services Committee, the House Science Committee, Office of the Secretary of Defense, DoD Defense Science Board, Army Science Board, NASA, DGA (France), NATO and the Aerospace Industries Association Board of Governors.

Chao earned dual Bachelor of Science degrees in Political Science and Management Science from MIT.

Discussant: John Birkler, senior management systems analyst at RAND, has been at RAND for almost 30 years, where he has led projects relating to weapon system acquisition across all the military services, the Office of the Secretary of Defense, the United Kingdom's Ministry of Defense, and the U.S. Coast Guard. In recent years, Birkler has specialized in directing complex projects on acquisition of air and naval systems. These projects—often mandated by the Congress or by senior U.S. or U.K. acquisition officials—involved budgets over $1 million and short timelines considering the level of effort. All these projects have been completed on time and within budget. Recent study topics have included developing acquisition strategies for U.S. and UK submarines, aircraft carriers, and surface combatants, competitive strategies for the Joint Strike Fighter, and the U.S. Coast Guard's Deepwater modernization plan. Over the past decade, Birkler has held a wide range of RAND management and research positions. He is now responsible for RAND's maritime research. A graduate of UCLA's Executive Management Program, Birkler earned an M.S. in nuclear physics from the University of South Carolina and, after three command tours, retired from the U.S. Naval Reserve as a Captain.

The Role of Trans-Atlantic Defense Alliances in a Globalizing World

Presenter: Dr. Nayantara Hensel has taught finance and economics at the Graduate School of Business and Public Policy at the US Naval Postgraduate School since 2004 and is a Research Associate for the Center for Defense Management Research. She received her BA (magna cum laude) from Harvard University where she was a member of Phi Beta Kappa. She received her MA and PhD from the Graduate School of Arts and Sciences at Harvard University in Business Economics (Applied Economics). She recently served as the Pentagon Scholar in Residence, attached to the Office of the Assistant Secretary of the Navy. Prior to joining the faculty at the US Naval Postgraduate School, Hensel served as a Senior Manager at Ernst & Young, LLP, and as the chief economist for one of its units, was a Post-Doctoral Research Fellow at the National Bureau of Economic Research, taught at Harvard University and the Stern School of Business at NYU, and was an economist at NERA (part of Marsh & McLennan). Hensel's recent research has examined the impact of consolidation in the defense industrial base, policy concerns in the recent tanker competition between Boeing and Northrop Grumman/EADS, the factors impacting personal discount rates for US Marine Corps personnel, the efficiency of IPO auctions, and economies of scale and density in the European and Japanese banking sectors. She has published over 19 articles and book chapters. Her most recent publications have been in *Business Economics,* the *International Journal of Managerial Finance,* the *Review of Financial Economics,* the *European Financial Management Journal,* the *Journal of Financial Transformation,* and *Harvard Business School Working Knowledge.* She is the Chair of the Financial Roundtable for the National Association of Business Economists (NABE) and is one of 34 elected members to NBEIC, which is a group composed of the top corporate economists in the US. Hensel has given seminars at a number of institutions and has appeared on CNBC, Bloomberg Radio, and CNNMoney.

Abstract

The purpose of this analysis is to discuss the importance of linkages between US and European defense manufacturers with the emergence of the common global threat of terrorism, the greater price sensitivity of governments concerning weapons systems costs, and the shrinkage of defense budgets. The article discusses the reasons behind the formation of alliances between US and European defense contractors, examines several case studies of alliances, assesses some of the patterns in alliance formation, and analyzes the potential for trans-Atlantic alliances between defense contractors in the future.

I. Introduction

The landscape of the global defense industry in the post-Cold War period has changed in a number of ways. First, the emergence of the terrorist threat has transcended the boundaries of nation-states and has led to the emergence of allied forces requiring interoperability of equipment and synergistic compatibility in computer systems. Cooperation in research, development, and technology transfer between defense contractors from various countries is important to produce the best product at the lowest cost. Second, the defense spending gap between Europe and the US continues such that the US remains a lucrative market for both European and US defense contractors. Third, the US defense industry experienced significant consolidation during the 1990s, which, in turn, contributed to greater consolidation among European defense contractors to remain competitive globally. This has limited the number of possible partners for additional mergers or alliances on both sides of the Atlantic. Fourth, as weapons systems become increasingly complex, it can be cost-effective to spread the research and development costs across different defense companies. Fifth, the trend toward globalization across industries and greater collaboration between companies in different countries has accelerated over the past twenty years.

Against this backdrop, there have been a number of studies across industries on mergers, as well as on alliances. Mergers have the benefit of leading to the formation of more permanent relationships between the merging companies. With the absorption of one company into another, there are greater opportunities for cost-cutting in eliminating duplicative workforces and in reorganizing the corporate hierarchy to better internalize and reduce the transactions costs that would have been present in an arm's-length relationship. The benefits of this absorption can also lead to substantive integration costs and cultural/communication difficulties, which can postpone or altogether eliminate the benefits of the merger. Mergers can have permanent or long-lasting effects on the market power of various companies, the ability of new firms to enter the industry, and market concentration levels. As a consequence, the regulatory scrutiny from the antitrust authorities is important in concluding the deal.

When mergers occur between companies from different countries, the magnitude of the opportunities for benefits relative to the costs changes. Absorption costs for an international merger can increase relative to a domestic merger, especially if there are cultural or communication incompatibilities between the merging parties. The issue of which country loses jobs to the other country is often magnified by the popular press and government officials. Although the impact on market power and market concentration may be less with an international merger than a domestic merger because the definition of the relevant market is geographically larger, the regulatory review process can become more complicated since regulatory authorities from multiple countries are involved.

Alliances can often be a good alternative to mergers. The parties involved in the alliance can obtain some of the benefits of a merger—joint investments in R&D expenses and production equipment, knowledge transfer and technology transfer, and access to new markets. Alliances can be easier to disassemble than mergers because less integration of operations is required. As a result, integration costs are lower, and the potential for cultural or communication clashes is less. Nevertheless, as discussed by Doz and Hamel (1998), in alliances in which generation of economies of scale is a motivation, the costs of exiting the alliance can be high due to the sunk costs of investment in equipment. Since alliances may lack the depth of integration found in mergers, there could be less of an incentive for parties to invest in relationship-specific assets and to produce the types of benefits and efficiencies that would be possible in a merger. Finally, although alliances may raise fewer regulatory concerns, the degree of technology transfer, etc., is still subject to review. Government officials can also protest ensuing job loss if combined production facilities from the alliance result in a loss of jobs in one country.

Alliances have become increasingly prevalent in a variety of industries; indeed, a number of studies on alliances have been cross-sectional, rather than focused on a specific industry, such as Yoshino and Rangan (1995) and Liedtka (1998). The importance of global competition as an impetus for alliance formation is discussed in Yoshino and Rangan (1995). Strategic alliances can even be a defensive strategy in that, as Gomez-Casseres (1994) discussed, as more alliances are formed, there are fewer possible partners available for firms that wish to form new alliances, and "strategic gridlock" can develop.

Alliances are helpful in the defense industry for several reasons. First, the R&D costs for development of a product can be high, which is why it is more cost-effective not to duplicate efforts. Second, the primary buyers are governments who are increasingly cash-constrained.

Collaboration between companies can be more cost-effective and successful than the competition between many different companies to chase a few contracts. Third, firms benefit from each other's skills without paying the integration costs and financial costs of a merger, which can lead to a higher return on investment from the collaboration because the costs of the investment are lower. This study analyzes the reasons behind the formation of alliances between US and European defense contractors, examines several case studies of alliances, assesses some of the patterns in alliance formation, and discusses the potential for trans-Atlantic alliances in the future.

II. Motivations for Trans-Atlantic Ties

One of the primary reasons for further developing trans-Atlantic ties between US and European defense contractors was the need for more synergistic and interoperable equipment among NATO members. In 1999, Alfred G. Volkman, US Acting Deputy Under Secretary for Defense, noted:

> The end of the Cold War, the break-up of the Soviet empire, the emerging power of rogue nations, and equally destabilizing geopolitical events are transforming our vision of the 21st century security needs and our NATO military strategy […]. In order to develop and field interoperable equipment, it is necessary that stronger transatlantic ties are forged […]. Governments would agree on common [military] requirements, then invite defense firms to form transatlantic competitive teams of their own choosing. (Sparaco, 1999)

Nevertheless, concerns over limitations on technology transfer on national security grounds between countries was one of the greatest stumbling blocks in strengthening trans-Atlantic ties. Indeed, in 1999,General Jean-Yves Helmer, Director of the DGA French armaments agency, noted, "the US and Europe do not share identical [defense] concepts and [operational] requirements. Nevertheless, there is ample room for synergy, **on the condition** that know-how and technology can circulate freely" (Sparaco, 1999, emphasis added). Barriers on export licensing and the transfer of technology limited the development of trans-Atlantic alliances in the late 1990s and early 2000s, but the "Declaration of Principles" signed by the US and the UK in February 2000 was an early step to greater joint research and development, and coordination of technology transfer, military requirements, etc. (Sparaco, 2000). Some argued, however, that with the exception of the UK and Canada, the US had a lack of trust for most other countries, especially in terms of technology-transfer issues (Barrie & Taverna, 2002).

European defense firms were also attracted to the US market because its defense market was much larger than the defense market in Europe. For example, in 2002, the US budget was three times that of EU countries. As a result, the investments of European companies in the US were 10 times greater than the value of US acquisitions in the European defense sector. In some sub-sectors of the defense market, the gap in spending and trade between the US and Europe was less. For example, Raytheon argued that in the areas on which the Thales Raytheon Systems focused—battlefield surveillance and command and control (C2) systems—there was less of a differential in spending (Barrie & Taverna, 2002). Consequently, the interest of the Europeans in the US defense market was driven both by disparities in spending, as well as by the perception that US R&D might drive the next generation of weapons systems—such that an alliance would give European countries access to the technologies without having to fund their development themselves (2002).

III. Historical Concerns over International Merger Activity Involving the US Defense Sector

Mergers or acquisitions involving the US defense market have historically been problematic. Although there may have been benefits from the acquisition, Congressional representatives are often concerned about job loss, as well as the national security issues inherent in technology transfer. As discussed in Hensel (2008), the acquisition is often formally disallowed, or the foreign entrant withdraws its bid in anticipation that the acquisition will be blocked if it proceeds further.

Hensel (2008) discusses, as an example, the concerns over the acquisition of Fairchild Semiconductors by Fujitsu, a Japanese firm, in the US semiconductor industry in the 1980s. Fujitsu announced that it planned to purchase 80% of Fairchild Semiconductors, which was the second largest seller of chips to the US military. The US semiconductor industry was important for early warning, air-defense, and air-to-surface attack systems, naval surface warfare, tanks, and conventional artillery. Between 1978 and 1987, Japan had increased its share of the semiconductor industry from 28% to 50%, while the share of the US in semiconductors had fallen from 55% to 44%. For particular types of chips, such as DRAM chips, the share of US companies fell from 90% in 1975 to 5% by 1986. A Congressional outcry ensued following Fujitsu's proposal. Senator Howard Metzenbaum of Ohio argued that jobs would be lost, while B. Jay Cooper, the press secretary for the Department of Commerce, argued that the deal would place "vital national interests at stake." Several proposals were suggested, including a proposal that the merged firm would not be allowed to have military contracts and a proposal that Fairchild would not provide Fujitsu with military technology. The outcome of the protests was that, in March, 1987, Fujitsu withdrew its offer, and National Semiconductor bought Fairchild and became the sixth largest chipmaker in the world (Dallmeyer, 1987).

Hensel (2008) discusses a more recent example of a failed attempt at entering the US market that occurred in 2005 in the US oil sector. As in the semiconductor case, the foreign acquirer withdrew its offer due to a substantive Congressional outcry. China National Overseas Oil Corporation (CNOOC), a Chinese state-owned company, tendered a bid to purchase Unocal Corp for $18.5 billion. Chevron, the other bidder, was offering only $17.1 billion, but it mobilized Congressional representatives to express their concerns about a Chinese firm playing a significant role in the US oil sector. In the wake of this outcry, CNOOC withdrew its bid even before the CFIUS review, and Chevron acquired Unocal (Shearer, 2006).

Hensel (2008) notes that concerns over national security can lead to some form of separation or divestiture of operating units linked to the defense sector so that the rest of the acquisition can proceed. One recent example, discussed in her article, is the merger of Alcatel (a French firm) and Lucent Technologies. Since Bell Labs, a division of Lucent, had undertaken a number of projects for the US government, Bell Labs would be insulated from the new firm and would become a separate US subsidiary with an independent board. A second example, discussed in her article, was the concern over the acquisition of Peninsula & Orient Steam Navigation, Co. (P&O), a British firm, by the state-owned Dubai Ports Worldwide (DPW). This acquisition provoked a Congressional outcry because it would have resulted in a foreign company managing 6 US ports. DPW agreed to sell the ports to a US company in the wake of strong Congressional opposition (Lynch, 2006; "Buy America," 2006; Shearer, 2006).

Hensel (2008), however, describes how the US is not the only country which uses protectionism to block mergers. For example, Dominique de Villepin, who served as the French Premier, designated 11 sectors of the French economy as sensitive for national security, and blocked the merger of PepsiCo (US) and Danone (French) under "economic patriotism." He further encouraged the merger of Gaz de France (a French gas supplier with significant state involvement) with Suez (a French power and water supplier) at the expense of a bid by the Italian company Enel. Similarly, Italy has blocked foreign takeovers of many of its banks (Pearlstein, 2006; Platt, 2006; Beattie, 2008). As globalization exposes vulnerabilities, countries will likely continue to promote domestic champions by preventing foreign acquisitions through protectionist concerns linked to national security.

IV. Patterns in Alliances between US Defense Contractors and Foreign Defense Contractors

Alliances between US defense firms and foreign firms are also exposed to some of the same concerns as mergers—such as concerns over the potential of US jobs going overseas and national security concerns over technology transfer. Nevertheless, although alliances undergo some scrutiny, it can be easier for the parties involved in the alliance to limit the degree of their involvement with each other, at least initially, than would be the case in a merger. As the alliance deepens and trust is built—both between the two parties concerned and between the two governments involved in the alliance—the degree of involvement can increase.

Butler, Kenny, and Anchor (2000) discuss strategic alliances within the European defense industry, as well as many of the changes to the defense sector. They describe how certain defense sub-sectors have more alliances than others and note that the electronics sector, the land vehicles sector, and the naval vessel sector have more alliances than the small arms and ordnance sector. Although they do not discuss why this might be the case, one possibility is that the sectors with more alliances are more R&D-intensive, and it is more cost-effective for the partners to share the costs than to bear the costs alone. They also discuss how cultural compatibility has not been necessary for the success of defense alliances, although 70% of UK contractors are in an alliance with a US firm. They find that many of the alliances are actually agreements for sub-contracting (in which the US firm is the lead contractor), or licensing agreements (in which the US firm is the licenser).

The author collected data on the number, type and details of joint ventures and alliances between 2002 and 2005 involving US defense contractors with both other US defense contractors, as well as foreign defense contractors. Her analysis of the data found that Lockheed Martin and Boeing had the greatest number of alliances with foreign defense contractors. Northrop Grumman, General Dynamics, and Raytheon had between 1/4 and 1/3 of the number of alliances with foreign contractors as Lockheed Martin and between 1/2 and 1/3 of the number of alliances with foreign contractors as Boeing. The fact that Boeing and Lockheed Martin had more alliances with foreign defense contractors during this period than other large US defense contractors may be a function of: (a) the opportunities for shared R&D in the weapons systems sub-sectors in which these alliances focused, as well as (b) the success of previous alliances made by these companies, which made them more likely to be willing to enter into additional alliances, thus creating a positive, self-reinforcing cycle.

In further examining the data, the author divided the foreign defense contractors involved in alliances with a US defense contractor by region—Europe, the UK/Australia/Canada, Asia, and the Middle East. Lockheed Martin contracted half of its alliances and joint ventures involving foreign contractors with UK, Australian and Canadian contractors and the other half with Asian contractors. Northrop Grumman contracted 2/3 of its foreign alliances with UK, Australian, and Canadian contractors, and 1/3 with Middle Eastern contractors. General Dynamics contracted

1/2 of its foreign alliances with European contractors and half with UK, Australian, or Canadian contractors. Raytheon had 100% of its foreign alliances with European contractors. Boeing had 1/3 of its foreign alliances with European contractors and 2/3 with Asian contractors. Lockheed Martin and Northrop Grumman did not form an alliance with a European contractor at all during this period, while Raytheon and Boeing, which did form alliances with European contractors, did not form any alliances with UK, Australian, or Canadian contractors over this period. The dominance of UK, Australian, Canadian, or European firms as foreign partners in these alliances suggests the importance of: (a) common language; (b) geographic proximity; (c) a prior history of successful alliances with firms in that country, leading to a positive, self-reinforcing cycle; and (d) the importance of these partner countries as allies in the Global War on Terror and the need for interoperability of equipment, especially in joint operations.

V. The Role of Alliances in Creating Additional Alliances among Competitors: A Case Study of the CFM Alliance and International Aero Engines

Alliances are often formed in order to combine different knowledge pools to create a new and superior product. As the market share for this product increases, the competitors in this product space may also form alliances to share knowledge and to develop an even better product than their allied competitors. The result of this defensive alliance formation can be an improved market sector—with several innovative and competing products for the end-user—developed by multiple competing alliances. The development of the CFM International alliance and the International Aero Engine alliance is an example of this.

CFM International is a joint venture between Snecma, formerly a French state-owned enterprise, and General Electric (GE). The alliance, which is one of the most successful and long-lasting alliances in the trans-Atlantic market, was formed in 1974 because GE and Snecma intended to leverage their skills developed in the engine market in the defense sector by entering the civilian market for engines, which was heavily dominated by Pratt & Whitney at the time. One of the initial hurdles was to convince the US government to allow GE to share its military technology with Snecma. As of 2007, the engines made by CFM (especially the CFM 56 engine) could be found in over 50% of the fleet of single-aisle planes with 100 seats or more and are often found in Airbus 320s and Boeing 737s. The way in which the alliance was structured was that each of the two partners would be involved with the design, production, and research of their respective modules/components within the engine. GE and Snecma's relationship has not been based on equity holdings. The two firms split the proceeds from the engines in half, based on notional costs, although neither company knows the true costs of its partners ("Business: Odd Couple," 2007).

During the early 1980s, Pratt & Whitney's market share began to fall in this product space. In 1983, it created an alliance—International Aero Engines (IAE)—with MTU (part of Daimler-Benz), Fiat, Rolls-Royce, and Japanese Aero Engines to develop an engine which would compete with CFM's engines ("Business: Odd Couple," 2007). This product alliance, like CFM International, was based around the design of an engine—in this case, the V2500 engine.

By 1995, CFM International and International Aero Engines controlled 26.6% of the aero engine sector. One benefit of the alliances within the civil engine arena has been that, although Rolls Royce, Pratt and Whitney, and GE were already involved in the civil engine market, the other members of the alliances, such as Snecma, through its development of the CFM56 engine with the CFM International alliance, and Daimler-Benz, through its development of the V2500 engine as part of the International Aero Engines alliance, were able to enhance and establish their positions in this market. The creation of the CFM International alliance allowed Snecma, which had manufactured jets for the French military, to use this expertise to enter the civilian aero engine market and to build up a significant presence through its development of the CFM56 engine. Consequently, by galvanizing Pratt & Whitney and other manufacturers to form International Aero Engines, alliance formation facilitated the development of several new engines, as well as a vibrant, competitive marketplace for the end-user (Smith, 1997).

VI. Trans-Atlantic Partnerships as a Means of Promoting National Defense Strategy: A Case Study of Trans-Atlantic Cooperation in Missile Defense

In 2002, Boeing entered into separate agreements at the Farnborough Air Show with BAE, EADS, and Alenia Spazio to cooperate on ballistic missile defense. The alliance planned to be an informational exchange in which Boeing would discuss with its European partners its approach to missile defense, and they would discuss the technologies they could incorporate into the missiles (Asker, Barrie & Taverna, 2002). Part of the purpose of the agreements was to galvanize the interest of European governments in larger ballistic missile defense programs, which they thought could be destabilizing, rather than just theater-wide missile defense. It could help the US convince the Europeans that larger missile defense programs could also cover NATO's European members and to show the Europeans that there would be jobs involved in it ("Business: Hands Across the Sea," 2002).

The various European partners in the alliance were chosen due to the contributions that their expertise would provide to the project. Alenia Spazio, part of Finnmeccanica, would add its expertise in supercomputers/data fusion, synthetic aperture radar satellites, and wideband secure telecommunications to the joint missile defense architecture discussions. EADS would add expertise in the space area from its affiliate, Astrium, as well as its knowledge of early warning satellite systems, which could locate the sites where the ballistic missiles were launched, the zone of potential impact, and the trajectory of the missile in the boos phase (Asker, Barrie & Taverna, 2002).

Part of the reason why there was an impetus for trans-Atlantic alliances in the missile area is that there have been several previous alliances in the missile product area.

For example, Boeing and EADS had collaborated on a study for NATO on tactical missile defenses (Asker, Barrie & Taverna, 2002), and Boeing had worked in marketing the Meteor missile, made by EADS and BAE. Most of the previous arrangements between Boeing and EADS had involved subcontracting or marketing, while this alliance involved sharing the product development responsibilities ("Business: Hands Across the Sea," 2002).

Consequently, this alliance was partially motivated by the need to convince the Europeans of the US perspective toward larger missile defense programs. It involved sharing of knowledge between the members and a fusion of their different capabilities to produce innovative products. Alliances, particularly between Boeing and EADS, had previously existed in the missile defense arena, and the positive momentum from these previous alliances had helped in building trust and, thus, helped to promote the development of subsequent alliances.

VII. Alliances Focused on Specific Product Areas: A Case Study on the Alliance between Raytheon and Thales

Many of the successful trans-Atlantic alliances between defense contractors have been focused on a specific product area. CFM International and International Aero Engines, discussed in Section V, are examples of successful alliances which concentrated on developing systems in a specific product area. Another example of this type of alliance is the alliance between Thales (formerly Thomson-CSF, a French company) and Raytheon. This alliance, Thales Raytheon Systems, was completed in early 2001. This alliance was created so the two contractors could collaborate on ground-based battlefield radar programs and air defense command/control (C2) programs (Taverna, 2001). By the end of 2001, Thales and Raytheon had collaborated on 17 projects ("US-Euro Strategic Alliances," 2001).

The alliance was a horizontal combination in which firewalls were built to protect against leakage of sensitive information. Thales Raytheon Systems was divided into two subsidiaries; Raytheon would have a 51% share in the US subsidiary, and Thales would have a 51% share in the European subsidiary. The revenues of Thales Raytheon Systems were split between France and the US (Taverna, 2001).

As was the case in the alliance formed between Boeing and EADS in the missile defense area, Thales Raytheon Systems was formed partially because the two companies involved had successfully collaborated on other fronts—thus building trust between the two parties and increasing their tendency to invest in relationship-specific assets, despite the more arm's-length nature of an alliance relative to a merger. Thales and Raytheon collaborated on the Air Command Systems International (ACSI), which was a venture established in 1997 to work on the Florako air defense radar project in Switzerland, and NATO's Airborne Command and Control System (LOC1). ACSI continued to be a separate entity, but was attached to Thales Raytheon Systems (Taverna, 2001).

VIII: The Role of Alliances in Sharing R&D Costs: A Case Study of Boeing's "Super-Jumbo" Jet Alliance

Mergers and alliances are often valuable in enabling the participating firms to generate economies of scale in both R&D costs and in production costs by sharing these costs or by spreading them over a greater number of units of output to lower per-unit costs. As weapons systems have become more complex, R&D has continued to be an important and costly phase of the product development cycle.

One example of an alliance which was formed to share R&D costs was an alliance—led by Boeing, and including the Airbus companies of Aerospatiale SA (France), British Aerospace, and Daimler-Benz—to develop a "super-jumbo" jet. The R&D costs to develop this jet, which would have carried between 600 and 800 passengers, were $15 billion. This was too much for one contractor to sustain and was more affordable when spread over an alliance of contractors (Cole, 1995).

The project first began development in January 1992, but collapsed in 1995 due to uncertainty in demand. Only Singapore Airlines and British Airways were willing to place orders. This underscores the importance of the need to share R&D costs, and hence the risk of product development, in an environment of uncertain demand. A second reason for the collapse of the project was the concern that it would consume so much capital that it would limit the development of the next generation of supersonic planes (Cole, 1995). Consequently, although alliances are important in sharing R&D costs, the placement of the product being developed has to be evaluated in the context of the costs of the estimated future trajectory in product development.

IX. The Role of Alliances in Developing Interoperable Equipment between Allied Forces: A Case Study of the Joint Strike Fighter

The development of the Joint Strike Fighter (JSF) is an example one of the most extensive alliances in the defense sector, involving 9 different contractors from various countries, led by Lockheed Martin. The JSF not only allows the various contractors to contribute their expertise to provide a better product, but also provides a strong basis for understanding the challenges facing global defense alliances in the future, ranging from cost-allocation issues, to technology transfer security issues, to global supply chain integration issues.

One of the main benefits of the creation of the JSF is that the new product—created by the sharing of technology between the various allied nations—will allow greater synchronization of subsequent operations of the coalition of allied countries and the development of more similar capabilities. The intention has been for the F-35 to replace 13 different types of aircraft across 11 different countries ("Lockheed Martin," 2008). Nine nations are participating in the JSF program, according to their levels of financial involvement. While the US is the primary customer, the UK is a Level I partner since it contributes 10% of the development costs, followed by Level II partners—the Netherlands and Italy, and then followed by Level III partners—Canada, Turkey, Australia, Norway, and Denmark ("F-35 Lighting II," 2009).

The international structure of the relationships between the US contractors and the foreign contractors on the JSF has drawn criticism. By mid-2003, one of the concerns was linked to the fact that the foreign contractors on the JSF did not have to share the growing development costs, which had already increased $3 billion since the start of the system development phase. The US defense representatives argued that they could ask for assistance from their foreign allies in handling cost overruns. A second concern, voiced by the chairman of the House Government Reform Panel, Representative Shays, was that too many US jobs on the JSF were going overseas—as of that point, 18% of the contracts on the JSF had gone overseas, valued at $2.2 billion. A third concern came from the partners on the other side of the Atlantic: the Chairman of Alenia Aeronautica noted his disappointment in the return on investment in the JSF. On the US side, there were concerns that program decisions might have to be made to increase the return on investment to partner countries, but which could also lead to delays or higher costs (Wall, 2003). Finally, a fifth concern arose surrounding technology-transfer issues. The UK threatened to exit the JSF program unless the US shared information on the stealth technologies, etc., related to the plane ("Politics and Economics," 2006). Britain had invested $2 billion in the plane as of the spring of 2006, when the discussions began about their concerns over the US not sharing this technology ("Strains in the Alliance," 2006). This disagreement was subsequently resolved.

Multinational military operations require a degree of synergy between the technology of the various allied powers; compatibility in computer systems and communications systems is important. Trans-Atlantic alliances can promote this, not only in the case of the JSF, but for subsequent products. The intention of Secretary of Defense Robert Gates to purchase more JSFs, as announced in April 2009, emphasizes the commitment of the US to systems that are compatible with its allies and that are developed through global alliances, as well as to the high quality of the collaboratively produced plane.

Section X: The Role of Alliances in Entering New Markets: A Case Study of the Northrop-Grumman/EADS Alliance on the KC-45a Tanker

One of the most recent chapters in the evolution of trans-Atlantic defense relations has been the alliance between Northrop-Grumman and EADS to supply the USAF with a new fleet of aerial refueling tankers. This contract may the largest defense contract in history with the exception of the F-35 Joint Strike Fighter. This is a landmark case not only in terms of the size of the defense contract, but also in terms of the relationship of the US with the broader European defense market, and the impact of the US reaction to the tanker competition on global perceptions concerning the openness of the US defense market.

As discussed in Hensel (2008), the tanker competition is very important to the USAF because the average age of the existing KC-135 tankers is 47 years; the planes were first put into service in 1957. The 2008 competition was initially over a $1.5 billion contract, covering 4 test aircraft. The intent was then to buy 175 more planes, for a total value of $35 billion. While the $35 billion amount would stretch over 10-15 years, an additional $60 billion in revenue could come from maintenance and parts such that the overall contract would be worth $100 billion ("Analysts," 2009; "Northrop group," 2008; Wolf and Shalal-Esa, 2008; Hinton, 2008).

Hensel (2008) discusses how, in this competition, Boeing displayed the behavior of a traditional incumbent. It had been the provider of refueling tankers to the USAF for almost 50 years and had what was often referred to as a " monopoly." When the Air Force announced that the Northrop Grumman/EADS team had won the contract on February 29, 2008, Boeing indicated shortly afterward that it was dissatisfied with the decision and lodged a series of protests with the GAO about the way in which the competition was conducted. The GAO recommended that the competition be reopened and upheld 8 of Boeing's 100 protests, although it stated that it found no evidence of "intentional wrongdoing" by USAF procurement officials (Randolph, 2008).

The USAF announced on July 9 that it would reopen the competition and would focus it on the 8 areas of protest sustained by the GAO. Unlike the previous competition, which was overseen by the USAF, this competition would be overseen by John Young, the chief of weapons procurement and the Undersecretary of Defense for Acquisition, Technology, and Logistics at the Pentagon. The Air Force stated explicitly that in the new competition, it would provide extra credit for a larger plane with additional fuel offload capacity (Shalal-Esa, 2008, July 9). Boeing, faced with the opportunity to propose the larger 777 in light of this "extra credit" suggested in the draft RFP, claimed that it would pull out of the competition if it were not provided with more time to develop a modified 777. The USAF decided to cancel the competition in the fall of 2008 and to re-open it again in the summer of 2009. The last chapter in this story remains to be written.

The alliance of Northrop-Grumman and EADS to build aerial refueling tankers differed from previous trans-Atlantic alliances due to the substantive investment that EADS planned to make in the US defense industrial base—both in terms of creating jobs and in terms of building production facilities. This was because it wanted to obtain a stronger base within the US to enter the US market, as well as to protect itself from currency fluctuations, which had hurt it in 2008. It pays suppliers in euros, but sells airliners in dollars, so moving production to dollar-zone countries was particularly helpful when the euro was strong relative to the dollar. About 60% of the Northrop/EADS tanker would be made in the United States. Some of the parts would be manufactured in Germany, France, Spain, and Great Britain, but assembly of the tanker would have occurred in Mobile, AL, where EADS planned to build the third largest manufacturing facility in the world and where it had also planned to assemble a commercial freighter version of the A330 (Wolf & Shalal-Esa, 2008).

Unfortunately, as extensively discussed in Hensel (2008), the Congressional representatives from the states which would have benefitted if Boeing had received the contract protested strongly that US jobs would be lost under the Northrop/EADS proposal. Despite the fact that the Northrop/EADS tanker would create 48,000 jobs in the US, Kansas Representative Tiahrt continued to argue that "'I cannot believe we would create French jobs in place of Kansas jobs'" (as cited in Drawbaugh, 2008, February 29). On the other hand, Senator McCain noted, "'I've never believed that defense programs should be—that the major reason for them should be to create jobs. I've always felt that the best thing to do is to create the best weapon system we can at cost to taxpayers'" (as cited in Drawbaugh, 2008, March 3). These thoughts were echoed in the comments of Pentagon acquisition chief John Young, who noted, "'I don't think anybody wants to run the department as a jobs program,"' further arguing that lawmakers usually focused on asking him to reduce the costs of weapons systems (as cited in Shalal-Esa, 2008, March 4).

As analyzed in Hensel (2008), the initial award of the contract to the team of Northrop/EADS reinforced the perception of many that, as Defense Secretary Robert Gates had stated, "'defense manufacturing is a global business'" ("Northrop Grumman Fires Back," 2008), particularly as the US had allied with many other countries in combating the War on Terror. Many perceived this initial award as the harvest of improved relations with France, and that it would be much harder for European manufacturers to claim that US markets were closed to them. French President Nicholas Sarkozy stated on March 3, 2008, "'If Germany and France had not shown from the beginning that we were friends and allies of the United States, would it have been possible to have such a commercial victory?"' (as cited in Hepher, 2008). Nevertheless, after the GAO handed down its ruling, several European officials expressed concerns that this signaled that US markets were not open to European products, despite the investment of the European alliance partner in the US defense industrial base. Others expressed concerns of retaliation on the part of European manufacturers if Northrop/EADS finally loses the contract when the competition is re-opened.

Section XI: Conclusion

The purpose of this analysis is to discuss the importance of linkages between US and European defense manufacturers with the emergence of the common global threat of terrorism, the greater price sensitivity of governments concerning weapons systems costs, and the shrinkage of defense budgets. Due to national security concerns and integration costs, alliances can often be easier to develop than mergers and can ultimately provide a prelude to an ultimate merger between the parties if the alliance is successful. Alliances can provide many of the benefits of mergers, such as sharing R&D costs or allowing access into new markets, without many of the costs of mergers: difficulty in exiting, substantive integration costs, etc.

The case studies in this analysis highlighted the role of trans-Atlantic alliances in achieving various outcomes—spurring alliances between competitors to ultimately create a market with several new products (CFM International and International Aero Engines), promoting national defense strategies (Boeing's alliance with EADS and other manufacturers in the missile arena), sharing R&D costs (the failed alliance between Boeing and other manufacturers to build a "super-jumbo" jet), developing interoperable equipment between allied nations (the JSF), and entering new markets (the alliance between Northrop Grumman/EADS to supply new aerial refueling tankers).

The last two cases—the JSF and the tanker competition—will have a significant impact on subsequent trans-Atlantic defense alliances. The JSF, because it unites manufacturers from 9 countries, will break new ground and set new precedents in how issues involving global supply chain problems, cost absorption, and technology transfer will be resolved in later trans-Atlantic alliances. The tanker competition—due to the magnitude of the contract, the size of EADS' proposed investment in the US, and the international publicity that the competition achieved from the dialogues of various Congressional representatives and government leaders—will affect perceptions about the openness of US markets to foreign manufacturers.

As countries are increasingly faced with budgetary strains from combating the current financial crisis, the fiscal strains imposed by an ageing population, and other areas such as education, infrastructure, etc., defense budgets will likely be under more pressure. Moreover, there will be a greater emphasis on obtaining innovative weapons systems products at low costs and in a timely manner. As supply chain issues are smoothed out, there will be a significant opportunity for global alliances in the defense sector to play a valuable role in helping governments meet the challenges of the new millennium.

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Summary of: New Patterns of Collaboration and Rivalry in the US and European Defense and Aerospace Industries

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Professor Udis' published work includes three books: *The Economic Consequences of Reduced Military Spending* (editor, 1973), *From Guns to Butter: Technology Organizations and Reduced Military Spending in Western Europe* (1978), and *The Challenge to European Industrial Policy: Impacts of Redirected Military Spending* (1987). In addition, he has published numerous articles in scholarly journals on defense industries and military power. These include "Offsets as Industrial Policy: Lessons from Aerospace" (with Keith Maskus, 1992), and "New Challenges to Arms Export Control: Whither Wassenaar?" (with Ron Smith, 2001). A number of his works are considered classics in defense economics and have been reprinted in collections such as *The Economics of Defence* (2001) and *ARMS TRADE, SECURITY AND CONFLICT* (2003).

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This is a summary of the report cited above for inclusion in the *Proceedings* of the Sixth Annual Acquisition Research Symposium hosted by NPS (May 2009). The report itself greatly exceeds the length guidelines for the *Proceedings*. The topics raised here are discussed in greater detail within the body of that report.

Summary

International defense industrial affairs are becoming increasing global and increasingly complex. This report is a continuation of the authors' efforts to provide insights and analytical frameworks useful for understanding ongoing developments in the global defense market.[1]

In this stage of that overall project, we focus primarily on defense industrial firms and their relationships with their sovereign customers—considering the organization of Boeing 787 development and production, the KC-45 aerial tanker competition, and European defense firms' direct investment in the US defense market.

Our Cases

In the 787 case (Section II), we observe that even experienced companies like Boeing can run afoul of the complexities of coordinating a multinational, multiform venture. We suspect this problem is not unique to Boeing, and will, if not satisfactorily addressed, limit the scope and success of multinational projects in the defense sector as well.

The KC-45 (Section III), at least to date, seems to illustrate a new weakness of defense establishments relative to their suppliers. The failure to successfully award a KC-45 contract to the EADS-Northrop Grumman team (after protest to the GAO) raises some troubling questions. Is it possible to award a protest-proof contract for a major defense system? Doesn't the buyer side of the US defense market more resemble a quarrelsome committee than the classic model of the sovereign monopsonist? With increasingly large, winner-take-all competitions, what's the potential for procurement gridlock—the apparent state of the KC-45? Will the concentration of buyer power (through smaller numbers) and the resultant increase in agility give suppliers exploitable advantages over their customers?

Our discussion of foreign direct investment in US defense industries focuses on three European firms: BAE, EADS and Finmeccanica (Section IV). Our research was informed in

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[1] Previous work by the authors includes *Echoes across the Pond* (NPS-AM-08-002). Monterey, CA: NPS, 2008.

significant part through confidential interviews with high-level, Washington-based officials intimately familiar with the issues at hand. The central theme of this discussion is the interplay between the motivations for these firms to enter the US defense market, the US regulatory environment (which constrains such entries), and the corporate strategies intended to work with (and around) those legal barriers.

Our discussion of these three firms suggests three interesting conclusions. First, entry into the US defense market is indeed motivated primarily by the relatively high level of the US defense budget, relative to those in Europe (consistent with prevailing conventional wisdom). Second, "Buy American" and restrictions on direct investment have proven to be penetrable—to a significant degree. Finally, a two-way street of defense industrial trade between the US and Europe appears to be emerging as fully fledged reality—after decades of heated debate and limited progress.

Conclusions

Our conclusions follow. Many are not striking (or new to us), but taken together, we feel they are significant and useful.

Complexity and cost have changed and are fundamentally changing the nature of economies of scale. Production runs that usefully exploit economies of scale and learning curves are increasingly beyond the reach of single nation-states. Accordingly, new weapon systems (such as the Joint Strike Fighter) have increasingly become international ventures—albeit with senior partners. On the supply side, defense firms have undertaken more projects featuring outsourcing arrangements and strategic partnerships. In addition, the number of first-tier defense suppliers has significantly declined.

Inter-firm relationships are much more a product of situation and project type than by the firm boundaries of more traditional thought. Even very large firms (such as Boeing and Lockheed-Martin) can compete in some areas and collaborate in others. This has contributed to the increased complexity of both the market structure and the management of major projects.

Finally, the combination of reduced numbers of suppliers and the complexity of globalized defense markets has significantly increased the market power of defense industrial suppliers relative to their (sovereign) customers. Among other things, it appears that the suppliers have been more agile in adapting to complexity than have their bureaucratic customers.

Panel 18 - Bid Protests: Causes, Trends, and Containment Strategies

Thursday, May 14, 2009	Panel 18 - Bid Protests: Causes, Trends, and Containment Strategies
1:45 p.m. – 3:15 p.m.	**Chair: G. Fred Thompson**, Goudy Professor of Public Management & Policy Analysis, Williamette University **Discussant: David M. Van Slyke**, Associate Professor of Public Administration, Syracuse University ***Bid Protests: Analyzing Recent Trends*** **William Lucyshyn, Jacques Gansler** and **Michael Arendt**, University of Maryland ***Innovations in Defense Acquisition: Asymmetric Information and Mechanism Design*** **William Gates** and **Peter Coughlin**, Naval Postgraduate School

Chair: Fred Thompson, PhD, is Grace & Elmer Goudy Professor of Public Management and Policy at the Atkinson Graduate School of Management and Director of the Willamette University Center for Governance and Public Policy Research. He is the only member of the Willamette University's faculty to have received all three of its top awards—for teaching, for research, and for service. He recently coauthored two books, *Digital State at the Leading Edge* (University of Toronto Press, 2007), and *From Bureaucracy to Hyperarchy: Netcentric and Quick Learning Organizations* (Information Age Publishing, 2007), and co-edited a third, *Public Ethics and Governance* (Elsevier JAI, 2006). His recent articles include "Responsibility Budgeting in the Air Force Materiel Command" (2006), "Netcentric Organization" (2006), and "Betting on the Future with a Cloudy Crystal Ball" (2007) in *Public Administration Review;* and "A Better Budget Rule" (2009) and a review of *The Oxford Handbook of Public Management* (2007) in *Journal of Policy Analysis and Management.* He also served on the United Nations Development Program's Blue Ribbon Commission on the Republic of Macedonia and helped write its report *Achieving Dynamic Economic Growth.* Last fall, he was a visiting professor in the Interdisciplinary Institute of Management at the London School of Economics, teaching organizational economics and mechanism design.

Thompson is a recipient of the NASPAA/ASPA Outstanding Research Award, ABFM's Wildavsky Award for lifetime scholarly achievement, and various best-article awards, including PAR's Mosher Award for best article by an academic. He currently sits on ten editorial boards and over his career has served on 18. He is the founding editor of the *International Public Management Journal* and currently edits the comparative statistics section of the *Journal of Comparative Policy Analysis*.

Thompson received his doctorate in Economics & Politics from Claremont Graduate University.

Discussant: David M. Van Slyke, PhD, is an instructor for the Acquisition Solution Training Institute™, responsible for training personnel to optimize their potential and helping organizations to achieve their acquisition goals and mission-critical objectives. Van Slyke brings nine years of experience teaching public administration and public affairs to university students. He specializes in public and nonprofit management, privatization and contracting, contract management, policy implementation, strategic planning and performance management, as well as faith-based organizations and philanthropy.

Van Slyke is an associate professor in the Department of Public Administration at the Maxwell School of Citizenship and Public Affairs, Syracuse University. He was tenured and promoted in March 2007, after having been an assistant professor since August 2004. Van Slyke also has been a senior research associate at the Campbell Institute of Public Affairs, Maxwell School of Citizenship and Public Affairs, since August 2004. In addition, he currently serves as a committee member on a transnational non-governmental organization project for the Moynihan Institute of Global Affairs at the Maxwell School.

Previously, Van Slyke spent six years as an assistant professor in the Department of Public Administration and Urban Studies at the Andrew Young School of Policy Studies, Georgia State University. He also was Director of the Nonprofit Studies program for three years.

Van Slyke has received numerous awards and grants during his career and has dozens of publications to his credit, many in the *American Review of Public Administration*, the *Journal of Public Administration Research and Theory*, and the *Nonprofit and Voluntary Sector Quarterly*. He also has written numerous working papers, reports, and editorials. He has been invited to present at various forums, and he most recently gave a speech entitled "Government Oversight, Accountability, and Contracting" to the Shenzhen Municipal Government Senior Leadership Delegation, Syracuse, New York, on September 6, 2007.

Van Slyke has been principal, co-principal, or investigator for several grants he has reviewed since 1999. Currently, he is serving as a principal investigator for "Relational Contracting, Contract Specificity, and Contract Management," which is funded through the Appelby-Mosher Endowment Fund, Maxwell School of Syracuse University, from April 2007 to June 2008.

Van Slyke received his PhD in Public Administration and Policy, with a concentration in public and nonprofit management, from the Rockefeller College of Public Affairs and Policy, University at Albany, State University of New York, in December, 1999. His dissertation was titled "Managing the Government-Nonprofit Contracting Relationship for Social Services in New York State." He received his Master of Science degree in educational administration and policy studies from the University at Albany, State University of New York, in August 1993. He holds a Bachelor of Science degree in economics from the College at Plattsburgh, State University of New York, in May 1990.

Van Slyke has participated in numerous executive training programs in Syracuse, New York. Ssince 2006, he has been part of the Phase IV Mid-Career Training Program for Indian Administrative Service Officers, sponsored by the Indian Department of Personnel Training in Mussoorie, India. In addition, he has been part of the Cornell Municipal Clerks Institute Training Program in Ithaca, New York, since 2005.

Bid Protests: Analyzing Recent Trends

Presenter: The Honorable Jacques S. Gansler, former Under Secretary of Defense for Acquisition, Technology, and Logistics, is a Professor and holds the Roger C. Lipitz Chair in Public Policy and Private Enterprise in the School of Public Policy at the University of Maryland. He is also the Director of both the Center for Public Policy and Private Enterprise and the Sloan Biotechnology Industry Center. As the third-ranking civilian at the Pentagon from 1997 to 2001, Gansler was responsible for all research and development, acquisition reform, logistics, advance technology, environmental security, defense industry, and numerous other security programs.

Before joining the Clinton Administration, Gansler held a variety of positions in government and the private sector, including Deputy Assistant Secretary of Defense (Material Acquisition), Assistant Director of Defense Research and Engineering (Electronics), Executive Vice President at TASC, Vice President of ITT, and engineering and management positions with Singer and Raytheon Corporations.

Throughout his career, Gansler has written, published, and taught on subjects related to his work. He recently served as the Chair of the Secretary of the Army's "Commission on Contracting and Program Management for Army Expeditionary Forces." He is also a member of the National Academy of Engineering and a Fellow of the National Academy of Public Administration. Additionally, he is the Glenn L. Martin Institute Fellow of Engineering at the A. James Clarke School of Engineering, an Affiliate Faculty member at the Robert H. Smith School of Business, and a Senior Fellow at the James MacGregor Burns Academy of Leadership (all at the University of Maryland). For 2003–2004, he served as Interim Dean of the School of Public Policy. For 2004–2006, Gansler served as the Vice President for Research at the University of Maryland.

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William Lucyshyn is the Director of Research and Senior Research Scholar at the Center for Public Policy and Private Enterprise in the School of Public Policy at the University of Maryland. In this position, he directs research on critical policy issues related to the increasingly complex problems associated with improving public sector management and operations, and how government works with private enterprise.

Current projects include modernizing government supply chain management, identifying government sourcing and acquisition best practices, and Department of Defense business modernization and transformation. Previously, Lucyshyn served as a program manager and the principal technical advisor to the Director of the Defense Advanced Research Projects Agency (DARPA) on the identification, selection, research, development, and prototype production of advanced technology projects.

Prior to joining DARPA, Mr. Lucyshyn completed a 25-year career in the US Air Force. Lucyshyn received his Bachelor Degree in Engineering Science from the City University of New York, and he earned his Master's Degree in Nuclear Engineering from the Air Force Institute of Technology. He has authored numerous reports, book chapters, and journal articles.

Michael Arendt is a Faculty Research Assistant at CPPPE and provides support for various research projects related to defense acquisition policy. Past reports he co-authored include "Achieving the Desired Structure of the Defense Industry in the 21st Century." His current research focus is on bid protests in defense acquisitions.

He is a current PhD student at the University of Maryland, School of Public Policy, with a research concentration in Management, Finance and Leadership. Arendt holds an MS in Defense and

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Abstract

The Government Accountability Office (GAO) provides an objective, independent, and impartial forum for the resolution of disputes concerning the awards of federal contracts. Over the years, their decisions in bid-protest cases have resulted in a uniform body of law applicable to the procurement process that is relied upon by the Congress, the courts, contracting agencies, and the public. Filing a bid protest is easy, inexpensive, and does not require the services of an attorney (although protesters may be represented by counsel). In general, the process is quicker than using court litigation.

Recently, there has been a perceived increase in the number of contract awards that are protested and a perception that firms may be protesting government contract awards as a strategy to negotiate their way into contracts or to derail an award process already in place. Are these perceptions accurate? Are firms protesting more frequently? If firms are protesting more frequently, then why? If not, perhaps there are simply more contracting actions that are resulting in a comparable increase in protests.

An examination of this phenomenon is important, as bid protests could have significant detrimental effects on the cost and schedule of defense programs. Our study will examine and evaluate bid-protest data from 2001 through 2008, use specific case studies to shed light on the current state of bid protests across the military services, and provide recommendations for moving forward. The study will be broken up into two parts.

Part One will offer an overview of the bid-protest process through the GAO. We will map the policies and procedures from start to finish for filing a protest with the GAO. Next, we will present an analysis for the open-source bid-protest data we have collected, our interpretation of the data, and its implications.

Part Two will examine specific bid-protest cases in greater detail. Each case will include background information, an overview of the contract, the items being protested, the result of the protest and the lessons learned in the process. These cases will include the Logistics Civil Augmentation Program (LOGCAP) IV case, Information Technology Enterprise Solutions 2 Services (ITES-2S) case, and the HRSolutions case.

Finally, we will provide specific recommendations for government acquisition planning and process actions that should be taken to minimize future problems.

Panel 19 - Evolutionary Acquisition of Software-intensive Systems

<table>
<tr><td>Thursday, May 14, 2009</td><td>Panel 19 - Evolutionary Acquisition of Software-intensive Systems</td></tr>
<tr><td>1:45 p.m. – 3:15 p.m.</td><td>Chair: Captain Al Grecco, US Navy, Program Manager, Combat Systems, PEO Integrated Warfare Systems

Application of Real Option Theory to Software-Intensive System Acquisition

Capt. Albert Olagbemiro, US Air Force (Reserve), Man-Tak Shing and Johnathan Mun, Naval Postgraduate School

Modeling Open Architecture and Evolutionary Acquisition: Implementation Lessons from the ARCI Program for the Rapid Capability Insertion Process

David Ford, Texas A&M University and John Dillard, Naval Postgraduate School

Supply Chain Planning with Incremental Development, Modular Design and Evolutionary Updates

Marie Bussiere, Betty Jester and Manbir Sodhi, Naval Undersea Warfare Center, Newport Division</td></tr>
</table>

Chair: Captain Albert J. Grecco is a native of Poughkeepsie, NY. He is a 1982 graduate of the United States Naval Academy, where he received a Bachelor of Science in Electrical Engineering and was commissioned.

Grecco's initial sea assignment was aboard USS KING (DDG 41), where he served as Gunnery Officer and TERRIER Missile Officer and completed a 1984 deployment to the Persian Gulf. He subsequently entered the Weapon Systems Engineering program at the Naval Postgraduate School, was redesignated as an Engineering Duty Officer, and graduated in 1988 with a Master's of Science in Engineering Science.

Grecco has served in acquisition billets at headquarters and in field assignments. He served as a Project Officer for the FFG-7 Shipbuilding Program Manager (PMS 314) and the MK 92 Program Manager (SEA 62Z3) at the Naval Ship Weapon Systems Engineering Station, where he led the introduction and development testing of MK 92 Mod 6 Fire Control System on USS INGRAHAM (FFG 61). Subsequent headquarters assignments included tours as Technical Director for the NAVSEA Surveillance Systems Subgroup (SEA 62X) and as a Ship Self-Defense System Engineer in the Program Executive Office, Theater Air Defense.

Grecco returned to sea to serve as Combat Systems Officer aboard USS TICONDEROGA (CG 47), where he completed a 1995 deployment to Sixth Fleet and conducted EASTPAC counter narcotic operations. He has subsequently served ashore as the first Combat Systems Officer for the DD 21 Program, as the AEGIS Shipbuilding Combat Systems, Test and Trials Officer (PMS 400D5), the AEGIS Combat Systems Engineer (PMS 400B3), and as the DD(X) Warfare Systems Engineer in the

Program Executive Office, Integrated Warfare Systems, and most recently as the Technical Director/Major Program Manager for the AEGIS Ballistic Missile Defense Program. Grecco's current assignment is Major Program Manager, Integrated Combat Systems (IWS 1.0), Program Executive Office, Integrated Warfare Systems.

Grecco's personal decorations include the Legion of Merit, Defense Meritorious Service Medal, Meritorious Service Medal with one gold star, Navy Commendation Medal with three gold starts, Navy Achievement Medal, and NATO medal. Grecco is married to the former Lacy Williams of Norfolk, VA, and has two daughters, Mary Lacy (1990) and Arleigh (1995).

Application of Real Options Theory to Software-intensive System Acquisitions

Presenter: Capt Albert Olagbemiro, PhD, is a Logistics Readiness Officer in the US Air Force Reserve and has served in both staff and operational logistics assignments. He is currently the Operations Officer at the 69th Aerial Port Squadron, Andrews AFB, MD. He holds both an MS in Computer Science and an MBA from Johns Hopkins University. He received his PhD in Software Engineering from the Naval Postgraduate School in 2008.

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Dr. Man-Tak Shing is an associate professor at the Naval Postgraduate School. His research interests include the engineering of software intensive systems. He is on the program committees of several software engineering conferences and is a member of the Steering Committee of the IEEE International Rapid System Prototyping Symposium. He received his PhD in computer science from the University of California, San Diego, and is a senior member of IEEE.

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Dr. Johnathan Mun is a research professor at the Naval Postgraduate School and Founder/CEO of Real Options Valuation, Inc. (software, training and consulting firm in Silicon Valley, focusing on advanced risk analytics, risk simulation, stochastic forecasting, portfolio optimization, strategic real options analysis, and general business modeling analytics). He received his PhD and MBA from Lehigh University and holds other financial charters and certifications in risk and financial analysis.

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Abstract[1]

In the Department of Defense (DoD), the typical outcome of a software acquisition program has been massive cost escalation, slipping planned delivery dates and making major cuts in the planned software functionality to guarantee program success. To counter this dilemma, the DoD put forth a new weapons acquisition policy in 2003 based on an evolutionary acquisition approach to foster increased efficiency while building flexibility in the acquisition process. However, the evolutionary acquisition approach often relies on the spiral development process, which assumes end-state requirements are known at the inception of the development process, a misrepresentation of reality in the acquisition of DoD software-intensive weapons systems. This article presents a framework to address requirements uncertainty as it relates to software acquisition. The framework is based on Real Options theory and aims at mitigating risks associated with requirement volatility based on the technology objectives—constraints as put forth by the customer at the acquisition decision-making level.

1. Introduction

The software acquisition lifecycle, which encapsulates the activities related to its procurement, development, implementation and subsequent maintenance, continues to present challenges to software executives and program managers due to increasingly complex organizational requirements and the ever-increasing role that software plays in US Department of Defense (DoD) weapons systems. Various factors and considerations, most of which are complex in nature, compound the software acquisition process: factors that present themselves in the form of "uncertainties," and which have the potential of introducing risks if the uncertainties are not adequately addressed and or resolved. In this paper, we address the issue of requirements uncertainty and propose a methodology for addressing this issue. Our approach addresses these issues by taking a proactive/preemptive approach to risk management by planning and paying up front for the risks associated with requirements. This is not to say that risk management strategies are not being adopted today; rather, there is a failure of management to take a strategic approach towards risk management. Currently, the status quo is to employ reactive risk management strategies that often result in the reduction of much-needed functionality from the scope of the software investment effort. We therefore propose a more proactive decision-making framework that involves identifying the risks, pricing risk upfront during the planning stages of the acquisition before a decision to commit resources is made.

2. The Requirements Dilemma

In software development, requirements instability has a profound impact on a program's schedule and drives up costs due to increases in Research, Development, Test & Evaluation (RDT&E) costs associated with the requirements changes. The lack of adequately defined requirements is one of the leading problems in the software development effort. Without adequate definition and validation of requirements and design, software engineers could be coding to an incorrect solution, resulting in missing functionality and errors. This dilemma is highlighted in a 2007 interview of the Army's Program Executive Officer (PEO) for Ammunition,

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[1] This work was supported in part by the NPS Acquisition Research Program—OUSD_08 (Project #:F08-023, JON: RGB58). The views and conclusions in this talk are those of the authors and should not be interpreted as necessarily representing the official policies or endorsements, either expressed or implied, of the US Government.

in which “the ability to acquire and maintain, safe, reliable supportable and modifiable software systems which met user requirements in an environment of rapid technological advances” was identified as their biggest challenge in software acquisitions (Starrett, 2007). Furthermore, the US Government Accountability Office (GAO), responsible for reviewing weapon systems investments, found consistent problems of cost increases, schedule delays, and performance shortfalls exacerbated by factors such as pressure on program managers to promise more than they could deliver. These concerns infer a resounding theme that continues to resonate within the software acquisition community: *Meeting customer requirements within cost and schedule constraints*.

Balancing the satisfaction of a customer’s ever-changing requirements within the realms of meeting both current and future uncertain operational needs against the costs and schedule constraints poses a cumbersome challenge to the software executive, thereby making software-investments a very risky venture. They are risky in the sense that software engineering and investment decisions are plagued by uncertainties that more often than not lead to varying degrees of risk ranging from operational shortfalls to cost and schedule overruns.

Ever-changing requirements continue to impact software acquisition efforts, and more often than not, force managers to choose between requirements, i.e., which requirements to accept and which requirements to reject with the full understanding that ignoring changes in requirements results in the delivered product failing to meet the customers needs while accepting changes in requirements has the potential of impacting costs and schedule.

Furthermore, changes in requirements while a software acquisition effort is under way poses the risk of introducing unwanted, unanticipated or unknown impact on existing requirements, not to mention associated costs and scheduled delays depending on the phase of the investment or software development process experiencing significant requirements changes. While the standard practice has been to “freeze” requirements prior to the commencement of any development activities, frequently, this does not work and is not representational of the DoD doctrine to support the flexible development and rapid delivery of products to meet the warfighters needs in an ever-changing environment in response to operational needs.

The inefficiencies of current management techniques as shown in Table 1 highlight the needs of new management approaches that proactively plan for and factor uncertainty into their acquisition strategy. This is because the acquisition of software, its development and the operational use of the software are dominated by human action, human judgment, decision-making and, inevitably, human error. The outcome is, therefore, often uncertain and unpredictable and leads to unavoidable uncertainties that introduce and drive risk (Starrett, 2007).

Table 1. Program Management Failures of Top Three Major Weapons Systems[2]

[2] Numbers were complied from various GAO reports and were current as of 2007.

Program	Initial Investment	Initial Quantity	Latest Investment	Latest Quantity	% Unit Cost Increase	% Quantity Decrease
Joint Strike Fighter	$189.8 billion	2,866 aircraft	$206.3 billion	2,459 aircraft	26.7	14.2
Future Combat Systems	$92 billion	18 System	$163.7 billion	14 systems	54.4	77.7
F-22A Raptor	$81.1 billion	648 aircraft	$65.4 billion	181 aircraft	188.7	72.1

We must, however, emphasize that uncertainty should not be confused with risk as there is an important distinction between the two. Risk is something one bears and is the outcome of uncertainty, as uncertainty is either resolved through the passage of action or left unattended due to inaction (Mun, 2006). The risks associated with the acquisition of the software need to be identified and analyzed very early in the decision-making process, and an approach to mitigate the high-priority risks must be incorporated into a software acquisition plan.

Therefore, in order to accurately estimate requirements volatility and its impact on the future value of a software-intensive-system under consideration for acquisition, the risk of requirements changes must be quantified, and it must also be specifically predicted and quantified based on the phase in the software development process in which the changes are more likely to occur. Hence, the need arises for an approach that would explicitly acknowledge the probability of occurrence based on previous objective estimates also in addition to the possibility of occurrence based on subject expert opinions (Delphi Method) that acknowledges either the degree of belief or ignorance in the objective probability estimates. (See Section 4 for details.)

3. The Real Options Approach

The Real Options approach is based on the concepts of financial options theory, and it builds on several tried-and-proven approaches of management. The study conducted by Olagbemiro (2008), showed how the Real Options approach could be used as a proactive risk management tool within a strategic decision-making level (executive level) pre-acquisition context—further complementing the spiral development approach at the "tactical level." It was also demonstrated using the US Army Future Combat Systems program as an example of how the traditional Real Options methodology, when enhanced and properly formulated around a proposed or existing software-investment, could provide a framework for guiding software acquisition decision-making by highlighting the strategic importance of managerial flexibility. This flexibility offers management the ability to balance the satisfaction of a customer's requirements within the realms of the associated cost and schedule constraints by developing the appropriate options during the acquisition decision-making phase and executing the options when optimal. However, the Real Options approach calls for the existence or satisfaction of certain pre-conditions before it can be applied. These pre-conditions, which correlate directly to the various activities associated with software related capital investments, are outlined in Mun (2006) as follows:

1. The existence of a basic financial model used to evaluate the costs and benefits of the underlying software asset (e.g., Net Present Value (NPV) as the Real Options approach builds on the existing tried-and-tested approaches of current financial modeling techniques.

2. The existence of uncertainties during the software-related capital investment decision-making process, otherwise the Real Options analysis becomes useless as everything is assumed to be certain and known.

3. The uncertainties surrounding the software-related capital investment decision-making process must introduce risks that directly impact the decision-making process. Real Options could then be used to hedge the downside risk and take advantage of the upside uncertainties.

4. Management must have the flexibility or option to make mid-course corrections when actively managing the project.

5. Management must be smart enough to execute the Real Options when it becomes optimal to do so.

3.1 Real Options Valuation

Real options valuation originated from research performed to price financial option contracts in the field of financial derivatives. The underlying premise of its suitability and applicability to software engineering is based on the recognition that strategic flexibility in software acquisitions decisions can be valued as a portfolio of options or choices in real "assets," akin to options on financial securities that have real economic value under uncertainty (Dixit & Pindyck, 1995). In contrast to financial options, real options valuation centers on real or non-financial assets and is valuable because it enables the option holder (i.e., software program manager) to take advantage of potential upside benefits while controlling and hedging risks. When extended to a real "asset," such as software, real options could be used as a decision-making tool in a dynamic and uncertain environment. An option gives its holder the *rights but without the obligations*, to acquire or dispose of a risky asset at a set *price* within a specified time period (Erdogmus, 1999). If the market conditions are favorable before the option expires, the holder exercises this right, thus making a profit—otherwise, the holder lets the option expire.

A necessary and key tenet of the real options approach is a requirement for the presence of uncertainties, a constraint that is widely characteristic of software acquisitions decision-making. Software acquisitions encapsulate the activities related to software procurement, development, implementation, and subsequent maintenance. The uncertainties that surround these activities are compounded by increasingly complex requirements demanded by the warfighter and present themselves in various forms: changing or incomplete requirements, insufficient knowledge of the problem domain, decisions related to the future growth, technology maturation, and evolution of the software.

To tackle the issue, we developed a formal and distinct uncertainty elicitation task as part of the software investment decision-making process (Figure 1) to obtain information on the relevant uncertainties from a strategic point of view. While this task would not include members of a typical requirements team, they would work in tandem with the requirements team to identify and document uncertainties as they are revealed from an independent point of view. Implementing an explicit uncertainty elicitation task would facilitate the identification of uncertainties very early in the acquisition process, so that the necessary steps could be taken to either refine the requirements to address the uncertainties or identify strategic options to mitigate the risks posed by the uncertainties.

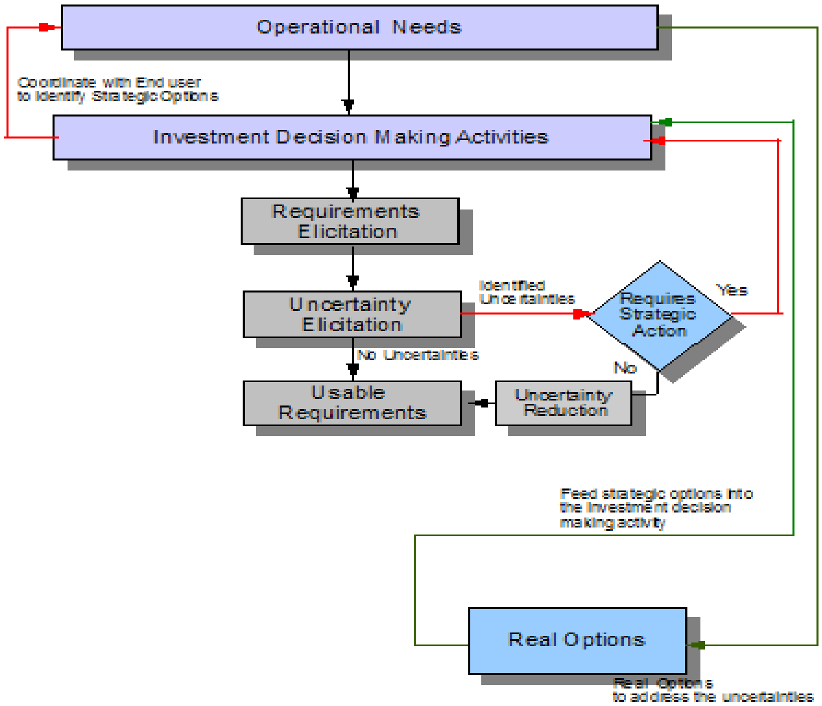

Figure 1. Uncertainty Elicitation Model

In the uncertainty elicitation step in the model, uncertainties are captured from two perspectives (the managerial and technical perspective) using what we call the "2 **T**" approach as illustrated in Figure 2. Managerial uncertainties of people, time, functionality, budget, and resources contribute to both estimation and schedule uncertainties that are considered to be pragmatic uncertainties. Technical uncertainties of incomplete requirements, ambitious, ambiguous, changing or unstable requirements contribute to software specification uncertainties. Such uncertainties lead to software design and implementation, software validation and software evolution uncertainties all of which can be categorized as exhibiting both Heisenberg-type and Gödel-like uncertainties.

If uncertainty cannot be resolved, strategic real options could be developed to address the risks posed by the uncertainty, providing management the flexibility to address the risks posed by the uncertainties when they become revealed at a later date during the acquisition effort.

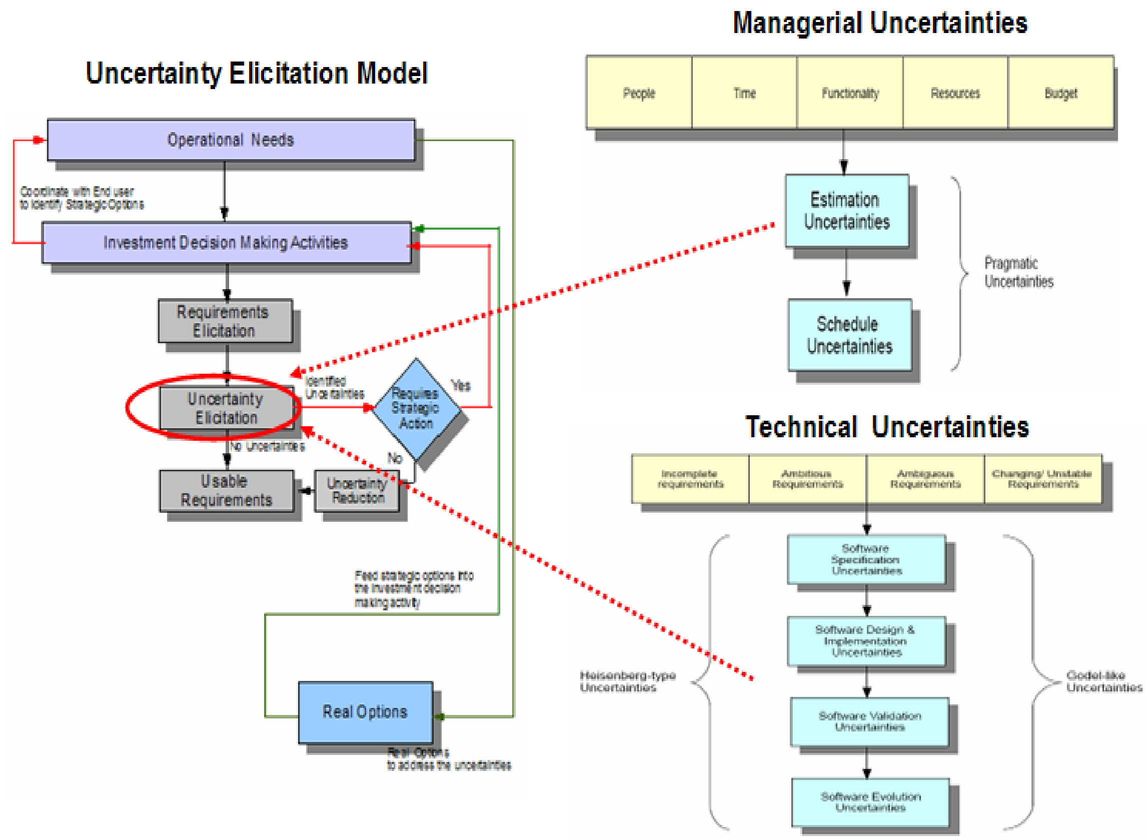

Figure 2. Expanded View of Uncertainty Elicitation Model

3.2 The Real Options Framework

To develop the appropriate options to hedge against the risks due to the uncertainties surrounding a software acquisition effort, we develop a generalized Real Options Framework (Figure 3) in line with the five preconditions outlined in Mun (2006). This proposed framework consists of the following four phases, each of which explicitly addresses and establishes compliance with the preconditions.

1. Study Phase
2. Data Collection and Preparation Phase
3. Analysis Phase
4. Execution Phase

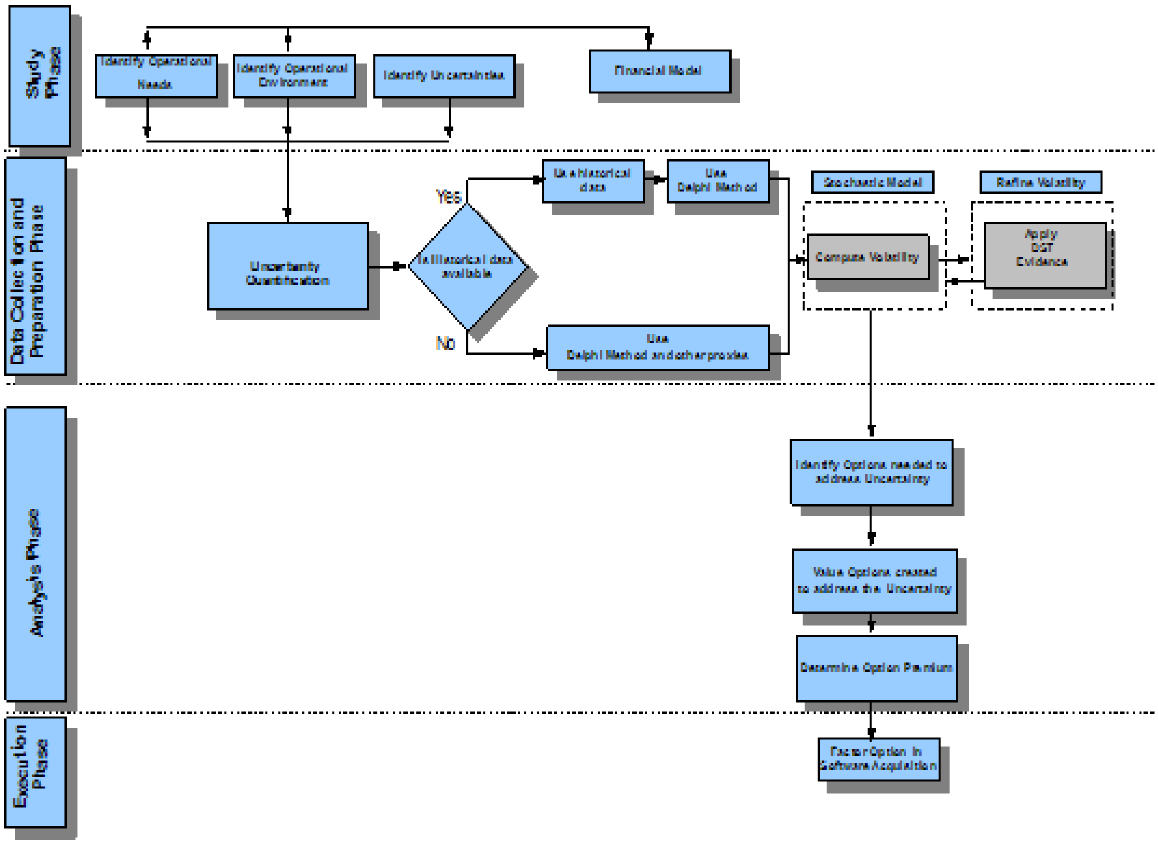

Figure 3. Real Options Framework

4. Addressing Uncertainty

Uncertainties permeate virtually every phase of the software acquisition process—ranging from procurement decision-making, requirements specification, software development and implementation, to the eventual evolution of the software. These uncertainties could be broadly categorized into the categories shown in Figure 4.

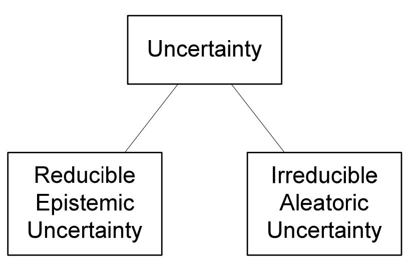

Figure 4. Taxonomy of Uncertainty

Epistemic uncertainties are reducible, and they deal with our lack of knowledge, lack of information and our own and others' subjectivity concerning an issue. Aleatoric uncertainties, on the other hand, are irreducible and they deal with the randomness (or predictability) of an event due to variability of input or model parameters when the characterization of the variability is available (Wojtkiewicz, Eldred, Field, Urbina, & Red-Horse, 2001). In other words, an aleatoric uncertainty is an inherent variation associated with the physical system or the environment. Both epistemic and aleotoric uncertainties are interwoven and form the general framework of uncertainties that plague software acquisition efforts from a requirements uncertainty perspective.

Since requirements uncertainty implies risk, consequently, uncertainty must be duly quantified as a risk factor to gauge the magnitude of its impact on the underlying asset. The process of translating or equating software engineering uncertainties into a quantifiable property begins with quantifying the identified requirements uncertainties, computing the impact of uncertainties and ultimately developing a risk analysis framework in which the associated risks are identified, predicted and modeled using simulation and the results analyzed and costs factored into the software acquisition as appropriate.

4.1 Estimating Requirements Volatility

While volatility is just one of the parameters needed for Real Options analysis, it is the most difficult of all the parameters to estimate. Given the impact that requirements instability has on costs, we attempt to determine the rate of requirement change or the volatility of requirements. We will then use volatility to quantify the risk of requirements changes in the proposed software acquisition effort.

In order to estimate the volatility of the returns associated with our current software investment effort, we attempt to gather evidence to help derive our estimates. Historically, gathering of evidence using previously completed software-related capital investments as a proxy is a difficult task for the following reasons:

1. The current software investment effort under consideration might be the first of its kind with no known comparables.
2. Information is rarely or actively collected and managed in a disciplined fashion.
3. Even when information is collected, accessibility by third parties is usually difficult due to the proprietary nature of the information.

Thus, more often than not, the software executive is faced with identifying alternate sources of information to either assert or dispute their initial volatility estimates. In our study, we propose to use either historical data (i.e., objective approach) or expert opinions obtained using the Delphi method (i.e., subjective approach). We choose to use both methods because we believe intuition and judgment (subjective approach) should supplement quantitative analysis (objective approach). More often than not, past success and failures serve as key indicators of the future. Historical data can be used to predict and explore “what-if” scenarios on future projects based on the use of forecasting and analytical analysis.

The Delphi Method is a technique first introduced by the RAND Corporation in the 1940’s as a methodology for the elicitation of the opinion of an expert or groups of experts to guide decision-making by the making predictions about future events. It places emphasis on an iterative, systematic, disciplined and interactive process of individual interviews (usually conducted using questionnaires) and the outcome is based on the Hegelian Principle of achieving consensus through a three-step process of thesis, antithesis, and synthesis (Stuter, 1996). In the thesis and antithesis steps, the team of experts present their opinion or views on the given subject, establishing views and opposing views, and consensus is ultimately reached during the synthesis phase as opposing views are brought together to form the new thesis.

Widely used as an estimating tool, the Delphi Method has been used to estimate values for factors (e.g., cost estimation) that appear in software estimation models such (Boehm, Abts, & Chulani, 2000) and risk estimation. Furthermore, it is one of the approved techniques published in February 2001 by the US Army Cost and Economic Analysis Center for preparing or reviewing economic analyses in support of the decision-making process.

In the event that there is no historical data available, the customer should resort to obtaining the required information using the Delphi Method. In the case that we do have historical data but are unable to find projects meeting any or all of the criteria above, we proceed to “fit” the data to as close as possible to mimic our current software investment effort by employing interpolation techniques to understand and forecast our project based on the trends depicted in the historical data.

To determine the rate of volatility, we employ the Caper Jones’ approach, which is a transposition from the financial industry (Kulk & Verhoef, 2008). Jones asserts that existing methods of average percentage of change of the overall requirements volume lacks information because it does not give any information on the time in which the change occurred—a key factor in determining software engineering since requirements changes become more expensive to implement the farther we are into the software development process.

Jones therefore uses the compound monthly requirements volatility rate to express the time aspect. Calculating monthly requirements volatility rates, as defined by Jones, is a transposition from the financial world. The time value or future value of money is well-known in the field of accounting as compound interest or CAGR, short for compound annual growth rate. By transposing from compound growth rate in finance, we assume that requirements are compounded within a project (Kulk & Verhoef, 2008). The basic financial equation is given as follows:

$$r = \left(\sqrt[t]{\frac{SizeAtEnd}{SizeAtStart}} - 1 \right) \times 100 \tag{1}$$

which translates to

$$r = \left(\sqrt[t]{\frac{SLOCAtEnd}{SLOCAtStart}} - 1 \right) \times 100 \tag{2}$$

where t is the time period in years during which the estimates were observed.

However, SLOC is not a suitable proxy for measuring requirements volatility because it is often dependent on the type of programming language being used and does not take COTS into consideration. In light of this finding, we proposed an alternative proxy: Function Points, which is a better metric for the size of the software requirements irrespective of how the software will be developed.

$$r = \left(\sqrt[t]{\frac{FuncPointAtEnd}{FuncPointAtStart}} - 1 \right) \times 100 \quad (3)$$

4.2 Refining Volatility Estimates

Volatility refinement based on the Dempster-Shafer Theory on Evidence was a key aspect of the framework proposed in Olagbemiro (2008). Since volatility is a key input parameter needed for Real Options analysis, we attempt to overcome the complexity of volatility estimation by proposing the use of Dempster-Shafer Theory on Evidence, a technique first proposed for application in the domain of *sensor fusion.* It is a mathematical theory of evidence based on *belief functions* and *plausible reasoning*, which is used to combine separate pieces of information (evidence) to calculate the probability of an event. We posit that it could be used to address both aleotoric and epistemic uncertainties inherent in software-related capital investments by "*fusing*" and reducing uncertainties to the maximum extent as they become revealed, thereby facilitating a more accurate estimate of the risks propagated by uncertainty and allowing us to develop the appropriate option in response based on a more accurate volatility measure.

We choose to use DST because while Bayesian inference requires all unknowns to be represented by probability distributions, which awkwardly implies the probability of an event for which we are completely ignorant, DST takes over by introducing belief functions to distinguish ignorance and randomness by assigning probability mass to subsets of parameter space, so that randomness is represented by the probability distribution and uncertainty is represented by large subsets (Gelman, 2006). In other words, while Bayesian theory requires probabilities for each uncertainty of interest, the theory of belief functions provides a non-Bayesian way of using mathematical probability to quantify subjective judgments (Shafer, 1996). It measures degrees of belief (or confidence) for one uncertainty on the probabilities for a related uncertainty.

The premise behind DST is it can be interpreted as a generalization of probability theory where probabilities are assigned to sets as opposed to mutually exclusive singletons. In the case that there is sufficient evidence to permit the assignment of probabilities to single events, the Dempster-Shafer model collapses to the traditional probabilistic formulation in which evidence is associated with only one possible event (Sentz & Ferson, 2002). DST relies on three basic functions: the basic probability assignment function, a primitive of evidence theory that does not refer to probability in the classical sense, and two non-additive continuous measures called *Belief* and *Plausibility* that are used to combine separate pieces of information (evidence) to calculate the probability of an event, while simultaneously defining the upper and lower bounds, respectively, of an interval that contains the precise probability of a set of interest.

Since evidence can be associated with multiple possible events (i.e., sets of events) the evidence in DST can be meaningful at a higher level of abstraction—a key benefit needed at the strategic decision-making level that eliminates resorting to assumptions about the events within the evidential set. Furthermore, the DST model can be used to cope with varying levels of precision regarding information with no further assumptions needed to represent the information, as demonstrated during a study in addressing uncertainties in systems (Sentz & Ferson, 2002). We posit that the demonstrated approach also allows for the direct representation of uncertainties associated with software-related capital investments since we can characterize vague inputs as sets or intervals with the resulting output being a set or an interval.

DST is a theory about two things: 1) Degrees of belief and 2) Weights of evidence. A key benefit of DST is the ability to represent ignorance in the face of uncertainty, especially when there is no information so far. In probability theory, uniform distributions are used to represent ignorance; however, the problem with this approach is that we represent the space of possibilities affected by the probabilities we get. The theory of belief functions is based on two ideas:

1. The idea of obtaining degrees of belief for one question from subjective probabilities of a related question, and
2. Dumpster's rule for combining such degrees of belief when they are based on independent items of evidence. Degrees of belief obtained in this way differ from probabilities in that they may fail to add to 100%.

Both ideas are consistent with the Real Options pre-conditions as the degrees of belief are established on a frame of discernment meant to address uncertainty. DST assumes a Universe of Discourse Θ, otherwise known as the Frame of Discernment, which is a set of mutually exclusive alternatives. Thus a frame of discernment A of a set of mutually exclusive alternatives or possibilities can be represented as

$$\Theta = \{A_1 \ldots\ldots\ldots A_n\} \quad (4)$$

where A_1 through A_n represents the set of possibilities or mutually exclusive alternatives.

A key stipulation of DST is that it should only be used to combine belief functions that represent independent items of evidence. The independence required is simply probabilistic independence applied to the questions for which we have probabilities, rather than directly to the question of interest. In other words, it means that the sources of information (or at least their current properties as sources of information) are selected independently from well-defined populations.

Combining information or evidence from multiple sources (historical data and Delphi method) in the form of belief assignments aggregates the information with respect to its constituent parts. Dempster proposed a standard combination rule that can be represented as:

$$m_{12}(A) = \sum_{B \cap C = A} \frac{m_1(B) m_2(C)}{1-K} \text{ when } A \neq \emptyset \quad (5)$$

where $K = \sum_{B \cap C = \emptyset} m1(B) m2(C)$

This rule is computed by summing the products of the belief probability assignments (bpa's) of all sets where the intersection is null, and represents basic probability mass associated with conflict. In addition, $m_{12}(A)$ is calculated from the aggregation of two bpa's m_1 and m_2.

Assuming we have two pieces of evidence, based on historical data and expert judgment (Delphi Method), we combine the pieces of evidence using the Dempster's combination rules by computing the orthogonal sum of both. First, we determine the pairs of sets whose intersection is A for a given set A such that $A_1 \cap A_2 = A$. We then add the products of the basic probability assignments $m_1(A_1)$ and $m_2(A_2)$, giving us

$$\sum_{A_1 \cap A_2 = A} m_1(A_1) m_2(A_2) \tag{6}$$

The orthogonal sum of m_1 and m_2 defined by $m = m_1 \oplus m_2$ could then be given as $m(\varnothing) = 0$ and is demonstrated in the matrix below (Table 2), in which we compute the orthogonal sum of three hypothetical risk factors (Risk1, Risk2 and Risk) affecting a software investment program based on two independent expert assessments.

			Independent Expert 1 Subjective estimates on Objective probabilities		
	Risk Factors		{Risk1} m1= 0.80	{Risk1,Risk2} m1= 0.15	{Risk1,Risk2,Risk3} m1 = 0.05
Independent Expert 2 Subjective estimates on 3 Objective probabilities	{Risk1}	m2 =0.70	m1({Risk1})*m2({Risk1})	m1({Risk1,Risk2})*m2({Risk1})	m1({Risk1,Risk2,Risk3})*m2({Risk1})
	{Risk1,Risk 2}	m2 =0.20	m1({Risk1})*m2({Risk1,Risk2})	m1({Risk1,Risk2})*m2({Risk1,Risk2})	m1({Risk1,Risk2,Risk3})*m2({Risk1,Risk2)
	{Risk1,Risk2,Risk3}	m2 =0.10	m1({Risk1})*m2({Risk1,Risk2,Risk3})	m1({Risk1,Risk2})*m2({Risk1,Risk2,Risk3})	m1({Risk1,Risk2,Risk3})*m2({Risk1,Risk2,Risk3})

Table 2. Orthogonal Sum of Basic Probability Assignments

Based on the sample matrix (Table 2), we can obtain the resulting three evidence functions.

$m_1 \oplus m_2$({Risk1})

= m_1({Risk1})*m_2({Risk1)} + m_1({Risk1,Risk2})*m_2({Risk1})

+ m_1({Risk1,Risk2,Risk3})*m_2({Risk1}) + m_1({Risk1})*m_2({Risk1, Risk2}) + m_1({Risk1})*m_2({Risk1, Risk2, Risk3})

$m_1 \oplus m_2$({Risk1,Risk2})

= m_1({Risk1,Risk2})*m_2({Risk1,Risk2})
+ m_1({Risk1, Risk2})*m_2({Risk1, Risk2, Risk3})
+ m_1({Risk1, Risk2, Risk 3})*m_2({Risk1, Risk2})

$m_1 \oplus m_2$({Risk1,Risk2,Risk3})

= m_1({Risk1,Risk2,Risk3})*m_2({Risk1,Risk2,Risk3})

Using on the information derived from the matrix, we can establish joint beliefs. Any variations between inferred probability assignments based on the mass of evidence under this joint belief and our initial volatility estimates based on our modified Caper Jones' equation (Eqn. 3) would reflect inconsistencies. These variations are captured and used to refine the initial probability estimates to reflect the new "findings" that are then modeled using a Monte Carlo simulation to derive new estimates for the requirements volatility and an overall volatility for the software acquisition effort.

5. Applying the Real Options Valuation Framework

In an attempt to validate our proposed approach, we applied the framework to the software component FCSN (Future Combat Systems Network) of US Army Future Combat System (FCS). The decision to select this case study as a validation mechanism was based on the recent nature of the project, the high-risks associated with software development due to the advanced technologies involved, the challenge of networking the FCS subsystems so that FCS-equipped units can function as intended, and the associated outcome had a Real Options approach been applied. This section summarizes our study. Readers can refer to Olagbemiro (2008) for the details of the study.

5.1 Development of a Business Case

We used a traditional discounted cash flow model to obtain a net present value (NPV) in terms of five high-level determinants (Erdogmus & Vandergraaf, 1999):

$$NPV = \sum \frac{(C_t - M_t)}{(1+r)^t} - I$$

where ***I*** is the (initial) *development cost of the FCSN*
t is the (initial) *development time* or time to deploy the FCSN.
C is the *asset value of the FCSN* over time *t*
M is the *operation cost* of the FCSN over time *t*
r is the rate at which all future cash flows are to be discounted (the *discount rate*).

A NPV of $6.4 trillion[3] was computed for the FCSN using estimated values based on key assumptions in Olagbemiro (2008).

5.2 Identification of Uncertainties and Risk Quantification

Using publicly available information (GAO, 2008), we determined that requirements uncertainty fostered by technology maturation issues plagued the FCSN program and resulted in the following uncertainties:

1. Requirements uncertainties
2. Integration uncertainties
3. Performance uncertainties
4. Estimation uncertainties (size and cost of the software)
5. Scheduling uncertainties.

In response, we developed Real Options to mitigate the risk due to requirements change. Due to the lack of publicly available historical data for the FCSN program, data from the Joint Strike Fighter program was fitted and utilized as a source of historical information for comparative purposes. The risk of requirements changes in the FCSN program was estimated

[3] NPV of $6.4 trillion is computed based on (1) Value of the FCSN program, (future value less operating costs, i.e., sum of (C – M), = $10 trillion), (2) Initial development cost I = $163.7 billion, (3) r = 3%, and (4) Time t to develop the FCSN = 13 years.

to be 12% (as oppose to 0.28% for the JSF program, which is 1/5 the size of the FCSN program) using Equation 1.[4]

We used requirements volatility to quantify the risk effect as variations in the returns associated with the investment. We ran Monte Carlo simulation of the risk model using the Risk Simulator software, taking into account interdependencies between the risk variables to emulate all potential combinations and permutations of outcomes. The analysis indicated that requirements volatility introduced an overall volatility of 0.0866% in the FCSN program. The volatility of 0.0866% resulted in a reduction in the NPV of the FCSN program from $6.4 trillion to $6.1 trillion. This reduction in NPV is a result of the potential increased costs in light of the risks facing the FCSN program, which ultimately reduces the value of the investment effort from a financial point of view.

To improve the accuracy of the volatility estimates, we chose to refine the volatility using the DST. This is accomplished by establishing "belief functions" that reflect the "degrees of belief" between our NPV estimates in light of the risks posed by requirements uncertainty and the FCSN cost estimates provided by two independent sources: the Cost Analysis Improvement Group (CAIG) and the Institute of Defense Analysis (IDA). The independent belief functions based on the CAIG and IDA, which inferred basic probability assignments associated with each of the FCSN risk factors (i.e., requirements, integration, estimation risk, etc) were combined using an orthogonal matrix to determine the most probable beliefs for the set of risk factors. Where the combined functions reflected "belief" in our estimates, the latter were considered valid and were left untouched. When the combined belief functions reflected conflict with our estimates, our estimates were revised accordingly. We ran the Monte Carlo simulation of the model with the revised risk estimates again. Based on the risk of requirements uncertainty presented in the FCSN, a resulting "refined" volatility of 0.0947% was obtained. The derived volatility, which reflects an increase from the initial volatility estimate of 0.0866%, results in a further reduction of NPV of the FCSN program from $6.1 trillion to $5.7 trillion. Details of the computation can be found in Olagbemiro (2008).

5.3 Options Development

The FCS software effort has been decomposed into six components: Combat Identification, Battle Command and Mission Execution, Network Management System, Small Unmanned Ground Vehicle, Training Common Component, and Systems-of-Systems Common Operating Environment. We consider a hypothetical scenario in which we assume that of the six component systems, the Systems-of-Systems Common Operating Environment is not facing uncertainty while the other five software components are facing uncertainty. We proceeded and developed two options to address this scenario: (1) Compound Option and (2) Deferment Option.

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[4] The requirements volatility of 12% was computed based on start and ending SLOC for the FCSN program. SLOC is used for demonstration purposes only. A more suitable metric, such as function points, is recommended.

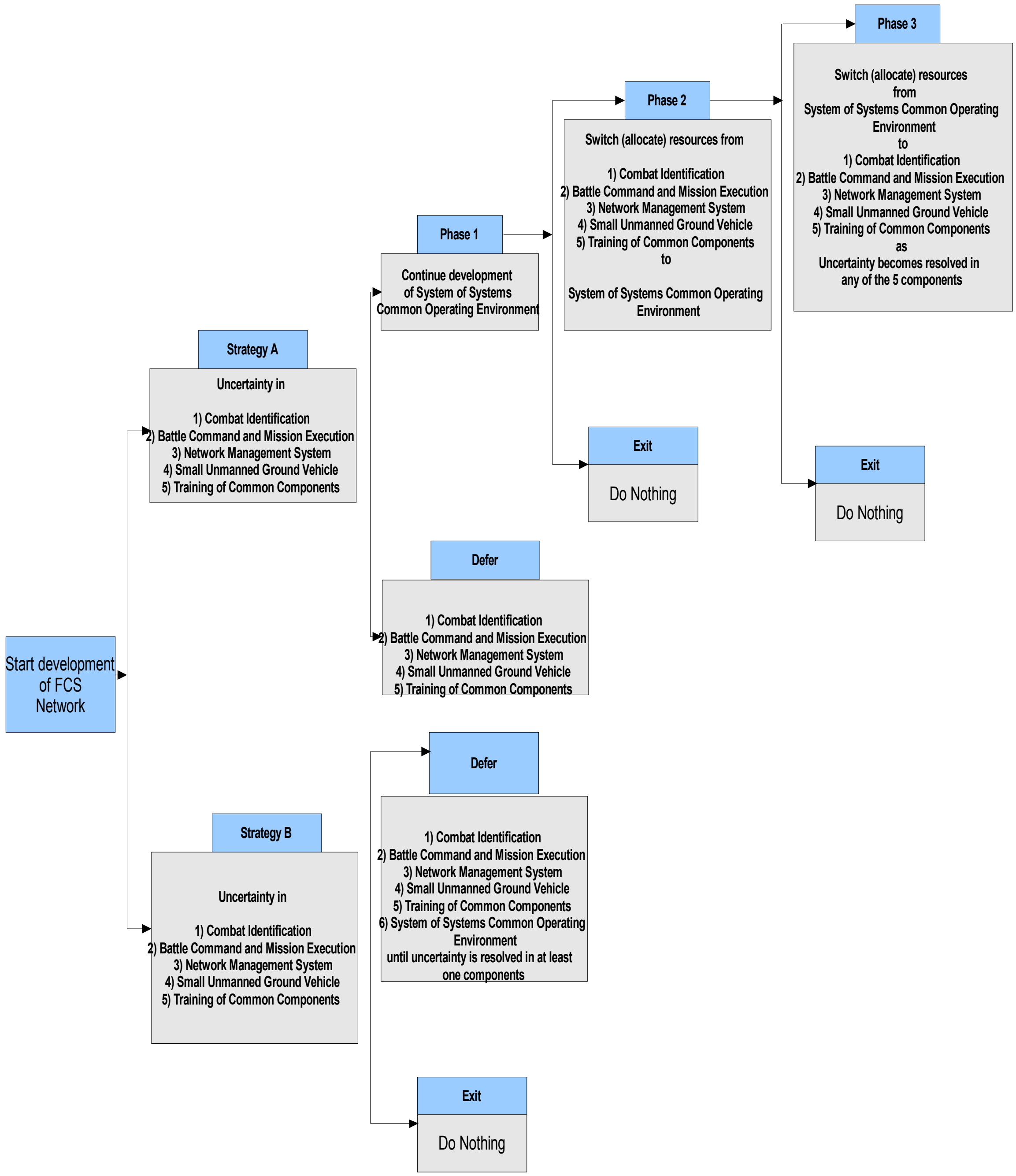

Figure 5. FCS Strategy Tree Depicting Strategy A and B for Given Scenario

(1) Strategy A—The Compound Option

In the event that at least one of the software components is not facing requirements uncertainty, with all the others facing requirements uncertainty, an option could be developed to scale down the resources/staff allocated to the software components facing requirements uncertainty. The staff could then be switched to work on the software component that is not facing requirements uncertainty, while the uncertainties in the other components are addressed using our uncertainty elicitation model.[5] We, therefore, frame the real options in this case as an *Option to Contract and Scale Down* from an uncertain system, *Option to Switch* resources to another system, *Optios to Expand and Scale Up* staff assigned to the development of a system not facing uncertainty (shown as Strategy A in Figure 5). Essentially, this is a compound option—an option whose "exercise" is contingent on the execution of the preceding option.

(2) Strategy B—The Deferment Option

In the event that five out of the six software components are facing requirements uncertainty, then an option could be developed to stop and defer all development to include the development of the software component that is not facing requirements uncertainty for a specified period until uncertainty is resolved (shown as Strategy B in Figure 5). This is an *Option to Wait and Defer*.

5.4. Options Valuation

We utilize the Real Options Super Lattice Solver (SLS) 3.0 software developed by Real Options Valuation, Inc., for the task.

(1) Strategy A

The Real Options SLS software was populated based on the following underlying values:

(1) Development/Implementation cost of FCSN is $163.7 billion,

(2) Value of underlying asset is $6.4 trillion,

(3) The risk-free rate is 3.0%,

(4) Volatility of the project is 0.0947,

(5) Duration of software development is 13 years, and

(6) Lattice steps was set to 300.

The value of the underlying asset was computed as $6.4 trillion, and the option analysis of the value of the option under Strategy A returned a value of $6.27 trillion.

(2) Strategy B

In Strategy B, which calls for a "defer and wait approach," an assumption is made that the duration for deferment option would be three years. We set up our model using the same assumptions used in strategy A, but we set the duration of the Deferment Option to three years. The value of the underlying asset was computed as $6.4 trillion, and the option analysis returned a value of $6.25 trillion.

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[5] Note: The assumption with this approach is that the software component development effort, which the staff engineers are being reallocated to work on, is not behind schedule and, therefore, does not violate Brooks Law.

5.5. Investment Valuation

Given the option value of $6.27 trillion under Strategy A, the intrinsic value of the compound option is determined to be $6.4 trillion—$6.27 trillion = $130 billion. Under Strategy B, the intrinsic value of the deferment option is determined to be $6.4 trillion—$6.25 trillion = $150 billion. This implies that under both Strategies A and B, the software executive should be willing to pay no more than (and hopefully less than) the option premium of $130 billion and $150 billion, respectively, in addition to the initial investment cost of $163.7 billion to increase the chances of receiving the initially projected NPV of $6.4 trillion for the FCSN as opposed to the current $5.7 trillion in light of the risks caused by the uncertainties in five of the six software components. This premium would also include the administrative costs associated with exercising an option from an integrated logistics support point of view (i.e., costs associated with contractual agreements, software development retooling costs, and costs associated with infrastructure setup of the infrastructure).

In analyzing both strategies, Strategy A is more attractive than Strategy B. Instead of waiting another three years at an additional potential cost of $150 billion (after which uncertainty would hopefully have been resolved) and then proceeding to spend $163.7 billion at once to develop all six software components, the staged-phase approach in Strategy A calls for spending up to $130 billion for the option up front plus some of the $163.7 billion for the Systems-of-Systems Common Operating Environment component, and then investing more over time as the requirements are firmed up for the other five components. Therefore, under these conditions, Strategy A—which employs the compound sequential options—is the optimal approach.

6. Conclusion

Uncertainties associated with software-related capital investments lead to unnecessary and sometimes preventable risks. As the DoD often sets optimistic requirements for weapons programs that require new and unproven technologies, the application of the real options valuation methodology would be beneficial to enable the DoD to incorporate the appropriate *strategic options* into the acquisition contracts. The options would serve as a contract between the software executive and the contractor—in the case of a government acquisition—to buy or sell a specific capability known as the options on the underlying project. The proposed real options valuation approach is able to overcome the limitations of traditional valuation techniques by utilizing the best features of traditional approaches and extending their capabilities under the auspices of managerial flexibility. The explicit uncertainty elicitation task, the development of options to hedge against the risk, and the timely execution of the options as they appear will allow decision-makers to better balance customer requirements as dictated by operational needs within financial viability and schedule constraints and manage risks proactively.

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Modeling Open Architecture and Evolutionary Acquisition: Implementation Lessons from the ARCI Program for the Rapid Capability Insertion Process

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Abstract

Providing system interoperability and evolving technologies in major DoD systems are two important acquisition challenges in preparing the military to meet current and future demands. The Acoustic Rapid COTS Insertion (ARCI) program successfully addressed many of the associated challenges. That program was studied as the basis for modeling the planned Rapid Capability Insertion Process (RCIP) approach for continuous, reduced-cost upgrading of assets. ARCI used atypical methods in the face of atypical program requirements and conditions. A previously developed acquisition program model was adapted to reflect ARCI and used for model validation. This model was then changed to reflect the basic conditions expected to be faced by RCIP programs. The model demonstrated the potential of RCIP to significantly improve program performance. However, implementation risks are identified that may degrade potential performance, including increased oversight, the use of more new development, and the resulting integration scope and risk. When incorporated into the model, these risks were shown to significantly decrease RCIP performance. Means for successfully managing the RCIP design based on the ACRI program and RCIP operations are suggested for use in addressing the identified implementation risks

Introduction

Providing system interoperability and evolving technologies in major DoD systems are two important acquisition challenges in preparing the military to meet current and future demands. The use of legacy and other weapons platforms, joint Service solutions, the information and communication needs of Network Centric Systems (NCS), and coordination with allies in joint operations require the development of weapons systems that can operate across system, platform, and systems-of-systems boundaries. Traditional DoD acquisition approaches do not fully provide the interoperability and development speed needed to meet these demands. The continued, and in some cases accelerating, evolution of technologies continuously creates new challenges that are difficult to forecast and require fast acquisition response. Threat matrices also evolve, changing the capabilities required to meet them. Short capability improvement cycle-times are needed to respond to these moving targets for acquisition efforts. The development of an Integrated Weapons System (IWS) for surface ships is an example of a major acquisition effort to provide system (and platform) interoperability and exploit technology evolution to meet changing threats. The current work focuses on acquisition approaches to meet these challenges.

Naval Open Architecture (OA) (DAU, 2009) is a breakthrough acquisition approach that develops and facilitates the use of acquisition processes, which integrate interoperable systems that evolve with technologies, threats, and program environments (e.g., funding). OA does this through five principles: 1) modular design and design disclosure, 2) reusable application software, 3) interoperable joint warfighting applications and secure information exchange, 4) lifecycle affordability, and 5) encouraging competition and collaboration through the development of alternative solutions and sources. Evolutionary Acquisition (EA) (DAU, 2009) is a somewhat recently developed acquisition approach that uses the repeated integration of only mature-enough technologies into products to speed capability improvement for warfighters. OA and EA can act synergistically to meet their objectives. However, effective implementation is critical for success. Particularly in large, complex systems that span platforms, the successful implementation of OA and EA is not obvious or easy.

Despite their potential, OA and EA have not yet been fully developed or implemented in DoD acquisition. Previous research (Ford & Dillard, 2008; Dillard & Ford, 2007) suggests that the DoD can successfully integrate open systems and Evolutionary Acquisition. This supports the Navy’s current development of the Rapid Capability Insertion Process (RCIP) to implement Open Architecture and Evolutionary Acquisition (described later). The Navy’s Acoustic Rapid COTS (commercial off-the-shelf) Insertion program (ARCI) experience (described later) demonstrates that these approaches can be integrated and applied successfully. An improved understanding of how OA and EA have been used successfully and can be used in RCIP is needed to better apply them across systems and platforms and, thereby, improve acquisition programs.

The Research Approach

Evolutionary Acquisition and open systems approaches combine to create a complex set of development processes that evolve over time. An improved understanding of these processes and their management is available through formal modeling of the most important components and relationships that drive system performance and risk. Due to the number and complexity of the components and their relationships, the formal model structure and rigor of calculations can simulate and forecast performance and risk better than informal, tacit predictions by humans. Therefore, we applied a computational experimentation approach to investigating Evolutionary Acquisition and open systems projects, integrating theory and practice in a computational tool that allows controlled experimentation through simulation.

Previous research and modeling of Open Architecture and Evolutionary Acquisition is being used as the foundation of the current work. That model was first revised and improved to reflect the ARCI program to develop a basis for understanding success factors in OA and EA implementation. This required the development of a deep understanding of the relevant aspects of the ARCI acquisition program (summarized next). The ACRI model was then revised to reflect the Rapid Capability Insertion Process. Model analysis was used to better understand the requirements for success in RCIP.

The System Dynamics Modeling Methodology

The system dynamics methodology was applied to model the ARCI program. System dynamics is one of several established and successful approaches to systems analysis and design (Flood & Jackson, 1991; Lane & Jackson, 1995; Jackson, 2003). The methodology has been extensively used for this purpose, including to study several aspects of development projects. System dynamics shares many fundamental systems concepts with other systems approaches, including emergence, control, and layered structures. Therefore, system dynamics can address issues such as risk in large complex systems such as the DoD acquisition projects (Lane, Größler & Milling, 2004). The methodology's ability to model many diverse system components (e.g., work, people, money, information), processes (e.g., design, technology development, quality assurance, rework), and managerial decision-making and actions (e.g., forecasting, resource allocation) makes it useful for investigating acquisition programs. Forrester (1961) develops the methodology's philosophy, and Sterman (2000) specifies the modeling process with examples and describes numerous applications.

The system dynamics methodology applies a control theory perspective to the design and management of complex human systems. The perspective focuses on how the internal structure of a system impacts managerial behavior and performance over time. The system dynamics approach is unique in its integrated use of stocks and flows, causal feedback, and time delays to model structures and policies. Stocks represent accumulations or backlogs of work, people, information, or other portions of the system that change over time. Flows represent the movement of those commodities into, between, and out of stocks. For example, Figure 1 shows a simple stock and flow diagram of one possible arrangement of the backlogs and movements of work within a single activity (e.g., Advanced Development) of an acquisition program. Stocks are represented by boxes. Flows are represented by arrows between the boxes with the valve symbols. Arrowheads indicate the direction of movement of the work.

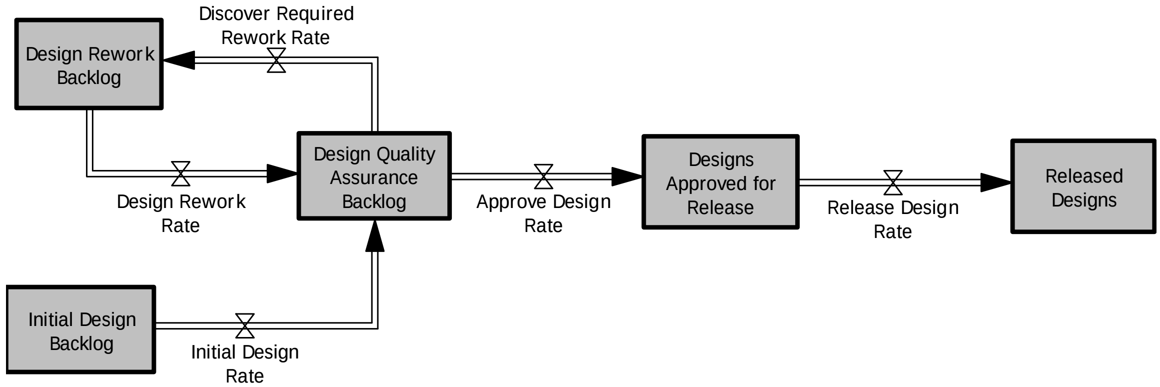
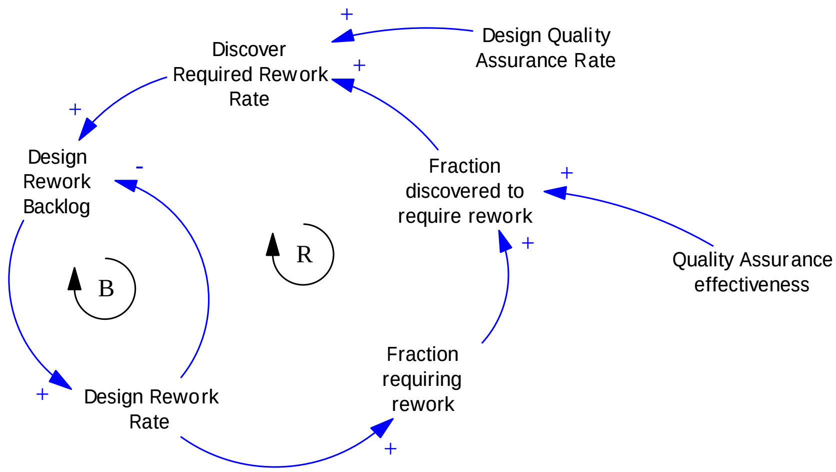


Figure 1. A Stock and Flow Diagram of Work Backlogs and Development Activities

Feedback is modeled conceptually in system dynamics with causal loop diagrams. Figure 2 shows a portion of a causal loop diagram for a single activity of an acquisition program. In causal loop diagrams, arrows indicate the direction of causal influence. The variable at the tail of an arrowhead influences the variable at the head of the arrow. A plus sign at an arrowhead indicates that the impacted variable and driving variable move in the same direction (i.e., an increase in the driving variable increases the impacted variable, and a decrease in the driving variable decreases the impacted variable). A negative sign at an arrowhead indicates that the impacted variable and driving variable move in opposite directions (i.e., an increase in the driving variable decreases the impacted variable, and a decrease in the driving variable increases the impacted variable). The two types of feedback loops are also illustrated in Figure 2. A balancing loop ("B" in Figure 2) tends to control or limit the movement of the variables in the loop. In contrast, a reinforcing loop ("R" in Figure 2) tends to move systems farther and farther from their initial conditions at faster and faster speeds. The behavior pattern generated by a specific feedback loop (e.g., exponential growth or movement toward a target) can be identified by sequentially tracing these impacts on variables through the series of causal links that describe the loop. See Sterman (2000) for a detailed description of the building and use of causal loop diagrams.



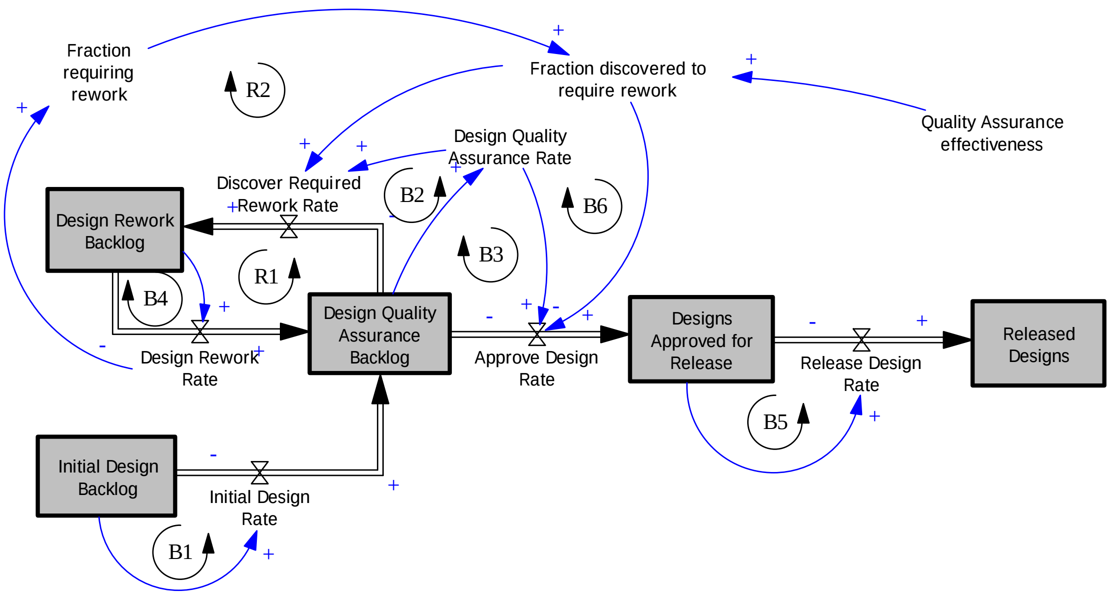
<u>Feedback Loop Legend</u>

B – Rework backlog increases rework rate, controlling the size of the backlog

R – Poor quality rework increases the work fraction requiring rework and rework backlog, further increasing the amount of work requiring rework

Figure 2. A Causal Loop Diagram of a Portion of an Advanced Development Phase

Stock and flow diagrams and causal loop diagrams can be integrated into system structure diagrams that simultaneously describe the feedback and accumulation/flow nature of the system being modeled. Figure 3 shows a system structure diagram of a model of an acquisition program phase. The diagram integrates the stock and flow diagram in Figure 1, the causal loop diagram in Figure 2, and some of the other important portions of the system. The feedback loop legend briefly describes how each feedback loop structure creates system behavior.



Feedback Loop Legend (partial)

B1 – An increase in the Initial Design Backlog increases the initial design rate, thereby controlling the backlog

B2 – An increase in the Quality Assurance (QA) Backlog increases the QA rate and discovery of rework, thereby controlling the backlog

B1 – An increase in the Quality Assurance (QA) Backlog increases the QA rate and design approval rate, thereby controlling the backlog

B4 – An increase in the Rework Backlog increases the rework rate, thereby controlling the backlog

B5 – An increase in the accumulation of approved designs increases the size of the design release, thereby controlling the Approved Design accumulation

B6 – An increase in the Quality Assurance (QA) Backlog increases the QA rate, discovery of rework, fraction discovered, and approval rate, thereby controlling the backlog

R1 – An increase in the Quality Assurance (QA) Backlog increases the QA rate, discovery of rework, Rework Backlog, and rework rate, thereby increasing the QA Backlog further

R2 – An increase in the rework rate increases the fraction requiring rework, fraction discovered, discovery rate, and Rework Backlog, thereby increasing the rework rate further.

Figure 3. A System Structure Diagram of a Portion of Advanced Development

The full power of system dynamics can be realized only through formal simulation of the system's evolution. Formal simulation models developed from conceptual models are sets of nonlinear differential equations simulated with difference equations. Because no closed-form solutions are known, system behaviors over time are simulated. The simulator uses initial or current conditions, calibration values of constant parameters, and the difference equations to calculate conditions in the nest time period. Although the methodology initially assumes that small changes over time can be used to describe systems (e.g., the continuous adjustment of resources toward demands for those resources); however, discrete changes (e.g., the release of a complete design) at specific dates (e.g., a scheduled upgrade date) can also be modeled.

When applied to development projects, system dynamics focuses on how performance evolves in response to interactions among development strategy (e.g., Evolutionary Acquisition versus traditional acquisition), managerial decision-making (e.g., the allocation of resources), and development processes (e.g., concurrence). System dynamics is considered appropriate for modeling acquisition programs because of its ability to explicitly model critical aspects of development projects (Ford & Sterman, 1998; Cooper, 1993a, September; 1993b, September; 1993c; Cooper & Mullen, 1993; Cooper, 1994). System dynamics has been successfully applied to a variety of project management issues, including prediction/discovery of failures in project fast-track implementation (Ford & Sterman, 2003b, September), poor schedule performance (Abdel-Hamid, 1988; Taylor & Ford, 2006; 2008), the impacts of changes (Rodriguez & Williams, 1998; Cooper, 1980), the planning of fast-track construction projects (Pena-Mora & Li, 2001; Pena-Mora & Park, 2001), construction innovation (Park, Napa & Dulaimi, 2004), change management (Lee, Pena-Mora & Park, 2005; 2006; Park & Pena-Mora, 2003), resource allocation (Lee et al., 2007), and concealing rework requirements on project performance (Ford & Sterman, 2003a, September). See Lyneis and Ford (2007) for a review and analysis of the application of system dynamics to projects.

The ARCI Program

Information on the ARCI program was collected as the basis for modeling the OA and EA aspects of its acquisition process. In particular, differences between ARCI and traditional acquisition with an evolutionary approach were investigated. Data was collected primarily through a review of Navy documents (Johnson, 2007; Chief of Naval Operations, 2009), contractor program documents (Lockheed Martin, 2003; 2009), defense analyst documents (Global Security, n.d.), previous research concerning the program (e.g., Beaudreau, 2006; Johnson, 2004), and an extended interview with Bill Johnson, who developed and managed the ARCI program (Johnson, 2009). The data collection focused on the acquisition (development) aspects of ARCI. A summary of the results of that data collection follow.

Although it occurred within the established DoD acquisition processes of its time, the ARCI program was atypical in several important ways. The description here focuses on the program's atypical nature, as it relates to the current work. See Beaudreau (2006) and Johnson (2004) for additional program descriptions. Three atypical aspects of the ARCI program in particular generated the need for and prompted the use of a new and different acquisition approach: 1) the urgent operational need, 2) tight constraints on funding, and 3) an environment of acquisition reform.

An Urgent Operational Need

In September of 1995, the Submarine Sonar Technology Panel reported a serious reduction in acoustic superiority. The reduced superiority resulted in reductions in the "stand off" distance between US submarines and other vessels (particularly other submarines), the distance at which US submarines recognize other vessels. The standoff distance is determined by the noise radiated from vessels and the capabilities of the recognizing ship through its sonar systems. Although the radiated noise of other vessels had progressively reduced (Figures 4 and 5), US sonar capabilities had not progressed in-step. Improved sonar systems could recapture the lost acoustic superiority. Importantly, the acoustic superiority loss had already occurred by 1995, and the need to regain it was considered urgent by the operating submarine fleet. *ARCI needed to develop solutions fast.* Figures 4 and 5 are examples of data used to support these findings and recommendations.

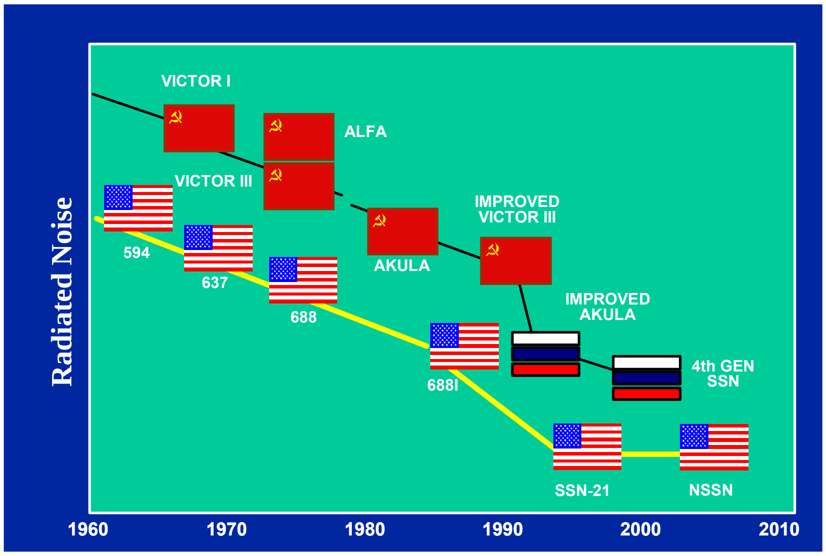


Figure 4. FSU (Former Soviet Union)/US Nuclear Stealth
(Johnson, 2007)

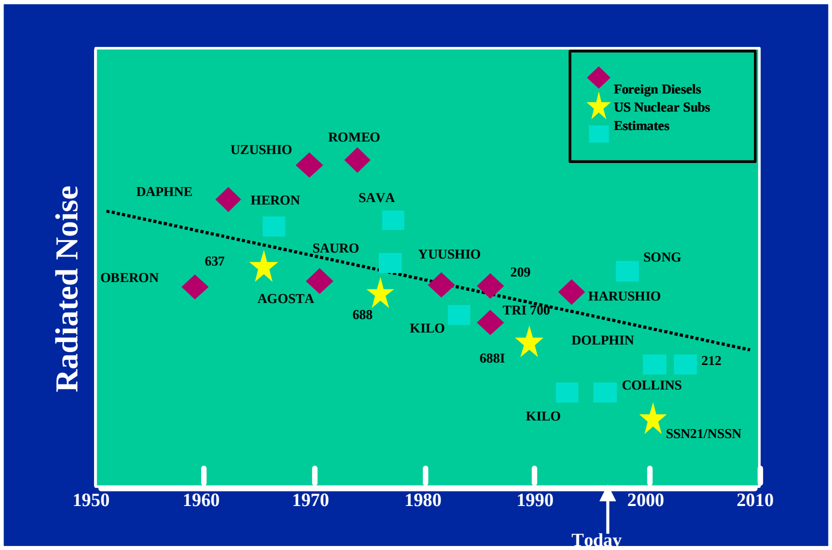


Figure 5. Diesel Rated Noise Trend
(Johnson, 2007)

Based on these findings, the Submarine Sonar Technology Panel recommended a radical transformation of the approach to designing and fielding sonar systems.

Tight Constraints on Funding

By 1995, the Cold War was over and funding for the DoD acquisition had reduced sharply, including Sonar Development and Combat Control Development funding (Figures 6 and 7).

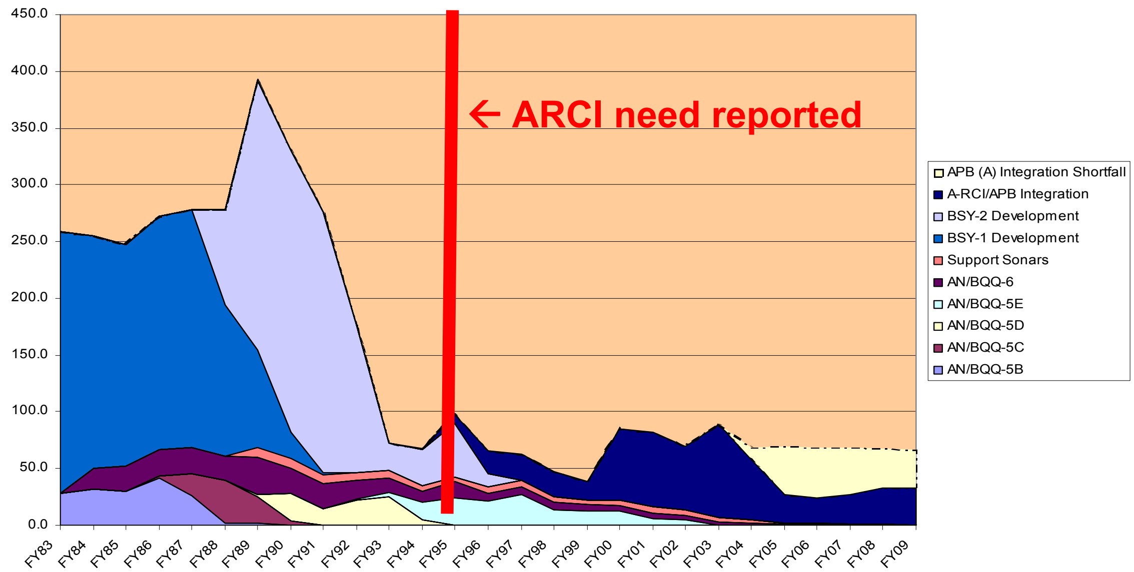


Figure 6. Sonar Development Funding
(Johnson, 2007)

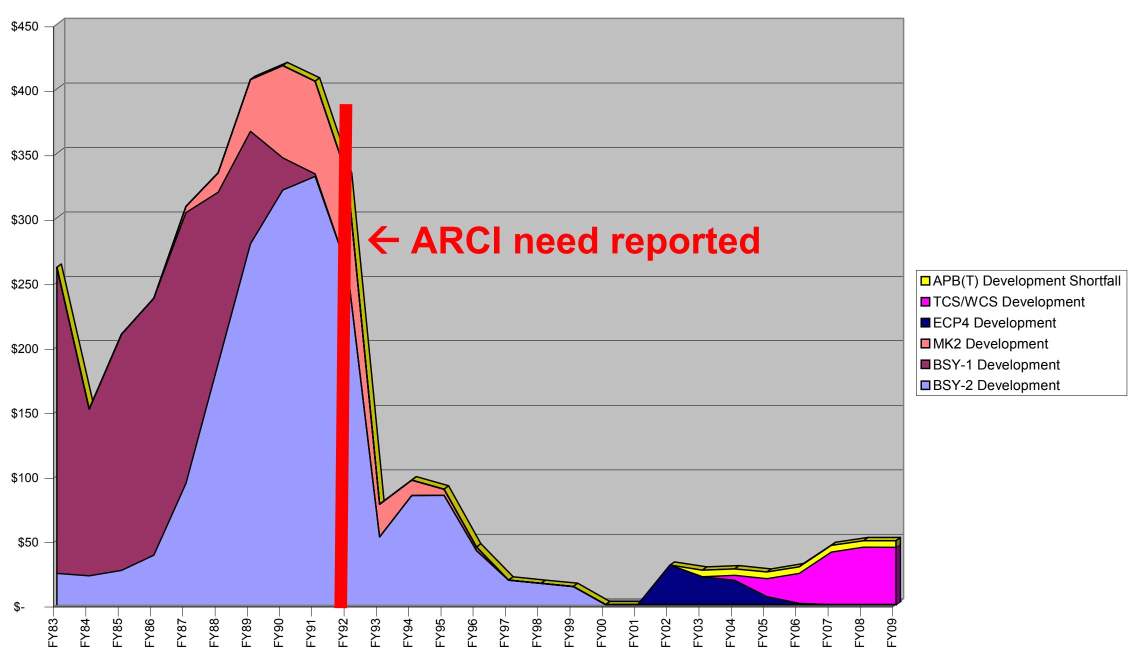


Figure 7. Combat Control Development Funding
(Johnson, 2007)

Traditional acquisition approaches, such as the development of unique systems for one or more sonar systems, were not available due to the large funding requirements of these approaches. ARCI had to develop solutions relatively inexpensively, at much less cost than required by the traditional DoD acquisition approaches.

An Environment of Acquisition Reform

Although not a characteristic of the ARCI program itself, the DoD acquisition processes were evolving faster than usual during the period in which ARCI began. This had potentially significant impacts on the program in terms of allowing it more than the usual amount of freedom to pursue and develop innovative acquisition perspectives, methods, and tools. These potential impacts are investigated later in the current work.

The ARCI Program Results

The ARCI program succeeded in significantly improving US submarine sonar systems quickly and at great savings. Figures 8 and 9 illustrate the demonstrated performance improvements.

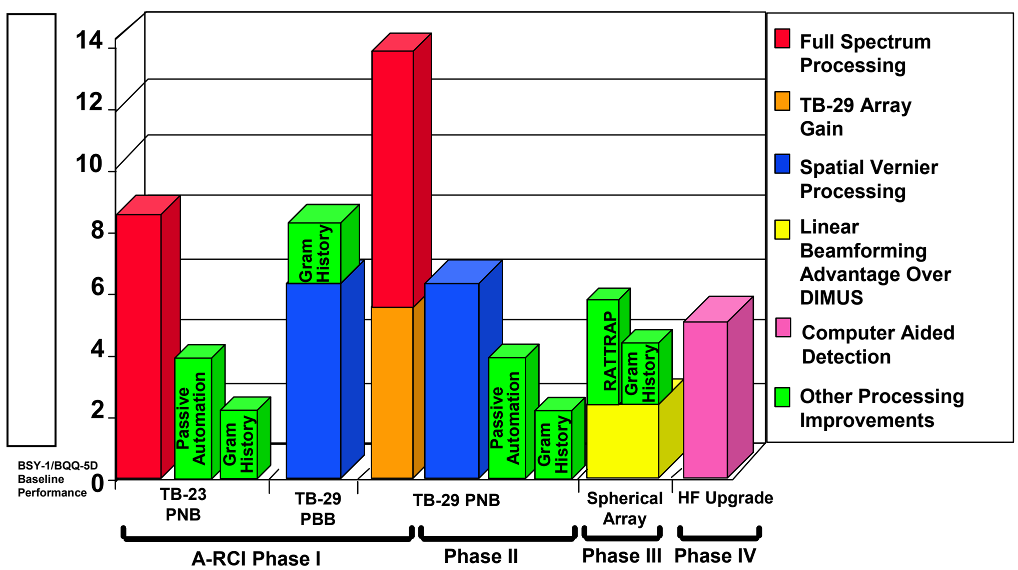


Figure 8. Demonstrated Performance Gains
(Johnson, 2007)

	AN/BQQ-5	A-RCI/APB-98	A-RCI/APB-00
Mean Operator Detection Success Rate	23%	49%	87%
	Improved by a Factor of ~ 4		
Mean # of False Alarms Per Run	1.0	0.92	0.58
	False Alarms Reduced by 40%		
Mean Initial Detection & Classification Time (When Detection Occurred)	Baseline	9 Min Earlier	27 Min Earlier
	Improved by 27 Minutes		
Mean Contact Holding Time* (When Detection Occurred)	Baseline	10 Min Longer	25 Min Longer
	Improved by 25 Minutes*		

* Measured holding time limited by the length of recorded tape.

Figure 9. Towed Array Processing Performance-improvement Trend
(Johnson, 2007)

ARCI performed quickly. Phase I improvements were installed on Agusta in December of 1997, and performance improvements delivered 18 months after the MDA decision. By the eighth anniversary of the ARCI MDA decision in June of 2004, ARCI had installed on over 50 submarines with at least four generations of hardware and software upgrades. These durations are much shorter than those in most comparable acquisition programs.

In addition to improving sonar system performance, ARCI generated large cost savings (Johnson, 2007) by reducing budget allocations across SCN, OPN, O&MN, RDT&E, and MilCon by over 50% ($7.6 billion to $3.6 billion) when the 1983-1993 budget allocations are compared to the 1996-2006 allocations. These savings reflect a reduction in Development and Production by a factor of six and a reduction in Operating and Support costs by a factor of eight. ARCI also realized over $25 million in cost avoidance for logistics support, including:

- Over $1 million in technical manuals,
- Over $2 million in direct vendor delivery,
- Over $19 million in interactive, multimedia instruction, and
- $3 million in outfitting spares reduction.

In summary, ARCI was an extremely successful acquisition program. A fundamental question for learning how to improve other acquisition programs is “Why was ARCI so successful?” Several factors, internal to the program and from its environment, help explain this success. Beaudreau (2006) focused on the role of the Modular Open Systems Approach (MOSA), now incorporated into the Navy’s Open Architecture approach, changing culture, and systems engineering (including spiral development, now termed Evolutionary Acquisition). The current work focuses on the dynamic nature of the ARCI program and what that nature suggests about the successful implementation of acquisition programs.

Open Architecture and Evolutionary Acquisition in the ARCI Program

ARCI was created in the early 1990s in an unusual acquisition environment that was dominated by an urgent need for significant improvement in active fleet capabilities, very constrained funding, and ongoing acquisition reforms. More specifically, submarine sonar hardware and software needed large improvements in performance. Complete solutions were not available and ready for operational testing when ARCI began. The need to develop solutions and make improvements quickly required an evolutionary approach. In addition, existing capabilities used legacy systems, which made repeated and fast changes difficult and expensive. Moving away from the legacy systems to an Open Architecture system potentially provided the flexibility needed for frequent upgrades as technologies developed. Program managers initially planned to replace legacy hardware with COTS (a central tenant of OA) to take advantage of the increased computing capability of hardware developed since the original system development and to facilitate future upgrades. Reduced hardware size provided space for the redesign of cabinets, etc. so that COTS products would meet military reliability requirements not met by those products "out of the box." ARCI managers originally planned to write middleware to link the new hardware and legacy software. However, analysis revealed that rewriting the operating software in a modern software platform (C++) was less expensive than developing middleware and also provided opportunities for an Open Architecture for software upgrades. Therefore, the Open Architecture approach was expanded to include software. Four acquisition iterations were initially designed (a central tenant of EA), each to address a different portion of the sonar system: 1) the towed array, 2) the hull array,[30] 3) the spherical array, and 4) the high frequency arrays. Each iteration used the standard DoD acquisition phases at the time of the program that identified and specified requirements, acquired technologies, designed and developed products, and integrated those solutions into ships.

As described so far, ARCI was a straightforward (albeit challenging) integration of Open Architecture and Evolutionary Acquisition. However, the ARCI program included some important features that distinguish it from known descriptions of the implementation of open systems and Evolutionary Acquisition. First, consider the dynamic nature of the need (evolving threats) and solutions (technology evolution). As hardware and software technologies improved and threats evolved, additional ARCI iterations would be needed. Improvements would be needed on an almost continuous basis to adequately improve fleet performance. Therefore, ARCI needed to be able to generate many repeatable capability upgrade iterations. This required ARCI to develop a process that integrated continuous processes with phased development, Open Architecture, and Evolutionary Acquisition. This was done partially by setting frequent upgrade release dates and not letting those dates slip. The first iteration was released 18 months after the identification of initial requirements, with subsequent upgrades every 12 months. This is much more frequent than the common DoD practice. The frequent integration of improvements was possible only by utilizing many previously developed technologies and solutions from a variety of sources (e.g., ONR, small businesses, academics). "Leverage, leverage, leverage" was a mantra in ARCI that referred to the program's emphasis on the use of existing technologies and solutions.

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[30] Some towed array upgrades were included in some of the second (hull array) iterations to respond to the fleet's overwhelming support based on the results of initial towed array improvement results and the fleet's urgent need for improvement.

ARCI completed frequent upgrades through a second important difference between ARCI and other OA and EA programs that is related to the relationship of requirements, technologies, products, and implementation to specific acquisition iterations. Traditional DoD acquisition (including traditional EA) strongly link specific requirements to specific development blocks at the start of the block. Tests for specific blocks can be failed if the requirements linked to that block are not met and development is slowed to be sure that promised requirements are included.[31] Strongly linking requirements to blocks before solutions have been developed requires a flexible schedule—in case of development problems—lots of money to speed development, or both. ARCI had little flexibility of time or money, so it made requirements flexible to meet iteration deadlines (i.e., the commitments to upgrade at specific intervals) and control costs. This was done with a combination of a deviation from the traditional acquisition process and the use of a different conceptualization and utilization of several acquisition processes. ARCI delayed the selection of technologies and products to be included in each iteration until as late as possible (typically, about six months before delivery) and only included (at the program manager's discretion) those improvements for which developed technologies and solutions were available and in-hand. Requirements for which solutions were not yet available were delayed until solutions had been developed. ARCI is distinguished from many other DoD programs by its ability to locate the authority to include or delay meeting requirements with the program managers. According to the program manager, this was accepted by the fleet largely because the frequent iterations provided an opportunity for delays in meeting requirements to be relatively short, and solutions were being developed relatively rapidly.

ARCI managers also adopted a fundamentally different mental model of the acquisition process than was described in the DoD policy at the time of the program (e.g., *5000.1*) and extended concepts that are described in current policy (USD (AT&L), 2003b, May 12, sections 1 and 2, pp. 12-13). Current policy describes sequential acquisition phases (Materiel Solution Analysis, Technology Development, and Engineering and Manufacturing Development) that are repeated after requirements are developed, with continuous technology development and maturation (USD (AT&L), 2003b, May 12, Figure 2). In contrast, ARCI used continuous requirements development, technology development, and advanced development. Only the six-month implementation phases (analogous to Manufacturing Development) were viewed as specific to individual upgrades. This, and the Open Architecture approach to solutions, required ARCI to aggressively pursue and actively manage and coordinate continuous and parallel requirements revision, technology identification and development, and product development. This approach (three continuous processes and one iteration-based phase) is fundamentally different than traditional acquisition (all iteration-based phases) or current policy (one continuous process and several iteration-based phases). This approach also required a different set of government and contractor skills and relationships.

ARCI changed important relationships among program participants. The prime contractor was forced to take a role of primarily providing coordination but not generating solutions. This was to prevent solution bias in choosing technologies and products for inclusion in upgrades. Solutions were developed by multiple and diverse organizations (e.g., academia, ONR, small businesses) and chosen based on transparent assessments by an objective team

[31] This may be part of why traditional EA is difficult to plan. Program managers must successfully predict which requirements will be filled through future technology development, product design, and implementation when they commit to meet specific requirements for specific development blocks, often long before that technology and product development has occurred or can be reliably forecasted.

of experts. This successfully prevented purposeful or accidental sole-source acquisition by providing suppliers that were not awarded contracts with realistic opportunities to fairly compete and potentially win future ARCI work. These changes required several atypical program management skills.

Modeling the ARCI Program

The simulation model used here is based on a previously developed formal (i.e., computer simulation) system dynamics model of a DoD acquisition project using Evolutionary Acquisition and some aspects of open systems. The model is purposefully simple relative to actual practice to expose the relevant relationships, with a focus on the open systems and Evolutionary Acquisition aspects. Therefore, although many development processes and features of program participants interact to determine program performance, only those features that describe the critical evolutionary, Open Architecture, and ARCI-specific nature of the program are included. For example, the model assumes that resource productivities are fixed, that work backlogs are available for development, and that work packages are completed in accordance with schedule requirements (i.e., work packages on the critical path are completed first) but does not identify specific critical-path work packages. The literature cited above investigates the impacts of these and other factors influencing program performance. The model generates complex and realistic behavior patterns despite its relative simplicity when compared to the actual DoD acquisition programs. A brief description of the conceptual model that was used as the basis for the formal model provides a foundation for describing the current model of ARCI. See Ford and Dillard (2008) for a detailed description of the previous model.

A Conceptual Model of an Evolutionary Acquisition Program

The model structure reflects the structure of development work moving through the separate development blocks of an acquisition project. In the model, four types of work flow through each block of an acquisition project: requirements, technologies, product component designs, and manufactured products. Each type of work flows through a development phase that completes a critical aspect of the project: 1) develop requirements, 2) develop technologies, 3) design product components (advanced development), and 4) manufacture products. The exception is requirements, which also measures progress through the final phase, 5) conduct user product testing. Figure 10 shows development phases and information flows in a single block.

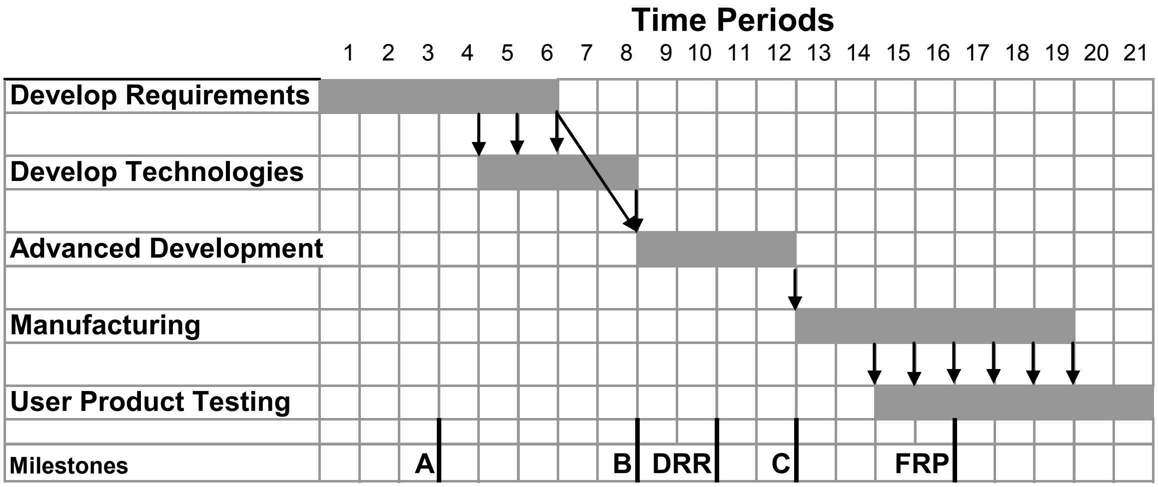

Figure 10. Information Flows in a Single-block Acquisition Project
(Ford & Dillard, 2008)

In Figure 10, arrows between phases indicate primary information flows. The start of all phases (except the development of requirements) is constrained by the completion of previous ("upstream") phases. These constraints are relaxed in the ARCI model to reflect continuous development phases. In the previous model, the completion of some requirements allows for the start of technology development, reflecting the concurrent nature of this portion of acquisition. Both requirements development and technology development must be completed for advanced development to begin. The completion of advanced development allows manufacturing to begin. When some products have been manufactured, they are shipped to users for readiness testing. Figure 10 also identifies the five major reviews within a single acquisition block (A, B, Design Readiness Review, C, and Full-rate Production) at their approximate times during a project.

Each of the five phases in a development block (shown in Figure 10) are modeled with the workflows through the phase as a value chain of alternating backlogs and development activities with two types of rework cycle (within phases and between phases). The value chain is described with the boxes and pipes and with valves along the bottom of Figure 11. The value chain passes from the Initial Completion Backlog, through the Initial Completion Rate, into the Quality Assurance Backlog, through the Approval Rate, into the stock of Work Approved, and through the Release Rate to the accumulation of Work Finished and Released. Rework cycles are inherent in development projects and have been modeled and used extensively to explain and improve project management (Lyneis, Cooper, & Els, 2001; Ford & Sterman, 1998; Cooper & Mullen, 1993; Cooper, 1980; 1993a, February; 1993b, February; 1993c; 1994; Taylor & Ford, 2006; 2008). The scope of work is measured with the number of equal-sized work packages that must be completed in a development phase.

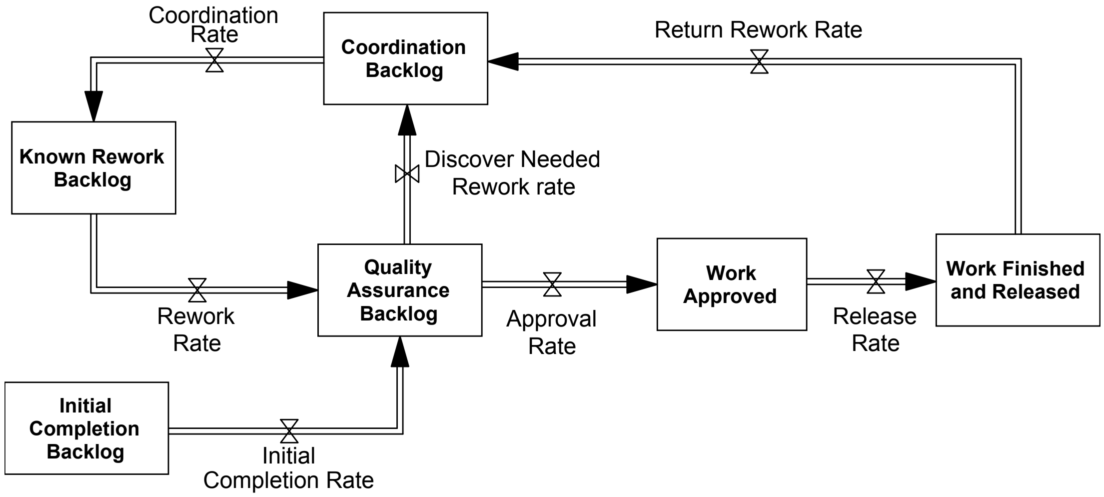

Figure 11. Work Backlogs and Flows through a Development Phase

For most phases in most blocks, all work starts in the backlog[32] of work needing to be initially completed ("Initial Completion Backlog" box at the bottom of Figure 11). The ARCI project includes an exception, which will be described later. As work is first completed, it enters the stock of work needing quality assurance (QA). Quality assurance could take many forms, including reviews of designs by senior engineers, prototype building and testing, and the inspection of work. Work needing quality assurance accumulates in a Quality Assurance Backlog (the box in the middle of Figure 11). If work passes QA (either because it is correct or the need for changes is not detected), it is approved and adds to the stock of Work Approved. When sufficient work has been approved, a package is released, adding to the stock of Work Finished and Released to other phases or users. The release package size is a management decision, often based on the characteristics of the phase. For example, in semiconductor development, the vast majority of the design code must be completed prior to release for a prototype build since almost all of the code is needed to design the masks. In other development settings, managers have broad discretion in setting release package sizes.

In rework cycles, between-phases work that is found to require changes moves into a stock of tasks that require changes that must be resolved through coordination with the phase responsible for the problem ("Coordination Backlog"). Classic examples include designers working with users to refine ambiguous or infeasible requirements or manufacturing engineers meeting with product designers to explain why parts can't be built as specified in the drawings. After coordination resolves the disputed issues, these tasks move to the stock of work known to need rework ("Known Rework Backlog") and are subsequently reworked and returned to quality assurance for re-inspection, testing, etc.

Since quality assurance is imperfect, some tasks requiring rework can be missed and erroneously approved and released. These rework requirements may be discovered later by another work phase. We assume that all defects are discovered in final product testing by users. When the phase that discovers the problem reports it, the generating phase is notified, and the affected tasks are moved from the stock of work considered finished to the coordination backlog

[32] Because the flows of development activities reflect the completion of the activity, the backlogs, as used here, include work in progress as well as work on which development has not yet been started.

and then eventually reworked. For example, a test phase may discover a short circuit across two layers in a prototype chip. If the error is traced to the design, test engineers must notify the designers and work with them to specify the location and characteristics of the short circuit. The designers must then rework, re-check and re-release the design, followed by changes in layout, tape-out, masking, and prototype fabrication.

The previous model of Open Architecture and Evolutionary Acquisition simulated the movement of work through an acquisition program. That model linked all five phases to specific iterations, which were completed at different intervals (Figure 10). Figure 12 depicts an acquisition project with multiple iterations or blocks. The first block is the same as Figure 10 above. Subsequent blocks have the same basic information flow, but can also be delayed by the completion of phases in previous blocks or constrained by the lack of progress in their own block.

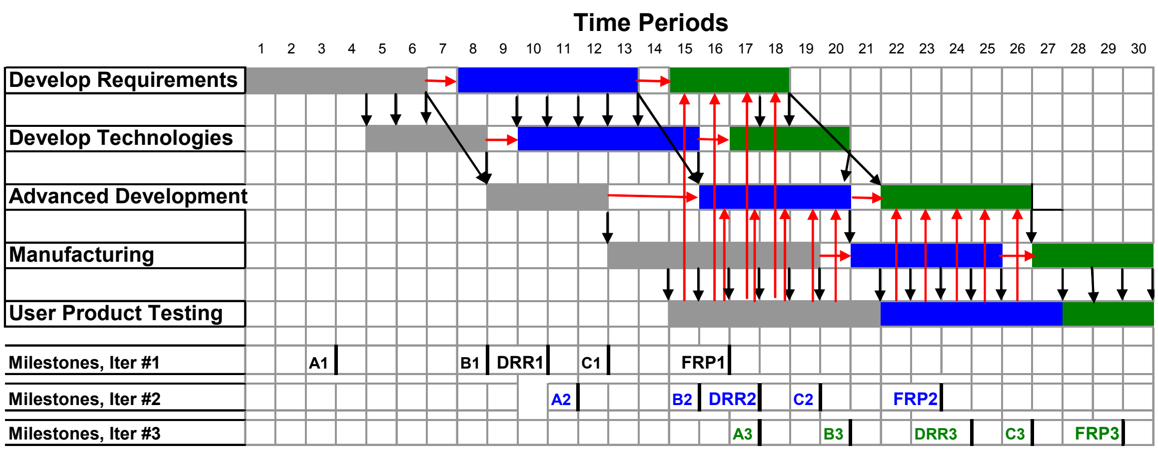

Figure 12. Information Flows in a Three-block Acquisition Project
(Ford & Dillard, 2008)

Modeling Open Systems in an Evolutionary Acquisition Program

The previous simulation model reflected some important aspects of open systems by changing model parameters to reflect impacts of open systems suggested by the literature. As an example, Table 1 describes some of the open systems impacts derived from Meyers and Oberndorf (2001) that were incorporated into the model.

Table 1. Impacts of Open Systems on Evolutionary Acquisition Due to Changes Suggested by Meyers and Oberndorf (2001)
(Ford & Dillard, 2008)

Change Required by Open Systems	Impact on Evolutionary Acquisition Processes
1) Build standards & COTS for program use	Increases Requirements scope in Block 1
	Increases Technology Development scope in Block 1
2) Build high-level model with open systems	Increases Technology Development scope in Block 1
3) Document use of OS	Increases Technology Development scope in all blocks
4) Coordinate standards	Increases scope of all phases in all blocks
5) Implement OS	Decreases Advanced Development scope in all blocks
	Fewer Advanced Development design problems in all blocks
6) Integrate components	More Advanced Development integration problems in all blocks
	More Manufacturing integration problems in all blocks

Model Changes to Reflect the ARCI Program

The structure of the simulation model of a traditional acquisition program that adopts Open Architecture and Evolutionary Acquisition approaches was changed to better reflect the ARCI program. The primary changes are:

- Rename “Advanced Development” as “Design” to reflect the broader acquisition approach to this phase in ARCI that often adopted existing solutions instead of developing new solutions such as is often done in many traditional programs.
- Rename the “Manufacturing” phase to the “Integration” phase to reflect the nature of this activity in ARCI.
- Model the Requirements, Technology, and Design phases as a single, continuous development activity that occurs throughout the program.
- Begin the program with a set of initially developed requirements to be addressed but no inflow of new requirements. This reflects the conditions at the beginning of the program and the nature of the needs that the program was addressing (i.e., largely understood and described).
- Model the Integration activity as separate phases (as in the previous model), but start those phases at specific times (6 months before release), and end them at specific Integration release dates.
- Fix Integration release dates at 1.5 years after the program start (MDA) for the first release and then annually thereafter (i.e., at weeks 78, 130, 182, and 234).
- Disaggregate supplier-resource types into three types, reflecting those addressing technology acquisition, design, and implementation. The resources include several types of suppliers: contractors, ONR, government labs, and academic agencies.

Resources-for-requirements was not separately modeled because the requirements were largely already developed at the start of the program, and resources for checking and revising requirements was not considered by the program manager to constrain program progress.

- Disaggregate government program-management resources into three types, reflecting the same three types of resources as supplier modeling: technology, design, and integration work.

Little specific data was available for model parameter estimates. Therefore, the ARCI model was calibrated using data collected through the interview with the program manager and with modeler estimates. Figure 13 shows typical simulated behavior patterns of the ARCI program.

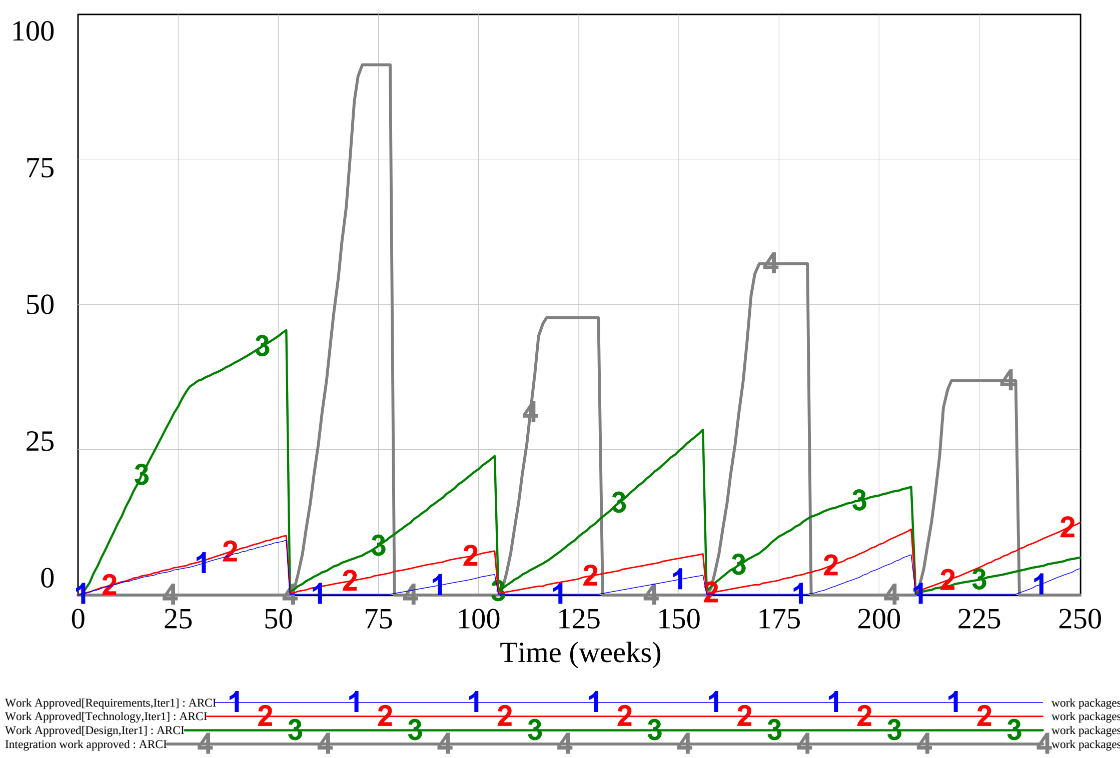

Figure 13. Approved Work in the Simulated ARCI Program

The vertical axis in Figure 13 is work packages, as described above. Figure 13 reflects the critical behavior patterns that describe the ARCI program. Work for each upgrade progresses first through the checking and revision (as required) of requirements (blue line #1 in Figure 13), subsequent acquisition of technologies to fulfill those requirements (red line #2 in Figure 13), and design of upgrade solutions using those technologies (green line #3 in Figure 13). As in the ARCI program, these continue throughout all upgrades (weeks 0–250 in Figure 13). But the accumulation of mature-enough requirements, technologies, and designs for each upgrade are collected at weeks 52, 104, and 156 (6 months before each release) to initiate the Integration phase for the upgrade. The four Integration phases (grey line #4 in Figure 13) each last six months and end at the release of each upgrade package to the fleet for operational testing and use. Consistent with ACRI, the revision of requirements, acquisition of technologies, and design of solutions does not stop during integration but continues, as show in Figure 13 by the overlapping of the progress rate lines during the Integration phases.

The ARCI model was tested for its usefulness for investigating implementation issues. Standard model tests as described by Sterman (2000) were used, including testing both the model structure and behavior. The model is based on previously developed system dynamics models of product development in several industries that have been developed and tested over several decades, as described and referenced above. Model structure was tested for similarity to the structure of the actual system through one-to-one linking of model components and specific parts of the system structure and units-consistency checks. Models were tested for their ability to generate “the right behavior patterns for the right reasons” (i.e., for the same reasons as in the actual system) using extreme-conditions testing and the comparison of simulated behavior patterns with an understanding of the behavior of the actual and similar systems. In extreme-conditions testing, one or more model parameter values are set to represent extreme conditions, which the modeler can use to predict correct model behavior. For example, the extreme condition of no resources should generate a program with no progress. The ARCI model generated reasonable behavior over a wide range of parameter values. The model behavior is similar to the described project behaviors, also supporting the model’s ability to reflect the relevant portions of the ARCI program. Based on these tests, the model was considered useful for investigating RCIP implementation issues.

Modeling RCIP

The Rapid Capability Insertion Process (RCIP) seeks to develop a process that can capture the types of performance improvements realized by ARCI in more and larger acquisition programs. The upgrading of AEGIS and its preparation for net-centric warfare is a potential application of RCIP. RCIP is based on the ARCI program and includes its core concepts and changes from most traditional acquisition projects, including those that adopt the Open Architecture and Evolutionary Acquisition approaches. However, based on an interview with one of the RCIP developers (2009), there will be differences between ARCI and RCIP, primarily:

- RCIP will be applied to larger acquisition efforts (e.g., AEGIS);
- After an initial start-up phase, RCIP will receive and develop a continuous stream of new requirements instead of having a fixed set of established requirements in place, as ACRI had;
- RCIP is initially planned to release upgrades to the fleet every two years, thereby adopting a cycle that is twice as long as that used in ARCI; and
- RCIP is planned to use 12-month integration periods, twice as long as those in ARCI.

These differences were integrated into the simulation model to provide an estimate of the potential of the RCIP approach. This represents a simple (and simplistic, as will be explained) scaling of the ACRI approach to RCIP. Figure 14 shows RCIP’s potential performance. Steady-state output exceeds the ARCI’s average output, although ARCI’s transitional (versus steady-state) nature and model calibration preclude useful direct comparisons.

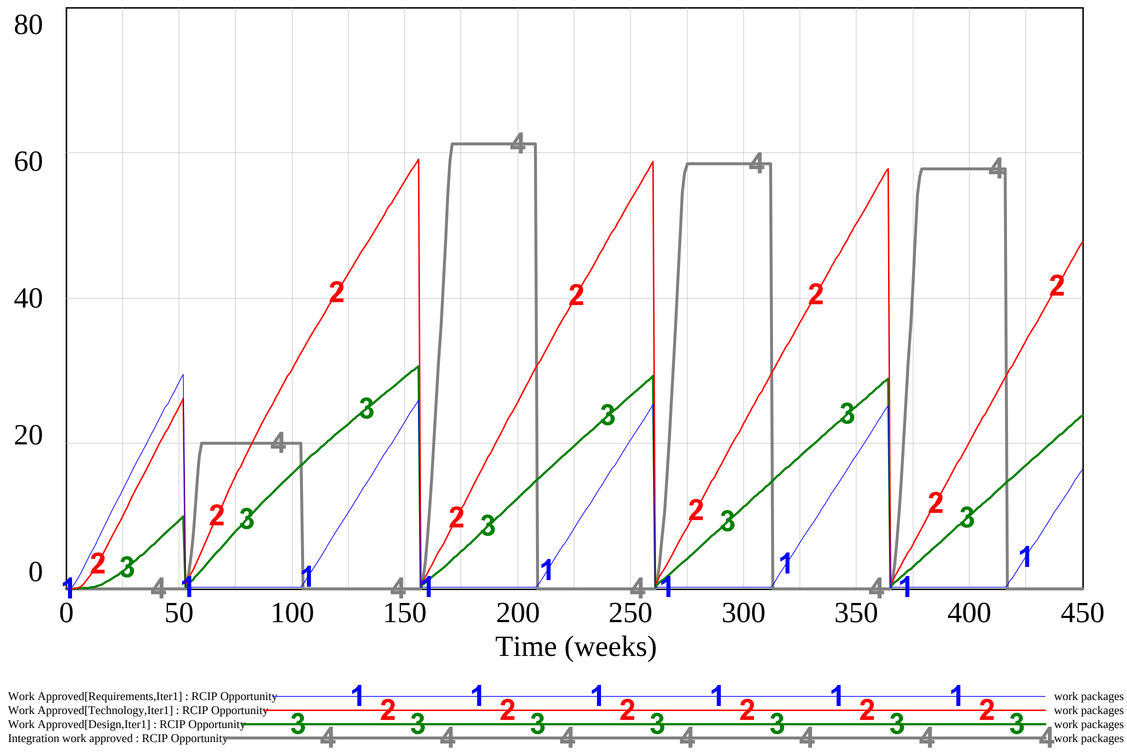

Figure 14. Simulated RCIP Program Behavior

Figure 14 includes the fundamental, desired behavior of RCIP, a basically continuous process of requirements development upgrades (after an initial start-up phase). While useful as a benchmark for the current work, important risks must be addressed to better reflect the RCIP approach.

The RCIP Implementation Risks

A simple scaling-up of the ARCI program into an RCIP program will not capture the potential performance (especially considering that the model above is simplistic) because it ignores important implementation risks that can degrade RCIP performance when compared to its potential. In addition to the changes from ARCI to RCIP listed above, several implementation challenges pose risks that may affect RCIP, including: 1), an increased pool of suppliers due to increased scale, 2) a reduced number of off-the-shelf technologies and designs available for use, resulting in a need for more new development, and 3) increased systems that solutions must be integrated across. Table 2 contrasts the three acquisition programs to highlight their differences and identify some RCIP implementation risks.

Table 2. Contrasts among Traditional Phased, ARCI, and RCIP Acquisition Programs

Acquisition Feature	Phased Program with OA & EA	ARCI Program	RCIP Programs (vs. ARCI)
Development processes (Req., Tech, AdvDev)	Repeated separate phases	Primarily continuous processes, known requirements	*Continuous processes with continuous inflow of requirements*
Innovation sources	Primarily through Prime Contractor	Primarily Off-the-shelf solutions	*Mix of new development & off-the-shelf. More new development*
Product System Modularity	Often integrated across phases & development blocks	Primarily separate systems (towed, hull, spherical, high frequency)	*More systems and system interactions. More inter-system integration required*
Govt./Supplier Relationships	Prime contractor	"Prime" coordinator & multiple solution suppliers	*Larger solution supplier pool*
Primary Locus of Performance Flexibility	Cost, Schedule	Scope	*Scope with possible flexibility in cost*

The Primary Locus of Program Flexibility (the last row in Table 2) describes a generic model of program management that can partially explain the ARCI success and facilitate the design and management of RCIP programs. The model describes how program management handles, in practice, the ubiquitous circumstances of having inadequate resources (broadly defined) to meet all performance targets (e.g., cost <= budget, completion date <= deadline, capabilities >= warfighter needs). In these circumstances, program management is forced to select one or more performance dimensions that will not meet targets and project by how much they will underperform. The dimension or dimensions that are chosen is the Primary Locus of Program Performance Flexibility. A common saying among commercial contractors (although perhaps not said to their clients) that captures the essence of this model is "Fast, cheap, good. Pick two." Table 2 identifies the Primary Locus of Performance Flexibility as a significant difference between traditional programs with Open Architecture and Evolutionary Acquisition and programs adopting the ARCI/RCIP approach. In the former, performance flexibility is primarily located in the cost and schedule dimensions. In contrast, in the ARCI program, it was in the scope included in the current upgrade. In the RCIP approach, it is expected to remain in the scope dimension, with the possibility that cost may also provide some flexibility.

The RCIP's expected implementation risks were integrated into the simulation model. Specifically:

- Increased scope is expected to attract increased oversight and, therefore, reduce productivity due to the use of resources (primarily labor) in the preparations for reviews, etc. (20% reduction estimated).

- Existing inventories of requirements, off-the-shelf technologies, and off-the-shelf designs were reduced by 50% to reflect the need for more new development. This will require their initial development in addition to the testing and revisions included in the ARCI model.

- Increased new development will also require more integration effort than off-the-shelf solutions, which have already been partially developed for integration upon adoption. Therefore, the amount of integration work was increased by 25%.
- Increased new development will also make integration more difficult than off-the-shelf solutions, which have been partially tested for integration upon adoption. Therefore, the amount of iteration required in the integration phases was increased by 25%.

Figure 15 shows the simulated RCIP program with implementation risks. The program retains its fundamental behavior pattern of a primarily continuous upgrade process.

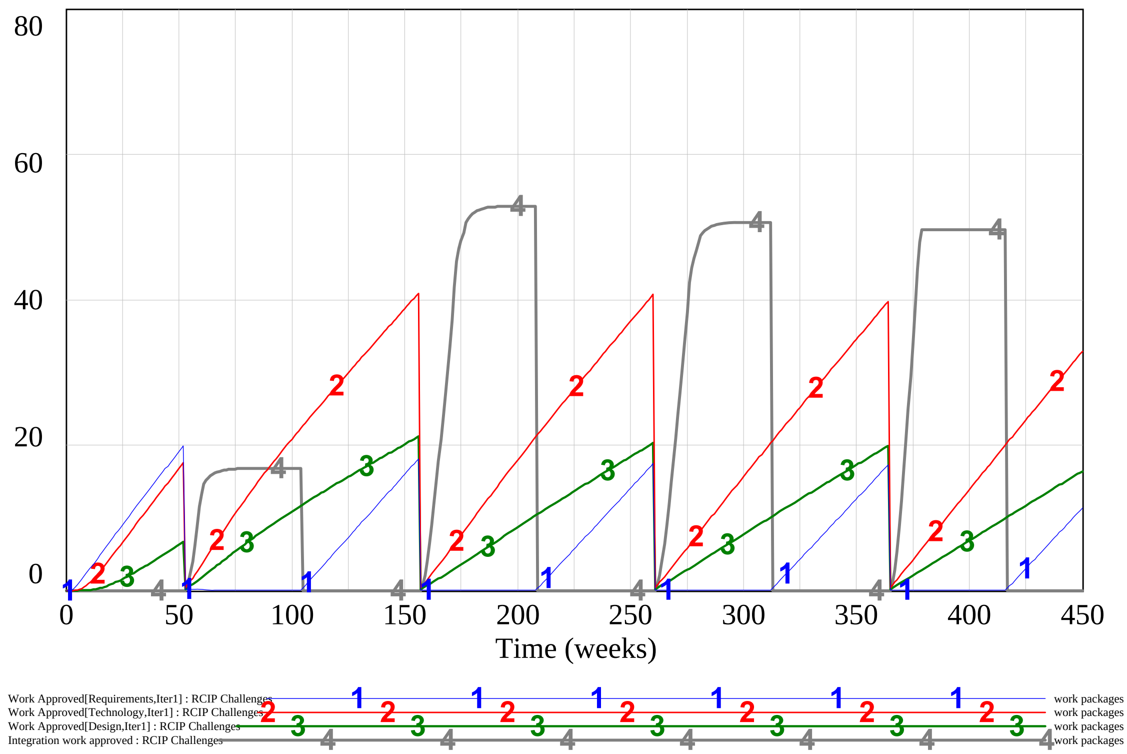

Figure 15. Simulated RCIP with Implementation Challenges

Implications of Implementation Risks for RCIP Success

The work completed and released to the fleet when RCIP implementation risks are considered (Figure 15) is significantly less than the potential (Figure 14). Figure 16 illustrates this difference (about 14% in the simulated program) by accumulating the Integration phase work released across four upgrades, without (blue line #1) and with (red line #2) implementation risks included. RCIP implementation risks must be addressed to capture the full potential of the ARCI approach in RCIP.

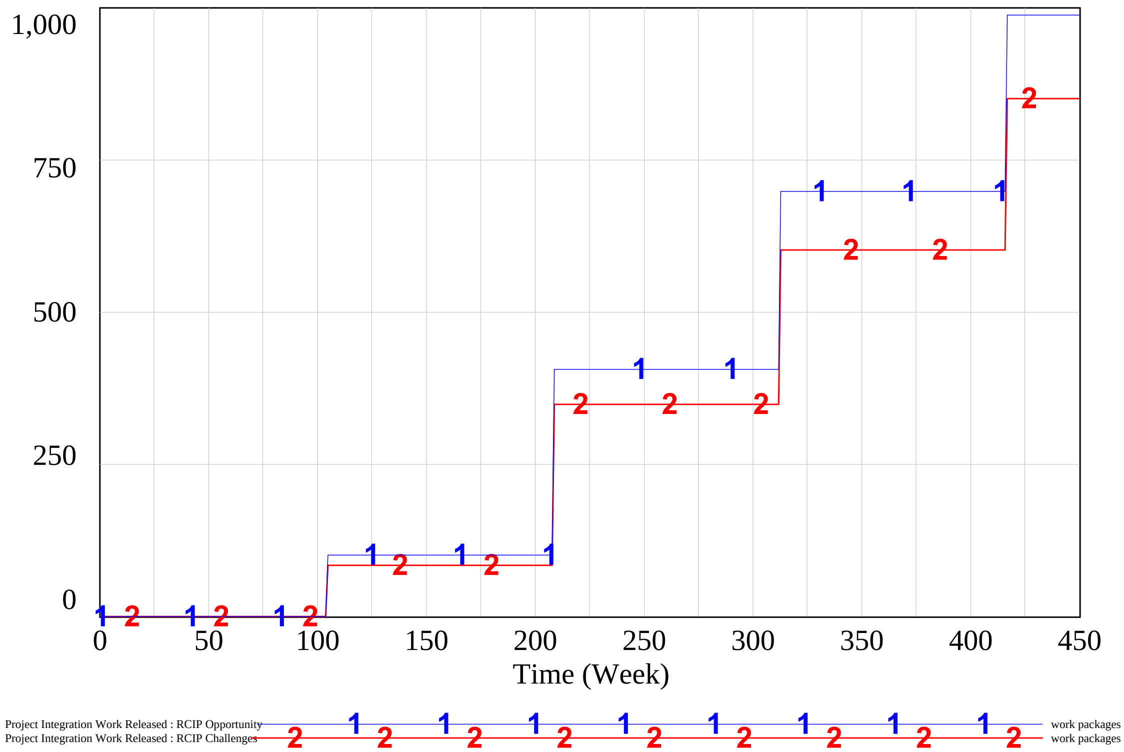

Figure 16. Cumulative RCIP Performance without and with Implementation Issues

Another RCIP implementation risk is program management burnout. The ACRI program manager specifically identified the potential of burnout in his program management team due to the repeated, intense Integration phases. To investigate the possibility and severity of this risk to RCIP implementation, the total required (but not necessarily provided) government program-management workforce size was simulated for the ARCI program, RCIP without implementation risks, and RCIP with implementation risks (Figure 17). Figure 17 clearly shows the spikes in demand for program management during the Integration phases for all three simulations. Notice that the peaks are significantly higher for both RCIP simulations than for the ACRI simulation. This suggests that the burnout risk will be larger for RCIP than it was for ACRI. *Successfully implementing a sustainable RCIP program will require a method to address potential burnout of the government program-management workforce.*

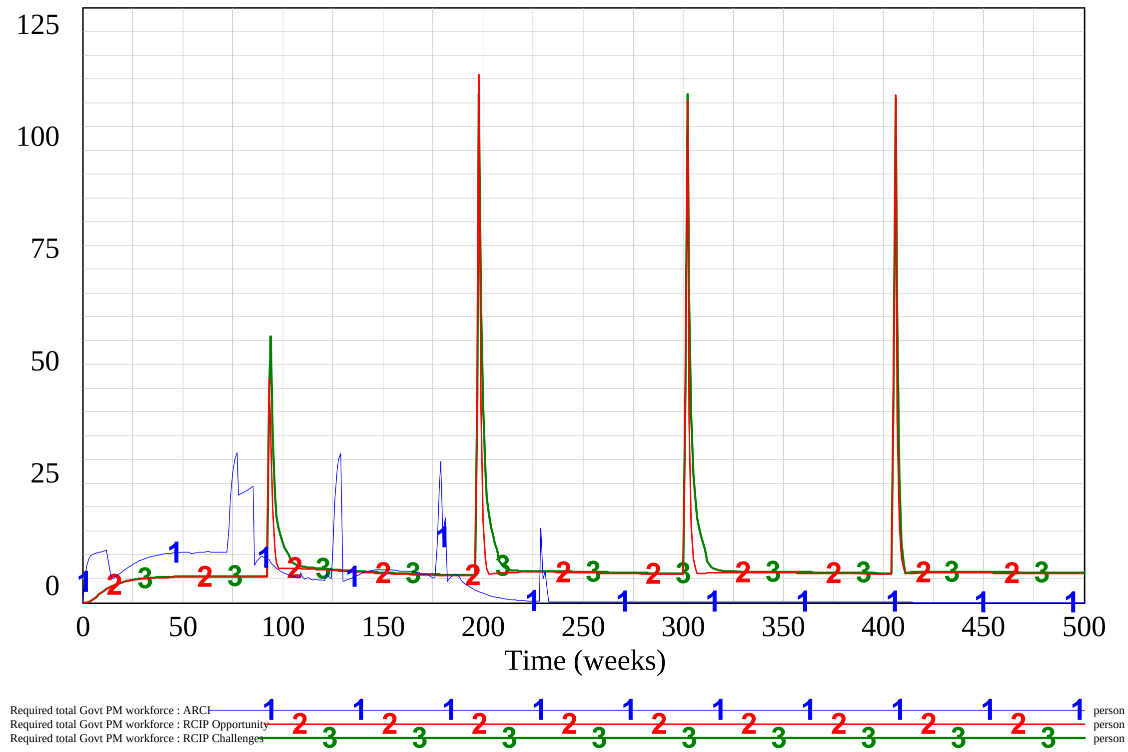

Figure 17. Simulated Total Required Government Program-management Workforce: ARCI, RCIP without and with Implementation Risks

Managing RCIP Implementation Risks

The RCIP's implementation risks can be managed through the careful design of its processes, organizations, and their interactions. Specific recommendations based on the ARCI program and the modeling and analysis discussed above are described in Table 3.

Table 3. Managing RCIP Implementation Risks

Acquisition Feature	ARCI Program	RCIP Programs (vs. ARCI)	RCIP Implementation Risk Management
Development processes	Primarily continuous processes, known requirements	Continuous processes with continuous inflow of requirements	*Standardize continuous processes and add rigor for sustainability*
Innovation sources	Primarily Off-the-shelf solutions	Mix of new development & off-the-shelf. More new development	1) *Adapt continuous processes into a mixture of off-the-shelf & new development solutions* 2) *Implement EA "only-mature-enough" strategy*
Product System Modularity	Primarily separate systems (towed, hull, spherical, high frequency)	More systems and system interactions. More inter-system integration required	*Operationalize modular configuration management for large-scale acquisition with focus on integration*
Government / Supplier Relationships	"Prime" coordinator & multiple-solution suppliers	Larger-solution supplier pool	*Formalize open, transparent, objective, & repetitive competition processes and organizations*
Primary Locus of Performance Flexibility	Scope	Scope with possible flexibility in cost	1) *Improve user-acquisition coordination to facilitate scope flexibility* 2) *Operationalize ARCI management of solution acquisition to make RCIP responsive to warfighter priorities*

Conclusions

The Acoustic Rapid COTS Insertion (ARCI) program was studied as the basis for modeling the planned Rapid Capability Insertion Process (RCIP) approach for continuous, reduced-cost upgrading of warfighting assets. ARCI used atypical methods in the face of atypical program requirements and conditions. ACRI was very successful in improving performance quickly for reduced costs. A previously developed acquisition program model was adapted to reflect ARCI and used for model validation. This model was then changed to reflect the basic conditions expected in RCIP programs. The model demonstrated the potential of RCIP to improve program performance. However, implementation risks were identified that may degrade potential performance, including increased oversight, the use of more new development, and the resulting integration scope and risk. When incorporated into the model, these risks were shown to significantly decrease RCIP performance. The means for successfully managing the RCIP design based on the ACRI program and RCIP operations are suggested for use in addressing the identified implementation risks

Based on the work described above, we conclude that RCIP has great potential to improve acquisition. But the failure to identify and successfully address implementation risks, in particular, can significantly constrain RCIP program performance. Special attention must be paid in the design of the RCIP approach to the differences between the ACRI program and the features, characteristics, and environmental conditions that RCIP programs will face. The five principles, concepts and tools and methods embodied in the Navy's Open Architecture approach to acquisition are likely to be particularly useful in developing RCIP and addressing its implementation risks. Many Open Architecture concepts were used successfully in the ACRI program, including modular design, design disclosure, interoperability, lifecycle affordability, and lots of vigorous (and vigorously managed) competition to generate a wide range of possible solutions from many sources. Applying Open Architecture required strong, assertive, government program management but provided the basis for extraordinary success. Similar extraordinary success is possible in RCIP programs but will also require a process based on Open Architecture and vigorous and assertive management by the government. By doing so, RCIP can become an example of effective and efficient acquisition for widespread adoption to many acquisition efforts.

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Supply Chain Planning with Incremental Development, Modular Design, and Evolutionary Updates

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Abstract

The policy specified by *DoDI 5000.02* (DoD, 2008, December 8) prescribes an evolutionary acquisition strategy. Products with long lifecycles such as torpedoes, evolutionary updates via incremental development, modular design updates, technology refreshes, technology insertions, and Advanced Processor Builds are all in play at the same time. Various functional elements of the weapon system are often redesigned during the lifecycle to meet evolving requirements. Component obsolescence and failures must also be anticipated and addressed in upgrade planning. Within each weapon system's evolutionary acquisition, cycle-changing requirements may expose weaknesses that have to be rectified across the inventory. New acquisition paradigms such as modular design have to be introduced into the supply chain while maintaining inventory levels of previously designed weapons at a high level of readiness. Thus, a diverse set of requirements must be satisfied with a finite set of resources. The acquisition policy does not provide guidance on how to address cross-coordination and optimization of project resources. This paper explores decision models for balancing conflicting demands and discusses the application of how these models address cross-coordination and optimization of project resources in the torpedo acquisition process while keeping the weapon's efficiency and inventory effectiveness at or above minimum specified levels.

Introduction

The policy specified by *DoDI 5000.02* (DoD, 2008, December 8) prescribes an evolutionary acquisition strategy. The Defense Acquisition Management System, as depicted in Figure 1, provides a framework in which to accomplish evolutionary updates in the Torpedo Enterprise. Evolutionary acquisition processes are deployed in the maintenance and upgrade of complex systems in an incremental manner to maximize the overall system efficiency and effectiveness. Technology-intensive products such as weapon systems are often redesigned during the lifecycle to meet changing requirements. Component obsolescence and failures must be anticipated and addressed in upgrade planning. Acquisition paradigms such as modular open systems approach (MOSA) are introduced while continuously maintaining unmodified inventory levels of previously designed weapons at a high level of readiness.

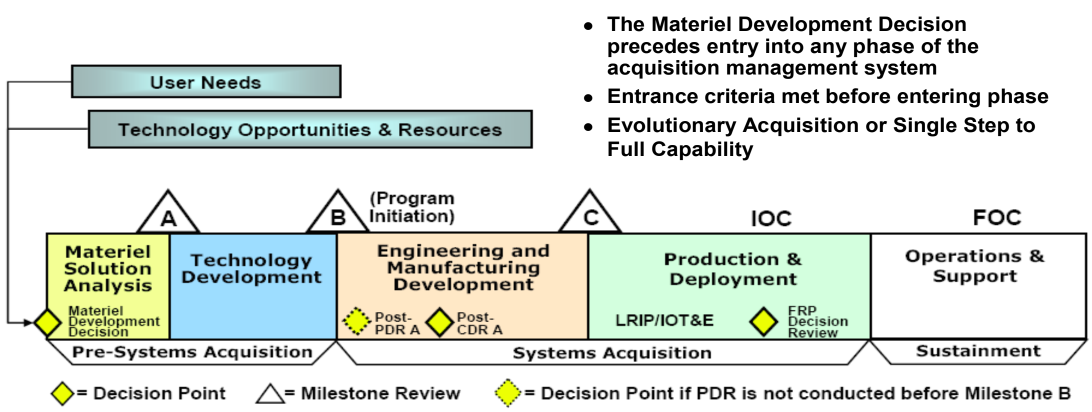

Figure 1. Overview of Defense Acquisition Management System

Prior to discussing how planning is conducted in the torpedo acquisition process, we define key terms used in the Torpedo Enterprise. These include evolutionary update, incremental development, modular design, technology refresh, technology insertion, Torpedo Modular Update, Advanced Processor Build, backwards compatible, lifecycle sustainment plan, weapon efficiency, and inventory effectiveness.

Evolutionary update: Planned or opportunistic updates to system hardware and software that address requirements relating to new customers, new technologies or innovations. Evolutionary updates can be fully implemented in a single step or implemented via an incremental development approach.

Incremental development: A development process in which hardware and/or software capability is delivered in increments, recognizing up front the need for future improvements. Each increment is a militarily useful and supportable operational capability. Each design increment goes through the entire design cycle of prototyping, testing, and release.

Modular design: A design in which hardware and software components are designed to be independently sustainable. The goal is for each module to stand on its own and interface to the required components via a standard set of Application Programming Interfaces (APIs).

Technology refresh: Planned obsolescence upgrades on existing product baselines. A technology refresh involves repairs/fixes/upgrades for existing components in an incremental manner.

Technology insertion (TI): Planned hardware capability upgrades either on existing or new product baselines. A technology insertion involves the introduction of new components that are functionally equal to or superior to existing components.

Torpedo Modular Update (TMU): An integrated/collaborative development, production and in-service approach to improve the overall effectiveness of torpedo inventories while addressing obsolescence issues and reducing Total Ownership Cost (TOC).

Advanced Processor Build (APB): Incremental software-capability improvement on either existing or new product baselines.

Backwards compatible: Hardware, technology refresh evolutions and software upgrades must be compatible with previous product baselines.

Lifecycle sustainment plan: The ability to maintain the product from the time that the user receives it to the time the product is disposed of.

Weapon efficiency: Weapon or torpedo efficiency is equivalent to torpedo effectiveness (T_{eff}). (This is not the weapon system's effectiveness but only that of the torpedo itself.) Torpedo effectiveness (T_{eff}) can be defined as the probability that all elements of the torpedo will work correctly after it is successfully launched and deployed in a manner that affords the torpedo an opportunity to detect a target that is acoustically and dynamically within the design capabilities of the torpedo. For a 100% reliable torpedo, all the subsystems of the torpedo (i.e., propulsion, guidance, detection, homing, and warhead) will function successfully until target destruction.

Inventory effectiveness: Inventory effectiveness is a gauge of how successful our inventory of torpedoes will be in eliminating a defined set of specific threat targets given precise operational scenarios. The threat target would be a class of submarines with a defined, acoustic signature/dynamic operational capability, operating with or without countermeasures. The operational scenario would be defined as the ocean environment in which the threat targets would be operating (i.e., shallow water, high sea states, specific world locations, and under ice). Given that the defined threat and the operating scenario are known, the number of torpedoes needed to eliminate the set of target threats can be calculated via simulation exercises. These exercises will give an indication of how effective our torpedo inventory is in eliminating the given threat under various environments. Such exercises establish torpedo inventory requirements. As torpedoes become more effective (T_{eff}), their ability to counter the enemy threat in all given conditions becomes greater, and the inventory levels required can be reduced with confidence.

For weapons or products with long lifecycles such as torpedoes, evolutionary updates via incremental development, modular design updates, technology refreshes, technology insertions, and Advanced Processor Builds are all in play at the same time. A wide-ranging and extensive set of requirements must be satisfied with a finite set of resources. The goal of keeping the weapon's efficiency and inventory effectiveness at or above minimum specified levels while optimizing program resources makes program planning very challenging. In this paper, we explore decision models for balancing these conflicting demands.

Historical Background

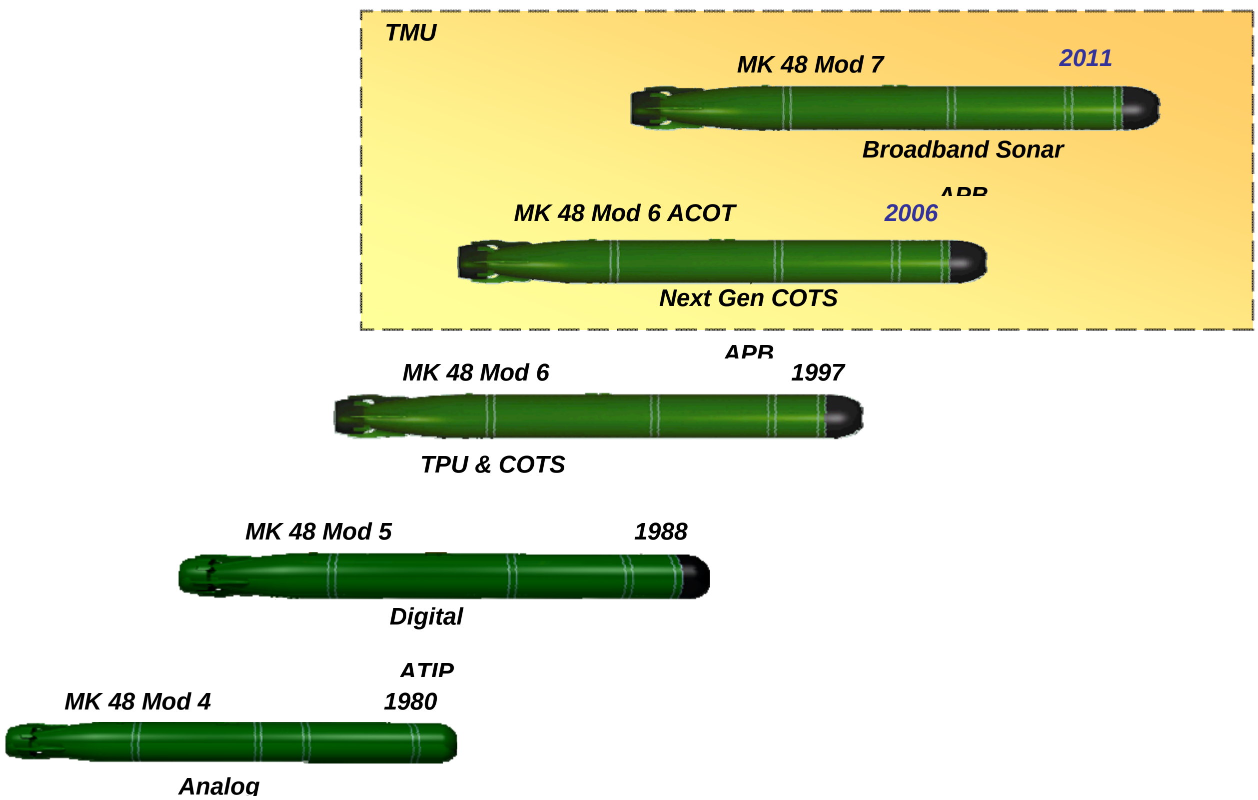

Figure 2. Torpedo Evolution

Since the Fleet introduction of the Torpedo MARK (Mk) 48 Modification (MOD) 4 in December 1980, the basic Torpedo Mk 48 has undergone several modifications. The torpedo evolution is shown in Figure 2. The most recent upgrade to the Fleet Torpedo Mk 48 occurred in December of 2006 with introduction of the Torpedo Mk 48 Mod 7 version.

In the '70s, the surprise emergence of a very fast and very deep-diving Soviet SSN (Alpha type) presented the US Navy a challenge. The new threat speed exceeded the Doppler detection/tracking capabilities of the mostly analog-based Torpedo MK 48 Mod 3 electronics, and the postulated threat depth capability was beyond the Mod 3's original design capability. In response, the MK 48 Mod 4 Ordnance Alteration (ORDALT) was initiated in late 1979 to address these shortcomings, and the first MK 48 Mod 4 was provided to the Fleet in December 1980. The Torpedo Mk 48 Mod 4 was gradually replaced by the upgraded versions of the Torpedo Mk 48, and in March 2008, the last Torpedo Mk 48 Mod 4 was withdrawn from the last US Navy submarine.

In parallel, the MK 48 Mod 5 Advanced Capability (ADCAP) heavyweight torpedo was designed in the early 1980s as a modular weapon based on a state-of-the-art, multi-beam, low-noise acoustic sensor array with very low self-noise. To counter the emergence of Soviet high-speed and deep-diving SSNs, the Mod 5 employed a modified MK 48 Mod 4 propulsion system that fully exploited the design margin in the engine and allowed operation at higher horsepower. The Mk 48 Mod 5 was introduced to the Fleet in August 1988.

With the end of the Cold War came the reduction in the Soviet's nuclear submarine fleet and the emerging growth of modern diesel-electric submarines; as a result, the US Navy began to give more serious attention to the development and proliferation of modern, very quiet, diesel-electric and air-independent propulsion submarines and advanced torpedo countermeasures in Rest-of-World (ROW) countries. In contrast to the Cold War, when Soviet submarines operated primarily in open-ocean *blue water*, these ROW diesel-electric submarines operated primarily in shallow, coastal, littoral waters where the environment presented a different, and more significant, set of challenges for acoustic torpedoes.

By the late 1990s, the concern that the next ASW operations might occur in the challenging *brown water* of the littorals against small, very quiet diesel-electric submarines prompted a review of the capabilities of US Navy torpedoes in shallow waters around the world. Testing confirmed that operation in the littoral presented problems to both the US submarine trying to detect and classify a threat and to the torpedo in effectively prosecuting an attack on that threat.

To fulfill this need, the Mk 48 ADCAP Torpedo Propulsion Upgrade (TPU) and the MODs Programs were initiated. This resulted in a program for the design of the Mk 48 Mod 6 torpedo. The MK 48 Mod 6 entered the Fleet in August 1997 at the Naval Submarine Base, New London, when USS Alexandria (SSN 757) loaded the first warshot MK 48 Mod 6 torpedoes.

In 2001, a partial redesign of the guidance hardware of the torpedo was undertaken to resolve critical parts obsolescence issues. In addition, the change incorporated component commonality with existing torpedoes for the guidance hardware. These changes, along with all future torpedo changes, were defined and developed as part of a newly implemented Advanced Processor Build (APB) process for the MK 48 and MK 54 torpedo programs. The APB process relied on rapid improvement in commercial off-the-shelf (COTS) advancements and was instituted to more rapidly field improved performance by finding the best-of-the-best sonar-signal processing algorithms from industry, academia, and Navy researchers and applying them to both lightweight and heavyweight torpedoes. Naval Undersea Warfare Center Division, Newport took on the APB leadership role to evaluate and integrate improved software and hardware capabilities into the torpedo inventory.

Although the Mk 48 Mod 6 upgrade addressed littoral operations, the fundamental challenge presented by these operations for active acoustic systems is the high levels of reverberation that often effectively mask low-target strength targets. One approach that mitigates this reverberation masking is using a broadband acoustic system that can take advantage of various waveforms and frequency diversity to discriminate target returns from the background reverberation.

In 1996, a concept-definition torpedo program was started in parallel with the Mk 48 Mod 6 upgrade. This torpedo configuration was referred to as the Torpedo Mk 48 Common Broadband Acoustic SONAR System (CBASS) and officially designated the Torpedo Mk 48 Mod 7. The CBASS program evolved as a result of concerns identified in reports that highlighted future vulnerabilities of US Navy torpedoes and noted that evolving threats will eventually reduce the effectiveness of the current torpedoes, Mk 48 Mod 5 and Mk 48 Mod 6. By employing a broadband sonar system and advanced broadband signal processing algorithms to enhance the detection and prosecution of threats, the Mk 48 Mod 7 program implemented the necessary hardware modifications and advanced software algorithms required to sustain undersea superiority well into the future.

The Mk 48 Mod 7 program was a two-phased evolutionary APB acquisition program. Phase I provided the enabling hardware required to support Phase II software enhancements. Phase I built upon current capabilities and introduced several guidance and control (G&C) performance enhancements, including new beam sets, narrow-band frequency agility, frequency selection, and enhanced target rejection tests. Phase I attained Initial Operating Capability (IOC) in FY06 with the preparation of four warshot Mk 48 Mod 7 torpedoes by a certified Fleet Intermediate Maintenance Activity (IMA). Phase II will incrementally improve, via the structured Torpedo Modular Upgrade (TMU) process, the sonar characteristics of the Mk 48 Mod 7 from a frequency-agile system to a fully coherent broadband system through three planned software APBs.

In April 2003, the United States of America and the Commonwealth of Australia signed an Armaments Cooperative Program (ACP) agreement for Mk 48 Mod 7 engineering and manufacturing development, production, and in-service support. Introduction of the Torpedo Mk 48 Mod 7 had a profound effect upon the Torpedo Enterprise both from a performance perspective and from an inventory management perspective. The overarching plan will convert the entire Mk 48 ADCAP inventory to the Mk 48 Mod 7 configuration through a cost-effective and controlled conversion program via an engineering change to the Mk 48 Mod 5, Mk 48 Mod 6, and the Mk 48 Mod 6 Advanced Common Torpedo (ACOT). The Mk 48 Mod 7 Full Operational Capability (FOC) is scheduled for FY11.

The Torpedo Acquisition Process

As noted in the historical background, torpedo evolution is a continuous process, which can be driven not only by a series of detailed, long-range plans but also by exigencies that emerge as the long-range plans are being implemented. Torpedo evolution is typically incremental and evolutionary versus revolutionary in scope.

In response to shortfalls in undersea weapon capability, identified in the Joint Requirements Oversight Council (JROC), approved Initial Capabilities Document (ICD), CNO-N87 together with PEO (SUB) and PMS 404 have initiated analysis to identify the best technical approach to deliver the capability identified in the ICD. A Capabilities Development Document (CDD) is currently being worked on to describe the approach for a material solution needed to deliver the capability required to meet the operational performance criteria specified in the ICD. With approval of the CDD, the Milestone Decision Authority (MDA) will be able to initiate a development program.

Through an examination of undersea weapon technology available in the current technology base, a phased technology integration approach through incremental development and technology insertion has been defined. Technology from the Defense Advanced Research Projects Agency and the Office of Naval Research will be assessed in terms of potential to improve weapon capability through technological advances in areas such as guidance and control processing, fiber connectivity, sonar signal and classification processing, sensing systems, processor systems, and hybrid propulsion systems.

Technologies are grouped in bundles and aligned to each incremental phase based on compatibility with current and planned technology insertion baselines, technology maturity, and relevance to fielding the required capability as defined by the CDD. Technologies identified for transition into system development and demonstration baselines are acquired using the Small Business Innovative Research (SBIR) program, competitive contracts with industry, University Affiliated Research Centers (UARCs), federally funded research and development centers such as the Massachusetts Institute of Technology Lincoln Laboratory, and through annual task negotiation with the Naval Undersea Warfare Center. Material solutions to the capability needs defined in the ICD and further developed in the CDD follow the Torpedo Modular Upgrade/Advanced Processor Build (TMU/APB) process for transition in torpedo acquisition and delivery to the Fleet.

At the completion of each incremental development phase, a Capability Production Document (CPD) will be developed to describe the actual performance of the undersea weapon system going into production. The approved CPD becomes the basis for the MDA decision to begin production of hardware technology insertions and/or operational software.

The current torpedo evolutionary acquisition process presents a number of challenges and benefits to torpedo program managers during each phase of the acquisition lifecycle. Although various torpedo programs may require increased or decreased emphasis on specific acquisition-lifecycle elements, Figure 3 and the narrative below provide a description of the general flow of torpedo hardware acquisition activities within the Defense Acquisition Management Framework.

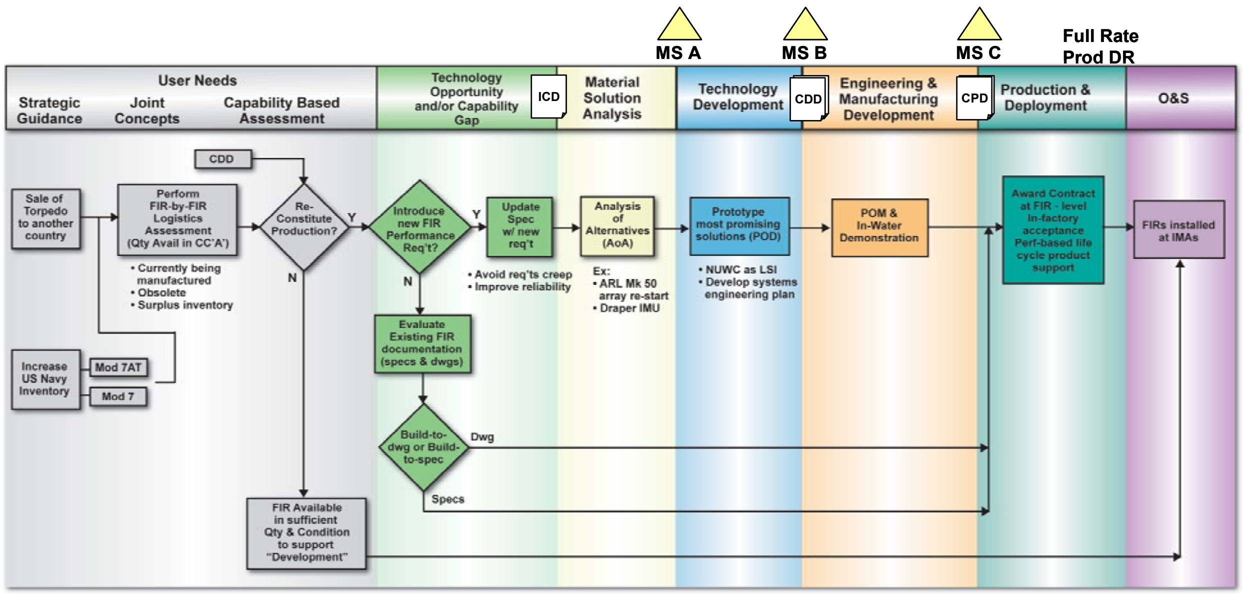

Figure 3. Acquisition Planning in the Torpedo Enterprise

User needs are the prime driver of the evolutionary acquisition process. From an operational perspective, user needs take the form of increased US Navy inventory requirements or the sale of torpedoes to other countries. The user demand signal triggers a logistics assessment at the lowest modular level of procurement. In the case of torpedoes, this is at the Functional Item Replacement, or FIR, level. This FIR-by-FIR logistics assessment provides insights into the availability of the required material and provides answers to such questions as:

1) Is there a surplus in current inventories to address the new user need? If there is a surplus, user needs can be satisfied by issuing the material to the Fleet for installation via the associated torpedo IMAs.

2) Are the needed items currently in production?

3) Are there any real or potential obsolescence issues which must be addressed via technology refresh?

4) Are there any near- or long-term program objectives or TIs planned that might impact the FIRs being considered for procurement? Torpedo near- and long-term program objectives are assessed via a continuous six-year Capability Development Document (CDD) generation process. The CDD forms the basis for formulation of a comprehensive Torpedo Technology Roadmap and subsequent focal point for a TMU/TI/APB program which addresses the full scope of future torpedo development and support initiatives. Feedback from the CDD/TMU/TI/APB and obsolescence assessments will contribute to the decision to either reconstitute production of the items or to perhaps merge the new user needs with a larger CDD/TMU/TI/APB effort and blend in the added quantities with ongoing redesign initiatives for the needed FIRs.

Once it is determined that the user needs can only be met by producing additional hardware, the information gathered relative to applicable obsolescence concerns and the CDD/TMU/TI status are used to determine if changes are needed to the affected FIR requirements. This assessment includes a review of reliability and availability factors to ensure that they are at acceptable levels before proceeding.

If no changes are needed to the FIR requirements, applicable and existing FIR documentation (i.e., specifications and standards) is reviewed and updated, if necessary, so that it can be utilized in a build-to-drawing or build-to-specification contract. The contract is awarded at the FIR level. An in-factory acceptance process and applicable performance-based lifecycle product support considerations are typically included in the contract.

If changes are needed to the FIR requirements, the applicable specifications are updated along with any necessary reliability/availability enhancements. The Defense Acquisition Management Framework is used as a guide to develop a set of specific acquisition-lifecycle elements that must be completed as the new FIR design proceeds through the various gates of the acquisition process. This process will vary with the scope of the FIR redesign being undertaken and will include at a minimum an analysis of alternatives, prototyping, Proof of Development (POD) and Proof of Manufacturing (POM) units, laboratory and in-water test and evaluation as well as modeling and simulation, if necessary. Once the upgraded design has been demonstrated as acceptable, a production contract will be competitively placed and hardware will be delivered to the Fleet IMA, following successful factory acceptance testing.

Torpedo software acquisition activities via the Torpedo APB program solicit inputs from the Science and Technology (S&T) community, including small businesses, as well as leveraging advancements from other undersea programs. It evaluates and selects the most promising solutions using common development and evaluation tools prior to implementation. Types of APB improvements include Signal Processing Algorithm Enhancements and Weapon Control Improvements. The Torpedo APB process for software enhancements is based on the existing and proven Submarine Acoustic APB four-step process:

1) Evaluation,
2) Assessment,
3) Implementation, and
4) System Assessment.

TMU/APB is embodied in three primary thrusts. First, obsolescence upgrades address production obsolescence and reduce total-ownership cost. Upgrades are planned every two years to leverage the APB cycle. Second, Advanced Processor Builds focus on software product to improve performance through increased effectiveness. Hardware compatibility is maintained within a technology insertion baseline. Third, hardware technology insertions are major hardware upgrades to enable further increase in torpedo effectiveness. Hardware technology insertions are accomplished at the inventory-maintenance due date.

Table 1. Torpedo Configurations

ACQUISITION PHASE

	"Technology Development" and "Engineering and Manufacturing Development" (RDT&E) Introduce New Capability	"Production and Deployment" (WPN) Build FIRs	"Operations and Sustainment" (OMN) Maintain the Inventory
Mod 6 baseline			• Sustainment "severe" obsolescence kit upgrade candidate • Reliability
Mod 6 ACOT			• Sustainment • Reliability • Maintenance s/w build
Mod 7 CBASS	• TMU Program • CBASS FOC (APB Spiral 4) • Develop New s/w algorithms (APB Spiral 5)	• CBASS Kit Production • Obsolescence • Open Architecture (APB Spiral 5)	• Sustainment • Reliability • Maintenance s/w build
Mod 8	• TMU Program • CDD requirements • Develop new h/w solutions (APB Spiral 6)		

Table 1 applies to torpedo lifecycle phases and various configurations of the active torpedo inventory, as described in the previous section. The information in this table shows the current activities that are occurring in each phase.

From the perspective of the "Technology Development" and "Engineering and Manufacturing Development" phases, the focus is on introduction of new capability. Introduction of new capability is tied to user requirements and transitioning technology developed by the Office of Naval Research (ONR). The CDD is currently being updated, and Tech Insertion 1 (new array ~ MK48 Mod 8) is being defined. The Enterprise is examining new CDD requirements and determining whether the existing capability of the MK48 Mod 7 CBASS can address any requirements gaps and whether the schedule for a new array is compatible. If so, then funding associated with the new array (Tech Insertion 1) could be re-programmed. From the software perspective, specific focus at this time is on delivery of an APB Spiral 4 software product, which provides the Full Operating Capability (FOC) for CBASS Mod 7. APB Spiral 5 software is currently being defined per the CDD.

From the perspective of the "Production and Deployment" phase, the government buys to a performance specification (government-controlled baseline). Also, the government awards annual production contracts and is prohibited from buying any material in advance of need (i.e., the torpedo program does not have multi-year procurement authority). Obsolescence issues with the current, contractor-controlled hardware design are discovered at contract-award on an annual basis. The extent of the obsolescence issues can result in reducing the quantity of kits procured. Furthermore, changing the design can result in unplanned software builds, which can also affect the quantity of kits procured. Reduction in kit quantity affects in-service supportability planning, particularly for the oldest torpedo configuration being supported since this configuration is the candidate pool for upgrade hardware coming off the production line. In addition, the Torpedo Enterprise is in the market-research phase of separating hardware/software interdependence via investment in Open-architecture solutions. Future upgrades in this area may necessitate changing the design and can result in further unplanned software builds.

As seen in Figure 4, from the perspective of the "Operations and Sustainment" phase, there is a fixed budget year-to-year, and the Torpedo Enterprise has three configurations in the Fleet that they are required to maintain: MK48 Mod 6 baseline, MK48 Mod 6 ACOT, and MK48 Mod 7 CBASS.

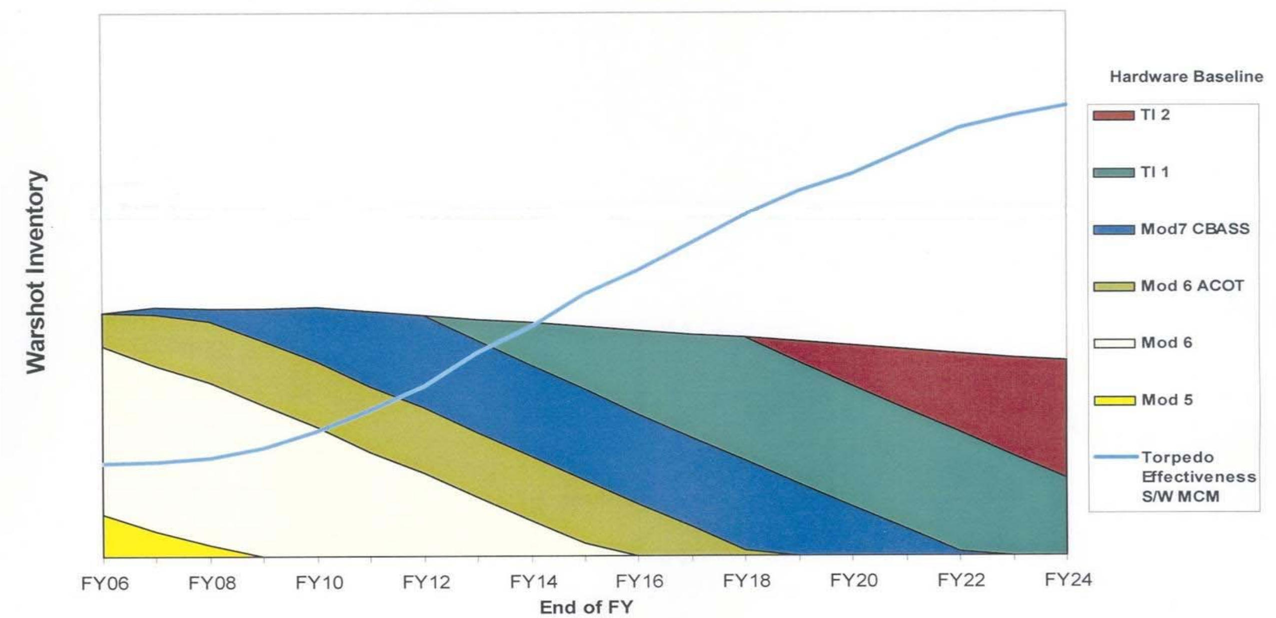

Figure 4. Planned Torpedo Configurations per Fiscal Year

The MK48 Mod 6 baseline configuration is faced with the most severe obsolescence impact and, therefore, the worst-case sustainment problem. These torpedoes are the candidate upgrade torpedoes (i.e., they will receive the resulting new production torpedo kits). The upgrade process creates spare parts for sustainment of the balance of the MK48 Mod 6 baseline inventory. Unexpected delays in receipt of production hardware for any reason mean that sustainment of this torpedo configuration is extended and is more costly than initially planned. Typically, software upgrade builds are not associated with the MK48 Mod 6 baseline configuration.

The MK48 Mod 6 ACOT configuration must be sustained since it comprises a large percentage of the inventory and will be in the inventory for many years. There may be high-priority software problems, which require unplanned maintenance builds that are not part of the APB process.

The MK48 Mod 7 CBASS configuration is just entering the "Sustainment" phase as CBASS units make their way from production to in-service. The supportability strategy is still evolving. Currently, all MK48 Mod 6 ACOT and MK48 Mod 7 CBASS torpedoes are produced by the same prime contractor. The Torpedo Enterprise FY09/10 procurement is competitive.

This could result in a different hardware baseline (the contractor controls the drawing baseline and the government controls the specification baseline). It remains to be seen what types of unplanned sustainment problems we will encounter with MK48 Mod 7 CBASS over its lifecycle.

Unplanned software builds for the MK48 Mod 6 ACOT or MK48 Mod 7 CBASS configurations divert resources from ongoing sustainment and reliability efforts, which are planned within the fixed budget.

Planning in the Torpedo Enterprise

In any given year, the program office has finite Research Development Test & Evaluation (RDT&E), Weapon Procurement, Navy (WPN), and Operations and Maintenance, Navy (OMN) budgets. The decisions to be made on how to expend these budgets are challenging. On a yearly basis, there is a torpedo production contract for some number of torpedo kits from the contractor. This raises several questions that must be answered. Is it possible to purchase the materials for the current design? If not, how extensive is this obsolescence problem? Is this just a matter of form, fit or functional replacement, or should effort be expended on the design of a new piece of hardware? Since the torpedo does not fully conform to a modular open system approach (MOSA), the implications of designing a new piece of hardware to meet a production contract are numerous and potentially expensive since a new software build will need to be synchronized with the hardware design. This will require careful planning as to where to introduce it into the program as well as resources to enable it to come to fruition. Another budget consideration is in the area of RDT&E, with respect to evolutionary acquisition of hardware and software. The Enterprise plans for technology insertions, and Advanced Processor Builds are in the forefront of the development community.

Unlike many other programs, the Torpedo Enterprise is not currently procuring new all-up-round torpedoes. At this time, FIRs are being procured to support upgrade of inventory quantities. The torpedo inventory is exercised in the Fleet, and torpedoes may become candidates for the upgrade pipeline based on budgets and “op-tempo” requirements. The torpedo has a number of FIRs and several specialized cable interconnects. Most mechanical and some other subassemblies are available in sufficient quantity and are maintained during routine turnaround periods. The persistent question is whether there are enough subassemblies on-hand to continue to keep up with current inventory requirements. If production is to be re-initiated, how will this be done? A decision to begin production of one or more FIRs is also an opportunity to consider upgrading other FIRs that may currently meet the needs but have not taken advantage of technological advances that could significantly increase capabilities.

Other complications may be introduced if the strategic guidance points to the sale of the torpedo to a foreign ally, or if there is a requirement to increase US inventory. A new torpedo variant may be produced with FIRS either off-the-shelf (existing designs), new (new production of an existing design) or newly designed. In addition to this complex combination of requirements is the desire to shift business models and move from a sole-source contract with a major industry partner to a competitive, cost-plus contract with potentially multiple industry partners for single FIRs.

Based on the challenges presented, it was decided that the Torpedo Enterprise would benefit from a decision model capable of balancing these conflicting demands while keeping the weapon’s efficiency and inventory effectiveness at or above minimum, specified levels. Typical scenarios and questions that face the decision-maker are listed below:

1. Given an incremental development strategy and a minimum system-effectiveness level, what budget do we need? Is it cost effective to maintain the current torpedo configurations?
2. Given that we know we have to plan for obsolescence and maintain inventory, which component, in which year, and in what quantity should we replace?

The system maintenance and upgrades are performed in cycles—each cycle focuses on technology insertions and refreshes for a set of components only. As is the case in real-world situations, there are budget and time constraints that limit the number of components that can be selected for upgrade as part of any cycle. The goal of the decision-maker is to identify the components for upgrade during each cycle, with the cycles being distributed over the lifetime of the system to ensure that some metric related to system performance is satisfied or maximized.

3. In the phase of "Operations and Sustainment," if an unplanned software build is required, what do we forgo in the area of reliability improvements and sustainment? If a downward trend in component reliability becomes apparent, what do we forgo in the area of software maintenance improvements and sustainment? Is unit quantity on the production contract impacted?
4. How should we allocate budgets between design upgrades and sustainment to maintain inventory at a minimum effectiveness level? If we progress to a modular design in the near-term, what budget becomes available for sustainment?
5. If we have fixed resource levels (other than budgets), what work can we accomplish given a minimum effectiveness requirement level?

Resource Optimization Modeling

A basic mathematical model for planning in the evolutionary acquisition process, as well as optimizing the budget required to maintain minimum system efficiency, is developed below. A single product efficiency maximizing model is first constructed. Given that the product is assumed to consist of N components, let the efficiency of component *i* in period *t* be denoted by f_{it}. The overall efficiency of the product is, for now, assumed to be a linear product of the efficiencies of all the constituent efficiencies. Thus, the efficiency in period *t* is:

$$S_t = \prod_{i}^{N} f_{it} \tag{1}$$

Various definitions of efficiency and effectiveness can be used to obtain a measure like Equation 1. For example, one definition of efficiency is the competence in performance (Blanchard, 2003). With this definition, the efficiency of each component can be referenced against the current capability of an opposing technology threat. Thus, a typical torpedo component such as an IMU, which is capable of maintaining a specified precision that met the needs at design-time, may be considered to have a lower efficiency when placed in operation against a newly developed, opposing technology threat that requires greater precision to neutralize. Another definition of efficiency is the accomplishment of or the ability to accomplish a job with a minimum expenditure of time and effort—if the existing range and endurance of the weapon is not capable of meeting current threats under all conditions, this can be captured by a degraded performance/efficiency metric. A related concept that can be applied instead is that of effectiveness. Effectiveness is usually defined as the adequacy in accomplishing a purpose (Fabrycky & Blanchard, 1991).

If B_t is the budget available for upgrading the product in period *t*, a mathematical formulation for determining the optimal upgrade strategy for maximizing the minimum efficiency required can be constructed. For this, let the value of binary variable X_{it} determine whether or not a component is upgraded in period *t*. The formulation follows:

Maximize Minimize System Effectiveness = Z (2)

subject to:

$$Z \leq S_t \quad \forall t \tag{3}$$

$$S_t = \prod_{i}^{N} f_{it} \quad \forall t \tag{4}$$

$$f_{it} = \max\{X_{it}, f_{it} * f_{i(t-1)}\} \quad \forall i, t \tag{5}$$

$$\sum_{i=1}^{N} X_{it} * c_i \leq B \quad \forall t \tag{6}$$

$$X_{it} \in \{0,1\} \quad S_t \geq 0 \tag{7}$$

In this model, the objective function represents the minimim efficiency attained by the product over the planning horizon. This minimum obtains its value from Equation 3, where SE_t is the efficiency of the product in period *t*. Inequalities (Equation 4) compute the efficiency of the torpedo in each period as the product of efficiencies of the constituent components. Equation 5 sets the efficiency of a component by either degrading the efficiency of the same component in the previous period by a discount factor (assumed constant here) or, if the component has been renewed, the efficiency is set to 1. In Equation 6, the cost expended in each period is maintained within the budget for the period—in this case, this is assumed to be the same throughout. Finally, the binary variables and system-efficiency variables are appropriately designated in Equation 7.

As formulated above, this model is non-linear; however, it can be log-linearized. Using a log-linearized version, a hypothetical scenario is illustrated using parameters from Table 2.

Table 2. Parameters for a Log-linearized Version Model

Component	1	2	3	4	5	6
Replacement Cost (x1000)	\$100	\$50	\$120	\$50	\$75	\$120
Degradation Factor/yr	0.95	0.98	0.92	0.99	0.875	0.92

Table 2 shows the replacement cost of a component and the degradation factors that are applied to the component on an annual basis. Thus, if component 5 is not replaced for three years, its effective degradation factor is $(0.875)^3 = 0.67$, and if all components other than component 5 are renewed annually, the system efficiency in period 3 would be 0.67 as well.

Using this data, the optimal solutions for a 10-year horizon, obtained using the formulations given in Equations 2-7 and a continuous replacement budget of $250,000 per year, are shown in Table 3.

Table 3. Optimal Solutions for a 10-year Horizon with $250,000-per-year Replacement Budget

Period	Component Replacement						Expenditure	System Effectiveness
	1	2	3	4	5	6		
1	1	1	1	1	1	1	515	1.00
2			1			1	240	0.81
3	1	1			1		225	0.83
4			1			1	240	0.79
5	1	1			1		225	0.81
6			1			1	240	0.77
7	1			1	1		225	0.81
8		1			1	1	245	0.80
9			1	1	1		245	0.81
10		1			1	1	245	0.78

The minimum system efficiency attained over the planning horizon is 0.77 in year 6. The model above is a highly simplified version of what occurs in reality. Practical matters that require inclusion in any “real” solution should include a more realistic deterioration factor. The formula used here is an exponential representation that assumes a constant deterioration rate, regardless of the state of the system. In practice, the deterioration functions are substantially more complicated. For mechanical components, the deterioration changes with the age of the part in a non-linear manner. Some electronics components fail at a higher-than-normal rate during an initial “burn-in” period but subsequently stabilize and are then subject to “random” failures.

Returning to the operational questions posed in the previous section, the model presented above can be restructured to provide answers as detailed below.

1. **Given an incremental development strategy and a minimum system-effectiveness level, what budget do we need? Is it cost effective to maintain the current torpedo configurations?**

This question is immediately addressed by altering the basic model configuration of Equations 2-7 in the following manner. The objective is reconfigured as a cost function, say, Minimize $\sum_{t=1}^{T} Budget \ for \ period \ t$,

and the system effectiveness for each period is constrained to meet a minimum requirement, η. This gives the efficiency constraints as:

$$\eta \leq S_t \quad \forall t \tag{8}$$

The budget for each period is then included as a decision variable, and constraints (6) are dropped from the formulation.

Using the data from Table 3, if a minimum system effectiveness of 0.75 is required for any given year, the upgrade strategy and minimum budgets necessary for meeting this requirement, computed using the modified model, are calculated as shown in Table 4.

Table 4. Upgrade Strategy and Minimum Budget Requirements

Year	1	2	3	4	5	6	7	8	9	10
Budget $ (X1000)	515	75	295	240	220	295	220	175	195	195
Component Upgrades	All	5	1,3,5	3,6	2,4,6	1,5,6	2,3,4	1,5	5,6	3,5

Figure 5 shows the budget requirements for the entire planning horizon (10 years) as a function of changing system-effectiveness specifications.

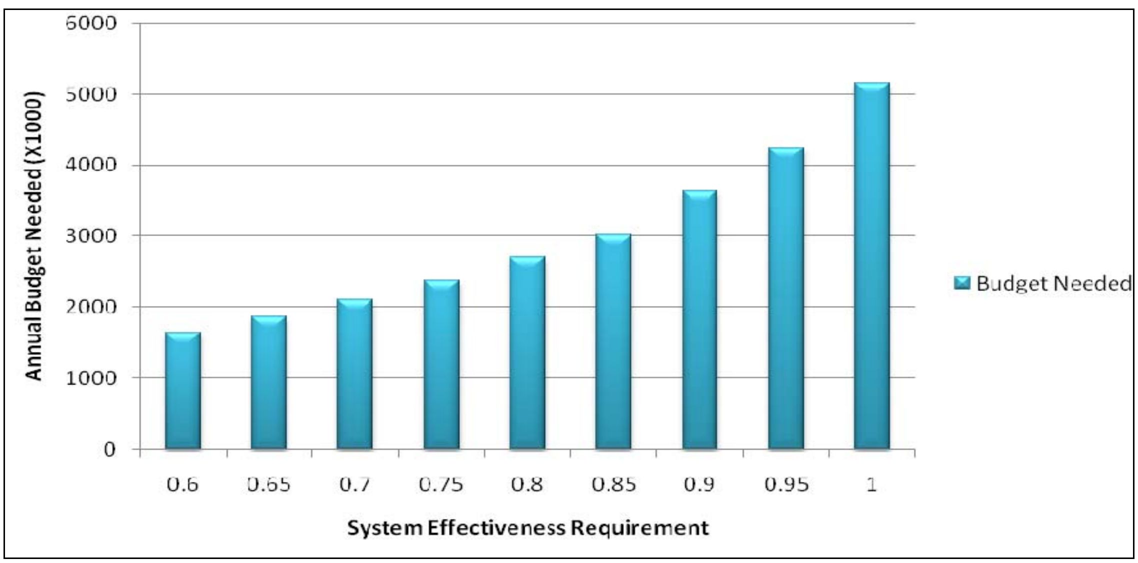

Figure 5. Budget Requirements as a Function of System Effectiveness

2. Given that we know we have to plan for obsolescence and maintain inventory, which component, in which year, and in what quantity should we replace?

Given the long lifecycle of torpedoes and the emphasis on the use of COTS components, the issue of obsolescence can occur frequently. Based on the analysis by Porter (1998), obsolescence can be addressed in several ways, as shown in Table 5.

Table 5. Obsolescence in COTS Components

OBSOLESCENCE SOLUTION	APPLIES TO (COMPONENTS)	COST
By selecting interchangeable replacement component	All	Minimal
Selecting alternate sources for components (which can require recertification)	All	Low/Medium
Use of alternate "upscalable" components found to be suitable based on screening to meet or exceed performance requirements	Electronic	Low
Part emulation, using newer-technology components that are packaged in the same form factor as the original part, that will emulate the component's functionality	Electronic, Electrical	Low
Use of a 3rd-party source to hold the manufacturing plans for the component at a future point in time	Electronic, Mechanical	Medium
Use of newer fabrication techniques for replacement of either a component or a component group	Electronic	Medium
Last-time buy of components	All	Medium
Line Unit Redesign (LRU)	All	High

In most cases, there is some advance notification of obsolescence. As shown in Table 6, the cost of mitigating obsolescence can vary, and, as it becomes clear that lower-cost solutions are not available, valuable budget- and effort-resources must be diverted from other activities in a timely manner for this purpose. The problem of planning resource expenditures to meet obsolescence has been previously considered in Brown, Lu, and Wolfson (1994), Rajagopalan (1992), Rajagopalan, Singh, and Morton (1998, January), and Singh and Sandborn (2006, April-June). In Brown et al. (1994), the obsolescence of a single item is evaluated under the assumption that obsolescence can occur unpredictably in future periods. Rajagopalan et al (1998) considers a planning model that determines how much capacity in current technology must be procured, assuming that deterioration and breakthroughs are uncertain—but distributionally known—for future periods.

This model can accommodate future obsolescence by adjusting the component efficiency appropriately. In particular, the parameters $f(i)$ can be replaced by $f(i,t)$, and a change can be forced in period t by setting $f(i,t)$ to 1 for the appropriate period.

3. **In the phase of "Operations and Sustainment," if an unplanned software build becomes required, what do we sacrifice in the area of reliability improvements and sustainment? If a downward trend in component reliability becomes apparent, what do we sacrifice in the area of software maintenance improvements and sustainment? Is unit quantity on the production contract impacted?**

A downward trend in component reliability may be tolerable in the short–term, if the overall system efficiency is not reduced below acceptable levels. Again, this can be accommodated with the model above by adding constraints on efficiency, η_t ,as shown in Equation 9.

$$S_t \geq \eta \quad \forall t \tag{9}$$

The objective function in this case can directly address the budget instead of targeting the minimum system efficiency.

As an example, if the drop in the efficiency rate of component 1 is assumed to be as shown in Figure 6, then the replacements recommended by solving the model and the budget requirements for the 10-year horizon are also as shown in Table 6.

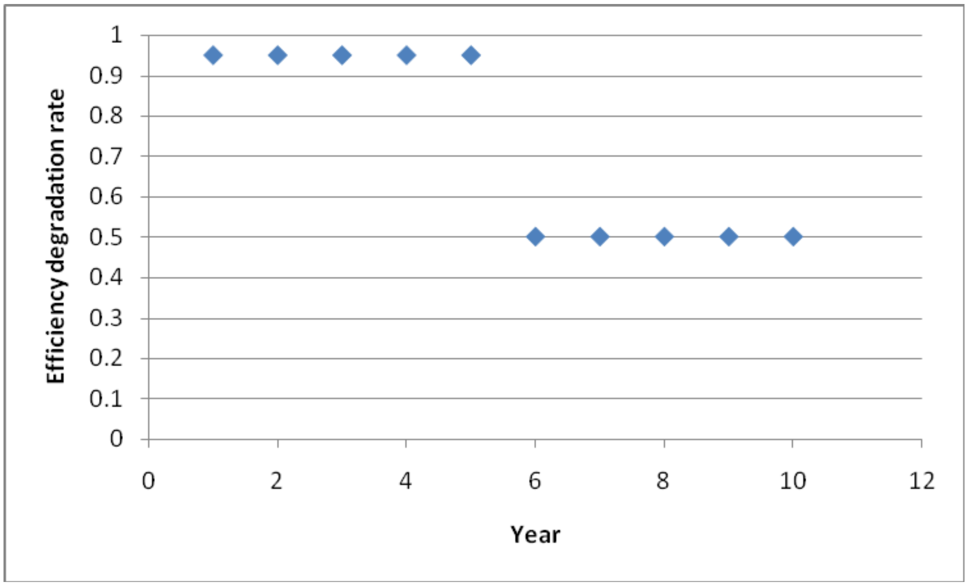

Figure 6. Drop in Efficiency of Component 1 in a 10-Year Horizon

Table 6. Upgrade Strategy and Budget Requirements Related to a Drop in the Efficiency of Component 1

Year	1	2	3	4	5	6	7	8	9	10
Budget $ (X1000)	515	75	340	125	245	220	275	295	220	225
Component Upgrades	All	5	1,3,6	4,5	2,3,5	1,6	1,2,4,5	1,5,6	1,3	1,2,6
System Effectiveness	1	0.78	0.82	0.76	0.76	0.77	0.78	0.76	0.76	0.76

4. How should we allocate budgets between design upgrades and sustainment to maintain inventory at a minimum effectiveness level?

Addressing budgets between design upgrades and sustainment to maintain inventory requires expansion of the model to include either/or choices for upgrades. This can be accommodated by adding binary choice variables and bringing these into the budget calculations appropriately. As an example, if there are several choices for upgrades (A_1, A_2, A_3, etc.) and the corresponding budgets for these are (B_1, B_2, B_3,etc.), then the choice can be enforced by imposing

$$A_1 + A_2 + A_3 \ldots \leq 1 \tag{10}$$

and the exact budget restriction is obtained by

$$B_1 A_1 + B_2 A_2 + B_3 A_3 \ldots \leq Total\, budget\, available. \tag{11}$$

5. If we have fixed resource levels (other than budgets), what work can we accomplish given a minimum effectiveness level?

The answer to this can be derived from the model by including additional constraints, limiting the use of various resources. Instead of the single constraint

$$\sum_{i=1}^{N} X_{it} * c_i \leq B \quad \forall t,$$

a set of constraints, identified by the index m, can be included as

$$\sum_{i=1}^{N} X_{it} * c_{im} \leq B_m \quad \forall m, t, \tag{12}$$

where B_m is the limit of resource type m available.

Multiple-product Evolutionary Design

Figure 7 illustrates a time-compressed representation of typical ongoing activities in progress in the Torpedo Enterprise. Three major acquisition projects, in different stages of realization, are shown simultaneously. In reality, the number of projects in play at the same time is in excess of a dozen.

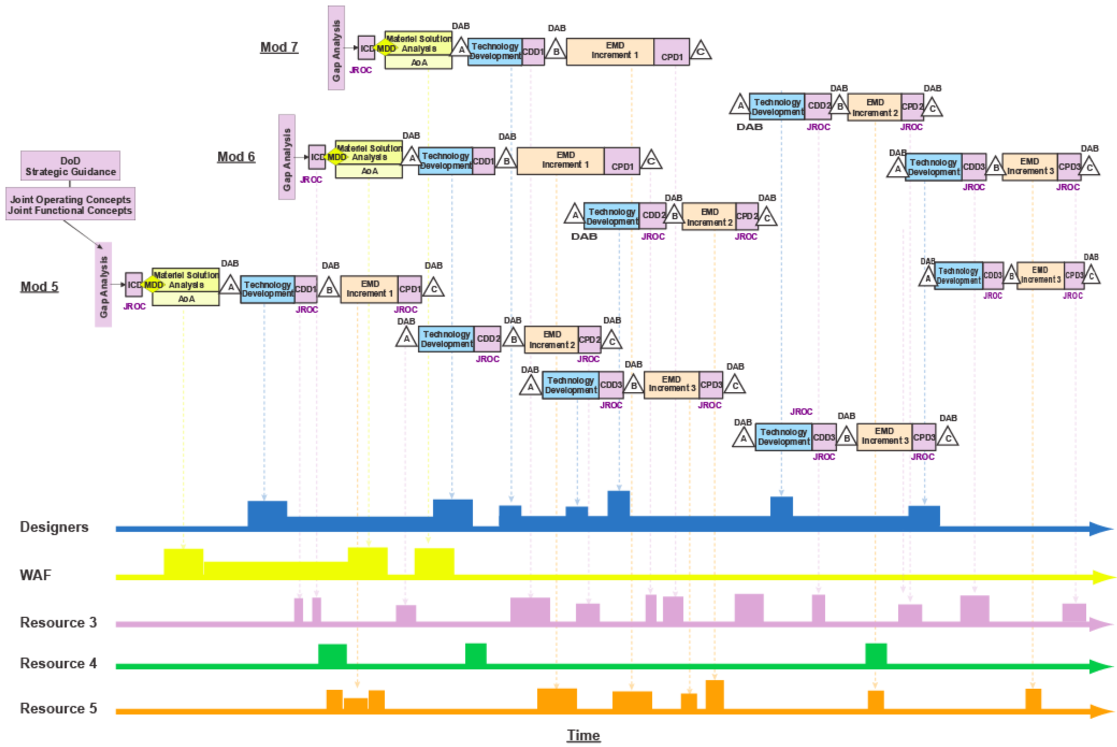

Figure 7. Multiple Cycles of the Torpedo Enterprise

As mentioned in the historical overview, as a result of emergent threats and technology upgrades, several designs of the torpedo are in service in the Fleet at any given point in time. In addition, because overall torpedo inventories are fixed, the upgrade process involves coordination of Fleet exercises, depot workloads, transportation times between locations, spares' availability and several resource considerations. Based on the depiction in Figure 7, the planning task involves determining not only the levels of effectiveness obtained by upgrading existing inventory, but also the scheduling of different design and maintenance activities over an extended-time horizon. Models 2-7 can be extended to include these considerations, but the resultant model is a large, mixed-integer programming formulation. Although this model has been solved for test cases using commercial mathematical-programming software, the solution times are considerable, and work on improving the solution efficiency is ongoing.

Conclusion

Planning in the Torpedo Enterprise is difficult because of various unique constraints. One of these is that the Torpedo Enterprise has not been procuring new torpedoes for the past two decades. New upgrades are introduced into the Fleet by taking existing inventory offline and updating specific hardware and software components. As discussed in the historical background section, changes in threats and new technology opportunities have resulted in multiple torpedo configurations concurrently in the Fleet. This compounds the planning problem. When budget decisions have to be made, torpedo effectiveness, inventory effectiveness, software capability upgrades, and technology insertions and refreshes must all be taken into consideration. To assist the decision-makers, a mathematical model has been developed that enables satisfaction of system-effectiveness requirements while meeting budgetary and programmatic constraints. This model is a linear, mixed-integer model, and it can be solved for problem sizes matching those corresponding to the decisions typically encountered in the torpedo domain within reasonable computation time. This model can be extended to answer typical programmatic questions such as the budget required to meet prescribed levels of system effectiveness, planned obsolescence upgrades, and tradeoff decisions between software upgrades, reliability improvements, or sustainment planning. The use of this model for multiple-project planning with several resource types is also presented. Program management, using the *DODI 5000.02*-prescribed framework (DoD, 2008, December 8), may reduce some uncertainties in resource utilization, but it does not eliminate them. The uncertainty remnants include reliability failures, resource reduction, component obsolescence, technology upgrades, and threat changes. The task of managing multiple projects and optimizing project resources remains a complicated endeavor.

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Panel 20 - Acquisition Program and Policy Analysis

Thursday, May 14, 2009	Panel 20 - Acquisition Program and Policy Analysis
3:30 p.m. – 5:00 p.m.	**Chair: Dr. Douglas A. Brook**, Director, Center for Defense Management Research, Naval Postgraduate School; former Acting Under Secretary of Defense (Comptroller) ***Examining the Institutional Factors Affecting Cost Growth in Defense Acquisition: Additional Insights May Yield More Effective Policy Interventions*** **Phil Candreva**, Naval Postgraduate School ***An Assessment of DOD's Acquisition Outcomes, Initiatives for Change, and Future Challenges*** **Michael Sullivan**, Government Accountability Office ***When Instructions Provide Too Much Flexibility, Establish Rules*** **J. David Patterson**, University of Tennessee

Chair: Douglas A. Brook, PhD, teaches and researches large-scale issues of budgeting and management in the Navy and DoD. He is interested in the management agendas of Navy and DoD senior leaders—what they are, where they come from, how they work, and what they accomplish—and in how senior leaders deal with resource-allocation challenges that they face as defense managers. Brook has served as Acting Under Secretary of Defense (Comptroller), Assistant Secretary of the Navy (Financial Management & Comptroller) and Assistant Secretary of the Army (Financial Management).

Examining the Institutional Factors Affecting Cost Growth in Defense Acquisition: Additional Insights May Yield More Effective Policy Interventions

Presenter: Phil Candreva's research investigates how government organizations use financial information in such areas as resource allocation decision-making, accounting, performance measurement, and management reform. Most contemporary public sector management reform efforts are either explicitly tied to financial decisions (e.g., performance-based budgeting) or are implicitly tied through other management efforts (e.g., efficiency programs). Since budgets are the battlefield on which public policy disputes are waged, public managers must become proficient at showing how effectively and efficiently those resources are being used in order to preserve or expand their resource base. Such efforts are a critical dimension of contemporary management reform.

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Executive Summary

The US Defense Department suffers from persistent, but not certain, cost growth within major acquisition programs. Over the past few decades, scores of empirical studies have examined the causes and consequences of cost growth and have shed light on characteristics of programs that fail to meet cost-performance goals. They have looked at factors such as the size of the program, its phase in the development cycle, the type of weapon being purchased and organizational structure. Other studies have taken a more qualitative view and have considered the interplay of actions within a program office and between a program office and its environment. Both types of studies have provided countless recommendations to fix defense acquisition. Yet, problems persist.

The question motivating the present study is: given the materiality of the problem (hundreds of billions of dollars), the number of times it has been studied, the attention of the highest levels of government, and numerous attempts to reform acquisition, why does the problem persist? What have the studies and policy prescriptions missed?

Two recent and important deviations from the norm of past studies focused less *on* the acquisition program and more on the decisions made by officials *about* the program. This paper was motivated by those studies and was further informed by various literatures, including behavioral finance, group decision-making psychology, and organizational failure. First, cost growth is a matter of financial behavior—allocations are made; funds are applied to particular objects of expense based upon estimates; new information becomes available and reallocations occur; additional funds are requested on a regularly recurring annual cycle. There are well-known biases in financial behavior derived in other contexts that may exist in defense acquisition. Second, some of those decisions are made by individuals, but many are group decisions. Fully informed, rational decisions may not be possible in the defense acquisition context because of political considerations, information limitations, limitations on information-processing capabilities, mental models and heuristics, the experience of participants, and other

factors. Third, there is a growing literature on the causes of organizational failure, and by most definitions, persistent cost growth is an example of such failure. Many of those studies cite sociological and cultural factors as causes. It is apparent that a sociological approach, rather than an economic or systems engineering approach, has the promise to provide fresh insights into an old problem.

This paper makes the case for the application of a framework taken from the worlds of political science and sociology to gain a better understanding of the problem of cost growth. The Institutional Analysis and Diagnosis (IAD) framework has been used to study the dynamics of complex decision-making processes involving collective resources. Those situations are similar to the resource-allocation processes in the DoD. The framework is focused on "action arenas" composed of actors who decide from among diverse actions based upon the role they play, their individual preferences, the information they possess, and the expected payoffs from potential outcomes. These action arenas are not situated in a sterile context. They are affected by the attributes of the environment, attributes of the communities within which the actors identify, rules, and institutional norms. Within the action area, patterns of interaction result in outcomes that can be evaluated based on some criteria.

While the DoD has codified processes that dictate how the PPBE process chooses programs and funds them and how acquisition programs operate, those rules are augmented and contravened by institutional norms. Changes to rules face cultural obstacles. A GAO Report (GAO-09-295R, 2009, February 27) commented on recently proposed reforms, "Our discussions with acquisition experts indicate that these changes may not achieve the desired improvement in acquisition outcomes unless they are accompanied by changes in the overall acquisition environment, its culture, and the incentives provided for success." The effect of culture on acquisition program performance is acknowledged, but it is not well understood. Given a better understanding, decision-makers can design more effective policy interventions.

Toward that end, this paper illustrates the application of the IAD framework to defense acquisition. The data set is a collection of studies of defense acquisition cost growth from government organizations, academics, and think tanks. Using a software tool, the content of those reports is analyzed according to the IAD framework.

The report then proposes a stream of research using the IAD framework—in conjunction with theories of behavior finance, group decision-making, and organizational failure—to improve our understanding of the dynamics and factors that result in cost growth. This framework has been successfully employed in other contexts to perform both qualitative field research and laboratory experimentation. Thus, the report proposes a mutually supportive set of studies that combine the realism of field studies with the ability to rigorously test hypotheses through models in computational and laboratory experiments.

By studying institutional variables that have not previously been considered, we may gain fresh insights on the problem. Those insights will provide an understanding of how and why various policy prescriptions may or may not result in better outcomes. By considering and applying various remedies in a laboratory setting, we may be able to design more effective policy interventions.

Defense Acquisitions: Assessments of Selected Weapon Programs

Presenter: Michael J. Sullivan

Why GAO Did This Study[1]

This is the GAO's seventh annual assessment of selected Department of Defense (DoD) weapon programs. The report examines how well the DoD is planning and executing its weapon acquisition programs, an area that has been on the GAO's high-risk list since 1990.

This year's report is in response to the mandate in the joint explanatory statement to the *Consolidated Security, Disaster Assistance, and Continuing Appropriations Act, 2009*. The report includes (1) an analysis of the overall performance of the DoD's 2008 portfolio of 96 major defense acquisition programs and a comparison to the portfolio performance at two other points in time—5 years ago and 1 year ago; (2) an analysis of current cost and schedule outcomes and knowledge attained by key junctures in the acquisition process for a subset of 47 weapon programs—primarily in development—from the 2008 portfolio; (3) data on other factors that could impact program stability; and (4) an update on changes in the DoD's acquisition policies. To conduct our assessment, the GAO analyzed cost, schedule, and quantity data from the DoD's Selected Acquisition Reports for the programs in the DoD's 2003, 2007, and 2008 portfolios. The GAO also collected data from program offices on technology, design, and manufacturing knowledge, as well as on other factors that might affect program stability. GAO analyzed this data and compiled one- or two-page assessments of 67 weapon programs.

What GAO Found

Since 2003, the DoD's portfolio of major defense acquisition programs has grown from 77 to 96 programs, and its investment in those programs has grown from $1.2 trillion to $1.6 trillion (fiscal year 2009 dollars). The cumulative cost growth for the DoD's programs is higher than it was 5 years ago, but at $296 billion, it is less than last year when adjusted for inflation. For 2008 programs, research and development costs are now 42% higher than originally estimated, and the average delay in delivering initial capabilities has increased to 22 months. The DoD's performance in some of these areas is driven by older programs, as newer programs, on average, have not shown the same degree of cost and schedule growth.

[1] Previously published as GAO-09-326SP, March 2009.

Figure 1. Analysis of DoD Major Defense Acquisition Program Portfolios
(Fiscal Year 2009 Dollars)

Portfolio status	Fiscal year 2003 portfolio	Fiscal year 2007 portfolio	Fiscal year 2008 portfolio
Number of programs	77	95	96
Total planned commitments	$1.2 trillion	$1.6 trillion	$1.6 trillion
Commitments outstanding	$724 billion	$875 billion	$786 billion
Change to total research and development costs from first estimate	37 percent	40 percent	42 percent
Change in total acquisition cost from first estimate	19 percent	26 percent	25 percent
Estimated total acquisition cost growth	$183 billion	$301 billion[a]	$296 billion
Share of programs with 25 percent or more increase in program acquisition unit cost	41 percent	44 percent	42 percent
Average delay in delivering initial capabilities	18 months	21 months	22 months

(GAO analysis of DoD data)

[a]Last year, the GAO reported total acquisition cost growth for the fiscal year 2007 portfolio was $295 billion in fiscal year 2008 dollars. This figure is now expressed in fiscal year 2009 dollars.

For 47 programs the GAO assessed in-depth, the amount of knowledge that programs attained by key decision points has increased in recent years; but most programs still proceed with far less technology, design, and manufacturing knowledge than best practices suggest and face a higher risk of cost increases and schedule delays. Early system engineering, stable requirements, and disciplined software management were also important, as programs that exhibited these characteristics experienced less cost growth and shorter schedule delays on average. Program execution could be hindered by workforce challenges. A majority of the programs the GAO assessed were unable to fill all authorized program office positions, resulting in increased workloads, a reliance on support contractors, and less personnel to conduct oversight.

In December 2008, the DoD revised its policy for major defense acquisition programs to place more emphasis on acquiring knowledge about requirements, technology, and design before programs start and on maintaining discipline once they begin. The policy recommends holding early systems engineering reviews; includes a requirement for early prototyping; and establishes review boards to monitor requirements changes—all positive steps. Some programs we assessed have begun implementing these changes.

When Instructions Provide Too Much Flexibility, Establish Rules Defense Acquisition Performance Assessment Redux: Unpredictability, Uncertainty and Program Failure: Implementing a Rule-set Can Be the Fix

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Abstract

More than three years have passed since the Defense Acquisition Performance Assessment (DAPA) project was completed and the results briefed to the study's sponsor, the Deputy Secretary of Defense. In that time, the Department of Defense has issued its fourteenth major change to the Department's Acquisition System management guidance. Combined with a shortfall of experienced and skilled acquisition business professionals, the result is a pervasive and troubling level of uncertainty and unpredictability regarding defense acquisition programs. The resulting Acquisition System including Planning, Programming, Budgeting and Execution (PPBE), Requirements and the little "a" Acquisition process lacks structure and discipline. What follows is persistent failures to meet cost, schedule and performance objectives. This paper presents a case for a mandatory set of Acquisition System rules to address this problem. Though by no means exhaustive, the recommended rules fit categories in the acquisition process, the requirements process and the PPBE process -- referred to here simply as the "Budget Rules." The premise of this paper is that the right mandatory set of rules applied to Major Defense Acquisition Programs would result in weapon systems and equipment critical to warfighter success being fielded more rapidly on cost, on schedule and performing as expected.

Introduction

More than three years have passed since the Defense Acquisition Performance Assessment (DAPA) project chaired by Lieutenant General Ronald Kadish, USAF (Ret.) was completed in November 2006 and the results briefed to the Deputy Secretary of Defense, the study's sponsor. Since that time, there have been several more attempts to describe the root cause of the flaws in the Department's Acquisition System. Most studies cover the same ground plowed by the DAPA project and previous studies, dating back to the 1985 *Packard Commission Report.* Despite these numerous evaluations of the Defense Acquisition System, none have advanced the discourse beyond what has been clear from the beginning. There is a fundamental lack of a budget process and requirements discipline that leads inexorably to programs that are over cost, behind schedule and not performing. Additionally, there is one factor that is common to serious analyses of the Department of Defense (DoD) Acquisition System.

The general discussion of reforming the Acquisition System with its many subsystems, procedures, and methodologies reveals that there is a basic failure to drive predictability regarding what the DoD can expect as a product (fielded weapon system) emerging from its acquisition process. In fact there is seldom any effort to make "predictable outcome" a program management priority. All program managers try to stay within budget or cost limits, meet schedule guidelines, and produce a weapon system or piece of equipment that performs to the level of stated requirements. But, is there any real certainty that the program manager's efforts, no matter how diligent, or adherence to the acquisition process will produce the desired result? The case presented here would answer, no. The DAPA study raised the issue of the government's inability to predict cost, schedule, and performance as a self-induced symptom of "instability" (Kadish, 2006, January). It is that instability in acquisition programs that defeats efforts to meet cost, schedule, and performance objectives.

The Problem Explained

Recent analyses of the troubles experienced in the DoD acquisition of weapons systems identify instability as a significant factor in program cost growth. A 2008 RAND Corporation study on cost growth of fixed-wing military aircraft identified the “practice of rotating officers through jobs every three to four years” as creating an unstable program management workforce (Arena, Younossi, Brancato, Blickstein & Grammich, 2008). This results in a management situation where experience gained in solving management problems is not effectively used over the term of the program and not available to those entering new to the program. The Aerospace Industries Association, in its November 2008 *Special Report, U.S. Defense Acquisition: An Agenda for Positive Reform,* raised instability as an area where the Defense Department should focus management attention.

Two elements combine to create instability in the acquisition of weapon systems. First, there seems to be no lasting agreement on what should be the DoD Acquisition System policy directions. Since Deputy Secretary of Defense Packard issued the first *DoD Directive 5000.1* in 1971, the regulations documents have been revised significantly about every three years: 14 times in 38 years. As Charles Cochrane (2009, January 1) so masterfully revealed in his presentation *Acquisition Management System from 1971 to 2008*, the *DoD 5000* series documents have provided direction varying from 8 pages to 840 pages of recommendations, suggestions, regulations, policy, procedures and definitions. No single Acquisition System approach has survived for more than five years, while the length of time for Major Defense Acquisition Programs to reach full operational capability is generally three times this Acquisition System regulation change cycle. For the purposes of this paper, reference to the most recent *Department of Defense Instruction 5000.02* (2008, December 8) shown in Figure 1,[1] will be used.

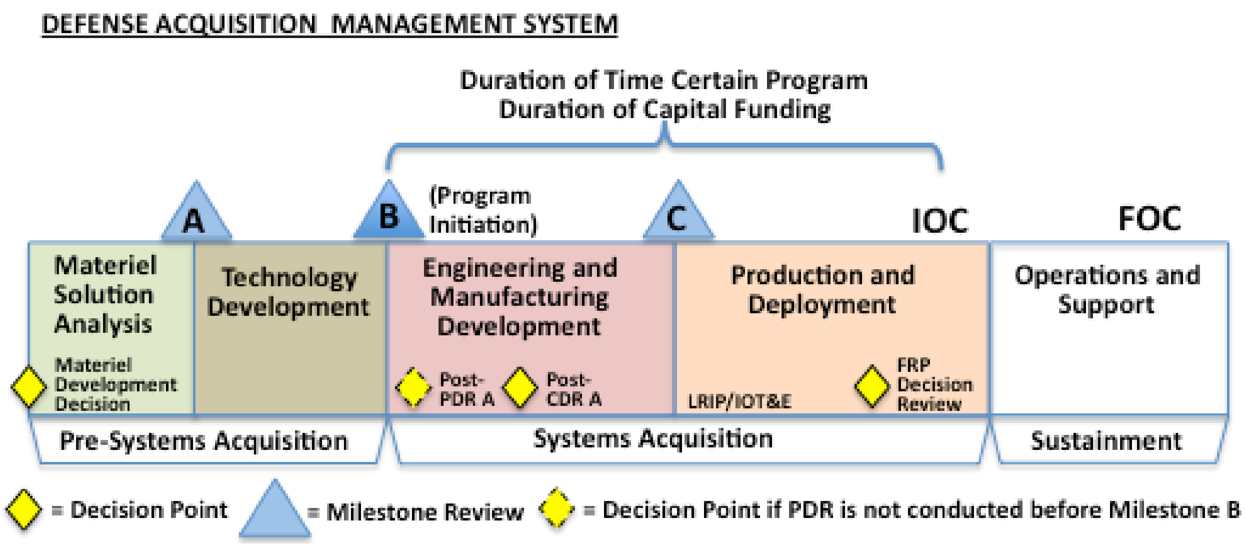

Figure 1. Defense Acquisition Management System
(used to identify where rules described later in the paper will apply)

Second, while the acquisition playing field is persistently changing, the workforce challenged with making the system successful has been reduced in numbers and experience. In the past, even though there were frequent modifications to the *5000* series Department guidance, there was also a cadre of experienced acquisition executives in the career ranks that could adjust with a modicum of disruption. The United States Senate and House Armed

[1] Adapted for use in this paper from the graphic presented on page 12 of the *DoDI 5000.02.*

Services Committees, in their respective committee reports supporting the FY 2008 National Defense Authorization Act, were very concerned that the numbers, years of experience and skill levels of the professional acquisition workforce had reached unacceptably low levels (US Congress, 2008). Particularly troublesome was the major reduction in the acquisition workforce within the Department of Defense during the 1990s, the workforce on whom the Department counted to make sense of the constantly changing *5000* series Department guidance.

However well-intentioned and necessary the Department's changes to the *5000* series guidelines were thought to be, the consequence was instability in acquisition programs—an unfortunate result of a purposeful action by department management. Instability drives uncertainty, creating an Acquisition System environment where the program outcome is unpredictable. When the program outcome is unpredictable, program risk is increased. There is a corresponding drive to reduce risk by increasing the cost as a premium or hedge against uncertainty. When the workforce does not have the experience to deal with program risk, because every program event is being seen for the first time, there is very little chance of maintaining cost, schedule and performance. The underpinning experience necessary to work through a "tried-and-true" process does not exist.

These circumstances hold true for the Acquisition System as a whole, not just for the acquisition process—or little "a" (SECDEF, 2007, July) as it is generally understood within the acquisition community. The distinction between little "a" and big "A" is best summarized with the diagram in Figure 2. Program instability is reflective of a systemic problem inherent in the big "A" versus simply fixing a process problem in the little "a." The mythology that attends the Venn diagram with the intersecting circles is that there is integration among the elements of the Acquisition System. The implication is that each of the elements contributes to and gains from being associated with the others. The intended result is a successful program defined by being on cost and on schedule and performing as expected. The reality is more accurately represented by Figure 3,[2] in which the three elements exist independently of one another by virtue of the fact that changing regulations and vague Acquisition System direction combined with an inexperienced workforce allows the independence to persist (Kadish, 2006, January).

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[2] Both Figures 2 and 3 are adaptations of figures used in the DAPA Report, p. 4.

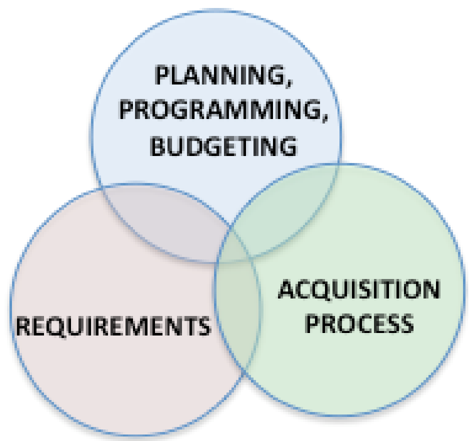

Figure 2. The Acquisition System

(This includes the Planning, Programming, Budgeting and Execution process and the Requirements process in addition to the little "a" Acquisition process.)

Figure 3. The Acquisition System

(In reality, the System is not cohesive, but more often three independent processes creating program instability resulting in cost increases schedule slips and uncertain performance.)

What results from the combination of changing acquisition regulations and a workforce that does not have a high enough number of acquisition professionals or the experience of seeing and working through a variety of program issues, is an inability to anticipate and prevent situations that put programs in jeopardy of failing the cost, schedule and performance standards. The DAPA study found that unstable programs did have a workforce component that contributed to the instability, and though there was also recognition during the subject-matter expert briefings that changing regulations and guidance might be troublesome in establishing stable programs, the combination of these two factors was not made prominent in the final report. Numerous studies have recommended solutions to the shortcomings of the Acquisition System, but for the most part, these fixes focus on the little "a" acquisition *process*, not on the larger systemic issues.

A focus on the acquisition process ("a") fails to address the larger contextual issue of the system-driven program instability. Mandating a rule set is necessary to establish discipline and structure. "Following the rules" helps to create an acquisition program where uncertainty and the resulting program instability are reduced. The need for acquisition program discipline was emphasized by Dr. Ashton Carter, newly confirmed Under Secretary of Defense for Acquisition, Technology and Logistics. Quoted in DefenseNews.com from his written testimony presented at his confirmation hearing, Dr. Carter made clear his position: "Development, procurement and sustainment of major weapon systems require experience with the Department of Defense and the defense industry, systems engineering at every stage and iron discipline" (Bennett, 2009, March 26).

The following are a set of rules for defense acquisition programs that resulted from the DAPA panel discussions, interviews, and subject-matter expert surveys conducted during the

DAPA project. This paper diverges from the DAPA project in that what the 2006 study presented as "recommendations" for consideration by the Department of Defense are offered here as "rules" to be followed. Additionally, the DAPA recommendations focused on six categories affecting the Acquisition System: organization, industry, workforce, requirements, budget and acquisition. However, only the last three categories are addressed in this paper as particularly appropriate for establishing rules to abide by for the acquisition of defense weapon systems. The list of rules is by no means exhaustive, but, rather, the list is intended to establish a foundation upon which additional rules may be considered, developed and applied. Rules that all the participants in the Acquisition System play by and are accountable to adds a level of transparency and predictability that can provide for stable programs.

Requirements Rules

For the purposes of this paper, two basic types of requirements are considered: customer requirements and derived requirements. Customer requirements are very straightforward and defined at the macro-level by approved Key Performance Parameters (KPPs)[3] and non-Key Performance Parameters.[4] Derived requirements, on the other hand, are requirements that the customer has not specified directly as a requirement but that emerge or *derive* from the design decisions that are made (Brooksby, 2003).[5]

Derived requirements are not capabilities that the customer specifically has identified. Particularly troublesome is a subset of derived requirements that fall into the category of engineering changes—those changes that improve on "good enough" and that have a combined effect of driving up costs and missing schedule milestones. In the absence of rules that prevent pursuing this type of engineering change as a derived requirement, the guiding thought process follows this logic: "because we can, we should; because we should, we must; and because we must, we will no matter how much it costs or how long it takes." According to a recent Under Secretary of Defense, Comptroller study, prepared by Monitor Company Group, L.P. and based on Selected Acquisition report data, engineering changes account for approximately 33% of the nearly $265 billion in program cost growth from 2000 to 2007 (Monitor, 2007). No doubt, some of the engineering changes were to correct design problems. However, the engineering

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[3] "Those attributes or characteristics of a system that are considered critical or essential to the development of an effective military capability and those attributes that make a significant contribution to the characteristics of the future joint force as defined in the Capstone Concept for Joint Operations. KPPs must be testable to enable feedback from test and evaluation efforts to the requirements process. KPPs are validated by the Joint Requirement Oversight Council (JROC) for JROC Interest documents, and by the DOD component for Joint Integration, Joint Information, or Independent documents. Capability development and capability production document KPPs are included verbatim in the acquisition program baseline" (CJCS, 2007, May 1). Occasionally, (some would say all too often) KPPs cannot be achieved with the level of technology existing now or in the foreseeable future. Approval of this category of KPP suffers from collective bad judgment, and no rule set will be a remedy. Consequently, this article does not address the development of this type of requirement.

[4] Non-Key Performance Parameters are requirements that are desired by the customer but not deemed critical or essential. Often, these requirements represent the trade-space in programs when budget constraints or program execution problems demand a de-scoping of the program.

[5] Though this reference defines requirements as they apply to software development, the relevance to weapons system program development generally is very compelling and appropriate and, therefore, is used here.

changes that simply improve on an otherwise sufficient, specification-compliant design while driving up costs and impacting schedule need to be reduced or eliminated.

As a result, what follows are recommended rules with appropriate rationale that should apply when considering the addition of both new customer requirements and derived requirements.

Requirements Rule One: Weapon system requirements will be fixed prior to Engineering and Manufacturing Development (EMD) or achieving Milestone B phase (see Figure 1 on page 4).

The prohibition of additional system requirements beyond the KPPs and the specific capabilities that contribute directly to them after approval for the EMD phase at Milestone B helps to ensure that Initial Operating Capability (IOC) will be met. Fielding weapon systems on schedule simply must be a program priority. By allowing requirements to be adopted beyond those identified prior to EMD, ensures that IOC will be slipped and the weapon system will not be fielded on schedule.

Requirements Rule Two: From the start of EMD (Milestone B, program initiation) to IOC, only safety-of-flight or other safety-related engineering changes will be allowed. The only exceptions are those design changes that can be proven to produce a three-to-one savings to investment while not missing schedule.

This rule addresses the insidious nature of an ever-growing number of engineering changes that routinely skulk their way into systems development. Additionally, the rule provides a potential for incentives that produce beneficial engineering changes and cost savings. Though some will attempt to insert engineering changes using “safety” as justification, specious arguments for such justification at least will have increased scrutiny, prompted by the deviation from rule two.

Requirements Rule Three: Any and all additional system requirements that are deemed essential following the start of EMD will be developed as unique block-up grades that will be introduced as blocks or variations after Full Operational Capability (FOC) has been certified (see Figure 1 on page 4).

There is a persistent need for a disciplined and structured way of incorporating meritorious capabilities enhancements to a weapon system while not disrupting the established design, cost, schedule, or performance. By following this rule, there is the added benefit of having some level of operational experience that can inform the development and insertion of weapon system improvements.

Requirements Rule Four: Holding to an established Initial Operational Capability as a time-certain for fielding the weapon system will be a Key Performance Parameter.

Weapon systems development and fielding plans must have some consideration of time-to-need as integral to the requirement for the capability. This rule makes the time-to–need, or fielding, an essential consideration in program development and planning. If there is no fully understood and accepted time by which a weapon system must be fielded, the importance of the capability to meet a threat is called into question.

Budget Rules

According to the DAPA report (Kadish, 2006, January), budget instability is a major contributor to acquisition program instability and the failure of acquisition programs to meet cost expectations. Lack of funding discipline on the parts of Congress, the military, and the Defense Department produces acquisition programs that are targeted as bill payers for other funding priorities or that are under-funded because of poor cost estimating.

In his written confirmation statement submitted to the Senate Armed Forces Committee and reported in DefenseNews.Com, Dr. Ashton Carter emphasized the importance of having "stable funding" (Bennett, 2006, March 26). He considered stable funding a key factor in choosing whether a weapon system contract is a fixed-price type contract or cost-plus (2006, March 26).

The DAPA report offers the following solution: the establishment of a funding account for the duration of the acquisition program from the program initiation at the beginning of EMD to IOC, referred to as a "Stable Program Funding Account" (see Figure 1 on page 4). In this article, the term "Capital Funding" is used to describe a stable funding account during the period from Milestone B, EMD to IOC that is tied to specific programs and funded by the individual Services with a fixed budgeted amount. Capital funding will apply initially only to MDAPs, though other acquisition programs could be considered. The Office of the Secretary of Defense and the Services will guarantee that programs identified for capital funding will not be used to pay other bills.

<u>Budget Rule One</u>: All Major Defense Acquisition Programs (MDAPs) will be evaluated as candidates for capital funding.

Though not all acquisition programs are suitable for a capital funding approach, MDAPs should at least be considered since these programs—because of their size—offer the most potential for reduced cost growth based on a guaranteed stable funding profile.

<u>Budget Rule Two</u>: Capital funding programs will:

a. *Have a fixed-funding profile from Milestone B (EMD) to Initial Operating Capability. Capital funding programs will not be used as bill payers during that timeframe.*

The timeframe for capital funding allows for follow-on increases in the unit quantity for the acquisition program after IOC while helping to ensure that fielding the program is on time. Put another way, this rule helps to ensure that funding is not the reason for not fielding a program on time.

b. *Provide bi-annual reports to Congress on cost-schedule and performance progress.*

Congress's responsibility and right for oversight of Defense spending must be addressed. By engaging with congressional staffs and principals to keep them informed of how effectively the Defense Department is spending taxpayer dollars for acquisition programs, the needs of Congress will be addressed. Frequent, statutorily mandated program reviews will provide Congress the opportunity to assess not only the program's progress but also the effectiveness of capital funding. The program should be reviewed with Congress twice annually. This provides congressional staff and principals an early understanding of developing trends. Failure to have a successful review (over cost, behind schedule or failing to perform) is addressed later in this paper.

c. Have a Technology Readiness Level of at least 6 at Milestone B (EMD).

Programs that move into EMD that do not have a Technology Readiness Level of 6 or better are destined to experience cost escalation, schedule slips, and unpredictable performance. Capital funding is predicated on the fact that costs can be controlled and schedule can be maintained. For capital funding to be effective, all aspects of an acquisition program must have as much stability as possible.

d. Be "time-certain" programs.

Capital funding success depends on strict adherence to a fully-agreed-to timeframe (by the government and the contractor) from Milestone B approval for EMD to IOC. This provides predictability regarding what to expect in the program in general. It also drives the government and industry program managers to be realistic in what they promise for the program and in how they propose to meet the program milestones to stay within the timeframe for system fielding.

e. Be cancelled if the program fails to meet established cost, schedule, and performance.

If a program fails to meet any one of the cost, schedule, and performance objectives established at program initiation after three consecutive congressional reviews, the program will be cancelled; not re-baselined or re-planned—cancelled. When government and industry program managers as well as the military departments and Defense Department program executives fully understand the consequences of program failure, the likely result will be greater management attention.

Acquisition Rules

Analysis of acquisition programs over time shows that programs generally grow about 50% in cost (Younossi et al., 2006). Larger Defense programs clearly are more prominent when analyzing program cost growth because the amounts of money are very large compared to programs managed by other Federal agencies. Though it may seem obvious, programs that have longer timeframes for EMD also experience greater cost growth (Younossi et al., 2006). Furthermore, missing from most, if not all, acquisition strategies is analysis that asks: "What does time, as an independent variable, do to the trade space defined by the minimum and optimum performance and cost?"

To address the importance of time as a consideration in developing acquisition strategies, the Special Assistant to the Deputy Secretary of Defense asked The Monitor Group (2003) to look at the value of establishing time as a boundary condition or driver in determining the desired timeframe between Milestone B and IOC. Time should be considered an independent variable, as should cost, especially when it is critical to field a capability in time to have a positive impact on a threat.

Time is not the only factor that works against well-run acquisition programs. We have developed an acquisition-workforce culture that has adopted "flexibility" as a means to acquiring more capable weapon systems, other equipment, and services. The consequence of this culture is that there is a deliberate attempt on the part of the acquisition community to establish the broadest interpretation of what constitutes best value, desired technology, and solicitation outcome. Unfortunately, "flexibility" often comes at the expense of discipline and structure as a means to achieve cost, schedule, and performance objectives.

Successful competitive solicitations, however, depend on discipline and structure in the way that the acquisition competition is managed. Competition management begins with development of and adherence to an acquisition management/master plan or strategy. That plan or strategy should inform the Request for Proposal and is the roadmap for the subsequent competition and program management.

<u>Acquisition Rule One:</u> *No MDAP will be considered for Milestone B certification without a comprehensive Single Acquisition Management Plan/Strategy to include at a minimum total system procurement quantity, explanation and rationale for the contracting methodology selected (i.e., prime contractor choosing subcontractors, leader-follower prime contractors, etc.), sustainment plan and how the Prime Contractor or Lead Systems Integrator will select and manage subcontractors.*

Most, if not all, programs that experience significant problems with cost, schedule, and performance have inadequate or flawed acquisition strategies or management plans. Often, the focus of the acquisition strategy is on what the weapon system should do, the plans of the Military Services to field the system, and the phasing of the number of units over time that are required. This approach, while important, does not comprise an acquisition strategy or management plan. The acquisition strategy should explain how the competition will be run; what management, technical, and cost elements are most important; and whether it will be a winner-take-all (and why that is the preferred choice), split-buy, leader/follower strategy, or some combination of each. These considerations in an acquisition strategy are important and will drive necessary program decisions in the follow-on program management.

Management and acquisition strategies should consider what must be fielded and when and how block upgrades will be completed, managed, and integrated after full operating capability is achieved. The acquisition strategy must describe how the winning contractor will manage subcontractor content. An annex to the acquisition strategy must be how the weapon system competition will be financed, and consideration must be given to any subsystem's commercial value in terms of design buy-back and production rights. In the past, the Department has either retained all of the design rights or retained none of the rights. Retaining substantial design rights while keeping open the opportunity for the contractor to benefit from any commercial markets that might emerge makes competing for the Department's business more appealing.

<u>Acquisition Rule Two</u>: *All MDAPs will be evaluated as "time-certain" programs, where the timeframe between Milestone B and IOC (see Figure 1 on page 4) will be established with a thorough analysis, using Time as an Independent Variable (TAIV). Additionally, the criteria that describe what must be accomplished in the EMD phase of the program cannot significantly change.*

When TAIV is applied to the development of an acquisition program, the importance of time in developing and defining the technology, as well as its design and production factors, are given prominence in the analysis of cost, schedule, and achieving the desired performance. Time-certain in this instance is not synonymous with schedule. Schedule is the sequential distribution of program events that, on completion, have a timeframe associated with them. We measure schedule with milestones accomplished. TAIV, on the other hand, is the analytic construct that identifies which out of a given list of performance capabilities are of marginal value when considering the amount of time necessary for a capability to be developed, incorporated into the weapon system, and fielded. The time-certain period is established with the results of the TAIV analysis. Schedule is, then, the sequence of events or program milestones that fit within the time-certain period. Though a recent Government Accountability report (GAO, 2009) points out that the DAPA report (Kadish, 2006, January, p.49) recommended that schedule be a Key Performance Parameter, this rule departs from DAPA in that the time between Milestone B and IOC be a time-certain period and that specific length of time be a Key Performance Parameter. Urgency for fielding a particular desired capability, then, has a context that can be used to describe what needs to be fielded or deployed and when.

Acquisition Rule Three: Aircraft programs will take no longer than five years from Milestone B (EMD) to Initial Operational Capability, again using TAIV as an analytic tool to validate the optimum timeframe.

Successful aircraft programs have been fielded in five years or less. The fielding of both the F-15 and F-16 were achieved in approximately five years, with the F-15E (Woods, 2008) fielded in approximately five-and-one-half years. Had management and budget attention been constant and sufficient, the C-17 cargo aircraft could have achieved IOC in five years. But after several false starts, it took almost 10 years. The complexity of the aircraft's technology demands is clearly important, but other factors seem to play roles as well. The EA-18G is planned for five years and nine months from Milestone B to IOC while the F/A-18E/F was planned for nine years and four months. It is true, however, that the EA-18G is basically an F/A-18F airframe integrated with an Improved Capability III, Airborne Electronic Attack (AEA) avionics suite (employed on the EA-6B) and should take less time to field. The accelerated development schedule (over its F/A-18E/F predecessor) probably can be attributed to the coupling of that proven, in-production airframe with an existing AEA technology.

The B-2 took 18 years from Milestone B to IOC for a variety of reasons, only some of which had to do with available technology. Budget and congressional interest played big roles in the length of time that it took for the B-2 to reach IOC. At 14 years and four months, the F-22 has taken the longest of any of the fighters to reach IOC. If the rules are followed that require capital funding and not being certified for EMD without achieving a TRL of 6, it is not a stretch for a well-managed program with stable funding that follows all of the rules described in this paper to reach IOC in five years. However, when the program becomes a bill payer for other Service needs or derived requirements are inserted before or during the EMD phase, five years will, of course, be a difficult achievement. The criteria that describe what must be accomplished in the EMD phase of the program cannot significantly change.

Acquisition Rule Four: Ship-building programs will take no longer than seven years from Milestone B (EMD) to Initial Operational Capability, again using TAIV as an analytic tool to validate the optimum timeframe.

Currently, the average time from Milestone B to IOC for US Navy ships entering the fleet is eight years, nine-and-one-half months (Costello, 2008). Size and complexity, however, do not seem to be what determines the length of time to get combat ships into the fleet. The range is from CVN21 (Gerald R. Ford Class modern aircraft carrier) taking 12-and-one-half years to strategic sealift ships taking five years, nine months. But, again, complexity or size does not seem to be the driving factor since a Supply Class Fast Combat Support Ship (AOE6) took over eight-and-one-half years to go from Milestone B to IOC while the aircraft carrier CVN74, USS John C. Stennis, took a little over eight years, four months to achieve IOC. An LPD 17 San Antonio Class amphibious docking ship took 11 years and one month to reach IOC while the Arleigh Burke Class (DDG 51) destroyer took nine years, three months to go from Milestone B to IOC. Arguably, to establish seven years as the time-certain for naval shipbuilding programs from program initiation at Milestone B to IOC will be a challenge—but a challenge that can be met if the time-certain constraint is one that both the contractor and the Department understand and capture in their Integrated Master Plan and Integrated Master Schedule. Also, the criteria that describe what must be accomplished in the EMD phase of the program cannot significantly change.

Acquisition Rule Five: *Requests for Proposals (RFP) will include a competition element that asks how the competitors plan to select, manage, and evaluate their subcontractors. Subcontractor management will be an element of the Contractor Performance Assessment report and considered in determining award and incentive fees.*

With regard to the issue of subcontractor management raised in Rule Four, how the winning prime contractor intends to select and manage its subcontractors and suppliers will be a prominent competition element in the Request for Proposal (RFP). The purpose of this rule is to discourage potential prime contractors from arbitrarily, and as the default position, choosing sister divisions as subcontractors. If a competitor must explain the rationale for selecting subcontractors' contributions and their cost and design advantages compared to sister divisions or other alternatives, sister divisions may not be as appealing of a choice as a program subcontractor. Knowing that the plan for selecting and managing subcontractors will be weighted in the management section of the RFP will provide more incentive to the potential prime contractor to give very careful consideration to subcontractor selection. Profit-on-profit should become more of a competitive liability.

Acquisition Rule Six: *No MDAP will be considered for Milestone B certification without a Test and Evaluation Master Plan that has been agreed to and approved.*

All too often, the test and evaluation process results in new requirements that exceed contract specifications. Ensuring that a fully agreed-to and approved Test and Evaluation Master Plan that clearly bounds the limits of what can be tested, including metrics for success that all understand, is essential. This will go a long way to precluding testing the driving engineering changes and requirements that exceed the contract defined design.

Acquisition Rule Seven: *Where the competitors offerings are comparable and the competition will allow, competitors for EMD will submit cost-model data and Most Probable Cost will be determined prior to final Request for Proposal release and shared with competitors. Most Probable Cost will be contract cost. Competitions will be based on technical and management risk.*

A long-held view in the defense industry is that any program vice president who loses a cost competition by not having the lowest cost is fired. What exactly drives the industry to hold this point of view? If you don't count their years of experience, a winning contractor believes that there is a better than 80% probability that the contract specifications that were bid will be changing as the ink is drying on the contract. The winning contractor can then charge full price on the updated program specifications, within the cost and pricing guidelines, and make up for any risk accepted in the original winning proposal.

This approach to an acquisition program is most often prevalent when the contract is a cost-plus arrangement, though fixed-price contracts experience the same type of expanding-contract cost growth with the emergence of derived requirements and engineering changes. The problem that occurs with fixed-price contracts that have engineering changes or derived requirements is that unless the contract is amended, the cost of the changes often turns up as claims against the government. Cost-plus contracts, on the other hand, only have the added costs show up as the "plus" in cost-plus.

The excuse often heard when costs rise is that the Department and the defense contractors do not have good cost estimates. This assertion does not generally prove to be true. When competing contractors reveal the output of their cost models and compare them with the Department's estimates, there is often very little difference. As a general rule, then, all the participants in acquisition competitions have a very good estimate of what the costs will be. Why then are competitions based on cost when everyone knows what the most likely cost will be? Cost should be taken off the table and the competition should be about which competitor has the better solution for management and technical risk, with subcontractor selection and management being prominent in that evaluation. Most Probable Cost, or the cost that the competitors and government models agree is the cost, should become the contract cost.

Acquisition Rule Eight: Competitions will be based on the motto: "the design you bid is the design you build."

A number of activities take place while the ink is drying on the contract. Not the least of these is that the government program manager and executive are saying to the winning contractor, "We know what we said we wanted, and what you proposed, but we have a few changes to the requirements we'd like you to adopt." To which the winning contractor readily replies, "Not a problem; just a few design changes, another year on the program, and an increase in cost." If both the winning contractor and the government program manager fully understand and believe that the design that was bid is the design that will be built, then their behavior will change to follow the rule.

Conclusion

The Department of Defense is now in a budget environment where it is directly competing with a formidable domestic agenda that will not be denied. In his January 2009 article A Balanced Strategy: Reprogramming The Pentagon For A New Age, published in *Foreign Affairs*, Secretary of Defense Robert Gates stated,

> *In recent years, these platforms have grown ever more baroque, have become ever more costly, are taking longer to build, and are being fielded in ever-dwindling quantities. Given that resources are not unlimited, the dynamic of exchanging numbers for capability is perhaps reaching a point of diminishing returns. A given ship or aircraft, no matter how capable or well equipped, can be in only one place at one time.* (Gates, 2009)

If Secretary Gates' message is going to be taken to heart by those charged with acquiring the "platforms" and those responsible for producing them, then far greater attention must be given to using the defense budget wisely, efficiently and effectively. Programs simply must be managed to cost, schedule and performance. A mandated set of rules that drive discipline into the Acquisition System is one answer.

This paper describes a few such rules that are worthy of implementing. They are by no means inclusive of all the rules that should be considered and established. Additionally, it should be clearly understood that for behaviors to change, all of the rules must be followed since no single rule or group of rules stands alone. For example, without a time-certain program, the discipline for capital funding will not be present and planning for funding over a well-defined time period will not be possible. The rules are interrelated, and these rules are necessary in order to re-establish an acquisition culture that is disciplined with a clear understanding of how to bring predictability and stability to the Department of Defense Acquisition System.

The institution of rules that are clearly communicated and consistent must be enforced to reinvigorate and support the acquisition workforce's enthusiasm for meeting cost, schedule, and performance as well as establishing discipline and structure in the Acquisition System. The Department of Defense establishes and follows checklists for any number of activities from flying airplanes to mailing packages. Rules are just another form of a checklist. With 91 major Defense Acquisition Programs with a combined value of over $1.6 trillion currently being managed, the result will be getting better weapon systems into the hands of the warfighter in time to make a difference on the battlefield.

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Panel 21 - Trends in Contracting Workforce Dynamics

Thursday, May 14, 2009	Panel 21 - Trends in Contracting Workforce Dynamics
3:30 p.m. – 5:00 p.m.	**Chair: Jeffrey P. Parsons**, Executive Director, Army Contracting Command, US Army Material Command ***Managing the Services Supply Chain in the Department of Defense: An Empirical Study of Current Management Practices*** **Aruna Apte, Uday Apte** and **Rene Rendon**, Naval Postgraduate School ***Contract Management Process Maturity: Analysis of Recent Organizational Assessments*** **Rene Rendon**, Naval Postgraduate School ***Army Contracting Command Demographics*** **David Lamm** and **Timothy Reed**, Naval Postgraduate School

Chair: Mr. Jeffrey P. Parsons is the Executive Director of the US Army Contracting Command, a new major subordinate command of the US Army Materiel Command (AMC). The Army Contracting Command provides global contracting support to the operational Army across the full spectrum of military operations and in garrison. Parsons commands over 5,500 military and civilian personnel worldwide, who award and manage over 270,000 contractual actions valued at more than $80 billion per fiscal year. He exercises command and procurement authority over two subordinate commands, the Installation Contracting Command and the Expeditionary Contracting Command, and also leads the AMC Acquisition Centers which support AMC's other major subordinate commands and Lifecycle Management Commands. Parsons was appointed to the Senior Executive Service on December 15, 2003.

Prior to assuming his current position, Parsons served as the Director of Contracting, Office of Command Contracting, Headquarters, AMC, Fort Belvoir, VA. Responsibilities from the Office of Command Contracting transitioned into the Army Contracting Command. Parsons continues to serve as the Principal Advisor to the Commanding General of AMC and his staff on all contracting matters and as the AMC Career Program Manager for the Contracting and Acquisition Career Program, with responsibility for the recruitment, training, education, and professional development of the civilian and military contracting professionals who are part of the acquisition workforce.

Prior to his appointment to the Senior Executive Service, Parsons was the Director of Contracting, Headquarters, US Air Force Materiel Command, Wright-Patterson Air Force Base, OH, where he retired from active duty as an Air Force Colonel after 26 years of service. He was responsible for developing and implementing contracting policies and processes to annually acquire $34 billion in research and development, production, test, and logistics support for Air Force weapon systems. He was directly responsible for the training, organizing, and equipping of more than 3,000 contracting professionals.

Parsons' contracting career began in 1977 as a base procurement officer supporting the 90th Strategic Missile Wing at F.E. Warren Air Force Base, WY. He held a variety of positions as a contracting officer with a wide range of experience touching on all aspects of systems, logistics, and operational contracting. He was the Director of Contracting for a multi-billion dollar classified satellite program operated by the National Reconnaissance Office and served twice as a plant commander in the Defense Contract Management Agency. Parsons also held several key staff positions at Headquarters, US Air Force, the Air Force Secretariat, and with the Office of the Secretary of Defense, in which he was responsible for the development, implementation, and management of integrated, coordinated, and uniform policies and programs to govern DoD procurement worldwide.

Parsons received his Bachelor's degree in Psychology from St. Joseph's University, Philadelphia, PA, and holds two Master's degrees—one in Administration with a concentration in Procurement and Contracting from George Washington University, Washington, DC, and the other in National Resource Strategy from the National Defense University. He is a graduate of the Industrial College of the Armed Forces and the Defense Systems Management College Executive Program Management Course. Parsons holds the Acquisition Professional Development Program's highest certifications in contracting and program management. He also is a Certified Professional Contracts Manager, National Contract Management Association.

Managing the Services Supply Chain in the Department of Defense: An Empirical Study of Current Management Practices

Presenter: Dr. Aruna Apte is an Assistant Professor in the department of Operations and Logistics Management, Graduate School of Business and Public Policy, at the Naval Postgraduate School, Monterey, CA. She received her PhD in Operations Research from the School of Engineering at the Southern Methodist University in Dallas, TX. Her earlier education includes a Master's in Mathematics and credits towards a PhD in Mathematics from Temple University, Philadelphia, PA. She has taught in the Cox School of Business, School of Engineering and the Department of Mathematics at Southern Methodist University. She has over twenty years of experience in teaching operations management, operations research, and mathematics courses at the undergraduate and graduate levels in the resident and remote programs.

Apte has successfully completed various research projects involving applications of mathematical models and optimization techniques. Her research interests are in the areas of developing mathematical models and algorithms for complex, real-world operational problems—especially in the area of humanitarian logistics and critical infrastructure networks using techniques of combinatorial optimization, network programming, and mixed-integer programming based on heuristic search methods. It is also important to her that her research is directly applicable to practical problems and has significant value-adding potential. Her research articles have been published in prestigious journals, including *Naval Research Logistics*, *Production and Operations Management*, and *Interfaces*. She has published several articles in the Acquisition Research Sponsored Report Series, GSBPP, NPS. She also has a patent pending for "SONET Ring Designer Tool," created when she worked as a consultant for MCI.

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Dr. Uday Apte is Professor of Operations Management at the Graduate School of Business and Public Policy, Naval Postgraduate School, Monterey, CA. Before joining NPS, Apte taught at the Wharton School, University of Pennsylvania, Philadelphia, and at the Cox School of Business, Southern Methodist University, Dallas. He is experienced in teaching a range of operations management and management science courses in the Executive and Full-time MBA, as well as the business undergraduate programs. His earlier education includes a B. Tech. in Chemical Engineering from the Indian Institute of Technology, Bombay, India, an MBA from the Asian Institute of Management, Manila, Philippines, and a PhD in Decision Sciences from The Wharton School, University of Pennsylvania, Philadelphia.

Apte is currently serving as the Vice President for Colleges, Production and Operations Management Society (POMS). In the past, he has served as the founder and President of the POMS College of Service Operations, as a board member of POMS, and as guest editor of *Production and Operations Management* journal. Prior to his career in academia, Apte worked for over ten years in managing operations and information systems in the financial services and utility industries. Since then, he has consulted with several major US corporations and international organizations. His recent consulting engagements have focused on process improvement using Lean Six Sigma and development of operations strategy.

Areas of Apte's research interests include managing service operations, globalization of information-intensive services, supply chain management, and technology management. He has published over 40 research articles, five of which have won awards from professional societies. His research articles have been published in prestigious journals, including *Management Science, Interfaces, Production and Operations Management, Journal of Operations Management, Decision Sciences, IIE Transactions, Interfaces*, and *MIS Quarterly*. He has co-authored two books, *Manufacturing Automation* and *Managing in the Information Economy*.

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Dr. Rene G. Rendon is a nationally recognized authority in the areas of supply management, contract management, and project management. He is currently on the faculty of the United States Naval Postgraduate School, where he teaches in the MBA and Master of Science programs. Prior to his appointment at the Naval Postgraduate School, he served for more than 22 years as an acquisition and contracting officer in the United States Air Force, retiring at the rank of Lieutenant Colonel. His Air Force career included assignments as a warranted contracting officer for the Peacekeeper ICBM, Maverick Missile, C-20 (Gulfstream IV), and the F-22 Raptor. He was also a contracting squadron commander for an Air Force pilot training base and the director of contracting for the Air Force's Space-based Infrared satellite system, and the Evolved Expendable Launch Vehicle rocket program.

Rendon has taught contract management courses for the UCLA Government Contracts program; he was also a senior faculty member for the Keller Graduate School of Management, where he taught MBA courses in project management and contract management. He is a graduate of the US Air Force Squadron Officer School, Air Command and Staff College, Air War College, and the Department of Defense Systems Management College. Rendon is Level III certified in both Program Management and Contracting under the *Defense Acquisition Workforce Improvement Act* (*DAWIA*) program. He is also a Certified Professional Contracts Manager (CPCM) with the National Contract Management Association (NCMA), a Certified Purchasing Manager (C.P.M.) with the Institute for Supply Management (ISM), and a certified Project Management Professional (PMP) with the Project Management Institute (PMI). He has received the prestigious Fellow Award from NCMA, and he was recognized with the United States Air Force Outstanding Officer in Contracting Award. He has also received the NCMA National Education Award and the NCMA Outstanding Fellow Award. Rendon is a member of the ISM Certification Committee and serves on the Editorial Review Board for the ISM *Inside Supply Management* magazine. He is a member of the NCMA Board of Advisors, as well as associate editor for its *Journal of Contract Management*. Rendon's publications include *Government Contracting Basics* (2007), *U.S. Military Program Management: Lessons Learned & Best Practices* (2007), and *Contract Management Organizational Assessment Tools* (2005). He has also published scholarly articles in the *Contract Management* magazine, the *Journal of Contract Management*, the *Program Manager* magazine, the *Project Management Journal*, and the *PM Network* magazine. He is a frequent speaker at universities and professional conferences and provides consulting to both government and industry.

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Abstract

This paper presents the results of our ongoing research on the management of services acquisition in the Department of Defense. In this empirical study, we developed and used a web-based survey to collect data on the acquisition strategy, procurement methods, and contract types used at Air Force and Navy installations. Specifically, we studied the current management practices in such areas as lifecycle approach, project management, organization/management structure, and training provided to services acquisition personnel.

We found that the majority of the services contracts awarded and administered conformed to our expectation. For example, most service contracts are competitively bid, fixed-priced awards without any type of contract incentive. However, we found that the Air Force and Navy use different contracting approaches in the following areas: organizational level of acquisition offices (regional versus installation), the use of project teams, leaders of the acquisition effort (program personnel versus contracting officers), and managers of the services requirement (program personnel, contracting officers, and customer organizations). We analyzed the implications and impact of different approaches on the effectiveness of the contract management process and make recommendations for improving the management of services acquisition in the Department of Defense.

Keywords: Service Supply Chain, Services Acquisition, Service Lifecycle, Contract Management, Project Management, Program Management

1.0 Introduction

Services acquisition in the US Department of Defense (DoD) has continued to increase in scope and dollars in the past decade. In fact, even considering the high value of weapon systems and large military items purchased in recent years, the DoD has spent more on services than on supplies, equipment and goods (Camm, Blickstein & Venzor, 2004). For example, the Department of Defense obligations on contracts have more than doubled between fiscal years 2001 and 2008—to over $387 billion, with over $200 billion spent just for services (GAO, 2009). The acquired services presently cover a very broad set of service activities—including professional, administrative, and management support; construction, repair, and maintenance of facilities and equipment; information technology; research and development; and medical care.

As the DoD's services acquisition continues to increase in scope and dollars, the DoD must give greater attention to proper acquisition planning, adequate requirements definition, sufficient price evaluation, and proper contractor oversight (GAO, 2002). Recently, the Director of Defense Procurement and Acquisition Policy (DPAP) identified the inappropriate use of services contracts in the DoD (Director, DPAP, 2007, March 2) and is planning to take actions to improve contracting for services throughout the Department (Director, DPAP, 2006, August 16). In many ways, the issues affecting services acquisition are similar to those affecting the acquisition of physical supplies and weapon systems. However, the unique characteristics of services, combined with the increasing importance of services acquisition, offer a unique and significant opportunity for research into the management of the service supply chain in the Department of Defense.

We have addressed the need for research in the area of services acquisition by undertaking a series of research projects. Thus far, we have completed three research projects, and the work on the fourth research project is currently in progress.

The first research project was exploratory in nature, wherein we tried to understand the major challenges and opportunities in the service supply chain in the DoD (Apte, Ferrer, Lewis & Rendon, 2006). As a part of this research study, we conducted in-depth case studies on acquisition of services in three different organizations: Presidio of Monterey, Travis AFB and the Naval Support Detachment Monterey (NSDM).

The lack of a well-developed program management infrastructure for the acquisition of services was a critical research finding that warranted further study. Therefore, our second research project was geared towards studying the program management infrastructure in the service supply chain in the DoD. In this research, too, we conducted two additional in-depth case studies of innovative project management approaches—both at the Air Education and Training Command (AETC) and at Air Combat Command (ACC). Based on these case studies, we developed a conceptual model of a service lifecycle that can be used to analyze and design the DoD's services acquisition process. In our project report (Apte & Rendon, 2007), we discussed the program management approach, identified basic project management concepts, described how these concepts are being used in the acquisition of defense weapon systems, and recommended how they can be adapted in the acquisition of services in the DoD.

This paper presents the results of our third research project consisting of an empirical study of the management of services acquisition in the Department of Defense. In this empirical study, we developed and used a web-based survey to collect data on the acquisition strategy, procurement methods, and contract types used at Air Force and Navy installations. Specifically, we studied the current management practices in such areas as lifecycle approach, project management, organization/management structure, and training provided to services acquisition personnel.

As mentioned earlier, the work on a fourth research project is currently in progress. In this research, we are continuing with the empirical study of current management practices in the Army.

2.0 Research Objectives

The objective of the third research project is to develop a more comprehensive understanding of how services acquisition is managed at a wide range of military bases throughout the Department of Defense. This research is focused on answering the following research questions:

1. What type of acquisition strategy, procurement method, and contracts are used in services acquisition?
2. How is the service acquisition process managed? What management concepts—such as a lifecycle, a program management or a project management approach—are used?
3. What training is given to contract and project/program management staff?
4. Are there any significant differences between the way services are acquired and managed in different DoD departments?

2.1 Development and Review of Survey Instrument

The methodology for this research involves the application of a survey instrument recently developed for this specific purpose. The MBA student team of Compton and Meinshausen, under the guidance of Professors Apte, Apte, and Rendon, developed the survey instrument as part of their MBA research project (Compton & Meinshausen, 2007). This was a web-based survey instrument developed using the survey software “Survey Monkey.” The developed survey was pilot tested for its validity and was used to collect additional empirical data regarding the current state of services acquisition management in the Navy and the Air Force at the installation level.

The services acquisition research survey begins with questions focusing on specific demographic data for each military department, major command, region, and military installation. The survey then asks specific questions related to the approach, method, and procedures used in the acquisition of services for certain specific categories of services. The specific categories of services targeted in this research are listed in Table 1 below. These service categories are considered to be the most common services acquired by the various DoD departments. Between FY99 to FY03, the DoD’s spending on these types of services increased by 66%; and in FY03, the DoD spent over $118 billion (or approximately 57% of total DoD procurement dollars) on these types of services (GAO, 2005, March). Table 1 also shows the individual service categories addressed in the responses received from the Air Force and the Navy.

Table 1. Service Categories

Service Category	Classification Code	Air Force	Navy
Professional, administrative, and mgmt. support	R	X	X
Maintenance and repair of equipment	J	X	X
Data processing and telecommunications	D	X	X
Utilities and housekeeping	S		X
Transportation and travel	V	X	

The survey instrument includes core questions related to the methods and procedures used in the acquisition of services for these five categories of services. These core questions focus on the following areas (Compton & Meinshausen, 2007):

Contract Characteristics. The purpose of this category of questions is to gain insight into the dominant procurement method and contract type used in the acquisition of services at the installation level. The contract characteristics examined in this section are degree of competition (competitively bid or sole-source), contract type (fixed-price or cost-type), and type of contract incentive (incentive-fee or award-fee or award-term).

Acquisition Management Methods. The purpose of this broad category of questions is to gain insight into the types of management methods and approaches used in the acquisition of individual services at each phase of the contract management process. For each of the contract management phases, the survey asks whether the phase was conducted at a regional, installation, or some other organizational level. This core question category also focused on whether a project-team approach was typically used in the acquisition of the respective service category at the installation level.

Project-team Approach. The purpose of this category of questions is to explore the installations that utilize a project-team approach in the services acquisition management method described above. The questions explore the position of the services acquisition project-team leader, such as a Program/Project Manager or Contracting Officer. This category of questions also explores information on the owner, generator, and approving authority of the requirement for a specific service being acquired. Another purpose of this category of questions is to explore services acquisitions in which a project management approach was not dominantly used. For this case, too, the questions explore the position of the person leading the services acquisition and information on the owner, generator, and approving authority of the requirement.

Other Program Management Issues. This last category of core questions is focused on the use of a lifecycle approach, length of assignments for services acquisition management personnel staff, use of market research techniques, level of staffing in services acquisition management, and level of training of services acquisition management personnel. These questions use a Likert-type scale to measure the level of agreement or disagreement amongst the respondents' statements.

Finally, the survey also solicits feedback and any general comments the respondents may want to share regarding the topic of services acquisition. This survey instrument also allows the researchers to collect data that will be subsequently analyzed to answer the research questions. This analysis is presented in the next section of this paper.

3.0 Survey Data and Observations

The objective of this study—understanding the acquisition of services at diverse military bases—benefits from the collection and analysis of the previously discussed survey responses. Although creating a validated survey instrument that can guide the data collection and help us answer the research questions was a challenging and time-consuming task, this survey has been instrumental in guiding the overall direction of the study.

In this section, we present a summary of the survey data we gathered and present our observations about the data. Specifically, the data concerning various contract characteristics and acquisition management methods for individual service categories will be presented using the logical structure depicted in Figures 1 and 2. We begin with a description of the Air Force survey results (see Tables 2, 3 and 4). This will be followed by a presentation of the Navy survey results (see Tables 5, 6, and 7). Our conclusions and recommendations based on our study will then be presented in subsequent sections.

3.1 Services Acquisition: Air Force Survey Results

3.1.1 Contract Characteristics

The data on contract characteristics prevalent in various service categories are shown in Table 2 below.

Table 2. Contract Characteristics: Air Force

Service category	Degree of Competition			Contract Type			Contract Incentive		
	Competitive	Sole Source	N/A	Fixed	Cost	N/A	Award Fee	Award Term	N/A
Professional, Administrative, and Management Support									
FY03	62%	6%	32%	59%	9%	32%	9%	0%	91%
FY04	59%	6%	35%	56%	9%	35%	9%	0%	91%
FY05	59%	9%	32%	62%	6%	32%	9%	0%	91%
FY06	71%	9%	21%	71%	9%	21%	12%	0%	88%
FY07	76%	9%	15%	79%	6%	15%	12%	0%	88%
Maintenance and Repair of Equipment									
FY03	65%	6%	29%	68%	3%	29%	3%	3%	94%
FY04	65%	6%	29%	68%	3%	29%	3%	3%	94%
FY05	65%	6%	29%	68%	3%	29%	3%	3%	94%
FY06	76%	6%	18%	79%	3%	18%	3%	6%	91%
FY07	85%	6%	9%	88%	3%	9%	3%	6%	91%
Data Processing and Telecommunication									
FY03	56%	3%	41%	50%	6%	44%	9%	0%	91%
FY04	56%	3%	41%	50%	6%	44%	9%	0%	91%
FY05	56%	3%	41%	50%	6%	44%	9%	0%	91%
FY06	62%	6%	32%	59%	6%	35%	9%	0%	91%
FY07	71%	3%	26%	65%	6%	29%	9%	0%	91%
Transportation and Travel									
FY03	38%	0%	62%	38%	0%	62%	3%	0%	97%
FY04	41%	0%	59%	41%	0%	59%	3%	0%	97%
FY05	38%	0%	62%	38%	0%	62%	3%	0%	97%
FY06	47%	0%	53%	47%	0%	53%	3%	0%	97%
FY07	53%	0%	47%	53%	0%	47%	3%	0%	97%

The responses from the Air Force addressed four service categories: (1) professional, administrative and management support, (2) maintenance and repair of equipment, (3) data processing and telecommunications, and (4) transportation and travel. For each service category, we collected data concerning the degree of competition, contract type and contract incentives used. To uncover salient trends, we requested respondents to provide annual data for the past five years—from FY03 to FY07. Following are some observations about the data. In the interest of brevity, we refer only to the data for FY07.

- Professional, Administrative, & Management Support Services: Based on Table 2, we see that a competitive approach is used 76% of the time, while sole-source is only used 9% of the time. Additionally, fixed-price-type contracts are used 79% of the time, while cost-type contracts are only used 6% of the time. Finally, contract incentives are rarely used in any capacity, only about 12% of the time.

- Maintenance and Repair of Equipment: In Table 2, we note that a competitive approach is used 85% of the time, while sole-source is only used 6% of the time consistently. Additionally, fixed-price-type contracts are used 88% of the time, while cost-type contracts are only used 3% of the time consistently. Contract incentives are rarely used in any capacity, only 9% of the time.

- Data Processing and Telecommunications: Based on Table 2, we see that a competitive approach is used 71% of the time, while sole-source is only used 3% of the time consistently. Additionally, fixed-price-type contracts are used 65% of the time, while cost-type contracts are only used 6% of the time consistently. Contract incentives are rarely but consistently used, only 9% of the time.

- Transportation and Travel: Again, Table 2 suggests that a competitive approach is predominantly used—53% of the time—while sole-source is not used at all. This may be due to the fact that many bases do not purchase transportation within their Contracting Squadron. Another answer to the high N/A (not applicable) number is the fact that contracting squadrons might issue delivery task orders from large indefinite-quantity, indefinite-delivery-type contracts; thus the respondents answered not applicable to this question. Additionally, fixed-price-type contracts are used 53% of the time, while cost-type contracts were not used at all. Contract incentives are only used 3% of the time consistently.

3.1.2 Acquisition Management Methods

The Air Force typically employs the acquisition of the services at the installation level. The administrative portion of the survey focused on the respondents' branch of service and MAJCOM. All 34 respondents were from the USAF. Out of the 34 respondents, 10 were on location with the Air Combat Command (ACC); 7 respondents were from the Air Mobility Command (AMC); 6 respondents were from the Air Education and Training Command (AETC); 6 respondents were from the Air Force Space Command (AFSPC); 4 respondents were from the Air Force Material Command (AFMC), and, finally, one respondent was from the Air Force Special Operations Command (AFSOC). Our team wanted this survey data to be unbiased, so we made the survey anonymous. However, as a by-product of this anonymity, we do not know the location of the specific bases that answered the survey.

Organizational Level

The survey respondents were asked to state the organizational level at which the specific services were acquired—that is, at what level were the procurement process for the services conducted? The results are shown in Table 3 below. The various DoD components acquire services either at the major command (MAJCOM) level, regional level or installation level. Below are the results of the survey. The responses indicate that during all phases of the services acquisition, for a large majority of the services acquired by the Air Force (in about 70% cases), the procurement was conducted at the installation level.

Table 3. Organization Level Used in Acquisition Phases: Air Force

Service/Acquisition Phase	Organization Level		
	Regional	Installation	N/A
Professional, Administrative, and Management Support			
Acquisition Planning	1	27	6
Solicitation	1	27	6
Source Selection	1	26	7
Contract Administration	0	27	7
Maintenance and Repair of Equipment			
Acquisition Planning	1	29	4
Solicitation	1	29	4
Source Selection	1	27	6
Contract Administration	0	29	5
Data Processing and Telecommunication			
Acquisition Planning	4	21	9
Solicitation	4	21	9
Source Selection	4	19	11
Contract Administration	3	22	9
Transportation and Travel			
Acquisition Planning	2	19	13
Solicitation	2	19	13
Source Selection	2	19	13
Contract Administration	1	19	14

Project-team Approach

The survey results about the use of the project-team approach (see Table 4) show that this approach was used in a majority of the acquisitions for all services categories (in about 65% of the cases).

Table 4. Project-team Approach: Air Force

Service Category	Total No. of Organiza-tions	Organizations Using Project Team Approach					Organizations Not Using Project Team Approach				
			Who leads acquisition?		Who owns requirments?			Who leads acquisition?		Who owns requirments?	
		SubTotal	Contracting Officer	Other (PM, QAE)	Contracting Officer	Customer (PM, QAE)	SubTotal	Contracting Officer	Other (PM, QAE)	Contracting Officer	Customer (PM, QAE)
Professional, Administrative, and Management Support	**34**	**25**	21	4	5	20	**9**	8	1	1	8
Maintenance and Repair of Equipment	**34**	**23**	17	6	4	19	**11**	10	1	2	9
Data Processing and Telecommunication	**34**	**21**	12	9	3	18	**13**	7	6	2	11
Transportation and Travel	**34**	**18**	16	2	3	15	**16**	5	11	0	16

Project-team Approach and Service Acquisition Leadership

Regardless of whether the respondents answered yes or no to the utilization of a project-team approach question, the respondents were asked the following two questions:

1. Who leads the acquisition of the service category?
2. Who owns the requirements or approves changes to the requirements?

As shown above in Table 4, the responses to these questions were relatively similar. In a majority of the cases, a contracting officer leads the acquisition process. This clearly indicates that program managers are usually not part of the acquisition process of procuring services at the installation level. Additionally, customers are usually responsible for owning and changing the requirements for services at the installation level.

3.2 Services Acquisition: Navy Survey Results

3.2.1 Contract Characteristics

The data on contract characteristics for various service categories are shown in Table 5 below. Selected observations about FY07 data are also stated below.

Table 5. Contract Characteristics: Navy

	Degree of Competition			Contract Type			Contract Incentive		
	Competitive	Sole Source	N/A	Fixed	Cost	N/A	Award Fee	Award Term	N/A
Professional, Administrative, and Management Support									
FY03	80%	0%	20%	80%	0%	20%	10%	0%	90%
FY04	80%	0%	20%	80%	0%	20%	10%	0%	90%
FY05	80%	0%	20%	80%	0%	20%	0%	10%	90%
FY06	80%	0%	20%	80%	0%	20%	0%	10%	90%
FY07	90%	0%	10%	90%	0%	10%	0%	10%	90%
Maintenance and Repair of Equipment									
FY03	80%	0%	20%	80%	0%	20%	0%	0%	100%
FY04	80%	0%	20%	80%	0%	20%	0%	0%	100%
FY05	80%	0%	20%	80%	0%	20%	0%	0%	100%
FY06	80%	0%	20%	80%	0%	20%	0%	0%	100%
FY07	80%	0%	20%	80%	0%	20%	0%	10%	90%
Data Processing and Telecommunication									
FY03	33%	0%	67%	33%	0%	67%	0%	0%	100%
FY04	33%	0%	67%	33%	0%	67%	0%	0%	100%
FY05	33%	0%	67%	33%	0%	67%	0%	0%	100%
FY06	33%	11%	56%	44%	0%	56%	0%	0%	100%
FY07	33%	11%	56%	44%	0%	56%	0%	0%	100%
Utilities and Housekeeping									
FY03	25%	25%	50%	60%	0%	40%	20%	0%	80%
FY04	25%	25%	50%	60%	0%	40%	20%	0%	80%
FY05	25%	25%	50%	60%	0%	40%	0%	20%	80%
FY06	25%	25%	50%	60%	0%	40%	0%	0%	100%
FY07	20%	40%	40%	60%	0%	40%	0%	0%	100%

- <u>Profession, administration, and management</u>: The data showed that in FY07, 90% of contracts were competitively awarded; 80% of contracts were fixed-price contracts, and 90% contracts have no incentives.
- <u>Maintenance and repair equipment</u>: In FY07, 80% of contracts were competitively awarded; 80% were fixed-price contracts, and just one contract had an incentive fee attached.

- Data processing and telecommunication: In FY07, 33% of the contracts were from a competitive source; 44% of the contracts were firm-fixed contracts, and no incentives were offered in any contract.

- Utilities and housekeeping: In FY07, 20% of the contracts administered were competitive, and 40% were sole-source; 60% of the contracts cut were firm-fixed-priced.

3.2.2 Acquisition Management Methods

The data was collected from the survey at the installation level. The data inputs were provided by the Navy Regions in charge of the installations in CONUS. We received inputs from 6 Regions—covering 66 Navy installations, plus Naval Supply (NAVSUP) and Naval Medical Logistics Command (NMLC).

Table 6. Organization Level Used in Acquisition Phases: Navy

Service/Acquisition Phase	Organization Level			Total
	Regional	Installation	N/A	
Professional, Administrative, and Management Support				
Acquisition Planning	5	2	3	10
Solicitation	5	2	3	10
Source Selection	5	3	2	10
Contract Administration	3	4	3	10
Maintenance and Repair of Equipment				
Acquisition Planning	4	3	3	10
Solicitation	4	3	3	10
Source Selection	4	3	3	10
Contract Administration	2	6	2	10
Data Processing and Telecommunication				
Acquisition Planning	3	1	5	9
Solicitation	3	1	5	9
Source Selection	3	1	5	9
Contract Administration	2	2	5	9
Utilities and Housekeeping				
Acquisition Planning	2	2	4	8
Solicitation	2	2	4	8
Source Selection	2	2	4	8
Contract Administration	2	2	4	8

Organizational Level

The data regarding the organizational level at which the specific services were acquired is shown in Table 6 below. The majority of the responses indicate that each of the services acquired by the Navy was procured at the regional level—specifically, 62% of the professional, administrative, and management services were acquired at this level. About 68% of the acquisition planning, solicitation and source selection for data processing and telecommunication services were performed at the regional level. The responses for utilities and housekeeping services showed half of the contracts were planned, solicited, selected, and administered at the regional level, and half at the installation level.

Project-team Approach

The results of our survey (see Table 7) show that a project-team approach was used in approximately 50% of the acquisitions for all services categories.

Table 7. Project-team Approach: Navy

Service Category	Total No. of Organiza-tions	Organizations Using Project Team Approach					Organizations Not Using Project Team Approach				
		SubTotal	Who leads acquisition?		Who owns requirments?		SubTotal	Who leads acquisition?		Who owns requirments?	
			Contracting Officer	Other (PM, QAE)	Contracting Officer	Customer (PM, QAE)		Contracting Officer	Other (PM, QAE)	Contracting Officer	Customer (PM, QAE)
Professional, Administrative, and Management Support	**10**	**6**	0	6	2	4	**4**	3	1	1	3
Maintenance and Repair of Equipment	**9**	**5**	4	1	1	4	**4**	4	0	1	3
Data Processing and Telecommunication	**9**	**2**	2	0	1	1	**7**	3	4	1	6
Utilities and Housekeeping	**7**	**5**	4	1	2	3	**2**	1	1	1	1

Project-team Approach and Service Acquisition Leadership

As we examine the results of our survey, we note a 50-50 split in a portion of the data: a program manager leads the acquisition team half the time, and a contracting officer leads the acquisition team half the time. Additionally, we see that approximately 30% of the time, a program manager, contracting officer, or customer owns and manages the requirement in these services contracts.

3.3 Program Management Issues for Both the Air Force and the Navy

In addition to the topics mentioned above, our research objective was also to investigate issues related to the personnel involved in and responsible for various aspects of services acquisition management. The issues include use of lifecycle approach, as well as the length, level, and qualifications of personnel in service acquisition management. We also explored the extent of market research used by decision-makers in awarding services contracts. Table 8 below describes the responses from the survey regarding the scope and ability of personnel responsible for service contracts. Responses for both the Air Force and the Navy (with the corresponding percent of responses) are given in the same table. (Contracting officer is abbreviated to CO, and Quality Assurance Evaluator is abbreviated to QAE.)

Table 8. Scope and Ability of Personnel Responsible for Service Contracts

	Air Force		Navy	
Who writes and awards contracts to provide services?	CO 100%		CO 100%	
Who is responsible for the surveillance of contractor's performance	QAE/COR 91%		QAE/COR 37.5%	CO 37.5%
What type of training do these personnel receive?	*DAWIA* 41%	Phase I and II 90%	*DAWIA* 41%	Phase I and II 36%
How much time was spent in the QAE position?	12-36 months 79%	Over 36 months 6%	12-36 months 37.5%	Over 36 Months 50%

The survey asked Likert-scale-based questions related to the use of a lifecycle approach for routine and non-routine services acquisition, the extent of the use of market research, billets for service acquisition management, and responsibilities of the QAE. These are described in Table 9 on the next page. Here, the answers are divided in three categories: percent of respondents that disagreed, were neutral, and agreed. Disagreed and agreed categories include those who disagreed or agreed strongly.

Table 9. Lifecycle Approach, Market Research, Billets and Responsibility

	Air Force			**Navy**		
	Disagree	Neutral	Agree	Disagree	Neutral	Agree
Lifecycle Approach	%	%	%	%	%	%
For routine services, this was the dominant strategy.	23.5	21	50	50	25	62
For non-routine services, this was the dominant strategy.	41	23.5	29	0	37.5	50
Market Research						
Market Research was conducted for the acquisition of services.	0	3	97	0	0	100
Services Acquisition Billets						
There is an adequate number of staff positions.	59	6	35	37.5	25	25
These positions are adequately filled.	65	9	18	50	12.5	25
These staff members are adequately trained.	9	21	53	12.5	25	50
These staff members are adequately qualified.	9	26.5	65	12.5	12.5	62.5
Responsibility of Staff Members						
Persons identifying requirement also write the SOW/SOO document.	6	3	91	62.5	12.5	2.5
QAE receive prior formal/documented training.	0	0	100	12.5	12.5	75
QAE submit written requests of performance and quality of work to CO.	9	6	85	12.5	25	62.5
Proper level of oversight is afforded to monitor contractor performance.	*15*	*6*	*79*	37.5	37.5	25

4.0 Research Findings and Recommendations

This research provided a first look at empirical data related to the acquisition of services within the Department of Defense. The application of the survey to Air Force and Navy acquisition offices provided some real-world data on the characteristics of services contracts (degree of competition, contract/incentive type), various management approaches used (organizational level and project-team approach), and other program management issues (use of project lifecycle, length of acquisition personnel service, extent of market research, level of staffing, and training of staffing). Below is a summary of our research findings. This is followed by our recommendations.

4.1 Research Findings

Contract Characteristics

The common contract characteristics reflect the use of competitively awarded, fixed-priced contracts. Additionally, contract incentives, or award fees, were typically not used in these services contracts.

Acquisition Management Methods

The Air Force and the Navy differed in terms of the organizational levels at which the acquisition contracts are managed. For the Air Force, the majority of the procurements conducted and contracts managed are done so at the installation level. On the other hand, the services contracts for the Navy are managed at the regional level. This difference in organizational levels may provide additional insight into the effectiveness of the Air Force's and Navy's services contract management. The relation of where the contracts are managed to where the services are actually performed may have an impact on the effectiveness of the contract management process.

In terms of the use of a project-team approach, another distinction can be made between the Air Force and the Navy. The Air Force used a project-team approach in managing its services contracts (64%) more than did the Navy (51%). Best practices in contract management reflect the use of project teams—specifically cross-functional teams—in the management of service procurement projects. Further analysis of the implications of not using a project-team approach in Navy contracts should be conducted.

Related to the use of project teams is the issue of who is to lead the acquisition effort at the installation. For Air Force services contracts in which a project team was used, 80% of the respondents stated that the contracting officer led the acquisition team, while only 20% stated that program personnel led the teams. For Navy services contracts in which a project team was used, 65% of the respondents stated that program personnel led the acquisition team, while 35% stated that contracting officers led the teams.

These results reflect the precarious situations in which contracting officers find themselves as they manage the services procurement process. Not only are they responsible for managing the contractual aspects of the project, they are also responsible for leading the acquisition team. Most of the acquisition team members are not even part of the contracting organization, nor do they work for the contracting officer. This may be problematic for the success of the contract management effort.

It is also interesting to note that at Air Force installations where a project team is not employed in the acquisition of services, the contracting officer is still responsible for leading the acquisition effort in 73% of the cases. At Navy installations where a project team is not employed in the acquisition of services, the contracting officer is still responsible for leading the acquisition effort in approximately 100% of the cases. This situation, in which the contracting officer must lead a coordinated effort (involving technical, financial, and customer personnel) in procuring critical services without the use of a project team, may catalyze some of the problems in managing services contracts that were identified by the GAO.

Also related to services acquisition leadership is the issue of who should own and manage the requirement. In this research, the requirement is the specific service that is being procured—for example, operations research services (a specific professional, administrative, or management service) for a DoD agency. It is important to note that the contract management process and, more specifically, the authorities and responsibilities of the contracting officer, do not include requirements-management activities (such as determining the requirement, modifying the requirement, assessing the effectiveness of the requirement). These activities belong to the requirements owner—usually the organization responsible for the function or service being procured. For example, an Air Force civil engineering organization would own and manage the grounds maintenance and custodial services being acquired by the contracting organization for that specific installation.

This research indicated that for Air Force services acquisitions in which project teams were employed, approximately 82% of the respondents stated that program management personnel owned the requirement (as opposed to contracting officers). For Navy services acquisitions in which project teams were employed, approximately 41% of the respondents stated that program management personnel owned the requirement, while approximately 30% of the respondents stated that either the contracting officer or customer owned the requirement. In Air Force services acquisition in which a project team was not used, approximately 85% of the respondents stated that program management personnel owned the requirement. In Navy services acquisition in which a project team was not used, approximately 67% of the respondents stated that customer personnel owned the requirement; approximately 33% of the respondents stated that contracting officers owned the requirement.

It is interesting to note that although program management personnel owned and managed the requirement in these services contracts, we still see contracting officers leading the acquisition effort (80% with project teams and 73% without). These situations—in which contracting officers are leading the acquisition teams although the requirements are owned and managed by program personnel—may prove problematic to the effectiveness of the services acquisition. This could result in the blurring of (or at least a conflict in) the roles and responsibilities of authorities in the acquisition of services and the management of service requirements.

Program Management Issues

The survey responses to the program management questions provide some additional and interesting insight into the acquisition of services by the Air Force and the Navy. These areas include responsibility for surveillance of contractor's performance and time spent performing QAE duties.

It is interesting to note that approximately 38% of the Navy respondents stated that the Contracting officer is responsible for providing surveillance of the contractor's performance. This differs from the Air Force respondents (91%), who stated that the QAE is responsible for contractor surveillance. Surveillance of contractor performance, especially for performed services, requires technical expertise in the service provided. For example, government information technology (IT) specialists should typically monitor the IT contractor performing IT support services. The level of technical expertise in the surveillance of contractor performance should be a concern for ensuring effective contact administration of services contracts. Contracting officers typically do not have the technical expertise needed to effectively perform contractor surveillance. Nor does the CO usually have the requisite expertise to develop the requirements documents (SOO or SOW) or the quality assurance surveillance plan. Thus, the question of “can the CO provide proper surveillance of the contractor” comes into discussion. We will further address this issue in the program management section below.

In the program-management-related questions, for routine services, over 50% of both Air Force and Navy respondents stated that a lifecycle approach was used. Of note is that only 29% of Air Force (compared to 50% of Navy) respondents stated that the use of a lifecycle approach was used in non-routine services. The use of a lifecycle approach should be a concern for ensuring proper project management of non-routine services contract acquisition. Since the services being acquired are of a non-routine nature, one would expect higher levels of uncertainty—and, thus, higher levels of project risk—in the acquisition process for these services. One method for reducing risk is through the use of a project lifecycle—with project phases, gates, and decision-points for monitoring and controlling the progression of the services acquisition process. Without the use of a project lifecycle, the services acquisition project may be vulnerable to excessive risk in terms of meeting cost, schedule, and performance objectives. This would especially be true in the acquisition of non-routine services.

The majority of both the Air Force and Navy respondents answered the question on the use of market research in the acquisition of services affirmatively. The data—97% (Air Force) and 100% (Navy)—suggest compliance with the requirement in the *Federal Acquisition Regulation* (*FAR*) to conduct market research as the first step in any acquisition. It would be interesting to conduct follow-on research to analyze the extent of documentation supporting the market research activities of these agencies. Recent GAO and Inspector General reports have suggested the lack and sufficiency of market research documentation in the DoD.

The survey results also provide some interesting insight into the staffing of services acquisition management billets. These questions focused on the number of billets, staffing of these billets, training of personnel in these billets, and the qualifications of the personnel in these billets. Of special note is that neither the Air Force nor Navy respondents felt there were an adequate number of services acquisition billets; indeed, only 35% and 25% (respectively) responded to the question in the affirmative. Additionally, neither the Air Force nor Navy respondents felt the services acquisition billets were adequately filled; only 18% and 25% (respectively) responded that they were. However, both the Air Force and Navy stated that the services acquisition management personnel were adequately trained (53% and 50%, respectively) and adequately qualified (65% and 62%, respectively).

In terms of the responsibility of the services acquisition personnel, we see some differences between the Air Force and the Navy. In particular, we see strong differences between the Air Force and Navy in who writes the requirement document, such as the SOO or the SOW. For the Air Force, 91% of respondents agreed that the person identifying the services acquisition requirement also writes the requirement document. On the other hand, only 2.5% of the Navy respondents agreed to this statement. There are also differences of opinion (79%, Air Force, and 25%, Navy) as to whether a proper level of oversight is afforded to monitor the contractor’s performance. These results are somewhat related to the question discussed above: “Can the CO provide proper surveillance of the contractor?”

The first area of difference between the two services’ respondents (the issues of identifying the requirement versus developing the requirements documents) may indicate a mixing of services acquisition roles and responsibilities. The significance of these activities reflects the distinction between the services acquisition requirements process and contracting process. The purpose of the requirements process is to determine, define, and develop the service requirement that will be acquired—for example, IT support services. Once the requirements agency identifies, develops, and defines the requirement, the contracting office performs the contracting activities to acquire the needed services. The contracting office does not identify or determine the service requirement. Contracting officers, however, may support the development of the requirements documents by providing business and procurement expertise in this area. When these two distinct processes are mixed, blurred, or performed by the same organization or individual, there is a potential for unsuccessful acquisition results, a higher risk of not meeting project objectives, and even the potential for procurement fraud.

The Air Force responses show a strong connection between the two activities of identifying the requirement and developing the requirements documents. Thus, within the Air Force, the requirements organization—where the technical expertise is located—manages these activities. The Navy, on the other hand, apparently separates the process of identifying the requirement from the process of developing the requirements documents. Although the survey does not ask who develops the requirement documents (if different than the requirements identification organization), one may assume that it may be the contracting officer, based on the previous survey question of who writes and awards the services contracts. In this situation, the Navy seems to have the organization with the technical expertise and responsibility for managing the requirement identifying the services acquisition requirement, and the contracting officer (who is not a technical expert) developing the requirements documents. Thus, within the Navy, the contracting officer not only conducts the contracting activities for the procured services, but also writes the requirements documents that communicate these services to potential offerors. This mixing of roles and responsibilities between requirements and contracting organizations may lead to ineffectiveness in the services acquisition process as well as vulnerabilities for procurement fraud. The question of whether the contracting officer has the requisite technical expertise to develop the SOW for the service requirement—IT support services, for example— raises a critical issue.

This issue of technical expertise is also raised in the survey. One question asks whether a proper level of oversight is afforded to monitor the contractor’s performance. In response to this question, the Air Force (79%) differed significantly from the Navy (25%). The strong Air Force response may be linked to the previous statement that the QAE, a technical expert, is responsible for contractor surveillance (91%), while the Navy response indicates that the contracting officer (37.5%) or the QAE (37.5%) is responsible for surveillance of the contractor’s performance. Regardless of inference, the fact that only 25% of the Navy respondents consider contractor oversight to be properly monitored is a strong message regarding the effective management of services acquisition.

4.2 Recommendations

The majority of the contracts administered conformed to the expectation of the researchers. The surveys indicate that most service contracts are competitively bid, fixed-priced awards without any incentive. The researchers discovered that the Navy had regionalized most contracting; in such cases, the contracting officer representative (COR) at the installation submits requirement requests to the regional offices. Table 8 indicates that the CO typically writes and awards the contracts, and the COR (or customer's organization) is responsible for surveillance of those contracts. The majority of the service acquisition personnel have a variety of training, from project management to *DAWIA*.

This empirical study on DoD services acquisition reflects that the Air Force and Navy use different contracting approaches in the following areas: organizational level of acquisition offices (regional versus installation), the use of project teams, leaders of the acquisition effort (program personnel versus contracting officers), and managers of the services requirement (program personnel, contracting officers, and customer organizations). Our research has identified some of the impacts and implications of the different approaches on the effectiveness of the contract management process. Further research should investigate the reasons why the Air Force and Navy use these different approaches and could identify any best practices and lessons learned resulting from the use of these approaches.

5.0 Current Research

The objective of the ongoing fourth research project is to collect empirical data on the current management practices of services acquisition within the US Army. To collect this data, an anonymous, web-based survey was employed using the survey software "Survey Monkey." The survey included a total of 81 questions; however, utilizing embedded logic functionality within the survey, participants only provided responses to approximately 60 questions.

The participants for this survey were selected based on the organization they worked for and their position within the organization. The goal was to gather data from every organization within the Army Contracting Command that directly manages or oversees the contracting of services. Once all of the organizations were identified, the individual personnel were selected based on their position within the organization. The researchers sought to have senior contracting officers within the selected organizations complete the survey. The purpose here was to ensure that the person completing the survey had a comprehensive view and understanding of how his/her organization managed services contracts.

The only exception to the criteria above was the exclusion of the Expeditionary Contracting Command from taking the survey. The researchers intentionally omitted the organization within this command for two primary reasons. First, because of the uniqueness of contracting that takes place during contingency operations, the researchers felt the data provided by the Expeditionary Contracting Command would not accurately reflect or correlate well with contracting practices during peacetime operations. Secondly, the researchers did not want to add additional work to these personnel because of the environment and existing workload that Expeditionary Contracting Command is already experiencing.

The survey link was sent to 81 organizations in February 2009. The survey remained available through mid-March, giving the participants sufficient time to respond. At the end of this period, a total of 61 surveys were fully completed, which represents a 75% response rate.

The survey responses are presently being compiled and analyzed. A report based on the survey results will be prepared in summer 2009.

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Contract Management Process Maturity: Analysis of Recent Organizational Assessments

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Abstract

This research builds upon the emerging body of knowledge on organizational assessments of contract management processes. Since the development of the Contract Management Maturity Model© in 2003, several DoD, Air Force, Navy, Army, and defense contractor organizations have undergone contract management process assessments as a part of their process-improvement effort. The assessments were conducted using the Contract Management Maturity Model (CMMM) as the initial step in a program of contract management process improvement. The purpose of this research is to use these combined contract management process assessment results to characterize the current state of practice of contract management within the Department of Defense and defense organizations. This extended abstract provides the conceptual framework for the Contract Management Maturity Model (CMMM) and discusses the components of the CMMM. The symposium presentation and resulting research report will summarize the CMMM assessment ratings, analyze the assessment results in terms of contract management process maturity, discuss the implications of these assessment results for process improvement and knowledge management opportunities, and provide insight on consistencies and trends in these assessment results to defense contract management.

Keywords: assessments, contracting, contract management, procurement.

Background

Procurement and contract management have become increasingly important in the commercial industry as well as in the federal government. As organizations continue to focus on core competencies and outsource non-core, yet critical functions, these organizations are relying on procurement processes as a key to achieving and maintaining a competitive advantage (Quinn, 2005; Patel, 2006). In addition, the federal government continues to increase its level of public spending for goods and services. The Department of Defense obligations on contracts have more than doubled between fiscal years 2001 and 2008—to over $387 billion, with over $200 billion just for services (GAO, 2009, February).

The extent and amount of federal procurement spending demands that these procurement processes be well managed (Thai, 2004). However, recent Government Accountability Office (GAO) reports reflect that this is not the case. The GAO has listed contract management as a "high risk" area for the federal government since 1990 and continues to identify it as high risk (GAO, 2007a, January). Within the federal government, the procurement and contracting function has been elevated to an organizational core competency (Kelman, 2001) and is receiving extensive emphasis in the areas of education, training, and the development of workforce competence models (Newell, 2007; GAO, 2007b, January).

In addition to a focus on increasing individual procurement competency, organizations are now focusing on increasing procurement process competence through the use of organizational process maturity models. Just as individual competence will lead to greater success in performing tasks, organizational process capability will ensure consistent and superior results for the enterprise (Frame, 1999; Kerzner, 2001).

The background and conceptual framework of procurement process maturity and, specifically, the Contract Management Maturity Model, will first be presented. The assessment sites will then be profiled, followed by the analysis of the assessment findings and implications for process improvement and knowledge management opportunities. Finally, a brief discussion on consistent trends in the practice of contract management throughout the federal government will be presented.

Conceptual Framework

A review of the procurement literature finds an established body of knowledge focused on the transformation of the procurement function from a tactical to a strategic perspective. Beginning with Henderson's (1975) prediction of the purchasing revolution in 1964, to Kraljic's work emphasizing the need for a strategic supply management perspective (1983) and Reck and Long's research on developing the purchasing function to be a competitive weapon (1988), the literature reflects the use of various organizational models for the development of the procurement function. These development models reflect the transition of procurement from a tactical to a strategic or integrative function. This discussion summarizes the most significant models used to measure the development of an organization's procurement function.

Reck and Long's (1988) model describes a four-stage development of the procurement function from passive, to independent, to supportive, and finally, integrative. Leenders and Blenkhorn (1988) model describes the three degrees of the procurement function's contribution to organizational objectives. Bhote's (1989) model reflects four stages of procurement development ranging from confrontation, arms' length, goal congruence, and finally, full partnership. Freeman and Cavinato (1990) present a four-stage procurement development model described as buying, purchasing, procurement, and supply. Burt, Dobler, and Starling (2003) present a four-stage progression to world-class supply management. This progression includes clerical, mechanical, proactive, and finally, world-class.

It should be noted that these procurement development models are based on the development of the procurement *function*—specifically, the procurement function's orientation and support of organizational strategy and objectives. As noted in the literature, some organizations' procurement functions reflect more of a tactical purchasing perspective, while other organizations' procurement functions reflect a more strategic perspective. The development models found in the literature reflect the stage of development of the organization's procurement function. These development models are not focused on the *capability* of the procurement processes or the *strength and maturity* of the procurement processes within the organization, but on the procurement function's orientation and support of organizational strategy and objectives. An organization's procurement function can be in the early stages of development from tactical to strategic, yet its procurement process may reflect a high level of maturity. On the other hand, an organization's procurement function may be at the later stages of development toward strategic procurement, but may have weak or immature procurement processes. Thus, these procurement developmental models reflect the transformation of the organization's procurement function, whereas capability maturity models are used to assess an organization's processes to determine the degree of capability or maturity of those processes. The next section will discuss the maturity model concept.

Capability maturity models have been used by many organizations to assess the level of capability and maturity of their most critical processes. In these maturity models, process capability is defined as "the inherent ability of a process to produce planned results" (Ahern, Clouse & Turner, 2001), and maturity is defined as "a measure of effectiveness in any specific process" (Dinsmore, 1998). Most maturity models are built on a series of maturity levels—each maturity level reflective of the level of competence for that process. As the organization gains process competence, it moves up the maturity scale. As maturity increases, so does capability and predictability, while risk decreases. Some of the more established capability maturity models include the Software Engineering Institute (SEI) Capability Maturity Model (SEI CMM) and the Project Management Maturity Model (PMMM). These will be discussed next.

In 1986, the Software Engineering Institute (SEI), with assistance from the MITRE Corporation, began developing a process maturity framework intended to assist organizations in improving their software engineering process. The fully developed Capability Maturity Model (CMM) and associated questionnaire was released in 1993 (Ahern et al., 2001). The SEI CMM has become the most influential quality management system in the United States software industry (Persse, 2001). The CMM is based on five maturity levels—Level 1- Initial, Level 2 - Repeatable, Level 3 - Defined, Level 4 - Managed, and Level 5 - Optimizing (Persse, 2001; Ahern et al., 2001).

The application of capability maturity models to the project management field has been the topic of recent field research—both within academia as well as project management training and consulting companies (Bolles, 2002; Crawford, 2001; Foti, 2002, Kerzner, 2001; Ibbs & Kwak, 2000; Jugdev & Thomas, 2002; Helms, 2002). This recent field research extends the theory of the Software Engineering Institute's CMM model and applies this framework to the project management discipline. There are several project management maturity models currently in use today. Kerzner's Project Management Maturity Model (PMMM), similar to the SEI CMM and the other project management maturity models, is comprised of five levels, with each level representing a different degree of organizational maturity in project management. The PMMM is based on five maturity levels—Level 1- Common Language, Level 2 - Common Processes, Level 3 - Singular Methodology, Level 4 - Benchmarking, and Level 5 - Continuous Improvement (Kerzner, 2001). The SEI CMM and Kerzner's PMMM maturity models are excellent examples of how the concept of capability maturity models have been applied to the software management and project management processes. The literature shows that maturity models are effective methods for assessing and improving organizational competence and maturity. The next section will discuss the application of the maturity model concept to contract management.

Contract Management Maturity Model

The maturity model concept was first applied to organizational contract management processes by Rendon in 2003 with the development of the Contract Management Maturity Model (Rendon, 2003). With the increase in importance of the procurement function and the procurement function's transformation from a tactical to strategic perspective as reflected in the procurement literature, the Contract Management Maturity Model (CMMM) was developed to assess the capability and maturity of an organization's contract management processes (Rendon, 2003). "Contract management," as used in the model, is defined as the "art and science of managing a contractual agreement throughout the contracting process" (Garrett & Rendon, 2005, p. 270). "Maturity," as defined in the model, refers to organizational capabilities that can consistently produce successful business results for buyers and sellers of products, services, and integrated solutions (2005). Thus, contract management refers to the buyer's (procurement) process as well as the seller's (business development and sales) process. The structure of the CMMM is based on six contract management key process areas and five levels of process maturity. The next section will discuss these components of the Contract Management Maturity Model.

CMMM Key Process Areas

The CMMM provides the organization with a detailed roadmap for improving the capability of its contract management processes. The model reflects the six contract management key process areas as well as key practice activities within each process area.

1. Procurement Planning: The process of identifying which organizational needs can be best met by procuring products or services outside the organization. This process involves determining whether to procure, how to procure, what to procure, how much to procure, and when to procure. Procurement planning activities include conducting stakeholder analysis, conducting outsourcing analysis, determining requirements and developing related documents, conducting market research, selecting the procurement method, and selecting the contract and incentive type.

2. Solicitation Planning: The process of preparing the documents needed to support the solicitation. This process involves documenting program requirements and identifying potential sources. Solicitation planning activities include developing solicitation documents such as RFPs (Request for Proposal) or IFBs (Invitation for Bid), developing contract terms and conditions, and developing proposal evaluation criteria.

3. Solicitation: The process of obtaining information (bids or proposals) from prospective sellers on how project needs can be met. Solicitation activities include advertising procurement opportunities, conducting industry and pre-proposal conferences, and amending solicitation documents as required.

4. Source Selection: The process of receiving bids or proposals and applying evaluation criteria to select a provider. Source-selection activities include evaluating proposals, negotiating contract terms and conditions, and selecting the contractor.

5. Contract Administration: The process of ensuring that each party's performance meets contractual requirements. Contract administration activities include conducting a post-award conference, monitoring the contractor's performance, and managing contract changes.

6. Contract Closeout: The process of verifying that all administrative matters are concluded on a contract that is otherwise physically complete. This involves completing and settling the contract, including resolving any open items. Contract closeout activities include verifying and documenting contract completion and compliance with requirements, making final payment, disposing of buyer-furnished property and equipment, documenting lessons learned and best practices, and collecting contractor past-performance information.

Each of these contract management key process areas includes various key practice activities supporting the specific process. The current state of practice of contract management includes various best practices in performing these key practice activities. How an organization performs the key process areas and the extent to which the key practices incorporate best practices will determine the organization's contract management process maturity level. The CMMM consist of five levels of maturity which are discussed next.

CMMM Maturity Levels

The CMMM consists of five levels of maturity applied to the six key process areas previously discussed. The five maturity levels reflected in the model allow an organization to assess its level of capability for each of the six key process areas of the procurement process. The six key process areas and related practice activities allow the organization to focus on specific areas and activities involved in procurement. The five levels of maturity range from an "ad hoc" level (Level 1), to a "basic," disciplined process capability (Level 2), to a fully "structured," established, and institutionalized process capability (Level 3), to a level characterized by processes "integrated" with other organizational processes resulting in synergistic, enterprise-wide benefits (Level 4), and finally, to a level in which "optimized" processes focus on continuous improvement and adoption of lessons learned and best practices (Level 5). The following is a brief description of each maturity level.

Level 1 – Ad Hoc: The organization at this initial level of process maturity acknowledges that contract management processes exist and that these processes are accepted and practiced throughout various industries and within the public and private sectors. In addition, the organization's management understands the benefit and value of using contract management processes. Although there are no organization-wide, established, basic contract management processes, some established contract management processes do exist and are used within the organization; however, these established processes are applied only on an ad hoc and sporadic basis to various contracts. There is no rhyme or reason as to which contracts these processes are applied. Furthermore, there is informal documentation of contract management processes existing within the organization, but this documentation is used only on an ad hoc and sporadic basis on various contracts. Finally, organizational managers and contract management personnel are not held accountable for adhering to, or complying with, any basic contract management processes or standards.

Level 2 – Basic: Organizations at this level of maturity have established some basic contract management processes and standards within the organization, but these processes are required only on selected complex, critical, or high-visibility contracts—such as contracts meeting certain dollar thresholds or contracts with certain customers. Some formal documentation has been developed for these established contract management processes and standards. Furthermore, the organization does not consider these contract management processes or standards established or institutionalized throughout the entire organization. Finally, at this maturity level, there is no organizational policy requiring the consistent use of these contract management processes and standards on other than the required contracts.

Level 3 – Structured: At this level of maturity, contract management processes and standards are fully established, institutionalized, and mandated throughout the entire organization. Formal documentation has been developed for these contract management processes and standards, and some processes may even be automated. Furthermore, since these contract management processes are mandated, the organization allows the tailoring of processes and documents in consideration for the unique aspects of each contract, such as contracting strategy, contract type, terms and conditions, dollar value, and type of requirement (product or service). Finally, senior organizational management is involved in providing guidance, direction, and even approval of key contracting strategy, decisions, related contract terms and conditions, and contract management documents.

Level 4 – Integrated: Organizations at this level of maturity have contract management processes that are fully integrated with other organizational core processes, such as financial management, schedule management, performance management, and systems engineering. In addition to representatives from other organizational functional offices, the contract's end-user customer is also an integral member of the buying or selling contracts team. Finally, the organization's management periodically uses metrics to measure various aspects of the contract management process and to make contract- related decisions.

Level 5 – Optimized: The fifth and highest level of maturity reflects an organization whose management systematically uses performance metrics to measure the quality and evaluate the efficiency and effectiveness of the contract management processes. At this level, continuous process improvement efforts are also implemented to improve the contract management processes. Furthermore, the organization has established lessons learned and best practices programs to improve contract management processes, standards, and documentation. Finally, contract management process streamlining initiatives are implemented by the organization as part of its continuous process-improvement program.

It should be noted that the CMMM uses a purposeful survey designed to acquire data on organizational contract management processes. The CMMM survey is only administered to fully qualified contracting officers and supervisors, as opposed to lower-level and inexperienced contract specialists. The assessment results are used to provide a qualitative assessment of organizational contract management process maturity and not an assessment of an individual's knowledge of contract management. Additional information on the CMMM key process areas, key process activities, and maturity levels are provided in Garrett and Rendon (2005).

The CMMM is limited as an assessment tool simply by the fact that it is based on qualitative survey data. Thus, it is only as effective as the responses to the survey questions. The CMMM should be used as an initial tool in assessing an organization's contract management processes. The CMMM results should be validated with follow-up assessments, including personal interviews based on the initial CMMM assessment results, audits of procurement files, and reviews of procurement process documentation. Additionally, comparison of CMMM results with other procurement metrics—such as procurement administrative lead time, small business awards, and number of protested contract awards—will also provide additional back-up to the CMMM assessment. It should also be noted that the CMMM assessments do not constitute a quantitative analysis nor do they provide any determination of statistical significance in the assessment results.

The remaining sections of this report will profile the organizations that were assessed using the CMMM, summarize the assessment ratings, analyze the assessment results in terms of contract management process maturity, discuss the implications of these assessment results for process-improvement and knowledge-management opportunities, and provide insight on consistencies and trends in these assessment results to defense contract management.

Editor's Note: This is the extended abstract of this research. The complete research report will be available at www.acquisitionresearch.org

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Army Contracting Command Demographics

Presenter: Dr. David Lamm, Professor Emeritus from the Graduate School of Business and Public Policy (GSBPP), served at NPS as both a military and civilian professor from 1978 through his retirement in January 2004, teaching a number of acquisition and contracting courses, as well as advising thesis and MBA project students. During his tenure, he served as the Academic Associate for the Acquisition & Contracting Management (815) MBA Curriculum, the Systems Acquisition Management (816) MBA Curriculum, the Master of Science in Contract Management (835) distance-learning degree, and the Master of Science in Program Management (836) distance-learning degree. He created the latter three programs. He also created the International Defense Acquisition Resources Management (IDARM) program for the civilian acquisition workforce throughout the country. Finally, in collaboration with the GSBPP Acquisition Chair, he established and served as (PI) for the Acquisition Research Program, including inauguration of an annual Acquisition Research Symposium. He also developed the Master of Science in Procurement & Contracting degree program at St. Mary's College in Moraga, CA, and served as a Professor in both the St. Mary's and The George Washington University's graduate programs.

He has researched and published numerous articles and wrote an acquisition text entitled Contract Negotiation Cases: Government and Industry, 1993. He served on the editorial board for the National Contract Management Journal and was a founding member of the editorial board for the *Acquisition Review Quarterly* now known as the *Defense Acquisition Review Journal*. He served as the NPS member of the Defense Acquisition Research Element (DARE) from 1983-1990.

Prior to NPS, he served as the Supply Officer aboard the USS Virgo (AE-30) and the USS Hector (AR-7). He also had acquisition tours of duty at the Defense Logistics Agency in Contract Administration and the Naval Air Systems Command, where he was the Deputy Director of the Missile Procurement Division.

He holds a BA from the University of Minnesota and a MBA and DBA both from The George Washington University. He is Fellow of the National Contract Management Association and received that association's Charles A. Dana Distinguished Service Award and the Blanche Witte Award for Contracting Excellence. He created the NCMA's Certified Professional Contracts Manager (CPCM) Examination Board and served as its Director from 1975-1990. He is the 1988 NPS winner of the RADM John J. Schieffelin Award for Teaching Excellence.

Author: Dr. Timothy Reed

Abstract

This study focuses on the demographics of contracting personnel in the newly formed Army Contracting Command (ACC) headquartered at Fort Belvoir in Northern Virginia. This new Command has approximately 4,100 civilian contracting personnel in the 1102 (contract management) occupational career field, and 255 military officers and enlisted all located around the globe. The new commander, Mr. Jeffrey Parsons, asked the Naval Postgraduate School (NPS) to undertake an effort to understand the nature (demographics) of his contracting workforce as well as how it compares to other similar contracting workforces in the DoD, the civilian Federal agencies and, to the extent possible, private industry.

Numerous acquisition studies and commissions have cited personnel management as one of the most critical factors contributing to the success or failure of buying organizations. Strategic human capital management and DoD Contract Management have been on the Government Accountability Office (GAO) High-risk List for the last several years. Actions to

understand the nature and dynamics of the acquisition workforce are a first step toward the development and execution of an integrated strategic human capital management plan.

Specific data for this study have come primarily from the Army Contracting Command personnel database. Additional data were obtained from the Defense Manpower Data Center (DMDC) and the Defense Acquisition University (DAU). Data at a more aggregate level have been obtained from the US Air Force, the Federal Acquisition Institute (FAI) and professional/industry associations, such as the National Contract Management Association (NCMA) and the Institute for Supply Management (ISM).

Demographic data initially explored include: Age, Gender, Grade Level, Years of Service, Pay Plan (civilians), Educational Level, Degree Type, Certification Level in Contracting, and Years to Anticipated Retirement. Other demographic data to be researched include: Year Certified at Current Level, Other Professional Certifications, Military Reserve Affiliation (civilians), Prior Military Service Organization (civilians), Prior Military Service Length (civilians), How Accessed in Current Position, Year Accessed into Current Position, and Professional Affiliation(s). Additional demographics, such as organizational factors, will be added as the research progresses. These data will be periodically extracted from the appropriate databases to establish trends and suggest management actions to address critical issues.

Closely related to an organization's demographics are the skills and competencies held by workforce members. Educational degrees and certification levels held by employees may be indicative of the ability of the workforce to perform effectively and efficiently; however, competency and technical/professional skill levels are also important indicators of the workforce's capabilities. The Office of the Secretary of Defense (OSD) and the Federal Acquisition Institute (FAI) have conducted competency studies that have attempted to identify contracting proficiency levels for various competencies generally grouped as being of either a business or technical nature. Examples of some of the more critical skills in each of these categories includes creative thinking, problem solving, customer service, and interpersonal skills in the business category; and cost/price analysis, proposal evaluation, negotiation, and source selection in the technical category. This research uses the OSD and FAI study results for comparison purposes.

In recent years, many DoD organizations have begun to contract with private firms to perform contracting functions. Several factors have led to an increased reliance upon the private sector to provide services, one of the most critical factors being the lack of adequate numbers of civil servants to perform the functions required of buying organizations. In order to get a general idea of the numbers and types of contractor personnel that may be under contract, a questionnaire was e-mailed to the fifteen ACC Principal Assistants Responsible for Contracting (PARCs). The questionnaire did not ask for names (firms/employees) or the specific functions contractor personnel performed. It did ask for numbers of contractor firms and employees, percentage of the workforce represented by contractor employees, gender, age ranges, educational credentials, years of contracting experience, and prior Government experience, including any *Defense Acquisition Workforce Improvement Act* (*DAWIA*) contracting certifications.

In summary, the objectives of this research are to: (1) identify, collect and maintain key demographics regarding the ACC contracting workforce, (2) analyze the demographic database, (3) establish a baseline for the training and competencies of ACC members, (4) identify a process to determine the key issues involved in member decisions to join and leave the contracting workforce, (5) identify best practices from government and industry regarding incentives to enhance contracting workforce performance, and (6) provide recommendations for improving the capability of the ACC contracting workforce.

Panel 22 - Assessing Collaborative Capacity and Collaborating in the Acquisition Domain

Thursday, May 14 2009	Panel 22 - Assessing Collaborative Capacity and Collaborating in the Acquisition Domain
3:30 p.m. – 5:00 p.m.	**Chair: James T. Simpson**, Dean, College of Business Administration, University of Alabama, Huntsville **Discussant: Michael Schwind**, Vice President, Maritime Solutions Sector, Siemens Product Lifecycle Management Software ***UK Defence Acquisition Process for NEC: Transaction Governance within an Integrated Project Team*** **Ermias Kebede, Eunic Maytorena, David Lowe** and **Graham Winch**, Manchester Business School ***The Theory and Measurement of Interorganizational Collaborative Capacity in the Acquisition and Contracting Context*** **Erik Jansen, Susan Hocevar, Rene Rendon** and **Gail Thomas**, Naval Postgraduate School

Chair: Dr. James (Jim) T. Simpson is Dean and Distinguished Professor of Marketing in the College of Business at the University of Alabama in Huntsville. Simpson received his BS and MBA degrees from the University of Southern Mississippi, and his PhD in Marketing and Applied Statistics from the University of Alabama. Prior to being appointed Dean in January 2008, Simpson served as the Chair of the Management and Marketing Department and for three years was the Director of the UAHuntsville Center for the Management of Science and Technology. In 2005, he was elected President of the American Marketing Association Technology and Innovation Special Interest Group. His research in the structure and behavior of supply chain systems, marketing high-technology products, and risk management in software development has been published in the leading US and international academic journals. Simpson has served as a visiting scholar and professor at some of the world's leading universities in Russia, Romania, France, England, China, Ireland, and Taiwan. In 2004, he received the Academy of Marketing Science National Outstanding Marketing Teacher Award. In 2005, the UAH business school alumni chose Simpson as the faculty member who has had the greatest impact on their lives. In addition to his academic work, he has consulted with numerous military and business organizations in the US and abroad. Simpson retired from the US Army Reserves in 1994 following 24 years as a field artillery officer.

Discussant: Michael A. Schwind is Vice President of Maritime Solutions, Siemens PLM. Schwind's professional career has encompassed the engineering and manufacturing lifecycle industries. In 1998, he commenced his employment as an employee of McDonnell Douglas Corporation. Since then, he has worked his way up through the organization and across several acquisitions (EDS, SDRC and Siemens). He has consulted with numerous *Fortune 100* companies such as General Electric, Ford, Boeing, Hewlett-Packard, Lockheed Martin, and Honeywell. In his current position as Vice President of Maritime Solutions, his relationships span across the Aerospace and Defense community—including the OEM Tier 1 Shipyards of Northrop Grumman Shipbuilding and General Dynamics Marine Systems. He has numerous relationships across the NAVY and Marine Corps. Schwind has been a guest speaker at multiple industry events and is a current member of Surface Navy Association (SNA) and American Society of Naval Engineers.

UK Defence Acquisition Process for NEC: Transaction Governance within an Integrated Project Team

Presenter: Mr. Ermias Kebede graduated from the School of Physics and Astronomy at the University of Manchester in 2006 with an Upper-Second Class Honours degree in Physics with Business and Management. He continued his education by undertaking a Master's in Business at MBS, for which he received a Merit. His Master's dissertation, "Privatising New Build," addressed issues concerning the privatisation of the construction of nuclear power stations in the UK. Kebede is a PhD candidate in his second year at MBS, researching UK defence acquisition applying a transaction cost approach.

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Dr. Eunice Maytorena completed her PhD degree at Bartlett School of Graduate Studies (UCL) in 2003 on the cognitive understanding of the building conversion process. An architect by training, her work experience includes architectural design and consultancy, research in various aspects of the built environment, and lecturing in project management. Maytorena worked on several research projects investigating risk perceptions and risk management in project forms of organisations. From 2006-2009, she was a researcher on NECTISE (Network Enabled Capability Through Innovative Systems Engineering), exploring organisational aspects of Through Life Systems Management. Maytorena became a lecturer in Construction Project Management for MBS in 2007.

Dr. David Lowe is a senior lecturer in Commercial Management at MBS. He is a Fellow of the Royal Institution of Chartered Surveyors (RICS) and a registered practitioner of the Higher Education Academy. Lowe is a member of the RICS UK Education Standards Board and the International Association for Contract and Commercial Management (IACCM). Lowe is an editorial board member for the *Journal of Financial Management of Property and Construction* and the RICS Research Paper Series. His consultancy work includes benchmarking the engineering and project management provision of an international pharmaceutical company. His research and teaching activities encompass a wide-range of project-based industries.

Prof. Graham Winch is the Director of the Centre for Research in the Management of Projects and the BP Managing Projects Executive Education programme at MBS. Winch is a member of the Comité Consultatif, Centre Scientifique et Technique du Bâtiment, France, the Comite Scientifique, Réseau Activités et Métiers de l'Architecture et de l'Urbanisme, the Peer Review College of the Engineering and Physical Sciences Research Council, and the Editorial Board of Construction Management and Economics. He is an advisor on construction innovation policy to the Dutch, French, and UK governments. He is an academic-lead in Through Life Systems Management for NECTISE from 2006-2009.

Abstract

Using a 3-tier framework for a study of the acquisition of an Advance Military Vehicle (AMV), we explore the shaping of the buyer-supplier relationship in the context of the UK defence acquisition process. This relationship encompasses the Ministry of Defence (MoD), a monopsonist, partnering with a monopolistic defence industry. The transition from an oligopolistic to monopolistic defence industry is a result of a number of government policies that

have created a consolidated defence industrial base. Defence industry relationships have historically been adversarial, making defence acquisition in the past inefficient. We identify Integrated Project Teams (IPTs) as being central to the institutional level aims of creating a collaborative industrial relation. IPTs characterise relational contracting practices at the governance level, which demands communication, collaboration and trust. However, difficulties at the process level in utilising relational contracting because of a lack of definition, communication and mutual gain within the day-to-day business of the IPT limit the benefits of this approach. This failure to create an effective partnership between the MoD and its prime contractors highlights the major challenge facing the UK defence sector in its transition towards capability acquisition, such as Network Enabled Capability (NEC). NEC demands a more collaborative, through-life approach to defence acquisition.

Introduction

Defence acquisition has undergone profound changes in recent years as the consolidation of the supply sector, the shift towards the acquisition of capability rather than platforms and the development of systems-of-systems technologies have generated major challenges for both demand and the supply sides. Through a case study of an Advanced Military Vehicle (AMV) and the Integrated Project Team (IPT) that is delivering it, we propose in this paper to explore these issues using a three-tier model that captures how institutional policies are experienced within the project team and how, in turn, those experiences shape institutional policies. Our conceptual framework for this analysis are drawn from Gidden's (1984) work on structuration and Williamson's (1975,1985) work on transaction cost economics (TCE) as a model of understanding managers' behaviour in an economic environment characterised by a complex and shifting mix of market and hierarchy in relationships between organisations. The model framework aims to provide an analysis of the institutional, governance and process levels of a transaction.

At the *institutional level*, we aim to understand the current acquisition policy of the buyer, the MoD, and how this impacts its suppliers in the defence industrial base. An historical review of defence industrial relations is therefore presented. It is shown that the MoD is shifting its acquisition policy from being platform-centric to capability-centric; coinciding with this modernisation programme is a gradual change in the structure of the defence sector. In the *governance level* section, we use a transaction cost approach to examine the choice of relational contracting, demonstrating how the IPT structure and ethos favours relational contracting practices. The discussions will emphasise the bidding process, contract award stage, and the demonstration phase, and the impact each has on the long-term relationship between the MoD and its prime contractor. The final level of the three-tier model is the *process level*. In the process level section, we consider the organisational structure of the IPT. We look closely at how the IPT works as a team, how they deliver the tasks for each phase in the context of the routines on the project. In our discussions, we emphasise the importance of cross-level interaction. We begin the paper by explaining our conceptual framework and method.

Conceptual Framework

Our conceptual framework for investigating the processes of the acquisition of military vehicles is derived from the general sociological work of Giddens (1984) on "structuration," which has been more recently developed as the "tectonic approach" to organisation (Winch 1994). Applying the tectonic approach to the management of projects identifies three levels of analysis that interact with each other in a recursive cycle of constraint and change (as illustrated in Figure 1). In the tectonic approach, the institutional level of analysis shapes and is shaped by decisions made at the governance level. Decisions at the governance level select the organisational structures within which the project process flows, but those processes also shape governance-level decisions. The process level is where the project is implemented through a flow of information, which initiates and controls a flow of materials.

The institutional level covers the wide range of issues around the features of the national and sectoral business systems, but in the defence sector, the principal institutional manifestation is the current defence ministry acquisition policy, and so it is this institutional aspect upon which this paper will concentrate.

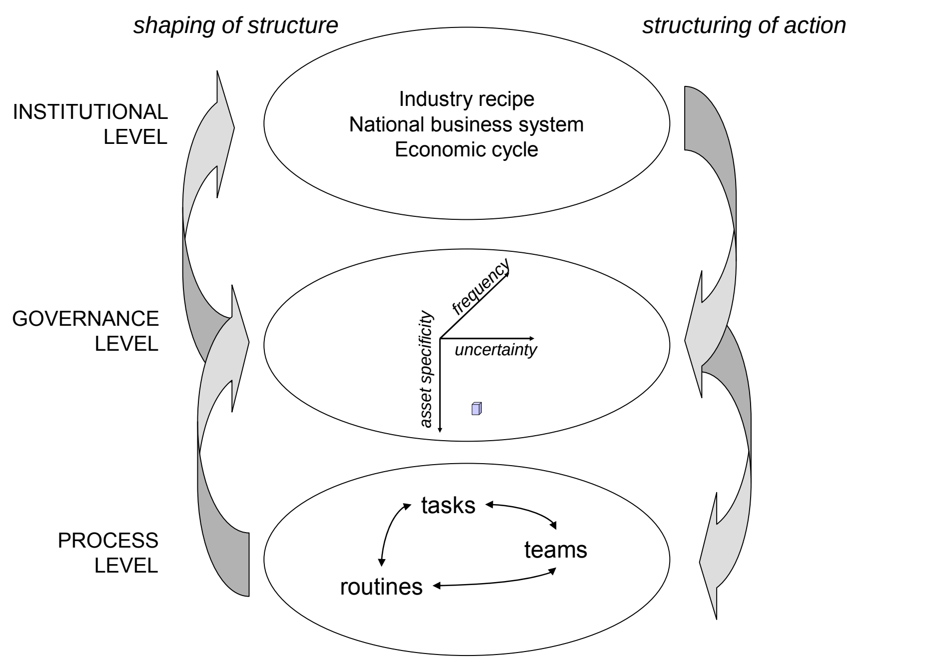

Figure 1. The Tectonic Model
(Winch, 2009)

The conceptual framework for the analysis of the governance level is derived from institutional economics, particularly the work of Williamson (1975, 1985) on transaction cost economics, as adapted for project organisations by Winch (2001). Williamson's basic proposition is that total costs of supply are derived from two main components—production costs and transaction costs. Production costs are well understood and, in essence, involve the efficient transformation of inputs into outputs, where prices are used to signal the most efficient choice of technology. Transaction costs are the costs of co-ordinating any complex production process and occur when a good or service crosses a "technologically separable interface." He argues that there are two basic options for co-ordinating—or governing—transactions. A *market transaction* is where independent buyers and sellers meet in the market to negotiate a price for the supply of a good or service in a spot contract—prices are set by what Adam Smith called the "invisible hand" of the market. An *hierarchical transaction* is on in which the transaction is governed internally by administrative means—prices are determined by what Alfred Chandler called the "visible hand" of management through an authority relation. Between these two polar forms of transaction governance lay a wide variety of mixed forms of *relational contracts*.

What determines the most efficient governance mode on a project? Williamson argued that there were three main characteristics of transactions that influenced the choice of how they are governed: uncertainty, frequency and asset specificity. Uncertainty affects transactions because it creates *bounded rationality* for decision-makers. This bounded rationality makes writing a complete and unambiguous contract between the parties impossible because of uncertainty regarding the precise conditions under which the contract will be executed and also makes it impossible to measure fully the performance of the contract. Asset specificity is the condition in which either the buyer or supplier is limited in its choice of transaction partner due to the specific nature of the resources to be supplied. This asset specificity may be pre-contract (in which case, the problem is one of monopoly or monopsony in the market), or it may be generated post-contract because contract-specific investments are made by one or both of the parties in the hold-up problem (Masten, Meehan & Snyder, 1991). This generates the possibility of *opportunism* on the part of one of the parties as they exploit the other's disadvantage—which often takes the form of withholding information from the other party. Frequency affects transaction governance because one-off transactions provide no opportunity to learn about the other party, while repeated transactions allow *learning* about the behaviour of the other party and hence the generation of trust. Thus, the most appropriate choice of transaction governance mode can be thought of as occupying a three-dimensional space in the manner indicated in the middle level of Figure 1.

Governance has two distinct aspects:

- The *contractual,* which captures the underlying legal basis of the relationship. While the precise formulation of these legal relationships varies significantly between countries, there is a large degree of functional equivalence in all developed economies between these formulations.
- The *relational,* which captures the interpersonal and interorganisational aspects (processes and behaviours) of the governance arrangements around issues such as trust and perceived equity in governance.

Within this perspective, the extremes of the governance continuum can be considered to be tending to zero on relationship aspects at the market end (pure spot contracting) and tending to zero on the contractual aspects at the hierarchy end (pure autocracy). Although some have argued that the contractual aspects can undermine the development of the relationship aspects, recent research has shown that they are more complementary than antagonistic dimensions of transaction governance (Poppo & Zenger, 2002).

The process level in Figure 1 is shaped by the institutional and governance levels and in turn shapes those levels, which shows how, for a given project mission, riding the project lifecycle is a dynamic interplay between routines, tasks, and teams (Manning, 2008):

- *Routines* are the learned practices developed within the industry recipe that are carried from project to project and then adapted to meet the needs of particular projects (Feldman & Pentland, 2003; Nelson & Winter, 1982). Routines therefore specify the *how* of riding the project lifecycle; they are an essential element of managerial activity, yet their implementation is contradictory in that they both constrain and enable managerial action.
- *Teams* are the *human resources* allocated from the resource bases mobilised on particular projects, providing the *who* of riding the project lifecycle.

- *Tasks* are the *what* of riding the project lifecycle—the set of tasks that has to be completed in order to realise the particular project mission, typically captured in the work breakdown structure.

Routines, tasks and teams are negotiated and renegotiated for a particular project chartered by its project mission. As the project moves through the lifecycle, the tasks change, and hence different teams that deploy different routines are mobilised. However, prior choices of routines also shape which teams are selected by which criteria and which tasks are deemed to be in scope to the project. The coordination routines used by project managers to organise task execution teams need to be continually adapted to the needs of the particular project, while retaining enough overt good practice to serve as a legitimation for the actions of the project manager. Thus, the project process is indeed a negotiated order in which "the bases of concerted action (social order) must be reconstituted continually; or [...] worked at" (Strauss, Schatzman, Ehrlich, Bucher & Shabshin, 1971, p. 104), and routines provide the raw material for this work in the context of governance and institutions.

Method

Our research method to explore the dynamics of defence acquisition is a case of the acquisition of an Advanced Military Vehicle (AMV) by the UK's Ministry of Defence (MoD). Our data on the institutional level come largely from a review of MoD policy documents complemented by a number of strategic-level interviews with key informants. Our data on the governance and process levels come from a case study of the AMV project organisation, which is delivering it for MoD, and consists of 19 field interviews with project participants and the collection of documentary data. The informants interviewed for this research are identified in Figure 3. This field research is still in progress, so the data reported here represent only a preliminary statement of our findings. The AMV is presently at the demonstration phase of the CADMID process presented in Figure 2.

The Institutional Level

The institutional level is represented by an evolving defence sector, characteristically dependent on national defence policy from successive governments. The UK defence sector is reliant on the buying behaviour of its largest single buyer (a monopsonist), the MoD. It is the MoD's buying power that enables it to "determine the size, structure, conduct and performance of defence industries" (Hartley, 1991, p. 79). To understand the complexity of the UK defence acquisition process, it is important to comprehend the specific nature of the defence industry, the defence business system (the defence industrial base), and the economic policies that have shaped the defence sector. This narrative will develop the institutional level analysis by charting evolutions: from privatisation to prime contracting, from a competitive industrial sector to a consolidated, monopolistic one, and from protectionism to liberalisation.

We begin our analysis of the defence sector at a critical point in UK defence history—the era of privatisation heralded by the Conservative Government of Margaret Thatcher. Of the five largest defence companies in 1979, four were state owned: British Aerospace, British Shipbuilders, Royal Ordnance Factories and Rolls Royce. The exception was General Electric Company (GEC) (Smith, 1990). The government favoured a free market policy in which the MoD could engage in competitive tendering. The newly privatised firms and new entrants in the defence sector would bid for defence contracts, and the invisible hand of the market would regulate the price of the bid. However, post-privatisation there was minimal evidence of competition because:

- Newly privatised firms were the recipient of vital technical and managerial knowledge, making the playing field unbalanced for new entrants;
- Protectionist policy that favoured domestic defence companies meant there was minimal competition from foreign-owned companies.

The lack of competition on the supply-side meant that the existence of monopolies was common in the defence sector, post-privatisation. The bargaining positions of the monopsonist buyer and monopolistic supplier were levelled by the buyer having regulatory powers and the supplier possessing monopoly powers. Furthermore, defence contracts predominantly incorporated cost-plus payment terms under which the MoD retained significant levels of project risk (Cullen & Hickman, 2001). Because of the complexity and uncertainty evident in defence projects, it is difficult to assess the efficiency of a cost-plus contract. A key part of cost-plus contracts is the cost-reimbursable aspect of the agreement, making costly investments attractive to contractors (Williamson, 1967) and it was, therefore, a common feature of defence acquisition projects.

The early days of privatisation were fraught with conflict between the MoD and the defence industry. “By the early 1980s there was considerable dissatisfaction with such traditional procurement policies. Lack of competition had, it was argued, created inefficiency in the defence sector, while cost-plus contracts created little incentives to keep costs down” (Bishop, 1995, p. 175). The MoD recognised that it had to change the nature of its role in the defence sector from its traditional monitoring and auditing function to a more stringent administrator role. It also acknowledged a desire to transfer the risk of defence projects to suppliers (Smith, 1990). Peter Levene, the MoD Chief of Defence Procurement (1984-91), was responsible for the implementation of the MoD’s new policy of “competition and collaboration.” The procurement reforms, more commonly known as the Levene reforms, targeted the “promotion of competition and the transfer of risk from the MoD to industry” (Macdonald, 1999, p. 6). The MoD was able to transfer the risk in procurement by replacing the cost-plus contracts with firm- or fixed-price contracts let by competitive tender. “Since 1983, MoD has become more conscious of the need to obtain better value for money in equipment procurement. As a result, it has become a more demanding customer, with competition as the central element in its more commercial approach” (Hartley, 1991, pp. 75-76).

As the Cold War neared its end, in the late 80s, the UK defence budget was reduced from its peak in 1985 by a gradual decrease of 18% in real terms between 1986-87 and 1990-91 (McIntosh, 1993). In addition, the MoD opened up defence contracts to foreign competition in a partial liberalisation of the defence sector: partial because the MoD continued to implement protectionist policies. The UK manufacturing sector was dependent, in supporting local economies and employment, on the defence sector; awarding defence contracts to foreign companies was politically sensitive. The Thatcher Government signed up to the Independent European Programme Group, which was geared towards opening up the European defence equipment market to greater international competition. Theoretically, overseas defence companies could compete for procurement contracts tendered by the MoD (Smith, 1990). However, it was evident that the MoD was not ready to pressure the domestic defence industry with competition from established foreign companies. In 1987-88, the only foreign-owned company belonging to the top 15 companies to receive a contract worth over £100 million was Boeing (Smith, 1990). The argument for the continuation of protectionist policies by the MoD was also due to the fear that key technological knowledge would be lost to foreign-owned companies. The prevailing view was this would damage the domestic defence sector and make the UK reliant on foreign technology.

Foreign-owned firms entered the UK defence sector in the more “acceptable” form of alliances, joint ventures and, mergers: safeguarding local jobs and preserving the domestic defence industries. The combination of competition, divestures and liberalisation brought about the restructuring of the UK defence industry. The larger defence companies moved to consolidate their positions by acquiring smaller firms.

> 1988-89 saw major changes in structure and corporate strategy in the European Defence Industries. The GEC-Siemens bid for Plessey, the Daimler-Chrysler acquisition of [Messerschmitt-Bölkow-Blohm], the merging of Aerospatiale’s avionics interests into Thomson CSF, were among the most notable of a range of acquisition and divestments, national and international, which have tended to increase concentration. (Smith, 1990, p. 200)

The restructuring of the UK defence sector transformed the defence industrial base from oligopolies to monopolies. Contrary to its own objectives of creating competition, the MoD was partly responsible for the creation of “industry champions.” When GEC moved to acquire Ferranti and VSEL, the Monopolies and Mergers Commission recommended against the acquisition. The MoD, however, intervened to encourage the acquisition in an overall aim to protect defence industrial capabilities, to ensure domestic demands were met, and support defence contractors to compete in the international defence exports market (Macdonald, 1999). Ironically, in 1999, GEC’s board decided to divest its defence business (Alenia Marconi Systems) to British Aerospace, which created the UK’s largest defence company, BAE Systems.

During the 1990s, competitive tendering was more evident in defence contracting. This, however, was counteracted by the increase in monopoly defence industries, which to a large extent was counter intuitively supported by the MoD. The MoD, in effect, created a defence sector with few players controlling their own specialist component industries. UK defence companies began expanding their activities internationally, e.g., BAE Systems North America, and reducing their reliance on their domestic market. The UK defence procurement supply-chain relationship in the late 90s was characterised by “global market conditions (concentration) and increased customer (MoD) sophistication to change” (Humphries & Wilding, 2004, p. 261). The restructuring of the defence sector combined with the introduction of firm and fixed price contracts had major effects on the once cosy relationship between the defence industry and ministry. The MoD moved to control the monopolistic supplier by introducing greater competition in the tendering process and by creating strict conditions on non-competitive contracts with monopoly suppliers. The “No Acceptable Price, No Contract” initiative was implemented in 1992 in non-competitive defence contracts. This initiative was introduced to ensure that contractors would abide by the “value for money” principles. Target Cost Incentive agreements were predominantly used for non-competitive defence contracts. The contracts stipulated that the MoD and its contractor would share the risk of cost-overruns or the savings accrued (Macdonald, 1999). In placing these stringent controls on their suppliers in terms of costs and performance, the MoD was entering into a more adversarial relationship with the defence industry. “There was also a decline in mutual co-operation as civil servants adopted more hostile attitudes during contract negotiations in order to secure the lowest prices possible” (Macdonald, 1999, p. 18).

Prime contracting was introduced as the mechanism for transferring risk from the customer (MoD) to the supplier. In the past, the MoD was responsible for integrating the separate components and systems of the platform (end product). The responsibility of systems integration was passed onto the main supplier (prime contractor) in the supply chain, and the prime contractor was responsible for overall supply chain management. In security-sensitive areas, the MoD maintained control over the selection of subcontractors. The prime contractor was given project milestones, such as technical demonstrations or systems delivery, linked to payment terms in either firm- or fixed-price contracts (Mathews & Parker, 1999). The allocation of a prime contractor to a defence project can be a complex issue.

The challenge of allocating a prime contractor rather than retaining systems production in-house (make-or-buy decision) is explainable using a transaction cost approach. The aim of prime contracting is to minimise the project risk. The risk is not always easy to identify, or cost, due to the complexities and uncertainties in defence contracting. The MoD is affected by information impactedeness problems (Williamson, 1975), as a result of the uncertainty/complexity being combined with bounded rationality. “MoD does not routinely obtain data on which to base an assessment of comparative costs” (Mathews & Parker, 1999, p. 36) making it difficult to choose the most cost-effective prime contractor. For the suppliers prime contracting was, at the beginning, a risky venture in terms of the costs or profits that could be recouped. Prime contractors responded by adding premiums for risk acceptance. When performance and budget milestones were achieved, the prime contractors gained premium payments on top of their profits. If the risk of overspending was not mitigated, then the contractor was damaged by the costs/penalties: thus the gamble. These uncertainties and complexities have, over time, become manageable: “Arguably, the UK defence industry is now more capable of developing weapon systems, rather than individual subsystems, than was previously the case” (Mathews & Parker, 1999, p. 37), through the advantages of what Winch (2001) terms the learning effects on transaction costs.

The introduction of prime contracting was part of the MoD’s strategy to position itself as an “intelligent buyer” in the defence industry. This was achieved through the transfer of project risk to the suppliers, the introduction of more stringent contractual agreements—such as firm, fixed-price and incentive-based contracts—and competitive tendering as well as non-competitive controls. The MoD, on the other hand, needed to address the adversarial nature of its relationship with industry. The introduction of the Strategic Defence Review (MoD, 1998) commenced the process of addressing the challenges in these relationships. It highlighted three areas in which defence procurement was failing to achieve efficiency (despite the changes mentioned above): poor value for money; poor project management; and poor industrial relationships. In order to tackle these issues, the MoD introduced the “Smart Procurement Initiative.” The initiative was a joint exercise with defence suppliers to identify a new set of procurement processes that would improve the way the MoD procured defence equipment. The changes were brought about with consultation from the Defence Industries Council and the Trade Associations.[1] The MoD restructured its organisation as a result. In 1999, the three single service logistic organisations for the Royal Navy, Royal Air Force, and Army, were unified to create the Defence Logistics Organisation (DLO). In the same year, the Procurement Executive was given agency status, and became the Defence Procurement Agency (DPA). The responsibilities of the DLO and DPA are shown in the lifecycle process CADMID (Concept, Assessment, Disposal, Manufacture, In-Service and Disposal) in Figure 2. “The CADMID cycle has been used since 1999, when it was devised as part of the ‘Smart Procurement’ initiative to

[1] The Defence Industries Council is chaired by the Defence Secretary and constitutes representatives from the defence industries and the four major trade associations (the Society of British Aerospace Companies, Defence Manufacturers Association, Federation of the Electronics Industry and British Naval Equipment Association). The purpose of the council is for the MoD to consult the defence industries on matters of common interest (MoD, 1998).

deliver equipment capability within agreed performance, cost and time parameters" (MoD, 2006, p. 13). The DPA was given responsibility for the procurement phase of the lifecycle (Concept-to-Manufacturing) with the DLO providing support for the operational phase (In service-to-Disposal).

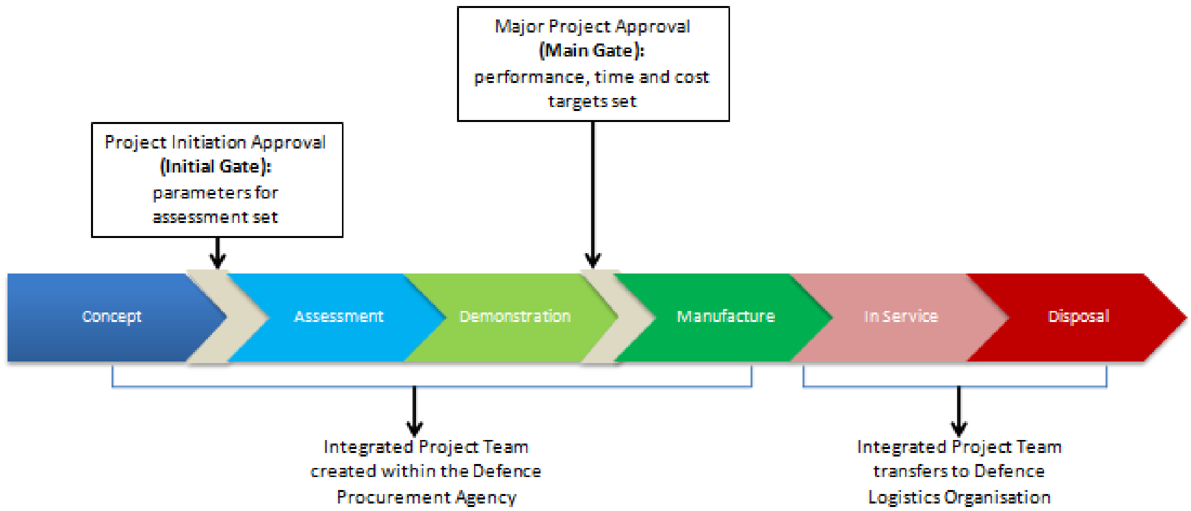

Figure 2. CADMID
(Adapted from NAO, 2004, p. 29)

The reforms within the Smart Procurement Initiative were aimed not only at restructuring the MoD but also at looking to create a partnership with prime contractors in which competition would create better value for money and customer service. "This introduces a 'whole-life approach' to acquisition, and has as one of the main tenets, the use of MoD Integrated Projects Teams to work closely with all contractors and their suppliers in order to identify 'Gainshare' opportunities" (Cullen & Hickman, 2001, p. 525). Gainshare is the mechanism by which the MoD promotes cooperation with its prime contractor and incentivises them to identify possible savings which can then be inserted into the contract agreement. IPTs[2] were created as an embodiment of the collaborative relationship between the MoD and its prime contractor. "The overriding objective of the IPTs is to reduce the costs of procurement by developing more open relationships with their contractors promoting innovation and monitoring all operations within a 'shared data environment'" (Cullen & Hickman, 2001, p. 527).

The Smart Procurement Initiative, while having many advantages, was restricted in scope. The MoD recognised that in order to reform its supply-chain strategy it needed to look beyond procurement and encompass the entire acquisition process. The effective acquisition and support of defence capability incorporates initial procurement and on-going support as integral parts of the overall acquisition process. The Smart Procurement Initiative was renamed Smart Acquisition in 2000. The aim of Smart Acquisition is "to enhance defence capability by

[2] IPTs consist of MoD personnel from key specialisations (such as finance and defence requirements office) working alongside business unit representatives from the prime contractor to deliver defence acquisition from concept-to-disposal.

acquiring and supporting equipment more effectively in terms of time, cost and performance" (MoD, 2001, p. 4). Smart Acquisition seeks to improve the relationship between the MoD and the defence sector based on seven principles:

- A whole life approach, typified by applying through life costing techniques
- Integrated Project Teams (IPTs) with clearly identified customers
- A better, more open relationship with industry
- More investment in the early phase of projects
- Effective trade-offs between system performance, through-life costs and time
- New procurement approaches, including incremental acquisition
- A streamlined process for project approval

With these principles, the MoD is making an implicit change in the way it wants to do business with its industrial base. The MoD wants to move away from the adversarial relationship which has typified defence equipment acquisition and create a partnership approach (MoD, 2002). The issue of responsibility for project risks was an important driver of the changes made to the acquisition process. With Public Private Partnerships and Private Finance Initiatives, becoming more evident in defence equipment projects (MoD, 2002), risk management has become central to how projects are managed and delivered. The MoD is intent on placing the risk on the prime contractor; however, this means that it has to relinquish the propriety rights, which provide the returns on risk. This affords prime contractor the chance to exploit opportunities in the export market (depending on regulatory rules imposed on defence exports) using their proprietary knowledge and products. The MoD loses the technical know-how that comes with development and is thus more reliant on its industrial base, making the relationship it has with its suppliers ever more important. Smart Acquisition attempts to apply a range of principles to create an efficient and effective defence acquisition process. The MoD continues to restructure its organisation so that it can improve the acquisition process. The latest of these restructures was the merger of the DLO, DPA and the DCSA (Defence Communication Service Agency) in April 2007 to create Defence Equipment and Support (DE&S). The DE&S has assumed all responsibilities of the previous departments and agency—the main aim of the integration being to create a coherent organisation and remove dual accountability problems inherent in the past configuration (MoD, 2007).

Central to the changing nature of defence industrial relationships is the formation of IPTs. The structure of the IPTs has slightly changed (with the restructuring of the MoD), but the vision remains the same as originally conceptualised. IPTs originally were dually accountable to the DPA and DLO, as shown in Figure 2. In the current DE&S structure, this dual accountability has been removed, however the day-to-day activities and the people working in IPTs remains the same as before (MoD, 2007).

> Although the main function of IPTs—the delivery of equipment and support to the Front Line—will remain fundamentally unchanged there will be differences to the ways in which they fulfil this role. In fulfilling these responsibilities, team leaders and their staff will, as now, be required to work within the overall DE&S governance framework and in accordance with its key processes. (MoD, 2007, p. 16)

The vision remains to create better engagement between the MoD and its supplier(s) through the IPT mechanism. This is a policy vision, which has been espoused in numerous MoD policy papers and publications (MoD, 1998; 2002; 2005). For example, at the institutional level, IPTs possess a policy context. On the governance level, they are identified in terms of the relational contracting approach they engender, and in investigating the day-to-day activities of IPT members, we can identify the "teams, tasks and routines," which characterise the process level. This does not, however, suggest that the levels are inherently synergetic. As we shall discuss in the following sections, there are stark differences in the vision outlined at the institutional level, the purpose at the governance level, and the reality at the process level.

A major development in UK defence acquisition in the last decade has been the transition towards "Capability Acquisition." IPTs are responsible for delivering the capabilities required by the end-use customer, the Armed Forces. As early as 1998, the UK viewed its acquisition policy in terms of capabilities rather than platforms. In the *Strategic Defence Review*, the MoD (1998) states its desire to change its equipment acquisition from a "one for one basis" towards a more collective acquisition policy offering a "new level of battlefield capability." "While the concept is still at a relatively early stage, we are now describing our Military Tasks in more generic terms using the language of effects. This supports a future force development process focussed on capability—able to contribute to delivering a range of effects—rather than like-for-like platform replacement" (MoD, 2003, p. 10). The transition towards an acquisition policy based on capabilities has transformed the scope of defence acquisition towards a whole-life and integrated systems approach. Through-life capability management (TLCM) was introduced as a way of managing capability acquisition.

> There is a general shift in defence acquisition away from the traditional pattern of designing and manufacturing successive generations of platforms—leaps of capability with major new procurements or very significant upgrade packages—towards a new paradigm centred on support, sustainability and the incremental enhancement of existing capabilities from technology insertions. The emphasis will increasingly be on through-life capability management, developing open architecture that facilitates this and maintaining—and possibly enhancing—systems engineering competencies that underpin it. (MoD, 2005, p. 19)

TLCM provides those in charge of delivering defence capability (IPTs and DE&S) with a holistic way of viewing current and future capability requirements, with incremental acquisition being a central part of the approach (MoD, 2006).

> TLCM will consider a much wider range of options for meeting capability needs, examining both new and in-service equipment solutions, exploring opportunities and implications for trading across all DLODs [Defence Lines of Development]—Equipment (including Support), Personnel, Training, Logistics, Infrastructure, Concepts—while considering capability delivery on a much longer term, programme basis. (MoD, 2007, p. 7)

"At the heart of the force structure and capabilities modernising programme is Network Enabled Capability (NEC)" (MoD, 2005, p. 20). The changes that are being planned at the operational level with Network Enabled Capability (NEC) has a direct effect on the overall strategic relationship between the MoD and industry. The MoD has identified, on the operational level, that it needs to use its information communication technology capability more effectively if it is going to meet the changing threats to national and international security. "NEC is crucial to the rapid delivery of military effect. The SDR New Chapter recognised NEC as being fundamental in counteracting terrorism abroad, with its ability to deliver precise and decisive military effects, with unparalleled speed and accuracy through linking sensors, decision-makers and weapon systems" (MoD, 2003, p. 11). Furthermore, NEC is the main focus of the response to the changing nature of warfare: “Network Enabled Capability comprises three core elements: sensors (to gather information); a network (to fuse, communicate and exploit the information); and strike assets (to deliver military effects)” (James, 2004, p. 15). The aim is to use embedded ICT systems to create a network which will follow C4ISTAR (Command, Control, Communication and Computers, Intelligence, Surveillance, Target Acquisition and Reconnaissance) capabilities.

Thus, the current dynamic in the UK defence sector is shaped by three different (and not always complementary) factors:

- Arrangements to cope with the effective bilateral monopoly in the markets for individual platform types by moving from competition to collaboration;
- Changes inherent in the transition to acquiring capability rather than platforms via long-term contracts
- Adapting to the opportunities offered by NEC integration across platforms to create systems of systems.

The MoD’s response to these challenges is that:

> the nature of acquisition is evolving and we face an increasingly demanding and complex environment. Closer collaborative engagement between us and our industrial suppliers will be vital if we are to continue to deliver the improvements that the Armed Forces and UK taxpayers demand. (MoD, 2005, p. 131)

Our preliminary research aims to identify how these institutional dynamics shape actions on the governance and process level, and consequently how actions at the process level shape the structure of governance, and in turn, the institutional level.

The Governance Level

The acquisition policies at the commencement of the project shaped significantly the governance arrangements. The feasibility stage in the mid-1990s involved 5 consortia; they are now all part of a single company. Of these proposals, 2 were taken forward and competing full proposals were submitted in 2001; the contract was awarded to the successful bidder in 2002. By 2004, these two former competitors had merged. This restructuring of the UK defence sector is experienced from the point of view of the governance level as a significant escalation of pre-contract asset specificities thereby increasing the risks of opportunism. As we shall see, the growing risk of opportunism is being mitigated by a shift towards more collaborative transaction governance arrangements. This is one example of the way in which acquisition policies at the institutional level that are based on competitive tendering—in principle, in the absence of pre-contract asset specificities—are being reshaped by changes at the governance level as the sector consolidates.

Economic theory would predict vertical integration in such a situation—see the classic Fisher Body/General Motors case (e.g., Klein, 1996)—but this is rendered nugatory by the low transaction frequency. The MoD will only purchase around 65 vehicles from a one-off design in a single contract. The MoD has, therefore, been trying to develop more collaborative relationships with its suppliers, which are institutionalised in the concept of the Integrated Project Team (IPT) which from the perspective of the governance level can be conceived as a governance mechanism.

In addition to rising pre-contract asset specificity due to reduced competition at the governance level, uncertainty is increasing because of the shift from the procurement of platforms to the acquisition of “capability.” Unlike the platform it replaces, the contract for the AMV has an expected life of 37 years. From the in-service date, the Contractor Logistic Support contract will run for 5 years before it is renegotiated for the subsequent period. Considerable uncertainties surround the operational environment for the AMV over that period. The renegotiation process 5 years hence will also involve high levels of asset specificity as neither party has a viable alternative customer or supplier. This combination of uncertainty and asset specificity is likely to make negotiations difficult in the absence of high trust.

Thus, one informant argued that

> *[T]he evolution will be more towards a partnering relationship. If we [company] get it right we get to the point where there is no competition, we are automatically seen as the preferred source* [...] *against this backdrop of technology insertion, relieving equipment as opposed to replacing equipment we have to place ourselves in the position where we do become the customers best friend* [...] *Ultimately [this company] are going to have to go to TLCM.*

In order to set out the more collaborative aspirations of the IPT from the outset, one informant told us that

> *The thing we did very early on when we signed the contract, is we got a joined IPT industry-MOD, we have a joint charter with a joint set of values* [...] *and the statement that we use collectively and the Project Manager from MOD coined at the time is we are wedded together in this, we all stand or fall together in success, if this doesn’t work there are no winners. And that has been the whole mentality behind it. So everybody is striving to make it work.*

This charter is presented in Panel 1.

We will

- Develop and maintain a team focused on delivering its commitments
- Be professional in every aspect of the project
- Recognise and celebrate success and progress at all levels of the team
- Develop, maintain and enhance communication
- Promote co-operation and joint problem solving
- Develop trust and openness at all levels of the team to build strong and honest relationships, eliminating secrecy and defensive attitudes
- Share knowledge throughout the project, enabling the provision of accurate information at all times

Panel 1. The AMV IPT Project Charter
(IPT documentation)

This approach has yielded many positive results. We were told, for instance, that

> *[T]his present MoD IPT in [programme name] is probably the best I have worked with in terms of friendliness, appreciative of our problems, sympathetic and working with us. There is a good work ethic in terms of wishing to work with us and help us help them.* and *It is very much, let’s take the customer along with us, let’s have the customer involved, so when we get to the milestone it is almost a rubber stamping exercise.*

However, this collaborative approach also encountered a number of difficulties. One important idea behind the IPT was to have a co-located project team that could take advantage of team working, good communication and cooperation. This notion was to be realized through continuous interaction enabled by prescribed tasks, teams and routines. The management of relationships (customer, user, suppliers) was therefore a key tactic in this programme. However, the original bid was won through competitive tendering, and the dynamics inherent in such a process have placed significant constraints upon the IPT's ability to collaborate because of the constraints of a project won by competition, with "a very tight contract, budget and margins squeezed to win the work." For example, the proposed shared data environment (SDE), which would enable improved communication and coordination between industry and customer, was not effectively implemented due to cost and commercial constraints.

The customer[3] expectations have their foundation on the key performance requirement specified by the customer as well as industry's offer—what was in the bid proposal. A challenge for the IPT is closing the gap between what was originally offered (the bid proposal) and the technical requirements specifications (TRS). Thus it was argued that

> *I think there is a need to change in relation to the relationship with the customer. I know industry is in business, it wants to win the contract, it wants to make profits. But sometimes I think defence industry will tell the MOD what it wants to hear rather than what it is actually capable. You know they will promise everything and then there will be delays to the programme, because they can't actually quite meet it.*

And that,

> *There were also occasions where [industry] didn't challenge the customer and say, do you really want this, is there a compromise here, explaining that what was being asked for as a requirement was unrealistic or unachievable or meant compromising something else. Sometimes to their detriment the team sat down and busted a gut to try and deliver what they promised and sometimes that was to their detriment; instead of turning around and saying look we are putting a lot of effort into this and actually it is unrealistic and unachievable.*

Thus, at the governance level, there is an understanding of the need to move towards a more collaborative approach as advocated by the IPT governance structure. However, this is constrained by the lingering effects of the competitive bidding process by which the supplier for the AMV was selected. This led to a highly resource-constrained environment, which meant that the appropriate investments in collaboration such as the SDE could not be fully implemented.

The Process Level

The IPT has around 120 members in all. The proposed structure, new to the prime contractor, was a direct response to the need of moving from platform to capability delivery. The IPT was structured around seven "ilities" or sub-system teams (e.g., reliability, mobility, software, C3I, fightability, survivability, Special To Role as highlighted in Figure 3) with a number of specialist functions in support (e.g., finance, contracts, programme, quality, supply

[3] In UK defence acquisition, the acquisition agency is known as "customer 1" and the final military user "customer 2."

chain and business development). Each “ility” is led by a Cost Account Manager (CAM) who is responsible for delivering the tasks associated with achieving each sub-system functionality and for ensuring they are “harmonised” when integrated into the larger project. This involves both project management responsibilities such as scheduling and budgeting, project controls and also systems engineering responsibilities. The CAMs report through the Chief Engineer, who is accountable for specifications and requirements, and supported by an integration team. In a classic project matrix, the Programme Manager supported by his own team is accountable for delivery against project objectives. This is illustrated in Figure 3. Commercial functions report outside of both of these. Thus the IPT consists of three main types of team responsible for three different types of tasks—engineering design focused on technical creativity; programme management, focused on team co-ordination; and commercial, focused on external supplier selection and management.

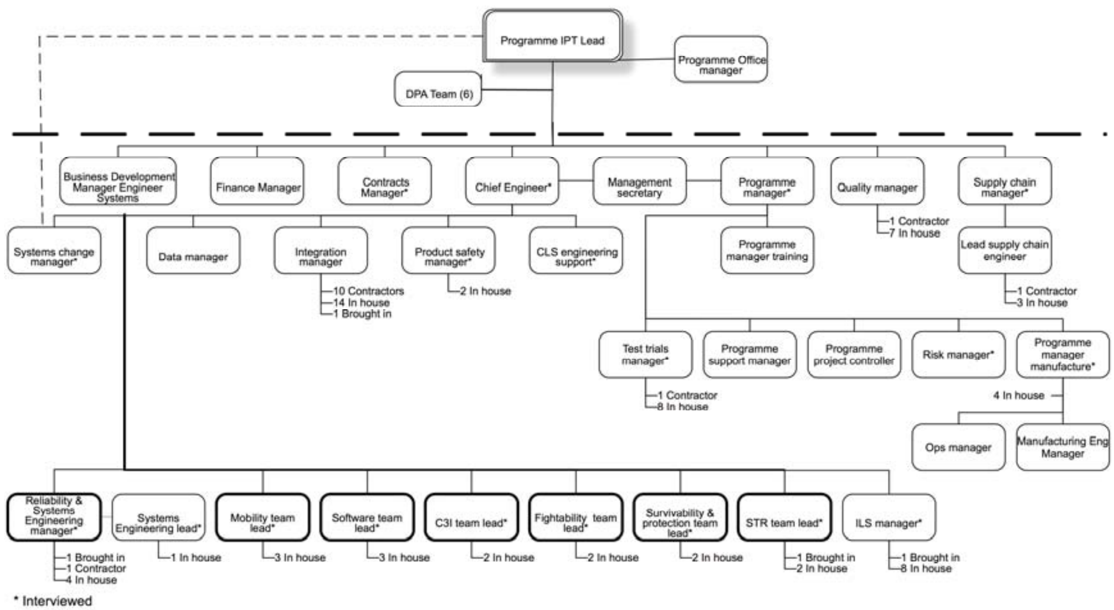

Figure 3. IPT Structure as of End of 2007
(IPT documentation)

The key player in this structure is the CAM, liaising with the Chief Engineer on engineering issues and the Programme Manager on project issues. This is perceived to be putting considerable strain on the CAMs, while there is also a perceived lack of system-level systems engineering to address cross-ility issues and a need for a “stronger systems engineering team.” This perception is a result of two things: first, the new structure to deliver capability means that system level responsibility and accountability lied within each “ility” rather than with a programme level systems engineering team, as had traditionally been the case on other programmes. The challenge was for the IPT to accept, understand and realise this new philosophy. Second, the constraints of the budget and schedule mean that the project was under-resourced. This resulted in not enough systems engineering being carried out at the front end of the project, which eventually had an impact on design development, and in CAMs being overloaded with systems engineering and project management type work.

However, we were informed of a further issue:

> *[T]he danger there is because there are different ilities, each of them then develops a way of working that is slightly different from the next ility, and so you carry through with it, it gets more entrenched. And at some point in the programme you are going to say to the ilities people, I'm sorry but you are going to have to align your processes now. And that gets painful. Yeah, this happened. It was all a jumping, because there was always going to be a winner and losers. There is always going to be one process in preference of another. And it is still going on now as we go forward. The issue was not identified until now. The business processes are outside the [name of the programme] team. This should be generated from the business. The business should be saying to us this is how you budget, supply and set up relationships, that is how you construct X, this is how you can manage the requirement. That wasn't there, so we had to generate all that ourselves. And all this was unplanned work.*

The dynamics of task and team are structured around a number of best practice routines at both the corporate and IPT levels, yet these are perceived to be inadequate. Those at the IPT level are mandated by the MoD; while those at the company level are mandated by the corporate level. These routines are perceived to constrain the dynamics of tasks and teams but also provide formalised processes that offer assurance for the customer and corporate levels. Generally acknowledged as necessary, they are also considered to be too procedural, constraining new ways of thinking, and to detract focus from systems engineering type work. Therefore decision making processes slow down, which in turn slows the project progress:

> *The process is a bit formalised, most things that are done here are very structured and very constrained by procedures. It is how the company has developed. I think years ago the company was run by people, now it seems to be run by processes. I think the advantage of having these processes is that everybody knows what they should be doing and it is not left to individuals, it cuts down the number of Mavericks in the business. In the old days, people ran the business and people were allowed to make decisions almost on the hoof. Now we have got a lot more checks and gates before we can go and do something else. The drawback is that it slows everybody down. It sometimes feels like you are just working processes rather than developing a vehicle...I remember in the old business...they said too many things are going wrong, so we have to do all these checks. We have checks in design reviews, but we are going to have far more of this, specific gate reviews. And we would do all that. And I remember thinking, wow! the pendulum has swung the other way, and eventually it is very heavily constrained, very procedural, much more like civil service, and suddenly everything is being clamped down...I thought we would find a happy medium, and I don't think that has happened.*

Despite the awareness and availability of these processes and guidelines some processes, which would indicate how certain tasks needed to be done, were not fully developed or were not available at the outset. For example, statements of work or technical requirement documentation, systems engineering processes were not available at a business level for example. This meant that "ility" team members had to develop new processes when required. But the development of these new processes was not aligned across the "ilities." Time spent defining and developing these processes detracted from the systems engineering work and in some cases this contributed to delays in the programme. The non-alignment of processes affected those "ilities" that needed to align their process with the chosen process.

These issues are compounded by the routines within the MoD. Overcoming the impact of change in customer personnel is another challenge for the IPT. The MoD has a policy that personnel on programmes should stay in post 2-3 years, which affects the nature of collaborative working. For long-term programmes, this means little continuity and stability from the customer, which destabilises the relationship and affects the perception of the quality of the relationship, which in turns affects behaviour and the propensity to work collaboratively because it

> *[M]eans that new relationships have to be developed, and that common understanding is no longer there. With the change of face you have different interpretations, it can take a new member up to six months to get up to speed, the knowledge, experience and skills differ from the previous person and interpretation of written requirements can vary […] it is difficult to write a requirement that can only be interpreted in one way."*

We can see, therefore, how the dynamics of tasks, teams and routines at the process level start to shape the level of collaboration that is possible at the governance level, while the lack of resources to support collaborative working is a result of the constraints imposed by how tendering at the governance level was organized.

Conclusions

Through our exploration of the dynamics of the UK defence acquisition, from policy initiatives to programme implementation, our preliminary research has shown how the institutional level dynamics shape actions at the governance and process level and how these in turn can potentially reshape the structure of governance and institutions. The dynamic between the institutional and governance level is exemplified in the way in which acquisition policies at the institutional level, based on competitive tendering, are being reshaped by changes at the governance level as the UK defence sector consolidates. Attempts by the MoD to develop more collaborative working relationships with its supply base have been institutionalised in the governance mechanism of the Integrated Project Team (IPT). This governance structure supports more collaborative approaches but, as we have explained, can be constrained by the effects of bidding process—a value for money approach at the governance level. At the institutional level, the policy shift from procurement of platforms to acquisition of capability influenced the decision for a new IPT structure at the process level. However, the opportunities for capability delivery offered by a new structure were only partially realised due to the highly resourced constrained team, a legacy of the bidding process.

At the process level, the dynamics of task and teams were structured around routines; the demands on the team to implement corporate routines and the lack of resources all had an impact on the effectiveness of task completion. At the same time, human resource routines mandating rotation of staff on the client side undermined the collaborative basis of the IPT. The dynamics of task, teams and routines at the process level can, therefore, potentially strain or enhance the collaborative mindset encapsulated through the IPT at the governance level. As a consequence, dynamics at the process level are continually reshaping the collaborative approach at the governance level.

This research contributes to our growing understanding of the UK defence acquisition process by using a Transaction Cost Economics (TCE) approach in a 3-tier (institutional, governance, process levels) conceptual framework. Through the AMV case, we have attempted to explore how these levels interact dynamically through time. In particular, we have shown how acquisition policy initiatives at the institutional level can be vitiated by operational routines at the process level, and how these routines then shape how the policy initiative is implemented. This paper is merely a first attempt at elaborating these dynamics and a full analysis will be forthcoming in due course.

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The Theory and Measurement of Interorganizational Collaborative Capacity in the Acquisition and Contracting Context

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Abstract

Interorganizational collaborative capacity (ICC) is the capability of organizations and sets of organizations to enter into, develop, and sustain interorganizational systems in pursuit of collective outcomes. This report presents an open systems model of collaborative capacity. The model comprises five domains: Purpose and Strategy, Structure, Lateral Processes, Reward Systems, and People. Scales have been created to assess twelve factors or dimensions of ICC: Need to Collaborate, Strategic Collaboration, Resource Investments, Structural Flexibility, Social Capital, Information Sharing, Collaborative Learning, Reward Systems, Metrics, Individual Collaborative Capacity, and Interagency Team Support. This study discusses the factors and uses them to compare two samples: Homeland Defense and Security and Acquisition and Contracting. It then demonstrates the diagnostic use of the ICC Survey by analyzing a major DoD Acquisition and Contracting organization's ICC with respect to a "normative" sample.

Keywords: Interorganizational collaboration, interagency collaboration, collaborative capacity

Interorganizational Collaborative Capacity: Development of a Database to Refine Instrumentation and Explore Patterns

Collaboration and the Acquisition Context

Interorganizational collaboration comprises a system of structures and processes by which organizations work together to accomplish complementary or common goals and objectives, including a common mission. Collaborations range from close partnerships in which employees throughout the organizations must work interdependently to low-level cooperation involving information sharing in which the focus is primarily on relatively independent actions. Collaboration is often used synonymously with partnering and is manifest when organizations form alliances. We formally define ***interorganizational collaborative capacity*** as the capability of an organization (or of a set of organizations) to enter into, develop, and sustain interorganizational systems in pursuit of collective outcomes.

Interorganizational Collaboration (ICC) has clear benefits, including better decision-making as a result of shared information, enhanced coordination among dispersed units, innovation resulting from the cross-pollination of ideas and recombination of scarce resources, as well as many forms of cost savings, ranging from reduced litigation and shared resources to the transfer of smart practices (Hansen & Nohria, 2004; Mankin, Cohen & Fitzgerald, 2004).

Given such benefits, it is not surprising that defense acquisition reform has included calls for improved collaboration among acquisition agencies and between the Department of Defense (DoD) and defense contractors. *DoD Directive 5000.1* states that teaming among warfighters, users, developers, acquirers, technologists, testers, budgeters, and sustainers is required during the capability needs definition phase of the acquisition lifecycle (USD (AT&L), 2003, paragraph E1).

Organizations often fall short when they attempt to develop effective collaborative relationships. Documented barriers include diverse and conflicting missions, goals, and incentives; entrenched histories of mistrust; leaders who do not actively support collaborative efforts; and inadequate systems and structures (GAO, 2005). Our research on ICC was initiated the summer of 2002 in response to the need to develop ICC in the emerging Homeland Defense and Security context. In 2005 we began to apply our methods and knowledge to a quite different but still critical context: DoD Acquisition and Contracting.

Our research program seeks to understand those factors that drive or enable ICC and those factors that are barriers to ICC. The ICC model and survey are designed to be used in an action research tradition. Action research is a collaborative undertaking in which the researchers work with organizational insiders to diagnose a relevant problem domain—in our case ICC—with the aim not only of increasing knowledge but also of improving effectiveness. Survey results, typically supported by interviews or focus groups, are a diagnostic vehicle for discourse, action planning and organizational development.

Developing the Interorganizational Collaborative Capacity (ICC) Model

Our team's research has moved through several stages. In a previous book chapter (Hocevar, Thomas & Jansen, 2006), we described an inductive study conducted in the context of the homeland defense and security community. This study identified factors (i.e., common themes) that facilitated and interfered with developing ICC. The success factors included a "Felt need" to collaborate, a common goal or recognized interdependence, sufficient authority of key participants, social capital (e.g., interpersonal networks), collaboration as a prerequisite for funding, effective information exchange, leadership support and commitment, trust and commitment. Barrier factors were often the antithesis of the success factors; they included divergent goals, impeding rules or policies, lack of familiarity with other organizations, inadequate information sharing, competition for resources, and lack of competency. ***These factors were organized within the five domains of Galbraith's (2002) star*** model: *Purpose and Strategy*, *Organizational Structure*, *Lateral Processes, Reward Systems*, and *People*.

Our inductive research, in conjunction with our literature reviews, led us to develop the ICC model illustrated in Figure 1. This model represents the simplest case of ICC involving only two organizations—A and B—in a shared problem space. The yellow arrows leading from each organization to "goals and objectives" indicate that each organization is oriented toward a set of common or complementary goals and objectives in a shared problem space. They operate within an interdependent relationship in which some degree of collaboration can improve their efficiency and effectiveness with respect to the shared problem space.[1]

As with other open systems models, the ICC model emphasizes that the effectiveness of each organization depends on the congruence or fit (i.e., fitness) of its subsystems. For example, fitness increases when an organization's reward systems are congruent with its strategic goals, structure of authority, and training. The double-sided, blue arrows within and between organizations indicate the dynamic processes of building and sustaining collaborative capacity.

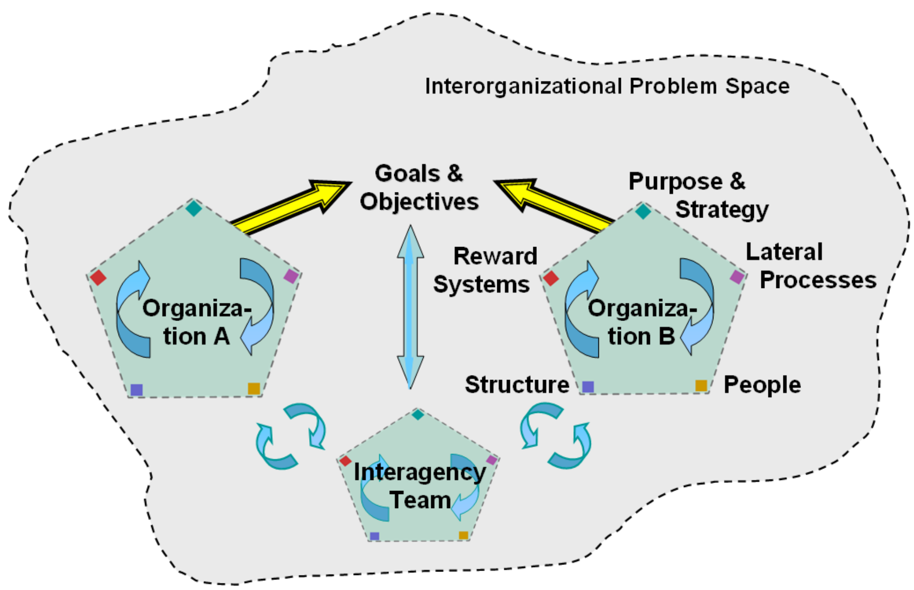


Figure 1. The Interorganizational Collaborative Capacity Model
(Hocevar et al., 2006)

The role of the interagency team is to generate ICC in both organizations. The team must also develop its own collaborative capacity. As there often are more than two collaborating organizations, there also may be multiple teams or task forces (e.g., tiger teams) focusing on and aligning specific subsystem domains (e.g., policies and procedures for sharing information).

Assessing Interorganizational Collaborative Capacity (ICC)

Our previous ICC literature review (cf. Bardach, 1998) revealed that a major stumbling block to advancing theory and practice is the measurement problem. We wrote:

> Collaborative capacity is an intuitively appealing construct but currently lacks clear operationalization. This deficiency is problematic for leaders and practitioners […] who want to identify the collaborative capacity of their agencies. The absence of

[1] This does not mean there are not conflicts or competitive aspects to their interactions. Ray Norda re-introduced the term "coopetition" to describe the complex dynamics in which organizations could be allies in one problem space and competitors in a different problem space (Fisher, 1992).

measurement models also is problematic for the advancement of the social science of interagency collaboration. (Hocevar et al., 2006, p. 273)

Items and Survey Development

Following the initial inductive phase of our research, we began writing six-point, Likert items to measure the identified key themes that had been identified (e.g., the "felt need" theme or factor we had placed in the Purpose and Strategy domain.) With the help of subject matter experts (SMEs), we developed two surveys: one for use with the Homeland Defense and Security (HDS) community and another to use within the Acquisition and Contracting (A&C) community[2] (Thomas, Hocevar, Jansen & Rendon, 2008). The surveys were administered to samples from both communities and scales were developed in an iterative process of collecting data, giving feedback to respondents on their results, and listening to their interpretations of their results. To be accepted for a scale or factor, the items had to pass basic statistical hurdles, make sense in feedback sessions with our SME respondents (see sample description below), as well as having value in suggesting courses of action in their discussions about developing ICC. This process resulted in items being deleted and added over multiple administrations and feedback sessions, and it accounts for the different sample sizes (different n's) associated with different statistics in the research.

Samples for Survey Development and Validation

The HDS sample comprised 145 students in six classes in a Master's Degree program in Homeland Security at the Naval Postgraduate School. They were experienced civilians or military officers working for civilian, government or military organizations from around the United States who had on-going Homeland Security responsibilities. Illustrative organizations (and positions) included: USNORTHCOM, US Coast Guard, (mid- to senior-level officers), the Center for Disease Control, Offices of Emergency Management, the FBI, municipal police and fire departments (Chiefs, Captains), and utilities (Directors).

The A&C sample comprised 49 DoD managers, specifically program managers, technical/engineering managers, and contract managers. They were in three classes pursuing an MS in Program Management (MSPM) though distance learning and employed full-time as members of the DoD acquisition workforce. They were experienced DoD acquisition managers, many of whom had already achieved Level II of the Defense Acquisition Workforce Improvement Act (DAWIA) certification program. The students were located across the United States at some of the DoD's major acquisition and procurement centers.

The A&C sample also included 79 federal employees from a DoD Research, Development and Fielding Organization that is responsible for engineering, technology, research, development, and fielding products primarily for individual military personnel. The organization comprises three interdependent *organizations* from each of the military services and works with academic organizations, research hospitals, businesses, and other government agencies.

The A&C sample also included 46 employees from a major DoD Contract Administration Organization (CAO) with the mission of improving integration of acquisition processes between

[2] This report focuses on assessing ICC with surveys, but we also developed interview questions to be used in individual interviews or focus groups.

DoD clients and contractors, improving cost efficiency, increasing process innovations, and ensuring compliance to standards and regulations in federal contracts.

ICC Survey Scales

The process of constructing scales is simultaneously a process of construct validation, of generating and validating a theoretical model. That is to say, the data are a reality test that typically requires a re-construction of the meaning of ICC as a theoretical construct. Our current conceptualization of ICC, based on our analysis, is that it comprises twelve scales or factors: *Need to Collaborate*, *Strategic Collaboration*, *Resource Investment in Collaboration*, *Structural Flexibility*, *Reward Systems, Metrics for Collaboration, Information Sharing*, *Collaborative Learning*, *Social Capital*, *Individual Collaborative Capacity*, *Barriers to Collaboration*, and *Interagency Teams*. As illustrated in Figure 2, they can be mapped with respect to the five domains of Galbraith's (2002) star model. The specific items that make up the scales discussed in this paper, along with item statistics, are presented in Jansen, Hocevar, Rendon and Thomas (2008).

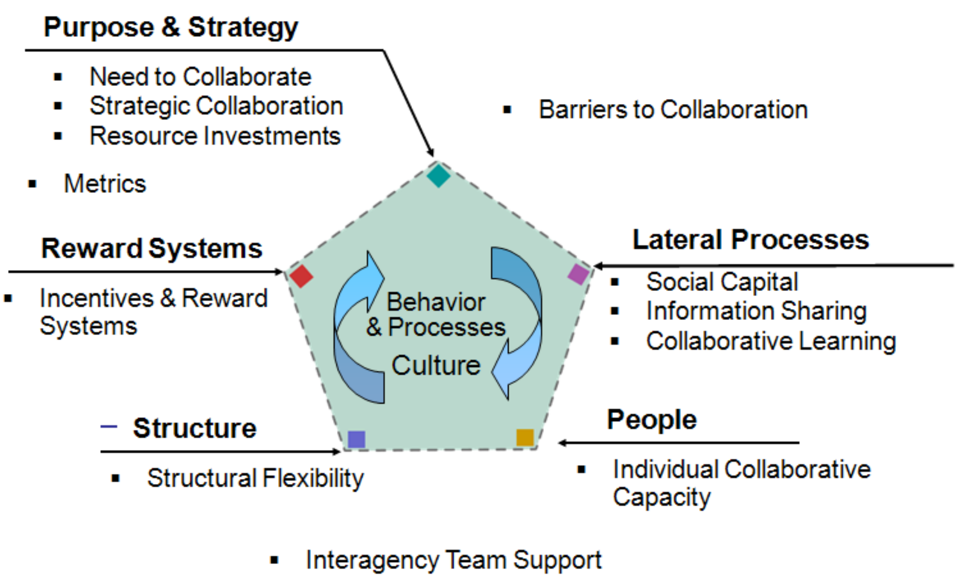


Figure 2. Interorganizational Collaborative Capacity Factors (or Dimensions) Organized by Organizational Domain

Table 1 presents scale statistics for the combined HDS and A&C samples for each scale, ranking them from high to low. All items use a 6-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree." Thus, 3.5 is the scale midpoint. Values higher than 3.5 indicate agreement, and values of 6 indicate unanimous agreement. A "don't know" response, which was a 7 on the scale, was re-coded as missing data. Because the *Barriers to Collaboration* scale is the only scale where a high value indicates a lack of collaborative capacity, it has been reverse-coded to facilitate comparison with other scales (the reverse-coded mean for a 6-point scale is determined by subtracting its mean from 7). Note also that the standard deviation is as important for interpreting results as the mean; focusing on a mean of 4.0, which indicates modest agreement, while ignoring a high standard deviation (e.g., 1.4) will lead to an under-appreciation of how many individuals are in disagreement.

The results in Table 1 represent a summary of individual perceptions of their organizations and individual interpretations of the survey items. Because of the idiosyncratic nature of individual assessments, surveys use broad-based sampling and more than a single item to assess any given factor. Coefficient Alpha reliability assesses the degree to which the items defining the scale are internally consistent, which is evidence that they measure an underlying common factor. These values, all of which are satisfactory, are discussed in Jansen et al. (2008).

Table 1. Means, Standard Deviations (S.D.), Sample Size (n), Number of Items, and Coefficients Alpha for the Collaborative Capacity Scales

Scale	Mean	S.D.	n	Number of Items	Coef. Alpha
Need to Collaborate	4.7	1.3	307	3	.81
Strategic Collaboration	4.3	1.4	251	5	.85
Social Capital	4.2	1.3	307	2	.79
Interagency Team	4.2	1.3	193	2	.85
Structural Flexibility	4.1	1.2	135	4	.78
Information Sharing	4.1	1.4	226	3	.83
Individual Collaborative Capacity	4.1	1.2	258	7	.86
Resource Investments	3.7	1.4	227	3	.88
Lack of Barriers to Collaboration*	(3.7)*	1.4	136	4	.75
Collaborative Learning	3.5	1.4	225	3	.85
Reward Systems	3.4	1.5	268	4	.86
Metrics for Collaboration	3.0	1.5	264	2	.83

*The Barriers to Collaboration scale is the only scale in which a higher value represents a lower collaborative capacity. It is thus reverse-coded so that it can be compared to the other scales and relabeled as Lack of Barriers to Collaboration.

The Interorganizational Collaborative Scales

In this section, we discuss the results in Table 1 in the context of the ICC model in Figure 2, and we include some observations from feedback sessions with HDS and A&C respondents.

The Domain of Purpose and Strategy

Three scales assess factors within the domain of Purpose and Strategy: Need to Collaborate, Strategic Collaboration, and Resource investments in collaboration.

*Need to Collaborate***.** Hocevar et al. (2006) used the term "felt need" to refer to a theme that emerged in their inductive, qualitative research as well as in their literature review. "Felt need" was taken from the organizational change literature (Jick & Peiperl, 2002) in which the construct is used to describe the strong motivational energy and effort needed to overcome the inertia of the status quo and generate change in organizational structures, processes and behaviors. The change literature asserts that a felt need or "sense of urgency" (Kotter, 2008) is a powerful factor that motivates individuals to make commitments to learning new skills and exploring new behaviors. Sample items include,

- My organization recognizes the importance of working with other agencies to achieve its mission.
- People in my organization understand the benefits of collaborating with other organizations.

Strategic Collaboration. A theme that emerged for successful collaboration in our inductive research was having "a common goal or recognized interdependence." This scale references establishing and addressing goals for collaboration and considering the interests of other organizations in planning. It assesses leaderships' role in addressing interorganizational goals and conferring with the leaders of other organizations. Sample items include:

- My organization's leaders meet and confer with the leaders of other organizations about mutual collaboration.
- My organization considers the interests of other agencies in its planning.

Resource Investment in Collaboration. Resource Investment in Collaboration emerged in the quantitative data as a theme in our inductive research. The scale focuses on investing, committing or assigning various resources to collaboration. This is placed in the domain of strategy and purpose because the strategic apex is where general resource decisions are typically made. A sample item is, "My organization has committed adequate time, budget, and personnel to interorganizational collaboration."

As Table 1 indicates, the **Need to Collaborate** scale typically has the highest mean in our various survey administrations. The respondents in both the HDS and A&C samples report that their organizations appreciate the need to collaborate. This will perhaps remain a common result across organizations actively involved in collaborations; typically, we work in contexts in which messages from the highest levels of the chain of command and even stories in the national media emphasize the critical importance of collaboration.

The *Strategic Collaboration* scale also typically has a relatively high mean, indicating a generally positive perception in the domain of strategy and purpose associated with setting goals and priorities and other leadership actions regarding collaboration. On the other hand, its mean is considerably lower than the *Need to Collaborate* mean. Lower still is the **Resource Investments** mean. In feedback sessions discussing the results, our respondents typically interpret these results in terms of the challenges of "walking the talk." It is far easier to send the message out on the importance and benefits of collaboration than to engage other organizations and their leaders to plan and set goals; it is harder yet to find and dedicate resources to make collaboration happen.

The Domain of Structure

Structure is currently represented by a single scale or factor: Structural Flexibility.

Structural Flexibility. Structural flexibility is viewed as important to effectiveness in dynamic environments (e.g., Mintzberg, 1993) and for effective organizational processes (e.g., Deming, 1982). In our inductive research, structural themes emerged but were mentioned more often as barriers than as success factors. In our quantitative research, *Structural Flexibility* assesses the degree to which respondents perceive that the organization is flexible and responsive, quickly forming and modifying policies, processes, procedures, and partnerships. A sample item is: “My organization is flexible in adapting its procedures to better fit those organizations with which we work”

The **Structural Flexibility** scale’s positive mean reveals more flexibility than many might expect, given that these respondents generally work for large government bureaucracies. As with the other scales, the standard deviation indicates that some individuals perceive more flexibility than others, but the overall distribution for these items is not consistent with dysfunctional rigidity as commonplace in these organizations. When the survey is given within a single organization, analyzing where there are higher or lower levels of perceived structural flexibility can be informative for action planning.

Metrics and the Reward Systems Domain

In Figure 2, the Metrics factor is placed between the Reward Systems domain and the Purpose and Strategy domain. On the one hand, metrics operationalize goals and serve as indicators of effectiveness. On the other hand, metrics are generally part of the performance appraisal process and thus part of the reward system.

Reward Systems. The *Reward Systems* scale assesses the degree to which collaborative activities and collaborative talents lead to rewards, career advancement, and promotions. In this domain, perceptions are critical: if individuals perceive collaborative actions go unrewarded, their behavior will reflect these perceptions. Sample items include:

- Engaging in interorganizational activities at work is important to career advancement in this organization.
- Collaborative talents and achievements are considered when people are reviewed for promotion.

The *Reward Systems* scale *s*hows a relatively low score; it is one of two scores that fall below the Likert scale’s mid-point of 3.5. For example, it is lower than the *Structural Flexibility* scale; some respondents argue that it is easier to reorganize and change procedures than to change institutionalized reward systems. Because incentives and rewards are especially powerful for generating organizational culture, discussions in which people explain how reward systems often fail to support collaborative activities typically represent a powerful opportunity for action planning.

Metrics for Collaboration. Metrics did not emerge as a theme in our inductive research, but it emerged as a measure in our quantitative research. The scale assesses the degree to which an organization has identified or established measurement criteria and performance standards to assess interorganizational collaboration efforts. A sample item is, “My organization has established clear performance standards regarding interorganizational work.”

Metrics for Collaboration is consistently among the lowest scores, and the low values promote interesting discussions. These include the issue of how important such measures really are, the degree to which such measures might produce counterproductive behaviors, and the role of leadership in assessing individuals and motivating performance. Individuals sometimes note that the ICC survey is itself an attempt to develop collaboration metrics.

The Domain of Lateral Processes

Three scales can be placed within the domain of Lateral Processes: *Social Capital*, *Information Sharing*, and *Collaborative Learning*.

Information Sharing. Information sharing was a theme in the Hocevar et al. (2006) research. The scale has diverse content, referring to people, the organization, and to organizational norms. Sample items include:

- My organization has strong norms that encourage sharing information with other organizations.
- People in my organization share information with other organizations.

As noted when we defined collaboration, some work relationships require low levels of interdependence (i.e., pooled interdependence) in which information sharing represents all that is required of organizational allies. Such organizations are able to accomplish their goals and objectives independently if information sharing is effective. More interdependent collaborative relationships (e.g., liaisons, regular task force meetings, and joint exercises) may require higher levels of lateral processes captured by Collaborative Learning.

*Social Capital***.** "Social capital" and "interpersonal networks" emerged in Hocevar et al. (2006). The scale assesses the degree to which organizational employees or members take the initiative to build relationships and know who to contact in other organizations or agencies. A sample item is: "Our employees know who to contact in other agencies for information or decisions." Some individuals see this as a pre-requisite to information sharing: how do you share if you don't know who values the information? Others emphasize information sharing as a means of developing social capital.

Collaborative Learning. When organizations face problems that require teamwork, either because of sequential or reciprocal interdependence, learning how to work with and adjust to organizational partners becomes more important (Thompson, 1967). The collaborative learning scale assesses the degree to which the organization commits resources to training, works with other organizations to identify lessons learned, and develops strong norms for learning from other organizations. They assess the degree to which the organization might be regarded as a collaborative learning organization. A sample item is, "My organization works with other organizations to identify lessons learned for improved collaboration."

The Lateral Processes Domain. Organizational theory emphasizes the importance of lateral processes to integrate and coordinate among differentiated units. Such horizontal processes take the burden off the vertical hierarchy, preventing overload and allowing actions to profit from local conditions and distributed knowledge. They are viewed as especially critical in ICC where vertical hierarchies of different organizations may not lead to a common boss.

The pattern of means within this domain is interesting: *Social Capital* and *Information Sharing* have comparable means, but the *Collaborative Learning* mean lags behind. This pattern suggests that knowing who to contact and develop relationships with can function primarily to serve the lower collaborative demands of information sharing; this is reflected in the higher means for these aspects of collaborative capability. On the other hand, the results suggest collaborative learning is unevenly developed and is a lagging capacity in the organizations. To the degree learning represents changing habits related to how one plans, organizes, leads, decides, and works, it is indeed a more challenging than simply sharing the information with the right people.

The Domain of People

The domain of People is represented by a single scale, which is labeled Individual Collaborative Capacity.

Individual Collaborative Capacity. Hocevar et al. (2006) identified a number of themes describing the collaborative capabilities and attitudes of individuals within the organization. Items referencing individuals tend to fall into a single scale in our research. The scale focuses on skills, capabilities and expertise; on an understanding and knowledge of how other organizations work; on a willingness to engage in shared decision-making, and on seeking input from the other organizations. Sample items include:

- Members of my organization understand how our work relates to the work of other organizations with which we need to collaborate.
- Members of my organization are able to appreciate another organization's perspective on a problem or course of action.

Barriers to Collaboration

All the items and scales described to this point have been facilitating factors or enablers that support the development and maintenance of collaborative capacity. In contrast, *Barriers to Collaboration* items focus on the challenges or impediments to collaboration. Agreement on these items is undesirable, whereas agreement on other items is desirable. This requires that the item means and the scale mean must be reverse-coded to compare it to other scales, subtracting it from 7 so that a mean of 3.3 becomes 3.7. This reversal is used in comparisons among scales (e.g., in Tables 1 and 2), and the scale is relabeled as Lack of Barriers to Collaboration—a double negative.

The items composing the *Barriers to Collaboration* scale are diverse; they assess interorganizational history, individual collaborative capacity, role conflict, policies, and requirements that are unique to an individual's organization. The items cover a number of domains within the collaborative capacity model and cannot be placed within a single domain. Two sample items are:

- A history of interorganizational conflict affects our interorganizational capability.
- I face incompatible requirements or requests when working with other organizations.

Interagency Teams

HDS respondents were directed to the items in this scale if they answered "yes" to the statement, "My organization has a representative on an interorganizational team." A&C respondents were directed to these items if they indicated they had served on one or more "interorganizational special project or tiger teams." The scale might be regarded as assessing an aspect of the domain of structure. The items are,

- My organization gives members of special project teams (or tiger teams) adequate authority to speak on behalf of the organization.
- My organization supports the decisions and recommendations of the special project or tiger team.

The mean also is close in its value to the *Structural Flexibility* mean.

Comparing the ICC of a Set or Community of Organizations

The ICC results can be used to compare samples from different organizational sets, different communities of practice, or even different industries. By administering surveys to individuals from multiple organizations, we should be able to describe the collaborative capacity of that organizational set. Table 2 compares the means of two such sets: the Homeland Defense and Security (HDS) and Acquisition and Contracting (A&C) samples.

Table 2. Means, Standard Deviation (S.D.), and Sample Sizes (n) for Homeland Defense & Security and for Acquisition & Contracting Communities

	Homeland Defense & Security			Acquisition & Contracting		
Scale	Mean	S.D.	n	Mean	S.D.	n
Need to Collaborate	5.0	1.0	145	4.3	1.2	49
Strategic Collaboration	4.4	1.0	145	3.8	1.3	49
Resource Investments	4.0	1.2	144	3.4	1.2	49
Structural Flexibility	4.1	1.0	145	4.1	1.1	49
Reward Systems	3.4	1.3	145	3.1	1.2	49
Metrics for Collaboration	2.9	1.2	141	2.8	1.2	49
Social Capital	4.5	1.1	144	3.9	1.2	49
Information Sharing	4.2	1.2	145	3.6	1.1	49
Collaborative Learning	3.7	1.1	145	2.9	1.0	49
Individual Collaborative Capacity	4.2	1.0	144	3.9	1.0	49
Lack of Barriers to Collaboration[*]	(3.7)[*]	1.0	145	(3.6)[1]	.9	49
Interagency Team	4.6	1.1	117	3.5	1.3	48

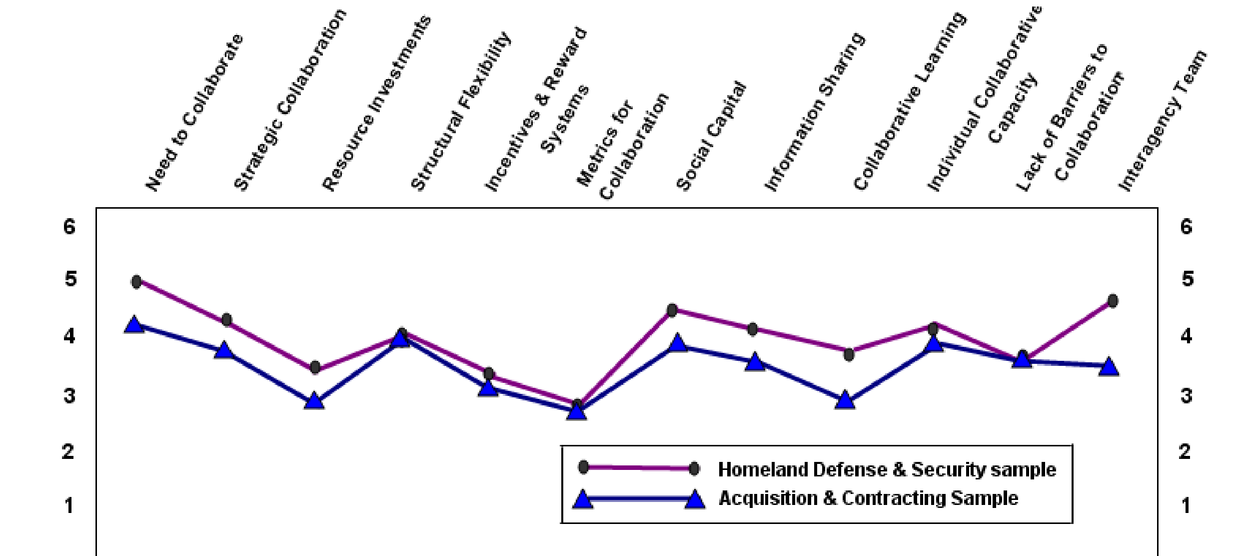
* The Barriers to Collaboration scale is the only scale in which a higher value represents a lower collaborative capacity. It is thus reverse-coded so that it can be compared to the other scales and relabeled as Lack of Barriers to Collaboration.

The means in Table 2 would seem to indicate no significant difference between organizational communities in terms of *Structural Flexibility*, *Reward Systems* and *Metrics for Collaboration*, *Individual Collaboration*, and *Barriers to Collaboration*. The main differences appear to be that the HDS's sample's means are somewhat higher in the strategic domain comprising *Need to Collaborate*, *Strategic Collaboration*, and *Resource Investments* and in the lateral processes domain of *Social Capital*, *Information Sharing*, and *Collaborative Learning*.

Figure 3 presents the pattern of results in graphic format and reveals that the profile patterns are generally parallel; their similarity is more dramatic than their differences. In a section below, the ideas of Leading and Lagging factors in generating Collaborative Capacity are discussed. Figure 3 suggests that some factors lag (e.g., *Metrics* and *Reward Systems*) and some lead (e.g., *Need for Collaboration*, *Strategic Collaboration*, *Social Capital* and possibly *Structural Flexibility*) in developing ICC.

Caution is required in making attributions about differences in organizationsal sets as diverse as HDS *versus* A&C. To generalize about mean differences, comparable sampling procedures for the two communities are required. Even with excellent sampling, the contextual frames of reference used by respondents as they take the survey need to be considered when interpreting these differences.

Here are a few of the contextual differences characterizing the individuals in the A&C *versus* HDS samples.



	Need to Collaborate	Strategic Collaboration	Resource Investments	Structural Flexibility	Incentives & Reward Systems	Metrics for Collaboration	Social Capital	Information Sharing	Collaborative Learning	Individual Collaborative Capacity	Lack of Barriers to Collaboration	Interagency Team	
	Homeland Defense and Security Means and Standard Deviations												
Mean	5.0	4.4	4.0	4.1	3.4	2.9	4.5	4.2	3.7	4.2	(3.7)*	4.6	Mean
Standard Deviation	1.0	1.0	1.2	1.0	1.3	1.2	1.1	1.2	1.1	1.0	1.0	1.1	Standard Deviation
	Acquisition and Contracting Means and Standard Deviations												
Mean	4.3	3.8	3.4	4.1	3.1	2.8	3.9	3.6	2.9	3.9	(3.6)*	3.5	Mean
Standard Deviation	1.2	1.3	1.2	1.1	1.2	1.2	1.2	1.1	1.1	1.1	0.9	1.3	Standard Deviation

Figure 3. Profiles with Means and Standard Deviations for the Homeland Defense & Security and the Acquisition and Contracting Samples

A&C is relatively mature and institutionalized, and interorganizational collaboration through various phases of the Acquisition lifecycle has long been inherent to the mission. By contrast, much of HDS has recently been reorganized to improve effectiveness through collaboration. A large minority of respondents report that they do not have a mandate to collaborate with other organizations, and collaboration often depends on local initiatives.

A&C comprises many functionally-focused, matrixed organizations with inherently conflicting intraorganizational goals and resulting role conflict. The functional areas have divergent cultures and goals; for example, Program Managers (PMs) have different goals than contracting officers and systems engineers. By contrast, HDS typically comprises independent organizations with distinct chains of command.

A&C comprises primarily civil service members of the DoD's acquisition workforce. HDS includes a small number of military officers, federal civil servants from diverse agencies, as well as employees of state, county, and city governments.

Our DHS respondents' perceptions of the consequences or risk in the face of a failure of interagency collaboration were significantly higher than the perception of risk in our A&C samples (Jansen et al., 2008).

Interpretive Norms

Comparing organizational capabilities of different organizations or sets of organizations raises the question of interpretive norms. Norms are "descriptive statistics that are compiled to permit the comparison of a particular score (or mean) with the scores (or means) earned by the members (or groups of members) of some defined population" (Thorndike, 1971, p. 533). Norms in this context would allow an organization to understand its relative standing on a scale or profile of scales compared to a defined reference group.

The concept of norms for organizations, in contrast to norms for people, is problematic. Norms can be developed and interpreted relatively easily for human beings. However, developing norms for aggregates of people in diverse organizations is far more difficult and ambiguous. This is because, in spite of our great diversity, there is more homogeneity among people than organizations that comprise people. Organizations differ vastly in size, age, history, mission, technology, member demographics, and other variables. In addition, organizations are nested hierarchically within other organizations, and sometimes they are matrixed; their boundaries are more ambiguous. Thus, the entire concept of individual vs. organizational norms requires rethinking. However, without specifically addressing these challenges, we argue that a wide and continuing sampling of individuals from particular classes of organizations (e.g., HDS or A&C) can be useful for comparative purposes. There are commonalities within various organizational sets and communities, and leadership can derive some sense of their organization's relative standing by cautiously comparing their results to the results of others. By increasing sample size and more rigorously collecting data across the acquisition community, it is possible to generate information akin to norms. We illustrate the potential value of this in the next section.

An Organizational Example of ICC in the Acquisition Context

In this section, we use the survey to do a brief, summary assessment of two units within a much larger organizational system. Table 3 shows the results for two units of a major DoD CAO that functions in an interorganizational context (cf. Kirschman & LaPorte, 2008). In the following discussion, quotations come from a teleconference interview conducted with the top leadership team of these units on June 22, 2007, and from comments made when the leadership of one unit who conducted a briefing for an NPS A&C class on August 6, 2008.

Table 3. Means, Standard Deviation (S.D.), and Sample Sizes (n) for a Major DoD Contract Administration Organization

Scale	Mean	S.D.	n
Need to Collaborate	4.5	1.1	46
Strategic Collaboration	4.2	1.2	46
Resource Investments in Collaboration	3.4	1.5	43
Structural Flexibility	4.0	1.0	46
Reward Systems	3.8	1.2	45

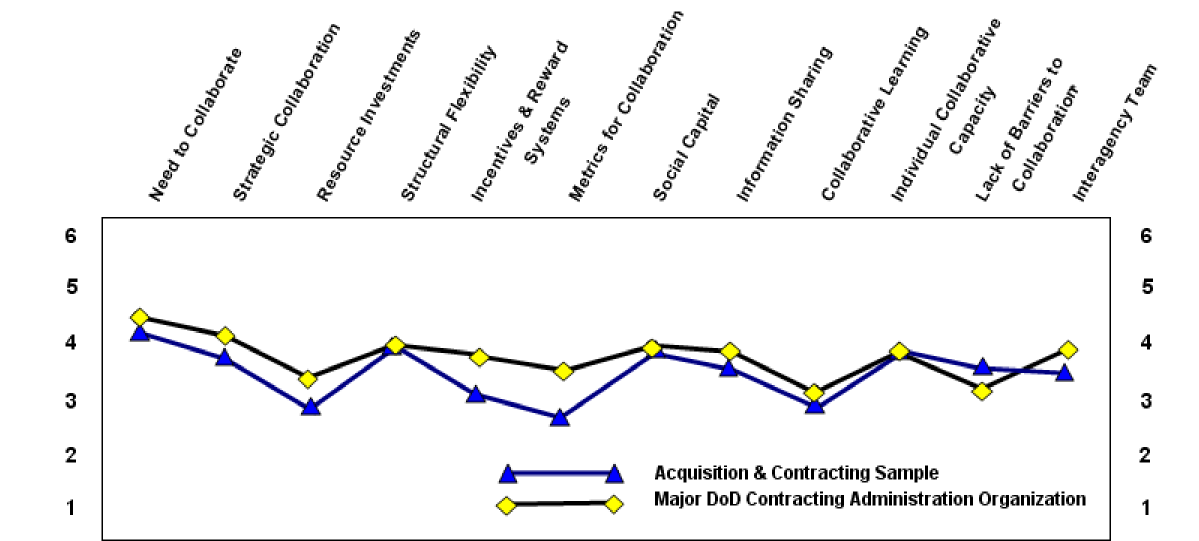
Metrics for Collaboration	3.6	1.4	43
Social Capital	4.0	1.2	46
Information Sharing	3.9	1.2	46
Collaborative Learning	3.2	1.3	46
Individual Collaborative Capacity	3.9	1.1	46
Lack of Barriers to Collaboration*	(3.2)*	1.1	46
Interagency Team	3.9	1.2	40

* The Barriers to Collaboration scale is the only scale in which a higher value represents a lower collaborative capacity. It is thus reverse-coded so that it can be compared to the other scales and relabeled as Lack of Barriers to Collaboration.

Context and Mission

The organization's mission is to enhance the integration of acquisition processes between DoD clients and contractors, generating cost savings, increasing process innovations, and ensuring compliance to standards and regulations in federal contracts. Prior to the survey administration, one manager said, "We are very much a customer support organization …and … in order to provide the support that our customers need, we've got to interact and collaborate with them …. We've got to sit down with our customers and agree and talk and discuss what's important to them." In this context, customers of the organization are other government agencies; they support these agencies with respect to contractors, typically involving major programs. Executing their mission requires "selling" organizational customers on the support they can provide. In order to be more effective with customers, the organization has gone through what one manager called a "realignment that puts us in a position where we are very focused on specific customers." The leadership team appeared to be dedicating considerable time and energy to generate and sustain ICC, which was congruent with their strong support in administering the survey.

Respondents express modest to moderate agreement on their organization's capacities with respect to most factors. However, there is, on average, mild disagreement regarding the adequacy of *Resource Investments* and engagement in *Collaborative Learning*, and there is mild agreement that there are *Barriers to ICC*. The standard deviations for two scales—*Resource Investments* and *Metrics for Collaboration*—appear relatively high, indicating less consensus among the organization's members on these dimensions. Figure 4 presents the results from Table 3 in the form of a line graph. It adds the results on multiple A&C organizations to serve as a surrogate for comparative norms.



	Need to Collaborate	Strategic Collaboration	Resource Investments	Structural Flexibility	Incentives & Reward Systems	Metrics for Collaboration	Social Capital	Information Sharing	Collaborative Learning	Individual Collaborative Capacity	Lack of Barriers to Collaboration	Interagency Team	
	Major DoD Contracting Administration Organization												
Mean	4.5	4.2	3.4	4.0	3.8	3.6	4.0	3.9	3.2	3.9	(3.2)*	3.9	Mean
Standard Deviation	1.1	1.2	1.5	1.0	1.2	1.4	1.2	1.2	1.3	1.1	1.1	1.2	Standard Deviation
	Acquisition and Contracting Means and Standard Deviations												
Mean	4.3	3.8	3.4	4.1	3.1	2.8	3.9	3.6	2.9	3.9	(3.6)*	3.5	Mean
Standard Deviation	1.2	1.3	1.2	1.1	1.2	1.2	1.2	1.1	1.1	1.1	0.9	1.3	Standard Deviation

Figure 4. Profiles with Means and Standard Deviations for a Major DoD Contract Administration Organization and an NPS Acquisition and Contracting Sample Representing an Organizational Set

Again, we should be cautious in our interpretations, but this comparison suggests a somewhat more positive perspective than we gain only by viewing the organizational profile in isolation. The pattern of comparisons shows the CAO as being equal to or higher than the normative sample (drawn from 49 different organizations) on all the enabling factors and shows higher ratings in the factors of Resource Investments, Reward Systems, and Metrics for Collaboration. This example suggests the interpretive value of having a larger, more representative data set for A&C organizations. In the next section, we discuss the subsystem domains and their factors, which are illustrated in Figure 5.

The Strategic Domain

In terms of the strategic domain, the *Need to Collaborate* scale and the *Strategic Collaboration* scales have relatively high values, with means of 4.5 and 4.2. This is congruent with the collaborative vision and statements expressed by the top leadership. A Deputy (personal communication, June 22, 2007) noted that, a “key point” for the organization was “bringing in the needed stakeholders, identifying what the key issues are, what the common ground is, and then understanding what we can do to complement each other.” Such efforts had been accelerated in the previous two years. The survey provides evidence of the degree to which the message behind thas been accepted.[3]

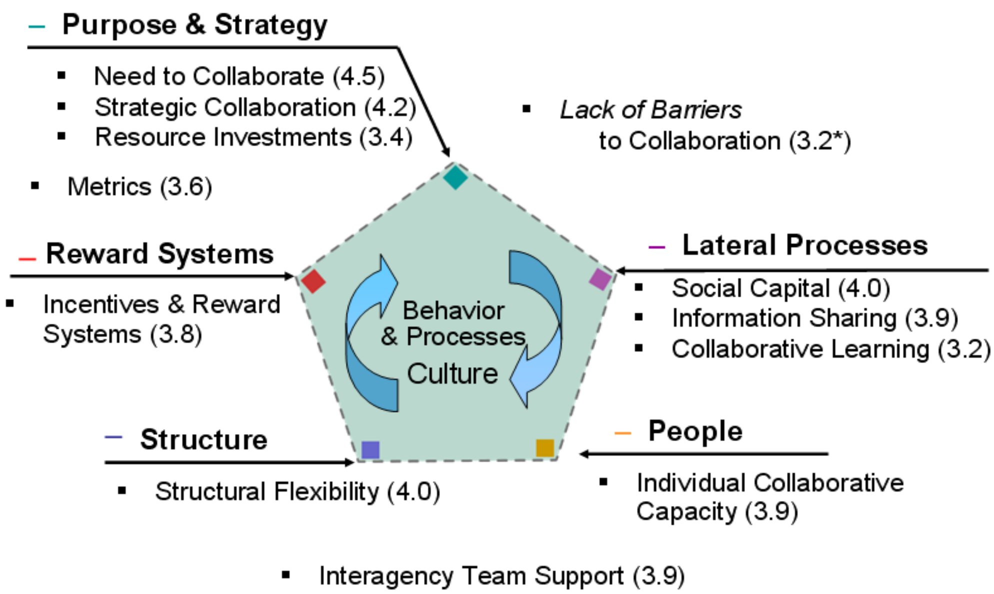


Figure 5. Interorganizational Collaborative Capacity Scale Means Organized by Domains for a Major DoD Contract Administration Organization

The *Resource Investments* scale, although higher than the "normative" sample result, remains low, with a mean of 3.4, which suggests that this may be a barrier to collaboration (being perceived as such by many in the organization). It was also raised as a primary issue or barrier by top leadership:

> One of the things that come to mind … is a resource situation and having the right talent … to be able to provide the support our customers need. This agency has gone down to—I've been here less than two years—so I have the 20,000 number—we are roughly a 10,000-person agency now. So our resources have gone down significantly. (personal communication, June 22, 2007)

Indeed, a commander of one of the units (personal communication, August 6, 2008) said he simply lacked the personnel and other resources to engage all the required tasks. A key part of his job involved assessing risks to determine where lack of oversight and slippage was least problematic. Thus the strategic resource picture with respect to collaborative capacity is trying to do more with less.

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[3] In the discussion of survey results, we use quotations from a teleconference interview conducted with the top leadership team of these units on June 22, 2007, and from a briefing to an NPS Acquisition and Contracting class on August 6, 2008. The organizations and their managers are quoted anonymously to maintain confidentiality.

The Structural Domain

The organization was created in a restructuring of service organizations into a joint entity. This was motivated by the need for greater efficiency and customer service. It allowed contractors building products for more than one service to simplify their interface problems with the DoD bureaucracy. The organization had thus been viewed as structurally inflexible in the recent past. A PowerPoint brief described this era as, "Someone above writes the rules—workers follow the rules—masters check to see that workers are following the rules and if they are, victory is proclaimed on all fronts" (personal communication, August 6, 2008). Current management was working to unlearn this rule-driven, behavioral legacy, calling it "too internally focused." They sought greater responsiveness to and collaboration with customers.

The organization had very recently reorganized from a geographic divisional structure to a more product-oriented structure. Although it remains a bureaucracy with regulatory responsibilities, such recent changes may well support perceptions of structural flexibility, especially given managements' desire to increase collaboration and customer responsiveness. The *Structural Flexibility* mean of 4.0 indicates some agreement that there is flexibility in the structural domain. This result can be viewed positively given the history of rule-driven behavior.

The Reward Systems Domain and Metrics

In the ICC model, metrics overlap two domains: Reward Systems and Strategy. Metrics relate to accomplishing strategic goals and objectives, but they also can be used to assess individual performance, in which case they are part of the reward system. Leadership in the CAO had invested considerable time, energy and resources to develop metrics and link them to performance. Leadership had invested in a tool to provide agency level visibility from the Director down to operational employees. One member of the top management team said:

> We have metrics, and we have a performance commitment that we set down with our customers; … we've agreed that this is important, and this is what we are going to do with you. And there's a way to grade those, and that's set out … and as a result of that, then we know … where we fall short. (personal communication, June 22, 2008)

The *Metrics for Collaboration* scale's mean value of 3.6 is no doubt less than the management team would like to see, but it appears to be a relatively high value for this scale in comparison with the "normative" sample.

As mentioned in the discussion of *Resource Investments*, the organization's efforts to reward and recognize individuals were made in the context of an understaffed organization with a mission of promoting interorganizational collaboration. The *Reward Systems* mean of 3.8 suggests somewhat positive results in a very difficult human resources context.

The People Domain—Individual Collaborative Capacity

Leadership reported that they sometimes lacked people with the required technical skill sets (e.g., engineering talent and software skills) (personal communication, June 22, 2007). They also asserted the importance of "critical thinking skills" and "soft skills" for dealing with conflict. However, they did not express any sense that the people in their organization were deficient in such skills; they noted that there was "always room for improvement." The discussion was consistent with the Individual Collaborative Capacity scale mean of 3.9: generally positive with room for improvement.

The Lateral Processes Domain

The *Social Capital* mean of 4.0 is somewhat positive, revealing moderate agreement with items indicating individuals take the initiative and know who to contact in other organizations. *Information Sharing* is also somewhat positive, with a mean of 3.9. *Collaborative Learning* would seem to be a more demanding level of lateral integration, and its lower mean of 3.2 is perhaps not surprising, especially (a) to the degree that this is an under-resourced organizational context and (b) to the degree that developing collaborative learning systems in a complex network of partnerships requires exceptionally high levels of integration.

Barriers to Collaboration

Individuals within the DoD CAO still perceive barriers to collaboration, as the relatively low reverse-coded mean of 3.2 suggests. This is an indicator of the inertia that leadership must still overcome as they develop ICC in this complex, under-resourced, bureaucratic context. In this scale, as with others, deeper insights emerge from looking at specific items that comprise the scales; space constraints prevent such analysis.

Leading and Lagging Factors in the Open Systems Organizational Models

The ICC model is an open systems model; it emphasizes that organizations depend on the congruence or fit (i.e., fitness) of their subsystems (i.e., domains) with respect to each other and the larger environment. To achieve fitness in their political, economic, social and organizational environments, organizations develop habitual routines and patterns of action. The commonality in the pattern of ICC profiles may thus reflect a systemic state of fitness and inertia of the public bureaucracies in our sample.

Organizational development and change—including developing ICC—requires a systemic approach if it is to be sustained. However, trying to change an organization in its entirety generally is not possible. Leadership must choose which subsystem domains to initially develop (i.e., leading factors) and which subsystem domains will be allowed to lag (i.e., lagging factors) and be changed in the future (Kaplan & Norton, 1992).

For the organizations in our sample, the *Metrics for Collaboration* scale has typically had the lowest—or one of the lowest—scores. By contrast, *Felt Need* is often one of the highest scores. Our feedback sessions with respondents are congruent with organizational change literature: generating a sense of felt need is often a lead factor in organizational change; managers typically begin such efforts by communicating a sense of urgency. By contrast, our feedback sessions suggest that developing metrics to assess collaboration often is a lagging effort, delayed because of the time and skill required for development and implementation. However, although it might not be typical, leaders may choose to use metrics to lead change efforts. The DoD CAO described in this report is consciously using a metrics management system as a leading factor in their change efforts. Using the ICC survey longitudinally may reveal how collaborative capacity is developing in the subsystem domains composing the organization.

Continuing and Future Research

Feedback workshops with students/SMEs (Thomas et al., 2008) combined with the item analysis and scale development (Jansen et al., 2008) lend considerable confidence to the dimensionality of the ICC model and operationalizations reported here.

Research is currently under way to analyze how the survey is used in the context of specific partners. The ICC survey described in this report diagnoses an organization's "general collaborative capacity" to enter into relationships with unspecified partners; it assesses ICC with respect to generalized others. By contrast, research in progress on "relative collaborative capacity" focuses on one specific partner; the survey questions name one specific organization and thus assess ICC for this one specific relationship.

It is possible to use the dimensions in the ICC model to generate a performance appraisal of collaborative relationships. In such a case, items would need to be rewritten or other summary scales created whereby the members of organizations judge their partner organizations with respect to on-going relationships. It is even conceivable that such measures could become integrated into performance appraisals, thus creating a metrics to drive incentives and reward actions that develop and sustain ICC.

Validation of the ICC survey requires research with dependent variables on interorganizational performance or alternative assessments of collaboration processes (e.g., nominations of extreme cases—excellent collaborators *versus* ineffective collaborators—by experts or top leaders). This would provide an external, empirical validation for the factors specified in the ICC model. This is the most challenging research to perform, requiring more resources and management support than previous efforts.

Richer diagnoses of an organization's ICC using qualitative methods in conjunction with the survey are also needed. Understanding collaborative capacity processes and dynamics requires qualitative methods such as interviews and focus groups as well as case studies. Such collaborative efforts between researchers and leaders/managers support the "action research" agenda of simultaneously improving organizational functioning and developing better theories and measurements.

These last two issues—research with dependent variables and qualitatively enriched research that is used in conjunction with the survey—are the necessary next steps to furthering our understanding of the dynamics of collaborative capacity and simultaneously improving ICC.

Conclusion

At this stage of our research, we have considerable confidence in the usefulness of the ICC model and the ICC survey scales reported here. The model of collaborative capacity in Figure 5 conceptualizes an organization's capability to enter into partnerships as a systemic state. It defines that state in terms of a set of factors (e.g., structural flexibility and metrics) organized into the subsystem domains of strategy, reward systems, structure, lateral processes, and people (Galbraith, 2002; Hocevar et al., 2006; Jansen et al., 2008). This fits into the themes and constructs identified in the literature and our own inductive research. We have created scales to assess the factors that define the state of ICC, and these possess internal-consistency reliability and convergent validity. The items composing the scales suggest action strategies for developing collaborative capacity. Although continuing refinement and validation is necessary, we believe our attempts are representative of the state of the art in theory and research on ICC.

The problems facing DoD's acquisitions and contracting community are extraordinarily complex and, given resource constraints, uncertain. They do not fit neatly into the categories of academic disciplines or of single agencies or organizations. They require collaboration among people, teams, and organizations from private and public sectors in a global context. Success increasingly requires collaboration to bring together information, knowledge and expertise located in diverse organizations. The ICC survey is designed to be a tool for leaders and managers who face the intellectually and emotionally challenging work of increasing their organizations interorganizational collaborative capabilities.

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