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Historical Analysis of Costs, Risks, and Uncertainties: Moving From a Proprietary to an Open Architected Systems (OA, SOA, MOSA), Open Business Acquisitions Management Approach

11 October 2011

by

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Abstract

The use of Open Architecture (OA) systems to guide acquisition of Naval systems and the "opening up" of proprietary systems is presumed to have produced significant cost savings. However, their use may have also introduced new forms of risk and uncertainty for the acquisition manager. Addressing this problem, several qualitative research studies were conducted to identify benefits, risks, and best practices from historical case data involving Open Architecture (OA), Service-Oriented Architecture (SOA), and Modular Open Systems Approach (MOSA) implementations.

Keywords: Risk, uncertainty, Open Architecture, Modular Open Systems Approach, Services Oriented Architecture

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I. Summary

The use of Open Architecture (OA) systems to guide acquisition of Naval systems and the “opening up” of proprietary systems is presumed to have produced significant cost savings. However, their use may have also introduced new forms of risk and uncertainty for the acquisition manager. Addressing this problem, several qualitative research studies were conducted to identify benefits, risks, and best practices from historical case data involving Open Architecture (OA), Service-Oriented Architecture (SOA), and Modular Open Systems Approach (MOSA) implementations.

The first study focused on cost savings from private sector implementations of SOA in several industries. SOA has proven beneficial in the private sector, which has derived benefits from SOA that include cost savings, agility, and flexibility. Because SOA and OA share comparable concepts, the Department of Defense (DoD) can expect to realize some of the same benefits using OA as the private sector gains from implementing SOA.. This study identified potential outcomes and industry best practices for the DoD. Its purpose was to establish a benchmark of performance outcomes, focusing on cost savings experienced in industry to determine what the DoD can expect in its push towards an open architecture model.

The second study identified OA-based acquisition risks and uncertainties and explored various tools and techniques used by program managers (PMs) in successful acquisition programs. At the onset of this study, it was not clear how risk was defined, perceived or tolerated at the DoD. Moreover, the issue of risk is a complicated problem. Unlike the private sector, the DoD does not tolerate or reward risk. OA introduces new risk elements to DoD systems development and upgrades; however, the overall acquisitions approach is essentially designed to suppress risks. It is imperative to understand the risk-suppression steps inhibiting OA’s potential ability to reduce costs and increase flexibility. In this part of the report, we show how

risk is suppressed, stifling innovation. The risk study is augmented by primary research interviews with acquisition professionals.

Specific research objectives for these studies included the following:

- examine relationships between OA, SOA, and Navy OA (NOA);
- establish cost-savings benchmarks based on industry performance for traditional proprietary architecture models and SOA;
- identify the risks to PMs in the Defense Acquisition Systems (DAS) ecosystem, including various organizations involved with acquisitions, ranging from Congress down to a program's Risk Project Team, along with environmental risks, consisting of rules, regulations, laws, and customs dictating organizational behaviors;
- evaluate if an OA strategy assists or hinders acquisition programs;
- ascertain if an OA strategy exposes a program to unique risks and uncertainties; and
- establish if OA has delivered its promised benefits to the DAS.

The results of the studies are presented in this report in several sections. Section 2 provides a framework for understanding the open system concepts and principles of OA, NOA and SOA. It concludes with a discussion of the similarities between SOA and NOA, and summarizes the methodology for implementing open architecture in the DoD–MOSA. Section 3 identifies potential benefits of SOA and OA. It summarizes the results from the qualitative research study on SOA, identifying potential benefits and best practices from case studies and industry surveys. Because SOA and OA share similar concepts, the DoD may be able to adapt some of the best practices from the SOA methodology. Section 4 analyzes the impact of risk and uncertainty on the DoD acquisitions system and the decision-making process of PMs. Risks and uncertainties are identified, and the issue of whether SOA and OA increase or decrease risks is addressed. Section 5 offers three case summaries of OA, SOA, and MOSA implementations. The implementation of Acoustic Rapid COTS (commercial off-the-shelf) Insertion (A-RCI)/Advanced Processor Build (APB), U.S. Military Entrance Command

(USMEPCOM), and Program Executive Office, Integrated Warfare Systems' (PEO IWS's) Software Hardware Asset Reuse Enterprise (SHARE) repository are summarized. The final section presents conclusions and recommendations.

Key findings from our research include the following:

A. Open Solutions

- Open solutions offer new possibilities for solving business problems, provide business interoperability by standardization and technology transparency, and decrease time to market for key products and services.
- Organizations are adopting open technology platforms and open-source software for critical business needs, and these technologies are moving into mainstream business practices in corporations such as IBM, Google, Intel, and Pfizer.
- The "open" movement has also changed how society interacts. Open architecture, open source, open access, and open standards have propelled social networking tools like Facebook and Twitter into astronomical growth. Facebook, Twitter, WordPress, and Firefox are all built on flexible platforms that enable co-development and co-creation to varying degrees and invite user opinions.
- SOA and OA are similar concepts, as seen in Table 1.

Table 1. Comparison of Open Systems to OA and SOA

Open Architecture Characteristics	Service-Oriented Architecture Characteristics
Modular design and design disclosure	Services are modular
Life-cycle affordability	Reliability and modifiability attributes decrease cost over the lifetime of the system.
Easily upgradable systems	Adaptability, extensibility, and modifiability provide ease of upgrading a system.
Core concepts of scalability and portability, and stated goal of interoperability	Quality attributes of scalability and interoperability
Goal to optimize system performance	Quality attribute of performance
Reusable application software	Reusable services
Interoperable joint warfighting applications and secure information exchange (common services and information assurance)	Quality attributes of usability (common services) and security

B. Potential Benefits

- SOA has proven beneficial in the private sector, deriving benefits such as cost savings, agility, and flexibility. Similar benefits could be achieved with OA at the DoD.

- Non-monetary benefits are staff efficiency, credibility, reduced duplication of effort, faster time-to-market, scalability, and flexibility.

- Industry best practices include adopting flexible and incremental approaches. Flexibility was often cited as a key objective and recognized as a benefit from implementing SOA. The second best practice is the use of an incremental approach. Companies did not attempt a massive replacement of all systems at once, but focused on specific areas needing improvement and then implementing a solution.

C. Risk and Uncertainty

- OA introduces new risk elements to systems development and upgrade projects in the DoD and the Navy, where the overall acquisitions approach is essentially designed to suppress risks. Risk suppression stifles innovation.

- The DoD anticipated that OA principles would enable small, innovative businesses to enter the defense market. The open business model "was envisioned to encourage competition at all system levels, therefore enabling small companies—who cannot compete with the likes of the large contractors for big Navy contracts—to compete their solutions at the sub-system or component level." (Computerworld 2007)

- Greater competition was expected to provide Small-Medium Sized Enterprises (SMEs) opportunities to enter the defense arena and end eras of stove-piped systems and the oligopoly of defense contractors who provide expensive, monolithic systems that do not interoperate.

- SMEs, however, cannot participate in the defense arena because of risk- suppression mechanisms and the exorbitant costs to enter the market. SMEs cannot afford to follow the bureaucratic rules and restrictions imposed by the current acquisition processes in the DoD.

- Systematic risk restrictions at the DoD and in the acquisitions process have resulted in programs still going over budgets and schedules, despite attempts to control budget and schedule risk. Until risk issues are addressed, the DoD will never achieve true portfolio management nor will it ever fully implement OA.

- The *Risk Management Guide for DoD Acquisition* does not prescribe specific methods or tools and only provides general guidance and accepted practices for DoD acquisition professionals to follow.
- DAS does not present PMs with different types of risk at different stages of their careers. Beyond cost, schedule, and performance risks, there is no formal recognition of other risk types. Despite this lack of risk recognition, budget and program risk are of constant concern to PMs.
- Critical risk areas cited in interviews conducted with acquisition professionals were budget uncertainty, program risk and uncertainty, and decreasing returns on increasing assets.
- Not unique to DAS, risks associated with misunderstandings between different functional areas, the "talking by each other" and linguistic discontinuity, are heightened by a lack of training and contradictory structural goals between functional areas of a program, such as between a PM and a contracting officer.
- DAS is highly structured, consisting of well-defined requirements and milestones, so there is little incentive for individual initiative in running projects or programs and little room for personnel flexibility.
- Although the DAS's bureaucratic nature is not a risk, it introduces or amplifies risk as many PMs develop a fatalistic attitude towards risk (i.e., "We have to play with the hand we are dealt."), delaying ramifications for incorrect or even illegal decisions that fall on the program long after the original participants have transferred.
- OA has delivered cost savings and allowed faster system development in certain cases; it has also increased complexity and risk for programs.

D. NOA Benefits and Lessons Learned

- ***Acoustic Rapid COTS Insertion (A-RCI) process.***

  The Submarine fleet saved $4 billion while increasing sensor performance seven-fold. (Computerworld 2007) OA also allows submarines to upgrade software every year and hardware every two years. This approach has been transferred successfully to other submarine systems as well as collaborative efforts of the cross-domain Anti-Submarine Warfare (ASW) community.

- ***Navy's Air Domain.***

The E-2 program transitioned to a commercial computing plant with a modular software design through OA. Acquisition cycle time was reduced from seven years to 2.5 years, and costs were reduced from over $200 million to under $11 million (Computerworld 2007).

According to a 2007 *Computerworld* case analysis of NOA, the greatest obstacles cited were the Naval acquisition and defense industry cultures. The greatest resistance to NOA came from those who did not understand the OA concept, who did not think it would work, or who were not comfortable with change. The most important obstacles to overcome were cultural issues:

- " "***Not invented here" syndrome.*** Navy personnel are resistant to being told by outsiders how to conduct their business. Program staff have generally been working within their programs for many years and are confident they know how best to continue conducting their program's business. Past contractors who are now employed by these programs also resist change. This insular environment limits the potential for new ideas and increases resistance to changes introduced from the outside.
- ***Complacency.*** Large defense industry companies were content with business as usual because they were making huge profits for shareholders. The companies that develop, build, and upgrade the Navy and Marine Corps' National Security Systems (NSS) had no incentive to change their business model while they were so profitable. The predominant industry players needed to be convinced that profits would falter if they did not start producing OA systems.
- ***Lack of asset sharing*.** This stems from the "not-invented-here" syndrome. It is the Naval Enterprise's reluctance to share assets among domains and programs. In addition, this internal attitude is the defense industry's propensity for building new systems from scratch rather than reusing assets that the government already owns and that provide the needed capability (Computerworld, 2007). "

Recommendations include the following:

- **Focus on Overall System Value.**

  The overall value offered by an open system should be considered and not only the cost savings. Benefits such as flexibility, scalability, and reusability position the DoD to rapidly adjust systems to changing combat missions and environments, while reducing future risk. The DoD should consider reducing the weight given to return on investment (ROI) as a result of cost savings in its decision-making process and attempt to incorporate all associated benefits.

- **Use an Incremental Implementation Approach.**

  SOA is not a one-size-fits-all solution. The DoD should adopt an incremental approach, implementing OA where results will be immediate. It should assess current DoD architecture to focus efforts on particular needs and requirements. The DoD should start small with near-term or easily implemented requirements, initially attacking the low-hanging fruit by introducing the SOA services that provide the most bang for the buck.

- **Provide Adequate Resources.**

  Continue building the DoD infrastructure to ensure any new initiatives are sufficiently resourced. SHARE is a warning on lack of resources, particularly the lack of personnel and time, which ensures contractors meet all administrative requirements concerning intellectual property rights. Implementations that do not have supporting infrastructure and proper resources could become costly disasters.

- **Provide Greater Initiative.**

  DAS has evolved into a system that concentrates on performance issues, even at the expense of costs and schedule. Delivery of world-class systems to operating forces should always remain a priority; however, the DoD should consider allowing PMs more flexibility in running programs. A-RCI showed how taking initial performance risks, security risks that use a COTS strategy, and potential cost and schedule risks that use a spiral development strategy could lead to program success.

- **Continue Accountability.**

  Many PMs inherit programs that have achieved initial success, but at the expense of future risks and stability. If a program is of such a length that a PM has transferred before improprieties or poor decisions are uncovered, then he should remain accountable for decisions in older programs if the PM is still in government service.

- **Support Greater Flexibility.**

  With a more flexible systems development approach, talent outside DAS could be tapped. Allowing for security concerns, modern problem-solving methods such as Topcoder could be used. The former helps solve technical problems for the pharmaceutical, biotechnology, consumer goods, and high technology industries with cash prizes. The latter allows the programming community to compete and collaborate on problems with contests where members compete for money and skill ratings.

- **Implement New Metrics.**

  Due to the innovativeness of implementing an open business model in DoD acquisitions, new metrics must be implemented. There are many methods available; however, the DoD should consider implementing metrics to measure the new economy based on intellectual capital and knowledge assets.

- **Conduct a New Study.**

  Conduct a study to determine which DAS areas would benefit from OA and which programs would be hindered by OA and SOA.

II. The Open Movement

Organizations have leveraged open technology platforms to achieve greater productivity and efficiency levels. These open solutions offer new possibilities for solving business problems, provide business interoperability through standardization and technology transparency, and decrease time-to-market for key products and services. Organizations are adopting open technology platforms and open-source software for critical business needs, and these technologies are moving into mainstream business practices in corporations such as IBM, Google, Intel, and Pfizer.

The open movement has not only changed the way businesses operate; it has changed how society interacts. Open architecture, open source, open access, and open standards have propelled social networking tools like Facebook and Twitter into astronomical growth. Facebook, Twitter, WordPress, and Firefox are all built on flexible platforms that enable co-development and co-creation to varying degrees and that invite user opinions (DoD, 2009).

This section provides a framework for understanding the open system concepts and principles of OA, NOA, and SOA. It concludes with a discussion of the similarities between SOA and NOA, and summarizes the MOSA methodology for implementing open architecture in the DoD.

A. Open vs. Closed Systems

There two general types of IT systems, open systems and closed systems. Closed systems are characterized by closely held and privately owned standards, protocols, languages, and data formats that are either unavailable to outsiders or available only at a very high license fee (Azani, 2001). Closed systems typically contain proprietary software designed for a single system. When proprietary systems require upgrades or maintenance, their unique design makes upgrades costly and technically difficult, leading to increased total life cycle costs. Because these systems are developed for a single purpose, interoperability with other systems suffers. Additional middleware[1] is often inserted to achieve interoperability between systems, adding an additional layer to the system that is potentially more costly to implement and maintain. With an open architecture approach, middleware solves the interoperability issue.

In an open systems environment, systems perform better and are cost efficient. In closed systems, upgrades providing greater processing capacity cannot be completed without overhauling current systems. However, in an open system, hardware and software can be modularized, making upgrades more efficient. Open systems leverage technological advances by using COTS technologies, enabling the most current technology to be used and allowing for competition (Uchytil, 2006). Closed systems tie the system owner to one sole-source contractor. Table 2 provides a comparison of some of the aspects of open versus closed systems.

[1] Middleware is software connecting two disparate and closed systems through defined interfaces.

Table 2. Open Systems vs. Closed Systems
(Azani, pg. 4)

Closed System Characteristics	Open System Characteristics
Use of closely held, private interfaces, languages, data formats, and protocols (government or vendor unique standards)	Use of publicly available and widely used interfaces, languages, data formats, and protocols
Critical importance given to unique design and implementation	Critical importance given to interface management and widely used conventions
Less emphasis on modularity	Heavy emphasis on modularity
Vendor and technology dependency	Vendor and technology independence
Minimization of the number of implementations	Minimization of the number of types of interfaces
Difficult and more costly integration	High degree of portability, connectivity, interoperability, and scalability
Use of sole-source vendor	Use of multiple vendors
Expansion and upgrading usually require considerable time, money, and effort	Easier, quicker, and less expensive expansion and upgrading
Higher total ownership cost	Lower total ownership cost
Slower and more costly technology to transfer	Technology transfer is faster and less costly.
Components, interfaces, standards, and implementations selected sequentially.	Components, interfaces, standards, and implementations selected interactively.
Systems with shorter life expectancy	Systems with longer life expectancy
Use of individual company preferences to set and maintain specifications	Use of group consensus process to maintain interface specifications
Less adaptable to change in threats and technologies	More adaptable to evolving threats and technologies
Focus mostly on development cost and meeting present mission	Focus on total costs of ownership, sustainment, and growth
User as the producer of system	User as the consumer of components
Rigid and slow system of influence and control	Real-time and cybernetic system of influence and control
Adversarial relationship with prime contractors/supplier/vendors	Symbiotic relationship with prime contractors/suppliers/vendors
Mostly confined to traditional suppliers	Non-traditional suppliers can compete
Simple conformance testing	Very challenging conformance testing

Many current legacy systems in the DoD and the Navy, in particular, follow the closed, proprietary system specifications identified in Table 2.

B. Open Architecture

An open architecture employs open standards for key interfaces within a system (Open Systems Joint Task Force [OSJTF], n.d.), allowing for interchangeable system components. One simple example of this is plug-and-play computer accessories. OA follows principles that enable modular, interoperable systems to adhere to open standards. Open standards are simply standards that are widely used, consensus based, published, and maintained by organizations that maintain industry standards (OSJTF, n.d.). There are four primary types of standards:

- Formal standards are formally recognized by a standards committee.
- Industry standards are formal or de facto standards that are widely accepted and broadly implemented.
- De facto standards are informal,, but have gained widespread acceptance by users.
- Proprietary standards have been published, but the number of vendor implementations is limited.

The goals of OA are to increase reuse, increase flexibility, shorten delivery time-to-market, reduce costs, leverage competition, and improve interoperability. Of these general goals, decreased delivery time and reduced total ownership costs are the key reasons behind the Navy's interest in OA.

C. Naval Open Architecture

The Navy has implemented its own open architecture policy, Naval Open Architecture (NOA), an "initiative for a multi-faceted strategy providing a framework for developing joint interoperable systems that adapt and exploit open-system design principles and architectures" (Defense Acquisition University, 2006 pg 10). NOA established a framework with a set of principles, including

- providing more opportunities for competition and innovation;
- fielding affordable, interoperable systems;
- minimizing total ownership cost;
- optimizing total system performance;
- yielding easily developed and upgradeable systems; and
- achieving component software reuse.

According to Nickolas Guertin, PEO -IWS Deputy Director for Open Architecture, ”Naval Open Architecture is the confluence of business and technical practices yielding modular, interoperable systems that adhere to open standards with published interfaces. OA delivers increased warfighting capabilities in a shorter time at reduced cost.” The Navy has been addressing business, technical, and cultural changes.

Figure 1. Business, Technical, and Cultural Changes
Source: Nickolas(Guertin, “Naval Open Architecture,” April 2009)

NOA is a systems design approach supported by governmental testing platforms such as the Open Architecture Computing Environment (OACE). OACE, a standards-based computing infrastructure used by Surface Command and Control domain software applications, attempts to implement open specifications interfaces and services. OACE is a compatible set of standards-based COTS components that provide the framework upon which support applications are built under OA guidelines (Department of Defense [DoD], Naval Sea Systems Command [NAVSEA], & Program Executive Office Integrated Warfare Systems [PEO IWS], 2004).

Few technologies guiding OACE include the use of middleware and wrappers. Middleware is important in software development, particularly in the context of enterprise application integration.[2] It provides proven ways to connect various software components in an application so they can exchange information using relatively easy-to-use mechanisms. Middleware is most often used to describe support software that facilitates interactions between major software components while masking differences in language, platform characteristics, message formats, communication protocols, data structures, and other factors (DoD, NAVSEA, & PEO IWS, 2004).

A wrapper is software that insulates applications from the applications' programmer interface (API) of another set of software by exporting a different API. The wrapper exposes the legacy application's functionality or data to the SOA as a service. All security, quality of service, and service orientation principles provided by any other OA service are provided by the wrapper. Wrappers provide a way to reuse applications that are already delivering business value.

In order for the Navy to implement OA, it first had to develop a NOA strategy that included a vision statement, principles, goals, and supporting objectives. The NOA vision statement is to "transform our organization and culture and align our resources to adopt and institutionalize open architecture principles and processes throughout the Naval community in order to deliver more warfighting capabilities to counter current and future threats" (Program Executive Office, Integrated Warfare Systems [PEO IWS], 2007b). Figure 2 describes the Department of the Navy (DoN) OA Strategy.

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[2] Middleware is a way of making separate applications communicate with one another without actually being integrated. It is the software infrastructure intended to support deployment of core, mission-critical applications (Minoli, 2008).

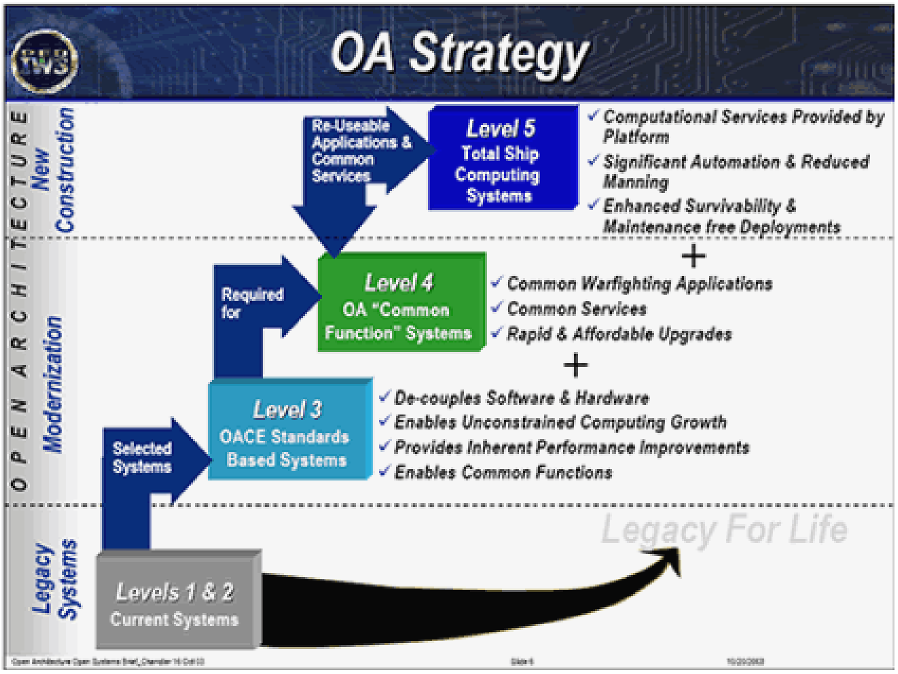

Figure 2. DoN OA Strategy
(As cited in Uchytil, 2006 pg 15)

To implement NOA, a Naval Open Architecture Enterprise Team (OAET) was established. One outcome of OAET was the development of the Open Architecture Assessment Model (OAAM), providing program managers with a way to describe the "openness" of a current or proposed system. In order to measure the openness, a program manager must use an Open Architecture Assessment Tool (OAAT), an analytical tool assessing the openness of a system based on interrelated business and technical questions.

D. Principles of Navy OA

To achieve NOA, five principles were identified by the Office of the Chief of Naval Operations Staff (OPNAV), Warfare Requirements and Programs (N6/N7; Deputy Chief of Naval Operations Warfare Requirements and Programs [OPNAV(N6/N7)], 2005). These principles are:

- **Competition and Collaboration Encouragement**

  Unlike systems acquired from a sole-source that restricts the full and open competition of resources, OA systems promote competition among industries, leading to better products at a reduced price. In addition, because open standards are used, competition in industry can be leveraged when completing system upgrades or when fielding an entirely new, but interoperable system.

- **Modular Design and Design Disclosure**

  This is the concept of decomposing a system into subcomponents. These subcomponents do not rely on another aspect of the system. In that way, they can change quickly and allow for interactions with other systems. This allows for the independent upgrade of subcomponents, instead of changing out an entire system.

- **Reusable Application Software**

  This software allows a system to use the same components and code that has been used in other platforms. Since the code has already been tested, certified, and approved, software reuse saves both time and money compared to developing new software independently.

- **Interoperable Joint Warfighting Applications and Secure Information Exchange**

  This option involves using common services and warfighting applications, as well as information assurance, and it requires these commonalities to be part of the basic design elements of any new system (DoD, NAVSEA, & PEO IWS, 2004).

- **Life Cycle Affordability**

  This principle includes all life cycle costs of system design, development, delivery, and support. Because this report is primarily concerned with cost savings, and we have determined that initial costs increase at implementation, life cycle affordability represents a key benefit.

Along with the five principles, several key attributes are required when building an OA framework. An OA framework should enable open systems to be designed and to continually evolve throughout their life cycle. In order to accomplish this, OA provides a group of core attributes that must be addressed. These concepts provide the foundation for an OA framework. Although not entirely encompassing, four core concepts are modularity, reuse, scalability, and portability. Modularity and reuse have already been identified.

- **Scalability**

  This concept refers to the ability to add new functionalities or resources without a major change or modification to the system. The ability to add new components, update current ones, or adjust the scale of the system with little disruption to the system's operations is the basic premise of the scalability attribute.

- **Portability**

  This concept refers to being able to move hardware or software from one platform to another. Proper implementation of portability into an OA allows for easy transition between many hardware and software platforms (Uchytil, 2006).

These core concepts are especially critical in today's world, where the rate of technological advancement is higher than it has ever been. In order to accomplish these concepts, the Navy established three primary goals, each of which has several subsets. The three primary goals are as follows ("Naval OA Strategy," 2008):

- change naval processes and business practices to utilize open systems;
- establish architectures in order to rapidly field affordable, interoperable systems;
- provide Naval OA systems engineering leadership to field common, interoperable capabilities more rapidly at reduced costs; and
- change Navy and Marine Corps cultures to institutionalize OA principles.

Implementing OA requires the commitment and participation of all stakeholders across the Naval Enterprise OA, as seen in Figure 3.

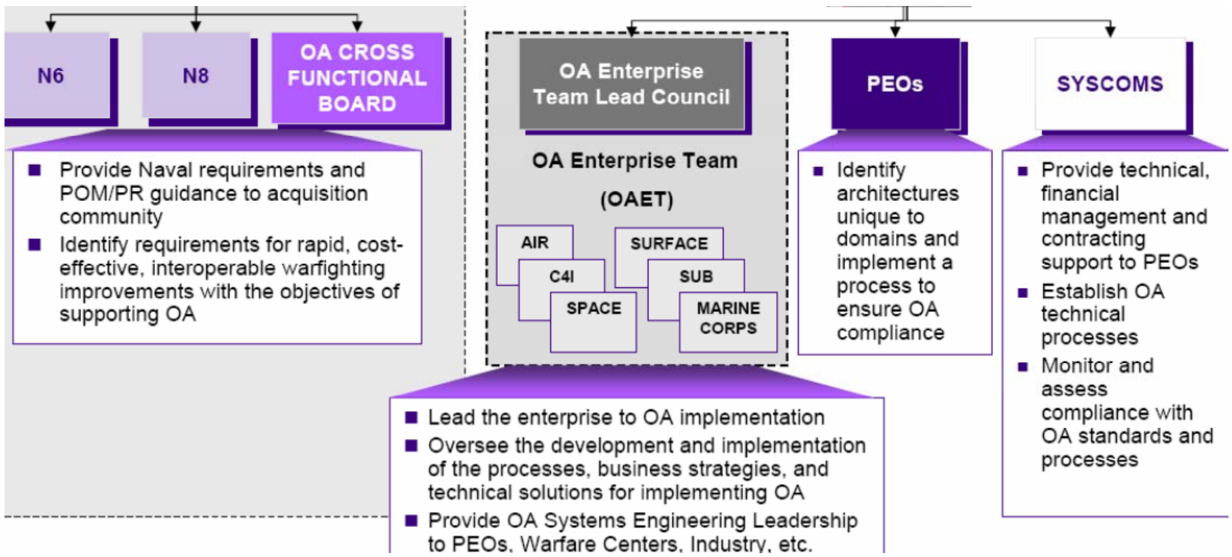

Figure 3. Naval Enterprise OA Stakeholders
(Guertin, 2009, pg. 4)

E. Service-Oriented Architecture (SOA)

In this section we offer several definitions of SOA, outline concepts and principles, and describe some benefits and challenges of implementing SOA. The term *service-oriented architecture* has no centrally defined meaning. Several organizations have provided definitions, but no concrete definition has been agreed upon. Even though the exact definition of SOA is elusive in the information technology industry, there are some basic and useful concepts that are generally accepted. Table 3 outlines the definitions of SOA utilized by various private sector entities.

Table 3. Private Sector Service-Oriented Architecture Definitions

COMPANY	DEFINITION
Hewlett–Packard (HP)	• Architectural approach built upon the concept of software services for designing, building, and managing the distributed computing infrastructure an enterprise requires to execute and achieve business strategy and goals. • Promotes use of loosely coupled, reusable, standards-based, and well-defined services to enable them to be discovered on the network and used by other applications or end users. (Hewlett–Packard [HP],2005)
IBM	• IT architectural style supporting transformation of business into a set of linked services, or repeatable business tasks that can be accessed when needed over a network. • May be a local network or Internet, or it may be geographically and technologically diverse, combining services in New York, London, and Hong Kong as though they were all installed on local desktop. • Services coalesce to accomplish a specific business task, enabling business to quickly adapt to changing conditions and requirements. (IBM, n.d.)
Business Transformation Agency (BTA)	• Describes an environment in terms of shared mission and business functions and of the services enabling them. • The Government Accountability Office (GAO) describes SOA as an "approach for sharing functions and applications across an organization by designing them as discrete, reusable, business-oriented services." (GAO, 2006 pg. 15 ; Business Transformation Agency [BTA], 2009)
	•

Although definitions for SOA vary, they all refer to services in one way or another. A definition of a service is "an implementation of a well-defined piece of business functionality, with a published interface that is discoverable and can be used by service consumers when building different applications and business processes" (O'Brien, Bass, & Merson, 2005, p. 1).

F. SOA Principles

A common set of principles most often associated with SOA include the following:

- **Services Are Reusable**

  Services are designed to support potential reuse, regardless of whether immediate reuse opportunities exist. By applying standards that allow reuse, the chances of accommodating future requirements with less development effort are increased (Erl, 2005a).

- **Formal Services Contract**

  Service contracts provide a formal definition of service endpoint, each service operation, and every input and output message supported by each operation. Furthermore, service contracts include rules and characteristics of the service and its operations. In order for services to interact, a formal contract is needed to define the terms of information exchange. Therefore, service contracts define almost all the primary parts of a SOA. This information establishes the agreement made by a service provider and service requestors (Erl, 2005a).

- **Loosely Coupled Services**

  Loose coupling maintains that for services to interact, they must be aware of one another's existence. Awareness is achieved through service descriptions, which establish a name of the service, a description of the data expected by the service, and a description of any data returned by the service (Erl, 2005b). Additionally, loose coupling maintains that each service should be self-contained, adding a level of abstraction and service autonomy. Finally, an advantage to loosely coupled systems is that they tend to have a shorter development time due to low inter-module dependency.

- **Service's Abstract Underlying Logic**

  The service's description is the only part of a service that is visible to the outside world. In SOA, aside from what is expressed in the description and formal contract, the underlying logic is invisible and irrelevant to the service requestors.

- **Composable Services**

  Groups of services can be assembled to form composite services. This possibility allows logic to be represented at different levels of granularity and promotes reusability and the creation of abstract layers (O'Brien et al., 2005).

- **Autonomous Services**

  Services have control over the logic they encapsulate. The logic governed by a service resides within an explicit boundary. Within this boundary, the service has complete autonomy, and it is not dependent on any other service. This freedom of dependency eliminates ties that could inhibit its deployment and evolution (Erl, 2005a).

- **Stateless Services**

  Services should not manage state information, as that may impede their ability to remain loosely coupled. Services should be designed to maximize statelessness (Erl, 2005b). A stateless condition for services is one that promotes reusability and scalability attributes.

- **Discoverable Services**

  Services should allow their descriptions to be discovered and understood by humans and service requestors so that they may be able to make use of the services' logic. Because each operation provides a potentially reusable piece of processing logic, the service needs to discover both the service's purpose as well as the functionality offered by its operations (Erl, 2005a). Services should be designed to be outwardly descriptive so they can be found and accessed by availability discovery mechanisms. This service discovery can be facilitated by the use of a directory provider.

- **Modular Services**

  Although often covered under the principle of loosely coupled, modularity deserves its own description. Modularity allows the logic required to solve large problems to be better constructed, carried out, and managed because modular services decompose this logic into a collection of smaller, related pieces (Erl, 2005a). Each piece addresses a specific part of the problem, but, when coupled, solves the larger problem. An often-used analogy that distinguishes the traditional architectural approach from the loosely coupled, modular design offered by SOA is to think of traditional architecture as a jigsaw puzzle, which is tightly coupled, and to think of SOA as a tangram puzzle, which is loosely coupled. Figure 4 provides an example of tight coupling versus loose coupling.

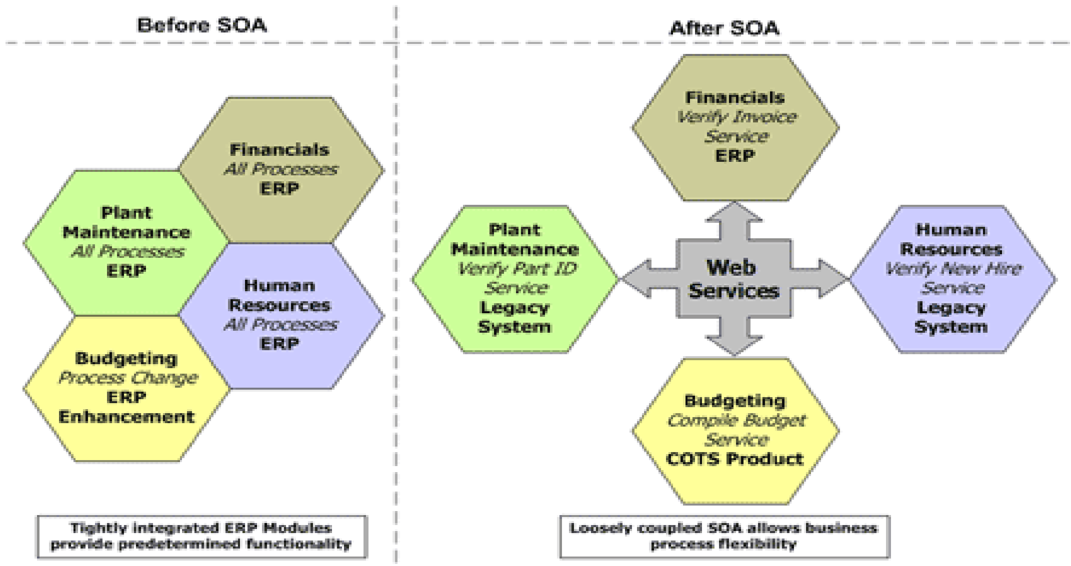

Figure 4. Before and After SOA
(as cited in Adler & Ahart, 2007)

Although all of the principles described in this section apply to SOA, autonomy, loose coupling, abstraction, and the need for a formal contract are often considered the core principles that establish the foundation of SOA (O'Brien et al., 2005).

G. SOA Quality Attributes

The principles described in the previous section lead to a set of quality attributes in the context of SOA.

- **Interoperability**

  This attribute refers to the ability of a collection of communicating entities to share specific information and to operate on it according to an agreed-upon standard. In general, interoperability requires some form of interchange between two or more entities (Brownsword et al., 2004). This allows common services to interact between new and legacy systems, regardless of specific characteristics. In addition, products from various vendors are able to operate successfully with each other. SOA allows data sharing between systems that were unable to communicate previously. Increased interoperability is the most prominent benefit of SOA, especially when we consider web services technology (McGovern, Tyagi, Stevens, & Matthew, 2003).

Finally, interoperability is directly related to the concept of reuse. As more services are reused, interoperability increases, providing a less burdensome IT structure.

- **Reliability**

  Simply stated, reliability is the ability of a system to keep operating over time (Clements, Kazman, & Klein, 2002). Many aspects related to reliability are important within SOA, particularly the reliability of the messages exchanged and the reliability of the services themselves. This can be of concern because different vendors may have different reliability requirements for their products, and, as the saying goes, a chain is only as strong as its weakest link.

- **Availability**

  Availability is the degree to which a system is accessible when it is required for use. SOA provides the advantage of constant availability because single components are responsible for compartmentalized data. However, because services are loosely coupled, if one service goes down, all other services that rely on that given service are affected. In this way, an entire system could be degraded. Therefore, when designing a SOA around critical systems, a backup should be considered (Brummett & Finney, 2008).

- **Usability**

  Usability is the measure of the quality of a user's experience in interacting with the service or information provided (O'Brien et al., 2005). A usable service is, therefore, one that provides a familiar feel and requires less user training .

- **Security**

  Security within SOA is of vital concern to the DoD. Generally, security involves four main principles: confidentiality, authenticity, integrity, and availability. The system must provide a certain level of trust that the information being accessed is from an authorized user. In addition, stronger security mechanisms often have a negative impact on performance. For these reasons, the security of SOA is considered a prime disadvantage and is covered in the section SOA Challenges.

- **Performance**

  Performance is related to response time (how long it takes to process a request), throughput (how many requests can be processed per unit time), and timeliness (the ability to process a request in an acceptable amount of time; O'Brien et al., 2005). With SOA, services may be spread over a vast area. This may affect the performance of the system with respect to latency. Furthermore, latency is correlated with the number of times a service is invoked.

- **Scalability**

  Scalability is the ability of the system to be changed in size or volume to meet increased user demand without any degradation to other quality attributes.

- **Extensibility**

  Extensibility refers to the ease with which new services can be added. Extensibility becomes vital in today's rapidly changing technology environment. Furthermore, services should have the ability to be added without affecting performance of other attributes or the user's interface, unless desired.

- **Adaptability**

  Adaptability is the degree to which existing services can be altered to better accommodate changing user requirements. As with extensibility, adaptability allows the system to stay current with rapidly changing technologies, changing environments, and changing missions.

- **Testability**

  Testability is the degree to which a service can be tested against a set of criteria, and the performance of that service can then be tested against that set of criteria. Testing can be complex for several reasons, including the fact that the service may act differently after it is coupled with other services. Trying to replicate all the issues a service may face in a test environment is extremely difficult. Within the DoD, testing of weapons platforms in expensive testing facilities is done extensively. As services move to connect formerly stove-piped platforms, testability becomes a critical attribute to ensure the systems remain functioning as they were meant to (O'Brien et al., 2005).

- **Modifiability**

  Modifiability is the ability to make changes to a system quickly and cost effectively (Clements et al., 2002). Modifiability tends to be a by-product of other SOA attributes. Because services are loosely coupled, self-contained, and modular, they tend to be modified quickly, easily, and cost-effectively.

H. SOA Technology and Standards

SOA offers electronic services across the web, web services that do not expose their implementations to clients, only their capabilities. The client application invokes the functionality of a web service by sending it messages, receiving return messages, and using the results within the client's applications. One key benefit of web services is that they are based on open standards, allowing them to be implemented in any language on any platform and to still be compatible with client applications. With this in mind, the following list includes definitions of a few technical terms encountered in the core set of SOA standards.

- **Extensible Markup Language (XML)**

  XML is a language for marking up data so that information can be exchanged between applications and platforms. SOA is made possible by the widespread acceptance of open standards, and XML is the common language used by nearly all web services.

- **Simple Object Access Protocol (SOAP)**

  For data to be transferred between computers, communication protocols must be established. SOAP is a messaging protocol for transporting information and instructions within a distributed environment using XML as a foundation for the protocol. SOAP is the most commonly used transport protocol standard for moving messages between services.

- **Web Service Description Language (WSDL)**

  WSDL is an XML-based language for describing web services and for publishing their interfaces to the network. WSDL enables a client application to determine the location of the web service, the functions it implements, and the accessibility and use each function. The WSDL serves as a contract between the web service and a consumer or potential consumer of that service. The WSDL file describes both the data to be passed and the method for passing the data.

- **Web Service Stack**

  The web service stack shows the collection of computer networking protocols that define, locate, implement, and make web services interact with each other. The World Wide Web Consortium's Web Services Architecture Working Group defined technical standards to ensure interoperability for SOAs.

I. SOA Benefits

SOA has several key advantages, as well as several challenges. The benefits are primarily SOA's guiding principles. First, SOA promotes software reuse, which reduces design and implementation time, and results in an overall cost reduction. Because applications are loosely coupled, testing of applications can be done independently on the application itself without affecting the entire system. In addition, service orientation attempts to solve problems of the past by using the following concepts (Erl, 2008):

- increased consistency in how functionality and data are represented,
- reduced dependencies between units of solution logic,
- reduced awareness of underlying solution logic design and implementation detail,
- increased opportunities to use a piece of solution logic for multiple purposes,
- increased opportunities to combine units of solution logic into different configurations,
- increased behavioral predictability,
- increased availability and scalability, and
- increased awareness of available solution logic.

J. SOA Challenges

The following are some of the challenges that SOA systems face (Erl, 2008, p. 85):

- **Increased Performance Requirements**

  As multiple systems reuse a single service, system performance needs to increase to keep up with demand and prevent latency issues. Performance measures will need to be developed for each service based on intended usage.

- **Reliability Due to Concurrent Usage**

  A service may exhibit reduced reliability if more than one system is requiring that service's functions at the same time. Controls to mitigate the risk of reduced reliability must be introduced for critical systems.

- **Single Point Failure**

  As an increasing number of systems rely on one service for a particular function or process, failure of the service will impact every system relying upon that service. Governance may aid in mitigating this risk. Backup systems are not ideal, but should be considered for high-risk processes.

- **Increased Demand on Hosting Environments**

  As demand on hosting environments increases, run-times may become excessive and lead to excessive latency issues. Hosting environments will need to be scalable to mitigate increased demand. Concurrent requests from multiple applications must be addressed to reduce latency issues as a service processes these requests.

- **Service Contract Versioning Issues and Redundant Service Contracts**

  Service contracts address how services will interface with various applications and describe their desired functionality. Versioning must be standardized to avoid confusion and redundant operations that may lead to increased run-time. Proper governance will reduce the likelihood of versioning issues and redundant service contracts.

- **Security Across the Architecture**

  While the loose coupling of the network connections between the service requester and service provider gives the global architecture resilience in recovery from intrusion, it also means that the system, much the same as the Internet, is virtually unbounded, and the number of users accessing services is unknown. Unnecessary requests for service or unauthorized service requests could go undetected, using up valuable bandwidth and possibly compromising the confidentiality of information without the network's owners discovering the loss until it is too late to recover. (Teply, 2009, p. 38)

K. OA and SOA: How SOA Accomplishes NOA Strategy

As shown in Table 4, SOA and OA are similar concepts. In addition, principles laid out by the Defense Acquisition System guiding DoD systems procurement resembles SOA. Moreover, MOSA is already in place for implementing open architecture in the DoD.

Table 4. Comparison of Open Systems to OA and SOA

Open System Characteristics	**Open Architecture Characteristics**	**Service-Oriented Architecture Characteristics**
Heavy emphasis on modularity	Modular design and design disclosure	Modular Services
Lower total ownership cost and systems with longer life expectancy	Life cycle affordability	Lifetime costs decreased by reliability and modifiability attributes
Easier, quicker, and less expensive expansion and upgrading	Easily upgradable systems	Easy system upgrades through adaptability, extensibility, and modifiability
High degree of portability, connectivity, interoperability, and scalability	Core concepts of scalability and portability, and stated goal of interoperability	Quality attributes of scalability and interoperability
Faster and less costly technology transfer	Goal to optimize system performance	Quality attribute of performance
	Reusable application software	Reusable services
	Interoperable joint warfighting applications and secure information exchange (common services and information assurance)	Quality attributes of usability (common services) and security

Note: This table was adapted from a similar table in Azani (2001).

L. Defense Acquisition System

The Defense Acquisition System(DAS) is a complex, multi-faceted system used by the DoD for acquisition of its national security systems. As laid out in DoD 5000.01 (Under Secretary of Defense for Acquisition, Technology, and Logistics [USD(AT&L)], 2003), five fundamental principles govern the DAS: flexibility, responsiveness, innovation, discipline, and streamlined and effective management. Each policy principle can be supported by SOA and OA.

- **Flexibility**

  Flexibility is achieved by both SOA and OA through increased agility and the potential for reuse. The more open the system becomes, the more quickly the system can adapt to changing needs or requirements, thereby increasing overall flexibility.

- **Responsiveness**

  SOA and OA provide necessary responsiveness by deploying systems to the warfighter in the shortest time practicable. Although a mature SOA or OA system is required for maximum responsiveness, the principle of responsiveness will be achieved through attributes such as modifiability and adaptability.

- **Innovation**

  Program managers should adopt innovative practices to include best commercial practices that reduce cycle time and cost. This can be accomplished by OA, since SOA practices have been proven in commercial industry. OA is intended to reduce costs and development times. It also will reduce future costs through reuse and interoperability. Furthermore, cycle time will be reduced because of the reduction in redundant DoD systems.

- **Discipline**

  The same level of discipline that applies to all acquisitions programs is required with OA. However, since these technologies are relatively new to the DoD, standard baseline parameters and exit criteria will need to be developed with data from programs using this technology.

- **Streamlined and Effective Management**

  Streamlined and effective management refers to the management of an acquisitions program, ensuring credibility in cost, schedule, and performance reporting. SOA and OA can contribute to this principle because proven technologies have enhanced management of the overall program by reducing risk.

M. Modular Open Systems Approach (MOSA)

MOSA is a way of implementing open architecture in the DoD. It is a strategy for developing a new system or modernizing an existing one. It uses widely supported commercial interface standards when developing systems. According to the Open Systems Joint Task Force (OSJTF, 2004), MOSA attempts to achieve the following goals:

- reduced acquisition cycle-time and overall life cycle cost,
- the ability to insert cutting-edge technology as it evolves,
- commonality and reuse of components among systems, and
- an increased ability to leverage commercial investment.

MOSA adheres to five major principles to achieve those benefits: establishment of a MOSA-enabling environment, employment of modular design, designation of key interfaces, use of open standards for key interfaces, and certification of conformance (OSJTF, 2004). Figure 5 identifies these principles alongside MOSA's associated benefits:

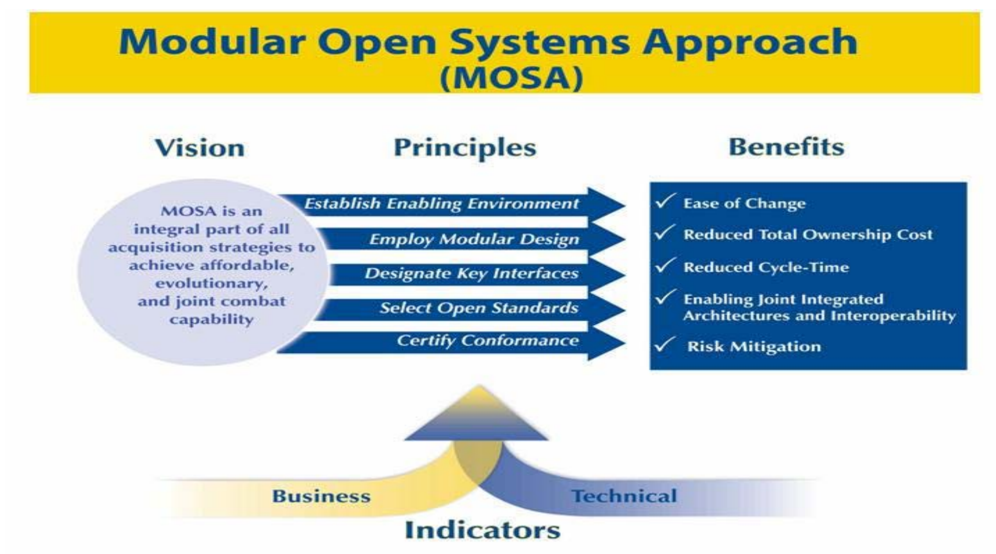

Figure 5. MOSA Vision, Principles, and Benefits
(OSJTF, 2004)

MOSA's goals, along with its guiding principles, closely relate to the strategies guiding SOA. Table 5 compares underlying technical concepts of MOSA to OACE and SOA.

Table 5. Comparison of MOSA Principles to OACE and SOA

MOSA Principles	OACE	SOA
Establish an enabling environment. Establish supportive requirements, business practices, technology development, acquisition, test and evaluation, and product support strategies.	Guidance concerning standards have already been published.	Already adheres to an enabling environment because many major companies are supporting SOA.
Employ modular design. Partitioned into scalable, reusable modules. Designed for ease of change.	Functional partitioning should support insertion of new functionality.	SOA services are modular.
Designate key interfaces. Identify interfaces that are highly reliable, technologically stable, and that pass vital interoperability information.	Use structured programming within components and middleware technologies for interconnections and integration among components.	Use of wrappers to connect key interfaces that must interoperate.
Use open standards. Standards must permit interchangeability, interconnections, and compatibility. Standards must be well defined, mature, widely used, readily available. Standards must be able to allow for future technology insertion.	OACE encourages standards-based technologies. Recognizes XML and SOAP as standards. Programming language should support open standards.	Uses open standards such as XML, SOAP, and WSDL to ensure interoperability among services.
Certify Conformance. Modules must conform to open interfaces to allow plug-and-play and reconfiguration of mission capability in response to new threats and technologies.	Existing systems may see little if any change at the periphery, but changes are made at the interface level.	Web services are based on open standards and only expose their capabilities to clients, not their implementations.

Note. This table was constructed using information from the following sources: OSJTF (2004) and DoD, NAVSEA, & PEO IWS (2004).

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III. Potential Benefits

In this section we identify potential benefits of SOA and OA. We begin with a discussion of ROI and then present results from a qualitative research study on SOA. Potential benefits and best practices from case studies and industry surveys are identified. Because SOA and OA share many similar concepts, it is reasonable to expect similar results: in this section we illustrate potential outcomes and industry best practices that may apply to the DoD. SOA has been proven beneficial in the private sector, which has derived benefits that include cost savings, agility, and flexibility. Extrapolations of benefits were conducted by the NPS researchers because of the limited implementation of OA in the DoD,

Since the 1990s technology boom, billions of dollars have been invested in IT with the goal of realizing significant returns. However, returns have not materialized as expected, leading Nobel Prize–winning economist Robert Solow to theorize the "productivity paradox," which explains that even though IT is embedded in more business processes, returns are not showing up in productivity statistics (as cited in Atkinson & Court, 2010). One possible reason for the productivity paradox is the fact that the returns produced by technology cannot be measured easily with current methods. ROI is one method for measuring returns that is frequently applied to IT systems. ROI, calculated as revenue or benefits of an investment minus investment cost and divided by investment cost, is often interpreted as a productivity measure (Nelson, 2010).

ROI is an important business measure, as evidenced by the fact that 80% of companies surveyed by *ComputerWorld* and Ernst & Young said the financial justification of IT projects is important.(Tain, Cao, Ding and Zang 2007) However, of the companies surveyed, only 40% perform a financial business case analysis on a regular basis. Additionally, 65% of companies indicated they do not have the knowledge or tools needed to calculate ROI, and 75% said they have no formal process for measuring ROI for IT projects. Finally, 68% said they do not perform a follow-up ROI calculation six months after implementing the project (Tian, Cao, Ding, Zhang, & Lee, 2007).

A widely accepted investment measurement tool in the private sector, ROI has gained more prominence in the public sector. The Clinger–Cohen Act (1996) mandates the assessment of cost benefits for IT investments. In addition, the GAO *Assessing Risks and Returns: A Guide for Evaluating Federal Agencies' IT Investment Decision-Making* (Version 1; 1997) requires IT investments be analyzed using ROI measures. Finally, DoD Directive 8115.01 (Assistant Secretary of Defense for Networks and Information Integration, 2005) issued in October 2005 mandates the use of performance metrics based on outputs, with ROI analysis required for all current and planned IT investments.

A. ROI for SOA

ROI for SOA is oftentimes difficult to calculate because attributes such as efficiency are not easy to quantify. However, calculating ROI is critical given that most businesses look for tangible ROI when evaluating or approving new or continuing investments. One British study found that 89% of companies use "intuition" or "guesswork" to calculate the ROI of their IT investments (DiMare, 2009, p. 5). According to ZapThink Research (as cited in Schmelzer, 2005), "Only by understanding the full range of SOA value propositions can companies begin to get a handle on calculating the ROI of SOA" (para. 2). Furthermore, Gartner analyst Randy Heffner (as cited in McKendrick, 2007) has said, "Any attempt to assign a specific ROI to SOA should be viewed with heavy skepticism" (para. 3). McKendrick (2007) further argued that SOA is a set of best practices that are relatively intangible. Some argue that not only should monetary values define ROI, but that ROI should be defined by return on closing capability gaps that are targeted by SOA implementation and by nonmonetary valuations such as customer satisfaction and avoidance of loss of life (Buck, Das, & Hanf, 2008). Figure 6 displays some nonmonetary considerations for analyzing ROI.

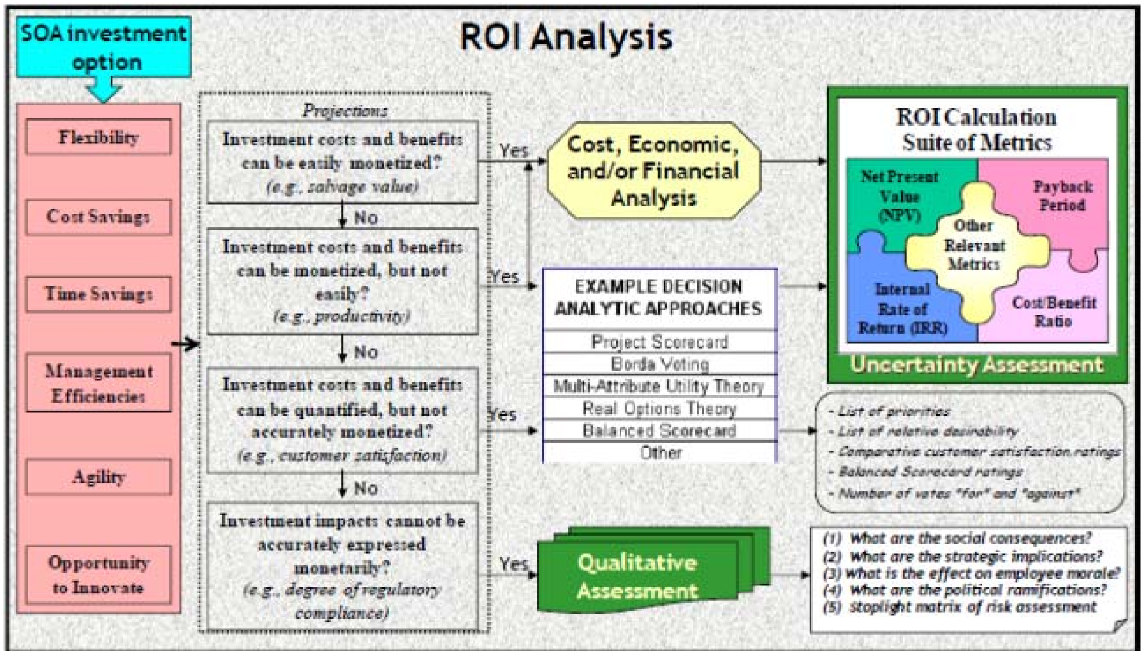

Figure 6. ROI Analysis Considerations for SOA
(Buck et al., 2008 pg. 13)

Because SOA is composed of a variety of service components that show their true value only when working together, measuring ROI for SOA becomes convoluted. ROI is easier to calculate when using single-purpose applications. Each application can be measured and translated to an understandable ROI. According to Erl (2008), "This type of reasoning is what has led to the popularity of siloed application environments" (p. 257).

Service reuse adds to the complexity associated with calculating the ROI of SOA because the benefits may not be realized initially. As a service is reused, ROI will continue to increase, as illustrated in Figure 7.

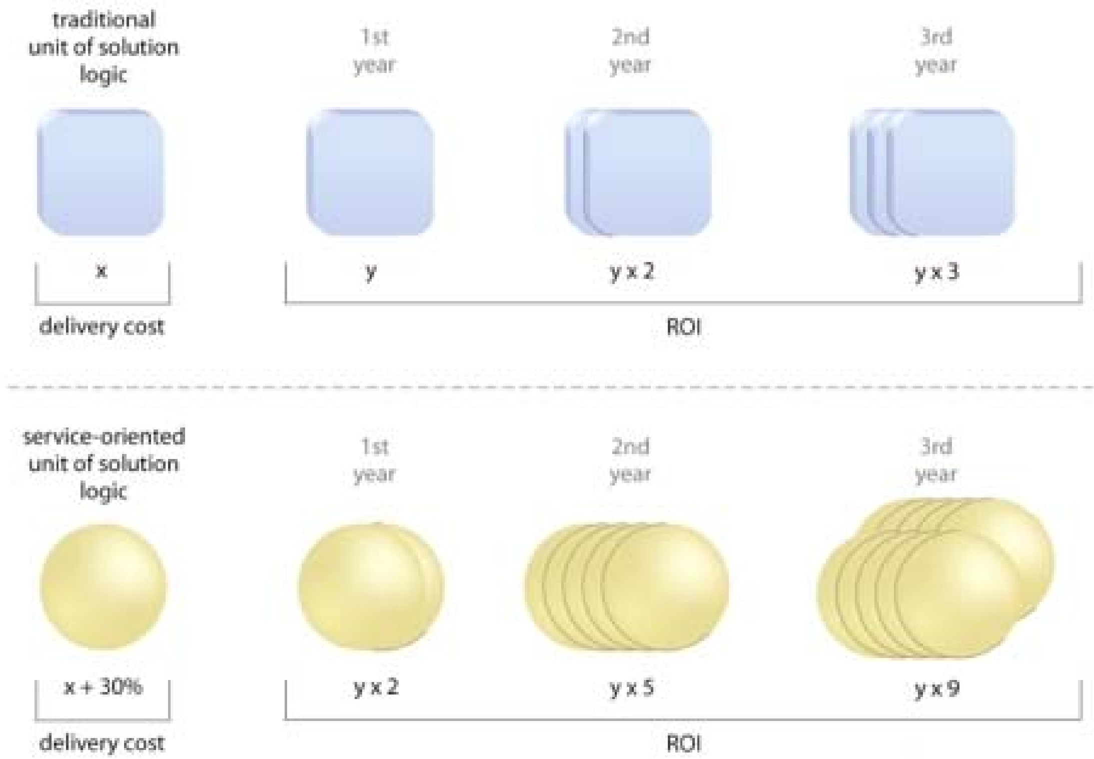

Figure 7. Example of ROI for SOA Projects
(Erl, 2008, p. 62)

Although experts disagree on how to calculate ROI within an SOA implementation, one recommendation is to divide SOA ROI calculations into three quantifiable benefits: “[1] Tactical ROI as a result of standards-based service oriented integration, [2] Operational ROI based on service and process reuse, and [3] Strategic ROI due to business and technology agility” (Gabhart, 2007, p. 2).

Tactical ROI focuses on reducing redundancy and other initial cost reductions, providing justification for initiating an SOA. The following four steps describe the method for calculating tactical ROI (Gabhart, 2007, p. 2):

1. Compute savings realized due to reduced middleware licensing costs.
2. Compute savings afforded due to reduced development time.
3. Project savings due to reduced maintenance costs.

4. Add the results of steps 1–3 together and fold them into whatever ROI formula the organization uses (i.e., net gain divided by investment).

Operational ROI provides feedback by analyzing various services' reuse and, in the process extends implementation beyond the initial time frame. Two methods for calculating operational ROI for SOA are the iterative reuse model and the calculated reuse model. When using the iterative reuse model, the "investment return is measured based on the number of times a service or process is reused rather than an arbitrary time frame" (Gabhart, 2007, p. 3). Writing a reusable program requires a greater initial investment than a traditional program; it is approximately 1.5 times or 50% more than writing software for one-time use (Poulin, 1997). Although reusable components initially cost more than non-reusable components, they provide a cost savings each time the service is reused. The reuse model requires an organization to compare current development costs with the costs required to develop reusable components. According to Gabhart (2007), the reuse model is a "mathematical model [that] computes SOA value based upon a few key variables such as number of services available for reuse, degree of reuse, and service complexity" (p. 3).

Strategic ROI should also be calculated to provide a complete analysis of the long-term benefits gained by implementing an SOA. As described by Gabhart (2007), strategic ROI is manifested though cost controls, risk mitigation, and new revenue generation resulting from agility. Calculating strategic ROI is considered more an art than a science, as seen in Table 6.

Table 6. Ideas for Calculating Strategic ROI

• System development and maintenance costs saved due to the ability to modify information systems with little to no coding required (simply modify or rearrange the orchestration of several services).
• Estimated legal costs and fines avoided due to faster and more reliable responsiveness to regulatory changes.
• Revenue generated via the rapid creation of new services as well as the manipulation and reconfiguration of existing ones.
• Revenue generated due to ability to expose internal capabilities as consumable services by business partners and clients (this potentially generates completely new streams of income.

(Gabhart, K., 2007, pg.4)

In addition to Gabhart's method, other methods have been introduced, such as resource-consumption-based pricing, in which the consumption of services is metered (Denne, 2007). Although experts cannot reach consensus, the previously mentioned methods are the most current theories on how to calculate ROI for SOA.

Commercial industry methods for calculating ROI do not readily translate to the DoD because the government is a non-profit entity. With no profit motive, public-sector entities typically measure monetary values such as cost savings, cost reduction, and cost avoidance (Phillips, 2002). However, some experts argue that non-quantifiable attributes must be analyzed as well. These attributes provide the overall value associated with implementing SOA and must be taken into account.

Nelson (2010) identified a couple of key concepts that professionals agree contribute to the difficulty of measuring the ROI in IT:

- the difficulty of defining the actual impact (benefits) of IT in terms of value because technology enhances an existing process or is embedded within many stand-alone processes, and

- the difficulty of assigning monetary value to intangible and tangible benefits
(i.e., customer satisfaction, customer retention, or time savings; p. 17)

There are several approaches for addressing these difficulties, including a cost-based method. The cost-based approach was adopted to overcome the lack of defined revenue and the difficulties of assigning monetary value to the impact provided by an IT investment. When profit margin cannot be calculated due to lack of revenue stream and cost-savings estimates are used as a surrogate for revenue to calculate benefits, this method is used.[3] Methods for calculating cost savings include the following:

- presuming that the cost to replace or outsource IT is, without proof, proportionate to the value it adds to process performance (Pavlou, Housel, Rodgers, & Jansen, 2005, p. 207);
- interpreting cost reductions achieved through staff reductions, consolidation of facilities, elimination of software licenses, or other results that decrease current expenditures as cost savings (Brandon, 2010);
- converting output data to monetary value by determining the amount of impact the technology had for each unit of cost reduction (Phillips & Phillips, 2002, p. 524);
- calculating the cost of quality and directly converting quality improvements to cost savings (Phillips & Phillips, 2002, p. 524); and
- cost savings converted from the participants' wages and benefit when employee time is saved. s (Phillips & Phillips, 2002, p. 524).

All of these cost savings or cost avoidances serve as a revenue replacement for ROI and are used to represent net benefits or the numerator of the ROI equation. The denominator of the ROI equation, the investment cost, is calculated by summing all the related costs of the IT. Sometimes, cost savings is the only measure used to calculate ROI. This assumes the net benefits did not change as a result of the cost reduction. When the net benefits (the numerator) are held constant while costs (the denominator) are reduced, the result equates to a positive ROI. Essentially, every

[3] Cost savings can be defined as the resulting reduction in expenditures from the IT implementation (Nelson, 2010).

time cost is reduced, ROI is increased. Using this logic, the goal would be to decrease costs to zero, thereby achieving an infinite ROI because a zero would be in the denominator. This result is obviously unrealistic because a company cannot exist without producing some type of cost. Therefore, a major limitation of cost-based ROI approaches is that they rely on cost to determine value. This creates a major problem when estimating ROI because cost and revenue need to be derived independently in order to derive a true numerator. Cost-based approaches lack a surrogate for revenue (Pavlou et al., 2005).

One way to curtail problems associated with cost-based approaches is the use of knowledge-value-added (KVA) methodology. KVA provides surrogate revenue streams at the sub-process level that are uniquely derived from common units of output. This is accomplished by providing an objective method to estimate value in terms of common units of output. In the non-profit sector, this allows the allocation of surrogate revenue streams by assuming a direct relationship between knowledge and the value stemming from it and describing all process outputs in common units (Housel, Kanevsky, Rodgers, & Little, 2009).

KVA methodology was applied to a pilot study that estimated the value created by inserting capabilities into the Aegis Weapons Systems (AWS) through the Advanced Capability Build process (Mun, Housel, & Wessman, 2010). In this study, called the Knowledge Value Added + Real Options + Integrated Risk Management + Portfolio Optimization (KVA + RO + IRM + PO) study, researchers inserted 23 capabilities into the AWS, and issues such as value to the warfighter, risks, and the effect of a constrained budget were analyzed. Using this toolset, the researchers quickly estimated the effects of varying capability insertions. They were also able to quickly change parameters, such as adding new capabilities or additional risk factors, which provided great flexibility to the decision-maker. Although not every system would require such an in-depth analysis, the KVA + RO + IRM + PO model could be applied to any investment to better manage acquisition projects.

The AWS study proved the successful use of KVA. The DoD could consider using KVA rather than ROI to measure the value of a project, because KVA uses a derived value for the numerator. This method would ensure benefits are analyzed in objective, common units and would provide a more accurate measure of value. This is important because in their study of the AWS, Mun, Housel, and Wessman (2010) found little correlation between the actual cost of insertions and their military value. The DoD could also consider implementing RO into its acquisition of OA systems. The use of RO would address the industry best practice of flexibility by allowing decisions to be made when more complete information is available. Furthermore, RO uses an incremental approach, another industry best practice, by allowing for phased options and the option to wait on or defer additional investments. Finally, because RO allows the decision-maker to assess the project at various points, it can be used to frame strategies to reduce risk.

Although other methods of measuring value, such as KVA, exist, many companies currently use cost-based ROI analysis to choose a particular investment option by considering resource constraints, and to measure the ongoing performance of the investment. However, using only cost savings typically does not tell the whole story, and decision-makers must be aware that analysis results can be readily manipulated (Buck et al., 2008).

B. SOA Benefits

We conducted a qualitative research study that analyzed a wide range of published reports, case studies and surveys in an effort to quantify the potential benefits of OA and SOA. In particular, the researchers analyzed case studies of SOA implementations in the private sector from several industries. Because methods for calculating ROI were not uniform across industries or companies, costs were broken out into the three quantifiable areas that are recognized in DoD financial management.[4] The three areas are

1. cost savings or actual reduction of cost in a current area;
2. cost avoidance, a reduction or elimination in a future requirement; and
3. productivity improvement, a reduction in future personnel time and effort (American Society of Military Comptrollers, 2009).

Researchers analyzed 34 case studies, 18 of which provided an overall ROI. 10 of these cases were broken down into various cost components. Based on the case studies, conclusions regarding benefits to industry and best practices were developed. As shown in Table 7, the overall ROI from industry SOA implementation was 305%, while the ROI from cost savings and cost avoidance was 72%.

Table 7 displays information from the 18 case studies reporting overall ROI.[5] ROI was calculated over a three- to six-year period. All companies calculated a net present value (NPV) with a discount rate of 12%. Furthermore, a payback period was calculated for most case studies. ROI was calculated with a process of measuring benefits, calculating total investment, and then projecting the investment and benefit over the time period designated.[6]

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[4] Some reports broke cost savings into costs avoided or into productivity improvements, of which only a percentage was provided or could be calculated, and others simply stated a dollar amount of cost savings without including supporting figures.

[5] Methods for calculating ROI varied because the case studies were conducted by different companies.

[6] The reports did not provide details on exactly how benefits were measured.

Table 7. Baseline Data—ROI Reported by 18 Selected Companies According to Case Study Reports[7]

Company	ROI	Benefit (discounted)	Investment (discounted)	NPV	Discount %	Discount Period (Years)	Payback (months)
Blue Cross Blue Shield of KC	332%	14,330,000	3,320,000	11,010,000	12%	6	20
Mobile Telecom	625%	10,120,000	1,400,000	8,720,000	12%	3	5.6
Real Time Services	215%	180,000	57,000	120,779		5	0
Global Provider for Info Mgmt Sys	470%	8,080,525	1,417,846	6,662,679	12%	3	2.5
Services and Fac Mgmt Co	360%	2,744,982	596,674	2,148,309	12%	3	4.6
European based telecom	212%	5,472,842	1,753,242	3,719,600	12%	3	9
International Finance Firm	252%	$6,627,447	$1,882,568	$4,744,879	12%	3	6.7
Healthcare Provider	356%	$13,475,631	$2,952,633	$10,522,889	12%	6	6.7
Global Media Consulting Firm	244%	$1,541,718	$447,938	$1,093,780	12%	3	8.2
Healthcare Services Provider	346%	$15,800,000	$3,500,000	$12,300,000	12%	3	4.8
Global Financial Services Firm	472%	$37,140,000	$6,490,000	$30,650,000	12%	3	3.9
Carphone	42%	$1,254,000	$812,000			3	30.6
Johnson Controls	81%	$370,000		$143,547		3	12
Bank of India	234%		$23,000,000			5	24
MoreDirect	428%	$445,395	$47,270	$332,251		5	5
International Insurance Provider	256%	$1,428,180	$401,607	$1,026,573	12%	3	8
Global Consumer Products Co	265%	$1,118,547	$306,370	$812,176		3	5.8
Quicken Loans	298%		$183,000				
Average	305%						9.4

Note: This table was constructed using information from the following case studies: Case Study Forum (2009a, b), IDC Business Value Spotlight (2009a, b, c, d, e, 2010a, b, c), IDC ExpertROI® Spotlight (2010a, b, c, d), "Shopping for SOA" (n.d), Nucleus Research (2007, 2008), and Thoughtware Worldwide (2010).

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[7] ROI = (Benefit – Cost of Investment)/Cost of Investment

Table 8 displays ROI for 10 companies and breaks out benefits into categories. The data was further broken down into either annual cost savings achieved by the SOA implementation, annual cost avoidance, or annual productivity improvement.[8] These costs were tangible benefits that could be programmed into a budget. Cost avoidance savings were planned costs that were not executed because of the SOA implementation.[9] Although still considered a cost benefit, cost avoidance savings were not considered true cost savings because it was unclear if these future costs would ever have been realized. All remaining quantifiable benefits fell into the productivity improvement category. To calculate ROI from cost savings/cost avoidance, the average annual cost savings and average annual cost avoidance columns were summed.

Productivity improvement was considered the ability to accomplish more tasks in the same amount of time with the same number of workers. Two primary examples were staff efficiency and improved system availability. Staff efficiency was calculated as work hours saved. If a job position was eliminated due to efficiency, it was considered a cost savings; however, if the majority of the time the worker was simply available to work on other projects it, was considered a productivity improvement. System availability, or reduced downtime, was also calculated on an hourly basis. The reduced downtime allowed workers to continue their jobs rather than stand idle while the system was unavailable.

Benefit and investment figures in the baseline Table 8 were discounted over a period of three to six years. However, the case studies did not provide detailed information on how total discounted numbers were calculated. For example, the case studies provided an investment discounted over a number of years, but they

[8] Cost savings is defined as the difference between historical costs and costs after implementing an SOA component.

[9] A few examples of cost avoidance were not hiring additional workers, not outsourcing, or not making a planned purchase. Additionally, if the case study stated the company saved some number of full-time equivalent (FTEs) workers, this was considered cost avoidance because they no longer needed to hire those workers.

did not identify when in time the investment was made. The investment could be assumed to have occurred at time zero, but without detailed information, adjustments had to be made. Along the same lines, the cost savings, cost avoidance, and productivity improvements were provided as an average annual savings. Most SOA investments produce greater benefits the longer the systems are used, so it could be assumed that over a period of 10 years, for instance, the ROI would be even greater. However, because the case studies did not report if the benefits were immediate, gradually grew, or gradually decreased over the time period, researchers could not determine this information.. In addition, the discount rates used in these cases were 12%, which is common for commercial industries.

Because the DoD is non-revenue-generating company, it does not have competing investments warranting such a high discount rate. The DoD can use risk-free Department of the Treasury rates as a more accurate measure of discount rates.[10] A direct comparison to the investments presented in Figure 8 would be unfair because the exact calculations conducted in the case studies were not stated. However, in general, using a lower, more accurate discount rate for DoD investments creates a much higher ROI when compared to the ROI realized in industry.

Table 8 also displays a calculated payback period.[11] To calculate the payback period, the annual cost savings/annual cost avoidance columns were summed to determine the net cash flow. The net cash flow calculated represents a periodic undiscounted cash flow.

[10] The daily Treasury yield rates for 2011 for three-year investments has fluctuated between .5% and 1.5%, with the average rate for the first six months of 2011 being 1.05%. (Department of Treasury, n.d.).

[11] Payback Period = (Investment/Net Cash Flow) * 12 months

Table 8. Calculated ROI from Cost Savings and Cost Avoidance

Company	Reported ROI	Calcuated ROI from Cost Savings / Cost Avoidance	Average Annual Cost Savings	Average Annual Cost Avoidance	Average Annual Productivity Improvement	Benefit (discounted)	Investment (discounted)	NPV	Discount %	Discount Period (Years)	Payback (months)
Blue Cross Blue Shield	332%	330%	$2,380,000	$0	$90,000	$14,330,000	$3,320,000	$11,010,000	12%	6	16.7
Mobile Telecom	625%	136%	$1,100,000	$0	$3,570,000	$10,120,000	$1,400,000	$8,720,000	12%	3	15.3
Global Provider for	470%	-18%	$0	$387,853	$2,827,485	$8,080,525	$1,417,846	$6,662,679	12%	3	43.9
Services and Fac Mgmt Co	360%	-100%	$0	$0	$1,140,000	$2,744,982	$596,674	$2,148,309	12%	3	
European based	212%	-18%	$478,463	$0	$1,801,860	$5,472,842	$1,753,242	$3,719,600	12%	3	44.0
International Finance Firm	252%	-31%	$101,015	$329,054	$2,669,439	$6,627,447	$1,882,568	$4,744,879	12%	3	52.5
Global Media Consulting	244%	107%	$111,609	$198,140	$332,626	$1,541,718	$447,938	$1,093,780	12%	3	17.4
International Insurance	256%	7%	$143,839	$0	$427,328	$1,428,180	$401,607	$1,026,573	12%	3	33.5
Healthcare Services	346%	146%	$0	$2,870,000	$3,720,000	$15,800,000	$3,500,000	$12,300,000	12%	3	14.6
Global Consumer	265%	165%	$270,689	$0	$195,366	$1,118,547	$306,370	$812,176	12%	3	13.6
Average	**336%**	**72%**									27.9

Note: This table was constructed using information from the following case studies: Case Study Forum (2009a, b), IDC Business Value Spotlight (2009a, b, c, d, e, 2010a, b, c), IDC ExpertROI® Spotlight (2010a, b, c, d), "Shopping for SOA" (n.d), Nucleus Research (2007, 2008), and Thoughtware Worldwide (2010).

Table 9 identifies cost benefits across all industries. These categories, or variations of them, constituted quantifiable cost savings, cost avoidance, and productivity improvement figures in Table 8.

Table 9. Quantitative Benefit Categories

Benefit Categories	Examples of Quantitative Measurements	Benefit Metrics Examples
Cost Reduction	Reduced software upgrade costs, elimination of hardware and associated operations costs, and reduced personnel required	Cost benefits are directly related to decreased software/hardware costs, licensing costs, or reduction in full-time equivalents (FTEs).
Avoidance of Future Costs	Decreased staff, decreased power consumption, and elimination of outsourcing	All costs possibly calculated based on current rates, adjusted for inflation.
Avoidance of New Investment Costs	Purchase of new infrastructure or software	Cost of replacing modular service compared with replacing an entire system
Increased IT Staff Efficiency	Reduced repair time for network services and security monitoring	Calculated difference between current maintenance costs and maintenance costs in an SOA project
Improved Administrative Efficiency/Enhanced User Productivity	Improved quality of the help desk and customer satisfaction.	Help desk knows of problem before users call to report, allowing them to answer the call quickly.
Increased Application Availability/Reduced Downtime	Downtime results in missed sales, trading opportunities lost, and a decrease in customer satisfaction and brand equity	Downtime can be related to productivity of a user by an hourly rate of pay. Sales can be calculated per hour to determine revenue lost.
Software Reuse	Less development time, less testing time, and overall lower project costs	Actual cost comparison of reused software to newly developed software. Training costs and productivity loss of users learning a new system.
Simplified User Interface	Decreased user learning time	Reduced training costs and increased productivity.

In addition to monetary cost savings, the case studies listed several benefits that had not been monetized or that the researcher removed because they did not correspond well to any of the three financial management characteristics of cost savings, cost avoidance, and productivity improvement. Table 10 expands on these categories and briefly describes how they may impact the DoD.

Table 10. Qualitative Benefit Categories

Benefit Categories	Examples of Qualitative Measurements	Relationship to the DoD
Business Staff Efficiency	Information delivered to managers more quickly and accurately improves decision-making.	Timely and accurate delivery of information vital to military leaders.
Business Credibility	Equates to more business because other companies view their system as available and reliable.	Productivity improvement. through availability and reliability of systems in the DoD is a
Reduced Duplication of Effort	Information entered once, available to all users.	Ensures accuracy and consistency of data. It also saves time inputting data or fixing mismatched data.
Faster Time-to-Market	Difference in the amount of time a product is available compared to the current time to market.	Faster delivery of vital intelligence or logistics when and where required.
Scalability	The ability to increase size or volume without degradation.	Scaling of service in accordance with changing mission.
Flexibility	Flexibility is achieved through increased agility and potential for reuse.	Flexibility allows for quick adaptation to environmental changes.

To complement the analysis specific case studies, published surveys were analyzed by the researchers. For example, the Aberdeen Group published a survey of 4,600 business and IT decision makers in January 2008. The survey asked what role participants thought IT would play in their businesses in the current year. The results of the survey are shown in Figure 8.[12]

[12] Of the six most-often cited categories in this survey, five were experienced by companies in the researchers' selected case studies. Only one, "improves communication," was not cited as a benefit.

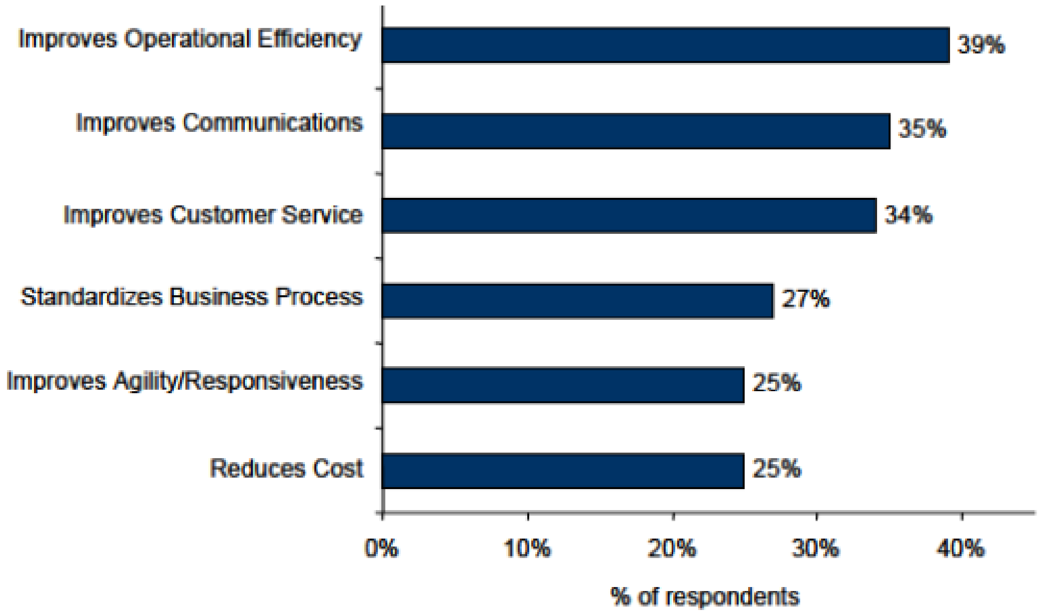

Figure 8. Primary Roles of Business Technologies in 2008
(Dortch, 2008 pg. 20)

Another survey of North American and European companies cited improved customer service and faster time-to-market as the largest benefit participants expected from their IT investments. These benefits were also identified as benefits in the case studies. However, when the same companies surveyed were asked to identify the primary driver of the SOA vision within their organization, IT cost savings was the most frequent answer, with 30% of respondents citing that reason, followed by customer service improvement and faster time-to-market at 23% and 21%, respectively (Ritter & Evans, n.d.).

The Aberdeen Group (2008) conducted a study of the SOA efforts of 400 companies, and among the companies identified as best-in-class, 62% reported improved business agility as their primary driver for SOA deployment. Reducing operating costs tied for third at 39% (Dortch, 2008). Forrester Research claimed 81–84% of SOA users identified the drivers for SOA as improving business and application flexibility, while 70–75% of SOA users responded that lowering business and application costs was the driver for SOA (Heffner & Fulton, 2008).

IBM conducted in-depth interviews with actual members of the project teams from 35 SOA implementations worldwide, spanning 11 industries. The benefits reported in these interviews are shown in Figure 9.

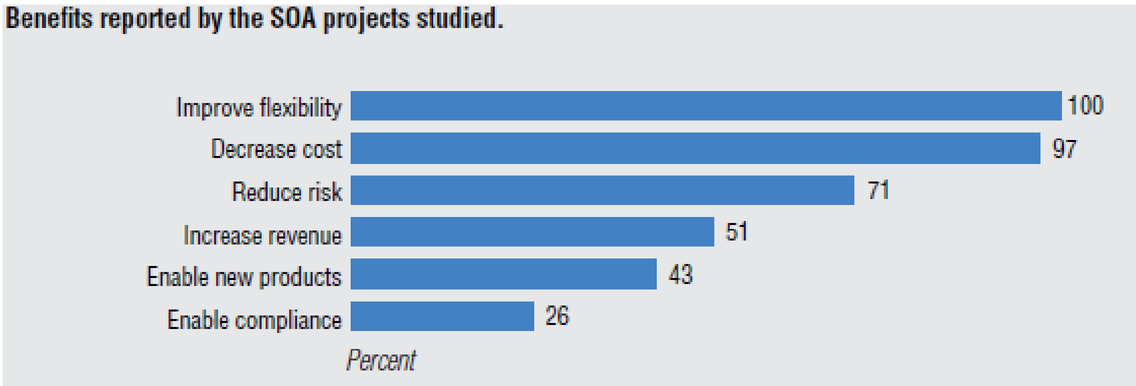

Figure 9. Benefits Reported by the SOA Projects Studied by IBM
(DiMare, 2009)

All but one company in the IBM study reported a decrease in costs as a benefit from SOA implementation (DiMare, 2009). In addition, in a study of over 900 IT and business decision makers, over 60% of the respondents who reported reducing cost as a major objective of SOA are currently meeting or exceeding their cost-reduction objectives (IBM Global Technology Services, 2009).

The data described in Figures 8 and 9, as well as data from the published surveys previously mentioned, support the fact that reducing costs is an important factor in industry, and most companies have been successful at achieving their cost-reduction goals. A report published in 2009 by Computer Economics concluded that only 6% of the organizations they surveyed after adopting an SOA had a negative ROI. Of the remainder, 57% broke even and 37% experienced a positive ROI (Computer Economics, 2009). This seems to be representative of the findings in the case studies, as six of the 10 selected cases reported a positive ROI. However, a positive ROI of cost savings is not a foregone conclusion. In fact, cost reduction by itself does not encompass all of the benefits offered by an SOA implementation. Furthermore, it is not always industry's primary driver in implementing SOA, as has been seen in several published surveys. Many other factors play into the decision.

As seen in Figure 9, a primary benefit reported in the SOA adoption survey is decreased risk. Risk mitigation encompasses many factors, including flexibility that allows IT to react more quickly to changing demands, scalability to increase scope as needed, and reusability that enables IT to implement proven technologies rather than attempting to develop a service from scratch. In addition, proven technologies increase the availability and stability factors of a system because they have been previously tested and implemented. Risk mitigation is extremely important in the DoD because, all too often, systems are delivered late, over budget, and without the capability to perform as they were meant to.

As mentioned, an important quality of risk mitigation is reusability. Reusability is often considered as a necessary component to making SOA cost effective. One reason for this, as stated by DiMare (2008) of the IBM Institute for Business Value, is that “increased reuse leads to reduced maintenance, which leads to decreased costs; or in another path, increased reuse leads to reduced integration time, which leads to reduced integration cost and thus to decreased costs” (p. 7). The true value of reuse is in the standardization of business processes (IBM, 2005). One survey concluded that 90% of organizations see reuse as a critical metric for success (Ritter & Evans, n.d.). Poulin and Himler (2006) suggested that the cost of reusing an SOA component is about half the cost of reusing traditional components. Forrester Research reports that SOA development can cost almost twice as much as traditional component development, but when the component is repeatedly reused, SOA becomes 30% more cost effective than traditional development. (Kobielus, 2005). As an example, Delta (as cited in HP, 2010) reported significant cost savings when reusing components. Furthermore, AT&T claimed that reuse of a single service saved it from 50–85% of the cost of building custom interfaces (Erickson, 2006).

Based on secondary research, we conclude that the private sector believes cost is an important facet of implementing SOA and companies would not move to SOA if it did not provide some type of positive ROI. However, a straight-line cost reduction was not typically the objective when implementing an SOA; instead, industry focused primarily on improving efficiencies and providing a flexible business position.

C. Industry Best Practices

The qualitative research provided insights into industry best practices. First, flexibility must be built into the implementation. As evidenced by the surveys and case studies, flexibility was at or near the top of the list of objectives when implementing SOA. In addition, it was often recognized as a valued benefit resulting from SOA. The ability to react and change course in a rapidly changing environment was considered an enormous benefit. As such, any SOA project the DoD intends to implement must ensure flexibility. Not only is the business environment changing rapidly but also the military environment is facing shifting threats unique to the various Services. Mass armies are no longer attacking one another and the face of warfare has become terrorist groups that continually change their tactics. Similarly, the DoD's acquisition strategy must be adaptive and reactive to these changes with flexibility being key.

The second best practice is the use of an incremental approach in implementing an SOA. Since it is difficult to gather resources to make an enterprise-wide conversion from legacy systems to SOA, it is better for companies to adopt SOA on an opportunistic basis, such as when legacy system integration is required (Computer Economics, 2009). In the same way, the DoD should start small with near-term or easily implemented requirements and build from there. Furthermore, the DoD should initially attack low-hanging fruit by introducing SOA services that provide an immediate bang for the buck. When analyzing best practices from the case studies, a commonality was the introduction of a specific service to solve a specific problem. Companies did not attempt a massive replacement of all their systems at once, but, instead, focused on specific areas needing improvement and implementing processes to address those areas. In addition to mitigating risk and reducing costs, this incremental approach allows organizations to learn from the early implementations, thereby reducing the learning curve for future implementations.

D. Implications for the DoD

The DoD can expect outcomes similar to those achieved by industry and can learn from industry best practices. Three key areas of interest for DoD acquisitions are cost, schedule, and performance. Although cost was the focus of this section on potential benefits, schedule and performance were very much impacted by SOA in the private sector. For example, ensuring a flexible system has a direct impact on schedule. Companies want a flexible system so they can quickly shift gears in a changing environment. Although schedule impact may not be seen in the initial investment, it becomes evident in subsequent investments.

Beyond improving schedules, increased performance was a benefit seen in the case studies. Often listed as staff efficiencies, workers were able to spend less time on issues such as maintenance and to focus, instead, on other areas that would benefit the company. The schedule- and performance-related benefits of SOA may be equally, if not more, beneficial than the potential cost savings.

DoD acquisitions would also benefit from the risk mitigation offered by SOA projects. Some best practices include reusability of technologies, using an incremental approach, and building the system with a high level of flexibility and scalability, all of which equate to reduced risk. Because many acquisitions programs fail to meet cost, schedule, and performance goals, these programs would benefit from the implementation of a methodology that reduces associated risks.

With a stove-piped architecture, there is very little flexibility at the system's inception and during its subsequent useful life. While in the development stage, the program may have already changed due to factors such as increased scope, technology obsolescence, and so forth. Even though the acquisition community requires a risk-mitigation strategy for its projects, this strategy is different from the risk mitigation offered by OA. Risk mitigation strategies for stove-piped systems are often implemented early on. This would mean that the features and requirements of a system would be decided early on in a program's development and would remain unchanged throughout the implementation phase. However, it is likely that requirements will change throughout the implementation because needs and technologies change, knowledge is incomplete at the start, or because of numerous other reasons (Campbell, 2010). Locking in requirements too early in the process may lead to inflexibility in the program (Patterson, Ott, & Giglio, 2009), resulting in the program not achieving all of its goals. OA offers the DoD the flexibility to adjust to this changing environment.

It is imperative for the DoD to develop a method of measuring the actual value of its investments, of ensuring flexibility in its systems, and of implementing risk mitigation strategies. Although several methods could accomplish these goals, KVA + RO + IRM + PO is a proven model that the DoD could adopt to solve these issues.

IV. Risk and Uncertainty

As seen in the previous section, SOA has proven benefits that should be seen in the result of OA implementation. Although we can learn from the commercial sector on potential benefits, we have to understand the risks involved as well. OA introduces new risk elements to systems development and upgrade projects in the DoD and the Navy, where the overall acquisitions approach is essentially designed to suppress risks. It is imperative to understand these risk-suppression steps, which inhibit OA's potential ability to reduce costs and increase flexibility. In this part of the report, we show how risk is suppressed, stifling innovation.

It was anticipated by the DoD that the application of OA principles would enable small, innovative businesses to enter the defense market. According to the 2007 Computerworld case analysis on Naval Open Architecture, the

> open business model, implemented through disclosure of system design documentation was envisioned to encourage competition at all system levels, therefore enabling small companies—who cannot compete with the likes of the large contractors for big Navy contracts—to compete their solutions at the sub-system or component level.

Greater competition was expected to provide SMEs opportunities to enter the defense arena and end eras of stove-piped systems and the oligopoly of defense contractors who provide expensive, monolithic systems that do not interoperate.

In reality, SMEs cannot participate in the defense arena due to risk suppression mechanisms and the exorbitant costs to enter the market. SMEs cannot afford to follow all the bureaucratic rules and restrictions imposed by the current DoD acquisition processes. The systematic risk restrictions at the DoD and in the acquisitions process have resulted in programs still going over budgets and schedules, as a result of attempts to control risk. Until risk issues are addressed, the DoD will never achieve true portfolio management nor will it ever fully implement OA.

This section seeks to understand risk issues and provide an overview of DAS and the risk types that different assessments, plans, and milestones attempt to mitigate. This secondary research is augmented by primary research to identify the risks that provide the biggest challenges to acquisition professionals. A series of interviews was conducted with a diverse group of current and former acquisition professionals with experience in Air Force, Army, and Navy acquisition programs. Most interviewees had work experience in at least one program manager position; all had DoD acquisition experience. Some interview subjects are currently filling various positions at PEO IWS and PEO LMW.

The *Risk Management Guide for DoD Acquisition* (DoD, 2006) defines risk as "a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule, and performance constraints."(pg. 40). This closely resembles the standard definition of risk in project management practice as "an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective" (Project Management Institute [PMI], 2008).

Risks contain three components:

- a future root cause, which, if eliminated or corrected, prevents a potential consequence from occurring;
- a probability assessed at the present time of that future root cause occurring; and
- the consequence of that future occurrence (DoD, 2006).

According to these three components, risk can only occur in the future. Once an event or cause has occurred, it is no longer a risk that can be mitigated, but an issue that needs to be managed (DoD, 2006).

For the purposes of this report, uncertainty is the state of not being sure if an event will occur. It can best be defined in its relationship to risk with this analogy: A coin is being tossed and it is uncertain if the coin will come up heads or tails. To the observer, there is no risk unless the observer bets a dollar on the result; the risk is then either gaining or losing a dollar (Mun, 2010). In the DAS, a PM may face a similar situation in that next year's budget allocations may be uncertain, but risk may or may not exist, depending upon the amount of money currently available in the program's accounts compared to the next year's resource requirements.

Uncertainties are categorized in three types: known, unknown, and unknowable. Known uncertainties are future events certain to occur, such as cars at an intersection stopping at a red light. We are fairly certain all cars will stop for a red light and, at times, risk our lives betting on this known uncertainty by crossing the street. On rare occasions, a car will run a red light so even though this uncertainity is known, there is always a chance we will be wrong. The unknown is what we do not know, but we can simulate it and, through the passage of time, events, and action, it will become known. The unknowable contains so much risk and uncertainty that the passage of time, events, or action may not reduce its levels of risk and uncertainty. For example, an unknowable event is an earthquake. Even after an earthquake hits, we are unsure when the next earthquake will hit (Mun, 2010).

A. Risk Management

Every project and program in the DAS encounters a wide array of risk and uncertainties. A typical example is the Virginia class submarine program, which saw increased costs, cut budgets, and changes to the basic shipbuilding plan. Because of the constant risks and uncertainties in the DAS, risk management plays an important role in helping its programs meet cost, schedule, and performance goals.

Risk management is defined as the "application of knowledge, skills, tools and techniques to project activities to meet project requirements" and is accomplished through "the application and integration of the project management processes of initiating, planning, executing, monitoring and controlling and closing" (PMI, 2008 pg 15). Besides risk management, a PM's time and effort must address other activities and requirements such as Project Integration Management, Cost Management, and Human Resource Management.

The goal of project risk management is to increase the probability and impact of positive events, and decrease the probability and impact of negative events in the project. This is done through a series of six processes of Project Risk Management: *Plan Risk Management, Identify Risks, Perform Qualitative Risk Analysis, Perform Quantitative Risk Analysis, Plan Risk Responses*, and *Monitor and Control Risks* (PMI, 2008). In practice, different PMs approach each step differently and some may not give equal weight to quantitative risk analysis as opposed to a qualitative approach. These six processes will be valid for most programs, especially in the DoD, as can be seen in Figure 10 that shows the DoD Risk Management Process along with the six processes of Project Risk Management.

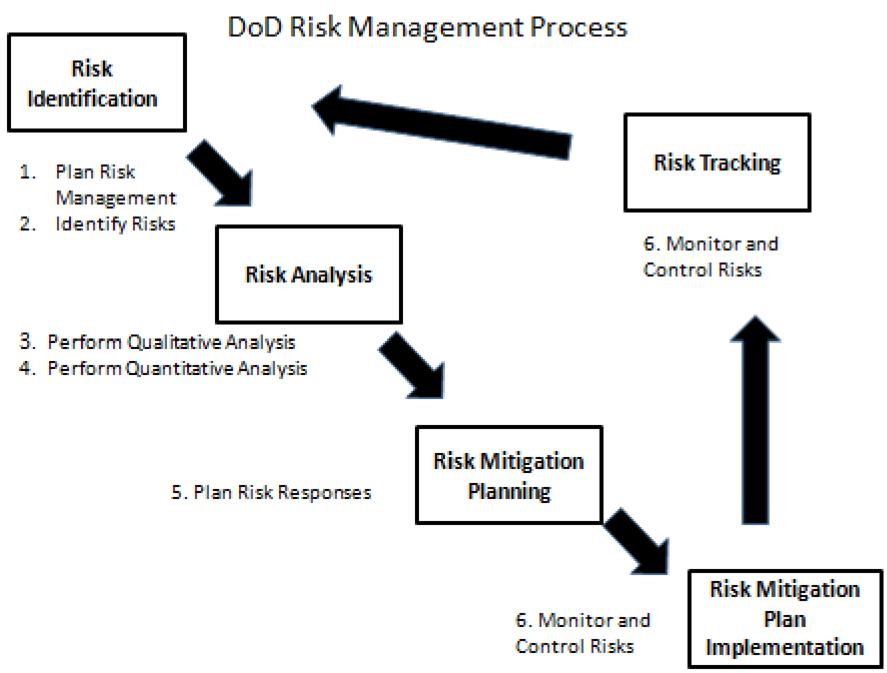

Figure 10. DoD Risk Management Processes with Six Processes of Project Risk Management
(DoD, 2006 pg 45)

Although risk management is most concerned with unknown and unknowable uncertainties, it is most useful in helping mitigate unknown uncertainties because unknowable factors can be hedged by insurance or risk acceptance (Mun, 2010).

B. Risk Analysis in the DoD

Risk analysis assesses the impact of potential risks on the cost, schedule, and performance of a program. The *Risk Management Guide for DoD Acquisition* (DoD, 2006) does not prescribe specific methods or tools and only provides general guidance and accepted practices for DoD acquisition professionals to follow. It is important to understand the commonly accepted tools and metrics used by contemporary DoD acquisition professionals in this report.

Any events potentially impacting a program are first identified and assessed in relation to the likelihood and consequence of their occurrence, and are then shown in a Risk Reporting Matrix. This matrix is shown in Figure 11 and reflects both the likelihood and the consequences of an event occurring—grades from one to five are given to each potential event for both likelihood and consequence, with one being the least likely or consequential event and five being most probable and severe event.

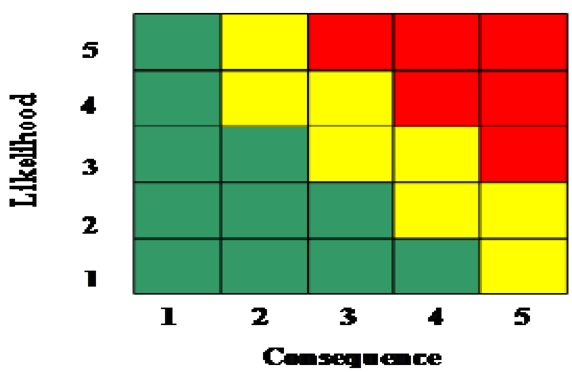

Figure 11. Risk Reporting Matrix
(DoD, 2006 pg 50)

Plotting the two grades results in one of 25 boxes in the matrix. The green shaded area indicates a low level of risk (consequence) and uncertainty (likelihood), while the yellow shaded areas are indicative of medium and significant levels of risk, uncertainty is found in the red shaded area.

The Probability of Occurrence is the sole factor used in determining the likelihood of a risk and the likelihood of occurrence is left to the user's discretion. Figure 12 illustrates the percent of likelihood associated with the 1-5 scale.

Likelihood

Level	Likelihood	Probability of Occurrence
1	Not Likely	~10%
2	Low Likelihood	~30%
3	Likely	~50%
4	Highly Likely	~70%
5	Near Certainty	~90%

Figure 12. Levels of Likelihood Criteria
(DoD, 2006pg 25)

C. Defense Acquisition Systems' Mitigation of Risk

To further the goals of the National Security Strategy (NSS) and the National Defense and Military Strategies resulting from it, DAS covers a diverse range of areas. From determining the problem's solution, to the deployment and eventual retirement of a system, oversight and review, contracting, logistics and long-term sustainment of the system, technical evaluations, and financial management are all factors in the process. Ultimate program success is determined by how well a program meets cost, schedule, and performance goals.

- **Initial Capabilities Document (ICD)**

  The ICD describes broad, time-phased, operational goals and capabilities needed by a single warfare community, or needed jointly by many communities within the DoD. If the ICD identifies a material solution then an Milestone Decision Authority (MDA) will be assigned to decide if the ICD contains sufficient information to proceed to the first phase. At this stage, the first attempts to mitigate technical risk start with the identification of promising foreign and domestic technical sources; however, PMs must allow more time for consideration of technologies under the Small Business Innovation Research Program. (USD [AT&L], 2008). This time cost does not yet present schedule risks, as the program has not yet officially entered the acquisition system at this stage.

  When designing system architecture by following the instruction (8000.1), integration risks(i.e. between systems, compatibility, etc) can be avoided.

- **Material Solution Analysis Phase**

  This phase begins with a Material Development Decision review and is concerned with the study of any alternatives available besides the solution articulated in the ICD. This serves to avoid costs spent on developing redundant systems and technologies. If reasonable alternatives are not found, then the material solution contained in the ICD will be reviewed for measures of effectiveness, cost, schedule, concepts of operations, and overall risk. The avoidance of program risk begins with the Analysis of Alternatives study assessing critical technology elements (CTE) of the material solution to include technology maturity, integration risk, and manufacturing feasibility (Under Secretary of Defense [USD(AT&L)], 2008).

  Future cost savings are sought by emphasizing innovation and competition when seeking the best possible system solution and this emphasis on competition has become a principle NOA. Future budget and integration risks are mitigated by the use of COTS solutions; however, this tends to increase security risks as exploits on commercial systems are more well know than on systems developed in-house by the DoD and not exposed to the public.

- **Technology Development Phase**

  Before beginning this phase, a program has to pass through Milestone A, which consists of the MDA reviewing the proposed material solution and the Technology Development Strategy drafted by the PM. After MDA approval, the Technology Development Phase begins.

  Once a determination is made that the program is worth the expense, and the technical and manufacturing processes have been assessed and demonstrated in a relevant environment, the program can exit the Technology Development Phase. Manufacturing risks will have been identified, and testing should confirm that the system can be developed within a short time frame, which is defined as less than five years for a weapons system (USD [AT&L], 2008).

  Before Milestone B, a Preliminary Design Review (PDR) is conducted. This report is given to the MDA and lists any trade-offs in requirements, based upon an assessment of cost, schedule, and performance risks. The MDA then decides if any remedial action is necessary before proceeding to the next phase.

- **Engineering and Manufacturing Development Phase**

  This phase begins at Milestone B in which the Acquisition Strategy and Acquisition Program Baseline is approved, addressing Integrated System Design and the System Capability and Manufacturing Process Demonstration. Key Performance Parameters (KPP) are identified and approved.

  Integration and system-level risks are mitigated during the Integrated System Design as system functionality and interfaces are defined, and a hardware and software design is produced. The establishment of a product baseline for all configuration items prevents integration risk.

  A system-level Critical Design Review (CDR) assesses the design maturity and feasibility of a program. Metrics include percentages of hardware and software products built to specifications; numbers of drawings completed; assessments of environmental, safety and occupational health risks; and the maturity of critical manufacturing processes. The MDA then conducts a Post-CDR Assessment and determines if the program can exit the Integrated System Design part of this phase. With MDA approval, the program moves to a System Capability and Manufacturing Process Demonstration. This is where performance risks are mitigated by determining if the system can operate in accordance with the KPPs and schedule risks are mitigated by demonstrating that the manufacturing processes can support system production goals.

- **Production and Deployment Phase**

  At Milestone C, the MDA decides if the DoD will be committed to production. Major systems will begin at a low rate of production, which helps prevent program, technical, and performance risks. These risks are avoided by the identification of any issues arising during the actual manufacturing of system components and the testing of these products before the full rate of production is achieved. Low rates of production are not applicable to automated information systems or software-intensive systems without developmental hardware, but this decision is left up to the PM (USD [AT&L], 2008). A Full-Rate Production Decision Review is required before the program can pass into full-rate production.

- **Operations and Support Phase**

  This phase begins with the delivery of the system to the operational forces with a goal of meeting operational and performance requirements in the most cost-effective manner over the system's life cycle. PM's used Performance Based Life Cycle Product Support planning, development, implementation, and management to achieve the goal of keeping the system reliable while keeping costs down.

- **Relative Weight of Mitigation for Various Risks in Defense Acquisitions Systems**

  Cost, schedule, and performance factors, and the mitigation of risks that can affect these factors, are the prime concerns of every program's PM and PEO, though a bird's-eye view of the DAS, as presented in the preceding paragraphs of this chapter, reveals an emphasis on mitigating integration and technical risks. Integration risks are a subset of performance risks; however, the attempt to achieve greater levels of integration in a system can also affect the cost and schedule of a program. The emphasis on integration risk is understandable due to the change in doctrine of the U.S. Armed Forces to Joint Warfare after the Goldwater-Nichols DoD Reorganization Act of 1986 and other federal legislation, such as the Clinger-Cohen Act of 1996, that mandates the way information technology is acquired.

  The mitigation of technical risks comprises 20% of the acquisition cycle as it is the goal of the Technology Development Phase, while performance, and the mitigation of risks associated with it, forms the basis for the remaining three phases after Milestone B. Budget risks are addressed primarily in the first two phases.

Manufacturing risks closely align with schedule risk, except that issues that arise in the manufacturing process that can influence cost and performance are emphasized after the system design has been proven. Most of the emphasis on mitigating manufacturing risks comes after the Post-CDR Assessment, in the Engineering and Manufacturing Development Phase, and never approaches the level of emphasis given to other areas of risk mitigation.

In the *Operation of the Defense Acquisition System*, DoDI 5000.02 (USD[AT&L], 2008), technical risks are mentioned more often than any other type of risk, while integration risk is mentioned less than other risk types. Table 11 lists the frequency of various risks mentioned in DoDI 5000.02.

Table 11. Risks Mentioned in DoDI 5000.02

Risk	Mentioned	Risk	Mentioned	Risk	Number of Times Mentioned
TECHNICAL	10	PERFORMANCE	6	ENVIRONMENT SAFETY & OCCUPATIONAL HEALTH	5
COST	5	SCHEDULE	4	MANUFACTURING	3
OPERATIONAL	2	INTEGRATION	2	ENTERPRISE ARCHITECTURE	2
SYSTEM LEVEL	2	MATERIAL	1	PROGRAM	1

D. Risk and Uncertainty as Perceived By Acquisition Professionals

A series of primary interviews was conducted from April to June 2011 with 10 different acquisition professionals. Interviews were conducted in person and over the telephone with subjects who have extensive experience serving either as PMs or Program Contract Management for various programs in all four Services of the DoD. Some are retired and some are teaching DAS subjects at the Graduate School of Business and Public Policy at the Naval Postgraduate School. The other interview subjects are currently working in various positions at PEO IWS and PEO LMW.

Interviews were free-flowing discussions, rather than specific question-and-answer sessions, which revealed some strong commonalities and consensus views.

This section begins with three critical subject areas for acquisition professionals: budget uncertainty, program risk and uncertainty, and decreasing returns on increasing assets. Interviewees devoted a significant portion of the conversation to these areas and, without researcher prompting, were almost unanimous in their opinions when these topics came up. This section ends with responses to specific interview questions.

E. Budget Uncertainty

"I spent over a quarter of my time either protecting my money or stealing someone else's money" - DAS Program Manager

The above quote by a PM describing his experiences succinctly summarizes the common concern over budget uncertainty revealed during the interviews. Although all interviewees gave equal weight to cost, schedule, and performance issues when discussing their programs and the acquisition system in general, the ever-present threat of budget reductions and program cancellations cast a constant shadow of uncertainty. Mitigating budget risk is specifically not mentioned in acquisition directives and instructions, and even though all interview subjects seemed to give an equal weight to cost, schedule, and performance, the primary interviews confirmed budget risks as a major area of uncertainty.

Budget uncertainty cannot be blamed on a lack of attention to costs in the acquisition cycle. For example, a good portion of the Materiel Solution Analysis Phase covers program feasibility and estimation of life cycle costs, while the PDR before Milestone B lists the trade-offs in functionality required to keep cost risk under control. The interview consensus was that political risk was a common cause of much budget uncertainty.

Political risk emerges from the Planning, Programming, Budgeting and Execution Process; it originates anywhere from a significant change in a new

Administration's NSS, to recent election results eliminating legislative support for a program, to a period of budget cuts and austerity. A typical manifestation of political risk mentioned by the interviewees was a Friday afternoon phone call from the PEO asking for a Plan of Action and Milestone by Monday morning on how cost, schedule, and performance would be affected by budget reclamation of money as changes in the political landscape slowly worked their way down to the program level. Many interview subjects believe that the DoD attempts to operate more programs that it can adequately oversee and manage. Lack of prioritization eventually leads to a mad scramble for money and Friday afternoon data calls for reclamation of funds when the DoD faces budgetary pressure.

The best strategy to mitigate budget risk and reduce the impact of the Friday afternoon phone call was to expect one's budget to come under review for cuts and to have plans and templates for various levels of budget cuts already drafted and readily on hand. In fact, one interview subject discounted any uncertainty when it came to his budget, because it was a "certain uncertain that I could count on folks coming to take my money." In order to achieve this level of preparation, it is not surprising that budget issues can take up 80% of a PM's time. "Stealing" another program's money is also time consuming, but can pay dividends for a PM who devotes the time necessary to follow the progress of other programs and capitalizes on opportunities to move money into his program if another program is terminated or money is reallocated elsewhere. To describe what happens in DAS when a larger program is terminated, one interviewee used the analogy of a large shark being overwhelmed by a swarm of smaller ACAT-level barracuda.

In the end, there is not much a PM can due to mitigate the political causes of budget risk except knowing what levels of budget-cutting pain programs can survive and still meet cost, schedule, and performance goals. In addition, keeping a level of awareness allows a PM to know when new sources of money may be available.

F. Keeping It All Together, Program Risk and Uncertainty

"Uncertainty equals many different independent parts." - Graduate School of Business & Public Policy Professor

When discussing the various ways risk and uncertainty have been defined in different industries and technical fields, a veteran acquisition professional offered the above quote. It was not his intention to mention program risks in DAS, but he inadvertently uncovered the most often mentioned risk type during the interview process. Without specifically asking interviewees what were the most problematic risks, 70% emphasized program risks over all others. All interview subjects, with the exception of one, spent a significant portion of the interviews discussing program risks. The same acquisition professional who gave the definition of uncertainty above defined it as programmatic risk, or a combination of requirement and budget risks and a companion to cost, schedule, and performance risks. For the purposes of this report, a program risk is defined as any risk that threatens to prevent a project or program from meeting its cost, schedule, and performance goals. These risks include those outside of requirements: risks emerging from areas such as the composition of the acquisition workforce; complexity of a system due to an abundance of rules and regulation; and even rules and regulations that contradict each other.

One recurring theme during the interviews, in the area of performance risks, was the problem that different groups and persons involved in DAS tended to "talk by each other" and battled in a "clash of perspectives" caused by conflicting rules between the functional areas at even the Integrated Product Team (IPT) level. A common cause of friction is the different priorities and motivations of a PM and a contracting officer. A contracting officer is assigned to a program not only to serve as the program's subject matter expert on contracting, but is also required to ensure that the program abides by the will of the executive and legislative branches of government as expressed in such legislation as the Truth in Negotiations Act, the Small Business Act, and the Anti-Deficiency Act.

Frictions also arise when a PM wants to avoid cost and schedule risks by relying upon a large defense contractor and possibly overlooking portions of the Small Business Act in order to avoid the risks associated with a smaller company that has limited production capability or that is more likely to go bankrupt than a larger company. Many PMs generally do not receive much in the way of contracting training and, in many programs, the PM is a senior field grade officer who may outrank the contracting officer by three or four pay grades. A PM may pressure a junior contracting officer to approve a contract that might not fully comply with various laws and regulations. The PM is under intense career pressure to meet sometimes unrealistic cost and schedule goals and many times is not responsible for the setting of these goals, because the program's original PM transferred after the goals were established. The PM may resort to a "mission first" approach, which is common in the military and is probably a factor in the PM's career success so far. If the PM is in an untenable situation and decides not to bend the rules to meet unrealistic goals, the PM could very well ruin his career. A junior contracting officer has the same choice when pressured by a PM to bend the rules. The contracting officer can refuse to bend the rules and risk career suicide or can go along with the PM and hope that the rule bending does not become an issue, especially if the trend on the project is to do what needs to be done rather than to do what is ethical.. A contracting officer may very well go along with a PM in approving a contract that, for example, breaks the Anti-Deficiency Act, especially because no one has ever been indicted for violating it (Arnold, 2009).

The myriad risks confronting a program are illustrated by the previous example. As seen in the example, frictions exist between the functional areas of contracting and program management: program risks can arise from legislative and regulation requirements, and from lack of training; risks are induced by personnel changes such as PMs transferring after cost and schedule goals have been established; there are pay grade differences between PMs and contracting officers; the military performance evaluation system and the sense that some rules and regulations may not be enforced.

Besides the inherent friction between the different functional areas in the DAS, there is also a risk of linguistic discontinuity such as language structure, semantics, grammar, and syntax. This type of risk was described in a paper (Riehle, 2006) exploring a problem inherent in software engineering in which many different linguistic styles are used to create software, often leading to confusion and rework within a project . An example is given in the paper of a software project PM who planned to use an object-oriented approach to the software design. A group outside of the PM's control used a popular computer- aided software engineering (CASE) tool that supported a structured design rather than an object-oriented approach, immediately introducing linguistic discontinuity between the CASE tool and the rest of the code, which necessitated extra work to make the dissimilar tools compatible.

Every software project will experience linguistic discontinuity of one form or another because language of the end users and operator is not as technical as that of the software programmers and designers . The phenomenon of linguistic discontinuity is not just a software engineering risk, but is apparent in any project, both in the DoD and in the business world. If software coders, who have the same skill sets and end goal, can misunderstand one another, the risk of linguistic discontinuity between the different functional areas of the DAS is much more intense. With linguistic discontinuity residing everywhere in the DAS—from within an IPT to between the functional specialists in the DAS, such as the PM, the contracting officer, and logistics—it is little wonder that program risk is a main concern of acquisition professionals.

A major program risk is that a system that is ready for deployment fails to meet end user requirements. The fear of either misunderstanding or overlooking vital end user requirements was a constant interview topic. PM's would stress the need to "define requirements with the end users up front" and to engage them constantly during the development cycle. The warning that a PM should "own your own requirements" refers to the common occurrence of the government providing general requirements and specifications to the contractor, but not following up on the contractor's work, and, as a result, being presented with an inadequate product. An example of an unforeseen user requirement that neither the end users or the Integrated Product Team thought of was given during an interview with an acquisition professional involved with upgrading the U.S. Military Entrance Processing Command's network. The goal of the upgrade was to allow the network to receive and store information from the end user's networks, in this case, from the various recruiting stations around the country. After a three-year development cycle, the vendor released its solution only to find that a data entry field for each recruit's shoe size was missing. The end users needed that information so they could send it to the various boot camps so that enough shoes of the proper sizes could be on hand. This omission, while minor, was one of the many cases of end user requirements not being met and, therefore, causing a delay in the release of the program.

Not all program risks can be attributed to misunderstandings or failure of the contractors to develop systems to government specifications. Another constant risk to all PMs as told to the researcher during the interview process was scope creep. Scope creep is a risk encountered when trying to mitigate the risk of misunderstanding user requirements. While all PMs agreed that constant communication and engagement between all parties was a key to a successful program, the tendency was for the government or the end users to add requirements that were not included in the initial capabilities document. Because of the complexity added by new requirements and the fact that "vendors don't do things for free," the program risk increases.

The interview subjects mentioned other areas that increase program risk, including a lack of accountability due to constant personnel rotation and senior leadership that "doesn't know what they don't know" and believes "brute force" leadership will work. A personnel problem mentioned in at least a third of the interviews was that despite a DoDI 5000.02 requirement that PMs serve in an ACAT

II level program for at least three years (four years for ACAT I), there are many cases in which a PM does not stay at that level for the required time due to a promotion, retirement, etc. A GAO (2005) report revealed that contrary to the DAS standard practice, civilian companies usually kept the same PM throughout the life span of a product, and this was these companies' main means of ensuring accountability while DoD PMs were rarely held accountable. Through the course of the interviews, it was discovered that the requirements placed upon PMs far exceeded the flexibility and decision-making power they were allowed so that "the system falls so far short of the mark that it would be almost criminally unfair to hold them [PMs] responsible for its failures" (Shoop, 2005).

Another personnel issue commonly mentioned was the nature of the Government Service (GS) personnel system, which emphasizes time-based service over a merit-based promotion or retention system. Personnel issues will continue to be an issue in the DAS as a GAO report mentioned in the DoD's acquisition workforce plan in which the DoD identified the need to increase the size of the acquisition workforce. The report found that the DoD had not yet assessed the skills and competencies of the workforce, or identified either the desired end state of the acquisition workforce or the funding required (Farrell & Hutton, 2011). The ongoing budget issues may stop any planned increases in the acquisition workforce, but the lack of prior planning given to how the DoD acquisition workforce will be structured in the future makes it extremely unlikely that there will be any major changes in the personnel system.

Problems associated with program risk are wide ranging and many are outside of the control of the DoD. The consensus of all interviewees can be summarized by the statement that "we are stuck with the hand we are dealt with when it comes to personnel." Various suggestions for mitigation strategies did come out of the interviews. One way to mitigate program risk was more training and education, especially training tailored to explaining other functional areas of the DAS, including the requirements, laws, and regulations unique to a functional area.

Most interviewees agreed that a PM was at the mercy of the policies of both the government and DoD personnel and acquisition workforce, and could not provide much practical advice on how to mitigate these issues. All agreed that the delay in ramifications for bad program decisions was an issue. For example, a PM might favor awarding a contract to the lowest bidder in an attempt to keep costs low, even at the expense of future integration or technical risks. If the PM knows that he/she will be transferred before the integration risks manifest, he may be tempted to award the contract to the low bidder.

G. Decreasing Returns on Increasing Investments

When discussing schedule risks, a common response was that the bureaucratic nature of the DAS placed time constraints on PMs. A consensus was that the overall trend was a continued movement towards more oversight and regulation as opposed to allowing PMs to exercise much in the nature of flexibility and initiative. The accumulation of rules, regulations, legislation, and procedures that has built up over the years and that forms the basis for the DAS is the result of various attempts to mitigate risks and uncertainties. With every mandatory process, test, piece of paperwork, and validation, an increase in costs and time can be expected. These increases in costs and time are worth the expense in order to assure successful performance and that a safe, secure system is delivered to the operating forces, a system upon which lives may depend.

Based on the interviews, we discovered that PMs view the bureaucratic nature of the DAS as a permanent feature, something they must endure. Trying to introduce efficiencies in the system or to fight for more flexibility and latitude in the day-to-day management of their programs would be a losing battle. This fatal outlook is driven by the main difference between the DAS and civilian industry. A business is more apt to change its internal business rules and personnel policies if they hinder the company's profitability. In addition, the company has full control over its own policies and only has to worry about the federal regulations that pertain to its specific business and workforce unlike the DAS. On the other hand, the DAS is once removed from the source of funding and many of the rules and regulations that originate in the Planning, Programming, Budgeting, and Execution Process. Much of the money that flows to the DAS is apportioned based on political reasons, such as the award of a contract in the home district of a legislator, or it comes with strings attached, such as the pots of money that are accessible only if the program awards the contract to a small or minority-owned business. Personnel policies are driven either by the DoD regulations for military personnel or GS regulations. A DAS PM generally has less flexibility in financial and personnel decisions than his civilian counterpart.

The result is a mountain of tasks, requirements, administrative requirements, reports, and paperwork that has slowly built up over the years in response to a real need or a political impulse. Taken individually, each task associated with the bureaucratic process is worthwhile and most PMs would agree that the cost and effort are worth it. Over time, the accumulation of controls has added so much time and monetary costs to daily operations that any new initiative comes at ever greater expense of time and money for diminishing real gains in efficiencies or social good.

H. Responses to Specific Research Questions

- **What are the Risks at Different Career Stages?**

  The purpose of this question was to determine risk categories important to acquisition professionals and, in particular, PMs. Differences in the amount of risk at different stages of one's career could indicate many things. Very high amounts of risk at the beginning of a PM's acquisition career could point to the fact that the DAS's operating principles and techniques were unique and that those with experience in other branches of the DoD and the government could not fall back on prior work experience to help them in their new career. High risk at the beginning of a career could also point to inadequate acquisition workforce accession programs and training, or it could point to a great disconnect between the operational forces and the acquisition system that is supposed to support them. Increased risks at the mid-point of a career and for well- seasoned acquisition professionals could point to a system that assigns riskier programs to employees with more experience or to a system where high-profile programs are subject to more interference and uncertainty. Inexperienced PMs may also have been assigned to projects that were virtually risk free.

Different types of risks at different stages of an acquisition professional's career would reveal a segregated system in which there were many programs and projects that either had different business rules or regulations applied to them. Discovery of different types of risk at different stages of a career might also point to the types of risk that the system found acceptable. For instance, inexperienced PMs might be assigned to programs where the DoD was willing to chance cost overruns and more experienced professionals would be assigned to programs with an ambitious schedule.

Among all interview subjects, the opinion was unanimous that except for the risk, common to all professions, that a newcomer, no matter how well trained, faces, there were no real differences in either the amount or the type of risks inherent in the different stages of an acquisition professional's career. Insignificant variations in the amount and type of risk over a typical career indicate that the DAS applies the same business rules to all programs and projects and that all programs and projects are handled in more or less the same way, no matter the ACAT level. The system benefits from well-defined rules and transitioning into the acquisition workforce is not problematic; however, the trade-off is that the constant level and type of risk leaves less room for individual initiative and an avoidance of seeking anything but a traditional solution to a problem.

- **What are the Risks Beyond Cost, Schedule, and Performance?**

Enquiring about risks other than cost, schedule, and performance was our attempt to find if any unique risks exist in the DAS or if a particular PM knew of a successful strategy to mitigate against various types of risk that were not well known.

Unsurprisingly, all interview subjects agreed that cost, schedule, and performance risks are their prime concerns. The first half of this chapter describes program risk which is described as a mix of requirement and budget risks, and the well-known political risks and feared budget risks that all interview subjects agreed were important. During the interviews, interviewees discussed many types of risks, such as design and component design risks and standards selection risks, but all with an eye to their impact on cost, schedule, and performance.

The researchers' conclusion is that this reveals the well-defined and rigid nature of the DAS. The risks inherent to the DAS are well known and understood, and a PM either is at the mercy of risks beyond his control or can expect to encounter more or less the same type of risks no matter the type of program.

- **What is the Definition of Uncertainty in the Defense Acquisition System?**

If risk can be quantified by measuring the probability of occurrence and the severity of the event (for example, by using the *Risk Management Guide's* Risk Reporting Matrix), then future research could reveal a method to quantify uncertainty in a way useful for PMs. A method for measuring things of which we have incomplete knowledge is beyond the scope of this report, but a thorough understanding of uncertainty as it pertains to the DAS might give us insight into the creation of a useful tool or method of addressing uncertainty, such as the Chicago Board Options Exchange Market Volatility Index, or VIX, which measures the 30-day expected volatility of the S&P 500. Some investors follow the VIX in order to gauge the general investor sentiment that could imply future up and down swings in the market, with greater volatility revealing investor uncertainty and lack of confidence (Chicago Board Options Exchange, 2009). VIX uses historical price data going back over 20 years and tracks the prices of put and call stock options. If the price of put and call options traded on the market can be used to gauge investor sentiment and the implied short-term course of the market up or down, there might be a facet of the DAS that could be utilized in a similar way.

The DAS does not give much thought to uncertainty beyond the dictionary definition, and there was no unique interpretation of uncertainty revealed in the interview process. When the interviewer bought up the idea of a future measurement of uncertainty applicable to the DAS, interviewees expressed only minimal interest in the subject, and the conversation soon changed subjects of its own accord. One interviewee stated that complexity was a proxy for uncertainty and that the Program Management technique of Progressive Elaboration was a means of dealing with uncertainty in a program.

The researcher's conclusion is that beyond the dictionary definition of uncertainty, most PMs think only in terms of risk and believe that any measurement of uncertainty in the DAS is a long way off. PMs are well-informed on Progressive Elaboration techniques and the need to invest as much time as possible in a program upfront in order to reduce risks and uncertainty. The DAS already practices a basic form of risk mitigation in the face of uncertainty by preferring fixed-price contracts when a program has lower levels of uncertainty and cost-type contracts for programs with high levels of uncertainty. This is an area in which more study and understanding is required before any useful measurement or tool can be developed.

- **Questions on the Impact of OA Approach**

During the interviews, interviewees generally avoided giving opinions concerning OA and its impact on the DAS. Even when pressed with the specific questions listed in the Appendix, half of the interview subjects talked in generalities, claiming that they had not had much experience with OA during their career. For those interview subjects who had extensive experience with OA, especially those working at PEO IWS, the consensus was that it is still too early to determine the impact of OA on the system as a whole, especially if OA and SOA have produced the desired results and efficiencies in the DAS.

The researcher also came across misunderstandings on OA and at what level in a program that OA resided. During one interview, when asked to provide an example of a successful use of OA, the PM instead gave a casebook example of an open business strategy. His program acquired extra funds by utilizing a small business, even though their hardware was not initially compatible with the planned architecture of the system, and he was able to divide the rest of the project's hardware requirements and the update of legacy software programs between two large defense contractors. The interview subject gave a good strategic overview of his program, but revealed little tactical success using OA principles, even though the program in question did, in fact, have to use a modular approach, The modular approach allowed integration of independently developed legacy systems, enabling reuse of many legacy system software and hardware components.

One area of agreement among interviewees was that OA increased the complexity involved in ensuring that systems met information security and information assurance requirements; however, much of the complexity was also attributed to the system and network accreditation process. Success stories, such as the Rapid COTS insertion process, were mentioned, along with problems in implementing a support system for OA-centric programs, such as PEO IWS's Share portal, but the general reluctance to pronounce on OA's effects on the DAS as a whole remained. The researcher interpreted the general inconclusiveness of the findings concerning OA in the DAS as indicating that the implementation of OA was still in its initial stages and that the supporting tools, systems, and procedures were at an immature level.

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V. Case Study Summaries

The DoD's limited implementation of OA has yielded a number of benefits, lessons learned, and best practices. Three examples of OA, SOA, and MOSA implementations are highlighted in this section. The first case summary is a successful implementation of MOSA and OA principles, Acoustic Rapid COTS Insertion (A-RCI)/Advanced Processor Build (APB). A-RCI initially attempted to improve the detection capability of towed-array sonar on the Los Angeles class of attack submarines, then expanded its functionality to include all sonar systems in the submarine fleet, along with some surface and aviation submarine detection systems.

The second case summary shows how an SOA strategy solved daunting integration issues. The U.S. Military Entrance Command (USMEPCOM) is a joint command, consisting of elements from all the Armed Services, including reserve components and the Coast Guard; USMEPCOM relies on each Service's legacy recruiting system to process applicants. An SOA strategy allowed smooth data flow from legacy recruiting systems into USMEPCOM's system.

The final case summary discusses PEO -IWS's Software Hardware Asset Reuse Enterprise (SHARE) repository, an online portal containing a library of combat system software and related assets, which is used by contractors in developing or suggesting improvements to Navy Surface Warfare Systems (Johnson and Blais, 2008). Not only does SHARE directly support SOA and OA principles of reusability, but it is part of a larger attempt to build a new infrastructure within the DAS, consisting of new tools, web portals, and ways of doing business, which will allow future projects and programs to use OA with minimal problems. Unlike the two successful cases, this implementation has encountered many problems.

A. NOA Benefits and Lessons Learned

With an open systems approach, the Navy has derived a number of benefits, including decreasing time to field and upgrading in-service systems faster, and modifying or changing capabilities per fleet at reduced cost. More specifically, OA resulted in the following benefits:

- *Acoustic Rapid COTS (commercial off-the-shelf) Insertion (ARCI) process.* OA also allows submarines to upgrade their software every year and their hardware every two years. This approach has been successfully transferred to other submarine systems, as well as to the joint, collaborative efforts of the cross-domain Anti-Submarine Warfare (ASW) community.
- ***Navy's Air Domain*.** Through OA, the E-2 program transitioned to a commercial computing plant with a modular software design. This reduced acquisition cycle time from seven years to 2.5 years and reduced costs from over $200 million to under $11 million**. (Computerworld 2007)**
- According to the Computerworld case analysis, the greatest obstacles to NOA were to overcome the Naval acquisition and defense industry cultures. Although there is full support from top Navy leadership, the rank and file or infrastructure provided the most resistant to change. The greatest resistance to NOA came from individuals who did not understand the OA concept, those who did not think it would work, or those who were not comfortable with change. The most important obstacles to overcome were the following cultural issues:

  - the not-invented-here syndrome, in which Navy programs are resistant to being told by outsiders how to conduct their business. Program staff have generally been working within their programs for many years and are confident they know how best to continue conducting these programs' business. Programs often retain support from contractors who have previously worked on them. This insular environment limits the potential for new ideas and increases resistance to changes introduced from the outside.
  - Large defense industry companies were content with business as usual because they were making huge profits for their shareholders

and, therefore, had no reason to change. The companies that develop, build, and upgrade the Navy and Marine Corps' National Security Systems had no incentive to change their business model while they were so profitable. The DAS community had to convince dominant industry players that their profits would suffer if they did not start building systems with an open architecture; as a result they have become fuller participants in the effort.

- The third cultural issue stems from the first—the not-invented-here syndrome. It is the Naval Enterprise's reluctance to share assets among domains and programs. In addition is the defense industry's propensity for building new systems from scratch rather than reusing assets that the government already owns and that provide the needed capability. (Computerworld, 2007).

B. Case Summary 1: Acoustic Rapid COTS Insertion

The Russian Akula class submarine is making 10 knots on course 275 under the Eastern Mediterranean Sea about 200 miles off the Syrian coast. Captain Spravtsev, commanding officer of the *Volk,* is nervously waiting for reports on a suspected contact, hopefully one of the American Los Angeles Class submarines. On patrol in support of the Admiral Kuznetsov battle group, the *Volk* has been attempting to track the NATO submarines that are themselves conducting reconnaissance on the Russian aircraft carrier's activities.

Earlier in the evening, the Officer of the Deck had called Spravtsev to the Control Room. Upon entering the cramped space and noticing the smiling faces and hushed commotion around the sonar operator, Spravtsev guessed instantly that they had significant contact. The Commanding Officer (CO) had to gently push the Officer of the Deck and an off-duty sonar operator aside in order to reach the console. In an excited whisper, the sonar operator told him that they were now tracking a Los Angeles Class submarine. The *Volk* had managed to track the 688

Class submarine for over two hours, but now had lost contact. It had been over 30 minutes and Spravtsev was nervous that the American submarine had suspected it was being tracked or had acquired his own sub as a contact. “Conning Officer slow to five knots,” said Spravtsev. He knew that his sub had an improved hull and was quieter than the first seven submarines in the class so that if he slowed down the Americans might not suspect he was there.

The US submarine had, in fact, acquired the Volk’s acoustic signature and had been tracking Spravtsev’s command for over an hour. There was a level of hushed excitement at picking up one of the new Akulas as a contact. Soon after Spravtsev gave the order to slow his submarine, the excitement onboard the American submarine died away and the watch team got down to the serious work of trying to reacquire the contact. Unlike the noisier Victor Class submarines, the *Volk’s* improved acoustic profile prevented the American submarine from acquiring her contact until after she surfaced two days later (Cole, 2011).

1. The United States Navy’s USN’s Response to the Loss of Acoustic Superiority

While testifying before the House National Security Committee on the Seawolf submarine program for the 1996 defense budget, then Chief of Naval Operations, Admiral Jeremy Boorda, stated that the Russian Navy was operating six submarines that were quieter than the USN’s then state-of-the-art class of submarines, the Los Angeles class. He described the difficulty that U.S. submarine commanders had in tracking the newer Russian Akula class submarines at slower speeds and expressed concerned over the proliferation of the quiet Kilo class electric diesel submarines in hostile countries’ submarine forces (Committee on National Security, 1995). The fictional account of the American submarine losing its target after Captain Spravtsev slowed his submarine had occurred all too often in real-life operations and was unnerving for a service that had relied on technical superiority to make up for a numerical inferiority.

Admiral Boorda was not only making the best case for spending limited defense dollars for the Seawolf submarine, but articulating the concern over the recent loss of the traditional U.S. acoustic superiority and submarine quieting technology over the world's navies. The loss of this vital edge in submarine warfare came at an inopportune time as the Navy was also fighting increased costs in developing new weapons systems, reduced budgets as part of the drawdown after the Cold War, debates over the future of the Seawolf submarine, and the subsequent decision to cancel the Seawolf submarine program in favor of the Virginia Class.

This sense of crisis over the lost technological edge and the need to regain it in a time of financial constraints facilitated unique and creative approaches to solving the problem that went against the structure and intent of many DAS and JCIDS requirements. In 1996, the PEO for submarines and the PM for the new Virginia class C3I (now C4I) conceived of the following guiding principles for a new initiative that would turn into the A-RCI and APB projects (Udicious, 2004):

- rapid COTS insertion means just that;
- deliver each sensor's full theoretical gain to the operator—all bearings, all frequencies, all the time;
- avoid modifying successful commercial products;
- use the lessons learned;
- use state-of-the-practice, not state-of-the-art systems—tactical sonar systems are not beta test sites;
- configuration management, not configuration control;
- software reuse is the key to affordability;
- no single organization has the full story; and
- sub acoustic superiority depends on the successful use of these axioms.

Many founding principles of A-RCI are directly related to the principles and essential performance characteristics of OA, SOA, and MOSA. Software reuse needs no explanation, but collaboration is mandated by the warning that no organization “has the full story” and the use of state-of-the-practice rather than state-of-the-art systems is key in ensuring interoperability, especially in a project operating on a compressed schedule. Using the lessons learned by other organizations, including the lessons learned in the civilian world, helped to achieve a consensus-based approach and prevented the DoD from trying to solve the problem with a proprietary solution.

2. A-RCI/APB Development Strategy

One of the first A-RCI tasks was to update legacy systems because existing sonar systems were not designed modularly. This introduced some short-term operational risk to the submarine forces as the first APB only allowed the towed sonar array to be operated at a single display station, rather than at one of the many other displays available (Boudreau, 2006). As part of the MOSA strategy, system improvements were divided between the hardware and software components, allowing for the use of COTS for hardware upgrades and the application software developed independently from the processors by the use of transportable middleware. Transportable middleware bridged the gap between different proprietary commercial technology for hardware, software developed for this hardware by other companies, and the specific needs of the military for how they wanted to use the technology. This allowed for quicker development and fielding of new upgrades and gave developers flexibility to change some parts of the system while leaving others alone (Boudreau, 2006). There were risks involved with the MOSA approach, because system development for different components proceeded independently , which introduced interoperability risks into the process. Extra time and expense were needed for tracking and version control of key software interfaces, standards, and protocols among the different development teams.

A-RCI used an open capabilities-based business model as opposed to the requirements-based business model that informs much of JCIDS (Udicious, 2004). In short, A-RCI sought currently available technology, rather than trying to either develop new technologies or improve a system in order to meet specific user requirements. A spiral development model was chosen that included a build/test/build sequence so that any new system additions were required to pass through a thorough demonstration process that included the evalution of new system capabilites against the previous system capabilities; collaboration and information sharing were expected (Boudreau, 2006).

Software development operated on an annual upgrade cycle through APB, while hardware was selected on a biannual schedule, which was described in a study as a “highly demanding acquisition op tempo” (Boudreau, 2006). This high op tempo was in conflict with the need-driven JCIDS and event-driven DAS. Fortunately the sense of crisis due to the loss of acoustic superiority at sea had the benefit of giving A-RCI high-level support, allowing the project to bypass various JCIDS and DAS milestones and requirements in favor of PM flexibility, technical innovation, and experimentation. The priorities were a quick development cycle and the release of improved sonar capabilities to the operating forces. If contractors could not stay on schedule, they were left behind for that development spiral (Boudreau, 2006).

A-RCI followed an innovative approach in order to leverage the benefits of collaboration between contractors, both small and large, academic laboratories, and government organizations. Lockheed Martin served as the prime contractor for A-RCI but the focus was changed to be a “prime system integrator.” Even though Lockheed Martin would play the major role in the contract, the door was opened to smaller contractors and other organizations that usually could not or would not participate in the acquisition process. The main vector for input from small contractors and nontraditional entities into A-RCI was the peer review process that selected between different alternatives and chose the best solution, usually after testing with real-world data (Boudreau, 2006). This strategy arose out of one of the founding guiding principles of the program in that “no single organization [had] the whole story.” The peer review process was conducted under the oversight of a Navy PM with the goal of preventing the usual tendency for the prime contractor to mold the program in the most profitable direction for it, possibly ignoring competitor’s solutions that may have been more suitable. The peer group structures were designed for flexibility, and an extensive set of working groups were set up to cover most aspects of the program, including a Tactical Integration Advisory Group; groups for specific sub systems, such as the APB-1/2 towed array; and, perhaps most important, an Operator Feedback group. The composition of the groups was fluid over the project life cycle with groups merging or even disbanding depending on the circumstances (Boudreau, 2006). The following table represents the ACRI process.

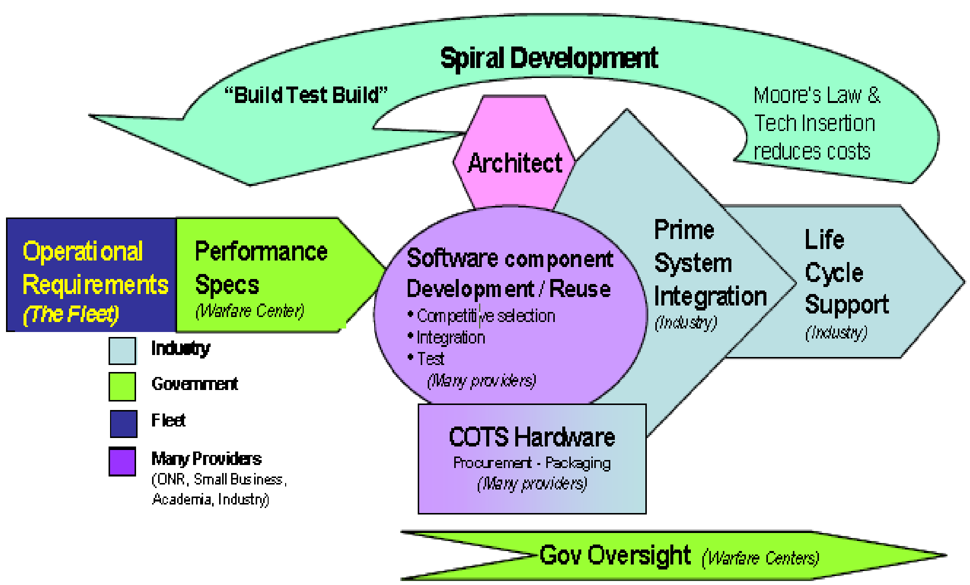

Figure 13. A-RCI System Development Model
(Barron, 2006 pg 54)

Figure 13 presents an overview of the A-RCI development model with the USN, providing the operational requirements and needed performance specifications to the collaborative heart of the program. The APB program depended on competitive selection and testing on an annual cycle, adjacent to but not fully dependent on the six-month COTS hardware development cycle. The DoD, with the spiral development method, hoped to leverage the improvements in technology by using cheaper COTS components on a rapid upgrade cycle in order to keep up with the comparatively rapid technological advances in civilian industry. The spiral process continued until the USN regained acoustic superiority at sea.

1. A-RCI Best Practices and Risk

Bureaucratic and security risks are involved for a DAS program that uses an open strategy. The risks are bureaucratic in the sense that COTS components require approval by both the JCIDS process and the end-to-end testing requirements. In A-RCI's case, the sense of crisis over the loss of technological superiority in a vital warfare area allowed the PMs to mitigate this risk by providing top cover to their middle management, which allowed them to proceed faster than the testing and JCIDS cycle would allow in a regular program, indicating that these processes might introduce impediments into the acquisition community.

The open capabilities-based model allowed A-RCI to leverage the rapid gains in computer processing power that the civilian industry was putting to good use at the time. This was contrary to the requirement-based model that lies at the heart of the DoD's transformation into a joint operating environment. In the rush to develop improved sonar technologies, the program introduced future integration risks. In A-RCI's case, the system they were developing would be the one that follow-on systems deployed to the surface forces and aviation assets would have to integrate with. The integration risks could prove too much for the rapid development of a system already tied in with numerous legacy weapons systems.

A COTS strategy can also introduce security risks when developing a military system, especially a system that uses sensitive technology or is designated Secret or above. The security risk can be in procuring software code with an unknown Trojan Horse hidden in it or in relying on hardware that might not be manufactured to military specifications.

A-RCI's spiral development strategy opened the door to operational risks, potential costs, and schedule risks. When following an incremental development strategy, technologies are released when they are "good enough" or are left behind to proceed in the next cycle. The cost and schedule risks arise when the system is never "good enough" for the end users or the development cycles stagnate into repetitive cycles with little gain. The operational risk was born by the submarine fleet in the initial deployment of the sonar system, but was never viewed as presenting too big of a challenge. Prior to implementing the program, A-RCI's PMs had a fair idea of the current state of the civilian technology available and the cost and schedule risk was deemed acceptable. The probability was that they would be able to achieve rapid improvement over the legacy system.

2. A-RCI and Associated Risks

Risks associated with A-RCI were generated by the unique development strategies pursed by program managers "and the friction between these strategies and the traditional development approached advocated by JCIDS and DAS best practices". The researchers assumed these risks to be relevant to any other program that uses MOSA and OA principles and a spiral development strategy.

- **Budget Risks**

  The initial A-RCI program was funded at lower levels than equivalent programs using a traditional approach and had different funding profiles necessitating "continuous streams" (Boudreau, 2006) of RDT&E, Procurement, and Operations and Support accounts. The mitigation to this budget risk was quick initial success and delivery of improved sonar capability to the fleet sooner than if the program had followed the usual path. The initial delivery of the system to the operational forces was not the final solution to the problem, but it did justify the funds allocated for the program and made it easier for the PMs to acquire more.

- **Program Risks**

  The emphasis given to schedule over performance generated many types of program risk. The crisis-driven focus on rapid deployment of new sonar technologies and reliance on future, though unproven at the time, cost benefits using a COTS development strategy was bound to cause friction between the program and elements of the DAS and JCIDS in place to reduce risk exposure to performance goals.

Even though A-RCI's Peer Review Groups were an integral part of a successful program, there was always the risk of stalemate within or between the various groups. The best mitigation factor against this risk was that all groups operated under the guidance of a Navy PM, who could cast a deciding vote and take ultimate responsibility for a final decision.

Testing played a vital role in A-RCI, especially in the build/test/build development phases and operational testing at sea; however, end-to-end testing, so important in the DAS for verifying performance goals, turned out to increase cost and schedule risks in light of the higher op tempo. This testing is especially problematic in a spiral development program that will proceed without any unready component at the end of a particular phase (Boudreau, 2006).

- **Integration Risks**

The rapid op tempo of A-RCI was incongruent with the slower JCIDS cycle. JCIDS helps ensure that a program addresses mission needs that originated in the NSS and prevents costly redundancy in systems procurement, especially redundant systems procured by different Services. A-RCI's rapid pace resulted in incomplete reviews that threatened future integration of the weapons system beyond the submarine force and the program's potential to operate in a joint environment. The mitigation of risk was to conduct annual JCIDS reviews synchronized to sequential development spirals (Boudreau, 2006). This was possible because subsurface operations and anti-submarine warfare, except for strategic nuclear forces, are almost wholly an USN mission. The question remains open if such an accommodation would be possible with JCIDS if the program in question would be needed to rapidly deploy an anti-aircraft or missile system that would be certain to operate in a joint environment.

- **Operational Risks**

The first operational risk was the initial deployment of the system not meeting the operational requirements of the fleet. The sonar system deployed after the first development cycle could only be accessed from a single console, which hampered the ability of the watch team to access information in a timely manner. The operators in the fleet were able to deal with the inconveniences and risks until subsequent releases were deployed with better accessibility.

> Operator and maintenance technicians also had to spend extra time and effort learning about each new iteration of the sonar system. When the cost and time burden is placed upon the operational user, it does not appear in the cost and schedule metrics of the systems program. A-RCI's success can be attributed to an emphasis on operator feedback, with working groups devoted to its concerns. The risk for future programs using a spiral approach is that cost and schedule burdens might actually be transferred to the operating forces where feedback might not flow back in time to allow adjustments in the developmental cycle.

3. The A-RCI Success Story

In 2006, then CNO Admiral Mullen sent a memo to the heads of various system commands and urged then to follow the best practices of the A-RCI program. He stressed the importance of going beyond using an OA approach to technical problems and also using an open business approach for "the acquisition and spiral development of new systems that enable multiple developers to collectively and competitively participate in cost effective and innovative capability to the Naval enterprise" (Mullen, 2006).

Some measurable effects of A-RCI included the following improvements to the acoustic capabilites of USN's operating forces (Boudreau, 2006):

- a seven-fold increase in processing capability;
- mean operator success rate increased by a factor of four;
- mean number of false alarms reduced by 40%;
- detection and classification time improved by 27 minutes; and
- mean hold time improved by 25 minutes.

Life cycle costs were improved by a factor of close to 5:1 (Boudreau, 2006) with many of the savings attributed to the implementation of the COTS strategy (Udicious, 2004). Risks taken to allow for the quick delivery of operational improvements to the fleet paid off.

Integration risks were taken, but they were always minimal because A-RCI was developing the next generation of sonar systems, and future surface and aviation sonar detection systems would be integrating with A-RCI, not the other way around. Leadership was confronted with the need to maintain a delicate balance between innovation-stifling centralization and bureaucracy, or the anarchy of too few interface definitions that would doom the integration of the different developments. An integrated product team approach was implemented that used collaboration between the government, industry, and even academic labs to keep an element of coordination between the different organizations (Udicious, 2004).

Program risk, especially the risk inherent in a collaborative system, was overcome through strong leadership, especially senior leadership, which provided "top cover" (Boudreau, 2006) by allowing middle management to innovate and intervening to break any stalemates in the various peer review groups. Input from the fleet was vital to providing program leadership and the peer review groups with feedback on what was working and what wasn't working so any arguments within the various peer review and other development groups were less theoretical and more technical, based on the operator's needs. The spiral development cycle introduced cost and schedule risks, but because A-RCI was a software and computer-processor intensive program, the spiral development strategy fitted in nicely with the rapid increases in processing power and technical advances that were widespread in the civilian academic and business realms.

Budget and cost risks are inherent in any spiral development strategy. In A-RCI's case, success led to success and the initial deployments of new sonar technology showed rapid improvement in the operational forces' acoustic capabilities. As the program matured it became more and more likely that the spiral development model would not bog down into repetitive cycles of minimal improvements with hardly noticeable technological improvements. During the interview process, the researcher uncovered a common belief among program managers that the longer a system's development cycle, the more risk is added, resulting in a higher overall chance of program failure. The spiral nature of A-RCI, with its series of short development cycles, delivered to the fleet the technological improvements available at that time so that the fleet did not have to wait for years to receive a supposedly state-of-the-art system. One key to the success of A-RCI's spiral strategy can be summed up by a PM's comment during the interview process: "sometimes good enough is good enough." In the software engineering field, it is well known that most costs of software development are incurred after most of the programming has been done.

C. Case Summary 2: U.S. Military Entrance Command Integration Problem with SOA Solution

USMEPCOM's mission is to review all recruit applications to the U.S. Armed Forces, it then processes records from the initial recruiter interview up to the new accession reports to a training facility. USMEPCOM processes approximately one million records a year and, at any given time, stores over 60 million records across all the Armed Services. Over 15,000 recruiters and 3,000 GS employees use the system to process the applications and exchange data with outside federal agencies, such as the FBI and even the Department of Motor Vehicles in all 50 states (Maravola, 2009). Internally, the USMEPCOM network serves 65 Military Entrance Processing Stations and 500 Military Entrance Testing sites (U.S. Military Entrance Processing Command [USMEPCOM], 2007)

Each application was processed by a recruiter from the particular branch of the Armed Services the recruit was joining, and each branch used its own proprietary system. Recruiters spent extra time and effort in entering redundant data into USMEPCOM's system, which included manually entering the data into a flat file for upload into USMEPCOM's database or making a tedious double entry directly into USMEPCOM's system soon after entering the data into the recruiter's system.

1. DE/TOSIP Overview

USMEPCOM's response to the integration problem between its system and the various Armed Services' recruiting networks was called the Data Exchange/Top of System Interface Process (DE/TOSIP). The initial goal of the program was reducing application processing time from 2.6 days to less than a day and allowing pre-qualification of 90% of the applicants, who no longer had to visit a central facility, such as a Military Entrance Processing Station (MEPS), in person. This would save a significant amount of time and expense, especially in recruiting regions where the MEPS facility is over 100 miles away from the recruiting office. The strategy selected was an "accepted standards based SOA interface" (Maravola, 2009) compliant with all Defense Information System Agency (DISA) system requirements.

The DE/TOSIP team contained representatives from USMEPCOM administration, Information Technology, budgeting, and contractor engineers and soon grew to include representatives from the military Services and federal agencies. Their development plan was based on using well-known commercial software from Oracle as the interface solution between USMEPCOM and the recruiting systems of the various branches of the Armed Services.

During the PM interview process, another important strategy came to light: The program was purposefully split into three smaller programs to avoid both the budget threshold requiring a PM and compliance with DAS milestones that would slow the project down. The first step, begun in 2006, was to implement SOA principles in USMEPCOM's network and demonstrate the practicability of the new system by generating service calls internally. In 2007, the second program was the electronic conversion of all paper records in preparation for direct access to information from a recruiter's work station, bypassing the need for a representative at USMEPCOM's facilities to answer the recruiter's data request. In 2008, the final program was the implementation of electronic security and privacy data features for the processing of recruits' personal information and the ability to gather and process biometric data. The program passed the budget threshold in 2008 and acquired a

PM. The development cycle has since slowed because of the many bureaucratic constraints discussed earlier in this report.

During our interview with the USMEPCOM acquisition professional, the topic of risks that the DE/TOSIP IPT encountered was discussed. The main risks to the program were scope creep on the part of both the end users and USMEPCOM, and getting the end users to buy into the proposed system solutions. The manager described how the general officers representing the different Service branches were usually happy with the proposed solutions, but it was problematic to get buy in from people that had to use the system on a day-to-day basis. The mitigation strategy against scope creep was to define the requirements with all parties at the beginning of the process and hold to those requirements unless the party requesting new features provided funding. Gaining user buy-in was a longer process and required tact and diplomacy by the IPT and necessitated a "lot of talking." There were no shortcuts to gaining user trust and confidence, but the time and effort spent in engaging the true end users paid off.

2. DE/TOSIP Results

The Air Force Reserve estimates annual savings of approximately $3,500,000 as a recruiter can now retrieve applicant data online instead of having to call the Air Force liaison at a USMEPCOM facility. Because the Air Force Reserve is only a small component of the total DoD recruiting force (about 2%), the estimated savings for the other Service components is substantial (Maravola, 2009).

Any system can benefit from significant cost savings when it is automated, but DE/TOSIP's ability to quickly access data from multiple systems using Oracle software as the key interface between systems illustrates a parallel to Metcalfe's Law in that the usefulness of the network increases by each outside network it exchanges data with.

The DE/TOSIP development team benefited from software reuse when designing a security module and in building the interface between USMEPCOM's system and the different Armed Services' Recruiting systems. A third-party analysis of the project found that the costs of enabling a virtual integration system saved about $56 million due to the SOA (Maravola, 2009).

D. Case Summary 3: SHARE and the Development of an Infrastructure to Support OA

Although A-RCI was a ground breaking program for OA, the ability of future programs to benefit from the principles of OA will be helped or hindered by the supporting infrastructure in the acquisition environment. This infrastructure can be anything from the recommendation of a JCIDS supplement concerning rapid op tempo spiral development programs (Boudreau, 2006), to collaboration portals, to the OA implementation assessment tool, to software reuse repositories.

This section describes the Software Hardware Asset Reuse Enterprise (SHARE) Repository Framework and discusses several issues encountered during implementation of this collaborative initiative. The issues in establishing infrastructure supporting one of the principles of OA are relevant to other future initiatives in building an OA friendly infrastructure.

1. Overview of SHARE

The SHARE repository was created in August 2006 under the auspices of PEO IWS, the USN's lead for OA. SHARE's goal was not only to enable the reuse of combat system software, but also to reuse related assets, facilitate prime and subcontractors' ability to reuse software, and to suggest improvements to Navy surface warfare systems (Johnson & Blais, 2008).

The SHARE library uses an online open source repository called SourceForge that can also be used as a project management tool. The library contains artifacts from various programs,including the AEGIS ship self-defense system, DDG-1000, and the Literal Combat Ship program, and is divided into classified and unclassified sections. Library materials are accesible online or through the delivery of physical media (Johnson & Blais, 2008). Before a contractor or government agency accesses library materials, both a license agreement and non-disclosure agreements must be signed and saved for future reference.

2. Collaborative Issues

When we discussed SHARE during interviews with PEO IWS personnel, it was discovered that not all contractors were willing to post artifacts to the library because there were concerns about intellectual and proprietary rights. PEO IWS noticed that the traditional larger and established contractors were more willing to participate; however, smaller firms avoided posting artifacts to the library. One of the goals of SHARE was to attract small, innovative firms that had never worked with the DAS, allowing the DoD access to sources of new technologies and system development strategies. SHARE would not only be a software reuse portal but also a marketplace of ideas in which a small company could post an artifact and essentially "shop" it to either the DoD or another contractor. In practice, this never happened because smaller companies were afraid of losing any technical advantage developed internally to larger companies. Smaller companies did not have the resources to fight protracted legal battles, and many companies relied on a very limited portfolio for their financial survival. There were many benefits to utilizing SHARE, yet the financial and intellectual property risks were too great for many of the smaller firms.

PEO IWS's initial response to this problem was to change user agreement forms to account for intellectual property rights and provide more oversight on the license agreements and non-disclosure agreements required by all users.

3. Oversight Issues

The attempt to solve the collaborative issues by applying more oversight of required licenses and non-disclosure agreements led to the second issue hindering successful implementation of SHARE. PEO IWS personnel discovered that a significant percentage of contractors were not keeping records of the various agreements and considerable effort had to be applied in order to get companies to comply. The planning for SHARE did not account for a much increased workload or for new positions to be added to PEO IWS, and, as a result, the workload to oversee compliance with the paperwork requirements fell on a workforce that was already fully tasked.

There are a few possible solutions to this problem, but all solutions have serious drawbacks. The first solution would be to penalize companies for breaking user agreements and not complying with the mandatory requirements. The drawback is that this could entangle the government in legal issues and even have the government take the side of one contractor over another. This approach would tend to lead many contractors away from participating in SHARE and would hinder its development.

A second solution to the oversight and compliance problem would be to fund extra positions at PEO IWS dedicated to the active management of user agreements and the protection of intellectual property rights. In effect, PEO IWS would be a neutral referee and keep subtle pressure, as opposed to applying penalties, on contractors who are delinquent in their paperwork requirements. This approach would be , but PEO IWS' budget does not allow for this and increases in funding are unlikely. The solution that PEO IWS is working on attempts to incentivize contractor compliance with the license and non-disclosure agreements.

4. Impact of SHARE

Unlike A-RCI, SHARE currently cannot be considered a success. The primary interviews with PEO IWS personnel revolved around problems facing system implementation. Despite the ongoing problems of the SHARE implementation and the lack of documented cost savings and achievements directly attributable to the project, we believe SHARE cannot be classified as a failure. The ongoing lessons learned by PEO IWS personnel will pay dividends in the future when the best strategies and solutions are figured out. These solutions might come after a period of trial and error, but it is a learning period that PEO IWS and the DAS as a whole have to pass through before they can build solid foundations for an infrastructure that supports the principles of OA and open business. An analogy would be sending green troops into combat. Only after serving on the battlefield and learning from many lethal and tragic mistakes will a combat organization emerge as a veteran one. Fortunately, implementation of SHARE is not as dramatic, and the time spent on developing the best implementation strategy is a small price to pay to build the expertise necessary.

E. Successful Strategies and Risk

Certain strategies helped create the success of the A-RCI and DE/TOSIP programs. Some of the strategies used are the same as the best practices used in applying SOA in the business world and other strategies may be unorthodox. This section explores strategies used by A-RCI and DE/TOSIP programs, and lists the risks taken to achieve program success. None of the risks taken had any lasting impact of these two successful programs, but they bear attention when implementing other programs that might operate under different conditions.

5. DE/TOSIP Best Practices and Risk

DE/TOSIP's main strategy was to avoid the requirements of the DAS altogether by splitting the program into three smaller programs and avoiding the budget threshold that would require a PM. The main risks to such a strategy are scope creep and budget risk. As the program was being developed, DE/TOSIP's IPT had to constantly contend with increased user requirements. As the user requirements built up, the scope of the program eventually surpassed the budget threshold and the program is now operating under the guidance of a PM. In addition, the program would be at risk of low scalability because a program that was split up and developed by smaller sub programs would not be able to rapidly meet unforeseen expansion requirements. Ironically, the very success of the DE/TOSIP caused it to grow to the point that the flexibility and initiative program management enjoyed with the smaller program was soon lost.

DE/TOSIP used an extreme COTS strategy in the decision to use Oracle products for their solution. This turned out to work well for program success, but did introduce the risk of relying on a single vendor. In DE/TOSIP's case, it would not have been cost effective and timely to try to introduce a collaboration-and competition-based strategy when the solution was readily at hand, but the single vendor solution might introduce too much friction with various DAS mandates, regulations, and laws for larger programs.

DE/TOSIP's rapid development cycle saved costs and allowed for the rapid delivery of the solution to the end users, but at the expense of performance risk. After the system was deployed and gained widespread use, requirement complexity increased and eventually slowed the development cycle down from a one-year increment to over three years. Due to the need to keep the program under a budget threshold, the DE/TOSIP development team was relatively small. The small team was constantly at risk of being overwhelmed. It was the COTS strategy and heavy reuse of components that allowed the team to keep up with the three-month development cycles (Maravola, 2009).

Table 12 lists the successful strategies and best practices used by the A-RCI and DE/TOSIP programs alongside these programs' potential risks.

Table 12. Best Practices and Risk of A-CRI and DE/TOSIP Programs

Best Practices and Successful Strategies	Introduced Risks
A-RCI	
COTS	Security Risk Program Risk (bureaucratic friction)
Incremental Strategy	Operational Risk (initial deployed system does not meet user requirements) Cost Risk Schedule Risk
MOSA	Integration Risk
Open Capabilities-Based Model	Integration Risk Program Risk (bureaucratic friction)
DE/TOSIP	
Avoided DAS Budget Threshold	Risks to Future Scalability Budget Risk
COTS	Program Risk (reliance on single vendor) Program Risk (lack of collaboration and cooperation in larger programs)
Rapid Development Increments	Performance Risk Schedule Risk

VI. Conclusions and Recommendations

The purpose of this report was to provide insights into the benefits, risks, and best practices of an open systems environment. To understand those issues, two qualitative studies were undertaken that analyzed historical case data involving OA, SOA, and MOSA implementations in the private sector and, to the extent possible, at the DoD and the Navy. Since SOA in the private sector and OA in the DoD can be considered comparable concepts, similar results from industry SOA implementations can be expected.

Although the industry achieved a 72% cost savings, the DoD must weigh other factors before it implements an SOA project. Benefits such as productivity improvements and non-quantifiable benefits should also be considered, along with factors such as flexibility, scalability, and reusability, which all allow for long-term improvements.

Beyond potential benefits, there are a number of significant risks with OA because it introduces new risk elements to systems development and upgrades in the DoD, where the overall acquisitions approach is essentially designed to suppress risks. It is imperative to understand these risk suppression steps that inhibit OA's potential ability to reduce costs and increase flexibility. In addition, the DoD's systematic risk restrictions in the acquisitions process have resulted in programs still going over budgets and schedules, despite attempts to control budget and schedule risk. Until risk issues are addressed, the DoD will never achieve true portfolio management nor will it ever fully implement OA. The DoD's risk suppression mechanisms, along with bureaucratic rules and restrictions, and exorbitant entry costs have excluded SMEs from participating in the defense arena. The DoD anticipated that greater competition would provide SMEs with opportunities to enter the defense arena and end eras of stove-piped systems and the oligopoly of defense contractors who provide expensive, monolithic systems that do not interoperate.

In the study focusing on risks, we discovered that the nature of DAS does not present PMs with different types of risk at different stages of their careers. Beyond cost, schedule, and performance risks, there was no formal recognition of other risk types by the interviewees. Even though they do not always recognize it, budget and program risk are of constant concern to PMs.

Risks associated with misunderstandings between different functional areas, the "talking by each other" and linguistic discontinuity, are also not unique to the DAS, but are heightened by a lack of training and contradictory structural goals between functional areas of a program: for example, between a PM and a contracting officer.   Since DAS is highly structured, consisting of well-defined requirements and milestones, there is little incentive for initiative in running projects or programs and little room for personnel flexibility.   Although the DAS's bureaucratic nature is not a risk, it introduces or amplifies risk as many PMs develop a fatalistic attitude towards risk (i.e., "we have to play with the hand we are dealt"), which delays the ramifications for incorrect or even illegal decisions that fall on the program long after the original participants have transferred. Although OA has delivered cost savings and allowed faster system development in certain cases, it has also increased programs' complexity and risk.

Based on the qualitative research and the primary interviews, it is possible to make a number of recommendations concerning the implementation of OA in the DoD.

A. Recommendations

- **Focus on Overall System Value**

  Overall value offered by an open system should be considered and not only cost savings. Benefits such as flexibility, scalability, and reusability would position the DoD to rapidly adjust systems to changing combat missions and environments, while reducing future risk.   The DoD should consider reducing the weight given to ROI as a result of cost savings in its decision-making process and attempt to incorporate all associated benefits.

- **Incremental Implementation Approach**

  SOA is not a one-size-fits-all solution. The DoD should adopt an incremental approach, implementing OA where results will be immediate. It should assess the current DoD architecture to focus efforts on particular needs and requirements. The DoD should start small with near-term or easily implemented requirements, initially attacking the low-hanging fruit by introducing SOA services that provide the most bang for the buck.

- **Provide Adequate Resources**

  Continue building the DoD infrastructure to ensure any new initiatives are sufficiently resourced. SHARE is a warning on lack of resources, particularly the lack of personnel and time that ensure contractors meet all administrative requirements concerning intellectual property rights. Implementations that lack a supporting infrastructure and proper resources could become costly disasters.

- **Provide Greater Initiative**

  DAS has evolved into a system concentrating on performance issues, even at the expense of costs and schedule. Delivery of world-class systems to operating forces should always remain a priority; however, the DoD should consider allowing PMs more flexibility in running programs. A-RCI showed how taking initial performance risks, security risks using a COTS strategy, and potential cost and schedule risks using a spiral development strategy could lead to program success.

- **Continued Accountability**

  Many PMs inherit programs that bought initial success at the expense of future risks and stability. If the program is of such a length that a PM has transferred before improprieties or poor decisions are uncovered, then the PM should remain accountable for his decisions in older programs if the PM is still in government service.

- **Greater Flexibility**

  There is a lot of talent working outside DAS that could be tapped with a more flexible systems development approach. PMs could use modern methods, such as Innovative.com or Topcoder. The former helps solve technical problems for the pharmaceutical, biotechnology, consumer goods, and high technology industries (Lakhani & Panetta, 2007). PMs post a problem and award cash prizes to a person or company offering the best solution. Topcoder is another example of a programming community competing and collaborating for solutions to specific client problems. TopCoder sets up contests where members compete for money and skill ratings (Lakhani, Garvin, & Lonstein, 2010). Although not at the risk of national security considerations, the DAS should consider allowing PMs to post problems in venues similar to Innovative.com or TopCoder.

- **Implement New Metrics**

  Because of the innovativeness of implementing an open business model in DoD acquisitions, new metrics must be implemented. There are many methods available; however, the DoD should consider implementing metrics to measure the new economy based on intellectual capital and knowledge assets.

- **Conduct a New Study**

  The final recommendation is to conduct a study to determine which DAS areas would benefit from OA and which programs would be hindered by implementing OA and SOA.

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