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RISK, UNCERTAINTY AND OPEN ARCHITECTURE IN THE DoD ACQUISITION SYSTEM

by

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September 2011

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This thesis analyzes the impact of risk and uncertainty on the Department of Defense (DoD) Acquisitions System and the decision making process of modern Program Managers. A number of risks and uncertainties will be identified and a determination will be made if Service Oriented Architecture (SOA) and Open Architecture (OA) decreases or increases risks and uncertainty. In addition, it explores whether SOA and OA has achieved projected significant cost savings.

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RISK, UNCERTAINTY AND OPEN ARCHITECTURE IN THE DOD ACQUISITION SYSTEM

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

A-RCI: Acoustic Rapid COTS Insertion

ACTA: Acquisition Category

AEGIS: Aegis missile guidance and combat system

APB: Advanced Processor Build

AT&L: Acquisition Technology and Logistics

C2: Command and Control

CDR: Critical Design Review

COTS: Commercial Off-the-Shelf

CTE: Critical Technology Elements

DAS: Defense Acquisition System

DoD: Department of Defense

DoDD: Department of Defense Directive

FY: Fiscal Year

GAO: Government Accountability Office

GS: Government Service Employee

IG: Inspector General

IPT: Integrated Product Team

JCIDS: Joint Capabilities Integration and Development System

JCS: Joint Chiefs of Staff

JROC: The JCS' Joint Requirements Oversight Council

KPP: Key Performance Parameters

MDA: Milestone Decision Authority

NSS: National Security Strategy

OA: Open Architecture

OPNAV: Office of the Chief of Naval Operations

PDR: Preliminary Design Review

PEO: Program Executive Office or Program Executive Officer

PEO-IWS: Program Executive Office – Integrated Warfare Systems

PEO-LMW: Program Executive Office – Littoral and Mine Warfare

PM: Program Manager

PMBOK: Project Management Body of Knowledge

RCID: Rapid Capability Insertion Process

SME: Small or Medium Enterprise, or Small and Medium Enterprises

SOA: Service Oriented Architecture

USD (AT&L): Undersecretary of Defense for Acquisition, Technology, and Logistics

USN: United States Navy

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I. INTRODUCTION

A. PURPOSE

A program manager (PM) is confronted by many risks and uncertainties beyond the common cost, schedule, and performance ones. Some of these risks are unique to the DoD acquisitions environment while others are known to any project or program attempting to leverage the benefits of Open Architecture (OA). This thesis discusses types of OA-based acquisition risks and uncertainties, and explores various tools and techniques used by PMs in previously successful acquisition programs. Finally, this research recommends several strategies, based on the primary and secondary research, to mitigate different risks and uncertainties.

B. BACKGROUND

The 2004 *National Military Strategy of the United States* stressed the importance of seamlessly integrated networks of complex weapons systems, intelligence platforms, and C2 mechanisms to facilitate joint operability of the DoD's service components. The Undersecretary of Defense for Acquisitions Technology and Logistics mandated that a ―modular, open systems approach shall be employed" in all acquisition programs in 2003.

Service Oriented Architecture (SOA), with its principles of reusable, loosely coupled and autonomous services enabled traditional ―stove piped" DoD systems to interact and share data. Cost savings could be achieved through software reuse and scalability, thus allowing a system change in size or volume more easily to meet increased user demand without quality degradation or other critical issues. Commercial SOA methods were subsequently adapted to military use; OA was adopted to address unique requirements of DoD systems such as information assurance, secure data exchange, and stringent performance thresholds critical to systems in which human lives depend upon.

C. RESEARCH OBJECTIVES

Research conducted for this thesis encompasses several objectives. First, risks to PMs in the DAS ecosystem are identified. This ecosystem represents various organizations involved with acquisitions, ranging from Congress down to a program's Risk Project Team, along with the environment, consisting of rules, regulations, laws, and customs dictating organizational behaviors. The second objective is to ascertain if there is an agreed upon definition of uncertainty in the DAS. The third objective is to discover if using an OA strategy assists or hinders an acquisition program. In addition, does an OA strategy expose a program to unique risks and uncertainties. Finally, this thesis attempts to discover if OA has delivered promised benefits to the DAS.

D. RESEARCH QUESTIONS

By answering the following questions, this thesis endeavors to aide DAS leadership in gaining a deeper understanding of the impact of risk and uncertainty. Moreover, this thesis attempts to develop the best strategies in mitigating negative consequences.

1. Do PMs encounter different risks at different stages of their career?
2. What are risks in the current DAS acquisitions process beyond cost, schedule, and performance?
3. What is the definition of uncertainty in the DAS?
4. Has OA added to the complexity of systems development?
5. Have regulations, policies, and procedures reduced or increased complexity and instability when using an OA approach?
6. What are sources of uncertainty in an OA environment?
7. Has SOA and OA produced desired results and promised efficiencies?

E. METHODOLOGY

A series of interviews were conducted with a diverse group with experience in Air Force, Army, and Navy acquisition programs. Most interviewees had work experience in at least one PM position; all had DoD acquisition experience. Some interview subjects are currently filling various positions at PEO-IWS and PEO-LMW.

During this primary research, an ethno methodological approach was taken when interviewing subjects with experience in DAS. Interviews were conducted with minimal directive questioning because the interviewer wanted to engage the subjects in a free flowing discussion without possible personal biases on the part of the interviewer. Common topics bought up spontaneously during an interview were viewed as more powerful than answers to a scripted list of questions because answers would not be limited by any intentional or unintentional framework imposed by the interviewer. In a free flowing discussion, the chances of an interviewee bringing up topics similar to topics bought up by other interviewees are miniscule unless the topic itself is of importance to DoD acquisition professionals.

Most interviews were conducted without interruption in the interviewee's offices at their convenience. Interviews with PEO-IWS and PEO-LMW personnel were done primarily over the telephone at a prearranged time with the exception of one PEO-IWS, which was conducted during lunch hour at a conference. This was the only interview that was rushed and ended prematurely while all other interview sessions averaging an hour. The main goal of the first round of interviews was defining elements of risk and uncertainty in DAS and the impact of OA and SOA.

A second round of interviews was conducted with additional questions asked and clarification of various data points after analysis of the first data set. For the second round, the primary goal was to explore commonalities found during the initial interview process. Additional information was collected from prior research theses, academic papers, Inspector General (IG) reports, and academic and business literature.

F. SCOPE

This research addresses various risks and uncertainties inherent in DAS and strategies used by PMs to overcome the effects. It includes a literature review addressing risk, the measurement of risk, OA, SOA, and the success or failure of SOA in the commercial sector.

After addressing risk and uncertainty issues, and reviewing past acquisition programs this research explores how the DoD acquisition cycle mitigates risks while aligning day to day efforts of acquisition professionals as discovered. Interviewees were selected based on the criteria of prior or current experience working in a DoD acquisitions organization. Interview subjects not currently working in acquisitions all teach acquisition management at the Naval Postgraduate School. Initial interview questions were selected after conducting research using current literature on risk, risk management, and OA, and SOA in the DoD.

This research also addresses whether SOA has been successful in the business world and references complementary research conducted by another student researcher. Finally, this explores whether OA and SOA has had a net positive or negative impact on DAS.

G. THESIS ORGANIZATION

This thesis is organized into five chapters in an effort to present a sequential flow of information. Chapter I provides an overview with regard to purpose, methodology, and scope. In this section, research questions and objectives are identified. Chapter II provides a background for understanding Navy OA, SOA, MOSA, and Open Systems. Similarities, differences, and emphasis between them are highlighted. An overview of contemporary DAS and the risk types that the different assessments, plans and milestones attempt to mitigate is also provided in this section. Chapter III takes the data gathered during the primary interview phase in conjunction with secondary research of case studies, papers and other literature, identifies risk areas providing the biggest challenges to acquisitions professionals. A determination will be made if OA and SOA have helped mitigate or increased risk and uncertainty. Moreover, this section discusses whether OA and SOA have provided cost savings and increased efficiencies by analyzing primary and secondary data. Chapter V presents conclusions, study shortcomings, and recommendations for future research.

II. LITERATURE REVIEW

A. RISK AND UNCERTAINTY

1. Definition

The *Risk Management Guide for DoD Acquisition* defines risk as “a measure of future uncertainties in achieving program performance goals and objectives within defined cost, schedule, and performance constraints” (DoD, 2006). 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, 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).

With these three components, it is obvious that risk can only occur in the future. Once an event or cause has come to pass 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 thesis, 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 then is 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 will stop 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 of being wrong. The unknown is what we do not know but is possible to simulate and will become known through the passage of time, events and action. The unknowable contains so much risk and uncertainty that the passage of time, events, or action may not reduce the levels of risk and uncertainty. For example, an unknowable event is an earthquake. Even after an earthquake hits, we are not sure the time of the next earthquake (Mun, 2010).

2. 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. With risks and uncertainties a constant in the DAS, risk management plays an important role in helping a program meet cost, schedule, and performance goals.

Risk management, a subcategory of Project 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" (Project Management Institute, 2008). 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 Quantitaive Risk Analyis, Plan Risk Responses*, and *Montior and Control Risks* (Project Management Institute, 2008). In practice, different PMs approach each step differently, as 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 1. It that shows the DoD Risk Management Process along with the six processes of Project Risk Management.

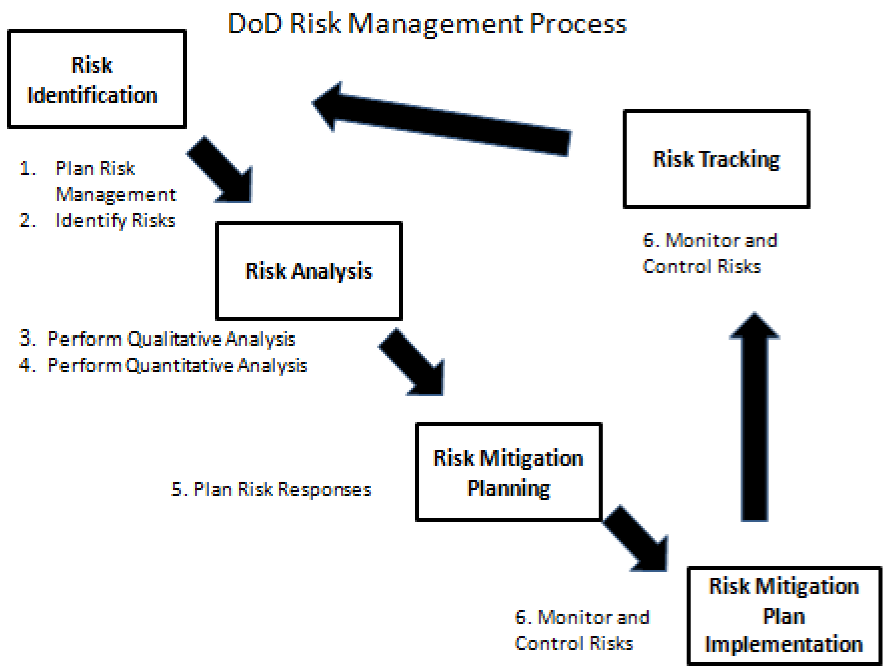

Figure 1. DoD Risk Management Processess with Six Processes of Project Risk Management (From DoD, 2006).

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).

3. 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* 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 for this thesis.

Any events potentially impacting a program are identified and assessed in relation the likelihood and consequence of occurrence are shown in a Risk Reporting Matrix. This matrix is shown in Figure 2 and reflects both the likelihood and consequences of an event occurring—grades are given from one to five, with one being the least likely or consequential and five being most probable and severe.

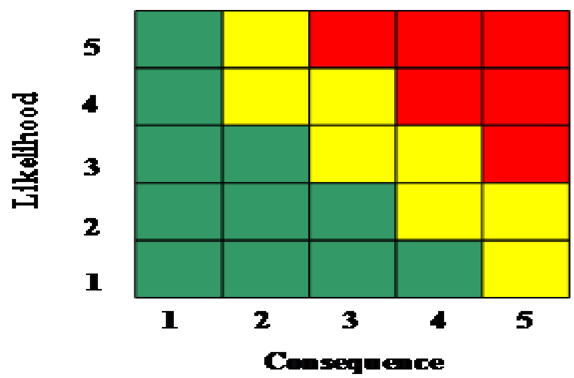

Figure 2. Risk Reporting Matrix (From DoD, 2006).

Comparing the two grades results in one of twenty-five boxes in the matrix. Results in the green shaded area contains a low level of risk (consequence) and uncertainty (likelihood). The yellow shaded areas are of medium and significant levels of risk while 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.

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 3. Levels of Likelihood Criteria (From DoD, 2006).

Levels of risk are directly linked with cost, schedule, and performance risks using the metrics of technical performance and supportability, ability to meet key dates and key program milestones, and the percentage of any budget or unit production cost increase.

B. OPEN SYSTEMS IN DEPARTMENT OF DEFENSE ACQUISITIONS

1. DoD Instructions and Guidance

An open systems approach was introduced into DAS with the publication of the 2003 *DoDD 5000.1.* The latest version of the directive leaves the original instruction unchanged:

> Acquisition programs shall be managed through the application of a system engineering approach that optimizes total systems performance and minimizes total ownership costs. A modular, open systems approach shall be employed, where feasible. (Undersecretary of Defense [AT&L], 2007)

In 2004, the Undersecretary of Defense for Acquisitions Technology and Logistics (AT&L) designated the Open Systems Joint Task Force (OSJTF) as his lead for a

Modular Open System Approach (MOSA) in the DoD (Undersecretary of Defense [AT&L]., 2004). *DoDD 5000.1* was ambiguous when it stated that a MOSA ―shall be employed, where feasible," though *DoDI 5000.2*, *Operation of the Defense Acquisition System* made MOSA mandatory:

> Program managers shall employ MOSA to design for affordable change, enable evolutionary acquisition, and rapidly field affordable systems that are interoperable in the joint battle space.

OSJTF's mission was to make MOSA an integral part of the acquistion process, provide expert assistance in applying MOSA, ensure application of MOSA by all acquisition programs, and colloborate with industry to ensure a viable open standards base. The mission statement along with directives and definitions of MOSA and open systems terms is found on their website: (http://www.acq.osd.mil/osjtf/mission.html).

OSJTF initially produced a Program Manager's guide (OSJTF, 2004); however, by 2011 OSJTF ceased operations. The Office of the Undersecretary of Defense for Systems Engineering assumed all OSJTF, and is now the DoD lead for MOSA. OSJTF terminology and principles for all aspects of open systems is still in use throughout the DoD and form the basis for many definitions in this thesis.

2. Open Architecture

a. Definition

An open architecture employs open standards for key interfaces within a system (Open Systems Joint Task Force [OSJTF], n.d.). Within the DoD, the U.S. Navy is the leading proponent of OA, and in late 2002, established a new Program Executive Office (PEO) for Integrated Warfare Systems (PEO-IWS). PEO-IWS is responsible for both surface and submarine combat systems, most missile systems and launchers, guns, and electronic warfare sytems. Additionally, PEO-IWS is responsible for integrating all antisubmarine warfare systems across all PEOs. PEO-IWS is now assigned overall responsibility for directing the Navy's OA effort and established an OA Enterprise team (OAET) comprising lead PEOs from the Navy's various warfare areas (Air, C4I, Subsurface, Surface, and Space). Subsequently, the Office of the Chief of Naval Operations (OPNAV) directed the implementation of OA principles across the Navy with the goal of delivering —timely, affordable, interoperable warfighting capability to the fleet, made sustainable by the flexible integration of emerging capabilities" (OPNAV [N6/N7], 2005).

3. Principles of Navy OA

The following are the Principles of Naval OA (OPNAV [N6/N7], 2005):

a. Modular Design and Design Disclosure

Permits evolutionary design, technology insertion, competitive innovation, and alternative competitive approaches from multiple qualified sources.

Traditionally, many weapon systems have been procured from a single vendor, which decreases compatibility issues but risks greater costs. The Navy hopes to benefit from significant costs savings that are possible in a competitive environment.

b. Reusable Application Software

Selection through open competition of —best of breed" candidates reviewed by subject matter expert peers and based on data driven analyses and experimentation to meet operational requirements. Design disclosure must be made available for evolutionary improvement to all qualified sources.

As software development accounts for an ever increasingly greater percentage of total ownership costs in DAS, the ability to reuse software could allow significant savings in development costs for other programs.

c. Interoperable Joint Warfighting Applications and Secure Information Exchange

Use of common services, common warfighting applications, and information assurance as intrinsic design elements.

Ease of interoperability between different services and allies along with the secure, reliable, and timely exchange of vital data are key performance parameters for the DoD and form the backbone of modern tactics and strategy.

Requirements for secure information exchange is one of the major design challenges with OA. The methods and techniques ensuring interoperability are almost diametrically opposed to ones keeping a system secure as interfaces and services from other systems open additional vectors for a network-based attack. Although there are many commercial systems such as medical and baking systems requiring high levels of security, DoD weapons systems must be designed to operate in a battlefield environment with lives at stake.

d. Life-Cycle Affordability

In system design development, delivery and support while mitigating commercial off the shelf (COTS) obsolescence by exploiting the Rapid Capability Insertion Process/Advanced Processor Build methodology (RCIP/APB).

RCIP is a continuous, reduced cost upgrade of hardware and software by bypassing expensive development costs and using COTS technology wherever feasible. In the past, DoD systems have taken relatively longer to field to operational forces, compared with new technology introduction into the commercial marketplace. By the time some systems are fielded, they are already technologically obsolete to what is available in the civilian space.

First developed by the Acoustic Rapid COTS Insertion (A-RCI) program, APB is a disciplined process to take new functionality and algorithms from the laboratory to the Fleet in under two years per Fleet requirements. APB methodology requires annual software updates to respond to changing requirements and advances in software capabilities while also relying on periodic technology insertions to maintain computing capacity at state of the practice values and mitigate against COTS obsolesence issues (Kerr, 2005).

e. Competition and Collaboration

Alternative solutions and sources creates competition between vendors, keeping costs lower than if the DoD relied on a single source. Collaboration pertains to both business and the DoD working together or to multiple contractors leveraging their areas of expertise to solve a problem. One organization may be able to produce better software at a lower cost and a more efficient timeframe than another just specializing in hardware. Through collaboration, both organizations benefit from cutting-edge technology without incurring the expenses and production time required to develop alternative solutions.

A recent change in acquisition strategy is to encourage competition and collaboration through the introduction of small and mediums sized firms (SME) into the acquisition ecosystem. Recently, the National Institute of Standards and Technology created the Technology Innovation Program to ―accelerate innovation through high risk, high reward research in areas of critical need" with the intent to provide grants to small and medium sized firms (Schacht, 2011).

4. Essential OA Performance Characteristics

MUIRSS describes essential OA performance characteristics of Maintainability, Upgradeability, Interfaces/Interoperability, Reliability, Safety, and Security. These characteristics are mainly derived from the basic principles of Navy OA (Naegle, B. , 2006).

a. Maintainability

Ability to maintain the system over the typically long life cycle of DoD systems is directly associated with the OA principle of *Life Cycle Affordability*.

b. Upgradeability

Supports OA principles of *Reusability* and *Life Cycle Affordability*. Upgradeability is a key facilitator of future software reuse.

c. Interfaces/Interoperability

Directly associated with the *Modular Design and Design Disclosure*, *Interoperable Joint Warfighting Applications* principle and the *Collaboration* principles.

d. Reliability

Closely associated with the principle of *Interoperable Joint Warfighting Applications,* although the emphasis is on interoperability as opposed to reliability. It is well understood that the DAS's highest priority should be given to delivering systems ensuring success of the war fighter on the battlefield. Systems need to be designed to operate under battlefield conditions with the highest levels of reliability.

e. Safety

Safety is not directly addressed in any of the principles of OA but is always a concern with any DoD system.

f. Security

Since a breach in system security can result in significant damage to the interests of the United States and / or significant loss of life, there is a stronger emphasis on the security of systems in the DoD compared to the commercial world where security breaches are usually measured only in monetary costs. This characteristic is directly associated with the Navy OA principle *of Secure Information Exchange.*

5. Service Oriented Architecture

SOA has played an increasingly important role in technology development in the business world and its principles and methods have found its way into the DAS.

a. Definition

There is not an agreed upon definition for SOA in the commercial sector. In a complementary thesis, the researcher found that definitions for SOA varied from company to company. For example, Hewlett-Packard defined SOA as an architectural approach of loosely coupled, reusable, standards based, and well defined software services easily discoverable by other applications or end-users on a network. IBM's definition is a set of linked services or repeatable business tasks that can be accessed when needed over a network. The Business Transformation Agency's defines SOA as an environment in terms of shared mission and business functions and the services enabling them (Wolff, 2011). However, all definitions empahsize the importance of services easily located by other services over a network.

b. SOA in the DoD

The military does not have its own definition of SOA nor is it mentioned in the many instructions mandating an open systems approach in DoD acquisitions. The lack of definition or mandate has not stopped the military from using SOA where feasible. PEO-IWS has been a proponant of SOA solutions given that the service and network based approach of SOA fits neatly into key Navy OA principles (i.e., modularity, reusability and interoperability). A major challenge remains of designing a network seamlessly integrating existing, planned and future platforms and systems into a secure, fully interoperable, near real time information system able to accomondate complex ―legacy" or traditionally ―stove piped" systems that may, or may not, have been designed with interoperability in mind (Naegle, 2006). Recently, limited test experiment proved SOA benefits when operating under a traditional ―stovepiped" DoD technology. The test created a simulated tactical environment based on AEGIS sytems, exchanging data in a C2 environment centered around open source SOA. The test was successful with the creation of resuable services, avoidance of complex software and larger code, and the services operating no matter the source, type of data or the protocols used (Fisher, 2011).

6. Open Systems

a. Definition

Systems employing modular design, uses widely supported and consensus based standards for its key interfaces, and has been subjected to successful validation tests to ensure the openness of its key interfaces (Open Systems Joint Task Force [OSJTF], n.d.).

Modular design uses popular standards allowing a system to benefit from a high dregree of portability, a key metric describing the ease in which the software can be reused along with ease of connectivity and interoperability with other programs.

Popular standards also make it easier to design a scalable program , allowing a system to adapt to future increased demands and user requirements. By building flexibility into acquisition development products with modularity and standardized key interfaces Open Systems allow flexibility in design helping to mitigate technological uncertainty (Dillard & Ford, 2008).

b. Impact of Open Systems on the DoD Acquisition System

A recent acquisition research paper described the impact of adopting and using open systems in the DAS. The paper identified important acquisition activities, assessed the impact of programs using an evolutionary acquisition process, and concluded that there were risks. These risks include reduced DoD control over standards, increased standards-selection risk due to ongoing evolution of standards, and increased testing requirements due to integration of evolving commercial items into DoD systems. Alternatively, design risks are reduced as components, subsystems, and systems are made consistent with established standards. In summary, use of open systems to evolutionary acquisition programs tended to trade away design risk for increased standards integration risk (Dillard & Ford 2008).

One of the biggest reasons leading to standards integration risk is that modern software engineering is far from mature, as compared to other industries such as aviation or the automotive industry. There are few commonly agreeded upon standards for languages, tools, architectures, resue, or procedures. To meet DAS complexities, there has been a general move away from the ADA programming language; a language still widely used in many legacy DoD systems to languages commonly used in commercial industry such as C++. Today's commonly agreed upon standards that are core to SOA, MOSA, and Open Systems may become obsolete in the future.

Practices and procedures enabling successful launches of sofware products in the commercial world may be ineffective in developing long-lived DoD software intensive, warfighting systems. DoD systems are designed to have a very long life span as opposed to commercially based software designs (Naegle, 2006). The USN's premier AEGIS combat system, for example, was first tested in 1973 and is still in widespread use around the world. The AEGIS system is ancient compared to the relatively short thirteen-year life span of the Netscape Navigator web browser.

7. MOSA

a. Definition

An integrated business and technical strategy employing a modular design and, where appropriate, defines key interfaces using widely supported, consensus-based standards that are published and maintained by a recognized industry standards organization. (Open Systems Joint Task Force [OSJTF], n.d.)

b. MOSA in the DoD

DoD 5000.1 mandates MOSA's as both a technical and organizational strategy for systems development and systems upgrades. The emphasis is on evolutionary acquisition and spiral software development using popular open standards with the goal of cheaper systems integration. The OSJTF was established to oversee this policy until its functions and responsibilities were transferred to the Assistant Secretary of Defense for Systems Engineering.

The DoD Acquisition Guidebook advises that PMs summarize their overall MOSA implementation plan throughout their program's life cycle.

8. Relationship between OA, SOA, MOSA and Open Systems

Modularity and a standards based methodology are the two key characteristics shared by all the Open System architectures. Reusability and common services or interfaces are also common characteristics between the systems.

Table 1 compares the principles of Navy OA with key words from the definitions and principles of the other three architectures OA was derived from. This table not only reveals subtle differences in emphasis of key principles and strategies but also provides a visual reference on principles that were developed to meet the needs of the Navy and DoD for their unique systems and acquisition environment. For other architectures, the principles of affordability and collaboration are usually not mentioned in the definitions or emphasized in the literature though both principles are unspoken goals. Security is not mentioned in other architectures and reflects the DoD's concern of keeping data secure from potential adversaries. For MOSA, SOA, and Open Systems the focus is on development of a system as a whole and their basic principles will remain constant for any code meant to be secure (i.e., such as medical or financial software) to code that is not meant to be secure. A strategy seeking competition from potential vendors to reduce costs is unique to Navy OA.

Principles Navy OA	**Open Systems**	**SOA**	**MOSA**
Modular	Modular design		Modular
Reusable	Widely supported, consensus based standards for key interfaces.	Reusable (Hewlett Packard)	
Interoperable	Widely supported, consensus based standards for key interfaces.	Standards based (Hewlett Packard). Shared functions (BTA). Linked services (IBM).	Consensus based standards.
Secure			
Affordable			Modularity leading to cheaper systems integration.
Competition			
Collaberation		Services easily discoverable on a network.	

Table 1. Comparison of OA with Opens Systems, SOA, and MOSA.

9. Risk and Small- to Medium-Sized Enterprises

Large defense companies have complied with the DoD's low-risk requirements primarily due to large monetary resources. However, these same requirements eliminate much of the potential competition and innovation available in small to medium sized enterprises (SMEs). Former NAVSEA commander, Paul Sullivan stated that the strategy of the open business model ―will bring small companies that are low cost and highly talented to the table to go and do a lot of this work for the Navy" (Fein, 2006). To capitalize on these potential benefits, the Navy's acquisitions program will need to drastically alter its definition of acceptable risk, because the ―low cost, highly talented companies" cannot provide the same level of risk accommodation that larger contractors have done over the years. Corporations take greater risks to garner potentially larger rewards; the DoD acquisition community has no real incentive to take risks because it is not profit driven. As such, current DoD acquisition programs conversely incentivizes risk suppression, a counterproductive strategy when attempting to foster an environment encouraging innovation.

If innovation is a motivation for utilizing an open architecture/business model, then the DoD faces a potentially crippling constraint from budget reductions. The overall federal R&D spending was reduced 3.5 percent from 2010, but 90.3 percent of those cuts came from the DoD (Hardy, 2011). Moving towards an open business model allowing innovative SMEs into the acquisitions process is one way of combating budget cuts since competition drives down the contract price. The SME business environment creates the necessity for innovation because the ―raison d'être of SMEs is to develop radical innovations that could make them more competitive in a market that is dominated by large firms and attractive for takeover by large firms" (Oke, Burke, & Myers, 2007).

Perhaps the reason why SMEs are more successful innovators is due to its use of intellectual capital. Intellectual capital is generally defined as all intangible assets, both potential and realized, contributing to a company's success (Housel & Lorentz, 2011; Grajkowska, 2011). The technological growth and importance of innovation has spawned a realization that intellectual capital is ―a critical force" for growth in our new economy (Kamukama, Ahiauzu, & Ntayi, 2010). Because SMEs rely on intellectual capital more, it makes sense that these types of companies better utilizing intangible assets are poised for greater success. These IC assets must ~~be~~ effectively managed in order to offer companies a source of competitive advantage" (Cohen & Kaimenakis, 2007). Innovative SMEs surviving in the volatile, high-risk marketplace seem to have proven they are effective managers of intellectual capital.

Uncertainty in investing in SMEs is created by the lack of competent methods to value intellectual capital and predict future success based on it. This creates an enormous obstacle for DAS personnel to overcome as part of the new challenge implicit in moving towards an open business model. With little track record and no book value to rely on, the DoD will have to develop metrics to value SMEs based on their primary asset of intellectual capital. Intellectual capital is so difficult to evaluate in a company because it is intangible; it is hard to assess the mental capacity and innovation of individual employees, let alone the entire company. Particularly relevant in software firms, individual employees represent the greatest asset and the greatest risk. Innovative SMEs are required to invest most of their limited capital in these employees, as they are the drivers of production and must be kept satisfied so they do not leave and take their IC to another corporation (Housel & Lorentz, 2011; Swart & Kinnie, 2003). A SMEs' reliance on human capital and other intangible assets eliminates the effectiveness of traditional accounting techniques have in determining their current value and future success.

C. THE DOD ACQUISITIONS SYSTEM

DAS's mission is to meet the goals of the National Security Strategy by managing technologies, programs, and product support needed to equip the U.S. Armed Forces. It is a management process by which the Department of Defense provides effective, affordable, and timely systems to the users (Undersecretary of Defense, [AT&L], 2007). A knowledge-based approach is used to review each program at key points in the acquisition process to reduce risks while milestones are set up throughout the cycle with specific criteria a system must pass through before being allowed to proceed.

1. DoD Decision Support Systems

The DoD Decision Support Systems is the environment within which the DAS operates. This triad of systems and processes is unique in that many elements of risk and uncertainty are introduced by the processes that the systems then attempt to mitigate.

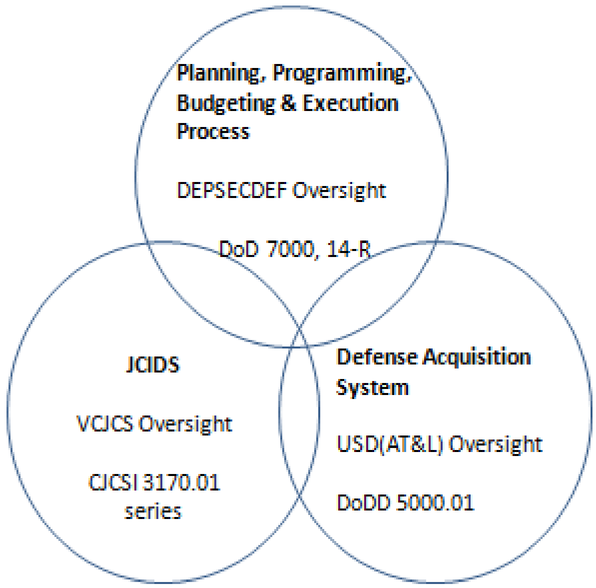

Figure 4. DoD Decision Support Systems

Figure 4 is a Venn diagram that shows the interrelations between the different components of the DoD Decision Support Systems Triad. Each element interacts with the other with the Joint Capabilities Integration and Development System (JCIDS) and the DAS, both of which seek to implement the goals of the Planning Programming, Budgeting, and Execution Process. The office responsible for oversight of each element is listed along with the relevant directives and instructions.

a. Planning, Programming, Budgeting and Execution Process

This is an annual, calendar driven process. The Commander-in-Chief formulates an overall National Security Strategy (NSS). The Secretary of Defense and Joint Chiefs of Staff then draft the National Defense and National Military Strategies, which are more detailed plans on the way forward to NSS implementation. The Defense Budget is submitted to the White House's Office and Management Budget in January and the President's Budget delivered to Congress on the first Monday in February. The Congressional budget process usually lasts from February to September, and once the various authorization and appropriation acts are passed, the appropriated funds to support contracts will be distributed.

Political and *budget risks* originate in this process. A new Commander in Chief may want to draw down the military or a Secretary of Defense might attempt to close down programs that do not coincide with a particular strategic view. Legislators will seek to provide benefits to their home districts by awarding contracts or maintaining defense, industrial, and research facilities. Depending on the political landscape during the budget process, a program may suddenly lose money or even be terminated.

b. Defense Acquisition System

This system is event driven in that specific criteria must be met before a program can enter a new phase. There are four major milestone decision points in which a program can be cancelled if it is not meeting cost, performance, and schedule goals.

Technology projects and acquisitions programs are categorized based on its location in the acquisition process, dollar value, and Milestone Decision Authority (MDA) special interest. Generally, the more expensive or important a project or program is, the higher the level of oversight and regulation.

The major Acquisition Categories (ACAT) are ranked from ACAT I to ACAT III. ACAT I projects and programs are estimated by the USD (AT&L) to require a total expenditure, development, test and evaluation (RDT&E) of more than $365 million based on Fiscal Year 2000 constant dollars or, for procurement, of more than $2.19 billion in FY 2000 constant dollars, while total expenditure for ACAT II RDT&E would be expected to cost more than $140 million in FY 2000 dollars and for procurement more than $660 million. ACAT III programs are smaller programs that do not meet the criteria for ACAT II and I programs (Undersecretary of Defense [AT&L]., 2008).

Two important roles in the acquisition system are those of the PM and MDA. This thesis will concentrate on how both PMs and MDA attempt to mitigate risk and uncertainty.

(1) Program Manager: A PM is assigned to every acquisition program and is experienced in DoD needs and constraints. They are also responsible for drafting achievable and measurable annual plans that are fully resourced and reflect the approved program (Undersecretary of Defense [AT&L], 2008). PMs report to a Program Executive Officer (PEO), which is an official responsible for directing several major acquisition programs, usually in the same technological area or warfare field. For example in the USN, PEO-IWS is responsible for integrated warfare systems and PEO-C4I is responsible for communications and intelligence systems.

The roles and responsibilities of a PM are all encompassing with the PM responsible for every facet of his or her program. On a day-to-day basis, a PM needs to demonstrate a wide variety of skills from technical expertise, leadership, management, communication, and administrative skills.

	Hard Skills
1.	Determine program goals, requirements, and specifications
2.	Determine program scope and deliverables
3.	Technical ability
4.	Document program constraints that could affect program completion
5.	Document program assumptions
6.	Define program strategy or alternative approaches
7.	Quality assurance
8.	Identify resources requirements
9.	Develop a budget
10.	Create a work breakdown structure (WBS)
11.	Develop a schedule
12.	Develop a resource management plan
13.	Establish program controls comparing actual against planned performance
14.	Develop program plan
15.	Communicate program status
16.	Measure program performance to identify program trends and variances
17.	Implement corrective action
18.	Implement change control
19.	Respond to risk
20.	Conduct administrative closure of the program upon completion
	Management / Leadership (Soft Skill) Competencies
1.	Project leadership
2.	Flexibility to adapt and deal with situations and manage expectations
3.	Sound business judgment
4.	Trustworthiness
5.	Communication style presents clear and unambiguous information without bias
6.	Listening skills
7.	Setting and managing expectations
8.	Negotiations
9.	Issue and conflict resolution
10.	Organizational skills
11.	Coaching
12.	Facilitation
13.	Decision Making
14.	Problem solving
15.	Team building

Table 2. List of PM Competencies (From Wood, 2010)

Table 2 displays data gathered from a survey of 146 civilian industry managers that listed common DoD PM competencies (Wood, 2010). The competencies are divided by 20 technical and business or “hard skills” and 15 leadership and management “soft skills.” The original intent of the survey was to determine how well DoD PMs are performing in certain skill areas though for the purpose of this thesis this list gives insight into the diversity of skill sets needed by PMs and the relative order of importance of different competencies as determined by their peers in civilian industry.

One compelling data point in Table 2 is that the competency of responding to risk is the only risk management competency listed and the skill was in responding to risk instead of risk prevention. Although it could be argued that, many other skills such as quality assurance and resources requirements identification serve as preventive measures against different types of risk. The survey ranked 35 competencies in order of importance and responding to risk was ranked 13th. Overall, the most important competencies were determining program goals and deliverables, and the trustworthiness and leadership ability of the PM followed by the administrative skill of developing a budget, then team building. From these rankings, we can determine that PMs are most interested in achieving a detailed knowledge of their programs and developing leadership skills, and that their attitude towards does not emphasize risk prevention.

A GAO report highlighted some factors that differentiate the environment that a DoD PM operates in compared to her civilian counterpart. One factor is that the GAO found that many programs began without a business case, meaning that there was not a sufficient understanding of the technical issues and future costs and time needed, despite the JCIDS requirements and the Material Solution Analysis Phase of a system’s life cycle. When confronted with problems a PM “cannot veto new requirements, control funding, or control staff” (U.S. Government Accountability Office, 2005). The result is that PMs must constantly advocate for their programs, which is another way to describe the attempt to mitigate political risk. This fact plays a large role in what one PM described in the interview process as spending a large portion of his time on protecting his budget.

(2) Milestone Decision Authority: Has overall responsibility over a program and establishes mandatory procedures for it. The MDA has the authority to approve entry of an acquisition program into the next phase of the acquisition process and shall be accountable for cost, schedule, and performance reporting to higher authority (Undersecretary of Defense [AT&L], 2008).

c. Joint Capabilities Integration and Development System

Need driven and requirements based, JCIDS serves to identify the capabilities required by the armed forces to support the National Defense Strategy and ensure these capabilities are identified with their associated operational performance criteria (CJCSI, 2009). JCIDS attempts to mitigate risks that can affect performance though costs are also taken into account. JCIDS determines if there is a capability gap between the National Defense Strategy and the order of battle of the Armed Forces and decides if non-material solutions (change in doctrine, procedure, regulations, etc.), material solutions, or both, will close the gap. Current weapons systems are screened to see if they can fill the capability gap with minor changes and proposed programs are reviewed for the technological feasibility to develop and deploy at a reasonable cost.

2. Defense Acquisition System's Mitigation of Risk

To further the goals of the NSS and the National Defense and Military Strategies that spring from it the DAS covers a diverse range of areas. Oversight and review, contracting, logistics and long term sustainment of the system, technical evaluations, and financial management all play a role in the process from determining the problem's solution, through to the deployment and eventual retirement of a system. Ultimate program success is determined by how well a program meets **cost, schedule, and performance** goals.

a. Initial Capabilities Document

An Initial Capabilities Document (ICD) describes broad, time phased, operational goals and needed capabilities from a warfare community, or jointly by many communities within the DoD. If the ICD identifies a material solution then a 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, though a price is paid in time by PMs for the mandatory consideration of technologies developed under the Small Business Innovation Research program (Undersecretary of Defense [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.

Future **integration risk** is mitigated by the requirement to abide by the DoD Enterprise Architecture (DoD Directive 8000.01) during information architecture development and that all standards used for form the technical view of integrated architectures are contained in the approved version of the DoD IT Standards Registry.

b. Material Solution Analysis Phase

This phase beings 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 shall 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 (Undersecretary of Defense [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 of Navy OA. Future **budget** and **integration risks** are mitigated by the use of COTS solutions though 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.

c. 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. From the DoDI 5000.02:

> The purpose of this phase is to reduce **technology risk**, determine, and mature the appropriate set of technologies to be **integrated** into a full system, and to demonstrate CTEs on prototypes.

This phase takes the theoretical ICD and the findings of the Material Solutions phase and starts physical testing and hands on development of new technologies. Future **budget risks** and threats to **cost** metrics are addressed in this phase. If the PM estimates that the cost estimate used by the MDA that was based on the Milestone A certification increases by over 25 percent then he shall notify the MDA who determines if the expense of system development can be justified in light of the priority level assigned by the Joint Requirements Oversight Council (JROC).

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 could be developed within a short timeframe, which is defined as less than five years for a weapons system (Undersecretary of Defense [AT&L], 2008).

Before Milestone B a PM shall conduct a Preliminary Design Review (PDR). 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 remidial action is necessary before proceding to the next phase.

d. 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 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** by demonstrating that the manufacturing processes can support system production goals.

e. 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 against **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 instead of issues developing during a full rate of production. 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 (Undersecretary of Defense [AT&L], 2008). A Full Rate Production Decision Review is required before the program can pass into full rate production.

f. Operations and Support Phase

This phase begins with 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 use Performance Based Life Cycle Product Support planning, development, implementation, and management. The goal is to keep the system reliable while keeping costs down.

This phase also includes the disposal portion in which a system is disposed of in accordance with legal and regulatory requirements.

g. Relative Weight of Mitigation for Various Risks in the Defense Acquisitions System

Cost, schedule, and performance and the mitigation of risks that can affect these areas are the prime concerns of every program's PM and PEO, though a bird's eye view of the DAS as revealed in the preceding paragraphs of this chapter reveals an emphasis on mitigating integration and technical risks. Integration risks are a subset of performance risks though 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 forms 20 percent of the acquisition cycle as it is the goal of the Technology Development Phase while performance, and the mitigation of risks associated with them form the basis for the remaining three phases after Milestone B. Budget risks are mostly addressed in the first two phases. Budget, performance, and technical risks have an equal weight when viewed in the system as a whole, but not on the scale of integration risks, which is emphasized throughout the whole cycle.

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

When reading *Operation of the Defense Acquisition System, DoDI 5000.02* with an eye towards the risks emphasized in the instruction a slightly different picture appears. Technical risks are mentioned more often than any other type of risk while integration risk is mentioned less than other types. Table 2 lists the various risks mentioned in DoDI 5000.2 and the frequency in which they appear throughout the instruction in order from most frequent to least. When counting the frequency of a type of risk the table ignores multiple mentions of the same type of risk in the same paragraph. For example, paragraph 9 of page 25 explains the selection of a contract type at Milestone B and mentions program risk six times, though in Table 2 it is only counted once, as it is not mentioned anywhere else in the instruction.

Risk	**Mentioned**	**Risk**	**Mentioned**	**Risk**	**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

Table 3. Risks Mentioned in DoDI 5000.02

One explanation on why an overview of the DAS highlights integration risk but fails to mention it as often in the instruction is that many mentions of technical risk consist of mitigating risks associated with the integration of different technologies. Additionally integration risk can be viewed as closely related to system level risk.

III. RISK AND UNCERTAINTY AS PERCEIVED BY ACQUISITION PROFESSIONALS

To investigate the questions posed by this thesis, a series of primary interviews was conducted from April to June 2011 with ten acquisition professionals. Interviews were conducted in person and over the telephone with subjects having 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. Many of the interviews were free-flowing discussions rather than specific question and answer sessions, revealing some strong commonalities and consensus views.

This chapter begins with subjects areas in which all interviewees devoted a significant portion of the conversation and which all subjects were almost unanimous in their opinions. The three critical subject areas for acquisition professionals are budget uncertainty, program risk, uncertainty, and decreasing returns on increasing assets. These subjects came up in discussions without the researcher's bias with a prepared set of questions. The second half of this chapter explores the interview subject's opinions concerning the thesis research questions.

A. 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 process 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, it was the ever present threat of budget reductions and program cancellations casting a constant shadow of uncertainty. Mitigating budget risk is specifically not mentioned in acquisition directives and instructions and all interview subjects seemed to give an equal weight to cost, schedule, and performance but 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; originating 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 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 its way down to the program level. Many interview subjects also agreed with a GAO report stating that many PMs believe that a lack of a strategic investment vision leads the DoD to "start more programs than it can afford and not prioritize them for funding purposes" (U.S. Government Accountability Office, 2005). 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 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 as 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 percent of a PM's time. "Stealing" another program's money is also time consuming but can pay dividends for a PM devoting 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. One interviewee used the analogy of what happens in DAS when a larger program is terminated to 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 against political causes of budget risk besides 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.

B. KEEPING IT ALL TOGETHER, PROGRAM RISK AND UNCERTAINTY

"Uncertainty equals many different independent parts"– Graduate School of Business & Public Policy professor

When discussing various ways risk and uncertainty has 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 mentioned risk type during the interview process. Without specifically asking interviewees what was the most problematic risks, 70 percent emphasized program risks over all others. All interview subjects, with the exception of one, spent a significant portion of the interviews discussing program risks, which the same acquisition professional that gave the definition of uncertainty above defined 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 thesis, a program risk is any risk threatening a project or program meeting its cost, schedule, and performance goals. These risks include those beyond requirements and include risks emerging from areas such as composition of the acquisition workforce; complexity of system due to an abundance of rules and regulation; and even rules and regulations contradicting each other. These risks are discussed further in this section.

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 are 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 as expressed in such legislation as the Truth in Negotiations Act, Small Business Act and the Anti-Deficiency Act.

Frictions also arise when a PM wants to avoid cost and schedule risk by relying upon a large defense contractor and possibly overlooking portions of the Small Business Act to avoid risks associated with a smaller company with limited production capability, or more likely to go bankrupt than a larger one. 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 that 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 pass muster 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 as the original PM transferred after the goals were established. The PM may resort to a ―mission first" approach common in the military and 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 may 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 go along with the PM and hope that the rule bending does not become an issue, especially if the trend is to do what needs to be done. A contracting officer may very well go along with a PM in approving a contract that, for example, breaks the Anti-Deficiency Act, especially since no one has ever been indicted for violating it (Arnold, 2009).

The myriad of risks confronting a program is illustrated by the above example. Frictions exist between functional areas of contracting and program management, along with risks introduced by the lack of training, and the personnel system.

Besides the inherent friction between the different functional areas in the DAS, there is also a risk of linguistic discontinuity. This type of risk was described in a paper 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 (Riehle, 2006) and can include language structure, semantics, grammar, and syntax. An example is given in the paper of a software project PM that planned to use an object oriented approach to the software design. A group outside of the PMs 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 necessitating extra work in making the dissimilar tools compatible.

Every software project will experience linguistic discontinuity of one form or another as the end user's and operator's language is not as technical as the software programmers and designers. The phenomena 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 can misunderstand one another when both have the same skill sets and end goal 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, 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 ready for deployment turns out not to meet end user requirements. The fear of either misunderstanding or overlooking vital end user requirements was a constant topic during the interview process for this thesis. 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, not following up on the contractor's work, only to be 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 be able 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 their solution only to find that a data entry field for each recruit's shoe size was missing. The end users needed that information to send on to the various boot camps so 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 that caused a delay in the program.

Not all program risks can be attributed to misunderstandings or failure of the contractors to develop systems to government specifications as another constant risk to all PMs as told to the researcher during the interview process was **scope creep**. Scope creep is a risk that one encounters when trying to mitigate against the risks 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 more requirements beyond the initial capabilities document. Through 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 to include a lack of accountability due to constant personnel rotation and senior leadership that ―doesn't know what they don't know" and believe that ―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 that long due to a promotion, retirement, etc. A GAO report revealed that in comparison with the DAS civilian companies usually kept the same PM throughout the life span of a product, and this was the main means of ensuring accountability (U.S. Government Accountability Office, 2005) while DoD PMs were rarely held accountable. Through the course of the interview process the researcher discovered a general agreement that the requirements placed upon PMs in the DAS far exceed the flexibility and decision making power allowed to achieve them 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 Government Accounting Office (GAO) report mentioned the DoD’s acquisition workforce plan, in which the DoD identified the need to increase the size of the acquisition workforce but 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 increased 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 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 interview subjects can be summarized in a statement given by one 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. On way to mitigate program risk was more training and education, especially training tailored to explaining other functional areas of the DAS to include the requirements, laws, and regulations unique to a functional area. Most interview subjects agreed that a PM was at the mercy of the government and DoD personnel and acquisition workforce policies and could not provide much practical advice on how to mitigate these issues. All agreed that a delay in ramifications for bad program decisions was an issue. For example, a Program Manager may favor awarding a contract to the lowest bidder in an attempt to keep costs low and at the expense of future integration or technical risk. If the PM is slated to transfer before the integration risks can manifest themselves he may be tempted to award the contract to the low bidder.

C. DECREASING RETURNS ON INCREASING INVESTMENTS

"The bureaucracy is expanding to meet the needs of the expanding bureaucracy."
–Oscar Wilde

When discussing schedule risks a commonality in the interview responses was the bureaucratic nature of the DAS and a consensus 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 have built up over the years and forms the basis for the DAS is the result of various attempts to mitigate risks and uncertainties. With every mandatory process, test, paperwork, and validation an increase in costs and time can be expected. The trade off is that the increase in costs and time are worth the expense in order to assure successful performance and a safe, secure, system delivered to the operating forces and upon which lives may depend.

After the interview process, the conclusion of the researcher is that PMs view the bureaucratic nature of the DAS as a permanent feature of the environment and is something that has must be endured as opposed to trying to introduce efficiencies in the system or fight for more flexibility and latitude in day-to-day management of their programs. 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 profitability of a company. Additionally, the company has full control over its own policies and only have to worry about as many Federal regulations that pertain to its business and work force as compared to 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 legislature or comes with strings attached such as pots of money only accessible 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 PM generally has less flexibility in financial and personnel decisions as 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 would agree that the cost and effort would be worth it. Over time, the cumulative accumulation of controls has added such time and money costs on daily operations that any new imitative comes at every greater expense of now limited time and money for smaller and smaller real gains in efficiencies or social good for politically inspired requirements.

D. RESPONSE TO RESEARCH QUESTIONS

1. Risks at Different Career Stages

This question was asked in order to determine the categories of risk important to acquisition professionals and PMs in particular. 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 one's acquisition career could point to the fact that the DAS's operating principles and techniques was unique and that those with experience in other branches of the DoD and 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 may also 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 higher risks for well seasoned acquisition professionals may point to a system that would assign riskier programs to the more those with more experience or to a system where high profile programs are subject to more interference and uncertainty. Another possibility would be that there might be programs and projects that were virtually risk free and that inexperienced PM could be assigned to them.

Different types of risks at different stages of an acquisition professionals career would reveal either a segregated system in which there were many programs and projects that either had different business rules and 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 would be more or less willing to endure. 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.

Amongst all interview subjects, the opinion was unanimous that besides the risk common to all professions that a newcomer, no matter how well trained, faces, there was no real difference in either the amount or type of risks inherent in different stages of an acquisition professional's career. The researcher's opinion is that insignificant variations in the amount and type of risk over a typical career indicates 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 that transitioning into the acquisition workforce is not problematic though 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.

2. Risks beyond Cost, Schedule, and Performance

Enquiring after risks beyond cost, schedule, and performance was an attempt to find if any unique risks in the DAS or if a PM had knowledge of a successful strategy to mitigate against various types of risk that was not well known.

Unsurprisingly, all interview subjects agreed upon cost, schedule, and performance risks as their prime concern. The first half of this chapter describes program risk; 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 many types of risks such as design and component design risks and standards selection risks were discussed but all with an eye to the impact on cost, schedule, and performance.

The researcher's 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.

3. Definition of Uncertainty in the Defense Acquisition System

This research question into the definition of uncertainty originated in the study of the hedging of risk by using portfolio management techniques. If risk can be quantified by measuring probability of occurrence and the severity of the event happening, (such as the *Risk Management Guide's* Risk Reporting Matrix), then the possibility arises that future research could reveal a way to quantify uncertainty in a way useful for PMs. The means of measuring things of which we have incomplete knowledge is beyond the scope of this thesis, but a thorough understanding of uncertainty as it pertains to the DAS might give insight into the creation of an useful tool or method of addressing uncertainty such as the Chicago Board Options Exchange Market Volatility Index, or VIX, which measures the thirty day expected volatility of the S&P 500. Some investors follow the VIX in order to gauge the general investor sentiment that may 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 twenty 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.

Beyond the dictionary given definition there is not much thought given in the DAS to the definition of uncertainty and no unique interpretation of uncertainty was revealed in the interview process. When the researcher bought up the idea of a future measurement of uncertainty applicable to the DAS the subject only elicited minimal interest and the subject of the conversation soon changed of its own accord. One interview subject did state 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 up front in a program 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.

4. Questions on the Impact of an OA Approach

During the course of the interview process, there was a general avoidance of giving opinion concerning OA and its impact on the DAS. Even when pressed with the specific questions listed in the Research Questions section of this thesis half of the interview subjects would talk in generalities claiming that they had not much experience with OA during their career. For those interview subjects that had extensive experience with OA, especially those working at PEO-IWS, the consensus was that it is still too early to tell the impact of OA on the system as a whole, especially if OA and SOA has produced the desired results and efficiencies in the DAS.

The researcher also came across a misunderstanding 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 to the planned architecture of the system and he was able to dividing 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 of any “tactical” success using OA principles even though the program in question did in fact have to use a modular approach, allowing integration of independently developed legacy systems with reliance on reuse of many legacy system software and hardware components.

One area of agreement during the interview process was that OA increased complexity when ensuring that systems met information security and information assurance requirements, though a lot 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 that the implementation of OA was still in its initial stages and that the supporting tools, systems, and procedures were at an immature level. The researcher was unsure if the data collected so far pointed to a general failure of OA in the DAS or that OA would be beneficial for certain types of programs and unsuitable for others. The researcher decided to begin secondary research into historical examples of OA in the DAS in an attempt to find the answers missing during the active interview process.

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IV. OA AND RISK AND UNCERTAINTY IN THE DOD ACQUISITION SYSTEM

This chapter will explore three different examples of the implementation of OA and SOA principles in the DoD and beings discussing the Acoustic Rapid COTS Insertion (A-RCI) / Advanced Processor Build (APB). A-RCI began an attempt to improve the detection capability of towed-array sonar on the Los Angeles class of attack submarines and soon expanded to include all sonar systems in the submarine fleet along with some surface and aviation submarine detection systems. Exploring the A-RCI program is worthwhile as it provides a good example of the successful implementation of MOSA and OA principles and is considered the ―poster child" for OA in the Navy (CHIPS, 2007). A-RCI is an example of the use of OA and SOA to improve an operational capability of the armed forces in a rapid manner, from awarding of the initial contracts to the delivery of new capabilities to the fleet. In the following section, an example is given of how a SOA strategy has solved daunting integration issues. The U.S. Military Entrance Command (USMEPCOM) is a joint command, consisting of elements from all the Armed Services, to include their reserve components as well as the U.S. Coast Guard that relies on each service's legacy recruiting system to process their applicants. A SOA strategy was used to allow the smooth flow of data from legacy recruiting systems into USMEPCOM's system.

The chapter will finish with a discussion of PEO-IWS's Software Hardware Asset Reuse Enterprise (SHARE) repository which is an online portal containing a library of combat system software and related assets for use by contractors for developing or suggesting improvements to Navy Surface Warfare Systems (Blais, 2008). Not only is the SHARE initiative directly supporting the SOA and OA principles of reusability but it is part of a larger overall attempt to build a new infrastructure within the DAS, an infrastructure consisting of new tools, web portals, and ways of doing business that will allow future projects and programs to use OA with the minimum of friction.

A. 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 him to the Control Room. Upon entering the cramped space and noticing the smiling faces and hushed commotion around the sonar operator Spravtsev only needed a second to guess that they had a significant contact. The 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 sub for over two hours but now had lost contact. It had been over thirty minutes, and Spravtsev was nervous that the American submarine had suspected they were being tracked or had acquired his own sub as a contact. ―Conning Officer slow to five knots." Spravtsev knew that his sub had an improved hull and was quieter than the first seven submarines in the class and that if he slowed down the Americans might not suspect he was there.

The American submarine had, in fact, acquired the Volk's acoustic signature and had been tracking Spravtsev's command for over an hour. There was the same level of hushed excitement of 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 their experience with the 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 USN's Response to the Loss of Acoustic Superiority

In 1995, 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 U.S. Navy'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. 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, debate over the future of the Seawolf submarine, and 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 opened the door for unique and creative approaches to solving the problem that went against the structure and intent of many of the 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**.
- Sub acoustic superiority depends on the successful use of these axioms.

Many of the 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 vice state of the art is key in ensuring interoperability, especially in a project operating on a compressed schedule. Using the lessons learned by other organizations, to include the lessons learned in the civilian world helped to achieve a consensus based approach instead of the DoD trying to solve the problem with a proprietary solution.

2. A-RCI/APB Development Strategy

The existing sonar systems at the time were not designed with modularity in mind and one of the first A-RCI tasks was to update the legacy systems. 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 one many of the 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. This allowed for quicker development and fielding of new upgrades and gave the developers the flexibility to change some parts of the system while leaving others alone (Boudreau, 2006). There were risks involved with the MOSA approach as system development for different components proceeded independently of each other and introduced interoperability risks into the process. Extra time and expense was needed on tracking and version control of key software interfaces, standards, and protocols amongst 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 would seek to use the technology available at the time instead of 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 with any new system additions required to pass through a thorough demonstration process that included the evalution of new system capabilites against the previous system capabilities though collaboration and information sharing were expected (Boudreau, 2006).

Software development operated on an annual upgrade cycle through the APB and the hardware would be selected operated 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 though the sense of crisis of the loss of acoustic superiority at sea had the benefit of giving A-RCI high level support allowing for the bypassing of various milestones and requirements in JCIDS and the DAS in favor of PM flexibility, technical innovation, and experimentation. The priority was a quick development cycle and release of improved sonar capabilities to the operating forces and 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 has the whole story.” The peer review process was conducted under the over site 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 instead of 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 to include a Tactical Integration Advisory Group, groups for specific sub systems such as the APB-1/2 towed array, and perhaps most importantly 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).

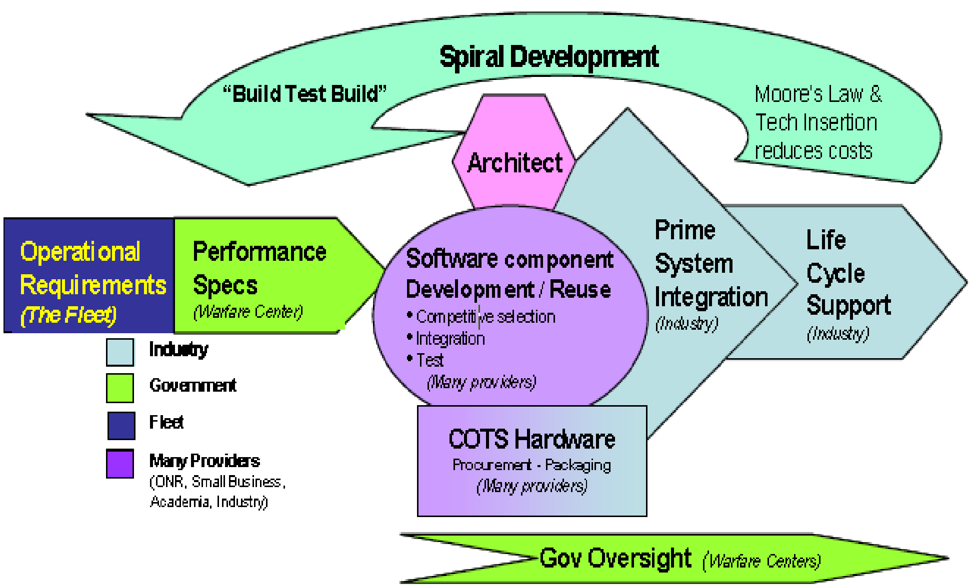

Figure 5. A-RCI System Development Model (From Barron, 2006)

Figure 5 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 with the APB program depending on competitive selection and test on an annual cycle, adjacent to but not fully dependent on the six month COTS hardware development cycle. The spiral development method hoped to leverage the increases 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 would continue until the USN regained acoustic superiority at sea.

3. A-RCI and Associated Risks

The risks associated with A-RCI were generated by the unique development strategies pursed by the PMs and the friction with the traditional developmental approach following JCIDS and DAS best practices. These risks can be assumed relevant to any other program following using MOSA and OA principles and using a spiral development strategy.

a. Budget Risks

The initial A-RCI program was funded at level less than equivalent programs using a traditional approach and had different funding profiles necessitating ―continuous streams" of RDT&E, Procurement, and Operations and Support accounts (Boudreau, 2006). The mitigation to this budget risk was quick initial success and delivery of improved sonar capability to the fleet sooner than if the program 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.

b. 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 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 though end to end testing, so important in the DAS to 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).

c. 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 threatening future integration of the weapons system beyond the submarine force and potential to operate in a joint environment. The mitigation was to conduct annual JCIDS reviews synchronized to sequential development spirals (Boudreau, 2006). This was possible because subsurface operations and anti-submarine warfare, besides strategic nuclear forces, is almost wholly an USN mission. The question remains open if such an accommodation would be possible with JCIDS if the program in question would rapidly deploy an anti-aircraft or missile system that would be certain to operate in a joint environment.

d. Operational Risks

The first operational risk was that the initial deployment of the system would not meet 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 in 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 their concerns. The risk for future programs using a spiral approach is that cost and schedule burdens may actually be transferred to the operating forces where feedback might not flow back in time to allow adjustments in the developmental cycle.

e. The A-RCI Success Story

Throughout the USN A-RCI is considered a MOSA / OA success story. In 2006, then CNO, Admiral Mullen sent a memo to the heads of various system commands and urged then to use follow the best practices of the A-RCI program. He stressed the importance of going beyond using an OA approach to technical problems and use an open business approach for ~~"t~~he 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 of the measurable effects of A-RCI included the following improvements to the USN's operating forces aucoustic capabilites (Boudreau, 2006):

- Sevenfold 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.
- Mean hold time improved by 25 minutes.
-

Life-cycle costs were improved by a factor of close to five to one (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 as 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. A-RCI's OA approach called for ―parallel developments by different organizations, using independent software development tools, and funded by multiple contracts" An integrated product team approach was used 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 were overcome through strong leadership, especially senior leadership providing ―top cover" in allowing middle management to innovate (Boudreau, 2006) and intervening to break any stalemate in the various peer review groups. Input from the fleet was vital to providing program leadership and the peer review groups 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 technically based on the operator's needs. The spiral development cycle introduced cost and schedule risks but since 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 lead to success and as 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 amongst program managers that the longer a system's development cycle, more risk is added and there is a higher overall chance of program failure. The spiral nature of A-RCI with a series of short development cycles, delivered to the fleet the technological improvements available at that time as opposed to waiting for years to deliver a supposedly state of the art system. One key to the success of A-RCI's spiral strategy can be summed up to a PM's comment during the interview process that "sometimes good-enough is good-enough." Instead of investing time and money into improving a system (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).

B. U.S. MILITARY ENTRANCE COMMAND INTEGRATION PROBLEM WITH SOA SOLUTION

USMEPCOM's mission is to review all applications of recruits to the U.S. Armed Forces and then process their records from the initial interview with a recruiter until the new accession reports to their training facility. USMEPCOM processes approximately 1 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 from 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 is processed by a recruiter from the particular branch of the Armed Services the recruit is joining and each branch uses their own propriety system. Extra time and effort was spent by the recruiters in the redundant entry of data into USMEPCOM's system, which could only be accomplished by manually entering the data into a flat file for upload into USMEPCOM's database or a tedious double entry directly into USMEPCOM's system soon after entering the system 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 the reduction of reducing application processing time from 2.6 days to less than a day, and allowing the prequalification of 90% of the applicants without the applicant having to visit a central facility in person such as a Military Entrance Processing Station (MEPS) This would save a significant amount of time and expense; especially in recruiting regions where the MEPS facility may be over 100 miles journey from the recruiting office. The chosen strategy was to use an ―accepted standards based SOA interface" that was compliant with all Defense Information System Agency (DISA) system requirements (Maravola, 2009).

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. Though the literature does not explicitly state it, it is the researcher's conclusion that Oracle software was chosen by the team for a variety of reasons to include cost savings using a COTS solution from a well known and popular vendor, the frequency in which Oracle products were used in the myriad of systems that DE/TOSIP would be required to exchange data with, and with an eye on future reuse of system components and ease of system scalability. This conclusion was confirmed in an interview with an USMEPCOM acquisition professional in the Acquisition and Initiatives Division serving at the time.

During the interview another important strategy came to light in that the program was purposefully split into three smaller programs to avoid 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 from a recruiter's workstation to the information, 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. In comparison, the program passed the budget threshold in 2008 and acquired a PM. The development cycle has since slowed due to the many bureaucratic constraints as discussed earlier in this thesis.

During the 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 those 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 would provide 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 available and the time and effort spent in engaging the true end users paid off.

2. DE/TOSIP Results

The U.S. Air Force Reserve estimated that they save around $350 annually from their recruiting budget as a recruiter can now retrieve applicant data online instead of having to call the Air Force liaison at a USMEPCOM facility. Since the Air Force Reserve is only a small component of the total DoD recruiting force (about 2 percent) 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 benefits from 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).

C. SHARE AND THE DEVELOPMENT OF AN INFRASTRUCTURE TO SUPPORT OA

A-RCI was a ground breaking program for OA in the DAS but 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), collaboration portals, the OA implementation assessment tool, and software reuse repositories.

This section will describe the Software Hardware Asset Reuse Enterprise (SHARE) Repository Framework and discuss some of the issues encountered in the 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 just to enable the reuse of combat system software but also related assets and to facilitate prime and subcontractors ability to reuse software and suggest improvement to Navy surface warfare systems (Johnson & Blais, 2008).

The SHARE library usues an online open source repository called SourceForge that can also be used as a project management tool. The library contains artifacts from various programs to include 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 discussing SHARE during interviews with PEO-IWS personnel it was discovered that not all contractors were willing to post artifacts to the library, as they were concerned about their intellectual and proprietary rights. PEO-IWS noticed that the traditional larger and well established contractors were more willing to participate but smaller firms tended to avoid 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 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, as 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 well being. There were many benefits to utilizing SHARE but the financial and intellectual property risks were too great for many of the smaller firms.

PEO-IWS' initial response to this problem was to change the 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 over the required license and Non-disclosure agreements led to the second issue to hinder the 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. Planning for SHARE did not account for a much increased workload or for new positions to be added to PEO-IWS and the work load 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 draw the government into legal issues and even have the government take the side of one contractor over another. This approach would tend to 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 delinquent in their paperwork requirements. This approach would be effective but PEO-IWS' budget does not allow for this and increases in funding are unlikely.

The solution that PEO-IWS is working on is one of trying to incentive compliance by contractors with the license and Non-disclosure agreements compliance. As of the interview process for this thesis, PEO-IWS has decided that it will see this approach but is still in the planning stage on the best approach to implement this solution.

4. Impact of SHARE

Unlike A-RCI, SHARE currently cannot be considered a success. During the interview process with PEO-IWS personnel, the majority of the conversation revolved around the problems that they faced in implementing the system. In the literature review for this thesis the researcher encountered very few mentions of SHARE outside of PEO-IWS authored material.

Despite the ongoing problems with the implementation of SHARE and the lack of well documented cost savings and achievements directly attributable to the project, it would be a mistake to classify SHARE as a failure. The ongoing lessons that are being 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 PEO-IWS and the DAS as a whole has to pass through before we 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, the 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.

D. SUCCESSFUL STRATEGIES AND RISK

Certain strategies help in the successful outcomes of the A-RCI and DE/TOSIP programs. Some of the strategies are the same as the best practices used in applying SOA in the business world and other strategies may be unorthodox. This section will explore the strategies used by the A-RCI and DE/TOSIP programs, and list 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 may operate under different conditions.

1. Best Practices in Civilian Industry

A researcher working on a companion thesis found that in civilian industry the two primary benefits of adopting SOA were decreased risk and reusability (Wolff, 2011). The researcher found that a key in reducing risk was the flexibility given to civilian management, increasing their ability to react to unforeseen events, a changing market, and evolving technologies. The researcher found that in surveys taken by civilian management that flexibility was ―almost always at, or near the top of the list of objectives when implementing SOA."

Reusability was key in many successful business strategies as the use of proven technologies increased the availability and stability factors of a system. Reusability combined with an incremental approach in the implementation of SOA proved to be a winning combination. A strategy of ―attacking the low hanging fruit" first and realizing the easy savings in costs and efficiencies was most effective (Wolff, 2011). Most companies did not launch overly ambitious projects but focused on the specific areas that were most problematic. This approach also provided an added benefit in allowing an organization to learn from early mistakes in the first development cycles.

2. A-RCI Best Practices and Risk

The heavy use of a COTS strategy is similar to the civilian industry best practices of using available, proven, state of the art technology and was one of the keys to the rapidly improvement in sonar technology. The risks involved for a DAS program to use this strategy are bureaucratic and security risks. Bureaucratic in that the COTS components would need to be approved in both the JCIDS process and by 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 and allowed them to proceed faster than the testing and JCIDS cycle would allow a regular program, indicating that these processes may introduce impediments into the acquisition community.

The open capabilities based model allow A-RCI to leverage the rapid gains in computer processing power that civilian industry was putting to good use at the time. This was contrary to the requirement based model that lies at the heart of DoD's transformation to 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. The integration risks may 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 the code to reliance on hardware that many not be manufactured to military specifications.

A-RCI’s spiral development strategy opened the door to operational risks, and potential costs and schedule risks. When following an incremental development strategy technologies will be 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.

3. 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 increase 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. Additionally the program would be at risk of low scalability as 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 does introduce the risk on relying on a single vendor. In DE/TOSIP’s case, it would not have been cost effective and timely to try and 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 mandates, regulations, and laws in the DAS 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 one year increments 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 4 lists the successful strategies and best practices used by the A-RCI and DE/TOSIP programs alongside the risks that can be introduced when pursing them.

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	
Avoid 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

Table 4. Best Practices and Risk

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSION

This thesis explored various risks and uncertainties in DAS to determine if using OA and SOA principles in a project or program increases or decreases risk and uncertainties, or presents the OA practitioner with unique risks. Additionally, this thesis attempted to determine if OA and SOA has delivered projected cost savings and increased efficiencies to DAS.

1. OA/SOA and Risk

During the interview process, it was 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 are no strict definitions of different types of risks or a specific definition of uncertainty.

Despite the lack of specific definitions for different types of risk, there are risk areas of constant concern to PMs. Although these risks may be classified in slightly different ways and have different mitigation strategies, budget and program risk are a constant presence in the DAS. The risks associated with misunderstandings between different functional areas, the ―talking by each other” and linguistic discontinuity, are not unique to the DAS but are increased by a lack of training emphasizing other functional areas of the DAS along with contradictory structural goals between functional areas of a program such as between a PM and a contracting officer.

The findings concerning the constant nature of risk throughout a PM’s career and widespread agreements amongst PMs of the nature of risk in the DAS helped lead the researcher to the conclusion that the DAS is highly structured, consisting of well defined requirements and milestones. There is little incentive for a PM’s initiative in running projects or programs and little room for flexibility in the personnel composition of their work force. The DAS’s bureaucratic nature is a constant and not viewed as a risk but 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 with") and delay ramifications for incorrect or even illegal decisions falls on the program long after the original participants have transferred.

Even though OA has delivered cost savings and allowed faster system development in certain cases it has also increased complexity and risk for programs in meeting the DISA network accreditation processes.

2. OA/SOA and Cost Savings in the DAS

Changes in the DAS for widespread use of OA and SOA principles have come at an upfront cost in the establishment of a basic supporting infrastructure. For example, the SHARE repository shows how unforeseen issues may arise when trying to facilitate OA principles such as collaboration and software reuse. Future programs would benefit from the lessons learned with A-RCI's faced paced, spiral development cycles and the JCIDS process. In order to implement a suggestion that JCIDS address A-RCI like programs, more investments must be made in reviewing all relevant instructions and regulations and make necessary updates, additions, or changes, without an adverse effect on more traditional programs.

The use of OA principles in A-RCI resulted in significant cost, schedule, and even, after an initial choice to field the first iteration of the system that was not up to the Fleet's requirements, performance benefits. A-RCI proves that cost and schedule benefits to a program are possible with OA, especially compared with a theoretical program developed in a traditional proprietary, stove piped system.

USMEPCOM's DE/TOSIP program shows that using OA strategies and principles can help mitigate serious integration issues as the DoD slowly moves to towards the seamless transmission of data throughout the DoD and other Federal agencies. The use of COTS software and reliance on software reuse resulted in both initial cost savings and follow on savings as work proceeded on new features to the USMEPCOM network.

B. RECOMMENDATIONS FOR THE DOD

Below are several recommendations based on thesis conclusions.

1. Provide Adequate Resources

The first recommendation is to continue work on building the DoD infrastructure and ensure any new initiatives are sufficiently resourced. The SHARE repository gives a warning on concerning the lack of resources, in SHARE's case the lack of personnel and time to ensure that contractors met all administrative requirements concerning intellectual property rights. For the near future, the DoD and DAS will face budget constraints but must avoid the temptation to implement new aspects of a supporting infrastructure without assigning the proper resources. What would be worse than a lack of supporting infrastructure for OA is new policies and procedures that eventually devolve into a ―check in the box" or paperwork drill due to the lack of proper enforcement or follow through.

2. Greater PM Initiative

The DAS should experiment with giving PMs more initiative in running programs. DAS has evolved into a system concentrating on performance issues, even at the expense of costs and schedule. The delivery of world class systems to our operating forces should always remain a priority but the DoD should look into allowing PMs more flexibility in running their 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 can lead to program success. Senior leadership had to provide top level coverage in order for A-RCI to proceed, even when not in sync with JCIDS requirements.

3. Continued Accountability

This recommendation addresses the delay ramifications for bad decisions in the DAS. 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 after improprieties or poor decisions are uncovered, then as long as the PM is still in government service, the PM should remain accountable for his decisions in older programs. This accountability would also temper excessive risk taking if PMs were given more flexibility in running their programs.

4. Greater Flexibility

A PM allowed flexibility in running his or her program could reap the benefits of Joy's Law, stating, ―no matter who you are, most of the smartest people work for someone else." Attributed to Sun Microsystems's founder Bill Joy, this quote not only applies to the tech industry, but to all organizations to include the DAS (Lakhani & Panetta, 2007). This law does not reflect poorly on the acquisition professionals working in the DAS but reflects the fact that there is a lot of talent outside of DAS that could be tapped into with a more flexible approach to systems development. Open source software projects such as of Linux offer many lessons and opportunities for PMs willing to risk costs and effort in exchange for access to knowledge and techniques outside of the DAS. Innocentive.com is a means by which PMs in the traditionally closed civilian pharmaceutical, biotechnology, consumer goods, and high technology industries help solve specific technical problems (Lakhani & Panetta, 2007). PMs can post the problem and the cash prize they will award the person or company that offers the best solution. Another example the DAS could follow is TopCoder, founded in 2001, that consists of a community of programmers that compete, as well as collaborate, in creating solutions to problems that TopCoder's clients had identified. The main means that TopCoder uses to solve client's problems is to set up contests in which community members compete for money and skill ratings (Lakhani, Garvin, & Lonstein, 2010).

DAS PMs running programs should be allowed to post problems, not at the risk of national security considerations, or the DAS should consider taking advantage of collaboration with the vast knowledge base in the world outside of the DAS and continue to build a supporting infrastructure for OA and SOA by launching the DAS's own version of Innovative.com or TopCoder.

5. New Metrics

Due to the innovativeness of implementing an open business model in DoD acquisitions, program Managers must be given an entirely new way of determining new metrics, perhaps similar to what SMEs use in measuring its use of intellectual capital. The finance industry has struggled to obtain a consistent, accurate method for valuing companies based on their intellectual capital, but has failed to produce any of great promise. Some academics advocate the use of Patent Citation Counts but others describe the method as inadequate (King & Zeithaml, 2003; Housel & Nelson, 2005). Various methods based on cost reduction and avoidance have also been proposed such as Book Value, Discounted Cash Flows, and Market Comparables (Housel & Lorentz, Understanding the risk of intellectual capital: the potential IC to real IC to conversion ratio, 2011). However, these often neglect approaches to IC other than traditional cost/benefit analysis; doing so neglects the source of innovative IC employees.

Instead of these inadequate forms of valuation, measuring the explicit potential innovative IC to realized innovative IC conversion ratio, as described by Housel and Lorentz, 2011, can provide dynamic and insightful data on which companies are better using their innovative IC as well as indicate whether their use of this asset is growing or remaining stagnant. Explicit potential intellectual capital is the knowledge contained within employees; knowledge that can be exponentially increased through education and training (Housel & Lorentz, 2011). ―Real or realized IC would represent an individual's ability to convert this available potential IC into observable outputs such as decisions, new product or service ideas, suggested productivity improvements, and other observable outputs" (Housel & Lorentz, Understanding the risk of intellectual capital: the potential IC to real IC to conversion ratio, 2011).

The explicit potential to realized IC conversion ratio is based on the physics concept of potential and kinetic energy. As an engine nears the 1:1 ratio of energy consumed to power produced, it becomes more efficient and productive; it is likely that so too would a company that neared a full utilization of its most important asset, intellectual capital. The explicit potential innovative IC to realized IC conversion ratio eliminates the problems associated with traditional valuation processes for innovative

SMEs because it deals directly with their intangible assets. Furthermore, as this ratio can be reevaluated over time, it may provide the DoD with a reasonable view of whether their efficiency is increasing, decreasing, or flat-lining.

Implementing this conversion ratio in the DoD acquisitions environment demands that a standard unit of measurement be assigned to potential and realized innovative IC. One way of determining that unit is through Knowledge Value Added theory. ―KVA analysis produces a return-on-knowledge (ROK) ratio to estimate the value added by given knowledge assets regardless of where they are located" (Housel & Bell, 2001). Unfortunately, these ratios have to be tailored to fit the industry that is to be examined, so there are no current standard units of value that the DoD can utilize immediately, and research will have to be conducted in order to determine these units for the different sectors farmed by the acquisitions process. If pursuing the open architecture/business model continues to remain important to the DoD, this research will provide a productive way to reduce risk and cost, without stifling the innovation, which is so desired by defense leaders.

6. New Study

The final recommendation is to conduct a study on which DAS areas would benefit from OA and programs hindered by implementing OA and SOA principles. The conclusions of this thesis point to the benefits of OA in addressing cost and schedule issues but increased risks with programs related to security and highly sensitive military technologies.

C. RESEARCH SHORTCOMINGS

The primary shortcoming of this thesis was the relatively limited numbers of subjects interviewed, in conjunction with the fact that only half of the interview subjects had more than passing experience with OA. There was also limited material publically available on program failures, particularly in failed programs that applying OA principles.

D. RECOMMENDATIONS FOR FUTURE STUDIES

The researcher feels that the following recommendations help DAS analyze the full impact of OA and SOA.

1. Identify Best Fit for OA

Categorize the most prevalent programs in the DAS. For example, missile systems, automotive transportation, aviation, networking, and network security should be categorized in an attempt to determine which programs and projects benefits from OA use and those programs, which would hinder it.

2. Categorize Best Tactics and Strategies

When implementing OA (COTS, software reuse), categorize the different strategies used. Then categorize the different tactics used to implement these strategies. For example, under software reuse the tactic would be to write all code with reuse in mind or only concentrate on future reuse possibilities for the software interfaces.

3. Expand Interview Pool and Add to the Case Studies

Expand interview subjects from different PEOs besides PEO-IWS for insight into how widespread OA use in DAS. Build upon initial case studies in this thesis to cover different DAS areas and provide either support or contrary evidence to the conclusions of this thesis.

4. Conduct Free-Flowing Interviews

During the interview process, it was discovered that all interview subjects responded negatively to the prospect filling in a questionnaire or participate in a highly structured interview. This proved to be true with both interview subjects working in DAS and those with DAS experience but currently serving in the academic field. All interview subjects preferred a free flowing conversation and a few refused to look at the initial list of questions presented by the researcher. Ultimately, interview subjects answered many of the prepared questions without reading from a script. For questions not addressed in conversation, it was easy to bring them up before the interview ended.

Another benefit from a free-flowing conversation was that many points were bought up that would not have come to the researcher's attention if the interview was kept to the researcher's original questions and format.

5. Expand Number and Diversity of Participants

Acquisition of research data was inhibited by the researcher's reliance on a limited pool of interview subjects. Unless interview subjects are retired, they will be busy pursing their careers and have limited time to give to a student researcher. A researcher should start the interview process as early as possible while politely and persistently pursuing the research. The researcher made the mistake of waiting too long for information and should have used the valuable waiting time seeking out new interview subjects. The earlier the researcher starts the interview process, the more time allowed for information gathering without the researcher pestering the subjects and the greater the number of interviews will surely lead to a diversity of opinion and many insights.

6. Map the Application and Mitigation of Risk

From case studies of OA and SOA based acquisition programs, map areas in which PMs choose to accept risk and which risks they decided to mitigate against to provide a visual summary useful for future research. This visual of risk types associated with certain types of programs and various tactics applied by PMs to either mitigate or accept risks to further cost, schedule and performance goals would be extremely useful.

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