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**Acoustic Rapid COTS Insertion:
A Case Study in Spiral Development**

30 October 2006

by

Michael Boudreau, Senior Lecturer
Naval Postgraduate School

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**Naval Postgraduate School
Monterey, California**

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Acoustic Rapid COTS Insertion (A-RCI) is a success story in the use of Modular Open Systems Approach (MOSA)/Open Architecture (OA)—beginning with towed-array sonar on 688 Class Submarines and later encompassing all sonar systems on all attack submarines, some surface ship sonar applications and even aviation anti-submarine warfare. The DoD has long considered Open Systems Design a "best practice" that should be used during system development. However, as is often the case with best practices, the "lessons learned" have not been trumpeted widely across DoD acquisition organizations; distillation of the reasons for success in A-RCI has not occurred as yet, and the A-RCI techniques used in Open Systems Design are not widely known and applied in other program offices or taught in our institutional "schoolhouses." One way for interested parties to learn the practice of Open Systems Design successfully is through case study. The purpose of this A-RCI case study is to create a learning vehicle for the application of MOSA/OA which then could be used for training and education of acquisition practitioners and future acquisition leaders.

The study considers such aspects as the PMO cultural environment, management techniques, open systems processes and controls, appropriate open systems metrics, resource impacts, the interface with JCIDS, user and contractor participation, logistics planning, operational testing, and required participant training.

14. SUBJECT TERMS
Advanced Processing Builds, Modular Open Systems Approach, Software Acquisition, Software Development, Joint Capabilities Integration and Development System (JCIDS), System Lifecycle Cost (LCC), Spiral Acquisition, COTS Processors, Maintenance Free Operating Period (MFOP), Reduction in Total Ownership Cost (R-TOC), Total Ownership Cost (TOC)

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Abstract

Objective:

The purpose of the A-RCI case study is to create a learning vehicle that describes spiral development through Open Systems Design, which then can be used for training and education of acquisition practitioners and future acquisition leaders. The study considers such aspects as the PMO cultural environment, management techniques, open systems processes and controls, appropriate open systems metrics, resource impacts, business-case analysis (ROI), user and contractor participation, logistics planning, and required participant training.

Summary:

Acoustic Rapid COTS Insertion (A-RCI) is a success story in the use of Modular Open Systems Approach (MOSA)/Open Architecture (OA)—beginning with towed-array sonar on 688 Class Submarines and later encompassing all sonar systems on all attack submarines, some surface ship sonar applications and even aviation anti-submarine warfare. The DoD has long considered Open Systems Design a "best practice" that should be used during system development. However, as is often the case with best practices, the "lessons learned" have not been trumpeted widely across DoD acquisition organizations; distillation of the reasons for success in A-RCI has not occurred as yet, and the A-RCI techniques used in Open Systems Design are not widely known and applied in other program offices or taught in our institutional "schoolhouses." One way for interested parties to learn the practice of Open Systems Design successfully is through case study. The purpose of this A-RCI case study is to create a learning vehicle for the application of MOSA/OA which then could be used for training and education of acquisition practitioners and future acquisition leaders.

The study considers such aspects as the PMO cultural environment, management techniques, open systems processes and controls, appropriate open

systems metrics, resource impacts, the interface with JCIDS, user and contractor participation, logistics planning, operational testing, and required participant training.

DoD Key Technology Areas:

Spiral Development, Advanced Processing Builds, Federated Software Systems, COTS Processors, Open Architecture, Joint Capabilities Integration and Development System (JCIDS), Maintenance Free Operating Period, Reduction in Total Ownership Cost (R-TOC), System Acquisition; Technical Refresh.

Keywords:

Advanced Processing Builds, Modular Open Systems Approach, Software Acquisition, Software Development, Joint Capabilities Integration and Development System (JCIDS), System Lifecycle Cost (LCC), Spiral Acquisition, COTS Processors, Maintenance Free Operating Period (MFOP), Reduction in Total Ownership Cost (R-TOC), Total Ownership Cost (TOC).

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Michael W. Boudreau, Colonel, US Army (Ret), has been a senior lecturer at the Naval Postgraduate School since 1995. While an active-duty Army Officer, he was the Project Manager, Family of Medium Tactical Vehicles, 1992-1995. He commanded the Materiel Support Center, Korea, 1989-1991, and the Detroit Arsenal Tank Plant, 1982-1984. COL Boudreau is a graduate of the Industrial College of the Armed Forces; Defense Systems Management College; Army Command and General Staff College; Long Armour-Infantry Course, Royal Armoured Corps Centre, United Kingdom; and Ordnance Officer Basic and Advanced courses. He earned Bachelor of Mechanical Engineering and Master of Business Administration degrees from Santa Clara University, California.

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ACQUISITION RESEARCH
CASE STUDY

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Acronym List

APB	Advanced Processing Build
A-RCI	Acoustic Rapid COTS Insertion
ASTO	Advanced Systems Technology Office
ASW	Anti-Submarine Warfare
AWG	Automation Working Group
CAIV	Cost As an Independent Variable
CDD	Capability Development Document
CJCS	Chairman, Joint Chiefs of Staff
CJCSI	Chairman, Joint Chiefs of Staff Instruction
CJCSM	Chairman, Joint Chiefs of Staff Manual
CONOPS	Concept of Operations
COSG	CONOPS and Operation-Machine Interface Support Group
COTS	Commercial-Off-The-Shelf
CNO	Chief of Naval Operations
DAG	Defense Acquisition Guidebook
DataSG	Data Support Group
DAU	Defense Acquisition University
DevSG	Development Support Group
DoD	Department of Defense
DoDI	Department of Defense Instruction
DOTMLPF	Doctrine, Organization, Training and Education, Materiel, Leadership, Personnel, and Facilities
FAR	Federal Acquisition Regulation
FoS	Family of Systems

GAO	Government Accountability Office (formerly, General Accounting Office)
HFPG	High Frequency Peer Group
ICD	Initial Capabilities Document
JCIDS	Joint Capabilities Integration and Development System
JCS	Joint Chiefs of Staff
JROC	Joint Requirements Oversight Council
LCC	Lifecycle Cost
MFOP	Maintenance Free Operating Period
MOSA	Modular Open Systems Approach
MPSG	Modeling and Prediction Support Group
NAVSEA	Naval Sea System Command
NOA	Naval Open Architecture
NTWG	Near Term Working Group
OA	Open Architecture
O&S	Operating and Support (cost)
OFIPT	Operator Feedback Integrated Product Team
OMI	Operator Machine Interface
OSD	Office of the Secretary of Defense
OSJTF	Open Systems Joint Task Force
PDSS	Post Deployment Software Support
PEWG	Parameter Estimation Working Group
PM	Program Manager, Project Manager, or Product Manager
PMS 425	Program Manager, Submarine Combat Systems
RFP	Request for Proposal
R-TOC	Reduction in Total Ownership Cost

SOIPT	Sensor Optimization Integrated Product Team
SoS	System of Systems
SDWG	Sonar Development Working Group
SPWG	Signal Processing Working Group
STRG	Submarine Tactical Requirements Group
TAG	Technical Advisory Group
TEASG	Test, Evaluation, Assessment and Support Group
TIAG	Tactical Integration Advisory Group
TOC	Total Ownership Cost
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology and Logistics

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I.   Executive Summary

A.   Background

In the mid-1990s, the submarine community recognized the impending loss of U.S. technical superiority in submarine acoustics when foreign submarines began to exhibit major reduction in noise signature. This resulted in a critical need to improve acoustic sensing systems to better identify and track foreign submarines. Although new capability was critically needed, required resources were not available to support the developmental effort. Critical need and the absence of sufficient funding constituted a *crisis*—demanding a revolutionary approach to achieve necessary technological improvement.

B.   A-RCI/APB Method

The approach came to be called A-RCI—Acoustic Rapid COTS Insertion/Advanced Processing Build, which might be characterized in the following manner:

- A-RCI used a modular open systems approach (MOSA). Hardware and software development would progress on different paths and time lines. Key interfaces, standards, and protocols would be rigorously controlled as necessary to insure that different modules would work together.

- Commercial-Off-The-Shelf (COTS) technology would be encouraged, and software reuse would be accomplished where feasible.

- Innovative solutions would be sought from a deliberately broadened array of participants, including defense contractors, Government labs, academia, and small innovative businesses.

- Technical performance would be demonstrated by testing against known (that is, operationally encountered and actually recorded) real-world performance data.

- Technical decisions would be validated by peer review.

1. **A-RCI/APB Benefits:**
   - A-RCI yielded major performance and logistics improvements. A-RCI/APB regained acoustic superiority. The maintenance burden of the A-RCI/APB systems was reduced through a new maintenance approach.

   - A-RCI/APB lifecycle cost was lower as a consequence of reduced cycle time, software reuse, transition to COTS processors, maintenance-free operating periods while deployed, reduced spare part requirements, and reduced maintenance training. The lifecycle cost of A-RCI/APB has improved by nearly 5:1 over its predecessor system.

   - Software and hardware improvements could be implemented in a significantly reduced cycle time. Software Advanced Processing Builds were developed annually and improved COTS processors acquired biannually. These rates supported software updates of each submarine every two years and installation of new processors every four years.

2. **Obstacles:**
   - Traditional end-to-end operational Testing (OT) was not a good fit for A-RCI/APB. The amount of OT became a major burden and an obstacle to the rapid op tempo of A-RCI/APB development.

   - The Joint Capability Integration and Development System (JCIDS) reviews occurred at a slower pace than the A-RCI/APB op tempo. The accommodation was to conduct annual JCIDS reviews for A-RCI/ APB, synchronized to sequential developmental spirals.

   - A-RCI/APB required less funding than would have been required using a traditional approach, but additionally, the funding profiles were shaped differently. Continuous streams of RDT&E, Procurement, and Operations and Support accounts were required to support A-RCI.

C. Conclusions

The A-RCI/APB case study arrived at the following conclusions and recommendations.

1. A-RCI has successfully applied MOSA, deriving major performance and logistics improvements.

2. A-RCI demonstrated significant Total Ownership Cost or system Lifecycle Cost benefits.

3.   The A-RCI/APB example shows that MOSA can be applied successfully to a legacy system.

4.   A-RCI/APB demonstrates that modular upgrades can be accomplished very rapidly through spiral development, in contrast to the longer duration needed for traditional systems development.

5.   A-RCI/APB experience suggests there are operational test issues that must be worked out.

6.   The op tempo of A-RCI/APB and the pace of JCIDS suggest possible synchronization issues that should be evaluated to ensure appropriate joint reviews proceed without delaying the spiral development process.

7.   Funding implications of A-RCI need to be studied and understood. Traditional funding profiles do not support the A-RCI example.

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II. Background

In the mid-1990s, the submarine community recognized the impending loss of U.S. technical superiority in submarine acoustics when foreign submarines began to exhibit major reduction in noise signature. This resulted in a critical need to improve acoustic sensing systems to better recognize foreign submarines. Although new capability was critically needed, required resources were not available to support the developmental effort. Critical need and the absence of sufficient funding constituted a *crisis*—demanding a revolutionary approach to achieve necessary technological improvement. See Figure 1.
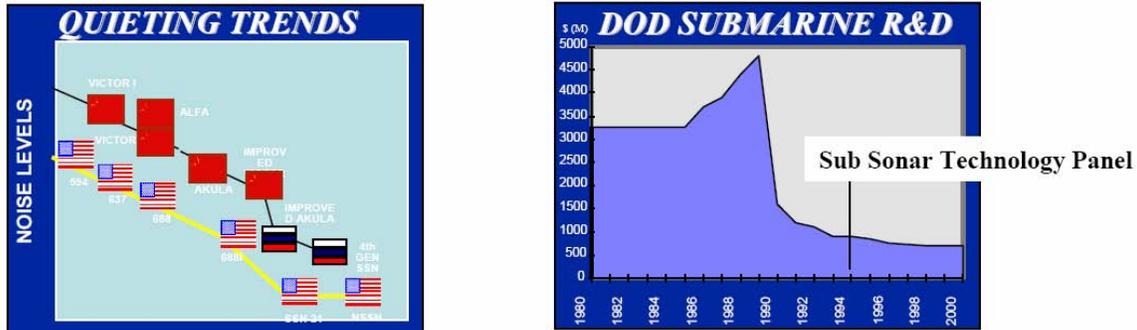
Figure 1. The "Crisis"—Slides Extracted from a Briefing by Dr. John Stapleton[1]

The approach came to be called A-RCI—Acoustic Rapid COTS Insertion, which might be characterized in the following manner:

- A-RCI uses modular open systems approach (MOSA).

- Hardware and software would progress on different paths and time lines.

- Key interfaces, standards, and protocols would be rigorously controlled as necessary to insure that different modules would work together.

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[1] John Stapleton, *Briefing*: "APB/A-RCI Performance Driven Acquisition Reform for Undersea Warfare Superiority," 26 September 2006, Slide 2.

- Commercial-Off-The-Shelf (COTS) products would be encouraged and software reuse would be accomplished where feasible.

- Innovative solutions would be sought from a deliberately broadened array of participants, including defense contractors, Government labs, academia, and small businesses.

- Technical performance would be demonstrated by testing against known (that is, operationally encountered and actually recorded) real-world performance data.

- Technical decisions would be validated by peer review.

The A-RCI approach demanded a new way of doing business.

- Technical approaches must compete on a level playing field.

- Contractual mechanisms must be established to address not only competition, but also cooperation among winning competitors once the selections were made.

- Intellectual property rights and the sharing of information must be carefully structured to achieve fairness as well as practicality.

- Rapid improvement must be brought to fielding via demanding schedules.

- The Navy's relationship with the prime contractor must change dramatically.

- The submarine user community must be intimately involved, particularly preparing for and during at-sea testing.

A-RCI took an integrated acoustic system that was difficult and time consuming to change and converted it into a federated system that could be upgraded in modules—that is, "plug and play." Such an approach was common in the private sector in the 1990s and even before. Although the idea wasn't new, the application of this approach to an existing warfighting system was daunting. As a point of reference, in the mid-1990s, IBM was struggling with similar arguments about changing the way it did business; that is, should IBM stick with mainframe computers running proprietary programs, or should the company pursue the integration of "best of breed" software solutions that could interoperate with competitors' software and run on computers manufactured by competitors of IBM?

Even today, there are arguments within the DoD about whether federated systems are a sound approach for warfighting systems.

Acoustic Rapid COTS Insertion progressed at a seemingly crushing pace, with software changes being implemented annually and hardware changes biannually. A-RCI was a "poster child" for evolutionary acquisition—because the endpoint of the effort was not clearly defined, but there was a recognized need for improvement.

The results of A-RCI were astounding cost reduction, dramatic improvement in technical performance, successful use of COTS hardware in a critical warfighting application, logistics support improvements, and an acquisition model that might have broad applicability across the DoD.

Together with A-RCI's amazing results came a series of questions that must be considered.

- Was A-RCI a one-time success, providing a model that could not be re-applied because of structural impediments within the DoD?

- Was A-RCI leadership a unique alignment of extraordinary people that brought about change but is unlikely to be duplicated for future systems?

- Is the DoD acquisition culture so rigid that it will stifle and kill future similar efforts?

- Will cooperation among the user community support similar efforts in the future?

- Are there such operational demands on the user community that they cannot tolerate the tempo of change that delivers new software or hardware technology annually or bi-annually?

- Is modular open systems architecture scaleable to large warfighting systems: fire control or command and control systems, for example?

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III. Scope

The scope of this research effort included several elements. The first was to interview key participants in A-RCI and to gain their perspective on key contributors to the success of A-RCI. Persons interviewed were asked to identify what they considered the unique A-RCI approaches and circumstances. The second element included literature research related to acquisition processes and practices, modular open systems approach (MOSA)/open architecture (OA), and written documentation related to A-RCI.

A. Definitions

Definitions of Evolutionary Acquisition, Spiral Acquisition, Modular Open Systems Approach, Open Architecture Implementation, and Acoustic Rapid COTS Insertion provide a foundation on which to base a discussion about A-RCI.

1. Evolutionary Acquisition:

Evolutionary acquisition is a developmental approach to achieve useful increments of military capability without having to delay an entire acquisition while awaiting lagging technology or awaiting clarification of the entire required end-state (objective solution). Evolutionary acquisition has recently become the preferred approach to satisfying operational needs, in an attempt to shorten acquisition cycles and place needed weapon systems into the hands of the military more quickly than in the past.[2]

2. Spiral Development:

Spiral Development is an evolutionary acquisition process used when a desired capability has been identified, *but the end-state requirements are not known at program initiation*. Requirements are refined through demonstration, user

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[2] Department of Defense, Instruction, *Operation of the Defense Acquisition System,* 12 May 2003, DoDI 5000.2, Paragraph 3.3.

feedback, and risk management. Each "spiral" provides the user an improved capability.[3]

3.   Modular Open Systems Approach (MOSA):

Modular Open Systems Approach is the breaking of systems or systems of systems into functional components—hardware and software—and then designating and controlling the key interfaces, standards, and protocols. Open standards are incorporated to ensure broadest compatibility. Conformance with these requirements must be certified by developers. MOSA is nurtured in an enabling environment. The result is "plug and play" components that can be separately updated or improved.[4,5] MOSA contains five elements that shape its technical and business strategies; these elements, or *principles*, are described in the *Program Manager's Guide: A Modular Open System Approach (MOSA) to Acquisition*, as follows.[6]

Principle 1. Establish an Enabling Environment

To adhere to this principle, the PM must establish supportive requirements, business practices, and technology development, acquisition, test and evaluation, and product support strategies needed for effective development of open systems. Assigning responsibility for MOSA implementation, ensuring appropriate experience and training on MOSA, continuing market research, and proactive identification and overcoming of barriers or obstacles that can potentially slow down or even, in some cases, undermine effective MOSA implementation are among the supportive practices needed for creating an enabling MOSA environment.

Principle 2. Employ Modular Design

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[3] Ibid.

[4] Defense Acquisition University, online course: Naval Open Architecture, CLE012; available from https://learn.dau.mil/html/clc/Clc.jsp; accessed 2 August 2006.

[5] Rene G. Rendon, *Using A Modular Open Systems Approach In Defense Acquisitions: Implications for The Contracting Process*, Acquisition Research Sponsored Report Series, NPS-AM-06-010 (Monterey, CA: Naval Postgraduate School, 30 January 2006).

[6] Open Systems Joint Task Force, *Program Manager's Guide: A Modular Open Systems Approach (MOSA) to Acquisition*, Version 2.0 (Washington, DC: author, September 2004).

Partitioning a system appropriately during the design process to isolate functionality makes the system easier to develop, maintain, and modify or upgrade. Given a system designed for modularity, functions that change rapidly or evolve over time can be upgraded and changed with minor impact to the remainder of the system. This occurs when the design process starts with modularity and future evolution as an objective. Modular designs are characterized by the following:

- o Functionally partitioned into discrete, scalable, reusable modules consisting of isolated, self-contained functional elements
- o Rigorous use of disciplined definition of modular interfaces, to include object-oriented descriptions of module functionality
- o Designed for ease of change to achieve technology transparency and, to the largest extent possible, to make use of commonly used industry standards for key interfaces

Principle 3. Designate Key Interfaces

The focus of MOSA is not on control and management of all the interfaces within and between systems. It will be very costly and perhaps impractical to manage hundreds and in some cases thousands of interfaces used within and among systems... MOSA manages the interfaces by grouping them into key and non-key interfaces. It distinguishes among interfaces that are between technologically stable and volatile modules, between highly reliable and more frequently failing modules, and between modules with least interoperability impact and those that pass vital interoperability information. Key interfaces should utilize open standards in order to produce the largest lifecycle cost benefits.

Principle 4. Use Open Standards

Interface standards specify the physical, functional, and operational relationships between the various elements (hardware and software), to permit interchangeability, interconnection, compatibility and/or communication, and improve logistics support. The selection of the appropriate standards for system interfaces should be based on sound market research of available standards and the application of a disciplined systems engineering process. In order to take full advantage of modularity in design, interface standards must be well defined, mature, widely used, and readily available. In general, popular open standards yield the most benefit to the customer in terms of ease of future changes to the system and should be the standards of choice. However, there are situations where proprietary standards are the correct choice. Standards should be selected based on maturity, market acceptance, and allowance for future technology insertion. As a general rule, preference is given to the use of open interface standards first, the de facto interface standards second, and, finally, government and proprietary interface standards. Open standards allow programs to leverage

commercially funded or developed technologies and to take advantage of increased competition. They also allow faster upgrade of systems with less complexity and cost. Bottom line, systems can be fielded that are more affordable.

Principle 5. Certify conformance

The program manager, in coordination with the user, should prepare validation and verification mechanisms such as conformance certification and test plans to ensure that the system and its component modules conform to the external and internal open interfaces—allowing plug-and-play of modules, net-centric information exchange, and re-configuration of mission capability in response to new threats and technologies. Open systems verification and validation must become an integral part of the overall organization change and configuration management processes. They should also ensure that the system components and selected commercial products avoid utilization of vendor-unique extensions to interface standards and can easily be substituted with similar components from competitive sources.

4. **Open Architecture Implementation:**

OPNAV has promulgated five OA reinforcing principles to support MOSA.[7]

- <u>Modular design and design disclosure</u> to permit evolutionary design, technology insertion, competitive innovation, and alternative competitive approaches from multiple qualified sources.

- <u>Reusable application software,</u> selected 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.

- <u>Interoperable joint warfighting application and secure information exchange </u>using common services (e.g., OA track manager) and information assurance as intrinsic design elements.

- <u>Lifecycle affordability </u>including system design, development, delivery and support while mitigating COTS obsolescence by exploiting the Rapid

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[7] Deputy Chief of Naval Operations (Warfare Requirements and Programs) (N6/N7), Requirement for Open Architecture (OA) Implementation (Washington, DC: author, 23 December 2005).

Capability Insertion Process/Advanced Processor [sic] build (RCIP/APB) methodology.

- Encouraging competition and collaboration through alternative solutions and sources.

5.   Acoustic Rapid COTS Insertion (A-RCI):

A-RCI is the spiral acquisition process applied to naval sonar systems. The approach was to break the system into hardware and software modules and then make incremental improvements to the system through upgrading the various hardware and software components. Developers were tightly linked to users, and each spiral was fully demonstrated prior to implementation.

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IV. Methodology

A. Expert Interviews

Development of this case study required discussions with persons who were intimately familiar with the A-RCI/APB processes and techniques, who were present as the A-RCI/APB initiative unfolded, and who understood the factors that contributed to its success.

B. Literature Research

Published information was used to document A-RCI outcomes, gain additional information on A-RCI/APB techniques and processes, and also to provide comparative background information. Information collected through a literature review was arranged and analyzed to gain greater understanding of the A-RCI/APB experience.

OSD and CJCS Regulatory Guidance. There is a body of mandatory and discretionary guidance published by the Office of the Secretary of Defense, the Chairman of the Joint Chiefs of Staff and by the DoD Components. Much of this material is on the AT&L Knowledge Sharing System website maintained by the Defense Acquisition University (DAU) for the Under Secretary of Defense (Acquisition, Technology and Logistics), USD (AT&L). The site provides current web-based materials that govern defense acquisition. Defense acquisition policy and processes are addressed in the DoD 5000 series.

Policy and practice on identification and documentation of user capabilities are addressed in the CJCS 3170 series.

1. Other Published Materials:

These include books, journals, periodicals, Government documents, reports, best practices, theses, studies, speeches, and briefings. Much has been written on

federated systems, Acoustic Rapid COTS Insertion (A-RCI), Modular Open Systems Approach (MOSA), and spiral acquisition.

The Defense Acquisition University has developed and compiled educational materials on spiral development and MOSA best practices and has placed significant materials online. Naval Open Architecture is a "Special Interest Area (SIA)" on the DAU Acquisition Community Connection website. This SIA site provides Navy Guidance on open architecture and offers useful tools and perspective, much of it derived from A-RCI/APB experience. The site provides a link to a self-paced learning module on Naval Open Architecture. The Naval OA SIA is an excellent site for anyone interested in using a modular open system approach (MOSA) to hardware and software development.

In addition to the DAU websites, there are other significant materials that are web accessible, including the Open Systems Joint Task Force website.[8]

Finally, considerable associated work has been commissioned by the Program Manager, Naval Open Architecture, Program Executive Office for Integrated Warfare Systems (PEO IWS).

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[8] Open Systems Joint Task Force, http://www.acq.osd.mil/osjtf/, Department of Defense, Accessed 28 October 2006

V. Data and Analysis

A.   The Crisis

During the mid-1990s, it became apparent that the U.S. Navy had lost its
acoustic superiority with the introduction of "quieting" technologies in other nations'
submarines.[9] At the same time, the Navy's priorities did not support funding a large
developmental effort as would have been undertaken during the Cold War. Not only
was there insufficient funding, there was not time: developmental programs for
warfighting systems stretched over ten or more years. Improvement in the Navy's
acoustic capability presented an immediate need, unsupported by necessary
funding. For submariners, this indeed was a *crisis.*

B.   The Strategy—Modular Open Systems Approach

Navy developers had to try a new approach in response to their crisis. Their
answer was a modular open systems approach. Federated systems were being
developed and used widely in the private sector, but such an approach was not well
understood for naval warfighting applications. In retrospect, it might seem that the
Navy was far behind commercial practice, but IBM was struggling through similar
difficulties during a corporate restructuring at roughly the same time. IBM's strategic
decisions were wrapped around some of the same concerns as A-RCI—the need to
tap innovative, cost-efficient software applications sought by IBM's customers, the
need for software called "middleware" that applications could link to, and portability
that would allow the software to be successfully operated on different hardware
platforms.[10]

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[9] Richard Scott, "Open for Business: a New Model for Submarine Sonar," *Jane's Navy International*, 1 March 2006.

[10] Louis V. Gerstner, Jr., *Who Says Elephants Can't Dance: Leading a Great Enterprise Through Dramatic Change* (New York: HarperCollins Publishers, 2003).

As noted above, A-RCI was a response to a difficult situation at a time when other entities were wrestling with similar problems; however, that does not provide a sufficient rationale for writing a case study. The A-RCI case study is worth relating because of the creative approaches taken by the submarine community. The path that A-RCI took was multifaceted, and the approaches used are instructive for others considering MOSA. The A-RCI effort was also daunting and, in many ways, inspiring.
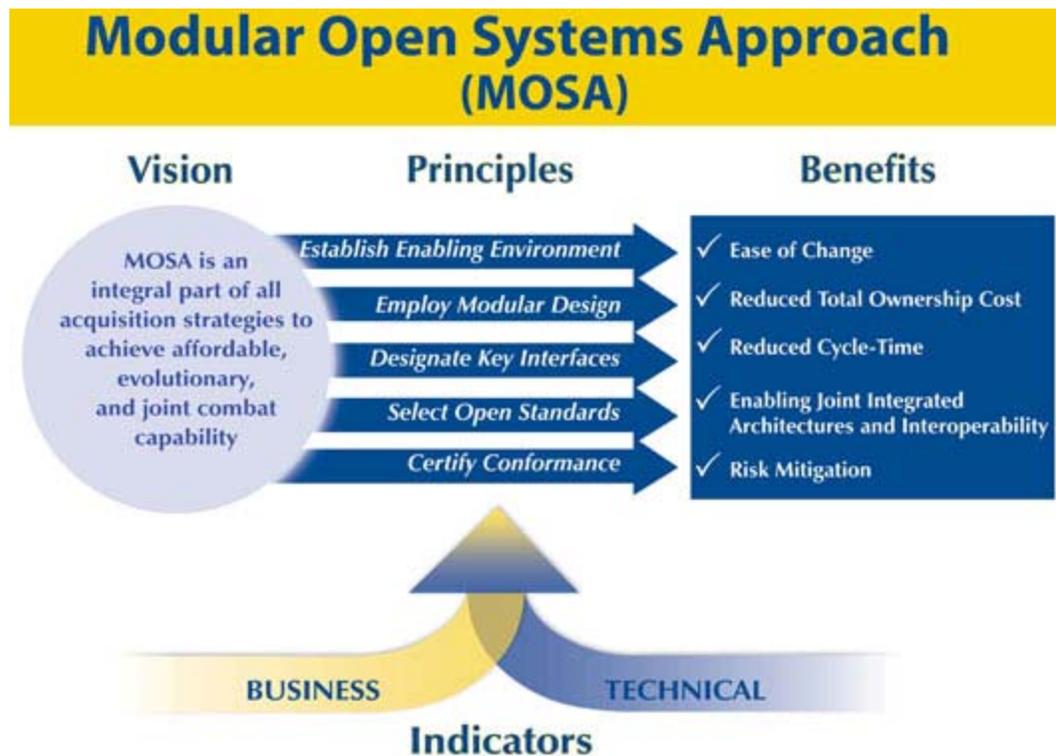
Figure 2. Modular Open Systems Approach (MOSA)[11]

Legacy Systems such as an existing submarine sonar system circa 1990 were not modular in their design. Therefore, the early A-RCI effort required modularizing the sonar systems. It is important to note that upgrade of a legacy system today might first require a business case analysis of whether modularization

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[11] Open Systems Joint Task Force, *Program Manager's Guide: A Modular Open System Approach (MOSA) to Acquisition*, Version 2.0 (Washington, DC: author, September 2004), 3.

is feasible and the best approach. For example, it might not make business sense to modularize a system whose replacement is entering its production and deployment phase.

It was necessary, then, that the operational community (i.e., submarine operators) accept operational limitations while the system was being modularized. In modularization of A-RCI, it was necessary in the first APB for the user temporarily to accept an operational compromise (limiting the towed array sonar to a single display station) rather than to retain the freedom to use any of the several onboard displays for towed-array sonar or any of the other sonar systems.

A-RCI's pursuance of modularity led to separation of hardware and software for purposes of system improvement. In this way, processors (the hardware) could be commercial-off-the-shelf (COTS) and could be upgraded in consonance with the evolving commercial market. The application software could be developed separately from the processors as long as the two would interoperate through use of transportable middleware. The transportable middleware provided freedom to run application software on different processors. All this was made possible through the control of key interfaces.

System modularity enabled acquisition speed and focus, facilitating change to parts of the system where necessary, while leaving other components undisturbed. Although this aspect might sound almost trivial, modular systems are very different from fully integrated systems, in which small software changes may have major unexpected consequences in functions that are seemingly unrelated to the change.

A requirement of MOSA is that the key interfaces must be carefully controlled. Although not trivial, the control of *key* interfaces is much easier than trying to understand and control *all* the internal interfaces within a large, fully integrated system. This is especially applicable when integrating COTS components where some interfaces are not accessible and, therefore, not controllable.

The A-RCI developmental process included a Build/Test/Build sequence. For A-RCI, the developmental processes required a thorough demonstration of new technical capabilities to verify system improvement. New system capabilities were compared to previous system capabilities. Additionally, new competing systems were compared one against another. A-RCI was able to demonstrate system upgrades through the use of recorded operational events. In this way, competing systems could be judged on their ability to process and display *real data* recorded during *actual* operational events. Competing systems could be peer reviewed both realistically and "on a level playing field," a situation that permitted competitive solutions to be judged solely on their merit.

1.   **MOSA Business Strategy:**

A-RCI evolutionary strategy was that software changes would be accomplished *annually* through a developmental effort called Advanced Processing Builds (APBs), while COTS processors (the hardware) would be selected *bi-annually*. This was a highly demanding acquisition "op tempo."

MOSA encourages materiel developers to broaden communication links with users, contractors, and research labs in order to orchestrate both a competitive and collaborative effort.

The competitive "playing field" had to be set up to attract innovative contractors who might be new to DoD contracting or might be intimidated by large prime contractors. Competition had to focus on best ideas and best performance, not on politics and not on a preordained hierarchy of competitors—that is, a competitive and *level* playing field where the best technical solutions would "win."

Intellectual Property rights had to be respected, while at the same time, data and design information needed to be shared through mechanisms that were perceived as fair to competitors. A-RCI/APB processes and structures were required to facilitate the competitive, collaborative environment. Intellectual property rights and the protection of proprietary data were addressed and controlled within the terms and conditions of the contract. These legal issues had to be worked out "on

the fly" during the A-RCI/APB effort. Today, as a result of A-RCI and other MOSA efforts, there is helpful guidance that can be used in constructing contracts. The Naval Open Architecture Contract Guidebook, Version 1, was published 7 July 2006, and provides suggested language that may be included in Sections C (i.e., in the Statement of Work), L, (Instructions to Offerors in the RFP) and M (Evaluation Factors in the RFP).[12] For the reader not familiar with contracting, the RFP is a document typically used by Government contracting activities, inviting potential contractors to compete for work by submitting their proposals. The RFP and the contract itself are arranged in accordance with the uniform contract format, which is described in the Federal Acquisition Regulation (FAR).

The A-RCI experience illustrated that open code and sharing of code enabled collaboration and enhanced the success of open systems design. However, intellectual property rights and proprietary information must be respected. Several practitioners associated with A-RCI/APB have made the point that intellectual property rights to portions of a warfighting system can hold the system hostage and prevent its continued improvement or reuse. Prevailing thinking was that intellectual property rights should be made available as part of the price of entering into the competition. In that way, code and design information could be shared with other participants to maximize progress. This thinking is consistent with the *NOA Contract Guidebook*, which states, "The U.S. Government's (hereinafter "Government") ability to acquire at least Government Purpose Rights (GPR) to data and intellectual property and to minimize proprietary elements to the lowest component level is critical to this effort."[13]

Each development "spiral" contained a highly competitive demonstration period, but collaboration and information sharing were expected. In A-RCI/APB, the collaboration was characterized as "winning together."

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[12] Program Executive Officer, Integrated Warfare Systems 7, *Naval Open Architecture Contract Guidebook*, Version 1 (Washington, DC: author, 7 July 2006).

[13] Ibid., 3.

All A-RCI participants had to be acutely attuned to the schedule. If competitors were unable to stay on schedule, they had to be left behind for that spiral. Rigorous adherence to schedule—schedule discipline—was a necessity to meet promised customer delivery dates.

C.   Changing the Culture

In reaching out to small innovative contractors, large contractors, academic labs, and Government activities, it was necessary in the case of A-RCI to change the nature of the "prime contractor." Retention of the prime contractor relationship would have been "business as usual" and not conducive to the participation by small innovative contractors and other non-traditional players. The outcome was that the prime contractor was removed from the source selection process and became the "prime system integrator." The competing solutions were demonstrated using real-world recorded sensor input, and the best solutions were selected through "peer review," which is further described below. A-RCI and APB upgrades—COTS processors and improved software algorithms—that successfully emerged from Build/Test/Build were handed over to the prime system integrator for integration and installation aboard submarines.

APB Keys to Success

No One Organization has the Whole Story
• SDWG members are experts in their field
• Organizational boundaries and biases are minimized

Peer Review of New Developments
• Tap expertise of all organizations early in cycle
• Ensure only the "Best of the Best" goes forward

Data Driven Testing ("Build-Test-Build")
• Use actual recorded sea data (including targets of interest)
• Prove algorithms on real world data while still in development

Verify Algorithms Prior to Implementation
• Perform modeling of new algorithms using several environments
• Generate "Consumer Reports" to document predicted performance

Significant Fleet Involvement
• Fleet members on SDWG and associated working groups
• Allows rapid feedback into development process

Continuing Assessments and Measurements
• Measure transition effectiveness
• Identify Improvement Areas

Figure 3. Advanced Processing Build Keys to Success[14]

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[14] Sonar Development Working Group (SDWG), *1998-99 Year in Review* (Washington, DC: author, 15 September 1999), 5.

Peer Review of New Developments is recognized within the A-RCI/APB program as being one of the primary reasons for success (See Figure 3, above). The Navy took a page out of academia and adapted it to ensure a fair playing field for competitors that would ensure selection of the best alternatives for further development. Peer review of Advance Processing Builds (APB) was conducted under the oversight of a Navy Program Manager and trusted advisors. Oversight of Peer Review is uniquely challenging and, at least in the A-RCI/APB experience, the PM needed the following characteristics to be successful.

1.   Technically Competent

Able to understand and work through the relevant technical issues.

2.   Proactive

Involved in the process and focused on performance and product delivery. Able to work in a competitive environment with multi-organizational intrigues while participants jockeyed for position.

3.   Disciplined/Structured

Willing to enforce professional and disciplined interaction among organizational entities to achieve an orderly and functional process.

The *peers* included fleet (user) representatives, algorithm developers, and evaluators. The program office, together with trusted advisors, selected persons with professional reputations for individual excellence, coupled with demonstrated ability to place Navy interests above organizational agendas. Peer appointment was announced by e-mail and in meetings. The announcements were made with sufficient formality or gravity that selection of peers was treated seriously, and such an appointment was sought after.

1.   Peer duration varied

In some cases, peers have served from 1997 through the present (2006). In other cases, peer duration was a year or two. Fleet representatives typically have served until their change of assignment—generally one or two years.

2. Peer funding differed according to circumstances

Participants were funded by one or more of the participating program offices for the time they spent on the peer group. This varied from ¼-time for meeting attendance and advice to full-time for peer group members who planned and conducted evaluations.

3. Peer group structure designed for flexibility

Different peer working groups were established. Two examples are the Automation Working Group and the Signal Processing Working Group (See 1998-99 Peer Working Groups at the right side of Figure 4, below.) Over time, the peer working group structure evolved as needs dictated. In some cases working groups merged; in other cases, groups disbanded when their work was completed.
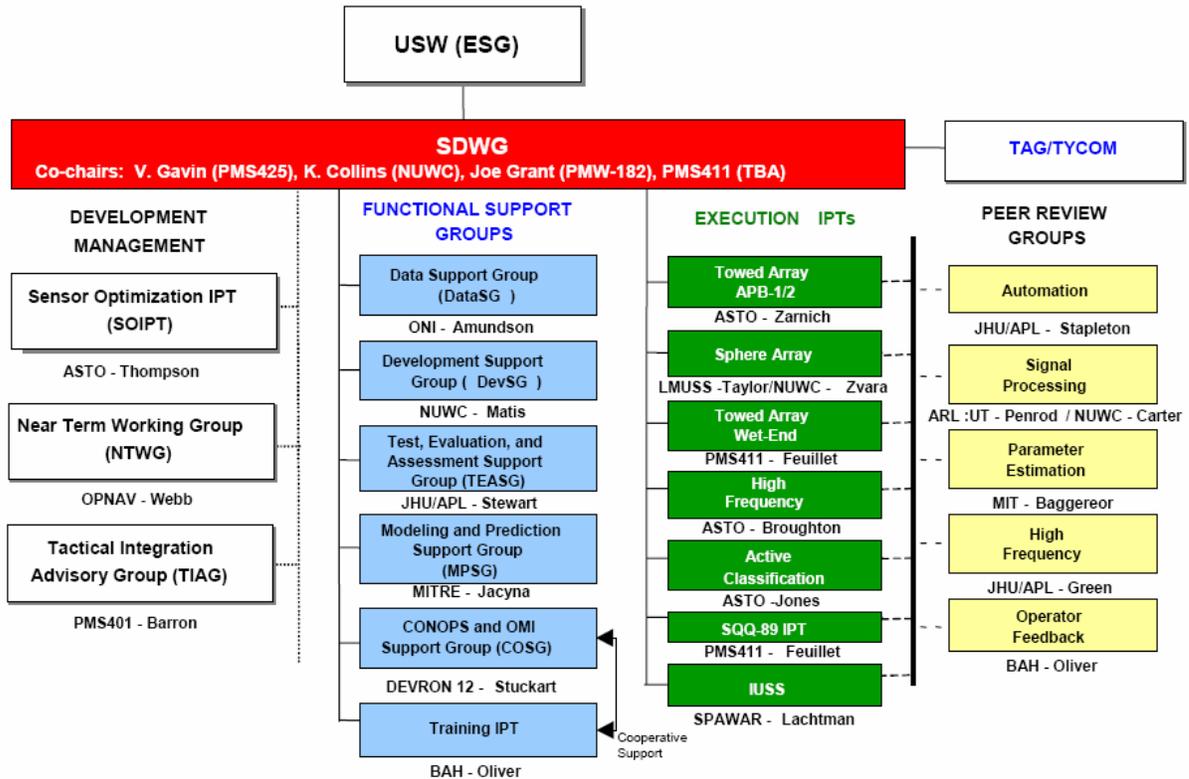

Figure 4. Sonar Development Working Group[15]

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[15] Sonar Development Working Group (SDWG), *1998-99 Year in Review*, (Washington, DC: author, 15 September 1999), 5.

1.   **Documentation:**

A partial list of peer group *documentation*, which guided the peer groups and reported their progress, is provided for illustrative purposes as follows:

- Advanced Processing Build Instruction, circa 2000.
- Briefings (in viewgraph format) for new developers, summarizing "rules of the road."
- Year in Review reports.
- "Snapshots" of metrics.
- Peer group evaluation reports as APBs progressed through Steps 1-4.
- Memoranda of Understanding of among various stakeholders.
- Checklists to guide algorithm developers through the approval process.
- Descriptions of open and closed data sets, against which the APBs would be tested.

Other Peer Group documentation includes the following outside studies.

- Air Force COTS study that reviewed A-RCI.
- NDIA Study of APB/A-RCI.

2.   **Systems Engineering:**

In the case of A-RCI/APB, a Systems Engineering Process (SEP) and structure were needed for guiding and synchronizing the work of the various players, accommodating a *complex* testing regimen, carefully controlling key interfaces, and incorporating standards to enable interoperability of hardware and software. During development, software took shape under the direction of the NAVSEA's Advanced Systems Technology Office (ASTO). Software development was accomplished by small innovative contractors, academic research labs, and Government labs participating competitively and collaboratively. But these entities were not, as yet, organized under a prime contractor. Later in the process, software development was consolidated under the direction of a software APB integrator. Following a cycle of Build/Test/Build, hardware and software systems and components were handed-off to the prime system integrator for assembly of the upgrade package and

installation onto submarines. All of this occurred at a rapid op tempo. As may be
envisioned, no single contractor was perfectly positioned to accomplish SEP from
beginning-to-end—as a prime contractor would have done in a traditional
development. Beyond the question of *who* should be responsible for the Systems
Engineering Process, end-to-end, over the entire developmental cycle, spiral
development required repetitive developmental cycles—further complicating
management of the SEP.
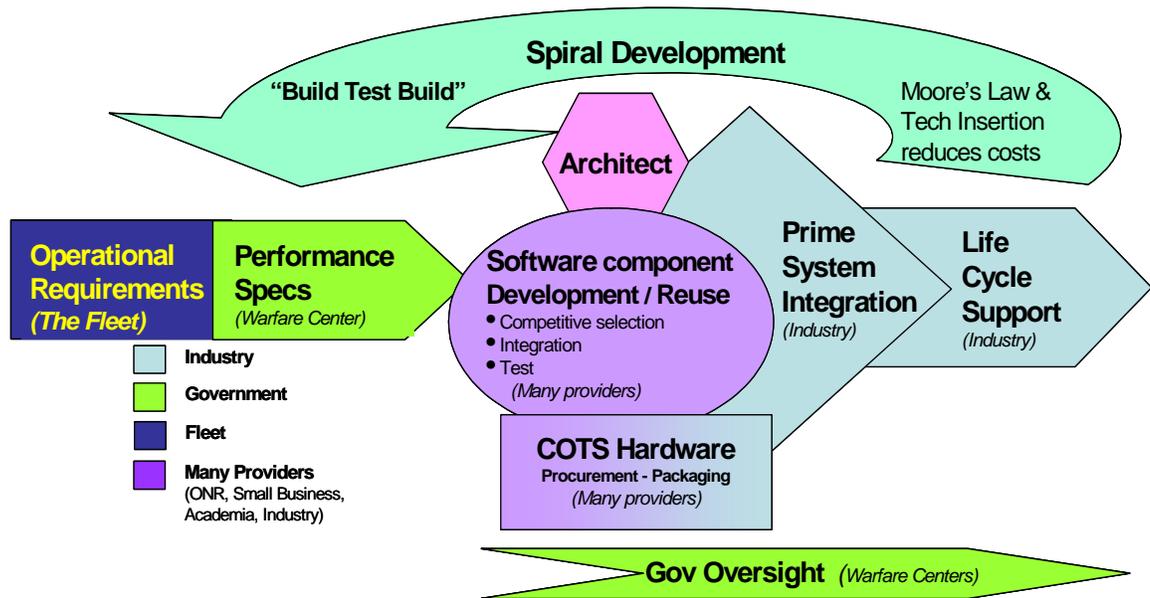
Figure 5. System Development Model[16]

A-RCI systems engineering was led by the Navy's PMS 425 using an IPT
arrangement. (See the process depiction in Figure 5, above.) Typically, the
applicable warfare center would have been the Systems Engineering Technical

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[16] C. E. Barron, "Naval Open Architecture Acquisition Approach (Draft): A Proven Acquisition Model
for a National Security Systems Acquisition in an Environment Dominated by Commercial Off the
Shelf Technologies" (Draft, August 2006), 15.

Authority (or Technical Design Agent as it was called at the time). But, in this situation, NUWC, the applicable Warfare Center, was a competitor in the Advanced Processing Build and could not perform both functions without at least the perception of "tipping" the playing field in their own favor. Responsibility for managing the A-RCI/APB Systems Engineering Process eventually would be handed off to the prime system integrator, Lockheed Martin; LM participated, therefore, as an important stakeholder throughout the SE IPT. Once again, prior to final integration, Lockheed Martin could not manage the SEP without risk to the competitive level playing field; but, they needed to be involved to help insure a smooth transition during system integration and installation. For future programs, SEP responsibility might reside with the Government materiel developer (or be separately contracted) during testing and Peer Review before being handed off to a prime system integrator. Needless to say, SEP management is potentially a serious risk area. On one side of the balance, the Government PM office might not have the necessary staffing for managing SEP; on the other side, contracting out SEP might damage the necessary sense of trust and confidence in a competitive level playing field.
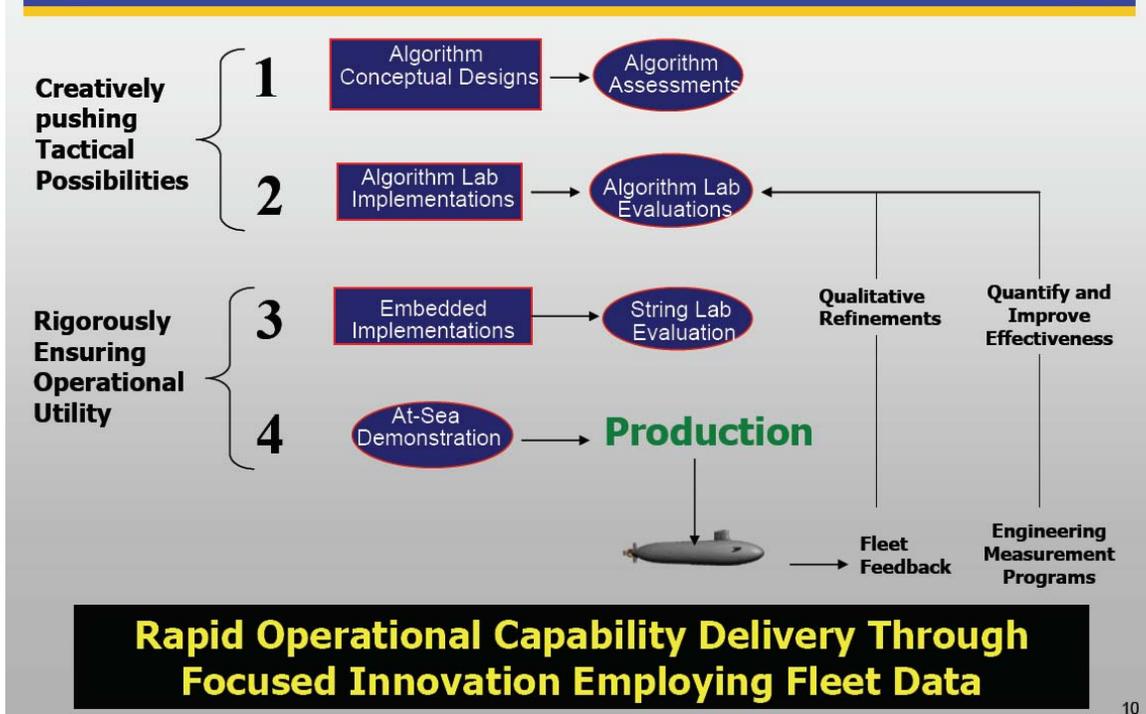
Figure 6. The 4-Step Process[17]

3. The 4-Step Process:

The rapid op-tempo of annual Advanced Processing Builds (APBs) was accomplished through a 4-Step Process, shown in Figure 6, above. Further description of the 4-Step Process is extracted from the SDWG *1998-99 Year in Review* Report to clarify the process[18]:

Step 1. Algorithm Survey:

Step 1 is a survey of promising algorithms from the R&D community including 6.2 and 6.3 activities, Office of Naval Research (ONR), Defense Advanced Research Projects Agency (DARPA), Industry Independent Research and

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[17] John Stapleton, *Briefing*: "APB/A-RCI Performance Driven Acquisition Reform for Undersea Warfare Superiority," 26 September 2006, Slide 2.

[18] Sonar Development Working Group (SDWG), *1998-99 Year in Review*, (Washington, DC: author, 15 September 1999), 3-4.

Development (IR&D), Broad Area Announcements (BAA's) and related Navy programs such as the Submarine Security Program and the Integrated Undersea Surveillance System (IUSS) community. The goal of Step 1 is to consider algorithms developed on other Navy funds and to determine their tactical importance, maturity, expected performance and computational resource requirement.

Step 2. Algorithm Testing:

Step 2 is a test of relatively mature algorithms that promise to provide performance improvements to the fleet. They transition to Step 3 based on tested performance using common data sets and common metrics developed by a working group of technical principals in conjunction with the developers and fleet representatives. Utilizing real world data sets collected from U.S. submarine exercises and provided by the Office of Naval Intelligence (ONI), this testing provides a projection of algorithm performance using real world ocean noise and target signatures of interest. Experience has shown that testing on synthetic data does little to uncover problems or project performance for sonar algorithms in fleet use. The APB Step 2 process is unique in that developers submit algorithms for testing with the expectation of useful feedback from the testing process. Algorithm promotion to Step 3 is based on acceptable performance as determined by the cognizant Peer Review group.

Step 3. String Testing:

Algorithms that demonstrate acceptable performance during Step 2 testing are passed to an integration agent for incorporation into an end-to-end sonar processing string on the IDP Multipurpose Processor (MPP) baseline. This processing string is called an APB. The Step 3 test, conducted by the Test, Evaluation and Assessment Support Group (TEASG) arm of the SDWG, [Groups descriptions are provided at Appendix 2.] provides an opportunity to independently test the APB string for compliance with performance requirements as well as fidelity with Step 2 performance results. It also serves to introduce fleet representatives to the new features in a string context and provide for fleet feedback. Similar to Step 2, real world data sets are used for this testing. Any identified issues resulting from the Step 3 testing are then forwarded to the integration agent for resolution prior to at-sea testing. Independent testing of the APB product is a critical step in the build-test-build process. It ensures readiness for at-sea testing and provides confidence to the community contributors that their ideas have been implemented properly.

Step 4. At-Sea Testing:

Step 4 is the at-sea test for APB, again conducted by the TEASG. This is the most important phase of testing the algorithms prior to inclusion in the IDP baseline and provides information on how the fleet sonar team interacts with the APB in time for enhancement or corrective action. The test provides the opportunity to verify APB algorithmic performance and collect calibrated data

for future use. The TEASG is also responsible for the evaluation and assessment of the test results as well as interpretation of algorithm and system-level results. (NOTE: The at-sea test conducted by the TEASG is not intended to serve as system certification. System certification is accomplished by the cognizant program office via separate testing after full integration of the APB into the baseline system.)

At the completion of Step-4 testing, the APB is delivered to the program office for integration into the baseline system. To assist in the successful transition of APB improvements, a Systems Engineering Working Group is established during Step 3 of the process (and continues through Step 4). This group ensures that issues related to the APB integration into the baseline sonar system are resolved as early as possible in the development cycle and that systems-level requirements are factored into the APB product. In Step 3, the group also initiates development of any required program office documentation such as specifications and change proposals to ensure the baseline system can readily incorporate the APB product.

The APB and IDP partnership (via ARCI introduction) have demonstrated that the Navy can affordably develop advanced acoustic processing capabilities and annually transition these new capabilities to submarine platforms in quantity.

4.   User Participation:

Involvement and stakeholder buy-in were major contributors to focusing and speeding the A-RCI/APB processes. The Submarine Tactical Requirements Group (STRG) set A-RCI/APB requirements that initiated each spiral. Beyond that, user groups provided feedback in such areas as ease of operation, suitability of configuration, required training, and supportability, for example. Users, of course, were heavily involved in at-sea testing and during submarine retrofit periods. Additionally, A-RCI user participants served as a communication link between developers and fleet users. The ensuing dialogue contributed substantially to sailor acceptance of A-RCI/APB in the fleet.

Communications Forums. Participation in essential dialogue involved many different forums and extended through each developmental sequence and into the next. The importance of dialogue between users, materiel developers, and

contractors cannot be overemphasized. To provide a glimpse into the intensity of communication, the different integrated groups that assisted A-RCI/APB are described in Appendix 2, extracted from Chapter 2 of the Sonar Development Working Group (SDWG) *1998-1999 Year in Review* report.[19]

In summary, at least six facets combined to make the A-RCI culture change revolutionary within the DoD. First was changing the nature of the prime contractor to a prime system integrator. Second was gaining the participation of non-traditional technical participants who brought fresh, innovative ideas. Third was the peer review process which leveled the competitive playing field, allowing good ideas to freely compete. Fourth was the op tempo of the spirals—annual software Advanced Processing Builds and bi-annual processor refreshment. Fifth was the intimate user participation. Sixth was the intricate communications structure that supported A-RCI/APB. In the aggregate, this effort took heroic commitment by many different parties who historically were not "friendly" or cooperative. How could this cultural change be catalyzed? Part of the answer lay in process and contractual mechanisms. Part also resulted from leadership, which is discussed below.

D.   Leadership

Strong leadership is essential to proactive change. Several of the A-RCI leadership aspects are as described below.

Mandate. Senior leaders provide pressure to change. Without this "forcing function," it is difficult for mid-level leaders/managers to achieve major change. In the case of A-RCI, senior leaders told the acoustic systems office to "make something happen." At the same time, senior leadership provided top-cover—protection from above—and empowered people to innovate. There were undoubtedly elements of positive and negative motivation; participants both wanted to effect change and also had the sense that if they could not get the job done, they

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[19] Sonar Development Working Group (SDWG), *1998-99 Year in Review* (Washington, DC: author, 15 September 1999), 8ff.

would be replaced. The "mandate" has to be balanced—in the case of A-RCI, senior leaders upheld such balance extraordinarily well, judging by the outcome.

Mid-level Leadership. A-RCI appeared to have excellent leaders in various positions who accepted the challenge and effected change. Several of the A-RCI stakeholders interviewed clearly saw themselves as empowered *agents of change*; they expanded "the vision," were not timid about making decisions, did not allow themselves to be defeated by bureaucratic obstacles, and motivated others to act. It is quite apparent with A-RCI that senior leadership vision required capable leaders at different levels and in different organizations to "take charge." This is what led to A-RCI's success.

Mr. Bill Johnson, deputy program manager, PMS 425B, Submarine Combat Systems, outlined specific leadership actions along the following lines:[20]

- Set and maintain the vision. Keep it simple and consistent.

- Develop a strategy to implement the vision. The A-RCI strategy incorporated a mixture of management, technical, and business aspects.

- Develop and cultivate allies at all levels. A-RCI included industry, Congressional members, senior leadership, a broad array of stakeholders within the developmental community, and fleet users.

- Instill within the team a sense of empowerment and entrepreneurial spirit. A-RCI encouraged members of their team to think and act like leaders.

- Set the expectations for excellence and the operational pace. The A-RCI leadership team established aggressive goals, supported by rigorous processes that paced the developmental effort.

In the aggregate, A-RCI worked because stakeholders, "formed a community that learned to be comfortable with change—not just technical things or even business processes. The real change involved learning to work with new people

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[20] William M. Johnson, "The A-RCI Process—Leadership and Management Principles*," Naval Engineers Journal* 116 (Fall 2004): 102-3.

from places we'd never dealt with before."[21] This is a reflection of a new leadership vision that was widely embraced by A-RCI participants.

E.   User Participation

Participation and buy-in were major contributors to focusing and speeding the process. The Submarine Tactical Requirements Group (STRG) was the user group that identified the required capability to be developed during each spiral. This activity provided user focus to A-RCI. The work of the STRG was very important to the user/developer dialogue; it set priorities and described to the developer community the relevant functional "shortfalls" or "opportunities."

Just as with other programs, there were many "voices" of the user. A group of Senior and Master Chiefs provided invaluable human system integration (HSI) insights. Their work provided feedback on APBs, processors, and displays. They also challenged sonar training by testing the competency of sonar technicians; this testing led to enhanced training that improved the detection skills of these technicians. The Senior and Master Chiefs thoroughly bought-in to A-RCI/APB improvements; for the first time, they could identify shortfalls and see resultant improvement by their next at-sea deployment. The Chiefs played an important role in getting the fleet to support sonar upgrades. They generated excitement in the fleet because system improvements could now arrive in time to be used by the sailors who had helped articulate and describe the needed improvements.

Operational users were heavily involved in at-sea testing and during submarine retrofit periods. This demanded system upgrade time, training time, and operator feedback.

Support of A-RCI may have pushed some within the user community well beyond their comfort zone. For example, modifications to training packages were very demanding, for trainers and students alike. Additionally, upgrades in hardware

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[21] William M. Johnson, personal e-Mail, 24 October 2006.

and software placed extra burdens on submarine crews while in port. At-sea testing of APBs and COTS hardware undoubtedly placed additional workload on submarine crews.

F.   Measurable Effects

1.   Technical Performance:

Within eighteen months, A-RCI had provided a 7-fold increase in processing capability. New algorithms provided clearer sonar information over longer engagement duration.

- Mean operator success rate increased by a factor of 4.
- Mean number of false alarm reduced by 40%.
- Detection and classification time improved by 27 minutes.
- Mean hold time improved by 25 minutes.

**Towed Array Processing
Performance Improvement Trend**

	AN/BQQ-5	A-RCI/APB-98	A-RCI/APB-00
Mean Operator Detection Success Rate	23%	49%	87%
	Improved by a Factor of ~ 4		
Mean # of False Alarms Per Run	1.0	0.92	0.58
	False Alarms Reduced by 40%		
Mean Initial Detection & Classification Time (When Detection Occurred)	Baseline	9 Min Earlier	27 Min Earlier
	Improved by 27 Minutes		
Mean Contact Holding Time* (When Detection Occurred)	Baseline	10 Min Longer	25 Min Longer
	Improved by 25 Minutes*		

Measured holding time limited by the length of recorded tape.   July 2002

Figure 7. Performance Improvement Trend[22]

2.   Reduced Lifecycle Cost

The Navy is currently validating a historical cost comparison of A-RCI and its predecessor system. Preliminary results compiled from 10 years of data on both A-RCI and its predecessor indicate that lifecycle cost has improved by nearly 5:1. This comparison includes development, production, and maintenance costs.

3.   Cost Avoidance

A-RCI provided many examples of cost savings/cost avoidance.

a.   Processor Cost

Processing cost was reduced by a factor of 60, that is, 1/60th the previous processing cost which had resulted from specially developed processors. [23]

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[22] William M. Johnson, *Briefing*: "Acoustics-Rapid COTS Insertion: A Changed Approach to Modernization," Unpublished, Slide 18.

b. Cost of Obsolescence

Although not quantified, there were two aspects to ARCI's obsolescence costs. First was use of upgrade to avoid paying the high cost required to provide outdated, scarce components. Second was harvesting obsolete components that had been removed from upgraded systems to support older systems that had not yet transitioned through upgrade.

c. Cost of Post-Deployment Software Support (PDSS)

Once modularized, post-deployment software support was less expensive. That is, software changes made to modular components were less complex (therefore, less expensive) than changes made to fully integrated systems. The reason was that the changes must be carefully controlled at key interfaces, but there was less work required to deal with unexpected secondary effects. The new application software was "plug and play," with minor or no changes to the middleware, while most other (unaffected) application software was simply reused. The portability of modular software to other systems and other platforms offered additional opportunity for PDSS cost savings or cost avoidance. In the A-RCI example, application software used in submarines for towed-array sonar might also be used in spherical, hull, and high-frequency sonar systems. That same application software might further be used in (or possibly originate from) surface ship sonar or aircraft anti-submarine warfare applications.[24]

d. Other Logistics Support Costs

Additional cost avoidance has accrued from logistics aspects of A-RCI, as shown below.[25]

- o Inventory, valued at $600 million was converted to Just-in-Time contractor-provided support. This initiative avoided $2 million in Navy Working Capital Funds.

- o Interactive multimedia instruction avoided $19 million.

- o Outfitting spares reduction avoided $3 million.

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[23] William M. Johnson, "The A-RCI Process—Leadership and Management Principles," *Naval Engineers Journal* 116 (Fall 2004): 101.

[24] Robert Zarnich, Briefing to Repository Workshop, "ASW Enterprise Open Architecture," 21 February 2006, Slides 19-23 incl.

[25] William M. Johnson, *Briefing*: "Acoustics-Rapid COTS Insertion: A Changed Approach to Modernization," Unpublished, Slides 19-20.

- o Interactive Electronic Technical Manuals (IETMs) avoided cost of more than $1 million.

4.   Logistics Impact

A-RCI impacts on logistics were generally very positive.

a.   Integration

In A-RCI/APB, systems development and logistics were integrated, obtaining several benefits. Software technicians who responded to "trouble calls," were also programmers—with the result that finding weaknesses in fielded software led to improvements in future Advanced Processing Builds. Additionally, many of the software products were re-used in Interactive Electronic Technical Manuals (IETMs), training devices, and in training curriculums. The system developer-logistician integration not only saved resources but also sped up logistics support—which typically lags behind system introduction. For A-RCI predecessors, "training lags of three years were not uncommon. Today, [A-RCI/APB] training lag time is measured in days."[26]

b.   Training

Modularized systems generically (and in the case of A-RCI) have the potential to reduce training burdens. Training packages, or portions thereof, could potentially be re-used—not only across systems but across platforms.

Sometimes offered as a criticism of A-RCI, operators and maintenance technicians needed frequent updates and, possibly, needed to be familiar with multiple generations of sonar systems. However, as cumbersome as this seems, it may have been no more difficult than in the past. Multiple generations of warfighting systems in service at the same time have been a fact of life for many years across the DoD. Nevertheless, there seems little question that the rapid op tempo of A-RCI evolutions did present training challenges for operators and maintainers.

c.   Maintenance Free Operating Period (MFOP)

One A-RCI initiative that was unforeseen at the outset was the creative employment of spare components in a way that reduced the need for

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[26] William M. Johnson, personal e-mail, 24 October 2006.

"open cabinet" repairs to sonar systems while on deployment. MFOP became feasible because commercial processors take less space than their developmental predecessors. It was found that sonar system spare components could be installed and fully powered in electronics cabinets, enabling them to be used in the event of a primary system malfunction. Then, if a system failure occurred in the operating system, that function could be switched to a "spare" module without physical access to the cabinet. The necessary quantities of "plugged-in" spares were calculated that would achieve a high likelihood of continued operation. As a result, "open cabinet" maintenance while underway has been virtually eliminated. MFOP has been a success in terms of quality of life because open-cabinet repair while underway was difficult to accomplish. There also have been system readiness ramifications because operational availability has increased. Finally, there have been maintenance-strategy implications, because now open-cabinet maintenance can be accomplished almost exclusively by contractor personnel after completion of a deployment.

- o A-RCI has demonstrated that system upgrades can include logistics focus. Maintenance Free Operating Period (MFOP), described above, is an example of logistics focus.

- o As previously pointed out, modularization impacts LCC through less expensive replacement of obsolete hardware and software.

- o PDSS is simplified because software is re-used where possible. A-RCI has also shown that much of the necessary maintenance can be shifted to contractor logistics support (CLS); demonstration has shown that some software defects can be addressed remotely by CLS, using secure networks.

- o The A-RCI experience has shown that the character of sonar training has changed. It has been re-focused to address performance weaknesses. Some maintenance training has been reduced or eliminated as the result of MFOP, providing the potential for increased employment training. Upgraded training packages still are necessary, of course, to achieve full benefit of the system modifications.[27]

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[27] Gibson Kerr, "COTS: We Can't Afford to Do It Any Other Way," US Naval Institute, *Proceedings* Vol. 132/10/1, no. 244 (October 2006): 69.

G. Other Ramifications

### 1.	Portability and Software Re-use

The portability of modular software to other systems and other platforms offers additional opportunity for cost savings or cost avoidance. In the A-RCI example, application software used in submarines for towed arrays has been re-used in spherical, hull, and high-frequency sonar systems. That same application software also has been, or potentially will be, used in surface ship applications and even in aircraft ASW applications. In addition to the potential cost savings or avoidance in software development and the use of common processors, there is also an expected reduction is PDSS.

### 2.	Scalability

One of the questions resulting from A-RCI is whether the modular open systems approach is applicable in larger, more complicated applications. For example, is MOSA applicable to other submarine systems, surface ship systems, aircraft, system of systems like the Army's Future Combat Systems, or even National Missile Defense? Portions of this question have been answered already, as described below.

### 3.	Implementation

Two warfighting systems, Virginia Class Submarine and E-2 Hawkeye Electronic Surveillance Aircraft have successfully implemented MOSA.

- Virginia Class Submarine Non-propulsion Electronic Systems (NPES) have been developed successfully using MOSA. This undertaking included 23 different sub-systems—including tactical control and weapons control—that form into a coherent warfare system of systems (SoS).

- E-2 Hawkeye Aircraft, a legacy system, has been modularized and upgraded.

Two of our most challenging warfighting systems, the Army's Future Combat Systems (FCS) and National Missile Defense, seem to be good candidates for MOSA.

- The FCS is a family of systems (FoS); it is expected to comprise 18 different platforms—a mix of manned and unmanned, air and ground systems—plus a network that will link the platforms. There will be modularization, system of systems (SoS) at the platform level. Insofar as the platforms are treated as a "family," reuse of software modules may offer significant savings; if MOSA is feasible, significant savings or cost avoidance potentially would extend from development through sustainment. MOSA seems to offer a useful technical and business strategy.

- Similarly, National Missile Defense must be modularized to permit development of the many different sensors, weapons platforms, command and control functions, and communications links. If feasible, MOSA seems an appropriate strategy for development, upgrade, and sustainment. There may be constraints to MOSA; for example, within the command and control system, real-time intercept calculations might limit the extent of modular design. However, TOC savings and a reduced logistics burden are worth pursuing. The DoD 5000.1 requires developers to employ MOSA, if feasible, but recognizes potential scalability limitations in the use of MOSA.[28]

4. Treatment of Obsolescence

From a logistics perspective, one of the major benefits of open systems is the freedom to exercise the "plug and play" feature at such time as a module becomes obsolete and no longer able to be supported. This is useful because all of our warfighting systems experience sustainment issues as soon as production has been completed. In some cases, this occurs due to competitive pressure—e.g., off-shore competition. In other cases, legal or environmental issues may motivate suppliers to stop producing—e.g., castings and forgings in the early 1970s, due to new

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[28] Department of Defense, Directive, *The Defense Acquisition System*, DoD Directive 5000.1, May 12, 2003, Encl. 1, para. 27, page 7.

environmental law. In yet other cases, vendors might leave a business due to other market pressures—e.g., a company's capability to accomplish programming support for a warfighting system in a particular software language might change as the result of unrelated market pressures. MOSA contributes flexibility to react to any of these examples. A-RCI/APB is now seen as an example of the flexibility to act proactively. In the future, that same flexibility may be useful in response to component obsolescence.

5.   Comparison of Legacy versus New Systems

Legacy warfighting systems that have converted to MOSA are in better competitive position for upgrade funding than those unable to become modularized. Stakeholders will gravitate to modularized systems and open systems architecture because of the likelihood of seeing results faster, with "more bang for the buck." New warfighting systems may contribute to their own "undoing" by failing to fully embrace MOSA, thereby becoming uncompetitive for future funding in the process. Based on the A-RCI experience (along with Virginia Class Submarine technical refreshment strategies), future ship acquisitions would appear to demand that aggressive technical refreshment strategies be used in new ship construction; the intended result would be installation of the latest mature technologies onto the Navy's newest warships, while minimizing the incidence of obsolete technologies at the time of a ship's entry into the fleet.

6.   Financial Management

A-RCI funding streams have changed from the widely recognized pattern of RDT&E, followed by Production, followed by O&M. As spiral development continues, there is need for continued RDT&E funding, albeit at a reduced level, taking advantage of MOSA. Processor and APB upgrades require a continuing stream of Procurement funding, but at a reduced level by taking advantage of COTS. Finally, O&M funding supports sustainment, just as in the traditional case but at a reduced level, taking advantage of CLS efficiencies and reduced life-of-type buys and obsolescence cost.

7.   JCIDS

Spiral Acquisition must be rooted in the JCIDS process to ensure proposed acquisitions address required capabilities, avoid unnecessary redundancy, and provide interoperability with other warfighting systems. The JCIDS process requires reviews and approvals that are important, but also are time-consuming and may contribute to program delays. There appears to be a risk that rapid op tempo spiral developments potentially may collide with slower-moving JCIDS processes, resulting in incomplete reviews, inadequate user direction, or program delay.

8.   Testing

A-RCI testing included Developmental Testing in support of market survey, in development (Build/Test/Build), and at sea to ensure that upgraded modules performed correctly in the system of systems or family of systems. New COTS hardware and Advanced Processing Builds (APB) get a thorough technical shakeout to ensure they work correctly. However, the A-RCI experience demonstrated a structural impediment to completion of operational testing. Operational Testing typically examines suitability and effectiveness of the warfighting system and is accomplished "end to end." Unfortunately, end-to-end testing is expensive and time-consuming for an operational asset. End-to-end operational testing has not synchronized well with the A-RCI/APB process as testing is time consuming, expensive and may not always be necessary with spiral upgrades. End-to-end operational testing has its place, but possibly not in every spiral of an evolutionary development.

In June 2005, COMOPTEVFOR published guidance and a framework for integrated testing—that is, combining operational testing (OT), developmental testing (DT), and contractor testing (CT). The intent of this directive was to identify and resolve Critical Operational Issues (COIs) as early as possible and to use

operational testing to confirm mission performance instead of conducting an "all encompassing system evaluation."[29]

H. Summary

Acoustic Rapid COTS Insertion/Advanced Processing Build (A-RCI/APB) shows the promise of a modular open systems approach (MOSA). A-RCI was a leader, finding its way when few rules and guidelines were available. Today, there is a body of information showing the benefits of A-RCI. Rules and guidelines have emerged to help guide other programs through MOSA; many of those guidelines are the result of the A-RCI experience. Other programs' successes, such as Virginia Class Non-Propulsion Electronic systems (NPES) and E-2 Hawkeye aircraft upgrade, suggest that A-RCI was not simply a one-time success. In the aggregate, these several successful programs are an indication that other acquisition programs might use MOSA with similar benefits. The A-RCI experience indicates that some Acquisition processes need to be retooled to interface with and reap the advantages of rapid spiral development.

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[29] Commander, Operational Test and Evaluation Force, U.S. Navy, "Operational Test and Evaluation (OT&E) Framework and the Integrated Testing (IT) Methodology" (Norfolk,VA: author, 28 June 2005), Encl 1. Policy and Information Notice 05-1.

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VI. Conclusions and Recommendations

1.   **A-RCI/APB has successfully applied MOSA, deriving major performance and logistics improvements.**

   The A-RCI program drastically changed its technical and business practices—embracing business and technical principles and disciplined processes that currently comprise the Modular Open Systems Approach. The results were a series of substantial technical improvements, reduced cycle-times, transition to COTS processors, and software sharing across weapon platforms.

2.   **A-RCI demonstrated significant Total Ownership Cost or system Lifecycle Cost benefits.**

   The Navy is currently validating a historical cost comparison of A-RCI and its predecessor system. Preliminary results compiled from 10 years of data on both A-RCI and its predecessor indicate that lifecycle cost has improved by nearly 5:1.

3.   **The A-RCI/APB example shows that MOSA can be applied to a legacy system.**

   A-RCI/APB was modularized by first separating software from hardware. The integrated software was further modularized into functionally partitioned software modules and transportable middleware. MOSA includes feasibility assessment of open system solutions—an essential business and technical consideration when starting with a fully integrated legacy solution.

4.   **A-RCI/APB demonstrates that modular upgrades can be accomplished very rapidly through spiral development, in contrast to traditional systems development.**

   A-RCI/APB was able to produce an Advanced Processing Build annually and upgrade COTS processing hardware every two years. Implementations in the submarine fleet resulted in each submarine getting upgraded software at about two-year intervals and new COTS processors at approximately four-year intervals.

5.   **A-RCI/APB experience suggests there are operational test issues that must be worked out.**

   Operational testers have a bias for end-to-end testing, which is expensive and slow, but thorough. Such an approach to testing does not fit well with rapid spiral development. A-RCI/APB included at-sea

testing on operational submarines, but this was not end-to-end testing in the traditional mold. OPTEVFOR's 2005 policy directive suggests that the Navy is trying to streamline OT to better fit rapid op tempo spiral development programs.

6. **The op tempo of A-RCI/APB and the pace of JCIDS suggest possible synchronization issues that should be evaluated to ensure that appropriate joint reviews proceed without delaying the spiral development process.**

   A-RCI/APB spirals are receiving an annual JCIDS review. Publication of a JCIDS supplement pertaining to rapid op tempo spiral developmental programs would be highly beneficial.

7. **Funding implications of A-RCI need to be studied and understood.**

   Traditional funding profiles do not support the A-RCI example. Traditional funding entails three overlapping funding profiles of increasing size: RDT&E, Procurement, and the O&S accounts (primarily O&M and military personnel). Annual increments of spiral development require continuous streams of RDT&E, Procurement, and the O&S accounts—smaller, more flat annual amounts, continuously, as long as the annual spirals continue.

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Appendix A. Potential Template Opportunities for Support of Modular Open Systems Approach (Based on A-RCI/APB Experience)

1. Technology Open Systems Strategy

2. Business Modular Open Systems Approach

3. Culture Changes Necessary to Support Modular Open Systems Approach

4. Leadership Support Required at Critical Levels

5. Users' Participation

6. Testing Interfaces that are Streamlined to Support Rapid Acquisition OPTEMPO

7. JCIDS Interfaces

8. Logistics—Sustainment Structures and Payoffs

9. Training Impacts

10. Upgrade Process/Implementation Strategy and Processes

11. Detailed Schedule Planning, Including Milestone Reviews

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Appendix B. A-RCI/APB Supporting Organizations

(Extracted from Sonar Development Working Group (SDWG), *1998-99 Year in Review*)

CHAPTER 2. ORGANIZATION
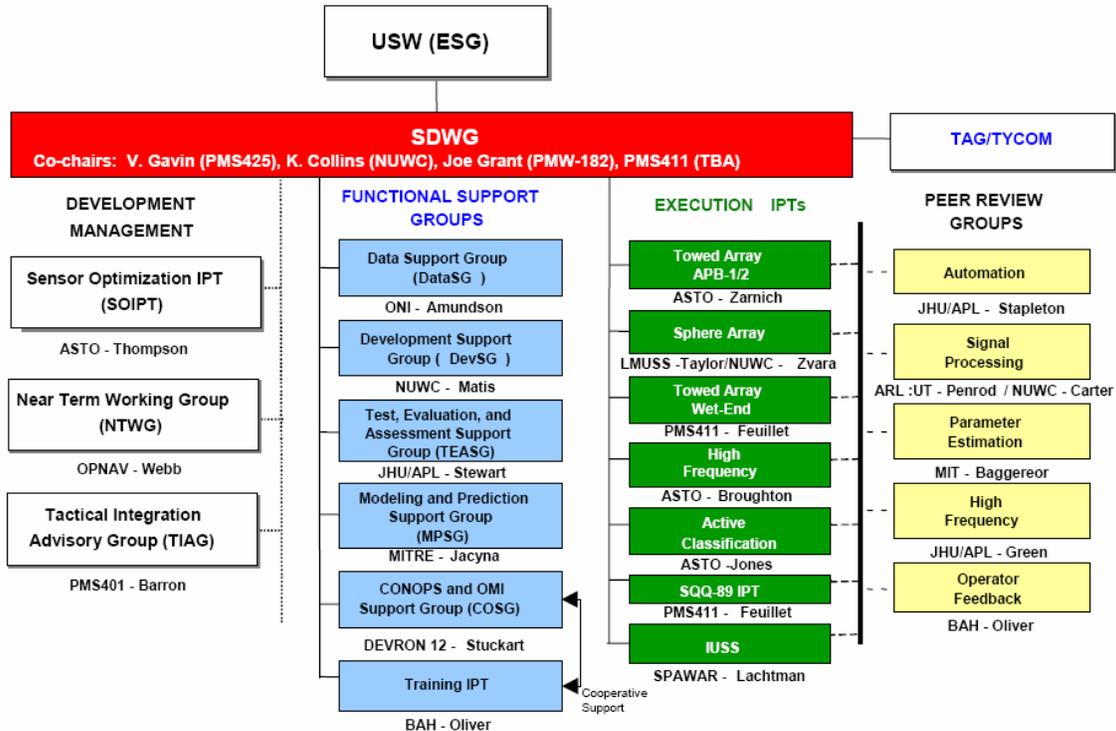
Figure 2-1. SDWG Organization

In order to manage the APB Process and the transition of new algorithms for fleet use, an Integrated Product Team (IPT) structure has been adopted and is provided in Figure 2-1. However, it should be noted that the management, direction and decision-making responsibility for the process and content of the individual systems continue to reside with the cognizant Program Offices: PMS425 for in-service submarine sonar, PMS401 for the VA Class submarine sonar system, PMS411 for the SQQ-89(V) program, PMS500 for DD-21 and PD-18 for the IUSS program. In concert with the Program Offices, ASTO has significant responsibility in delivering the APB technologies for insertion into the baseline sonar systems.

Various working groups, chartered by the program offices, are chaired according to personnel expertise and provide a broad representational cross-section of the best and brightest from the fleet, Navy Laboratories, University Laboratories and industry.

2.1 SDWG

The SDWG, jointly chaired by Victor Gavin (PMS425), Kevin Collins of the Naval Undersea Warfare Center Division Newport (NUWCDIVNPT) and Joe Grant (PMW-182), provides a monthly forum for discussion of topics, updates and issues related to the APB process. It provides a clearinghouse for communication across the working groups and a forum to brief recommendations and works in progress from the various working groups. Meetings are held monthly and agenda items are developed based on priorities established by the fleet and the sponsor (Chief of Naval Operations (CNO) N87) with inputs from the Program Offices and working group constituents.

2.2 Advisory/Review Groups

2.2.1 Technical Advisory Group (TAG)

The TAG, an extension of the original SSTP including additional advisors of national repute and organizational leads from key laboratories, advises the Program Offices, the SDWG and the sponsor on all matters related to the APB process. Chaired by Jim Griffin (N875T), the TAG provides an additional check and balance to ensure integrity across the entire APB process described in Chapter 1. The TAG reviews issues such as progress toward the dB budget, plans for Step 3 and Step 4 APB testing, results of Step 2 algorithm testing and various other technical issues.

2.2.2 Near Term Working Group (NTWG)

A sister organization to the SDWG, the NTWG is chartered to coordinate the procurement, testing and assistance to the submarine Type Commanders (TYCOMs) for the shipboard installation of advanced augmentation bridge systems for fleet deployments. Chaired by LCDR Rutledge Webb, Office of the Chief of Naval Operations (OPNAV), the NTWG provides recommendations and assessments to N87 with respect to the following:

- Procurement and Support of acoustic and combat control augmentation systems required to improve submarine acoustic superiority and tactical control

- Augmentation system installation configuration and support for fleet needs

- APB functions, test and evaluation process

- Planned improvements/upgrades to fleet acoustic and combat control systems

The NTWG is responsible for migrating the APB-99 technology into the Automated Fleet Towed Array System (AFTAS) hardware suite under the AEP program described more fully in Chapter 3. The AEP is scheduled for fleet introduction in late 1999.

2.2.3 Sensor Optimization IPT (SOIPT)

The SOIPT is a senior level organization providing high-level management peer review to advanced development programs. Chaired by James Thompson (ASTO), the SOIPT assists in R&D program planning and provides recommendations for funding of future advanced development initiatives.

2.2.4 Tactical Integration Advisory Group (TIAG)

The TIAG is a forum of senior representatives established to monitor the future of tactical control initiatives. Chaired by CAPT Claude Barron (PMS401), the TIAG provides support and recommendations to the SDWG in defining requirements for APBs and their utility in improving tactical control.

2.3 Functional Support Groups

The Functional Support Groups carry out the essential tasks to support the transition of the APBs to the target program including end-to-end string testing in the laboratory and at-sea, predictions of the performance improvements of the processing and the development of laboratory and database infrastructure.

2.3.1 Data Support Group (DataSG)

The DataSG is responsible for coordinating data collection requests and identifying and providing data segments from relevant blue-on-blue and blue-on-orange encounters for controlled distribution. The DataSG provides open sets (signatures known prior to user review) to the R&D community and open and closed data sets (signatures revealed only during testing) to various SDWG groups including the Signal Processing Working Group (SPWG), the Automation Working Group (AWG) and the TEASG. The DataSG is chaired by Bob Amundson (ONI).

2.3.2 Development Support Group (DevSG)

The DevSG is responsible for defining and implementing the equipment suites required for the research, development and testing of the APBs. The DevSG is also chartered to support the rapid dissemination of approaches to industry and development of the Middleware Support/Certification Plan. Chaired by Rich Matis of NUWCDIVNPT, the DevSG includes representatives from ONI, NUWCDIVNPT, JHU/APL, Digital Systems Resources (DSR), Massachusetts Institute of Technology/Lincoln Laboratory (MIT/LL), and Naval Surface Warfare Center Crane Division (NSWCCD).

2.3.3 Test, Evaluation, Assessment and Support Group (TEASG)

The TEASG is responsible for providing independent test and evaluation for both in-lab (Step 3) and at-sea (Step 4) testing of the APBs. Chaired by Tom Stewart (JHU/APL), the TEASG is also responsible for managing evaluation-to-evaluation compatibility and providing a performance comparison with the baseline system. The TEASG is comprised of representatives from NUWCDIVNPT, JHU/APL, Applied Research Laboratory, University of Texas (ARL:UT), MITRE, DSR, ONI and Commander, Submarine Development Squadron 12 (CSDS-12).

At-sea testing is the principal focus of the APB test process, permitting live examination of the strengths and weaknesses of the new build and quantitative measurements of performance. Weaknesses can be addressed and mitigated during transition to IDP. In addition, at-sea testing provides the essential confidence required by the TYCOMs to endorse the use of the new processing for patrols and deployments. Well-constructed at-sea tests also provide important data collection opportunities for further R&D tasking. Laboratory testing provides the essential looks at diverse threat signatures and geometries that are unavailable in at sea blue-on-blue testing, adding an additional level of understanding and confidence in the algorithms. It also provides assurance to the community contributors that

their algorithms have been implemented and perform properly. Finally, laboratory testing provides an early opportunity for crew familiarization and training with the new processing.

In addition to testing of APBs, the TEASG oversees the continued measurement and assessment of fielded ARCI systems through the ARCI Engineering Measurement Program. The TEASG can then assess performance of the fielded system, compare the performance with that expected based on APB testing and feed back assessment results into development.

2.3.4 Modeling and Prediction Support Group (MPSG)

The MPSG provides analytical bounds on performance of the algorithms incorporated in an APB. It also provides for the development of models to adequately project, with meaningful metrics, the performance of the sonar system in areas of interest. The MPSG is chaired by Garry Jacyna (MITRE) and includes representatives from NUWCDIVNPT and JHU/APL.

2.3.5 Concept of Operations (CONOPS) and Operator-Machine Interface (OMI) Support Group (COSG)

The COSG defines the OMI (notional control and display schemes) and operational utilization of the processing algorithms developed by the SPWG and the AWG. The primary fleet voice for determining the priority of APB improvements in the areas of acoustic signal detection, system automation and tactical information management, the COSG also develops and conducts crew familiarization training for platforms receiving the APB system upgrades.

The COSG is chaired by STSCM Terry Stuckart (CSDS-12) and is comprised principally of active duty senior enlisted personnel, civilian representatives from the program offices, system development contractors (Lockheed Martin Undersea Systems (LMUSS) and DSR), and ACINT experts from the fleet.

2.3.6 Training IPT

The Training IPT is responsible for the development of a process for a common training approach among the submarine operational, technical, training, and intelligence communities. Once this process is developed and approved, the Training IPT will oversee its implementation and provide periodic assessments to the program office with prioritized recommendations for APB changes and training improvements.

Areas of focus for the process are the development of metrics, training of operators on system installations and upgrades, improving maintenance training and identification of potential system upgrades to enhance operator performance.

The Training IPT is chaired by a PMS4252 representative and is comprised of representatives from CNO N872, CNO N879, the TYCOMs, NAVSEA 92L1, Chief of Naval Education and Training (CNET), ONI, JHU/APL, SOBT and LMUSS.

2.4 Execution IPTs

Execution IPTs are chartered to provide program direction and asset management for the Peer Review Working Groups. Although the Execution IPTs may merge over the next two

years as the APB process stabilizes and cross-sensor fusion is addressed, the following provides a summary listing of the current Execution IPTs and their responsibilities.

2.4.1 Towed Array Execution IPT

Chaired by Bob Zarnich (ASTO), this IPT has responsibility for the delivery of towed array and hull array APB processing. The IPT composition is determined by ASTO and PMS425 and currently includes representatives from PMS425, NUWCDIVNPT, the chairs of the Peer Review Working Groups and DSR, the towed array/hull array APB integration agent for APB-98 and APB-99.

2.4.2 Sphere Array Execution IPT

Co-chaired by George Zvara (NUWCDIVNPT) and Howard Taylor (LMUSS), this IPT has responsibility to manage the advanced development of improved sonar Spherical Array (SA) detection, classification and localization functionality. ASTO and PMS425 determine the IPT representatives. A merger of the Sphere Array Execution IPT with both the Towed Array Execution IPT and the High Frequency Execution IPT is planned in the near future to support a common Low Frequency (LF), Medium Frequency (MF) and High Frequency (HF) Execution IPT.

2.4.3 Towed Array-Wet End Execution IPT

Representatives from the Towed Array-Wet End Execution IPT have been monitoring the Navy's efforts over the course of the past year to develop a common thin line array and/or common components for a thin line array to support the submarine, surface and IUSS communities. Chaired by Jean-Pierre Feuillet (PMS411), the Towed Array-Wet End Execution IPT will become more actively engaged in this effort in the near future once the initiative leaves the planning stages and is under contract.

2.4.4 High Frequency Execution IPT

The High Frequency Execution IPT maintains responsibility for the delivery of high frequency sail and chin processing for the HF APB-99 build and development of HF APB-01. The IPT, chaired by Jim Broughton (ASTO), consists of representatives from ASTO, PMS425, NUWCDIVNPT, ARL:UT and LMUSS. As stated previously, plans call for a future merger of the HF Execution IPT with the Towed Array and Sphere Array Execution IPTs.

2.4.5 Active Classification Execution IPT

Active Classification is fundamentally different than passive classification. Chaired by Jeff Jones (ASTO), the Active Classification IPT is examining technologies to improve the active classification process. Committee membership presently is comprised of NUWCDIVNPT, ASTO, and CSDS-12. The focus during 1998 and 1999 has been to examine the viability of transition of automation technology from the surface ship combatant community. These efforts are more fully detailed in Chapter 3.

2.4.6 SQQ-89 Execution IPT

The SQQ-89 Execution IPT, chaired by Jean-Pierre Feuillet (PMS411), was established in late 1998 under the joint PMS425/PMS411/PMS415 MOU described in Chapter 1. The

focus of this IPT is on extending the application of a common acoustic processing system to surface ships. The IPT provides technical direction to the respective program offices for development of the Common Acoustic Processor for Surface Combatants (SURCAP). The IPT will be co-chaired by a PMS425 designated representative.

2.4.7 IUSS Execution IPT

Chartered in 1998, the IUSS Execution IPT is responsible for providing all technical direction for development of the NCAP and for managing the integration of the APB-developed NCAP components with other IUSS processing components. The IUSS Execution IPT is chaired by S. Lachtman (SPAWAR).

2.5 Peer Review Groups

The Peer Review Groups address the functional and technical issues required leading to the recommendations for improvements to the sensor processing. The groups provide recommendations to the Execution IPTs on R&D priorities, including tasking for each funded organization and provide independent test and evaluation of candidate algorithms. These working groups collectively survey, develop and test the algorithms and displays (Step 1 and Step 2 of the APB process) and monitor progress through Step 4. The Program Office leads of the Execution IPTs determine the chairs and membership of the Peer Groups, focusing on the talents, experience and capabilities of the individuals rather than organizational ties.

2.5.1 Automation Working Group (AWG)

The focus of the AWG is on algorithms intended to automate the use of data generated by the signal processor and available for display. This typically includes processing which replaces, assists or extends the traditionally operator-intensive functions (i.e., source detection and recognition, tracking, source correlation, classification and extraction of tactical information) and also may include source intercept and identification, echo steal, source localization and decision aids for vulnerability assessment and planning.

Working with fleet representatives from CSDS-12 and the COSG, the AWG identifies and prioritizes automation needs that are most effective for fleet use. Following the four-step APB process, the AWG identifies candidate solutions for those needs by leveraging the best algorithms available throughout the R&D community. AWG members evaluate those algorithms for potential use, and recommend selected automation products for integration into the APB baseline. The AWG also develops effective concepts for interface, display and control of automation information, and encourages developers to work those key improvement areas. The AWG works with the SPWG and system developers to ensure that its recommendations properly account for processing performance and system sizing constraints.

John Stapleton (JHU/APL) chairs the AWG which is comprised of representatives from MITRE, DSR, CSDS-12, LMUSS, MIT/LL and NUWCDIVNPT. Non-members can participate in open sessions of the AWG known as the Friends of AWG (FoAWG).

2.5.2 Signal Processing Working Group (SPWG)

The SPWG is responsible for the sonar signal processing which includes array processing, adaptive beamforming and range focusing as well as narrowband and broadband detection

improvements. The SPWG is jointly chaired by Clark Penrod (ARL:UT) and Cliff Carter (NUWCDIVNPT). The SPWG includes representatives from LMUSS, ONI, Orincon, DSR, JHU/APL and CSDS-12. Similar to the AWG, non-members can participate in open sessions of the SPWG known as the Friends of the SPWG (FoSPWG).

2.5.3 Parameter Estimation Working Group (PEWG)

The PEWG addresses issues associated with extracting target and noise parameters from the array data. These include parameters for bearings and ranges as well as their rates, frequencies and Dopplers. The initial focus of the PEWG has been on the trackers and identifying the causes of their failures and the need to reinstate them. Both broadband and narrowband trackers have been examined. Art Baggeroer (MIT) chairs the PEWG which includes representatives from AET, George Mason University, MIT/LL, NUWCDIVNPT, SAIC and DARPA.

2.5.4 High Frequency Peer Group (HFPG)

The HFPG is responsible for initiating the APB process for the HF program (including establishing the criteria for and determining APB content) and for reviewing all hull-mounted active sonar improvements and recommendations. The HFPG is chaired by Larry Green (JHU/APL) and includes representatives from ARL:UT, NUWCDIVNPT, LMUSS, PMS425, JHU/APL, MITRE, Arctic Submarine Lab, EG&G, A&T, ASTO and ARL:PSU. The HFPG focuses on the following HF improvement areas:

- Mine avoidance

- Bottom mapping

- Passive and Active Anti-Submarine Warfare (ASW)

- Low Probability of Intercept Waveforms

The peer group has covered all aspects of the HF APB including signal processing, automation (termed Computer-Aided Detection (CAD)), OMI, and test and evaluation.

In addition, the HFPG community will begin participating as subgroups within the COSG, SPWG and AWG as part of the planned merger of the Towed Array, Sphere Array and HF Execution IPTs.

2.5.5 Operator Feedback IPT (OFIPT)

The OFIPT combines the efforts of the operational, technical, training and intelligence communities to establish feedback in the form of training and operational performance measurements. This includes a process to provide feedback to program offices and the training community on the submariner's performance in the operation of the sonar system. The feedback will be used to enhance the effectiveness of improvements in sonar upgrades by determining where measurable improvements can be made through changes to the sonar training or system development processes.

A primary goal of the OFIPT is to gain near-term improvements that will have an immediate payoff for improved sensor performance. To support this goal and develop an objective

operator performance feedback process, Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) must be established first in order to focus on those skills most effective for operators.

This IPT, chaired by Tim Oliver (Booz-Allen), includes representatives from LMUSS, ONI, JHU/APL, NAVSEA 92L1 and the submarine TYCOMs. The OFIPT complements the AEMP system evaluations with assessments of operator performance.

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