JOURNAL OF PUBLIC PROCUREMENT, VOLUME 4, ISSUE 2, 238-267 2004

EVOLUTIONARY ACQUISITION: AN ANALYSIS OF DEFENSE PROCUREMENT AND RECOMMENDATIONS FOR EXPANDED USE[1]

Ryan M. Novak, Trevor T. Sthultz, Timothy S. Reed, Christopher C. Wood, Jesse A. Kirstein, and Jason A. Whittle*

ABSTRACT. United States Air Force (USAF) acquisition programs have historically suffered from extended acquisition cycle times and cost and schedule overruns. Department of Defense senior leadership has called for "transformation" of the acquisition process. In this article, we investigate an Evolutionary Acquisition (EA) strategy and the spiral development process. This article presents the case study analysis of three USAF acquisition programs: Global Hawk, B-2 Bomber, and Unmanned Combat Air Vehicle (UCAV). Data were collected through extensive literature review, interviews with acquisition experts from the three program offices, and completed questionnaires from members of Air Force Materiel Command's (AFMC) Acquisition Center of Excellence (ACE), Aeronautical Systems Center's (ASC) Transformation Team, and ASC's ACE.

INTRODUCTION

Air Force acquisition programs have historically suffered from extended acquisition cycle times and cost and schedule overruns.

** Ryan M. Novak (M.B.A., Captain), Trevor T. Sthultz (B.B.A., Captain), and Christopher C. Wood (MA, Lieutenant) currently are Masters students in the Strategic Purchasing program, Air Force Institute of Technology. Timothy S. Reed, Ph.D., Lieutenant Colonel, is currently assigned to Headquarters USAF in the Procurement Transformation office. His research interests include implementing an entrepreneurial mindset in large organizations and procurement transformation. Jesse A. Kirstein, MS, Captain, is currently a contracting officer in the GPS Joint Program Office, Los Angeles AFB, California. Jason A. Whittle, MS, Captain, is a contracting officer in the Air Vehicles directorate of the Air Fore Research Laboratory.*

Wayne M. Johnson (2002, p. 175) described the problem by stating: "The acquisition process for defense in the United States is considered broken." The push for system improvements was clearly outlined in the AF Transformation Team's statement: "Transformation is not optional, we have been challenged by the Air Force leadership to implement new initiatives to reduce overall acquisition time by a factor of 4:1" (Air Force Transformation Team, 2002). Evolutionary Acquisition (EA) is an acquisition strategy that seeks to solve the woes of previous strategies that were plagued by cost overruns, late schedules, and warfighter expectations that went unfulfilled (Johnson, 2002).

We began our research with a thorough literature review and information gathered from completed questionnaires by experts at AFMC's Acquisition Center of Excellence (ACE), ASC's Transformation and Divestiture Team, and ASC's ACE. Furthermore, we studied three different Program Offices: the Global Hawk Program Office, B-2 System Program Office (SPO), and UCAV Program Office, interviewing key personnel and processes within each respective program.

Evolutionary Acquisition – What Is It?

EA is defined as:

> "An acquisition strategy that defines, develops, produces or acquires, and fields an initial hardware or software increment (or block) of operational capability. It is based on technologies demonstrated in the relevant environments, time-phased requirements and demonstrated manufacturing or software deployment capabilities. These capabilities can be provided in a shorter period of time, followed by subsequent increments of capability over time that accommodate improved technology and allow full and adaptable systems over time" (Aldridge, 2002, p. 2).

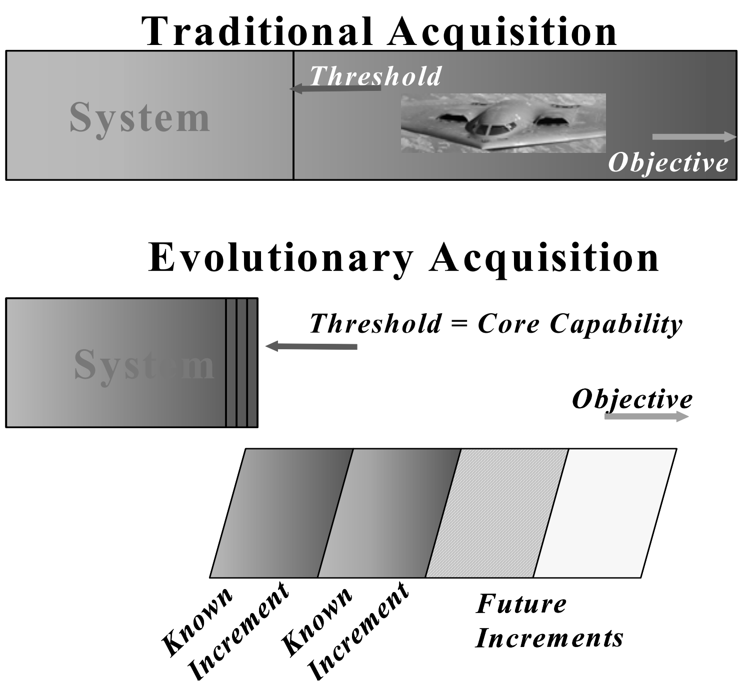
EA allows for the ultimate functionality to evolve as requirements and technology evolves. Colonel Johnson stated, "The succeeding spirals are based on the success of the previous spiral, changing requirements priorities, feedback from the field, or changing budgets and speed of development" (Johnson, 2002, p. 178).

The primary objective of using EA strategies is to reduce acquisition cycle time and produce successful programs. As noted by Dr. Marvin Sambur, Assistant Secretary of the Air Force for Acquisition, "The success of an acquisition program hinges on up-front, collaborative and concurrent planning…" and, "the goal is to establish, at the outset of the program, mutual, realistic expectations for content delivered, schedule of delivery, and cost" (Sambur, 2002, p. 3). EA is a strategy best suited to achieve reduced acquisition cycle time and ultimately, successful programs. Figure 1 depicts McNutt's (2000) analysis model for any program considering the use of EA and compares the Traditional Acquisition Approach versus the EA Approach that utilizes increments.

Spiral Development

Spiral development is a process for implementing EA and is defined as "an iterative process for developing a defined set of capabilities within

FIGURE 1
Traditional Vs. Evolutionary Acquisition



Source: McNutt (2000).

one increment." Further, "In this process, the requirements are refined through experimentation and risk management, there is continuous feedback, and the user is provided the best possible capability within the increment" (Aldridge, 2002, p. 2). Sambur's Reality-based Acquisition System Policy Memo clearly states "spiral development is the preferred process to execute EA strategy" (Sambur, 2002, p. 2).

Evolutionary Acquisition: Advantages and Disadvantages

Air Force-level guidance on use of EA and spiral development is clear. However, as with any systemic approach there are numerous advantages and disadvantages that must be understood and analyzed.

EA Advantages

There are several noticeable advantages of EA. The main advantages include fielding a core capability quickly, wide applicability throughout the DOD, and the application of risk management techniques.

The main advantage of EA is the ability to field a core capability to the warfighter faster (Ayres, 2002). The intent of the increments is to provide warfighter needs in a rapid manner while maximizing the use of mature technology. EA allows the user to evolve their missions, tactics and overall requirements. The world is dynamic, military threats are dynamic and EA offers an acquisition approach that is flexible to meet the changing needs of the warfighter based on actual fielded experience and changing threats.

Another advantage of EA is its applicability to various programs within DOD. When is EA suitable? According to the Office of the Assistant Secretary of the Air Force for Acquisition (SAF/AQ) *Air Force EA Acquisition Guide*, EA may be suitable when the "…ultimate system requirement is uncertain or immature, where there is a need for <u>continuous feedback</u> to help refine the requirement…and where the operational capability is needed in a short time frame" (SAF/AQ, 2002). There are numerous current and future programs within DOD suited for EA. We focused on three (Global Hawk, B-2, and UCAV).

Another strong advantage of EA is its support of risk management techniques. DOD is attempting to move from the traditional risk-averse mindset toward the practice of good risk management. Risk management is a key component in DOD's strategy for acquiring and sustaining weapons (United States Air Force, Air Force Acquisition Reform, 2000). When risk management becomes an integral part of the program's planning and management, it enhances the integrated product team's ability to effectively balance performance, schedule, and cost requirements (United States Air Force, Air Force Acquisition Reform, 2000). EA, along with spiral development, strives to rapidly field performance in a short amount of time. Embracing the concepts of risk management is essential to the success of EA. While the examples above are the primary advantages of EA, there are many more. Some of these advantages include the dispersion of risk across spirals, the ability to incorporate lessons learned between spirals and the ability to shelve residual technologies for future spirals or independent derivatives (Johnson, 2002).

EA Disadvantages

While EA presents numerous advantages as outlined above, there are also some disadvantages inherent to the strategy. These drawbacks include the possibility of delivering an incomplete product; cost control, development integration and user input issues; ill-defined requirements; and lack of planning resulting in poor reliability, supportability, and maintainability of the fielded systems.

The first and most obvious disadvantage of EA is delivery of a product that is essentially incomplete. Warfighters are accustomed to an acquisition system that provides them with a final and complete product. When presented with an item that reflects an 80% solution of full capability, questions arise as to how flexible and capable the use of EA is to the warfighter (Johnson, 2002). Further, the rapid movement of technology to the field increases the possibility of glitches and higher failure rates. Poor performance or failure of a system in early increments could dramatically affect warfighter confidence in the system.

Another major disadvantage of an evolutionary strategy is cost control. Very little literature presents evolutionary acquisition as a cost saving approach and there is a reason for this. In all acquisitions, the government must consider and balance three key factors: cost, speed, and quality. An unfortunate reality of these factors is that a combination of any two may exist, but not all three at once. In the case of EA, speed is achieved through rapid fielding of succeeding increments. Quality is also achieved through continuous testing and feedback loops. The weakness of EA lies in cost. Initial costs of EAs can be extremely high compared to traditional acquisitions. This means that the ultimate outcomes are long term, and the amount of money infused in the beginning does not equate to initial outcomes (Markowski, 2000).

Development integration and user input are critical facets of EA and another area of concern. Developmental integration can only occur if a systems engineering approach is taken. This requires a well thought out plan and a high level of cross-functional communication and cooperation. Having a user that cannot convey their needs or one that is operating in functional stovepipes can seriously hamper acquisitions conducted using the EA strategy. A major challenge of making the process work is getting buy-in from all functionals involved and major end-user involvement. Achieving these high levels of coordination and integration requires a significant human capital investment.

Another potential disadvantage of EA is ill-defined requirements. The flexibility of EA can mislead those involved into the danger of not carefully considering requirements. This can occur because there is a tendency to believe that new requirements can be rolled into subsequent increments. In reality, requirements must be properly and accurately determined at the start of the project in order for it to be successful (Markowski, 2000). This is the essence of systems engineering. Only minor requirements changes or enhancements should be made between increments. Bounds should also be set during requirement generation to control the scope of the project and to control costs.

Lastly, while the core advantage of EA is the faster fielding of technology, this may result in less planning for long-term supportability and maintainability of the asset. "Reliability, maintainability, and availability are atrocious. We've lost 25 of the 80 predators built--primarily through reliability issues, not combat. Three of the six Global Hawks have been lost…" (Rumsfeld, 2002, p. 29). Table 1 summarizes the advantages and disadvantages of EA.

METHODOLOGY

The aim of this research is to identify EA best practices and lessons learned. After conducting a thorough literature review, the authors developed a survey instrument to gather expert perceptions on EA and sent questionnaires to members of the AFMC ACE, ASC ACE, and

TABLE 1
Advantages and Disadvantages of Evolutionary Acquisition

Advantages of EA	Disadvantages of EA
EA allows rapid fielding of core capability	EA does not provide 100% capability initially
EA is inherently flexible and allows injection of emerging technology	EA's open system architecture makes cost estimation and control difficult
EA can be applied to most systems acquisitions	EA is based on systems engineering and requires support from multiple functional areas
EA's incremental structure supports risk management	EA's inherent flexibility can lead users to provide poor requirements

ASC's Transformation and Divestiture Team. Members of all three organizations returned completed questionnaires, which served as a foundation for the analysis on application of EA within the Air Force. The five questions on the questionnaire were as follows:

- To what extent do you feel Evolutionary Acquisition is being implemented throughout AF acquisition?
- How well do you feel the practitioners (Centers, SPOs, Integrated Project Teams or IPTs, individuals) are handling Evolutionary Acquisition issues?
- What are some Evolutionary Acquisition "best practices?"
- What are some Evolutionary Acquisition "lessons learned?"
- What in the DOD culture and/or environment (laws, regs, programs, mindset) act as opportunities and threats to the future utilization of Evolutionary Acquisition?

After examining the completed surveys discussed above, the authors conducted interviews with key personnel from the Global Hawk program, UCAV program, and B-2 program. These interviews were semi-structured in nature with several pre-defined questions sent to the program offices prior to the execution of the formal interview. The interviews were unstructured in the sense that interviewees presented information such as program schedules, statements of work, and other program documents that raised additional questions that resulted in a more thorough analysis. The findings of the research are broken down into three main categories: how were practitioners handling EA; EA best practices within the programs; and EA lessons learned from within the programs that can be employed across DOD.

Case Selection

The need for a system that satisfies user needs in a timely and cost effective manner has always been apparent. However, in today's dynamic environment, it becomes imperative to maintain capabilities. The United States faces different kinds of opposition, from adolescent suicide bombers, to conventional armies, to hijacked airliners used as missiles. In addition to these outside threats, diminishing manufacturing sources have left the DOD with very few source options and even fewer sources for technical innovations. The days when contractors independently researched new innovations and technologies and sold them to the military are gone. Today's lean defense market requires government partnerships with contractors to find the needed innovations, ensuring the U.S. military's capabilities remain unmatched into the future.

EA is the next step in achieving the needed results from the military acquisition system. It enables and fosters the needed teamwork throughout the acquisition process by all the participants to ensure the warfighter's needs are met. EA enables rapid technology insertion into systems that will allow for continued system improvement, ensuring the changing needs of the warfighter are rapidly met. The future of the acquisition process begins with Evolutionary Acquisition.

The Global Hawk, B-2, and UCAV programs were selected as cases based on (1) their use of EA and (2) their current and projected future contribution to the transformed military. The first point is intuitive; if the program is not using EA, then we could not study the program's use of EA. The second point is more subjective, but has gained importance as our military transforms while also fighting wars in Afghanistan and Iraq. The Global Hawk, B-2, and UCAV program offices continue to prove themselves to be force multipliers, with their collective ability to gather intelligence and inflict massive damage and casualties on the enemy while minimizing the threat of friendly fire to U.S. and allied fighters. These systems seem to represent the fulfillment of warfighters' needs during a very dynamic time. Our research supports the belief that these systems' utilization of EA are paving the way for future warfighting capabilities.

RESULTS

Global Hawk UAV Mission and Objectives

The Global Hawk Unmanned Air Vehicle (UAV) is an unmanned, high altitude, long endurance air vehicle. Global Hawk UAV supports DOD's intelligence, surveillance, and reconnaissance missions with integrated sensors (electro-optical/infrared, synthetic aperture radar (SAR) for all weather and future signals intelligence (SIGINT) capabilities) (GH Overview, 2001). The program office's mission is to rapidly develop, acquire, modernize, sustain and integrate aerospace intelligence, surveillance and reconnaissance unmanned platforms, sensors, data links, and associated ground segments in support of warfighter needs (M. Zywien, personal communication, November 15, 2002). Figure 2 highlights Global Hawk's design specifications, performance goals, and major accomplishments to date.

FIGURE 2
Global Hawk Overview

Global Hawk's general design specifications:

Wing Span:	116 ft
Length:	44 ft
Height:	15 ft

Global Hawk's performance goals:

Range:	12,500 nmi
Endurance:	35 hours
Altitude:	65,000 ft
True Airspd:	350 kts

Global Hawk's major accomplishments:

- Over 100 Missions
- Over 2000 flight hours
- Over 10,000 images taken
- World record altitude & endurance
- 2000 Collier Trophy
- 2001 David Packard Award

Mission Needs & Requirements

The mission need for the Global Hawk program derives from the warfighter's requirement for Near-Real Time (NRT) reconnaissance information as articulated in multiple Mission Need Statements including: Advanced Imagery Reconnaissance Capability, Long Endurance Reconnaissance, Surveillance, and Target Acquisition (RSTA) Capability, and Theater Airborne Reconnaissance System. Global Hawk supports each element of the air, land, sea, space, and special operations team to facilitate the application of "over-whelming force" (Operational Requirements Document [ORD], 2001). Global Hawk's mission needs and requirements are documented in the ORD and there are four key performance parameters: long endurance, world wide operations, information exchange requirements, and dynamic control (M. Zywien, personal communication, November 15, 2002).

Evolutionary Acquisition and Global Hawk

Global Hawk entered Engineering, Manufacturing, and Development (EMD) in December of 2001 under a Federal Acquisition Regulation (FAR)-based Cost Plus Award Fee, spiral development contract. Our research focused on Global Hawk Program's EMD Transformation Program that utilizes EA and the spiral development approach, reflecting this UAV's "evolutionary capability growth" (ORD, 2001).

How the Program Office is Meeting the Challenges of EA & Best Practices

The Global Hawk Program is setting the pace for other acquisition programs currently using EA. Lieutenant Colonel Mike Zywien, Global Hawk Program Manager, stated, "I think we are out ahead of the comfort zone of a lot of decision makers, and we are having to slow down so they can keep up!" (M. Zywien, personal communication, November 15, 2002). The Global Hawk Program Office is using spiral development along with yearly lot improvements and seamless verification. Each spiral is a negotiated modification to the basic EMD contract. The program office utilizes "…key processes that are needed to control this evolutionary approach including EVMS, alpha contracting, risk management, critical path schedules, Joint CCB, etc." (Global Hawk questionnaire, personal communication, November 20, 2002).

The contracting team at Global Hawk is "thinking outside of the box." There are currently no checklists or guidance on how to formulate an evolutionary-type contract that utilizes spiral based acquisition. Lt Col Zywien (personal communication, November 15, 2002) stated, "My experience says no one is doing it quite like we are, and most offices are struggling with integrating all the concepts and precepts." The Global Hawk's contracting team is chartering new paths in acquisition and has formulated an approach that seems to be working well. Their Transformation contract, like its evolutionary requirements, is dynamic in nature. The contractual statement of work (SOW) captures and reserves future "known" requirements, covering for any possible scope issues. Furthermore, the contracting team works very hard at configuration control of the Transformation contract. In other words, the team keeps the contract updated to the current configuration of the requirements. Although this process sounds simple, the nature of EA and spiral development makes this task difficult as requirements are quite dynamic in nature.

Global Hawk is leading the way as an EA pioneer. The program office has placed an early emphasis on documented plans and processes and utilizes an incremental ORD and evolving baseline. The organization meets quarterly with the user, Air Combat Command, to define future requirements and discuss current progress in the Requirements Working Group. Furthermore, the UAV platform utilizes an Open Systems Architecture that ultimately establishes a path for the future, as requirements and technology change. This open system architecture establishes the "hooks" for the platform so that future requirements and evolving technology can easily be inserted (M. Zywien, personal communication, November 15, 2002).

EA also produces a lot of inherent risk due to its rapid pace, dynamic requirements, and state-of-the-art technology. The Global Hawk team considers risk management to be central to the program and to program management. A joint risk management plan and database have been established and are shared throughout the IPT. This risk management program emphasizes the importance of risk evaluations to the ultimate success of the program and necessitates that everyone, from the working level to the management level, be involved with its implementation and execution.

Global Hawk also utilizes the concept of seamless verification in testing the UAV in order to effectively and efficiently execute its overall

EA strategy. The program office along with the Air Force Operational Test and Evaluation Center (AFOTEC), has combined DT/OT for this spiral program, "…providing a continuous, incremental test process with formal test points where they make sense" (M. Zywien, personal communication, November 15, 2002). Operational assessment (OA) of the system is scheduled in fiscal year (FY) 2004 and Initial Operational Test and Evaluation (IOT&E) is scheduled in FY 2006. These test results directly influence the program's production and retrofit decisions and delivery schedule. For this reason alone, it is important that the test community be made an integral part of any EA. Global Hawk has made AFOTEC part of their test program from the beginning and even had AFOTEC members deploy on several occasions with their team.

The Global Hawk Program Office has drafted a time-phased Operations Requirements Document for Spirals 3 and 4 and a Test and Evaluation Master Plan (TEMP) update is currently being drafted to capture these requirements and to develop a combined DT/OT plan (Pathfinder, 2002). One of the major challenges that Global Hawk is facing is funding instability. Currently, Global Hawk is a Pathfinder program and is receiving no special consideration for this, as the program continues to be taxed. (Pathfinder, 2002). The Joint Affordability Team (JAT) produced a plan that would ultimately save thousands of dollars for the taxpayers. These savings have already been "…removed from the budget prior to the SPO building AF consensus around and assessing how and when savings should be implemented (M. Zywien, personal communication, November 20, 2002; Pathfinder, 2002).

B-2 System Program Office – Radar Modernization Program (RMP)

The B-2 SPO is responsible for acquisition of the multi-role bomber capable of delivering both conventional and nuclear munitions. A dramatic leap forward in technology, the bomber represents a major milestone in the U.S. bomber modernization program. The B-2 brings massive firepower to bear, in a short time, anywhere on the globe through previously impenetrable defenses (Please note any references to "RPP" in the following sections pertain to the program's former name, "Radar Pathfinder Program". In particular, the RPP Single Acquisition Management Plan (SAMP) citations remain valid as the document has not been changed to reflect the name change).

Mission & Objective

The RMP's mission is to develop and field a modification to the B-2 radar system while ensuring the continuous availability of a radar system to support all B-2 mission requirements. The RMP's objective is to employ agile EA strategy precepts by implementing a spiral development process to accomplish the mission. Figure 3 highlights the B-2's design specifications and performance goals.

Mission Needs & Requirements

The fielded B-2 radar system operates within a portion of the electromagnetic spectrum where the U.S. Government is designated as a secondary user. Interference with primary users by a secondary user constitutes a criminal offense. Due to planned expansion of primary users in the fielded radar system frequency band, the B-2 will no longer be able to operate without high probability of interference with primary users.

In order to ensure the continued operation of the B-2 weapon system, the B-2 radar must be modified to allow operation in another portion of the electromagnetic spectrum where the U.S. Government is guaranteed primary user status.

Evolutionary Acquisition and the RMP

According to the program manager for the B-2 Radar Modernization Program, EA is the primary philosophy behind the program's success in

FIGURE 3
B-2 Bomber Overview

B-2	
Wing Span:	172 ft
Length:	69 ft
Height:	17 ft
B-2's performance goals:	
Range:	Intercontinental
Altitude:	50,000 ft
True Airspd:	High Subsonic
Payload:	40,000 pounds

meeting warfighter requirements (K. Fletcher, personal communication, November 20, 2002). Due to a very rigid need date, the program is on an extremely tight schedule to deliver the necessary capability. The user has voiced the required capability in terms of time-phased requirements to which the program's spiral development approach is responding.

How the Program Office is Meeting the Challenges of Evolutionary Acquisition

The RMP is meeting the challenges of EA by implementing a spiral development process to develop and field the radar modification while ensuring continuous availability of the current radar system to support mission requirements. Currently, no new capability beyond the fielded system is planned. However, the program's acquisition strategy is intentionally flexible to support the implementation of additional increments should Air Combat Command validate new operational requirements. The program's strategy currently includes three increments consisting of five spirals each. Additional spirals or re-definition of the spirals may occur as the B-2 RMP Team works through the collaborative requirements process (U.S. Air Force, 2002).

How Well Practitioners Are Handling the Issue

When asked how well practitioners are handling EA issues, Fletcher's opinion was that most individuals are still in a learning mode, since EA is still a relatively new strategic philosophy. He also mentioned that along with the learning process comes some awkward decision-making that should become smoother as policies become clearer and culture shifts toward a war-fighting capabilities focus (K. Fletcher, personal communication, November 20, 2002). Also, as the RMP SAMP stated, "The B-2 RMP will focus on a collaborative spiral requirements process and seamless verification to ensure expeditious delivery of incremental capability to the field" (U.S. Air Force, September 2002). B-2's RPP Team is doing an excellent job with EA and is working with ACC to define the "best approach" via a Supplemental Operational Requirement Agreement Document (SORAD). Finally, the RMP Team is currently updating the TEMP to reflect its seamless verification testing (U.S. Air Force, September 2002).

Threats to Effective Utilization of Evolutionary Acquisition

The primary threat to effective utilization of EA identified by Fletcher was a general lack of understanding of the concept by practitioners in the field, at all levels. Fletcher confirmed that many people mistakenly use the terms "Evolutionary Acquisition" and "Spiral Development" interchangeably, thinking the terms are synonymous when, in fact, they are not (K. Fletcher, personal communication, November 20, 2002).

Opportunities for Growth of Evolutionary Acquisition

When asked about the potential growth of EA, Fletcher's comments centered on the fact that motivation for future growth has been stipulated by our leaders. In particular, he discussed guidance set forth in a 4 June 02 memo by Sambur (SAF/AQ). The memo states the Secretary of the Air Force (SECAF) and the Chief of Staff of the Air Force's (CSAF) intent is that "The primary mission of our acquisition system is to rapidly deliver to the warfighters affordable, sustainable capability that meets their expectations" and that "EA is the preferred acquisition strategy for achieving the Commander's Intent."

Best Practices

When asked about the program's EA "best practices," Fletcher singled out the program's establishment of formal Overarching Integrated Product Teams (OIPTs) and Integrating Integrated Product Teams (IIPTs). These teams, according to Fletcher, facilitate the program's acquisition strategy by involving multi-functional experts up front and early into the program (K. Fletcher, personal communication, November 20, 2002). In addition, the teaming structure within the program including industry, the user, and the program office, also assists in accelerated management of the program. Fletcher commented that the relationships among all members have yielded a very open and barrier-free communication structure between government and contractor personnel.

Lessons Learned

Fletcher did not identify any specific lessons learned, since the program is still in its early stages. He did note, however, that up front and early planning in every facet of the program is vital to continued success.

Unmanned Combat Aerial Vehicle (UCAV) Program Office

Mission and Objective

The UCAV program is a joint Defense Advanced Research Projects Agency (DARPA), Air Force, and Boeing effort to successfully demonstrate the technical feasibility to effectively and affordably achieve Suppression of Enemy Air Defense (SEAD) and combat strike missions. The UCAV vision is to develop an affordable weapon system that expands tactical mission options and provide revolutionary warfare. Colonel Earl Wyatt, Program Director for DARPA's Tactical Technology Office (TTO), describes the UCAV program as a revolutionary new tactical airpower. The program is a new paradigm in aircraft affordability with goals of 50% reduced acquisition costs and 75% reduced operational and supportability costs. Figure 4 highlights the two UCAV prototype and demonstration aircraft design specifications and performance goals.

FIGURE 4
X-45 Overview

X-45A/B UCAV	
Wing Span:	33.8 ft/47 ft
Length:	26.5 ft/36 ft
Height:	3.7 ft/4 ft
Payload capability:	1,500 lb/2,000 lb
Operating Altitude:	35,000 ft/40,000 ft

Mission Needs & Requirements

The critical components of UCAV include command, control, communications, human-systems interaction, targeting and weapons delivery, and air vehicle design. To reach full development of operational capability, two prototypes, the X-45A and the X-45B, will test the full range of performance measures.

The first prototype, the X-45A, will complete over 200 demonstration requirements. The second prototype, X-45B, will more closely resemble the final operational product. The X-45B will include integrated avionics, two fully functional weapons bays, incorporation of low observable technologies, and provisions for aerial refueling. The UCAV program office has outlined four principle elements to complete the requirements demonstration: a sophisticated system simulation, a set of representative air vehicles, a suite of mission control items, and key supportability-related components. According to Wyatt, other requirements include all weather strike capability and preemptive and reactive SEAD. Six outlined required functions of the final operational asset are: Find, Fix, Track, Target, Attack, and Assess. There is a heavy focus on preemptive attack, reactive attack, and electronic attack (Wyatt, 2002). Other mission requirements include high supportability and maintainability. The UCAV program office is tracking all aspects of global movement of the warfighting asset to include ease of transportation to keeping the maintainer in mind.

How the UCAV Program Office is Meeting the Challenges of EA

The structure of the UCAV development begins with an approximately 3-4 year long system collaborative demonstration phase followed by three separate spirals resulting in final production of the UCAV. Before the UCAV program can begin the three spirals, the system collaborative demonstration phase must successfully demonstrate certain new technologies. This collaborative phase centers on the test flight of the UCAV prototypes X-45A and X-45B. As of 21 November 2002, two X-45A UAV's have flown successfully. The first X-45A flew on 22 May 2002 and demonstrated all required capabilities. This first flight successfully demonstrated the UCAV's flight characteristics and the basic aspects of aircraft operations, particularly the command and control link between the aircraft and its Mission Control Station (Haire, 2002). The second X-45A flew on 21 November 2002 and also demonstrated all outlined capabilities. This flight test validated the functionality of the UCAV flight software on the second air vehicle and demonstrated that there are essentially no differences in the operation of the two vehicles (DARPA, 2002). Following a successful demonstration phase is the first spiral. Spiral one is scheduled to begin in FY 2006 at which time the UCAV will begin limited production for warfighter use. Following spiral one are spirals two and three where UCAV production will increase based on continuous feedback from the user. This user feedback is critical to the success of effective implementation of EA as well as to the success of the UCAV program in general. Built into the program following the demonstration phase as well as each spiral is the concept of Continuous User Assessment. Each spiral will continue to hone and enhance requirements based on the fielded technologies and user feedback. Following the three spirals, final production of the UCAV is tentatively scheduled to begin in FY 2011.

How Does UCAV Benefit from EA and Future Implications

Long-term benefits of the UCAV program include projected savings of up to 65 percent over the cost of future manned fighter aircraft (Boeing, September 2002). Additional cost savings include up to 75 percent savings on operation and maintenance over current systems (Boeing, September 2002). An additional benefit to the UCAV program is the planning of joint-operability. Boeing is currently working on a Navy UCAV-N program. The company envisions a significant amount of subsystem and software commonality between the (Air Force and Navy) programs, an arrangement that could reduce cost and risk associated with both efforts (Boeing, May 2002). In the end, DARPA, USAF, and Boeing represent a revolutionary new weapon system that can significantly increase the effectiveness and flexibility available to military commanders while lowering the overall cost of combat operations (DARPA, 2002). Further research may want to look at innovative technologies learned from the UCAV program such as Boeing's "Bird of Prey" project.

EA: Impact on Current/Future AF Acquisition

Alexander Slate, author of *Evolution Acquisition—Breaking the Mold—New Possibilities From a Changed Perspective*, defines EA as "…the process of acquiring either a new or improved capability where, for whatever reason, it is not possible or not practical to acquire it in a single acquisition" (Slate, 2002). This relatively new concept has evolved to address the pitfalls of past acquisitions and as a necessary change to get capable systems in the hands of the warfighter when they are needed. EA is here to stay and the only alternative is the traditional acquisition process that is often slow and recalcitrant.

EA is an acquisition strategy that defines, develops, produces or acquires, and fields an initial hardware or software increment of operational capability (Aldridge, 2002). EA is based on technologies that have been demonstrated in real-world environments and time-phased requirements, and ultimately have demonstrated the ability to be manufactured and deployed to the warfighter. The focus of EA is speed and flexibility, and it involves delivery of increments of capability and injecting new technology as it becomes available. Secretary Aldridge (USDAT&L) stated that EA "provides the best means of getting advanced technologies to the warfighter quickly while providing for follow-on improvements in capability" (Aldridge, 2002). The future brings new battlefronts with both known and unknown enemies. EA brings new warfighting capabilities to help ensure we are ready to meet these future challenges.

DISCUSSION

Recommendations for Execution and Application of EA

Based on our literature review, analysis of the history of the EA programs studied, and interviews with key personnel in the program offices, we have identified ten emergent patterns relative to EA. In this section we identify the patterns and provide corresponding recommendations for acquisition professionals considering the use of EA.

Recommendation 1: The user must accept the fielding of a 60% to 80% solution.

As Lt Col Zywien (personal communication, November 15, 2002) stated, "Waiting for perfect usually means getting nothing." Warfighters must be able to accept these early configurations and know that the final product will take several increments, as technology matures (Hawthorne, 2002). Col Johnson stated that the "…spiral approach does not work if the user cannot accept fielding an 80% solution in the beginning" (2002). A spiral approach requires an evolving requirements document with full "buy-in" from the user community and a firm commitment from all of the stakeholders including the pentagon, system program office, testing community, contractor, and the ultimate user (Johnson, 2002). This commitment must be focused on the long-term because everything is dynamic—user requirements and technology evolve with time. Johnson (2002) stated, "The financial community and leadership must accept that content in later spirals is subject to change based on technology and user needs."

Recommendation 2: An Evolutionary Approach Requires Evolving Requirements Documents (Johnson, 2002).

One of the biggest challenges of executing EA is that the normal acquisition processes have not been established to support this strategy. Currently there are no help guides within DOD on how to write a Statement of Work, Test and Evaluation Master Plan, or Award Fee Plan for an EA. These documents have to be flexible enough to capture changing requirements and evolving technology and have to allow for scope issues. However, these documents also have to be "tight" enough to be able to enforce and manage the contract according to the FAR. "The requirements must be sufficiently broad to give the acquisition community latitude to make trade-offs, yet give sufficient guidance so the acquisition team knows where it is trying to head" (Johnson, 2002). One Global Hawk acquisition professional described this same situation by stating that they often found themselves developing acquisition documents that were evolutionary in themselves. We suggest the ACEs establish guidelines, best practices, and training sessions for acquisition employees utilizing EA and spiral development. Also, quarterly EA Conferences should be held between all parties within DOD currently using EA and those intending on using EA in the future.

Recommendation 3: The financial community needs to be flexible and trained in evolutionary acquisition.

EA demands that the financial community's processes change. As technology and user requirements evolve, the financial community must be flexible and adapt to the dynamic nature of evolving requirements. Also, this community must also receive specialized training in EA and the effects it has on their cost estimates and budgeting procedures. EA essentially requires a more complex life cycle cost analysis since the number of variables increases with unstable and dynamic requirements. Finally, the financial community plays a critical role in budgeting for future requirements, committing funds, and justifying future money for the program. "Flexible programs are easier to cut and the financial community must accept that content in later spirals is subject to change" (Johnson, 2002).

Warfighters often fear that top-level support and funding for their program will diminish during the first couple of evolutions. "Users fear that support for programs will dry up before they get a lot of the capabilities that they need—that the EA approach will be arbitrarily short-circuited" (Slate, 2002). The user community should have an ombudsmen in place at the program office so that they are intimately familiar with the layout of the program and the funding profile that reflects it. Also, this partnership would allow the program office finance team more flexibility, innovation, and speed in capturing future funding for the program.

Recommendation 4: There must be a solidified government-contractor-user IPT that works well together (Johnson, 2002).

A program team must be formed upon requirement identification, and market research and requirements definition/tailoring/prioritization must be conducted right away. "The makeup of this team must be distributed between acquisition, test, and user communities" (Slate, 2002). The teaming concept is essential to the implementation of EA.

Terry Little, director of AF ACE, stated, "One of the reasons that our cycle times are so long is because when we start programs, you've got a whole bunch of people pulling in different directions, and ultimately all those different directions get incorporated into a program" (Druyun, 2001). Again, the user should be an integral part of the program and be involved in the acquisition processes and program (Druyun, 2001). Several personnel from the end-user should be located and working with the program office (depending on size and importance of program). This early and intense involvement and communication by and with the user, will ultimately speed the acquisition process and mitigate potential risks to the program, its dynamic requirements, and future technology evolution. EA has to utilize collaborative relationships in order to make it work. As the Air Force Transformation Team stated, "The principles of sense of urgency, discipline, teamwork, trust, agility, intelligence, and economy of force result in success in combat. They must also be taken advantage of to make success in acquisition" (Air Force Transformation Team, 2002). In order to make EA succeed, teamwork is critical. It is this teamwork and continuous communication that reduces risk within a program. The user, pentagon staff, program office, and contractor must have continuous contact and communication, and a regular formal meeting with all stakeholders is a must (Johnson, 2002).

Recommendation 5: Flexibility is critical to effective and efficient implementation EA.

Zywien (personal communication, November 15, 2002) recounts "Faced with a 20-yr threat, we respond with a 15-yr plan, programmed in 6-yr POMs, managed by 3-yr personnel, Who develop 2-yr budgets, funded by a 1-yr appropriation, Formulated over a 3-day weekend, and approved in a 1-hr decision brief."

Flexibility within the program office and its processes is critical to executing EA and "making it work." Acquisition professionals must be trained in this area of EA and must know technology. Before EA, engineers were solely responsible for attending technology conferences and keeping updated on emerging technology. Now, the acquisition community must join the ranks and keep up-to-date on emerging technology in order to be able to effectively and efficiently make programmatic decisions.

Flexibility does not mean "no accountability" (M. Zywien, personal communication, November 15, 2002). The program office, while maintaining flexible working documents, must ensure that both government and contractor maintain a sense of urgency that is called for by EA. "Regular reviews of risk mitigation plans, critical path schedules, and EVMS data will help reduce volatility within the program", while "…tailoring award fee criteria will help incentivize these new behaviors you're trying to reward" (M. Zywien, personal communication, November 15, 2002).

Recommendation 6: Logistics Issues must be looked at, analyzed, and planned for early in the program.

Multiple configurations are hard to avoid with this approach, and retrofit must be planned and budgeted for by the program office. "The logistics community must buy into having multiple configurations in the field" (Johnson, 2002) and keep updated configuration management. Spares and logistics support are critical in the EA approach as rapid change and multiple configurations in inventory are often more severe in the EA approach. Logistics personnel should constantly manage risks on operational and supportability impacts, and vigorously continue to maintain configuration control. Once the asset is fielded, those who will maintain the assets are key to the success of the program for the duration of its life. Logistics issues and long-term planning must not be underestimated (Johnson, 2002).

Recommendation 7: The testing community must be incorporated early into the program.

AFOTEC should be part of the program office from its inception. The test community must be an integral part of the acquisition team in order to negate an automatic failure in any testing scenario (Johnson, 2002). This ultimately forces the testing community to have buy-in and learn about and provide feedback on program development. Ultimately, though, this will reduce risk, as the testing community will share in the new paradigm that comes with EA. "The testing community cannot become rigidly fixed on an end requirement, or a spiral development will not work" and "the definition of effective and suitable is going to be widened to fit EA strategy" (Johnson, 2002). Also, the testing community must accept operational flights (e.g. Afghanistan and Iraq operations) in lieu of formal test flights (M. Zywien, personal communication, November 15, 2002). As Slate stated, "Perhaps using limited fielding to provide real-world data for operational assessment is the way to go, or perhaps the correct course is hybrid testing, which involves testing only those items absolutely necessary to address safety and health concerns prior to fielding, and following up with field data on other capabilities later" (Slate, 2002).

Recommendation 8: Open Systems Architecture coupled with the KISS ("Keep it simple, stupid"). Principle is vital to EA success.

The increments within each spiral should be independent by nature, ultimately reducing risk caused by reduced interdependency between requirements (Johnson, 2002). If there is parallel development there is more risk as one requirement essentially depends on the positive outcome of another (Johnson, 2002). Risk reduction is critical to effective EA and spiral development. Col Johnson stated, "If too many risky projects need to occur before any project can have success, it is not a critical path, it is a train wreck" (Johnson, 2002). Open systems architecture should be used to provide the infrastructure hooks for future requirements and evolving technology. This essentially allows you to figure it out later—matching evolving state-of-the-art technology to the user's dynamic needs as it becomes available.

EA should be looked at compartmentally at first, and then systemically. Carl Johnson, VP of Northrop Grumman Integrated Systems and lead program manager for Global Hawk, and Colonel Johnson (retired), former Program Director for the Global Hawk Program at WPAFB, stated, "You can make the rock so big, no one can carry it. By cutting the development into smaller compartments, a spiral approach can manage that risk" (Johnson, 2002, p. 181).

Recommendation 9: Stabilize funding and requirements.

Funding and requirements stability are critical to the effective execution of EA as they are in any acquisition as seen by the USAF's C-17 and F-22 case studies. General (retired) Ron R. Fogleman stated, "If you are successful in shortening the development process, you're not going to have that many technological changes…take what you have…and baseline it with that" (Battershell, 1999).

Requirements must be clearly stated and stable for technologies to develop appropriately in each spiral (Aldridge, 2001). As Slate stated, "No creeping requirements [should be] allowed!" (Slate, 2002). Also, funding stability is critical to evolving requirements and evolving acquisitions. The all too familiar DOD acquisition "death spiral" has to be nullified by full and complete "buy-in" from the acquisition community, user community, and, most importantly, the pentagon and Congress. Slate makes two recommendations: 1) a program utilizing EA should be provided stable funding. "For this type of program, money is available when needed, as opposed to only being available in particular years" and 2) the program office and user must be proactive and address future budgeting concerns as requirements change (Slate, 2002). Slate stated, "The biggest problem is the time necessary to get the money for these programs into the POM cycle. A sufficiently placed wedge in the POM as soon as a need is identified will help matters" (Slate, 2002).

Recommendation 10: Cultural changes that support flexible, concentrated efforts.

An overarching need for effective EA implementation is a total culture change within the acquisition system. Everybody, including Congress, the end-user, Pentagon staff, and acquisition implementers, needs to change his or her outlook of what a successful program is. Conflicts of interest must be removed from programs and personnel evaluation systems must be revamped to ensure that evolutions are not undertaken for the sake of action but for the purpose of mission fulfillment.

Technology development and implementation require risk taking that inevitably means mistakes will be made. Program office personnel should not fear punishment for taking calculated risks. For years, private firms have understood that failures are inevitable during technology exploration and that these "failures" and "mistakes" are great learning tools. The acquisition system also needs to support and encourage the prioritization of programs within DOD. Programs that are infeasible need to be discontinued as soon as possible to free resources that are necessary for other efforts. In today's dynamic defense environment, enemies are constantly evolving to exploit weaknesses. It must be understood that a system that is today's 60% solution may be useless in the near future. Many private firms constantly monitor their competition and markets to ensure that their new products address the current demands. When there is a gap, stage gates or milestones should be used to readdress and possibly "evolve" program requirements. Table 2 summarizes the 10 recommendations for the execution and application of EA.

Contract Administration Issues

EA is unique in the sense that it can be applied to nearly all contract types. In the Air Force alone, examples of EA exist in contracts ranging from fix-priced type contracts to cost plus award fee type contracts.

TABLE 2
Recommendations for Execution and Application of EA

1.	The user must accept the fielding of a 60% to 80% solution in early articles.
2.	An evolutionary approach requires evolving requirements documents.
3.	Financial management officesneed to be flexible and know EA.
4.	There must be a solidified and cooperative government-contractor-user IPT.
5.	Flexibility.
6.	Early Logistics analysis and planning.
7.	Early involvement of testing community.
8.	Open Systems Architecture and Keep it Simple.
9.	Stabilize funding and requirements.
10.	Cultural Changes that Support Flexible, Concentrated Efforts.

FAR Part 39 addresses issues that are relevant to incorporation of EA procedures. While FAR Part 39 focuses on acquisition of information and electronic technology, the recurring theme of rapidly changing technology closely aligns it with the concepts of EA. FAR Part 39 states, "When developing an acquisition strategy, contracting officers should consider the rapidly changing nature of information technology through market research (see Part 10) and the application of technology refreshment techniques." This requirement also applies to the spiral development aspect of EA. This high rate of technological advancement dictates careful planning and administration of the contract in a way that allows the injection of new technology as it emerges. This ensures the highest possible level of operational capability at any point in time.

As shown in our analysis, mitigation of risk is a major consideration in incorporating EA practices in any acquisition. All aspects of contract administration serve to mitigate this risk. This is accomplished through utilization of modular contracting; thorough acquisition planning tied to budget planning by the program, finance and contracting offices; continuous collection and evaluation of risk-based assessment data; prototyping prior to implementation; post implementation reviews to determine actual project cost, benefits and returns; and focusing on risks and returns using quantifiable measures (FAR, 2002). All of these measures provide clear visibility of where an acquisition stands and what contractual actions must take place to maintain desired outcomes.

Recommended Procedures for Review and Evaluation

As with any strategy or process, some method of review and evaluation must be put in place to ensure a minimum set of standards are met and put into practice. EA is still in a stage of relative infancy. As organizations continue to explore its application, some standards or norms will inevitably be established. This is the first step in creating a review system to evaluate program success. This system not only provides the acquisition team with feedback on performance, but also an opportunity to learn from successes and failures.

The Air Force must go beyond fixing a project specific problem and work at fixing the underlying norms and policies of the entire system that may cause the specific problem. This is the fundamental benefit of taking a *double-loop learning* approach to improving the system as a whole, versus taking a reactionary approach. "Double-loop learning occurs when error is detected and corrected in ways that involve the modification of an organization's underlying norms, policies and objectives" (Argyris & Schön, 1978). In addition to double-loop learning, the concepts of appropriate feedback and systems thinking must be applied when evaluation takes place. "The systems viewpoint is generally oriented toward the long-term view. That's why delays and feedback loops are so important . . . they only come back to haunt you" (Senge, 1990). While it is too early to recommend procedures for review and evaluation of EA strategies, it is clear that this process must start at the organizational level and progress to Air Force level implementation. This process starts with evaluation of what organizations have done and continue to do to make EA a reality. While a comprehensive analysis of procedures for review and evaluation is beyond the scope of this research effort, our findings serve as a good starting point for future analysis.

Evolutionary Acquisition and Systems Thinking

As discussed and evidenced throughout, EA is a strategy aimed at rapidly acquiring and sustaining a core capability with the ability to incrementally insert new technology or additional capability. This requires the acquisition and requirements communities to maintain continuous and effective communications with each other, as well as with the operational user, contractor, and other functional communities. EA gives the military extra leverage in rapidly obtaining evolving technology. This leverage comes in part from systems thinking. The bottom line of systems thinking is leverage—seeing where actions and changes bring about dramatic, long-term improvements (Senge, 1990). In short, successful implementation of an EA strategy requires systems thinking.

The goal of the traditional, single-step approach to acquisition is to satisfy a requirements document and typically drives extended development times, high costs, technology obsolescence, and outdated user requirements. This approach is characterized by "stovepipe" thinking, where each functional area focuses on its defined role in the process, often missing the relationships among the parts—the "bigger picture." In contrast to the traditional approach, EA strives to field an initial level of user-defined operational capability as quickly as possible. This change in approach requires all players in the acquisition process to embrace a shift in thinking. All personnel involved must develop the mindset of systems thinking; that is, to look at the process as a whole.

When each person better understands where he or she fits into the big scheme of things, the process works better as a whole. "Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than seeing things" (Senge, 1990). This shift towards a systems-view, looking at interrelationships, processes, and future evolutions, requires a great change in culture but is necessary for successful implementation of EA.

Systems thinking principles suggest that organizations must be innovative, more efficient, and become learning organizations in order to survive. Without systems thinking, there is neither the incentive nor the means to integrate the learning disciplines once (the strategy) has come into practice (Senge, 1990). This mindset should be embedded in the EA strategy.

NOTES

1. The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

REFERENCES

Argyris, C., & Schön, D. (1978). *Organizational Learning: A Theory of Action Perspective.* Reading, MA: Addison Wesley.

Air Force Transformation Team. (2002). *White Paper on Collaborative Relationships*. Washington, DC: Author.

Aldridge Jr., E.C. (2002, April). *EA and Spiral Development*. Washington, DC: Author.

Ayres, B. (2002, Fall). *Lecture on Cycle Time Reduction and Evolutionary Acquisition.* Wright-Patterson AFB, OH: Air Force Institute of Technology.

Battershell, A.L. (1999). *The DOD C-17 vs the Boeing 777*. Washington, DC: National Defense University Press.

"Boeing X-45A Unmanned Combat Air Vehicle Begins Flight Testing." (2002, May). *Boeing News Release.* [On-line]. Available at: www.boeing.com/news/releases/2002/q2/nr_020523m (Retrieved on November 15, 2002).

"Boeing Previews UCAV System." (2002, September). *Boeing News Release.* [On-line]. Available at: www.boeing.com/news/releases/2000/news_release_000927n. (Retrieved on November 15, 2002).

Druyun, D. (2001, October). *SAF/AQ Presentation to Corona Conference.* [On-line]. Available at www.InsideDefense.com (Retrieved on December 15, 2002).

Federal Acquisition Regulation, Part 39 (2002, November). [On-line]. Available at: http://farsite.hill.af.mil (Retrieved on November 5, 2002).

Haire, J. (2002, May). *Unmanned Combat Air Vehicle Completes First Flight.* [On-line]. Available at: www.af.mil/news/May2002/n20020523_0841 (Retrieved on November 25, 2002).

Hawthorne, S. (2002, August). "EA and Spiral Development," *CrossTalk: The Journal of Defense Software Engineering, Vol 15:8, p. 14.*

Johnson, W.M. & Johnson, C.O. (2002, Summer). "The Promise and Perils of Spiral Acquisition," *Acquisition Review Quarterly.* [On-line]. Available at: www.dau.mil/pubs/arq/2002arq/JohnsonSM2.pdf (Retrieved on November 10, 2002).

Markowski, S. (2000, March). *Incremental Acquisition and Leasing in Australasia* [On-line]. Available at http://www.dau.mil/international/presentations/markowski%202000.ppt (Retrieved on October 30, 2002).

McNutt, R. (2000, October). *Reducing Air Force Acquisition Response Times: Evolutionary Acquisition and Spiral Development Briefing.* Washington, DC: Author.

"Rumsfeld's Rules." (2002, September 9). *Aviation Week and Space Technology.* [On-line]. Available at: http://ebird.dtic.mil/Sep2002/s20020909rules (Retrieved October 22, 2002).

SAF/AQ (Office of the Assistant Secretary of the Air Force for Acquisition). (2002). *Air Force EA Acquisition Guide*. [On-line]. Available at: http://www.safaq.hq.af.mil/ACE (Retrieved on November 12, 2002).

Sambur, M. (2002, June). *Reality-Based Acquisition System Policy for All Programs*. Washington, DC: Author.

"Second Unmanned Combat Air Vehicle Completes First Test Flight." (2002, November). *DARPA News Release*. [On-line]. Available at: www.darpa.mil/ucav (Retrieved on November 25, 2002).

Senge, P. (1990). *The Fifth Discipline*. New York, NY: Doubleday.

Slate, A. (2002, May/June). "Breaking the Mold—New Possibilities from a Changed Perspective," *Program Manager, 31* (3): 6-15.

Wyatt, E. (2002, August). *DARPA/USAF UCAV System Demonstration Program Update Briefing.* [On-line]. Available at http://www.darpa.mil/ucav/images/SlidesPage/UCAV_Overview.pdf (Retrieved on November 20, 2002).