



Lean Aerospace Initiative (LAI)

LAI Research Studies

Applicable to Acquisition

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This publication contains abstracts for past research projects related to acquisition completed within the LAI research group at Massachusetts Institute of Technology. Links are provided to the full thesis documents.

LAI Website: <http://lean.mit.edu/>

If this report was useful to you, we would appreciate your feedback and comments.

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Acquisition Research Overview

LAI@MIT has been active in acquisition research since its inception. Over the last decade, we have generated 21 theses and papers. Figure 1 below, shows the chronological distribution of theses/ papers since 1994. Figure 2, shows the research focus on acquisition.

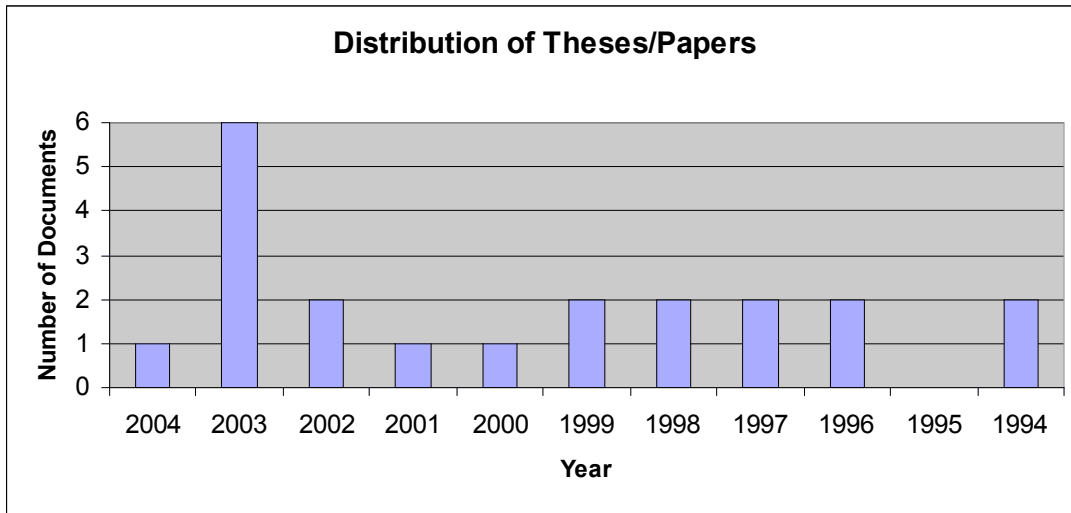


Figure 1. Theses/Paper Distribution

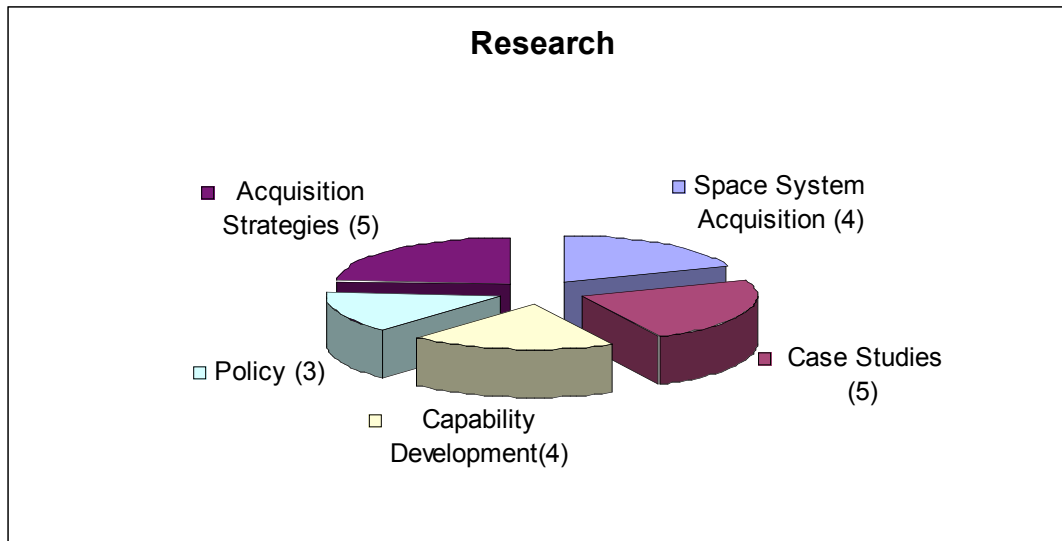


Figure 2. Research Focus

Space System Acquisition

Modularity as an Enabler for Evolutionary Acquisition

Shah, Nirav

May, 2004

Thesis

The end of the cold war witnessed several significant changes in the defense acquisition environment. Budgets declined and the scope of missions expanded. At first, the DoD did not respond well to these pressures resulting in cost overruns and schedule delays becoming the norm. In an effort to change this situation, national security officials decided to fundamentally change the way systems were acquired, shifting the focus to systems that could evolve/adapt to changing resources and needs. To operationalize this shift they recommended implementing an evolutionary acquisition strategy using a spiral development process. The fundamental characteristic of the evolutionary acquisition strategy is a focus on delivering a minimum capability early and then building upon that capability as risks are resolved. This imposes requirements on the acquisition process and the system architecture. From a process perspective, since needs and resources are changing over time, involving all relevant stakeholders is key to successful evolutionary acquisition. Since the objective was to prevent cost overruns and schedule slips, understanding and mitigating key risks is central. From an architectural perspective, the ability to update the system to allow for enhanced capability is important. The MATE-CON process can be used to satisfy the process related requirements of evolutionary acquisition. MATE-CON uses a multi-attribute utility theory to capture the diverse and changing needs of decision makers. Then tradespace exploration is used to fully reveal the impact of design decision on decision maker perceived value. By representing both value and expense in terms of metrics that all stakeholders can understand, MATE-CON facilitates effective collaboration between stakeholders. A modular architecture provides the architectural flexibility required when using evolutionary acquisition. By separating system components into a few decoupled modules, the modular architecture allows enhancements to be made to the modules without adversely affecting the rest of the system. Changes can be made to accommodate new needs or incorporate new capabilities. This flexibility in-service come at the price of a possible loss of performance and/or design efficiency. Thus valuation of the flexibility gained is crucial. An options framework that incorporates risk identified by the stakeholders should be used. The Space Based Radar is a good example of a system that demonstrates the challenges faced by defense acquisition identified above. The most recent attempt at an actual hardware demonstration was canceled because of cost overruns and schedule slip. Using the MATE-CON approach and a modular constellation architecture, evolutionary strategies for space-based radar can be found.

Tools for Evolutionary Acquisition: A Study of Multi-Attribute Tradespace Exploration (MATE) Applied to the Space Based Radar (SBR)

Spaulding, Timothy J.

June 2003

Thesis

The purpose of this thesis, broadly stated, is to further the state of knowledge regarding the evolutionary acquisition of weapons systems for the United States Air Force. With that umbrella objective in mind, it attacks a much narrower field of study related to the tools and processes that

must be developed in order to enable the evolutionary acquisition strategy. Specifically, one such tool is examined: the Multi-Attribute Tradespace Exploration (MATE).

[Architecting Evolutionary Strategies Using Spiral Development for Space-based Radar](#)

Roberts, Christopher J.

May 2003

Thesis

The Department of Defense has identified the Space Based Radar (SBR) Program as a candidate for evolutionary acquisition to be implemented by the spiral development process. However, spiral development was originally developed in the software industry, and a consensus has not emerged about its applicability to space systems. In addition, space systems typically have not been developed with explicit considerations of architectural modularity and scalability, features necessary to enable evolutionary acquisition strategies. A stakeholder based system architecting process known as multi-attribute tradespace exploration (MATE) provides a framework for combining computer based modeling and simulation of complex engineering systems with decision theory. The MATE process has been successfully applied to several space system projects, yielding illustrative trades analysis along the dimensions of utility and cost. However, no previous attempt has been made to incorporate the schedule dimension, a step that is critical for architecting evolutionary strategies. Qualitative comparisons between software systems and SBR in the context of spiral development suggest a fundamental difference in system evolution and risk mitigation strategies, yet found the spiral development and evolutionary acquisition framework to be suitable to SBR. A quantitative MATE SBR software model enabled an analysis of architectural modularity and scalability, successfully incorporated the addition of the schedule dimension, and demonstrated the concept of acquisition tradespace exploration. These analyses led to insights regarding the objectives, challenges, and limitations of applying computer based modeling and simulation as a tool for spiral development of evolutionary complex engineering systems. Finally, policy recommendations for improving cost accounting, key stakeholder participation, and evolutionary options analysis were made based on findings of the research.

[Multi-Attribute Tradespace Exploration and its Application to Evolutionary Acquisition](#)

Derleth, Jason E.

May 2003

Thesis

This thesis shows that MATE (Multi-Attribute Tradespace Exploration) is a useful tool for a systems engineer working on an EA system. There are many benefits to the use of MATE in EA, including but not limited to: a better understanding of the end user's desires and requirements for the system; the ability to optimize the system for the first evolution; the possibility of understanding what will become optimal in later evolutions; quick redesign time if circumstances or preferences change; and further insight into systems level considerations

Acquisition Strategies

Product Development Strategies in Evolutionary Acquisition

Ferdowski, Bobak

August, 2003

Thesis

Organizations are always pushed to develop new products to capitalize on advances in technology as well as to stay ahead of the competition. In the case of the Air Force, the challenge is to provide the user—the warfighter—with the best capability possible. This challenge is magnified by the number of uncertainties and risks the program expects and will experience throughout the product development process. These product development processes, of which there are a variety that address different uncertainties, are the means by which the program grows a solution from a perceived need. As a result of a number of common challenges in the Air Force and the rest of the aerospace community—namely increasing development times and costs for new products—the Air Force has decided to implement an evolutionary acquisition strategy, meaning the development process focuses on delivering incremental capabilities through short increments or spirals. The question, however, is whether this strategy makes sense across the broad spectrum of Air Force programs. More important, how can the Air Force, and aerospace programs in general, decide what product development strategy applies to each program? An extensive literature review yielded a number of relevant questions regarding product development. The hypothesis of this research is that this selection should be based on attributes of the product, the program goals, the uncertainties, and stakeholder involvement.

Stakeholder Collaboration in Air Force Acquisition: Adaptive Design Using System Representations

Dare, Robert E.

May, 2003

Thesis

Air Force development of new or evolutionary weapon systems is a complex endeavor due to the involvement of many stakeholders and the presence of considerable uncertainty in the acquisition environment. The ability to adapt a weapon system while it is still being designed affords a means to respond to this complexity. The fundamental motivation for this research is to discover how Air Force development programs, operating within established constraints, can improve their adaptability during the design phase to provide more value to the warfighter.

The thesis of this research is that the quality and nature of collaboration between stakeholders during the design phase of weapon system development programs determines how effectively they share knowledge, which in turn drives the level of program adaptability. Eight case studies were conducted on Air Force development programs. Data were collected on collaborative practices and patterns of adaptability demonstrated during design. The research placed an emphasis on usage of “system representations” such as prototypes and beta software releases that acted as a form of boundary object to facilitate knowledge sharing across organizational boundaries.

As programs used system representations to provide higher levels of knowledge sharing, they were found to be more adaptable. System representations were more effective at promoting adaptability when they represented the design with higher fidelity, providing system-level detail and covering stakeholder emphasis areas. Lastly, certain key stakeholder roles were found to contribute both flexibility and structure, facilitating a “zone of novelty” in which the

stakeholders could exercise creativity and evaluate design options while still executing the program within established constraints.

This research indicates that the pressing need for Air Force programs to be able to adapt in today's uncertain acquisition environment can be addressed to a significant degree through the usage of effective system representations in conjunction with supporting patterns of stakeholder interaction. Specific recommendations for Air Force acquisition policy makers and practitioners are provided.

Managing Subsystem Commonality

Nuffort, R. Matthew

February, 2001

Thesis

Common systems satisfy the requirements of multiple platforms and meet designated architecture, performance, life cycle cost, and interface standards. Commercial industry has leveraged commonality strategies, such as modular and platform-based design, to reduce product development times and costs. This research seeks to understand whether similar strategies can apply to the defense aerospace industry. The work (1) explores the benefits and costs of increased subsystem commonality in the aerospace industry, (2) addresses when it is appropriate, and (3) examines the organizational structures necessary to achieve greater commonality. The analysis draws on eight case studies of both commercial and military aerospace organizations to address the three primary research topics from a total life cycle perspective.

Best Practices In User Needs/Requirements Generation

Wirthlin, J. Robert

February, 2000

Thesis

An idealized process framework for the front-end of product development was developed. The framework covers the process space from an initial need (or recognition of a need) to the decision for a product/development program launch. The framework focuses on the activities required for the development of requirements needed for a business case decision. The framework was developed through a thorough examination of the literature relating to product development and addresses not only the activities required to traverse the front-end of product development, but also metrics and a process maturity matrix by which an organization's process can be evaluated

Reducing DoD Product Development Time: The Role of the Schedule Development Process

McNutt, Ross.

December, 1998

Thesis

According to the Packard Commission, "Unreasonably long acquisition cycles -- ten to fifteen years for major weapon systems is a central problem from which most other acquisition Problems stem." Since the commission issued its report in 1986, the time required to develop new military systems has only grown. This research and its recommendations are intended to identify and eliminate the causes of those long development times for military systems. This report addresses a key factor in determining the development time for military projects: the project's initial schedule.

Capability Development

[Applying the Lessons of “Lean Now” To Transform the US Aerospace Enterprise](#)

Jobo, Maj. Major USAF
Report

August, 2003

Lean is common sense and good business sense. As organizations grow and become more successful, they begin to lose insight into the basic truths of what made them successful. Organizations have to deal with more and more issues that may not have anything to do with directly providing products or services to their customers. Lean is a holistic management approach that brings the focus of the organization back to providing value to the customer.

In August 2002, Mrs. Darleen Druyun, the Principal Deputy to the Assistant Secretary of the Air Force for Acquisition and government co-chairperson of the Lean Aerospace Initiative (LAI), decided it was time for Air Force acquisitions to embrace the concepts of lean. At her request, the LAI Executive Board developed a concept and methodology to employ lean into the Air Force’s acquisition culture and processes. This was the birth of the “Lean Now” initiative. An enterprise-wide approach was used, involving Air Force System Program Offices (SPOs), aerospace industry, and several Department of Defense agencies. The aim of Lean Now was to focus on the process interfaces between these “enterprise” stakeholders to eliminate barriers that impede progress. Any best practices developed would be institutionalized throughout the Air Force and the Department of Defense (DoD).

The industry members of LAI agreed to help accelerate the government-industry transformation by donating lean Subject Matter Experts (SMEs) to mentor, train, and facilitate the lean events of each enterprise. Currently, the industry SMEs and the Massachusetts Institute of Technology are working together to help the Air Force develop its own lean infrastructure of training courses and Air Force lean SMEs.

The first Lean Now programs were the F/A-22, Global Hawk, and F-16. Each program focused on specific acquisition processes. The F/A-22 focused on the Test and Evaluation process; the Global Hawk focused on Evolutionary Acquisitions; and the F-16 focused on improving the Contract Closeout process.

Through lean, each enterprise made many significant improvements. The F/A-22 was able to reduce its Operational Flight Plan (OFP) Preparation and Load process time of 2 to 3 months down to 7 hours. The Global Hawk developed a new production plan that increases the annual production of its Integrated Sensor Suite from 3 per year to 6 per year. The F-16 enterprise generated and is working 12 initiatives that could result in a contract closeout cycle time reduction of 3 to 7 years. Each enterprise continues to generate more lean initiatives that focus on other areas and processes within their respective enterprises.

From the observations of the three Lean Now prototype programs, a common methodology for implementing lean can be developed. This methodology has three distinct phases: 1) Set-up

Phase, 2) Planning Phase, 3) Execution and Follow-through. Within each phase are distinct steps that must occur in order for the lean initiative to be successful.

[The Pursuit of Acquisition Intrapreneurs](#)

Foreseth, Christopher E.

September, 2002

Report

This report features research focused on identifying Acquisition Intrapreneurs, viewed and defined for the purpose of this research as, individuals within the acquisition profession who take direct responsibility for turning ideas into products through assertive risk taking. The basis for this research stems from the agile acquisition push for “breeding innovators” to achieve a leaner and more responsive approach to the design, build, test and fielding of warfighting systems

[Fostering Innovation Across Aerospace Supplier Networks](#)

Kirtley, Aaron

June, 2002

Thesis

The supplier base accounts for a large share of the total cost and technology content of major defense aerospace acquisition programs, such as the F-22 Raptor. Also, a significant share of technological innovation across many industries takes place at the interface between customer companies and their suppliers. This research seeks to determine what incentives, practices, and tools aerospace companies can employ to foster greater innovation across their supplier networks, thereby optimizing weapon systems’ performance and affordability. It also attempts to understand how the defense contracting policies of the US government may encourage or act as barriers to innovation in supplier relationships. These questions are addressed through in-depth case studies focused on two major avionics subsystems of the F-22 Raptor. The case studies explore the interactions between the prime contractor, major subcontractors, and sub-tier suppliers involved in the subsystems’ design, development, and production.

[Cultural Analysis Case Study: Implementation of Acquisition Reform within the Department of Defense](#)

Doane, Donna R., and Susan Spencer

June, 1997

Thesis

Over the past 20 years, the DOD has attempted to reform their acquisition policies but has failed to address the significance of culture in the implementation of reform. This thesis focuses on the impact and importance of culture on implementing and sustaining long-term change efforts. Edgar H. Schein's framework for analyzing culture within the organization is the model for the analysis focusing on the essential elements; mission and strategy, goals, means, measurement, and correction. Using case study analysis, the primary research focused on a large Navy and Air Force procurement under the new Acquisition Reform philosophy. The organizational structure of the program, roles, responsibilities, accountability, incentives and motivations of all levels within the Department of Defense workforce is defined and analyzed. The results of the analysis will be integrated into Schein's framework to identify common themes that exist across the services and the specific organizations

Policy

Economic Incentives in Aerospace Weapon Systems Procurement

Cowap, Stacey A.

February, 1998

Thesis

In the last several years, policy makers have attempted to make changes in the defense acquisition system to allow for a structure that provides for the selection and budgeting of the most cost-effective weapons. Senior Department of Defense officials are attempting to shift away from regulation and oversight and towards economic incentives for the procurement of higher quality and lower cost weapon systems. This thesis provides a framework for the establishment of incentives within an aerospace weapon system program. The objective of this thesis is to provide a framework for government and contractor program managers to develop economic incentives in the future. Changing acquisition policies challenge program managers as they attempt to structure procurement contracts that meet government and company goals and objectives. The framework developed highlights the critical link between the management processes within a weapon system acquisition program and the establishment of economic incentives.

Preliminary Observations on Program Instability.

Rebentisch, Eric

October, 1996

White Paper

This white paper reports emerging findings at the end of Phase I of the Lean Aircraft Initiative in the Policy focus group area. Its objective is to discuss high-level findings detailing: 1) the relative contribution of different factors to a program's overall instability; 2) the cost impact of program instability on acquisition programs; and 3) some strategies recommended by program managers for overcoming and/or mitigating the negative effects of program instability on their programs. Because this report comes as this research is underway, this is not meant to be a definitive document on the subject. Rather, it is anticipated that this research may potentially produce a number of reports on program instability-related topics.

Acquisition Reform

Sapolsky, Harvey

June, 1994

Report

A review of the six most recent major acquisition reform reports, starting in 1949 with the Hoover Commissions and including McNamara's Totalpackage Procurement, Fitzhugh Commission, the Commission on Government Procurement, the Grace Commission, and ending with the Packard Commission report in 1986. They frame the weapons acquisition process as a tradeoff between technical and political uncertainty by the program manager. Political uncertainty can be managed either by multi-year procurement or by reducing technological uncertainty and time-to-market. The reports' recommendations are divided into six areas: centralized procurement, professionalization of the acquisition corps, management improvements, changes in contracting procedures, new development strategies, and legislative/executive relations.

Case Studies

[Causes and Impacts of Class One Engineering Changes: An Exploratory Study Based on Three Defense Aircraft Acquisition Programs](#)

Hsu, Teng-Cheng

June, 1999

Thesis

Past studies on engineering changes have focused on products other than defense aerospace products, and have concentrated primarily on the design-manufacturing interface within single companies. Thus, engineering changes in the context of US defense aerospace product development - where the user community, the acquisition community, and the contractors share the responsibility for developing a product - remain largely unexplored. This research focused on three defense aircraft acquisition program case studies, referred to hereafter as Programs A, B, and C. The primary goal of these studies was to develop a better understanding of the causes and impacts of Class I engineering changes in the US defense aerospace product development context. Class I engineering changes, simply referred to as engineering changes below, are those that fundamentally modify the form, fit, and/or function of a product such that the results before and after the engineering changes are different, and are visible to all communities involved with developing the product. In addition, this research sought to identify ways in which contractors and customers may help to reduce the number of undesirable engineering changes.

[The Cost and Cycle Time Implications of Selected Contractor and Air Force System Office Management Policies During the Development Phase of Major Aircraft Acquisition Programs](#)

Morgan, Sean

May, 1999

Thesis

The interactions between an Air Force System Program Office (SPO) and the prime contractor during the research and development phase of a major aircraft acquisition program are investigated using continuous-time simulation models. The cost and cycle time implications of select management policies are evaluated. The work confirms the high degree of interdependence inherent in the SPO-contractor relationship, indicating that a systems approach to managing this system is desirable. It also demonstrates that effective use of staffing policies and management reserves, as well as attention to process quality, can result in significant cost and schedule performance improvements.

[A Study of the Federal Government's Experiences with Commercial Procurement Practices in Major Defense Acquisition](#)

Anderson, Michael

June, 1997

Thesis

The continual decline in our country's defense budget has severely impacted both government and the defense industry. To cope, the government has increasingly relied on the use of commercial procurement practices, a central tenet of federal acquisition reform. This thesis examines the impact of new commercial procurement practices from the perspective of the average defense acquisition manager. Using research information gathered from 23 current

defense acquisition programs which used commercial procurement practices successfully, the thesis identifies specific practices in use, documents lessons learned from practice implementation, and investigates five core hypotheses regarding the direct impact of the practices on acquisition costs, acquisition schedule, quality, life cycle support, and life cycle costs.

Supplier Management Practices of the Joint Direct Attack Munition Program.

Lucas, Malee V

June, 1996

Thesis

U.S. defense aerospace contractors have been in the process of reducing the supplier base and delegating greater responsibilities to key suppliers in order to remain competitive in the face of defense cutbacks. The trend towards greater outsourcing has meant that new products and modifications of existing systems are being designed, developed, and produced by first tier and lower tier suppliers. Supplier management becomes increasingly important as suppliers take on a greater role in product development. The Joint Direct Attack Munition (JDAM) program reveals changes in the model for supplier relationships in the defense aerospace industry that have been accompanied by unprecedented results. The joint Air Force and Navy program was designated a Defense Acquisition Pilot Program by the Department of Defense to implement acquisition reform -- particularly the reform measures of the Federal Acquisition Streamlining Act of 1994. Changes in decision-making, program structure, and organizational culture occurred as the result of reform measures and the product development administration of the program. The changes implemented by the Government as well as the innovative supplier management practices of the prime contractor showed progress in the general model for supplier relationships towards a more collaborative, team-oriented partnership. The JDAM program not only reveals the use of a new model for supplier relationships and management but also reveals that the underlying corporate strategies of subcontractor firms influenced the types of information exchanged within the program. Limitations in certain types of information exchanged, however, did not necessarily limit subcontractor contributions to product development and to program affordability goals. It was also revealed that the dynamics behind JDAM team formation influenced the type of innovation in development of the Guidance Control Unit. The linkages of the suppliers and the supplier designs resulted in innovations that changed the system architecture. In future programs, the Government, prime contractors, and suppliers may be able to manage the types of resulting designs and innovations by focusing on team dynamics and inter-relationships.

Critical Examination of a Complex and Critical Major Acquisition for the Department of Defense: The Advanced Medium Range Air-to-Air Missile (AMRAM)

Robbins, James F

April, 1994

Thesis

In 1976, a group of United States Air Force and United States Navy fighter aircraft pilots told the acquisition professionals of the Armament Development and Test Center at Eglin Air Force Base in Florida the operational requirements for a new, lightweight air-to-air missile. They dreamed that the engineers and scientists of the US aerospace community could put an entire radar system more powerful than most aircraft radar into a 7-inch diameter and that the resulting missile would let them launch multiple missiles at multiple enemy aircraft from beyond visual range. As

of March 1994, the operational forces have received over 3,000 missiles that surpass all expectations in performance and reliability. This thesis is a case study of the acquisition strategy and Government organization that the Department of Defense used to acquire the AMRAAM system. The AMRAAM program is explained and analyzed from a managerial perspective from the genesis of the operational requirements until March of 1994. Positive and negative lessons learned, as well as critical programmatic issues, are described for research and development, introduction of production competition through a leader/follower technique, pre-planned product improvements to sustain system performance well beyond the year 2010, management in the joint-service environment, and multi-national participation. The thesis concludes with alternative acquisition strategies that the Air Force has for the AMRAAM program. The road to AMRAAM's success as a program was long and difficult. Current and future Department of Defense programs will be benchmarked against the AMRAAM accomplishments.