3-2001

An Identification and Discussion of Key Success Factors in the Acquisition of Commercial-off-the-shelf (COTS-) Based Systems

John F. Corbett

AN IDENTIFICATION AND DISCUSSION OF KEY SUCCESS FACTORS IN THE ACQUISITION OF COMMERCIAL-OFF-THE-SHELF (COTS-) BASED SYSTEMS

THESIS

John F. Corbett, Captain, USAF

AFIT/GAQ/ENV/01M-03

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY
AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT/GAQ/ENV/01M-03

AN IDENTIFICATION AND DISCUSSION OF KEY SUCCESS FACTORS IN THE ACQUISITION OF COMMERCIAL-OFF-THE-SHELF (COTS-) BASED SYSTEMS

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Acquisition Management

John F. Corbett, B.S.

Captain, USAF

March 2001

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

AFIT/GAQ/ENV/01M-03

AN IDENTIFICATION AND DISCUSSION OF KEY SUCCESS FACTORS IN THE ACQUISITION OF COMMERCIAL-OFF-THE-SHELF (COTS-) BASED SYSTEMS

John F. Corbett, B.S.
Captain, USAF

Approved:

David Petrillo, Lt Col, USAF (Chairman) — 02 MAR 01 — date

Paul W. Thurston, Jr., Maj, USAF (Member) — 02 Mar 01 — date

Acknowledgements

Although this thesis effort is credited one author, the final product would not have been accomplished without the help of many others. The first person I would like to thank is my thesis advisor, Lt Col David Petrillo. His constant editing and guidance resulted in a product that is immensely more professional and grammatically correct than could have ever been done by me alone. I also would like to thank all of the people I interviewed from the programs studied in the thesis. They were all extremely professional and quick in their responses when they did not need to be.

I am also indebted to several of my classmates. With deadlines looming, Rachael Harris provided the direction I needed to complete this project. Capt Paul Porter provided the help I needed with the computer programs without fail and without complaint. Capt Tommy Gates, 1st Lt Dan Shingledecker, Capt Bill Elyea, Capt Doug Thrailkill, and Capt Ron Tougaw (*back row*) ensured that I kept the correct perspective while completing the thesis.

John F. Corbett

Table of Contents

Page

Acknowledgements iv

List of Figures viii

List of Tables ix

Abstract x

I. Introduction 1

Overview 1
Best Value 1
Problems 2
Acquisition Strategy 2
Problem Statement 3
Research Objectives 5
Research Questions 5
Methodology 6
Scope 6
Organization of Thesis 7

II. Literature Review 8

Overview 8
Background 8
Types of COTS-based Systems 9
Benefits 9
Regulatory Guidance 11
Problems 12
Inflexible Requirements 12
Technology Cycle Time 12
Upgrades 13
Budget 13
Risks 14
Upgrade 14
Quality 15
Security 15
Funding 16
Risk Reduction 16
System Acquisition 17

Page

Commercial Practices 17
Configuration Management 17
Correct Vendor 17
Strategy 18
Definition 18
Guidance 18
Research 19
Identification of Key Factors 20
Critical Items 28
Qualitative Follow-up 28
Summary 28

III. Methodology 30

Overview 30
Research Questions 30
Scientific Advisory Board 31
Research Method Selection 32
Qualitative Research 33
Case Study 34
Types of Case Studies 34
Sources of Evidence 34
Data Analysis 35
Theory 35
Analysis Coding 35
Application 36
Analysis of Key Factors 36
Analysis of Critical Factors 37
Qualitative Follow-up 38
Criteria for Evaluating Research Quality 38
Construct Validity 38
Internal Validity 39
External Validity 39
Reliability 39
Summary 40

IV. General Results and Analysis 41

Overview 41
Key Factor Analysis 41
TOC/CAIV 52
Critical Item Analysis 54
Qualitative Follow Up 57
Cost as an Independent Variable 58

Page

Total Ownership Cost 60
Summary 63

V. Findings and Conclusions 64

Overview 64
COTS 65
TOC/CAIV 65
Analysis 66
Flexible Requirements 66
Upgrades 68
Limitations 69
Recommendations For Future Research 70
Closing Remarks 71

Appendix A. Interview Questions 73

Bibliography 74

Vita 77

List of Figures

Figure   Page

1. Typical Cost Distribution..14

2. TOC Drivers..42

List of Tables

Table | Page

1. Key Factor Identification 21

2. Relevant Situations for Different Research Strategies 32

3. Key Factor Analysis 45

4. Critical Item Analysis 54

5. Unanimous Results 56

AFIT/GAQ/ENV/01M-03

Abstract

The purpose of this research was to explore COTS-based systems as they are acquired by the Air Force. Current guidance related to the acquisition of COTS-based systems is explored. Based upon the literature reviewed, the research targeted the specific area of acquisition plans. A multiple case study of acquisition plans from several COTS-based systems was performed.

Current guidance related to acquisition plans has not been specifically tailored to COTS-based systems. The results of the analysis of the COTS-based systems showed that the use total ownership cost (TOC) and cost as an independent variable (CAIV) enabled a system to be highly successful. The use of TOC combined with the use of CAIV in a COTS-based system ensures a system has flexible requirements. This flexibility will lead to maintaining or lowering costs while increasing operational capabilities. Additionally, a plan for upgrades in a COTS-based system, that includes TOC and CAIV, provides for reduced life cycle costs while allowing for system upgrades. It is imperative that any future acquisition guidance related to COTS-based systems includes TOC, CAIV and a plan for upgrades.

AN IDENTIFICATION AND DISCUSSION OF KEY SUCCESS FACTORS IN THE ACQUISITION OF COMMERCIAL-OFF-THE-SHELF (COTS-) BASED SYSTEMS

I. Introduction

Overview

In recent years, the DoD has experienced shrinking budgets. Although yearly budgets have been smaller, the DoD still realizes the importance of acquiring the best possible weapons systems. Commercial-off-the-shelf (COTS) items have been offered as a means for DoD programs to reduce acquisition costs while keeping current technology in the hands of the warfighter. In COTS-based systems, commercial hardware and software is used to satisfy the needs of the system.

Best Value. Acquisition professionals determine which items to purchase by performing a value analysis. A value analysis is the relationship between value, attributes, and cost. The user subjectively determines the value of the item. The attributes of the item are associated with the product or service itself. Quality, delivery, maintenance and ease of use are all attributes of an item. As an equation, the value analysis is the relationship between value, attributes, and cost:

Value = Attributes of the Item / Cost of the Item

The value of an item increases when the cost decreases and the attributes remain the same. The value of an item can also increase if its attributes are enhanced while the cost remains the same or is lowered (Monczka, 1998). The DoD hopes to achieve the best value when acquiring COTS-based systems.

Problems. Recent studies have shown problems with COTS-based systems. Although costs may be lower in the development stage, unforeseen sustainment issues have caused total life cycle costs to be higher than traditionally developed systems. In COTS-based systems these life-cycle costs in the acquisition, operation, support, and disposal of the system are difficult to determine. In addition to the cost problems, COTS-based systems have different risks associated with them, especially with regard to interoperability. Interoperability is the ability of one system to work with another system (AFI 10-601, 1998). COTS products are developed by vendors for the commercial marketplace with little regard for the military system in which they are included (Tracz, 2000). Product upgrades are also developed for the commercial marketplace. These upgrades may or may not work in a COTS-based system. Interoperability of the COTS-based system is risked each time a vendor upgrades its product.

Acquisition Strategy. To overcome these problems, a recent Air Force Scientific Advisory Board (SAB) recommended that the Air Force prepare and promulgate policy with regard to the acquisition strategy used for COTS-based systems. An acquisition strategy is developed to manage the acquisition to meet the user's needs within resource constraints (DoD 5000.2R, 1999). The acquisition strategy is then documented in the acquisition plan, which is required for all acquisitions. Currently, Air Force guidance on acquisition plans does not specifically address issues with COTS-based systems.

Due to the development process, technology cycle time, upgrade issues, and budget differences, Air Force policy needs to address the strategy used in acquiring a

COTS-based systems. Typical system development in the DoD has been accomplished by defining the need, designing the item, and then implementing the solution. This is known as waterfall development. COTS systems require simultaneous definition, design, and implementation of new technology. This approach is called spiral development (Grant, 2000).

COTS-based systems are developed in order to take advantage of the most current technology. Military systems, built to last 20 years or more, are antiquated by technology that can change every 18 months. This technology cycle time creates an imbalance that can be taken advantage of by using COTS-based systems. Typically, DoD systems do not rely on the marketplace to control upgrades. Changes are usually determined more by the system designers than the marketplace. In order to ensure vendor support, upgrades need to be made to COTS-based systems. These changes, which are determined by the marketplace, can affect the interoperability of COTS-based systems. These continuous systems upgrades affect the operations and support costs of COTS-based systems. The development processes, technology cycle time, upgrade issues, and budgetary problems in COTS-based systems requires the development of new acquisition plan guidance.

Problem Statement

COTS-based systems have been proposed as a solution to budget problems in the military. However, problems such as life-cycle cost and interoperability can reduce the benefits attained by COTS-based systems. COTS-based systems need to be developed in a spiral approach rather than a waterfall approach. They also need to have continuous upgrades as determined by the commercial marketplace. These upgrades lead to increased interoperability problems in COTS-based systems. In order to attain the maximum benefits from COTS-based systems, their acquisition plans need to be tailored specifically to COTS-based systems. This leads to the specific problem statement: ***Currently, there is no standardized guidance for the development of an acquisition plan for a COTS-based system.***

There is no guidance or model of an acquisition plan specifically tailored to the acquisition of COTS-based systems. DOD 5000.2R, *Mandatory Procedures for Major Defense Acquisition Programs and Major Automated Information Systems Acquisition Programs*, provides guidance for developing acquisition strategy. A plethora of information is available for DoD acquisition professionals to use in developing acquisition strategies. However, the DoD has only recently published considerations and lessons learned for COTS-based systems. This still does not provide specific guidance for developing an acquisition strategy for COTS-based systems. Acquisition professionals do not have a reference to use in developing acquisition plans for COTS-based systems. This study examines the acquisition plans used in COTS-based systems and provides recommended guidance in the acquisition plans for these systems. Specifically, this research focuses on how acquisition plans affects the success of COTS based-systems.

Research Objective

In order to supply a solution to the problem statement, two research objectives were identified. The first research objective was to develop key success factors to be included in the acquisition plans of COTS-based systems. The second research objective was to identify which critical items need to be included in the acquisition plans of COTS-based systems. Reaching these objectives should enable the development of acquisition plan guidance.

Research Questions

To develop the guidance for COTS-based systems acquisition plans, key success factors in the acquisition plans of successful COTS-based systems were identified. The key success factors were reviewed to determine how they impacted program success. Critical factors were also developed and reviewed. Additionally, the quantity of critical factors was reviewed to determine if not one, but a combination of common items led to success. The problem statement was investigated by addressing these questions:

Research Question 1. "Is there a relationship between key factors of an acquisition plan and highly successful programs?"

Research Question 2 "How do the key success factors affect success of the program?"

Research Question 3. "How many critical items need to be present in the acquisition plan for the program to be rated highly successful by the SAB?"

Methodology

In answering the research questions, real world case studies were used to analyze the COTS-based programs rated highly successful and COTS-based programs not rated highly successful. Current literature was reviewed to identify key factors. The acquisition plans from these case studies were then compared to determine which factors led to the program being rated highly successful. Once these items were identified, they were studied to see how they affected the success of the program. Additionally, critical items were identified from the key success factors. The critical items were viewed cumulatively to determine if a certain number of critical item in an acquisition plan leads to program success.

Scope

This research effort examined the COTS-based systems identified in the Air Force SAB report entitled *Ensuring Successful Implementation of Commercial Items in Air Force Systems*. The SAB studied 34 different COTS-based systems to develop a checklist of actions that need to take place to ensure the successful integration of COTS into Air Force systems (Grant, 2000). While the SAB provided a checklist of items, this study attempts to determine which factors are most important to the success of a system and if a certain number of factors present leads to a highly successful system. One of the recommendations of the SAB was to prepare a policy to drive acquisition strategy of COTS-based system. Acquisition plans from five COTS-based programs rated highly successful and from five programs that were not rated highly successful were reviewed.

Since the SAB researched only military systems, this research was also specific to military systems and did not take into consideration COTS-based systems outside of the DoD. However, the ten systems studied did have many different types of applications from information systems to guidance kits for munitions. The research focused on the acquisition strategy plans as outlined in the *Air Force Single Acquisition Management Plan (SAMP) Guide* (Guide, 1996). The acquisition plans were studied to determine which items may have affected program success.

Organization of Thesis

This chapter provided background information regarding COTS. Chapter 2, Literature Review, supplies more detailed background information about COTS-based systems and reasons why this thesis is needed. Chapter 3, Methodology, presents the process for gathering and analyzing the data and supports the method used. Chapter 4, Analysis of Findings, shows the results of the data gathering and provides an analysis of that data. Chapter 5, Summary of Findings, presents recommendations and conclusions based on the analysis of findings.

II. Literature Review

Overview

This chapter provides a basis of knowledge from which the research questions can be answered. The chapter begins by defining COTS-based systems and explaining why COTS-based systems are used. Following this, problems associated with using COTS-based systems are explored. The chapter then explores the risks related to problems with COTS-based systems. The means of overcoming these risks are then examined. After this, the chapter addresses acquisition strategy. Acquisition strategy is defined and available guidance for acquisition professionals is explored. Next, reasons for this research are provided and the key factors and critical items are explained. Finally, the chapter concludes by stating the need for further studies in acquisition strategy of COTS-based systems.

Background

One of the basic questions regarding the acquisition of a COTS based system is, *What constitutes* a *COTS-based system?* A simplified answer to this question is any system that uses COTS-items. However, most systems often do contain some amount of COTS items. The difference with COTS-based systems now is the wide availability of commercial items and the need to increase their use in DoD systems to provide the warfighter with the latest technological advantage (Albert and Morris, 2000). As defined in the *Guidelines for Successful Acquisition and Management of Software-Intensive Systems*, a COTS item is one which has been developed, produced, and tested to military or commercial standards and specifications to environmental conditions equal to or exceeding those required by the weapon system. Additionally, the *Guidelines For Successful Acquisition and Management of Software Intensive Systems* states that a COTS-item is readily available for delivery from an industrial source and may be acquired without charge (Guidelines, 2000). This definition then begets questions about COTS-based systems.

Types of COTS-Based Systems. COTS-based systems are easily defined; however, there are different types of COTS-based systems. Simply put, a COTS-based system is one that contains components that are COTS products (Clapp, 1998). The different types of COTS-based systems fall on a continuum. At one end of the continuum are COTS-solution systems. These systems are a single product, provided by one vendor, that provides for the users needs. An example of this is a computer program that provides all the needs of the user. On the other end of the continuum, COTS-aggregate systems are made up of many COTS product from many different vendors that are integrated together to fulfill the users need (Brownsword, 2000). This is like a custom-made computer bought from a small computer store. Still other COTS-based systems, in the middle of the continuum, will integrate some commercial items within a military developed system (Albert and Morris, 2000). This definition of COTS-based systems provides a starting point to examine the reasons to use COTS-based systems.

Benefits. Multiple benefits can be attained when acquiring a COTS-based system. A recent Air Force Scientific Advisory Board (SAB) report stated "taking advantage of COTS products seems like a logical way to achieve significant cost savings with very little sacrifice"(Grant, 2000:1). A Pentium-class microprocessor costs between $250M and $400M to develop, and development costs are escalating at nearly 40% per year. The Air Force can not afford expenses of this magnitude and therefore must use COTS (Grant, 2000).

COTS–based systems also allow the military to quickly incorporate new technology into weapons systems (Alford, 2000). This rapid insertion of new technology is made possible in COTS-based systems by using open systems architecture. Open systems adhere to commercial interface standards and are easily upgraded. This can be compared to plug and play components in personal computers (Oberndorf, 1998). A military advantage goes to the nation that captures the best commercially available technologies, incorporates them in weapons systems, and gets them fielded first (Hanratty, 1999). The Air Force Airborne Warning and Control System (AWACS) computer modernization acquisition used an open system architecture. By using open systems, future upgrades and new mission capabilities may be integrated with minimal integration and testing requirements (Milligan, 2000).

Other potential benefits are lower life cycle costs, greater reliability and availability, and increased support from the industrial base (Albert and Morris, 2000). Life cycle costs are the costs attributable to acquisition, operation, support, and disposal of a system (FAR, 2000). Lower life cycle costs in COTS-based systems come from decreased development costs during acquisition. In the commercial marketplace, a competitive advantage goes to the companies that provide items with the best value. Part of measuring best value is reliability and availability. Companies that make highly reliable items available in the marketplace will have a competitive advantage. Those companies will be selected as vendors for COTS items. As communications and transportation have improved, the number of vendors available to provide support for government contracts has increased. Support from the industrial base increases because more companies will be able to provide support, not just the government contractor. Using COTS-based systems to achieve these benefits is best summed up by Oberndorf and Carney, "In systems where the use of existing commercial components is both plausible and feasible, it is no longer acceptable for the government to specify, build, and maintain a large array of comparable proprietary products" (Oberndorf and Carney, 1998: 1).

Regulatory Guidance. Due to the benefits of COTS-based systems, regulations now mandate their use when possible. The Federal Acquisition Regulation (FAR) applies to all Department of Defense purchases. FAR Part 12.101 calls for market research to be done and states "agencies shall acquire commercial items or non-developmental items when they are available to meet the needs of the agency" (FAR, 2000:12.101). DOD Directive 5000.1, which applies to all DOD acquisition program, states that the use of commercial items in DOD systems is the preferred approach for meeting operational requirements (Albert and Morris, 2000). The FAR, along with DOD Directive 5000.1, ensures that COTS items will be purchased and used in military systems. Even though complex defense systems may not be manufactured as end items on commercial lines, their subsystems and components may well be (Grant, 2000).

Problems

Organizations attempt to incorporate new technology and reduce development cost by integrating COTS items. Although various benefits can be realized when using COTS-based systems, problems have been encountered in their use (Holmes, 2000). Inflexible requirements, technology cycle time, upgrades, and budgetary problems in COTS-based systems can lead to system failure.

Inflexible Requirements. The biggest pitfall of all in COTS systems is inflexible requirements. If the COTS needs to be changed to meet requirements, the cost and schedule reductions disappear (Grant, 2000). Cost and schedule reductions are achieved through lack of product development. When the COTS item is changed, product development takes place, erasing some of these benefits. To compound the problem, vendors may not offer support for items that have been modified.

Technology Cycle Time. The amount of time it takes for technological advancements to be designed, developed, and fielded -- technology cycle time -- also causes problems in COTS-based systems (Gillis, 1999). The life of a typical military acquisition exceeds 20 years (Alford, 2000). The development time for new DOD major systems is between 8 and 15 years. The commercial marketplace has drastically faster technology cycle times. These include computer technology with a cycle time of 18 months, 6 years for avionics, and 14 years for aircraft engines (Gillis, 1999). If the development of a new system takes 8 years and the life of the system is 20 years, computer technology will have changed 18 times since inception of the system. The system will more than likely be outdated in this time frame. According to Kurt Wallnau of the Software Engineering Institute, you need to plan on evaluating a new version of a COTS product every six months (Tracz, 2000).

Upgrades. In COTS-based systems, the manufacturer is free at any time to make changes or even discontinue the manufacture of the COTS item without notice. When these changes affect the form, fit, or function of an item, it can cause significant problems with the COTS-based system. Upgrades to items may not work with the COTS system and replacements may not be available (Alford, 2000). Integration of various commercial items also causes problems with COTS. As the number of COTS components and COTS vendors increase, the interplay among them becomes more complex. In the event of system failure, it may be difficult to prove which vendors product is really at fault. At a minimum, system integrators will struggle with ways to keep abreast of current technology and which products best suit their needs (Tracz, 2000). These are not the only problems that plague COTS-based systems. COTS-based systems can also have significant budgetary problems.

Budget. Budgetary problems in a COTS-based system come from the incorrect application of life cycle costs. COTS components provide immediate solutions at a fixed cost. However, since most components will be upgraded during the life of the system, it is unrealistic to assume that support costs will be zero (Tracz, 2000). Figure 1 shows that the cost of operations and support is almost three fourths of a typical system (Alford, 2000). In some instances, total life cycle costs of COTS-based systems have been greater than they would have been using a traditional approach (Grant, 2000). Operations and support costs of COTS-based systems are high due to continuous upgrade of items and

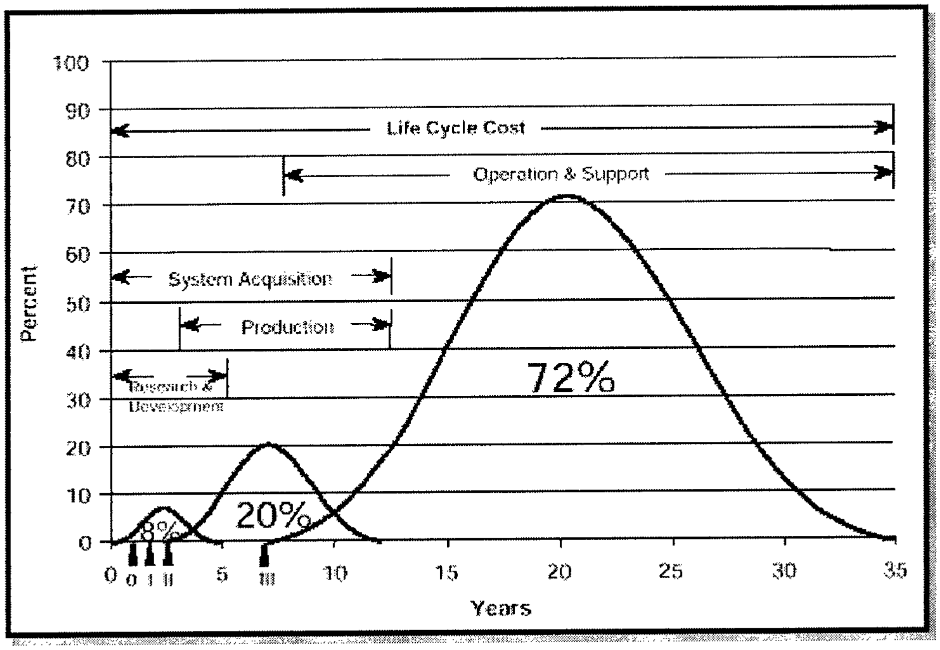

Figure 1. Typical Cost Distribution (Alford, 2000: 13)

changing logistics needs for these upgraded items. However, program guidance and budget direction does not reflect the need for greater sustainment costs (Clapp, 1998). These problems with COTS-based systems can be directly linked to the risks associated with acquiring the systems.

Risks

As evidenced by the problems mentioned above, some level of risk is involved in acquiring COTS-based systems. These risks involve software/hardware upgrade, quality, security, and funding.

Upgrade. Failing to upgrade to the latest version of software/hardware can result in loss of vendor support for prior versions and the inability to buy new copies or obtain additional copies of the version that is in place. Imagine trying to upgrade a computer from DOS® to Windows® ME without having had all of the upgrades in between. It might just be easier to erase the hard drive and install a full version of Windows® ME. Conversely, upgrading to the latest version can result in the new version being incompatible with the rest of the system, increased consumption of time or memory, and operational capabilities of the system which may not be fully supported (Clapp, 1998). When installing the upgrades from DOS® to Windows®, some DOS based programs such as Enable might not work on the system anymore. Additionally, new hardware might need to be added to the system to ensure the software can run.

Quality. Quality of a COTS-based system is risked because quality is a subjective measure depending on the supplier's point of view. Traditional systems are designed to military specifications with quality being one of the criteria. The quality of traditional systems is assured by manufacturing oversight and design reviews. In a COTS-based system, the DoD looses the ability to provide design specifications and oversee the manufacture of items. Quality of an item, especially an upgraded item, may not be sufficient for exacting military systems. This can be especially troublesome problem with software, since vendors typically fix problems in the next version of the product (Tracz, 2000). If an upgraded item is installed in a system, it may cause the whole system to shut down. Therefore, new versions of COTS items must be tested before insertion in the system (Clapp, 2000).

Security. Security risks also present a problem with COTS-based systems. According to the DoD *Year 2000 Management Plan*, primary vendors may have subcontractors who use additional subcontractors that employ foreign nationals to do the actual coding of the COTS (Year, 1998). This makes COTS software especially susceptible to a trap door or "Trojan Horse" (Grant, 2000). A trap door is a hidden software or hardware mechanism that permits systems protection mechanisms to be circumvented. A Trojan Horse is a computer program with an apparently useful function that contains hidden functions that surreptitiously exploit the legitimate authorizations of the invoking process to the detriment of security. A computer virus is a form of a Trojan Horse (DoD 5200.28, 1999). When buying a specialized piece of COTS hardware, there will usually be software embedded in the equipment (Vigder, 2000). Therefore, COTS hardware and software are both susceptible to security problems.

Funding. Funding also provides some risk in COTS-based systems. COTS-based systems have all the funding risks of traditional systems and more. The uncertainty of product upgrades, coupled with changes that may need to be made to the rest of the system, make it difficult to estimate proper funding requests (Clapp, 1998). Cost models for COTS can be helpful, but the development of new publicly available COTS cost estimation techniques and models is still in its infancy (Brownsword, 2000). With all of these risks, COTS-based systems would never succeed if there were no means of risk reduction.

Risk Reduction

Overcoming the risks inherent in a COTS-based system requires a paradigm shift in system acquisition, use of commercial practices, better configuration management, and the right vendor.

System Acquisition. The paradigm shift to overcome is from developing a specific product for a specific system requirement to adjusting specifications to what the commercial marketplace has to offer. In COTS-based systems, requirements of the system must change to meet the ability of products available commercially. The marketplace drives the implementation of the commercial item; therefore, it is imperative to know the fundamental differences between integrating commercial items and developing a custom capability (Albert and Morris, 2000).

Commercial Practices. Programs are more effective when adopting commercial practices. Understanding the nature of the commercial marketplace will help reduce risk associated with COTS solutions (Task Order 054, 1999). As vendors need to adapt to the government bureaucracy, procurement organizations will see costs rise (Albert and Morris, 2000). Therefore, if the DOD is acquiring a COTS-based system, it needs to do business in a more commercial manner (Brownsword, 2000).

Configuration Management. Another means of reducing risk is good configuration management. Since COTS items seldom fit together well with other system components, adaptation is needed to make the items fit together (Brownsword, 2000). Configuration management consists of tracking which versions of upgrades are available from the vendors, which are installed, and at which sites (Vigder, 1996).

Correct Vendor. Identifying the best contractor can also lead to risk reduction. Typically, contractors have not been selected for their ability to integrate items, knowledge of the marketplace, or expertise with specific commercial items. In COTS-based systems, these factors will be as significant as traditional factors in source selection (Albert and Morris, 2000). DOD organizations must also take into account stability of the vendor and willingness to work with the DOD as part of the acquisition (Brownsword, 2000). While these efforts can reduce the risk associated with acquiring COTS-based systems, a strategy is needed for their implementation.

Strategy

Definition. An acquisition strategy provides direction for acquiring a system from program initialization through post-production support. The primary goal of developing an acquisition strategy is to minimize the time and cost to satisfy a user's acquisition needs. The acquisition strategy addresses such issues as open systems, sources, risk management, cost as an independent variable, contract approach, management approach, environmental considerations, warranty considerations, and sources of support. Acquisition strategy is tailored to meet the needs of the individual program (DoD 5200.2-R, 1999). Development of the acquisition strategy is part of acquisition planning (FAR, 2000).

Guidance. Available guidance in the DoD states that all acquisitions should promote and provide for acquisition of commercial items (FAR, 2000). However, guidance on the acquisition strategy of commercial items and COTS-based systems is lacking. DoD 5000.2-R requires that contractors incorporate commercial items as components of items supplied. It further states that commercial items selected shall be based on open systems and commercial item descriptions to the maximum extent practicable (DoD 5200.2-R, 1999). While this guidance allows for flexibility and creativity in acquiring COTS-based systems, it does not provide management with enough direction to ensure a COTS-based system will have an adequate acquisition plan.

The available guidance on COTS-based acquisitions is limited. The Software Engineering Institute (SEI) at Carnegie Mellon University has produced two documents that provide lessons learned in regards to COTS-based systems, *Lessons Learned Applying Commercial Off-the-Shelf Products* and *Commercial Items Acquisition: Considerations and Lessons Learned.* Neither of these documents specifically address acquisition plans. However, the SEI has published an article called *An Activity Framework for COTS-Based Systems* (Brownsword, 2000). In this article, Brownsword, Oberndorf, and Sledge identify nine activities to help develop acquisition strategy for COTS-based systems (Brownsword, 2000:11):

1. Identify COTS-based system goals, constraints and assumptions.
2. Identify COTS-related risks.
3. Identify relevant market segments.
4. Identify alternative COTS-based solutions.
5. Reassess COTS-based system strategy as necessary.
6. Assess/evaluate/tradeoff alternative COTS-based solutions.
7. Recommend an overall COTS-based system strategy.
8. Create a corresponding COTS-based system plan, including contingency plans.
9. Reassess and revise COTS-based system strategy as necessary.

While this information is integral to building an acquisition plan, more information is needed in the specific areas of the acquisition plan.

Research

Acquisition professionals need more guidance in the specific areas of open systems, sources, risk management, cost as an independent variable, contract approach, management approach, environmental considerations, warranty considerations, and sources of support to properly develop an acquisition strategy. This is why the Scientific Advisory Board recommended "that the Air Force prepare and promulgate an implementation policy for the acquisition and sustainment of COTS-based systems. This policy should drive acquisition strategy…"(Grant, 2000). In order to gain knowledge of acquisition strategy, this study reviewed acquisition plans of COTS-based systems rated both highly successful and not rated highly successful. The AFSAB study provided examples of both types of programs. In order to eliminate researcher bias, this study was limited to those programs identified in the SAB study.

Identification of Key Factors. In determining what to include in an acquisition plan, potential key success factors were identified. The following questions were used to study the potential key success factors in the acquisition plans of COTS-based systems. They were derived by taking inputs from recommendations contained in articles on COTS-based systems and reviewing the *Single Acquisition Management Plan Guide.* Italicized questions are additionally identified as critical factors for use in research question 3. Critical factors were recommended to be included in COTS-based systems by more than one source. Table 1 presents the questions with the source(s) that recommended their use.

1. *Are the requirements flexible*?

Albert and Morris state that requirements must be flexible and negotiable (Albert and Morris, 2000). Both NASA and SEI have emphasized the need to adapt operational requirements to the availability of the COTS components (Vigder, 1996). A *yes* will be given if the acquisition plan states that requirements are flexible. Additionally, a *yes*

	Carney and Oberndorf	Grant and Others	Brownsword and Place	Albert and Morris	Brownsword and others	SAMP Guide
Question						
Mission						
Are the requirements flexible?	X	X	X	X	X	X
Program Content						
Does the system interface with other programs?					X	
Is this a joint program?						X
Does the system need to be certified before being put into operation?		X				
Is system certification done by the military?		X				
Acquisition Strategy						
Is the R&D contract Cost Plus?						X
Is the support contract Fixed Price?						X
Is the acquisition sole source?						X
Is COTS use part of the decision criteria for award?					X	
Is the prime contractor required to have experience in development of COTS-based systems?	X	X	X	X	X	
Engineering and Technical Approach						
Is open-systems architecture used?		X			X	
Is a plan for upgrades/obsolescence included?	X			X	X	
Is modification of COTS item unacceptable?		X	X	X	X	
Will the military retain data rights to the item?			X			
Support Strategy						
Will the prime contractor support the system throughout the entire life cycle?					X	
Is a warranty from the prime contractor included?	X	X				X
Test Strategy						
Is testing on a system test-bed required before upgrades are included in the system?		X		X		
Management Strategy						
Is use of an IPT structure identified?		X		X		X
Is the contractor included in government IPT's?		X		X		X
Is use of commercial practices identified in the SAMP?			X	X		
Financial Management						
Is CAIV analysis used?		X		X		X
Is TOC used in tracking costs?		X		X	X	

Table 1. Key Factor Identification

answer will be given if the acquisition plan provides minimum requirements and objectives for either requirements or key performance characteristics. A *no* will be given if the acquisition plan does not allow for flexibility or if the issue is not addressed.

2. Does the system interface with other programs?

Interfacing with other programs could make some engineering requirements fixed. These requirements could take away some of the flexibility engineers have in design of the system. A *yes* will be given if the acquisition plan specifically addresses interfacing with other systems or programs. This interface could be either physical or non-physical such as computer links. A *no* will be given if the acquisition plan identifies the program as being stand-alone or if system interface is not addressed.

3. Is this a joint program?

A joint program is one that is procured by more than one branch of the military. Joint programs have an additional risk of needing to satisfy multiple users. This could lead to increased oversight, schedule delays, and cost increases. A *yes* will be given if the acquisition plan identifies the program as being joint. A *no* will be given if the program is identified as being procured by only one service or is not identified.

4. Does the system need to be certified before being put into operation?

Certification typically requires adhering to standards of an outside organization (such as the Federal Aviation Administration). Certification was reviewed to see if adhering to these standards causes positive or negative effects on a system. A *yes* will be given if the system certification is mentioned in the acquisition plan. A *no* will be given if the system does not need to be certified or is certification is not mentioned in the acquisition plan. An asterisk will be given if certification does not apply to the system.

5. Is systems certification done by the military?

Systems that are developed by the military may have an advantage if they are also certified by the military. Systems that are certified by another organization may be at a disadvantage. Military certification was reviewed to determine if programs are affected by military or outside certification. A *yes* will be given if certification is done by the military. A *no* will be given if certification is done outside the military or certification is not required. An asterisk will be given if certification does not apply to the system.

6. Is the R&D contract Cost Plus?

Research and development contracts have additional technical risks that are imposed on the contractor. One means of mitigating this risk is to use a Cost Plus type of contract. A cost plus type contract would allow the contractor to concentrate more on the technical aspects of the research without fear of incredible cost risks. A *yes* will be given of the R&D contract was Cost Plus. A *no* will be given of the contract is other than cost type contract. An asterisk (*) will be given if the type of R&D contract is not addressed or if there was no R&D performed.

7. Is the support contract Fixed Price?

Support contracts are generally considered to be of lower risk to the contractor. Therefore, support contracts are generally fixed price. A *yes* will be given of the support contract is fixed price. A *no* will be given if the contract is other than fixed price. If system support is not addressed in the acquisition plan, an asterisk will be given.

8. Is the acquisition sole source?

Sole source contracts are awarded to a single contractor. Source selection activities are avoided. This enables the government and contractor to focus on performance of the contract instead of awarding the contract. A *yes* will be given for sole source acquisitions. If the contractor for the program was selected competitively, a *no* will be given.

9. Is COTS use part of the decision criteria for award?

COTS use, as part of the decision criteria for award, would ensure government and contractor personnel know that COTS items will be used in the system or the system as a whole will be a COTS-item. A *yes* will be given if COTS use is stated as award criteria or the acquisition plan states that COTS use is encouraged. A *no* will be given if the acquisition plan states hat COTS will not be a criteria for award or if COTS use is not addressed in the acquisition plan.

10. *Is the prime contractor required to have experience in the development of COTS-based systems?*

In developing COTS-based systems, integrating commercial items requires extensive expertise (Albert and Morris, 2000). Experience is a critical factor to success of a COTS-based system (Grant, 2000). A *yes* will be given if the acquisition plan sates that the prime contractor is required to have expertise/experience in development of COTS-based systems. A *no* will be given if the expertise/experience is not required or is not mentioned. An asterisk will be given if experience in developing COTS-based systems does not apply.

11. Is open-systems architecture used?

System architecture must be flexible enough to incorporate new releases of commercial items and to remove obsolete commercial items (Albert and Morris, 2000). Open systems architecture combines standard interfaces with modularity of components. This allows for the flexibility to incorporate new releases and remove obsolete items. A *yes* will be given if the acquisition plan states that open systems architecture was used. A *no* will be given if open systems is not used or if open systems is not addressed.

12. *Is a plan for upgrades/obsolescence included*?

Most commercial items must eventually be upgraded (Albert and Morris, 2000). In order to maintain vendor support or replace obsolete items, upgrades must be done. A *yes* will be given if the acquisition plan identifies a plan for upgrades. A *no* will be given if there is no plan for upgrades or if a plan for upgrades is not addressed.

13. *Is modification of COTS items unacceptable*?

Modification of commercial items can lead to program failure (Albert and Morris, 2000). Even if the modification is unavoidable, program risk is increased. Modification of commercial items makes the item government unique. Vendors may not support the item and upgrades of the item may not be compatible with the system. A *yes* will be given if modification of COTS items is not allowed. A *no* will be given if modification is allowed or if modification is not addressed in the acquisition plan.

14. Will the military retain data rights to the item?

Licenses and data rights can define the relationship with the vendor (Albert and Morris, 2000). If the government will retain any or all of the data rights, a *yes* will be given. If the government will not retain data rights, or data rights are not addressed, a *no* will be given.

15. Will the prime contractor support the system throughout the entire life cycle?

Having to provide support for the system after development could provide encouragement to the prime contractor to engineer the system for ease of maintenance.

Failure to engineer the system for life cycle support could result in a system that cannot be maintained as vendors drop support for obsolete items (Albert and Morris, 2000). A *yes* will be given if the acquisition plan identifies that the prime contractor will provide support for the system. A *no* will be given of the prime contractor is not required to provide support or if support is not addressed.

16. *Is a warranty from the prime contractor included?*

A system may have hidden costs due to warranties, especially of the commercial warranty does not suit your needs (Carney and Oberndorf, 1997). On the other hand, warranties with cost savings co-sharing allow for reduction in total ownership costs (Grant, 2000). As *yes* will be given if a warranty for any or all of the system is included in the acquisition plan. A *no* will be given if warranties are not provided or not addressed.

17. *Is testing on a system test bed required before upgrades are included in the system?*

Carney and Oberndorf recommend as one of their commandments of COTS, "Understand the impact of COTS products on the testing process" (Carney and Oberndorf, 1997). System level testing of all COTS items needs to be accomplished to avoid disaster. Albert and Morris support this by stating, "A test bed is an excellent mechanism for gaining insight into the design and behavior of a commercial item" (Albert and Morris, 2000). A *yes* will be given for systems that identify a requirement for test beds to be used. A *yes* will also be given for those systems that test items on an actual end item (i.e. one aircraft) before inclusion into all systems (i.e. entire fleet of those aircraft). A *no* will be given if testing on a system test bed is not required or is not addressed in the acquisition plan.

18. *Is the contractor included in government IPTs*?

Including the contractor in government integrated product teams (IPT) allows for the contractor to be involved in tradeoff discussions when possible (Grant, 2000). For acquisition plans that identify contractors as part of some or all of the IPTs, a *yes* will be given. If the acquisition plan states that the contractor is not allowed to participate in government IPTs, the issue is not addressed, or IPTs are not used, a *no* will be given.

19. Is an IPT structure used?

A *yes* will be given if IPTs are used in the program. A *no* will be given if IPTs are not used or not addressed.

20. *Is use of commercial practices identified in the acquisition plan*?

Use of COTS items requires use of commercial practices that are required with the commercial item (Albert and Morris, 2000). When purchasing COTS-based systems, the DoD must be prepared to operate in a more commercial manner (Brownsword and Place, 2000). If use of commercial practices is identified in the acquisition plan, a *yes* will be given. If commercial practices are not used, or the subject is not addressed, a *no* will be given.

21. *Is CAIV/tradeoff analysis addressed*?

Tradeoff analysis is essential to a successful COTS-based system (Grant, 2000). A *yes* will be given if CAIV or tradeoff analysis is used. A *no* will be given if CAIV or tradeoff analysis are not used or are not addressed.

22. *Is TOC used in tracking costs*?

Commercial and DoD programs frequently underestimate sustainment costs associated with COTS-based systems. Therefore, program decisions should reflect total ownership costs (TOC) (Albert and Morris, 2000). Using TOC in a COTS-based system promotes reduced costs over the life cycle of a weapons system (Grant, 2000). A *yes* will be given if TOC is used. A *no* will be given if TOC is not used or is not addressed.

Critical Items. The critical items were chosen from the investigative questions. These questions were determined as critical to the success of a COTS-based system because the underlying concepts were identified in more than one source as recommended for COTS-based systems. The critical questions were not only reviewed to see if they were exclusive to successful systems, but also reviewed to see if a certain number of critical items need to be present for the system to be successful.

Qualitative Follow up. Once key success factors and critical items were determined, interview questions were developed. The interview questions were used to determine how the key success factors affected program success. These questions were asked to key acquisition personnel from the applicable program.

Summary

This chapter provided the information necessary to develop the point that more guidance is needed in developing an acquisition plan for COTS-based systems. COTS-based systems provide the DOD with a means of incorporating commercial items into military systems. These systems can provide benefits such as lower development costs and rapid technology insertion. COTS-based systems also allow the DOD to give the warfighter the military advantage. However, there are some problems with using COTS-based systems. Inflexible requirements and technology upgrades can lead to higher costs than initially planned. Failure to adequately budget for appropriate life-cycle costs also leads to problems with COTS-based systems. These problems are attributable to risks associated with COTS-based systems from software/hardware upgrades, product quality, military security, and funding. These risks can be reduced through a change in thinking, use of commercial practices, better configuration management, and choosing the correct vendor. However, risk reduction is not enough to ensure successful implementation of COTS-based systems. An acquisition plan tailored to a COTS-based system is needed to ensure the system can be highly successful. While there is some information available for developing an acquisition plan for COTS-based systems, acquisition professionals need more guidance in specific areas.

Chapter 3, Methodology, will explore the research methods used to develop the guidance acquisition professionals need with regard to COTS acquisition strategy. It will relate how programs will be studied and how the acquisition plans will be studied.

III. Methodology

Overview

The chapter begins by providing the research questions developed for the study of acquisition plans. The rationale is provided for studying the cases analyzed by the Software Advisory Board (SAB). Next, the chapter explores the research methods available for conducting the analysis in Chapter 4. Case study research is presented as the appropriate research method. The process of data analysis is then reviewed. This includes stating how the analysis in chapter 4 was conducted. The chapter ends by providing criteria for evaluating the quality of research.

Research Questions

The objective of this research is to identify some critical success factors that need to be included in the acquisition plan of a COTS-based system for the program to be considered highly successful. Determination of 'highly successful' was made by the SAB, and their criteria for such a determination are covered in the next section. There were no anticipated results prior to conducting the research and data collection. Acquisition plans are complex documents that convey the acquisition strategy of a program. Acquisition plans contain information about the program content, acquisition strategy, engineering and technical approach, support strategy, test strategy, management strategy, and financial management of a program. The information in an acquisition plan is at the strategic level. A detailed analysis of each specific area is usually included in another plan, such as the Test and Evaluation Master Plan (TEMP).

The strategic level of the acquisition plan provides an upper-level view of the entire program, rather than analysis of a specific area. For this reason, the scope of this research was limited to the strategic level view through the posing of three research questions. The three research questions are:

1. Is there a relationship between key factors of an acquisition plan and highly successful programs?
2. How do the key success factors affect the success of the program?
3. How many critical items need to be present in the acquisition plan for the program to be rated highly successful by the SAB?

Critical items are those that are recommended for inclusion in COTS-based systems by more than one source.

Scientific Advisory Board

The cases studied in this thesis were all part of a previous Air Force Scientific Advisory Board study done in April 2000. Representatives from both government and industry were included on the SAB. The purpose of the SAB was to "develop a checklist of actions that need to take place in order to ensure the integration of COTS into Air Force systems results in products that perform as advertised initially and through subsequent upgrades, are affordable through their life cycle, are safe, are not made obsolete by a vanishing or changing industrial base" (Grant, 2000:Intro). Determination of 'highly successful' was made based on these factors. The highly successful programs were selected to "represent the best program attributes by both government and industry officials" (Grant, 2000:18). The cases identified by the SAB were used in this study because the determination of 'highly successful' had already been made. Both the 'highly successful' cases and the other than highly successful cases were taken from the SAB study. Using these cases allowed the researcher to remain unbiased at determining the success of the program.

Research Method Selection

The table below provides a method to determine which research method to use.

Strategy	Form of Research Question	Requires Control Over Behavioral Events?	Focuses on Contemporary Events?
Experiment	how, why	yes	no
Survey	who, what,* where, how many, how much	no	yes
Archival Analysis (e.g., economic study)	who, what,* where, how many, how much	no	yes/no
History	how, why	no	no
Case Study	**how, why**	**no**	**yes**

- "What" questions, when asked as a part of an exploratory study, pertain to all five strategies (Yin, 1994:33)

Table 2. Relevant Situations for Different Research Strategies

Three aspects of the research are analyzed to determine which strategy is appropriate. The first aspect of research reviewed in developing a research strategy is the form of the research questions. The form of the research questions in this study are both *how* and *what*. This eliminates the archival analysis and survey strategies. The next question to answer is "Does the research require control over behavioral events?" The research questions in this effort do not require control over behavioral events; therefore, the experiment strategy was not used. The final question to answer in determining research strategy is "Does the research focus on contemporary events?" The research questions do focus on contemporary events; thus the history strategy was eliminated. By focusing on the questions posed by Yin, a case study strategy was the only appropriate strategy for the research questions. Therefore, this study used the case study strategy to perform the research.

Qualitative Research

According to Strauss and Corbin, qualitative research can be reported in one of three different ways. In the first category of reporting data, researchers gather and report data without any bias from the researcher. In the second category of data reporting, researchers provide an accurate description of the data. Since the data gathered is usually large, it needs to be presented in a useful manner. In the third category, researchers use qualitative research to build theories. They believe that theories represent the most systematic ways to gain knowledge (Strauss and Corbin, 1990). This thesis tries to both present an 'accurate description' of acquisition plans to be used in COTS-based systems and provide a theories that can be used to gain knowledge.

Case Study

As defined by Yin, a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context when the boundaries between phenomenon and context are not clearly evident and in which multiple sources of evidence are used (Yin, 1994). Research into contracting techniques for COTS based systems clearly fits this definition. 'Real-life' was provided by the different systems that were studied. The systems studied supplied pertinent information to the phenomenon of COTS-based systems. Finally, multiple sources of evidence (different programs) were used. Therefore, this study fits the definition of a case study.

Types of Case Studies. The type of case study to be used is an embedded, multiple case design. An embedded design is one in which multiple units of analysis are used. The key factors derived from the acquisition plans are the multiple units being examined in this study. Since there are multiple units of analysis, this research follows an embedded design. Since several COTS-based systems rated highly successful and several not rated highly successful were studied, this is also a multiple case design (Yin, 1994). This multiple case, embedded research design study was used to gather data about COTS-based systems from their acquisition plans.

Sources of Evidence. According to Yin, there are six sources of evidence: documentation, archival record, interviews, direct observations, participant observations, and physical artifacts (Yin, 1994). The sources of evidence used in this effort were documentation (in the form of acquisition plans) and interviews. The acquisition plans from various programs were used to gather data for the three research questions. In addition to the acquisition plans, interviews were used to provide information for research question three.

Data Analysis

Theory. Yin provides four techniques for analyzing data gathered in a case study: pattern-matching, explanation-building, time-series analysis, and program logic models. This study used explanation-building to study the data. Explanation-building involves analyzing the case study by building an explanation about the case. Explanation-building was used for research question three. Yin further states that analyzing embedded units is a lesser mode of analysis that can be used with explanation-building. The embedded units of analysis - the factors - are studied first within each case and then across cases (Yin, 1994). Analyzing embedded units was used in examining the three research questions.

Analysis Coding. Three types of analysis coding were used during different parts of the evaluation (Strauss and Corbin, 1990). These coding types are open coding, axial coding, and selective coding. Open coding is used to obtain and document data from each of the cases. This was done by reviewing the acquisition plans for key factors. Axial coding is used to detect emerging phenomena across the cases. This was done in determining both the key success factors and the critical factors among the acquisition plans. Selective coding is used in maturing a model to explain the phenomena. Selective coding was used when gathering responses to the interview questions and in developing the ultimate assertions I make in Chapter 5.

In performing the analysis of the factors, the researcher answered the questions based on the acquisition plan for that program. In order to achieve increased validity and reliability in this analysis, outside sources were also used in factor analysis. Acquisition plans from one highly successful and one other than highly successful program were randomly selected for analysis by an outside source. Since the answers provided by the researcher matched the answers provided by the outside source, validity and reliability of the research was increased.

Analysis of Critical Factors. Ten of the factors were considered to be critical factors (questions previously italicized). They were identified as critical factors because underlying concepts behind these questions appeared in more than one source recommending them for use in COTS-based systems. These investigative questions were also posed as *yes/no*, but a *yes* also meant that this was a positive aspect for the system to have.

The programs were looked at individually to determine how many of the critical factors were included in that program. An average was determined for the number of critical factors contained in the acquisition plans for both highly successful and other than highly successful programs. The averages were then compared to determine if, on average, the highly successful programs contain more critical items than the other than successful programs. This analysis attempted to determined if a certain number of critical factors were needed to be present for a system to be rated highly successful, notwithstanding which ones were present.

Further analysis was performed on the critical factors. The critical factors were reviewed to determine which ones were contained in all of the successful programs. This analysis was done to see which critical factors could be integral to the success of all programs.

Qualitative Follow-up. The qualitative analysis needed for research question number 3 was done by interview. The program manager, deputy program manger, or a contracting officer from each program was interviewed to see why he or she felt the identified item led to success of their program. The interview question for each aspect was "How did (factor) enabled the program to be highly successful?" Programs that did not include the factor in the acquisition plan were asked if the factor was, in fact, used, notwithstanding its absence from the acquisition plan. If it was used, they were also asked why it was not included in the acquisition plan. Interview questions are presented in Appendix A. Explanations were built by comparing the responses to the interviews from the different programs. By comparing responses across multiple cases an explanation was constructed.

Criteria for Evaluating Research Quality

In order to ensure the research presented is of a high quality, the research was designed with Yin's four tests in mind. Yin developed four tests applicable to case studies to ensure research quality: construct validity, internal validity, external validity, and reliability (Yin, 1994).

Construct Validity. Construct validity relates to establishing the correct measure for the concepts being studied. According to Yin, construct validity can be achieved by using multiple sources of evidence. One way of using multiple sources of evidence is data triangulation (Yin, 1994). In order to ensure construct validity, multiple sources of evidence were used in this case study. Review of current literature enabled identification of the key factors. The acquisition plans were studied to review the key factors. Interviews were also accomplished in light of the data gathered from the literature and acquisition plans. This provided triangulation of data to ensure construct validity in the research.

Internal Validity. Internal validity relates to establishing a causal relationship. Pattern matching is one of the most desirable strategies in performing a case study (Yin, 1994). In this study, performing the numerical coding in the data analysis and then performing interviews in the explanation building contributed to internal validity. Factors were only studied in depth after the need was determined by the initial data analysis.

External Validity. External validity is the process of establishing a population of which the results of the study can be applied. Using replication data in multiple case studies is one means of establishing external validity (Yin, 1994). External validity was achieved in this study by analyzing multiple cases. All five of the highly successful programs and five of the programs not rated highly successful identified by the SAB were used to analyze the factors.

Reliability. Reliability in a case study deals with the ability to repeat the findings with the same results. Reliability is enhanced by using a case study protocol (Yin, 1994). A case study protocol was used in this research. Data was coded first by the researcher. Then others replicated coding 20% of the data. The results of the researcher and the others were the same. Additionally, the interview protocol used (Appendix A) ensured that the results of the interviews were reliable.

Summary

To gather contracting data from existing COTS-based systems, an embedded multiple case study design was performed. A pattern matching technique was used that employed first within-case and then across-case analysis. The pattern-matching analysis provided enough information to further perform a qualitative analysis on each identified key success factor. The result of this study provided enough information to develop a theory that will aid acquisition professionals in the development of acquisition plans for use in COTS-based systems.

IV. General Results and Analysis

Overview

This chapter presents the results of the study outlined in chapter 3. First, the key factors are analyzed in identifying the possible key success factors. Since they were found to be possible key success factors, a review on total ownership cost (TOC) and cost as an independent variable (CAIV) is presented. Next, the critical factors are reviewed across the cases to determine if a certain number of critical items have an effect on program success. Finally, qualitative analysis is performed to determine why certain factors lead to program success.

Key Factor Analysis

This part of the research was accomplished to identify key success factors in the acquisition plans of COTS-based systems. Key success factors are elements of the acquisition plan that correlate to a COTS-based system being successful. In order to do this, the data was coded from reviewing the acquisition plans of each program for each factor. Table 3 summarizes the results of the research. The table shows the questions on the left side with the applicable programs across the top. Critical questions, as defined in Chapter 3, are italicized. Programs not rated highly successful by the SAB are labeled cases A through E. The programs rated highly successful are labeled cases F through J.

The results of the analysis suggest that the only key success factors are TOC and CAIV. The following is an analysis of each question.

1. *Are the requirements flexible*?

Among the acquisition plans from the rated highly successful systems, four programs allowed for flexibility of requirements. Three of the not rated highly successful programs identified flexibility of requirements in their acquisition plans. These cases either specifically stated the requirements were flexible or identified requirements in terms of minimum objectives and goals. The one rated highly successful case that was coded *no*, case G, did not mention flexibility in the acquisition plan. However, the procurement contracting officer stated "Since CAIV was included in the acquisition plan, flexible requirements were a given." Identifying flexible requirements would have been redundant. One not rated highly successful case, case C, did not mention flexibility either. Case D, while coded *no*, did mention trade off analysis on the basis of cost, schedule, risk, and performance. Overall, four rated highly successful and three not rated highly successful systems included flexibility of requirements in the acquisition plans. The difference of 1 between the two groups suggests that flexibility of requirements is not a key success factor.

2. Does the system interface with other programs?

All systems, except case G, had acquisition plans that addressed interface with another program. Most systems interfaced electronically with other systems, such as aircraft systems communicating with other aircraft. Cases D, H, and I specifically mention electronic and physical interface with another systems. Nine of the 10 programs address

	Not Rated Highly Successful					Rated Highly Successful				
Question	A	B	C	D	E	F	G	H	I	J
Mission										
Are the requirements flexible?	X	X			X	X		X	X	X
Program Content										
Does the system interface with other programs?	X	X	X	X	X	X		X	X	X
Is this a joint program?	X							X	X	
Does the system need to be certified before being put into operation?	X		X		X	X			*	X
Is system certification done by the military?	X		X		X	X			*	X
Acquisition Strategy										
Is the R&D contract Cost Plus?		X	*	X	X	*	X		X	X
Is the support contract Fixed Price?	X	X	*	X	X	*	*	X	X	*
Is the acquisition sole source?			X			X	X			
Is COTS use part of the decision criteria for award?	X	X	X				X	X	*	X
Is the prime contractor required to have experience in development of COTS-based systems?	X							X	*	
Engineering and Technical Approach										
Is open-systems architecture used?				X	X		X	X		X
Is a plan for upgrades/obsolescence included?		X	X	X	X	X	X	X	X	X
Is modification of COTS item unacceptable?								X	*	
Will the military retain data rights to the item?			X		X	X	X			*
Support Strategy										
Will the prime contractor support the system throughout the entire life cycle?	X	X	X	X	X	X	X	X	X	
Is a warranty from the prime contractor included?	X	X	X			X	X	X	X	X
Test Strategy										
Is testing on a system test-bed required before upgrades are included in the system?			X	X	X	X	X		X	
Management Strategy										
Is use of an IPT structure identified?	X	X	X		X	X	X	X	X	X
Is the contractor included in government IPT's?	X	X	X		X	X	X	X	X	X
Is use of commercial practices identified in the SAMP?	X	X	X		X		X	X	X	X
Financial Management										
Is CAIV analysis used?			X		X	X	X	X	X	X
Is TOC used in tracking costs?	X		X			X	X	X	X	X

Table 3. Key Factor Analysis

interface issues. The difference of 1 between the two groups suggests that interfacing with other programs is not a key success factor.

3. Is this a joint program?

Cases A, H, and I are all joint programs. The seven other cases are not joint. Overall, two rated highly successful programs and one not rated highly successful program are joint programs. The difference of 1 between the two groups suggests that a program being joint is not a key success factor.

4. Does the system need to be certified before being put into operation?

Four programs did not identify certification in their acquisition plans -- cases B, D, G, and H. In case I, certification did not apply. All other cases identified a certification requirement. Overall, the acquisition plans of 2 rated highly successful programs and three not rated highly successful programs identified a need for certification. The difference of 1 between the two groups suggests that certification is not a key success factor.

5. Is systems certification done by the military?

All systems that required certification needed to be certified by the military. The difference of 1 between the two groups suggests that military certification is not a key success factor.

6. Is the R&D contract type cost plus?

Three of acquisition plans of the rated highly successful programs identified a cost plus type of contract for R&D. Of those, case G used a cost plus fixed fee contract and case J used a cost-plus award fee contract. Case F, coded with an asterisk, was an overarching widely-scoped Indefinite Delivery / Indefinite Quantity (IDIQ) contract that allowed for flexibility in determining contract type on each specific delivery order. Case H did not have R&D performed. The acquisition plans of three of the not rated highly successful programs also identified a cost plus type of contract for R&D. Cases B, D and E all used cost plus award fee contracts for R&D. Case A used a fixed price incentive fee contract. Case C, coded with an asterisk, was also an IDIQ type contract. The difference of 0 between the two groups suggests that using a cost plus contract for R&D is not a key success factor.

7. Is the support contract Fixed Price?

Of the rated highly successful programs, the acquisition plans for cases G and J did not address type of contract for system support in the SAMP. Case F, coded with an asterisk, used an IDIQ format. Cases H and I both used a fixed price type of contract for support. Of the not rated highly successful programs, case C used an IDIQ format. All other programs used fixed price contract for system support. The difference of 2 between the two groups suggests that using a fixed price contract for support is not a key success factor.

8. Is the acquisition sole source?

Of the rated highly successful programs, contracts for cases F and G were awarded sole source. For cases H, I, and J the contractor was selected on a competitive basis. Of the not rated highly successful programs, all but case C were awarded on a competitive basis. The difference of 1 between the two groups suggests that sole sourcing is not a key success factor.

9. Is COTS-use part of the decision criteria for award?

Of the rated highly successful programs, the acquisition plans of three cases required COTS use in the decision criteria for award. Case H states that the program "will acquire a COTS application to meet the required functionality." The acquisition plan for case G states "use of COTS…to meet performance specification requirements is encouraged." Case J included a similar statement. Case F mentions COTS use, but does not specify it as decision criteria in any way. Of the programs not rated highly successful, three required COTS use in the decision criteria for award. The acquisition plan for case A stated the need to procure commercial items wherever possible. Case B contained a similar statement. The difference of 0 between the two groups suggests that COTS-use as a decision criteria for award is not a key success factor.

10. *Is the prime contractor required to have experience in the development of COTS-based systems?*

The acquisition plans of one program from each category required the contractor to have experience in the development of COTS-based systems. The difference of 0 between the two groups suggests that COTS development experience is not a key success factor.

11. Is open-systems architecture used?

Of the rated highly successful programs, the acquisition plans of three identified use of an open systems architecture. The acquisition plan for case G provided for open-systems use by stating that the program would use an open systems architecture by emphasizing COTS and other non-developmental items in hardware/software introduction. The acquisition plan for case J provided several paragraphs on the use of open systems and open systems design. The acquisition plan for case H stated the application must be capable of operating in an open system. Two of the not rated highly successful programs identified use of an open systems architecture. The acquisition plan for case D stated " a development methodology will be implemented that provides for installation and validation of new functions in a new distributed open systems architecture." The difference of 1 between the two groups suggests that use of open system architecture is not a key success factor.

12. *Is a plan for upgrades/obsolescence included*?

All of the rated highly successful programs identified a plan for upgrade/obsolescence in their acquisition plans. The contract type (IDIQ) and contract duration of 18 years for case F allows for upgrades to the system. Case J included plans for upgrades in the section on open systems design. Four of the not rated highly successful programs include a plan for upgrades/obsolescence. Case B requires the prime contractor to develop a capability to provide updates. The difference of 1 between the two groups suggests that including a plan for upgrades/obsolescence is not a key success factor.

13. *Is modification of COTS items unacceptable*?

One of the acquisition plans of the rated highly successful programs, case H, did not allow for modification of the COTS items. This acquisition plan stated that enhancements would only be done as the developer released upgrades to the program. The acquisition plan for case I did not address the issue. The acquisition plans of all other programs did not restrict the modification of COTS items. The difference of 1 between the two groups suggests that restriction of modification is not a key success factor.

14. Will the military retain data rights to the item?

In the rated highly successful programs, two acquisition plans stated that data rights would be retained by the military. The acquisition plan for one rated highly successful program did not address data rights. In the not rated highly successful programs, again two acquisition plans stated the data rights would be retained by the military. Case C stated that limited data rights would be acquired. All other acquisition plans stated that data rights would not be retained by the military. The difference of 0 between the two groups suggests that retention of data rights is not a key success factor.

15. Will the prime contractor support the system throughout the entire life cycle?

All programs except case J required prime contractor support for the system throughout the entire life cycle. The acquisition plan for case J had a support plan but did not have a contractor selected. The difference of 1 between the two groups suggests that prime contractor support is not a key success factor.

16. *Is a warranty from the prime contractor included?*

All of the acquisition plans of the rated highly successful programs provided a warranty from the prime contractor. Case F sought warranty protection for new systems with enforcement of COTS warranties. Case G required the use of commercial warranties. Three of the acquisition plans for the not rated highly successful programs included warranties from the prime contractor. Cases A and B require the prime contractor to warrant the system and administer all vendor warranties. The acquisition plan for case D, while being coded *no*, stated that warranties may be applicable to firm fixed price modification only. The difference of 2 between the two groups suggests that prime contractor warranty is not a key success factor.

17. *Is testing on a system test bed required before upgrades are included in the system?*

Three of the acquisition plans from each category included requirements for testing on a systems test bed before upgrades are included in the system. The acquisition plan for case D required a full test lab with simulation while case C required upgrade testing on a test system. The acquisition plan for case B did not directly address testing for upgrades, but made reference to the TEMP. Case B was coded *no*. Of the rated highly successful programs, case F required testing before installation in the system. Case J, coded *no*, addressed a system test bed, but did not specifically address upgrades being tested in the test bed. The difference of 0 between the two groups suggests that testing before upgrades is not a key success factor.

18. Is use of Integrated Product Teams (IPTs) identified?

Acquisition plans for five of the rated highly successful and four of the not rated highly successful programs included use of an IPT structure. The difference of 1 between the two groups suggests that use of IPTs is not a key success factor.

19. *Is the contractor included in government IPTs?*

Acquisition plans for five of the rated highly successful and four of the not rated highly successful programs had provisions for including the prime contractor in IPTs. The difference of 1 between the two groups suggests that including contractors in IPTs is not a key success factor.

20. *Is use of commercial practices identified in the acquisition plan?*

Among the acquisition plans for the rated highly successful programs, four programs identified use of commercial practices. The acquisition plan for case F makes no mention of commercial practices or best practices. The acquisition plan for case G, coded *yes*, did not mention commercial practices, but did state "contractors are encouraged to further streamline activities" and that "commercial warranties would be used." The acquisition plan from case J, coded *yes*, identified use of best practices from acquisition reform. Among the acquisition plans for the not rated highly successful programs, four programs identified use of commercial practices. The acquisition plan for case A while calling for use of commercial practices also stated a task force was formed to make the acquisition more like a commercial acquisition. The acquisition plans for cases B and C encouraged the use of commercial practices. The difference of 0 between the two groups suggests that inclusion of commercial practices in the acquisition plan is not a key success factor.

21. *Is CAIV analysis used*?

All five of the rated highly successful programs identified CAIV in their acquisition plans. Case H did not identify CAIV specifically. However, the program manager stated that CAIV was considered in the TOC analysis that was included in the acquisition plan. Therefore, case H was determined to be a *yes*. Two of the not rated highly successful programs identified use of CAIV. Three did not use CAIV. However, according to the acquisition plan, case D did use a tradeoff analysis that "will be conducted throughout the life of the contract on an as required basis for cost, schedule, risk, and performance." This seemed to be similar to trade space analysis done in a CAIV analysis. Although it did seem similar to CAIV, this was classified as a *no*. ***The difference of 3 between the two groups suggests that CAIV is a key success factor.***

22. *Is TOC used in tracking costs*?

All five of the rated highly successful systems used TOC to track costs. The acquisition plan for case F had a full paragraph on TOC within the program. The plan for case G identified TOC used at the system level, which supported their department's overall goals. The plan for case J imposed TOC goals and measurements for contractors achieving those goals. Two of the not rated highly successful programs identified TOC use for tracking costs. Case A, coded *yes*, identified lowest total system life cycle cost as a factor in evaluating proposals. The plan for case C, coded *yes*, identified a "performance based business focus on RTOC". The acquisition plan for case B, coded *no*, identified a life cycle cost model in cost budgeting, but not in actual tracking of costs. The plan for case D, coded *no*, stated that by increasing overall reliability and maintenance, overall LCC will be reduced, but did not identify TOC. The acquisition plan for case E identified TOC as being used. However, since the acquisition plan did not consider O&M cost in TOC, the case was coded *no*. ***The difference of 3 between the two groups suggests that use of TOC is a key success factor.***

In this part of the research, two key success factors were identified. The first key success factor found was including CAIV analysis in the acquisition plan. Additionally, using TOC in tracking costs was identified as a key success factor. These two factors are reviewed in the next section.

TOC/CAIV

In order to understand Total Ownership Cost (TOC), as used by the Air Force, the terms must first be defined. The Air Force views TOC in two different ways, DoD TOC and Defense Systems TOC. The Air Force *Reduction in Total Ownership Cost CAIV/TOC Guidebook* presents DoD TOC as "…the sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals…" (Reduction, 1999:5). The guidebook defines Defense System TOC as Life Cycle Costs (LCC).

> LCC includes not only acquisition program direct costs, but also indirect costs attributable to the acquisition program (i.e., costs that would not occur if the program did not exist). For example, indirect costs would include the infrastructure that plans, manages, and executes a program over its full life and common support items and systems (Reduction, 1999:6).

DoD TOC is a three dimensional concept consisting of Defense System Performance and Design, Resources to Operate, and Operational/Warfighting Concepts. Defense System Performance and Design includes costs that are a direct result of weapons system design such as those considered in LCC. Resources to Operate encompasses infrastructure and force structure costs not directly attributable to weapons systems such as base operating support (BOS) or transportation. Operational/Warfighter Concepts includes costs driven by specific concepts such as the Air Expeditionary Force (AEF) concept (Reduction, 1999).

Defense System TOC (LCC) is driven by requirements pull and technology push as shown in the Figure 2. As the warfighter engages in new threats, their requirements change which 'pulls' resources. At the same time, new technologies are being developed that increase system performance and are 'pushed' into the weapons systems. To maintain a system that meets the new threats, incorporates new technologies, and remains

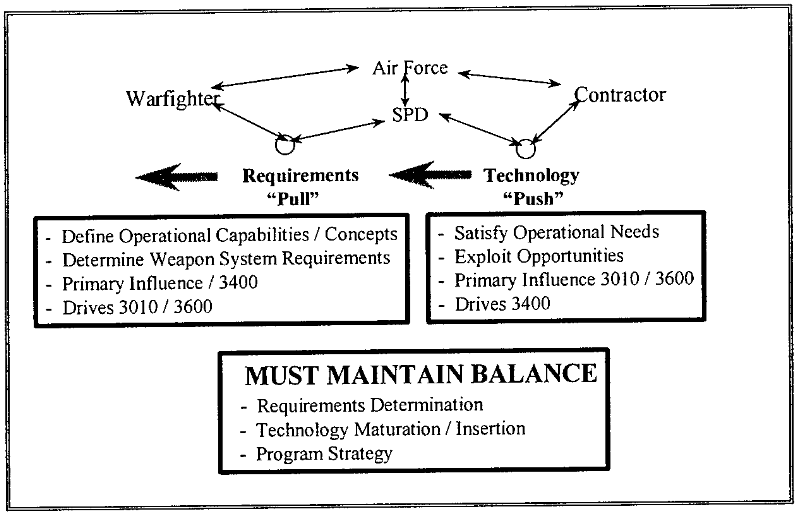

Figure 2. TOC Drivers (Reduction, 1999:9)

cost effective a balance is needed between operational capability and system costs (Reduction, 1999). The means of attaining this balance is through a CAIV analysis.

Cost-as-an-independent-variable is the primary strategy used in Defense Systems Performance and Design to reduce life cycle costs (defense systems TOC). CAIV is used in system design to obtain the best possible system with the lowest life cycle cost. CAIV, as defined in Air Force Instruction (AFI) 10-601, is:

> The process of using better business practices, allowing "Trade Space" for industry to met user requirements, and considering operations and maintenance costs early in the requirements definition in order to procure systems smarter and more efficiently (AFI 10-601, 1998:Atch. 1).

Placing a cap on systems cost is a principle of CAIV. Any additional funds needed must be taken from the program itself, not other programs or force modernization efforts. Trade Space is another principle for decision making when using CAIV. Trade Space is the range of alternatives available to decision makers. Key performance parameters

(KPP) are set with thresholds and objectives. Decision makers view the alternatives to each KPP and try to reach thresholds without jeopardizing objectives for other KPPs . Decisions are made based upon impacts to cost (LCC), schedule, performance, and risk (Reduction, 1999). Decision makers try to reach a decision that balances operational requirements against life cycle costs.

Critical Item Analysis

This part of the analysis focuses on the critical items identified in Chapter 3. The critical items were all recommended for use in COTS-based systems by more than one source. The questions for the critical items were written so that a *yes* answer was a positive system attribute. The analysis was first done to see how many of the critical items were contained in the acquisition plans of each program. The average for the rated highly successful programs was compared against the average of the not rated highly successful systems. Additionally, each critical factor was looked at individually to see which had a unanimous result in either of the categories. Table 4 shows the results of this analysis.

The programs were analyzed to determine if the number of critical factors included in the acquisition plans of the rated highly successful programs was higher than that of the not rated highly successful programs. In this analysis, the rated highly successful programs included an average of 7.6 of the ten critical factors in their acquisition plans. The not rated highly successful programs included an average of 5.2

	Not Rated Highly Successful					Highly Successful				
Question	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Are the requirements flexible?	X	X			X	X		X	X	X
Is the prime contractor required to have experience in development of COTS-based systems?	X							X	*	
Is a plan for upgrades/obsolescence included?		X	X	X	X	X	X	X	X	X
Is modification of COTS item unacceptable?								X	*	
Is a warranty from the prime contractor included?	X	X	X			X	X	X	X	X
Is testing on a system test-bed required before upgrades are included in the system?			X	X	X	X	X		X	
Is the contractor included in government IPT's?	X	X	X		X	X	X	X	X	X
Is use of commercial practices identified in the SAMP?	X	X	X		X		X	X	X	X
Sub Totals	**5**	**5**	**5**	**2**	**5**	**5**	**5**	**7**	**6**	**5**
Is CAIV / tradeoff analysis addressed?			X		X	X	X	X	X	X
Is TOC used in tracking costs?	X		X			X	X	X	X	X
Totals	**6**	**5**	**7**	**2**	**6**	**7**	**7**	**9**	**8**	**7**
Average Highly Successful	7.6									
Average Others	5.2									
Difference	2.4									

Table 4. Critical Item Analysis

critical factors. This resulted in a difference of 2.4 more critical factors included in the acquisition plans of the rated highly successful programs over the not rated highly successful programs. Table 4 also provides a subtotal of critical items before TOC and CAIV are included. This subtotal shows there is minimal difference in the programs before TOC and CAIV are included.

Due to the limited number of samples (5 each), this analysis was taken one step further. Case D, a not rated highly successful program, contained only two of the critical factors. No other program came close to having that few critical factors. (This case was ultimately terminated at SAF/AQ direction.) Case H, a rated highly successful program, contained the most critical factors of any program - nine. To determine if these outlying cases had an extreme effect on the results, the analysis was conducted with these two cases removed. With these two extreme cases removed from the analysis, the rated highly successful programs contain an average of 7.25 critical factors. The not rated highly successful programs contain an average of 6 critical factors. This still provides a difference of 1.25 more critical factors for the rated highly successful programs. Furthermore, two of the critical factors for case I were identified as not applicable to the program. In the above analysis this was factored with the same weight as a *no*. This was seen as penalizing the highly successful programs. The analyses done without the penalty results in a difference of 2.7 before the extreme cases are factored out and 1.6 after the extreme cases are factored out. Therefore, the difference in the number of critical factors in the acquisition plans of rated highly successful programs versus the not rated highly successful programs is as high as 2.7 and as low as 1.25.

The critical factors were also looked at to determine which ones had unanimous results in either of the categories. Among the rated highly successful programs, five of the critical factors were included in all of the acquisition plans. The critical factors included in all of the rated highly successful programs are: including a plan for upgrades/obsolescence, a warranty from the prime contractor is included, the contractor is included in government IPTs, CAIV analysis is used, and TOC is used in tracking costs. CAIV and TOC were both also identified as key success factors. Among the not rated highly successful programs, one critical factor was unanimously not included in the acquisition plans. Modification of COTS items being unacceptable was not included in any of the acquisition plans of the programs. These results are shown in Table 5.

	Not Rated Highly Successful					Highly Successful				
Question	A	B	C	D	E	F	G	H	I	J
Is a plan for upgrades/obsolescence included?		X	X	X	X	X	X	X	X	X
Is modification of COTS item unacceptable?								X	*	
Is a warranty from the prime contractor included?	X	X	X			X	X	X	X	X
Is the contractor included in government IPTs?	X	X	X		X	X	X	X	X	X
Is CAIV / tradeoff analysis addressed?			X		X	X	X	X	X	X
Is TOC used in tracking costs?	X		X			X	X	X	X	X

Table 5. Unanimous Results

Qualitative Follow Up

This section is concerned with the explanation of the key success factors. Interviews were accomplished at each program to determine how these key success factors positively impacted the program. Key factor analysis identified two areas that could have an impact on the success of COTS-based systems. In this phase of the research, interviews were accomplished to further explore the relationships these areas had with program success. Key personnel from the rated highly successful programs were asked to identify reasons the key success factor led to program success. Key personnel from the not rated highly successful programs were also asked questions about the key success factor. Personnel from cases A and C were unable to provide interview responses.

Cost as an Independent Variable. In the response to the investigative question 'How did use of CAIV affect system success?' all five of the rated highly successful programs identified CAIV analysis in their acquisition plans.

In case F, the chief of the program management and operations division was contacted. The division chief related that the program was initiated well before CAIV became an Air Force policy. However, the program did use various forms of tradeoff analysis to fit the program within budget. Without these trades, budgets would never have been approved. The tradeoffs were not truly CAIV, but were similar to the CAIV analysis that is done today. In this program, performance tradeoffs were used to obtain an operationally capable system while meeting cost objectives.

In case G, the contracting officer and business manager were interviewed. The technical requirements were 'soft' or flexible requirements. Flexibility of requirements enabled the more affordable COTS-items to be used. This flexibility provided the prime contractor with the means to control costs.

In case H, the program manager was interviewed. This system was not made up of some items that were COTS, but the entire system was a COTS item. In acquiring a full COTS solution, it was unlikely that any one COTS application would satisfy all of the user requirements. Performing a CAIV analysis for a full COTS solution meant that some system requirements might not be met. The acquisition team selected the system that gave the best value by satisfying the most requirements while at the same time providing required scalability, flexibility, and technical environment at an affordable and reasonable cost. The comparison of costs resulted in acquisition of a substantially cheaper COTS solution. In this case, CAIV was used successfully by not just trading performance parameters, but entire performance requirements.

In case I, the three different procurement contracting officers were contacted. The consensus of the group was that the CAIV analysis identified threshold and objective platforms with key performance parameters that could not be traded. The threshold and objectives were the minimum and maximum of affordability of that parameter. In this case, CAIV analysis was performed as outlined in the *CAIV/TOC Guidebook*.

In case J, an operations research systems analyst allowed an interview. Although not a contracting officer or program manager, this person was in charge of the acquisition plan for the program. The analyst stated that tradeoff analysis was used within the principles of CAIV analysis. This tradeoff analysis led to changes in the design of the system that allowed different components to be used. These components either cost less to use in the production of the system or reduced operating and support costs. In either case, the components selected for use were more reliable than the ones they replaced. By selecting the best COTS-item for inclusion in the system, life cycle costs were reduced. Again, CAIV analysis was performed as outlined in the CAIV/TOC Guidebook.

Among the not rated highly successful programs, three of the programs were coded as not using CAIV analysis. In case B, both the program manger and the contracting officer on the program were contacted. Both responded that CAIV was in its infancy and not required at the time the request for proposals was released. The procurement-contracting officer in case D also stated that CAIV analysis was not used at the time.

Case E did require use of CAIV. CAIV was used in respect to design to cost (DTC) and life cycle cost (LCC) efforts. A target price was also set for the program. Performance goals were defined that were influenced by LCC. LCC were reviewed in design of systems, subsystems, support systems, and training systems. Additionally, significant efforts were made in the EMD phase of the acquisition to get a reduction in operating costs. However, data is not in yet on the results of those efforts. In this case, CAIV was used as outlined in the *CAIV/TOC Guidebook.*

In using CAIV analysis, all of the rated highly successful programs traded off performance parameters for cost objectives. One of the programs even traded performance *requirements* for cost. These tradeoffs led to a reduction in cost while maintaining operational capability. Identification of requirements and parameters that are flexible was the key to CAIV success. **For CAIV to work effectively in a COTS-based system, requirements must be flexible enough to identify tradeoffs in performance parameters.**

Total Ownership Cost. In response to the investigative question 'Is TOC used in tracking costs?' all five of the rated highly successful programs were coded *yes.*

In case F, the chief of the program management and operations division stated that reduction in life cycle (total ownership) costs was a goal of the program. CAIV and

TOC were used together to meet those cost goals. This reduction in costs was attained through improved reliability and maintenance.

In case G, TOC was used extensively in reducing logistics costs. TOC and CAIV are used together to reduce life cycle costs. Additionally, a just in time logistics system is being used effectively eliminating spare parts. When upgrades are proposed for inclusion in the system, obsolete spare parts are not part of the cost analysis. Newer technology has allowed for upgrades to be included that are generally cheaper than older systems. This in turn reduces total ownership costs.

In case H, the program manager stated that the Total Ownership Cost (TOC) was substantially reduced in the program. He believed this was due to the acquisition strategy. The acquisition was approached with the attitude that lower TOC was a result of smart acquisition planning and execution. TOC was a result, not a goal in and of itself. The advantage of using a true COTS system was that license fees, annual maintenance, and labor rates were all awarded using a firm fixed price contract. This produced a true CAIV analysis that allowed for reduced TOC. Again, TOC and CAIV were used together to attain reduced life cycle costs.

In case I, TOC was used in viewing the operational and sustainment costs for the life of the system. As part of the affordability requirement, TOC was one of the criteria used in the selection of a contractor. TOC and CAIV were used together to reduce life cycle costs.

In case J, TOC was used as part of the CAIV analysis. The program office could not have used CAIV without using TOC or TOC without CAIV. Therefore, TOC was used as a part of the component selection process to reduce production and operating and support costs.

Of the not rated highly successful programs, three did not identify use of TOC in their acquisition plan. In cases B and D, TOC was not used because it was not required at the time. In case E use of TOC was not readily apparent, but it was used in the program.

Case E, coded *no*, did actually use TOC. An interview was done with an acquisition consultant to the program who is in charge of the acquisition plan to determine why TOC was not identified well in the acquisition plan. The acquisition plan for the program identified use of TOC, but did not use operations and maintenance costs in the analysis or tracking. The consultant stated that direction to the contractor about life cycle costs and TOC was provided in the contract. The contract provided goals for life cycle cost and directed the contractor to perform life cycle costs studies throughout product development. Life cycle cost analysis was also provided in the operational requirements document (ORD) to keep operations and support costs low. Additionally, the tenets of TOC and CAIV are part of the program. However, the consultant noted that TOC and LCC are not obvious in the acquisition plan. Even though this program was not rated highly successful, CAIV and TOC seemed to be applied correctly.

All of the highly successful programs identified use of TOC in tracking costs. They also identified that CAIV and TOC were used together and were not easily separated. All of the benefits received from using CAIV apply to TOC as well. **TOC and CAIV together allowed programs to lower operations and support costs and meet cost goals.**

Summary

This chapter provided the results and analysis of the research. The key factors were analyzed to determine if they could be considered a key success factor. Both CAIV and TOC were determined to be key success factors. Critical factors were analyzed next. The difference in the amount of critical factors in rated highly successful programs versus other programs was 2.4. Five of the critical factors were included in all of the rated highly successful programs. One of the critical factors was not included in all of the not rated highly successful programs. TOC and CAIV were also found to be critical factors that were present in all of the rated highly successful systems. In the qualitative analysis, interviews were accomplished to determine how these factors affected program success. Flexibility of requirements allowed for the tradeoffs to be made in a CAIV analysis. TOC and CAIV were used together to reduce operating and support costs. TOC and CAIV also allowed programs to meet life cycle cost goals. Chapter five will develop a theory that can be used to explain the relationship of TOC and CAIV to the success of COTS-based systems.

V. Findings and Conclusions

Overview

COTS-based systems have been offered as a way for the DoD to reduce costs while keeping current technology in the hands of the warfighter. COTS-based systems have different risks and problems associated with them than traditional military systems. Currently, Air Force policy on acquisition strategy does not specifically address issues with COTS-based systems. The acquisition strategy of a program is documented in the program's acquisition plan. Currently, there is no standard guidance for the development of an acquisition plan for COTS-based systems. This chapter provides a theory based on the preceding research of how total ownership cost (TOC) and cost as an independent variable (CAIV) can work together to affect the success of a COTS-based system. Initially, COTS problems are reviewed. Then the relationships between TOC and CAIV are presented. Subsequently, two theories are presented on how TOC and CAIV can lead to the success of a COTS-based system. First, the use of CAIV and TOC will lead to the success of a COTS-based system through mandating flexible requirements. Second, the use of TOC and CAIV can reduce problems associated with system upgrades. Next, the limitations of the research are explored. Finally, recommendations for future research are offered.

COTS

As shown in chapter 2, COTS-based systems have certain problems and risks associated with them. Problems in COTS-based systems are due to inflexible requirements, technology cycle time, upgrades, and budget. Inflexible requirements restrict the number of COTS-items that can be proposed for use in a system. Technology cycle time can lead to problems in COTS-based systems because the life of a typical military system usually exceeds 20 years. Upgrades in technology can quickly make a military system obsolete. Another problem is COTS-based systems is upgrades of COTS-items. Upgrades to one COTS-item may cause problems with another COTS-item in the same system. Budgetary problems in a COTS-based system come from the incorrect application of life cycle costs. Operations and support costs of COTS-based systems can be high due to changing logistics needs of upgraded items. Risks in COTS-based systems are associated with upgrades, quality, security, and funding. Failure to upgrade to the newest version of a COTS-item can result in loss of vendor support for the item. Quality in a COTS-based system is risked because quality is a subjective measure based on the supplier's point of view. Security is a risk because COTS-based systems are particularly susceptible to a trap door or a Trojan Horse.

TOC/CAIV

There seems to be a relationship between TOC and CAIV with respect to reducing defense systems life cycle costs. Defense systems TOC is defined as life cycle costs. Life cycle costs are driven by requirements 'pull' and technology 'push'.

Requirements pull starts when a system operator encounters a new threat. A new threat leads to weapons systems requirements change. Systems are then changed to meet this new threat. Technology push starts when new capabilities are developed. Systems are then upgraded to include the newest capabilities. Both requirements 'pull' and technology 'push' increase operational capabilities and change system costs. A balance is needed between operational capabilities and system costs. Cost as an Independent Variable (CAIV) is the tool used to achieve this balance. CAIV is used to obtain the best system with the lowest total ownership cost. Achieving the lowest TOC is made possible by ensuring the review of not only short term costs, but also costs including research and development, investment, operations and support, and disposal of a system. Two principles are used within CAIV to achieve the balance between operational capabilities and system costs. First, a cap is placed on system costs. Second, trade space is used to identify a range of alternatives in system requirements. Having this range in each requirement allows decision makers to identify options that balance operational requirements with system costs.

Analysis

Flexible Requirements. The use of CAIV mandates the use of flexible requirements. In performing a CAIV analysis, trade space needs to be defined. This trade space is made available by identifying key performance parameters. Key performance parameters are identified by setting goals and thresholds for certain requirements. By setting goals and thresholds, the system requirements are made flexible. This is shown in the analysis of the key factors at Table 3. Each of the programs rated highly successful by the Scientific Advisory Board used CAIV. All of these systems also have flexible requirements. Although case G was coded *no* regarding flexible requirements, the requirements were flexible as stated by the contracting officer. Flexibility of requirements in this case was not specifically addressed in the acquisition plan because flexibility was understood to be included when using CAIV.

In the programs not rated highly successful by the Scientific Advisory Board, case E was the only one of the acquisition plans that identified both CAIV and flexible requirements. While this case was not rated highly successful, it may have still been a successful system. The SAB did not delineate between levels of success. Therefore, any of the cases that were not rated highly successful could have been good programs but did not earn the rating of highly successful. Case E did not include operations and support costs in their analysis of total costs. This could have led to the program not being rated highly successful.

Another program not rated highly successful, case C, had CAIV and TOC identified in the acquisition plan but did not have flexible requirements identified in the acquisition plan. This may have been the reason the program was not rated highly successful. Without flexible requirements, CAIV will not work. CAIV requires trade space that is not available without flexible requirements. Flexible requirements may have been assumed to be present with CAIV use, but the acquisition plan did not address the issue. Interviews may have helped determine the cause of the disparity. However, personnel from this case were unable to provide interview responses. Without interview responses, case C presents a problem with the results of the study. The acquisition plan for this case included TOC, CAIV, and 7 critical factors. The only real difference in this case, from the highly successful programs is not including flexible requirements. Further research, beyond the scope of this effort, is needed to determine why case C was not rated highly successful.

Since all of the highly successful systems used CAIV, this ensured that requirements of the systems were flexible. Having flexible requirements allows decision makers to obtain the COTS-items that will maintain a balance between operational capabilities and system costs. In CAIV, system costs are capped. When using TOC, total life cycle costs are used in developing cost estimates. Each requirement will then be balanced in terms of increased operational capability and total system life cycle costs. This balance is accomplished while maintaining system costs that are capped. **Therefore, the use of CAIV and TOC in a COTS-based system leads to maintaining or lowering costs while increasing operational capability.**

While the relationship may not be causal, there seems to be a strong correlation between the use CAIV, TOC, and flexible requirements with the success of a COTS-based system.

Upgrades. Technology cycle time leads to the need for upgrades in COTS-based systems. If upgrades are not performed, programs run the risk of losing vendor support. Upgrades are also needed as the result of requirements pull from system operators. Life cycle costs escalate due to system upgrades. However, when using CAIV, system costs are capped. Through interviews with key personnel, TOC and CAIV used together were determined to lower life cycle costs. By placing a cap on systems costs and ensuring review of the life cycle costs, TOC and CAIV work together to reduce the costs of systems upgrades. Upgraded items will only be included in the system if life cycle costs will not increase. All of the highly successful programs identified use of TOC and CAIV together. Additionally, all of those cases included a plan for upgrades. One of the programs not rated highly successful, case C, also included CAIV, TOC, and a plan for upgrades. The exception of this case was discussed above. **A plan for upgrades using TOC and CAIV provides for reduced life cycle costs in COTS-based systems while allowing for system upgrades.**

Again the relationship may not be causal; however, there seems to be a strong correlation between the use CAIV, TOC, and a plan for upgrades with the success of a COTS-based system.

Limitations

Several limitations concerned me throughout this project. The acquisition plans studied were not all from the same phase of the life cycle of the system. While some systems were in the development phase, others were in production, and one system was terminated. Different areas of the acquisition pan are emphasized during different phases of the system life cycle. This may be why some acquisitions identified a key factor and others did not. Also, the acquisition plans came from different years. While most of the plans were from 1998 through 2000, the acquisition plan from one program was written in 1994. If certain key factors were not developed at the time, the acquisition plans would not contain them. Also, not all programs were able to release their acquisition plan to me. The contracting officer from case I would not release the acquisition plan to me, but did review the acquisition plan and provided the answers to key factor analysis for that program. This may have resulted in answers to questions being biased on the part of the contracting officer.

The limitation that caused the greatest concern was the definition of a 'highly successful' program. This study relied on the Scientific Advisory Boards (SAB) decision that the programs were highly successful. However, the SAB did not delineate between the degrees of success of the remaining systems. This is especially problematic with the analysis of case C. The acquisition plan for case C included the key success factors, 7 of the critical items, and all of the critical items unanimous to the highly successful programs. If this case was considered to be near the highly successful range, validity would be added to this research. However, if this case was not near the highly successful range, the validity of this research would be decreased. Additionally, the requirements for a system to be rated highly successful were subjective. The SAB report did say that all highly successful programs "were selected to represent the best program attributes by both government and industry officials" (Grant, 2000:18). This subjectivity may have led to systems being improperly included in or excluded from the highly successful range. This would also lead to decreased validity of the research.

Recommendations For Future Research

As a result of my experiences throughout this endeavor, I have identified some opportunities for future research. With respect to COTS-based systems, an accurate cost analysis tool needs to be developed for setting baselines and tracking costs. Engineering and support costs are different with COTS-based systems due to the cycle of continuous upgrades. The importance of TOC and CAIV point to the importance of controlling costs in a COTS-based system. An adequate tool needs to be devised that will help set a baseline for a system and track costs accurately.

Another area of research that needs to be developed is with respect to the role of the systems engineer. A systems engineer typically is responsible for ensuring all of the parts of a system work together. This can be difficult with a COTS based system due to continual updates of COTS products. Systems engineers need to keep abreast of the market conditions and trends that lead to upgrades of their systems. They also need to budget for the upgrades in order to keep the system current. Additionally, they need to ensure these upgrades do not cause problems with other COTS-items in their system. The role of the systems engineer needs to be redefined with respect to COTS-based systems.

Closing Remarks

COTS-based systems are being used by the DoD as a means of reducing costs and infusing current technology into systems. However, COTS-based systems have certain requirements, cost structure, and risks associated with them. While the use of COTS-based systems seems to be the direction the Air Force is heading, the training and tools available to the people acquiring these systems needs to change. The use of TOC and CAIV can have a significant effect on the success of a COTS-based system. These items need to be included in the acquisition strategy of COTS-based systems. While this research may not provide a full answer, it should provide a good starting point for those that need to establish policy in regards to acquisition plans of COTS-based systems.

Appendix A: Interview Questions

Questions for the highly successful programs

How did CAIV / tradeoff analysis lead to system success?
Was TOC part of the CAIV analysis?

All of the responses included TOC as a part of CAIV. Therefore, further questions were not needed to analyze how TOC led to system success.

Questions for the programs not rated highly successful with acquisition plans that did not identify use of CAIV

Was CAIV used?
If yes, why was CAIV not included in the acquisition plan?
If yes, was TOC used as a part of the CAIV analysis?

Questions for the programs not rated highly successful with acquisition plans that did not identify use of TOC

Was TOC used to track costs?
If yes, why was it not addressed in the acquisition plan?
If yes, was CAIV used as part of the TOC analysis?

Bibliography

Albert, C., and E. Morris. Commercial Item Acquisition: Considerations and Lessons Learned. Software Engineering Institute, Carnegie Mellon University (June 2000). http://www.acq.osd.mil/ar/doc/cotsreport.PDF

Alford, Lionel D. "Supporting Commercial Software," Crosstalk, 13: 13 – 16 (September 2000).

Brownsword, Lisa, and Patrick Place. Lessons Learned Applying Commercial Off-the-Shelf Products Manufacturing Resource Planning II Program. Software Engineering Institute, Carnegie Mellon University (June 2000). http://www.sei.cmu.edu/publications/pubweb.html

Brownsword, Lisa, and others. "An Activity Framework for COTS-Based Systems," Crosstalk, 13: 8 - 12 (September 2000).

Carney, David and Patricia Oberndorf. "The Commandments of COTS," Crosstalk, 10: 1-9 (May 1997). http://www.stsc.hill.af.mil/CrossTalk/1997/may/commandments.asp

Clapp, Judith A. and Audrey E. Taubb. A Management Guide to Software Maintenance in COTS-Based Systems. Mitre Company. Bedford Mass. (November 1998). http://www.mitre.org/resources/centers/sepo/sustainment/manage_guide_cots_base.html

Department of the Air Force. "COTS Sustainment Study Report," USAF Contract F04606-95-D-0239-0014 Task Order 054, Lockheed Martin Mission Systems January 1999.

Department of the Air Force. Guidelines for Successful Acquisition and Management of Software-Intensive Systems. Software Technology Support Center, Hill AFB UT May 2000. http://www.stsc.hill.af.mil

Department of the Air Force. Mission Needs and Operational Requirements Guidance and Procedures. AFI 10-601. Washington: HQ USAF, 1 October 1998.

Department of the Air Force. Reduction in Total Ownership Cost CAIV/TOC Guidebook. Washington DC: HQ USAF. May 1999. http://www.safaqxt.rtoc.hq.af.mil/library.cfm

Department of the Air Force. Single Acquisition Management Plan Guide. Washington DC: HQ USAF April 1996.

Department of Defense. Department of Defense Manual Cost Analysis Guidance and Procedures. DoD Directive 5000.4M. Washington: GPO, December 1992.

Department of Defense. Department of Defense Trusted Computer System Evaluation Criteria. DoD Directive 5200.28-STD. Washington: GPO, 11 May 1999.

Department of Defense. Mandatory Procedures for MDAPs and MAIS Acquisition Programs. DoD Directive 5000.2R. Washington: GPO, 11 May 1999.

Department of Defense. Year 2000 Management Plan. DoD Policy Letter. Washington:, June 1998

Gillis, Matt. "Open Systems Joint Task Force Gets the Word Out," Program Manager, 28: 44-47 (July – August 1999).

Grant, Jeffrey E., and others. Ensuring Successful Implementation of Commercial Items in Air Force Systems. AF/SB Pentagon, Washington DC April 2000.

Hanratty, Michael, Robert H. Lightsey, and Arvid G. Larson. "Open Systems and the Systems Engineering Process," Acquisition Review Quarterly, 6: 47-59 (Winter 1999).

Holmes, Lori A. "Evaluating COTS using Function Fit Analysis," Crosstalk, 13: 26 - 30 (February 2000).

Monczka, Robert M. and others. Purchasing and Supply Chain Management. Cincinnati: South-Western College Publishing, 1998.

Milligan, Michael K.J. "Implementing COTS Open Systems Technology on AWACS," Crosstalk, 13: 21 - 25 (September 2000).

Oberndorf, Patricia, and David Carney. A Summary of DoD COTS-Related Policies. Software Engineering Institute, Carnegie Mellon University (September 1998). http://www.sei.cmu.edu/publications/pubweb.html

Oberndorf, Patricia. COTS and Open Systems—An Overview. Software Engineering Institute, Carnegie Mellon University (April 1998). http://www.sei.cmu.edu/str/descriptions/cots_body.html

Strauss, Anslem and Juliet Corbin. Basics of Qualitative Research. Newbury Park: SAGE Publications, Inc., 1990.

Tracz, Will. "Architectural Issues, Other Lessons Learned in Component-Based Software Development," Crosstalk, 13: 4 - 7 (January 2000).

U.S. Government. Office of Management and Budget. Office of Federal Procurement Policy The Federal Acquisitions Regulation. Washington: GPO, August 2000. http://farsite.hill.af.mil

Vigder, Mark R., W. Morven Gentleman, and John Dean. COTS Software Integration: State of the Art. National Research Council Canada, Institute for Information Technology, January 1996

Yin, Robert K. Case Study Research: Design and Methods(Revised Edition). Newbury Park: SAGE Publications, Inc., 1994.

Vita

Capt John Corbett hails from the great state of Illinois. He grew up in University Park and graduated from Marian Catholic High School in Chicago Heights, Illinois in 1984. He enlisted in the Air Force in October of 1985. In May of 1994 he graduated with honors form the University of Southern Mississippi with a Bachelor of Science Degree in Technical and Occupational Education. He attended Officer Training School in November of 1994. He graduated from Officer Training School on March 17, 1995, a truly fitting day.

Upon earning his commission, he was assigned to the 21st Contracting Squadron at Peterson AFB, CO. He served as a contract specialist and contract administrator. While there, he earned APDP-Contracting Level I and Level II certifications. In September of 1997 he was transferred to the 6th Contracting Squadron at MacDill AFB, Florida. While there he served as Chief, Commodities Flight and Unit Deployment Manager. In September, 1999 he entered the Graduate Acquisition Management program, school of Engineering and Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Training Systems Program Office, Hill Air Force Base, Utah.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
20-03-2001	Master's Thesis	Sep 1999 – Mar 2001

4. TITLE AND SUBTITLE

AN IDENTIFICATION AND DISCUSSION OF KEY SUCCESS FACTORS IN THE ACQUISITION OF COMMERCIAL-OFF-THE-SHELF (COTS-) BASED SYSTEMS

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Corbett, John F., Captain, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)

Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 P Street, Building 640
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GAQ/ENV/01M-03

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

SMC / Det 11 / CZSI
Attn: Mr. Mike Morgan
1050 E. Stewart Ave
Peterson AFB, CO 80914 DSN: 834-2502

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The purpose of this research was to explore COTS-based systems as they are acquired by the Air Force. Current guidance related to the acquisition of COTS-based systems is explored. Based upon the literature reviewed, the research targeted the specific area of acquisition plans. A multiple case study of acquisition plans from several COTS-based systems was performed. Current guidance related to the acquisition plan has not been specifically tailored to COTS-based systems. The results of the analysis of the COTS-based systems showed that the use total ownership cost (TOC) and cost as an independent variable (CAIV) enabled a system to be highly successful. The use of TOC combined with the use of CAIV in a COTS-based system ensures a system has flexible requirements. This flexibility will lead to maintaining or lowering costs while increasing operational capabilities. Additionally, a plan for upgrades in a COTS-based system, that includes TOC and CAIV, provides for reduced life cycle costs while allowing for system upgrades. It is imperative that any future acquisition guidance related to COTS-based systems includes TOC, CAIV and a plan for upgrades.

15. SUBJECT TERMS

Commercial Off the Shelf (COTS), Acquisition Plan, Total Ownership Cost (TOC), Cost as an Independent Variable (CAIV), Flexible Requirements, Upgrades

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** / **19b. TELEPHONE NUMBER** *(Include area code)*
U	U	U	UU	89	Lt Col David Petrillo, ENV / (937) 255-3636, ext 4799