9-1998

Analysis of USAF Medium and Heavylift Space Launch Mission Reliability Requirements

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THESIS

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THESIS

Presented to the Faculty of the Graduate School of Logistics

and Acquisition Management of the 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 Logistics Management

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September 1998

Acknowledgements

The thesis is one of the most challenging and rewarding experiences at the Air Force Institute of Technology, as most of the AFIT graduate students would probably attest. Such extensive and worthwhile endeavors are seldom accomplished in a vacuum. As such, there are many individuals to whom I would like to express a sincere appreciation.

According to the professional support that I have received, I would like to express a sincere appreciation to several individuals. My thesis advisor, Major Alan Johnson, besides being a respected instructor, has provided me with tremendous support, insight and patience in my thesis efforts. My reader, Major Steve Swartz, with his analytical insight, provided valuable guidance. Mr. Tony Pausz, of the Launch Programs System Program Office and my previous supervisor, enthusiastically supported me in my quest of pertinent subject information.

I would like to thank my parents, Sonny and Barbara Dawkins, for instilling in me the strength and motivation to accomplish such admirable endeavors. Most importantly, I would like to express a special and heart-filled appreciation to my wife, Cindy, and my young daughter, Summer, for the time they endured that I spent on this thesis effort, as with the rest of the program. Their sacrifice is not unnoticed and I love both of you more than words can express.

Arthur R. Dawkins

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Abstract

The launch services that the USAF procures to carry DOD payloads into orbit are characterized by high risks and high costs. If a launch vehicle experiences a catastrophic failure, the cost of the entire launch vehicle, the launch processing, and the payload are completely lost (often in excess of 1.5 billion dollars.) Despite this enormous risk for the payload customer, and indeed the launch provider, launch success rates around the world are not much above 90 percent.

The current USAF medium and heavylift launch systems are often based on technology that is 20 years old and older. Furthermore, little historical data exists because of the complex technologies used and the unique nature of individual missions. As such, reliability management is limited and faces serious shortcomings.

This research investigates the various shortcomings associated with mission reliability measurement and management. Through literature review, case study analyses and interviews, the shortcomings are determined and analyzed.

The results of this thesis effort demonstrate these shortcomings. Recommendations are presented for immediate improvement to selected shortcomings and suggestions are made for further research.

ANALYSIS OF USAF MEDIUM AND HEAVYLIFT SPACE LAUNCH MISSION RELIABILITY REQUIREMENTS

I. Introduction

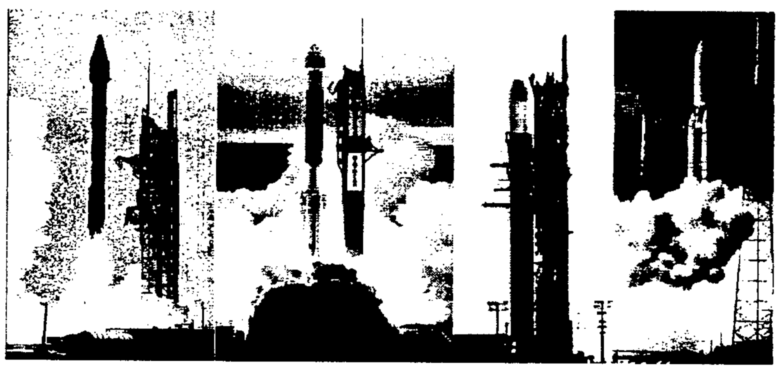
> We are now transitioning from an *air* force to an air *and space* force on an evolutionary path to a *space and air* force. The threats to Americans and American forces from the use of space by adversaries are rising while our dependence on space assets is also increasing. The medium of space is one which cannot be ceded to our nation's adversaries. The Air Force must plan to prevail in the use of space. Space is already inextricably linked to military operations on land, sea and in the air. Several key military functions are migrating to space: Intelligence, Surveillance and Reconnaissance (ISR); warning; position location; weapons guidance; communications; and, environmental monitoring. Operations that now focus on air, land and sea will ultimately evolve into space. (Widnall, 1998)

These words were stated by the former Secretary of the Air Force Sheila Widnall and Air Force Chief of Staff Ronald Fogleman within the United States Air Force's new vision, *Global Engagement: A Vision for the 21st Century Air Force*. The application of space power as an instrument for future national and military interests is thus made evident.

The advent of space exploitation, emerging technology, and recent Department of Defense (DOD) business reform policies have indeed had a profound effect on the nation. Coupled with this new frontier, as with any new endeavor, is a string of unknowns and assumptions that induce serious inefficiencies and a need for continuous improvement efforts. One aspect within this environment is the critical and costly process of launching payloads into space.

Program Background

The United States Air Force (USAF) commands the majority of the launch market (DOD, civil, and commercial payloads) within the United States. This paper focuses on the four operational medium and heavylift space launch vehicles managed by the USAF: the Atlas II, Delta II, Titan II (TII), and Titan IV (TIV) boosters (see Figure 1).



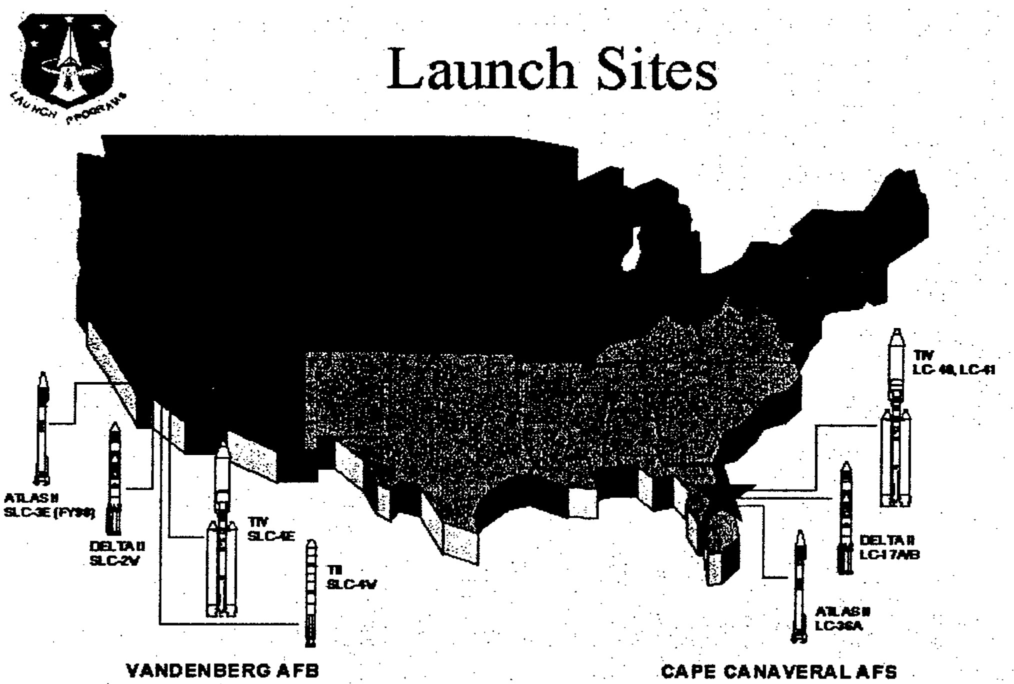
Atlas II Delta II Titan II Titan IV

Figure 1. USAF Medium and Heavylift Launch Vehicles (CL, 1998)

The TIV booster is the only system with heavylift capabilities. The Atlas II, Delta II, and TII vehicles are mediumlift vehicles.

These launch vehicles are acquired and managed by the Launch Programs System Program Office (SPO) at Space and Missile Systems Center (SMC) at Los Angeles Air Force Base, California. The specific acquisition responsibilities of the SPO are directed by Headquarters USAF in the Program Management Directive (PMD).

The using (operating) command is Air Force Space Command (HQ AFSPC), headquartered at Peterson Air Force Base, Colorado. HQ AFSPC has assigned Wings to oversee the operations and maintenance of the contractors' launch processing. The 30th Space Wing has the oversight responsibility of all four launch vehicles at Vandenberg Air Force Base (VAFB), California. The 45th Space Wing has the oversight responsibility of the Atlas, Delta, and Titan IV vehicles at Cape Canaveral Air Station (CCAS), Florida (see Figure 2).



"SLC" is "Space Launch Complex", "LC" is "Launch Complex"; these are the designations of the launch pads from which the appropriate boosters are launched.

Figure 2. Launch Sites (CL, 1998)

Today's business environment dictates that the DOD use prime contractors to support DOD systems (SAMP Guidelines, 1998). The Atlas, TII, and TIV vehicles are manufactured by Lockheed Martin Astronautics (LMA). The Delta launch vehicle is manufactured by Boeing-McDonnell Douglas Astronautics, previously McDonnell Douglas Aerospace (MDA). Accordingly, the operations and maintenance procedures of each vehicle are conducted by the respective prime contractor with USAF "insight" to ensure reliability.

Problem Statement

On 12 August, 1998, a Titan IV launch vehicle self-destructed 40 seconds after launch. The reason of failure has not yet been determined. Besides the cost of the launch vehicle and the associated processing costs, a National Reconnaissance Office payload was destroyed (Titan explosion, 1998).

The high cost of failure and associated risk, thus exemplified, necessitates continuous improvement and close management attention. Difficulties in defining quantifiable launch requirements contribute to the problem and plague the USAF launch market. This lack of quantifiable requirements was noted in a 1994 Government Accounting Office (GAO) report (GAO, 1994).

Several factors contribute to this problem. Space technology is relatively new and rapidly evolving. As such, a shortage of historical data prevents a strong baseline on which to set requirements. The relatively few number of launches (likened unto sorties in the aircraft world) further contributes to this lack of historical data. Furthermore, various characteristics of the U.S. launch market (identified in the Summary of Propositions) contribute to the limited size of the market and impacts DOD costs accordingly. The reliability requirements that the USAF *does* impose are not valid and accurate measures, not contractually enforced, and thus are a waste of USAF resources and taxpayers' dollars. DOD contractual limitations exacerbate the problem even more.

Research Objective

This research provides an analysis of USAF medium and heavylift launch program mission reliability requirements. As such, it examines the existing mission reliability requirements within the USAF medium and heavylift space launch programs. The rationale behind the requirements is first considered. This research then addresses the various issues associated with the lack of solid, quantifiable requirements. The primary mission reliability measurement, Launch Effectiveness, is discussed in depth. The existing reliability requirements are traced to actual program impacts by defining failures in terms of cost impact. This research attempts to disprove the validity and applicability of the contractual requirements by disproving the validity of the actual measurement quantitatively and qualitatively. The research benefit is that the USAF is able to define better launch mission reliability requirements, while gaining insight into cost drivers, and improving management of launch programs.

To provide a comprehensive analysis of the issues, this objective is best met through the sequential analysis of four interrelated propositions. Each of the propositions builds on the previous one (See Table 1).

Table 1. Summary of Propositions

Proposition 1	Intrinsic characteristics of spacelift launch missions (launch market, new technology, unique missions, lack of historical data, legal limitations) contribute to the difficulty in quantitatively defining launch mission reliability requirements.
Proposition 2	The method of procurement significantly contributes to the difficulty in quantitatively defining launch mission reliability requirements.
Proposition 3	The liability clause employed, Total System Performance Responsibility, contributes to the difficulty in quantitatively defining launch mission reliability requirements.
Proposition 4	The primary mission reliability requirement does not accurately measure program performance (definition, cost measurement, etc).

This research provides an exploratory analysis of spacelift launch systems and discussion of the lack of quantifiable mission reliability requirements. The complex nature of spacelift launch precludes a completely quantitative analysis. A literature review, expert testimonies, and a case study are used to address the four propositions and the investigative questions (discussed below).

Finally, suggestions are provided for immediate reliability measurement improvement and for future research. To improve the current mission reliability requirement, a new requirement is suggested and matched to past performance of the different launch vehicles primarily to demonstrate 1) possible requirement tracking application, 2) actual program performance, and 3) inconsistencies between program performance and the requirements / measurements.

Investigative Questions

A set of investigative questions was developed to guide this research effort. The author's experience in the Launch Programs' SPO provided insight into the current dilemma and development of the investigative questions. Answering these questions should provide significant visibility into the current problems of defining quantifiable mission reliability requirements and lead to improvement in the USAF's management of medium and heavylift launches. The investigative questions are as follows:

1. What are the factors that influence the definition and application of launch mission reliability measurements?

2. What is the method of procurement of USAF medium and heavylift launch programs and how does it effect mission reliability requirements?

3. What techniques does the USAF employ to ensure mission success / reliability?

4. What are the current measurements for mission reliability and what are the contractual requirements?

5. How does the USAF track the measurement?

6. How do the USAF medium and heavylift launch programs compare to a) each other, b) other US launch programs, and c) international launch programs according to performance and cost?

These investigative questions were researched and summarized to form the basis of the propositions.

Summary

Recently, consortia have appeared such as the Motorola sponsored Iridium organization and the Gates-McCaw sponsored Teledesic organization which desire to launch large constellations of communications satellites (66 and 840 satellites, respectively). These new customers desire, and in the case of the Teledesic group require, a drastic reduction in the cost of space launch. An extraordinary opportunity therefore exists to create a new U.S. launch system to meet the pressing needs of the new commercial communications satellite consortia. It is also clear that, in these times of budget cutbacks, in meeting the needs of these economically minded commercial customers, a new inexpensive US launch system can and will capture the majority of the government business (Pioneer, 1998).

"To date, neither the government nor industry has attempted to approach space launch as they do cargo transport by truck, rail, ships, or aircraft. In these areas, standardization, rugged design, performance margins, low cost, and responsiveness are of overriding importance" (GAO, 1994). This statement in a GAO report to Congress further exemplifies problem areas in the USAF's space launch programs.

The "overriding importance" in the GAO report ultimately equates to lower costs and satisfactory mission performance. To achieve lower costs and satisfactory mission performance, the USAF manager must be able to accurately measure performance and set solid, quantifiable mission reliability requirements.

The **Literature Review** in Chapter II looks at standard business practices (other USAF space, foreign and commercial programs) corresponding to launch business practices that relate to this research. It specifically addresses 1) standard reliability definitions and processes, 2) comparable reliability systems and requirements, 3) standard DOD procurement methods, and 4) standard liability and warranty procedures. Notable authors in the respective fields are cited. Successful programs are examined to consider similar processes that may provide opportunities for improvement. Chapter III, **Methodology**, explains the process by which the required information was obtained. Much of the information was obtained by researching the literature applicable to each topic. USAF program documents, contractor data, and personal interviews were the primary sources of obtaining the information. The validity of key parameters was determined by considering if the definitions were appropriate. The research results are presented in Chapter IV, **Findings**. Specific recommendations, for immediate improvements to the requirements process and for long-term opportunities, are discussed in the final chapter, Chapter V, **Recommendations and Conclusions**. Applicable information relating to or explaining the research is listed in the appendices (acronyms, definitions, interview questions, and points of contact).

II. Literature Review

> To maintain what is called in the business an adequate or warm defense technology and industrial base, the United States needs to be producing, year in and year out, sufficient modern weapon systems and sustaining components to allow us to maintain technological superiority in mission decisive areas and expand production on short notice. (Boezer, 1997:26-27)

Overview

The USAF is seriously concerned with developing reliable and cost effective launch vehicles to carry military payloads into space. The USAF medium and heavylift launch programs are extremely costly and critical endeavors. Due to the decreasing national defense budget and intense competition, reliability and requirement definition management must continue to grow. Several opportunities exist in which to improve reliability measurement and management.

The purpose of this literature review is to examine four specific arenas in which reliability measurement and reliability management can be improved. It initially looks at various reliability definitions and measurement processes. Secondly, it looks at various mission readiness and performance indicators from other DOD space programs. It next considers the various procurement methods that effect reliability management. Lastly, it considers different types of warranties and liabilities that could incentivize the prime contractor to ensure mission success and cost effective management.

Reliability Systems / Requirements

When any organization makes or buys a particular service or product, it has an inherent vested interest for that service or product to perform according to given expectations. Those expectations can include specific performance parameters (like an automobile having the capability to reach speeds of over 60 miles per hour) and/or cost objectives (like the automobile must cost less than $12,000.) The following discussion concerns commonly accepted definitions of reliability measurement terms. The discussion is extracted primarily from academic literature and DOD sources.

A Department of Defense weapon system acquisition is initiated by the recognition of a specific, unfulfilled requirement. A requirement is defined as the determination that a specific need exists that must be satisfied (Arnavas, 1994:2.14) and is contractually stated in the Operational Requirements Document (ORD) (Glossary, 1998). These requirements eventually equate to specifications that generally fall into one of two major groups: design and performance specifications. In design specifications, the DOD specifically identifies the materials to be used and manner in which the work is to be performed. In performance specifications, the DOD describes the performance desired of the end product without specifying the precise method to reach the desired results (Arnavas, 1994:8.2 - 8.3). USAF medium and heavylift launch contracts utilize primarily performance requirements. The ultimate desired result is a successful and cost effective launch mission.

When assessing the overall value of a system, one must consider both the technical characteristics of the system and the system cost. Numerous effectiveness factors can be expressed as figures of merit, representing the extent to which the system fulfills the intended requirements in a cost-effective manner. These measures must be tailored to the particular system and/or mission scenario. Common system effectiveness measurements include system technical and performance parameters (speed, range, accuracy, throughput, reliability, etc.), availability, and dependability. Common examples of cost-effectiveness measurements include [system effectiveness / life-cycle cost] and [system availability / life-cycle cost].

The importance of cost-effectiveness measurement and control techniques is being highlighted with acquisition reform policies and the DOD concept of "Cost as An Independent Variable" (CAIV). CAIV is defined as:

> methodologies used to acquire and operate affordable DOD systems by setting aggressive, achievable life cycle cost objectives, and managing achievement of these objectives by trading off performance and schedule, as necessary. Cost objectives balance mission needs with projected out-year resources, taking into account anticipated process improvements in both DOD and industry. CAIV has brought attention to the government's responsibilities for setting/adjusting life-cycle cost objectives and for evaluating requirements in terms of overall cost consequences. (Glossary, 1998)

The DOD uses many other costing tools to measure cost-effectiveness. The DOD compares Budgeted Cost of Work Scheduled (BCWS - the sum of the budgets for all work scheduled to be accomplished within a given time period) to Budgeted Cost of Work Performed (BCWP - measurement of work performed). The DOD also compares cost performance to baselines (defined quantity or quality used as starting point for subsequent efforts and progress measurement that can be a technical cost or schedule baseline.) The DOD tracks cost-effectiveness according to the Cost Performance Assessment Report (CPAR - a monthly report procured by the program manager from the contractor to obtain report data from the contractor's management system) (Glossary, 1998). Each of the cost-effectiveness measurements are standard tools used in the decision-making process.

Dr. Charles E. Ebeling, an associate professor of engineering management and systems in the School of Engineering, University of Dayton, addresses this concern of performance expectations. He qualitatively defines this concern, the amount by which the service or product satisfies the user's (customer's) requirements, as "quality". He states that reliability is closely associated with quality and is often considered a subset (Ebeling, 1997:6).

Dr. Ebeling defines reliability as "the probability that a component or system will perform a required function for a given period of time when used under stated operating conditions"; i.e., as the probability of nonfailure over time. He stresses the necessity of first establishing an unambiguous and observable description of a failure. Secondly, he notes that the unit of time (or a measurement such as miles or missions operated) must be identified. Third, he states that the system should be observed under normal performance or conditions (Ebeling, 1997:5).

The DOD defines reliability as "the ability of a system and its parts to perform its mission without failure, degradation, or demand on the support system" (Glossary, 1998). Though these two definitions of reliability are similar, the main difference between the two definitions is the inclusion of the time consideration in Dr Ebeling's definition. As will be addressed later, this seemingly slight discrepancy contains severe implications.

Before reliability factors can be stated for components, an acceptable reliability factor for the system must be established. As overall system performance is determined by individual performance of its components, it becomes necessary to establish requirements at the component level to ensure that the system requirement will be met.

A typical top-down approach involves the allocation of requirements at the system level down to the various applicable components of the system. These requirements, stated both qualitatively and quantitatively, are then included in second tier specifications used in the procurement of those components. The lower level components that must receive allocation of the system level requirement include the various subsystems, units, assemblies, and so on. This allocation of requirements is typically accomplished with the generation of a reliability block diagram. The intent is to develop a reasonable approximation of those elements or items that must function for the successful operation of the system, see Figure 3.

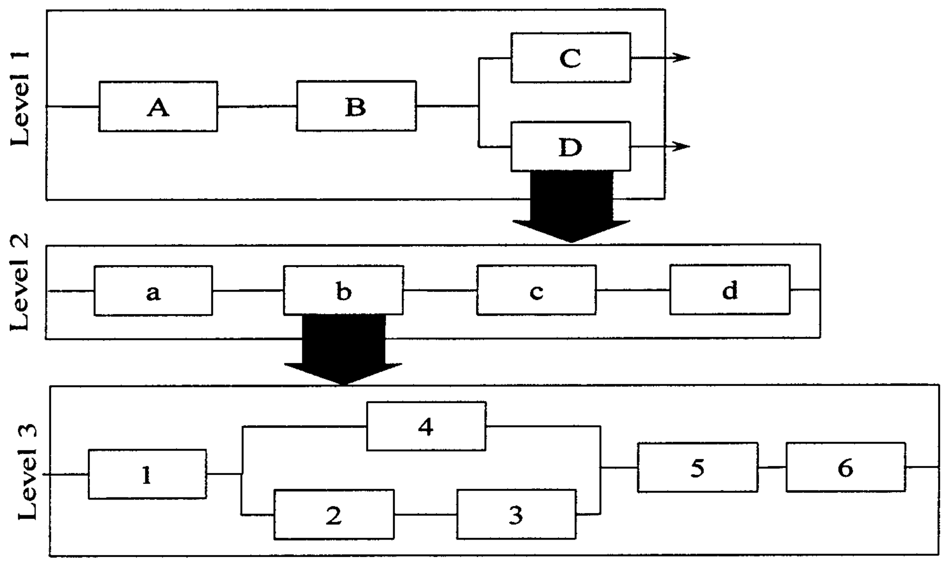


Figure 3. Reliability Block Diagram for Allocation (Blanchard, 1995:187-189)

Other common terms regarding reliability and system effectiveness measurement are listed below. A few terms particularly relative to this research are defined here. The rest are defined in **Appendix B - Definitions**, taken from the Glossary: Defense Acquisition Acronyms And Terms, 8th edition. Some of the more common terms are Availability, Effectiveness, Failure, Inherent Availability, Maintainability, Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), and Operational Availability.

Availability: A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) point in time.

Effectiveness: The extent to which the goals of the system are attained, or the degree to which a system can be elected to achieve a set of specific mission requirements.

Failure: The event in which any part of an item does not perform as required by its performance specification.Failure: The event in which any part of an item does not perform as required by its performance specification.

Mean Time Between Failures (MTBF): For a particular interval, the total functional life of a population of an item divided by the total number of failures within the population. The definition holds for time, rounds, miles, events, or other measures of life unit. A basic technical measure of reliability.

The requirements for launch mission reliability are designated in particular contractual documents (such as the Operational Requirements Document for the Titan IV, other launch programs' regulatory documents include Payload Interface Control Documents, Program Management Directives, etc.). The general description for the four measurements were defined (for all four of the USAF medium and heavylift launch programs) in Air Force Regulation 57-9, *Launch Readiness Indicators* (or its replacement, if applicable).

The primary reliability measurement considered in this research effort is that of Launch Effectiveness (LE). Launch Effectiveness consists of three components. Launch Effectiveness is the product of Launch Availability (LA), Launch Dependability (LD), and Launch Reliability (LR): LE = LA x LD x LR. In the following paragraphs, each of the components is defined according to program implementation. The Titan IV program is used as a case study since it has the most comprehensive measurement system of all the four USAF medium and heavylift launch programs, though still not adequate, to be exhibited in Chapter IV, **Findings**.

Launch Availability is the measure of degree to which the launch vehicle is operable and capable of performing its mission profile within a predetermined LA timeline. It is measured as $LA = 1 - downtime_{LA} / total\ time_{LA}$. All downtimes must be identified in days. The LA timeline for the Titan IV system begins with initial processing in the Vertical Integration Building (VIB) and ends with initiation of R-count.

Launch Dependability is the measure of degree to which the launch vehicle is operable and capable of performing its mission profile within a predetermined LD timeline. It is measured as $LD = 1 - downtime_{LD} / total\ time_{LD}$. All downtimes must be identified in days. The LD timeline for the Titan IV system begins with initiation of R-count through actual launch.

Launch Reliability is the measure of degree to which the launch vehicle is operable and capable of performing its mission profile within the LR timeline. The LR timeline is different than the previous measurements in that it is not measured in days. For all systems, LR is measured from launch commit through payload separation. It is measured as LR = 1 - mission failures/total missions. Launch Reliability is the probability that once the vehicle is launched, it will successfully complete its mission. Reliability deficiencies include catastrophic failure, guidance set failures, or any other non-payload related reason for mission failure. This is calculated as the proportion of launches without a critical failure (DAF, 1994).

Only failures that are attributable to the specific launch contractor (or applicable DOD) processing are considered. For days of delay, the failures do not inlcude payload or weather related delays. Mission failures caused by payload or weather are similarly excluded from consideration. Though these causes of failures (whether delay or mission failure) are researched for possible improvement, they are not considered in requirements reporting for the launch contractors.

These definitions prescribe the LA and LD measurements as percentages of number of days without a delay to the total number of days in the respective timeline. The intent is to track efficient operation in the launch processing timeline. The purpose of measuring the downtimes links back to the importance of measuring the costs involved with days of delay in the launch processing sequence. The purpose of measuring LR links back to the obvious importance of mission success and the costs associated with mission failure. These cost are transferred to the government according to the guidelines of the Cost-Plus, Award-Fee type contract and the Total System Performance Responsibility clause (to be presented in the following two sections in this chapter; and discussed in depth under the findings under Propositions 2 and 3, respectively, in Chapter IV, **Findings**.

Procurement Methods

Government contracting is an arena filled with many unique problems and pitfalls. The USAF purchases major weapon systems, to include the medium and heavylift launch systems, within this playing field and its associated limitations. A key Government person in any Government procurement is the Contracting Officer, who determines how to conduct the procurement. The procurement may be either competitive or non-competitive. Competitive contracts are preferred due to the increased competition decreasing the price for the Government. Under the Federal Acquisition Regulation (FAR), "full and open competition" is required unless waived for several enumerated justifications (Arnavas, 1994:2.16-2.18).

After the method of procurement has been determined, the contract type must be chosen. There are basically two categories of contract types: the Firm-Fixed-Price contract and the Cost-Reimbursement contract. There are many variables that affect the decision of which type of contract, and variations thereof, to choose (Arnavas, 1994:2.19-2.20). A list of the variations of the Firm-Fixed-Price and the Cost-Reimbursement contracts are included in **Appendix C.**

The Firm-Fixed Price contract provides that the Government pay a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. This type of contract places maximum risk of and full responsibility for resulting profit or loss upon the contractor. It also provides maximum incentive for the contractor to control costs, and imposes a minimum administrative burden on the government. Due to the cost control incentives provided, it is the preferred method of contracting, particularly when requirements and processes are well-defined (Arnavas, 1994:2.19-2.20).

The Cost-Reimbursement type contract provides that the Government pay the contractor all allowable costs incurred in the performance of the contract, to the extent prescribed in the contract. This type of contract establishes an estimate of total cost for the purpose of obligation of funds. It establishes a ceiling which the contract may not exceed (except at his own risk) without prior approval or subsequent ratification of the contracting officers (Arnavas, 1994:2.19-2.20).

The USAF medium and heavylift launch contracts are Cost-Plus-Award-Fee contracts. While Fixed-Price contracts would normally be preferred, cost-reimbursement methods are used due to the complex nature of the launch contracts. The Award-Fee variation is used to provide an incentive to the contractor to perform efficiently (keep costs low) and allow for government input to ensure effective processing.

Liabilities / Warranties Process

While the CPAF procurement method described above provides incentives to the contractors to perform according to DOD expectations, this method does not entirely alleviate the DOD's risk of mission failure. According to DOD specifications, the contractor is obligated to deliver a successful and cost effective launch mission. The Federal Acquisition Regulation (FAR) succinctly sets forth the DOD's general policy regarding the contractor's obligation to comply with specifications: the DOD is entitled to strict compliance with the contract's requirements (USG, 1998:46.102). This point begs the question of what recourse the DOD has if a successful launch mission is *not* delivered (such as a catastrophic failure on lift-off)?

An implied warranty is an integral part of this issue. The DOD defines a warranty in the Glossary: Defense Acquisition Acronyms and Terms as "a promise or affirmation given by a contractor to the Government regarding the nature, usefulness, or condition of the supplies or performance of services furnished under a contract" (Glossary, 1998).

The specific type of warranty utilized in the USAF medium and heavylift launch contracts is "Total System Performance Responsibility" (TSPR). This clause holds the contractor responsible and liable to deliver a successful launch. Discussion of the TSPR clause, and its associated shortcomings applicable to medium and heavylift launch contracts, is contained in Chapter IV, **Findings**.

Reliability Management Comparisons

Reliability and system effectiveness measurements from other space programs are presented in this section. The intent is to exhibit similar measurements that may be considered to improve USAF launch reliability measurement.

All of the major USAF space acquisition programs (primarily launch vehicles and satellites) are managed at the Space and Missiles System Center (SMC) at

Los Angeles Air Force Base. Reliability measurements across most DOD programs are best articulated in the Sustainment Executive Management Report (SEMR), a SAF/AQ-directed review of various sustainment indicators (Sustainment, 1998). The primary indicators of system readiness and performance are defined in Table 2 on the following page. The measurements/indicators from the Launch SPO are included (which does not include the launch reliability measurements discussed at length later in this effort). A brief discussion addresses similarities and differences between launch programs and the various satellite measurements.

Many of these space measurements involve tailored definitions of mean time between failure. The Launch Programs' measurements, described subsequently, are similar, differing mainly on the point of definition of failure.

Summary

As mentioned later in this research effort, differences exist between launch programs and other typical programs. These differences are exemplified if the previous explanation of space programs' reliability measurements. For example, many of the satellite programs consider mission duration of the satellite which is not comparable to launch programs. Similarities do exist, however. Various definitions of availability and mean time between failures can be compared to measurements of launch programs.

Table 2. Definitions of Selected Reliability Measurements of Space Programs (Sustainment: 1998)

Military Satellite Communications (MILSATCOM) System

Operational Availability (Ao) is the probability that a system is operational and ready to perform its intended mission at any given time within its operational environment. It includes scheduled and unscheduled downtimes. A_o is calculated as the Mean Time Between Downing Events (MTBDE) divided by the MTBDE and the Mean Time To Restore System (MTTRS).

MILSTAR Control Segment Operational Dependability (Do) is the measure of the degree to which a system is operable and capable of initiating a mission at an unknown (random) time, given the system is available to start the mission. D_o measures both inherent Reliability & Maintainability (R&M) parameters and logistics support effectiveness that relates to mission time only.

MILSTAR Control Segment Mean Time Between Critical Failure (MTBCF) is the average time between critical failures for the Constellation Control System (CCS). MTBCF is calculated as the total number of operating hours divided by the total number of critical failures.

MILSTAR Control Segment Mean Time to Repair (MTTR) is the average on-equipment organizational level corrective maintenance time required to return a system to operational status after a critical failure. MTTR is calculated as the Total on-equipment repair time in hours divided by the total number of critical failures.

Satellite Support (Mission Control Element Mission) Effectiveness is the control of the MILSTAR constellation (Threshold Requirement). The MCE is calculated as the Success Rate of Total Supports minus Lost and/or Failed Supports divided by the Total Supports.

Defense Satellite Communication System (DSCS)

Operational Availability (A_o) is its readiness to perform its intended mission at any given time within its operational environment. DSCS A_o is based on available channels on it primary satellites.

Launch Readiness is the availability of a Satellite to be launched within a specific time frame. Rating based on how long it will currently take to launch a DSCS satellite from a given order.

Air Force Satellite Communications (AFSATCOM) System

Operational Availability (A_o) (Single Channel Transponder System (SCTS) is its readiness to perform its intended mission at any given time within its operational environment. SCTS A_o is based on availability of the SHF up-link and SHF down-link pathways of the SCT payload on the primary DSCS III spacecraft.

Operational Availability (A_o) (Polar AFSATCOM) is defined as the availability of a System and its readiness to perform its intended mission at any given time within its operational environment. Polar AFSATCOM A_o is based on the proper phasing of sufficient payloads in Molniya orbits to provide coverage.

Mean Mission Duration (MMD) (SCTS) is the performance of payload based on an expected average life of 68 months. MMD is calculated as the total months of service provided by payloads now failed divided by the number of failed payloads.

Defense Meteorological Satellite Program (DMSP)

Operational Availability (A_o)is the percentage of time that DMSP has two operational satellites on-orbit supplying primary sensor data to customers. Constellation Availability is calculated as the time meeting on-orbit mission requirements divided by the Cumulative on-orbit time and then multiplied by 100.

Launch Readiness is the measure of preparedness to launch on demand in number of days to support a launch. Less than or equal to 90 days. Launch Readiness is a subjective calculation based on the number of days required to support a launch.

III. Methodology

Introduction

The methodologies described in this chapter reveal the data necessary to reach the given objectives. Three different methods were used to satisfy the objectives, as presented through the investigative questions, propositions, and recommendations. Applicable documents (program and contractual documents, sustainment reports, performance reports, regulations, etc) were reviewed and key representatives (in **Appendix G - Key Representatives**) were interviewed (by telephone, e-mail, or personal visit) to meet the final objectives. The data were used to understand the processes and shortcomings associated with launch mission reliability measurement and develop recommended improvements.

Investigative Questions

Investigative Question 1. What are the factors that influence the definition and application of launch mission reliability measurements?

A literature review was performed to determine the factors that influence the definitions and application of launch mission reliability measurements. Interviews with USAF and contractor representatives also revealed information that led to the results described in Chapter IV, **Findings**.

Investigative Question 2. What is the method of procurement of USAF medium and heavylift launch programs and how does it impact the reliability measurement system?

The method of procurement was determined from program office documents and personal interviews. A qualitative analysis of the various types of procurement methods was performed primarily through the literature review of government and industry contracting guides and standards. Economic implications of the space launch market characteristics were considered. The number of customers and suppliers, the DOD portion of the market, and specific legal limitations, all impact procurement decisions. These characteristics are discussed accordingly.

Investigative Question 3. What techniques does the USAF employ to ensure mission success / reliability?

The technique(s) the USAF employs to ensure mission success / reliability were again determined from program office documents (Single Acquisition Management Plan (SAMP)) and personal interviews (with USAF program officials). Analysis was performed by conducting a literature review of government contracting information and other systems' applications.

Investigative Question 4. What are the current measurements for mission reliability and what are the contractual requirements?

Program documents were reviewed to determine current reliability measurements and requirements. The primary sources for this information (applicable to individual systems) are program Operational Requirements Documents (ORDs), Concepts of Operations (CONOPs), and Payload Interface Control Documents (ICDs). The research findings were verified with program managers within the Launch Program SPO (SMC/CLL) and Headquarters Space Command (HQ AFSPC/LGML).

Investigative Question 5. How does the USAF track the measurement?

The specific procedure that the USAF uses to track the reliability measurements was explored. The probable candidates for ownership of the process, according to USAF standards, were SPO or HQ AFSPC personnel. Accordingly, direct communication (telephone calls, electronic mail messages, etc) was made to obtain the specific process methods. Contractor personnel were similarly queried to determine if reliability data was indeed requested by USAF personnel and specifically by whom.

Investigative Question 6. How do the USAF medium and heavylift launch programs compare to a) each other and other launch programs according to performance, and b) each other and other launch programs according to cost?

Comparisons were performed of USAF medium and heavylift launch programs to each other and to other launch programs, according to performance and cost, to search for possible opportunities of improvement. Extensive comparative efforts were not known to previously exist. Accordingly, it was deemed necessary to search for specific comparative processes and owners of the processes. Literature reviews and interviews were used to determine if comparative analyses existed and to collect the data necessary to perform comparative analyses if not. If processes did indeed exist, an analysis of the processes was performed. If not, various comparisons were constructed and analyzed accordingly. The comparisons and analyses simply constituted highlighting specific cost and performance characteristics, noting top level considerations that may contribute to differences.

a) each other and other launch programs according to performance

According to the analyses within the USAF medium and heavylift launch vehicles (that did not exist and correspondingly had to be developed), performance data (number of days of delay and success rates) were averaged over the specified number of years. The results were analyzed to determine if any top level differences existed between the corresponding performance characteristic (management responsibility, payload capacity, etc.)

Additionally, performance comparisons were discovered to already exist through the literature review. Actual comparisons were found through program documents (Aerospace Failure Analysis Study) and the Launch Programs SPO homepage.

b) each other and other launch programs according to cost

A literature review was the method used to determine the cost comparison between USAF medium and heavylift space launch systems and other launch systems. A chart was discovered on the internet and is displayed within the findings under Investigative Question 6 in Chapter IV, **Findings**.

Through the presentation and discussion of these comparisons, the scope of specific problems within the USAF medium and heavylift launch programs could be put into perspective. If mission and cost performance were favorable compared to other programs, the overall impact of the problems were diminished. If, on the other hand, mission and cost performance for USAF medium and heavylift launch programs were significantly lower than other programs, the impact of the problems were highlighted. For programs with significantly better mission and cost performance parameters, the specific reasons for better performance were sought. Furthermore, correlations between characteristics and significantly lower performance lead to suggested possible areas of future research. These areas for improvement opportunity must be carefully scrutinized for applicability to USAF medium and heavylift launch programs.

Propositions

The methodology for each proposition differs according to the type of data sought. The specific methods for each proposition are discussed below.

Proposition 1	Intrinsic characteristics of spacelift launch missions (launch market, new technology, unique missions, lack of historical data, legal limitations) contribute to the difficulty in quantitatively defining launch mission reliability requirements.

Proposition 1 is the evolved research objective from Investigative Question 1. According to the methodology described for Investigative Question 1, literature reviews and interviews were used to determine the primary factors that influence launch mission reliability measurement. The results of these efforts are listed in Chapter IV, **Findings**, according to each specific factor. The various factors are discussed according to the applicable information: economic implications, comparative analyses, contractual and legal implications, program documents, GAO reports, etc. The results of this discussion are also listed in Chapter IV, **Findings**.

Proposition 2	The method of procurement significantly contributes to the difficulty in quantitatively defining launch mission reliability requirements.

Similar to Investigative Question 2, the method of procurement was determined by previous personal work experience, personal interviews, and program applicable documents (primarily the SAMP.) Analysis of the various types of DOD procurement methods was performed through the literature review of government contracting guides (the Federal Acquisition Regulation, Acquisition Reform policies, etc.) The different methods of procurement were analyzed individually and application to launch programs was considered.

Through literature review and research into the new USAF launch program procurement, Evolved Expendable Launch Vehicle (EELV), other procurement "techniques" were identified. These techniques are discussed through similar methods and discussed in Chapter IV, **Findings**.

Proposition 3	The liability clause employed, Total System Performance Responsibility, contributes to the difficulty in quantitatively defining launch mission reliability requirements.

Proposition 3 is a culmination of Investigative Questions 1 and 3. Proposition 3 affects the USAF's reliability management and is a specific tool used to ensure mission success. Information concerning the liability clause, TSPR, was investigated according to applicable DOD documents (SAMP, AFMC Acquisition Guide) and literature review. A qualitative analysis of TSPR is presented and discussed in Chapter IV, **Findings**. The purpose and benefits of implementing the TSPR clause in the contracts are presented. Specific limitations are also included and discussed in depth.

Proposition 4	The primary mission reliability requirement does not accurately measure program performance (definition, cost measurement, etc).

Proposition 4 is an overarching objective that encompasses Investigative Questions 3 through 7. Specifically, it is a direct translation of Investigative Question 5, but concerns the other Investigative Questions as well.

The accuracy and validity of the primary mission reliability requirement, Launch Effectiveness, was analyzed according to program documents (AFR 57-9), applicable contractual requirements (as described in the ORD, Payload ICDs, etc), and cost data. A literature review was conducted to determine the definitions concerning the measurements.

The definition of Launch Effectiveness and its components were thus determined. Launch Effectiveness is the product of three separate components (as described in Chapter II, **Literature Review**). The *components* of Launch Effectiveness hold equal weight within the overall measurement but not in actual performance and cost impact. The definitions of the individual measurements and the different definitions of failures corresponding to the measurements were related to cost and shown not to be consistent.

The information used to report reliability measurement was collected from personnel within the Launch Programs SPO and the corresponding prime contractor of the launch system. Cost data was matched to the performance data for the Titan IV program. This launch vehicle was the only one considered in this analysis (among the four USAF medium and heavylift launch programs) primarily because the Titan IV system is the most mature system concerning data collection corresponding to the reliability measurements.

Summary

The determination of the adequacy of the reliability measurements is an integral part of this entire research effort. Comprehensive coverage of these conclusions was again verified with program managers within the Launch Program SPO and Headquarters Space Command. According to the methodologies described in this chapter, information was gathered and presented concerning the background of the problems associated with quantifiably defining launch reliability requirements. Several specific issues are discussed in depth. Improvements are suggested and discussed in Chapter V, **Recommendations and Conclusions**. Opportunities are also presented and discussed that, through future research and management attention, could lead to better reliability requirements definitions in upcoming system procurements.

IV. Findings

Within this chapter, the findings of the specific methodologies, traced to the corresponding Investigative Question or Proposition, are presented. The results of the Investigative Questions are discussed first. The Investigative Questions are generally more direct in nature than the Propositions. As such, a more concise response is presented in most cases. The Propositions, on the other hand, are the research objectives of the thesis effort, derived from the Investigative Questions, and generally require more in depth discussion and analysis.

Investigative Questions

IQ 1. What are the factors that influence the definition and application of launch mission reliability?

The literature review of USAF medium and heavylift launch systems to determine the factors that influence launch mission reliability measurements extended into a myriad of sources. The sources include, but were not limited to: USAF program officials and documents, the respective contractor personnel and information, market information, etc. Key topics were searched according to internet sources, GAO reports, periodicals, and more.

Several subject areas were found that influence reliability management. Though more characteristics undoubtedly exist, the following list of factors seemed to have a particular impact:

a) the launch vehicles' economic market,

b) the aging technology of USAF medium and heavylift launch systems,

c) the unique missions characterized by specific payload and requirements,

d) a lack of centralized management, and

e) the legal and/or contractual environment.

These particular factors are presented again and analyzed under Proposition 1 findings.

IQ 2. What is the method of procurement of USAF medium and heavylift launch programs?

The method of procurement of USAF medium and heavylift launch systems was determined by looking at program office documents, specifically the SAMP. The procurement method used by the Launch Programs SPO is the Cost Plus Award Fee (CPAF) contract. The CPAF contract was discussed in Chapter II, **Literature Review**. The implications to USAF medium and heavylift reliability management of the contract type decision and the economic setting are discussed in depth under Proposition 2.

IQ 3. What techniques does the USAF employ to ensure mission success / reliability?

Literature review of program contractual documents revealed a specific tool the USAF uses to ensure mission success / reliability. This tool is the implementation of the Total System Performance Responsibility (TSPR) clause. TSPR is a DOD contracting technique that places the liability of mission failure on the contractor, thus encouraging the contractor to complete a mission successfully. The implications of and limitations caused by the TSPR clause are discussed fully under Proposition 3.

IQ 4. What are the current measurements for mission reliability and what are the contractual requirements?

Through research into several USAF launch program documents (as described in the methodology discussion in Chapter III), the current mission reliability measurements and contractual requirements were determined. The primary measurement is Launch Effectiveness, which is the product of three components, Launch Availability, Launch Dependability, and Launch Reliability. The definitions of each of these measurements are presented in Chapter II, the **Literature Review**. Discussion concerning the validity and applicability of the measurements is discussed under Proposition 4 findings.

The performance requirements for the Titan IV program for each of the measurements are taken from the TIV draft ORD and are as follows:

Measurement	Requirement	
LE	.84	
LA	.90	
LD	.95	
LR	.96	(TIV ORD, 1994)

IQ 5. How does the USAF track the measurement?

A literature review was performed (with the SAMP, CONOPs, etc.) and personal interviews were conducted (with Launch Programs SPO and Headquarters Air Force Space Command officials) in an attempt to discover the process by which the USAF uses to track reliability requirements/measurement. Though the measurements are defined and the requirements are presented in various documents, it appears the USAF does not analyze the data closely nor base decision-making off the information (Pausz, 1998), (Adams, 1998). The performance data relating to the Launch Effectiveness measurement is collected exclusively by the prime contractor for the Titan IV program (White, 1998). This information is used by the SPO primarily though a sustainment report called the Sustainment Executive Management Report (SEMR) (Pausz, 1998). Though this report is delivered to upper level management (HQ AFMC, SAF/AQ) and seen throughout the chain of command (each launch vehicle program manager, the System Program Director, SMC/CC, HQ AFSPC/LG), very little action is taken corresponding to the information provided (Pausz, 1998).

This lack of a valid tracking process presumably results from the lack of valid reliability measurements. This lack of valid measurements obviously limits the *usefulness* of the measurement. It is exacerbated by the ambiguity of ownership responsibility, resulting primarily from the mentality of "the contractor being responsible for a successful launch mission".

IQ 6. How do the USAF medium and heavylift launch programs compare to a) each other and other launch programs according to performance, and b) each other and other launch programs according to cost?

Despite an extensive literature review, few comparative efforts associated with USAF medium and heavylift launch vehicles were found to exist. Both the

Launch SPO and HQ AFSPC/DOOL collected performance data. Unique requirements between specific launch missions (even on the same launch vehicle) preclude a formal comparative process that in turn limits managerial actions (as described in depth under Proposition 1 findings.) Ambiguity and complexity of launch vehicles' comparisons were driven by 1) the small and/or significantly different number of launches (sample size) between different launch vehicles and 2) differences between performance requirements (payload weight, intended orbit. etc.)

In the following section, several different formats of comparative analyses are presented. Some of these comparisons were constructed by the author of this thesis while other comparisons were extracted from analyses already performed. The overall intent is to present a comprehensive coverage of the different comparisons and the different formats.

a) Comparison of USAF medium and heavylift launch programs between each other and other launch programs according to performance.

The number of days of delays were compared according to the performance reports obtained from HQ AFSPC/DOOL. Table 3 presents the means and the variances of the given characteristics according to launch.

Table 3. Launch Vehicles' Comparisons

Atlas vs Delta		
Atlas	Mean	19.55556
	Variance	3016.616
Delta	Mean	18.65217
	Variance	1811.476

Atlas vs Titan IV		
Atlas	Mean	19.55556
	Variance	3016.616
Titan IV	Mean	93.27778
	Variance	31653.39

East vs West		
East	Mean	31.97778
	Variance	8946.247
West	Mean	36.61538
	Variance	3876.726

Commercial vs DOD		
Commercial	Mean	49.6383
	Variance	16915.19
DOD	Mean	22.42593
	Variance	1475.343

Commercial vs NASA		
Commercial	Mean	49.6383
	Variance	16915.19
NASA	Mean	19.06667
	Variance	1093.924

DOD vs NASA		
DOD	Mean	22.42593
	Variance	1475.343
NASA	Mean	19.06667
	Variance	1093.924

Notes:

1.) Titan II was not analyzed due to its small number of launches compared to the other launch vehicles (only 4 launches).

2.) Titan IV is not as easily comparable to the other three boosters since it is the only heavylift program.

Further analysis could be performed which may present more usable results. The large variances must be addressed to determine if significant differences exist (specifically address outliers.) A possible explanation of the large variance is the difference between missions, even on the same launch vehicle, as discussed in Proposition 1 findings. Again, part of the intent of the comparative analyses is to present a methodology format and highlight potential problem areas for future management attention.

Further comparisons were performed according to the a number of delays according to launch vehicle and launch site, and manufacturing contractor, presented in Table 4, USAF Launch Vehicle Comparison Overview.

Table 4. USAF Launch Vehicle Comparison Overview (Performance, 1998)

Booster/Site	Avg Delays	# of Launches
Atlas/EAST:	21.93	42
Atlas/WEST:	17.00	6
Delta/EAST:	16.05	37
Delta/WEST:	29.33	9
Titan II/WEST:	64.75	4
Titan IV/EAST:	114.67	12
Titan IV/WEST:	46.71	7

Contractor	Avg Delays	# of Launches
LMA	42.33	70
MDA	18.65	46

Customer	Avg Delays	# of Launches
DOD	22.43	54
NASA	19.07	15
Commercial	49.64	47

Notes:

1.) "EAST" is East Coast (Cape Canaveral Air Station). "WEST" is West Coast (Vandenberg AFB).

2.) "LMA" is Lockheed Martin Astronautics (Atlas, Titan II, and Titan IV). "MDA" is McDonnell Douglas (Delta).

Figure 4 on the following page compares Air Force to non-Air Force (Commercial and NASA) success rates. The USAF has performed significantly better than the "Non-AF" launch vehicles. However, analyzing comparisons with specific launch vehicles shows a somewhat different picture, discussed next.

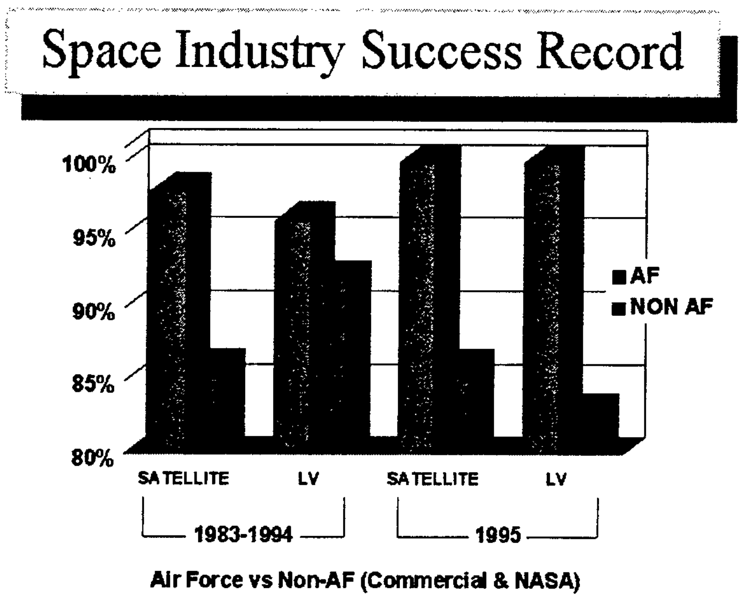


Figure 4. USAF Medium and Heavylift Launch Performance Comparison (CL Launch, 1998)

More in depth comparison tables, from 1983 to 1996, from *the Aerospace Executive Failure Analysis Report, 1997,* are included in the appendices. The tables in the appendices compare USAF launch vehicles as follows:

1) to success rate of each other (Appendix D),

2) to success rate of World launch vehicles (Appendix E),

Of particular note is the larger number of launches and higher success rate of Russia compared to the US: 1011 launches for Russia vs 300 for the US; 96.4% success rate for Russia vs 93.7% for the US, respectively (Chang, 1997).

b) Comparison of USAF medium and heavylift launch programs between each other and other launch programs according to cost.

A cost comparison of planned and existing space launch systems is shown in Table 5. It can be seen that several manufacturers have an absolute advantage in cost over the USAF medium and heavylift launch systems (discussed immediately following the table).

Table 5. Summary of Launch Costs (Pioneer, 1998)

Launch System	Company	Payload to LEO (lbs)	Price (Millions)	Price (per lb)	Status
Scout	LTV	460	$12.0	$26,100	Obsolete
MSLS	LMA	800	$5.0	$6,250	Limited**
Pegasus	OSC	900	$13.0	$14,400	Operational
LLV 1	LMA	1,200	$15.0	$12,500	Operational
K-1	Kistler	2,000	$7.0	$3,500	Planned
Pathfinder	Pioneer	2,200	$4.5	$2,045	Planned
Pathfinder	Pioneer	2,920	$4.5	$1,541	Planned
ROTON	HMX	?	?	?	Planned
Taurus	OSC	3,000	$23.0	$7,666	Operational
Titan II	Lockheed Martin	4,200	$27.0	$6,428	Operational
Eclipse	Kelly	4,250	?	?	Planned
Med-Lite	MDA	5,000	$36.0	$7,200	Planned
Delta 7920	MDA	10,000	$58.0	$5,800	Operational
Long March 3	GW/China	11,000	$33.0	$3,000	Operational
Soyuz	Korolev/Russia	15,000	$30.0* ($65.0)	$2,000	Operational
Ariane 44L	CNES/France	16,900	$110.0	$6,508	Operational
Atlas 2AS	LMA	17,000	$90.0	$5,300	Operational
Sea Launch	Boeing	22,000	$77.0	$3,500	Planned
Ariane 5	CNES/France	26,400	$130.0	$4,924	Operational
Titan IV	LMA	35,000	$160.0	$4,570	Operational
Proton	LKE/Russia	35,000	$70.0* ($149.0)	$2,000	Operational
Shuttle	NASA	40,000	$500.0	$12,500	Operational

The purpose of presenting this table, besides comparing significantly different performance levels between systems and looking for possible improvement areas, is to provide a reference for information according to numerous other launch programs. Several notable results from this comparison come to light.

The Russian and Chinese rockets are significantly less expensive than the comparable USAF medium and heavylift launch vehicles:

a) Delta costs $5,800 per pound versus:

- Long March 3 (China) costs $3,000 per pound
- Soyuz (Russia) costs $2,000 per pound

b) Atlas costs $5,300 per pound versus

- Soyuz (Russia) costs $2,000 per pound
- Sea Launch (Boeing) costs $3,500 per pound

c) Titan IV costs $4,570 per pound versus

- Proton (Russia) costs $2,000 per pound

(Consideration must be specifically addressed due to the many variables when analyzing these cost differences: weight *to particular orbit* (low earth versus geosynchronous), whether the customer pays for *payload capability or actual weight* of payload, etc.)

The lower cost of these foreign launch services attracts US commercial payload customers. This further exacerbates the limited launch market discussed in the Proposition 1 findings. This migration also has national security implications: US customers using foreign services led to the controversial technology transfer incident that occurred when a US satellite company (Intelsat) lost a satellite because of a Chinese launch vehicle failure (Stein, 1996).

Propositions

Proposition 1	Intrinsic characteristics of spacelift launch missions (launch market, new technology, unique missions, lack of historical data, legal limitations) contribute to the difficulty in quantitatively defining launch mission reliability requirements.

Launch Market

"The military DOD space program and the commercial space program are inextricably entwined. We all must become more competitive because our commercial program is just as vital to the strategic importance of this nation as is our military" (James, 1993:1) General Charles Horner, former Commander of U.S. Space Command (USPACECOM), thus emphasizes the link between the military and the commercial space program.

One point within the link between DOD and the commercial sector that relates to specific USAF launch requirements is that the potential market for future launches is limited. A 1994 Commercial Space Transportation Advisory Committee report estimated that only about 17 commercial payloads per year will be available from 1993-2010. Reasons for the small and decreasing market include a) the relative early development stage of space travel, b) the extremely high cost of (payload) market entry and operation, and c) better payloads are continually increasing mission performance (e.g., satellites have increased capabilities, are longer-lasting, etc.) (GAO, 1994). The implication of this market trend relates directly to the DOD concern of whether to initiate a new spacelift program, continue with current launch program missions, or completely outsource DOD spacelift requirements. The method of procurement will determine how the USAF will set its requirements, which in turn will determine the required amount of USAF visibility into the launch process (contractual liability, Commercial-Off-the-Shelf (COTS) practices, or USAF ownership).

Aging Technology

The current launch programs within the U.S. are all relatively old systems (average system age is 20 years, with various modifications and follow-on contracts from previous procurements.) Serious shortcomings in launch programs within the United States have been identified corresponding to outdated technology and degraded mission performance (from factors such as corrosion) (GAO, 1994). This limitation will influence the decision of procurement (new procurement, follow-on contracts, relying on a commercial market.)

Unique Missions

Though the basic configuration of boosters within a specific launch system remains the same, each launch mission is an individual production with performance parameters specific to the mission (due to specific payload interfaces, thrust and orbital requirements, etc.) These mission-specific parameters are thus determined by the specific payload to be transported and orbit required. Specific mission requirements preclude the USAF's ability to define 100% standard requirements.

Though many requirements cannot be completely standardized, booster-related processing is similar enough to attribute standard processing requirements. The inherent complexity, the long schedules, and significant variations in processing each mission, however, often result in over-burdened government management and oversight resulting in a profound lack of adequate process visibility, which is an underlying issue within this report.

Lack of Centralized Management

The problems associated with mission-specific parameters and processes previously noted somewhat preclude DOD opportunities for standardization and achieving economies of scale. This point directly relates to the finding of a 1994 GAO report of a "serious lack of central management" within DOD launch programs. Though this paper addresses USAF launch systems specifically, the Department of Defense has other launch system management spread throughout many organizations, to include the Air Force, Army, Navy, Ballistic Missile Defense Organization, Advanced Research Projects Agency, and National Reconnaissance Office. A GAO report states that this point results in 1) fragmented responsibilities; 2) duplicate facilities, staffs, and infrastructures, 3) deficiencies in achieving economies of scale; and 4) less effective forces because several organizations are developing space hardware that are not interoperable, thus complicating joint military operations (GAO, 1994). Such diverse management responsibility and associated inefficiencies leads to a lack of a solid, single mission statement and performance requirements.

Legal/Contractual Environment

The legal and contractual constraints imposed upon the USAF launch programs dictate many specific processes and result in otherwise inefficient operations. Besides the matters previously mentioned relating to direct DOD procurement, political constraints exist that preclude the DOD from realizing opportunities from procuring (or outsourcing) launch services from foreign suppliers. The government is constrained by political regulations to buy launch services only from within the United States (USC, 1998:25.102). This constraint allows U.S. launch contractors to operate at possibly higher prices than the market would otherwise have dictated. This constraint thus forces the USAF to remain in the already-discussed limited U.S market and prevents the USAF from purchasing launch services from a possibly cheaper launch source.

The price quoted for the Soyuz and Proton is the price for which the Russian organizations have said they would be willing to sell them. However, US law forbids the marketing of Russian vehicles for U.S. launches for any price less than 93% of the price of comparable US launch vehicles. Therefore, for U.S. customers, the cost of a Soyuz would be about $65 million (93% the cost of an Atlas), while the Proton would be about $149 million (93% the cost of a Titan IV) (Pioneer, 1998).

Environmental issues significantly drive up the costs of launch vehicles. These issues contribute to the purpose of standard, quantifiable requirements: to keep costs low. Besides the impact on cost, specific environmental laws may influence the contractor's processing of the launch vehicle.

The geographic locations of the two USAF launch sites are heavily environmentally regulated. The two USAF launch sites are located on the East and West coasts of the United States to minimize the environmental/safety impact of launching over heavily populated areas and to achieve more efficient trajectories. However, the environmental impacts of launching near U.S. coastal regions are heavily regulated. Vandenberg AFB, CA, for example, is located in Santa Barbara County, which is one of the most environmentally regulated counties in the United States. The fact that various other countries may not regulate the environmental impacts so heavily would drive down their costs significantly which, in turn, contributes to the commercial demand to seek foreign services. U.S. commercial customers using foreign launch services decrease the demand of U.S. launch services, which indirectly causes the DOD to pay higher prices.

Proposition 2	The method of procurement significantly contributes to the difficulty in quantitatively defining launch mission reliability requirements.

The argument against outsourcing launch services is a direct consequence of the vested interest the DOD has in developing specific contracts with the launch suppliers. The government maintains a majority (60%) of the U.S. launch services market (GAO, 1994). Under the theory of monopsonies, the U.S.

government has a significant influence on the launch suppliers. Consequently, this point lends strength to the argument that the USAF should continue contracting with suppliers directly rather than just buying specific launch missions from commercial sources.

Recall that the exorbitant cost of new development is a serious constraint on effective management of spacelift systems. The USAF's acquisition strategy for launch vehicles is inextricably tied to the commercial market. One U.S. space launch contractor noted that the potential commercial market is too small to recoup an investment in a new launch vehicle in a reasonable period. (GAO, 1994).

Consequently, the limited number of suppliers diminishes the USAF's influence on the market and also has a significant impact on the future of DOD launch procurements. The current oligopolistic market, reflective of the few suppliers, strengthens the suppliers' influence on DOD launch procurements. Concurrent with current DOD acquisition strategy, the DOD often will award contracts with the intent of keeping defense contractors as viable launch supply sources in order to reduce singular contractor's powers, correspondingly strengthening the DOD's position, and significantly reducing costs (USC, 1998:6.302.3). Within the United States, only 2 or 3 reasonable sources of launch capability exist (primarily Lockheed Martin and Boeing-McDonnell Douglas Astronautics).

The supply-side economic theory maintains that attention to long-term economic growth is more important than short-term manipulation of demand. Economic growth requires an expansion in the productive capacity of society. It thus increases the overall supply of goods and services and holds down prices through competition. Inflation is reduced. The nation's standard of living is improved with the availability of more goods and service at stable prices (Dye, 1998:221).

From this broad, macroeconomic view, the United States Air Force has a policy of encouraging competition. "Ever since the enactment of the Competition in Contracting Act of 1984 (CICA), "full and open competition" has become the byword of all Government procurement" (Arnavas, 1994:2.16). Furthermore, if a monopolistic or even oligopolistic market exists (one or few suppliers), the DOD, concurrent with DOD acquisition strategy, will award contracts with the intent of keeping defense contractors as viable sources of supply. This practice reduces singular contractor's negotiating powers, correspondingly strengthening the DOD's position, and significantly reduces prices (USC, 1998:6.302.3).

In 1994, the DOD developed a space launch modernization plan (the Moorman study) that led to the Evolved Expendable Launch Vehicle (EELV) program. The DOD's initial acquisition strategy was to select one contractor for final development and production. However, in November of 1997, DOD approved a revised acquisition approach designed to award the contract to each of two prime defense contractors. This strategy would maintain competition for final development and production (GAO, 1998:1-2).

The perceived benefits of awarding multiple contracts concern the previously discussed strategy to maintain multiple sources of supply and the consequential lower prices. Considering the large costs involved and the uncertainty of realizing these savings, the argument not to award both of these contracts is strong indeed. The USAF cost share of the development efforts is $1 billion: $500 million to each contractor (GAO, 1998:1-2).

Furthermore, another government financial concern that necessitates strong insight is the point that the current USAF medium and heavylift launch program contracts are "Cost-Plus, Award Fee (CPAF)", as described in Chapter II. The "cost-plus" portion of the contract term indicates that the government will reimburse the prime contractor for all costs plus a predetermined profit margin:

> A cost-plus-award-fee contract is a cost-reimbursement contract that provides for a fee consisting of (a) a base amount (which may be zero) fixed at inception of the contract and (b) an award amount, based upon a judgmental evaluation by the Government, sufficient to provide motivation for excellence in contract performance. (USC, 1998:16-305).

The "award fee" portion provides a further incentive to the contractor to successfully complete a mission. It thus becomes necessary for the government to measure not just mission performance, but also contractor processes, in terms of cost-savings and reliability. The inherent contractor control of launch processing contributes to lack of centralized management and closely related to the subsequent discussion of Total System Performance Responsibility (TSPR).

Proposition 3	The liability clause employed, Total System Performance Responsibility, contributes to the difficulty in quantitatively defining launch mission reliability requirements.

Besides the specific implications associated with the methods of procurement, specific wording within the actual contracts significantly constrain the USAF's influence in launch processing, creates serious inefficiencies, and causes the need to develop viable means to overcome associated negative effects. The DOD is required to use warranties in the acquisition of weapon systems (Title 10 U.S.C. §2403). According to the defense contractor's responsibility to deliver a launch capability, they are financially liable for the mission's success. This brings to light the importance of the USAF having strong insight into the contractor's process, since the contractor is financially liable for a mission failure. The contractor is held accountable for a failure through the legal tool "Total System Performance Responsibility (TSPR)".

> Although making TSPR a contract requirement is not new, it is highlighted because TSPR will be used with increased frequency as the means to divest government program offices from system integration responsibilities. Simultaneously, its implementation provides industry not only increased latitude in the design process for implementing system level solutions aimed at long-term sustainment, but provides clear accountability in design (CAID). Under TSPR, the government continues to control system functional requirements while industry controls design/product requirements. Thus, the contractor is fully responsible for the integration of all systems, subsystems, components, government furnished property (GFP), contractor furnished equipment (CFE),

> and support equipment and must ensure no performance degradation after integration. Expected benefits from including TSPR as an element of the acquisition strategy include decreased product to user time, reduced costs and data, reduced SPO manpower, fewer engineering change orders/ECPs, and increased product quality. (AFMC Guide, 1998)

While TSPR inarguably incentivizes a contractor to complete the mission successfully, the DOD is not removed from financial risk of a mission failure. Besides the inherent risk of mission impact on DOD interests, the massive cost of mission failure is too great for the contractor to handle alone. A small number (or even one) of mission failures could bankrupt even the financially powerful defense contractors involved. A mission failure (presumably the loss of the launch vehicle, payload, and associated costs) could realistically bankrupt even a company as large as LMA or MDA or preclude their efforts to deliver a successful service. (The exorbitant cost of a mission failure is demonstrated by the cost of launching the Cassini program, at approximately $500 million for the Titan IV vehicle alone, not including the Cassini program itself) (GAO, 1995).

As a result, TSPR limits the contractor's liability to a predetermined dollar amount with the remaining (vast majority) cost being allocated to the government. The bankruptcy of a contractor is an unacceptable risk due to the corresponding loss of launch capability and future launch business competition.

Another shortcoming caused by the TSPR clause is that it effectively limits the USAF's authority to influence launch processing. According to specific wording within the standard TSPR clause, any effect the USAF has on negatively affecting the contractor's launch processing capability that may be linked to mission failure will release the contractor from liability. The courts have interpreted the ambiguity in these words quite liberally over the years. USAF executive management is extremely leery of imposing USAF influence on specific processing when questioned by the contractor (AFMC Guide, 1998).

Proposition 4	The primary mission reliability requirement does not accurately measure program performance (definition, cost measurement, etc).

Cost-savings opportunities in a contractor's processing of a launch mission is no trivial matter, considering the scope of the mission and the vast amount of dollars involved. The government's insight into the contractor's process results in the need to measure the probability of mission success and efficient operations.

Measurement Discussion

The magnitude of the importance of measuring efficient operations is exemplified by the exorbitant cost of singular days of delay in the launch processes and schedule. These avoidable costs due to delays and possible slips in schedules primarily result from wasted labor costs from contractors' and DOD's "standing armies" and possible delays in other launch vehicles' schedules (as a result of missed "windows of launch" predicated by weather, orbital requirements, and range-related factors.) The distinction between measuring mission success and efficient operations will be more clearly visible in the reliability measurements to be discussed next.

Launch Effectiveness

The singular most quantifiable measurement of mission success and efficient operations across the four USAF medium and heavylift launch vehicles is the Launch Effectiveness requirement. Launch Effectiveness will be defined subsequently according to current program documentation, contractual requirements with sources will be listed, and shortcoming will be expounded. To simplify discussion, only the Titan IV program will be considered. The other systems have similar requirements though exact definitions differ slightly according to timeline delineation and source documents. The definitions and inherent shortcomings, however, are similar enough in intent to preclude inclusion.

Following the general discussion of reliability measurement presented in Chapter II, **Literature Review**, the importance of "establishing unambiguous and observable description of failures" is now addressed. Failures measured in the primary mission reliability measurement for USAF medium and heavylift launch programs include days of delay and complete mission failures (failure to reach the intended orbit). These two factors, days of delay and mission failures, are measured due to the associated significant cost impact to the USAF.

A critical problem with these measurements is woven into the specific definitions. The definitions prescribe measuring downtime in days. Due to the contractual implications, it becomes critical to provide a precise definition of a "a day of downtime". Though at first glimpse the definition of a day of downtime seems trivial, several questions arise. Is it an "8 AM to 4 PM question" (probably not since most processing are not directly linked to daily schedules)? Should the impact of the downtime be considered ("no harm done" vs a team of 4 technicians having to wait two days to start their assigned responsibility vs equipment impact)? Does the downtime affect a launch window and consequently other vehicle's launch parameters? The costs associated with delays vary significantly and are made even more important due to the fact that it measures performance contractually.

Another vital discrepancy within the overall Launch Effectiveness is that the three components (LA, LR, LD) are all given equal weight in reaching the LE product. The structure of the given formula would imply that the components have equal impact on the program (cost and otherwise). Though costs would have to be matched to each, this is logically not the case at all. Launch Availability and Launch Reliability measure days of delay whereas Launch Dependability measures actual mission success and failure. This is basically equating the cost of delay to the cost of mission failure. The cost of a failure is vastly greater than the cost of a day of delay.

V. Recommendations and Conclusions

Introduction

The reliability issues facing the USAF medium and heavylift launch programs have been demonstrated up to this point in the paper as indeed being critical and requiring management close scrutiny. The future environment (to include the evolving space era, downsizing efforts, acquisition reform, cost savings focus, etc.) necessitates immediate and lasting change. Avoidable inefficiencies that preclude effective mission reliability management definitely exist and must be addressed.

Within this chapter, current (immediate) and over-arching problems are highlighted. Corresponding suggested resolutions/improvements are presented. Areas for possible research and opportunities for future improvement are included.

Some characteristics of the launch world seem to be primarily inherent vices, merely the nature of the business. Evolving technology indeed requires specific problems to be resolved but the improvements obviously outweigh the disadvantages. TSPR is another good example of an inherent vice. Though the problems associated with TSPR mentioned in Chapter IV, **Findings**, are indeed serious, an obvious necessity exists to provide both an incentive for mission reliability and financial protection for the launch contractor. TSPR may be the best tool the USAF has at the present time. Thus, there may be no immediate resolution, but this research is a first step toward advancing improvement efforts and a better tool may eventually be developed.

Recommendations for Improvement

Proposition 1	Intrinsic characteristics of spacelift launch missions (launch market, new technology, unique missions, lack of historical data, legal limitations) contribute to the difficulty in quantitatively defining launch mission reliability requirements.

Responsibility to resolve problems inherent to launch programs must be addressed and specifically assigned. Similar to the "lack of central management" problem, too many parties are involved without specific responsibility which has evidently lead to social loafing - assumption of responsibility being assigned to another party. The System Program Director (SPD, having ultimate responsibility of USAF management of a system), should assign a member of the SPO to lead an Integrated Product Team (IPT). This IPT could consist of perhaps the using command, the operational users, the prime contractors, and any other necessary manpower resources available. Their specific responsibility could be to resolve such problems as developing consistent definitions, standardizing source documents, tracking associated cost data, etc.

One of the main characteristic of launch programs that contributes to the difficulty in quantitatively defining mission reliability requirements is the noted lack of central management. Within the 1994 GAO report, several ideas were presented on how to better manage space launch acquisition programs:

a) U.S Space Command approach to place acquisition responsibility within the Air Force.

b) U.S. Space Command approach to place acquisition responsibility within the AirForce, but through joint program offices.

c) Navy suggestion to create a space system procurement executive office within the Office of Secretary of Defense (OSD), supported by each service.

d) An Air Force suggestion was to create a space corps within the Air Force to separately acquire and operate space systems.

e) OSD alternative being considered to create a defense space agency to acquire and manage space systems. (GAO, 1994)

I perceive the best option to be option (d): to manage space systems within the Air Force by a specific space corps. The Air Force is the logical service in which to entrust space systems management due to the overwhelming majority of space systems within the DOD managed by the Air Force and the expertise associated with that management over the years. A space corps should be developed *separately* due to the significant differences involved between space and the aircraft world (and other DOD systems like communications, electronics, munitions, etc, for that matter). Though Air Force Specialty Codes (AFSCs) distinguish space operations and maintenance from aircraft operations and maintenance, an Air Force acquisition manager moves between a variety of space and aircraft acquisition jobs independent of whether it is space or aircraft. This movement significantly decreases the manager's space-related expertise, continuity, and effectiveness. Retaining space acquisition managers within the space arena will undoubtedly build effective management. Crossflow into space acquisitions management from other space fields (like maintenance and operations), could further increase effective management.

Another inherent characteristic specific to launch systems that could be changed is the federal policy to purchase weapon systems only from within the United States. While certain characteristics exist that seem "too inherent" to solve by managerial decision-making, this limitation results from national policy and could feasibly be changed by legal proceedings. Perhaps efforts to render launch procurements as exceptions to this rule should be considered due to the limited size of the U.S. launch market and the cost savings that could be realized.

Data according to the defined reliability measurements and corresponding timelines, as well as the cost impact of delays and mission failure, must be collected and tracked. Formal data collection and tracking procedures must be implemented in all current and future DOD launch programs. Comparisons with other launch systems must be continually tracked to realize any opportunities that may present themselves.

Legal limitations (such as environmental and procurement regulations) are definitely currently addressed. However, environmental (and procurement, safety, etc) regulations are constantly changing. Opportunities for reliability/efficiency improvement must be constantly monitored. Likewise, technology continues to emerge that may provide further opportunities for reliability/efficiency improvement.

General responsibilities for launch programs' management is described in the Program Management Directive. The SPD must be proactive when considering responsibility assignment not specifically addressed.

Proposition 2	The method of procurement significantly contributes to the difficulty in quantitatively defining launch mission reliability requirements.

The specific procurement decision must be continuously addressed. New techniques (such as the "other transaction" acquisition technique currently being implemented in the EELV contract) must be researched (GAO, 1998). The technique to use Award Fee is a strong incentive for the contractor to perform according to the USAF's expectations. Award fee tracking procedures are currently being performed by the SPO. Attention must be given to ensure effective and quantitative management of performance according to Award Fee tracking.

Proposition 3	The liability clause employed, Total System Performance Responsibility, contributes to the difficulty in quantitatively defining launch mission reliability requirements.

Similar to the recommendations described for Proposition 2, the contract clause of TSPR must continuously addressed. Innovative and evolving contracting techniques must be continuously explored. TSPR may currently be the best tool that management has to incentivize the contractor towards performance, but limitations exist that necessitate improvement.

Proposition 4	The primary mission reliability requirement does not accurately measure program performance (definition, cost measurement, etc).

The Launch Effectiveness performance and efficiency measures, as previously mentioned, contain serious inadequacies that must be resolved to make the measurement effective. As such, there are three main recommendations for specific measurement improvement:

1) The definition of a "day of delay" must be quantified.

2) The cost impact of a day of delay and total mission failure must be accurately determined.

3) The Launch Reliability component should be weighted within the LE measurement to increase the corresponding increased impact of a mission failure over the cost of a day of delay. The weighting factor should be mathematically determined, perhaps with an exponent factor for the LR component.

Considering historical performance as it relates to individual components measurement, the relative weight of LR could be increased by using a [1/k] factor as an exponent for LA and LD. Similarly, including a [k] factor as an exponent for LR would also increase its relative weight. The decision between the two factors must be matched to attainable performance.

Suppose the average cost of a day of delay is $200,000 and the cost of a mission failure is approximately $200,000,000. The ratio is thus 1 to 1000. The cost of a mission failure (as represented in the LR component) is 1000 times that of a day of delay (as represented in the LA and LD components). The equation for Launch Effectiveness should thus be changed to $LE = LA^{1/1000} \times LD^{1/1000} \times LR$ to increase the relative importance of the LR component. This ratio between LR and LA and LD could be changed with each mission. An average weighting factor could be implemented or specific data according to each mission could be tracked. This example greatly changes the current measurement. A k factor could be arbitrarily chosen by management to reflect less weight to the LR factor (since the contractor is already greatly incentivized to deliver a successful mission).

As industrial globalization increases and barriers with foreign governments decrease (Russia, China, etc.), more insight into their management practices may be possible. Considering the lower costs and better performance from specifically Russian launch programs, Russian management practices may be applied which could improve U.S. launch performance and lower costs. It is important to consider the differences which may preclude a straight comparison and adapting practices, however: environmental and safety regulations, different requirements (turn around time - Launch Rate Throughput, intended orbit - Launch Accuracy, etc.)

Conclusion

The problems associated with spacelift launch programs are indeed serious. Many reasons to overlook issues facing spacelift launch, attributing them to the "nature of the business", can be cited. "Launch is not like the aircraft world," "The USAF is not ultimately responsible - we have bought a service from the contractor," etc. While these points may be valid, they are not acceptable excuses for poor management. The Air Force manager must work diligently to overcome these hurdles, research the topic to fully understand, and be aware of opportunities to help resolve specific issues.

Appendix A - Acronyms

The following list of acronyms is used throughout this research effort and provide the reader a quick reference:

AFMC	Air Force Materiel Command
AFSC	Air Force Specialty Code
AFSPC	Air Force Space Command
CAID	Computer Aided Interface Design
CCAS	Cape Canaveral Air Station, Florida
CFE	Contractor Furnished Equipment
CLNL	Acquisition Logistics Office within Systems Engineering Division, Launch Programs SPO
COTS	Commercial off the Shelf – supplies bought from the commercial sector with no specific government design specifications
CPAF	Cost Plus, Award Fee - DOD contract type that implies government coverage of contractor costs, plus fixed profit, plus award fee amount based on government's subjective satisfaction with performance of contract
ECP	Engineering Change Proposal
EELV	Evolved Expendable Launch Vehicle
FAR	Federal Acquisition Regulation
GAO	Government Accounting Office
GFP	Government Furnished Property

LA	Launch Availability
LD	Launch Dependability
LE	Launch Effectiveness
LGML	Spacelift Hardware office within Logistics Group at HQ AFSPC
LMA	Lockheed Martin Astronautics
LMI	Logistics Management Institute
LR	Launch Reliability
LRT	Launch Rate Throughput
MDA	McDonnell Douglas Astronautics
MLV	EELV Logistics Division
OSD	Office of the Secretary of Defense
SMC /CL	Space and Missile Systems Center, Launch Programs, at Los Angeles Air Force Base, California
SPD	System Program Director – manager responsible for DOD weapon system acquisition and management
SPO	System Program Office
TII	Titan II
TIV	Titan IV
TSPR	Total System Performance Responsibility
VAFB	Vandenberg, Air Force Base, California
VIB	Vertical Integration Building

Appendix B - Definitions

The following definitions are taken from the Glossary: Defense Acquisition Acronyms And Terms, 8th edition (last revised: 05/06/98):

Acquisition: The conceptualization, initiation, design, development, test, contracting, production, deployment, logistic support (LS), modification, and disposal of weapons and other systems, supplies, or services (including construction) to satisfy DOD needs, intended for use in or in support of military missions.

Acquisition Reform: An ongoing series of initiatives sponsored by OSD (especially USD(A&T) and DUSD(AR)) to streamline and tailor the acquisition process. Initiatives include statutory and regulatory reform, CAIV, reform of specifications and standards policy, preference for commercial items, electronic data interchange and the use of the IPPD/IPT management philosophy for systems development and oversight.

Availability: A measure of the degree to which an item is in an operable and committable state at the start of a mission when the mission is called for at an unknown (random) point in time.

Avoidable Delay: Any time during an assigned work period which is within the control of the worker and which he/she uses for idling or for doing things unnecessary to the performance of the operation. Such time does not include allowance for personal requirements, fatigue, and unavoidable delays.

Buy-American Act: Provides that the U.S. government generally give preference to domestic end products. (Title 10 U.S.C. § 41 A-D). This preference is accorded during the price evaluation process by applying punitive evaluation factors to most foreign products. Subsequently modified (relaxed) by Culver-Nunn Amendment (1977) and other 1979 trade agreements for dealing with North Atlantic Treaty Organization (NATO) allies.

Centralized Management: The concept of using a single, designated management authority. It includes system management, program/project management, and product management.

Contractor Logistics Support (CLS): The performance of maintenance and/or material management functions for a DOD system by a commercial activity. Historically done on an interim basis until systems support could be transitioned to a DOD organic capability. Current policy now allows for the provision of system support by contractors on a long-term basis. Also called Long-Term Contractor Logistics Support.

Effectiveness: The extent to which the goals of the system are attained, or the degree to which a system can be elected to achieve a set of specific mission requirements.

Failure: The event in which any part of an item does not perform as required by its performance specification.

Federal Acquisition Regulation (FAR): The regulation for use by federal executive agencies for acquisition of supplies and services with appropriated funds. The FAR is supplemented by the Military Departments and by DOD. The DOD supplement is called the DFARS (Defense FAR Supplement).

General Accounting Office (GAO): An agency of the Legislative Branch, responsible solely to the Congress, which functions to audit all negotiated government office contracts and investigate all matters relating to the receipt, disbursement, and application of public funds. Determines whether public funds are expended in accordance with appropriations.

Implementing Command: The command responsible for the acquisition and/or modification of the system (USAF).

Incentive (incentivize): Motivating the contractor in calculable monetary terms to turn out a product that meets significantly advanced performance goals, to improve on the contract schedule up to and including final delivery, to substantially reduce costs of the work, or to complete the project under a weighted combination of some or all of these objectives.

Inherent Availability: Availability of a system with respect only to operating time and corrective maintenance. It ignores standby and delay times associated with preventive maintenance as well as administrative and logistics down time.

Integrated Product Team (IPT): Team composed of representatives from all appropriate functional disciplines working together to build successful programs, identify and resolve issues, and make sound and timely recommendations to facilitate decision making . . . may include representatives from both government and after contract award industry.

Maintainability: The ability of an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair. (See Mean Time To Repair (MTTR).)

Mean Time Between Failures (MTBF): For a particular interval, the total functional life of a population of an item divided by the total number of failures within the population. The definition holds for time, rounds, miles, events, or other measures of life unit. A basic technical measure of reliability.

Mean Time To Repair (MTTR): The total elapsed time (clock hours) for corrective maintenance divided by the total number of corrective maintenance actions during a given period of time. A basic technical measure of maintainability.

Operational Availability: The degree (expressed in terms of 1.0 or 100 percent as the highest) to which one can expect an equipment or weapon systems to work properly when it is required. The equation is uptime over uptime plus downtime, expressed as Ao. It is the quantitative link between readiness objectives and supportability.

Operational Requirements: User-or user representative-generated validated needs developed to address mission area deficiencies, evolving threats, emerging technologies or weapon system cost improvements. Operational requirements form the foundation for weapon system unique specifications and contract requirements.

Operational Requirements Document (ORD): Documents the users objectives and minimum acceptable requirements for operational performance of a proposed concept or system. Format is contained in Appendix II, DOD 5000.2-R.

Prime Contractor: The entity with whom an agent of the United States entered into a prime contract for the purposes of obtaining supplies, materials, equipment, or services of any kind.

Procurement: Act of buying goods and services for the government.

Program Management Directive (PMD): The official Headquarters (HQ) U.S. Air Force document used to direct acquisition responsibilities to the appropriate Air Force major commands, agencies, program executive offices (PEOs), or designated acquisition commander. All Air Force acquisition programs require PMDs.

Risk: A measure of the inability to achieve program objectives within defined cost and schedule constraints. Risk is associated with all aspects of the program, e.g., threat, technology, design processes, Work breakdown structure (WBS) elements, etc. It has two components:

1) The probability of failing to achieve a particular outcome; and
2) The consequences of failing to achieve that outcome.

Standardization: The process by which DOD achieves the closest practicable cooperation among forces; the most efficient use of research, development, and production resources; and agreement to adopt on the broadest possible basis the use of common or compatible operational, administrative, and logistics procedures and criteria; common or compatible technical procedures and criteria; common or compatible, or interchangeable supplies, components, weapons, or equipment; and common or compatible tactical doctrine with corresponding organizational compatibility.

System Program Office (SPO): The office of the program manager (PM) and the single point of contact (POC) with industry, government agencies, and other activities participating in the system acquisition process. (AF)

Total Asset Visibility (TAV): The ability to gather information at any time about the quantity, location, and condition of assets anywhere in the DOD logistics system.

User: An operational command or agency that receives or will receive benefit from the acquired system. Commanders-in-Chief (CINCs) and the Services are the users. There may be more than one user for a system. The Services are seen as users for systems required to organize, equip, and train forces for the CINCs of the unified command.

Appendix C - Variations of Contracts

Firm Fixed Price Contracts

Firm Fixed Price (FFP): Provides for a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. This type of contract places upon the contractor maximum risk and full responsibility for all costs and resulting profit or loss. Provides maximum incentive for the contractor to control costs, and imposes a minimum administrative burden on the government.

Fixed Price With Economic Price Adjustment (FPEPA): This fixed-price contract provides for upward or downward revision of the stated contract price based upon contingencies specified in the contract. Adjustments may reflect increases/decreases in actual costs of labor or material, or in specific indices of labor or material costs.

Fixed Price Incentive (FPI): This fixed-price contract includes an incentive whereby the contractor's profit is increased or decreased by a pre-determined share of an overrun or underrun. A firm target is established from which to later compute the overrun or underrun. A ceiling price is set as the maximum amount the government will pay. Necessary elements for this type of contract are: target cost - best estimate of expected cost; target profit - fair profit at target cost; share ratio(s) - to adjust profit after actual costs are documented; and, ceiling price - limit the government will pay.

Cost-Reimbursement Contracts

Cost-Sharing: This cost-reimbursement contract provides that the Government and the contractor share the burden of the costs. This type is used when benefits may accrue to both parties (such as a research and development effort).

Cost-Plus-Fixed Fee (CPFF): This cost-reimbursement contract includes a fixed fee to be paid to the contractor. The fixed fee once negotiated does not vary with actual cost, but may be adjusted as result of any subsequent changes in the scope of work or services to be performed under the contract.

Cost-Plus-Incentive-Fee (CPIF): This cost-reimbursement contract includes a provision for a fee which is adjusted by formula in accordance with the relationship which total allowable costs bear to target costs. The provision for increase or decrease in the fee, depending upon allowable costs of contract performance, is designed as an incentive to the contractor to increase the efficiency of performance.

Cost-Plus-Award-Fee: This cost-reimbursement contract includes an "award fee" to be paid to the contractor. This award fee is at the discretion of the Government, a subjective evaluation of the quality of the contractor's performance. It provides an incentive to the contractor to perform to government expectations (in most cases, to minimize costs).

(Glossary,1998)

Appendix D - USAF Launch Vehicles Comparison to Success Rates of Each Other

	STS		Titan		Atlas		Delta		Taurus		Conestoga		LMLV		Pegasus		Scout		U.S. Total		
year	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	year
1983	4	0	3	0	6	0	8	0									1	0	22	0	1983
1984	5	0	7	0	4	1	4	0									1	0	21	1	1984
1985	9	0	1	1	5	0	0	0									2	0	17	1	1985
1986	1	1	0	1	3	0	1	1									1	0	6	3	1986
1987	0	0	3	0	2	1	2	0									1	0	8	1	1987
1988	2	0	2	1	2	0	1	0									4	0	11	1	1988
1989	5	0	4	0	1	0	8	0									0	0	18	0	1989
1990	6	0	4	1	3	0	11	0							1	0	1	0	26	1	1990
1991	6	0	2	0	3	1	5	0							0	1	1	0	17	2	1991
1992	8	0	3	0	4	1	11	0							0	0	2	0	28	1	1992
1993	7	0	1	1	5	1	7	0							2	0	1	0	23	2	1993
1994	7	0	5	0	7	0	3	0	1	0					2	1	1	0	26	1	1994
1995	7	0	4	0	12	0	2	1	0	0	0	1	0	1	1	1			26	4	1995
1996	7	0	4	0	7	0	10	0	0	0	0	0	0	0	4	1			32	1	1996
Total	74	1	43	5	64	5	73	2	1	0	0	1	0	1	10	4	16	0	281	19	Total
succ rate	98.7 %		89.6 %		92.8 %		97.3 %		100.0 %		0.0 %		0.0 %		71.4 %		100.0 %		93.7 %		succ rate

Appendix E - USAF Launch Vehicles Comparison to Success Rates of World Launch Vehicles

	U.S.		CIS/USSR		Europe		Japan		China		India		Israel		Total		
year	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	succ	fail	year
1983	22	0	97	3	2	0	3	0	1	0	1	0			126	3	1983
1984	21	1	97	1	4	0	3	0	2	1	0	0			127	3	1984
1985	17	1	97	2	3	1	2	0	1	0	0	0			120	4	1985
1986	6	3	91	3	2	1	2	0	2	0	0	0			103	7	1986
1987	8	1	95	3	2	0	3	0	2	0	0	1			110	5	1987
1988	11	1	90	5	7	0	2	0	4	0	0	1	1	0	115	7	1988
1989	18	0	74	1	7	0	2	0	0	0	0	0	0	0	101	1	1989
1990	26	1	74	5	5	1	3	0	5	0	0	0	1	0	114	7	1990
1991	17	2	59	2	8	0	2	0	0	1	0	0	0	0	86	5	1991
1992	28	1	53	2	7	0	1	0	3	1	1	0	0	0	93	4	1992
1993	23	2	46	2	7	0	1	0	1	0	0	1	0	0	78	5	1993
1994	26	1	48	1	6	2	2	0	5	0	2	0	0	0	89	4	1994
1995	26	4	31	2	11	0	1	1	2	1	0	0	1	0	72	8	1995
1996	32	1	23	4	10	1	1	0	2	2	1	0	0	0	69	8	1996
Total	281	19	975	36	81	6	28	1	30	6	5	3	3	0	1,403	71	Total
succ rate	93.7 %		96.4 %		93.1 %		96.6 %		83.3 %		62.5 %		100.0 %		95.2 %		succ rate

Appendix F - Sample Interview Format

These interviews were conducted by telephone and/or electronic-mail. The information used in the research effort is cited accordingly. A list of key representatives is presented in Appendix F.

Interviewee: ______________________________
Office: ______________________________
Address (phone, e-mail): ______________________________
Position: ______________________________

What are the current reliability requirements for the USAF medium and heavy spacelift vehicles and where are they prescribed?

Are the current requirements (specifically Launch Availability, Launch Dependability, Launch Reliability, Launch Effectiveness) are adequate? Why or why not?

What efforts currently exist to improve reliability measurements?

This research effort is intended to look at the current reliability status and consider opportunities for improvement. Accordingly, do you have any personal ideas for areas of improvement or research?

Please describe the Total System Performance process. Do you feel it is effective? What are any specific limitations?

Please describe the Cost-Plus-Award-Fee contract. Do you feel it is the best means to achieve DOD objectives? What are any specific limitations?

Appendix G- Key Representatives

Organization	Point of Contact / Address (phone, e-mail)	Position / Remarks
* SMC/CL DSN 833-1860	Col Jeffery Norton Launch Systems SPO JefferyNorton@losangeles.afb.af.mil	System Program Director
* SMC/CLNL DSN 833-1860	Tony Pausz,GS-13 Launch Systems SPO tpausz@losangeles.afb.af.mil	Acquisition Logistics manager
SMC/CLK DSN 833-1860	Launch Systems SPO -------------@losangeles.afb.af.mil	Contracting Office
* SMC/MVL DSN 833-1110	Capt James Gordon EELV System Program Office jgordon@losangeles.afb.af.mil	Acquisition Logistics manager
HQ AFSPC/LGML DSN 692-xxxx	Spacelift Hardware Headquarters, AFSPC	Logistics manager
* HQ AFSPC/DOOL DSN 692-xxxx	Capt Tim Adam Headquarters, AFSPC "tadam@spacecom.af.mil"	Operations manager
* HQ AFMC/DR DSN 256-3930	Tom Showers, GS-13	Space Programs lead, Materiel Command
5 SLS	Delta Spacelift Maintenance	
USAF/ILS	Lt Col Terry Faulk Headquarters, USAF	Space logistics lead
LMI	Mr. Bob Hemm	
* LMA	Mr. Norm White Mr. James Purkey	TIV Logistics Lead, CCAS TIV Logistics Lead, VAFB

* Indicates that a representative was consulted within this thesis effort.

Bibliography

Adams, Timothy. Telephone Interview. Operations Manager, Headquarters Air Force Space Command, Peterson AFB CA, 17 March 1998.

"AFMC Guide to Acquisition Reform/Acquisition Strategy/Major Changes to the Process." n.pag. WWWeb, http://www.afmc.wpafb.af.mil/HQ-AFMC/DR/dri-home/acqref/aqustrat/aqstrat.htm. 5 June 1998.

Arnavas, Donald P. and William J. Rubbery. Government Contracting Guidebook, 2nd Ed. Washington DC: Federal Publications Inc, 1994.

Blanchard, Benjamin S. and others. Maintainability: A Key to Effective Serviceability and Maintenance Management. New York: John Wiley and Sons, Inc., 1995.

Boezer, Gordon, Ivars Gutmanis, and Joseph E. Muckerman II. "The Defense Technology and Industrial Base: Key Component of National Power," Parameters: US Army War College Quarterly, Vol. XXVII, No. 2: 26-51 (Summer 1997).

Chang, I-Shih. Failure Study for Space Launch Vehicles (1983-1996). Contract F04701-93-C-0094. El Segundo CA: Aerospace Corporation, May 1997 (TOR-97 (8504)-3).

"CL Launch Success Rate." n.pag. WWWeb, http://www.laafb.af.mil/SMC/CL/ success.htm. June 1998.

Department of the Air Force (DAF). Launch Readiness and Sustainment, draft. AFR 57-9. Washington: HQ USAF, 1994.

Dye, Thomas R. Understanding Public Policy (Ninth Edition). New Jersey: Prentice Hall, 1998.

Ebeling, Charles E. Reliability and Maintainability Engineering. New York: McGraw Hill Companies, Inc., 1997.

"Glossary: Defense Acquisition Acronyms and Terms" (eighth edition). n. pag WWWeb, http://www.dsmc.dsm.mil/pubs/glossary/append_b.htm. May 1997.

Government Accounting Office (GAO). Estimated Launch Costs for NASA's Mission to Saturn. Report NSIAD-95-141BR. Washington: GPO, 5/8/95. n. pag WWWeb, http://www.gpo.ucop.edu/cgi-bin/gp.../diskb/wais/data/gao/ns95141b.txt.

----. Evolved Expendable Launch Vehicle: DOD Guidance Needed to Protect Government's Interest. Report NSIAD-98-151. Washington: GPO, 11 June 1998.

----. National Space Issues: Observations on Defense Space Programs and Activities. Report NSIAD-94-253. Washington: GPO, 16 August 1994. n. pag WWWeb, http://www.gpo.ucop.edu/cgi-bin/gp.../diskb/wais/data/gao/ns94253.txt.

James, Larry D. DOD Space Systems – Reducing the Cost. Air War College, Maxwell AFB AL, 1993.

Pausz, Antone. Telephone Interview. Acquisition Logistics Manager, Titan Lead, Launch Programs System Program Office, Los Angeles AFB CA, 18 March 1998.

"Pioneer Rocketplane." n.pag. WWWeb, http://www.rocketplane.com/index.html. May 1998.

"SAMP Guidelines." paragraph g, Support Strategy. Defense Acquisition Deskbook, May 1998.

Stein, Keith. "Intelsat Launch Failure: Chinese Booster Explodes After Lift-off." n. pag. WWWeb. http://newproducts.jpl.nasa.gov/calander/intelsat708.html. 15 February 1996.

"Sustainment Executive Management Report, draft". Headquarters AFMC/DR. Wright-Patterson AFB OH, 1998.

"Titan explosion update." Air Force News Release, n. pag. WWWeb, http://www.pafb.af.mil/photo.htm. 12 August 1998.

"Titan IV Operational Requirements Document, draft". Launch Systems System Program Office, Space and Missile Systems Center, Los Angeles AFB, CA. 1994.

United States Congress (USC). Federal Acquisition Regulation. Washington: Government Printing Office, 1998.

White, Norman. Telephone Interview. Titan IV Logistics/Operations Lead, Lockheed Martin Astronautics, Cape Canaveral Air Station FL, 19 March 1998.

Widnall, Sheila and Ronald Fogleman. "Global Engagement: A Vision for the 21st Century Air Force," n.pag. WWWeb, http://www.xp.hq.af.mil/xpx/21/airs.htm. May 1998.

Vita

Captain Arthur R. Dawkins was born on [redacted]. He graduated from Salado High School in Salado, Texas in May 1987. He entered undergraduate studies at the United States Air Force Academy, Colorado in June 1987 where he graduated with a Bachelor of Science degree and a Regular Commission in May 1991.

His first assignment was at Columbus AFB as a student in Undergraduate Pilot Training in September 1991. In April 1992, he was assigned to the 351st Missile Wing, Whiteman AFB, Missouri, where he served as a missile maintenance officer. In June 1994, he was assigned to the Launch Programs System Program Office at the Space and Missile Systems Center, Los Angeles AFB, California, where he served as an acquisition logistics officer. In May 1997, he entered the Graduate Logistics Management program, School of Logistics and Acquisition Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the 576th Test Squadron, Vandenberg AFB, California.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1998	**Master's Thesis**

4. TITLE AND SUBTITLE

ANALYSIS OF USAF MEDIUM AND HEAVYLIFT SPACE LAUNCH MISSION RELIABILITY REQUIREMENTS

5. FUNDING NUMBERS

6. AUTHOR(S)

Arthur R. Dawkins

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

Air Force Institute of Technology
2950 P Street
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GLM/LAL/98S-4

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

SMC/CLL
Los Angeles AFB, CA

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 Words)***

The launch services that the USAF procures to carry DOD payloads into orbit are characterized by high risks and high costs. If a launch vehicle experiences a catastrophic failure, the cost of the entire launch vehicle, the launch processing, and the payload are completely lost (often in excess of 1.5 billion dollars.) Despite this enormous risk for the payload customer, and indeed the launch provider, launch success rates around the world are not much above 90 percent.

The current USAF medium and heavylift launch systems are often based on technology that is 20 years old and older. Furthermore, little historical data exists because of the complex technologies used and the unique nature of individual missions. As such, reliability management is limited and faces serious shortcomings.

This research investigates the various shortcomings associated with mission reliability measurement and management. Through literature review, case study analyses and interviews, the shortcomings are determined and analyzed.

The results of this thesis effort demonstrate these shortcomings. Recommendations are presented for immediate improvement to selected shortcomings and suggestions are made for future research.

14. Subject Terms	15. NUMBER OF PAGES
Launch Vehicles; Spacecraft; Reliability; Availability	**89**
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	**UNCLASSIFIED**	**UNCLASSIFIED**	**UL**

AFIT Control Number AFIT/GLM/LAL/98S-4

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