AFIT/GLM/LSQ/92S-27

REVIEW OF FACTORS IMPACTING WARRANTY COST-BENEFIT ANALYSIS FOR THE SENSOR FUZED WEAPON SYSTEM

THESIS

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FOR THE SENSOR FUZED WEAPON SYSTEM

THESIS

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Master of Science in Logistics Management

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Preface

The primary purpose of this research effort was to identify factors that affect the warranty cost-benefit analysis (CBA) for the Sensor Fuzed Weapon (SFW) System because a waiver to the essential performance requirement (EPR) warranty was under consideration. The study began with an investigation of the history of several dormant weapon systems similar to the SFW and concluded by comparing similarities in the nature of the systems and the cost-effectiveness analyses performed for the warranties.

This study could not have been completed without the assistance and insight of my thesis advisors. Dr. Ben Williams and Mr. Carroll Widenhouse, both with extensive experience in reliability and maintainability, helped in developing a structure for this research effort. Next, I would like to express my appreciation to Major Michael Urban and Mr. Edward Muller, of the Sensor Fuzed Weapon and Airfield Attack System Program Office at Eglin AFB, for sharing their knowledge and experience with me.

Donna E. Kehrt

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Abstract

The purpose of this research effort was to identify factors that affect the warranty cost-benefit analysis (CBA) for the Sensor Fuzed Weapon (SFW) System since an essential performance requirement (EPR) warranty waiver was under consideration. Defense funding has become scarce, and the limited dollars must be spent wisely. A CBA should provide a relevant projection of cost-effectiveness based on the best available data. The SFW and other dormant systems present difficulties in determining cost-effectiveness because the systems most probably will be non-operating, non-reusable, and non-restorable. Three recommendations were made, relevant to dormant weapon systems, that pert ined to further cost analysis and review of overall warranty effectiveness. The SFW's EPR warranty will become effective in 1996. In the meantime, the program manager can examine more closely the feasibility of the EPR warranty and the warranty in total.

REVIEW OF FACTORS IMPACTING
WARRANTY COST-BENEFIT ANALYSIS
FOR THE SENSOR FUZED WEAPON SYSTEM

I. Introduction

General Issue

Public law mandates the use of warranties for DOD weapon systems acquisition (22:1). Exceptions to complying with the law are the warranty is not cost-effective, or the warranty was not in the best interest of national defense; and a waiver to the public law should be requested for the exceptions. The General Accounting Office (GAO), the DOD Inspector General, and RAND Corporation represent a sample of the organizations that have expressed concerns regarding the validity of weapon system warranty (WSW) cost-benefit analyses (CBAs). Without an adequate CBA, the warranty purchase decision cannot be made with confidence.

Background

Title 10, Section 2403, of the United States Code mandates the use of warranties for acquisition of DOD weapon systems with a unit cost of more than $100,000 or total procurement cost in excess of $10 million. In 1983 Congress passed the law to require manufacturers to provide weapon system warranties. Three types of warranties are required: design and manufacturing, materials and workmanship, and performance specifications. Congressional interest in warranties remains high due to the media visibility that occurs when the government procures a system that does not work effectively. The warranty requirement was intended to prevent these procurement "horror stories". Recently, however, review organizations have questioned whether some warranties should have been purchased. The GAO issued a report stating the government spends hundreds of millions of dollars every year on warranties and questions whether they were all cost-effective (23:3).

Problem Statement and Research Objective

The specific problem was to: 1) analyze the unique attributes of the Sensor Fuzed Weapon (SFW) System's performance requirements to determine how they impact the cost-effectiveness and future desirability of a warranty, and 2) review SFW and other dormant system CBAs to determine if a general methodology can be developed to improve future cost benefit analysis efforts.

Investigative Questions

Two investigative questions were developed to answer the research objective. First, what system attributes make the SFW different from the typical warranted system, and how do these attributes impact the warranty effectiveness? Second, are cost analyses for dormant systems similar, and would it be possible to develop a general CBA methodology?

Definitions

The following terms used throughout the document are defined below. The definitions for EPR and WSW come from AFR 70-11, Acquisition Management: Weapon System Warranties (11:1-2):

1. Cost-Benefit Analysis (CBA): An analytical procedure to compare the cost of the warranty to the potential benefits derived from the purchase of a warranty.

2. Essential Performance Requirement (EPR): Measurable, verifiable, trackable, and enforceable operating capabilities and/or maintenance and reliability characteristics of a weapon system that are determined necessary for the system to fulfill the military requirement for which the system is designed.

3. Sensor Fuzed Weapon (SFW) System: A munition system in the form of a cluster bomb unit.

4. Weapon System Warranty (WSW): A promise or affirmation given by the contractor to the government regarding the nature, usefulness, or condition of the supplies or performance of services furnished under the contract.

Scope and Limitations

The research was limited to the SFW and similar dormant Air Force weapon systems. The analysis performed may be applicable to other systems in the Air Force as well as other Defense Agencies.

Summary

The investigative questions are interrelated for the following reason. The warranted performance requirements should be selected based on operational performance requirements for which compliance cannot be determined with certainty prior to or during acceptance testing (11:4). The cost-benefit analysis, therefore, must provide a relevant projection of the future based on the stated performance requirements.

This chapter reviewed the general issue, presented background, stated the problem and research objective, stated the investigative questions, provided definitions, and the scope and limitations of the topic. Chapter two reviews the literature on warranties, chapter three describes the methodology, chapter four describes the findings, and chapter five presents the conclusions drawn from the findings.

II. Literature Review

Introduction

Topic Statement and Brief Explanation of Key Terms. The purpose of this chapter was to examine literature on weapon system warranty (WSW) cost-benefit analyses (CBAs) for the Department of Defense (DOD) and to review EPR warranties and system redundancy as they relate to the SFW system. The Defense Federal Acquisition Regulation Supplement (DFARS) and Air Force regulations require a CBA be performed prior to the purchase of a warranty. The program manager makes his warranty purchase decision based upon the CBA. The decision may be based on erroneous results if the analysis is not performed adequately; therefore, CBAs must be accurate.

Keywords. The following terms or acronyms were used throughout the literature review:

1. CBA: Cost-Benefit Analysis
2. DOD: Department of Defense
3. DFARS: Defense Federal Acquisition Regulation Supplement
4. FAR: Federal Acquisition Regulation
5. GAO: General Accounting Office
6. SFW: Sensor Fuzed Weapon
7. WSW: Weapon System Warranty

Justification of the Search and Review. The government may spend funds on warranties that are not cost-effective.

For a major system, the cost of a warranty can be a significant portion of total system cost. Therefore, the CBA is a necessary internal control measure. The analysis must justify either the purchase of a warranty or the need to obtain a waiver if the warranty is shown not to be cost-effective. Several government organizations found deficiencies in CBAs, and they recommend improvement of the analysis process.

Scope and Limitations of Research Topic. The objective was to: 1) analyze the unique attributes of performance requirements for one-time-use systems, specifically for the Sensor Fuzed Weapon (SFW) System, to determine how the attributes impact cost-effectiveness and future desirability for a warranty, and 2) review SFW and other dormant system CBAs to determine if a general methodology can be developed to improve future cost benefit analysis efforts. The topic was limited to the SFW and similar dormant systems, although applicability to other Department of Defense systems may be valid.

Method of Treatment and Organization. To ensure an understanding of the issue, a background of the history of Air Force warranties was accomplished. The background was followed by collecting a list of the current governing regulations impacting WSWs. A brief synopsis of literature regarding warranty CBAs was presented, and was followed by general CBA guidance. The CBA reviews were presented chronologically to illustrate the consistency of the problem since the inception of the public law. Comments on the status of warranties today was given, followed by an overview of the cost analysis for the SFW. A short discussion on Air Force warranty waivers approved was presented, and EPR warranties and the redundancy aspects of the SFW were described. A summary was presented last.

Discussion of the Literature

Background. The warranty provision was mandated by public law after Congress voted in 1983 to require manufacturers to provide weapon system warranties. The requirement stemmed from the procurement "horror stories" in the early 1980s (9:574). Senator Mark Andrews, a republican from North Dakota, initiated the effort. In defending the proposed law, he argued that his tractor had a warranty, and therefore, a weapon system should also have a warranty. Much debate about the issue occurred at the Armed Services Hearing in February 1984. Several witnesses spoke against the proposed law. Secretary of Defense Richard D. DeLauer, the chief Pentagon witness stated, "We can't afford and probably don't need to guarantee everything" (9:576). Air Force Lt Gen James W. Stansberry warned the panel, "Once modest, unchallenging [performance] goals are set, they tend to become self-fulfilling prophecies" (9:576). The article further explained that warranties do not provide incentives to contractors to make improvements in technology past what is required by the warranty.

Contractors presented several arguments against the proposed law. First, warranties discouraged innovations and breakthroughs in technology (9:576). Second, critical differences existed between commercial and military equipment, and these differences were not being considered (9:576). Third, the Department of Defense, as well as the contractor, controls the design of a system (9:576). Therefore, the government shares responsibility with the contractor in this area. Sen. Andrews continued to maintain his position arguing that warranties work in the private sector.

Congressional interest remained high, and the public law was passed as part of the 1984 Defense Appropriation Act. "The law requires that the prime contractor for a production weapon system provide written guarantees, starting with procurements after 1 January 1985" (4:2-3). The three guarantees required were 1) design and manufacturing, 2) materials and workmanship, and 3) performance specifications.

Current Governance. The current regulations governing weapon system warranties are listed:

1. Federal Acquisition Regulation (FAR), Subpart 46.7, FAC 84-58,
2. Defense Federal Acquisition Regulation Supplement (DFARS), Subpart 46.770-8, DAC 88-15,

3. Air Force Regulation (AFR) 173-15, Cost Analysis, 4 Mar 88, and

4. Air Force Regulation (AFR) 70-11, Acquisition Management: Weapon System Warranties, 1 Dec 88.

The public law is contained in 10 United States Code (USC) 2403. The AFR 70-11 states the requirement for a cost-benefit analysis:

> It is DOD policy to obtain only cost-effective WSWs. Therefore, a CBA must be done to determine whether the contemplated WSW, which will be in the production contract, is cost effective. A CBA must be done, even though the contractor may propose a "no-cost" WSW, to compare the government's cost of administering and enforcing the WSW to the potential benefits to be derived from the proposed WSW. (9:4)

Affordability must be considered in relation to potential benefits derived from the warranty. The CBA should indicate the potential benefits relative to the expected cost.

Synopsis of Reports on Cost of Weapon System Warranties. A chronological synopsis of various reports and articles concerning warranty CBAs shows a continued concern about the validity of CBA procedures. A synopsis of CBA guidance was obtained and is provided, and it illustrates the nonspecific nature of the guidance. This was followed by an article and a report containing general CBA comments regarding the current status of warranties.

CBA Literature. The RAND Corporation published a report in 1987 regarding weapon system warranties. The report reviewed implementation and theory of warranties, and it attempted to answer the question, "Can warranties help in improving weapon cost, schedule, performance, and reliability" (21:iii)? The authors were concerned that DOD was spending funds on negotiating, implementing and enforcing warranties, and DOD had no knowledge of the cost-effectiveness. One of the recommendations from the report was:

> . . .there is a real need for improved evaluation criteria and procedures--and this includes procedures for *a priori* cost-effectiveness estimates as well as *ex post* cost and benefit evaluations. So long as those procedures are limited to logistics or life-cycle costs, it is unlikely that any part of the project office, or the user or support communities, will be concerned with more important and more general benefits. (21:67)

Procedures may need to be improved, and a comprehensive review process may need to be implemented. The report also stated concern regarding the lack of waiver requests submitted, and said more policy is needed in this area.

The RAND Corporation published another report on warranties during early 1989. It was entitled A New View of Weapon System Reliability and Maintainability. While the report was primarily directed towards a review of reliability and maintainability weaknesses in the Air Force systems, it also addressed the cost of warranties. The author stated, as in the previous RAND report, the services are spending money without knowing if benefits will be derived. He said, "...data and contractual language are being gathered sporadically by various agencies..." (15:64). The report said a process to systematically gather and coordinate information and data does not exist. The warranty effectiveness cannot be evaluated if the essential data cannot be gathered. The article stated that there should be evidence of a connection between use of warranties and increased levels of reliability and maintainability prior to purchase of a warranty.

The United States General Accounting Office (GAO) published a report to the Secretary of Defense on DOD warranties in September 1989. One purpose of the GAO review was to determine if cost-effectiveness analyses were being performed as required by both DOD and service regulations. The review was justified because hundreds of millions of dollars are spent on warranties each year by the services (23:2). The principal findings of the report were stated as follows:

> Procurement activities included in GAO's review either have not been performing cost-effectiveness analyses or have prepared analyses that do not adequately support conclusions that proposed warranties are cost effective. As a result, procurement activities were not considering waiver requests in their decisions on proposed warranties because their analyses did not provide a convincing basis to support requests for waivers in cases where warranties may not have been justified because they would not be cost-effective. (23:3)

The GAO audited three procurement activities and discovered CBAs were either not being performed or they were not prepared adequately, and therefore, did not support a valid conclusion that the proposed warranty was cost-effective. They also stated the services were not considering waivers as an option during the procurement process (23:19). The official finding of the report reflected the inadequacy of CBAs.

The final report of the System Acquisition Management Inspection (SAMI) of WSWs was published in August of 1990. The team reviewed several aspects of warranties, one of which was the CBA. The team reported deficiencies in the data base and review process for CBAs and stated, "as a result of this problem, many CBAs may be invalid" (16:10). The problem referred to the deficient data base. The result was an inefficient CBA that cannot adequately support a decision regarding cost-effectiveness. The team also commented that a good CBA process had not been implemented in any of the organizations reviewed. Uncertainty about the validity of a warranty CBA was the result of a poor process. The recommendation from the review was, "Devise and build a data base of essential cost parameters and relationships to support effective warranty CBAs" (16:10).

Guidance for Performing CBAs. The Air Force Communications Command at Scott Air Force Base developed a Warranty Guide published in April 1991. The guide provides general information on warranties. A small section covers, "What Should a Warranty Cost" (1:4). The section begins with the statement, "It's difficult to say exactly what a warranty should cost" (1:4). It then suggests the analyst should ask the contractor what is covered. A later section describes the first step as using a life-cycle cost model, and then proceeds to list very general questions to answer, when using the model, that pertain to the potential costs and benefits. The model does not address any specific guidelines for performing the CBA. The contents of this warranty guide illustrates the need for stronger guidance for performing CBAs.

Comments on CBAs - Current Status. Brig Gen Lewis E. Curtis, III published an article in the Program Manager Magazine, "Time for a Relook at Weapon System Warranties: The Shotgun Approach Needs to Be Replaced With More Accurate Targeting" (July-Aug 1990). Gen Curtis began by saying, "...with the benefit of five years, it is time to revisit requirements of the law and its application" (10:34). Weapon system warranties do not make sense in every procurement situation (10:34). Specifically, he was referring to sole-source and cost-type acquisitions. Unless it could be clearly shown to be beneficial, he said it makes good business sense to pursue a waiver (10:37).

During 1990, Lt Col John P. Clarke led a working group to define an implementable warranty program. Although the copy of the report that was available was not dated, it is believed to have been published in early 1991. Lt Col Clarke does not specifically address CBAs in his report; however, some of the issues covered relate to a cost analysis. He states the purpose for a warranty: "Clearly the government is too large to be protected against catastrophic financial loss by any contractor. Only the taxpayer is financially more capable than we [the government]" (8:4). He questions the validity of saying a warranty is not cost effective because an item did not break often enough during the period warranted to recover the cost. In contrast, the increased reliability may indicate the warranty is working. Lt Col Clarke concluded, "In sum, we suggest that the only logical purpose for our obtaining a warranty is to improve the quality of the product" (8:5).

A personal interview was conducted with Mr. Stephen Dizek of The Analytical Sciences Corporation (TASC) to discuss the CBA methodology used for the SFW warranty . In 1987 Mr. Dizek performed a CBA for the system; and this was prior to availability of actual test data. He used a risk analysis comparing government versus contractor potential risks. Mr. Dizek stated that typically a combination of several accepted CBA methodologies are utilized. The choice depends upon availability of data and the life cycle stage of the system. He said the analyst should have an understanding of statistical and probabilistic methods to conduct an adequate CBA (13).

On 5 Nov 1991, a telephone interview was conducted with Maj Thomas DiNino, SAF/AQCS . Maj DiNino is the Air Force warranty focal point for contracting policies and procedures. The discussion regarded Air Force approved warranty waivers. Maj DiNino stated there have been six Air

Force warranty waivers approved to date; and all of the waivers were for systems of the "one-time use" type (12). Further investigation indicates that only two waivers were approved for systems in full-rate production. The other waivers were for the low-rate initial production, and is exempt by public law upon request by the agency.

EPR Warranty Background

The EPR warranty is described at this point because it is the major area of interest in the review of warranty effectiveness for the SFW. A system's EPR warranty typically drives the major portion of warranty cost. As a weapon system moves away from the concept exploration stage, the likelihood of influencing design to affect EPRs decreases (11:4). Once a system is in the engineering and manufacturing development stage, it would be very costly for the contractor to improve essential performance if it does not meet the requirements and the customer's expectations. Deficiencies are detected through operational tests and evaluations (OT&E). Warranty claims can be made for test failures, and remedies vary with different contracts. However, a test failure does not always prompt the contractor to redesign a system to meet the EPR requirement. The contractor's analysis may indicate it is more cost effective to pay the remedies for breaching the EPR warranty, as opposed to making an engineering change to the system to meet the EPR. The warranty contract should specifically state redesign as a remedy so the contractor has an obligation to perform the redesign effort. Zero failures for systems should be a target, but is an unrealistic expectation.

Relationship Between EPR and Design and Manufacturing Warranties. Product improvement efforts are required to mature reliability and maintainability characteristics (15:61). The design of a system and the manufacturing processes employed have a direct relationship with the EPR warranty. Reliability is designed into the system during the development stages by methods such as fault tree analysis, simplification of design, redundancy, derating, and using more reliable components. Manufacturing process such as environmental stress screening and statistical process control can improve a systems reliability by detecting faulty workmanship and manufacturing process. The manufacturing process can then be improved, and the result would be a higher level of reliability. These relationships are discussed to point out the interrelationship of the warranty parts: 1) defects in material and workmanship, 2) design and manufacturing, and 3) essential performance requirements. If EPRs are satisfactorily met, then it is likely that the other parts of the warranty would be positively affected.

EPR Selection. Operational performance requirements are the basis for the EPR warranty. The requirements for the EPR should be selected based on attributes that cannot be determined with certainty prior to or during acceptance testing. Verification of EPRs occurs during the operations phase after the system is fielded. EPRs should be measurable and verifiable in order to make valid claims and to perform valid CBAs. Availability, mission capability, and turn-around time are examples of potential EPRs. Clear and concise requirements and measurements must be stated in the warranty. For example, a warranty may state the requirement for a mean-time-between-maintenance of 250 hours. The EPR is derived from the Operational Requirements Document (ORD) and by the user and is the basis for the requirement in the warranty clause (11:4-5).

Essential Performance Parameters (EPPs) for Typical Systems. Essential Performance Parameters (EPPs) for a typical weapon system are monitored continuously by analyzing measurements collected during normal field operation and maintenance of the weapon system (11:5). An example of a typical system is an aircraft engine that accumulates flying hours on a steady basis. Maintenance and repair actions are tracked, and a mean-time-between maintenance can be calculated. Also, during downtimes, estimates of the spares required to maintain readiness can be calculated. Aircraft, vehicles, avionics, and support equipment can all be monitored in a similar manner because of the regularity of field use.

EPPs for Dormant Systems. Warranty administration for dormant weapon systems, such as the Advanced Cruise Missile (ACM) Propulsion System, indicates that EPPs for dormant systems are difficult to monitor because they are not operated in field conditions on a regular basis (24). A dormant system usually undergoes a preacceptance test prior to delivery to the government. Following delivery the system is stored, and at some specified point in time, the depot may perform service maintenance on the system. Service maintenance may include replacing some components or performing an external check for rust and humidity damage; and it can include both replacement and external checks. The system may be tested at specified intervals, determined by the warranty contract, to verify the EPPs against the EPRs. Destructive testing is the only test option for some systems while test sets can be used for other systems.

Built-In System Redundancy

A discussion of the SFW's built-in system redundancy is important to the warranty issue because it may have an impact on the reliability. In reliability engineering, redundancy can be defined as the existence of more than one means for accomplishing a given task (3:197). The classic type of redundancy is employed by reducing the number of single point failures by having two or more ways for the system to operate. Active redundancy means that all the redundant components are continuously energized and are employed in the performance of the function (3:199). Standby redundancy means that the duplicate elements do not perform any function unless the primary element fails (3:199). The SFW employs redundancy in a nonclassical sense. Tactical redundancy results from the system's ability to hit the same target more than one time.

The quantifiable and non-quantifiable costs must be considered in the evaluation of the cost-effectiveness of redundancy. The non-quantifiable costs are considered to be indirect, but should be evaluated since they impact total life-cycle cost of the system (4:7-11). The quantifiable costs would be incurred with the increased number of systems or units procured. Additional maintenance could occur for reparable systems. The non-quantifiable costs would be incurred in the additional weight and complexity of a system because of the additional units, elements or systems involved. However, the higher investment costs must be weighed against the lower operating and support costs and the higher overall reliability of the system. The high up front acquisition life cycle costs would be offset by the increased mission support capabilities of the system.

Conclusion

In 1984, Congress mandated DOD weapon system warranties through the Public Law 98-525. The only exceptions to the warranty requirement are when the warranty is not cost effective, or it is not in the best interest of national defense. Although CBAs are required as an internal control procedure to show taxpayer's money is spent wisely, only limited guidance has been provided to assist in performing CBAs.

Subsequent reports written illustrate significant improvements are needed in CBAs. The RAND Corporation suggests knowledge of a connection between warranties and improved levels of reliability and maintainability should be present prior to the purchase of a warranty (15:65). Reviews and inspections will continue as warranties become institutionalized, and it is evident CBAs will continue to be criticized.

The GAO report issued in 1989 said the government spends hundreds of millions of dollars on warranties every year in DOD and questions whether all warranties purchased were, in fact, cost-effective. Waivers are a viable option if the CBA indicates the warranty is not cost-effective.

EPRs and system redundancy were discussed in this chapter. Both of these issues are relevant to the warranty effectiveness question for the SFW.

The next chapter describes the methodology used for the research, and chapter four describes the findings. Chapter five presents the research conclusions.

III. Methodology

Introduction

This chapter describes the methodology used to answer the investigative questions. The research objective was to 1) analyze the unique attributes of performance requirements for one-time-use systems, specifically the Sensor Fuzed Weapon (SFW) System, to determine how they impact the cost-effectiveness and future desirability for a warranty, and 2) review SFW and other dormant system CBAs to determine if a general methodology can be developed to improve warranty CBAs. Two investigative questions were developed to answer the research questions. First, what system attributes make the SFW different from the typical warranted system, and how do these attributes impact warranty effectiveness? Second, when examining the cost-effectiveness of a one-time-use system, what factors are similar for dormant systems, and is it possible to develop a general CBA methodology?

Justification for Method Selected

The requirement for a weapon system warranty is relatively new, and a limited amount of guidance for analysis of a system warranty is available. The SFW is used as the subject for analyzing one-time-use systems. The SFW is currently in low-rate-initial production and has initial test data available. Destructive testing is used for this system; the system is no longer useable following the test.

The Combined Effects Munition (CEM) System was the predecessor to the SFW, from the warranty point of view, and served as a baseline.

Methodology

Investigative Question One. What system attributes make the system different; and how do these attributes affect the warranty? This question prompts research into the unique system attributes that affect the warranty requirement for a one-time-use system. The subsystems for the SFW will be analyzed by investigating the past history of testing, technological developments, stability, and reliability. The life-cycle stage of the system will indicate if a warranty provides potential improvements in system design (11:4). EPR warranties for the Advanced Cruise Missile (ACM), ACM engine, Peacekeeper Missile, and Maverick Missile will be reviewed for additional information on dormant systems as they relate to the warranty requirement. The investigation may reveal similar attributes between the dormant systems that may impact the warranty applicability of other systems.

Investigative Question Two. Are cost analyses for dormant systems similar; and is it possible to develop a general CBA methodology? To address the second investigative question, the CBA for the SFW, as well as other above mentioned one-time-use systems, will be examined. Commonality between CBAs may indicate that a general methodology can be applied. The categories for costs and benefits used in the CBAs will be compared to determine if a general methodology would be applicable for dormant system CBAs.

Support

Support for the research is provided by the Sensor Fuzed Weapon and Airfield Attack System Program Office, ASD/YB, Eglin AFB, Florida. They provided funds to visit the program office to gather information and data. The Armament Division at Ogden AFB, OO-ALC/LIWB, provided historical data on the CEM System.

Validation and Historical Accuracy of Method

Actual data available for dormant weapon systems will be used to perform the analyses. Documentation on how to conduct a warranty analysis on a one-time-use system does not exist. Therefore, the researcher will use comparisons between dormant systems on which to base conclusions.

Summary

This chapter described the methodology to answer the investigative questions. Data and information gathering is ongoing, and the proposed methodology is viewed as the most reasonable based on current information. The next chapter will describe the research findings, and conclusions will be presented in chapter five.

IV. Findings

Introduction

Chapter Three provided a general background on warranties and discussed current issues. The focus of this research is on the essential performance requirements (EPR) portion of the warranty. An EPR is a measurable, verifiable, trackable, and enforceable operating or maintenance capability and reliability characteristic of a weapon system that is determined to be necessary for the system to fulfill the military requirement for which the system is designed (11:1). The intent of the warranty requirement must be examined prior to presenting the research findings since chapter three gave a brief warranty background for understanding. Defining the intent of DOD warranties provides a baseline for the review of various EPR warranties in this chapter. The requirement was mandated by Congress in 1984. The general intent was to provide a means to match contractor's promised performance specifications, during the bidding process, with measured performance in the field. The types of warranties are 1) an assurance warranty that induces the manufacturer to produce a product or system that performs as advertised and guarantees quality, performance, and design levels, and 2) A reliability improvement warranty (RIW) that induces the manufacturer to exceed minimum requirements by providing incentives. The systems discussed in this chapter are of the assurance type. To differentiate from a commercial warranty, the following objectives for a military weapon system warranty are provided.

> To mature the weapon system to a point where there is an acceptable probability that the system will deliver the full measure of its designated capability whenever called upon in combat. (15:63)

The Air Force Regulation for warranty acquisition provides the following definition.

> Weapon system warranties (WSW) provide the Air Force ways to motivate contractors to design, produce, and deliver quality weapon systems as well as a means to correct defects for which the contractor is responsible. (11:1)

The findings presented in this chapter will reveal how a warranty on a dormant system relates to the warranty objectives, and if a general cost-benefit analysis methodology can be developed to improve CBAs. These objectives provide a basis for research on the validity of an EPR warranty for a dormant weapon system. A dormant weapon system is one that is kept in storage until demand for actual usage occurs. Missiles, bombs, and munitions typically fall into this category. Actual use of the system results in its destruction.

Findings for Research Question One.

Research question one's objective was to analyze the unique attributes of performance requirements of one-time use systems, specifically for the SFW, and determine how the attributes impact future desirability for a warranty. This section discusses the research findings.

Application of EPRs for Specific Dormant Systems. The EPR warranties for the Peacekeeper Missile Propulsion System, Advanced Cruise Missile (ACM), ACM Propulsion System, and Maverick Missile were reviewed to see if similarities exist between dormant systems. The following information was obtained for each system: 1) specific EPRs warranted, 2) type of tests performed to determine if a breach in EPR warranty has occurred, and 3) program office comments about the EPR warranty. Each system review is presented below, and a total assessment follows the review.

Peacekeeper Missile Propulsion System. The specific EPRs covered under the warranty were: action time, total impulse, instantaneous thrust, thrust tailoff, ignition delay, thrust vector actuator (TVA) enable time, TVA action time, TVA slew rate, TVA duty cycle, stage IV duty cycle. The test performed was operational test and evaluation (OT&E). OT&E included random selection and testing of deployed missiles from those on alert at operational missile wings. OT&E was used to verify the actual performance reliability of their operational missile fleet. A waiver to the EPR warranty was granted in 1988 based on non-cost effectiveness and included the warranties for Stage IV production contract and beyond. Comments regarding the warranty were obtained from the waiver application.

> There is little or no opportunity to determine if the missile will successfully perform. The OT&E program would not be useful as a warranty enforcement tool because the data obtained are insufficient to pinpoint the specific point of failure (if any) thus allow the Government to assign fault for a problem. Instrumentation on OT&E tests is limited to that on the operational missiles so SAC can obtain a valid picture of their ICBM weapon system's accuracy and reliability. No additional subcomponent performance or failure analysis instrumentation is added because of the added weight for such incorporation and the associated range and payload penalties. (5:6)

Advanced Cruise Missile (ACM) System. The specific EPR warranted is stated as percentage of systems available. Determination of a breach of warranty is based on assessed distribution of the missile's reliability during ground tests. The specific tests are loaded launcher pylon test (LLPT) and system integration test (SIT). Comments obtained are as follows:

> While OT&E flights are accomplished on the ACM, they are too infrequent to be statistically relevant, and the selection of test missiles is driven by an operational need for random selection. Thus the program office cannot be assured that a sufficient quantity of any given contract buy will be flown during a reasonable warranty period. In conclusion, the ACM's performance on ground testing remains the only measurable essential performance parameter. Since there is no redundancy in the missile's design, a quality problem will impact the government. (18)

The comments above state that the OT&E flights were too infrequent to be statistically relevant. The test plan could have been developed to be statistically relevant. In addition, random selection is an acceptable sampling technique; the statement above implies that it is not a problem. The ACM System Program Office intends to submit a total warranty waiver application for the latest negotiated lot buy based on non-cost effectiveness. The ACM has been in limited production for three years.

ACM Propulsion System. The specific EPR warranted was defined as a failure rate. The types of tests performed under the Warranty Demonstration Test Program were the Product Assurance Test (PAST), Effectiveness Verification and Improvement Program (EVIP), Operational Test Launch (OTL), and Run as Received (RAR). Comments on the warranty were obtained from the waiver application.

> Unlike manned or reusable drone aircraft engines, whose performance characteristics may be evaluated at regular intervals, cruise missile engines remain dormant in the field. They sit dormant for years with no scrutiny whatsoever except for periodic electrical tests of the fuel control. Any other actual or incipient failures would go undetected until the missile is actually flown. It would be difficult to recover enough hardware in the event of a failure, to conclusively prove what element of the engine failed. (24:3)

The last statement above implies that hardware must be recovered to show the cause of engine failure. However, the event of a failure should be sufficient to make a claim of some kind. A full warranty waiver was granted for the system in March 1991. The ACM propulsion system was in the production lot III buy at the time the waiver was granted.

Maverick Missile System. The specific EPR warranty states that ninety-six percent of inspected missiles shall pass an inspection cycle. The type of tests performed are visual and functional testing on approved test sets. Comments were obtained from an interview with the warranty manager.

> The missile has been in production for more than twenty years and has had an EPR warranty except for the low-rate initial production lot. The provisions state that the Air Force is responsible for the first four percent of failures (previously five percent); subsequent failures are the responsibility of the contractor. The missile program has never had a breach of the EPR warranty. The warranty is not priced separately, and the cost is included in the total missile cost. The program office feels the EPR warranty has provided incentive for the contractor to improve the failure rate, as evidenced by the recent reduction from five percent to four percent. (19)

Combined Effects Munition System. The EPR warranty states that the function rate of the system will not degrade below a specific percentage. The function rate is defined as the number of units (bomblets) that function from all successful dispenser events divided by the total number of units released from all successful dispenser events minus no-test units. Triennial testing of 30 systems per production lot for the 10-year warranty is the basis for measuring the function rate. The system was produced by two contractors until 1990. In 1990 the system came under a sole-source contract. To date no warranty claims have been made against the EPR warranty. However, a claim was made against a defective item.

Assessment of System Reviews. The systems reviewed are summarized as follows:

1. The Peacekeeper Missile System Program Office was successful in obtaining a waiver in 1988. The waiver was for the EPR warranty only.

2. In 1991, the ACM propulsion system was granted a full warranty waiver; the waiver was for defects in material and workmanship, design and manufacturing, as well as the EPR warranty.

3. The ACM Program Office is preparing to submit a full waiver request, including all three warranty parts as described in 2. above, for the missile system.

4. Although the Maverick Missile Program Office is satisfied with their warranty, can they be positive that the warranty is cost effective if the warranty is not separately priced? The costs and benefits of a warranty must be compared to determine cost-effectiveness. Although the warranty is not separately priced, it is most likely built into other costs. A valid cost-effectiveness analysis is not possible in this instance.

5. Two views of warranty effectiveness for the CEM can be taken. First, the EPR warranty has been effective since the system is performing satisfactorily with no failures. The warranty may be working as intended since the contractor apparently produced a system that has not failed. Second, a warranty has been purchased, but the government is not receiving tangible benefits such as warranty repairs; therefore, the warranty is not cost-effective because the measurable benefits are zero.

These system assessments were performed to assist in the review of the Sensor Fuzed Weapon System (SFW) EPR warranty.

All of the systems discussed in the previous section are one-time-use systems similar to the SFW. This section focuses on the Combined Effects Munition (CEM) since it is the predecessor to the SFW from the warranty point of view, and therefore, it will provide the best history for comparison with the SFW. A brief description of the SFW and CEM will be given in the next paragraph for comparison purposes. A brief history of both systems will follow the description.

The SFW and the CEM are cluster munitions that are unpowered and unguided free-fall devices, stored and transported as an all-up-round in a container. Both of the systems provide a conventional force multiplier capable of achieving multiple kills per pass. The difference between the systems is the SFW is effective against armor, while the CEM is not.

History of the Combined Effects Munition (CEM). Review of the CEM system warranty provides a baseline for determining applicability of the EPR warranty to the SFW. A report on CEM Warranty Evaluation was published in November of 1990 by ARINC Research Corporation. Production of the system began in 1984 with Aerojet Ordnance as the prime contractor and Honeywell as a subcontractor for TMD production. Dual source production began in 1985. In 1991 the program went sole-source to Honeywell because of the high cost of high cost of maintaining dual source production and the changing political scene in Europe (2:1-4). The CEM program office developed the warranty during the latter stages of engineering and manufacturing development.

The basic format was that of a storage verification warranty with penalties for the contractors (2:1-5). The current warranty clause provides for liquidated damages (monetary payments) to the Government should the product fail to meet a reliability requirement of 87%, at the system level, based upon triennial flight testing. It also provides a vehicle for the Government to require "no-cost" engineering changes for future production if testing indicates that the reliability has not reached or is falling below the prescribed levels (2:1-6). Cost of processing and evaluating ECPs will be absorbed by the contractor. The costs associated with implementing and performing the ECPs are covered in the contractor's total liability limits (2:B-8). The warranty provides the contractors protection by limiting their liability to approximately eight to ten percent of the total contract value. Financial catastrophe to the contractor's business cannot occur under this warranty contract.

As part of the review for the report, several questions were asked of contractor and Government procurement personnel relating to whether or not the warranty motivated the contractors to provide a better product. Government personnel were generally non-committal, although several indicated that they sensed little motivation as a result of the warranty (2:2-3). The contractors, on the other hand, stated that the warranty was a significant factor in the way that they approached the CEM program and their obligation to provide a quality product to their customer. Aerojet Ordnance lobbied for the inclusion of a warranty as part of their marketing strategy (2:2-3). Once the warranty was in effect, ARINC's review of the procurement contracting officer's (PCOs) warranty files indicated only two letters in the entire file relating to directed warranty modifications to the CEM. Although one contractor indicated that they had performed a significant amount of analysis of component designs prior to initially signing up to the warranty, ARINC saw little evidence that they had used the results of their analysis to alter or improve component design (2:2-3). However, if the design was already acceptable, the contractor may not have the need to improve design. In this case, the warranty would provide protection against catastrophic failure, similar to insurance coverage.

Sequential Bayesian testing techniques were used to reduce test costs. This method enables up to two-thirds of the flight tests to be avoided because a decision to accept the lot can be made before the maximum amount of destructive testing is performed. An accept or reject decision can be made based upon the number of test failures per a specific number of tests performed. A numerical estimate of true reliability would require a larger sample size and would yield higher statistical accuracy (2:2-4). According to the test plan, using an example of ten tests performed, the lot is accepted if zero failures occur in ten tests. If three failures occur in ten tests, the lot is rejected. The maximum number of tests is 30, if results continue to fall in the region between accept and reject. Refer to Figure 1 for an illustration of the sampling plan.

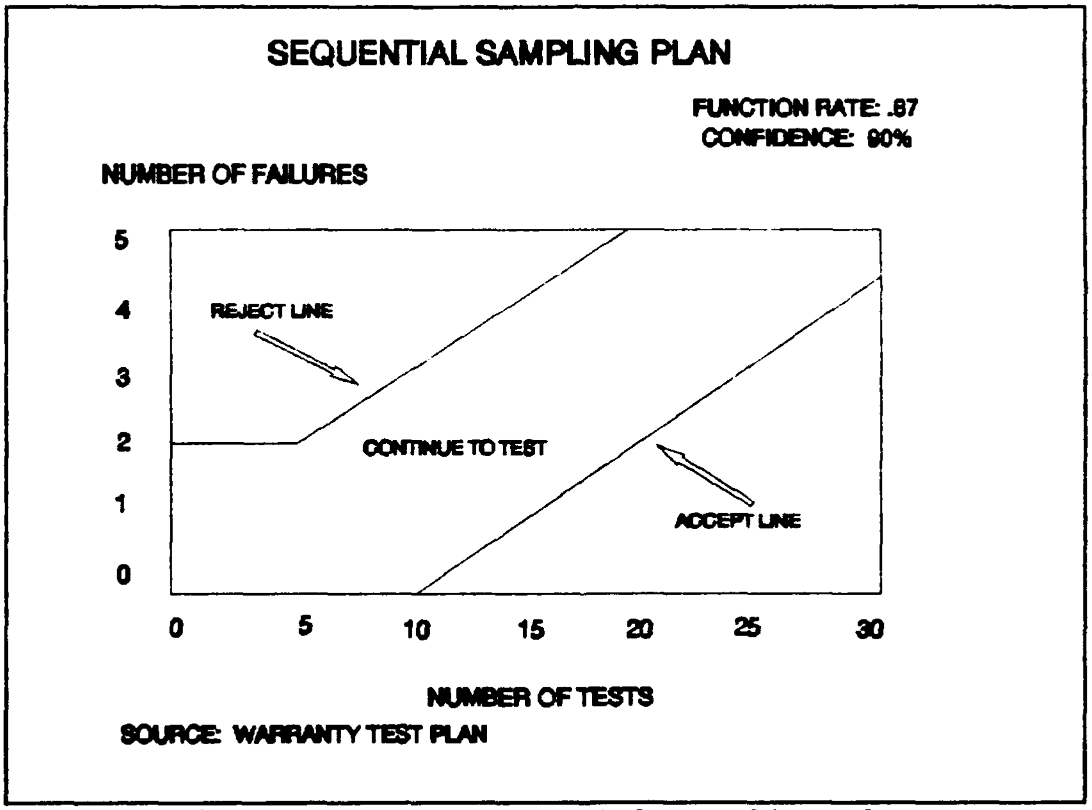


Figure 1. CEM Sequential Sampling Plan

ARINC performed a cost-benefit evaluation on the CEM and estimated system life cycle warranty costs of $15 million and potential warranty benefits of $22 million. "The evaluation showed the savings accrued through lower testing costs rather than any clear and quantifiable improvements brought about by warranty incentives" (2:2-7). To date, no warranty claims have occurred under the EPR warranty. Since no claims have occurred, the CEM appears to be an acceptable operational system. However, it cannot be shown that the warranty had an effect on the system reliability.

History of the Sensor Fuzed Weapon (SFW) System. Primary differences between the systems are the SFW dispenser skin peels and the nose and tail remain; the CEM dispenser spins and ejects the bomblets while the SFW uses the tactical munitions dispenser (TMD) fuze with no-spin settings. The SFW program milestones are as follows:

1. Initiated in June 1984 as a risk reduction phase with an option for full scale development (FSD).
2. In November of 1985, the FSD option was exercised.
3. The critical design review was conducted in 1989.
4. The live fire test and evaluation was performed in 1990.
5. A production transition program was initiated in July of 1990.
6. The developmental test and evaluation (DT&E) was successfully conducted between December 1988 and April 1991.
7. Following the DT&E, initial operational test and evaluation (IOT&E) was successfully completed in December 1991.

8. The full-scale production is estimated to begin in 1995.

The Analytical Sciences Corporation performed a warranty analysis on the SFW in 1987. Equipment characteristics were reviewed, and similarities with CEM were identified as follows:

> As a "one shot" device, it has an operating time so short that reliability is not affected by wear-out or time during operation. Reliability depends on the probability that parts will function properly at the moment required. (14:3-2)
>
> As in CEM, SFWs are non-operating, non-reusable, and non-restorable systems. Consequently, application redundancy, pipeline spares and maintainability as influences on availability are generally irrelevant. (14:3-2)
>
> Transportation costs are the major component of SFW operations and maintenance costs, and are relatively fixed. O&M represents only one-percent of the total life cycle costs. Thus, the opportunity to focus on O&M costs with a warranty is minimal. (14:3-3)
>
> Automated and/or nondestructive test techniques that monitor the "health" of the system will not be used on SFWs once they are stored at operational locations. Such information on SFW must be gathered primarily through discrete, destructive testing. (14:3-3)
>
> SFW will be stored for long (up to 10 years, or longer) periods of time, and then be expected to function whenever required. The "all up round" -- build it, store it, don't disturb it, use it when required -- is specifically applicable to SFW as it was for CEM. (14:3-3)

TASC performed an analysis to determine the overall effect of a warranty on the SFW program. A comparison was made between government economic risk without a warranty and the government economic risk with a warranty. The analysis concluded that there is a significant benefit in having a warranty for the correct price, over not having one. The conclusion was based on the assumption that the warranty would motivate the contractor to build SFWs that degrade at 0.01 per year, versus 0.021 per year without a warranty (14:4-5).

Specific Findings for the SFW. The methodology used to measure EPR effectiveness for the SFW is a test of hypothesis using the t-statistic. Six systems from each full-rate production lot buy will be tested at the four year and eight year points. The 12 systems are tested based on the assumption that the characteristics of the sample will resemble population characteristics.

The sample is limited because testing a large sample is cost prohibitive. The unit cost could be as high as $249,000.00 each, and testing 12 results in destruction of systems costing $2.98M each lot, since destructive testing is utilized. The attribute being measured is degradation of the system over time.

Table 1, on the following page, contains the total program quantities by year. Low-rate production occurs between 1992 and 1995, and 521 systems will be acquired. The system will then be in full-rate production between 1996 and 2004, and 9,479 systems will be acquired during this period. The total quantity to be produced is 10,000 systems.

TABLE 1

SFW PROGRAM QUANTITIES
BY YEAR

FISCAL YEAR	LOTS	NUMBER OF SYSTEMS
1992	LRIP 1	98
1993	LRIP 2	23
1994	LRIP 3	175
1995	LRIP 4	225
1996	FRP 1	480
1997	FRP 2	870
1998	FRP 3	1156
1999	FRP 4	1236
2000	FRP 5	1330
2001	FRP 6	1366
2002	FRP 7	1439
2003	FRP 8	1447
2004	FRP 9	155

LRIP: low-rate initial production
FRP: full-rate production

The current test plan for the SFW calls for the limited testing of a maximum of six systems at the four and eight year points following delivery of the system. According to the program manager, the high cost of destructive testing prohibited the use of sequential sampling. For comparison purposes, the MX ballistic missile costs for each follow-on operational test and evaluation (FOT&E) is estimated at $85 million per launch. The ground tests include some destructive and some nondestructive. The program office was forced to reduce the number of flight tests from seven to three and rely on ground tests and analysis for estimates of degradation (6:42). Although the test costs for the SFW are much smaller, limited funding can significantly reduce the number of tests performed.

The weakness in using the t-statistic for the SFW's measurement of degradation is that a small sample provides the contractor more leeway because of the large acceptance region for the test. A larger sample size and tighter acceptance region could have the potential to make the contractor more responsible. In addition, the measurement of test results occurs with each of the two sets of six tests for each lot. The result of this method of testing is a "point-in-time" measurement over all of the lots and not a cumulative measurement that shows improvements over time. This method of measurement could potentially result in a more costly warranty because the contractor is liable for meeting requirements based on each individual test, and the result is higher risk for the contractor. On the other hand, a cumulative measurement point, or points, would translate to a lesser number of times for potential invoking of remedies.

The decision to limit testing to 12 systems and use the t-statistic was based on the cost of destructive testing. The resulting reduction in potential contractor liability would be considered in an analysis. Tradeoffs looking at the increased confidence in the test of hypothesis verses the resulting increased cost of testing would also be considered in an analysis.

Another factor to be considered is the number of systems tested relative to the production time of the system. Potential exists for the contractor to close down the production line following the last production lot in 2006. Only forty-eight systems from production lots 1996-2000 would have been tested, leaving 72 from the remaining production lots to be tested after the production line is closed. Modifications to the system could occur prior to closing of the production line. However, after the production line is closed, only monetary remedies could be collected from the contractor. The drawback to receiving monetary remedies is that the U.S. Treasury, and not the Air Force or program office, is the recipient of the funds. Funds to correct any deficiencies would have to come from some other source since the contractor's remedy payment goes to the U.S. Treasury. Refer to Appendix A for details of the test plan.

The SFW System has some redundancy characteristics. At the system level, a typical load of four SFW's (CBU-97B) are carried on an aircraft. Each SFW contains ten TMD's (BLU-108/B). Each of the ten TMDs contains four projectiles. The total number of projectiles per SFW is 40, so the typical load of four SFW's would contain 160 projectiles. In addition to the redundant components, tactical redundancy also exists because of the possibility for a target to be detected and hit more than one time. Redundancy was designed into the system, but it was not specified as a requirement to meet the minimum performance level.

The drawbacks of additional weight and complexity do not affect this system. The SFW is a 1000 pound class munition of common design, and the user requirements of four SFWs per F-16 aircraft to eight SFWs per F-111 aircraft are within the weight allowances. Also, the SFW is a nonreparable system and, therefore, additional maintenance is not a factor. The warranty test at years four and eight for each lot consists of destructive testing of six systems. Maintenance actions or remove and replace actions do not occur. This system benefits from the additional reliability without suffering any of the potential drawbacks of redundancy.

The formula, proposed by the system program office for system reliability that considers redundancy, appears in Appendix B. The subsystem reliability inputs to the formula were based on an average from repeated simulations. The simulations utilized a scenario that was accepted by the user as an expected mission scenario. The using command made the decision to use a formula for reliability for a series system. A series system formula is simply the reliability of each subsystem multiplied together to equal the system reliability. The formula in Appendix B is more appropriate because it models the tactical redundancy characteristics, while the series formula does not.

The life-cycle stage of the SFW system was considered important in this research. Systems in the early development stage, when the system is not proven, can benefit from the EPR warranty. The warranty provides the contractor with a goal for meeting the stated requirements for performance. Design and manufacturing processes can both be influenced early in a program. As the system matures and design stabilizes, only manufacturing processes can be influenced. A system that has been fielded for many years will not benefit as greatly from the warranty, as will an unproven system. Several of the components of the SFW system have had many years of testing, as well as Desert Storm usage behind them. An extensive full-scale development effort for the SFW began in 1985. Some of the common components between the CEM and the SFW are the FZU-39/B proximity sensor, TMD internal fuze, TMD dispenser, and the CNU 411 A/E weapons container. The TMD dispenser is a component that is not redundant and could cause a catastrophic failure if it did not operate properly. However, it has been produced successfully for over 10 years.

Considering all the field experience for the CEM, the EPR has been successfully met to date. Thirty DT&E and twenty-five IOT&E tests have been performed for the SFW System. These tests confirm the basic design of the system.

Findings for Research Question Two

Research question two's objective was to review the SFW's and other dormant system's CBAs to determine if a general methodology could be developed to improve CBAs. This section provides the findings for research question two. The first section provides a general overview of the methodologies used for the CBAs for Peacekeeper Missile, ACM, ACM Propulsion System, Maverick Missile, CEM, and the SFW. Next, the effects of sole-source contracts are discussed.

System CBAs Described. The Peacekeeper Missile CBA is described as follows: For warranties, the benefit derived is the cost avoidance to the Government that results from having the contractor perform repair and replacement actions or correct problems at his own expense, plus the cost avoidance from not having to maintain an organic repair shop and train and pay repair technicians. The cost of warranty is that of buying coverage from the contractor plus the cost of a system to document, track, and report claims against the warranty (5:17).

Factors included in the analysis were cost of acquisition, cost of preparing or setting up each item (aircraft, missile, ship, truck, computer, etc.) for operation, cost of routine preventative maintenance, cost of failure repair, cost of spare parts, and the cost of having or contracting a repair shop, including labor (5:17).

Comparison of life cycle cost with and without warranty was performed.

The Advanced Cruise Missile (ACM) CBA is described as follows: The ACM System Program Office (SPO) maintains reliability assessments of ground test reliability for Level 1 tests in the form of a cumulative distribution function. The probability of the missile failing a Level 1 test by a given percentage is extracted from a distribution function. Next, each percentage is applied to a Cumulative Availability Rate (CAR) formula to determine a breech or compliance with CAR provisions. Given a breech, the cost of a warranty engineering change proposal (ECP) (determined from program historical data) was added to the calculated risk. Then a percentage of the total missile failure rate was assumed to be corrected by the ECP (in the year the CAR was calculated) and a new failure rate is established. This compiled failure rate was reapplied to the next CAR period and the process was repeated until either the CAR exceeds the requirement or the warranty period is expired. Sensitivity analyses were performed, varying the failure rate from 10 to 40 percent. The cost of money was included in the CBA. The last CBA performed indicated that one of the contractor's warranties (dual sourced) was not cost-effective, and the program office is currently seeking a waiver.

The ACM Propulsion System CBA is described as follows: The CBA for the ACM propulsion system was based on historical data for that system, as well as the predecessor system. The data consisted of the number and types of failures that occurred, and the cost of repair for those failures. In addition, an engineering projection for reliability and projected overall failure rates were used. A sensitivity analysis was performed comparing expected costs and benefits against a worst case scenario in which the benefits would be lower than expected. The sensitivity analysis was important because the SPO was requesting a waiver to the warranty. Non-quantifiable factors such as missile deliveries falling behind schedule were included in the narrative. The lagging delivery of missiles caused the loss of warranty coverage time for the engines . The narrative also included the judgement that the probability of exceeding the liability ceiling was very low, thus, representing a low risk to the contractor. A comparison of life cycle costs with and without the warranty was made. The last CBA performed indicated the warranty was not cost-effective, and a waiver to the total warranty was obtained in March of 1991.

The Maverick Missile System CBA is described as follows: The Maverick Cost-of-Ownership Model (MAVCOM) calculates all support life cycle costs (cost of ownership) associated with maintaining the inventory of the Maverick missile throughout its operational life. The model assesses the cost differences associated with incorporating an engineering change into production or with changing an operational or support parameter. A baseline failure rate is used because the government is responsible for failures up to four percent. A five percent failure rate is then calculated to obtain the costs to repair warranted failures. The predicted repair actions are the delta between the failure rates at four and five percent.

The SPO has never encountered a breach of the EPR warranty, and the warranty is not separately priced. It is questionable that a warranty can be identified as cost-effective if it is not separately priced. However, the SPO feels that it has provided incentive for the contractor to reduce the failure rate from five percent to four percent. The missile has been in existence for over twenty years.

Combined Effects Munition (CEM) CBA is described as follows: The CBA for the CEM compares the government cost with and without a warranty for the following factors: warranty price, warranty administration, test administration, conduct of testing, and ECPs. The analysis indicated that government costs were higher without a warranty due to the higher cost of test administration and higher cost of conducting tests. Therefore, the purchase of a warranty was determined to be cost-effective. To date, no EPR warranty claims have been made.

Sensor Fuzed Weapon (SFW) System CBA is described as follows: The CBA for the SFW identifies differences in degradation per year and reliability over the warranty period with and without a warranty. The expected value of "good" assets was computed based on the differences previously mentioned. Many sensitivities were performed by changing the degradation rate, reliability, and contractor liability cap. The cost of money was considered by discounting using ten percent per year. Expected value of "good" assets at ten years, with and without a warranty, was computed. Net warranty CBA was the difference between total EPR warranty cost and total expected EPR warranty pay back plus total expected value of "extra good" assets. The SFW is not a reparable system, and the analyst determined to use the value of "good" assets with and without a warranty to perform the CBA. A narrative that describes many non-quantifiable costs or factors that affect the warranty is included with the CBA. The CBA indicated that the warranty is not cost-effective.

Summary of the CBAs. Appendix C compares the cost and benefit categories used for each of the warranties discussed. The typical method of computing warranty benefits is to project repair costs for the period warranted. The benefits are then compared to the cost of the warranty, or potential cost of projected repair, to arrive at a benefit to cost ratio or delta. The SFW is distinguished from the other systems because it is nonreparable. The difficulty for a dormant, nonreparable system is determining what to measure to represent benefits. The method of using estimated "good" assets is a reasonable measure.

Sole-Source Versus Competitive Contracts. A sole-source contract poses difficulties relative to the warranty issue. An increasing number of firms use warranties as an offensive marketing weapon that is an integral part of their overall strategy. The objective is to differentiate the product in a competitive environment (17:69). Understanding the driving, hostile forces of a competitive environment, management recognizes the necessity of acquiring new and repeat customers (20:44).

Loss of government leverage occurs in a sole-source environment. The SFW system program was down-selected to a single-source. The negotiation of an effective warranty becomes difficult in this scenario.

> Sole-source acquisitions pose a variety of unique challenges. Without pressures of the marketplace, difficulties of assuring a fair and reasonable price are magnified. In the warranty area, too, dealing with a single-source requires special considerations. The government leverage in assuring a reasonable assessment of risk by the contractor is significantly reduced. Without competition, the contractor will take an extremely conservative approach, which translates into high warranty costs or low-performance parameters, or both. Flexibility given by the law to negotiate is a double-edged sword which, in a sole-source environment, can lead to extended negotiations where the contractor can wear down the government until it gets a meaningless, watered-down warranty simply to satisfy requirements of the law. (10:35)

Sole-source contractors do not have the motivation to provide a good warranty to differentiate themselves from competitors. The waiver authority under the law should provide relief in the situation that a warranty from a sole-source contractor is not cost-effective. The GAO criticized the Air Force for conducting extended negotiations rather than requesting a waiver (10:35).

A contractor has to accept high risk on a conceptual system utilizing leading edge technology. The complexities of a new system demand greater risk coverage, and therefore, higher warranty costs. However, as discussed in the system history, the SFW is a proven system for most of the components, including the ones that could cause a catastrophic failure. The contractor for the system, nevertheless, is risk averse as evidenced by the anticipated high cost of warranty compared to anticipated benefits. The non-competitive aspect of the system can be a major factor in the contractor not accepting risk.

Summary

This chapter presented the findings for:
1) application of essential performance requirements (EPR) warranty relative to the SFW, and 2) review of cost-benefit analyses to determine if a general methodology could be developed were addressed. The next chapter presents conclusions and recommendations for the research questions.

V. Conclusions and Recommendations

Introduction

The previous chapter covered detailed findings for this research. This chapter summarizes the conclusions and provides recommendations.

Conclusions

The first objective of this research was to analyze the unique attributes of the Sensor Fuzed Weapon (SFW) System's performance requirements to determine how they impact the cost-effectiveness and future desirability for a warranty. The SFW program office is considering waiving the EPR warranty requirement based on the most recent CBA that indicated the warranty was not cost-effective. They are justified in questioning the purchase of an EPR warranty. The conclusions based on the areas reviewed are presented below.

Review of similar dormant weapon systems indicated a unique attribute was the method of testing (destructive testing) for measurement of essential performance requirements. Destructive testing was required and resulted in a limited number of tests being performed to detect if a system's performance requirements were satisfactorily met. Destroying systems for test purposes made it cost prohibitive to have a large test sample. Two of the systems reviewed had warranty waivers granted based on the CBA indicating the warranties were not cost-effective. The rationale included the dormant nature of the system, as well as limited testing opportunities due to random selection and destructive testing. The SFW's testing is limited, and if the production line closes in 2006 as projected, less than half of the total population of systems would have been subjected to testing by the end of the production warranty. After the production line closes, the only remedy available for a breech in warranty would be monetary and would not result in a system improvement. The monetary remedy would then most likely go to the U.S. Treasury and would not benefit the program or the Air Force. Also, a breach in the warranty contract is based on the method of measuring essential performance parameters at "points-in-time". This method may drive up warranty cost because of higher risk to the contractor. An alterative would be to measure performance on a cumulative basis.

The CEM, SFW's predecessor system in the warranty point of view, has had no claims against the EPR warranty. However, the CEM program office continues to purchase the warranty. The success of the CEM has benefited the SFW system because the systems are similar and have some common components.

Redundancy aspects of the SFW are that it has multiple identical canisters and projectiles, and that targets are expected to be hit more than one time each. Redundancy increases system reliability. The formula developed by the system program office to calculate system reliability seemed appropriate because it included the redundancy aspects of the system. The series reliability formula currently in use, per direction from the using command, does not project system reliability based on an expected mission scenario, as the redundancy formula did. The two formulas result in different reliability estimates, and in turn will result in different projections for the cost-effectiveness of the warranty.

The relationship between the EPR warranty and the defects in material and workmanship and design and manufacturing warranty should be investigated. Would it be possible to make valid warranty claims for the other two parts of the warranty, 1) design and manufacturing, and 2) defects in material and workmanship, if the EPR warranty were waived? It seems that it would be difficult to make claims if the only method of detecting defects and faulty design is by visual inspection only.

The following are recommendations to consider for further evaluation of the warranty effectiveness:

1. Consider performing a cost-effectiveness sensitivity analysis using the reliability formula that considers redundancy.
2. Determine that the other two parts of the warranty can be enforced without the EPR warranty if it were waived.
3. Perform an analysis to compare the "point-in-time" versus the cumulative measurement methods used to

detect a breach in the EPR warranty, relative to the expected contractor cost for the warranty. The potential cost and benefit differences should then be analyzed. The possibility exists that the warranty could be cost-effective if an alternate method of measurement were used for the EPR warranty. That possibility could be investigated.

The second objective of this research question was to review the SFW's and other dormant system's CBAs to determine if a general methodology could be developed to improve the CBAs.

Several CBAs for dormant systems were examined, and the general methodology used for all of the CBAs included utilization of historical data and projections for future costs versus expected benefits. Sensitivity analysis was performed to varying degrees. All analyses performed, except for the Maverick Missile, also included life cycle cost with and without a warranty. The Maverick Missile CBA appears to be the weakest for the following reasons: 1) it does not compare life cycle cost with and without a warranty, 2) the only cost-benefit sensitivity performed compares a four and five percent failure rate for the EPR warranty, and 3) the cost of the warranty is not known (cost is included in the missile price). The Maverick Missile warranty, however, is the only one that shares risk with the contractor by accepting responsibility for the first four percent of failures. Risk sharing reduces the warranty cost.

Appendix C illustrates that, for the warranty CBA, the systems reviewed use many different cost categories, and only a few categories are used to measure benefits. Intangible benefits such as increased mission readiness and increased availability were not included in any of the CBAs. The fact that benefits were omitted tends to supports the GAO's findings that CBAs are inadequate.

The recommendation is to tailor the CBAs specifically to correspond with the warranty contract. Although some similarity exists between the CBAs, the differences in the individual warranties do not suggest a universal methodology should be developed. Warranties are tailored to meet the requirements of the specific system, and none are exactly alike. The remedies specified in each individual warranty determines the factors that should be used to calculate costs and benefits. The SFW system has a sole-source contract. An acceptable warranty is practically impossible to negotiate in a sole-source situation. This impediment should be a consideration when planning the warranty strategy.

Recommendations for Further Research

Dormant weapon system present a unique challenge when developing a warranty contract and deciding how to enforce the contract. Although a limited number of warranties on dormant systems currently exist, further research could be performed to assess warranty feasibility as more data becomes available.

Summary

The purpose of this research effort was to identify factors that affect the CBA for the Sensor Fuzed Weapon (SFW) System because an essential performance requirement (EPR) warranty waiver was under consideration. Defense funding has become scarce, and the government must spend the limited dollars wisely. A CBA should provide a relevant projection of cost-effectiveness based on the best available data. The SFW and other dormant systems present difficulties in determining cost-effectiveness because the systems most probably will be non-operating, non-reusable, and non-restorable. The recommendations for the SFW program office were 1) perform cost-effectiveness sensitivity analysis using initial reliability formula, 2) insure warranty remedies could be enforced for the other two warranty parts if the EPR warranty is waived, and 3) review the method of measurement for EPR effectiveness by performing a CBA comparing the current method of using "points-in-time" with the alternate method of using a cumulative measurement. The SFW's EPR warranty will become effective in 1996. In the meantime, the program manager can examine more closely the feasibility of the EPR warranty and the warranty in total.

Appendix A: SFW Sampling Plan

SAMPLING PLAN

TEST INTERVALS — IN PRODUCTION / OUT OF PRODUCTION

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14
96			6				6								
97				6				6							
98					6				6						
99						6				6					
00							6				6				
01								6				6			
02									6				6		
03										6				6	
04											6				6
PER YEAR			6	6	6	6	12	12	12	12	12	6	6	6	6
CUMULATIVE			6	12	18	24	36	42	60	72	84	90	96	102	108

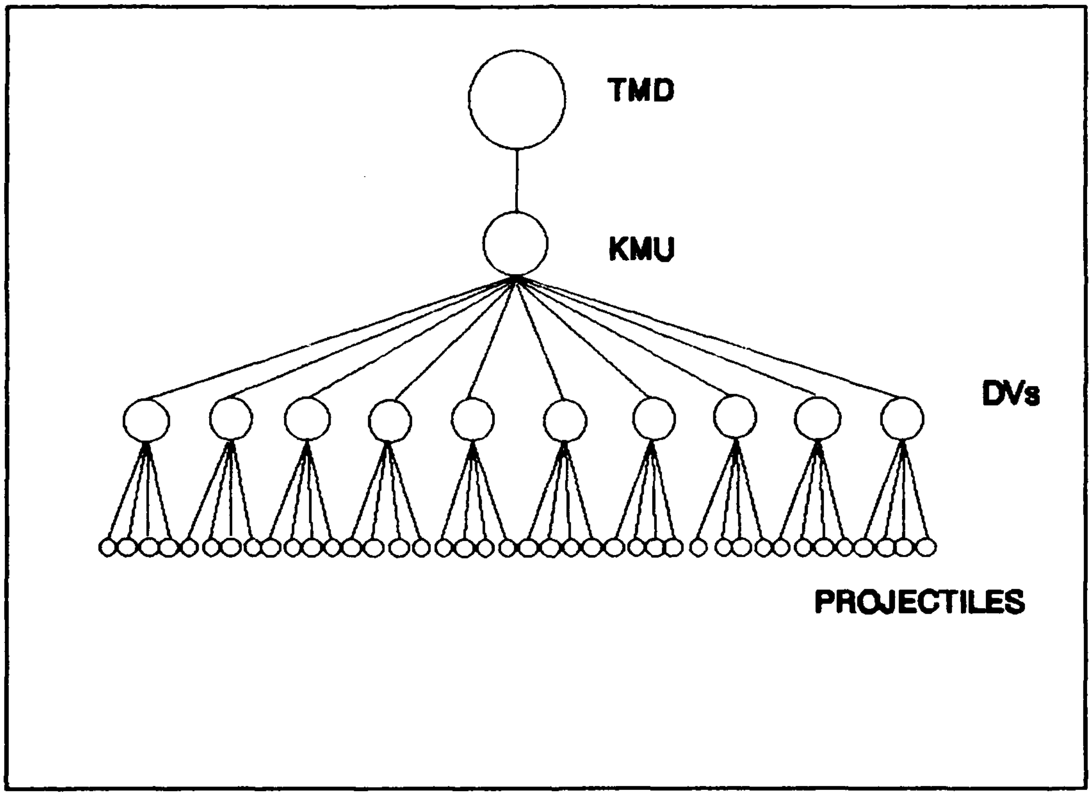
NUMBER TESTED

Appendix B: Reliability Formula and Redundancy Figure

Shown below is the formula used to calculate the system reliability that considers redundancy:

$$R_{SYS} = [1-(1-R_{TMD})^{N_{TMD}}] \times [1-(1-R_{KMU})^{N_{KMU}}]$$
$$\times [1-(1-R_{DV})^{N_{DV}}] \times [1-(1-R_{PROJ})^{N_{PROJ}}]$$

A graphical view of the reliability tree displaying system redundancy is shown below:



Where TMD is a Tactical Munitions Dispenser,
KMU is an adapter kit (KMU-488),
DV's are Delivery Vehicles, and
Projectiles

Appendix C: Comparison of Cost-Benefit Analysis Inputs

	Systems					
Costs	Peace-keeper	ACM	ACM Prop.	Maverick	CEM	SFW
Acquisition	✓					
Set up for Operation	✓					
Preventative Maint.	✓					
Warranty Cost	✓				✓	✓
Administration		✓	✓		✓	✓
Egineering Change Proposals					✓	
Parts		✓				
Materials				✓		
Fuel Leaks		✓				
Cost of Money		✓				✓
Testing					✓	✓
Essential Performance Requirements			✓			
Design and Manufacturing			✓			
Materials and Workmanship			✓			
Facilities				✓		
Training				✓		
Packing and Shipping				✓		✓
Technical Manuals				✓		
Support Equipment				✓		
Labor				✓		
Benefits						
Failure Repair	✓	✓	✓	✓	✓	
Spare Parts	✓					
Repair Shop	✓					
Test (Analysis of Results)					✓	
Good Units						✓

Systems Identified:

- Peacekeeper Missile Propulsion System
- Advanced Cruise Missile (ACM) System
- ACM Propulsion System
- Maverick Missile System
- Combined Effects Munition System
- Sensor Fuzed Weapon System

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The purpose of this research effort was to identify factors that affect the warranty cost-benefit analysis for the Sensor Fuzed Weapon (SFW) System since an essential performance requirement (EPR) warranty waiver was under consideration. Defense funding has become scarce, and the limited dollars must be spent wisely. A cost-benefit analysis should provide a relevant projection of cost-effectiveness based on the best available data. The SFW and other dormant weapon systems present difficulties in determining cost-effectiveness because the systems most probably will be non-operating, non-reusable, and non-restorable. Three recommendations were made, relevant to dormant weapon systems, that pertained to further cost analysis and review of overall warranty effectiveness. The SFW's EPR warranty will become effective in 1996. In the meantime, the program manager can examine more closely the feasibility of the EPR warranty and the warranty in total.

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